ATTACHMENT C

OPERATION AND MAINTENANCE MANUAL FOR SVE SYSTEM

ATTACHMENT C (Application APPENDIX G)

OPERATION AND MAINTENANCE MANUAL, SOIL VAPOR EXTRACTION SYSTEM

OPERATION AND MAINTENANCE MANUAL

SOIL VAPOR EXTRACTION SYSTEM

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PINAL COUNTY, ARIZONA

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ATTACHMENTS

1. INTRODUCTION

A solar-powered soil vapor extraction (SVE) system is designed and constructed by at the Page-Trowbridge Ranch Landfill (PTRL) in Pinal County, Arizona (Attachment A, Drawing 1).

This Operations and Maintenance (O&M) Manual is intended to act as a guide for the operation and maintenance of the Interim Measures (HGC, 2005b). The SVE system is located between landfill units A and B at the PTRL (Attachment A, Drawing 2).

The purpose of this document is to provide operating personnel with the basic knowledge necessary to start, operate, troubleshoot, and maintain the SVE system and identify the sampling activities necessary to evaluate system performance. This document is based on Revision 2 of the O&M Manual, which outlines O&M procedures based on conditions at the time of its preparation, after the system was in operation for 12 months. Revisions in this document include updating the air permit status in Section 1.1, revising the SVE operation strategy in Section 3.1, removing photoionization detection (PID) monitoring from operation procedure, adding a new Section 6.3 on operational parameters for the SVE system, and revising reporting requirements in Section 8.

Operation of a treatment system is an evolving process. The user should evaluate the document for errors, make corrections, and suggest improvements or modifications to operating procedures or performance monitoring descriptions included herein. This document should be reviewed periodically for changes and modified in accordance with the findings of that review.

1.1 Background and General System Description

The SVE system consists of two, solar-powered, positive displacement blower units (SVE-1 and SVE-2) connected to associated SVE wells. SVE-1 is designed to extract soil gas from Well SGS (Soil Gas Shallow) at a rate of 85 standard cubic feet per minute (scfm). SVE-2 is designed to extract soil gas from Well SGD (Soil Gas Deep) at a design rate of 40 scfm, or the flow can be reversed to inject air into this well at 40 scfm. The extracted soil gas streams from the two SVE units are combined at a total design rate of 125 scfm when SVE-2 is in extraction mode. The extracted soil gas stream is then passed through two granular activated carbon (GAC) adsorbers in series for removal of VOCs prior to atmospheric discharge.

Based on influent concentrations measured from 2010 through 2011, the rated capacity of the blowers, and the maximum hours of operation per day, the remediation system does not exceed the 5.5 pound per day or the one ton per year potential to emit permit threshold limit (Pinal County Rule 1-1-140). An air quality permit for this system is therefore not required based on the current system configuration and influent concentrations. During the operation of the SVE system, the VOC concentrations and extraction rates will continue to be used to verify that an air quality permit will not be required.

1.2 Key Project Contacts

Key project contacts for the SVE system O&M are presented in Table 1 with their affiliation, role, telephone, and e-mail contacts.

1.3 Contaminants of Concern

The contaminants of concern (COCs) consist of the following VOCs present in soil gas at PTRL that were identified and collectively evaluated as a potential threat to groundwater or human health via inhalation pathways (HGC, 2005a):

- Carbon tetrachloride
- Chloroform
- Dichlorodifluoromethane (Freon 12)
- 1,1-Dichloroethene (1,1-DCE)
- Methylene chloride
- Tetrachloroethene (PCE)
- Trichloroethene (TCE)
- Trichlorofluoromethane (Freon 11)
- Trichlorotrifluoroethane (Freon 113)

1.4 SVE System Components

The SVE system consists of the following components, as detailed in the as-built drawings included as Attachment A (Drawings 2, 3, 4, and E-2A):

- SVE wells SGS and SGD
- Solar-powered, skid-mounted, vacuum blower package identified as SVE-1:
  - belt-driven, positive displacement (rotary lobe type) blower configured for 85 scfm;
  - 2-horsepower (hp), 120 volt alternating current (VAC), totally-enclosed fan cooled (TEFC) motor;
  - condensate separator;
  - seven 185-watt photovoltaic (PV) panels and one 170-watt PV panel on common support rack mounted above vacuum blower unit skid;
  - four 175-watt PV panels on common support rack and post;
  - a 3900-watt, 24 volt direct current (VDC) to 120 VAC inverter with remote control for programming;
  - electrical control panels for enclosure of solar power operating, control and monitoring equipment, and instrumentation;
  - flow rate sensor and vacuum gauge; and
  - branch valve ports for soil gas sampling or pressure monitoring
- Solar-powered, skid-mounted, vacuum blower package identified as SVE-2:
  - Belt-driven, positive displacement (rotary lobe type) blower configured for 40 scfm;
  - 1-hp, 24 VDC, brushed, TEFC motor;
  - condensate separator;
  - three 185-watt PV panels and five 175-watt PV panels on common support rack mounted above vacuum blower unit skid;
  - four 175-watt PV panels on common support rack and post;
  - electrical control panels for enclosure of solar power operating, control and monitoring equipment, and instrumentation;
  - flow rate sensor and vacuum gauge; and

    - branch valve ports for soil gas sampling or pressure monitoring
- 55-gallon, buried condensate sump along the pipeline from Well SGS to SVE-1;
- 16 each, 6-volt, 224 ampere-hours (AH) at standard 24-hour duration, absorbed gel mat (AGM) batteries within electrical panel enclosures, arranged as four parallel sets of four batteries in series for 24 VDC output;
- interconnecting piping and valving from SVE wells to SVE system and GAC absorbers; and
- two 2,000-pound capacity GAC adsorbers with interconnecting pipes/hoses.

2. EQUIPMENT DESCRIPTION

The SVE system consists of two, skid-mounted, solar-powered vacuum blower units, SVE-1 and SVE-2, attached to Wells SGS and SGD, respectively (Attachment A, Drawing 2). The larger capacity unit, SVE-1, is designed to extract up to 85 scfm of soil gas from the shallow vadose zone via Well SGS. The smaller capacity unit, SVE-2, is designed to extract up to 40 scfm of soil gas from the deep vadose zone via Well SGD or inject fresh air into the same zone at roughly the same rate. The vacuum blower discharge stream from SVE-1 (and SVE-2 if operating in SVE service) is passed through two GAC adsorbers, connected in series, for removal of VOCs prior to atmospheric discharge.

2.1 Equipment Compound

The aboveground components of the SVE system are located south of the service road between landfill units A and B (Attachment A, Drawing 2). This equipment compound is unfenced, allowing access to all aboveground system components. These components consist of two, skid mounted SVE units, each with eight PV panels attached to support racks; two sets of four PV panels attached to support poles independent of the SVE unit skids; interconnecting piping and hoses attached to a support framework near the two 2,000-pound GAC adsorbers. The adsorbers are located near the service road, permitting easy access for periodic carbon replacement. All above ground process piping is painted white for protection from solar degradation. Additionally, the white finish serves to minimize temperature increases within the process gas stream prior to reaching the GAC adsorbers, since adsorber efficiency increases with decreasing process temperatures.

2.2 Wells, Vaults, and Laterals

Well SGS is located near the southeast corner of landfill unit A (Attachment A, Drawing 2). As depicted on the lithologic log and well completion diagram provided in Attachment B, the well is constructed of 4-inch diameter, polyvinyl chloride (PVC) casing to a depth of 255 feet below ground surface (bgs) with slotted screen casing from 98 to 255 feet bgs for extracting soil gas. Additionally, a ½-inch diameter PVC soil-vapor monitoring probe, SGS-SP, is installed adjacent to the 4-inch well casing, enabling soil gas to be monitored from a slotted screen interval occurring at 73 to 83 feet bgs. The annular space around of the well between the sand packs surrounding the 4-inch well screen and ½-inch vapor probe screen, and from the ½-inch vapor probe screen to land surface (well vault), is sealed with 30-percent high-solids bentonite.

Well SGD is located between landfill units A and B (Attachment A, Drawing 2). As depicted on the lithologic log and well completion diagram (Attachment B), the well is constructed of 2-inch PVC casing to a depth of 605 feet bgs with slotted screen casing from 435 to 605 feet bgs. The well is accompanied by two ½-inch diameter PVC soil-vapor monitoring probes, SGD-SP and SGD-MP, enabling soil gas to be monitored from slotted screen intervals occurring at 98 to 123 feet and 193 to 217 feet bgs, respectively. The annular space around the well between the sand packs surrounding the 2-inch well screen and ½-inch vapor probe screens is sealed with 30-percent high-solids bentonite.

An additional ½-inch PVC soil-vapor monitoring probe, SGD-DP (or SGD-2), is located just west of Well SGD within a separate borehole with soil gas monitoring enabled via a slotted screen interval occurring at 325 to 355 feet bgs.

Both extraction well heads, with sampling ports and connected lateral lines with isolation ball valves (BV-1 and BV-2), are enclosed within traffic-rated vaults made of composite materials. The vault lids can be lifted with a lid hook hanging on the pipe support rack adjacent to the GAC adsorbers.

From the SVE well heads, the respective lateral lines extend below grade to their respective SVE system skids (Attachment A, Drawing 2). The lateral line from Well SGS is sloped downward at a minimum of one percent to the condensate sump (Section 2.3), both from the well head and skid. Any condensed soil gas moisture within this 4-inch lateral line should flow by gravity into the sump for subsequent removal on a periodic basis. From SVE-2, the respective lateral line slopes approximately one percent toward the well to permit drainage of condensate back to the well. Within each pipe trench previously advanced for lateral line installation, a 12-gauge tracer wire exists above the pipeline for pipeline location purposes, should nearby excavation be necessary in the future (Attachment A, Drawing 4).

2.3 Well SGS Condensate Sump

A condensate sump, consisting of a 55-gallon drum, is installed at the low point in the 4-inch lateral line from Well SGS to SVE-1 (Attachment A, Drawing 4). As indicated on Detail 4, condensate enters the top of the sump through a bulkhead fitting from a low-point branch tee within the 4-inch lateral line. Another bulkhead fitting on the top of the sump provides access from the surface through a 2-inch PVC standpipe or riser stub. Upon removing a 2-inch threaded plug from the end of this standpipe, the condensate level within the sump can be measured, and the condensate removed by a bailer or a suitable pump.

2.4 Common Battery Array

The solar arrays and associated control panels of SVE-1 and SVE-2 are connected to a common battery array located between the two skids. The battery array consists of sixteen, 6-volt, AGM, 224 AH batteries manufactured by Concorde Battery Corporation. The batteries are connected as four parallel sets of four batteries in series for 24 VDC service at a combined electrical storage capacity of 896 AH. This electrical storage capacity serves as an electrical energy buffer between the fluctuating rate of solar power production and the nearly constant rate of DC power draw by the vacuum blower motors. The battery array receives solar power simultaneously from both charge controllers. Electrical power is discharged from the battery array to SVE-1 and SVE-2, upon demand, for blower operation.

The load controllers are programmed to 1) allow battery array charging from the charge controllers without blower operation when the battery voltage decreases to 24.2 volts and 2) limit further battery array charging (or overcharging) when the battery voltage increases to 27.2 volts. The battery rest voltages when fully charged and fully discharged (100% and 0% states-of-charge) are 26.5 and 22.8 volts, respectively. The above programming is intended to maintain the battery state-of-charge above 65% (minimum rest voltage of 25.2 volts) and the depth-of-discharge above 50%, resulting in at least 1000 charge/discharge life cycles at one cycle per day.

2.5 SVE-1 Equipment Skid and Auxiliary Solar Panel Array

As depicted on Drawings E-2A and 3 (Attachment A), the SVE-1 equipment skid features a condensate separator, vacuum blower and motor with associated belt drive, interconnecting PVC piping, instruments, control panel, and 8-panel PV array mounted to an overhead support rack. An auxiliary, pole-mounted, 4-panel PV array is provided near the SVE-1 skid. SVE-1 is interconnected to Well SGS and the GAC absorbers (Section 2.7) via field-limit piping connection points located on the north side of the skid.

2.5.1 Condensate Separator

The condensate separator or "knockout tank" (KO-1) removes any free aqueous condensate from the extracted soil gas stream not collected in the condensate sump (usually from October through April) prior to this gas stream passing through the SVE-1 vacuum blower and downstream equipment. KO-1 consists of a vertical, cylindrical steel vessel with tangential inlet and top center outlet. The lateral line from Well SGS extends above grade and enters this vessel at the tangential inlet for removal of any entrained soil gas moisture (mist) by centrifugal forces and impingement against the vessel sidewall. A pressure gauge (0 to 30 inches water column (WC) vacuum) is provided on this inlet riser pipe for monitoring vacuum pressure at this point. The top outlet piping conveys the moist soil gas stream, less the free moisture, to the inlet port of the vacuum blower.

Any aqueous condensate that impinges against the sidewall of KO-1 falls to the bottom of and accumulates in this vessel. A clear plastic sight gauge is provided on the side of KO-1 for inspection of liquid level. Within this site gauge, a high level switch (LSH-1) is installed for automatic shut down of the vacuum blower. Should the liquid level within KO-1 reach a maximum operating level, LSH-1 would actuate to prevent water from being drawn into the outlet pipe and potentially damaging the blower. While SVE-1 is down for routine maintenance, condensate is removed from KO-1 by opening a drain valve at the bottom of the vessel (see Section 4.3).

2.5.2 Extraction Blower, Motor, and Belt Drive

The extraction blower, PDB-1, consists of a Dresser-Roots Model URAI 42 rotary-lobe type, positive displacement blower. PDB-1 serves as the prime mover for the extraction of soil gas from Well SGS at an extraction rate of 85 scfm and subsequent conveyance through the GAC adsorbers (Section 2.7). The blower is dual-belt driven from a 2-hp Dayton motor (M-1) using 120 VAC power from the Magnum RD3924 DC-to-AC Inverter which uses 24 VDC power from the common battery array (Section 2.6) and solar power system (Sections 2.4.3 and 2.4.4). Manufacturer's specifications for the motor and blower are provided in Attachment C. The motor is thermally protected; if the motor exceeds the temperature rating, the motor will need to be manually reset.

Within the 2-inch diameter inlet pipe to the blower, an averaging Pitot tube (FE-1) is installed for local indication of soil gas flow rate by an associated Dwyer Magnehelic® flow velocity indicator (FM-1) located on the side of the control panel. Alternatively, the differential pressure across the

Pitot tube may be measured directly from the interconnecting tubing to FM-1, along with the discrete line pressure, for calculation of flow rate using the Pitot tube equation.

At the inlet and discharge ports of the blower, branch valve ports are provided for periodic gas pressure measurements directly across the blower for calculation of brake horsepower draw by gas compression.

2.5.3 Solar Panel Arrays

An 8-panel PV array is mounted above the SVE-1 skid, consisting of seven 185-watt Sharp ® single-crystal silicon PV panels and one 170-watt Sharp polycrystalline silicon PV panel. Additionally, an auxiliary PV array, consisting of four 175-watt BP Solar polycrystalline silicon nitride PV panels, is mounted to a support rack and pole located adjacent to SVE-1. The tilt angle on both PV arrays can be periodically adjusted (twice per year) for proper alignment of the arrays relative to the azimuth of the sun. Tilt angle adjustment is accomplished by reworking the guy wires that extend from the support racks to concrete anchors.

Collectively, the 8-panel and 4-panel arrays (24 VDC nominal output per panel) are cabled together as six sets of two panels in series for nominal 48 VDC solar power output to control panel CP-1. The positive cable from each panel set extends to a 10 amp circuit breaker within CP-1. The negative cable from each panel set extends to a common negative bus bar within CP-1.

2.5.4 Control Panel and Electrical System

Control panel CP-1, mounted on the north side of SVE-1, contains the electrical controls and circuitry necessary to deliver solar (direct current) power from the six-set PV array to the common battery array (Section 2.6) and the DC-to-AC inverter which provides power to the blower motor (M-1).

The six 10-amp circuit breakers for the positive cables of the PV array are connected to a common bus bar. The positive cable from this bus bar is routed through a main disconnect switch (mounted on the side of CP-1) and then to the charge controller.

The Outback FLEXmax 80 charge controller (SC-1) is state-of-the-art relative to the control of solar power from the PV array to the common battery array and blower motor. The Outback charge controller has a digital display screen with a menu of settings and display options for the various operating parameters. On the PV array side, the controller features Maximum Power Point Tracking (MPPT) capability, which automatically and continually extracts the optimum or maximum DC power output from the nominal 48-volt PV array. On the charge side, the controller transmits up to 97.5% of the solar power to the common battery array and blower motor at the required voltage (nominal 24-volts) while increasing (more than doubling) the current at the reduced voltage, thereby eliminating any electrical power loss resulting from a loss of voltage through the controller. The voltage output from the controller is programmed for battery array charging in three modes: bulk, absorb, and float. In bulk mode, the output power (voltage and current) is maximized for quick recharging of the batteries. If and when the charge voltage reaches a programmed set-point value, the absorb mode begins for a programmed duration, which may be extended by the controller if the charge voltage is not maintained at or above the programmed set-point value. If and when the absorb mode ends, the float mode begins. During the float mode, the charge voltage is programmed at a lower set-point value that matches the battery array voltage at 100% state-of-charge or fully charged state. Considering the variable solar power input to the controller during the day and the operation of the blower motor, the actual voltage output to the battery array and blower motor will be generally less than the programmed voltage set-points for bulk and absorb modes.

From the charge controller, the positive cable passes through an 80-amp circuit breaker and then splits to the blower motor start circuit, including the Magnum RD3924 3900 watt 24 VDC to120 VAC inverter, and common battery array (Section 2.6) after passing through the main disconnect switch. The blower motor start circuit features an “On/Off” selector switch (HS-1) located on the face of CP-1 for enabling blower operation. Downstream of this switch, the start circuit passes through normally-closed, high level switch LSH-1; the positive side of the load controller (LC-1), and then through the control side of a solenoid relay (SS-1) to the negative side of the common battery array. At the load side of SS-1, a positive cable from the charge controller and common battery array passes through SS-1, followed by a 30-amp fuse, the load controller, and to the blower motor. Upon switching HS-1 to the “On” position, the blower motor start circuit becomes energized to the load controller, unless this leg of the circuit is opened by a high level condition (LSH-1 actuated). When the battery array voltage increases to a set-point value programmed within the load controller, the load controller will close an internal switch, thereby closing the blower motor start circuit to energize relay SS-1, which closes the DC power circuit to the DC-to-AC inverter and blower motor. When the battery array voltage decreases to a set-point value programmed within the load controller, the load controller will open the internal switch to de-energize the blower motor start circuit. Switching HS-1 to the “Off” position will disable SS-1, thereby also disabling DC power to the blower motor. Power from the PV and battery arrays can be interrupted by moving the main disconnect switch (KS-1) to the “Off” position.

The load controller (LC-1), consisting of a Morning Star Tri-Star 60 Solar System Controller, senses the battery array voltage at the battery array. This controller functions only as a high and low voltage switch for proper operation of the battery array and blower motor as described above.

The inverter is a Magnum 3924, 3900 watt, 24 VDC-to-120 VAC inverter capable of handling 30 amps continuous and a 93% efficiency rating. The inverter has the ability to handle 1 millisecond of surge current at 150 amps AC, and 100 milliseconds of surge current at 90 amps AC in order to handle the start-up current draw of the motor. The inverter is housed in a separate box to protect it from the elements. The box, previously used to house the batteries in the initial electrical configuration, has been retrofitted with air vents allowing for airflow to cool the inverter. The inverter features a modified sine wave output, remote control port, and thermal protection.

The inverter operating parameters are set with the Magnum ME-RC remote control. The remote control is located in CP-1, and is connected to the inverter via a standard phone cable. This remote control is used to set the low battery cut-out which is presently set to ensure that the load controller shuts off the motor as opposed to the inverter shutting of the motor. Other parameters that can be set by the remote control are necessary only if the inverter is also being used to charge the batteries. Since the battery charging is controlled by the FLEXmax 80 charge controller, these settings do not need to be changed. The remote control is also used to determine system status and fault mode messages via the LCD screen. This last feature is useful to determine what caused the inverter to shut off if it is found in such a state upon arrival at the site for maintenance. Possible conditions that may cause the inverter to shut off include:

1. Exceeding the temperature rating of the internal components. The inverter does include thermal protection and the inverter should restart once the unit has cooled down;
2. Exceeding the current ratings of the inverter. If the current overload condition occurs for less than 3 seconds, the inverter will restart. If the current overload lasts for more than 10 seconds, the unit will shut down and the inverter will need to be restarted manually;
3. Exceeding the internal field effect transistor's (FET) safe operating condition. If this occurs then the system will require a manual restart;
4. Unknown fault: if this message is displayed, then technical support will need to be contacted.

CP-1 is also equipped with an hour meter to better facilitate monitoring of system performance. The hour meter is connected to the motor circuit and energized when the blower motor is in operation. The amperage drawn by the 2 hp 120 VAC motor is monitored via the use of a multi-meter with an ammeter probe.

2.6 SVE-2 Equipment Skid

The SVE-2 equipment skid features a condensate separator, vacuum blower and motor with associated belt drive, interconnecting PVC piping, instruments, control panel, and 8-panel PV array mounted to an overhead support rack (Drawings E-2A and 3 [Attachment A]). An auxiliary, pole-mounted, 4-panel PV array is provided near to the SVE-2 skid. SVE-2 is interconnected to Well SGD and the GAC adsorbers (Section 2.7) via field-limit piping connection points located on the north side of the skid.

2.6.1 Condensate Separator

The condensate separator or "knockout tank" (KO-2) removes any free aqueous condensate from the extracted soil gas stream or ambient air prior to this gas stream passing through the SVE-2 vacuum blower and downstream equipment. KO-2 consists of a vertical, cylindrical steel vessel with tangential inlet and top center outlet. The lateral line from Well SGD extends above grade and enters this vessel at the tangential inlet for removal of any entrained soil gas moisture (mist) by centrifugal forces and impingement against the vessel sidewall. A pressure gauge (0 to 30 inches WC vacuum) is provided on this inlet riser pipe for monitoring vacuum pressure at this point. The top outlet piping conveys the moist soil gas stream, less the free moisture, to the inlet port of the vacuum blower.

Any aqueous condensate that impinges against the sidewall of KO-2 falls to the bottom of this vessel and accumulates. A sight gauge, constructed of clear plastic, is provided on the side of KO-2 for inspection of liquid level within. Within this site gauge, high level switch (LSH-2) is installed for automatic shut down of the vacuum blower. Should the liquid level within KO-2 reach a maximum operating level, LSH-2 would actuate to prevent water from being drawn into the outlet pipe and potentially damaging the blower. While SVE-2 is down for routine maintenance, condensate is removed from KO-2 by opening a drain valve at the bottom of the vessel (see Section 4.3).

2.6.2 Extraction Blower, Motor, and Belt Drive

The Dresser-Roots Model URAI 42 rotary-lobe type, positive displacement blower, PDB-2, serves as the prime mover for the extraction of soil gas from Well SGD and subsequent conveyance through the GAC adsorbers (Section 2.7), or injection of ambient air into Well SGD, at a rate of 40 scfm at 25 inches WC vacuum. The blower is dual-belt driven from a 1-hp Leeson motor (M-2) using 24 VDC power from the common battery array (Section 2.6) and solar power system (Sections 2.5.4 and 2.5.5). Manufacturer's specifications for the motor and blower are provided in Attachment C.

Within the 2-inch diameter inlet pipe to the blower, an averaging Pitot tube (FE-2) is installed for local indication of soil gas flow rate by an associated Dwyer Magnehelic® flow velocity indicator (FM-2) located on the side of the control panel. Alternatively, the differential pressure across the Pitot tube may be measured directly from the interconnecting tubing to FM-2, along with the discrete line pressure, for calculation of flow rate using the Pitot tube equation.

At the inlet and discharge ports of the blower, branch valve ports are provided for periodic gas pressure measurements directly across the blower for calculation of brake horsepower draw by gas compression.

2.6.3 Air Inlet and Filter

SVE-2 is also equipped to inject air into the subsurface through Well SGD. During air injection mode, ambient air is drawn into SVE-2 through a 2-inch air inlet filter and isolation valve (BV3) located at a branch point just upstream of KO-2. The filter removes particulate matter from the air stream prior to injection into the vadose zone soil via Well SGD. Just upstream of the air filter branch point, another isolation valve, B-4, is closed to direct air flow through KO-2 to the vacuum blower inlet. On the 2-inch PVC discharge line from the blower (downstream of the discharge hose), a 2-inch PVC branch line with isolation valve, BV-6, is connected to the Well SGD lateral line (2-inch PVC) where extending above grade. Another isolation valve, BV-5, is provided just downstream of this branch point to isolate SVE-2 from the GAC adsorbers. With BV-6 open and BV-5 closed, the air stream from PDB-2 is directed into the Well SGD lateral line for injection into Well SGD.

2.6.4 Solar Panel Arrays

An 8-panel PV array is mounted above the SVE-2 skid, consisting of three 185-watt Sharp single-crystal silicon PV panels and five 175-watt BP Solar polycrystalline silicon nitride PV panels. Additionally, an auxiliary PV array, consisting of four 175-watt BP Solar polycrystalline silicon nitride PV panels, is mounted to a support rack and pole located adjacent to SVE-2. The tilt angle on both PV arrays can be periodically adjusted (twice per year) for proper alignment of the arrays relative to the azimuth of the sun. Tilt angle adjustment is accomplished by reworking the guy wires that extend from the support racks to concrete anchors.

Collectively, the 8-panel and 4-panel arrays are cabled together as six sets of two panels in series for nominal 48 VDC solar power output to control panel CP-2. The positive cable from each panel set extends to a 10 amp circuit breaker within CP-2. The negative cable from each panel set extends to a common negative bus bar within CP-2.

2.6.5 Control Panel and Electrical System

Control panel CP-2, mounted on the north side of SVE-2, contains the electrical controls and circuitry necessary to deliver solar power from the six-set PV array to the common battery array (Section 2.6) and blower motor (M-2).

As a continuation of Section 2.5.4, the six 10-amp circuit breakers for the positive cables of the PV array are connected to a common bus bar. The positive cable from this bus bar is routed through a main disconnect switch (mounted on the side of CP-2) and then to the charge controller.

The Outback FLEXmax 80 charge controller (SC-2) is described in Section 2.4.4. From the charge controller, the positive cable passes through an 80-amp circuit breaker and then splits to the motor controller and common battery array (Section 2.6) after passing through the main disconnect switch. Power supply to the PDB-2 motor start circuit originates from the PDB-1 motor start circuit at SS-1 within CP-1. As a subsurface performance provision, this configuration enables PDB-2 to start only when PDB-1 is in operation. Power is supplied to the PDB-2 motor start circuit from an "On/Off" selector switch (HS-2) located on the face of CP-2. Downstream of this switch, the start circuit passes through normally-closed, high level switch LSH-2; the positive side of the load controller (LC-2), and then through the control side of a solenoid relay (SS-1) to the negative side of the common battery array. At the load side of SS-1, a positive cable from the charge controller and common battery array passes through SS-1, followed by a 60-amp fuse, the load controller, and the motor controller, to the blower motor. Upon switching HS-2 to the "On" position, the blower motor start circuit is enabled to the load controller (from SVE-1), unless this leg of the circuit is opened by a high liquid level condition (LSH-2 actuated). When the battery array voltage increases to a set-point value programmed within the load controller, the load controller will close an internal switch to further enable the blower motor start circuit to relay SS-1. When PDB-1 is in operation, SS-1 then becomes energized, thereby closing the DC power circuit to the motor controller and blower motor. When the battery array voltage decreases to a set-point value programmed within the load controller, the load controller will open the internal switch to de-energize the blower motor start circuit. Switching HS-2 to the "Off" position will disable SS-1, thereby also disabling DC power to the blower motor. Power from the PV and battery arrays can be interrupted by moving the main disconnect switch (KS-2) to the "OFF" position.

The load controller (LC-2), consisting of a Morning Star Tri-Star 45 Solar System Controller, senses the battery array voltage at a terminal block located within CP-2. This controller functions only as a high and low voltage switch for proper operation of the battery array and blower motor as described above. The set-point value for this switch is identical to that for LC-1, resulting in PDB-1 and PDB-2 starting and stopping together.

The motor controller (MC-2) consists of a Minarek DC 60-12/24, pulse-width modulated, adjustable speed drive for DC brush motors. MC-2 features a speed-adjust potentiometer that fixes the normal voltage output to the blower motor to realize the desired blower speed and throughput. Other variable controls are provided for smooth start-up and operation of the blower motor, as well as for current limit protection.

CP-2 is also equipped with an hour meter and ammeter to better facilitate monitoring of system performance. The hour meter is connected to the motor circuit and energized when the blower motor is in operation. The ammeter is connected to the motor circuit at a shunt to measure the DC amperage drawn by the motor.

2.7 GAC Adsorbers and Piping / Hose Connections

The 3-inch PVC blower discharge lines from SVE-1 and 2-inch PVC discharge line from SVE-2 are connected to a common 3-inch PVC line. Near this connection, both discharge lines contain a flapper-type check valve to prevent the reverse flow. The soil gas stream passes through a 3-inch PVC riser pipe (R-INF) attached to a steel support framework, followed by a 6-feet long, heavy-duty hose with Camlock couplers (inlet hose 1 – IH1), to the top, or inlet, of lead GAC adsorber. From the bottom of the lead adsorber, the treated soil gas stream is conveyed through outlet hose 1 (OH1) connected to the bottom of an adjoining section of 3-inch PVC riser pipe (R1) that is also mounted to the steel support framework. The top of R1 is connected to inlet hose 2 (IH2) which connects to the inlet (top) of the lag GAC adsorber for continued soil gas flow through this vessel, in series. From the lag adsorber, the treated soil gas stream is discharged to the atmosphere through an outlet hose 2 (OH2) and 3-inch PVC vent pipe (R2), also mounted to the steel support framework.

Each GAC adsorber contains 2,000 pounds of activated carbon for removal of VOCs from the combined soil gas stream by the process of activated carbon adsorption. The VOC loading within the lead adsorber is monitored to predict when the GAC will become spent or requires replacement with fresh carbon. When the carbon within the lead adsorber is replaced, the roles of the two adsorbers are to be switched by reconfiguring the hoses. The canister with the clean carbon should always be the lag GAC adsorber. If ACF-1 is the lead adsorber, this is accomplished by disconnecting IH1 from R-INF and IH2 from R1 and then connecting IH2 to R-INF and connecting IH1 to R2.

3. OPERATION PROCEDURES

The SVE system is composed of two units, SVE-1 and SVE-2, which are connected to a common battery array. SVE-1 extracts soil gas from the 98 to 255-feet bgs interval via shallow Well SGS at a flow rate of approximately 85 scfm. SVE-2 can either extract soil gas from or inject fresh ambient air into the 435 to 605-feet bgs interval through deep Well SGD at a flow rate of 40 scfm. SVE-1 can be operated independently of SVE-2. Through an electrical interlock provision, SVE-2 cannot be operated in soil gas extraction or air injection mode unless SVE-1 is in operation. Operation of both units in soil gas extraction mode is referred to as “extraction-extraction” mode. Operation of SVE-1 in extraction mode and SVE-2 in injection mode is referred to as “extraction-injection” mode. Under normal condition, SVE-1 and SVE-2 should be operated in the “extraction-injection” mode.

Prior to operation of SVE-1 only or SVE-1 and SVE-2 together, certain isolation valves must be properly configured as further described in the following sections.

3.1 Operating Strategy

SVE-2 should be operated in air injection mode along with SVE-1 operation in extraction mode, since the injection of fresh air into the deep zone will displace soil gas with any contaminants radially outward and then upward through Well SGS to the surface, as induced by the SVE process driven by SVE-1. Otherwise, if SVE-2 were in extraction mode under the same operating condition, soil gas with higher concentrations of contaminant vapor (at shallower depths) would be drawn towards the screened interval of Well SGD, having the undesirable effect of drawing contaminants deeper into the vadose zone and closer to groundwater.

As stated above, SVE-2 is electrically interlocked to prevent operation in injection mode (or extraction mode) without SVE-1 operating in extraction mode. This forbidden operation prevents the potential displacement of contaminant vapor radially outward toward the property boundaries and eventually into the atmosphere, as well as downward to the aquifer.

When preparing SVE-2 for operation in injection mode, the respective isolation valves should be configured as indicated in the table below. **All system valves must be checked when restarting SVE-2 after an extended period of inactivity to ensure that they are in the proper configuration.**

SVE-2 Injection Configuration

Valve Number	Injection Configuration
BV-3	Open
BV-4	Closed
BV-5	Closed
BV-6	Open

For reference purpose only, the configuration of isolation valves for operation SVE-2 in extraction model are listed below. **However, SVE-2 should normally be operated in injection mode**

SVE-2 Extraction Configuration

Valve Number	Extraction Configuration
BV-3	Closed
BV-4	Open
BV-5	Open
BV-6	Closed

3.2 GAC Adsorber Lead-Lag Configuration

The SVE system is intended to operate with the combined soil gas stream passing through the GAC adsorbers in series. Series flow enables the carbon within the lead adsorber to become “loaded” by adsorbing most of the VOCs from the soil gas flow stream, while the “lag” adsorber captures any VOCs that may pass through the “lead” adsorber. When the carbon within the lead adsorber can no longer capture all the VOCs from the soil gas stream, the carbon within the lead adsorber is to be replaced with fresh activated carbon. This former lead adsorber then becomes the lag adsorber by reconfiguring the hose connections. In this way, a bed of “fresh” carbon is maintained within the lag adsorber as an effective “polishing” provision for removal of any VOCs that pass through the lead adsorber.

3.3 Normal Start-up of SVE Units

Prior to start-up of SVE-1 with SVE-2 in injection or extraction mode, the following conditions are to be verified:

1. The isolation valve on the lateral line near the associated wellhead (BV-1 or BV-2) is open and wellhead port valves are closed.
2. Relative to SVE-2, valves BV-3 through BV-6 are properly positioned according to the intended operating mode, either extraction or injection.
3. The associated condensate separator is drained of any accumulated condensate.

4. The associated blower is checked for appropriate level of gear-case oil and proper greasing of drive bearings. Also, the belt cage is installed.
5. At SVE-2, the inlet air filter is cleaned.
6. All process piping is inspected for any cracks or other failures and repaired as necessary.
7. At the GAC adsorbers, the interconnecting hoses/pipes are properly configured and securely connected.
8. The main disconnect switches on the respective control panels are in the “Off” position.
9. On the respective control panels, HS-1 and HS-2 are switched to the “Off” position. Also, the respective charge, load, and motor controllers are properly configured/programmed (see Section 3.5).
10. All personnel are clear of equipment.

After the above conditions are verified, rotate the main disconnect switch on the SVE-1 control panel to the “On” position and then enable SVE-1 (PDB-1) operation by switching HS-1 to the “Start” position. The system may not start in the early morning if the battery array does not have sufficient charge. When the battery array voltage reaches a set-point value of 27.2 volts, the SVE-1 load controller will initiate DC power to the motor controller and blower motor, thereby causing PDB-1 to start automatically.

Once PDB-1 is in operation, SVE-2 (PDB-2) is then enabled to operate. After rotating the main disconnect switch to the “On” position, start PDB-2 by switching HS-2 to the “Start” position. Thereafter, PDB-2 will automatically start and stop along with PDB-1. Initiate operations monitoring as described under Section 6.

3.4 Shutdown of SVE Units

To shut down the SVE units, disable PDB-1 and PDB-2 by switching HS-1 and HS-2 to the “Off” position and then rotating the main disconnect switches on the respective control panels to the “Off” position. At this point, DC power continues to be “live” within each main disconnect switch on the “hot” side. Further, DC power from the solar arrays continues to be “live” within each control panel across the 10-amp circuit breakers to the “hot” side of the main disconnect switch. Any maintenance work on the electrical system should only be performed by a qualified electrician to avoid possible electrocution.

3.5 Normal Operation of SVE Units

Both SVE units, SVE-1 and SVE-2, feature the following three operating subsystems: 1) solar power production and control, 2) battery array discharge and voltage control, and 3) blower motor control. Each subsystem operates automatically and in concert with each other for unattended operation. Operating efficiencies relative to solar power production, battery array power and life cycle, and blower operating time may be further optimized (maximized) by reprogramming, adjusting, and/or configuring of the various electronic equipment components, given the time of year and other external conditions.

In the following sections, operating descriptions and initial control set-points are presented for each subsystem to provide the operator with a general understanding of SVE system function and operation. Such understanding is intended to eventually result in the optimization of operating efficiencies and the prompt identification and troubleshooting of abnormal operating conditions. Considering that normal operating conditions vary with the time of day and year, as well as the prevailing extent of atmospheric occlusion, an Excel spreadsheet is presented in Attachment E as a prime reference for the identification of any abnormal operating conditions.

3.5.1 Solar Power Production and Control

The solar arrays are comprised of twenty-four (24) individual photovoltaic (PV) panels, each having a nameplate rating for solar power output (watts) and maximum operating voltage and current at a standard solar flux or insolation value of 1,000 watts per square meter. Nameplate ratings for the three different PV panels employed within the solar arrays (Sharp 185 Watt, Sharp 170 Watt, and BP Solar 175 Watt) are presented in the manufacturer's specification sheets (Attachment D). As indicated, the nameplate ratings are rather similar, resulting in a satisfactory degree of compatibility relative to solar power production efficiency.

Solar power output from a given PV panel, consisting of DC power at a variable voltage output and current, is dependent upon the magnitude of the insolation (time of day, time of year, and extend of atmospheric occlusion), the operating life of the PV panel (integrity of panel surface), the temperature of the PV panel, the cleanliness of the PV panel surface, the use of diodes for prevention of reverse flow of electricity back to the panel, and the solar power output from the mating PV panel connected in series. Each of these factors is modeled within an Excel spreadsheet, which calculates predicted values of average solar power production from the solar arrays for each month of the year. A printout of this spreadsheet is provided in Attachment E for reference.

On average, a single PV panel will produce nearly 5 amps of DC power with a voltage output of 36 volts, while the PV panel temperature is at 25 degrees Celsius (C) or 77 degrees Fahrenheit (F) and the insolation is 1,000 watts per square meter (high noon). With two PV panels connected in series, the panel set will produce nearly 5 amps of DC power with a voltage output of 72 volts under the same conditions. The twelve sets of PV panel pairs that comprise the four solar arrays will produce nearly 60 amps of DC power (30 amps to each SVE unit) with a voltage output of 72 volts under the same conditions.

As may be concluded above, the PV panels have an insolation conversion efficiency of about 14% at the rated conditions, meaning that only 14% of the solar radiation is actually converted to solar DC power. The remaining 86% of the solar radiation is absorbed by the PV panels (black body absorbers) as sensible heat gain, causing the bulk temperature of the PV panels to increase above the surrounding ambient temperature. As the PV panel temperature increases, the internal resistance of the panel to the flow of electricity increases, resulting in a proportional decrease in the voltage (and solar DC power) output. For every one degree Celsius (C) increase in PV panel temperature above 25 degrees C, the rated maximum voltage output of the panel will decrease by ½ %, which has the effect of decreasing the insolation conversion efficiency to as low as 11.5% (hottest days of the year).

During each day, as the sun traverses across the sky, the insolation available for solar DC production will vary from zero to nearly 1,000 watts per square meter (high noon) and then back to zero. The voltage output across each PV panel will vary proportionally with the magnitude of the insolation at a steady current of nearly 5 amps, and then reach a maximum inflection point (see Sharp 185 Watt performance chart in Attachment D). Maximum solar DC output from the PV panels is realized when the output voltage is able to be controlled either at, or near to, the maximum rated value.

The charge controllers employed for SVE-1 and SVE-2 each control the solar DC power production from six parallel sets of two PV panels connected in series (see OutBack Power Systems Flexmax 80 User's Manual in Attachment D). Each (identical) controller features Maximum Power Point Tracking capability, which automatically controls the overall output voltage across the two solar arrays (8 panel and 4 panel) at the maximum value at the prevailing conditions (72 volts maximum at PV panel temperature of 25 degrees C). The controllers modulate this output voltage by regulating the solar DC power passing through the unit to the battery array. Through this modulation, the maximum output voltage is continually sensed and then converged upon, thereby maintaining maximum solar DC power production from the solar arrays.

Within the charge controllers, approximately 96.8 % of the solar DC power production passes through to the battery array and load controllers. On this downstream side, the charge controllers have the capability of stepping down the voltage for proper charging of the 24-volt battery array and operation of the 24-volt blower motors while also conserving solar DC power by stepping up the current proportionally (from approximately 30 to over 70 amps).

The charge controllers have LCD displays for monitoring and recording of the following solar DC power parameters: instantaneous solar DC input voltage and current, instantaneous charge voltage and current, instantaneous DC power (watts), daily accumulated DC power (kilowatt-hours), and daily peak input voltage.

3.5.2 Battery Array Charging / Discharging and Voltage Control

To realize a battery array life of nearly three years (1,000 charge cycles), the battery array is comprised of sixteen, 6-volt, AGM batteries that are to be maintained at a state-of-charge ranging from approximately 75 to 100%, which corresponds to an approximate maximum depth-of-discharge of 50% for the site-specific conditions (see Technical Manual for Sun Xtender® Batteries, Attachment D). This state-of-charge range corresponds to a battery rest voltage range of 25.2 to 26.5 volts @ 25 degrees C. At a 50% depth-of-discharge, the battery discharge voltage approaches 24.2 volts. As discussed below, the battery discharge voltage is limited to 24.2 volts as a control parameter. However, the battery rest voltage may exceed 26.5 volts, potentially reaching 28.0 volts, if the blowers are manually shut down (HS-1 and HS-2 switched to "Off") while the solar arrays continue to charge the battery arrays (main disconnect switches still in the "On" position).

During battery charging, the charge voltage (charge controller output voltage) is greater than the rest voltage, since current is flowing into the batteries and overcoming the resistance to current flow imposed by the battery internals. The greater the current flow into the batteries, the greater the charge voltage relative to the prevailing battery array rest voltage. The difference in the charge and rest voltages represents a proportional loss of DC power during charging. This loss of power exists in the form of internal heat gain and resulting temperature increase within the batteries.

Conversely, during battery discharging, the discharge voltage is less than the rest voltage, since current is flowing out of the batteries and overcoming the resistance to current flow imposed by the battery internals. The greater the current flow out of the batteries, the lesser the discharge voltage relative to the prevailing battery array rest voltage. The difference in the discharge and rest voltages represents a proportional loss of DC power during discharging. This loss of power also exists in the form of internal heat gain and temperature rise within the batteries.

At the beginning of each operating day (sunrise to about 9:00 AM), the battery array is charged by the solar arrays via the charge controllers at an increasing current (up to 130 amps) and charge voltage. When the charge voltage reaches 26.6 volts, the blower motors will start (see Section 3.5.3), thereby diverting a portion of the charge current (approximately 80 amps) from the battery array to the blower motors. As a result, the charge voltage may not further increase with increasing current output from the charge controllers. When the charge current from the charge controllers becomes no longer great enough to power the blower motors, the battery array begins to discharge current to the blower motors, thereby causing the charge voltage to decrease below the prevailing rest voltage of the battery array.

The charge controllers at SVE-1 and SVE-2 are programmed for proper control of charge voltage to the battery array and blower motors (when in operation), as sensed at the controllers. This voltage control only pertains to maximum voltage (and current) limits for three-stage, battery array charging. In the bulk (first) stage, which begins each morning with the vacuum blowers shut down and the battery arrays in need of charging, DC power is applied to the battery array at a current limit set-point of 80 amps and maximum voltage set-point of 28.0 to 28.7 volts, depending on the time of year (battery temperature). The actual charge voltage during the day will increase from an initial value of approximately 25.2 volts to a maximum value that may reach the maximum voltage set-point value. Should the charge voltage reach the maximum voltage set-point, then the absorb (second) stage will begin. The absorb stage will continue over a duration set-point of one hour or longer, depending on the estimated time duration in which the actual charge voltage could potentially exceed the maximum voltage set-point. During this absorb period (continuation of bulk charge period), the charge controller will attempt to maintain the charge voltage at the maximum voltage set-point. Should this charge voltage set-point be reached during the absorb period, then the float (third) stage will begin. During the float stage, the charge controller will reduce the maximum charge voltage to a set-point of 26.0 to 26.7 volts, depending on the time of year (battery temperature), which corresponds to the battery array being fully charged at rest (no current flow to or from the battery array). The float stage continues until the charge controller senses the end of the solar day. During the next morning, the charge controller senses the beginning of the next solar day and initiates the bulk charging stage once again.

On the following table, set-point values for maximum charge voltages under bulk / absorb and float modes, as well as absorb durations, are given for each month of the year. These set-point values are to be programmed into each charge controller during the midpoint of each month.

Monthly Set-point Values for Charge Controllers

Month	Bulk / Absorb Voltage Set-point (V) (in ppbv)	Float Voltage Set-point (volts)	Absorb Duration (hours)
January	28.7	26.7	1
February	28.6	26.6	1
March	28.6	26.6	1
April	28.4	26.4	1
May	28.2	26.2	1
June	28.0	26.0	1
July	28.0	26.0	1
August	28.1	26.1	1
September	28.1	26.1	1
October	28.3	26.3	1
November	28.4	26.4	1
December	28.6	26.6	1

The LCD displays on the charge controllers also indicate the daily accumulated absorb and float times for monitoring and recording.

3.5.3 Blower Motor Control

The source of DC power to the SVE-1 and SVE-2 blower motors is shared by the common battery array and the respective solar arrays via the respective charge controllers. DC power is enabled to the DC-to-AC inverter for SVE-1 and the motor controller for SVE-2, and blower motors via respective load controllers only when the charge voltage to the battery array increases to 26.6 volts, as sensed by the load controllers. Later in the day, when the discharge voltage from the battery array decreases to 24.2 volts, DC power is disabled to the blower motors, as sensed again by the load controllers. This load control provision 1) prevents the depth-of-discharge of the battery array from decreasing below 50% and 2) protects the blower motors from a potentially damaging overload (high current) condition at the reduced voltage.

The load controllers are programmed to energize and de-energize relay SS-1 upon actuation of internal high and low voltage switches, respectively, resulting in the starting and stopping of the respective blower motors (see Morningstar Tri-Star Solar System Controller Installation and Operation Manual in Attachment D). Only the low voltage switch set-point (24.2 volts) is programmed within the load controller (by configuring the DIP switches). The high voltage switch set-point (26.6 volts) is programmed into the load controller via associated software.

The AC power to the SVE-1 blower motor is controlled through the Magnum RD3924 DC-to-AC inverter (see Magnum RD Series Inverter/Chargers Operators Manual in Attachment D). The operating parameters for the inverter are set with the Magnum ME-RC Remote Control (see Magnum ME-RC Remote Control Owner's Manual in Attachment D). Normal operating parameters have been set for the inverter, and changes are not anticipated to be necessary. The remote control is also used to diagnose faults that may occur.

The DC power to the SVE-2 blower motor is controlled through a motor controller (see Minarik Automation & Control User's Manual in Attachment D). The motor controller features a speed-adjust potentiometer that limits motor (and blower) speed, as well as several dashpots for adjustable control of motor starting and stopping characteristics and current draw limitation. The appropriate adjustments have been applied to the motor controller. Further adjustments are not anticipated to be necessary.

4. ROUTINE MAINTENANCE PROCEDURES

Routine inspection and maintenance of the SVE units are to be performed on an intermittent to periodic basis, concurrently with operations monitoring activities. As described below and summarized in Table 2, inspection and maintenance activities are to be conducted for PDB-1 and PDB-2 and associated belt drives, the air filter at SVE-2, Well SGS condensate sump, both condensate separators, and both GAC adsorbers. Each maintenance activity may be initiated after completing the proper shutdown of the SVE units, if necessary, as described under Section 3.4. Upon completion of a given maintenance activity with the SVE units shut down, the SVE units are to be restarted as described under Section 3.3.

Usually, inspection and maintenance activities may be performed by one technician. However, two technicians are required when the maintenance activity poses an undue risk of injury, as discussed under Section 5.

4.1 Routine Inspection and Maintenance

4.1.1 Weekly Inspections and Maintenance

During operation, the following inspections and maintenance tasks are to be conducted on a weekly basis along with operations monitoring activities:

- Check Pitot tubes for proper orientation (dynamic port on axis with pipe). If Pitot tube reading does not appear to be normal, then disconnect tubing from Pitot tube to allow any condensate within Pitot tube to be drawn out by vacuum pressure. Also, drain any condensate from connecting tubes and reconnect to Pitot tube. Also check for any cracking in the nylon Pitot tubes as cracks will allow leakage, resulting in erroneous readings. Cracked tubing should be repaired or replaced.
- Usually from October through April, measure and record condensate levels within condensate separators and Well SGS condensate sump.
- Apply grease to all blower shaft bearings at zerk fittings using No. 2, high-temperature grease, as specified in the blower manufacturer’s instructions (Attachment C).

While in operation, extraction blowers PDB-1 and PDB-2 are to be observed for any of the following conditions:

- unusual or excessive noise or vibration;
- leaking oil;
- overheating;
- reduced throughput (SVE rate);
- oscillating blower / motor speed; and
- excessive inlet vacuum or discharge pressure.

In the unlikely event of an excessive blower inlet vacuum or discharge pressure, check upstream and downstream piping segments, respectively, for cause of apparent flow restriction and resolve. Such condition would cause blower overheating and reduced throughput, and possibly cause unusual or excessive noise or vibration. If excessive inlet or discharge pressure is not observed, then any unusual or excessive noise or vibration, along with reduced throughput, would likely indicate a failing blower fluid end (e.g., rotary lobes out of alignment or worn shaft bearings), unless the blower gear box was unlikely overfilled with oil. In response to this observation, the blower must be immediately shut down. The blower is to be removed and delivered to a qualified blower repair specialist for repair, adjustment, and/or replacement. Consult the blower manufacturer's maintenance and parts manual in Attachment C for further information and instructions.

Should the blower exhibit an oscillating speed, check the respective charge and motor controllers for proper adjustments (see Section 3.5).

4.1.2 Quarterly Inspections and Maintenance

On a quarterly basis, with extraction blowers PDB-1 and PDB-2 shut down and with the associated belt guards removed, inspect belt drives for proper alignment and any worn or frayed belts. Realign belt drive and replace belts, as necessary. As a final preventative maintenance measure, change blower gear box oil (after each 1,000 hours of operation or approximately every three months) as instructed within the blower manufacturer's instructions (Attachment C). Check the brushes on the 1-hp 24 VDC motor on SVE-2 for wear and replace as per manufacturer's instructions (usually when 5/8 inches or less of the brush is remaining). Restart PDB-1 and PDB2 as described under Section 3.4, after cleaning the inlet air filter at SVE-2 (if previously operating in injection mode).

With SVE-1 and SVE-2 in operation, check all process piping for any apparent leakage. Repair any leaks, as appropriate.

Check vacuum gauges for proper function by measuring vacuum pressure with water or oil-filled manometer as calibration device. Adjust zero or span on gauge as necessary.

Check surface of solar arrays for presence of dust of other foreign matter (e.g., bird droppings). If dust or other matter is apparent, attempt to clean surface of solar array first with dry mop and squeegee (for bird droppings). Clean water may be used to help dislodge certain foreign matter. Immediately remove excess water with squeegee before any streaks or mineral scaling occurs upon drying.

4.2 GAC Adsorbers Maintenance

As discussed under Section 2.7, GAC adsorbers ACF-1 and ACF-2 are operated in series to remove VOCs from the extracted soil gas stream prior to atmospheric discharge. When the "lead" adsorber can no longer remove VOCs from the soil gas stream, the resulting "breakthrough" condition (to the "lag" adsorber) requires SVE system shut down and replacement of the 2,000-pound carbon bed within the lead adsorber. During operation, potential breakthrough of VOCs from the lead adsorber to the lag adsorber is monitored at a frequency no less than twice annually by collecting process stream vapor samples. When the concentrations of Freon 11 and chloroform in the sample taken from in-between the lead and the lag adsorbers exceeds 65% of the respective concentrations in the influent sample, the carbon in the lead canister is to be replaced. Because the thresholds in Pinal County air quality permit are based on mass flux of total organics instead of individual organic compound, the criteria for carbon change out are based on the concentrations of the two most abundant VOCs in the extracted soil vapor, Freon-11 and chloroform, which account for approximately 80% to 90% of the total VOC mass in extracted soil vapor.

Carbon replacement within the lead adsorber requires removal of the “spent” carbon and replacement with 2,000 pounds of fresh (reactivated) carbon by a GAC services firm (e.g., Siemens Water Technologies). Spent carbon removal is accomplished by vacuuming the material out of the adsorber via the top manway and into a dust collector for continued recovery within bulk bags. The spent carbon within the bulk bags is transported to an off-site carbon reactivation facility (Siemens facility in Parker, Arizona) for recycling. The fresh carbon, delivered within bulk bags, is charged to the adsorber from the top manway.

Once the adsorber is refilled with fresh carbon, the “lead” and “lag” configuration of the two canisters is reversed by changing the configuration of the hoses from the SVE blowers to the outlet stack. This requires the hoses are switched on the inlets and outlets of both canisters such that the old “lead” canister becomes the new “lag” canister (filled with new carbon) and the old “lag” canister becomes the new “lead canister (see Section. 2.7)

4.3 Soil gas Condensate Management

During the cool season from approximately October through April, soil gas moisture will condense within the lateral lines from Wells SGS and SGD to associated condensate separators. The condensate sump within the 4-inch lateral line between Well SGS and SVE-1 will accumulate condensate at the rate of about 6 to 8 inches (10 to 13 gallons) per week during operation in the cool season. At least once per month during operation, with the SVE system inactive during the early morning hours, condensate should be removed from this sump with a bailer or small electric pump to a nearby 55-gallon drum. Failure to remove condensate from this sump could result in the flow of soil gas being restricted within the Well SGS lateral, causing excessive vacuum pressures at PDB-1 and potential blower damage.

When a few inches of condensate are observed within the sight glass of condensate separator KO-1 or KO-2, condensate should be drained from the separator and transferred into a 55-gallon drum (see below). To drain each separator, shut down the respective SVE unit and place a container below the drain valve of the separator and open the valve. When the flow of liquid stops or the container nearly fills, close the valve, empty the container into the drum and repeat, as necessary. Restart the SVE system.

If condensate is observed from the drain valve of a GAC adsorber, then drain the condensate into a container and transfer into a 55-gallon drum.

Condensate removed from the Well SGS condensate sump, KO-1 and KO-2, and GAC adsorbers is placed within the open-top, 55-gallon drums (located near to the condensate sump) and allowed to evaporate. The drums are covered with metal screen to prevent wildlife from entering.

4.4 Solar Array Adjustment

Twice per year, the planar angle of the solar arrays relative to horizontal is to be adjusted to increase the effective area available for solar energy capture. These adjustments should be made near the time of the equinox (approximately April and October). The technicians can discuss the need for this adjustment. The present capacity of the solar arrays (4295 watts) is considerably greater than the power needed to run both blower motors (approximately 2200 to 2300 watts). The SVE components receive more protection from the sun with the panels set at 48 degrees relative to horizontal. If the system operating time starts to decrease as the summer months approach, then the planar angle of the solar arrays can then be adjusted.

4.4.1 Spring Adjustment

4.4.1.1 SVE-1and SVE-2 Solar Arrays and Auxiliary Arrays

- At the SVE-1 solar array, unclip the guy wires from the concrete anchors on the south side of the array.
- Tilt the array back (down on the north side) and remove the lowest section of chain on the north side of the array until the planar angle of the array relative to horizontal is 18 degrees.
- Place the sections of chains removed from the north side of the array and insert inwires on the south side of the array and reattached to the concrete anchors. Adjust the turnbuckles to remove the slack in the wires.
- On each auxiliary array, loosen the wing nuts on the side of the support rack mounting collar and the nuts on the pivot point of the panel array where it connects to the support pole. Adjust the solar array to an angle of 18 degrees from horizontal, as indicated on the collar. Tighten all nuts.

4.4.2 Fall Adjustment

4.4.2.1 SVE-1and SVE-2 Solar Arrays and Auxiliary Arrays

- At the SVE-1 solar array, unclip the guy wires from the concrete anchors on the north side of the array.
- Tilt the array forward (up on the north side) and remove the lowest section of chain from the south side of the array until the planar angle of the array relative to horizontal is 48 degrees.
- Insert the chain removed from the south side into the north side of the array and reattached to the concrete anchors. Adjust the turnbuckles to remove the slack in the wires.
- On each auxiliary array, loosen the wing nuts on the side of the support rack mounting collar and the nuts on the pivot point of the panel array where it connects to the support pole. Adjust the solar array to an angle of 48 degrees from horizontal, as indicated on the collar. Tighten all nuts.

5. SITE HEALTH AND SAFETY

A number of potential health hazards are present on site, as there are in any industrial process operation. Operations at the site will be accomplished in accordance with established health and safety guidelines. In addition to the general health and safety concerns for work at the site, specific potential hazards associated with the SVE system are outlined below. Please note that other hazards not listed below may be present at the site.

5.1 Electrical

Direct human contact with DC electricity could result in severe injury or death. **Any servicing, modification or rewiring of the electrical system must be performed by a qualified electrician.** Before servicing any electrical systems (e.g., control panels, motors, solar panels), the source of electrical power to the system (i.e., solar and battery arrays) must first be isolated and then verified by the use of a voltmeter.

Electrical power to a given control panel is isolated by rotating the respective main disconnect switch to the “Off” position. **Be aware that power from the solar panels to the “hot” side of the 10-amp circuit breakers is still present even if the circuit breakers are off, provided the panels are receiving solar radiation. Electrical power to the “hot” side of the circuit breakers can only be isolated by disconnecting the positive cables at the disconnect fittings located directly beneath the solar arrays.**

The battery array, consisting of 16 each, 6-volt AGM batteries, interconnected as four parallel sets of four batteries in series, is a source of 24-volt DC power to each control panel, in addition to the solar arrays. DC power from the battery array is isolated at each main disconnect switch. The battery array has an electrical rating of 896 AH over a 24-hour duration, and is capable of delivering over 100 amps of DC power. For this reason, the battery array is housed within two, grounded electrical cabinets for personnel protection. The battery array does not require routine maintenance, as each battery is sealed. Eventually, the batteries will require replacement (after roughly 1,000 cycles or three years), which must be performed only by a qualified electrician.

With each main disconnect switch in the “off” position, the “hot” side of each switch will continue to be “hot” where connected to the battery array. For this reason, servicing of each main disconnect switch must be performed by a qualified electrician.

5.2 Blower Belt Drives

SVE blowers PDB-1 and PDB-2 are driven by the electric motors via belt drives that transfer torsional power from the motors to the blowers. Belt guards enclose the belt and sheave assemblies to prevent possible injury. The blowers must not be operated without the belt guards in place, unless the shaft rotational speeds of the blowers and motors are being measured. **During shaft rotational speed measurement, a second technician must be present to shut down the SVE system should the first technician inadvertently come in contact with the rotating belt drive.**

5.3 Biological Hazards

The SVE system is located in an unpaved, rural setting with arid climate. Rattlesnakes, poisonous insects, and arachnids may be present around and beneath system components. Personnel should use caution when approaching system components and when placing hands and other unprotected skin in concealed areas.

5.4 Lifting

Back strain and other injuries can occur when lifting heavy objects. Use proper lifting techniques and lift with the legs, keeping the back straight. Heavy objects, such as blowers, motors, and other equipment may require two people or mechanical assistance, such as a forklift.

5.5 Slipping, Tripping, and Falling

Personnel may encounter muddy or uneven walking surfaces during operating and maintenance activities. Proper footwear and vigilance will help prevent injury. All work areas should be maintained in a neat, orderly fashion. All tools and supplies must be properly stored and secured when not in use.

Ladders used to access the GAC adsorbers, solar arrays, or other system equipment must be used as intended by the manufacturer. Place ladders on stable, solid ground that will not shift or enable slippage. Under no circumstances shall anyone stand on the top rung of a ladder.

6. OPERATING PERFORMANCE MONITORING AND SAMPLING PLAN

When the SVE system is in operation, on a weekly, monthly, and quarterly basis, in combination with routine inspection / maintenance activities, the SVE system (SVE-1 and SVE-2) is to be monitored for proper performance by recording applicable operating parameters indicated by local instruments, measuring and recording other operating parameters with hand-held instruments (Section 6.1), and collecting process gas samples for laboratory analysis (Section 6.2), as described below. Performance monitoring and inspection/maintenance activities may not be performed when the SVE system is not operating.

6.1 Operating Performance Monitoring

Various operating parameters are to be monitored on a regular basis to ensure proper system function and performance. These operating parameters are characterized as either process or electrical parameters. The process parameters (Section 6.1.1) apply to the flow of soil gas and VOCs through the SVE system. The electrical parameters (Section 6.1.2) apply to the flow of DC and AC power through the SVE system, from the solar and battery arrays to the blower motors.

6.1.1 Process Parameters

From the process parameters identified below, daily and cumulative soil gas extraction volumes and VOC recoveries are to be calculated for SVE-1 and SVE-2 (if operating in extraction mode) within an Excel spreadsheet. Additionally, daily and cumulative air injection volumes are to be calculated for SVE-2, if operating in air injection mode. Respective AC or DC power requirements are also to be calculated for air compression through the blowers, enabling the calculation of blower mechanical efficiencies from certain electrical parameters.

Weekly Process Data Collection during Operation

During operation, the following process parameters are to be recorded on a weekly basis on field data sheets (Attachment F) for subsequent transfer into the Excel spreadsheet:

- Hour meter reading on each SVE system control panel;
- Well SGS and SGD wellhead pressures as measured by a portable pressure gauge;
- Vacuum pressure at inlet to each condensate separator as indicated by a portable vacuum pressure gauge;
- Differential pressure across Pitot tube within each vacuum blower inlet pipe as indicated from associated Magnehelic® gauge or hand-held, digital differential manometer;
- Blower inlet and discharge pressures as measured by respective, portable pressure gauges; and
- Water level within condensate separator as indicated within associated site glass;
- Pressures at inlet and outlet of lead GAC adsorber as measured by a portable pressure gauge.

Monthly Process Data Collection during Operation

During operation, on a monthly basis, soil gas (process stream) samples are to be collected from the valve port at Lead GAC adsorber inlet, and valve port between GAC adsorbers and the valve port on the outlet stack prior to atmospheric discharge, and analyzed for the presence of VOCs using EPA Method TO-15 (see Section 6.2.2). The laboratory results are to be applied to the Excel spreadsheet for use in calculating daily VOC recoveries from the extracted soil gas streams, as well as for confirming whether VOC breakthrough is occurring from the lead GAC adsorber.

Quarterly Process Data Collection during Operation

During operation, on a quarterly basis, during maintenance of each blower belt drive, the blower and motor shafts speeds are to be measured with a tachometer. The indicated speeds are to be recorded on field data sheets (Attachment F) for subsequent transfer into an Excel spreadsheet.

Quarterly Process Data Collection Summary

Data Collection Point	Parameter
SVE-1 Blower Shaft	Shaft Rotational Speed (tachometer reading)
SVE-1 Blower Motor Shaft	Shaft Rotational Speed (tachometer reading)
SVE-2 Blower Shaft	Shaft Rotational Speed (tachometer reading)
SVE-2 Blower Motor Shaft	Shaft Rotational Speed (tachometer reading)

6.1.2 Electrical Parameters

From the electrical parameters identified below, the collective electrical performances of the four solar arrays, SVE-1 and SVE-2 control panels, common battery array, and blower motors are monitored with time to identify changes that may require operating or maintenance actions. The following electrical parameters are to be recorded on a weekly basis during operation on field data sheets (Attachment F) for subsequent transfer into an Excel spreadsheet:

- From the status screen of each charge controller, the instantaneous input voltage and current, instantaneous output (charge) voltage and current, the instantaneous DC power (watts), and the daily accumulated DC power (kilowatt-hours);
- From the end of day summary screen of each charge controller, the peak input voltage and DC power (kilowatt-hours), the maximum and minimum output (charge) voltage, the peak output current, the accumulated amp-hours and DC power (kilowatt-hours), and the accumulated absorb and float times.
- Instantaneous motor current readings as indicated by the ammeter mounted on the control panel CP-2 and via a hand-held multi-meter with an ammeter probe for SVE-1.

6.2 Process Gas Sampling

The following procedures are to be followed for collecting soil gas samples for laboratory analysis (Section 6.2.2). Soil gas samples shall be collected from the valve port at Lead GAC adsorber inlet, the valve port between GAC adsorbers, and the valve port on the outlet stack prior to atmospheric discharge.

Gas samples are to be collected in sample containers provided by the analytical laboratory in accordance with analytical method and sampling protocol. Sample containers shall be prepared by the laboratory and certified as being clean. Sample containers are to be ordered from the laboratory a few days prior to a sampling event.

Gas samples are to be collected in the following order: from 1) the valve port on the outlet stack prior to atmospheric discharge, 2) the valve port between GAC adsorbers, and 3) the valve port at Lead GAC adsorber inlet using the following procedure:

1. Ensure SVE system has been operating normally for at least one-half hour prior to sample collection.
2. Collect gas sample from valve port to be sampled.
3. Purging is not necessary. Connect short length of Teflon or PVC tubing from flow control valve of canister to hose barb on sampling port.
4. Open sample valve and then open canister valve. Leave canister valve open for duration stipulated on flow control valve or as specified by the Analytical Laboratory. Then close sample and canister valves.
5. Remove tubing from valve port and canister.
6. Label canister with sample number (provide by laboratory), date, and time of collection, and enter information on chain-of-custody form.

Sample containers are to be stored in a container in accordance with laboratory requirements and kept under chain of custody until transferred to the laboratory. Collected samples are to be expeditiously transferred to the designated laboratory for analysis of VOCs by EPA Method TO-15.

6.3 Operational Parameters for the SVE System

The operational parameters for the SVE system are summarized below..

- The SVE system shall operate for a minimum of three months within a twelve-month period. Annual average extraction and injection rates (total extraction/injection volume divided by total elapsed time) shall be at or above 9.2 and 3.75 scfm, respectively.

- The SVE system may be operated in a pulsed operation mode to assist in detecting potential threats to groundwater quality.

7. WASTE MANAGEMENT

Wastes generated during O&M of the SVE system consist primarily of soil gas condensate and spent carbon, as addressed in the following sections. Paper towels, rags, product packaging, and other incidental trash generated during the course of O&M activities are to be removed from the site and deposited in a trash receptacle. Used blower oil is to be contained, removed from the site, and recycled. Old grease expelled during blower shaft bearing lubrication is to be scraped from the blower floor plate, contained, and deposited in a trash receptacle.

7.1 Spent Carbon

As discussed in Section 4.2, when “breakthrough” of VOCs occurs from the lead GAC adsorber, the spent carbon within this adsorber is to be replaced with fresh carbon by a GAC services firm. Prior to transporting the spent carbon to an off-site reactivation facility for recycling, the carbon must be sampled, analyzed, and profiled for acceptance by the reactivation facility and proper waste identification for over-the-road transport. Previously, a sample of the spent carbon was analyzed in the laboratory and found not to exceed the toxicity characteristic leaching procedure (TCLP) criteria for any regulated VOC. Accordingly, the spent carbon does not need to be manifested for shipping as a hazardous waste. The spent carbon profile has been accepted by the reactivation facility.

The existing waste profile expired on March 12, 2011.Laboratory analyses and profiling of spent carbon will be updated.

7.2 Condensate Disposal

As discussed in Section 4.3, soil gas condensate is recovered to 55-gallon drums from the Well SGS condensate sump, condensate separators, and GAC adsorbers. Waterproof gloves (e.g., latex) are to be worn to limit exposure when handling condensate. Previously, the condensate has been sampled, analyzed, and found to contain low concentrations of VOCs (<700 µg/L based upon tetrachloroethene). Accordingly, the condensate is not characterized as a RCRA waste. For this reason, the aqueous condensate and any dissolved VOCs are allowed to evaporate to the atmosphere from within the drums, as the selected disposal option. Additional sampling and analysis of the drummed condensate should not be necessary, unless the disposal option is changed.

8. DATA MANAGEMENT AND REPORTING

Operating performance monitoring and sampling data collected from the SVE system (Section 6) are to be assembled during each month when the system is in operation, along with a description of any extraordinary maintenance activities. Operating performance monitoring data are to be transferred into an Excel spreadsheet from completed field data sheets and project field notebook entries. In addition, soil gas analytical laboratory reports are recorded electronically with laboratory data also entered into the Excel spreadsheet for calculation of VOC recovery and carbon spending rates.

Reporting to regulatory agency will be performed in accordance with the most current version of the Expanded Groundwater Detection Monitoring Plan.

9. REFERENCES

HGC, 2005a, Preliminary Screening Risk Assessment, University of Arizona Page-Trowbridge Ranch Landfill, Pinal County, Arizona. January 20, 2005

HGC, 2005b, Page-Trowbridge Ranch Interim Measures Package Description Document, Page-Trowbridge Ranch Interim Measures—Issue for Construction. September 30, 2005.

TABLES

TABLE 1

SVE System Contact List

Page-Trowbridge Ranch Landfill

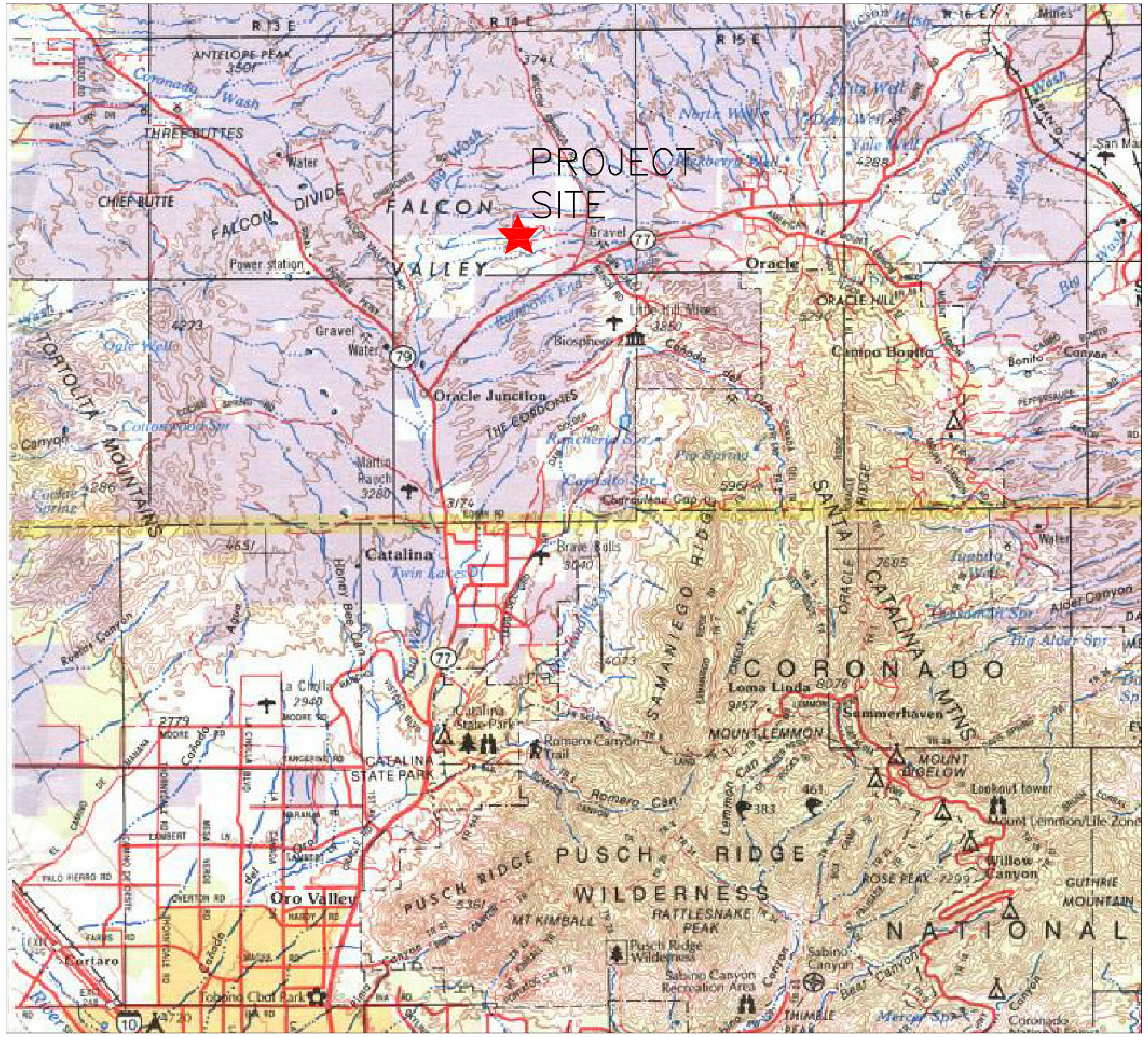
Contact	Affiliation	Role	Phone Numbers	E-mail Address
Steve Holland	University of Arizona	Risk Manager	(520) 621-1790	sholland@email.arizona.edu
Lloyd Wundrock	University of Arizona	Site Manager	(520) 621-1590	lloydw@email.arizona.edu
Jeff Christensen	University of Arizona	Hazardous Waste Supervisor	(520) 621-5861	jgchrist@email.arizona.edu
Scott Winegarden	Siemens Water Technologies	Carbon Vendor	(602) 421-8305	scott.winegarden@siemens.com
Gilbert Preciado	Sunstate Equipment	Rental Equipment	(520) 623-6121	
	Solberg Mfg	Air Filter	(630) 773-1363	

TABLE 2
Maintenance Schedule
Page-Trowbridge Ranch Landfill

Task	Weekly	Quarterly	As Required
Record date and time of site visit	X		
Check Pitot tubes	X		
Check for condensate accumulations - transfer to drums	X		
Observe PDB-1 and PDB-2 for any abnormal conditions	X		
Inspect belt drives - realign or replace belts		X	
Lubricate PDB-1 and PDB-2 - change gear oil		X	
Inspect process piping for leakage		X	
Check accuracy of vacuum gauges		X	
Check / clean surface of PV panels		X	
Adjust tilt angle of solar arrays			X
Carbon replacement			X

ATTACHMENT A

AS-BUILT DRAWINGS	
Drawing 1	Cover Sheet
Drawing 2	Overall Site Plan & Compound Plan
Drawing 3	Process Flow Diagram
Drawing 4	Details
Drawing E-2A	Electrical Single-Line Diagram



LOCATION MAP

NORTH

0 4 8

SCALE IN MILES

DRAWING INDEX

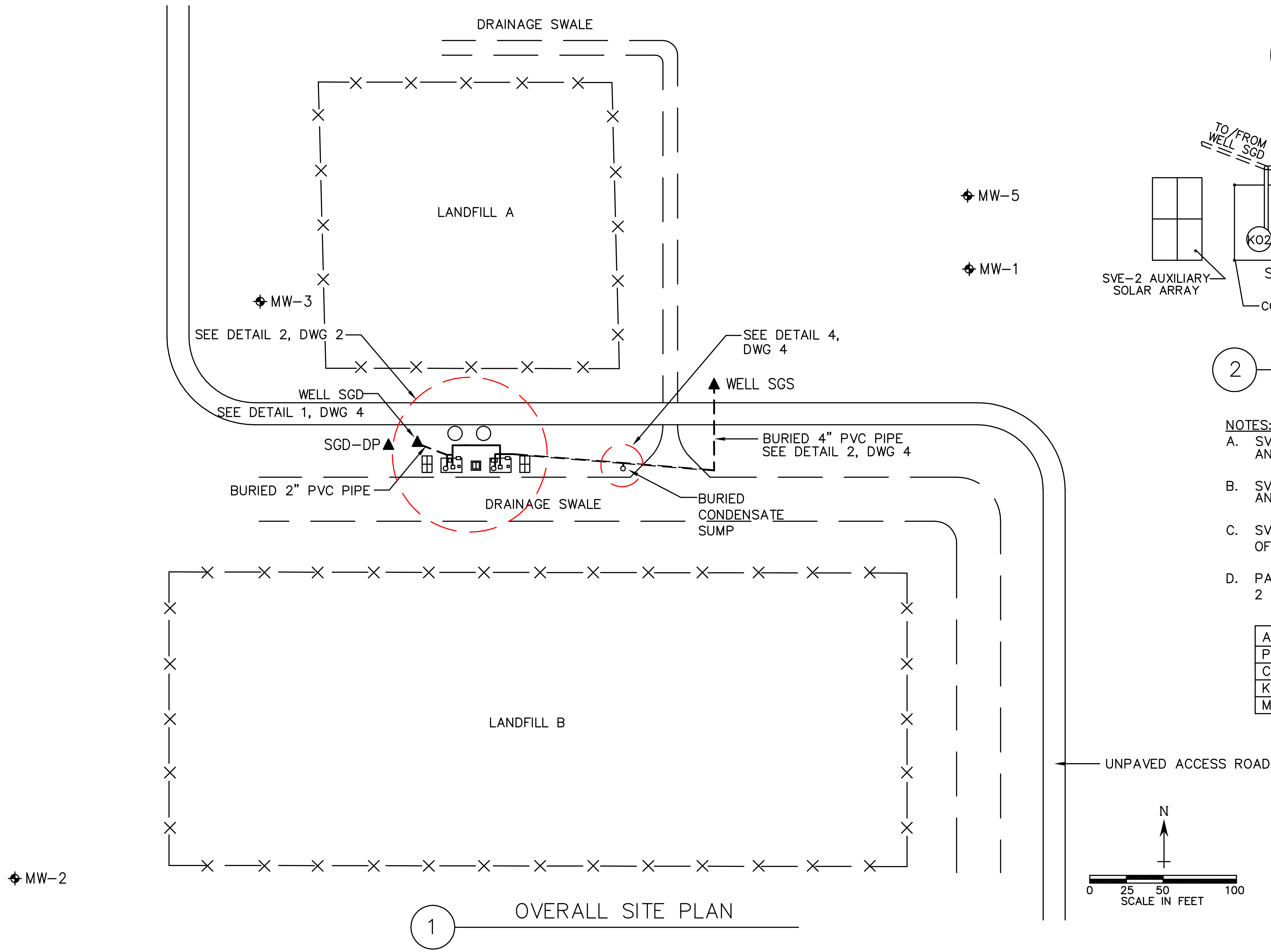
DWG NO.	TITLE
1	COVER SHEET
2	OVERALL SITE PLAN & COMPOUND PLAN
3	PROCESS FLOW DIAGRAM
4	DETAILS
E-2A	ELECTRICAL SINGLE-LINE DIAGRAM

DRAWINGS FOR:

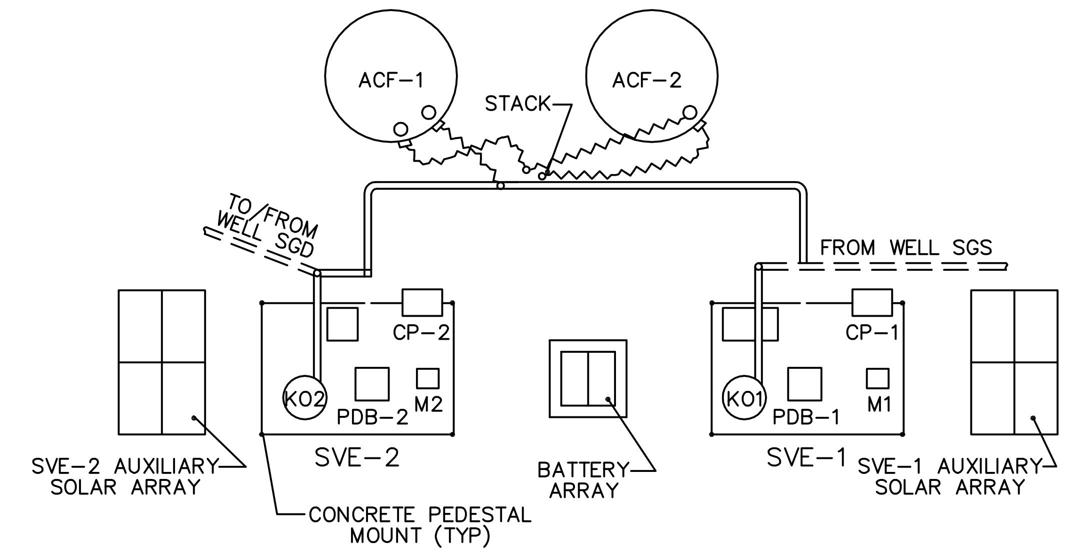
STATE OF ARIZONA DEPT. OF ADMINISTRATION
PAGE-TROWBRIDGE RANCH LANDFILL INTERIM MEASURES

BY:
HYDRO GEO CHEM, INC.

HYDRO GEO CHEM, INC.	PAGE RANCH LANDFILL INTERIM MEASURES COVER SHEET					
	Approved	Date	Revised	Date	Reference	Figure
	DAD	12/04/08			7934004A	1



1 OVERALL SITE PLAN



2 COMPOUND PLAN

NTS

NOTES:

A. SVE-1 SOLAR ARRAY CONSISTS OF SEVEN 185 WATT PANELS AND ONE 170 WATT PANEL.

B. SVE-2 SOLAR ARRAY CONSISTS OF THREE 185 WATT PANELS AND FIVE 175 WATT PANELS.

C. SVE-1 AND SVE-2 AUXILIARY SOLAR ARRAYS EACH CONSIST OF FOUR 175 WATT PANELS.

D. PAINT ALL EXPOSED PVC PIPES WITH WHITE LATEX PAINT, 2 COATS.

ACF-1, ACF-2	GAC ADSORBERS
PDB-1, PDB-2	POSITIVE DISPLACEMENT BLOWERS
CP-1, CP-2	CONTROL PANELS
KO1, KO2	KNOCKOUT TANKS
M1, M2	24 VOLT DC MOTORS

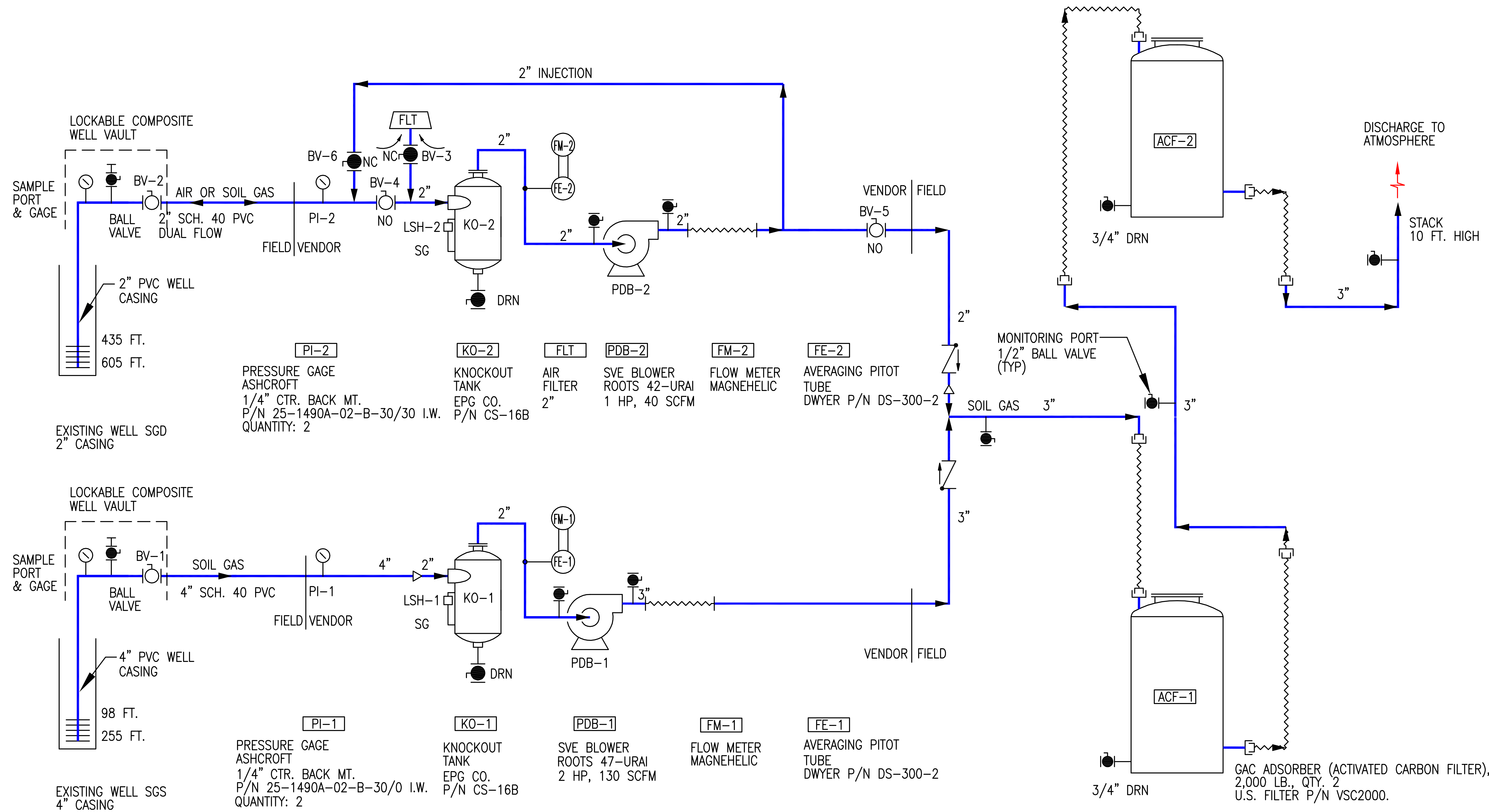
EXPLANATION

- ⌖ EXISTING MONITORING WELL
- ▲ SOIL VAPOR MONITORING WELL

HYDRO GEO CHEM, INC.

PAGE RANCH LANDFILL INTERIM MEASURES
OVERALL SITE PLAN & COMPOUND PLAN

Approved	Date	Revised	Date	Reference	Figure
DAD	12/04/08			7934005A	2

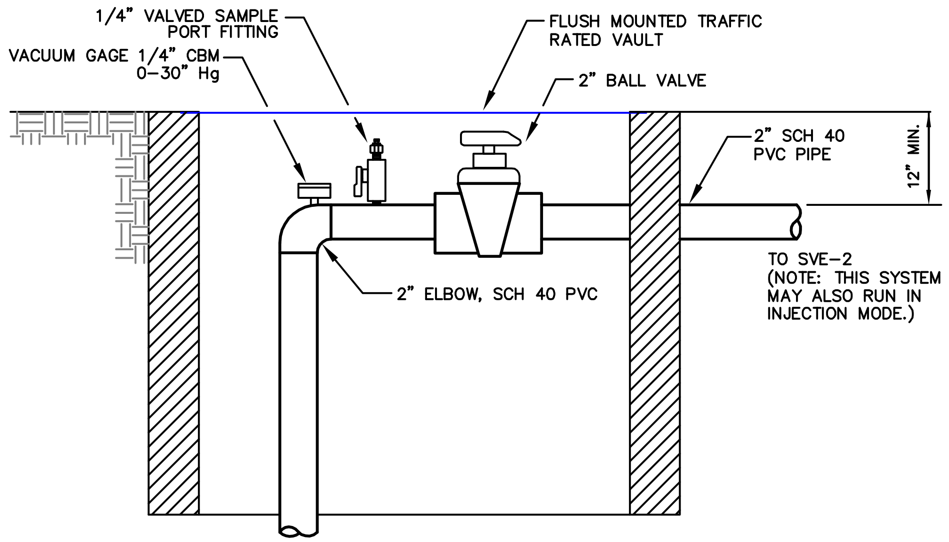


NC = NORMALLY CLOSED
NO = NORMANLLY OPEN
PIPE MATERIALS:
ALL FIELD PIPING IS PVC, SCH. 40, SOLVENT JOINTS.
SKID PIPING IS PVC, SCH. 40, SOLVENT JOINTS.

HYDRO GEO CHEM, INC.

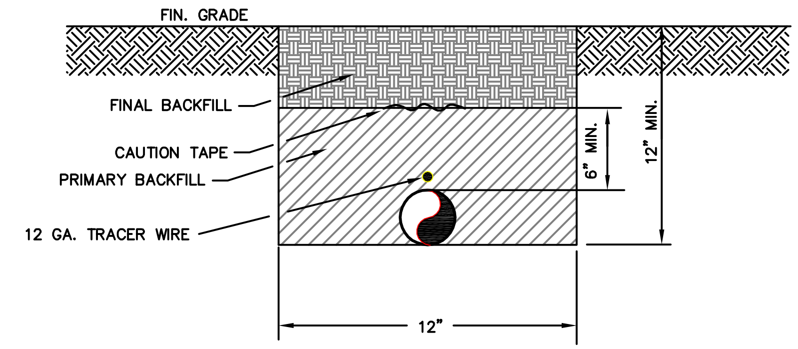
PAGE RANCH LANDFILL INTERIM MEASURES PROCESS FLOW DIAGRAM

Approved	Date	Revised	Date	Reference	Figure
DAD	12/04/08			7934006A	3



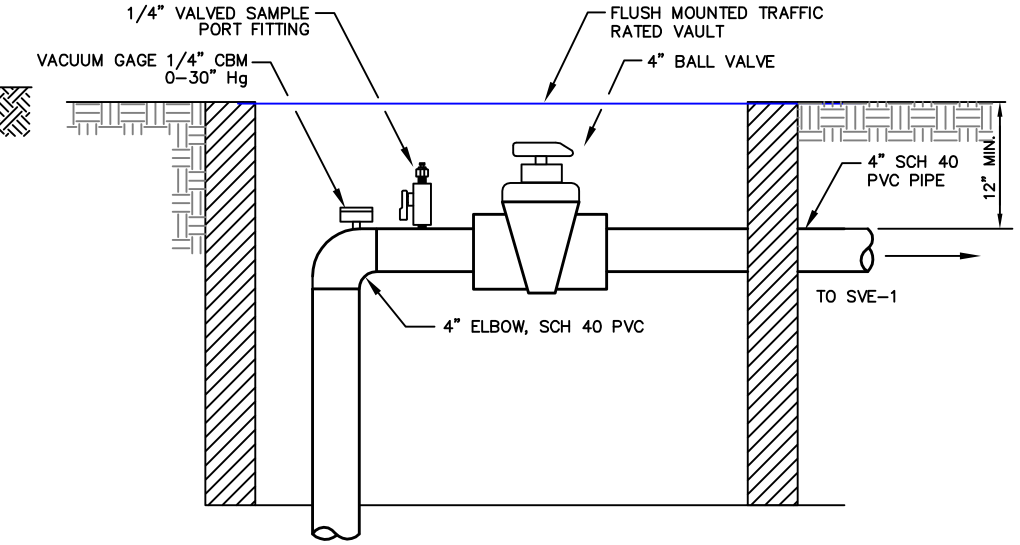
NOTE: SLOPE PIPE MIN. 1% TOWARD WELLHEAD FOR CONDENSATE MANAGEMENT.

(1) 2" DEEP SVE EXTRACTION WELLHEAD ASSEMBLY
NTS



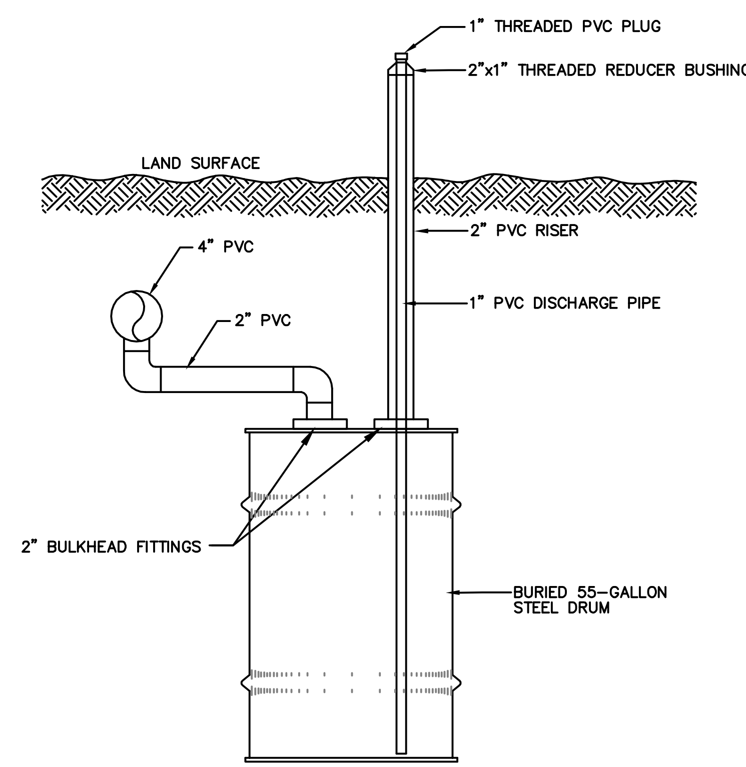
NOTE: TRENCH DEPTH VARIES DUE TO SLOPE GRADIENT TOWARD WELL HEAD OR CONDENSATE SUMP AS PART OF CONDENSATE MANAGEMENT SYSTEM

(2) TRENCH SECTION - SINGLE PIPE
NTS



NOTE: SLOPE PIPE MIN. 1% TOWARD SUMP FOR CONDENSATE MANAGEMENT.

(3) 4" SHALLOW SVE EXTRACTION WELLHEAD ASSEMBLY
NTS

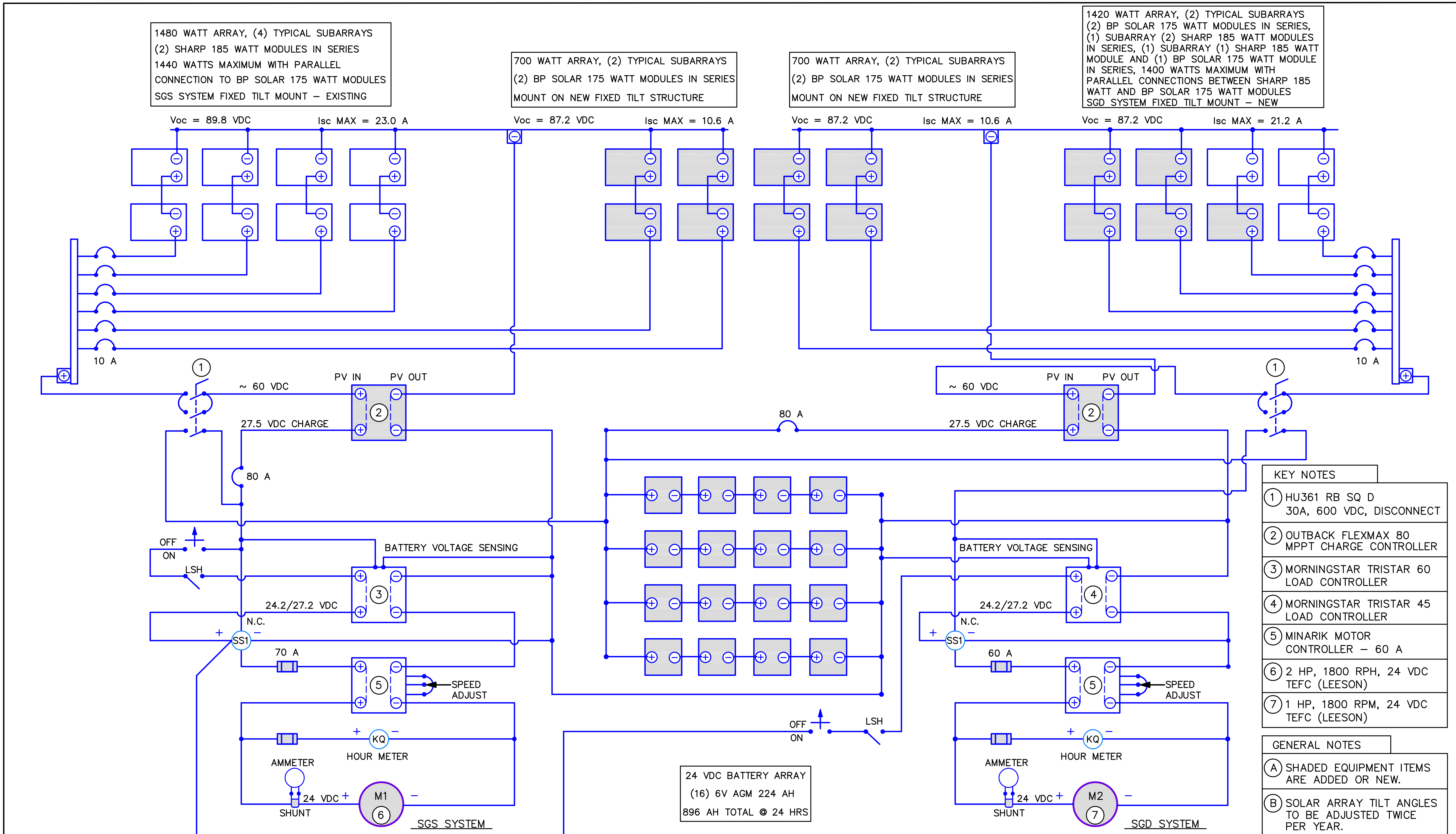


(4) BURIED CONDENSATE SUMP
NTS

HYDRO GEO CHEM, INC.

PAGE RANCH LANDFILL INTERIM MEASURES
DETAILS

Approved	Date	Revised	Date	Reference	Figure
DAD	12/04/08			7934003A	4



HYDRO GEO CHEM, INC.

PAGE TROWBRIDGE RANCH LANDFILL SVE SYSTEM
ELECTRICAL SINGLE-LINE DIAGRAM
AS-BUILT

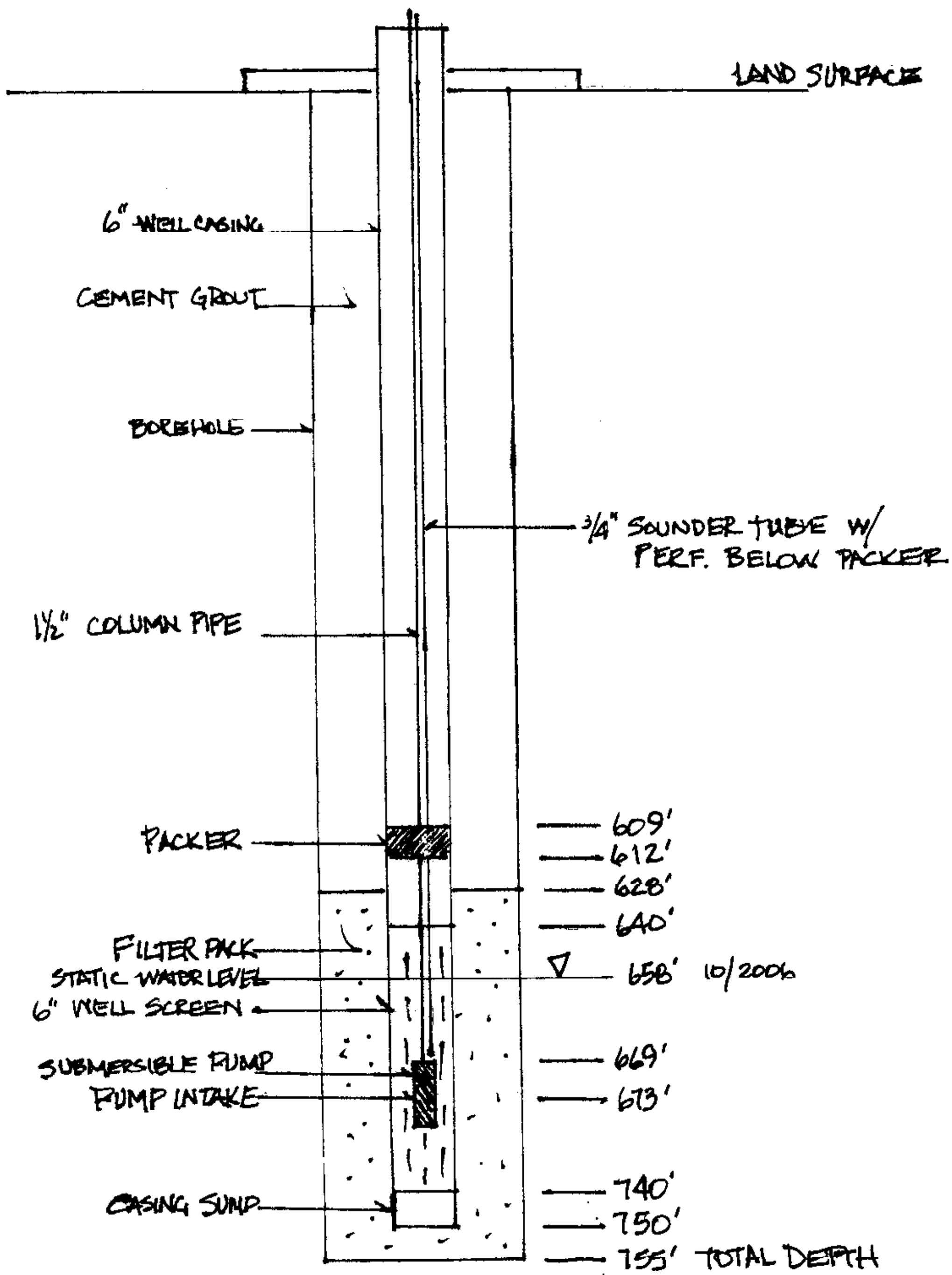
Approved	Date	Revised	Date	Reference	Figure
DAD	12/04/08			7934002A	E-2A

ATTACHMENT B

LITHOLOGIC LOGS AND WELL CONSTRUCTION DETAILS

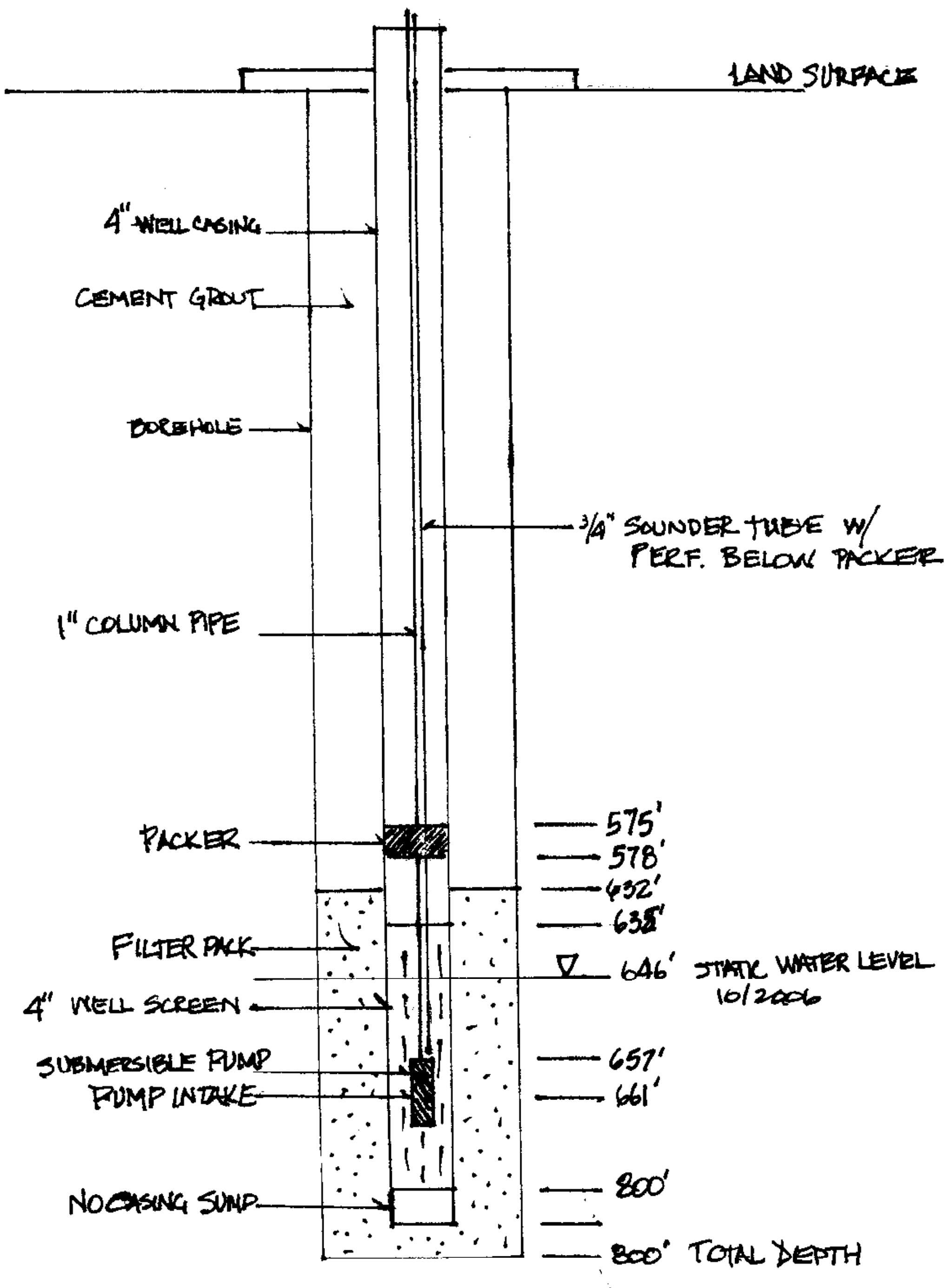
MW-5
MW-2
Well SGS with SGS-SP
Well SGD with SGD-SP and SGD-MP
SGD-2 (SGD-DP)

PAGE-TROWBRIDGE RANCH
MONITOR WELL MW-5



PAGE-TROWBRIDGE RANCH

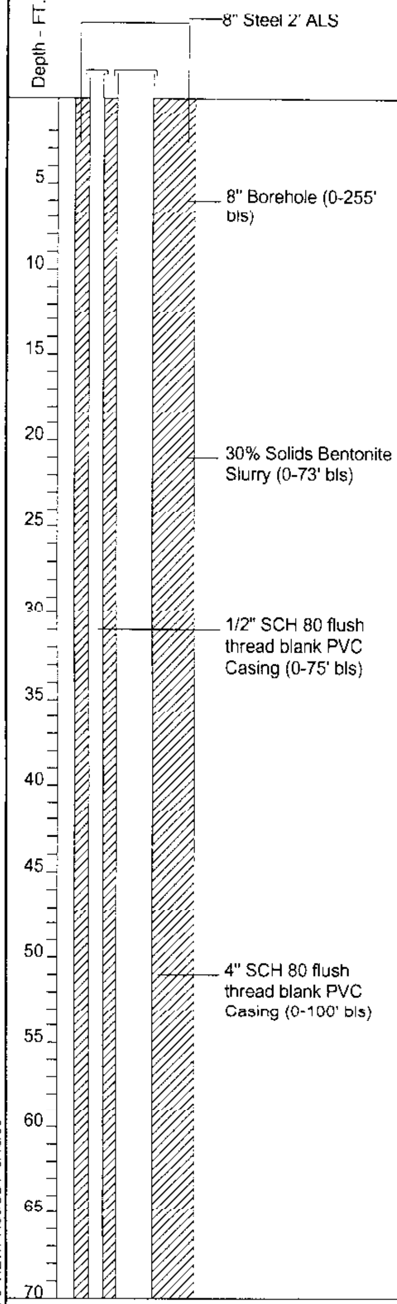
MONITOR WELL MW-2



Project: Page-Trowbridge Ranch Landfill | **Boring:** SGS | Pg. 1 of 4

Drilling Co:	Water Development Corp.	Drilling Method:	Air Rotary	Date Started:	12/2/03
Location:	Between Cells A&B 20' North of Access Road	Sampler:		Date Completed:	12/5/03
		Desc. of Meas Pt:	Land Surface Elev.	Logged by:	W.Thompson
Land Surf. Elev:		Meas. Pt. Elev:		Reviewed by:	B. Anderson

WELL COMPLETION



Depth - FT.	Samples	DESCRIPTION	USCS Symbol	GR	SA	FI	Moisture
0–8	G	SILTY SAND, very pale brown (10YR 7/3); Sand fraction is fine to very fine grained with a few small fractions (less than 5%) up to 2mm in diameter; generally poorly graded; loose; strong reaction to HCl; dry	SM	0	75	25	D
8–21	G	SILTY SAND; pinkish gray (7.5 YR 6/2); as described above, few sand clasts to 3/4" max diameter, subangular to to well rounded, crystalline, quartz, granite; considerable CaCO3 cementaion as caliche; very strong reaction to HCl; dry.	SM	2	68	30	D
21–46		Silt with Sand; light brown (7.5YR 6/4); sand fraction is very fined grained; calcareous; soft, loose; very strong reaction to HCl; dry.	ML	0	10	90	
46–51	G	SILT with SAND; light brown (7.5YR 6/4); cuttings are very consistent. Sand fraction is very fined grained; some fine gravel clasts; quartz to 1/2" max diameter; some calcareous cementation; very strong reaction to HCl; (no moisture given)	ML	2	13	85	
51–56	G	SANDY SILT; pink (7.5YR 7/4);sand fraction is coarse through very fine grained, overall poorly graded; soft, loose, some cementation; very strong reaction to HCl; damp.	ML	0	20	80	M
56–70	G	SILT; light brown (7.5YR 6/4); soft, loose, flour-like texture;very strong reaction to HCl; slightly damp.	ML	0	5	95	M

Columns also present (blank): Blow Count, % Recovery, PID (ppm), Graphic Log.

HYDRO GEO CHEM, INC.

Lithologic Log and Well Construction Details of SGS

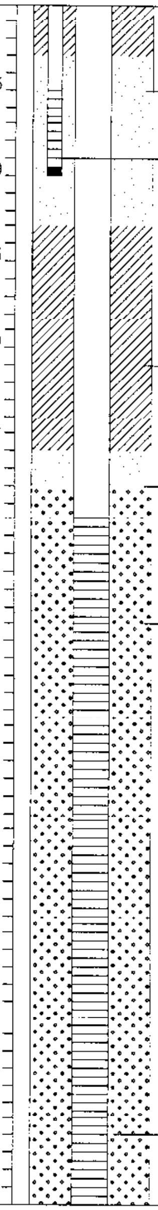
Approved	Date	Revised	Date	Reference:	FIG.
T.Schrauf	1/26/04			793100	1a

HGC-WELL 793100.GPJ NEWPROJ.GDT 9/18/06

Project: Page-Trowbridge Ranch Landfill | **Boring:** SGS | Pg. 2 of 4

Drilling Co:	Water Development Corp.	Drilling Method:	Air Rotary	Date Started:	12/2/03
Location:	Between Cells A&B 20' North of Access Road	Sampler:		Date Completed:	12/5/03
		Desc. of Meas Pt:	Land Surface Elev.	Logged by:	W.Thompson
Land Surf. Elev:		Meas. Pt. Elev:		Reviewed by:	B. Anderson

WELL COMPLETION



- 20/40 Mesh Colorado Silica Sand (73-83' bls)
- 1/2" SCH 80 PVC screen 0.020" slot (75-80' bls)
- 30% Solids Bentonite Slurry (83-96' bls)
- 20/40 Mesh Colorado Silica Sand (96-98' bls)
- 8" Borehole (0-255' bls)
- 4" SCH 80 PVC screen 0.080" slot (100-220' bls)

Depth - FT.	DESCRIPTION	USCS Symbol	GR	SA	FI	Moisture
73-76	SILT; light brown (7.5YR 6/4); soft, loose, flour-like texture;very strong reaction to HCl; slightly damp.*(continued)*					
76-81	SAND with SILT; pinkish gray (7.5 YR 6/2); sand fraction is very coarse through very fine grained; quartz, crystalline aphenites, hues range from white to pink and light through dark gray, fairly well graded; strong reaction to HCl; slightly damp.	SW-SM	0	90	10	M
81-91	SILTY SAND; as above except for an increase in silt fraction.	SM	0	75	25	M
91-101	SANDY SILT; light yellowish brown (10 YR 6/4);sand fraction is fine to very fine grained, well graded to silt fraction; loose, soft; strong reaction ot HCl; slightly damp.	ML	0	30	70	M
101-111	SILTY SAND with GRAVEL; very pale brown (10 YR 7/3); gravel to 1.5" max diameter, subangular to well rounded, crystalline gray aphenite quartz; sand fraction is coarse through very fine grained but is primarily fine grained, loose mix; strong reaction to HCl; dry.	SM	20	60	20	D
111-116	SILT with SAND; brown (7.5 Y5/4); sand fraction is fine to very fine grained; loose, soft; strong reaction to HCl; slightly damp.	ML	0	10	90	M
116-121	SILTY SAND; very pale brown (10 YR 7/3); sand fraction is very fine grained; loose, soft, strong reaction to HCl; slightly damp.	SM	0	60	40	M
121-126	SILT with SAND; brown (7.5 Y5/4); sand fraction is fine to very fine grained; loose, soft; strong reaction to HCl; damp.	ML	0	10	90	M
126-136	SILT; brown (7.5 YR 5/3); soft flour-like texture; very strong reaction to HCl; slightly damp.	ML	0	0	100	M
136-140	SILT with SAND; as above except for trace amount of very fine grained sand.	ML	0	5	95	M

(Columns Blow Count, % Recovery, PID (ppm) blank; Samples: G at each interval.)

HYDRO GEO CHEM, INC.

Lithologic Log and Well Construction Details of SGS

Approved	Date	Revised	Date	Reference:	FIG.
T.Schrauf	1/26/04			793100	1b

Project: Page-Trowbridge Ranch Landfill | **Boring:** SGS | Pg. 3 of 4

Drilling Co:	Water Development Corp.	Drilling Method:	Air Rotary	Date Started:	12/2/03
Location:	Between Cells A&B 20' North of Access Road	Sampler:		Date Completed:	12/5/03
		Desc. of Meas Pt:	Land Surface Elev.	Logged by:	W.Thompson
Land Surf. Elev:		Meas. Pt. Elev:		Reviewed by:	B. Anderson

WELL COMPLETION

1/4 x 1/8" pea gravel (98-255' bls)

4" SCH 80 PVC screen 0.080" slot (100-220' bls)

DESCRIPTION	USCS Symbol	GR	SA	FI	Moisture
SILT with SAND; as above except for trace amount of very fine grained sand. *(continued)*					
SILT with SAND; light yellowish brown (10 YR 6/4); sand fraction is very fine grained; loose, soft, gritty; strong reaction to HCl; damp.	ML	0	10	90	M
WELL GRADED SAND with SILT; light yellowish brown (10 YR 6/4); sand fraction is coarse through very fine grained, subangular to rounded, faily well graded through to silt fraction; loose;strong reaction to HCl; slightly damp.	SW-SM	0	90	10	M
SANDY SILT; light yellowish brown (10 YR 6/4); sand fraction is medium through very fine grained-primarily fine grained; soft, gritty texture; strong reaction to HCl; slightly damp.	ML	0	40	60	M
SANDY SILT; as above except sand fraction is fine to very fine grained and silr fraction has increased.	ML	0	20	80	M
SILTY SAND; pale brown (10 YR 6/3); sand fraction is fine to very fine grained, homogeneous; loose; strong reaction to HCl; slightly damp.	SM	0	80	20	M
SILTY GRAVEL with SAND; pale brown (10 YR 6/3);gravel fraction is fine graded to 1/2" max diameter, subangular to well rounded, dark through light gray cyrstalline aphentites and quartz; sand fraction is coarse through very fined grained, fairly well graded throughout; loose; strong reaction to HCl; damp.	GM	60	20	20	M
SANDY SILT; very pale brown (10 YR 7/3); sand fraction is very fine grained; soft, gritty, loose; Strong reaction to HCl; damp.	ML	0	40	60	M
SILT with SAND; as above with much less sand; soft; slightly damp.	ML	0	10	90	M
SILTY SAND; very pale brown (10 YR 7/3); sand fracrion is very fined grained; very loose; strong reaction to HCl; slightly damp	SM	0	60	40	M

HGC-WELL 793100.GPJ NEWPRO.GDT 9/18/06

HYDRO GEO CHEM, INC.

Lithologic Log and Well Construction Details of SGS

Approved	Date	Revised	Date	Reference:	FIG.
T.Schrauf	1/26/04			793100	1c

Project: Page-Trowbridge Ranch Landfill | **Boring:** SGS | Pg. 4 of 4

Drilling Co: Water Development Corp.	Drilling Method: Air Rotary	Date Started: 12/2/03	
Location: Between Cells A&B 20' North of Access Road	Sampler:	Date Completed: 12/5/03	
	Desc. of Meas Pt: Land Surface Elev.	Logged by: W.Thompson	
Land Surf. Elev:	Meas. Pt. Elev:	Reviewed by: B. Anderson	

WELL COMPLETION: 1/4 x 1/8" pea gravel (98-255' bls)

Samples: G (approx. 212–215'), G (approx. 216–220'), G (approx. 220–255')

Depth - FT.	DESCRIPTION	USCS Symbol	GR	SA	FI	Moisture
212–216	SANDY SILT; as above except that the silt fraction has ?increased?	ML	0	30	70	M
216–221	SILTY SAND; pinkish gray (7.5 YR 7/3); trace gravels, gravel fraction is fine to 1/2" max diameter and is ?tomb?; sand fraction is fine to very fine grained; loose; strong reqaction to HCl; damp.	SM	5	55	40	M
221–255	SANDY SILT; very pale brown (10 YR 7/3); sand fraction is very fine grained; soft; loose; very strong reaction to HCl; slightly damp.	ML	0	25	75	M
255	TD @ 255' bls	ML	0	25	75	M

HGC-WELL 793100.GPJ NEWPROJ.GDT 9/18/06

HYDRO GEO CHEM, INC.

Lithologic Log and Well Construction Details of SGS

Approved	Date	Revised	Date	Reference	FIG.
T.Schrauf	1/26/04			793100	1d

Project: Page-Trowbridge Ranch Landfill | **Boring:** SGD-1 | Pg. 1 of 9

Drilling Co:	Water Development Corp.	Drilling Method:	Air Rotary	Date Started:	12/5/03
Location:	Between Cells A&B South of Access Road	Sampler:		Date Completed:	12/9/03
		Desc. of Meas Pt:	Land Surface Elev.	Logged by:	W.Thompson
Land Surf. Elev:		Meas. Pt. Elev:		Reviewed by:	B. Anderson

WELL COMPLETION

- 10" Steel 2' ALS
- 12" Borehole (0-605' bls)
- 30% Solids Bentonite Slurry (0-98' bls)
- 1/2" SCH 80 flush thread blank PVC Casing (0-100' bls)
- 1/2" SCH 80 flush thread blank PVC Casing (0-195' bls)
- 2" SCH 80 flush thread blank PVC Casing (0-480' bls)

Depth - FT.	Samples	DESCRIPTION	USCS Symbol	GR	SA	FI	Moisture
0–13	G	SILT, pink (7.5YR 7/4); trace sand, sand fraction is fine to very fine grained; slightly cemented, easily broken up; soft; strong reaction to HCl; dry	ML	0	5	95	D
13–21	G	SILT, as above except for very small amount of gravel, subangular to rounded, crystalline aphentites, dark through light gray, some quartz; loose; strong reaction to HCl; dry	ML	2	5	93	D
21–26	G	SILT; light brown (7.5 YR 6/4); soft, powdery, flour-like texture; very strong reaction to HCl; dry	ML	0	0	100	D
26–32	G	SILT; with trace sand; light brown (7.5 YR 6/4); sand fraction coarse through very fine grained; weekly cemented; strong reaction to HCl; dry.	ML	0	5	95	D
32–41	G	SILT; light brown (7.5 YR 6/4); soft, powdery, flour-like texture; slight cementation; strong reaction to HCl; dry.	ML	0	0	100	D
41–46	G	SILTY SAND; light brown (7.5 YR 6/4); sand fraction is medium to very fine grained; minor cementation, fairly loose; strong reaction to HCl; dry.	SM	0	65	35	D
46–51	G	SANDY SILT; light brown (7.5 YR 6/4); sand fraction as described above; moderate cementation; strong reaction to HCl; dry.	ML	0	25	75	D
51–56	G	SANDY SILT; as above, less sand, more silt.	ML	0	10	90	D
56–61	G	SILT; light brown (7.5 YR 6/4); soft, powdery, flour-like texture; strong reaction to HCl; dry.	ML	0	0	100	D
61–66	G	SILT with SAND; light brown (7.5 YR 6/4); sand fraction is fine to very fine grained; soft, gritty texture; strong reaction to HCl; moist.	ML	0	10	90	M
66–70	G		SM	10	50	40	M

HYDRO GEO CHEM, INC.

Lithologic Log and Well Construction Details of SGD-1

Approved	Date	Revised	Date	Reference:	FIG.
T.Schrauf	1/27/04			793100	2a

Project: Page-Trowbridge Ranch Landfill
Boring: SGD-1
Pg. 2 of 9

Drilling Co: Water Development Corp.
Drilling Method: Air Rotary
Date Started: 12/5/03
Location: Between Cells A&B South of Access Road
Sampler:
Date Completed: 12/9/03
Desc. of Meas Pt: Land Surface Elev.
Logged by: W.Thompson
Land Surf. Elev:
Meas. Pt. Elev:
Reviewed by: B. Anderson

WELL COMPLETION

- 1/2" SCH 80 PVC Screen 0.020" slot (100-120' bls)
- 20/40 Mesh Colorado Silica Sand (98-123' bls)
- 30% Solids Bentonite Slurry (123-193' bls)

Depth - FT.	DESCRIPTION	USCS Symbol	GR	SA	FI	Moisture
72-77	SILTY SAND with GRAVEL; light brown (7.5 YR 6/4); gravel fraction to 1" max diameter, subangular to rounded, crystalline; sand fraction is coarse to very fine grained but is primarily fine grained; loose mix; strong reaction to HCl: moist.*(continued)*					
77-84	SAND with SILT; light brown (7.5 YR 6/4); sand fraction is fine to very fine grained; soft; strong reaction to HCl; moist.	ML	0	10	90	M
84-91	SILTY SAND with GRAVEL; brown (7.5 YR 5/4); gravel clast to 1" max diameter, subangular to rounded, crystalline aphentites; sand fraction coarse to very fine grained; loose; strong reaction to HCl; moist.	SM	35	50	15	M
91-96	SILT with SAND; light brown (7.5 YR 6/4); trace gravel to 1/2" max diameter, subangular to rounded; sand fraction is very fine grained; soft; strong reaction to HCl; moist.	ML	5	10	85	M
96-101	SILT; light brown (7.5 YR 6/4); soft, flour-like texture; strong reaction to HCl; moist.	ML	0	0	100	M
101-106	SILTY SAND; light yellowish brown (10 YR 6/4); sand fraction is fine to very fine grained; soft, loose mix; strong reaction to HCl; moist.	SM	0	60	40	M
106-116	WELL-GRADED SAND with GRAVEL; light yellowish brown (10 YR 6/4); gravel fraction is fine grained to 1/2" max diameter, subangular to rounded; sand fraction is coarse to very fine grained, fairly well graded; loose; strong reaction to HCl; moist.	SW	10	85	5	M
116-121	SILTY SAND; with trace gravel; yellowish brown (10 YR 5/4), as described above except for decrease in gravel fractions and increase in silt fraction.	SM	5	75	20	M
121-126	SANDY SILT; light yellowish brown (10 YR 6/4); sand fraction is very fine grained; soft, gritty texture; strong reaction ot HCl; moist.	ML	0	25	75	M
126-136	SILT; light yellowish brown (10 YR 6/4); soft, flour-like texture; strong reaction to HCl; moist.	ML	0	5	95	M
136-140	SILT; with gravel and sand; yellowish brown (10 YR 5/6); gravel fraction to 1" max diameter, subangular to rounded; soft, loose; strong reaction to HCl; moist.	ML	10	10	80	M

HYDRO GEO CHEM, INC.

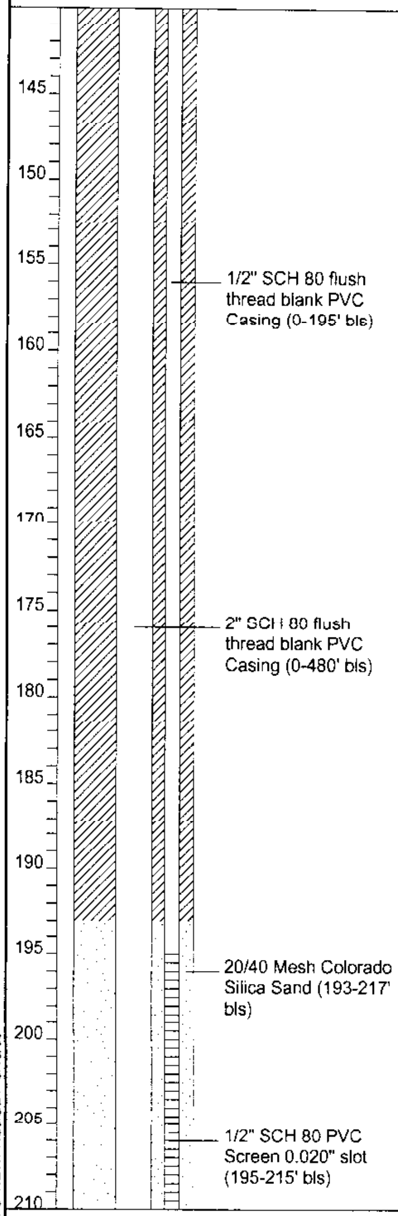
Lithologic Log and Well Construction Details of SGD-1

Approved	Date	Revised	Date	Reference:	FIG.
T.Schrauf	1/27/04			793100	2b

Project: Page-Trowbridge Ranch Landfill | **Boring:** SGD-1 | Pg. 3 of 9

Drilling Co: Water Development Corp.	Drilling Method: Air Rotary	Date Started: 12/5/03	
Location: Between Cells A&B South of Access Road	Sampler:	Date Completed: 12/9/03	
	Desc. of Meas Pt: Land Surface Elev.	Logged by: W.Thompson	
Land Surf. Elev:	Meas. Pt. Elev:	Reviewed by: B. Anderson	

WELL COMPLETION



Depth - FT.	Samples	DESCRIPTION	USCS Symbol	GR	SA	FI	Moisture
146–151	G	SANDY SILT; light yellowish brown (10 YR 6/4); sand fraction is fine to very fine grained; soft, flour-like texture; strong reaction to HCl; moist.	ML	0	15	85	M
151–156	G	SANDY SILT; as described above except for increase in sand fraction.	ML	0	40	60	M
156–163	G	GRAVELLY SILT with SAND; yellowish brown (10 YR 5/4); gravel fraction to 1" max diameter, subangular to rounded, crystalline aphentites, dark through light gray, quartz; sand fraction is coarse through fine grained but primarily fine grained; loose mix; strong reaction to HCl; moist.	SM	30	40	30	M
163–176	G	SANDY SILT; yellowish brown (10 YR 5/4); sand fraction is fine to very fine grained; soft, powdery, gritty texture; strong reaction to HCl; moist.	ML	0	20	80	M
176–181	G	GRAVELLY SILT; light yellowish brown (10 YR 6/4); gravel fraction to 1/2" max diameter, subangular to rounded; sand fraction is coarse through very fine grained, well graded to silt fraction; loose; strong reaction to HCl; moist.	SM	20	65	15	M
181–186	G	SILTY SAND; brown (7.5 YR 5/4); sand fraction is fine to very fine grained; loose; strong reaction to HCl; moist.	SM	0	80	20	M
186–191	G	SILT with SAND; brown (7.5 YR 5/4); sand fraction is fine to very fine grained; soft, gritty, flour-like texture; strong reaction to HCl; moist.	ML	0	10	90	M
191–196	G	SILT with SAND; as describe above except for a small amount of gravel to 1" max diameter, subangular to rounded, crystalline.	ML	5	10	85	M
196–201	G	SILTY SAND with GRAVEL; brown (7.5 YR 5/4); gravel fraction is fine grained to 1/2" max diameter, subangular to rounded; sand fraction is coarse to very fine grained, fairly well graded; loose; strong reaction to HCl; moist.	SM	10	65	25	M
201–210	G	as above except for increase in silt fraction.	ML	0	60	40	M

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HYDRO GEO CHEM, INC.

Lithologic Log and Well Construction Details of SGD-1

Approved	Date	Revised	Date	Reference:	FIG.
T.Schrauf	1/27/04			793100	2c

Project: Page-Trowbridge Ranch Landfill | Boring: **SGD-1** | Pg. 4 of 9

Drilling Co: Water Development Corp. | Drilling Method: Air Rotary | Date Started: 12/5/03

Location: Between Cells A&B South of Access Road | Sampler: | Date Completed: 12/9/03

Desc. of Meas Pt: Land Surface Elev. | Logged by: W.Thompson

Land Surf. Elev: | Meas. Pt. Elev: | Reviewed by: B. Anderson

WELL COMPLETION

- 30% Solids Bentonite Slurry (217-433' bls)
- 2" SCH 80 flush thread blank PVC Casing (0-480' bls)

Depth - FT.	Samples	DESCRIPTION	USCS Symbol	GR	SA	FI	Moisture
212-216	G	as above except for increase in silt fraction. *(continued)*					
216-231	G	SANDY SILT; brown (7.5 YR 5/4); sand fraction is fine to very fine grained; soft, gritty texture; strong reaction to HCl; moist.	ML	0	30	70	M
231-251	G	SANDY SILT; brown (7.5 YR 5/4); as above except for increase in silt fraction.	ML	0	20	80	M
251-280	G	SILTwith SAND; brown (7.5 YR 5/4); sand fraction is very fine grained, flour-like texture; strong reaction to HCl; moist.	ML	0	10	90	M

Columns also printed: Blow Count, % Recovery, PID (ppm), Graphic Log. ESTIMATED % OF: GR, SA, FI.

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HYDRO GEO CHEM, INC.

Lithologic Log and Well Construction Details of SGD-1

Approved	Date	Revised	Date	Reference:	FIG.
T.Schrauf	1/27/04			793100	2d

Project: Page-Trowbridge Ranch Landfill — **Boring:** SGD-1 — Pg. 5 of 9

Drilling Co: Water Development Corp.	Drilling Method: Air Rotary	Date Started: 12/5/03	
Location: Between Cells A&B South of Access Road	Sampler:	Date Completed: 12/9/03	
	Desc. of Meas Pt: Land Surface Elev.	Logged by: W.Thompson	
Land Surf. Elev:	Meas. Pt. Elev:	Reviewed by: B. Anderson	

WELL COMPLETION

- 30% Solids Bentonite Slurry (217-433' bls)
- 2" SCH 80 flush thread blank PVC Casing (0-480' bls)

Depth - FT.	Samples	DESCRIPTION	USCS Symbol	GR	SA	FI	Moisture
283-291	G	SILTwith SAND, brown (7.5 YR 5/4); sand fraction is very fine grained, flour-like texture; strong reaction to HCl; moist.*(continued)*					
291-299	G	SAND with SILT; very pale brown (10 YR 7/3); sand fraction is medium through very fine grained, fairly well graded to silt fraction; loose; strong reaction to HCl; moist.	SW-SM	0	90	10	M
299-331	G	SANDY SILT; brown (7.5 YR 5/4); sand fraction is fine to very fine grained; soft, gritty flour-like texture; strong reaction to HCl; moist.	ML	0	20	80	M
331-336	G	SAND with SILT; yellowish brown (10 YR 5/4); sand fraction is medium through very fine grained, fairly well graded through to the silt fraction; loose strong reaction to HCl; moist.	SW-SM	0	90	10	M
336-346	G	SILTY SAND; dark yellowish brown (10 YR 4/4); sand fraction is very fine grained; soft; strong reaction to HCl; moist.	SM	0	60	40	M
346-350	G	SANDY SILT with minor clay; dark yellowish brown (10 YR 4/4); sand fraction is very fine grained; soft, slightly ?cohesive?, slightly sticky; strong reaction to HCl; moist.	ML	0	40	60	M

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Lithologic Log and Well Construction Details of SGD-1

Approved	Date	Revised	Date	Reference:	FIG.
T.Schrauf	1/27/04			793100	2e

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Project: Page-Trowbridge Ranch Landfill | **Boring:** SGD-1 | Pg. 6 of 9

Drilling Co: Water Development Corp. | Drilling Method: Air Rotary | Date Started: 12/5/03

Location: Between Cells A&B South of Access Road | Sampler: | Date Completed: 12/9/03

Desc. of Meas Pt: Land Surface Elev. | Logged by: W.Thompson

Land Surf. Elev: | Meas. Pt. Elev: | Reviewed by: B. Anderson

Depth - FT.	Well Completion	Samples	Depth - FT.	Description	USCS Symbol	GR	SA	FI	Moisture
352–360		G	352–360	SANDY SILT; as describe above except that clay fraction is absent and silt fraction has increased.	ML	0	30	70	M
360–405		G	360–405	SILTY SAND; dark brown (7.5 YR 4/?)???doesn't match; sand fraction is coarse through very fine grained but, is primarily fine grained; soft, gritty texture; weak reaction to HCl; moist.	SM	0	70	30	M
405–415	30% Solids Bentonite Slurry (217-433' bls)	G	405–415	SANDY SILT; dark brown (10 YR 4/3??doesn't match???); sand fraction is very fine graded; soft; strong reaction to HCl; moist.	SM	0	20	80	M
415–420	2" SCH 80 flush thread blank PVC Casing (0-480' bls)	G	415–420	SILTY SAND; brown (10 YR 5/3); sand fraction is medium through very fine grained; soft, gritty texture; weak reactiuon to HCl; moist.	SM	0	75	25	M

Columns also printed: Blow Count, % Recovery, PID (ppm), Graphic Log (blank/graphic).

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Lithologic Log and Well Construction Details of SGD-1

Approved	Date	Revised	Date	Reference:	FIG.
T.Schrauf	1/27/04			793100	2f

HGC-WELL 793100.GPJ NEWPROJ.GDT 9/18/06

Project: Page-Trowbridge Ranch Landfill

Boring: **SGD-1**

Drilling Co: Water Development Corp.
Drilling Method: Air Rotary
Date Started: 12/5/03
Location: Between Cells A&B South of Access Road
Sampler:
Date Completed: 12/9/03
Desc. of Meas Pt: Land Surface Elev.
Logged by: W.Thompson
Land Surf. Elev:
Meas. Pt. Elev:
Reviewed by: B. Anderson

Depth - FT.	WELL COMPLETION	Depth - FT.	DESCRIPTION	USCS Symbol	GR	SA	FI	Moisture
425–435		425–435	SILTY SAND; brown (10 YR 5/3); sand fraction is medium through very fine grained; soft, gritty texture; weak reactiuon to HCl; moist.*(continued)*					
435–453	20/40 Mesh Colorado Silica Sand (433-435' bls)	435–453	WELL-GRADED SAND with SILT; yellowish brown (10 YR 5/4); very minor gravel to 1/2" max diameter, subangular to rounded; sand fraction is coarse to very fine grained, fairly well graded; loose; strong reaction to HCl; moist.	SW	2	88	10	M
453–476	1/4 x 1/8" pea gravel (435-605' bls)	453–476	WELL-GRADED SAND with GRAVEL; yellowish brown (10 YR 5/4); gravel fraction is fine grained to 1/2" max diameter, sub angular to rounded, dark through light gray aphentiss with quartz; sand fraction is verycoarse through fine grained, well graded throughout, fairly clean, loose, weak reaction to HCl; ???moisture???	SW	30	65	5	
476–490	2" SCH 80 PVC Screen 0.080" slot (480-540' bls)	476–490	SILTY SAND; yellowish brown (10 YR 5/4); sand fraction is coarse through very fine grained, fairly well graded through to the silt fraction; loose; weak reaction to HCl; moist.	SM	0	85	15	M

Columns also present (empty): Blow Count, % Recovery, PID (ppm), Samples, Graphic Log. ESTIMATED % OF: GR, SA, FI.

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Lithologic Log and Well Construction Details of SGD-1

Approved	Date	Revised	Date	Reference:	FIG.
T.Schrauf	1/27/04			793100	2g

Project: Page-Trowbridge Ranch Landfill | **Boring:** SGD-1 | Pg. 8 of 9

Drilling Co:	Water Development Corp.	Drilling Method:	Air Rotary	Date Started:	12/5/03
Location:	Between Cells A&B South of Access Road	Sampler:		Date Completed:	12/9/03
		Desc. of Meas Pt:	Land Surface Elev.	Logged by:	W.Thompson
Land Surf. Elev:		Meas. Pt. Elev:		Reviewed by:	B. Anderson

WELL COMPLETION (Depth - FT. 495–560)

- 2" SCH 80 PVC Screen 0.080" slot (480-540' bls)
- 1/4 x 1/8" pea gravel (435-605' bls)
- 2" SCH 80 flush thread blank PVC Casing (540-560' bls)

Depth - FT.	Samples	DESCRIPTION	USCS Symbol	GR	SA	FI	Moisture
495–505	G	WELL-GRADED SAND with SILT; brown (10 YR 5/3); gravel fraction to 1/2" max diameter, subangular to rounded; sand fraction is coarse through very fine grained, fairly well graded to silt fraction; loose weak reaction to HCl; moist.	SW sm	5	85	10	M
505–515	G	WELL-GRADED SAND with GRAVEL; light yellowish brown (10 YR 6/4); gravel fraction is fine grained to 1/2" max diameter, subangular to rounded; sand fraction is coarse through fine grained, well graded, fairly clean; loose; weak reaction to HCl; moist.	SW	20	75	5	M
515–525	G	SILTY SAND; light yellowish brown (10 YR 6/4); gravel fraction to 1/4" max diameter very minor; sand fraction is coarse through very fine grained, fairly well graded throughout, loose, strong reaction to HCl; moist.	SM	3	82	15	M
525–540	G	WELL-GRADED SAND with SILT(???or is this SP-SM???); brown (10 YR 5/3); sand fraction is medium through very fine grained, well graded to silt fraction; loose; weak reaction to HCl; moist.	SW-sm	0	90	10	M
540–555	G	SILT with SAND; yellowish brown (10 YR 5/6); sand fraction is fine to very fine grained; soft, gritty texture; strong reaction to HCl; moist.	ML	0	40	60	M
555–560	G	SILTY SAND; yellowish brown (10 YR 5/4); sand fraction is fine to very fine grained; soft, gritty texture; strong reaction to HCl; moist.	SM	0	70	30	M

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Lithologic Log and Well Construction Details of SGD-1

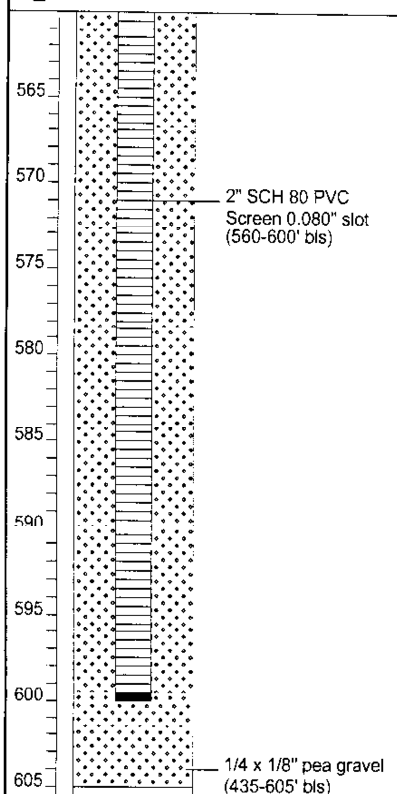
Approved	Date	Revised	Date	Reference:	FIG.
T.Schrauf	1/27/04			793100	2h

Project: Page-Trowbridge Ranch Landfill

Boring: SGD-1 | Pg. 9 of 9

Drilling Co:	Water Development Corp.	Drilling Method:	Air Rotary	Date Started:	12/5/03
Location:	Between Cells A&B South of Access Road	Sampler:		Date Completed:	12/9/03
		Desc. of Meas Pt:	Land Surface Elev.	Logged by:	W.Thompson
Land Surf. Elev:		Meas. Pt. Elev:		Reviewed by:	B. Anderson

WELL COMPLETION



Depth - FT.	Blow Count	% Recovery	PID (ppm)	Samples	Graphic Log	DESCRIPTION	USCS Symbol	GR	SA	FI	Moisture
562				G (568)		WELL-GRADED SAND; brown (10 YR 5/3); sand fraction is coarse through very fine grained, well graded through to the silt fraction; loose; weak reaction to HCL; moist.	SW	0	95	5	M
577				G (590)		WELL-GRADED SAND with GRAVEL; brown (10 YR 5/3); gravel fraction is minor to 1/4" max diameter, subangular to rounded; sand fraction is coarse through very fine grained, well graded; loose; weak reaction to HCl; moist.	SW	10	85	5	M
605						TD @ 605' bls	SW	10	85	5	M

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Lithologic Log and Well Construction Details of SGD-1

Approved	Date	Revised	Date	Reference:	FIG.
T.Schrauf	1/27/04			793100	2i

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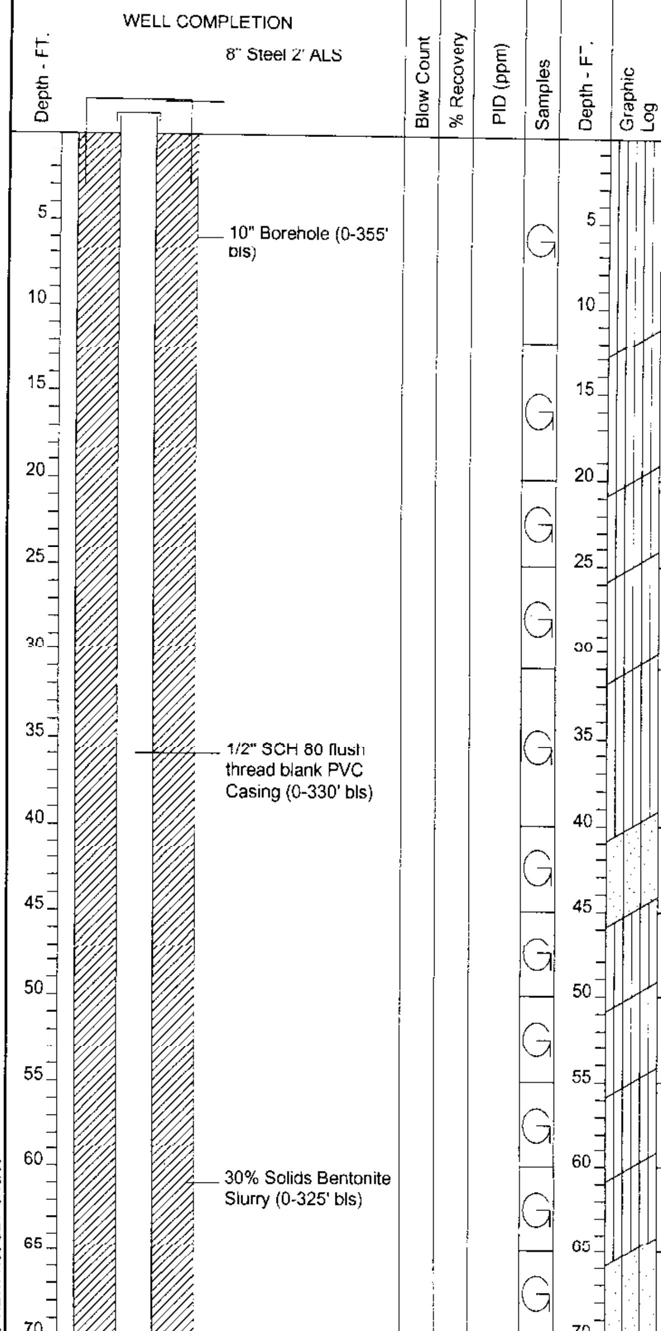
Project: Page-Trowbridge Ranch Landfill **Boring:** SGD-2 Pg. 1 of 6

Drilling Co:	Water Development Corp.	Drilling Method:	Air Rotary
Location:	10' West of SGD (Deep)	Sampler:	
		Desc. of Meas Pt:	
Land Surf. Elev:		Meas. Pt. Elev:	
Date Started:	12/12/03	Date Completed:	12/13/03
Logged by:	W.Thompson	Reviewed by:	B. Anderson



DESCRIPTION	USCS Symbol	GR	SA	FI	Moisture
SILT; pink (7.5YR 7/4); trace sand-sand fraction is fine to very fine grained; slightly cemented-easily broken up; soft; strong reaction to HCl; dry	ML	0	5	95	D
SILT, as above except for very small amount of gravel clast, subangular to rounded, crystalline aphentiss, dark through light gray, some quartz; loose; strong reaction to HCl; dry	ML	2	5	93	D
SILT; light brown (7.5 YR 6/4); soft, powdery, flour-like texture; very strong reaction to HCl; dry	ML	0	0	100	D
SILT; with trace sand; light brown (7.5 YR 6/4); sand fraction coarse through very fine grained; slightly cemented; strong reaction to HCl; dry.	ML	0	5	95	D
SILT; light brown (7.5 YR 6/4); soft, powdery, flour-like texture; slight cementation; strong reaction to HCl; dry.	ML	0	0	100	D
SILTY SAND; light brown (7.5 YR 6/4); sand fraction is medium to very fine grained; minor cementation, fairly loose; strong reaction to HCl; dry.	SM	0	65	35	D
SANDY SILT; light brown (7.5 YR 6/4); sand fraction as described above, moderate cementation; strong reaction to HCl; dry.	ML	0	25	75	D
SANDY SILT; as above, less sand, more silt.	ML	0	10	90	D
SILT; light brown (7.5 YR 6/4); soft powder, flour-like texture; strong reaction to HCl; dry.	ML	0	0	100	D
SILT with SAND; light brown (7.5 YR 6/4); sand fraction is fine to very fine grained; soft, gritty texture; strong reaction to HCl; moist.	ML	0	10	90	M
	SM	10	50	40	M

HYDRO GEO CHEM, INC.

Lithologic Log and Well Construction Details of SGD-2

Approved	Date	Revised	Date	Reference:	FIG.
T.Schrauf	1/29/04			793100	3a

Project: Page-Trowbridge Ranch Landfill | **Boring:** SGD-2 |

Drilling Co: Water Development Corp. | Drilling Method: Air Rotary | Date Started: 12/12/03

Location: 10' West of SGD (Deep) | Sampler: | Date Completed: 12/13/03

Desc. of Meas Pt: | Logged by: W.Thompson

Land Surf. Elev: | Meas. Pt. Elev: | Reviewed by: B. Anderson

WELL COMPLETION:

- 1/2" SCH 80 PVC screen 0.020" slot (330-350' bls)
- 30% Solids Bentonite Slurry (0-325' bls)

Depth - FT.	DESCRIPTION	USCS Symbol	GR	SA	FI	Moisture
72–78	SILTY SAND with GRAVEL; light brown (7.5 YR 6/4); gravel fraction to 1" max diameter, subangular to rounded, crystalline; sand fraction is coarse ot very fine grained but is primarily fine grained; loose mix; strong reaction to HCl: moist.*(continued)*	ML	0	10	90	M
78–84	SAND with SILT; light brown (7.5 YR 6/4); sand fraction is fine to very fine grained; soft; strong reaction to HCl; moist.					
84–91	SILTY SAND with GRAVEL; brown (7.5 YR 5/4); gravel clast to 1" max diameter, subangular to rounded, crystalline aphentiss; sand fraction coarse to very fine grained; loose; strong reaction to HCl; moist.	SM	35	50	15	M
91–96	SILT with SAND; light brown (7.5 YR 6/4); trace gravel to 1/2" max diameter, subangular to rounded; sand fraction is very fine grained; soft; strong reaction to HCl; moist.	ML	5	10	85	M
96–101	SILT; light brown (7.5 YR 6/4); soft, flour-like texture; strong reaction to HCl; moist.	ML	0	0	100	M
101–106	SILTY SAND; light yellowish brown (10 YR 6/4); sand fraction is fine to very fine grained; soft, loose mix;Strong reaction to HCl; moist.	SM	0	60	40	M
106–116	WELL-GRADED SAND with GRAVEL; light yellowish brown (10 YR 6/4); gravel fraction is fine grained to 1/2" max diameter, subangular to rounded; sand fraction is coarse to very fine grained, fairly well graded; loose; strong reaction to HCl; moist.	SW	10	85	5	M
116–121	SILTY SAND; with trace gravel; yellowish brown (10 YR 5/4), as described above except for decrease in gravel fraction and increase in silt fraction.	SM	5	75	20	M
121–126	SANDY SILT; light yellowish brown (10 YR 6/4); sand fraction is very fine grained; soft, gritty texture; strong reaction ot HCl; moist.	ML	0	25	75	M
126–136	SILT; light yellowish brown (10 YR 6/4); soft, flour-like texture; strong reaction to HCl; moist.	ML	0	5	95	M
136–140	SILT; with gravel and sand; yellowish brown (10 YR 5/6); gravel fraction to 1" max diameter, subangular to rounded; soft, loose; strong reaction to HCl; moist.	ML	10	10	80	M

Lithologic Log and Well Construction Details of SGD-2

HYDRO GEO CHEM, INC.

Approved	Date	Revised	Date	Reference:	FIG.
T.Schrauf	1/29/04			793100	3b

Project: Page-Trowbridge Ranch Landfill | **Boring:** SGD-2 | Pg. 3 of 6

Drilling Co: Water Development Corp. | Drilling Method: Air Rotary | Date Started: 12/12/03
Location: 10' West of SGD (Deep) | Sampler: | Date Completed: 12/13/03
Desc. of Meas Pt: | Logged by: W.Thompson
Land Surf. Elev: | Meas. Pt. Elev: | Reviewed by: B. Anderson

WELL COMPLETION (Depth - FT. 145–210):
- 1/2" SCH 80 flush thread blank PVC Casing (0-330' bls)
- 30% Solids Bentonite Slurry (0-325' bls)

Samples: G at approx. 143, 148, 153, 159, 169, 178, 183, 188, 193, 198, 205 ft.

Depth - FT.	DESCRIPTION	USCS Symbol	GR	SA	FI	Moisture
145–150	SANDY SILT; light yellowish brown (10 YR 6/4); sand fraction is fine to very fine grained; soft, flour-like texture; strong reaction to HCl; moist.	ML	0	15	85	M
150–155	SANDY SILT; as described above except for increase in sand fraction.	ML	0	40	60	M
155–163	GRAVELLY SILT with SAND; yellowish brown (10 YR 5/4); gravel fraction to 1" max diameter, subangular to rounded, crystalline aphentiss, dark through light gray, quartz; sand fraction is coarse through fine grained but, primarily fine grained; loose mix; strong reaction to HCl; moist.	SM	30	40	30	M
163–175	SANDY SILT; yellowish brown (10 YR 5/4), sand fraction is fine to very fine grained; soft, powdery, gritty texture; strong reaction to HCl; moist.	ML	0	20	80	M
175–180	GRAVELLY SILT; light yellowish brown (10 YR 6/4); gravel fraction to 1/2" max diameter, subangular to rounded; sand fraction is coarse through very fine grained, well graded to silt fraction; loose; strong reaction to HCl; moist.	SM	20	65	15	M
180–185	SILTY SAND; brown (7.5 YR 5/4); sand fraction is fine to very fine grained; loose; strong reaction to HCl; moist.	SM	0	80	20	M
185–190	SILT with SAND; brown (7.5 YR 5/4); sand fraction is fine to very fine grained, soft, gritty, flour-like texture; strong reaction to HCl; moist.	ML	0	10	90	M
190–195	SILT with SAND; as describe above except for a small amount of gravel to 1" max diameter, sub???? to rounded, crystalline.	ML	5	10	85	M
195–200	SILTY SAND with GRAVEL; brown (7.5 YR 5/4); gravel fraction is fine graded to 1/2" max diameter, subangular to rounded; sand fraction is coarse to very fine grained, fairly well graded; loose; strong reaction to HCl; moist.	SM	10	65	25	M
200–210	as above except for increase in silt fraction.	ML	0	60	40	M

HYDRO GEO CHEM, INC.

Lithologic Log and Well Construction Details of SGD-2

Approved	Date	Revised	Date	Reference:	FIG.
T.Schrauf	1/29/04			793100	3c

Project: Page-Trowbridge Ranch Landfill | Boring: **SGD-2** | Pg. 4 of 6

Drilling Co: Water Development Corp. | Drilling Method: Air Rotary | Date Started: 12/12/03

Location: 10' West of SGD (Deep) | Sampler: | Date Completed: 12/13/03

Desc. of Meas Pt: | Logged by: W.Thompson

Land Surf. Elev: | Meas. Pt. Elev: | Reviewed by: B. Anderson

Depth - FT.	WELL COMPLETION	Blow Count	% Recovery	PID (ppm)	Samples	Depth - FT.	DESCRIPTION	USCS Symbol	GR	SA	FI	Moisture
210–215	30% Solids Bentonite Slurry (0-325' bls)				G		as above except for increase in silt fraction. *(continued)*					
215–230					G	215	SANDY SILT; brown (7.5 YR 5/4); sand fraction is fine to very fine grained; soft, gritty texture; strong reaction to HCl; moist.	ML	0	30	70	M
230–250					G	230	SANDY SILT; brown (7.5 YR 5/4); as above except for increase in silt fraction.	ML	0	20	80	M
250–280	1/2" SCH 80 flush thread blank PVC Casing (0-330' bls)				G	250	SILTwith SAND; brown (7.5 YR 5/4); sand fraction ism very fine grained, flour-like texture; strong reaction to HCl; moist.	ML	0	10	90	M

Estimated % of: GR, SA, FI

HYDRO GEO CHEM, INC.

Lithologic Log and Well Construction Details of SGD-2

Approved	Date	Revised	Date	Reference:	FIG.
T.Schrauf	1/29/04			793100	3d

HGC-WELL 793100.GPJ NEWPROJ.GDT 9/18/06

Project: Page-Trowbridge Ranch Landfill

Boring: SGD-2 | Pg. 5 of 6

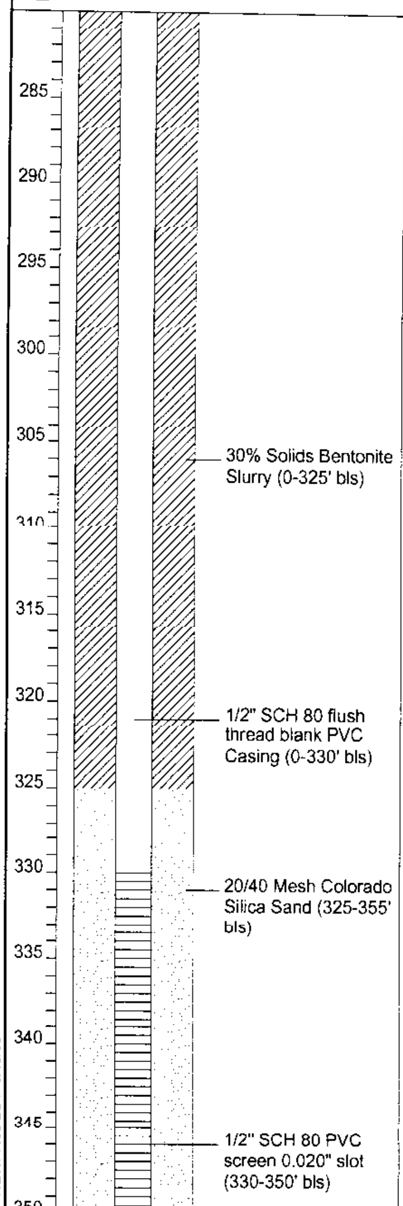
Drilling Co: Water Development Corp. | Drilling Method: Air Rotary | Date Started: 12/12/03

Location: 10' West of SGD (Deep) | Sampler: | Date Completed: 12/13/03

Desc. of Meas Pt: | Logged by: W.Thompson

Land Surf. Elev: | Meas. Pt. Elev: | Reviewed by: B. Anderson

WELL COMPLETION



Samples	Depth - FT.	DESCRIPTION	USCS Symbol	GR	SA	FI	Moisture
G	283–290	SILTwith SAND; brown (7.5 YR 5/4); sand fraction ism very fine grained, flour-like texture; strong reaction to HCl; moist.*(continued)*					
G	290–299	SAND with SILT; very pale brown (10 YR 7/3); sand fraction is medium through very fine grained, fairly well graded to silt fraction; loose; strong reaction to HCl; moist.	SW-SM	0	90	10	M
G	299–331	SANDY SILT; brown (7.5 YR 5/4); sand fraction is fine to very fine grained; soft, gritty flour-like texture; strong reaction to HCl; moist.	ML	0	20	80	M
G	331–336	SAND with SILT; yellowish brown (10 YR 5/4); sand fraction is medium through very fine grained, fairly well graded through to the silt fraction; loose strong reaction to HCl; moist.	SW-SM	0	90	10	M
G	336–346	SILTY SAND; dark yellowish brown (10 YR 4/4); sand fraction is very fine grained; soft; strong reaction to HCl; moist.	SM	0	60	40	M
G	346–350	SANDY SILT with minor clay; dark yellowish brown (10 YR 4/4); sand fraction is very fine grained; soft, slightly ?cohesive?, slightly sticky; strong reaction to HCl; moist.	ML	0	40	60	M

HYDRO GEO CHEM, INC.

Lithologic Log and Well Construction Details of SGD-2

Approved	Date	Revised	Date	Reference:	FIG.
T.Schrauf	1/29/04			793100	3e

Project: Page-Trowbridge Ranch Landfill

Boring: **SGD-2**

Drilling Co: Water Development Corp.

Drilling Method: Air Rotary

Date Started: 12/12/03

Location: 10' West of SGD (Deep)

Sampler:

Date Completed: 12/13/03

Desc. of Meas Pt:

Logged by: W.Thompson

Land Surf. Elev:

Meas. Pt. Elev:

Reviewed by: B. Anderson

Depth - FT.	WELL COMPLETION	Blow Count	% Recovery	PID (ppm)	Samples	Depth - FT.	Graphic Log	DESCRIPTION	USCS Symbol	ESTIMATED % OF GR	SA	FI	Moisture
355					G	355		SANDY SILT; as describe above except that clay fraction is absent and silt fraction has increased.	ML	0	30	70	M
								TD @ 355' bls	ML	0	30	70	M

HYDRO GEO CHEM, INC.

Lithologic Log and Well Construction Details of SGD-2

Approved	Date	Revised	Date	Reference.	FIG.
T.Schrauf	1/29/04			793100	3f

HGC-WELL 793100.GPJ NEWPRO.GDT 9/18/06

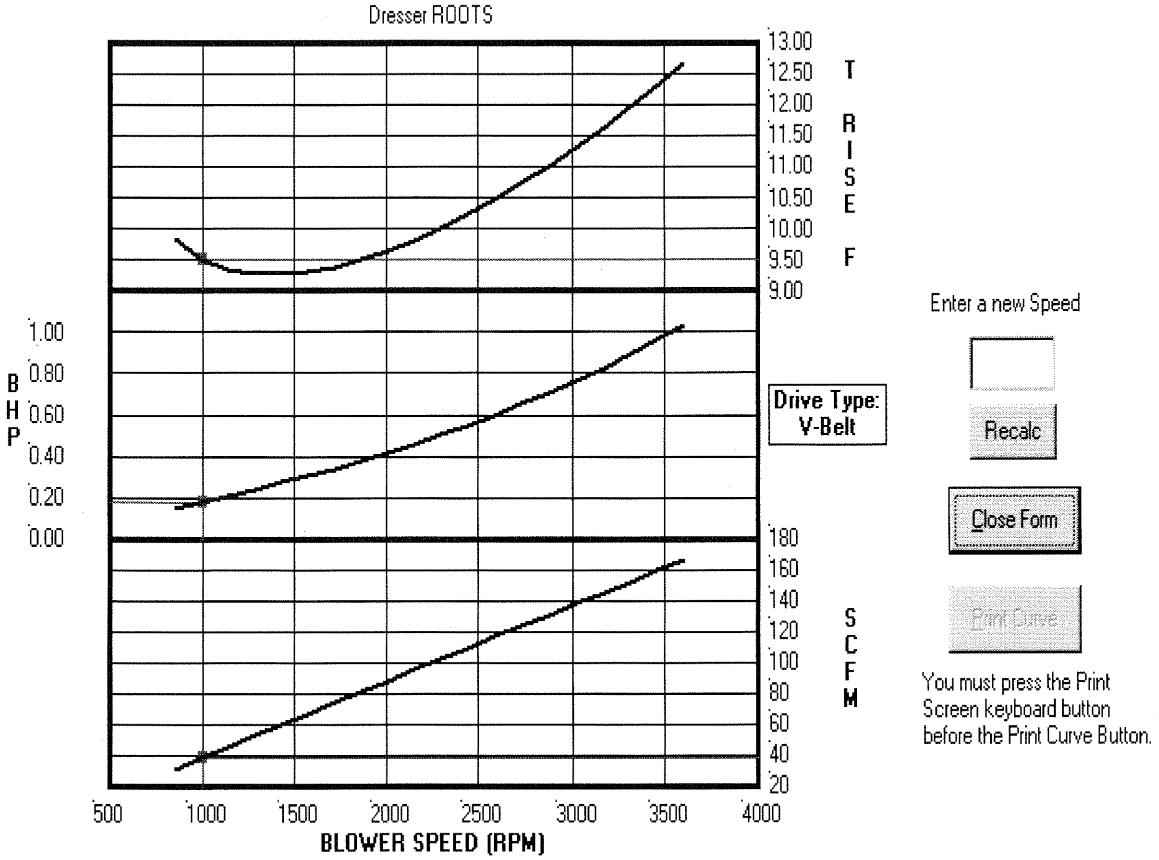
ATTACHMENT C

PROCESS EQUIPMENT SPECIFICATIONS AND MANUFACTURERS' USER MANUALS

Roots Universal RAI Rotary Positive Blowers Brochure
Leeson DC Motors, Low Voltage, NEMA Frame, Spec Sheet
Dayton 2-hp 120vac Motor

42 URAI: Variable Speed Performance

Dresser ROOTS



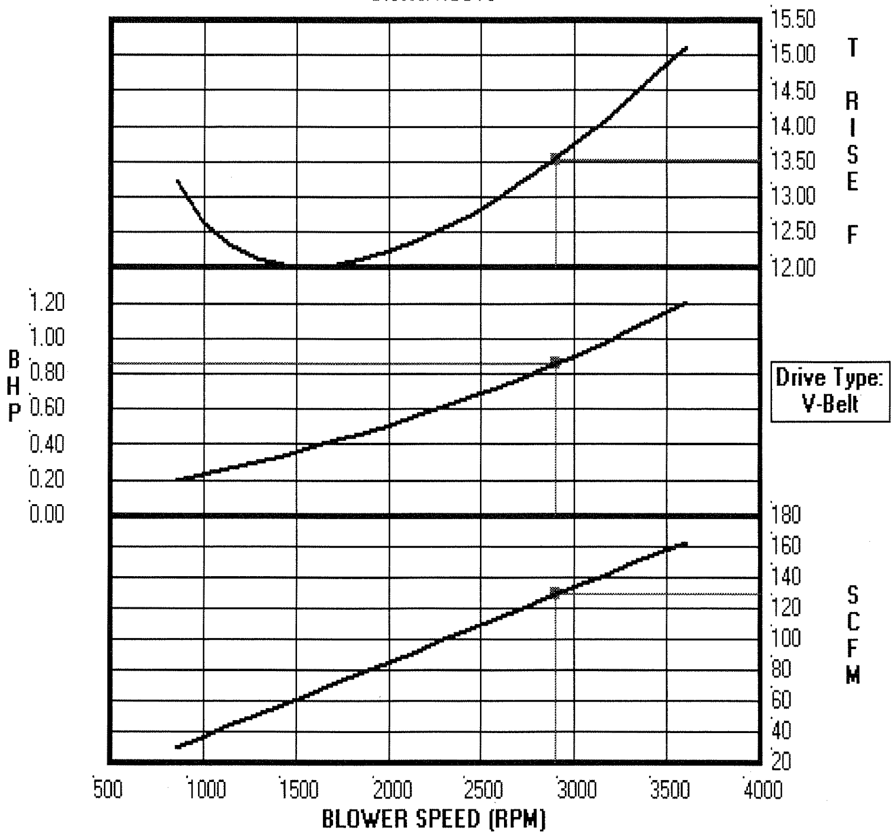
INLET CONDITIONS: AIR
RH = 80.00%, MW = 28.616, k = 1.392, Tin = 80 deg F
DESIGN: Speed = 1000 RPM
System Inlet P = 7 in H20 Vac, Inlet P Loss = 0.2 PSI
System Disch P = 12.92 PSIA, Disch P Loss = 0.2 PSI
STD: RH = 36%, T = 68 deg F, P = 14.7 PSIA

Design Data ———

CUSTOMER:
PROJECT:

42 URAI: Variable Speed Performance

Dresser ROOTS



Enter a new Speed

Recalc

Close Form

Will not print if this button is used.

Print Curve

You must press the Print Screen keyboard button before the Print Curve Button.

```
INLET CONDITIONS: AIR
                  RH = 80.00%, MW = 28.611, k = 1.392, Tin = 80 deg F
          DESIGN: Speed = 2900 RPM
                  System Inlet P = 12 in H2O Vac, Inlet P Loss = 0.2 PSI
                  System Disch P = 12.92 PSIA, Disch P Loss = 0.2 PSI
STD:       RH = 36%, T = 68 deg F, P = 14.7 PSIA
```

Design Data ————

CUSTOMER:
PROJECT:

printed March 1, 2010

Farm Duty Motor, 2 HP, 1725, 115/230v, 56HZ

Farm Duty Motor, Capacitor-Start, Capacitor-Run, Totally Enclosed Fan-Cooled, 2 HP, 1725 Nameplate RPM, 115/230 Voltage, 56HZ NEMA/IEC Frame, Service Factor 1.15, 60 Hz, Base Mounting, Sealed Ball Bearings, Thermal Protection Manual, Full Load Amps 18.8/9.4, Ambient 40 C, Rotation CW/CCW, Shaft Dia 7/8 In, Shaft Length 2 1/4 In, Insulation Class B

Grainger Item #	1TMW1
Price (ea.)	**$339.75**
Brand	DAYTON
Mfr. Model #	1TMW1
Ship Qty.	1
Sell Qty. (Will-Call)	1
Ship Weight (lbs.)	49.95
Usually Ships	Today
Catalog Page No.	51

Price shown may not reflect your price. Log in or register.

Additional Info

High- and Extra-High-Torque Capacitor-Start Totally Enclosed Fan-Cooled Motors

Features include gasketed conduit box, capacitor cover, and rubber boot over the manual protector reset button, sealing motor against weather and contaminants.

Oversized conduit boxes make connections easier. Shaft slinger included. UL Recognized and CSA Certified.

Uses: For conveyors, silo unloaders, barn cleaners, compressors, and manure pumps.

- Max. ambient: 40 DegreeC
- Thermal protection: manual
- Bearings: sealed ball on 56 through 184T frames; shielded on 215T frames
- Rotation: CW/CCW
- Duty: continuous
- Color: green

High-Torque

Perform well under the dirtiest and dustiest of farm conditions.

Tech Specs

Item: Farm Duty Motor
Motor Type: Capacitor-Start, Capacitor-Run
Enclosure: Totally Enclosed Fan-Cooled
HP: 2
Nameplate RPM: 1725
Voltage: 115/230
NEMA/IEC Frame: 56HZ
Service Factor: 1.15
Hz: 60
Mounting: Base
Mounting Position: Horizontal
Shaft Orientation: Horizontal
Bearings: Double-Sealed Ball
Thermal Protection: Manual
Full Load Amps: 18.8/9.4
Ambient (C): 40
Rotation: CW/CCW
Length Less Shaft (In.): 12 5/8
Shaft Dia. (In.): 7/8
Shaft Length (In.): 2 1/4
Insulation Class: B
Phase: 1
Capacitor Required: Included
Agency Compliance: UL Recognized (E47479), CSA Certified (LR44256)
Replacement For: 4K041, 4K090
Finish: Green Baked-on Enamel
Mfr. Stock No.: 21
Conduit Box: Gasketed
Duty: Continuous
Fan Blade Material: Plastic
RPM Range: 1400-1800
Frame Material: Rolled Steel
Includes: Shaft Slinger

Optional Accessories

There are currently no optional accessories for this item.

Alternate Products

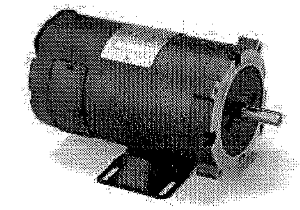
There are currently no alternate products for this item.

Repair Parts

Repair Parts Information is available for this item.

LEESON DC MOTORS
NEMA FRAME • LOW VOLTAGE 12 & 24 VOLTS

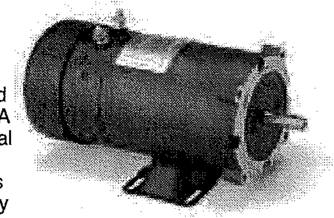
NEMA FRAME LOW VOLTAGE MOTORS



General Specifications:

Low voltage permanent magnet DC motors are suitable for installations having battery or solar powered operations, or generator supplied low voltage DC.

Mechanical Features:



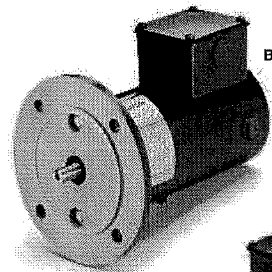
Unique brush holder design provides easy access to brushes and integral, constant pressure brush/spring assembly for servicing. Larger over-sized brushes assure longer brush life. Heavy-duty, stamped steel, bolt-on base (removable). NEMA C face mounting flange at no additional cost. High strength rolled steel frame. Rugged die cast aluminum endshields with steel bearing inserts. Permanently lubricated sealed ball bearings. May be converted to NEMA 48 frame base dimensions or NEMA 42/48 frame C face dimensions using modification kits noted on page 79.

Electrical Features:

High starting torques for heavy load applications. Linear speed/torque characteristics over entire speed range. Capable of dynamic braking for faster stops. Reversible rotation and simple two-lead connection. Convenient wiring access.

DC METRIC (IEC) FRAME MOTORS IP54

General Specifications:

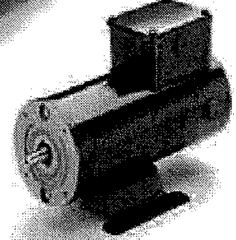


B5 IEC 56 & 63

These metric dimensioned motors are built to IEC 34-1 electrical and mechanical standards.

The IEC 63 and smaller frames are stocked with an integral B5 flange or B14 face less base. An optional B3 rigid base kit is available.

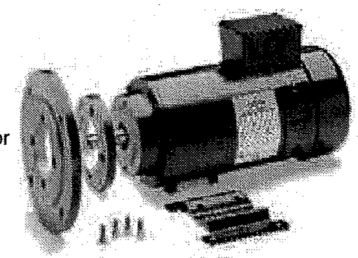
A unique modular approach for IEC 71 frame and larger allows the motor to be field modified to B3 rigid base mounted construction, B5 flange mounted or B14 face mounted construction using conversion kits. Please note that one or more of the mounting kits must be used with IEC motors of these frame sizes. See listing on page 83 for B5 flange and B14 face kits. B3 rigid base kits are listed below.



B14 IEC 56 & 63

Electrical & Mechanical Features:

A terminal board is provided for connections. All fasteners are metric. Electrical and mechanical features are the same as listed for the NEMA frame motors on the opposite page. Tachometer mounting kits are available—please contact LEESON for data.



71 & 80 IEC with Modular Flange & Base Kits

LOW VOLTAGE (12 & 24V) • TENV/TEFC NEMA C FACE WITH REMOVABLE BASEΣ

HP	Full Load RPM	NEMA Frame■	Catalog Number	List Price	Disc. Sym.	App. Wgt. (lbs.)	Arm. Volts DC	F.L. Amps DC	"C" Dim. (Inches)
1/4	1800	S56C	108045♣●	$498	A	21	12	21.0	10.44
1/3	1800	S56C	108046♣●	548	A	24	12	27.0	11.44
	1800	S56C	108050♣●	524	A	22	24	13.5	10.94
1/2	1800	S56C	108047♣●	569	A	29	12	39.0	12.44
	1800	S56C	108051♣●	544	A	29	24	20.0	11.94
	1800	SS56C	098381	517	A	29	36	13.5	10.81
	1800	SS56C	098382	500	A	29	48	11.0	10.81
3/4	1800	S56C	108048◆	629	A	30	12	58.0	13.81
	1800	S56C	108052	568	A	30	24	29.0	12.81
1	1800	S56C	108322◆	749	A	39	12	80.0	13.81
	1800	S56C	108053◆	690	A	37	24	39.0	13.81
	1800	S56C	109101	660	A	37	36	25.5	13.81
	1800	S56C	109102	637	A	37	48	18.5	13.81
1½	1800	S56CZ	109103◆❑	1006	A	39	24	60.0	17.38
	1800	S56CZ	109104◆❑	993	A	37	36	36.0	17.38
	1800	S56CZ	109105◆❑	959	A	37	48	27.0	17.38
2	1800	S56CZ	109106◆❑	1259	A	42	24	70.0	16.31
	1800	S56CZ	109107◆❑	1165	A	42	36	49.0	16.31
	1800	S56CZ	109108◆❑	1120	A	42	48	38.0	16.31

♣ Built-in conduit box located at 12:00.
◆ Studs at 12:00.
Σ If base is removed, do not reinstall bolts without using washers to compensate for thickness of base.
❑ S56CZ motors have mounting bases with NEMA 56 mounting holes, NEMA 56/143-5T C-face and a NEMA 143-5T shaft extension (7/8" dia. x 2 1/4" long).
● These motors are totally enclosed, non-ventilated.
■ SS56C motors have a 4.88 inch diameter frame.
S56C motors have a 5.61 inch diameter frame.

METRIC (IEC) FRAME • LOW VOLTAGE (24V) • TEFC/TENV • MODULAR DESIGN

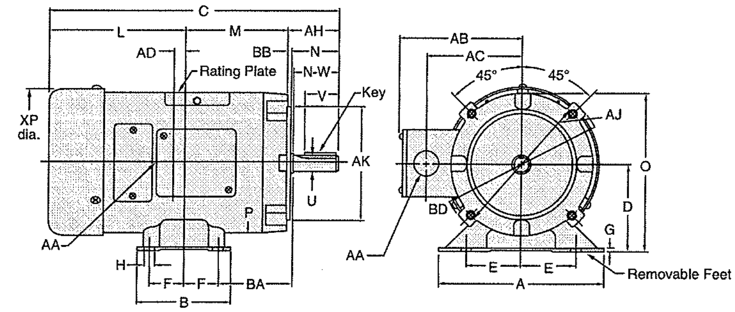
kW/HP	Full Load RPM	IEC Frame	Catalog Number	List Price	App. Wgt. (lbs.)	F.L. Amps DC	C Dim. (inches)
0.06/1/12	3000	56	M1110025^●	$270	5	3.3	5.34
	1800	56	M1110026^●	306	6	3.4	6.34
0.18/1/4	3000	63	M1130206*	345	13	11.0	7.75
	3000	63	M1130296^	345	9	11.0	7.75
	1800	63	M1130207*	395	13	10.0	8.75
	1800	63	M1130297^	395	9	10.0	8.75
	1800	71	098065	473	19	11.0	10.77
0.37/1/2	3000	71	098066	489	23	20.0	11.27
	1800	71	098067	517	23	20.0	12.27
0.75/1	3000	80	108456◆	567	33	40.0	14.14
	1800	80	108455◆	664	52	39.0	14.64
1.1/1½	3000	80	108457◆	632	33	65.0	15.64
1.5/2	3000	80	108458◆	726	43	78.0	17.14

IMPORTANT: IEC 71 and 80 frame motors in this chart are round body and require either B14 face, B5 flange or B3 foot from kits shown on pages 82-83.

* Dedicated B5 Flange
^ Dedicated B14 Face
● These motors are totally enclosed, non-ventilated. Others are TEFC/IC41 cooling – external cooling fan on motor shaft.

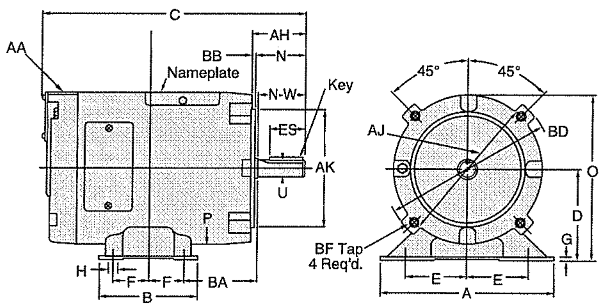
K

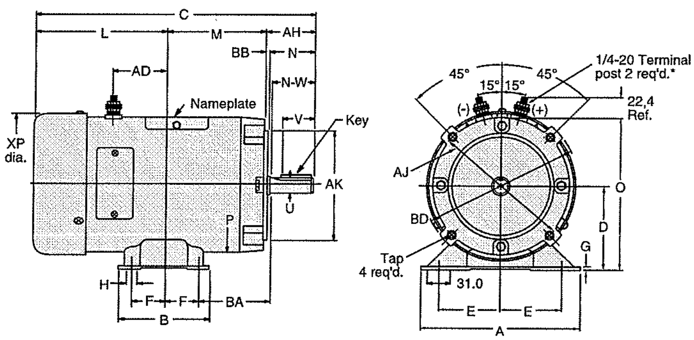
NEMA FRAMES, THYRISTOR RATED



L

NEMA FRAMES, LOW VOLTAGE





NEMA FRAMES (mm)

NEMA Frame	Mounting Foot 2E	A	2F	B	BA	D	G	H	Shaft U	AH	V	Mounting Face AK	AJ	BD	TAP	BB	General P	O	AA
42	89	121	43	62	52	67	3	10	10	33	25	76	95	124	1/4-20	3	124	129	95
48	108	146	70	89	64	76	3	9	13	43	35	76	95	127	1/4-20	3	142	148	13
SS56	124	165	76	102	70	89	3	9	16	52	36	114	149	165	3/8-16	3	124	129	13
S56	124	165	76	102	70	89	3	9	16	52	36	114	149	165	3/8-16	3	142	160	13
56	124	165	76	102	70	89	3	9	16	52	36	114	149	165	3/8-16	3	166	197	13
143T	140	165	102	165	70	89	3	9	22	54	36	114	149	165	3/8-16	3	166	197	19
145T	140	165	102	165	70	89	3	9	22	54	36	114	149	165	3/8-16	3	166	197	19
182/145TC	191	216	114	140	89	114	3	10	22	54	36	114	149	165	3/8-16	3	166	197	29

*143-5TC NEMA C Face BA dimension is 70mm.

For C dimension, see motor selection charts.

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Contents

CHAPTER I

Electric Motor History and Principles

The electric motor in its simplest terms is a converter of electrical energy to useful mechanical energy. The electric motor has played a leading role in the high productivity of modern industry, and it is therefore directly responsible for the high standard of living being enjoyed throughout the industrialized world.

The beginnings of the electric motor are shrouded in mystery, but this much seems clear: The basic principles of electromagnetic induction were discovered in the early 1800's by Oersted, Gauss and Faraday, and this combination of Scandinavian, German and English thought gave us the fundamentals for the electric motor. In the late 1800's the actual invention of the alternating current motor was made by Nikola Tesla, a Serb who had migrated to the United States. One measure of Tesla's genius is that he was granted more than 900 patents in the electrical field. Before Tesla's time, direct current motors had been produced in small quantities, but it was his development of the versatile and rugged alternating current motor that opened a new age of automation and industrial productivity.

An electric motor's principle of operation is based on the fact that a current-carrying conductor, when placed in a magnetic field, will have a force exerted on the conductor proportional to the current flowing in the conductor and to the strength of the magnetic field. In alternating current motors, the windings placed in the laminated stator core produce the magnetic field. The aluminum bars in the laminated rotor core are the current-carrying conductors upon which the force acts. The resultant action is the rotary motion of the rotor and shaft, which can then be coupled to various devices to be driven and produce the output.

Many types of motors are produced today. Undoubtedly, the most common are alternating current induction motors. The term "induction" derives from the transference of power from the stator to the rotor through electromagnetic induction. No slip rings or brushes are required since the load currents in the rotor conductors are induced by transformer action. The induction motor is, in effect, a transformer - with the stator winding being the primary winding and the rotor bars and end rings being the movable secondary members.

Both single-phase and polyphase AC motors are produced by LEESON and many other manufacturers. In polyphase motors, the placement of the phase winding groups in conjunction with the phase sequence of the power supply line produces a rotating field around the rotor surface. The rotor tends to follow this rotating field with a rotational speed that varies inversely with the number of poles wound into the stator. Single-phase motors do not produce a rotating field at a standstill, so a starter winding is added to give the effect of a polyphase rotating field. Once the motor is running, the start winding can be cut out of the circuit, and the motor will continue to run on a rotating field that now exists due to the motion of the rotor interacting with the single-phase stator magnetic field.

In recent years, the development of power semiconductors and micro-processors has brought efficient adjustable speed control to AC motors through the use of inverter drives. Through this technology, the most recent designs of so-called pulse width modulated AC drives are capable of speed and torque regulation that equals or closely approximates direct current systems.

LEESON Electric also produces permanent-magnet direct current motors. The DC motor is the oldest member of the electric motor family. Recent technological breakthroughs in magnetic materials, as well as solid state electronic controls and high-power-density rechargeable batteries, have all revitalized the versatile DC motor.

DC motors have extremely high torque capabilities and can be used in conjunction with relatively simple solid state control devices to give programmed acceleration and deceleration over a wide range of selected speeds. Because the speed of a DC motor is not dependent on the number of poles, there is great versatility for any constant or variable speed requirement.

In most common DC motors, the magnetic field is produced by high-strength permanent magnets, which have replaced traditional field coil windings. The magnets require no current from the power supply. This improves motor efficiency and reduces internal heating. In addition, the reduced current draw enhances the life of batteries used as power supplies in mobile or remote applications.

Both AC and DC motors must be manufactured with a great deal of precision in order to operate properly. LEESON and other major manufacturers use laminated stator, rotor and armature cores to reduce energy losses and heat in the motor. Rotors for AC motors are heat treated to separate the aluminum bars from the rotor's magnetic laminations. Shaft and bearing tolerances must be held to ten thousandths of an inch. The whole structure of the motor must be rigid to reduce vibration and noise. The stator insulation and coil winding must be done in a precise manner to avoid damaging the wire insulation or ground insulation. And mountings musts meet exacting dimensions. This is especially true for motors with NEMA C face mountings, which are used for direct coupling to speed reducers, pumps and other devices.

The electric motor is, of course, the very heart of any machine it drives. If the motor does not run, the machine or device will not function. The importance and scope of the electric motor in modern life is attested to by the fact that electric motors, numbering countless millions in total, convert more energy than do all our passenger automobiles. Electric motors are much more efficient in energy conversion than automobiles, but they are such a large factor in the total energy picture that renewed interest is being shown in motor performance. Today's industrial motors have energy conversion efficiency exceeding 95% in larger horsepowers.

This efficiency, combined with unsurpassed durability and reliability, will continue to make electric motors the "prime movers" of choice for decades to come.

CHAPTER II

General Motor Replacement Guidelines

Electric motors are the versatile workhorses of industry. In many applications, motors from a number of manufacturers can be used.

Major motor manufacturers today make every effort to maximize interchangeability, mechanically and electrically, so that compromise does not interfere with reliability and safety standards. However, no manufacturer can be responsible for misapplication. If you are not certain of a replacement condition, contact a qualified motor distributor, sales office or service center.

Safety Precautions

- Use safe practices when handling, lifting, installing, operating, and maintaining motors and related equipment.

- Install motors and related equipment in accordance with the National Electrical Code (NEC) local electrical safety codes and practices and, when applicable, the Occupational Safety and Health Act (OSHA).

- Ground motors securely. Make sure that grounding wires and devices are, in fact, properly grounded.

Failure to ground a motor properly may cause serious injury.

Before servicing or working near motor-driven equipment, disconnect the power source from the motor and accessories.

Selection

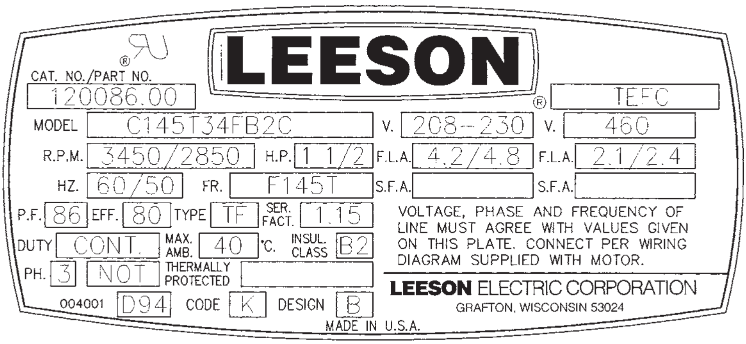
Identifying a motor for replacement purposes or specifying a motor for new applications can be done easily if the correct information is known. This includes:

- Nameplate Data
- Mechanical Characteristics
- Motor Types
- Electrical Characteristics and Connections

Much of this information consists of standards defined by the National Electrical Manufacturers Association (NEMA). These standards are widely used throughout North America. In other parts of the world, the standards of the International Electrotechnical Commission (IEC) are most often used.

Nameplate

Nameplate data is the critical first step in determining motor replacement. Much of the information needed can generally be obtained from the name-plate. Record all nameplate information; it can save time and confusion.



Important Nameplate Data

- Catalog number.
- Motor model number.
- Frame.
- Type (classification varies from manufacturer to manufacturer).
- Phase - single, three or direct current.
- HP - horsepower at rated full load speed.
- HZ - frequency in cycles per second. Usually 60 hz in United States, 50 hz overseas.
- RPM - revolutions per minute.

- Voltage.
- Amperage (F.L.A.) - full load motor current.
- Maximum ambient temperature in centigrade - usually +40°C (104°F).
- Duty - most motors are rated continuous. Some applications, however, may use motors designed for intermittent, special, 15, 30 or 60 minute duty.
- NEMA electrical design - B, C and D are most common. Design letter represents the torque characteristics of the motor.
- Insulation class - standard insulation classes are B, F, and H. NEMA has established safe maximum operating temperatures for motors. This maximum temperature is the sum of the maximum ambient and maximum rise at maximum ambient.
- Code - indicates locked rotor kVA per horsepower.
- Service factor - a measure of continuous overload capacity.

CHAPTER III

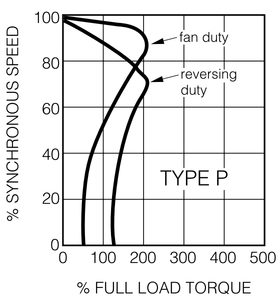
Major Motor Types

Alternating current (AC) induction motors are divided into two electrical categories based on their power source – single phase and polyphase (three phase).

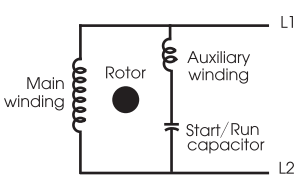
AC Single Phase Types

Types of single-phase motors are distinguished mostly by the way they are started and the torque they develop.

Shaded Pole motors have low starting torque, low cost, low efficiency, and no capacitors. There is no start switch. These motors are used on small direct drive fans and blowers found in homes. Shaded pole motors should not be used to replace other types of single-phase motors.



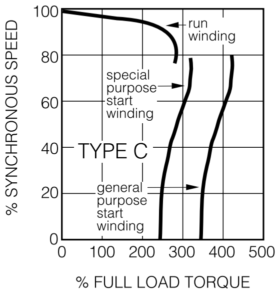
PSC (Permanent Split Capacitor) motors have applications similar to shaded pole, except much higher efficiency, lower current (50% - 60% less), and higher horsepower capability. PSC motors have a run capacitor in the circuit at all times. They can be used to replace shaded pole motors for more efficient operation and can be used for fan-on-shaft fan applications, but not for belted fans due to the low starting torque.

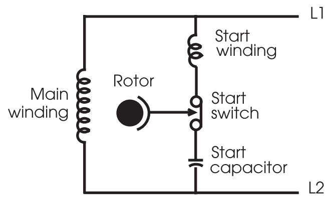


PSC circuit diagram

Split Phase motors have moderate to low starting torque (100% - 125% of full load), high starting current, no capacitor, and a starting switch to drop out the start winding when the motor reaches approximately 75% of its operating speed. They are used on easy-to-start belt drive fans and blowers, as well as light-start pump applications.

Capacitor Start motors are designed in both moderate and high starting torque types with both having moderate starting current, high breakdown torques.





Cap start circuit diagram

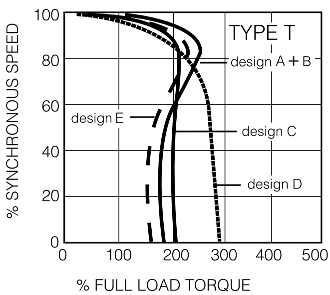
Moderate-torque motors are used on applications in which starting requires torques of 175% or less or on light loads such as fans, blowers, and light-start pumps. High-torque motors have starting torques in excess of 300% of full load and are used on compressors, industrial, commercial and farm equipment. Capacitor start motors use a start capacitor and a start switch, which takes the capacitor and start winding out of the circuit when motor reaches approximately 75% of its operating speed.

Capacitor Start/Capacitor Run motors have applications and performance similar to capacitor start except for the addition of a run capacitor (which stays in circuit) for higher efficiency and reduced running amperage. Generally, start/ capacitor run motors are used for 3 HP and larger single-phase applications.

On industrial duty motors, capacitors are usually protected by metal cases attached to the motor frame. This capacitor start/capacitor run motor has two cases.

A heavy-duty polyphase motor with cast-iron frame.

AC Polyphase



Polyphase (three-phase) induction motors have a high starting torque, power factor, high efficiency, and low current. They do not use a switch, capacitor, relays, etc., and are suitable for larger commercial and industrial applications.

Polyphase induction motors are specified by their electrical design type: A, B, C, D or E, as defined by the National Electrical Manufacturers Association (NEMA). These designs are suited to particular classes of applications based upon the load requirements typical of each class.

The table on the next page can be used to help guide which design type to select based on application requirements.

Because of their widespread use throughout industry and because their characteristics lend themselves to high efficiencies, many types of general-purpose three-phase motors are required to meet mandated efficiency levels under the U.S. Energy Policy Act. Included in the mandates are NEMA Design B, T frame, foot-mounted motors from 1-200 HP.

The following table can be used to help guide which design type should be selected:

NEMA Electrical Design Standards

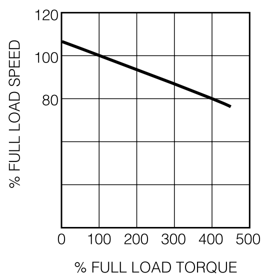
Polyphase Characteristics	Locked Rotor Torque (Percent Rated Load Torque)	Pull-Up Torque (Percent Rated Load Torque)	Break-down Torque (Percent Rated Load Torque)	Locked Rotor Current (Percent Rated Load Current)	Slip	Typical Applications	Relative Efficiency
Design A High locked rotor torque and high locked rotor current	70-275	65-190	175-300	Not defined	0.5-5%	Fans, blowers, centrifugal pumps and compressors, motor-generator sets, etc., where starting torque requirements are relatively low	Medium or high
Design B Normal locked rotor torque and normal locked rotor current	70-275	65-190	175-300	600-700	0.5-5%	Fans, blowers, centrifugal pumps and compressors, motor-generator sets, etc., where starting torque requirements are relatively low	Medium or high
Design C High locked rotor torque and normal locked rotor current	200-285	140-195	190-225	600-700	1-5%	Conveyors, crushers, stirring motors, agitators, reciprocating pump and compressors, etc., where starting under load is required	Medium
Design D High locked rotor torque and high slip	275	NA	275	600-700	5-8%	High peak loads with or without flywheels such as punch presses, shears, elevators, extractors, winches, hoists, oil-well pumping and wire-drawing motors	Low
Design E Normal locked rotor torque and current, low slip	75-190	60-140	160-200	800-1000	0.5-3%	Fans, blowers, centrifugal pumps and compressors, motor-generator sets, etc., where starting torque requirements are relatively low	High

Direct Current (DC)

Another commonly used motor in industrial applications is the direct current motor. It is often used in applications where adjustable speed control is required.

Permanent magnet DC designs are generally used for motors that produce less than 5 HP. Larger horsepower applications use shunt-wound direct current motors.

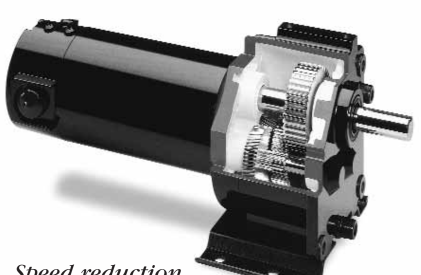
DC motors can be operated from rectified alternating current of from low-voltage battery or generator source. This is a low-voltage design, which includes external connection lugs for the input power. With the rear endshield removed, as in this view, the brush assemblies and commutator that form a DC motor's electrical heart are clearly visible.



Both designs have linear speed/torque characteristics over the entire speed range. SCR rated motors – those designed for use with common solid-state speed controls – feature high starting torque for heavy load applications and reversing capabilities, and complementary active material to compensate for the additional heating caused by the rectified AC input. Designs are also available for use on generated low-voltage DC power or remote applications requiring battery power.

Gearmotors

A gearmotor is made up of an electric motor, either DC or AC, combined with a geared speed reducer. Spur, helical or worm gears may be used in single or multiple stages. The configuration may be either that of a parallel shaft, emerging from the front of the motor, or a right-angle shaft. Gearmotors are often rated in input horsepower; however, output torque, commonly measured in inch-pounds, and output speed are the critical values.



Speed reduction gearing is visible in this cutaway view of a parallel-shaft gearmotor. Shown is a small, sub-fractional horsepower gearmotor.

Gearmotors may be either integral, meaning the gear reducer and motor share a common shaft, or they may be created from a separate gear reducer and motor, coupled together. Integral gearmotors are common in sub-fractional horsepower sizes; separate reducers and motors are more often the case in fractional and integral horsepowers. For more on gear reducers and gearmotors, see Chapter IX.

Brakemotors

A brakemotor is a pre-connected package of industrial-duty motor and fail-safe, stop-and-hold spring-set brake. In case of power failure, the brake sets, holding the load in position. Brakemotors are commonly used on hoists or other lifting devices. Brake features can also be added to standard motors through conversion kits that attach to the shaft end of either fan-cooled or open motor.

A three-phase brakemotor. Note the brake on the fan end. Like many brakemotors, this model has a NEMA C face for direct mounting to the equipment to be driven.

Motors for Precise Motion Control

These motors are always part of integrated motor-and-controller systems that provide extreme accuracy in positioning and speed. Common applications include computer-controlled manufacturing machines and process equipment. Servomotors are the largest category of motors for precision motion control. AC, DC brush-type, and brushless DC versions are available. Closed-loop control systems, common with servomotors, use feedback devices to provide information to a digital controller, which in turn drives the motor. In some cases, a tachometer may be used for velocity control and an encoder for position information. In other cases, a resolver provides both position and velocity feedback.

Step (or stepper) motors, which move in fixed increments instead of rotating continuously, provide another means of precision motion control. Usually, they are part of open-loop control systems, meaning there are no feedback devices.

CHAPTER IV

Mechanical Considerations

Enclosures and Environment

Open Drip Proof (ODP) motors have venting in the end frame and/or main frame, situated to prevent drops of liquid from falling into the motor within a 15° angle from vertical. These motors are designed for use in areas that are reasonably dry, clean, well-ventilated, and usually indoors. If installed outdoors, ODP motors should be protected with a cover that does not restrict air flow.

Totally Enclosed Non-Ventilated (TENV) motors have no vent openings. They are tightly enclosed to prevent the free exchange of air, but are not air tight. TENV motors have no cooling fan and rely on convection for cooling. They are suitable for use where exposed to dirt or dampness, but not for hazardous locations or applications having frequent hosedowns.

Totally Enclosed Fan Cooled (TEFC) motors are the same as TENV except they have an external fan as an integral part of the motor to provide cooling by blowing air over the outside frame.

Totally Enclosed Air Over motors are specifically designed to be used within the airflow of the fan or blower they are driving. This provides an important part of the motor's cooling.

Totally Enclosed Hostile and Severe Environment motors are designed for use in extremely moist or chemical environments, but not for hazardous locations.

Explosion Proof motors meet Underwriters Laboratories or CSA standards for use in the hazardous (explosive) locations shown by the UL/CSA label on the motor. The motor user must specify the explosion proof motor required. Locations are considered hazardous because the atmosphere contains or may contain gas, vapor, or dust in explosive quantities. The National Electrical Code (NEC) divides these locations into classes and groups according to the type of explosive agent. The following list has some of the agents in each classification. For a complete list, see Article 500 of the National Electrical Code.

Class I (Gases, Vapors)

Group A	Acetylene
Group B	Butadiene, ethylene oxide, hydrogen, propylene oxide
Group C	Acetaldehyde, cyclopropane, diethlether, ethylene, isoprene
Group D	Acetone, acrylonitrile, ammonia, benzene, butane, ethylene dichloride, gasoline, hexane, methane, methanol, naphtha, propane, propylene, styrene, toluene, vinyl acetate, vinyl chloride, xylene

Class II (Combustible Dusts)

Group E	Aluminum, magnesium and other metal dusts with similar characteristics
Group F	Carbon black, coke or coal dust
Group G	Flour, starch or grain dust

The motor ambient temperature is not to exceed +40°C or -25°C unless the motor nameplate specifically permits another value. LEESON explosion proof motors are approved for all classes noted except Class I, Groups A & B .

Hazardous Duty Motor Area Classification Chart

Class I Area Classification (Flammable Gases, Vapors or Mists)				Class II Area Classification (Combustible Dusts)			
North America		Europe - ATEX (Category G - Gases)		North America		Europe - ATEX (Category D - Dusts)	
Division 1 Explosion Proof	**Division 2 TEFC & TENV**	**Zone1 Flameproof**	**Zone 2 Non-Sparking**	**Division 1 Explosion Proof**	**Division2**	**Zone 21 Flameproof**	**Zone 22 Non-Sparking**
Group A ①	Group A	Group IIC, Category G ①	Group IIC, Category G	-	-	-	-
Group B ①	Group B	Group IIC, Category G ①	Group IIC, Category G	-	-	-	-
Group C	Group C	Group IIB, Category G	Group IIB, Category G	-	-	-	-
Group D	Group D	Group IIA, Category G	Group IIA, Category G	-	-	-	-
-	-	-	-	Group E ①	-	-	-
-	-	-	-	Group F	Group F ①	Category D	-
-	-	-	-	Group G	Group G ①	Category D	-

- Group is not applicable to that Division or Zone, or is not defined.

① Group is not available from LEESON Electric or Lincoln Motors.

Hazardous Duty Motor Temperature Code Chart

	TEMPERATURE CODES		Division 1 Explosion Proof/Zone 1 Flameproof		Division 2/Zone 2 Non-Sparking
			Class I Area Classification (Flammable Gases, Vapors or Mists)	**Class II Area Classification* (Combustible Dusts)**	**Class I Area Classification (Flammable Gases, Vapors or Mists)**
Temp.	UL/CSA	ATEX	Division 1/Zone 1	Division 1/Zone 21	Division 2/Zone 2
280°C	T2A	T2(280)	Explosion Proof - Class I, Group D (Group C as noted)		
260°C	T2B	T2(260)			
215°C	T2D	T2(215)			
200°C	T3	T3			
165°C	T3B	T3(165)	Explosion Proof - Class I, Group D (Group C as noted), Sine wave or PWM power	Explosion Proof - Class II, Groups F & G, Sine wave or PWM power	
160°C	T3C	T3(160)	Contact Factory	Contact Factory	
135°C	T4	T4	ATEX compliant motors	ATEX compliant motors	

* Class II, Division 2 motors are not available from LEESON Electric / Lincoln Motors, Zone 22 groups are not defined by ATEX.

NEMA Frame/Shaft Sizes

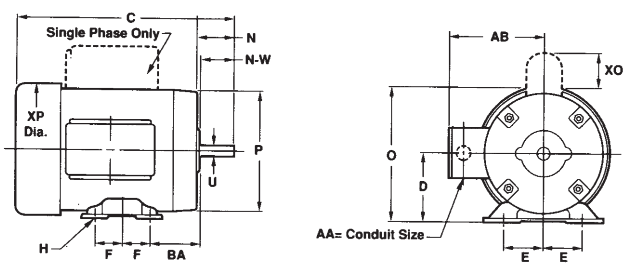
Frame numbers are not intended to indicate electrical characteristics such as horsepower. However, as a frame number becomes higher so in general does the physical size of the motor and the horsepower. There are many motors of the same horsepower built in different frames. NEMA (National Electrical Manufacturers Association) frame size refers to mounting only and has no direct bearing on the motor body diameter.

In any standard frame number designation there are either two or three numbers. Typical examples are frame numbers 48, 56, 145, and 215. The frame number relates to the "D" dimension (distance from center of shaft to center bottom of mount). For example, in the two-digit 56 frame, the "D" dimension is $3^{1}/_{2}$", 56 divided by 16 = $3^{1}/_{2}$". For the "D" dimension of a three-digit frame number, consider only the first two digits and use the divisor 4. In frame number 145, for example, the first two digits divided by the constant 4 is equal to the "D" dimension. 14 divided by 4 = $3^{1}/_{2}$". Similarly, the "D" dimension of a 213 frame motor is $5^{1}/_{4}$", 21 divided by 4 = $5^{1}/_{4}$".

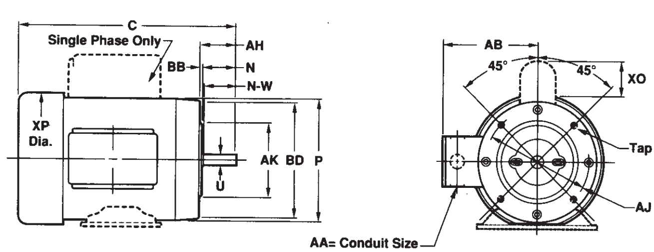
By NEMA definition, two-digit frame numbers are fractional frames even though 1 HP or larger motors may be built in them. Three-digit frame numbers are by definition integral frames. The third numeral indicates the distance between the mounting holes parallel to the base. It has no significance in a footless motor.

A summary of NEMA standard dimensions is on the facing page.

RIGID BASE



C FACE



Motor Frame Dimensions (inches)

NEMA Frame Size s	D	E	F	H	N	O	P	U	N-W	AA	AB	AH	AJ	AK	BA	BB	BD	XO	XP	TAP **	KEY
42	2 5/8	1 3/4	27/32	9/32 Slot	1 1/4	5 1/16	4 7/8	3/8	1 1/8	3/8	4 1/2	1 5/16	3 3/4	3	2 1/16	1/8	4 7/8	1 5/8	5 1/8	1/4-20	3/64 Flat
48	3	2 1/8	1 3/8	11/32 Slot	1 9/16	5 13/16	5 19/32	1/2	1 1/2	1/2	4 7/8	1 11/16	3 3/4	3	2 1/2	1/8	5	2 1/4	5 7/8	1/4-20	3/64 Flat
S56 56	3 1/2	2 7/16	1 1/2	11/32 Slot	1 15/16	6 5/16 6 13/16	5 19/32 6 19/32	5/8	1 7/8	1/2	4 7/8 5 5/16	2 1/16	5 7/8	4 1/2	2 3/4	1/8	6 1/2	2 1/4	5 7/8 7 5/32	3/8-16	3/16
143T 145T	3 1/2	2 3/4	2 2 1/2	11/32	2 3/8	6 13/16	6 19/32	7/8	2 1/4	3/4	5 5/16	2 1/8	5 7/8	4 1/2	*2 1/4	1/8	6 1/2	2 1/4	7 5/32	3/8-16	3/16
182T 184T	4 1/2	3 3/4	2 1/4 2 3/4	13/32	2 7/8	8 3/4	8 15/32	1 1/8	2 3/4	3/4	6 3/8	2 5/8	7 1/4	8 1/2	*2 3/4	1/4	8 7/8	2 1/4	9 3/32	1/2-13	5/16
S213T 213T 215T	5 1/4	4 1/4	2 3/4 2 3/4 3 1/2	13/32	3 1/2 —	9 15/16 10 11/16	8 15/32 10 13/16	1 3/8	3 3/8	3/4 1	6 3/8 8 5/16	3 1/8	7 1/4	8 1/2	*3 1/2	1/4	8 7/8 9	2 1/4	9 3/32 11 3/32	1/2-13	5/16
254T 256T	6 1/4	5	4 1/8 5	17/32	—	12 15/16	13 1/4	1 5/8	4	1 1/4	11 5/8	3 3/4	7 1/4	8 1/2	*4 1/4	1/4	9 5/8	—	12 7/8	1/2-13	3/8
284TS 284T 286TS 286T	7	5 1/2	4 3/4 5 1/2	17/32	—	14 1/2	14 3/4	1 5/8 1 7/8 1 5/8 1 7/8	3 1/4 4 5/8 3 1/4 4 5/8	1 1/2	11 3/4	3 4 3/8 3 4 3/8	9	10 1/2	4 3/4	1/4	11	—	14 1/2	1/2 13	3/8 1/2 3/8 1/2
324TS 324T 326TS 326T	8	6 1/4	5 1/4 6	21/32	—	15 3/4	15 3/4	1 7/8 2 1/8 1 7/8 2 1/8	3 3/4 5 1/4 3 3/4 5 1/4	2	13 1/2	3 1/2 5 3 1/2 5	11	12 1/2	5 1/4	1/4	13 3/8	—	15 3/4	5/8 11	1/2
364TS 364T 365TS 365T	9	7	5 5/8 6 1/8	21/32	—	17 13/16	17 3/8	1 7/8 2 3/8 1 7/8 2 3/8	3 3/4 5 7/8 3 3/4 5 7/8	3	15 7/16	3 1/2 5 5/8 3 1/2 5 5/8	11	12 1/2	5 7/8	1/4	14	—	17/3/4	5/8 11	1/2 5/8 1/2 5/8
404TS 404T 405TS 405T	10	8	6 1/8 6 7/8	13/16	—	19 5/16	19 1/8	2 1/8 2 7/8 2 1/8 2 7/8	4 1/4 7 1/4 4 1/4 7 1/4	3	16 5/16	4 7 4 7	11	12 1/2	6 5/8	1/4	15 1/2	—	19 3/8	5/8 11	1/2 3/4 1/2 3/4
444TS 444T 445T 447TZ	11	9	7 1/4 7 1/4 8 1/4 10	13/16	—	22 1/4	22	2 3/8 3 3/8	4 3/4 8 1/2 8 1/2 10 1/8	3	21 11/16	8 1/4	14	16	7 1/2	1/4	18	—	19 3/8	5/8 11	5/8 7/8 7/8 7/8

Shaded area denotes dimensions established by NEMA standard MG-1. Other dimensions will vary among manufac-tures.

NEMA Frame Suffixes

C	=	NEMA C face mounting (specify with or without rigid base)
D	=	NEMA D flange mounting (specify with or without rigid base)
H	=	Indicates a frame with a rigid base having an F dimension larger than that of the same frame without the suffix H. For example, combination 56H base motors have mounting holes for NEMA 56 and NEMA 143-5T and a standard NEMA 56 shaft
J	=	NEMA C face, threaded shaft pump motor
JM	=	Close-coupled pump motor with specific dimensions and bearings
JP	=	Close-coupled pump motor with specific dimensions and bearings
M	=	$6^3/_4$" flange (oil burner)
N	=	$7^1/_4$" flange (oil burner)
T,TS	=	Integral horsepower NEMA standard shaft dimensions if no additional letters follow the "T" or "TS".
TS	=	Motor with NEMA standard "short shaft" for belt-driven loads.
Y	=	Non-NEMA standard mount; a drawing is required to be sure of dimensions. Can indicate a special base, face or flange.
Z	=	Non-NEMA standard shaft; a drawing is required to be sure of dimensions.

Frame Prefixes

Letters or numbers appearing in front of the NEMA frame number are those of the manufacturer. They have no NEMA frame significance. The significance from one manufacturer to another will vary. For example, the letter in front of LEESON's frame number, L56, indicates the overall length of the motor.

Mounting

Unless specified otherwise, motors can be mounted in any position or any angle. However, unless a drip cover is used for shaft-up or shaft-down applications, drip proof motors must be mounted in the horizontal or sidewall position to meet the enclosure definition. Mount motor securely to the mounting base of equipment or to a rigid, flat surface, preferably metallic.

Types of Mounts

Rigid base is bolted, welded, or cast on main frame and allows motor to be rigidly mounted on equipment.

Resilient base has isolation or resilient rings between motor mounting hubs and base to absorb vibrations and noise. A conductor is imbedded in the ring to complete the circuit for grounding purposes.

NEMA C face mount is a machined face with a pilot on the shaft end which allows direct mounting with the pump or other direct coupled equipment. Bolts pass through mounted part to threaded hole in the motor face.

NEMA D flange mount is a machined flange with rabbet for mountings. Bolts pass through motor flange to a threaded hole in the mounted part. NEMA C face motors are by far the most popular and most readily available. NEMA D flange kits are stocked by some manufacturers, including LEESON.

Type M or N mount has special flange for direct attachment to fuel atomizing pump on an oil burner. In recent years, this type of mounting has become widely used on auger drives in poultry feeders.

Extended through-bolt motors have bolts protruding from the front or rear of the motor by which it is mounted. This is usually used on small direct drive fans or blowers.

Motor Guidelines for Belted Applications

The information contained in this document is intended to be used for applications where LEESON Electric and Lincoln Motors motors are connected to other equipment through the use of a V-belt drive. These are to be used as guidelines only since LEESON Electric and Lincoln Motors does not warrant the complete drive system.

The goal of any belted system is to efficiently transmit the required torque while minimizing the loads on the bearings and shafts of the motor and driven equipment. This can be accomplished by following these four basic guidelines:

1. Use the largest practical sheave diameter.
2. Use the fewest number of belts possible.
3. Keep sheaves as close as possible to support bearings.
4. Tension the belts to the lowest tension that will still transmit the required torque without slipping.

1. Sheave Diameter Guidelines

In general, smaller sheaves produce greater shaft stress and shaft deflection due to increased belt tension. See Table 1 for minimum recommended sheave diameters. Using larger sheaves increases the contact with belts which reduces the number of belts required. It also increases the belt speed, resulting in higher system efficiencies. When selecting sheaves, do not exceed the manufacturer’s recommended maximum rim speed. Typically 6,500 feet per minute for cast iron sheaves, 8,000 feet per minute for ductile iron and 10,000 feet per minute for steel. The following formula will determine sheave rim speed:

$$\frac{\text{Shaft RPM} \times 3.14 \times \text{Sheave Dia. in inches}}{12}$$

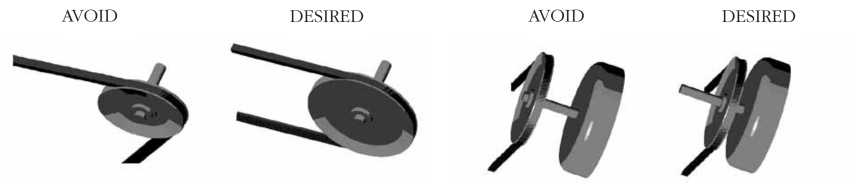
2. Number of Belts

In general, use the fewest number of belts that will transmit the required torque without slipping. See Table 1 for maximum recommended number of belts. Each belt adds to the tension in the system which increases load on the shafts and bearings. Belts are most efficient when operated at or near their rated horsepower.

If the sheaves have more grooves than the number of belts required, use the grooves closest to the motor.

3. Sheave Location

Install sheaves as close to the housings as possible to increase the bearing life of the motor and driven equipment.



4. Belt Tension

In general, belt tensions are to be kept as loose as possible while still transmitting the required torque without slipping. Belt tensions must be measured with a belt tension gage. These inexpensive gages may be obtained through belt manufacturers, or distributors.

Proper belt tension is determined by measuring the required force to deflect the center of the belt at a given distance. See Fig. 3. The proper deflection (in inches) is determined by dividing the belt span in inches by 64. Calculate the proper deflection and then see Table 1 for the required belt deflected force to achieve the calculated deflection.

After tensioning the belt, rotate the sheaves for several rotations or start the system and run for a few minutes if possible to seat belts into the grooves, then re-tension the belts.

Belt tensioning by feel is ***NOT*** acceptable. Tensioning by "feel" can be very misleading, and can damage equipment. New belts will stretch during use, and should be retensioned after the first eight hours of use.

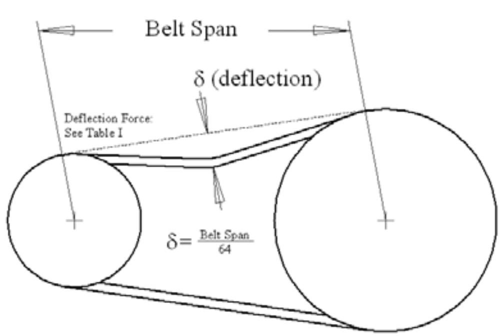


Table 1: Recommended Sheave Diameters, Belt Type and Number of Belts

Motor Hp	1200 rpm Min. Sheave Dia. (in.)	1200 rpm Belt Type	1200 rpm Max. # of Belts	1200 rpm Belt Deflected Force (lbs.)	1800 rpm Min. Sheave Dia. (in.)	1800 rpm Belt Type	1800 rpm Max. # of Belts	1800 rpm Belt Deflected Force (lbs.)	3600 rpm Min. Sheave Dia. (in.)	3600 rpm Belt Type	3600 rpm Max. # of Belts	3600 rpm Belt Deflected Force (lbs.)
0.75	2.2	3VX	1	3.4	2.2	3VX	1	2.2	2.2	3VX	1	1.3
1	2.4	3VX	1	4.0	2.2	3VX	1	3.1	2.2	3VX	1	1.6
1.5	2.4	3VX	2	3.1	2.4	3VX	2	2.1	2.2	3VX	1	2.5
2	2.4	3VX	3	2.8	2.4	3VX	2	2.9	2.4	3VX	1	2.7
3	3.0	3VX	2	2.9	2.4	3VX	3	2.9	2.4	3VX	2	2.3
5	3.0	3VX	3	4.0	3.0	3VX	3	3.7	2.4	3VX	3	2.5
7.5	3.8	3VX	4	4.7	3.0	3VX	4	4.1	3.0	3VX	2	4.2
10	4.4	3VX	4	5.4	3.8	3VX	4	4.3	3.0	3VX	3	3.8
15	4.4	3VX	5	5.4	4.4	3VX	4	5.4	3.8	3VX	3	4.4
20	5.2	3VX	6	6.0	4.4	3VX	6	4.8	4.4	3VX	3	5.0
25	6.0	3VX	7	5.6	4.4	3VX	7	5.2	4.4	3VX	4	4.7
30	6.8	3VX	7	6.0	5.2	3VX	7	5.3	In general, 3600 RPM motors 30 HP and larger are not belted due to bearing speed-load limitation.			
40	6.8	5VX	4	12	6.0	3VX	7	6.0				
50	8.2	5VX	4	14.5	6.8	3VX	8	6.0				
60	8.2	5VX	5	14	7.4	5VX	4	13.5				
75	10.0	5VX	5	14.5	8.6	5VX	4	14.5				
100	10.0	5VX	6	16	8.6	5VX	6	13				
125	12.0	5V	7	14	10.5	5V	6	13				
150	13.2	5V	7	15.5	10.5	5V	7	13.5				
200	15.0	5V	8	16	13.2	5V	8	13	NEMA sheave sizes			
250	15.0	8V	6	28	14.0	5V	9	14	Above - NEMA Sheave sizes			
300	16.0	8V	7	27	14.0	5V/8V	11 / 7	14 / 24				
350	16.5	8V	7	30	14.5	5V/8V	12 / 7	14 / 26				
400	17.5	8V	8	29	15.0	5V/8V	13 / 8	15 / 26				
450	18	8V	8	32	16.0	5V/8V	14 / 9	15 / 25	Exceeds cast iron sheave rim speed – special sheave material required			
500	18.5	8V	9	31	16.5	5V/8V	15 / 9	15 / 27				
600					17.5	8V	11	26				
700					19.0	8V	12	27				
800					20.0	8V	13	28				

Notes:

1. Horsepowers are nameplate motor horsepowers, and RPMs are motor (driver) speeds.
2. NEMA minimum sheave diameters are from NEMA MG 1, Part 14, Table 14-1.
3. Consult LEESON Electric for applications utilizing (1) smaller sheaves and/or more belts than specified (2) variable speed applications (3) values outside these recommendations.
4. Selections are based on a 1.4 service factor, 5 to 1 speed ratio and various Power Transmission Manufacturer's catalogs used as reference.
5. These selections are for Narrow V-belt sections only. Consult LEESON Electric for details on conventional V-belt sections (A, B, C, D and E), or other belt types.
6. Belt deflected force is per section 4 of this document and is the average force required to deflect the center of a belt 1/64 of the belt span distance. Tolerance on this force is ± 0.5 lbf. for forces 6 lbs, and ± 2 lbf. for forces > 6 lbs.

CHAPTER V

Electrical Characteristics and Connections

Voltage, frequency and phase of power supply should be consistent with the motor nameplate rating. A motor will operate satisfactorily on voltage within 10% of nameplate value, or frequency within 5%, or combined voltage and frequency variation not to exceed 10%.

Voltage

Common 60 hz voltages for single-phase motors are 115 volt, 230 volt, and 115/230 volt.

Common 60 hz voltage for three-phase motors are 230 volt, 460 volt and 230/460 volt. Two hundred volt and 575 volt motors are sometimes encountered. In prior NEMA standards these voltages were listed as 208 or 220/440 or 550 volts. Motors with these voltages on the nameplate can safely be replaced by motors having the current standard markings of 200 or 208, 230/460 or 575 volts, respectively.

Motors rated 115/208-230 volt and 208-230/460 volt, in most cases, will operate satisfactorily at 208 volts, but the torque will be 20% - 25% lower. Operating below 208 volts may require a 208 volt (or 200 volt) motor or the use of the next higher horsepower, standard voltage motor.

Phase

Single-phase motors account for up to 80% of the motors used in the United States but are used mostly in homes and in auxiliary low-horse-power industrial applications such as fans and on farms.

Three-phase motors are generally used on larger commercial and industrial equipment.

Current (Amps)

In comparing motor types, the full load amps and/or service factor amps are key parameters for determining the proper loading on the motor. For example, never replace a PSC type motor with a shaded pole type as the latter's amps will normally be 50% - 60% higher. Compare PSC with PSC, capacitor start with capacitor start, and so forth.

Hertz / Frequency

In North America 60 hz (cycles) is the common power source. However, most of the rest of the world is supplied with 50 hz power.

Horsepower

Exactly 746 watts of electrical power will produce 1 HP if a motor could operate at 100% efficiency, but of course no motor is 100% efficient. A 1 HP motor operating at 84% efficiency will have a total watt consumption of 888 watts. This amounts to 746 watts of usable power and 142 watts loss due to heat, friction, etc. (888 x .84 = 746 = 1 HP).

Horsepower can also be calculated if torque is known, using one of these formulas:

$$HP = \frac{\text{Torque (lb-ft)} \times \text{RPM}}{5{,}250}$$

$$HP = \frac{\text{Torque (oz-ft)} \times \text{RPM}}{84{,}000}$$

$$HP = \frac{\text{Torque (lb-in)} \times \text{RPM}}{63{,}000}$$

Speeds

The approximate RPM at rated load for small and medium motors operating at 60 hz and 50 hz at rated volts are as follows:

	60 hz	50 hz	Synch. Speed
2 Pole	3450	2850	3600
4 Pole	1725	1425	1800
6 Pole	1140	950	1200
8 Pole	850	700	900

Synchronous speed (no-load) can be determined by this formula:

$$\frac{\text{Frequency (Hertz)} \times 120}{\text{Number of Poles}}$$

Insulation Class

Insulation systems are rated by standard NEMA classifications according to maximum allowable operating temperatures. They are as follows:

Class	Maximum Allowed Temperature*	
A	105°C	(221°F)
B	130°C	(266°F)
F	155°C	(311°F)
H	180°C	(356°F)

* *Motor temperature rise plus maximum ambient*

Generally, replace a motor with one having an equal or higher insulation class. Replacement with one of lower temperature rating could result in premature failure of the motor. Each 10°C rise above these ratings can reduce the motor's service life by one half.

Service Factor

The service factor (SF) is a measure of continuous overload capacity at which a motor can operate without overload or damage, provided the other design parameters such as rated voltage, frequency and ambient temperature are within norms. Example: a 3/4 HP motor with a 1.15 SF can operate at .86 HP, (.75 HP x 1.15 = .862 HP) without overheating or otherwise damaging the motor if rated voltage and frequency are supplied at the motor's leads. Some motors, including most LEESON motors, have higher service factors than the NEMA standard.

It is not uncommon for the original equipment manufacturer (OEM) to load the motor to its maximum load capability (service factor). For this reason, do not replace a motor with one of the same nameplate horsepower but with a lower service factor. Always make certain that the replacement motor has a maximum HP rating (rated HP x SF) equal to or higher than that which it replaces. Multiply the horsepower by the service factor for maximum potential loading.

For easy reference, standard NEMA service factors for various horsepower motors and motor speeds are shown in this table.

	FOR DRIP PROOF MOTORS Service Factor Synchronous Speed (RPM)			
HP	**3600**	**1800**	**1200**	**900**
$^1/_6$, $^1/_4$, $^1/_3$	1.35	1.35	1.35	1.35
$^1/_2$	1.25	1.25	1.25	1.25
$^3/_4$	1.25	1.25	1.15	1.15
1	1.25	1.15	1.15	1.15
$1^1/_2$ up	1.15	1.15	1.15	1.15

The NEMA service factor for totally enclosed motors is 1.0. However, many manufacturers build TEFC with a 1.15 service factor.

Capacitors

Capacitors are used on all fractional HP induction motors except shaded-pole, split-phase and polyphase. Start capacitors are designed to stay in circuit a very short time (3-5 seconds), while run capacitors are permanently in circuit. Capacitors are rated by capacity and voltage. Never use a capacitor with a voltage less than that recommended with the replacement motor. A higher voltage is acceptable.

Efficiency

A motor's efficiency is a measurement of useful work produced by the motor versus the energy it consumes (heat and friction). An 84% efficient motor with a total watt draw of 400W produces 336 watts of useful energy (400 x .84 = 336W). The 64 watts lost (400 - 336 = 64W) becomes heat.

Thermal Protection (Overload)

A thermal protector, automatic or manual, mounted in the end frame or on a winding, is designed to prevent a motor from getting too hot, causing possible fire or damage to the motor. Protectors are generally current- and temperature-sensitive. Some motors have no inherent protector, but they should have protection provided in the overall system's design for safety. Never bypass a protector because of nuisance tripping. This is generally an indication of some other problem, such as overloading or lack of proper ventilation.

Never replace nor choose an automatic-reset thermal overload protected motor for an application where the driven load could cause personal injury if the motor should restart unexpectedly. Only manual-reset thermal overloads should be used in such applications.

Basic types of overload protectors include:

Automatic Reset: After the motor cools, this line-interrupting protector automatically restores power. It should not be used where unexpected restarting would be hazardous.

Manual Reset: This line-interrupting protector has an external button that must be pushed to restore power to the motor. Use where unexpected restarting would be hazardous, as on saws, conveyors, compressors and other machinery.

Resistance Temperature Detectors: Precision-calibrated resistors are mounted in the motor and are used in conjunction with an instrument supplied by the customer to detect high temperatures.

Individual Branch Circuit Wiring

All wiring and electrical connections should comply with the National Electrical Code (NEC) and with local codes and practices. Undersized wire between the motor and the power source will limit the starting and load carrying abilities of the motor. The recommended copper wire and transformer sizes are shown in the following charts.

Single Phase Motors - 230 Volts

Transformer		Distance – Motor to Transformer (Feet)				
HP	kVA	100	150	200	300	500
1.5	3	10	8	8	6	4
2	3	10	8	8	6	4
3	5	8	8	6	4	2
5	7.5	6	4	4	2	0
7.5	10	6	4	3	1	0

WIRE GAGE

Three Phase Motors - 230 & 460 Volts

Transformer			Distance – Motor to Transformer (Feet)				
HP	Volts	kVA	100	150	200	300	500
1.5	230	3	12	12	12	12	10
1.5	460	3	12	12	12	12	12
2	230	3	12	12	12	10	8
2	460	3	12	12	12	12	12
3	230	5	12	10	10	8	6
3	460	5	12	12	12	12	10
5	230	7.5	10	8	8	6	4
5	460	7.5	12	12	12	10	8
7.5	230	10	8	6	6	4	2
7.5	460	10	12	12	12	10	8
10	230	15	6	4	4	4	1
10	460	15	12	12	12	10	8
15	230	20	4	4	4	2	0
15	460	20	12	10	10	8	6
20	230	Consult Local Power Company	4	2	2	1	0
20	460		10	8	8	6	4
25	230		2	2	2	0	0
25	460		8	8	6	6	4
30	230		2	1	1	0	0
30	460		8	6	6	4	2
40	230		1	0	0	0	0
40	460		6	6	4	2	0
50	230		1	0	0	0	0
50	460		4	4	2	2	0
30	230		1	0	0	0	0
60	460		4	2	2	0	0
75	230		0	0	0	0	0
75	460		4	2	2	0	0

WIRE GAGE

Motor Starters

As their name implies, motor starters apply electric power to a motor to begin its operation. They also remove power to stop the motor. Beyond merely switching power on and off, starters include overload protection, as required by the National Electrical Code. The code also usually requires a disconnect and short circuit protection on motor branch circuits. Fused disconnects and circuit breakers provide this and are often incorporated into a motor starter enclosure, resulting in a unit referred to as a combination starter.

Full-voltage starters, also called across-the-line starters, apply full line voltage directly to the motor, either through manual or magnetic contacts. Magnetic starters are used on larger horsepowers. Reversing starters, which allow the switching of two leads to change motor rotation, are also usually magnetic.

Reduced-voltage starters, also called soft-starts, apply less than full voltage during the starting sequence of a motor. This reduces current and torque surges, easing the strain on power supply systems and driven devices. Resistors, transformers or solid-state devices can achieve this voltage control. In addition, AC drives offer soft-start inherently. (See Chapter X for complete information on AC drives.)

Both the National Electrical Manufacturers Association (NEMA) and the International Electrotechnical Commission (IEC) rate starters to aid in matching them to the motor and application.

Reading a LEESON Model Number

There is no independently established standard for setting up a motor's model number, but the procedure is typically tied to descriptions of various electrical and mechanical features. While other manufacturers use other designations, here is how LEESON model numbers are configured.

EXAMPLE:

Position No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Sample Model No.	**A**	**B**	**4**	**C**	**17**	**D**	**B**	**1**	**A**	**(A-Z)**

Position 1: U.L. Prefix

- A— Auto protector. U.L. recognized for locked rotor plus run, also recognized construction (U.L. 1004)*.
- M— Manual protector. U.L. recognized for locked rotor plus run, also recognized construction (U.L. 1004)*.
- L— Locked rotor protector (automatic). U.L. recognized for locked rotor only, also recognized construction (U.L. 1004)*.
- C— Component recognition. (U.L. 1004) No protector.
- U— Auto protector. Not U.L. recognized.
- P— Manual protector. Not U.L. recognized.
- T— Thermostat, not U.L. recognized.
- N— No overload protection.

*This applies only to 48, S56, and 56 frame designs through 1 HP, Open & TENV.

Position 2: (Optional)

This position is not always used.

- M— Sub-Fractional HP Motors.
- Z— BISSC Approved.
- Other— Customer Code

Position 3: Frame

4 - 48 Frame	23 - 23 Frame	40 - 40 Frame
6 - 56 Frame	30 - 30 Frame	43 - 43 Frame
42 - 42 Frame	34 - 34 Frame	44 - 44 Frame
143 - 143T Frame	36 - 36 Frame	53 - 53 Frame
145 - 145T Frame	38 - 38 Frame	65 - 65 Frame
182 - 182T Frame	39 - 39 Frame	
184 - 184T Frame		
213 - 213T Frame		
215 - 215T Frame		

Position 4: Motor Type

C— Cap. Start/Ind. Run	T—Three Phase
D— Direct Current	B—Brushless DC
K— Cap. Start/Cap. Run	H—Hysteresis Sync.
P— Permanent Split	R—Reluctance Sync.
S— Split Phase	

Position 5: RPM

RPM-Single Speed	RPM-Multi-Speed
34 - 3450 RPM 60 Hz 2 Pole	24 - 2 and 4 Poles
28 - 2850 RPM 50 Hz 2 Pole	26 - 2 and 6 Poles
17 - 1725 RPM 60 Hz 4 Pole	82 - 2 and 8 Poles
14 - 1425 RPM 50 Hz 4 Pole	212 - 2 and 12 Poles
11 - 1140 RPM 60 Hz 6 Pole	46 - 4 and 6 Poles
9 - 950 RPM 50 Hz 6 Pole	48 - 4 and 8 Poles
8 - 960 RPM 60 Hz 8 Pole	410 - 4 and 10 Poles
7 - 720 RPM 50 Hz 8 Pole	412 - 4 and 12 Poles
7 - 795 RPM 60 Hz 10 Pole	68 - 6 and 8 Poles
6 - 580 RPM 50 Hz 10 Pole	
6 - 580 RPM 60 Hz 12 Pole	

Odd frequencies other than 50 Hz show synchronous speed code.

DC and special motors may have one, two, or three digits indicating motor speed rounded to the nearest hundred RPM.

Position 6: Enclosure

- D— Drip-Proof
- E— Explosion-Proof TENV
- F— Fan Cooled
- N— TENV
- O— Open
- S— Splashproof
- W— Weatherproof, Severe Duty, Chemical Duty, WASHGUARD™ - TEFC
- X— Explosion-Proof TEFC
- V— Weatherproof, Severe Duty, Chemical Duty, WASHGUARD™ - TENV

Position 7: Mounting

- B— Rigid base standard
- C— "C" face - no base - NEMA
- D— "D" flange - no base - NEMA
- H— 48 frame - 56 frame mounting/shaft rigid
- J— 48 frame - 56 frame mounting/shaft resilient
- K— Rigid mount with "C" flange
- L— Rigid mount with "D" flange
- M— Motor parts - rotor and stator
- R— Resilient base
- S— Shell motor
- T— Torpedo (face-less/base-less)
- Z— Special mounting

Position 8: Sequence Number

Number assigned as required when new designs with new characteristics are needed.

Position 9: Modification Letter

Major modification letter. Used when revisions made in existing model ***will*** affect service parts.

Position 10: (Optional)

A date code consisting of either A-Z, and two digits 00-99.

Reading a Lincoln Motors Model Number

There is no independently established standard for setting up a motor's model number, but the procedure is typically tied to descriptions of various electrical and mechanical features. While other manufacturers use other designations, here is how Lincoln Motors model numbers are configured

EXAMPLE:

Position No.	A	B	C	D	E	F	G	H
Sample Model No.	**SRF**	**4**	**S**	**0.5**	**T**	**C**	**1C6028**	**TP2**

Position A: Frame Material

A, AA = Extruded aluminum
AV = Alum 63 frame
AP = Alum 71 frame
AR = Alum 80 frame
C = Cast iron
M = Steel (encapsulated windings, 284T-445T frames)
S = Steel (143T-449T frames)

Signature Series Motors
SP = Steel (48 frames)
SR = Steel (56 frames)
SS = Steel (143T-215T frames)
CC = Cast iron (143T and larger)

Enclosure (follows Frame Material*):

A = TEAO	FW = TEFC, Washdown
B = TEBC	FX = TE, Explosion-proof
D = ODP	NW = TENV, Washdown
E = ODP-Encapsulated	RA = TEAO, Steel
EW = Wash-Thru™ Motor	NX = XP, TENV
F = TEFC	YF = TEFC, Metric
RN = Steel TENV 48 frame	PA = Steel 48 frame
N = TENV	PN = Steel TENV 48 frame
P = Severe Duty IEEE 841	RN = Steel TENV 48 frame
S = Severe Duty	

Position B: Number of Magnetic Poles: this leads to motor synchronous speed (rpm).

Poles	Speed 60 Hz	Speed 50 Hz
2	3600 RPM	3000 RPM
4	1800	1500
6	1200	1000
8	900	750

Single speed motors:
4 = 1800 (60 Hz) or 1500 (50 Hz)

Two speed motors:
2/4/1 = 3600 and 1800 (60 Hz), one winding
4/8/2 = 1800 and 900 (60 Hz), two windings

Position C: Efficiency Level:

B = Exceeds NEMA MG-1 Table 12-10
G = Below NEMA MG-1 Table 12-10, GM7EQ
P = Meets EPAct, NEMA MG-1 Table 12-10 and GM-7EH.
S, H = Below NEMA MG-1 Table 12-10

Position D: Horsepower:

Single speed motor examples: 0.25, 0.5, 1.5, 75, 800

Horsepower range example: 5-7 = 5 to 7

Two speed motor example:
10/2.5 = 10 HP high speed, 2.5 HP low speed

Position E: NEMA Frame Series and Dimensions:

T or U = sets frame number and dimensions in accordance with NEMA T or U design standards for the motor's HP, speed and enclosure.
E = Metric design IEC

Position F: Shaft and Mounting:

AD = Auger drive	R = Resilient mount
C = C-Face, B14	S = NEMA short shaft
D = D-Flange, B5	Y = special mounting (ie. extended thru-bolts)
J = Jet Pump	Z = non-standard shaft dimensions (-1, -2, -3, etc. will appear at the end of the Model Number)
JM = JM Pump Mount	
JP = JP Pump Mount	
L = Locked bearing	
N = No feet	

Double shaft motors are identified by two symbols, the first for the "normal drive end" and the second for the "opposite normal drive end": SD4B30TTM61Y and SD4P75TSTS61Y

Each end of the double shaft can have its own mounting: MD4S125TSCTSC61 and CS6P15TTMC61Y

Mounting symbols are listed in alphabetical order when more than one is specified: SSD2S25TJMN61

Position G: Electrical Type (Single Phase Only):

1A = permanent split capacitor
1B = capacitor start, capacitor run
1C = capacitor start, induction run
1N = split phase start, capacitor run
1S = split phase

Frequency:
6_ = 60 Hz and 5_ = 50 Hz

Voltage:

The specific number has no significance. Lincoln will assign the next number in sequence to a new, previously unmanufactured voltage when it is ordered.

Position G: Electrical Type (Single Phase Only): [cont'd]

Commonly used voltage codes:

60 Hz	50 Hz
61 = 230/460 V	51 = 220/380 V
62 = 200/400	52 = 240/415
63 = 208	53 = 230/400
64 = 460	54 = 200/400
65 = 575	55 = 380
66 = 230	56 = 400
67 = 440	57 = 415
68 = 380	58 = 440
69 = 480	59 = 220/440
6003 = 220/380	5001 = 190/380
6004 = 220/440	5007 = 346
6020 = 2300	5012 = 550
6021 = 4000	5014 = 380-415
6024 = 2300/4000	
6026 = 208-230/460	
6027 = 115/230	
6028 = 115/208-230	
6029 = 208-220/440	

Reduced Voltage Start Capability:

P = Part winding start (PWS)
Y = Wye-delta start (YDS)
PY = PWS and YDS

Position H: Options/Modifications:

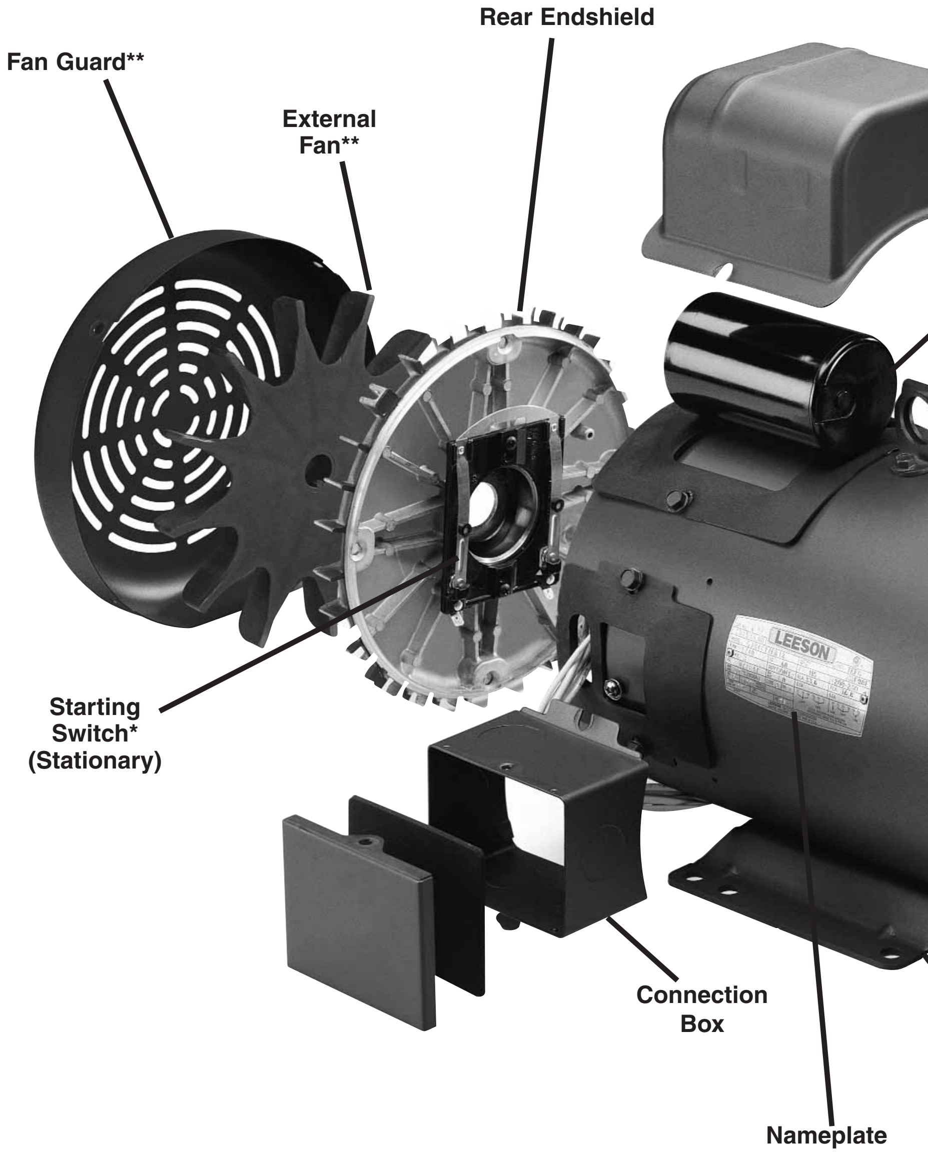
If a motor has more than one Option / Modification, the symbols will appear in alphabetical order.

AP1	CE Compliant Motor
AP5	Fire Pump certified
AP7	Farm Duty, High Torque
AP8	Farm Duty, Extra High Torque
AP9	Grain Stirring
AP10	PSC Variable Speed
AP11	PSC Variable Speed, expanded speed range
AP13	UL Listed Class 1 Groups C & D and Class 2 Groups F & G, thermostats
AP14	UL Listed Class 1 Groups C & D and Class 2 Groups F & G, auto reset thermal protector
AP15	UL Listed Class 1 Group D and Class 2 Groups F & G, thermostats
AP21	Non NAFTA Qualified
AP23	Non NAFTA Qualified
AP25	Non NAFTA Qualified
B	F-2 Mount
C_	Ceiling Mount - NEMA position follows "C"; 1-2
E3	Class H Insulation
E5	Class H Insulation & High Temperature Grease
F	Fungus Proofing (Tropicalization)
H4	Leads exit motor at 12 o'clock position
HS	Precision Dynamic Balance
HT1	Space Heater, 120V
HT2	Space Heater, 240 V
K	Omit Terminal Box
L_	Additional Lead Length - "L" followed by additional length in inches
MB3	Insulated bearings, both ends
MB6	Double sealed bearings, both ends
MK_	Brake installed on motor
Q10	CTAC® Inverter Duty Motor with provision for mounting feedback device
Q15	CTAC Inverter Duty Motor with factory installed Dynapar 625 1024 ppr encoder

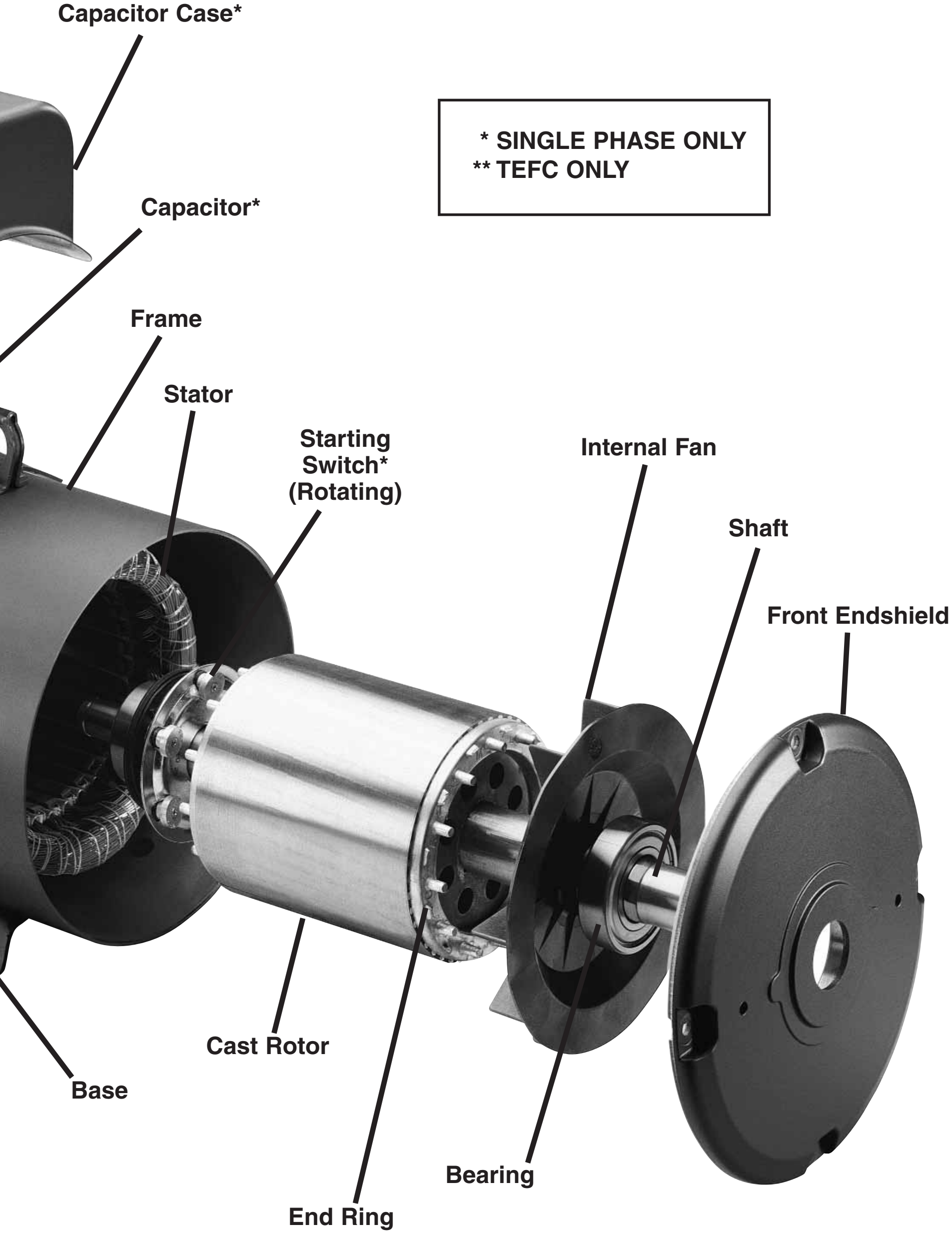
Position H: Options/Modifications: (cont'd)

Q15_	CTAC Inverter Duty Motor with factory installed encoder - letter following "Q15" represents brand and ppr rating of encoder, A through S.
Q20	CTAC Inverter Duty motor without provision for mounting feedback device
Q40	CTAC Inverter Duty Motor without provision for mounting feedback device
QS10	Crop dryer (single phase, auto reset)
QS11	Crop dryer (single phase, thermostats)
QS12	Crop dryer (three phase, thermostats)
RB	Roller bearing on drive end
T1	Thermostats, Class F, 3 in series
T5	Thermostats (2) Class F
TD1,2	RTD - Winding, 100 Ω platinum
TD4	RTD - Winding, 10 Ω copper
TD6	RTD - Winding, 120 Ω nickel
TP1	Overload protection, manual reset
TP2	Overload protection, auto reset
TX1	Thermistors, 3 in series
W_	Wall Mount - W followed by NEMA position number, 1-8
X_	Paint color deviation

Major Components



# of an Electric Motor



* SINGLE PHASE ONLY
** TEFC ONLY

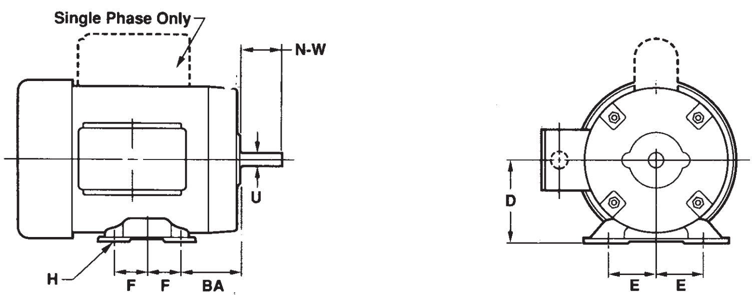
CHAPTER VI

Metric (IEC) Designations and Dimensions

The International Electrotechnical Commission (IEC) is a European-based organization that publishes and promotes worldwide mechanical and electrical standards for motors, among other things. In simple terms, it can be said that IEC is the international counterpart to the National Electrical Manufacturers Association (NEMA), which publishes the motor standards most commonly used throughout North America.

Dimensionally, IEC standards are expressed in metric units.

IEC / NEMA Dimensional Comparison



NOTES

* *Shaft dimensions of these IEC frames may vary between manufacturers.*

** *Horsepower listed is closest comparable rating with similar mounting dimensions. In some instances, this results in a greater HP rating than required. For example, 37 kW 4 pole converts to 50 HP but nearest HP rating in the NEMA frame having comparable dimensions is 75 HP. OBSERVE CAUTION if the drive train or driven load is likely to be damaged by the greater HP.*

Equivalent HP can be calculated by multiplying the kW rating by 1.341. Multiply HP by .7457 to convert HP of kW.

To convert from millimeters to inches multiply by .03937.

To convert from inches to millimeters multiply by 25.

IEC	NEMA	Dimensions in Millimeters							KW/HP** Frame Assignments		
		D	E	F	H	U	BA	N-W	3 Phase – TEFC		
									2 Pole	4 Pole	6 Pole
56	NA	56 –	45 –	35.5 –	5.8 –	9 –	36 –	20 –	– –	– –	– –
63	NA	63 –	50 –	40 –	7 –	11 –	40 –	23 –	.25KW 1/3HP	.18KW 1/4HP	– –
71	42	71 66.7	56 44.5	45 21.4	7 7.1	14 9.5	45 52.4	30 –	.55 3/4	.37 1/2	– –
80	48	80 76.2	62.5 54	50 34.9	10 8.7	19 12.7	50 63.5	40 38.1	1.1 1-1/2	.75 1	.55KW 3/4HP
90S	56	90 88.9	70 61.9	50 38.1	10 8.7	24 15.9	56 69.9	50 47.6	1.5 2	1.1 1-1/2	.75 1
90L	56	90 88.9	70 69.8	62.5 50.8	10 8.7	24 22.2	56 57.2	50 57.2	2.2 3	1.5 2	1.1 1-1/2
100L	145T	100 88.9	80 69.8	70 63.5	12 8.7	28 22.2	63 57.2	60 57.2	3 4	2.2 3	1.5 2
112L	182T	112 114.3	95 95.2	57 57.2	12 10.7	28 28	70 70	60 69.9	3.7 5	2.2 3	1.5 2
112M	184T	112 114.3	95 95.2	70 68.2	12 10.7	28 28	70 70	60 69.9	3.7 5	4 5-4/5	2.2 –
132S	213T	132 133.4	108 108	70 69.8	12 10.7	38 34.9	89 89	80 85.7	7.5 10	5.5 7-1/2	3 –
132M	215T	132 133.4	108 108	89 88.8	12 10.7	38 34.9	89 89	80 85.7	– –	7.5 10	5.5 7-1/2
160M*	254T	160 158.8	127 127	105 104.8	15 13.5	42 41.3	108 108	110 101.6	15 20	11 15	7.5 10
160L*	256T	160 158.8	127 127	127 127	15 13.5	42 41.3	108 108	110 101.5	18.5 25	15 20	11 15
180M*	284T	180 177.8	139.5 139.8	120.5 120.2	15 13.5	48 47.6	121 121	110 117.5	22 –	18.5 25	– –
180L*	286T	180 177.8	139.5 139.8	139.5 139.8	15 13.5	48 47.6	121 121	110 117.5	22 30	22 30	15 20
200M*	324T	180 203.3	159 158.8	133.5 133.4	19 16.7	55 54	133 133	110 133.4	30 40	30 40	– –
200L*	326T	200 203.2	159 158.8	152.5 152.4	19 16.7	55 54	133 133	110 133.4	37 50	37 50	22 30
225S*	364T	225 228.6	178 117.8	143 142.8	19 16.7	60 60.3	149 149	140 149.2	– –	37 50/75	30 40
225M*	365	225 228.6	178 177.8	155.5 155.6	19 16.7	60 60.3	149 149	140 149.2	45 60/75	45 60/75	37 50
250M*	405T	250 254	203 203.2	174.5 174.6	24 20.6	65 73	168 168	140 182.2	55 75/100	55 75/100	– –
280S*	444T	280 279.4	228.5 228.6	184 184.2	24 20.6	75 85.7	190 190	140 215.9	– –	– –	45 60/100
280M*	445T	280 279.4	228.5 228.6	209.5 209.6	24 20.6	75 85.7	190 190	140 215.9	– –	– –	55 75/125

See notes on facing page.

IEC Enclosure Protection Indexes

Like NEMA, IEC has designations indicating the protection provided by a motor's enclosure. However, where NEMA designations are in words, such as Open Drip Proof or Totally Enclosed Fan Cooled, IEC uses a two-digit Index of Protection (IP) designation. The first digit indicates how well-protected the motor is against the entry of solid objects; the second digit refers to water entry.

By way of general comparison, an IP 23 motor relates to Open Drip Proof, IP 44 to totally enclosed.

Protection Against Solid Objects		**Protection Against Liquids**	
No.	***Definition***	***No.***	***Definition***
0	No protection.	0	No protection.
1	Protected against solid objects of over 50mm (e.g. accidental hand contact).	1	Protected against water vertically dripping (condensation).
2	Protected against solid objects of over 12mm (e.g. finger).	2	Protected against water dripping up to 15° from the vertical.
3	Protected against solid objects of over 2.5mm (e.g. tools, wire).	3	Protected against rain falling at up to 60° from the vertical.
4	Protected against solid objects of over 1mm (e.g. thin wire).	4	Protected against water splashes from all directions.
5	Protected against dust.	5	Protected against jets of water from all directions.
6	Totally protected against dust. Does not involve rotating machines.	6	Protected against jets of water comparable to heavy seas.
		7	Protected against the effects of immersion to depths of between 0.15 and 1m.
		8	Protected against the effects of prolonged immersion at depth.

IEC Cooling, Insulation and Duty Cycle Indexes

IEC has additional designations indicating how a motor is cooled (two-digit IC codes). For most practical purposes, IC 01 relates to a NEMA open design, IC 40 to Totally Enclosed Non-Ventilated (TENV), IC 41 to Totally Enclosed Fan Cooled (TEFC), and IC 48 to Totally Enclosed Air Over (TEAO).

IEC winding insulation classes parallel those of NEMA and in all but very rare cases use the same letter designations.

Duty cycles are, however, different. Where NEMA commonly designates either continuous, intermittent, or special duty (typically expressed in minutes), IEC uses eight duty cycle designations.

S1 Continuous duty. The motor works at a constant load for enough time to reach temperature equilibrium.

S2 Short-time duty. The motor works at a constant load, but not long enough to reach temperature equilibrium, and the rest periods are long enough for the motor to reach ambient temperature.

S3 Intermittent periodic duty. Sequential, identical run and rest cycles with constant load. Temperature equilibrium is never reached. Starting current has little effect on temperature rise.

S4 Intermittent periodic duty with starting. Sequential, identical start, run and rest cycles with constant load. Temperature equilibrium is not reached, but starting current affects temperature rise.

S5 Intermittent periodic duty with electric braking. Sequential, identical cycles of starting, running at constant load, electric braking, and rest. Temperature equilibrium is not reached.

S6 Continuous operation with intermittent load. Sequential, identical cycles of running with constant load and running with no load. No rest periods.

S7 Continuous operation with electric braking. Sequential identical cycles of starting, running at constant load and electric braking. No rest periods.

S8 Continuous operation with periodic changes in load and speed. Sequential, identical duty cycles of start, run at constant load and given speed, then run at other constant loads and speeds. No rest periods.

IEC Design Types

The electrical performance characteristics of IEC Design N motors in general mirror those of NEMA Design B – the most common type of motor for industrial applications. By the same token, the characteristics of IEC Design H are nearly identical to those of NEMA Design C. There is no specific IEC equivalent to NEMA Design D. (See chart on Page 13 for characteristics of NEMA design types.)

IEC Mounting Designations

Three common IEC mounting options are shown in this photo. From left, a B5 flange, B14 face and rigid B3 base. In this case, any of the options can be bolted to a modularly designed round-body IEC 71 frame motor.

CHAPTER VII

Motor Maintenance

Motors, properly selected and installed, are capable of operating for many years with a reasonably small amount of maintenance.

Before servicing a motor and motor-operated equipment, disconnect the power supply from motors and accessories. Use safe working practices during servicing of the equipment.

Clean motor surfaces and ventilation openings periodically, preferably with a vacuum cleaner. Heavy accumulations of dust and lint will result in overheating and premature motor failure.

Lubrication Procedure

Motors 10 HP and smaller are usually lubricated at the factory to operate for long periods under normal service conditions without re-lubrication. Excessive or too frequent lubrication may actually damage the motor. Follow instructions furnished with the motor, usually on the nameplate or terminal box cover or on a separate instruction. If instructions are not available, re-lubricate according to the chart on the next page. Use high-quality ball bearing grease. Grease consistency should be suitable for the motor's insulation class. For Class B, F or H, use a medium consistency polyurea grease such as Shell Dolium R.

If the motor is equipped with lubrication fitting, clean the fitting tip, and apply grease gun. Use one to two full strokes on NEMA 215 frame and smaller motors. Use two to three strokes on NEMA 254 through NEMA 365 frame. Use three to four strokes on NEMA 404 frames and larger. For motors that have grease drain plugs, remove the plugs and operate the motor for 20 minutes before replacing the plugs.

For motors equipped with slotted head grease screws, remove the screw and insert a two-inch to three-inch long grease string into each hole on motors in NEMA 215 frame and smaller.

Insert a three-inch to five-inch length on larger motors. For motors having grease drain plugs, remove the plug and operate the motor for 20 minutes before replacing the plugs.

Relubrication Intervals Chart
For Motors Having Grease Fittings

Hours of Service Per Year	HP Range	Suggested Relube Interval
5000	1/18 to 7 1/2 10 to 40 50 to 100	5 years 3 years 1 year
Continuous Normal Applications	to 7 1/2 10 to 40 50 to 100	2 years 1 year 9 months
Seasonal Service - Motor is idle for 6 months or more	All	1 year (beginning of season)
Continuous high ambient, high vibrations, or where shaft end is hot	1/8 to 40 50 to 150	6 months 3 months

Caution: Keep grease clean. Lubricate motors at a standstill. Do not mix petroleum grease and silicone grease in motor bearings.

DC Motor Trouble-Shooting Chart

LEESON® Lincoln MOTORS

More Than Just a Motor Company

CAUTION

1. Disconnect power to the motor before performing service or maintenance.
2. Discharge all capacitors before servicing motor.
3. Always keep hands and clothing away from moving parts.
4. Be sure required safety guards are in place before starting equipment.

Problem	Likely Causes	What To Do
Motor fails to start upon initial installation.	Motor is miswired.	Verify that the motor is wired correctly.
	No output power from controller.	Measure voltage coming from the controller.
	Motor damaged and the fan guard is contacting the cooling fan.	Replace fan guard.
	Motor damaged and the armature is rubbing against the magnets.	Disassemble motor and see if the armature can be realigned by reassembly. Motor may have to be replaced.
Motor runs in the wrong direction.	Incorrect wiring.	Interchange the two motor leads.
Motor runs ok but has a clicking noise.	Suspect a burr on the commutator.	Stone the armature commutator with a commutator stone to remove burr.

DC Motor Trouble-Shooting Chart (cont'd)

Problem	Likely Causes	What To Do
Motor has been running, then fails to start.	Fuse or circuit breaker is tripped	Replace the fuse or rest the breaker
	Armature is shorted or went to ground. Motor may make a humming noise and the circuit breaker or fuse will trip.	Disassemble motor and inspect the armature for a burnt coil. Inspect the commutator for burnt bars. If this condition exists, the motor needs to be replaced. To test, set your OHM to the RX1 scale, touch probes to bars 180 degrees apart all around the commutator. The reading should be equal.
	The brushes may be worn down too far and no longer make contact with the commutator.	Inspect the brushes to make sure that they are still making contact with the commutator. Refer to manufacturer's recommended brush length chart.
	Controller may be defective.	Verify voltage is coming out of the controller.
Motor runs but loses power.	Load has increased.	Verify the load has not changed. Measure the amp draw of motor against the full load amp rating of the motor. If the amp draw is higher than rating, motor is undersized for application.
	Motor controller not properly set.	Check controller manual for adjustments. The torque and/or IR compensation settings may need adjustment.
	Motor may have an open connection.	Inspect the armature for an open connection.
	Brushes may not be seated properly or worn beyond their useful length.	Verify that the brushes are properly seated and measure their length against the recommended brush length chart.
Motor takes too long to accelerate.	Motor controller not properly set.	The accel trim pot of the controller should be adjusted.
	Brushes are worn.	Verify brush length.
	Bearings may be defective.	Inspect bearings for proper service. Noisy or rough bearings should be replaced.

Motor Trouble-Shooting Chart

More Than Just a Motor Company

CAUTION

1. Disconnect power to the motor before performing service or maintenance.
2. Discharge all capacitors before servicing motor.
3. Always keep hands and clothing away from moving parts.
4. Be sure required safety guards are in place before starting equipment.

Problem	Likely Causes	What To Do
Motor fails to start upon initial installation.	Motor is miswired.	Verify that the motor is wired correctly.
	Motor damaged and rotor is striking stator.	May be able to reassemble; otherwise, motor should be replaced.
	Fan guard bent and contacting fan.	Replace fan guard.
Motor had been running, then fails to start.	Fuse or circuit breaker tripped.	Replace fuse or reset breaker.
	Stator is shorted or went to ground. Motor will make a humming noise and the circuit breaker or fuse will trip.	Disassemble motor and inspect windings and internal connections. A blown stator will show a burn mark. Motor must be replaced or the stator rewound.
	Motor overloaded or load jammed.	Inspect to see that the load is free. Verify amp draw of motor versus nameplate rating.
	Capacitor (on shingle phase motor) may have failed.	First discharge capacitor. To check capacitor, set volt-ohm meter to RX100 scale and touch its probes to capacitor terminals. If capacitor is OK, needle will jump to zero ohms, and drift back to high. Steady zero ohms indicates a short circuit; steady high ohms indicates an open circuit.

Motor Trouble-Shooting Chart (cont'd)

Problem	Likely Causes	What To Do
Motor had been running, then fails to start. (cont'd)	Starting switch has failed.	Disassemble motor and inspect both the centrifugal and stationary switches. The weights of the centrifugal switch should move in and out freely. Make sure that the switch is not loose on the shaft. Inspect contacts and connections on the stationary switch. Replace switch if the contacts are burned or pitted.
Motor runs but dies down.	Voltage drop.	If voltage is less than 10% of the motor's rating contact power company or check if some other equipment is taking power away from the motor.
	Load increased.	Verify the load has not changed. Verify equipment hasn't got tighter. If fan application verify the air flow hasn't changed.
Motor takes too long to accelerate.	Defective capacitor.	Test capacitor per previous instructions.
	Faulty stationary switch.	Inspect switch contacts and connections. Verify that switch reeds have some spring in them.
	Bad bearings.	Noisy or rough feeling bearings should be replaced.
	Voltage too low.	Make sure that the voltage is within 10% of the motor's nameplate rating. If not, contact power company or check if some other equipment is taking power away from the motor.
Motor runs in the wrong rotation.	Incorrect wiring.	Rewire motor according to wiring schematic provided.
Motor overload protector continually trips.	Load too high.	Verify that the load is not jammed. If motor is a replacement, verify that the rating is the same as the old motor. If previous motor was a special design, a stock motor may not be able to duplicate the performance. Remove the load from the motor and inspect the amp draw of the motor unloaded. It should be less than the full load rating stamped on the nameplate.

Motor Trouble-Shooting Chart (cont'd)

Problem	Likely Causes	What To Do
Motor overload protector continually trips. (cont'd)	Ambient temperature too high.	Verify that the motor is getting enough air for proper cooling. Most motors are designed to run in an ambient temperature of less than 40° C. (Note: A properly operating motor may be hot to the touch.)
	Protector may be defective.	Replace the motor's protector with a new one of the same rating.
	Winding shorted or grounded.	Inspect stator for defects, or loose or cut wires that may cause it to go to ground.
Motor vibrates.	Motor misaligned to load.	Realign load.
	Load out of balance. (Direct drive application).	Remove motor from load and inspect motor by itself. Verify that motor shaft is not bent. Rule of thumb is .001" runout per every inch of shaft length.
	Motor bearings defective.	Test motor by itself. If bearings are bad,you will hear noise or feel roughness. Replace bearings. Add oil if the bearing is a sleeve bearing type or replace bearings. Add grease if bearings have grease fittings.
	Rotor out of balance.	Inspect motor by itself with no load attached. If it feels rough and vibrates but the bearings are good, it may be that the rotor was improperly balanced at the factory. Rotor must be replaced or rebalanced.
	Motor may have too much endplay.	With the motor disconnected from power turned shaft. It should move but with some resistance. If the shaft moves in and out too freely, this may indicate a preload problem and te bearings may need additional shimming.
	Winding may be defective.	Test winding for shorted or open circuits. The amps may also be high. Replace motor or have stator rewound.

Motor Trouble-Shooting Chart (cont'd)

Problem	Likely Causes	What To Do
Bearings continuously fail.	Load to motor may be excessive or unbalanced.	Besides checking load, also inspect drive belt tension to ensure it's not too tight may be too high. An unbalanced load will also cause the Bearings to fail.
	High ambient temperature.	If the motor is used in a high ambient, a different type of bearing grease may be required. You may need to consult the factory or a bearing distributor.
The motor, at start up, makes a loud rubbing or grinding noise.	Rotor may be striking stator.	Ensure that motor was not damaged in shipment. Frame damage may not be repairable. If you cannot see physical damage, inspect the motor's rotor and stator for strike marks. If signs of rubbing are present, the motor should be replaced. Sometimes simply disassembling and reassembling motor eliminates rubbing. Endbells are also sometimes knocked out of alignment during transportation.
Start capacitors continuously fail.	The motor is not coming up to speed quickly enough.	Motor may not be sized properly. Verify how long the motor takes to come up to speed. Most single phase capacitor start motors should come up to speed within three seconds. Otherwise the capacitors may fail.
	The motor is being cycled too frequently.	Verify duty cycle. Capacitor manufactures recommend no more than 20, three-second starts per hour. Install capacitor with higher voltage rating, or add bleed resistor to the capacitor.
	Voltage to motor is too low.	Verify that voltage to the motor is within 10% of the nameplate value. If the motor is rated 208-230V, the deviation must be calculated from 230V.
	Starting switch may be defective, preventing the motor from coming out of start winding.	Replace switch.
Run capacitor fail.	Ambient temperature too high.	Verify that ambient does not exceed motor's nameplate value.
	Possible power surge to motor, caused by lightning strike or other high transient voltage.	If a common problem, install surge protector.

CHAPTER VIII
Common Motor Types and Typical Applications

Alternating Current Designs

Single Phase * Rigid Base Mounted * Capacitor Start * Totally Enclosed Fan Cooled (TEFC) & Totally Enclosed Non-Vent (TENV)
General purpose including compressors, pumps, fans, farm equipment, conveyors, material handling equipment and machine tools.

Single Phase * Rigid Base Mounted * Capacitor Start * Open Drip Proof (ODP)
General purpose including compressors, pumps, conveyors, fans, machine tools and air conditioning units - usually inside or where protected from weather, dust and contaminants.

Three Phase * Rigid Base Mounted * TEFC
General purpose including pumps, compressors, fans, conveyors, machine tools and other applications where three-phase power is available.

Three Phase * Rigid Base Mounted * ODP
General purpose including pumps, compressors, machine tools, conveyors, blowers, fans and other applications requiring three-phase power, usually inside or where protected from weather, dust and contaminants.

Single Phase * NEMA C Face Less Base * Capacitor Start * TEFC & TENV
Pumps, fans, conveyors, machine tools and gear reducers.

Single Phase * NEMA C Face Less Base * Capacitor Start * ODP
Fans, blowers, compressors, tools and speed reducers.

Three Phase * NEMA C Face Less Base * TEFC & TENV
Fans, blowers, compressors, tools and speed reducers where three-phase power is suitable.

Three Phase * NEMA C Face Less Base * ODP
Fans, blowers, compressors, tools and speed reducers.

Wash-Thru and Multiguard Motors
Used in applications involving moisture, vibration, dust and some chemical contact. The motor's windings are impregnated and encapsulated in a thermosetting that protects them from contaminants for long motor life.

Automotive Duty Motors
Suited for a wide variety of tough applications found in automotive manufacturing facilities and other industries utilizing U-Frame motors. Meets or exceeds General Motors GM-7EH and –7EQ, Ford EM1 and Chrysler NPEM-100 specifications.

Crusher Duty Motors
Ideally suited for size reduction equipment including rock crushers and pulverizers and other uses the aggregate and construction industries. They are designed for belted (radial) loads only utilizing roller bearings on the Drive-end side of the motor.

Washdown-Duty * Single & Three Phase * TENV & TEFC
Extended life in applications requiring regular hose-downs with cleaning solutions, as in food processing and for applications in wet, high humidity environments. Also available in direct current designs.

Explosion Proof * Single & Three Phase * TENV & TEFC
Designed and listed for application in hazardous environments having certain explosive gases or materials present on equipment, such as blowers, pumps, agitators or mixers.

Chemical Service Motors * Rigid Base
Petrochemical plants, foundries, pulp and paper plants, waste management facilities, chemical plants, tropical climates and other processing industry applications requiring protection against corrosion caused by severe environmental operating conditions.

Brakemotors * Single & Three Phase
Machine tools, hoists, conveyors, door operators, speed reducers, valves, etc., when stop and hold performance is required when power is removed from the motor by the use of a spring-set friction brake.

Resilient Mounted * Single & Three Phase * Moderate Starting Torques
General purpose applications where quiet operation is preferred for fan and blower service.

Resilient Mounted * Single & Three Phase * Two Speed * Two Winding * Variable Torque:
Belted or fan-on-shaft applications.

Rigid Mounted * Totally Enclosed Air Over (TEAO) * Single & Three Phase
Dust-tight motors for shaft-mounted or belt-driven fans. The motor depends upon the fan's airflow to cool itself.

HVAC Blower Motors * Three Phase * Automatic Reset Overload Protector * Resilient Base * ODP
Heating, ventilating and air conditioning applications requiring moderate starting torque and thermal protection.

Condenser Fan Motors * Three Phase * Belly Band Mount * ODP
For operating vertical shaft-up on condenser fan, air-over applications, such as rooftop air conditioning units.

Two Speed * Three Phase * Variable Torque
Fans, blowers and centrifugal pumps. Variable torque motors have horsepower ratings that vary as the square of the speed, while torque varies directly with the speed.

Two Speed * Three Phase * Constant Torque
Mixers, compressors, conveyors, printing presses, extractors, feeders and laundry machines. Constant torque motors are capable of developing the same torque for all speeds. Their horsepower ratings vary directly with the speed.

Two Speed * Three Phase * Constant Horsepower
Machine tools, such as drills, lathes, punch presses and milling machines. Constant horsepower motors develop the same horsepower at all operating speeds, and the torque varies inversely with the speed.

Jet Pump Motors * Single & Three Phase
Residential and industrial pumps, plus swimming pool pumps. The pump impeller is mounted to the motor shaft.

JM Pump Motors * Single & Three Phase
Continuous duty service on close-coupled pumps using NEMA JM mounting provisions. Commonly used for circulating and transferring fluids in commercial and industrial water pumps.

Compressor Duty * Single & Three Phase
Air compressor, pump-fan and blower duty applications which require high breakdown torque and overload capacity matching air compressor loading characteristics.

Woodworking Motors * Single Phase * TEFC
High torques for saws, planers and similar woodworking equipment.

Instant Reversing Motors * Resilient Mount * Single Phase * ODP
Specially designed motors for use on instant-reversing parking gates, doors, slide gates or other moderate starting torque instant reversing application; capable of frequent reversing service.

Pressure Washer Pump Motors * Rigid Mount & Rigid Mount with NEMA C Face * Single Phase * ODP
Hot or cold pressure washers and steam cleaners.

IEC Metric Motors * Three Phase
For replacement on imported machined tools, textile machinery and other equipment having metric dimensioned motors. Also available in direct current designs.

Farm Duty * High Torque & Extra High Torque * Rigid Base Mount & C Face Less Base
Severe agricultural equipment applications requiring high torques under adverse operating conditions such as low temperatures.

Agricultural Fan Duty * Resilient & Rigid Base Mount * Single & Three Phase * TEAO
Dust-tight fan and blower duty motors for shaft-mounted or belt-driven fans. The motor depends upon the fan's air flow to cool itself.

Feed-Auger Drive Motors * Single Phase
Dust-tight auger motors eliminate damage caused when the motor is overspeeded by an obstructed auger. Special flange mounts directly to the auger gear reducer.

Hatchery/Incubator Fan Motor * Band Mounted * Single Phase * TEAO
Replacement for use on poultry incubator fans. Includes extended through bolts for attaching farm shroud.

Feather Picker Motor * Rigid Mount * Three Phase * TEFC
Washdown-duty motor replaces the MEYN drive motor of a processing machine that removes feathers from poultry.

Milk Transfer Pump Motor * Rigid Base * Single Phase * TENV
Replacement in dairy milk pumps.

Grain Stirring Motors * Rigid Base * Single Phase * TEFC
Designed to operate inside agricultural storage bins for stirring grain, corn, and other agricultural products during the drying and storage process.

Irrigation Drive Motors * C Face Less Base * Three Phase * TEFC
For center pivot irrigation systems exposed to severe weather environments and operating conditions. Drives the tower that propels sprinklers in a circle around the well.

Elevator Motors

Submersible Hydraulic Elevator Pump Motors
Used in Elevator systems for applications in hydraulic passenger, service, freight and low-rise elevators.

Hydraulic Elevator Pump Motors
Used in Hydraulic pump passenger, service, freight and dumbwaiter low rise elevators

VVVF (Variable Voltage Variable Frequency) Traction Elevator Hoist Motors
Designed for Geared and Gearless Traction Elevators.

High-Voltage, SCR-Rated Brush-Type * Permanent Magnet Field * C Face With Removable Base * TEFC

Generally used for conveyors, machine tools, hoists or other applications requiring smooth, accurate adjustable-speed capabilities through the use of thyristor-based controls, often with dynamic braking and reversing also required. Usually direct-coupled to driven machinery, with the motor often additionally supported by a base for maximum rigidity. Such motors are also applicable where extremely high starting torque, or high intermittent-duty running torques are needed, even if the application may not require adjustable speed.

High-Voltage, SCR-Rated Brush-Type * Permanent Magnet Field * Washdown-Duty Enhancements * C Face With Removable Base * TENV

Designed for extended life on food-processing machines or other high-humidity environments where adjustable speed is required.

Low-Voltage Brush-Type * Permanent Magnet Field * C Face With Removable Base * TENV

For installations operating from battery or solar power, or generator-supplied low-voltage DC. One key application is a pump operating off a truck battery. Like high-voltage counterparts, low-voltage designs provide linear speed/torque characteristics over their entire speed range, as well as dynamic braking, easy reversing and high torque.

CHAPTER IX

Gear Reducers and Gearmotors

A gear reducer, also called a speed reducer or gear box, consists of a set of gears, shafts and bearings that are factory-mounted in an enclosed, lubricated housing. Gear reducers are available in a broad range of sizes, capacities and speed ratios. Their job is to convert the input provided by a "prime mover" into output of lower RPM and correspondingly higher torque. In industry, the prime mover is most often an electric motor, though internal combustion engines or hydraulic motors may also be used.

Cutaway view shows key components of an industrial-duty worm gear reducer. Note steel worm and bronze worm gear. Seals on both input and output shafts prevent lubricant leakage.

There are many types of gear reducers using various gear types to meet application requirements as diverse as low first cost, extended life, limited envelope size, quietness, maximum operating efficiency, and a host of other factors. The discussion that follows is intended only as a brief outline of the most common industrial gear reducer types, their characteristics and uses.

Right-Angle Worm Gear Reducers

The most widely used industrial gear reducer type is the right-angle worm reducer. Worm reducers offer long life, overload and shock load tolerance, wide application flexibility, simplicity and relatively low cost.

In a worm gear set, a threaded input shaft, called the worm, meshes with a worm gear that is mounted to the output shaft. Usually, the worm shaft is steel and the worm gear is bronze. This material combination has been shown to result in long life, smooth operation, and noise levels acceptable for industrial environments.

The number of threads in the worm shaft, related to the number of teeth in the worm gear, determine the speed reduction ratio. Single-reduction worm gear reducers are commonly available in ratios from approximately 5:1 through 60:1. A 5:1 ratio means that motor input of 1750 RPM is converted to 350 RPM output. A 60:1 ratio brings output RPM of the same motor to 29 RPM. Greater speed reductions can be achieved through double-reduction – meaning two gear reducers coupled together.

The flip side of "geared-down" speed is "geared-up" torque. For the majority of gear reducers in North America, output torque is expressed in inch-pounds or foot-pounds. Outside of North America, the metric unit of torque, newton-meter, is most common. Output speed and output torque are the key application criteria for a gear reducer.

Parallel-Shaft Gear Reducers

Parallel-shaft units are typically built with a combination of helical and spur gears in smaller sizes, and all helical gears in larger sizes. Helical gears, which have teeth cut in helixes to maximize gear-to-gear contact, offer higher efficiencies and quieter operation – though at a correspondingly higher cost than straight-tooth spur gears.

Single-reduction speed ratios are far more limited in parallel-shaft reducers than in right-angle worm reducers, but multiple reductions (or gear stages) fit easily within a single parallel-shaft reducer housing. As a result, the availability of higher ratios is usually greater in parallel-shaft reducers and gearmotors; ratios as high as 900:1 are common in small gearmotors.

Combination of spur and helical gears can be seen in this cutaway view of a sub-fractional horsepower parallel-shaft gearbox. Note multiple gear stages.

Three-phase NEMA C face AC motor combined with flanged worm gear reducer results in a "workhorse" industrial gear-motor. This straightforward mounting approach is common with motors ranging in sizes from fractional through 20 HP and larger.

An electric motor combined with a gear reducer creates a gearmotor. In sub-fractional horsepower sizes, integral gearmotors are the rule – meaning the motor and the reducer share a common shaft and cannot be separated. For application flexibility and maintenance reasons, a larger gearmotor is usually made up of an individual reducer and motor coupled together. This is most often accomplished by using a reducer having a NEMA C input flange mated to a NEMA C face motor. LEESON uses the term Gear+Motor™ for its separable reducer and motor packages.

At left, a quill-style input worm gear reducer uses a hollow input shaft and a shallow mounting flange. At right, extended mounting flange accommodates a solid-shaft to solid-shaft input with a flexible coupling joining the two shafts.

NEMA C flange reducers are of two basic types based on how the motor and reducer shafts are coupled. The most straightforward type, and the most commonly used in smaller horsepower applications, has a "quill" input – a hollow bore in the worm into which the motor's shaft is inserted. The other type, involving a reducer having a solid input shaft, requires a shaft-to-shaft flexible coupling, as well as an extended NEMA C flange to accommodate the combined length of the shafts.

Installation and Application Considerations

Mounting: In the majority of cases, gear reducers are base-mounted. Sometimes, mounting bolts are driven directly into pre-threaded holes in the reducer housing. Other times, accessory bases are used. Output flange mountings are also available.

Quill-style input reducer with added base;"worm over" mounting position

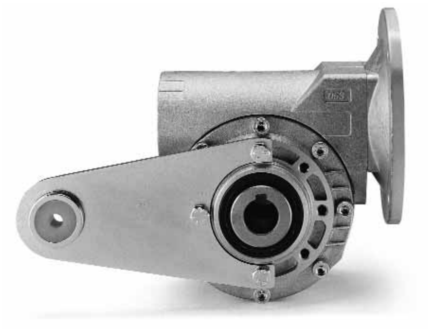
Shaft-input reducer in vertical position, deep NEMA C flange, plus "J style" base

Vertical output shaft, extended-height base, solid input shaft with no mounting flange

Quill-input reducer with output flange added

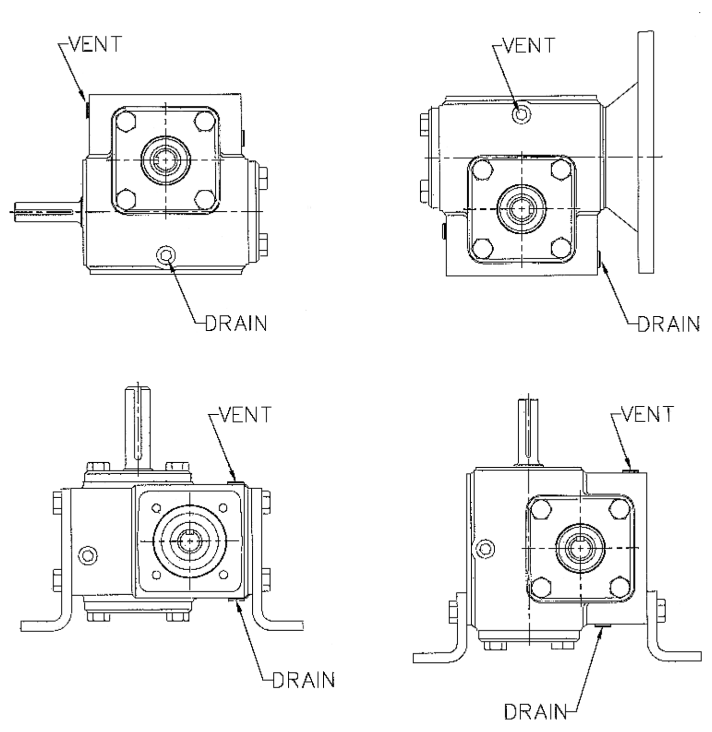
Basic worm gear reducers can be easily modified with mounting accessories to meet application needs. Four examples are shown.

Reducers having hollow output shafts are usually shaft-mounted to the driven load. If no output flange or secondary base is used, a reaction arm prevents the reducer housing from rotating.



Hollow output shaft reducer with reaction arm mounted. This model also has quill input and shallow NEMA C input flange.

Do not mount reducers with the input shaft facing down. Other than that, they may generally be mounted in any orientation. If the reducer is vented, be sure the vent plug is moved to a location as close as possible to the top of the unit, as shown in the examples below.



Output Speed and Torque: These are the key criteria for matching a gear reducer to the application needs.

Center Distance: The basic measurement or size reference for worm gear reducers. Generally, the larger the center distance, the greater the reducer capacity. Center distance is measured from the centerline of the input shaft to the centerline of the output shaft.

Horsepower: A reducer's input horsepower rating represents the maximum prime mover size the reducer is designed to handle. Output horsepower, while usually listed by reducer manufacturers, has little application relevance. Speed and torque are the real considerations.

Overhung Load: This is a force applied at right angles to a shaft beyond the shaft's outermost bearing. Too much overhung load can cause bearing or shaft failure. Unless otherwise stated, a reducer manufacturer's overhung load maximums are rated with no shaft attachments such as sheaves or sprockets. The American Gear Manufacturers Association provides factors, commonly called "K" factors, for various shaft attachments by which the manufacturer's maximum should be reduced. Overhung load can be eased by locating a sheave or sprocket as close to the reducer bearing as possible. In cases of extreme overhung load, an additional outboard bearing may be required.

The following formula can be used to calculate overhung load (OHL):

$$\text{OHL (pounds)} = \frac{\text{Torque (inch-pounds)} \times \text{K (load factor constant of overhung load)}}{\text{R (radius of pulley, sprocket or gear)}}$$

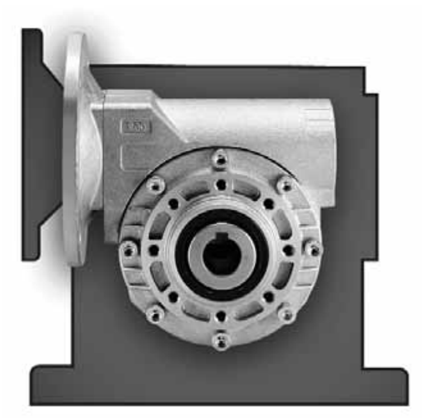
where, K equals 1.00 for chain and sprocket, 1.25 for a gear, and 1.5 for a pulley and v-belt.

Thrust Load: This is a force applied parallel to a shaft's axis. Mixers, fans and blowers are among driven machines that can induce thrust loads. Exceeding manufacturers' maximums for thrust loading can cause premature shaft and bearing failure.

Mechanical and Thermal Ratings: Mechanical ratings refer to the maximum power a reducer can transmit based on the strength of its components. Many industrial reducers, including LEESON's, provide a 200% safety margin over this rating for start-ups and momentary overloads.

Thermal rating refers to the power a reducer can transmit continuously based on its ability to dissipate the heat caused by operating friction.

In practice, the mass of a cast iron reducer housing and its oil lubrication system provide sufficient heat dissipation so that mechanical and thermal ratings are essentially equal. Aluminum-housed or grease-lubricated reducers have less heat dissipation mass and therefore require consideration of thermal rating.



Graphic shows compact size of an aluminum-housed worm gear reducer compared with a cast iron housed reducer of the same center distance. Smaller size and lighter weight can be an application advantage in many cases, but reduced mass means that the reducer's thermal rating must be carefully considered.

Service Factor: Established by the American Gear Manufacturers Association (AGMA), gearing service factors are a means to adjust a reducer's ratings relative to an application's load characteristics. Proper determination of an application's service factor is critical to maximum reducer life and trouble-free service. Unless otherwise designated, assume a manufacturer's ratings are based on an AGMA-defined service factor of 1.0, meaning continuous operation for 10 hours per day or less with no recurring shock loads. If conditions differ from this, input horsepower and torque ratings must be multiplied by the service factor selected from one of the tables below. In addition, AGMA has standardized service factor data for a wide variety of specific applications. Contact your manufacturer for this information.

Input Speed: Gear reducers are best driven at input speeds common in industrial electric motors, typically 1200, 1800 or 2500 RPM. This provides sufficient "splash" for the reducer's lubrication system, but not so much as to cause oil "churning." For input speeds under 900 RPM or above 3000 RPM, consult the manufacturer. Alternative lubricants may be suggested.

Service Factor Conversions for Reducers With Electric or Hydraulic Motor Input

Duration of Service (Hours per day)	Uniform Load	Moderate Shock	Heavy Shock	Extreme Shock
Occasional 1/2 Hour	--*	--*	1.0	1.25
Less than 3 Hours	1.0	1.0	1.25	1.50
3 - 10 Hours	1.0	1.25	1.50	1.75
Over 10 Hours	1.25	1.50	1.75	2.00

* Unspecified service factors should be 1.00 or as agreed upon by the user and manufacturer.

Service Factor Conversions for Reducers With Engine Input

Hydraulic or Electric Motor	Single Cylinder Engines	Multi-Cylinder Engines
1.00	1.50	1.25
1.25	1.75	1.50
1.50	2.00	1.75
1.75	2.25	2.00
2.00	2.50	2.25

Special Environmental Considerations

Gear reducers are extremely rugged pieces of equipment with long life in most types of power transmission applications. Modern components, including seals and synthetic lubricants, are designed for sustained high-temperature operation. Extreme heat, however, can be a problem. As a rule of thumb, maximum oil sump temperature for a speed reducer is 200ºF, or 100ºF above ambient temperature, whichever is lower. Exceeding these guidelines can shorten the reducer's life. Be sure to provide adequate air space around a reducer for heat dissipation. In some cases, it may be necessary to provide an external cooling fan. In a gearmotor application, the fan on a totally enclosed, fan cooled motor can also aid in cooling the reducer.

Moisture or high humidity is another concern. A key instance of this is a food processing environment requiring washdowns. In such cases, consider reducers with special epoxy coatings, external shaft seals, and stainless steel shaft extensions and hardware. If a gearmotor is used, be sure the motor has similar washdown-duty features.

Gear Reducer Maintenance

Industrial gear reducers require very little maintenance, especially if they have been factory-filled with quality, synthetic lubricant to a level sufficient for all mounting positions. In most cases, oil change will not be necessary over the life of the reducer. It is recommended that oil be changed only if repair or maintenance needs otherwise dictate gearbox disassembly.

Oil level should, however, be checked periodically and vent plugs inspected to ensure they are clean and operating.

Otherwise, general maintenance procedures for any industrial equipment apply. This includes making sure mounting bolts and other attachments are secure and that no other unusual conditions have occurred.

CHAPTER X

Adjustable Speed Drives

By definition, adjustable speed drives of any type provide a means of variably changing speed to better match operating requirements. Such drives are available in mechanical, fluid and electrical types.

The most common mechanical versions use combinations of belts and sheaves, or chains and sprockets, to adjust speed in set, selectable ratios – 2:1, 4:1, 8:1 and so forth. Traction drives, a more sophisticated mechanical control scheme, allow incremental speed adjustments. Here, output speed is varied by changing the contact points between metallic disks, or between balls and cones.

Adjustable speed fluid drives provide smooth, stepless adjustable speed control. There are three major types. Hydrostatic drives use electric motors or internal combustion engines as prime movers in combination with hydraulic pumps, which in turn drive hydraulic motors. Hydrokinetic and hydroviscous drives directly couple input and output shafts. Hydrokintetic versions adjust speed by varying the amount of fluid in a vortex that serves as the input-to-output coupler. Hydroviscous drives, also called oil shear drives, adjust speed by controlling oil-film thickness, and therefore slippage, between rotating metallic disks.

An eddy current drive, while technically an electrical drive, nevertheless functions much like a hydrokinetic or hydroviscous fluid drive in that it serves as a coupler between a prime mover and driven load. In an eddy current drive, the coupling consists of a primary magnetic field and secondary fields created by induced eddy currents. The amount of magnetic slippage allowed among the fields controls the driving speed.

In most industrial applications, mechanical, fluid or eddy current drives are paired with constant-speed electric motors. On the other hand, solid state electrical drives (also termed electronic drives), create adjustable speed motors, allowing speeds from zero RPM to beyond the motor's base speed. Controlling the speed of the motor has several benefits, including increased energy efficiency by eliminating energy losses in mechanical speed changing devices. In addition, by reducing, or often eliminating, the need for wear-prone mechanical components, electrical drives foster increased overall system reliability, as well as lower maintenance costs. For these and other reasons, electrical drives are the fastest growing type of adjustable speed drive.

There are two basic drive types related to the type of motor controlled – DC and AC. A DC direct current drive controls the speed of a DC motor by varying the armature voltage (and sometimes also the field voltage). An alternating current drive controls the speed of an AC motor by varying the frequency and voltage supplied to the motor.

DC Drives

Direct current drives are easy to apply and technologically straightforward. They work by rectifying AC voltage from the power line to DC voltage, then feeding adjustable voltage to a DC motor. With permanent magnet DC motors, only the armature voltage is controlled. The more voltage supplied, the faster the armature turns. With wound-field motors, voltage must be supplied to both the armature and the field. In industry, the following three types of DC drives are most common:

A general-purpose DC SCR drives family. From left, NEMA 4/12 "totally enclosed" version, chassis-mount, NEMA 1 "open" enclosure.

DC SCR Drives: These are named for the silicon controlled rectifiers (also called thyristors) used to convert AC to controlled voltage DC. Inexpensive and easy to use, these drives come in a variety of enclosures, and in unidirectional or reversing styles.

Regenerative SCR Drives: Also called four quadrant drives, these allow the DC motor to provide both motoring and braking torque. Power coming back from the motor during braking is regenerated back to the power line and not lost.

Pulse Width Modulated DC Drives: Abbreviated PWM and also called, generically, transistorized DC drives, these provide smoother speed control with higher efficiency and less motor heating. Unlike SCR drives, PWM types have three elements. The first converts AC to DC, the second filters and regulates the fixed DC voltage, and the third controls average voltage by creating a stream of variable width DC pulses. The filtering section and higher level of control modulation account for the PWM drive's improved performance compared with a common SCR drive.

AC Drives

AC drive operation begins in much the same fashion as a DC drive. Alternating line voltage is first rectified to produce DC. But because an AC motor is used, this DC voltage must be changed back, or inverted, to an adjustable-frequency alternating voltage. The drive's inverter section accomplishes this. In years past, this was accomplished using SCRs. However, modern AC drives use a series of transistors to invert DC to adjustable-frequency AC.

With advances in power electronics, even so-called "micro" drives can be used with motors 40 HP or higher. Full-featured unit shown includes keypad programming and alphanumeric display.

This synthesized alternating current is then fed to the AC motor at the frequency and voltage required to produce the desired motor speed. For example, a 60 hz synthesized frequency, the same as standard line frequency in the United States, produces 100% of rated motor speed. A lower frequency produces a lower speed, and a higher frequency a higher speed. In this way, an AC drive can produce motor speeds from, approximately, 15 to 200% of a motor's normally rated RPM – by delivering frequencies of 9 hz to 120 hz, respectively.

Today, AC drives are becoming the systems of choice in many industries. Their use of simple and rugged three-phase induction motors means that AC drive systems are the most reliable and least maintenance prone of all. Plus, microprocessor advancements have enabled the creation of so-called vector drives, which provide greatly enhance response, operation down to zero speed and positioning accuracy. Vector drives, especially when combined with feedback devices such as tachometers, encoders and resolvers in a closed-loop system, are continuing to replace DC drives in demanding applications.

"Sub-micro" drives provide a wide array of features in a very small package.

By far the most popular AC drive today is the pulse width modulated type. Though originally developed for smaller-horsepower applications, PWM is now used in drives of hundreds or even thousands of horsepower – as well as remaining the staple technology in the vast majority of small integral and fractional horsepower "micro" and "sub-micro" AC drives.

Pulse width modulated refers to the inverter's ability to vary the output voltage to the motor by altering the width and polarity of voltage pulses. The voltage and frequency are sythesized using this stream of voltage pulses. This is accomplished through microprocessor commands to a series of power semiconductors that serve as on-off switches. Today, these switches are usually IGBTs, or isolated gate bipolar transistors. A big advantage to these devices is their fast switching speed resulting in higher pulse or carrier frequency, which minimizes motor noise.

Encoders

Encoders are devices that translate a signal, whether motion into position or velocity feedback for a motion control system. Take a conveyor system as an application. You want to run the conveyor at 100 feet per minute. The motor that powers this conveyor has an encoder mounted to its shaft. Output from the encoder goes into the controller and as long as the output signal is telling the controller that everything is fine – the motor is running at the correct speed - it continues running at the current speed. If the load on the conveyor changes, like it is being overloaded due to additional weight of product added to the conveyor, the controller should notice a change in pulses from the encoder, for the speed of the conveyor slows down from this additional weight, and the controller will send a signal to the motor to speed up to compensate for this load change. Once the load has been returned to the standard expected load, the control will again see a signal from the encoder and will slow the motor down to the needed speed.

Encoders can be added to inverter-duty three-phase motors for use in closed-loop vector drive systems.

There are two main types of Encoders, Rotary and Linear and each type can use different sensing technologies. They include Optical, Magnetic or Inductive. Optical Rotary encoders are the most common type used.

"One Piece" Motor/Drive Combinations

Variously called intelligent motors, smart motors or integrated motors and drives, these units combine a three-phase electric motor and a pulse width modulated inverter drive in a single package. Some designs mount the drive components in what looks like an oversize conduit box. Other designs integrate the drive into a special housing made to blend with the motor. A supplementary cooling fan is also frequently used for the drive electronics to counteract the rise in ambient temperature caused by being in close proximity to an operating motor. Some designs also encapsulate the inverter boards to guard against damage from vibration.

Size constraints limit integrated drive and motor packages to the smaller horsepower ranges and require programming by remote keypad, either hand-held or panel mounted. Major advantages are compactness and elimination of additional wiring.

One-piece motor and drive combinations can be a pre-packaged solution in some applications. Unit shown incorporates drive electronics and cooling system in a special housing at the end of the motor.

AC Drive Application Factors

As PWM AC drives have continued to increase in popularity, drives manufacturers have spent considerable research and development effort to build in programmable acceleration and deceleration ramps, a variety of speed presets, diagnostic abilities, and other software features. Operator interfaces have also been improved with some drives incorporating "plain-English" readouts to aid set-up and operation. Plus, an array of input and output connections, plug-in programming modules, and off-line programming tools allow multiple drive set-ups to be installed and maintained in a fraction of the time spent previously. All these features have simplified drive applications. However, several basic points must be considered:

Torque: This is the most critical application factor. All torque requirements must be assessed, including starting, running, accelerating and decelerating and, if required, holding torque. These values will help determine what current capacity the drive must have in order for the motor to provide the torque required. Usually, the main constraint is starting torque, which relates to the drive's current overload capacity. (Many drives also provide a starting torque boost by increasing voltage at lower frequencies.)

Perhaps the overriding question, however, is whether the application is variable torque or constant torque. Most variable torque applications fall into one of two categories – air moving or liquid moving – and involve centrifugal pumps and fans. The torque required in these applications decreases as the motor RPM decreases. Therefore, drives for variable torque loads require little overload capacity. Constant torque applications, including conveyors, positive displacement pumps, extruders, mixers or other "machinery" require the same torque regardless of operating speed, plus extra torque to get started. Here, high overload capacity is required.

Smaller-horsepower drives are often built to handle either application. Typically, only a programming change is required to optimize efficiency (variable volts-to-hertz ratio for variable torque loads, constant volts-to-hertz ratio for constant torque loads). Larger horsepower drives are usually built specifically for either variable or constant torque applications.

Speed: As mentioned, AC drives provide an extremely wide speed range. In addition, they can provide multiple means to control this speed. Many drives, for example, include a wide selection of preset speeds, which can make set-up easier. Similarly, a range of acceleration and deceleration speed "ramps" are provided. Slip compensation, which maintains constant speed with a changing load, is another feature that can be helpful. In addition, many drives have programmable "skip frequencies." Particularly with fans or pumps, there may be specific speeds at which vibration takes place. By programming the drive to avoid these corresponding frequencies, the vibration can be minimized. Another control function, common with fans, is the ability for the drive to start into a load already in motion – often called a rolling start or spinning start. If required, be sure your drive allows this or you will face overcurrent tripping.

Current: The current a motor requires to provide needed torque (see previous discussion of torque) is the basis for sizing a drive. Horsepower ratings, while listed by drives manufacturers as a guide to the maximum motor size under most applications, are less precise. Especially for demanding constant torque applications, the appropriate drive may, in fact, be "oversized" relative to the motor. As a rule, general-purpose constant torque drives have an overload current capacity of approximately 150% for one minute, based on nominal output. If an application exceeds these limits, a larger drive should be specified.

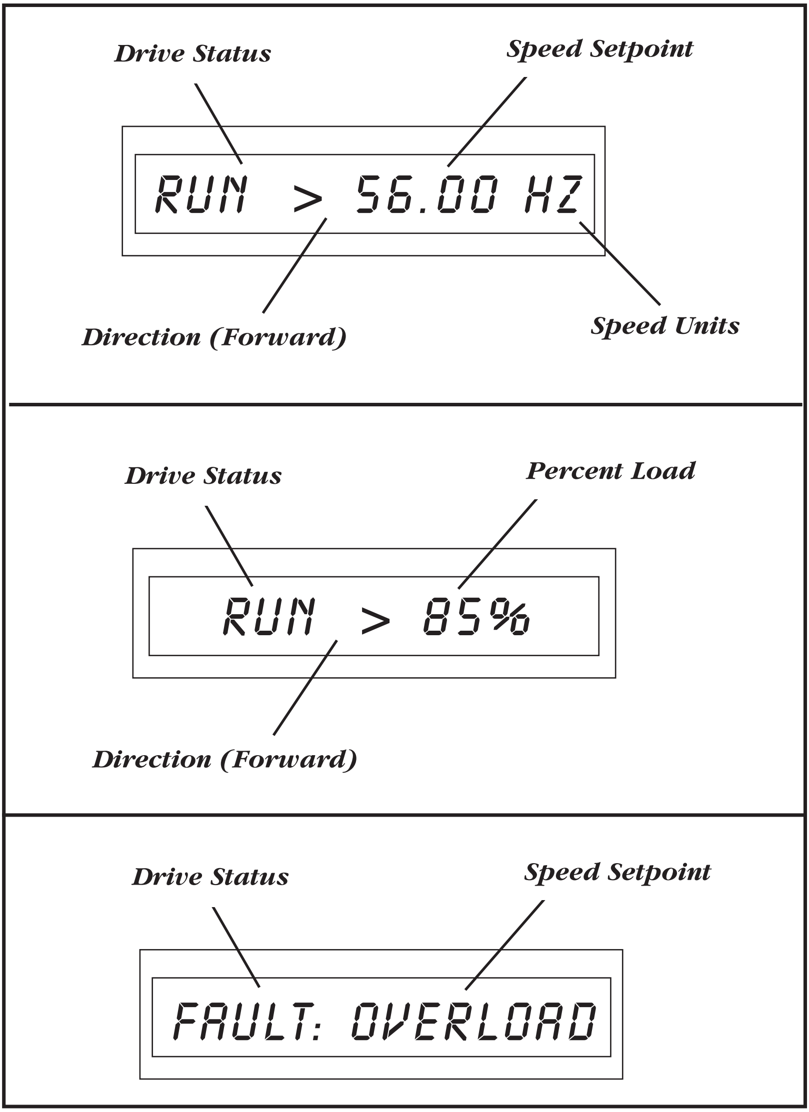
Power Supply: Drives tolerate line-voltage fluctuations of 10-15% before tripping and are sensitive to power interruptions. Some drives have "ride-though" capacity of only a second or two before a fault is triggered, shutting down the drive. Drives are sometimes programmed for multiple automatic restart attempts. For safety, plant personnel must be aware of this. Manual restart may be preferred.

Most drives require three-phase input. Smaller drives may be available for single-phase input. In either case, the motor itself must be three-phase.

Drives, like any power conversion device, create certain power disturbances (called "noise" or "harmonic distortion") that are reflected back into the power system to which they are connected. These disturbances rarely affect the drive itself but can affect other electrically sensitive components.

Control Complexity: Even small, low-cost AC drives are now being produced with impressive features, including an array of programmable functions and extensive input and output capability for integration with other components and control systems. Additional features may be offered as options. Vector drives, as indicated previously, are one example of enhanced control capability for specialized applications.

In addition, nearly all drives provide some measure of fault logging and diagnostic capability. Some are extensive, and the easiest to use display the information in words and phrases rather than simply numerical codes.



Examples of operating and diagnostic displays in a modern AC drive.

Environmental Factors: The enemies of electronic components are well-known. Heat, moisture, vibration and dirt are chief among them and obviously should be mitigated. Drives are rated for operation in specific maximum and minimum ambient temperatures. If the maximum ambient is exceeded, extra cooling must be provided, or the drive may have to be oversized. High altitudes, where thinner air limits cooling effectiveness, call for special consideration. Ambient temperatures too low can allow condensation. In these cases, or where humidity is generally high, a space heater may be needed.

Drive enclosures should be selected based on environment. NEMA 1 enclosures are ventilated and must be given room to "breath." NEMA 4/12 enclosures, having no ventilation slots, are intended to keep dirt out and are also used in washdown areas. Larger heat sinks provide convection cooling and must not be obstructed, nor allowed to become covered with dirt or dust. Higher-horsepower drives are typically supplied within NEMA-rated enclosures. "Sub-micro" drives, in particular, often require a customer-supplied enclosure in order to meet NEMA and National Electrical Code standards. The enclosures of some "micro" drives, especially those cased in plastic, may also not be NEMA-rated.

Motor Considerations With AC Drives

One drawback to pulse width modulated drives is their tendency to produce voltage spikes, which in some instances can damage the insulation systems used in electric motors. This tendency is increased in applications with long cable distances (more than 50 feet) between the motor and drive and with higher-voltage drives. In the worst cases, the spikes can literally "poke a hole" into the insulation, particularly that used in the motor's windings. To guard against insulation damage, some manufacturers now offer inverter-duty motors having special insulation systems that resist voltage spike damage. For example, LEESON's system, used in all three-phase motors 1 HP and larger, is called IRIS™ (Inverter Rated Insulation System).

Particularly with larger drives, it may be advisable to install line reactors between the motor and drive to choke off the voltage spikes. In addition, some increased motor heating will inevitably occur because of the inverter's "synthesized" AC wave form. Insulation systems on industrial motors built in recent years, and especially inverter-duty motors, can tolerate this except in the most extreme instances. A greater cooling concern involves operating for an extended time at low motor RPM, which reduces the flow of cooling air and especially in constant torque applications where the motor is heavily loaded even at low speeds. Here, secondary cooling such as a special blower may be required.

Constant-speed blower kits can be added in the field, providing additional cooling to motors operated at low RPM as part of an adjustable speed drive system.

Routine Maintenance of Electrical Drives

Major maintenance, troubleshooting and repair of drives should be left to a qualified technician, following the drive manufacturer's recommendations. However, routine maintenance can help prevent problems. Here are some tips:

- Periodically check the drive for loose connections or any other unusual physical conditions such as corrosion.
- Vacuum or brush heatsink areas regularly.
- If the drive's enclosure is NEMA 1, be sure vent slots are clear of dust or debris.
- If the drive is mounted within a secondary enclosure, again be sure vent openings area clear and that any ventilation fans are operating properly.
- Unless it is otherwise necessary for major maintenance or repair, the drive enclosure should not be opened.

CHAPTER XI

Engineering Data

Temperature Conversion Table

Locate known temperature in °C/°F column.
Read converted temperature in °C/°F column.

°C	°C/°F	°F	°C	°C/°F	°F	°C	°C/°F	°F
-45.4	-50	-58	15.5	60	140	76.5	170	338
-42.7	-45	-49	18.3	65	149	79.3	175	347
-40	-40	-40	21.1	70	158	82.1	180	356
-37.2	-35	-31	23.9	75	167	85	185	365
-34.4	-30	-22	26.6	80	176	87.6	190	374
-32.2	-25	-13	29.4	85	185	90.4	195	383
-29.4	-20	-4	32.2	90	194	93.2	200	392
-26.6	-15	5	35	95	203	96	205	401
-23.8	-10	14	37.8	100	212	98.8	210	410
-20.5	-5	23	40.5	105	221	101.6	215	419
-17.8	0	32	43.4	110	230	104.4	220	428
-15	5	41	46.1	115	239	107.2	225	437
-12.2	10	50	48.9	120	248	110	230	446
-9.4	15	59	51.6	125	257	112.8	235	455
-6.7	20	68	54.4	130	266	115.6	240	464
-3.9	25	77	57.1	135	275	118.2	245	473
-1.1	30	86	60	140	284	120.9	250	482
1.7	35	95	62.7	145	293	123.7	255	491
4.4	40	104	65.5	150	302	126.5	260	500
7.2	45	113	68.3	155	311	129.3	265	509
10	50	122	71	160	320	132.2	270	518
12.8	55	131	73.8	165	329	136	275	527

°F = (9/5 x °C) + 32

°C = 5/9 (°F - 32)

Mechanical Characteristics

To Find:	Use:
Torque in Inch-Pounds	$\frac{\text{HP x 63,025}}{\text{RPM}}$
Horsepower	$\frac{\text{Torque (lb. in.) x RPM}}{\text{63,025}}$
RPM	$\frac{\text{120 x Frequency}}{\text{Number of Poles}}$

Converting Torque Units

Inch-Pounds and Newton Meters

Torque (lb. in.) = 8.85 x Nm or = 88.5 x daNm
Torque (Nm) = $\frac{\text{lb. in.}}{8.85}$
Torque (daNm) = $\frac{\text{lb. in.}}{88.5}$

Electrical Characteristics

To Find:	Use: SIngle Phase	Or: Three Phase
Amperes Knowing HP	$\frac{\text{HP x 746}}{\text{E x Eff x PF}}$	$\frac{\text{HP x 746}}{\text{1.73 x E x Eff x PF}}$
Amperes Knowing kW	$\frac{\text{kW x 1000}}{\text{E x PF}}$	$\frac{\text{kW x 1000}}{\text{1.73 x E x PF}}$
Amperes Knowing kVA	$\frac{\text{kVA x 1000}}{\text{E}}$	$\frac{\text{kVA x 1000}}{\text{1.73 x E}}$
Kilowatts	$\frac{\text{I x E x PF}}{1000}$	$\frac{\text{1.73 x I x E x PF}}{1000}$
kVA	$\frac{\text{I x E}}{1000}$	$\frac{\text{1.73 x I x E}}{1000}$
HP (output)	$\frac{\text{I x E x Eff x PF}}{746}$	$\frac{\text{1.73 x I x E x Eff x PF}}{746}$

I = amperes
Eff = efficiency
PF = power factor
RPM = revolutions per minute
E = volts
kW - kilowatts
HP = horsepower
kVA = kilovolt amperes

Fractional/Decimal/Millimeter Conversion

Fraction		Decimal		Millimeter	Fraction		Decimal		Millimeter	MM		Inch
1/64	-	.015625	-	0.397	33/64	-	.515625	-	13.097	1	-	.039
1/32	-	.03125	-	0.794	17/32	-	.53125	-	13.494	2	-	.0790
3/64	-	.046875	-	1.191	35/64	-	.546875	-	13.891	3	-	.1181
1/16	-	.0625	-	1.588	9/16	-	.5625	-	14.288	4	-	.1575
5/64	-	.078125	-	1.984	37/64	-	.578125	-	14.684	5	-	.1969
3/32	-	.09375	-	2.381	19/32	-	.59375	-	15.081	6	-	.2362
7/64	-	.109375	-	2.778	39/64	-	.609375	-	15.478	7	-	.2756
1/8	-	.125	-	3.175	5/8	-	.625	-	15.875	8	-	.3150
9/64	-	.140625	-	3.572	41/64	-	.640625	-	16.272	9	-	.3543
5/32	-	.15625	-	3.969	21/32	-	.65625	-	16.669	10	-	.3937
11/64	-	.171875	-	4.366	43/64	-	.671875	-	17.066	11	-	.4331
3/16	-	.1875	-	4.762	11/16	-	.6875	-	17.462	12	-	.4724
13/64	-	.203125	-	5.129	45/64	-	.703125	-	17.859	13	-	.5119
7/32	-	.21875	-	5.556	23/32	-	.71875	-	18.256	14	-	.5519
15/64	-	.234375	-	5.953	47/64	-	.734375	-	18.653	15	-	.5906
1/4	-	.25	-	6.350	3/4	-	.75	-	19.050	16	-	.6300
17/64	-	.265625	-	6.747	49/64	-	.765625	-	19.447	17	-	.6693
9/32	-	.28125	-	7.144	25/32	-	.78125	-	19.844	18	-	.7087
19/64	-	.296875	-	7.541	51/64	-	.796875	-	20.241	19	-	.7480
5/16	-	.3125	-	7.938	13/16	-	.8125	-	20.638	20	-	.7874
21/64	-	.328125	-	8.334	53/64	-	.828125	-	21.034	21	-	.8268
11/32	-	.34375	-	8.731	27/32	-	.84375	-	21.431	22	-	.8661
23/64	-	.359375	-	9.128	55/64	-	.859375	-	21.828	23	-	.9055
3/8	-	.375	-	9.525	7/8	-	.875	-	22.225	24	-	.9449
25/64	-	.390625	-	9.921	57/64	-	.890625	-	22.622	25	-	.9843
13/32	-	.40625	-	10.319	29/32	-	.90625	-	23.019			
27/64	-	.421875	-	10.716	59/64	-	.921875	-	23.416			
7/16	-	.4375	-	11.112	15/16	-	.9375	-	23.812			
29/64	-	.453125	-	11.509	61/64	-	.953125	-	24.209			
15/32	-	.46875	-	11.906	31/32	-	.96875	-	24.606			
31/64	-	.484375	-	12.303	63/64	-	.984375	-	25.003			
1/2	-	.5	-	.12.700	1	-	1.	-	25.400			

To convert millimeters to inches, multiply by .03937
To convert inches to millimeters, multiply by 25.40

CHAPTER XII

Glossary

Actuator: A device that creates mechanical motion by converting various forms of energy to rotating or linear mechanical energy.

Adjustable Speed Drive: A mechanical, fluid or electrical device that variably changes an input speed to an output speed matching operating requirements.

AGMA (American Gear Manufacturers Association): Standards setting organization composed of gear products manufacturers and users. AGMA standards help bring uniformity to the design and application of gear products.

Air-Over (AO): Motors for fan or blower service that are cooled by the air stream from the fan or blower.

Alternating Current (AC): The standard power supply available from electric utilities.

Ambient Temperature: The temperature of the air which, when coming into contact with the heated parts of a motor, carries off its heat. Ambient temperature is commonly known as room temperature.

Ampere (Amp): The standard unit of electric current. The current produced by a pressure of one volt in a circuit having a resistance of one ohm.

Armature:
- The rotating part of a brush-type direct current motor.
- In an induction motor, the squirrel cage rotor.

Axial Movement: Often called "endplay." The endwise movement of motor or gear shafts. Usually expressed in thousandths of an inch.

Back Driving: Driving the output shaft of a gear reducer – using it to increase speed rather than reduce speed. Worm gear reducers are not suitable for service as speed increasers.

Backlash: Rotational movement of a gear reducer's output shaft clockwise and counter clockwise, while holding the input shaft stationary. Usually expressed in thousandths of an inch and measure at a specific radius at the output shaft.

Bearings:

Sleeve: Common in home-appliance motors.

Ball: Used when high shaft load capacity is required. Ball bearings are usually used in industrial and agricultural motors.

Roller: Use on output shafts of heavy-duty gear reducers and on some high-horsepower motors for maximum overhung and thrust load capacities.

Breakdown Torque: The maximum torque a motor can achieve with rated voltage applied at rated frequency, without a sudden drop in speed or stalling.

Brush: Current-conducting material in a DC motor, usually graphite, or a combination of graphite and other materials. The brush rides on the commutator of a motor and forms an electrical connection between the armature and the power source.

Canadian Standards Association (CSA): The agency that sets safety standards for motors and other electrical equipment used in Canada.

Capacitance: As the measure of electrical storage potential of a capacitor, the unit of capacitance is the farad, but typical values are expressed in microfarads.

Capacitor: A device that stores electrical energy. Used on single-phase motors, a capacitor can provide a starting "boost" or allow lower current during operation.

Center Distance: A basic measurement or size reference for worm gear reducers, measured from the centerline of the worm to the centerline of the worm wheel.

Centrifugal Starting Switch: A mechanism that disconnects the starting circuit of a motor when the rotor reaches approximately 75% of operating speed.

Cogging: Non-uniform or erratic rotation of a direct current motor. It usually occurs at low speeds and may be a function of the adjustable speed control or of the motor design.

Commutator: The part of a DC motor armature that causes the electrical current to be switched to various armature windings. Properly sequenced switching creates the motor torque. The commutator also provides the means to transmit electrical current to the moving armature through brushes that ride on the commutator.

Counter Electromotive Force: Voltage that opposes line voltage caused by induced magnetic field in a motor armature or rotor.

Current, AC: The power supply usually available from the electric utility company or alternators.

Current, DC: The power supply available from batteries, generators (not alternators), or a rectified source used for special applications.

Duty Cycle: The relationship between the operating time and the resting time of an electric motor. Motor ratings according to duty are:
• ***Continuous duty,*** the operation of loads for over one hour.
• ***Intermittent duty,*** the operation during alternate periods of load and rest. Intermittent duty is usually expressed as 5 minutes, 30 minutes or one hour.

Efficiency: A ratio of the input power compared to the output, usually expressed as a percentage.

Enclosure: The term used to describe the motor housing. The most common industrial types are: Open Drip Proof (ODP), Totally Enclosed Fan Cooled (TEFC), Totally Enclosed Non-Ventilated (TENV), Totally Enclosed Air Over (TEAO). (See Chapter IV for additional information).

Endshield: The part of a motor that houses the bearing supporting the rotor and acts as a protective guard to the internal parts of the motor; sometimes called endbell, endplate or end bracket.

Excitation: The act of creating magnetic lines of force from a motor winding by applying voltage.

Explosion-Proof Motors: These motors meet Underwriters Laboratories and Canadian Standards Association standards for use in hazardous (explosive) locations, as indicated by the UL label affixed to the motor. Locations are considered hazardous because the atmosphere does or may contain gas, vapor, or dust in explosive quantities.

Field: The stationary part of a DC motor, commonly consisting of permanent magnets. Sometimes used also to describe the stator of an AC motor.

Flanged Reducer: Usually used to refer to a gear reducer having provisions for close coupling of a motor either via a hollow (quill) shaft or flexible coupling. Most often a NEMA C face motor is used.

Foot-Pound: Energy required to raise a one-pound weight against the force of gravity the distance of one foot. A measure of torque. Inch-pound is also commonly used on smaller motors and gear reducers. An inch-pound represents the energy needed to lift one pound one inch; an inch-ounce represents the energy needed to lift one ounce one inch.

Form Factor: Indicates how much AC component is present in the DC output from a rectified AC supply. Unfiltered SCR (thyristor) drives have a form factor (FF) of 1.40. Pure DC, as from a battery, has a form factor of 1.0. Filtered thyristor and pulse width modulated drives often have a form factor of 1.05.

Frame: Standardized motor mounting and shaft dimensions as established by NEMA or IEC.

Frequency: Alternating electric current frequency is an expression of how often a complete cycle occurs. Cycles per second describe how many complete cycles occur in a given time increment. Hertz (hz) has been adopted to describe cycles per second so that time as well as number of cycles is specified. The standard power supply in North America is 60 hz. Most of the rest of the world has 50 hz power.

Full Load Amperes (FLA): Line current (amperage) drawn by a motor when operating at rated load and voltage on motor nameplate. Important for proper wire size selection, and motor starter or drive selection. Also called full load current.

Full Load Torque: The torque a motor produces at its rated horsepower and full-load speed.

Fuse: A piece of metal, connected in the circuit to be protected, that melts and interrupts the circuit when excess current flows.

Generator: Any machine that converts mechanical energy into electrical energy.

Grounded Circuit:

- An electrical circuit coupled to earth ground to establish a reference point.
- A malfunction caused by insulation breakdown, allowing current flow to ground rather than through the intended circuit.

Hertz: Frequency, in cycles per second, of AC power; usually 60 hz in North America, 50 hz in the rest of the world. Named after H. R. Hertz, the German scientist who discovered electrical oscillations.

High Voltage Test: Application of a voltage greater than the working voltage to test the adequacy of motor insulation; often referred to as high potential test or "hi-pot."

Horsepower: A measure of the rate of work. 33,000 pounds lifted one foot in one minute, or 550 pounds lifted one foot in one second. Exactly 746 watts of electrical power equals one horsepower. Torque and RPM may be used in relating to the horsepower of a motor. For fractional horsepower motors, the following formula may be used.

HP = T (in.-oz) x 9.917 x N x 107

where,

HP = horsepower

T = Torque

N = revolutions per minute

Hysteresis: The lagging of magnetism in a magnetic metal, behind the magnetizing flux which produces it.

IEC (International Electrotechnical Commission): The worldwide organization that promotes international unification of standards or norms. Its formal decisions on technical matters express, as nearly as possible, an international consensus.

IGBT: Stands for isolated gate bipolar transistor. The most common and fastest-acting semiconductor switch used in pulse width modulated (PWM) AC drives.

Impedance: The total opposition in an electric circuit to the flow of an alternating current. Expressed in ohms.

Induction Motor: The simplest and most rugged electric motor, it consists of a wound stator and a rotor assembly. The AC induction motor is named because the electric current flowing in its secondary member (the rotor) is induced by the alternating current flowing in its primary member (the stator). The power supply is connected only to the stator. The combined electromagnetic effects of the two currents produce the force to create rotation.

Insulation: In motors, classified by maximum allowable operating temperature. NEMA classifications include: Class A = 105°C, Class B = 130°C, Class F = 155°C and Class H = 180°C.

Input Horsepower: The power applied to the input shaft of a gear reducer. The input horsepower rating of a reducer is the maximum horsepower the reducer can safely handle.

Integral Horsepower Motor: A motor rated one horsepower or larger at 1800 RPM. By NEMA definitions, this is any motor having a three digit frame number, for example, 143T.

Inverter: An electronic device that changes direct current to alternating current; in common usage, an AC drive.

Kilowatt: A unit of power equal to 1000 watts and approximately equal to 1.34 horsepower.

Load: The work required of a motor to drive attached equipment. Expressed in horsepower or torque at a certain motor speed.

Locked Rotor Current: Measured current with the rotor locked and with rated voltage and frequency applied to the motor.

Locked Rotor Torque: Measured torque with the rotor locked and with rated voltage and frequency applied to the motor.

Magnetic Polarity: Distinguishes the location of north and south poles of a magnet. Magnetic lines of force emanate from the north pole of a magnet and terminate at the south pole.

Mechanical Rating: The maximum power or torque a gear reducer can transmit. Many industrial reducers have a safety margin equal to 200% or more of their mechanical rating, allowing momentary overloads during start-up or other transient overloads.

Motor Types: Classified by operating characteristics and/or type of power required. The AC induction motor is the most common. There are several kinds of AC (alternating current) induction motors, including, for single-phase operation: shaded pole, permanent split capacitor (PSC), split phase, capacitor start/induction run and capacitor start/capacitor run.

Polyphase or three-phase motors are used in larger applications. Direct current (DC) motors are also common in industry as are gearmotors, brakemotors and other types. (See Chapter III for additional details).

Mounting: The most common motor mounts include: rigid base, resilient base C face or D flange, and extended through bolts. (See Chapter IV for additional details). Gear reducers are similarly base-mounted, flange-mounted, or shaft-mounted.

National Electric Code (NEC): A safety code regarding the use of electricity. The NEC is sponsored by the National Fire Protection Institute. It is also used by insurance inspectors and by many government bodies regulating building codes.

NEMA (National Electrical Manufacturers Association): A non-profit trade organization, supported by manufacturers of electrical apparatus and supplies in the United States. Its standards alleviate misunderstanding and help buyers select the proper products. NEMA standards for motors cover frame sizes and dimensions, horsepower ratings, service factors, temperature rises and various performance characteristics.

Open Circuit: A break in an electrical circuit that prevents normal current flow.

Output Horsepower: The amount of horsepower available at the output shaft of a gear reducer. Output horsepower is always less than the input horsepower due to the efficiency of the reducer.

Output Shaft: The shaft of a speed reducer assembly that is connected to the load. This may also be called the drive shaft or the slow speed shaft.

Overhung Load: A force applied at right angles to a shaft beyond the shaft's outermost bearing. This shaft-bending load must be supported by the bearing.

Phase: The number of individual voltages applied to an AC motor. A single-phase motor has one voltage in the shape of a sine wave applied to it. A three-phase motor has three individual voltages applied to it. The three phases are at 120 degrees with respect to each other so that peaks of voltage occur at even time intervals to balance the power received and delivered by the motor throughout its 360 degrees of rotation.

Plugging: A method of braking a motor that involves applying partial or full voltage in reverse to bring the motor to zero speed.

Polarity: As applied to electric circuits, polarity indicates which terminal is positive and which is negative. As applied to magnets, it indicates which pole is north and which pole is south.

Poles: Magnetic devices set up inside the motor by the placement and connection of the windings. Divide the number of poles into 7200 to determine the motor's normal speed. For example, 7200 divided by 2 poles equals 3600 RPM.

Power Factor: The ratio of "apparent power" (expressed in kVA) and true or "real power" (expressed in kW).

$$\text{Power Factor} = \frac{\text{Real Power}}{\text{Apparent Power}}$$

Apparent power is calculated by a formula involving the "real power," that which is supplied by the power system to actually turn the motor, and "reactive power," which is used strictly to develop a magnetic field within the motor. Electric utilities prefer power factors as close to 100% as possible, and sometimes charge penalties for power factors below 90%. Power factor is often improved or "corrected" using capacitors. Power factor does not necessarily relate to motor efficiency, but is a component of total energy consumption.

Prime Mover: In industry, the prime mover is most often an electric motor. Occasionally engines, hydraulic or air motors are used. Special application considerations are called for when other than an electric motor is the prime mover.

Pull Out Torque: Also called breakdown torque or maximum torque, this is the maximum torque a motor can deliver without stalling.

Pull Up Torque: The minimum torque delivered by a motor between zero and the rated RPM, equal to the maximum load a motor can accelerate to rated RPM.

Pulse Width Modulation: Abbreviated PWM, the most common frequency synthesizing system in AC drives; also used in some DC drives for voltage control.

Reactance: The opposition to a flow of current other than pure resistance. Inductive reactance is the opposition to change of current in an inductance (coil of wire). Capacitive reactance is the opposition to change of voltage in a capacitor.

Rectifier: A device or circuit for changing alternating current (AC) to direct current (DC).

Regenerative Drive: A drive that allows a motor to provide both motoring and braking torque. Most common with DC drives.

Relay: A device having two separate circuits, it is constructed so that a small current in one of the circuits controls a large current in the other circuit. A motor starting relay opens or closes the starting circuit under predetermined electrical conditions in the main circuit (run winding).

Reluctance: The characteristics of a magnetic field which resist the flow of magnetic lines of force through it.

Resistor: A device that resists the flow of electrical current for the purpose of operation, protection or control. There are two types of resistors - fixed and variable. A fixed resistor has a fixed value of ohms while a variable resistor is adjustable.

Rotation: The direction in which a shaft turns is either clockwise (CW) or counter clockwise (CCW). When specifying rotation, also state if viewed from the shaft or opposite shaft end of motor.

Rotor: The rotating component of an induction AC motor. It is typically constructed of a laminated, cylindrical iron core with slots for cast-aluminum conductors. Short-circuiting end rings complete the "squirrel cage," which rotates when the moving magnetic field induces a current in the shorted conductors.

SCR Drive: Named after the silicon controlled rectifiers that are at the heart of these controls, an SCR drive is the most common type of general-purpose drive for direct current motors.

Self-Locking: The inability of a gear reducer to be driven backwards by its load. Most general purpose reducers are not self-locking.

Service Factor for Gearing: A method of adjusting a reducer's load carrying characteristics to reflect the application's load characteristics. AGMA (American Gear Manufacturers Association) has established standardized service factor information.

Service Factor for Motors: A measure of the overload capacity built into a motor. A 1.15 SF means the motor can deliver 15% more than the rated horsepower without injurious overheating. A 1.0 SF motor should not be loaded beyond its rated horsepower. Service factors will vary for different horsepower motors and for different speeds.

Short Circuit: A fault or defect in a winding causing part of the normal electrical circuit to be bypassed, frequently resulting in overheating of the winding and burnout.

Slip: (1) The difference between rotating magnetic field speed (synchronous speed) and rotor speed of AC induction motors. Usually expressed as a percentage of synchronous speed. (2) The difference between the speed of the rotating magnetic field (which is always synchronous) and the rotor in a non-synchronous induction motor is know as slip and is expressed as a percentage of a synchronous speed. Slip generally increases with an increase in torque.

Speed Regulation: In adjustable speed drive systems, speed regulation measures the motor and control's ability to maintain a constant preset speed despite changes in load from zero to 100%. It is expressed as a percentage of the drive system's rated full load speed.

Stator: The fixed part of an AC motor, consisting of copper windings within steel laminations.

Temperature Rise: The amount by which a motor, operating under rated conditions, is hotter than its surrounding ambient temperature.

Temperature Tests: These determine the temperature of certain parts of a motor, above the ambient temperature, while operating under specific environmental conditions.

Thermal Protector: A device, sensitive to current and heat, which protects the motor against overheating due to overload or failure to start. Basic types include automatic rest, manual reset and resistance temperature detectors.

Thermal Rating: The power or torque a gear reducer can transmit continuously. This rating is based upon the reducer's ability to dissipate the heat caused by friction.

Thermistors: Are conductive ceramic materials, whose resistance remains relatively constant over a broad temperature range, then changes abruptly at a design threshold point, creating essentially a solid-state thermal switch. Attached control modules register this abrupt resistance change and produce an amplified output signal, usually a contact closure or fault trip annunciation. Thermistors are more accurate and faster responding than thermostats.

Thermostat: A protector, which is temperature-sensing only, that is mounted on the stator winding. Two leads from the device must be connected to a control circuit, which initiates corrective action. The customer must specify if the thermostats are to be normally closed or normally open.

Thermocouple: A pair of dissimilar conductors joined to produce a thermoelectric effect and used to accurately determine temperature. Thermocouples are used in laboratory testing of motors to determine the internal temperature of the motor winding.

Thrust Load: Force imposed on a shaft parallel to a shaft's axis. Thrust loads are often induced by the driven machine. Be sure the thrust load rating of a gear reducer is sufficient so that its shafts and bearings can absorb the load without premature failure.

Torque: The turning effort or force applied to a shaft, usually expressed in inch-pounds or inch-ounces for fractional and sub-fractional HP motors.

> *Starting Torque:* Force produced by a motor as it begins to turn from standstill and accelerate (sometimes called locked rotor torque).
>
> *Full-Load Torque:* The force produced by a motor running at rated full-load speed at rated horsepower.
>
> *Breakdown Torque:* The maximum torque a motor will develop under increasing load conditions without an abrupt drop in speed and power. Sometimes called pull-out torque.
>
> *Pull-Up Torque:* The minimum torque delivered by a motor between zero and the rated RPM, equal to the maximum load a motor can accelerate to rated RPM.

Transformer: Used to isolate line voltage from a circuit or to change voltage and current to lower or higher values. Constructed of primary and secondary windings around a common magnetic core.

Underwriters Laboratories (UL): Independent United States testing organization that sets safety standards for motors and other electrical equipment.

Vector Drive: An AC drive with enhanced processing capability that provides positioning accuracy and fast response to speed and torque changes. Often used with feedback devices in a closed-loop system.

Voltage: A unit of electromotive force that, when applied to conductors, will produce current in the conductors.

Watt: The amount of power required to maintain a current of 1 ampere at a pressure of one volt when the two are in phase with each other. One horsepower is equal to 746 watts.

Winding: Typically refers to the process of wrapping coils of copper wire around a core. In an AC induction motor, the primary winding is a stator consisting of wire coils inserted into slots within steel laminations. The secondary winding of an AC induction motor is usually not a winding at all, but rather a cast rotor assembly. In a permanent magnet DC motor, the winding is the rotating armature.

⚠ IMPORTANT INFORMATION ⚠

Please Read Carefully

This Basic Training Manual is not intended as a design guide for selecting and applying LEESON electric motors, gear drive products, or adjustable frequency drives. It is intended as a general introduction to the concepts and terminology used with the products offered by LEESON. Selection, application, and installation of LEESON electric motors, gearmotors, and drives should be made by qualified personnel.

General Installation & Operating Instructions are provided with all LEESON motors, gearmotors, and drives. These products should be installed and operated according to those instructions. Electrical connections should be made by a licensed electrician. Mechanical installation should be done by a mechanical contractor or maintenance engineer that is familiar with installing this type of equipment. Injury to personnel and/or premature, and possibly catastrophic, equipment failure may result from improper installation, maintenance, or operation.

LEESON Electric makes no warranties or representations, express or implied, by operation of law or otherwise, as to the merchantability or fitness for a particular purpose of the goods sold as a result of the use of this information. The Buyer acknowledges that it alone has determined that the goods purchased will suitably meet the requirements of their intended use. In no event will LEESON Electric be liable for consequential, incidental, or other damages the result from the proper or improper application of this equipment.

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Keep current on the latest at LEESON by visiting us on the internet at www.leeson.com for U.S. customers and www.leeson.ca for Canadian customers.

In addition to company and product news, you'll find a complete array of downloadable literature and technical bulletins – plus, our on-line, interactive stock catalog.

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MISSISSAUGA (TORONTO), ONTARIO L5T 2N7

2/08

Roots Blowers, Compressors and Controls

INSTALLATION, OPERATION & MAINTENANCE

Universal RAI®, URAI-J™,URAI-DSL, URAI-J™ DSL, URAI-G™ and Metric Series Blowers

Contents

Do These Things To Get The Most From Your ROOTS™ blower

❏ Check shipment for damage. If found, file claim with carrier and notify Roots.

❏ Unpack shipment carefully, and check contents against Packing List. Notify Roots if a shortage appears.

❏ Store in a clean, dry location until ready for installation. Lift by methods discussed under INSTALLATION to avoid straining or distorting the equipment. Keep covers on all openings. Protect against weather and corrosion if outdoor storage is necessary.

❏ Read OPERATING LIMITATIONS and INSTALLATION sections in this manual and plan the complete installation.

❏ Provide for adequate safeguards against accidents to persons working on or near the equipment during both installation and operation. See SAFETY PRECAUTIONS.

❏ Install all equipment correctly. Foundation design must be adequate and piping carefully done. Use recommended accessories for operating protection.

❏ **Make sure both driving and driven equipment is correctly lubricated before start-up. See LUBRICATION.**

❏ Read starting check points under OPERATION. Run equipment briefly to check for installation errors and make corrections. Follow with a trial run under normal operating conditions.

❏ In event of trouble during installation or operation, do not attempt repairs of Roots furnished equipment. Notify Roots, giving all nameplate information plus an outline of operating conditions and a description of the trouble. Unauthorized attempts at equipment repair may void Roots warranty.

❏ Units out of warranty may be repaired or adjusted by the owner. Good inspection and maintenance practices should reduce the need for repairs.

NOTE: Information in this manual is correct as of the date of publication. Roots reserves the right to make design or material changes without notice, and without obligation to make similar changes on equipment of prior manufacture.

For your nearest Roots Office, dial our Customer Service Hot Line toll free; 1 877 363 ROOT(S) (7668) or direct 832-590-2600.

ROOTS™ products are sold subject to the current General Terms of Sale, GTS-5001 and Warranty Policy WP-5020. Copies are available upon request.

Contact your local Roots Office or Roots Customer Service Hot Line 1-877-363-ROOT(S) (7668) or direct 832-590-2600.

Safety Precautions

It is important that all personnel observe safety precautions to minimize the chances of injury. Among many considerations, the following should be particularly noted:

- Blower casing and associated piping or accessories may become hot enough to cause major skin burns on contact.
- Internal and external rotating parts of the blower and driving equipment can produce serious physical injuries. Do not reach into any opening in the blower while it is operating, or while subject to accidental starting. Protect external moving parts with adequate guards.
- Disconnect power before doing any work, and avoid bypassing or rendering inoperative any safety or protective devices.
- If blower is operated with piping disconnected, place a strong coarse screen over the inlet and avoid standing in the discharge air stream. **CAUTION: Never cover the blower inlet with your hand or other part of body.**
- Stay clear of the blast from pressure relief valves and the suction area of vacuum relief valves.
- Use proper care and good procedures in handling, lifting, installing, operating and maintaining the equipment.
- Casing pressure must not exceed 25 PSI (1725 mbar) gauge. Do not pressurize vented cavities from an external source, nor restrict the vents without first consulting ROOTS.
- Do not use air blowers on explosive or hazardous gases.
- Other potential hazards to safety may also be associated with operation of this equipment. All personnel working in or passing through the area should be trained to exercise adequate general safety precautions.

Operating Limitations

A ROOTS blower or exhauster must be operated within certain approved limiting conditions to enable continued satisfactory performance. Warranty is contingent on such operation.

Maximum limits for pressure, temperature and speed are specified in TABLE 1 for various models & sizes of blowers & exhausters. These limits apply to all units of normal construction, when operated under standard atmospheric conditions. Be sure to arrange connections or taps for instruments, thermometers and pressure or vacuum gauges at or near the inlet and discharge connections of the unit. These, along with a tachometer, will enable periodic checks of operating conditions.

PRESSURE – The pressure rise, between inlet and discharge, must not exceed the figure listed for the specific unit frame size concerned. Also, in any system where the unit inlet is at a positive pressure above atmosphere a maximum case rating of 25 PSI gauge (1725 mbar) should not be exceeded without first consulting Roots. Never should the maximum allowable differential pressure be exceeded.

On vacuum service, with the discharge to atmospheric pressure, the inlet suction or vacuum must not be greater than values listed for the specific frame size.

TEMPERATURE – Blower & exhauster frame sizes are approved only for installations where the following temperature limitations can be maintained in service:

- Measured temperature rise must not exceed listed values when the inlet is at ambient temperature. Ambient is considered as the general temperature of the space around the unit. This is not outdoor temperature unless the unit is installed outdoors.
- If inlet temperature is higher than ambient, the listed allowable temperature rise values must be reduced by 2/3 of the difference between the actual measured inlet temperature and the ambient temperature.
- The average of the inlet and discharge temperature must not exceed 250°F. (121°C).
- The ambient temperature of the space the blower/motor is installed in should not be highter than 120°F (48.8°C).

SPEED – These blowers & exhausters may be operated at speeds up to the maximum listed for the various frame sizes. They may be direct coupled to suitable constant speed drivers if pressure/temperature conditions are also within limits. At low speeds, excessive temperature rise may be a limiting factor.

Special Note: The listed maximum allowable temperature rise for any particular blower & exhauster may occur well before its maximum pressure or vacuum rating is reached. This may occur at high altitude, low vacuum or at very low speed. The units' operating limit is always determined by the maximum rating reached first. It can be any one of the three: Pressure, Temperature or Speed.

ROOTS blowers & exhausters are treated after factory assembly to protect against normal atmospheric corrosion. The maximum period of internal protection is considered to be one year under average conditions, if shipping plugs & seals are not removed. Protection against chemical or salt water atmosphere is not provided. Avoid opening the unit until ready to start installation, as corrosion protection will be quickly lost due to evaporation.

If there is to be an extended period between installation and start up, the following steps should be taken to ensure corrosion protection.

- ❑ Coat internals of cylinder, gearbox and drive end bearing reservoir with Nox-Rust VCI-10 or equivalent. Repeat once a year or as conditions may require. Nox-Rust VCI-10 is petroleum soluble and does not have to be removed before lubricating. It may be obtained from Daubert Chemical Co., 2000 Spring Rd., Oak Brook, Ill. 60521.
- ❑ Paint shaft extension, inlet and discharge flanges, and all other exposed surfaces with Nox-Rust X-110 or equivalent.
- ❑ Seal inlet, discharge, and vent openings. It is not recommended that the unit be set in place, piped to the system, and allowed to remain idle for extended periods. If any part is left open to the atmosphere, the Nox-Rust VCI-10 vapor will escape and lose its effectiveness.
- ❑ Protect units from excessive vibration during storage.
- ❑ Rotate shaft three or four revolutions every two weeks.
- ❑ Prior to start up, remove flange covers on both inlet and discharge and inspect internals to insure absence of rust. Check all internal clearances. Also, at this time, remove gearbox and drive end bearing cover and inspect gear teeth and bearings for rust.

Because of the completely enclosed unit design, location of the installation is generally not a critical matter. A clean, dry and protected indoor location is preferred. However, an outdoor location will normally give satisfactory service. Important requirements are that the correct grade of lubricating oil be provided for expected operating temperatures, and that the unit be located so that routine checking and servicing can be performed conveniently. Proper care in locating driver and accessory equipment must also be considered.

Supervision of the installation by a ROOTS Service Engineer is not usually required for these units. Workmen with experience in installing light to medium weight machinery should be able to produce satisfactory results. Handling of the equipment needs to be accomplished with care, and in compliance with safe practices. Unit mounting must be solid, without strain or twist, and air piping must be clean, accurately aligned and properly connected.

Bare-shaft Units: Two methods are used to handle a unit without base. One is to use lifting lugs bolted into the top of the unit headplates. Test them first for tightness and fractures by tapping with a hammer. In lifting, keep the direction of cable pull on these bolts as nearly vertical as possible. If lifting lugs are not available, lifting slings may be passed under the cylinder adjacent to the headplates. Either method prevents strain on the extended drive shaft.

Packaged Units: When the unit is furnished mounted on a baseplate, with or without a driver, use of lifting slings passing under the base flanges is required. Arrange these slings so that no strains are placed on the unit casing or mounting feet, or on any mounted accessory equipment. **DO NOT** use the lifting lugs in the top of the unit headplates.

Before starting the installation, remove plugs, covers or seals from unit inlet and discharge connections and inspect the interior completely for foreign material. If cleaning is required, finish by washing the cylinder, headplates and impeller thoroughly with an appropriate solvent. Turn the drive shaft by hand to make sure that the impellers turn freely at all points. Anti-rust compound on the connection flanges and drive shaft extension may also be removed at this time with the same solvent. Cover the flanges until ready to connect piping.

Mounting

Care will pay dividends when arranging the unit mounting. This is especially true when the unit is a “bare-shaft” unit furnished without a baseplate. The convenient procedure may be to mount such a unit directly on a floor or small concrete pad, but this generally produces the least satisfactory results. It definitely causes the most problems in leveling and alignment and may result in a “Soft Foot” condition. Correct soft foot before operation to avoid unnecessary loading on the casing and bearings. Direct use of building structural framing members is not recommended.

For blowers without a base, it is recommended that a well anchored and carefully leveled steel or cast iron mounting plate be provided. The plate should be at least 1 inch (25 mm) thick, with its top surface machined flat, and large enough to provide leveling areas at one side and one end after the unit is mounted. It should have properly sized studs or tapped holes located to match the unit foot drilling. Proper use of a high quality machinist’s level is necessary for adequate installation.

With the mounting plate in place and leveled, set the unit on it without bolting and check for rocking. If it is not solid, determine the total thickness of shims required under one foot to stop rocking. Place half of this under each of the diagonally-opposite short feet, and tighten the mounting studs or screws. Rotate the drive shaft to make sure the impellers turn freely. If the unit is to be direct coupled to a driving motor, consider the height of the motor shaft and the necessity for it to be aligned very accurately with the unit shaft. Best unit arrangement is directly bolted to the mounting plate while the driver is on shims of at least 1/8 inch (3mm) thickness. This allows adjustment of motor position in final shaft alignment by varying the shim thickness.

Aligning

When unit and driver are factory mounted on a common baseplate, the assembly will have been properly aligned and is to be treated as a unit for leveling purposes. Satisfactory installation can be obtained by setting the baseplate on a concrete slab that is rigid and free of vibration, and leveling the top of the base carefully in two directions so that it is free of twist. The slab must be provided with suitable anchor bolts. The use of grouting under and partly inside the leveled and shimmed base is recommended.

It is possible for a base-mounted assembly to become twisted during shipment, thus disturbing the original alignment. For this reason, make the following checks after the base has been leveled and bolted down. Disconnect the drive and rotate the unit shaft by hand. It should turn freely at all points. Loosen the unit foot hold-down screws and determine whether all feet are evenly in contact with the base. If not, insert shims as required and again check for free impeller rotation. Finally, if unit is direct coupled to the driver, check shaft and coupling alignment carefully and make any necessary corrections.

In planning the installation, and before setting the unit, consider how piping arrangements are dictated by the unit design and assembly. Drive shaft rotation must be established accordingly and is indicated by an arrow near the shaft.

Typical arrangement on vertical units has the drive shaft at the top with counterclockwise rotation and discharge to the left. Horizontal units are typically arranged with the drive shaft at the left with counterclockwise rotation and discharge down. See Figure 4 for other various unit arrangements and possible conversions.

When a unit is DIRECT COUPLED to its driver, the driver RPM must be selected or governed so as not to exceed the maximum speed rating of the unit. Refer to Table 1 for allowable speeds of various unit sizes.

A flexible type coupling should always be used to connect the driver and unit shafts.

When direct coupling a motor or engine to a blower you must insure there is sufficient gap between the coupling halves and the element to prevent thrust loading the blower bearings. When a motor, engine or blower is operated the shafts may expand axially. If the coupling is installed in such a manner that there is not enough room for expansion the blower shaft can be forced back into the blower and cause the impeller to contact the gear end headplate resulting in damage to the blower. The two shafts must be in as near perfect alignment in all directions as possible, and the gap must be established with the motor armature on its electrical center if end-play exists. Coupling manufacturer's recommendations for maximum misalignment, although acceptable for the coupling, are normally too large to achieve smooth operation and maximum life of the blower.

The following requirements of a good installation are recommended. When selecting a coupling to be fitted to the blower shaft ROOTS recommends a taper lock style coupling to insure proper contact with the blower shaft. If the coupling must have a straight bore the coupling halves must be fitted to the two shafts with a line to line thru .001" interference fit. Coupling halves must be warmed up per coupling manufacturer's recommendations. Maximum deviation in offset alignment of the shafts should not exceed .005" (.13 mm) total indicator reading, taken on the two coupling hubs. Maximum deviation from parallel of the inside coupling faces should not exceed .001" (.03 mm) when checked at six points around the coupling.

When a unit is BELT DRIVEN, the proper selection of sheave diameters will result in the required unit speed. When selecting a sheave to be fitted to the blower shaft ROOTS recommends a taper lock style sheave to insure proper contact with the blower shaft. This flexibility can lead to operating temperature problems caused by unit speed being too low. Make sure the drive speed selected is within the allowable range for the specific unit size, as specified under Table 1.

Belt drive arrangements usually employ two or more V-belts running in grooved sheaves. Installation of the driver is less critical than for direct coupling, but its shaft must be level and parallel with the unit shaft. **The driver should be mounted on the inlet side of a vertical unit (horizontal piping) and on the side nearest to the shaft on a horizontal unit. SEE PAGE 6 - Acceptable Blower Drive Arrangement Options.** The driver must also be mounted on an adjustable base to permit installing, adjusting and removing the V-belts. To position the driver correctly, both sheaves need to be mounted on their shafts and the nominal shaft center distance known for the belt lengths to be used.

CAUTION: Drive couplings and sheaves (pulleys) should have an interference fit to the shaft of the blower (set screw types of attachment generally do not provide reliable service.) It is recommended that the drive coupling or sheave used have a taper lock style bushing which is properly sized to provide the correct interference fit required. Drive couplings, that require heating to fit on the blower shaft, should be installed per coupling manufacturer recommendations. A drive coupling or sheave should not be forced on to the shaft of the blower as this could affect internal clearances resulting in damage to the blower.

Engine drive applications often require special consideration to drive coupling selection to avoid harmful torsional vibrations. These vibrations may lead to blower damage if not dampened adequately. It is often necessary to install a flywheel and/or a torsionally soft elastic element coupling based on the engine manufacturer recommendations.

The driver sheave should also be mounted as close to its bearing as possible, and again should fit the shaft correctly. Position the driver on its adjustable base so that 2/3 of the total movement is available in the direction away from the unit, and mount the assembly so that the face of the sheave is accurately in line with the unit sheave. This position minimizes belt wear, and allows sufficient adjustment for both installing and tightening the belts. After belts are installed, adjust their tension in accordance with the manufacturer's instructions. However, only enough tension should be applied to prevent slippage when the unit is operating under load. Excessive tightening can lead to early bearing concerns or shaft breakage.

Before operating the drive under power to check initial belt tension, first remove covers from the unit connections. Make sure the interior is still clean, then rotate the shaft by hand. Place a coarse screen over the inlet connection to prevent anything being drawn into the unit while it is operating, and avoid standing in line with the discharge opening. Put oil in the sumps per instructions under **LUBRICATION.**

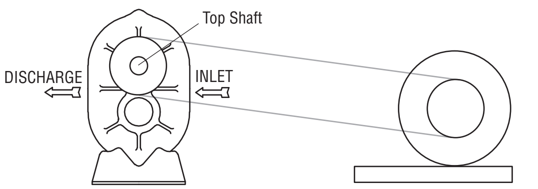
Piping

Before connecting piping, remove any remaining anti-rust compound from unit connections. Clean pipe should be no

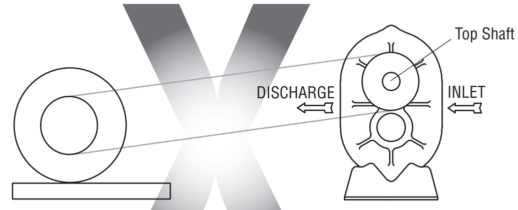
Acceptable Blower Drive Arrangement Options

ACCEPTABLE

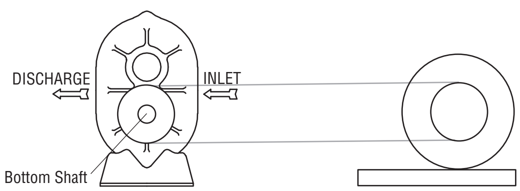
UNACCEPTABLE



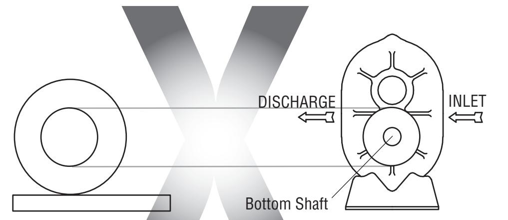
Motor On Inlet Side of Blower (Top Shaft)



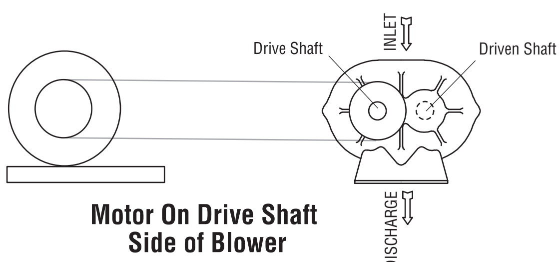
Motor On Discharge Side of Blower (Top Shaft)



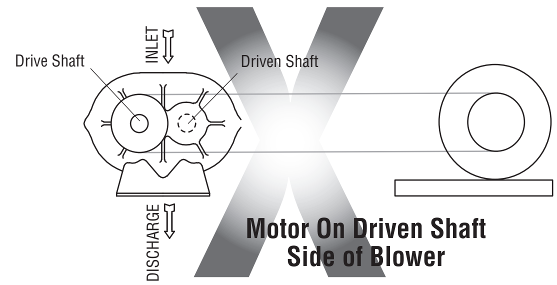
Motor On Inlet Side of Blower (Bottom Shaft)



Motor On Discharge Side of Blower (Bottom Shaft)



Motor On Drive Shaft Side of Blower



Motor On Driven Shaft Side of Blower

smaller than unit connections. In addition, make sure it is free of scale, cuttings, weld beads, or foreign material of any kind. To further guard against damage to the unit, especially when an inlet filter is not used, install a substantial screen of 16 mesh backed with hardware cloth at or near the inlet connections. Make provisions to clean this screen of collected debris after a few hours of operation. It should be removed when its usefulness has ended, as the wire will eventually deteriorate and small pieces going into the unit may cause serious damage.

Pipe flanges or male threads must meet the unit connections accurately and squarely. DO NOT attempt to correct misalignment by springing or cramping the pipe. In most cases this will distort the unit casing and cause impeller rubbing. In severe cases it can prevent operation or result in a broken drive shaft. For similar reasons, piping should be supported near the unit to eliminate dead weight strains. Also, if pipe expansion is likely to occur from temperature change, installation of flexible connectors or expansion joints is advisable.

Figure 3 represents an installation with all accessory items that might be required under various operating conditions. Inlet piping should be completely free of valves or other restrictions. When a shut-off valve can not be avoided, make sure a full size vacuum relief is installed nearest the unit inlet. This will protect against unit overload caused by accidental closing of the shut-off valve.

Need for an inlet silencer will depend on unit speed and pressure, as well as sound-level requirements in the general surroundings. An inlet filter is recommended, especially in dusty or sandy locations. A discharge silencer is also normally suggested, even though Whispair units operate at generally lower noise levels than conventional rotary blowers. Specific recommendations on silencing can be obtained from your local ROOTS distributor.

Discharge piping requires a pressure relief valve, and should include a manual unloading valve to permit starting the unit under no-load conditions. Reliable pressure/vacuum gauges and good thermometers at both inlet and discharge are recommended to allow making the important checks on unit operating conditions. The back-pressure regulator shown in Figure 3 is useful mainly when volume demands vary while the unit operates at constant output. If demand is constant, but somewhat lower than the unit output, excess may be blown off through the manual unloading valve.

In multiple unit installations where two or more units operate with a common header, use of check valves is mandatory. These should be of a direct acting or free swinging type, with one valve located in each line between the unit and header. Properly installed, they will protect against damage from reverse rotation caused by air and material back-flow through an idle unit.

After piping is completed, and before applying power, rotate the drive shaft by hand again. If it does not move with uniform freedom, look for uneven mounting, piping strain, excessive belt tension or coupling misalignment.

DO NOT operate the unit at this time unless it has been lubricated per instructions.

Technical Supplement for 32, 33, 36, 42, 45, 47, 53, 56, 59, 65, 68, 615 Universal RAI-G blowers

ROOTS Universal RAI-G rotary positive gas blowers are a design extension of the basic Universal RAI blower model. URAI-G blower uses (4) mechanical seals in place of the standard inboard lip seals to minimize gas leakage into the atmosphere. The seal chambers are piped to plugged connections. These should be opened periodically to confirm that there is no build-up of oil due to leakage by the mechanical seal. Special traps may be required for vacuum operation. These units are intended for gases which are compatible with cast iron case material, steel shafts, 300/400 series stainless steel and carbon seal components, viton o-rings and the oil/grease lubricants. If there are any questions regarding application or operation of this gas blower, please contact factory.

Precaution: URAI-G blowers: Care must be used when opening the head plate seal vent chamber plugs (43) as some gas will escape–if it is a pressure system, or the atmospheric air will leak in-if the system is under vacuum. There is a possibility of some gas leakage through the mechanical seals. This leakage on the gear end will escape through the gear box vent, and on the drive end, through the grease release fittings. If the gas leakage is undesirable, each seal chamber must be purged with an inert gas through one purge gas hole (43) per seal . There are two plugged purge gas holes(1/8 NPT) provided per seal. The purge gas pressure must be maintained one psi above the discharge gas pressure. Also, there exists a possibility of gear end oil and drive end grease leakage into the gas stream.

The lubricants selected must be compatible with the gas.

URAI GAS Blower Oil and Grease Specifications

The specified oil should be ROOTS synthetic P/N 813-106- of the proper viscosity.

When servicing drive end bearings of a Gas blower, use the specified NLGI #2 premium grade aluminum complex* grease, ROOTS P/N T20019001, with 300°F (149°C) service temperature and moisture resistance and good mechanical stability.

*ROOTS Synthetic Oil & Grease is superior in performance to petroleum based products. It has high oxidation stability, excellent corrosion protection, extremely high film strength and low coefficient of friction. Typical oil change intervals are increased 2-3 times over petroleum based lubricants. Also, ROOTS Synthetic Oil is 100% compatible with petroleum based oils. Simply drain the oil in the blower and refill the reservoirs with ROOTS Synthetic Oil to maintain optimum performance of your ROOTS blower.

Due to sludge build-up and seal leakage problems, Roots recommendation is **DO NOT USE** Mobil SHC synthetic oils in Roots blowers.

For Units with a Grease Lubricated Drive End

A simple but very effective lubrication system is employed on the drive shaft end bearings. Hydraulic pressure relief fittings are provided to vent any excess grease, preventing pressure build-up on the seals. A restriction plug and metering orifice prevent loss of lubricant from initial surges in lubricant pressure but permit venting excess lubricant under steadily rising pressures.

For grease lubricated drive end blowers see page 16, table 4, regarding specified greasing intervals.

When servicing drive end bearings of Non Gas blower, use the specified NLGI #2 premium grade microgel grease with 250°F (121°C) service temperature and moisture resistance and good mechanical stability. ROOTS specifies Shell Darina EP NLGI Grade 2. Product Code 71522 or Shell Darina SD 2 product code 506762B.

URAI GAS Blower Oil and Grease Specifications

The specified oil should be ROOTS synthetic P/N 813-106- of the proper viscosity.

When servicing drive end bearings of a Gas blower, use the specified NLGI #2 premium grade aluminum complex* grease, ROOTS P/N T20019001, with 300°F (149°C) service temperature and moisture resistance and good mechanical stability.

NOTE: Lithium based greases are not compatible with the ROOTS Synthetic grease used when assembling a Gas blower or the non-soap base grease used when assembling a standard URAI blower. Lithium based grease is not approved for any ROOTS blowers.

Using a pressure gun, slowly force new lubricant into each drive end bearing housing until traces of clean grease comes out of the relief fitting. The use of an electric or pneumatic grease gun could force the grease in too rapidly and thus invert the seals and should not be used.

To fill the gearbox, remove the breather plug (25) and the oil overflow plug (21) - see page 14. Fill the reservoir up to the overflow hole. Place the breather and the overflow plug back into their respective holes.

After a long shutdown, it is recommended that the grease fittings be removed, the old grease flushed out with kerosene or #10 lubricating oil, drained thoroughly, and bearings refilled with new grease. Be sure grease relief fittings are reinstalled. Grease should be added using a hand operated grease gun to the drive end bearings at varying time intervals depending on duty cycle and RPM. Table 4 has been prepared as a general greasing schedule guide based on average operating conditions. More frequent intervals may be necessary depending on the grease operating temperature and unusual circumstances.

For Units with Splash Lubrication on Both Ends

Bearings and oil seals are lubricated by the action of the timing gears or oil slingers which dip into the main oil sumps causing oil to splash directly on gears and into bearings and seals. A drain port is provided below each bearing to prevent an excessive amount of oil in the bearings. Seals located inboard of the bearings in each headplate effectively retain oil within the sumps. Any small leakage that may occur should the seals wear passes into a cavity in each vented headplate and is drained downward.

Oil sumps on each end of the blower are filled by removing top vent plugs, Item (25), and filling until oil reaches the middle of the oil level sight gauge when the unit is not operating, Item (45 or 53), DO NOT FILL PAST THE MIDDLE OF THE SIGHT GLASS.

Initial filling of the sumps should be accomplished with the blower not operating, in order to obtain the correct oil level. Approximate oil quantities required for blowers of the various models and configurations are listed in Table 3. Use a good grade of industrial type non-detergent, rust inhibiting, anti-foaming oil and of correct viscosity per Table 2. ***ROOTS synthetic oil (ROOTS P/N 813-106-) is highly recommended and specified.** ROOTS does not recommend automotive type lubricants, as they are not formulated with the properties mentioned above.

The oil level may rise or fall on the gauge during operation, to an extent depending somewhat on oil temperature and blower speed.

Proper lubrication is usually the most important single consideration in obtaining maximum service life and satisfactory operation from the unit. Unless operating conditions are quite severe, a weekly check of oil level and necessary addition of lubricant should be sufficient. During the first week of operation, check the oil levels in the oil sumps about once a day, and watch for leaks. Replenish as necessary. Thereafter, an occasional check should be sufficient. It is recommended that the oil be changed after initial 100 hours of operation. Frequent oil changing is not necessary unless the blower is operated in a very dusty location.

Normal life expectancy of petroleum based oils is about 2000 hours with an oil temperature of about 180°F (82°C). As the oil temperature increases by increments of 15-18°F (8°C - 10°C), the life is reduced by half. Example: Oil temperatures of 210-216°F (99°C - 102°C) will produce life expectancy of 1/4 or 500 hours. Therefore, it is considered normal to have oil change periods of 500 hours with petroleum based oils.

Normal life expectancy of ROOTS™ Synthetic Oil is about 4000 to 8000 hours with an oil temperature of about 180°F (82°C). As the oil temperature increases by increments of 15-18°F (8°C - 10°C), the life is reduced by half. Example: Oil temperatures of 210-216°F (99°C - 102°C) will produce life expectancy of 1/4 or 1000 to 2000 hours.

NOTE: To estimate oil temperature, multiply the discharge temperature of the blower by 0.80. Example: if the discharge air temperature of the blower is 200° F, it is estimated that the oil temperature is 160° F.

*ROOTS™ Synthetic Oil & Grease is superior in performance to petroleum based products. It has high oxidation stability, excellent corrosion protection, extremely high film strength and low coefficient of friction. Typical oil change intervals are increased 2-3 times over petroleum based lubricants. Also, ROOTS™ Synthetic Oil is 100% compatible with petroleum based oils. Simply drain the oil in the blower and refill the reservoirs with ROOTS™ Synthetic Oil to maintain optimum performance of your ROOTS™ blower.

Before operating a blower under power for the first time, recheck the unit and the installation thoroughly to reduce the likelihood of avoidable troubles. Use the following procedure check list as a guide, but consider any other special conditions in the installation.

- ❑ Be certain that no bolts, tools, rags, or debris have been left in the blower air chamber or piping.
- ❑ If an outdoor intake without filter is used, be sure the opening is located so it cannot pick up dirt and is protected by a strong screen or grille. Use of the temporary protective screen as described under INSTALLATION is strongly recommended.
- ❑ Recheck blower leveling, drive alignment and tightness of all mounting bolts if installation is not recent. If belt drive is used, adjust belt tension correctly.
- ❑ Turn drive shaft by hand to make sure impellers still rotate without bumping or rubbing at any point.
- ❑ Ensure oil levels in the main oil sumps are correct.
- ❑ Check lubrication of driver. If it is an electric motor, be sure that power is available and that electrical overload devices are installed and workable.
- ❑ Open the manual unloading valve in the discharge air line. If a valve is in the inlet piping, be sure it is open.
- ❑ Bump blower a few revolutions with driver to check that direction of rotation agrees with arrow near blower shaft, and that both coast freely to a stop.

After the preceding points are cleared, blower is ready for trial operation under "no-load" conditions. The following procedure is suggested to cover this initial operation test period.

a. Start blower, let it accelerate to full speed, then shut off. Listen for knocking sounds, both with power on and as speed slows down.

b. After blower comes to a complete stop, repeat above, but let blower run 2 or 3 minutes. Check for noises, such as knocking sounds.

c. After blower comes to a complete stop, operate blower for about 10 minutes unloaded. Check oil levels. Observe cylinder and headplate surfaces for development of hot spots such as burned paint, indicating impeller rubs. Be aware of any noticeable increase in vibration.

Assuming that all trials have been satisfactory, or that necessary corrections have been made, the blower should now have a final check run of at least one hour under normal operating conditions. After blower is restarted, gradually close the discharge unloading valve to apply working pressure. At this point it is recommended that a pressure gauge or manometer be connected into the discharge line if not already provided, and that thermometers be in both inlet and discharge lines. Readings from these instruments will show whether pressure or temperature ratings of the blower are being exceeded.

During the final run, check operating conditions frequently and observe the oil levels at reasonable intervals. If excessive noise or local heating develops, shut down immediately and determine the cause. If either pressure rise or temperature rise across the blower exceeds the limit specified in this manual, shut down and investigate conditions in the piping system. Refer to the TROUBLESHOOTING CHECKLIST for suggestions on various problems that may appear.

The blower should now be ready for continuous duty operation at full load. During the first few days make periodic checks to determine whether all conditions remain steady, or at least acceptable. This may be particularly important if the blower is supplying air to a process system where conditions can vary. At the first opportunity, stop the blower and clean the temporary inlet protective screen. If no appreciable amount of debris has collected, the screen may be removed. See comments under INSTALLATION. At this same time, verify leveling, coupling alignment or belt tension, and mounting bolt tightness.

Should operating experience prove that blower capacity is a little too high for the actual air requirements, a small excess may be blown off continuously through the manual unloading or vent valve. Never rely on the pressure relief valve as an automatic vent. Such use may cause the discharge pressure to become excessive, and can also result in unsafe operation of the valve itself. If blower capacity appears to be too low, refer to the TROUBLESHOOTING CHECKLIST.

Vibration Assessment Criteria

With measurements taken at the bearing locations on the housings, see chart below for an appropriate assessment guide for rotary lobe blowers rigidly mounted on stiff foundations.

In general, blower vibration levels should be monitored on a regular basis and the vibration trend observed for progressive or sudden change in level. If such a change occurs, the cause should be determined through spectral analysis.

As shown on the chart below, the level of all pass vibration will determine the need to measure discrete frequency vibration levels and the action required.

All Pass Vibration (in/sec)	Discrete Frequency Vibration (in/sec)	Action
0.45 or less	N/R	Acceptable
Greater than 0.45 but 1.0 or less	0.45 or less @ any frequency	Acceptable
	Greater than 0.45 @ any frequency	Investigate
Greater than 1.0	Less than 1.0	Investigate
	Greater than 1.0	Investigate

Troubleshooting Checklist

Trouble	Item	Possible Cause	Remedy
No flow	1	Speed too low	Check by tachometer and compare with published performance
	2	Wrong rotation	Compare actual rotation with Figure 1 Change driver if wrong
	3	Obstruction in piping	Check piping, valves, silencer to assure open flow path
Low capacity	4	Speed too low	See item 1, If belt drive, check for slippage and readjust tension
	5	Excessive pressure rise	Check inlet vacuum and discharge pressure and compare with Published performance
	6	Obstruction in piping	See item 3
	7	Excessive slip	Check inside of casing for worn or eroded surfaces causing excessive clearances
Excessive power	8	Speed too high	Check speed and compare with published performance
	9	Excessive pressure rise	See Item 5
	10	Impeller rubbing	Inspect outside of cylinder for high temperature areas, then check for impeller contact at these points. Correct blower mounting, drive alignment
	11	Scale, sludge, rust or product build up	Clean blower appropriately
Damage to bearings or gears	12	Inadequate lubrication	Check oil sump levels in gear and drive end headplates
	13	Excessive lubrication	Check oil levels. If correct, drain and refill with clean oil of recommended grade
	14	Excessive pressure rise	See Item 5
	15	Coupling misalignment	Check carefully. Realign if questionable
	16	Excessive belt tension	Readjust for correct tension
Vibration	17	Misalignment	See Item 15
	18	Impellers rubbing	See Item 10
	19	Worn bearings/gears	Check gear backlash and condition of bearings, and replace as indicated
	20	Unbalanced or rubbing impeller	Scale or process material may build up on casing and impellers, or inside impellers. Remove build-up to restore original clearances and impeller balance
	21	Driver or blower loose	Tighten mounting bolts securely
	22	Piping resonances	Determine whether standing wave pressure pulsations are present in the piping
	23	Scale/sludge build-ups	Clean out interior of impeller lobes to restore dynamic balance
	24	Casing strain	Re-work piping alignment to remove excess strain
Driver stops, or will not start	25	Impeller stuck	Check for excessive hot spot on headplate or cylinder. See item 10. Look for defective shaft bearing and/or gear teeth
	26	Scale, sludge, rust or product build-up	Clean blower appropriately
Excessive breather	27	Broken seal	Replace seals
Blow-by or excessive oil leakage to vent area	28	Defective O-ring	Replace seals and O-ring
Excessive oil leakage in vent area	29	Defective/plugged breather	Replace breather and monitor oil leakage
	30	Oil level too high	Check sump levels in gear and drive headplates.
	31	Oil type or viscosity incorrect	Check oil to insure it meets recommendations. Drain then fill with clean oil of recommended grade.
	32	Blower running hot	Check blower operating conditions to ensure they are within the operating limitations defined in this manual.

A good program of consistent inspection and maintenance is the most reliable method of minimizing repairs to a blower. A simple record of services and dates will help keep this work on a regular schedule. Basic service needs are:

- Lubrication
- Checking for hot spots
- Checking for increases or changes in vibration and noise
- Recording of operating pressures and temperatures

Above all, a blower must be operated within its specified rating limits, to obtain satisfactory service life.

A newly installed blower should be checked often during the first month of full-time operation. Attention there after may be less frequent assuming satisfactory performance. Lubrication is normally the most important consideration and weekly checks of lubricant levels in the gearbox and bearing reservoirs should be customary. Complete oil change schedules are discussed under **LUBRICATION.**

Driver lubrication practices should be in accordance with the manufacturer's instructions. If direct connected to the blower through a lubricated type coupling, the coupling should be checked and greased each time blower oil is changed. This will help reduce wear and prevent unnecessary vibration. In a belted drive system, check belt tension periodically and inspect for frayed or cracked belts.

In a new, and properly installed, unit there is no contact between the two impellers, or between the impellers and cylinder or headplates. Wear is confined to the bearings (which support and locate the shafts) the oil seals, and the timing gears. All are lubricated and wear should be minimal if clean oil of the correct grade is always used. Seals are subject to deterioration as well as wear, and may require replacement at varying periods.

Shaft bearings are designed for optimum life under average conditions with proper lubrication and are critical to the service life of the blower. Gradual bearing wear may allow a shaft position to change slightly, until rubbing develops between impeller and casing. This will cause spot heating, which can be detected by observing these surfaces. Sudden bearing situations is usually more serious. Since the shaft and impeller are no longer supported and properly located, extensive general damage to the blower casing and gears is likely to occur.

Oil seals should be considered expendable items, to be replaced whenever drainage from the headplate vent cavity becomes excessive or when the blower is disassembled for any reason. Some oil seal leakage may occur since an oil film under the lip is required for proper operation. Periodically leaked oil should be wiped off from surfaces. Minor seal leakage should not be considered as indicating seal replacement.

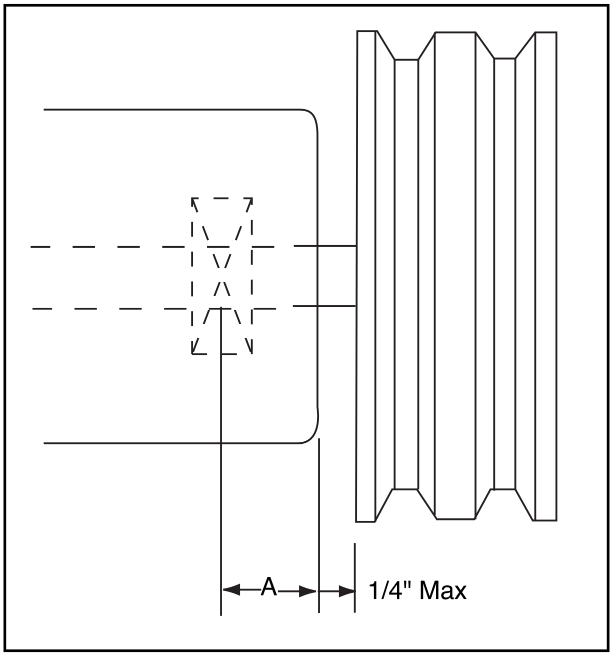
Timing gear wear, when correct lubrication is maintained, should be negligible. Gear teeth are cut to provide the correct amount of backlash, and gears correctly mounted on the shafts will accommodate a normal amount of tooth wear without permitting contact between lobes of the two impellers. However, too high an oil level will cause churning and excessive heating. This is indicated by unusually high temperature at the bottom of the gear housing. Consequent heating of the gears will result in loss of tooth-clearance , backlash and rapid wear of the gear teeth usually will develop. Continuation of this tooth wear will eventually produce impeller contacts (knocking), and from this point serious damage will be unavoidable if blower operation is continued. A similar situation can be produced suddenly by gear tooth fracture, which is usually brought on by sustained overloading or momentary shock loads.

Problems may also develop from causes other than internal parts damage. Operating clearances within a blower are only a few thousandths of an inch. This makes it possible for impeller interference or casing rubs to result from shifts in the blower mounting, or from changes in piping support. If this type of trouble is experienced, and the blower is found to be clean, try removing mounting strains. Loosen blower mounting bolts and reset the leveling and drive alignment. Then tighten mounting again, and make sure that all piping meets blower connections accurately and squarely Foreign materials in the blower will also cause trouble, which can only be cured by disconnecting the piping and thoroughly cleaning the blower interior.

A wide range of causes & solutions for operating troubles are covered in the **TROUBLE SHOOTING CHECKLIST.** The remedies suggested should be performed by qualified mechanics with a good background. Major repairs generally are to be considered beyond the scope of maintenance, and should be referred to an authorized ROOTS distributor.

Warranty situations should not be repaired at all, unless specific approval has been obtained through ROOTS before starting work. Unauthorized disassembly within the warranty period may void the warranty.

Figure 2 - Allowable Overhung Loads for V-Belt Drives Universal RAI®/URAI®-J Units



$$\text{Belt Pull lbs} = \frac{252100 \cdot \text{Motor HP}}{\text{Blower RPM} \cdot \text{Sheave Diameter}}$$

$$\text{Shaft Load (lb.in)} = \text{Belt Pull} \cdot \left(A + 1/4'' + \frac{\text{Sheave Width}}{2}\right)$$

Frame Size	Dim. "A"	Max. Allow. Shaft Load (lb-in.)	Min. Sheave Diameter	Max. Sheave Width
22, 24	0.61	150	4.00	1.75
32, 33, 36	0.80	400	5.00	1.91
42, 45, 47	1.02	650	5.00	2.31
53, 56, 59	1.13	1,325	6.00	3.06
65, 68, 615	1.36	2,250	8.00	3.44
76, 711, 718	1.16	2,300	9.50	3.75

NOTE:

Arc of sheave belt contact on the smaller sheave not to be less than 170°

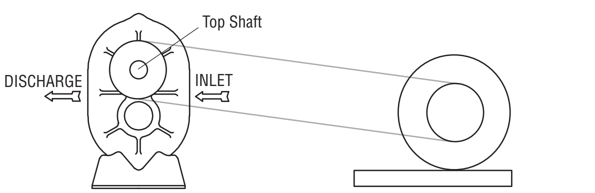
Driver to be installed on the inlet side for vertical units, and on the drive shaft side for horizontal units.

ROOTS recommends the use of two or more 3V, 5V or 8V belts and sheaves.

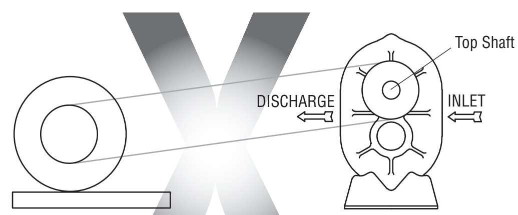
Acceptable Blower Drive Arrangement Options

ACCEPTABLE

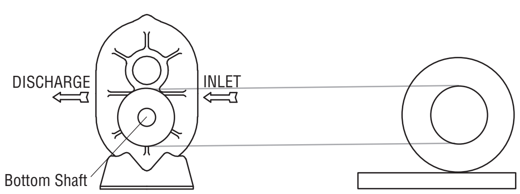
UNACCEPTABLE



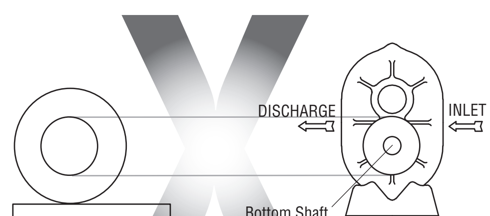
Motor On Inlet Side of Blower (Top Shaft)



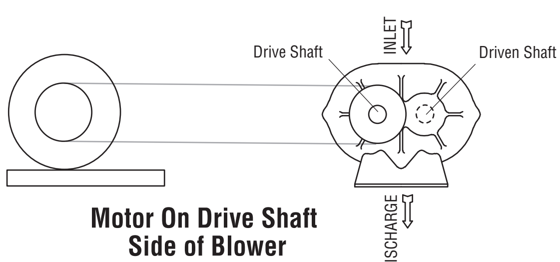
Motor On Discharge Side of Blower (Top Shaft)



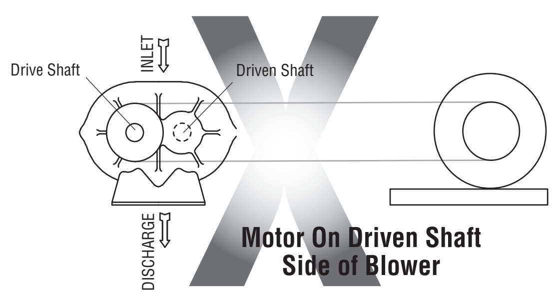
Motor On Inlet Side of Blower (Bottom Shaft)



Motor On Discharge Side of Blower (Bottom Shaft)

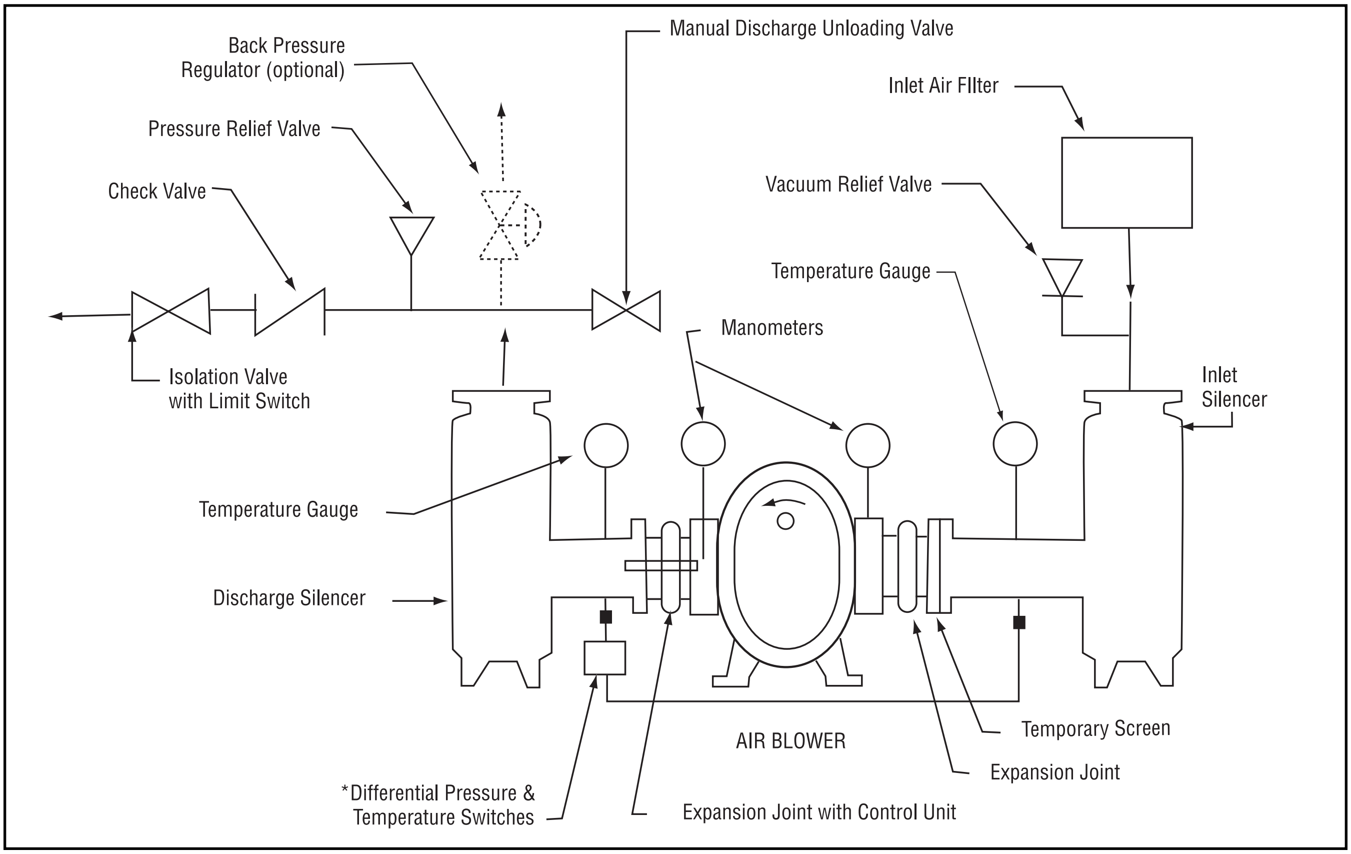


Motor On Drive Shaft Side of Blower



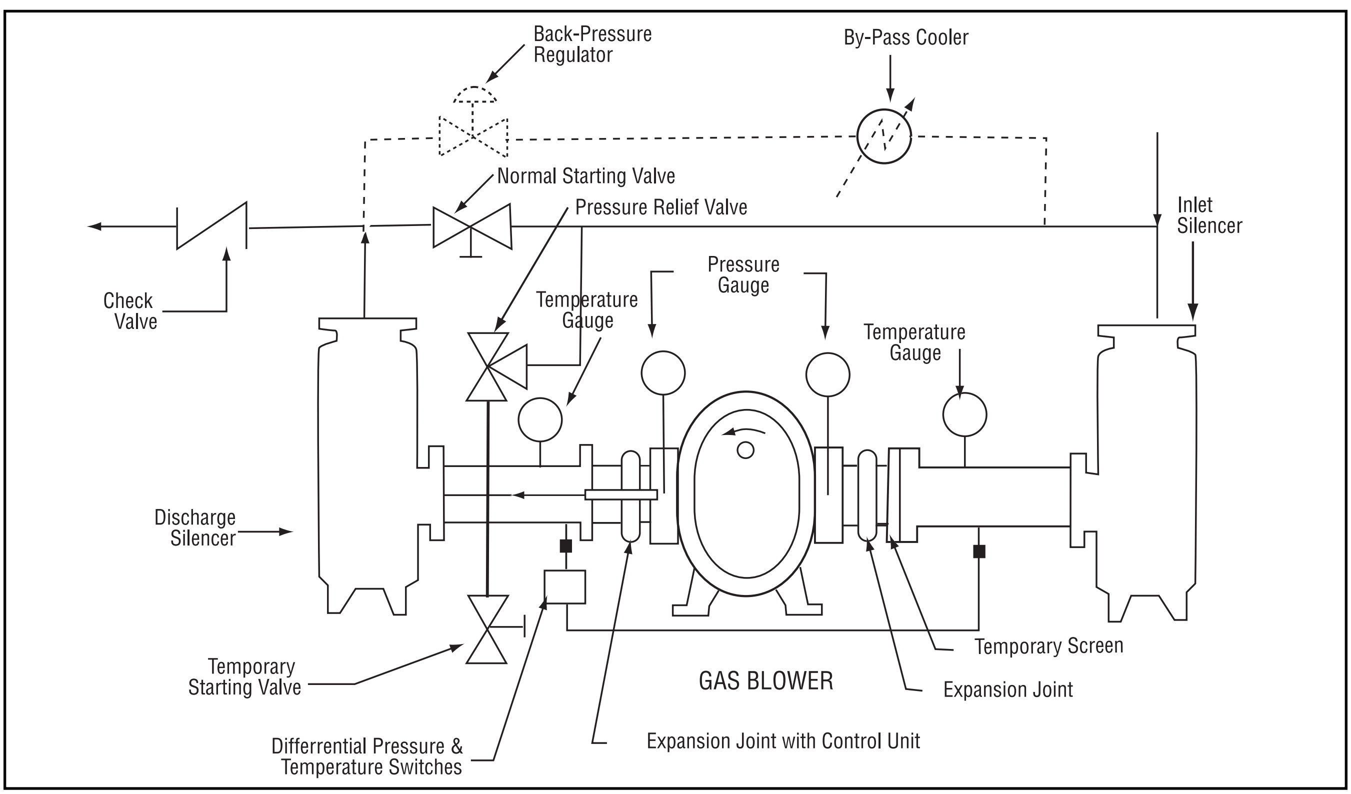
Motor On Driven Shaft Side of Blower

Figure 3a - Air Blower Installation with Accessories



Above are suggested locations for available accessories.

Figure 3b -Gas Blower Installation with Accessories



Above are suggested locations for available accessories.

Figure 4

Blower Orientation Conversion

Model	Reversible Rotation	Whispair™ Design
Universal RAI	yes	no
URAI-J Whispair™	no	yes
URAI-G	yes	no

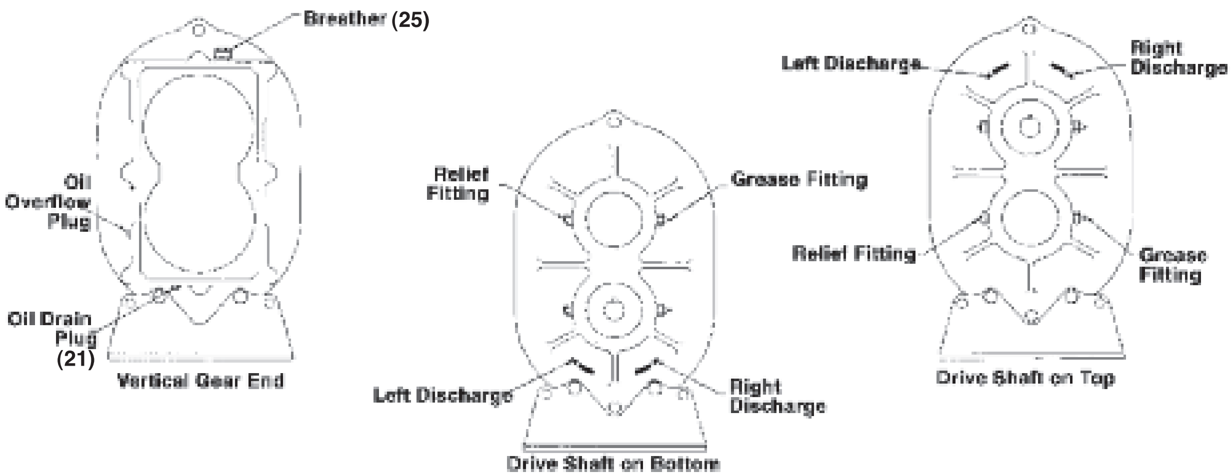
Special Note: WHISPAIR™ models are designed to operate with only one shaft rotation direction to take full advantage of the Whispair feature. Therefore, a WHISPAIR™ blower may be operated in the following combinations.

- CCW Rotation: Bottom Shaft; Right side discharge or a Left Shaft; Bottom discharge
- CCW Rotation: Top Shaft; Left side discharge or a Right Shaft; Top discharge

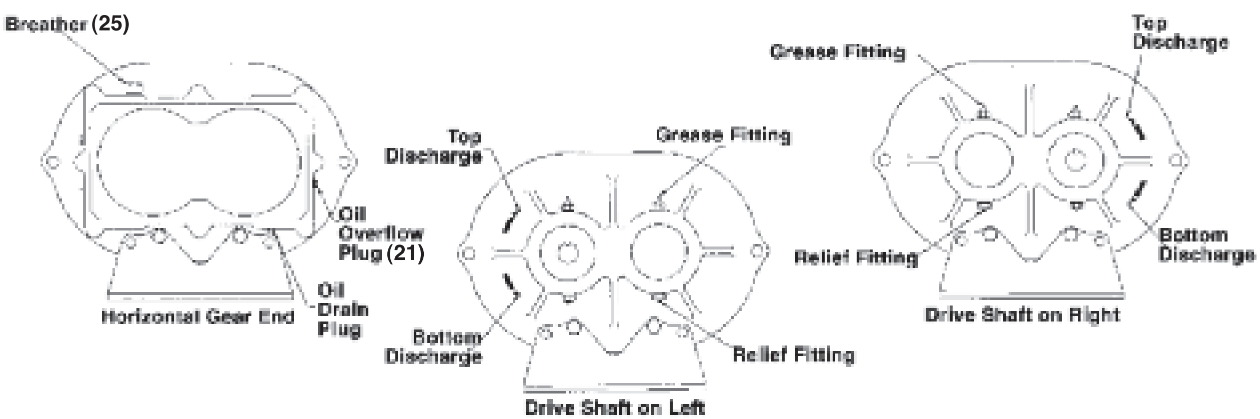
or

- CW Rotation: Bottom Shaft; Left side discharge or a Right Shaft Bottom discharge
- CW Rotation: Top Shaft; Right side discharge or a Left Shaft Top discharge

Blower Orientation and Lubrication Points: Grease Lubricated Drive End
Universal RAI series & URAI-G gas blowers



Vertical Mounting



Horizontal Mounting

Drive End Breather Orientation for U-RAI series - DSL with Oil Lube

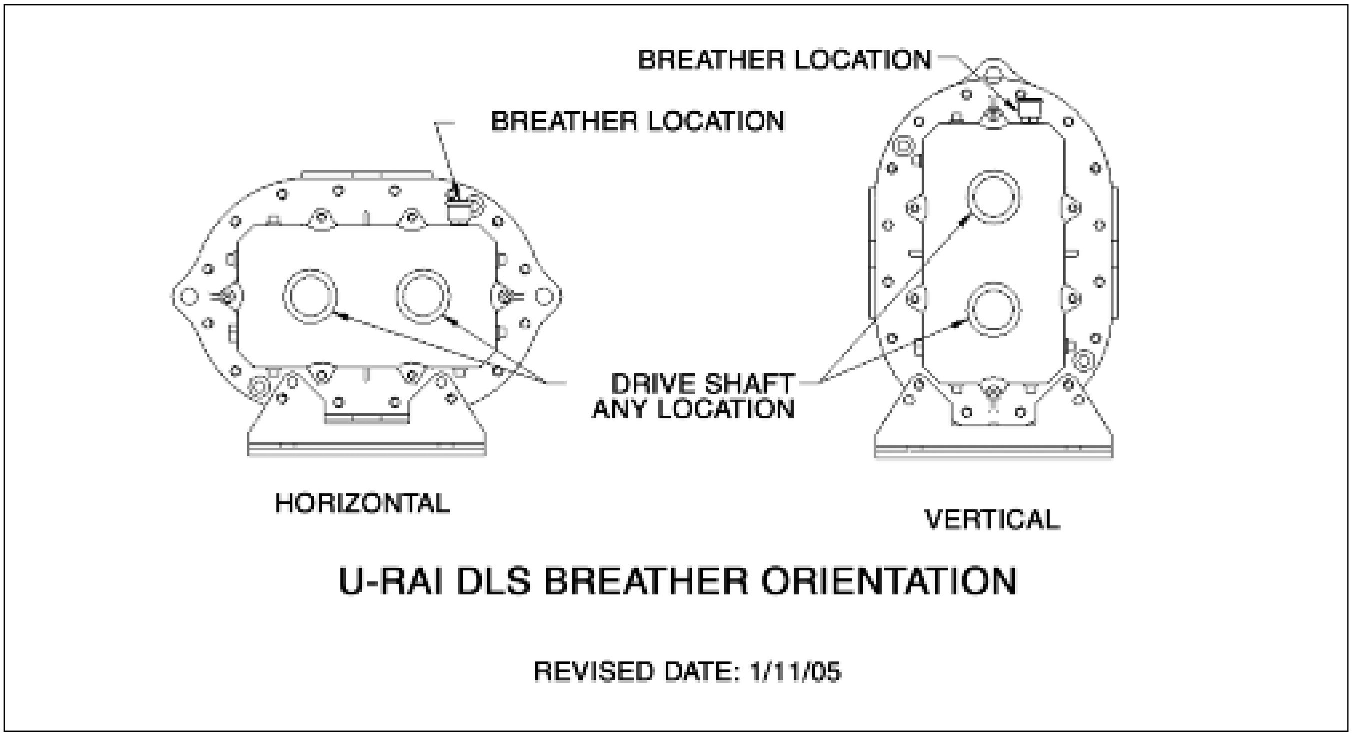


Table 1 - Universal RAI series, Universal URAI-DSI & URAI-G gas blower, Maximum Allowable Operating Conditions

Frame Size	Gear Diameter (Inch)	Speed RPM	Temp. Rise F°	(C°)	Delta Pressure PSI	(mbar)	Inlet Vacuum INHG	(mbar)
22	2.5	5275	225	(125)	12	(827)	15	(500)
24	2.5	5275	210	(117)	7	(483)	15	(500)
32	3.5	3600	240	(133)	15	1034	16	(539)
33	3.5	3600	225	(125)	12	(827)	15	(500)
36	3.5	3600	225	(125)	7	(483)	15	(500)
42	4.0	3600	240	(133)	15	(1034)	16	(539)
45	4.0	3600	225	(125)	10	(690)	16	(539)
47	4.0	3600	225	(125)	7	(483)	15	(500)
53	5.0	2850	225	(125)	15	(1034)	16	(539)
56	5.0	2850	225	(125)	13	(896)	16	(539)
59	5.0	2850	225	(125)	7	(483)	15	(500)
65	6.0	2350	250	(130)	15	(1034)	16	(539)
68	6.0	2350	240	(133)	14	(965)	16	(539)
615	6.0	2350	130	(72)	7	(483)	14	(472)
76	7.0	2050	250	(139)	15	(1034)	16	(539)
711	7.0	2050	225	(125)	10	(690)	16	(539)
718	7.0	2050	130	(72)	6	(414)	12	(405)

Table 2 - Recommended Oil Grades

Ambient Temperature °F (°C)	ISO Viscosity No.
Above 90° (32°)	320
32° to 90° (0° to 32°)	220
0° to 32° (-18° to 0°)	150
Below 0° (-18°)	100

URAI GAS Blower Oil and Grease Specifications

The specified oil should be ROOTS synthetic P/N 813-106- of the proper viscosity.

Table 3 - Approximate Oil Sump Capacities

These capacities are provided to assist in stocking the correct amount of oil. Exact sump capacities may differ slightly. See "Lubrication" section for proper filling instructions.

UNIVERSAL RAI, URAI-J, URAI-G

Frame Size	Gear End Capacity Fl. Oz. (Liters)	
	Vertical	Horizontal
22	3.4 (.1)	6.1 (.18)
24	3.4 (.1)	6.1 (.18)
32	8.5 (.25)	10.5 (.31)
33	8.5 (.25)	10.5 (.31)
36	8.5 (.25)	10.5 (.31)
42	12.7 (.37)	14.5 (.43)
45	12.7 (.37)	14.5 (.43)
47	12.7 (.37)	14.5 (.43)
53	16.0 (.47)	27.6 (.82)
56	16.0 (.47)	27.6 (.82)
59	16.0 (.47)	27.6 (.82)
65	28.3 (.84)	52.1 (1.54)
68	28.3 (.84)	52.1 (1.54)
615	28.3 (.84)	52.1 (1.54)
76	32.3 (.96)	59.5 (1.76)
711	32.3 (.96)	59.5 (1.76)
718	32.3 (.96)	59.5 (1.76)

See page 14 and 15 for illustration of vertical and horizontal configurations.

UNIVERSAL URAI series-DSL Splash Lubricated Drive End

Note that the gear end sump capacity is provided on the adjacent table.

Frame Size	Drive End Capacity Fl. Oz. (Liters)	
	Vertical	Horizontal
32	4.0 (.12)	6.5 (.19)
33	4.0 (.12)	6.5 (.19)
36	4.0 (.12)	6.5 (.19)
42	5.5 (.16)	10.8 (.32)
45	5.5 (.16)	10.8 (.32)
47	5.5 (.16)	10.8 (.32)
53	7.5 (.22)	14.8 (.44)
56	7.5 (.22)	14.8 (.44))
59	7.5 (.22)	14.8 (.44)
65	16 (0.47)	31 (0.91)
68	16 (0.47)	31 (0.91)
615	16 (0.47)	31 (0.91)

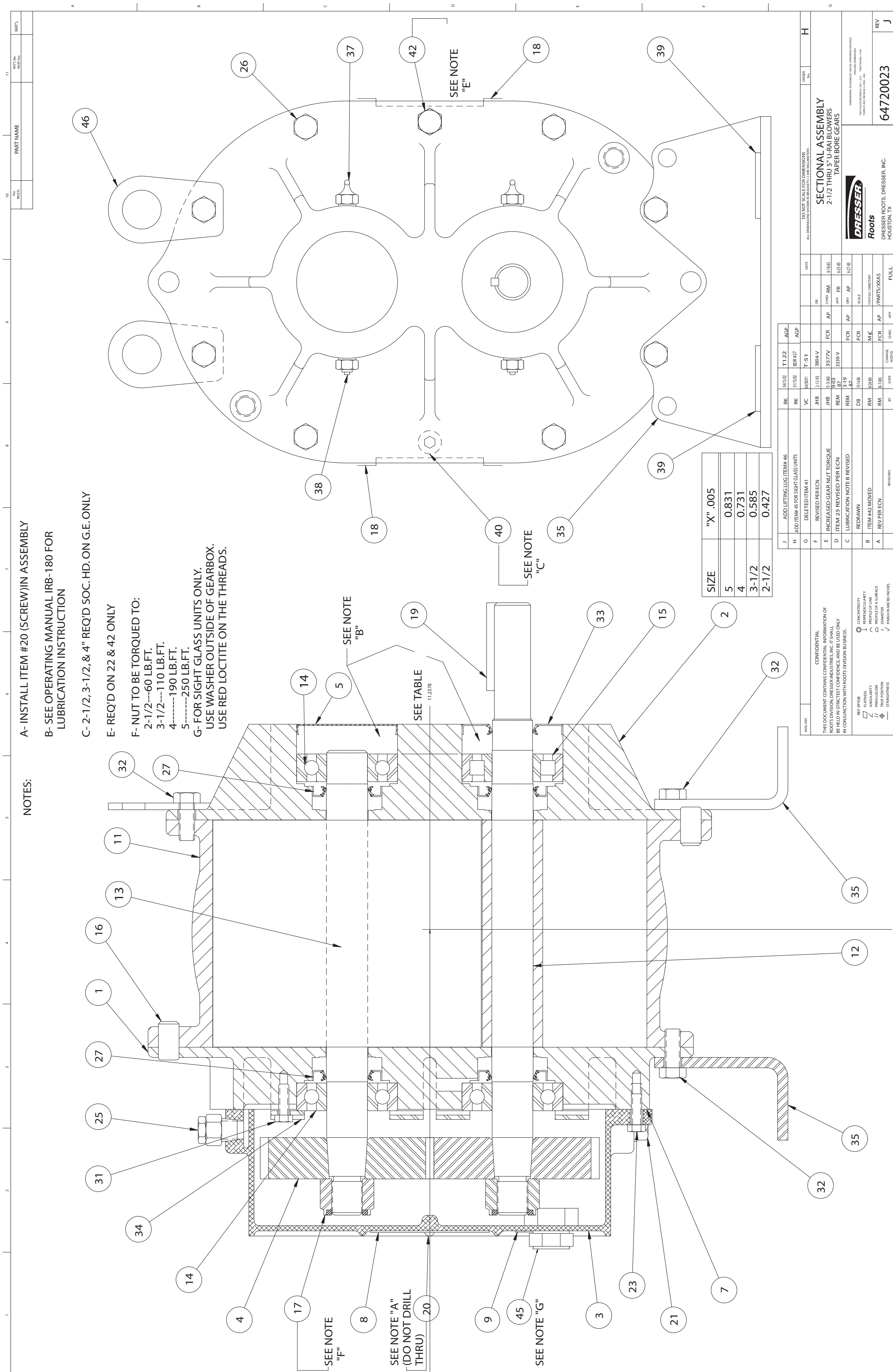
Table 4 - Universal URAI series with Grease Lubricated Drive End: Specified Bearing Greasing Intervals

Speed In RPM	Operating Hours Per Day		
	8	16	24
	Greasing Intervals in Weeks		
750-1000	7	4	2
1000-1500	5	2	1
1500-2000	4	2	1
2000-2500	3	1	1
2500-3000	2	1	1
3000 and up	1	1	1

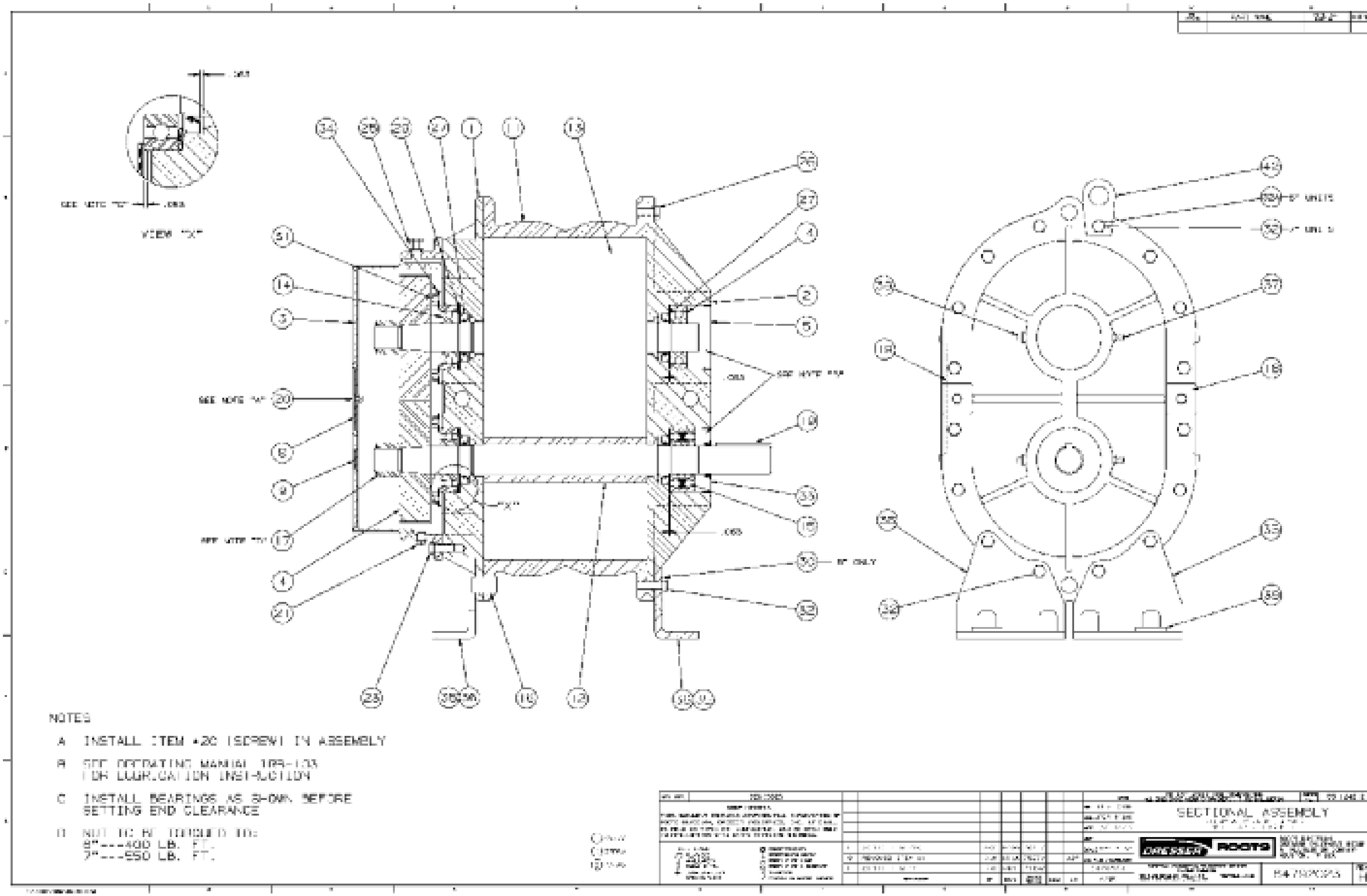
The specified grease for servicing drive end bearings of a Gas blower, use a NLGI #2 premium grade aluminum complex* grease, ROOTS P/N T20019001 with 300°F (149°C) service temperature and moisture resistance and good mechanical stability.

When servicing drive end bearings of Non Gas blower, use a NLGI #2 premium grade microgel grease with 250°F (121°C) service temperature and moisture resistance and good mechanical stability. ROOTS specifies Shell Darina EP NLGI Grade 2. Product Code 71522.

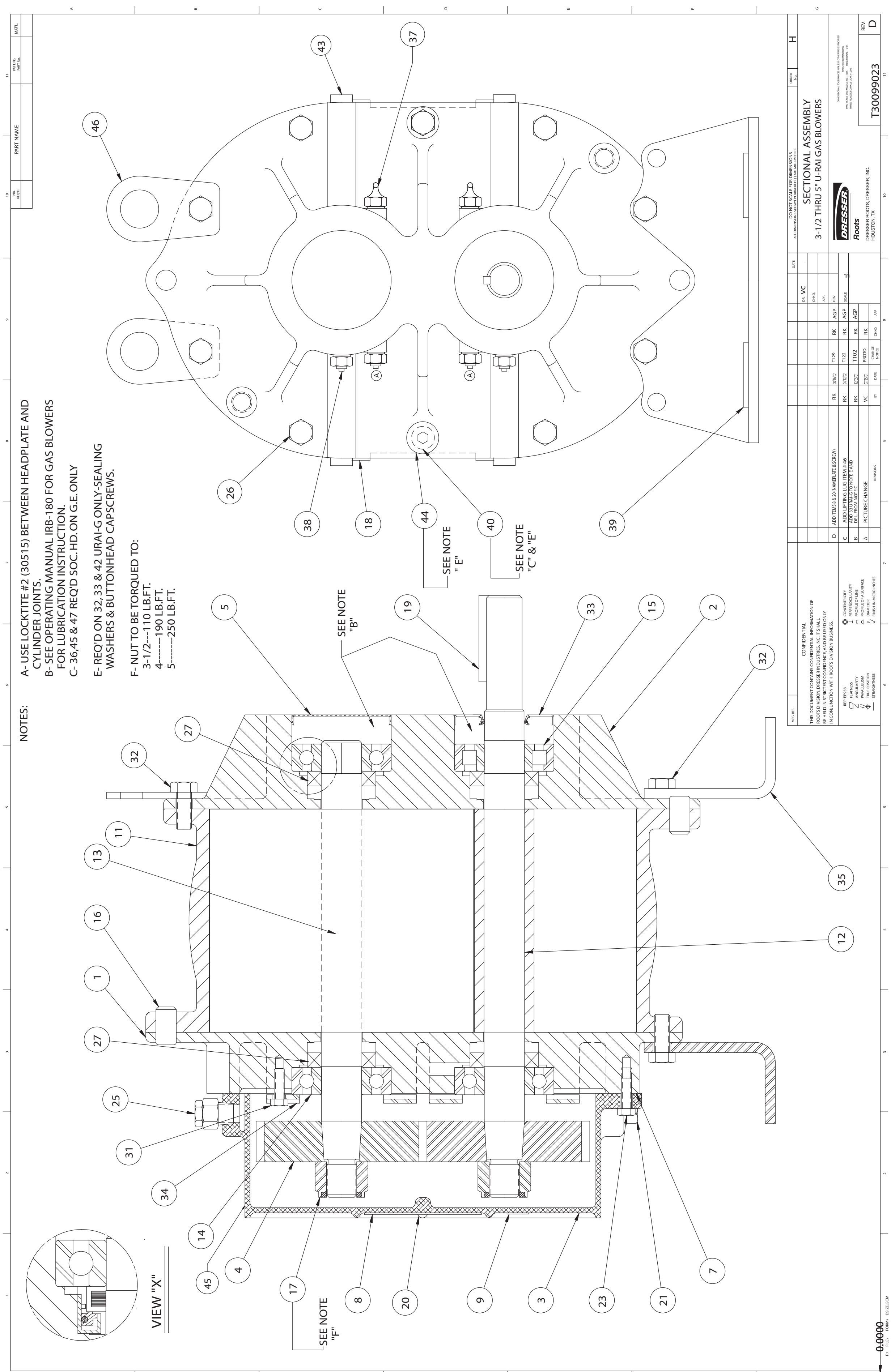
NOTE: Lithium based greases are not compatible with the ROOTS Synthetic grease used when assembling a Gas blower or the non-soap base grease used when assembling a standard URAI blower. Lithium based grease is not approved for any ROOTS blowers.



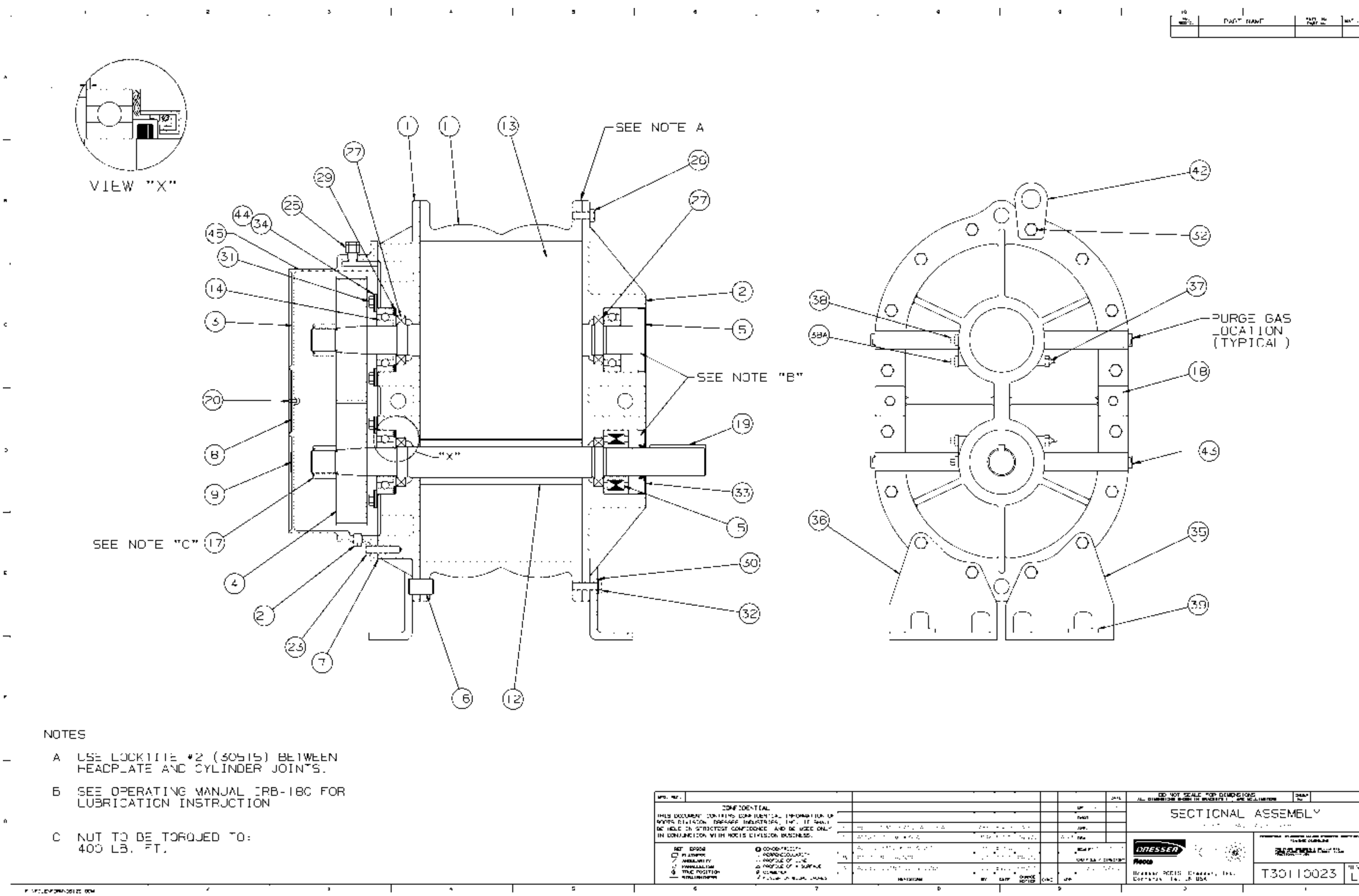
Assembly of UNIVERSAL RAI Series, Air Blowers, 2-1/2" Through 5" Gear Diameter



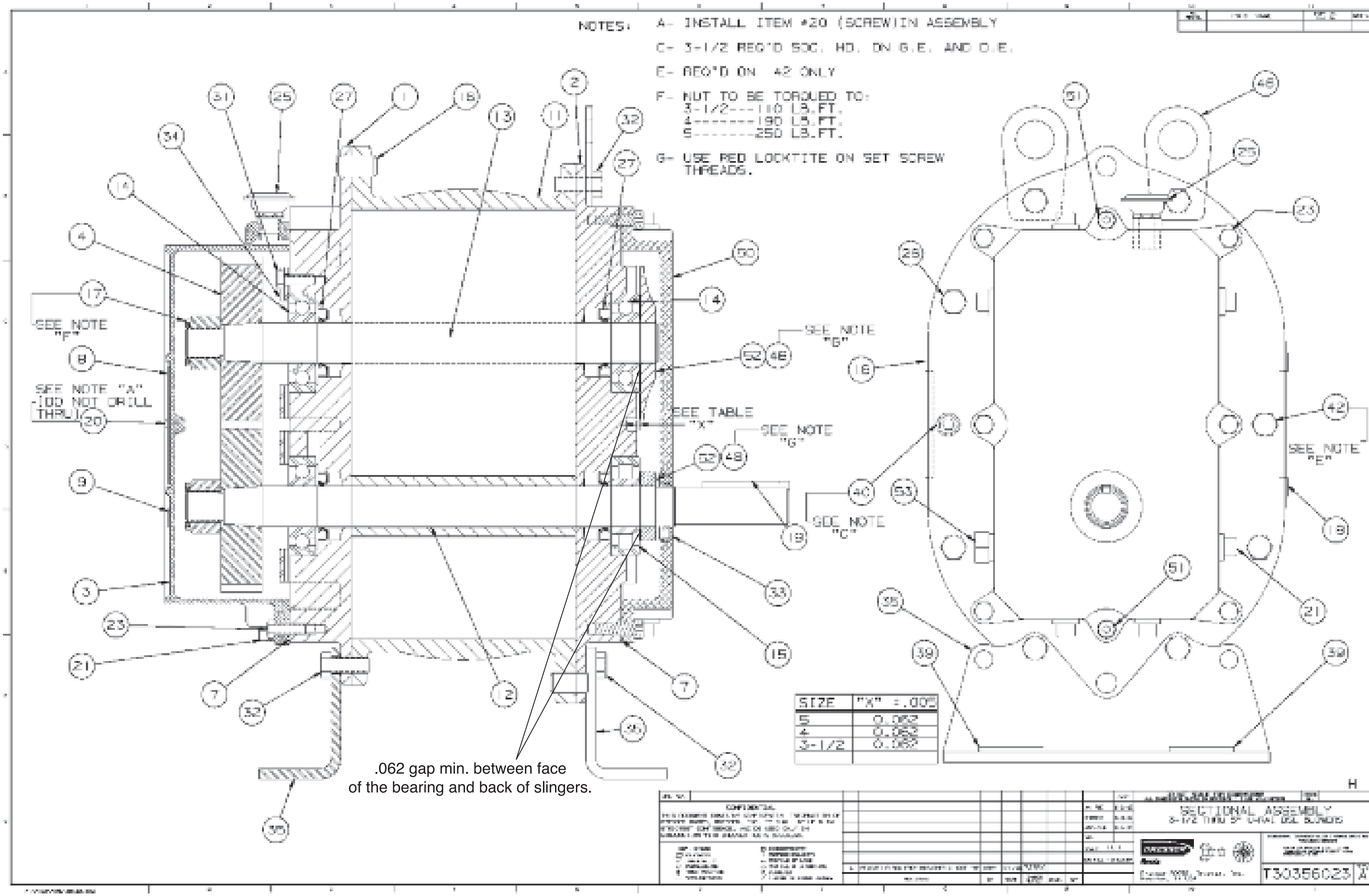
Assembly of UNIVERSAL RAI Blowers, 6" and 7" Diameter



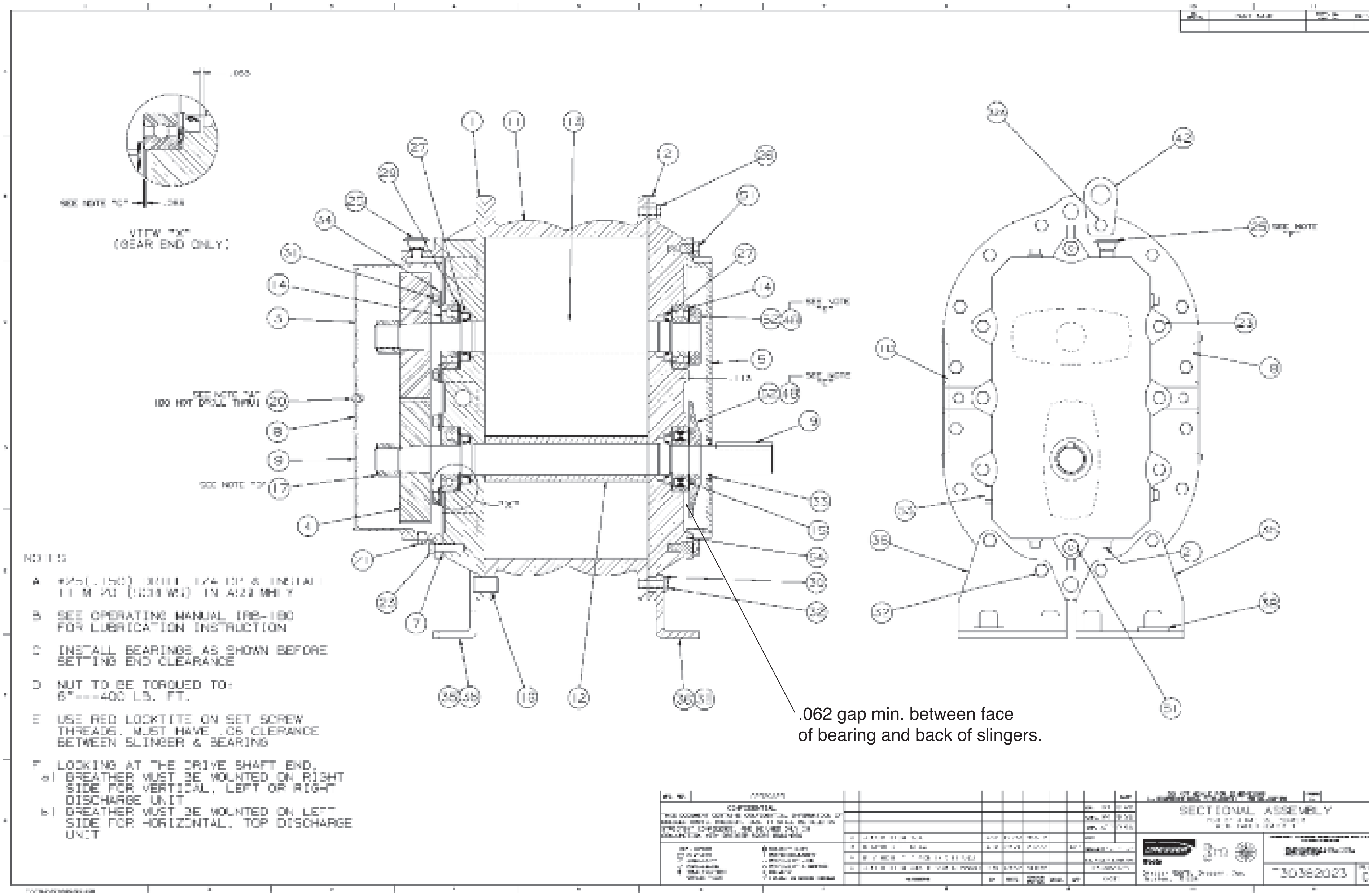
Assembly of UNIVERSAL RAI-G Series Gas Blowers, 3-1/2" Through 5" Gear Diameter



Assembly of UNIVERSAL RAI Series Gas Blowers, 6" Gear Diameter



Assembly of UNIVERSAL RAI Series - DSL with Splash Lubricated Drive End 3-5" Gear Diameter



Assembly of UNIVERSAL RAI Series - DSL with Splash Lubricated Drive End 6” Gear Diameter

Universal RAI Series Blowers Parts List 2-1/2" – 5" Gear Diameter

(Refer to drawing #64720023)

Item #	Part Name	Qty.
1	Headplate Gear End	1
2	Headplate Drive End	1
3	Gearbox	1
4	Timing Gears	2
5	Cover-Blind (Plug Opening)	1
7	Gasket, Gear Box	1
11	Cylinder	1
12	Impeller & Shaft Drive	1
13	Impeller & Shaft Driven	1
14	Bearing, Ball	3
15	Bearing, Roller	1
16	Pin, Dowel	4
17	Gear Nut	2
19	Key	1
21	Plug, Pipe	3
23	Screw Hex	6
25	Breather (Plug Vent)	1
26	Screw, Hex	*
27	Seal, Lip Bearing	4
31	Screw, Hex, Nylock	4
32	Screw, Hex	6
33	Seal Lip-Drive	1
34	Clamp Plate	2
35	Foot	2
37	Fitting, Grease	2
38	Fitting, Relief	2
39	Washer Mounting	4
40	Screw Socket	2
42	Screw Hex	2

*Quantities vary by blower.

Universal RAI Series Blowers Parts List 6" & 7" Gear Diameter

(Refer to drawing #64792023)

Item #	Part Name	Qty.
1	Headplate Gear End	1
2	Headplate Drive End	1
3	Gearbox	1
4	Timing Gears	2
5	Cover-Blind (Plug Opening)	1
7	Gasket, Gear Box	1
11	Cylinder	1
12	Impeller & Shaft Drive	1
13	Impeller & Shaft Driven	1
14	Bearing, Ball	3
15	Bearing, Roller	1
16	Pin, Dowel	4
17	Gear Nut	2
19	Key	1
21	Plug, Pipe	3
23	Screw Hex Nylock	8
25	Breather (Plug Vent)	1
26	Screw, Hex	*
27	Seal, Lip Bearing	4
29	Washer, Spring Wavy	2
31	Screw, Hex, Nylock	4
32	Screw, Hex	10
33	Seal Lip-Drive	1
34	Clamp Plate	2
35	Foot	2
37	Fitting, Grease	2
38	Fitting, Relief	2
39	Washer Mounting	4

*Quantities vary by blower.

Universal RAI-DSL Series Blowers Parts List 3-1/2" – 5" Gear Diameter

(Refer to drawing #T30356023)

Item #	Part Name	Qty.
1	Headplate Gear End	1
2	Headplate Drive End	1
3	Gearbox	1
4	Timing Gears	2
7	Gasket, Gear Box, DE Cover	1
11	Cylinder	1
12	Impeller & Shaft Drive	1
13	Impeller & Shaft Driven	1
14	Bearing, Ball	3
15	Bearing, Roller	1
16	Pin, Dowel	4
17	Gear Nut	2
19	Key	1
21	Plug, Pipe	3
23	Screw Hex	6
25	Breather (Plug Vent)	1
26	Screw, Hex	*
27	Seal, Lip Bearing	4
31	Screw, Hex, Nylock	4
32	Screw, Hex	6
33	Seal Lip-Drive	1
34	Clamp Plate	2
35	Foot	2
39	Washer Mounting	4
40	Screw Socket	2
42	Screw Hex	2
48	DE Oil Slinger Set Screw	4
50	Drive End Cover	1
52	Drive End Oil Slinger	2
53	Oil Sight Glass	2

*Quantities vary by blower.

Universal RAI®-DSL Series Blowers Parts List 6" Gear Diameter

(Refer to drawing #T30382023)

Item #	Part Name	Qty.
1	Headplate Gear End	1
2	Headplate Drive End	1
3	Gearbox	1
4	Timing Gears	2
7	Gasket, Gear Box	1
11	Cylinder	1
12	Impeller & Shaft Drive	1
13	Impeller & Shaft Driven	1
14	Bearing, Ball	3
15	Bearing, Roller	1
16	Pin, Dowel	4
17	Gear Nut	2
19	Key	1
21	Plug, Pipe	3
23	Screw Hex Nylock	8
25	Breather (Plug Vent)	1
26	Screw, Hex	*
27	Seal, Lip Bearing	4
31	Screw, Hex, Nylock	4
32	Screw, Hex	10
33	Seal Lip-Drive	1
34	Clamp Plate	2
35	Foot	2
39	Washer Mounting	4
48	DE Oil Slinger Set Screw	4
50	Drive End Cover	1
52	Drive End Oil Slinger	2
53	Oil Sight Glass	2

*Quantities vary by blower.

Universal RAI Series Gas Blowers Parts List
3-1/2" & 5" Gear Diameter

(Refer to drawing #T30099023)

Item #	Part Name	Qty.
1	Headplate Gear End	1
2	Headplate Drive End	1
3	Gearbox	1
4	Timing Gears	2
5	Cover-Blind (Plug Opening)	1
7	Gasket, Gear Box	1
11	Cylinder	1
12	Impeller & Shaft Drive	1
13	Impeller & Shaft Driven	1
14	Bearing, Ball	3
15	Bearing, Roller	1
16	Pin, Dowel	4
17	Gear Nut	2
19	Key	1
21	Plug, Pipe	3
23	Screw Hex	8
25	Breather (Plug Vent)	1
26	Screw, Hex	14*
27	Seal, Bearing	4
31	Screw, Hex	4
32	Screw, Hex	4
33	Seal Lip-Drive	1
34	Clamp Plate	2
35	Foot	2
37	Fitting, Grease	2
38	Fitting, Relief	2
39	Washer Mounting	4
40	Screw Socket	2
42	Screw Hex	2

*Quantities vary by blower.

Specified Lubricants

ROOTS Synthetic Oil: ISO-VG-220 Grade

	Part Number
Quart	813-106-001
Gallon	813-106-002
Case (12 qts)	813-106-008

ROOTS Synthetic Oil: ISO-VG-320 Grade

	Part Number
Quart	813-106-004
Gallon	813-106-005
Case (12 qts)	813-106-007

ROOTS Synthetic Grease: NLGI #2

	Part Number
14.5 oz. Tube	T200019-001
5 Gallon Pail	T200019-003
Case (30 tubes)	T200019-002

Universal RAI Series Gas Blowers Parts List
6" Gear Diameter

(Refer to drawing #T3011023)

Item #	Part Name	Qty.
1	Headplate Gear End	1
2	Headplate Drive End	1
3	Gearbox	1
4	Timing Gears	2
5	Cover-Blind (Plug Opening)	1
7	Gasket, Gear Box	1
7*	Gasket DE Cover	1
11	Cylinder	1
12	Impeller & Shaft Drive	1
13	Impeller & Shaft Driven	1
14	Bearing, Ball	3
15	Bearing, Roller	1
16	Pin, Dowel	4
17	Gear Nut	2
19	Key	1
21	Plug, Pipe	3
23	Screw Hex Nylock	8
25	Breather (Plug Vent)	1
26	Screw, Hex	14**
27	Seal, Bearing	4
31	Screw, Hex	4
32	Screw, Hex	10
33	Seal Lip-Drive	1
34	Clamp Plate	2
35	Foot	2
37	Fitting, Grease	2
38	Fitting, Relief	2
39	Washer Mounting	4
40	Screw Socket	2
42	Screw Hex	2
43	Plug	8
51	Shoulder Bolt	2
53	Oil Sight Glass	2

*DE cover gasket is not the same as the gasket used on the GE. You must specify the gasket required when ordering.
**Quantities vary by blower.

UNIVERSAL RAI (URAI) AIR BLOWERS

URAI AIR BLOWERS (with Grease Lubricated Drive End)

BOM # *	FRAME SIZE	INLET/DISCH CONN.	SHAFT DIAMETER	BARE WEIGHT
65102020	22	1" NPT	0.625"	32
65103020	24	2" NPT	0.625"	43
71046020	32	1.25" NPT	0.750"	69
65105020	33	2" NPT	0.750"	74
65106020	36	2.5" NPT	0.750"	102
65108020	42	1.5" NPT	0.875"	88
65109020	45	2.5" NPT	0.875"	109
65110020	47	3" NPT	0.875"	126
65112020	53	2.5" NPT	1.125"	143
65113020	56	4" NPT	1.125"	170
65114020	59	4" NPT	1.125"	204
65116020	65	3" NPT	1.375"	245
65117020	68	5" NPT	1.375"	265
65118020	615	6" Flange	1.375"	425
65120020	76	4" NPT	1.562"	400
65121020	711	6" Flange	1.562"	530
65122020	718	6" Flange	1.562"	650

Refer to Specification Sheet S-12934

URAI-DSL AIR BLOWERS (with Dual Splash Lubrication *DSL*)

BOM # *	FRAME SIZE	INLET/DISCH CONN.	SHAFT DIAMETER	BARE WEIGHT
T30378020	32	1.25" NPT	0.750"	72
T30379020	33	2" NPT	0.750"	77
T30380020	36	2.5" NPT	0.750"	105
T30352020	42	1.5" NPT	0.875"	92
T30353020	45	2.5" NPT	0.875"	113
T30354020	47	3" NPT	0.875"	132
T30359020	53	2.5" NPT	1.125"	148
T30360020	56	4" NPT	1.125"	175
T30361020	59	4" NPT	1.125"	209
T30384020	65	3" NPT	1.375"	250
T30385020	68	5" NPT	1.375"	290
T30386020	615	6" Flange	1.375"	430

Refer to Specification Sheet S-27900

Universal RAI air blowers include detachable mounting feet which permit vertical or horizontal installation. The units are center timed for rotation in either direction. The bearings on the URAI are grease lubricated on the drive end and splash lubricated on the gear end. The URAI-DSL is splash lubricated on BOTH ends.

UNIVERSAL RAI (URAI) GAS BLOWERS

URAI-G™ GAS BLOWERS (with Grease Lubricated Drive End)

BOM # *	FRAME SIZE	INLET/DISCH CONN.	SHAFT DIAMETER	BARE WEIGHT
710460G0	32	1.25" NPT	0.750"	69
651050G0	33	2" NPT	0.750	74
651060G0	36	2.5" NPT	0.750	102
651080G0	42	1.5" NPT	0.875"	88
651090G0	45	2.5" NPT	0.875	109
651100G0	47	3" NPT	0.875	126
651120G0	53	2.5" NPT	1.125"	143
651130G0	56	4" NPT	1.125	170
651140G0	59	4" NPT	1.125	204
651160G0	65	3" NPT	1.375"	245
651170G0	68	5" NPT	1.375	265
651180G0	615	6" NPT	1.375	425

Refer to Specification Sheet S-63A01

Universal RAI-G™ gas blowers include detachable mounting feet which permit vertical or horizontal installation. **Feet are different for vertical and horizontal mounting.**

The units are center timed for rotation in either direction. The bearings on the Universal RAI-GTM are grease lubricated on the drive end and splash lubricated on the gear end. ROOTS Synthetic lubricant is recommended.

UNIVERSAL RAI (URAI-J) WHISPAIR AIR BLOWERS

URAI-J WHISPAIR AIR BLOWERS (with Grease Lubed Drive End)

BOM # *	FRAME SIZE	INLET/DISCH CONN.	SHAFT DIAMETER	BARE WEIGHT
74065020	33J	2" NPT	0.750"	84
74066020	36J	2.5" NPT	0.750	112
74068020	45J	2.5" NPT	0.875"	119
74087020	47J	3" NPT	0.875	138
74067020	56J	4" NPT	1.125"	180

Refer to Specification Sheet S-33A03

URAI-J-DSL WHISPAIR AIR BLOWERS (with Dual Splash Lubrication DSL)

BOM # *	FRAME SIZE	INLET/DISCH CONN.	SHAFT DIAMETER	BARE WEIGHT
TS0417020	33J	2" NPT	0.750"	87
TS0418020	36J	2.5" NPT	0.750	115
TS0410020	45J	2.5" NPT	0.875"	122
TS0412020	47J	3" NPT	0.875	141
TS0415020	56J	4" NPT	1.125"	185

Refer to Specification Sheet S-30S03

URAI-J METRIC WHISPAIR AIR BLOWERS (with Grease Lubed Drive End)

BOM # *	FRAME SIZE	INLET/DISCH CONN.	SHAFT DIAMETER	BARE WEIGHT
TBD	33J	2" BSP	19 mm	84
740660M0	36J	2.5" BSP	19 mm	112
TBD	45J	2.5" BSP	24 mm	119
TBD	47J	3" BSP	24 mm	138
TBD	56J	4" BSP	28 mm	180

URAI-J-DSL METRIC WHISPAIR AIR BLOWERS (with Dual Splash Lubrication DSL)

BOM # *	FRAME SIZE	INLET/DISCH CONN.	SHAFT DIAMETER	BARE WEIGHT
TBD	33J	2" BSP	19 mm	87
T304660M0	36J	2.5" BSP	19 mm	115
TBD	45J	2.5" BSP	24 mm	122
T304550M0	47J	3" BSP	24 mm	141
TBD	56J	4" BSP	28 mm	185

Universal RAI-J air blowers incorporate the patented Whispair/TM design in addition to the same features as the original URAI blowers. The URAI-J's are center timed, however the Whispair/TM benefits can only be realized when the jet is located in the discharge position.

UNIVERSAL RAI METRIC (URAI-M) AIR BLOWERS

NOTE: METRIC URAI product has metric shaft diameter and connection sizes

URAI-METRIC AIR BLOWERS (with Grease Lubricated Drive End)

BOM # *	FRAME SIZE	INLET/DISCH CONN.	SHAFT DIAMETER	BARE WEIGHT
651020M0	22	1" BSP	16 mm	32
651030M0	24	2" BSP	16 mm	43
710490M0	32	1 1/4" BSP	19 mm	69
651050M0	33	2" BSP	19 mm	74
651060M0	36	2 1/2" BSP	19 mm	102
651080M0	42	1 1/2" BSP	24 mm	88
651090M0	45	2 1/2" BSP	24 mm	109
651100M0	47	3" BSP	24 mm	126
651120M0	53	2 1/2" BSP	28 mm	143
651130M0	56	4" BSP	28 mm	170
651140M0	59	4" BSP	28 mm	204
T30392050	65	3" BSP	32 mm	245
T30394050	68	5" BSP	32 mm	265
T30390050	615	150 NP10	32 mm	425
T30396050	76	4" BSP	38 mm	400
T30398050	711	150 NP10	38 mm	530
T30400050	718	200 NP10	38 mm	650

URAI-DSL-METRIC AIR BLOWERS (with Dual Splash Lubrication DSL)

BOM # *	FRAME SIZE	INLET/DISCH CONN.	SHAFT DIAMETER	BARE WEIGHT
T30463050	32	1 1/4" BSP	19 mm	72
T30464050	33	2" BSP	19 mm	77
T30465050	36	2 1/2" BSP	19 mm	105
T30451050	42	1 1/2" BSP	24 mm	92
T30452050	45	2 1/2" BSP	24 mm	113
T30453050	47	3" BSP	24 mm	132
T30459050	53	2 1/2" BSP	28 mm	148
T30460050	56	4" BSP	28 mm	175
T30461050	59	4" BSP	28 mm	209
T30472050	65	3" BSP	32 mm	250
T30473050	68	5" BSP	32 mm	290
T30474050	615	150 NP 10	32 mm	430

Universal RAI air blowers include detachable mounting feet which permit vertical or horizontal installation. The units are center timed for rotation in either direction. The bearings on the URAI are grease lubricated on the drive end and splash lubricated on the gear end. The URAI-DSL is splash lubricated on BOTH ends.

About Dresser, Inc.

Dresser, Inc. is a leader in providing highly engineered infrastructure products for the global energy industry. The company has leading positions in a broad portfolio of products including air and gas handling equipment, valves, actuators, meters, switches, regulators, piping products, natural gas-fueled engines, and retail fuel dispensers and associated retail point of sale systems. Leading brand names within the Dresser portfolio include Dresser ROOTS™ blowers, compressors and controls, Wayne® retail fueling systems, Waukesha® natural gas-fired engines, Masoneilan® control valves, Mooney® regulators, Consolidated® pressure relief valves, and ROOTS® rotary gas meters. It has manufacturing and customer service facilities located strategically worldwide and a sales presence in more than 100 countries. The company's website can be accessed at www.dresser.com

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ISRB-2002 rev.0808

ATTACHMENT D

SOLAR POWER PRODUCTION AND CONTROL EQUIPMENT SPECIFICATIONS AND MANUFACTURERS' USER MANUALS

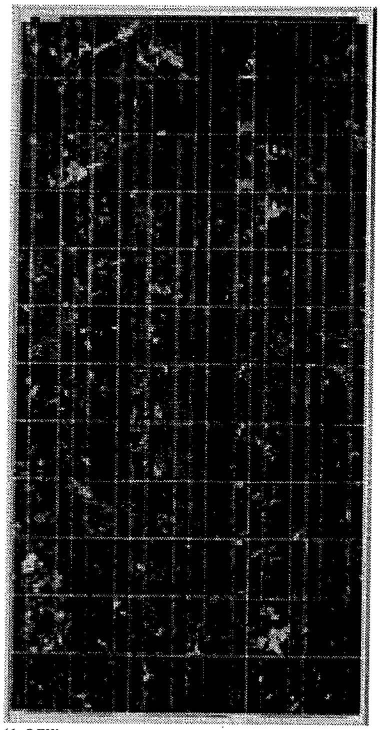
Sharp 185 Watt (NT-185U1) Spec Sheet
Sharp 170 Watt (NT-170U1) Spec Sheet
Bp Solar 175 Watt (SX 3175) Spec Sheet, Warranty, and Installation Instructions
Outback FLEXmax 80 User's Manual
Technical Manual for Sun Xtender Batteries (Concorde Battery Corporation)
TriStar Solar System Controller Installation and Operation Manual
Minarik Automation & Control User's Manual, DC Series (DC60-12/24)
Magnum ME-RC Owners Manual
Magnum RD Series Inverter Manual

bp solar

SX 3175

175 Watt Photovoltaic Module

High-efficiency photovoltaic module using silicon nitride multicrystalline silicon cells.



Performance

Rated power (P_{max})	175W
Power tolerance	± 9%
Nominal voltage	24V
Limited Warranty[1]	25 years

Configuration

N SX 3175N   Clear universal frame with Wirehold J-Box and polarized Multicontact (MC) connectors

Electrical Characteristics[2]	SX 3175	SX 3165
Maximum power (P_{max})[3]	175W	165W
Voltage at Pmax (V_{mp})	36.1V	35.2V
Current at Pmax (I_{mp})	4.85A	4.70A
Warranted minimum P_{max}	159.3W	150.2W
Short-circuit current (I_{sc})	5.3A	5.1A
Open-circuit voltage (V_{oc})	43.6V	43.6V
Temperature coefficient of I_{sc}	(0.065±0.015)%/ °C	
Temperature coefficient of V_{oc}	-(160±20)mV/°C	
Temperature coefficient of power	-(0.5±0.05)%/ °C	
NOCT (Air 20°C; Sun 0.8kW/m^2; wind 1m/s)	47±2°C	
Maximum series fuse rating	15A	
Maximum system voltage	600V (U.S. NEC & IEC 61215 rating)	

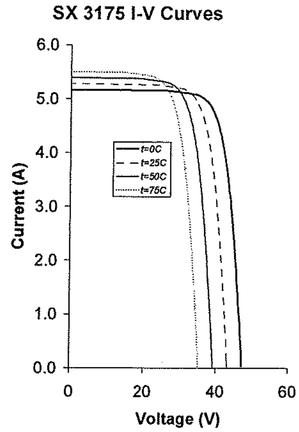
Mechanical Characteristics

Dimensions	N	Length: 1593mm (62.8") Width: 790mm (31.1") Depth: 50mm (1.97")
Weight	N	15.4 kg (33.9 pounds)
Solar Cells	N	72 cells (125mm x 125mm) in a 6x12 matrix connected in series
Output Cables	N	RHW-2 AWG# 12 (4mm^2) cable with polarized weatherproof DC rated Multicontact connectors with enhanced clip connection at module end; asymmetrical lengths - 1250mm (-) and 800mm (+)
Diodes	N	***IntegraBus***™ technology includes Schottky by-pass diodes integrated into the printed circuit board bus
Construction	N	Front: High-transmission 3mm (1/8th inch) tempered glass; Back: Polyester Encapsulant: EVA
Frame	N	Clear anodized aluminum alloy type 6063T6 Universal frame; Color: silver

1. Module Warranty: 25-year limited warranty of 80% power output; 12-year limited warranty of 90% power output; 5-year limited warranty of materials and workmanship. See your local representative for full terms of these warranties.
2. This data represents the performance of typical BP modules, and are based on measurements made in accordance with ASTM E1036 corrected to SRC (STC.)
3. During the stabilization process that occurs during the first few months of deployment, module power may decrease by approx. 1% from typical P_{max}.

Quality and Safety

ESTI	Module power measurements calibrated to World Radiometric Reference through ESTI
UL	Modules listed by Underwriter's Laboratories for electrical and fire safety (Class C fire rating)

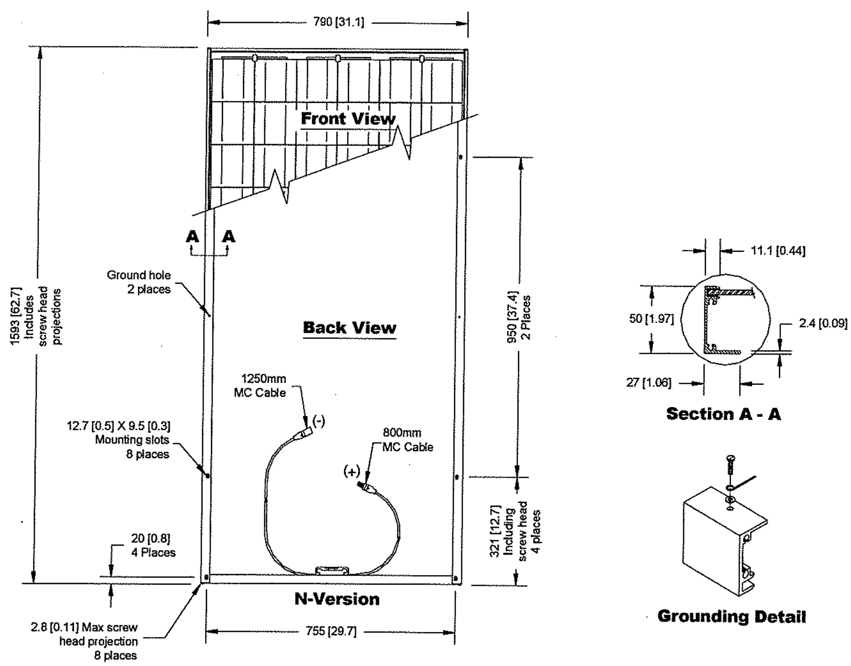


Qualification Test Parameters

Temperature cycling range	-40°C to +85°C (-40°F to 185°F)
Humidity freeze, damp heat	85% RH
Static load front and back (e.g. wind)	50psf (2400 pascals)
Front loading (e.g. snow)	113psf (5400 pascals)
Hailstone impact	25mm (1 inch) at 23 m/s (52mph)

Module Diagram

Dimensions in brackets are in inches. Un-bracketed dimensions are in millimeters. Overall tolerances ±3mm (1/8")



Included with each module: self-tapping grounding screw, instruction sheet, and warranty document.

Note: This publication summarizes product warranty and specifications, which are subject to change without notice. Additional information may be found on our web site: **www.bpsolar.com**

bp solar

BP SOLAR LIMITED WARRANTY CERTIFICATE

BP SOLAR provides the following limited warranties to purchasers of BP SOLAR products according to the warranty level specified on the label on the back of your BP Solar product (hereinafter referred to as Your BP SOLAR Product), and subject to the exclusions contained in Section 2, and in Section 3 hereof. The Warranty applicable to Your BP SOLAR Product's warranty level is located in the corresponding columns to the right of Your BP SOLAR Product's applicable warranty level in the Warranty Information Chart below. If your product's warranty level is not listed contact your customer service center or sales representative. Warranty is from date of initial purchase.

WARRANTY INFORMATION CHART		
WARRANTY LEVEL	MATERIALS & WORKMANSHIP	PERCENTAGE OF SPECIFIED POWER OUTPUT
25-12-5	5-Year Limited Warranty of Materials and Workmanship	25 – Year Limited Warranty of 80% Power Output 12 – Year Limited Warranty of 90% Power Output
0-12-2	2 -Year Limited Warranty of Materials and Workmanship	12 –Year Limited Warranty of 90% Power Output

SECTION 1. WARRANTY DESCRIPTIONS

Your BP SOLAR Product may have one or more of the following warranties. See the Warranty Information Chart above to determine which warranty or warranties applies to Your BP SOLAR Product.

A. Limited Warranties of Materials and Workmanship:
5 -Year Limited Warranty of Materials and Workmanship
2 -Year Limited Warranty of Materials and Workmanship

If Your BP SOLAR Product comes with a Limited Warranty of Materials and Workmanship, BP SOLAR warrants that for the term of your warranty (see Warranty Information Chart) Your BP SOLAR Product sold hereunder shall be free from defects in materials and workmanship. If, during the term of your warranty, there is such a defect, then BP SOLAR will, at its sole option, repair or replace Your BP SOLAR Product with an equivalent product, or refund the purchase price to you.

This Limited Warranty of Materials and Workmanship does not warrant a specified level of power output. The Limited Warranties of Percentage of Specified Power Output described below may warrant power output.
The term of your warranty is for the length of time stated in the name of your warranty type measured from the date of initial purchase.

B. Limited Warranties of Percentage of Specified Power Output:
25 - Year Limited Warranty of 80% of Power Output
12 - Year Limited Warranty of 90% of Power Output

IF YOUR BP SOLAR PRODUCT comes with a Limited Warranty of a Specified Power Output, BP SOLAR warrants Your BP SOLAR Product against defects in materials and workmanship that result in Your BP SOLAR Product's failure to produce your warranted percentage (see Warranty Information Chart) of the minimum power output specified in BP SOLAR's applicable written specifications, for the term of your warranty (see Warranty Information Chart). If BP SOLAR determines, using standard BP SOLAR test conditions, that Your BP SOLAR Product is not providing your warranted percentage of its specified minimum power output during the term of your warranty, then BP SOLAR will, at its sole option, repair or replace Your BP SOLAR Product, or provide you with additional component(s) to bring the aggregate power output to at least your warranted percentage of the specified minimum power output. The term of your warranty is for the length of time stated in the name of your warranty type measured from date of initial purchase.

SECTION 2. GENERAL INFORMATION

The following applies to ALL WARRANTED BP SOLAR PRODUCTS:

A. BP SOLAR may, at its discretion, use new, remanufactured or refurbished parts or products when repairing or replacing Your BP SOLAR Product under this warranty. Replaced parts or products will become the property of BP SOLAR.

B. BP SOLAR is not responsible for, and purchaser hereby agrees to bear, the costs of any on-site labor and any costs associated with the installation, removal, reinstallation or transportation of Your BP SOLAR Product or any components thereof for service under this limited warranty.

C. Notwithstanding anything to the contrary in this warranty certificate, the warranties provided herein shall apply only so long as the product(s) warranted hereby are owned by either (i) the first purchaser who has purchased the product(s) for its, his, or her own use and not for purposes for resale or (ii) by purchasers of buildings on which the product was first mounted.

SECTION 3. WARRANTY EXCLUSIONS AND LIMITATIONS

The following applies to ALL WARRANTED BP SOLAR PRODUCTS:

A. The warranties provided herein do not cover damage, malfunctions or service failures caused by:
   1) Failure to follow BP SOLAR's installation, operation or maintenance instructions;
   2) Repair, modifications, or movement of Your BP SOLAR Product by someone other than a service technician approved by BP SOLAR, or attachment to Your BP SOLAR Product of non-BP SOLAR equipment;
   3) Abuse, misuse, or negligent acts;
   4) Power failure surges, lighting, fire, flood, pest damage, accidental breakage, actions of third parties and other events or accidents outside BP SOLAR's reasonable control and not arising under normal operating conditions; and
   5) Breakage of laminates when mounted in customer-designed mounting systems.

B. BP SOLAR MAKES NO WARRANTIES, EXPRESS OR IMPLIED OTHER THAN THE WARRANTIES MADE HEREIN, AND SPECIFICALLY DISCLAIMS ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE.

BP SOLAR LIMITED WARRANTY CERTIFICATE

C. ANY WARRANTIES IMPLIED BY, INCLUDING THOSE OF MERCHANTABILITY AND FITNESS FOR PARTICULAR PURPOSE, WHICH ARE NOT EFFECTIVELY EXCLUDED HEREIN ARE LIMITED IN DURATION TO THE TERMS STATED IN THIS WARRANTY.

D. BP SOLAR IS NOT RESPONSIBLE FOR ANY SPECIAL INCIDENTAL, CONSEQUENTIAL OR PUNITIVE DAMAGES ARISING FROM THE USE OR LOSS OF USE OF OR FAILURE OF YOUR BP SOLAR PRODUCT TO PERFORM AS WARRANTED, INCLUDING BUT NOT LIMITED TO DAMAGES FOR LOST SERVICES, COST OF SUBSITUTE SERVICES, LOST PROFITS OR SAVINGS, AND EXPENSES ARISING OUT OF THIRD-PARTY CLAIMS. BP SOLAR'S MAXIMUM LIABILITY UNDER ANY WARRANTY, EXPRESSED, IMPLIED, OR STATUTORY, OR FOR ANY MANUFACTURING OR DESIGN DEFECTS, IS LIMITED TO THE PURCHASE PRICE OF THE PRODUCT. THE PURCHASER'S EXCLUSIVE REMEDY FOR BREACH OF WARRRANTY OR FOR MANUFACTURING OR DESIGN DEFECTS SHALL BE ONLY AS STATED HEREIN.

E. WHERE THE PURCHASER IS A NATURAL PERSON AND IF AND TO THE EXTENT REQUIRED BY APPLICABLE LAW, NOTHING IN THIS LIMITED WARRANTY SHALL OPERATE OR SHALL BE CONSTRUED TO OPERATE SO AS TO EXCLUDE OR RESTRICT THE LIABILITY OF BP SOLAR FOR DEATH OR PERSONAL INJURY CAUSED TO THE PURCHASER BY REASON OF THE NEGLIGENCE OF BP SOLAR OR ITS SERVANTS, EMPLOYEES OR AGENTS.

F. The rights granted by this Warranty are in addition to any statutory or other legal rights granted or existing under laws of the country or State in which the BP Solar Product was purchased and those legal rights are not affected by this Warranty.

G. Some States do not allow limitations on how long an implied warranty lasts, so the above limitation may not apply to you.

H. Some States do not allow the exclusion or limitation of incidental or consequential damages, so the above limitation or exclusion may not apply to you.

Any claim or dispute arising under or in connection with this warranty certificate must be brought in the courts of the State of Maryland, U.S.A., unless the original product was purchased in a member state of the European Union or in the country of Australia. In the event the original product was purchased in a member state of the European Union, any claim or dispute arising from or in connection to this warranty certificate must be brought in the courts of Spain. In the event the original product was purchased in the country of Australia, any claim or dispute arising from or in connection to this warranty certificate must be brought in the courts of the State of New South Wales.

SECTION 4. HOW TO GET WARRANTY SERVICE and/or INFORMATION REGARDING DISPOSAL AND RECYCLING OPTIONS

For warranty service, disposal and/or recycling options, please contact the distributor you purchased Your BP SOLAR Product from or the customer service representative at regional customer service center at BP Solar. BP Solar regional customer service center contact numbers can be found at (http://www.bpsolar.com/).

Crystalline Products:

BP SOLAR EUROPE & AFRICA
POL. IND. TRES CANTOS, S/N ZONA OESTE
28760 TRES CANTOS, MADRID
SPAIN
Phone +34 (91) 8071600

BP SOLAR AUSTRALIA
HBB WAREHOUSE
BP SOLAR PTY LTD
2 AUSTRALIA AVE
SYDNEY OLYMPIC PARK, NSW 2127
AUSTRALIA
Phone: +61 (2) 8762 5777

BP SOLAR INTERNATIONAL, LLC
6900 ENGLISH MUFFIN WAY
SUITE J
FREDERICK, MD 21703
USA
Phone: +1 (800) 521 7652 (US only Toll-Free)
+1 (301) 698 4200

bp solar

Instruction Sheet
Crystalline Silicon Photovoltaic Modules

Gebrauchsanweisung
PV-Module aus kristallinem Silizium

Hoja de instrucciones
Módulos fotovoltaícos de silicio cristalino

Fiche d'instructions
Modules photovoltaïques au silicium cristallin

手引書
結晶シリコン太陽光発電モジュール

General Information

This instruction sheet provides information about BP Solar crystalline silicon photovoltaic modules.

NOTE

Read this instruction sheet in its entirety before installing, wiring, or using a module. Module installation and wiring should be performed by or under supervision of a licensed electrician.

Disclaimer of Liability

Since the conditions or methods of installation, operation, use and maintenance of PV modules are beyond its control, BP Solar does not assume responsibility and expressly disclaims liability for loss, damage or expense arising out of or in any way connected with such installation, operation, use or maintenance.

Limited Warranties

Module Limited Warranties are described on the Warranty Certificate.

General Handling and Use

⚠ WARNING

Electrical Shocks & Burn Hazards

Photovoltaic (PV) modules generate electricity when exposed to light, even when they are not connected in a circuit. Shocks and burns can result from contact with module output wiring. These hazards are increased when multiple modules are interconnected to increase array output current or voltage.

Cover module front surfaces completely with an opaque cloth or other opaque material before performing any operation involving module or system electrical connections. Use appropriate safety equipment (insulated tools, insulating gloves, etc.) and procedures.

CAUTION

It is recommended to handle modules by their long sides only.

- Do not walk on, bend or disassemble modules.
- Take care not to damage the backsheet. Keep sharp objects away from the module surface when handling. Do not attach anything to the back of the module.
- Do not attempt to increase module output by concentrating light on its surface.
- If the PV power system includes other components (batteries, charge controllers, inverters, etc.) be sure to follow the safety recommendations of their manufacturers.

Mounting Instructions

⚠ WARNING

Falling Hazard

Use caution and be aware of slippery surfaces when installing modules on a roof. Falling can cause serious injury or death.

NOTE

It is the customer's responsibility to assure that its mounting systems are capable of safely supporting BP Solar modules or laminates. BP Solar does not warrant laminates against glass breakage, when mounted in customer-designed systems. All mounting structures must be reviewed by a professional mechanical engineer for wind load and other external loading conditions at that particular site.

Mount modules at an angle of at least 10 degrees from horizontal, and avoid mounting them with the junction box at the lower edge.

Mounting Framed Modules

NOTE

BP Solar modules are certified to IEC 61215 and UL 1703 standards when they are mounted on rigid beams at four inner mounting holes on their side frames as shown in Figures B-1 and B-2. Failure to comply with instructions may invalidate module warranties.

- To support our modules so that they can perform mechanically to the levels specified in UL1703 our product needs to be attached and supported in the region of its mounting bolt holes (~20% in from the ends), either with bolts through those holes or by an appropriate clamping means, sufficently to support 45 lbs per square foot (both positive and negative), it is then the structure manufacturer's responsibility to prove and certify that their structure can provide this support.
- Standoff or rack methods are acceptable when installing modules on a building. Other methods that have been successfully applied to crystalline modules may also be acceptable.

Mounting Laminates (Unframed Modules)

For a BP Solar Laminate Mounting Systems

- If your laminates have been sold as part of BP Solar UL-listed mounting system, follow the installation and operating instructions provided with the mounting system.

For a Customer-Designed Laminate Mounting System

- Ensure laminate glass does not contact metal or other hard materials under all predictable on-site thermal and mechanical conditions.
- Ensure no shear loads are applied to the laminate. If supporting laminates on only two sides, the supported sides must be the laminate long sides.
- Do not mount laminates by bonding their glass directly to metal or other support beams. Differential thermal expansion in such a system can break the laminate.
- Ensure edges of laminate are protected from damage.
- A BP Solar installation kit may be required for some mounting methods to comply with local electrical and building codes. Contact your distributor or a BP Solar representative for details.

Application Information

BP Solar PV modules produce DC electricity. They may be used in single-module and multiple-module systems to meet the current or voltage requirements of a wide range of applications. Some applications may require the use of a blocking diode, which prevents battery discharge during periods of darkness, or a battery charge regulator, which prevents overcharging and possible battery damage. Contact your distributor or a BP Solar representative for additional information.

Codes

In some areas, local or national codes (such as the United States NEC) may govern the installation and use of PV modules. In particular, these codes may specify requirements for module installation on rooftops, exterior walls, and vehicles. Installers must comply with these codes when applicable.

To comply with Canadian requirements, the installation shall be in accordance with CSA C22.1, Safety Standard for Electrical installations, Canadian Electrical Code, Part 1.

Underwriters Laboratories (UL) Listing Information

To satisfy the conditions of the UL Listing for modules installed in a system, you must: mount modules using standoff or rack methods when installing on a building. The module listing does not cover modules mounted integral with the roof or wall of the building and does not cover marine or vehicle application, where additional requirements may apply. If using laminates as part of BP Solar UL-listed mounting system, follow the installation and operating instructions provided with the mounting system.

FM Approved Installations

If your module is FM approved and installed in a location that requires FM approval, then the system voltage must not exceed 48 Vdc.

Module Characteristics

Table C-1 presents the electrical and mechanical characteristics of BP Solar crystalline silicon PV modules, and the major electrical characteristics at Standard Test Conditions (STC) appear on each module label. Standard Test Conditions are irradiance of 1000W/m², AM 1.5 spectrum, and cell temperature of 25°C. P_{max}, V_{oc}, and I_{sc} of any individual module will be within 10% of these specified values.

Under certain conditions, a module may produce more current or voltage than reported at STC. Accordingly, a module's open-circuit voltage and short-circuit current at STC should be multiplied by 1.25 when determining component ratings and capacities. An additional 1.25 multiplier for short-circuit current (for a total of 1.56), and a correction factor for open-circuit voltage (see Table 1 below) for sizing conductors and fuses is applicable, as described in Section 690-8 of the U.S. NEC.

Lowest Expected Ambient Temperature (°C/°F)	Correction Factor
25 to 10 / 77 to 50	1.06
9 to 0 / 49 to 32	1.10
-1 to -10 / 31 to 14	1.13
-11 to -20 / 13 to -4	1.17
-21 to -40 / -5 to -40	1.25

Table 1. Low Temperature Correction Factors Table For Open-Circuit Voltage

Electrical Connections

⚠ WARNING

Grounding

To avoid electrical shock, ground the frame of module or array before wiring the circuit. Attach a ground conductor at one of the ground holes on the module frame using the self-tapping screw supplied with the module. This may be required by your local codes.

NOTE

Use wiring and connection techniques consistent with outdoor installations. Wiring should be placed in conduit that is sunlight-resistant or, if exposed, should be sunlight-resistant type UF cable. Alternative grounding methods in compliance with articles 690 and 250 of the US NEC may be used.

CAUTION

To prevent stripping junction box screws, observe the torque limits in Table 2. Use wires of the same type (stranded or solid) under one terminal. If different wire gauges are used, limit the difference to 2 mm² or one AWG number.

Maximum Torque	
Junction box lid screws	0.57 N.m (5 in-lb)
Terminal block screws	
Conductor 6 or 4 mm² (AWG # 10 or # 12)	2.7 N.m (24 in-lb)
Conductor smaller than 4 mm² (AWG # 12)	2.3 N.m (20 in-lb)

Table 2. Maximum Torque for Junction Box and Terminal Block Screws

NOTE

Bypass diodes must be axial-lead Schottky diodes with a rating of at least 150°C junction temperature and current and voltage ratings as shown on the module label. See Table C-1 for maximum number of modules to be connected in parallel or series. Modules wired in the 6V configuration, or modules with 30V maximum system voltage rating should not be connected in series.

- **ONLY** use modules of same type for series and parallel connections.
- For modules equipped with Junction Box, see Figures A-1 through A-6 for parallel and series wiring details. Refer to Figure A-8 for proper removal of knockouts from the Junction Box.
- Modules with plug-and-socket cables are connected in series by connecting the positive (+) connector of one module to the negative (-) connector of the adjacent module. Use UL listed wire kits available from BP solar for array output wiring.

Parallel Connection - If modules or strings of modules are connected in parallel, it is recommended that each string be protected by an externally mounted blocking diode to prevent shaded parallel elements from interacting with unshaded elements.

Series Connection - If two or more crystalline modules are connected in series, a bypass diode is required to protect each cell series string (typically 18 cells.) Modules with rated output above 69W are factory-equipped with bypass diodes. Diodes must be customer-installed on smaller modules as shown in Figures A-1 through A-7.

Maintenance

- Inspect all electrical and mechanical connections annually for tightness and freedom from corrosion.
- Periodically, clean the module surface with a soft cloth or sponge using water and mild detergent.

Disposal Considerations

This product must be disposed of in accordance with all relevant local, state, and national laws and regulations. It is the responsibility of the user to ensure that this product is disposed of properly. Please contact BP Solar if you have any questions concerning the proper disposal of this product.

Allgemeine Information

Diese Gebrauchsanweisung enthält wichtige Hinweise und Information über kristalline photovoltaische Module von BP Solar.

ANMERKUNG

Lesen Sie diese Gebrauchsanweisung vollständig, bevor Sie ein Solarmodul anschließen, installieren oder benutzen. Es wird empfohlen, dass die Installation und der Anschluss der Module durch einen geprüften Elektriker (oder unter Aufsicht einer Fachkraft) erfolgt.

Haftungsbeschränkung

Da die Bedingungen unter denen das Modul installiert wird, der Betrieb und die Wartung außerhalb unser Kontrolle sind, übernimmt BP Solar keinerlei Verantwortung für Vorfälle, die in Zusammenhang mit der Installation, des Betriebes und der Wartung entstehen und schließt ausdrücklich die Gewährleistung bei Verlust, Schäden (auch Personenschäden) oder entstehende Kosten jeder Art aus.

Beschränkte Garantie

Der Garantiezeitraum für Leistungs- und Produktgarantie geht aus dem Garantiezertifikat hervor.

Allgemeine Informationen zu Handhabung und Benutzung

⚠ WARNUNG

Elektrische Schläge und Verbrennungsgefahr

Photovoltaische (PV) Module erzeugen Gleichstrom (DC), wenn sie der Sonne oder anderen Lichtquellen ausgesetzt sind. Auch wenn ein einzelnes Modul eine vergleichbar niedrige Spannung erzeugt, kann es bei Berührung der Anschlusskabel zu elektrischen Schlägen oder Verbrennungen kommen. Dieses Risiko wird dann erhöht, wenn mehrere Module in Reihe oder parallel geschaltet werden um Spannung oder Strom zu erhöhen.
PV Module müssen nicht angeschlossen sein (z.B. an eine Last) um Elektrizität zu erzeugen. Da PV Module Elektrizität erzeugen, sobald eine bestrahlende Lichtquelle vorhanden ist, sollte die Modulvorderseite mit einem lichtundurchlässigen Tuch oder anderen Material bedeckt sein, bevor an elektrischen Anschlüssen oder anderen Teilen des Systems gearbeitet wird.

ACHTUNG

Es ist zu empfehlen, dass Sie nur die langen Seiten der Module behandeln.

- Biegen Sie das Modul nicht.
- Treten Sie nicht auf die Module
- Demontieren Sie das Modul nicht.
- Seien Sie vorsichtig um die Rückfolie nicht zu beschädigen. Benutzen Sie keine scharfen Gegenstände, und halten Sie diese generell fern von den Modulen. Installieren oder kleben Sie nichts auf die Rückseite.
- Versuchen Sie nicht, die Modulleistung durch Konzentration von Licht auf seiner Oberfläche zu erhöhen.
- Sollte Ihr PV-System andere Komponenten enthalten (Batterien, Laderegler, Wechselrichter usw.), dann beachten Sie bitte die Gebrauchsanweisung der jeweiligen Hersteller.

Installationsanweisungen

⚠ WARNUNG

Absturzgefahr

Seien Sie vorsichtig achten Sie auf glatte und rutschige Oberflächen, wenn Sie Module auf dem Dach installieren. Bei Arbeiten auf dem Dach seien Sie sich der Absturzgefahr bewusst.

ANMERKUNG

Der Kunde trägt die Verantwortung dafür, sicherzustellen, dass die von ihm eingesetzte Trägerkonstruktion stabil genug ist um BP Solar Module oder Laminate sicher zu befestigen. BP Solar übernimmt keine Haftung für Glasbruch bei Laminaten, wenn die Trägerkonstruktion vom Kunden ausgelegt wurde. Alle Trägerkonstruktionen müssen von einem Spezialisten für die Verwendbarkeit bei verschiedenen Belastungen (z.B. Windlast, Schneelast, etc.) am betreffenden Aufstellungsort überprüft und bestätigt werden.

Module sollten mit einem Winkel von mindestens 10° zur Horizontale befestigt werden. Die Installation mit der Anschlussdose an der unteren Seite des Moduls ist zu vermeiden.

Installation von gerahmten Modulen

ANMERKUNG

Module von BP Solar sind gemäss IEC-61215 und UL1703 zertifiziert, wenn sie auf festen Metallprofilen an den inneren vier Befestigungslöchern angebracht sind, wie in Zeichnung B-1 und B-2 zu sehen ist. Bei Nichtbeachtung dieser Anweisungen erlischt unter Umständen jeglicher Garantieanspruch.

- Für die Installation auf einem Gebäude sind Aufdachsysteme oder Strukturen möglich.
- Bei der Aufstellung unserer Module müssen diese, um in mechanischer Hinsicht wie in UL1703 spezifiziert zu funktionieren, im Bereich der Befestigungslöcher (etwa 20 % von den Enden einwärts) befestigt und unterstützt werden – entweder mit Hilfe von Schrauben durch oder mit Hilfe von

Appendix – Anhang – Apéndice – Annexe – 付録

Electrical Connections – Elektrischer Anschluss – Conexiones eléctricas – Connexions électriques – 電気接続

Series and Parallel Connections

For proper connection, select the accessible junction box type matching the one on your product, as shown in Table C-1 (see separate sheet). Install jumpers as required and as shown by (1). For conductor larger than 6 mm^2 (AWG #10), use the optional Add-On Terminal Kit WK2ATK.

Parallel- und Reihenverschaltung von Modulen

Bitte ermitteln Sie den Anschlussdosen-Typ an Ihrem Modul anhand der Tabelle C-1 (siehe Extraseite). Installieren Sie die nötige Brücke wie in (1). Für Kabelquerschnitte mit mehr als 6mm^2 (AWG #10), benutzen Sie bitte das zusätzlich erhältliche Terminal-Kit (Bestellnummer "W2ATK") um die Verbindungen herzustellen.

Conexiones en serie y en paralelo

Para obtener conexiones correctas, seleccione el tipo de caja de conexiones accesibles que coincidan con su producto, como se muestra en la Tabla C-1 (ver hoja aparte). Instale adecuadamente los puentes como se muestra en (1). Para utilizar un conductor mayor de 6 mm^2 (AWG Nº 10), utilice el juego de ampliación de terminales opcional WK2ATK.

Connexions en parallèle et série

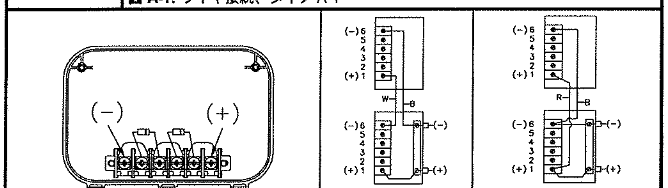
Pour une connexion correcte, sélectionnez le type de boîte de jonction correct qui correspond à celui de votre produit, ainsi qu'indiqué dans le Tableau C-1 (voir fiche séparée). Installez les cavaliers comme indiqué sous le sigle (1). Si vous avez un conducteur de plus de 6 mm^2 (AWG #10), utilisez le Kit de jonction complémentaire disponible en option (kit WK2ATK).

直列および並列接続

適切な接続をするには、表 C-1 (別紙参照).に示されているとおり、商品に適合するアクセス可能接続箱を選択してください。(1)の要件にそって、示されたとおり、ジャンパを設置してください。6 mm^2 (AWG #10),以上の導体については、任意のアドオン端末キット WK2ATK をお使いください。

A-1

Figure A-1. Wiring Connections, Type A-1
Zeichnung A-1. Anschlussbelegung, Typ A-1
Figura A-1. Conexión de cables, Tipo A-1
Figure A-1. Connexions, type A-1
図 A-1. ワイヤ接続、タイプ A-1



Series – in Reihe
Serie – Série – 直列

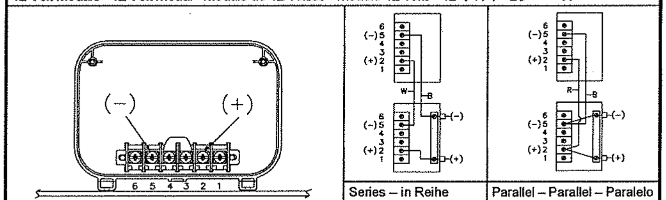
Parallel – Parallel – Paralelo
Parallèle – 並列

For modules with dual voltage 6V & 12V and rated power < 70 Watts
Für Module mit zwei Spannungen 6V & 12V und Nennleistung < 70 Watt
Para módulos con voltaje dual 6V y 12V y una potencia asignada < 70 Vatios
Pour les modules avec double tension 6V et 12V et puissance théorique < 70 watts
重電圧 6V & 12V および定格電源 70 ワット以上のモジュールについて

A-2

Figure A-2. Wiring Connections, Type A-2
Zeichnung A-2. Anschlussbelegung, Typ A-2
Figura A-2. Conexión de cables, Tipo A-2
Figure A-2. Connexions, type A-2
図 A-2. ワイヤ接続、タイプ A-2

12 Volt Module - 12 Volt Modul - Módulo de 12 voltios - Module 12 volts - 12 ボルトモジュール

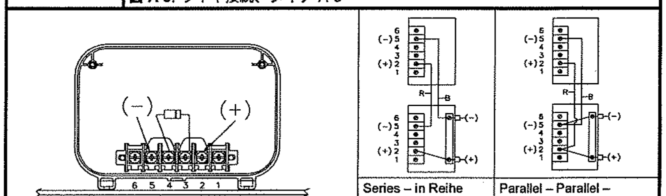


Series – in Reihe
Serie – Série – 直列

Parallel – Parallel – Paralelo
Parallèle – 並列

A-3

Figure A-3. Wiring Connections, Type A-3
Zeichnung A-3. Anschlussbelegung, Typ A-3
Figura A-3. Conexión de cables, Tipo A-3
Figure A-3. Connexions, type A-3
図 A-3. ワイヤ接続、タイプ A-3

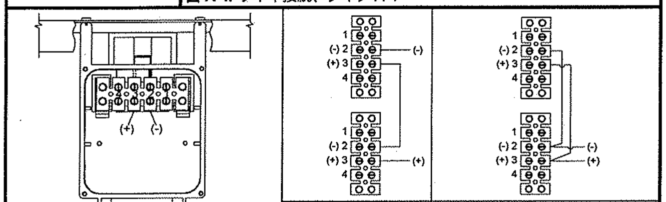


Series – in Reihe
Serie – Série – 直列

Parallel – Parallel –
Paralelo Parallèle – 並列

A-4

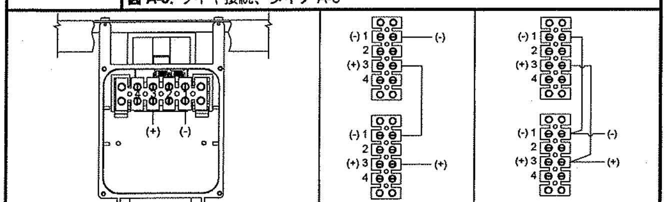
Figure A-4. Wiring Connections, Type A-4
Zeichnung A-4. Anschlussbelegung, Typ A-4
Figura A-4. Conexión de cables, Tipo A-4
Figure A-4. Connexions, type A-4
図 A-4. ワイヤ接続、タイプ A-4



Series – in Reihe Serie – Série – 直列	Parallel – Parallel – Paralelo Parallèle – 並列

A-5

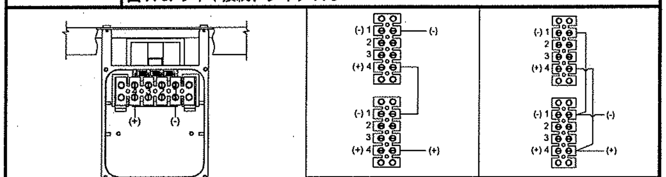
Figure A-5. Wiring Connections, Type A-5
Zeichnung A-5. Anschlussbelegung, Typ A-5
Figura A-5. Conexión de cables, Tipo A-5
Figure A-5. Connexions, type A-5
図 A-5. ワイヤ接続、タイプ A-5



Series – in Reihe Serie – Série – 直列	Parallel – Parallel – Paralelo Parallèle – 並列

A-6

Figure A-6. Wiring Connections, Type A-6
Zeichnung A-6. Anschlussbelegung, Typ A-6
Figura A-6. Conexión de cables, Tipo A-6
Figure A-6. Connexions, type A-6
図 A-6. ワイヤ接続、タイプ A-6

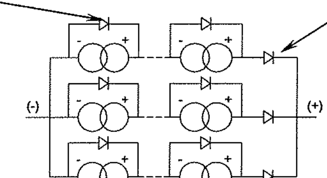


Series – in Reihe Serie – Série – 直列	Parallel – Parallel – Paralelo Parallèle – 並列

A-7

Figure A-7. Blocking and bypass diodes installation in series/parallel connections
Zeichnung A-7. Strangsicherungen und Bypass-Dioden in Reihen- und Parallelschaltungen
Figura A-7. Instalación de diodos de bloqueo y derivación en conexiones en serie o paralelo
Figure A-7. Installation des diodes de by-passe anti-retour (connexions série/parallèle)
図 A-7. 直列 / 並列接続でのブロックおよびバイパスダイオード設置

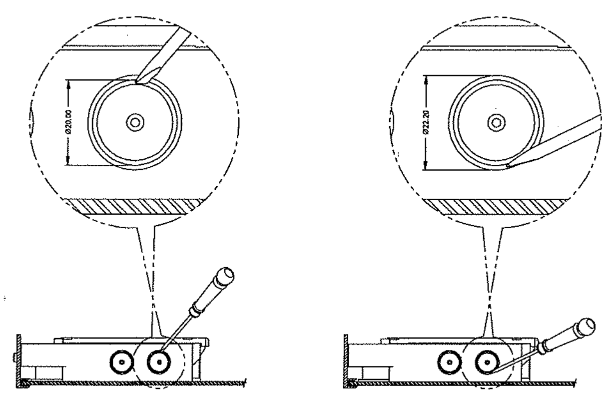
Bypass Diode
Bypass-Diode
Diodo de derivación
Diode de by-pass
バイパスダイオー



Blocking Diode
Strangdiode
Diodo de bloqueo
Diode anti-retour
ブロックダイオ

Solar Module
Solarmodul
Módulo solar
Module solaire
ソーラーパネ

Figure A-8. Knockout details for attaching Cable Glands on BP Junction Box
Zeichnung A-8.
Figura A-8.
Figure A-8.
図 A-8. . (ケーブルグランドを BP 接続箱に接続するためのノックアウトの詳細)



(For M20 or PG 13.5 knockout)
(Für M20 oder PG13.5 PG-Verschraubung)
(Para los prensaestopas o terminales de salida de métrica M20 ó PG13.5)
(Pour presse-étoupes ou passe-fils métriques M20 ou PG 13.5)
(M20/PJ 13.5 ノックアウトを取り外すには)

(For 1/2" knockout)
(Für ½" Verschraubungen)
(Para los prensaestopas o terminales de salida de 1/2")
(Pour presse-étoupes ou passe-fils de 1/2")
(½ " ノックアウトを取り外すには)

Use 5 or 6 mm wide flat screwdriver to knock out the holes as shown above
Benutzen Sie einen 5 oder 6mm breiten flachen Schraubenzieher um die vorgestanzten Teile zu entfernen, so wie im Bild gezeigt
Use destornillador plano de 5 ó 6 mm para abrir los terminales, tal y como se muestra en la figura
Utilisez un tournevis plat de 5 ou 6 mm pour défoncer les trous selon le schéma ci-dessus.
(ケーブルグランド接続用 BPJB のノックアウトの詳細
上図のように穴をノックアウトするには、5mmか6mm幅のフラットスクリュードライバーをお使い下さい。)

Mounting Instructions – Installationsanweisungen – Instrucciones de montaje – Instructions de montage – 取付手順

Recommended hardware:

- **Mounting modules with support members** – Use stainless steel hardware; (hex head bolt, flat washer, lock washer, and hex nut) in each of the 4 mounting holes. Use 8mm (5/16") or 6mm (1/4") depending on the size of the mounting hole in your module.
- **Mounting modules on roof** – Use 8 mm (5/16") steel lag bolt with sufficient length, and stainless steel flat washer per mounting hole.
- Maximum allowable bolt torque is 13.5 N.m (120 lb.in or 10 lb.ft).

Empfohlene Stahlwaren:

- **Installation der Module auf Befestigungsschienen / Strukturen** – Benutzen Sie rostfreie Eisenwaren (Sechskantschrauben, flache Unterlegscheiben, Sicherungsscheiben und Sechskantmuttern) in allen vier Befestigungslöchern. Benutzen Sie 8mm (5/16") oder 6mm (1/4") Schrauben, je nach Größe der Befestigungslöcher an Ihrem Modul.
- **Installation der Module auf dem Dach** – Benutzen Sie eine 8mm-Schraube (5/16") aus rostfreiem Stahl und eine flache Unterlegscheibe pro Befestigungsloch. Isolieren Sie die Schraube gegen den Modulrahmen, sodass nur eine mechanische aber keine elektrische Verbindung entsteht.
- Maximal erlaubtes Drehmoment für die Schrauben ist 13.5 Nm (120 lb in oder 10 lb.ft).

Hardware recomendado:

- **Montaje de los módulos con miembros de soporte** – Utilice materiales de acero inoxidable (tornillo de cabeza hexagonal, arandela plana, arandela plana, arandela de bloqueo y tuerca hexagonal) para cada agujero de montaje. Utilice 8mm (5/16") o bien 6mm (1/4") según el tamaño del agujero de montaje del módulo.
- **Montaje de módulos en techos** – Utilice un tornillo de acero revestido de 8 mm (5/16") con suficiente longitud y una arandela plana de acero en cada agujero de montaje.
- La máxima torsión que se debe de aplicar a los tornillos es de 13,5 N.m (120 lb.pulg. o 10 lb.pie).

Visserie recommandée :

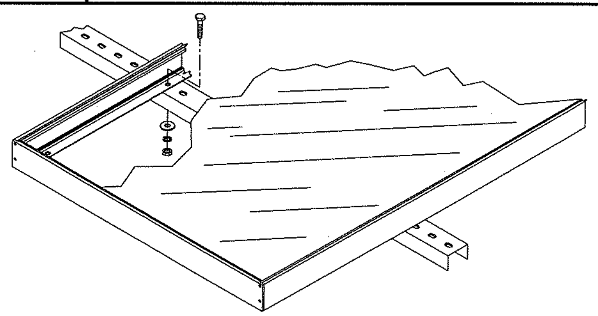
- **Montage des modules avec membres support** – Utilisez des boulons, rondelles et écrous en acier inoxydable. Suivant le type de module, utilisez des boulons à tête hexagonale de 6mm (1/4") ou 8 mm (5/16").
- **Installation des modules sur toit** – Utilisez un boulon acier 8 mm (5/16") suffisamment long, et une rondelle plate inoxydable, pour chaque orifice de montage.
- Le couple de serrage maximum est de 13.5 N.m (120 lb.in ou 10 lb.ft).

推奨装具

- **支え部材付取付モジュール** – 4個の各取付け穴にはステンレススチール製のハードウェア（六角頭ボルト、平座金、歯付座金、六角ナット）をお使いください。お持ち のモジュールの取付け穴のサイズにより、8mm (5/16") か 6mm (1/4")のものを使います。.
- **屋根の上の取付モジュール** – 取付穴別に、長さが十分な 8 mm (5/16") もくねじとステンレススチール平座金を使います。
- **注**: 最大許容ボルトトルクは 13.5 N.m (120 lb.in または 10 lb.ft)です。

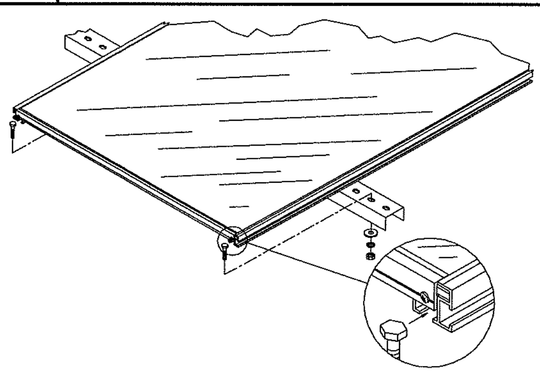
B-1

Figure B-1. Universal Frame Mounting
Zeichnung B-1. Installation des Universal-Rahmens
Figura B-1. Montaje para módulos con marco universal
Figure B-1. Montage pour cadre type "universel"
図 B-1. ユニバーサルフレームの取付



B-2

Figure B-2. Multi-Mount Frame Mounting
Zeichnung B-2. Installation des Vielzweck-Rahmens
Figura B-2. Instalación de módulos con marco de montaje múltiple
Figure B-2. Montage des modules à cadre du type «Multi-Mount»
図 B-2. 複数取付フレームの取付



Notes – Anmerkungen – Notas – Remarques – 注

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Main Offices – Hauptgeschäftsstelle – Oficinas Principales

Principaux Bureaux – 主なオフィス

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RD Series
Inverter / Chargers

Operator's Manual

MAGNUM
ENERGY

IMPORTANT SAFETY INSTRUCTIONS

This manual contains important safety instructions that must me followed during the installation and operation of this product.

To reduce the risk of electrical shock, fire, or other safety hazard, the following safety symbols have been placed throughout this manual to indicate dangerous and important safety instructions.

WARNING - Indicates a dangerous voltage or condition exists.

CAUTION - Indicates a critical step necessary for the safe installation and operation of this device.

NOTE - Indicates an important statement. Follow these instructions closely.

ATTENTION - Electrostatic Sensitive Devices. Observe precautions for handling.

All electrical work must be performed in accordance with local, state and federal electrical codes.

Read all instructions and safety information contained in this manual before installing or using this product.

This product is designed for indoor / compartment installation. It must not be exposed to rain, snow, moisture or liquids of any type.

Use insulated tools to reduce the chance of electrical shock or accidental short circuits.

Remove all jewelry such as rings, watches, bracelets, etc., when installing or performing maintenance on the inverter.

Always disconnect the batteries or energy source prior to installing or performing maintenance on the inverter.

Live power may be present at more than one point since an inverter utilizes both batteries and AC.

Always verify proper wiring prior to starting the inverter.

There are no user serviceable parts contained in this product.

SAVE THESE INSTRUCTIONS

IMPORTANT
BATTERY SAFETY INSTRUCTIONS

Wear eye protection such as safety glasses when working with batteries.

Remove all jewelry such as rings, watches, bracelets, etc., when installing or performing maintenance on the inverter.

Never work alone. Always have someone near you when working around batteries.

Use proper lifting techniques when working with batteries.

Never use old or untested batteries. Check each battery's label for age, type and date code to ensure all batteries are identical.

Batteries are sensitive to changes in temperature. Always install batteries in a stable environment.

Install batteries in a well ventilated area. Batteries can produce explosive gasses. For compartment or enclosure installations, always vent batteries to the outside.

Provide at least one inch of air space between batteries to provide optimum cooling.

Never smoke when in the vicinity of batteries.

To prevent a spark at the battery and reduce the chance of explosion, always connect the cables to the batteries first. Then connect the cables to the inverter.

Use insulated tools at all times.

Always verify proper polarity and voltage before connecting the batteries to the inverter.

To reduce the chance of fire or explosion, do not short-circuit the batteries.

In the even of accidental exposure to battery acid, wash thoroughly with soap and water. In the even of exposure to the eyes, flood them for at least 15 minutes with running water and seek immediate medical attention.

Recycle old batteries.

SAVE THESE INSTRUCTIONS

Magnum Energy
RD Series Inverter/Charger

Table of Contents

Table of Contents, continued

1. Features and Benefits

Congratulations on your purchase of the ME Series inverter/charger from Magnum Energy. The RD Series is a "new generation" inverter designed especially for rugged recreational vehicle usage. Powerful, yet simple to use, the Magnum Energy inverter will provide you with years of trouble-free performance so you can enjoy the all of the comforts you have come to expect from your RV, all backed by our limited 2 year (24-month warranty).

Installation is easy. Simply connect the inverter's output to your distribution circuits or electrical panel; connect your shore power cable (AC) to the inverter's easy-to-reach terminal block; connect the batteries, and then switch on the power. Using the optional remote control, you can easily operate your inverter from anywhere within your motor coach.

2. Standard Features

- Four Power Models (RD1824,RD2824,RD4024)
- Shelf, Bulkhead or Upside Down Mounting
- Modified Sine Wave Output
- Power Factor Corrected Charger (Sine Wave)
- RS485 Communication Port
- Remote Port
- Flash Programming
- ON/OFF Inverter-mounted Switch with LED Indicator
- 50 Amp Transfer (on Dual IN / Dual OUT Models)
- Extra Large AC Access Cover with Terminal Screw Block
- 360 degree DC Connection Terminals with Covers
- Battery Temperature Sensor - for optimum battery charging (optional)
- Aluminum Cover
- Smooth, Aesthetically Pleasing Design

The following accessories are also available for RD Series products:

Remote Control - for convenient finger tip operation
AGS Module - automatically starts and stops your generator
Smart Shunt - provides precise voltage to DC current
Stacking Cable Kit - designed to accommodate dual inverter configurations

Figure 1
RD Series Inverter / Charger

3. How an Inverter/Charger Works

An inverter takes direct current (DC) from your batteries and turns it into alternating current (AC), exactly like you use at home. It also takes alternating current when your motor coach is connected to shore power and transforms it into direct current to recharge your batteries.

There are two modes of operation associated with an inverter/charger:

Inverter Mode:
Direct current (DC) from the vehicle's batteries is transformed into alternating current (AC) for use with you household electrical appliances.

Charger Mode:
Alternating current (AC) is taken directly from shore power (or other AC sources) and passed directly to your household appliances. At the same time, the incoming AC is also converted to DC to recharge the vehicle's batteries.

4. Appliances and Run Time

The RD Series inverter/charger can power a wide range of household appliances including small motors, hair dryers, clocks and other electrical devices. As with any appliance using batteries for power, there is a certain length of time that it can run - this is called "run time." Actual run time depends on several variables including the size and the type of appliance, the type of batteries installed in your recreational vehicle, as well as the battery's capacity and age. Other factors such as the battery's state of charge and temperature can also affect the length of time your appliances can run.

Appliances such as TVs, VCRs, stereos, computers, coffee pots, incandescent lights and toasters can all be successfully powered by your inverter. Larger electrical appliances, however, such as stoves, water heaters, etc., can quickly drain your batteries and are not recommended for this application.

All electrical appliances are rated by the amount of power they consume. The rating is printed on the product's nameplate label, usually located on its chassis near the AC power cord. Even though it is difficult to calculate exactly how long an inverter will run a particular appliance, the best advice is trial and error. Your RD Series inverter has a built-in safeguard that automatically protects your batteries from over discharge.

NOTE: For optimum performance, a minimum battery bank of 200 AHr is recommended.

Device	Load	Device	Load
Blender	400 W	Coffee Maker	1200 W
Computer	300 W	Color TV	150 W
Drill	500 W	Hair Dryer	1000 W
Hot Plate	1800 W	Iron	1000 W
Light (Flo)	10 W	Light (Inc)	100 W
Microwave	1000 W	Refridgerator	500 W

Table 1 - Typical Appliance Power Consumption

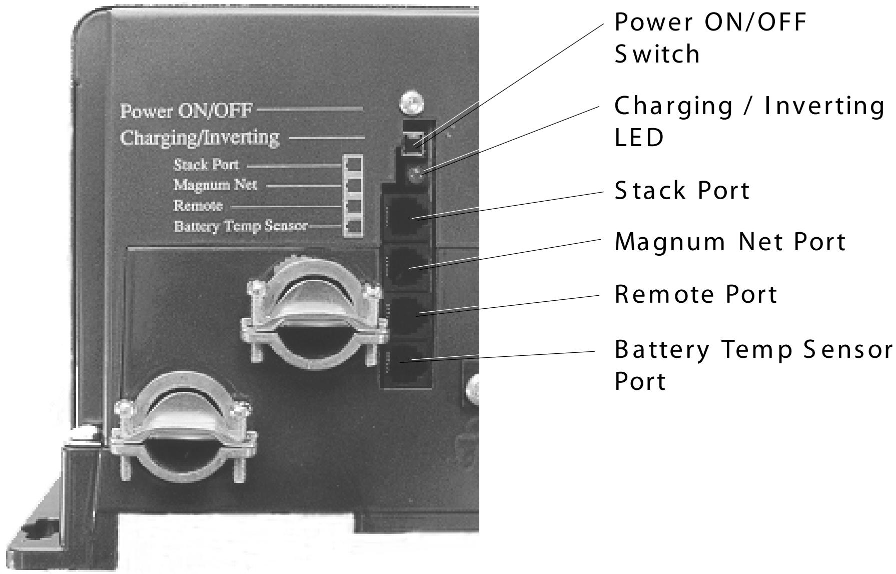

Figure 2
RD Series Inverter / Charger
Switch, LED and Connection Ports

Figure 3
RD Series Inverter / Charger
Electrical Connection Points

5. The RD Series Inverter/Charger

The RD Series inverter/charger is designed to allow easy access to wiring, circuit breakers, controls and LED status indicator. Its die cast baseplate with one piece aluminum cover ensures maximum durability with minimum weight, as well as cooler more efficient operation. The inverter is equipped with the following features:

ON / OFF Switch - used to manually switch the inverter ON and OFF.

Green LED Indicator

- Medium flash (1 every 2 seconds)

Indicates connected loads are being powered from the batteries (inverting).

- Fast flash (1 per second)

Indicates "search" mode, conserving power when appliances are switched OFF.

- Solid

Indicates "bulk" charge when the batteries are low and the inverter is connected to shore power.

- Fast flash (1 per second)

Indicates "absorption" charge when the batteries are almost fully recharged and the inverter is connected to shore power.

- Slow flash (1 every 8 seconds)

Indicates "float" charge when batteries are fully charged and the inverter is connected to shore power.

- LED off

Indicates a "fault" condition such as low battery, overload or over temperature.

Remote Control Port - accepts connector for Magnum remote control cable.

BTS Port - accepts connector for remote battery temperature sensor cable.

MagnumNet Communication Port - accepts connector for Auto Gen Start or Smart Shunt (DC current display) cable.

Positive Battery Terminal - provides 360 degree connection point for the positive (+) cable from the vehicle's batteries.

Negative Battery Terminal - provides 180 degree connection point for the negative (-) cable from the vehicle's batteries.

Chassis Ground Connector - accepts chassis ground cable.

AC Access Cover - provides access to internal AC screw terminal connections.

AC Input Circuit Breaker - protects main AC (shore power) input circuit.

AC Output 1 Circuit Breaker (optional) - protects the primary AC output circuit (on dual out units only).

AC Output 2 Circuit Breaker (optional) - protects secondary AC output circuit (on dual out units only).

RD Series Nameplate Label - provides product and safety information.

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1. Unpacking and Inspection

Carefully remove the RD Series inverter from its shipping container and inspect all contents. If items appear to be missing or damaged, contact Magnum Energy at (425) 353-8833 or your authorized Magnum Energy dealer. If at all possible, retain the shipping container in the event the unit ever needs to be returned for factory service.

ATTENTION: Electrostatic Sensitive Devices. Observe precautions for handling.

2. Pre-Installation

Before installing the inverter, read all of the instructions and cautionary markings contained in this manual.

NOTE: The inverter is heavy. Use proper lifting techniques during installation to prevent personal injury.

Locating the Inverter

The inverter must be mounted in a clean, dry, ventilated environment where the ambient temperatures will not exceed 122 °F (50 °C). The location must be fully accessible and protected from exposure to heat producing devices. You can mount the inverter horizontally, vertically or upside-down. It must be securely fastened to a shelf, bulkhead, or other structural part.

Allow enough clearance to access the AC and DC connection points as well as the inverter's controls and status indicator. As with any inverter, it should be located as close to the batteries as possible. Longer battery cable runs tend to loose efficiency and reduce the overall performance of an inverter.

Locating Dedicated Batteries (optional)

Dedicated batteries must be mounted in a clean, dry, ventilated environment where they are protected from high and low temperatures. The batteries must be mounted upright (if using liquid batteries). The location must be fully accessible and protected from exposure to heat producing devices.

To ensure optimum performance, a ventilated battery enclosure is recommended. The batteries should be located as close as possible to the inverter. Longer battery cable runs tend to loose efficiency and reduce the overall performance of an inverter. Also, do not mount the batteries beneath the inverter (or in the same compartment). Batteries emit corrosive fumes which could damage the inverter's electronics.

NOTE: For optimum performance, Magnum Energy recommends using AGM (absorbed glass mat) batteries such as Lifeline™ brand batteries.

2. Pre-Installation, continued

Hardware / Materials Required

Conduit, strain-reliefs and appropriate fittings
1/4" mounting bolts and lock washers
Electrical tape
Wire ties

Tools Required

Misc screw drivers	Level	1/2" wrench
Drill and drill bits	Pliers	Wire strippers
Level	Pencil or Marker	Multimeter

Wiring

Pre-plan the wire and conduit runs. For maximum safety, run both AC and DC wires/cabling in (separate) conduit. Direct current wiring, due to its potential to generate RFI, should be tied together with electrical tape. Wiring and installation methods must conform to all applicable electrical codes.

NOTE: Run DC cabling in twisted pairs, keeping the runs as short as practical.

AC Connections

Use #10 AWG (or larger) THHN wire for all AC wiring. The inverter's AC terminal blocks accept up to #6 AWG wire.

DC Connections

Battery to inverter cabling should be only as long as required. If using #2/0 AWG cables, do not exceed 5 feet (one way) for 12 VDC systems.

Crimped and sealed copper ring terminal lugs with a 5/16" hole should be used to connect the battery cables to the inverter's DC terminals.

AC Grounding

The AC Ground connection located in the AC compartment must be wired to the main AC Ground of the distribution panel.

DC Grounding

The inverter/charger should always be connected to a permanent, grounded wiring system. For the majority of installations, the negative battery conductor is bonded to the vehicle's safety-grounding conductor (green wire) at only one point in the system. The size for the conductor is usually based on the size of the largest conductor in the DC system. DO NOT connect the battery negative (-) cable to the vehicle's safety ground. Connect it only to the inverter's negative battery terminal. If there are any non-factory installed DC appliances on board the vehicle, DO NOT ground them at the safety ground. Ground them only at the negative bus of the DC load center (as applicable).

2. Pre-Installation, continued

Torque Requirements

Torque all AC wiring connections to 16 inch pounds. Torque DC cable connections to 10-12 foot pounds.

AC Main Panel

If the installation will be powering a wide-range of appliances throughout the vehicle, an AC main panel is often recommended. This is similar in appearance and function as your home’s circuit breaker panel, providing an additional level of control and protection for the various circuits. Always refer to electrical codes for safe wiring practices.

Circuit Protection

If using a AC main panel for distribution, always use breakers that provide the correct ampere branch circuit protection in accordance with the National Electric Code. The breakers must also be properly rated for the appliances that will be powered.

NOTE: Both AC and DC disconnects / overcurrent protection must be provided as part of the installation.

Wire Routing

Determine all wire routes throughout the vehicle both to and from the inverter. Conductors that are at risk to physical damage must be protected by conduit, tape, or placed in a raceway. Conductors passing through walls, bulkheads or other structural members must be protected to minimize insulation damage such as chafing. During the installation, always avoid placing conductors near sources of chafing caused by vibration or constant rubbing.

CAUTION: Always check for existing electrical, plumbing or other areas of potential damage prior to making cuts in structural surfaces, bulkheads or walls.

Typical routing scenarios are:

- AC Input wiring from the shore power source to the inverter
- AC Input wiring from a generator (optional) to the inverter
- DC Input wiring from the batteries to the inverter
- AC Output wiring from the inverter to the coach’s AC main panel or to dedicated circuits
- Battery Temperature Sensor cable (optional) from the inverter to the batteries
- Remote Control cable (optional) to the inverter
- Ground wiring from the inverter to an external vehicle ground

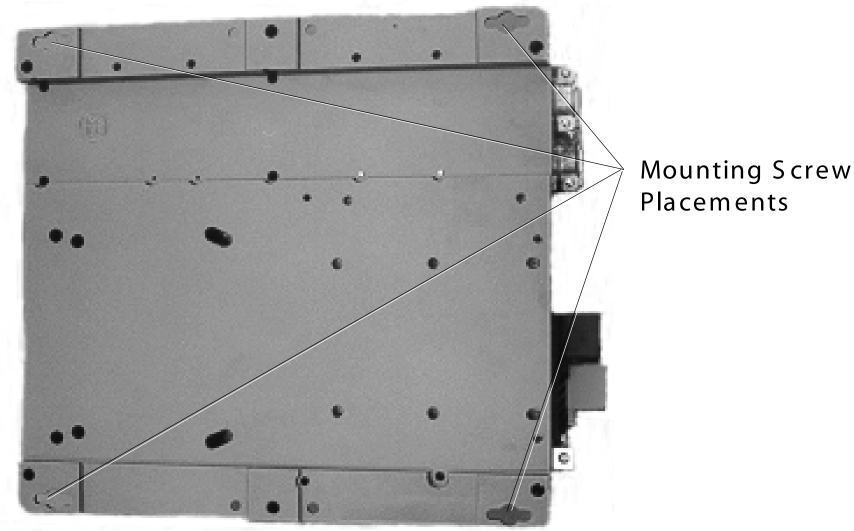

Figure 4
RD Series Inverter / Charger Base Plate

Inverter	RD1824	RD2824	RD4024
DC Rating	90 amps	140 amps	180 amps
@ 1 to 3 ft	# 2/0 AWG	# 2/0 AWG	# 4/0 AWG
@ 3 to 5 ft	# 4/0 AWG	# 4/0 AWG	# 4/0 AWG
@ 5 to 10 ft	# 4/0 AWG	# 4/0 AWG	# 4/0 AWG

Table 2 - Recommended Battery Cable Sizing

3. Installation

NOTE: Read all instructions and cautionary markings located at the beginning of this manual and in the pre-installation section, before installing the inverter and batteries.

CAUTION: Do not mount the inverter or the batteries near the vehicle's gasoline or propane fuel tanks.

Mount the inverter only on a "non-combustable" surfaces.

Maximum abient temperature MUST NOT exceed 113 °F (45 °C).

For Canadian installations, the inverter's vents must face downward.

Inverter Mounting

Position the inverter in the designated mounting location horizontally, vertically or upside-down. Allow enough clearance to access the AC and DC connection points as well as the inverter's controls and status indicator. Also allow for air flow in to and around the inverter, especially near the cooling fans (approximately 3").

Mark the mounting holes in the base of the inverter's chassis. Remove the inverter and drill pilot holes into the mounting surface.

Secure the inverter to the mounting surface using appropriate screws and lockwashers.

Remove the inverter's AC access panel in accommodate the AC Input and Output wiring and conduit.

Battery Installation

NOTE: To ensure the best performance from your inverter system, do not use old or untested batteries. Batteries must be of the same size, type, rating and age.

NOTE: For optimum performance, Magnum Energy recommends using AGM (absorbed glass mat) batteries such as Lifeline™ brand batteries.

NOTE: If using Flooded Lead Acid batteries, they must be mounted upright.

CAUTION: Install batteries in a well ventilated area. Batteries can produce explosive gasses. For compartment or enclosure installations, always vent batteries to the outside.

Place the batteries as close as practical to the inverter, preferably in an insulated and ventilated enclosure. Allow adequate space above the batteries (+/- 6" above the batteries) to access the terminals and vent caps (as applicable). Also allow at least 1" of space between the batteries to provide good air flow. DO NOT mount the batteries directly under the inverter.

Secure the batteries to the mounting surface with battery hold down clamps.

3. Installation, continued

Battery Cables and Sizing

Select the correct battery cables for the installation from the table. It is important to use the correct cable to achieve maximum efficiency from the system and reduce fire hazards associated with overheated cables. Undersized cables can also lower the inverter's peak output voltage as well as reduce its surge power capability. Long cable runs also reduce efficiency due to resistance in the cable. Always keep your cable runs a short as practical.

Battery cables must be color coded with colored tape or heat shrink tubing: RED for positive (+); BLACK for negative (-); and GREEN for DC ground.

The cables must have soldered and crimped lugs, crimped copper compression lugs, or aluminum mechanical lugs. Soldered connections alone are not acceptable for this application.

DC Wiring

Refer to the safety information at the beginning of the manual before proceeding. DC wires and cables should be tied together with wire ties or electrical tape approximately every 6 inches.

WARNING: De-energize all sources of power including batteries (DC), shore power (AC), and AC generator (if applicable).

CAUTION: Inverter is NOT polarity protected. Verify proper polarity BEFORE connecting the battery cables.

NOTE: DO NOT connect the battery cables to the inverter until all wiring is complete and the correct DC voltage and polarity has been verified.

NOTE: Make sure cables have a smooth bend radius and do not become kinked. Place long cable runs in conduit and follow existing wire runs where possible.

DC Grounding

Route a grounding cable (GREEN) from the inverter's ground lug to a dedicated vehicle ground.

Negative Cable

Route a negative cable (BLACK) from the house battery bank (or dedicated battery compartment) to the inverter's negative terminal

Positive Cable

Route a positive cable (RED) from the house battery bank (or dedicated battery compartment) to the Fuse Block assembly (DC Disconnect). The DC disconnect is usually located next to or near the batteries. DO NOT connect the positive cable to the batteries at this time.

Route a positive cable (RED) from the Fuse Block assembly (DC Disconnect) to the inverter's positive terminal DO NOT connect the positive cable to the inverter at this time.

3. Installation, continued

Battery Wiring

WARNING: During the installation and wiring process, cover exposed battery cable ends with electrical tape to prevent shorting the cables.

NOTE: DO NOT connect the positive cable to the inverter at this time.

Depending upon the type of battery you use in the installation (6 or 12 VDC), the batteries must be wired in series, parallel or series/parallel to provide 12 VDC. The interconnecting battery cables must be sized and rated exactly the same as those that used to connect the inverter.

When connecting the cable to the battery terminal, hardware should be installed in the following order: bolt, ring washer, cable lug, (battery terminal), ring washer, lock washer, nut. Tighten terminal connections to at least 10 to 12 foot pounds.

When two cables are connected to a terminal (i.e., negative terminal), the hardware should be installed in the following order: bolt, ring washer, DC negative cable lug, inverter negative cable lug, (battery terminal), ring washer, lock washer, nut.

Series Connection
(multiple 6 VDC batteries to create a 24 VDC string)

A parallel connection combines overall battery capacity by the number of batteries in the string. Even though there are multiple batteries, the voltage remains the same. In the example on the next page (Figure 7), four, 6 VDC, 220 AHr batteries are combined into a single string, resulting in a 24 VDC, 220 AHr bank.

Connect the positve battery terminal to the next battery's negative terminal repeating the step for the next 2 batteries.

Connect the negative battery cable (BLACK) from the inverter to the negative terminal of the end battery.

Connect the positive (RED) battery cable from the inverter to the positive terminal of the battery at the opposite end of the string.

NOTE: A fuse must be placed between the positive terminal and the positive (RED) battery cable to the inverter.

Once the batteries are completely wired and tested, coat the terminals with an approved anti-oxidizing spray.

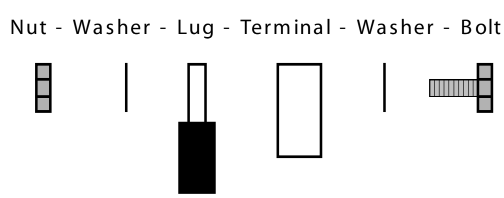

Figure 5
Battery Hardware Installation

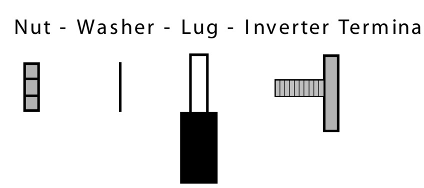

Figure 6
Inverter Hardware Installation

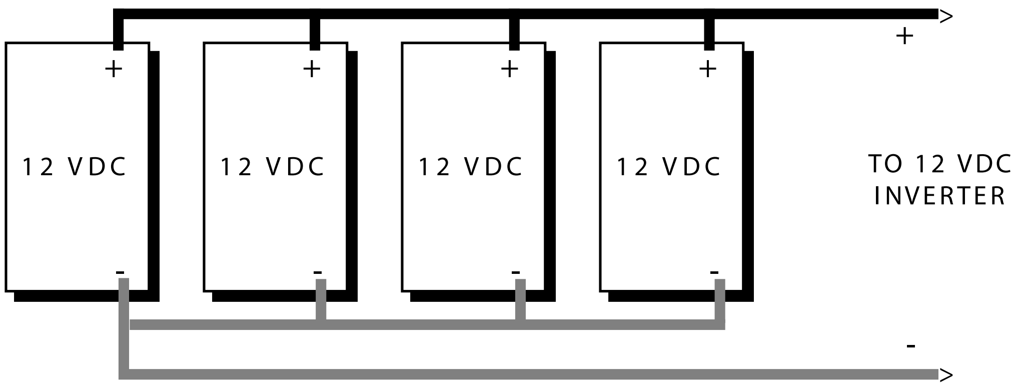

Figure 7
Parallel Battery Wiring
individual battery capacity = 100 AHr @ 12 VDC
combined battery capacity = 400 AHr @ 12 VDC

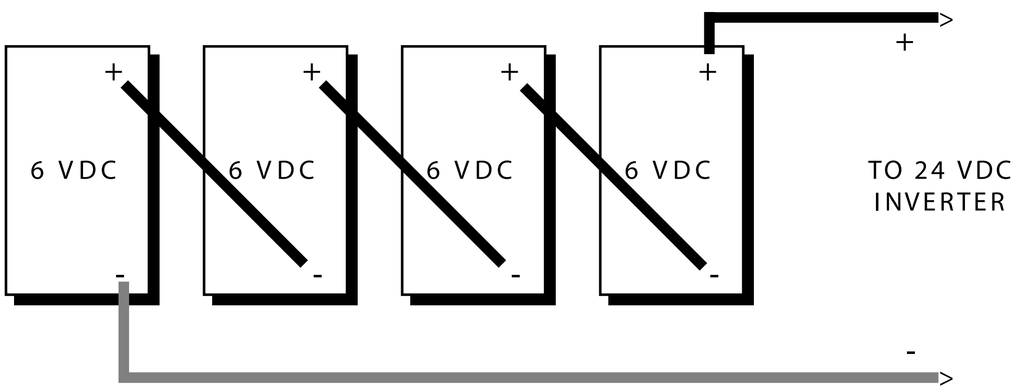

Figure 8
Series Battery Wiring
individual battery capacity = 200 AHr @ 6 VDC
combined battery capacity = 200 AHr @ 24 VDC

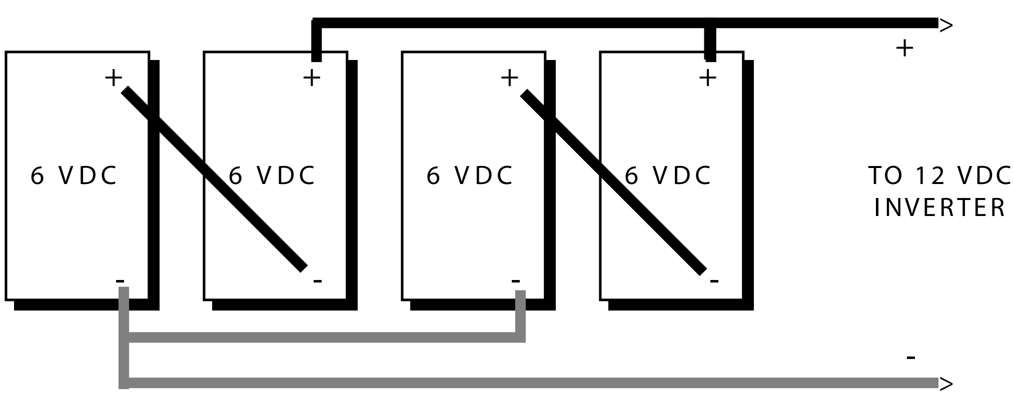

Figure 9
Series/Parallel Battery Wiring
individual battery capacity = 220 AHr @ 6 VDC
combined battery capacity = 400 AHr @ 12 VDC

3. Installation, continued

Series Connection
(four 6 VDC batteries to create a 24 VDC bank)

A series connection combines overall battery voltage by the number of batteries in the string. Even though there are multiple batteries, the capacity remains the same. In the example at the left (Figure 8), four 6 VDC, 100 AHr batteries are combined into a single string resulting in a 24 VDC, 200 AHr bank.

Connect the negative battery terminal of one battery to the positive of the other using a short cable.

Connect the negative battery cable (BLACK) from the inverter to the open negative terminal of one of the batteries. At the same time, connect a DC ground cable between the negative terminal and the vehicle’s DC grounding bus.

Connect the positive battery cable (RED) from the inverter to the positive terminal of the opposite battery.

NOTE: A fuse must be placed between the positive terminal and the positive (RED) battery cable to the inverter.

Once the batteries are completely wired and tested, coat the terminals with an approved anti-oxidizing spray.

Series/Parallel Connection
(four 6 VDC batteries to create a 12 VDC bank)

A series/parallel connection increases both voltage and capacity using smaller, lower-voltage batteries. In the example at the left (Figure 9) four 6 VDC, 200 AHr batteries are combined into two pairs resulting in a 12 VDC, 400 AHr bank.

Connect the negative battery terminal of one 6 VDC battery to the positive of the next (creating a pair) using a short battery cable.

Connect the negative battery terminal of another 6 VDC battery to the positive of its next using a short battery cable (creating a second pair).

Connect the remaining negative battery terminal of the first pair to that of the second pair using a short battery cable.

Connect the remaining positive battery terminal of the first pair to that of the second pair using a short battery cable.

Connect the negative battery cable (BLACK) from the inverter to the end battery’s negative terminal. At the same time, connect a DC ground cable between the negative terminal and the vehicle’s DC grounding bus.

Connect the positive battery cable (RED) from the inverter to the opposite end battery’s positive terminal.

NOTE: A fuse must be placed between the positive terminal and the positive (RED) battery cable to the inverter.

Once the batteries are completely wired and tested, coat the terminals with an approved anti-oxidizing spray.

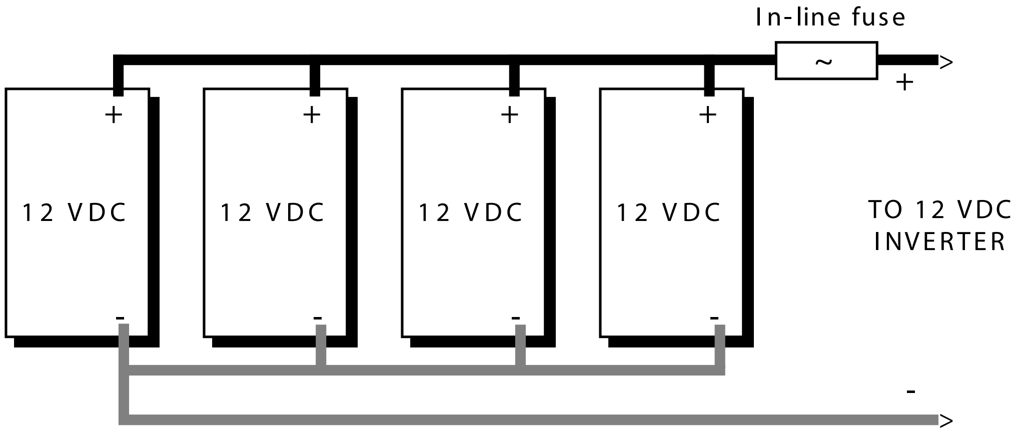

Figure 10
Parallel Battery Wiring - Fuse Placement

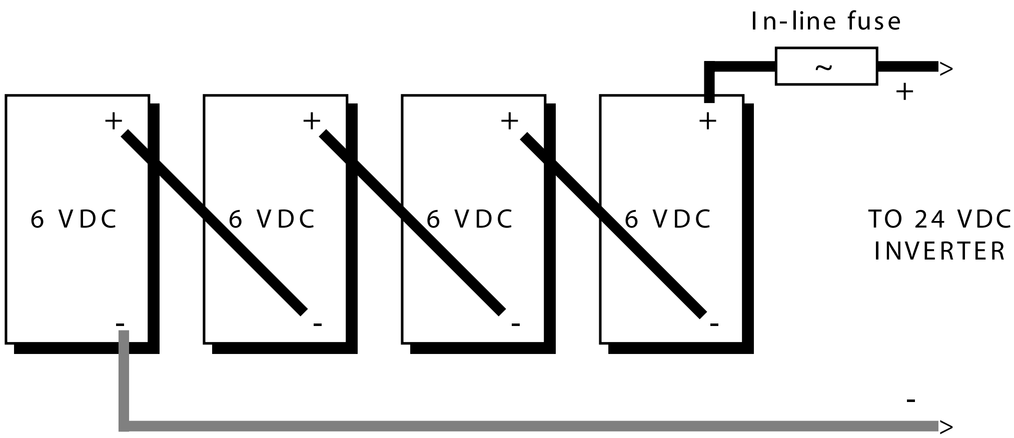

Figure 11
Series Battery Wiring - Fuse Placement

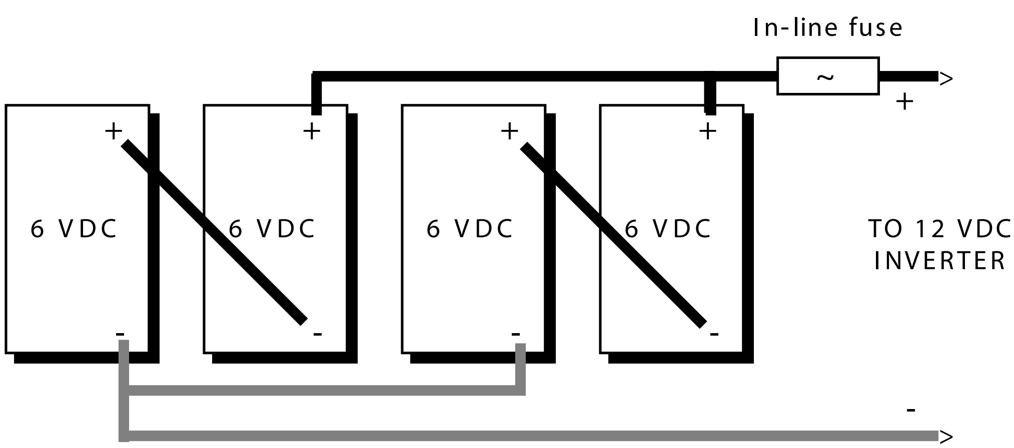

Figure 12
Series/Parallel Battery Wiring - Fuse Placement

3. Installation, continued

DC Fuse Block

A fuse or circuit breaker must be located within 18 inches of the battery to protect the DC wiring system. The device must be rated to match the size of the cable, but can be rounded up to the next larger size (i.e., a cable rated at 150 amps can accept a 175 amp fuse) as necessary.

Mount the fuse block (or circuit breaker assembly) as near as practical to the batteries.

Remove the fuse (or open the circuit breaker) and connect a short cable (same rating as the battery cables) to one end of the fuse block.

Connect the short cable to the positive battery terminal.

Connect the positive cable (RED) from the inverter to the assembly. DO NOT connect the positive cable to the inverter at this time.

Securely tighten the fuse block's lugs. Once the entire installation is complete, reinsert the fuse into the fuse block before connecting the positive cable to the inverter.

Conductor Size	#2 AWG	#2/0 AWG	#4/0 AWG
Rating (conduit)	115 A max	175 A max	250 A max
Rating (free air)	170 A max	265 A max	360 A max
Breaker	N/A	DC175	DC250
Fuse	200 A	300 A	400 A

Table 3 - DC Fuse Rating

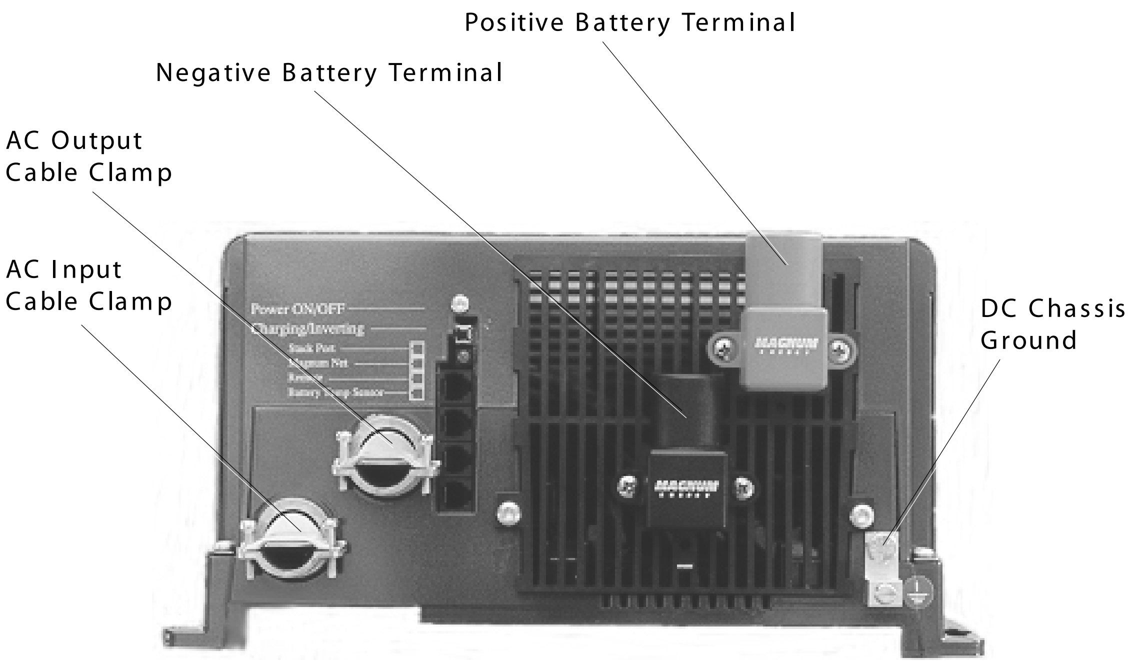

Figure 13
RD Series Inverter / Charger - AC Wiring

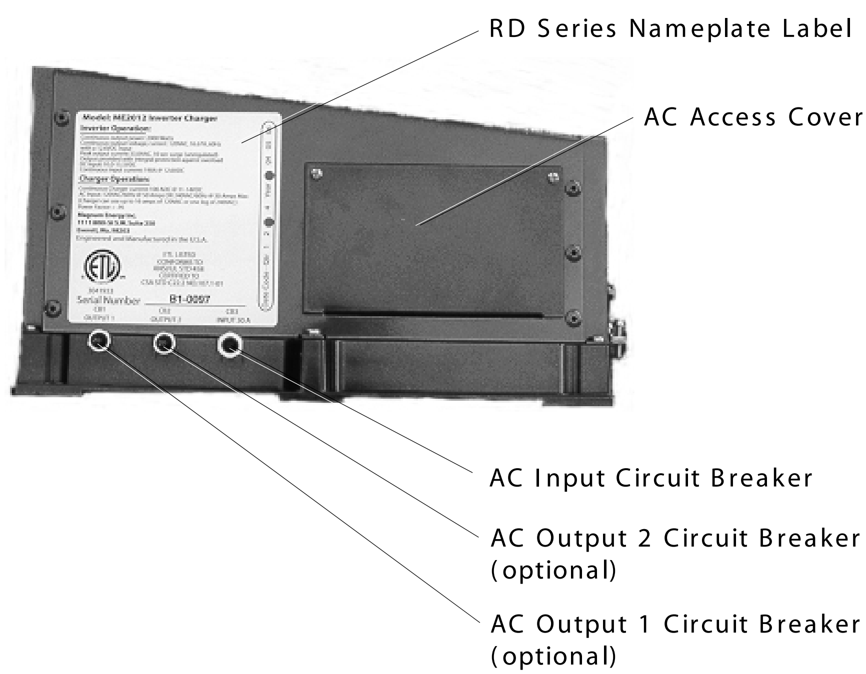

Figure 14
RD Series Inverter / Charger - AC Wiring (Access Panel)

3. Installation, continued

AC Wiring

WARNING: De-energize all sources of power including batteries (DC), grid power (AC), and AC generator (if applicable).

AC wiring must be performed by a qualified person or licensed electrician.

DO NOT connect the inverter's output to an AC power source.

WARNING: Risk of electric shock. Use only the ground-fault circuit interrupter [receptacles(s) or circuit breaker(s)] specified in the installation and operating instructions manual supplied with the inverter. Other types may fail to operate properly when connected to this inverter equipment.

Ground-fault circuit interrupters must be installed in the vehicle's wiring system to protect all branch circuits.

CAUTION: DO NOT place AC cabling in the same conduit with DC cabling.

NOTE: Read all instructions and cautionary markings located at the beginning of this manual and in the pre-installation section, before installing the inverter and batteries.

The minimum wire size for all RD Series models must be #10 AWG. The installer must provide the appropriate circuit protection for the wire size used.

Refer to appropriate electrical codes for wire sizing and circuit protection.

AC Input (Shore Power) Routing

Route a 30 amp service (grid power) to the inverter. If the installation includes a generator, route a 30 amp service (shore power) to an approved selector switch and then to the main AC panel.

AC Input (Generator) Routing

Route a 30 amp service (generator) to an approved selector switch and then to the main AC electrical panel.

Main AC Electrical Panel Routing

Route the AC Output from the inverter's internal terminal block to the 30 amp breaker in the sub panel.

Inverter	ME1512	ME2012	ME2512
Power Rating	1800 Watts	2800 Watts	4000 Watts
Input Breaker	30 A	30 A	30 A
Input Wiring	#10 AWG	#10 AWG	#10 AWG
Output Wiring	#10 AWG	#10 AWG	#10 AWG

Table 4 - Recommended AC Wire Ratings for 120 VAC Applications

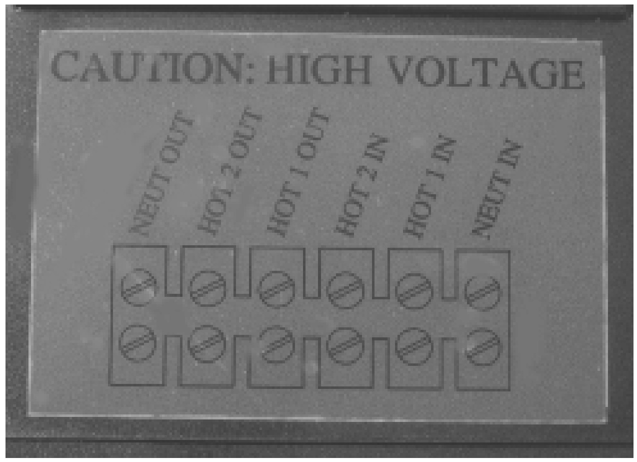

Figure 15
RD Series Inverter / Charger - AC Wiring Diagram
(located on back of cover plate)

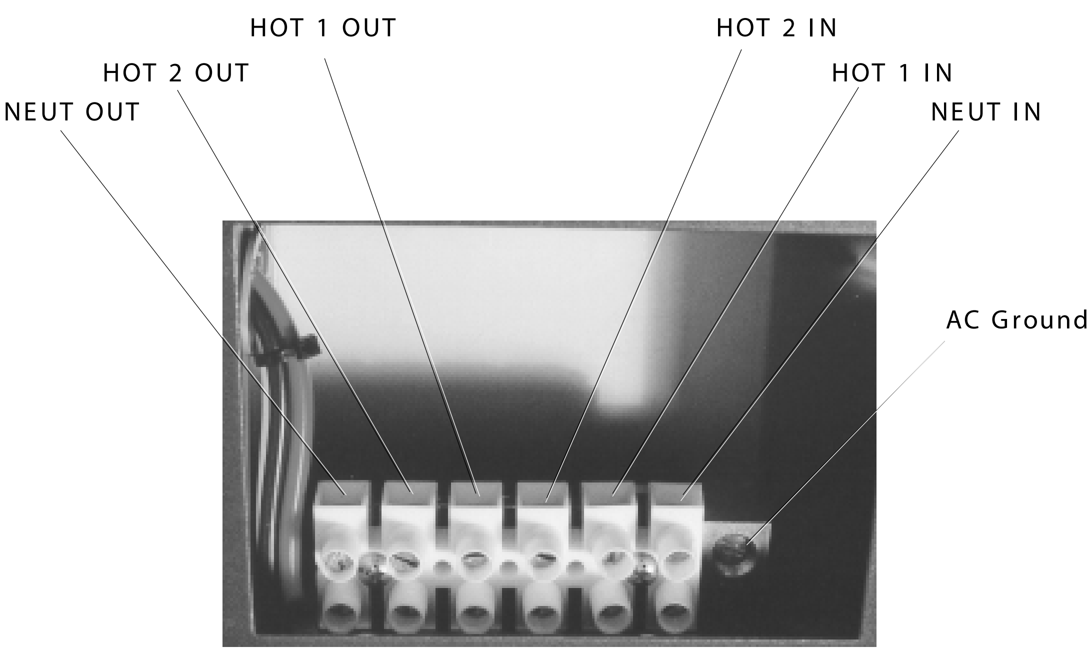

Figure 16
RD Series Inverter / Charger - AC Terminal Block

3. Installation, continued

Wiring the Inverter AC Input (refer to diagrams on the following pages)

Remove the chassis AC access cover to access the internal terminal block.

Route the cable and conduit from the main panel, approved bypass selector switch or main AC panel to the inverter's AC INPUT conduit clamp. Tighten the clamp securely on the conduit. Always leave a little extra slack in the wiring.

Connect the hot wire (BLACK) from the main panel's dedicated 30 amp breaker to the "AC INPUT (HOT 1 IN)" terminal. Tighten the screw terminal to 16 inch-pounds.

NOTE: If using dual inputs, connect the RED wire from the main panel to AC INPUT (HOT 2 IN)

Connect the neutral (WHITE) from the main panel's neutral bus bar to the "AC INPUT (NEU)" terminal. Tighten the screw terminal to 16 inch-pounds.

Connect the ground (GREEN) wire from the main panel's neutral bus bar to the "GROUND" terminal. Tighten the terminal to 16 inch-pounds.

Wiring the Inverter AC Output (refer to diagrams on the following pages)

Route the cable and conduit from the AC distribution panel to the inverter's AC OUTPUT conduit clamp. Tighten the clamp securely on the conduit.

Connect the hot (BLACK) wire to the "AC OUTPUT 1 (HOT)" terminal. Tighten the terminal to 16 inch-pounds.

NOTE: If using dual outputs, connect the RED wire to the "AC OUTPUT 2 (HOT)" terminal.

Connect the neutral (White) wire to the "AC OUTPUT (NEU)" terminal. Tighten the terminal to 16 inch-pounds.

Connect the ground (Green) wire to the "GROUND" terminal. Tighten the terminal to 16 inch-pounds.

Final Inspection

Verify all cables / conduit runs are secured with wire ties or other nonconductive fasteners to prevent chafing or damage from movement and vibration.

Verify strain reliefs or grommets are in place to prevent damage to the wiring or conduit where it passes through walls, bulkheads or other openings.

Verify all AC connections are correct and torqued to 16 inch pounds.

Replace the covers on the main electrical / distribution panel.

Replace the chassis access cover.

Verify the inverter's front panel switch is in the "OFF" position.

NOTE: If required by code, have the installation inspected by an electrical inspector.

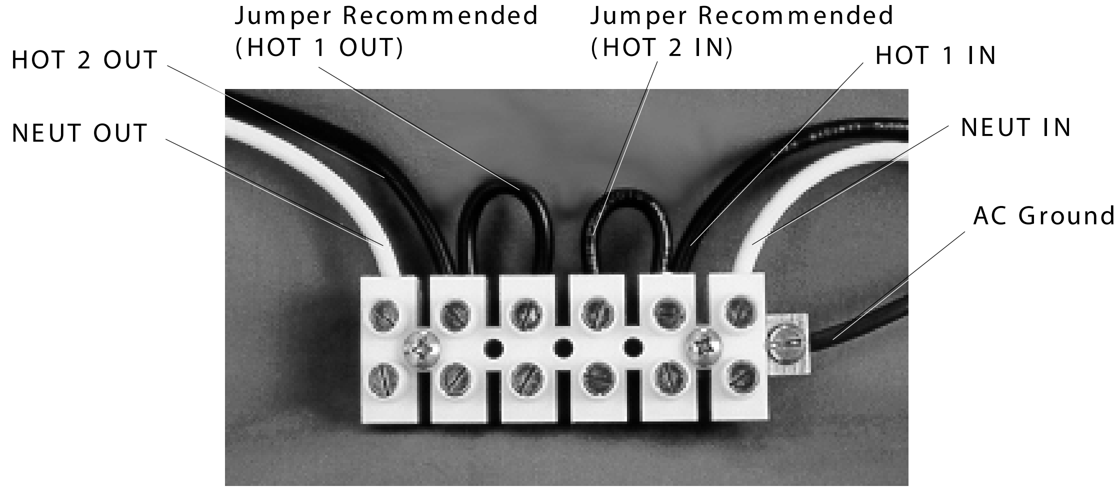

Figure 17a
Typical Wiring - Single IN / Single OUT (120 VAC)

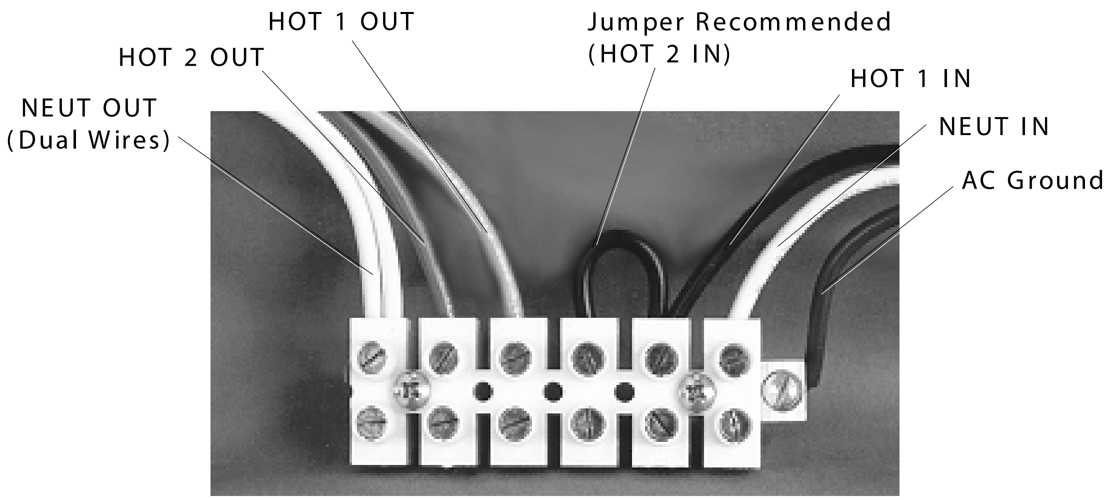

Figure 18a
Typical Wiring - Single IN / Dual OUT (120 VAC)

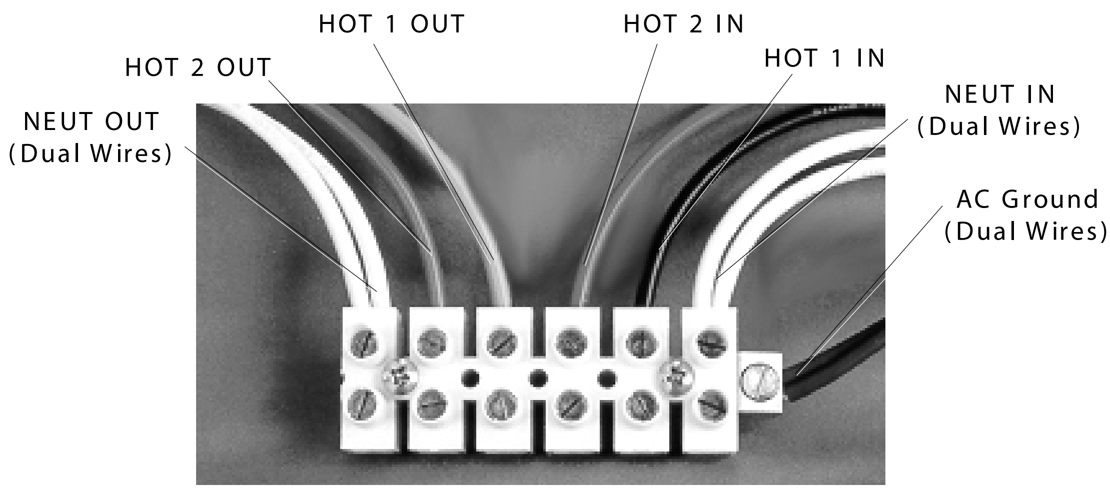

Figure 19a
Typical Wiring - Dual IN / Dual OUT (120 VAC / 240 VAC)

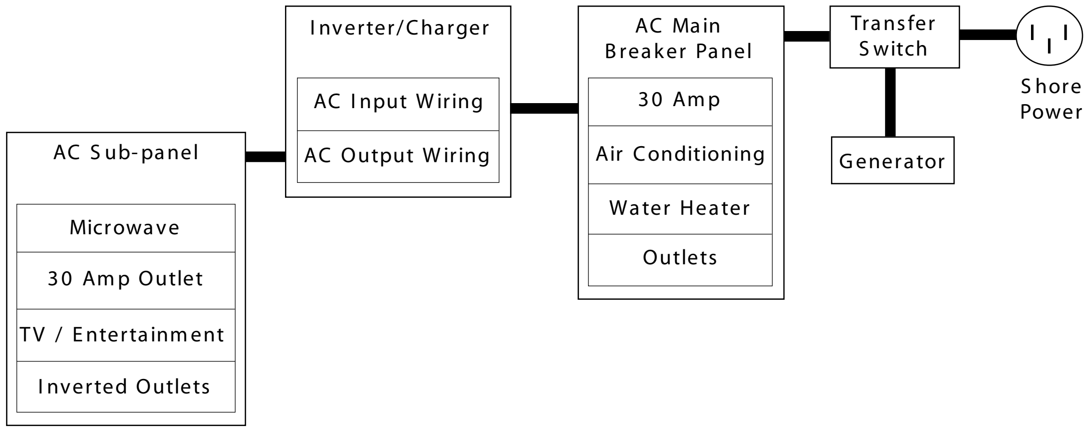

Figure 17b
Typical Wiring - Single IN / Single OUT (120 VAC)

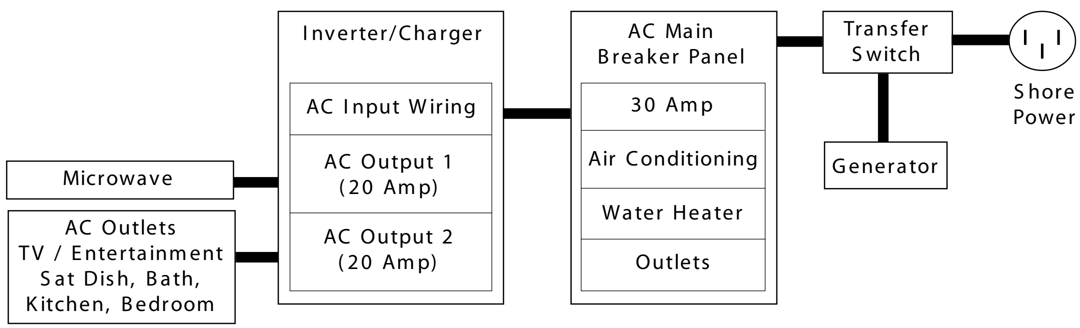

Figure 18b
Typical Wiring - Single IN / Dual OUT (120 VAC)

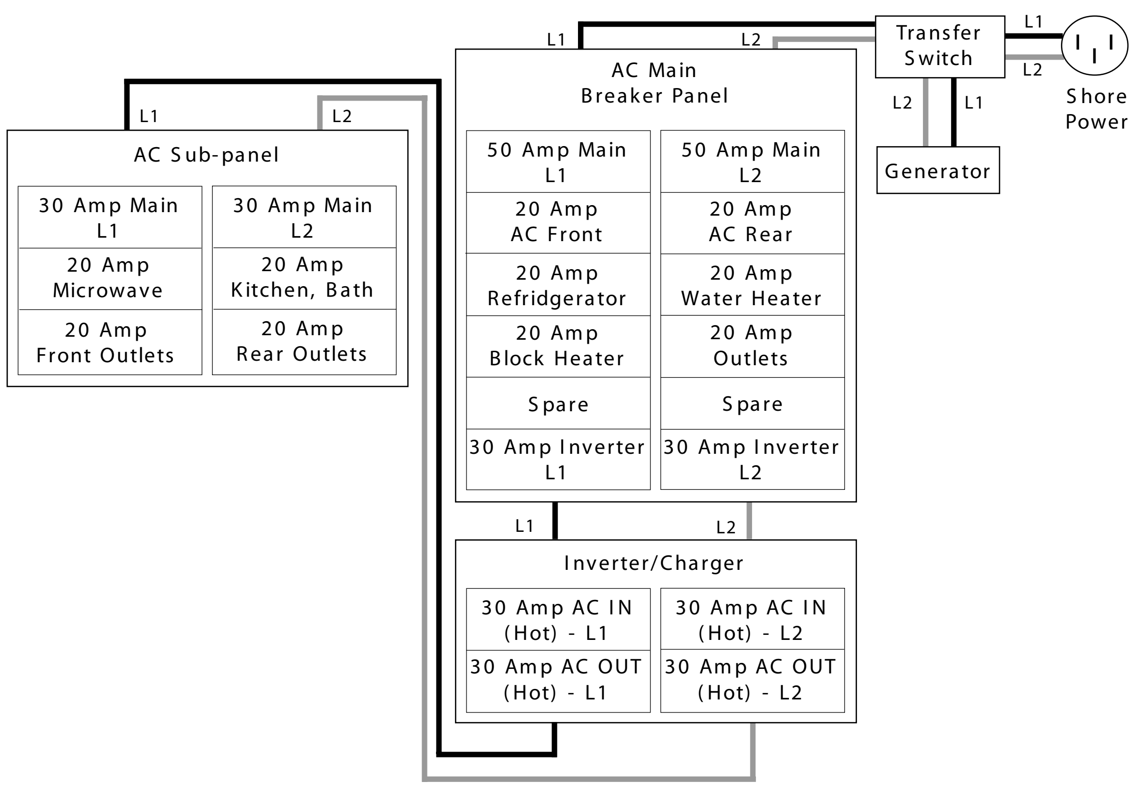

Figure 19b
Typical Wiring - Dual IN / Dual OUT (120 VAC / 240 VAC)

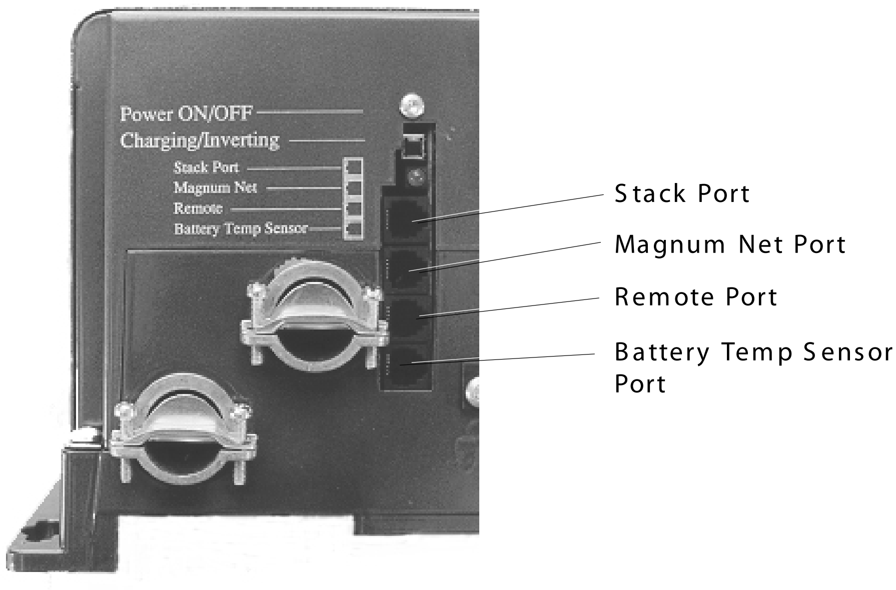

Figure 20
RD Series Inverter / Charger - Option Connection Ports

4. Options

Battery Temperature Sensor Installation and Wiring

Attach the ring terminal end of the Battery Temperature Sensor to the negative battery terminal.

Route the sensor's cable to the inverter following existing wire runs.

Connect the cable to the BTS port on the inverter's chassis.

Remote Control Installation and Wiring

Mount the remote control in a convenient location using four mounting screws (refer to the ME Series Remote Control Operator's Manual).

Route the cable to the inverter following existing wire runs.

Connect the cable to the remote port on the inverter's chassis.

AGS Module

future option - available soon

Smart Shunt

future option - available soon

Stacking Cable Kit

future option - available soon

5. Start-up and Test

Connecting the Batteries to the Inverter

After all electrical connections have been completed, connect the batteries to the inverter to begin the start-up process.

CAUTION: Verify correct battery voltage and polarity before connecting the cables to the inverter.

Replace the fuse or (close the breaker) at the DC disconnect.

Remove the electrical tape from the cable lugs and verify 12 VDC at the cable connectors using a multimeter. Verify correct polarity: Black is negative (-); Red is positive (+).

Connect the negative (BLACK) battery cable to the inverter's negative terminal. The cable lug must be flush to the terminal's surface. Place a lock washer and nut over the lug and torque the connection to 10 to 15 foot pounds.

NOTE: There may be a spark (and audible snap) when the cable lug first contacts the inverter's positive terminal. This is a normal condition.

Connect the positive (RED) battery cable to the inverter's positive terminal. The cable lug must be flush to the terminal's surface. Place a lock washer and nut over the lug and torque the connection to 10 to 15 foot pounds.

Verify all cables and connectors are properly secured.

Place the red and black terminal covers on the inverter's DC connector. Secure the covers with enclosed hardware.

If the batteries are in an enclosure, perform a final check of the hold down brackets and all connections. Close and secure the battery enclosure.

Final Inspection and Power-up

Prior to starting the inverter, make sure all connected appliances are switched OFF or disconnected from the AC receptacles.

Use a multimeter to verify 24 VDC at the inverter's DC connectors.

Switch the inverter power switch to ON. The inverter's LED will flash indicating DC power and the start-up sequence.

NOTE: When using the remote control, the inverter's ON/OFF switch is disabled in Charge mode.

Verify the breakers on the distribution panel are switched ON.

Use a true RMS multimeter to verify 120 VAC at the coach's AC outlets.

Connect the inverter to shore power and switch the main circuit breaker ON.

Verify the inverter's LED switches from INVERTER to AC IN (GRID POWER).

Use a true RMS multimeter to verify 120 VAC at each of the coach's AC outlets.

Switch the Shore Power OFF. Verify the inverter's LED switches to inverter mode.

5. Start-up and Test, continued

Configuring the Inverter

The RD Series inverter/charger must be configured for Low Battery Cutoff (LBCO), Shore Power Current, Charger Amps, Battery Size and Battery Type. These operational parameters must be configured using the optional remote control.

Refer to the ME Series Remote Control operator's manual to configure the following parameters:

Shore (5, 10, 15, 20, 30, 50)

AGS OFF

Enable

Meter DC

AC

Setup Search

LBCO

Battery Bank

Battery Type

Charge Rate

Contrast

Factory Reset

Tech Temps

Fault Record

The RD Series inverter/charger also allows you to select an equalize charge for the batteries. Press and hold the Charger ON/OFF switch for 4 seconds. The Equalize (EQ) function will be initiated (and the correct code will be sent to the remote.) The EQ function automatically terminates after 4 hours of operation. You can also manually stop the equalize mode by pressing and holding the Charger ON/OFF switch while the inverter is in EQ mode.

Function	Default
Search	5 watts
LBCO	22 VDC
Battery Bank	400 AHr
Battery Type	Liquid Lead Acid
Charge Rate	100 %
Contrast	75 %

Table 5 - Factory Default Settings

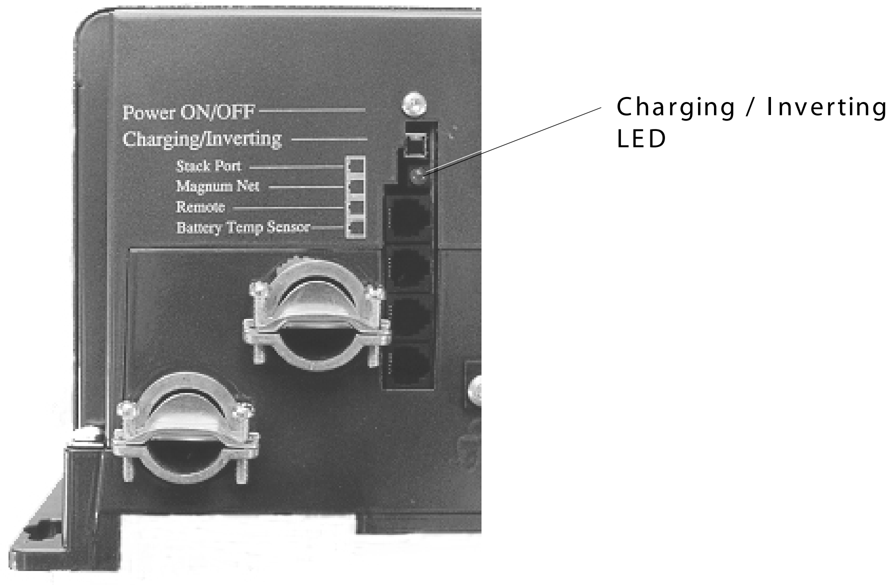

Figure 21
RD Series Inverter / Charger - LED Indicator

1. Operating the Inverter

The RD Series inverter/charger has two modes of operation: INVERTER (providing power to your appliances from the batteries) and AC (running from shore power or a generator). Whenever the inverter is in AC mode, it passes power directly to your appliances as well as recharges the batteries using a 3-stage battery charger (Bulk, Absorption and Float). This approach to battery charging provides rapid and complete charging cycles without placing undue stress on the batteries. Inverter operation is fully automatic.

Search

With search mode enabled, the inverter pulses the AC output looking for an electrical appliance (typically 5 to 100 watts, depending upon the setting you've selected). Whenever there is no load detected, the inverter automatically goes into search mode (sleep) to minimize energy consumption. During this time, the inverter's green LED flashes (fast) to indicate SEARCH mode. When an appliance is switched on inside the coach, the inverter recognizes the need for power and automatically starts the inverter

Inverter Mode

Whenever AC Shore Power is no longer sensed, the inverter automatically transfers to battery power with no interruption to your appliances. The inverter's green LED flashes once every 2 seconds (medium flash) to indicate it is running on battery power and providing AC to the coach.

AC Shore Power Mode

Whenever AC Shore Power is sensed, the inverter automatically transfers to the shore power with minimal interruption to your appliances.

Bulk Charge Mode

Whenever the inverter is running on nominal AC Shore Power, it charges the batteries. The inverter's green LED stays ON (solid) to indicate the first stage of charging. During bulk charging, the charger supplies the maximum amount of constant current to the batteries. As the battery voltage rises to a set value (typically 28.2 VDC for GEL, 28.6 VDC for AGM, and 29.2 VDC for liquid lead acid), the charger will then switch to the next charging mode.

Absorption Charge Mode

As the inverter continues to run on nominal AC Shore Power, and the batteries have been successfully bulk charged, the charger enters its second stage of charging. The inverter's green LED flashes once every second (fast flash) to indicate absorption charging for 1 - 3 hours depending upon battery bank selection (refer to the ME Series Remote manual). The charger then switches to its final charging mode.

Float Charge Mode

As AC shore power continues, the inverter's green LED flashes once every 8 seconds (slow flash) to indicate the third and final stage of charging. The batteries are held at the float voltage (typically 13.6 VDC for GEL, 26.2 VDC for AGM, and 13.4 VDC for liquid lead acid) as long as AC is present at the inverter's input. Float charging reduces battery gassing, minimizes watering requirements (for flooded batteries) and ensures the batteries are maintained at optimum capacity.

Battery Saver™ Mode

Designed to keep batteries fully charged over long periods (storage) without drying them out. Whenever the charger is in float for 4 hours with no DC loads running, the charger will turn OFF. If the battery voltage drops below 25.0 VDC, the charger will automatically initiate float mode to return them to a full charge.

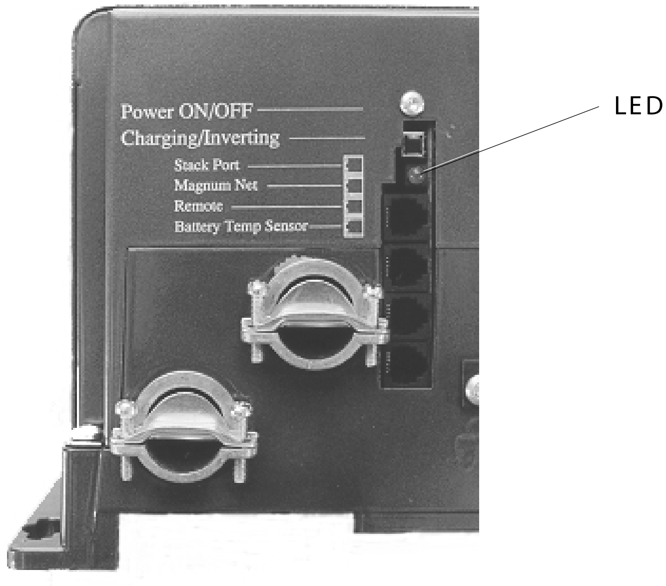

Figure 22
RD Series Inverter / Charger - Fault Conditions

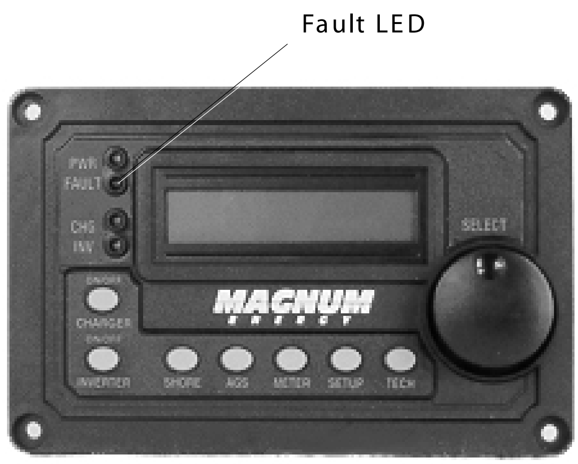

Figure 23
Optional RD Series Remote Control - Fault Conditions

1. Operating the Inverter, continued

Fault or Alarm Conditions

The inverter monitors the AC Shore Power, the batteries and itself. Whenever a condition occurs that is outside the normal operating parameters, the inverter will take the necessary steps to protect your appliances, batteries or itself from damage.

Low Battery

Whenever the battery voltage reaches a low level, the inverter will initiate Low Battery Cutoff (LBCO) which automatically shuts the inverter down, along with all connected loads, to protect the batteries from over-discharge damage. The inverter's LED turns OFF to indicate the fault condition.

High Battery

As the inverter is charging, it constantly monitors the batteries. In the event the battery voltage approaches too high of level, it automatically turns off the battery charger to protect the batteries from damage. The inverter's LED turns OFF to indicate the fault condition.

NOTE: High battery voltage may be caused by excessive voltage from the alternator, solar panels or other external charging sources.

Overload

During inverter and AC Grid Power operation, the inverter monitors the AC and DC circuits. In the event of a short-circuit or overload condition, the inverter will shut down. The inverter's LED turns OFF to indicate the fault condition.

Overtemperature

During inverter operation, if the inverter becomes overheated, it will shut down to protect itself from damage. The inverter's LED turns OFF to indicate the fault condition.

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1. Basic Troubleshooting

The ME Series inverter/ charger is a fairly simple device to troubleshoot. There are only two active circuits (AC and DC) as well as a charging circuit. The following chart is designed to help you quickly pinpoint the most common inverter failures.

WARNING: De-energize all sources of power including batteries (DC), shore power (AC), and AC generator (as applicable).

Symptom	Possible Cause	Recommended Solution
No output power. Inverter LED is OFF.	Inverter is switched OFF. Battery voltage is too low.	Switch the inverter ON. Check battery voltage, fuses, breakers and cable connections.
No output power. Inverter LED is OFF.	High or low battery voltage.	Check the battery voltage at the inverter's terminals. Discharge or charge batteries. Replace the batteries.
No output power. Green LED is flashing.	Load is too small for search mode circuit detection.	Reduce the search threshold or defeat search mode.
Low output power.	Low batteries.	Check and recharge batteries.
Appliances turn OFF/ ON. Green LED is flashing.	Loose or corroded battery cables. Low batteries. Loose AC output connections.	Clean and tighten all cables. Recharge or replace batteries. Tighten AC output connections.
AC output voltage seems too low when using a meter.	Wrong type of voltmeter used (displays 80 VAC to 100 VAC).	Use a "true" RMS voltmeter.
Low surge power.	Low batteries. Battery cables are the wrong length or gauge.	Check and recharge batteries. Verify recommended cable lengths and gauges from the manual. Replace cables as necessary.
Low charging rate when connected to grid power.	Charge rate set too low. Low AC voltage (< 90 VAC).	Adjust charge rate from remote. Check AC input wiring.
Low charging rate when using a generator.	Generator output is too low to power both load and charger.	Reduce the load. Increase the generator's RPMs.
Charger doesn't charge.	Loose or corroded battery cables. Defective batteries. Wrong charger settings. Wrong AC input voltage.	Clean and tighten battery cables. Replace batteries. Adjust the charger settings. Verify proper AC input voltage and frequency.

1. Recommended Inverter and Battery Care

The RD Series inverter/ charger is designed to provide you with years of trouble-free service. Even though there are no user-serviceable parts, it is recommended that every 6 months you perform the following maintenance steps to ensure optimum performance and extend the life of your batteries.

WARNING: Prior to performing these checks, switch both the AC and DC circuits OFF.

Visually inspect the batteries for cracks, leaks, or swelling - replace if necessary

Use baking soda to clean and remove any electrolyte spills or buildups

Check and tighten all battery hold down clamps

Clean and tighten (10 to 12 foot pounds) all battery terminals and connecting cables

Check and fill battery water levels (Liquid Lead Acid batteries only)

Check individual battery voltages (replace those that vary more than 0.3 VDC of each other)

Check all cable runs for signs of chafing - replace if necessary

Check the inverter's cooling vents - clean as necessary

Check and tighten (16 foot pounds) the inverter's internal AC terminal block connections

2. Off-Season Storage

When placing the coach into seasonal storage, it is recommended that you perform the following to ensure the system is properly shutdown (or properly configured for seasonal storage). This is especially important for maintaining the batteries.

Non-protected Storage

Perform the recommended maintenance steps above
Fully charge the batteries
Connect shore power and verify the breaker to the inverter is switched ON
Verify the inverter is switched ON
Switch OFF all unnecessary AC and DC loads

Protected Storage

Perform the recommended maintenance steps above
Fully charge the batteries
Switch OFF all AC and DC loads
Verify the inverter is switched OFF
Remove shore power and disable the generator (if installed)

RD Series Specifications

MODEL	RD1824	RD2824	RD4024
Input Voltage (nominal):	24 VDC	24 VDC	24 VDC
Input Voltage (range):	21.6-31.0 VDC	21.6-31.0 VDC	21.6-31.0 VDC
Power Rating @ 45°C:	1800 watts	2800 watts	4000 watts
Surge Rating:	3600 watts	5200 watts	8000 watts
Rated Power:	95 amps	142 amps	189 amps
Full Voltage:	0.750 amps	0.850 amps	0.900 amps
Search Mode:	0.025 amps	0.030 amps	0.030 amps
Short Circuit:	285 amps	475 amps	595 amps
Inverter Efficiency:	94% max	94% max	94% max
Charger Efficiency:	85% max	85% max	85% max
Charger (power factor):	> 0.95	> 0.95	> 0.95
Charge Rate (adjustable):	0-65 amps	0-80 amps	0-120 amps
Battery Protection (variable):	10-11.5 VDC	10-11.5 VDC	10-11.5 VDC
Unit Weight:	38lb (17kg)	40lb (18kg)	45lb (20kg)

Common Specifications

Output Voltage:	120 VAC	Frequency Regulation:	60 Hz ± .04%
Voltage Regulation (max):	±5%	Voltage Regulation (typ):	±2.5%
Waveform:	modified sine	Power Factor:	0 to 1
Adjustable Load Sensing:	5 to 100 watts	Automatic Transfer Relay:	30 amps at 120 VAC
Remote Control:	optional		50 amps at 240 VAC
Charging Profiles:	liquid lead acid, AGM, and GEL	Four Stage Charging:	bulk, absorb, float and Battery Saver™
Forced Air Cooling:	variable speed fan	Temp Comp Probe:	yes (optional)
DC Load Disconnect Sensing:	on/off (high/low DC signal)	Remote Dry Contact:	optional pigtail (inverter on/off)
Series Operation:	240 VAC (future)		

Environmental Characteristics

Operating Ambient Temp:	-4 °F to +120 °F (-20 °C to +50 °C)
Max Altitude (operating):	15,000 feet (4.57 km)
Dimensions (HxWxD):	13.75″ x 12.65″ x 8″ (34.9 cm x 32.1 cm x 20.3 cm)
Mounting:	shelf (top or bottom up) or bulkhead

Specifications @ 25 °C - Subject to change without notice

24 Month Limited Warranty

Magnum Energy, Inc., warrants the RD Series Inverter / Charger to be free from defects in material and workmanship that result in product failure during normal usage, according to the following terms and conditions:

1. The limited warranty for the product extends for 24 months beginning from the product's original date of purchase.

2. The limited warranty extends to the original purchaser of the product and is not assignable or transferable to any subsequent purchaser.

3. During the limited warranty period, Magnum Energy will repair, or replace at Magnum Energy's option, any defective parts, or any parts that will not properly operate for their intended use with factory new or rebuilt replacement items if such repair or replacement is needed because of product malfunction or failure during normal usage. The limited warranty does not cover defects in appearance, cosmetic, decorative or structural parts or any non-operative parts. Magnum Energy's limit of liability under the limited warranty shall be the actual cash value of the product at the time the original purchaser returns the product for repair, determined by the price paid by the original purchaser. Magnum Energy shall not be liable for any other losses or damages.

4. Upon request from Magnum Energy, the original purchaser must prove the product's original date of purchase by a dated bill of sale, itemized receipt.

5. The original purchaser shall return the product prepaid to Magnum Energy in Everett, WA. Magnum Energy will return the product prepaid to the original purchaser after the completion of service under this limited warranty.

6. This limited warranty is voided if:
   - the product has been modified without authorization
   - the serial number has been altered or removed
   - the product has been damaged through abuse, neglect, accident, high voltage or corrosion.
   - the product was not installed and operated according to the owner's manual.

IN CASE OF WARRANTY FAILURE, CONTACT MAGNUM ENERGY INC. FOR A RETURN AUTHORIZATION (RA) NUMBER BEFORE RETURNING THE UNIT FOR REPAIR.

MAGNUM
ENERGY
1111 80th Street SW - Suite 250
Everett, WA 98203
p: 425.353.8833
f: 425.353.8390

MAGNUM ENERGY

1111 80th Street SW - Suite 250
Everett, WA 98203
p: 425.353.8833
f: 425.353-8390

p/n 64-0003 rev. 2 9/03

MAGNUM
ENERGY

ME-RC
Remote Control

Owner's Manual
(for revision 1.6 or higher)

Disclaimer of Liability

Since the use of this manual and the conditions or methods of installation, operation, use and maintenance of the ME-RC are beyond the control of Magnum Energy Inc., this company does not assume responsibility and expressly disclaims liability for loss, damage or expense, whether direct, indirect, consequential or incidental, arising out of or anyway connected with such installation, operation, use, or maintenance.

Due to continuous improvements and product updates, the images shown in this manual may not exactly match the unit purchased.

Restrictions on Use

The ME-RC remote shall not be used in connection with life support systems, life saving or other medical equipment or devices. Using the ME-RC with this particular equipment is at your own risk.

Important Product Safety Instructions

This manual contains important safety instructions that must be followed during the installation and operation of this product. Read all instructions and safety information contained in this manual before installing or using this product.

- All electrical work must be performed in accordance with local, state and federal electrical codes.
- This product is designed for indoor / compartment installation. It must not be exposed to rain, snow, moisture or liquids of any type.
- Use insulated tools to reduce the chance of electrical shock or accidental short circuits.
- Remove all jewelry such as rings, watches, bracelets, etc., when installing or performing maintenance on the inverter.
- Always disconnect the batteries or energy source prior to installing or performing maintenance on the inverter. Live power may be present at more than one point since an inverter utilizes both batteries and AC. Turning off the inverter may not reduce this risk. As long as AC power is connected, it will pass thru the inverter regardless of the power switch on the inverter or the ON/OFF INVERTER pushbutton on the remote.

Safety Symbols

To reduce the risk of electrical shock, fire, or other safety hazard, the following safety symbols have been placed throughout this manual to indicate dangerous and important safety instructions.

Warning: This symbol indicates that failure to take a specified action could result in physical harm to the user.

Caution: This symbol indicates that failure to take a specified action could result in damage to the equipment.

Info: This symbol indicates information that emphasizes or supplements important points of the main text.

Remedy: This symbol provides possible solutions for related issues.

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1.0 Overview

The ME-RC remote control allows you to monitor and customize the operating parameters to your Magnum inverter/charger. It is the same remote used on all Magnum inverter/charger models in the ME, MM, MS, and the RD Series lines so there is no cross-platform confusion.

The ME-RC50 comes standard with a 50 foot, 4-conductor (twisted-pair) telephone cable and includes non-volatile memory; which preserves adjustable settings, even if power to the remote or inverter is removed. The Magnum remote control has all of the programming and operation functions included in an easy-to-use package.

This manual is for the ME-RC with revision 1.6 or higher; see the *TECH: 02 Revisions* display on page 16 for information on how to determine your revision level.

Figure 1-1, Front Panel Features

The ME-RC is equipped with the following features:

- **LED Indicators -** The at-a-glance LEDs provide the inverter/charger status in a straightforward way.
- **LCD Display -** The LCD display is a 16 x 2 line (32 characters total), alphanumeric display, used for setting up the inverter/charger operation as well as viewing current status or fault messages.
- **ON/OFF Pushbuttons (x2) -** Allows the inverter or charger to be independently and quickly enabled or disabled.
- **Menu Pushbuttons (x5) -** The menu pushbuttons allow the inverter or charger to be configured to your specific system preferences. These menus also allow simple access to menu items that can help with monitoring and troubleshooting your inverter/charger system.
- **Rotary Knob -** The rotary encoder knob is similar to a dash radio knob and used to quickly scroll through and select various menu items and settings. Push the rotary knob to “SELECT” a menu item or to “save” a setting once it is displayed on the LCD screen.

2.0 Installation

Before installing the remote, read the entire installation section to determine how you are going to install your ME-RC. The more thorough you plan in the beginning, the better your inverter needs will be met.

Info: Installations should be performed by qualified personnel, such as a licensed or certified electrician. It is the installer's responsibility to determine which safety codes apply and to ensure that all applicable installation requirements are followed. Applicable installation codes vary depending on the specific location and application.

Info: Review the "Important Product Safety Information" on the front inside cover page before any installation.

2.1 Installation Guidelines

• Before connecting any wires, determine the remote cable route throughout the home or vehicle/boat both to and from the inverter.

• Always check for existing electrical, plumbing or other areas of potential damage BEFORE drilling or cutting into walls to mount the remote.

• Make sure all wires have a smooth bend radius and do not become kinked.

• If installing this remote in an boat, RV or truck; ensure the conductors passing through walls, bulkheads or other structural members are protected to minimize insulation damage such as chafing, which can be caused by vibration or constant rubbing.

2.2 Tools Required

Installing the remote control is a simple process and requires the following tools:

- Phillips screwdriver
- Cut-out tool (knife/saw)
- Level
- Pencil
- Drill
- Drill Bit (7/64")

2.3 Installation Procedure

1. Select an appropriate location to install the remote control. Allow ample room to access the remote's adjustment dial and to view the LEDs. Ensure the viewing angle of the display is appropriate.

2. Refer to figure 2-1 for hole and cutout dimensions.

3. Run the remote cable between the remote and the inverter/charger. This cable is a 4-wire, twisted-pair, telephony standard with RJ11 connectors on each end. A standard telephone cable may be substituted if the provided remote cable is not able to be used.

4. Connect the remote cable into the RJ11 "Remote" port (has dark blue label) on the inverter/charger (see figure 2-2).

5. Have the inverter connected to batteries, but ensure the inverter is off and that no AC power is connected to the inverter.

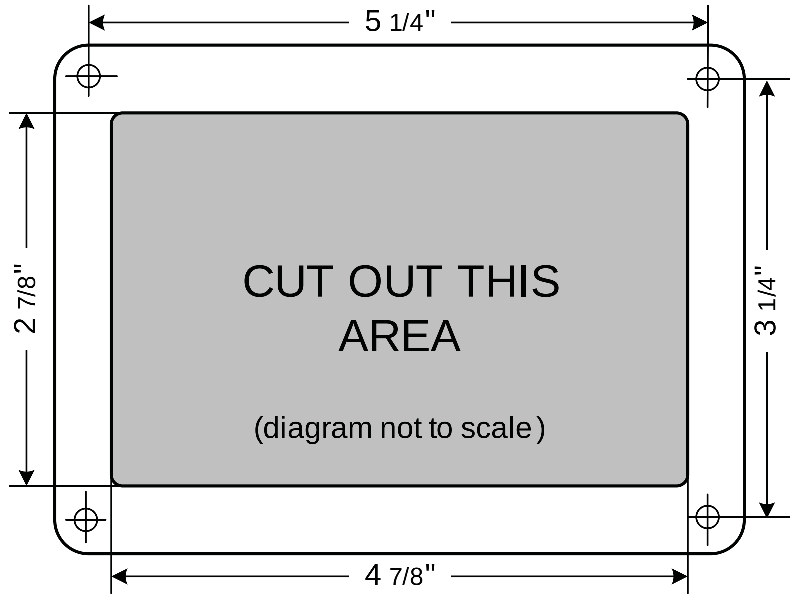


Figure 2-1, Remote Cut-Out Dimensions

Info: All power to operate the remote control is provided by the inverter/charger through the remote cable.

6. While monitoring the front of the remote, connect the other end of the cable into the RJ11 jack on the back-side of the remote (see figure 2-2).

7. Immediately upon connecting the remote cable, all the LED's will come on as the unit goes through a self-test. After the initial self-test completes, text should appear with a system status message indicating the current state of the inverter/charger. If not, please refer to the troubleshooting section.

8. Secure the remote to the wall using the four 6 x 3/4" screws provided.

9. The remote is ready for set-up.

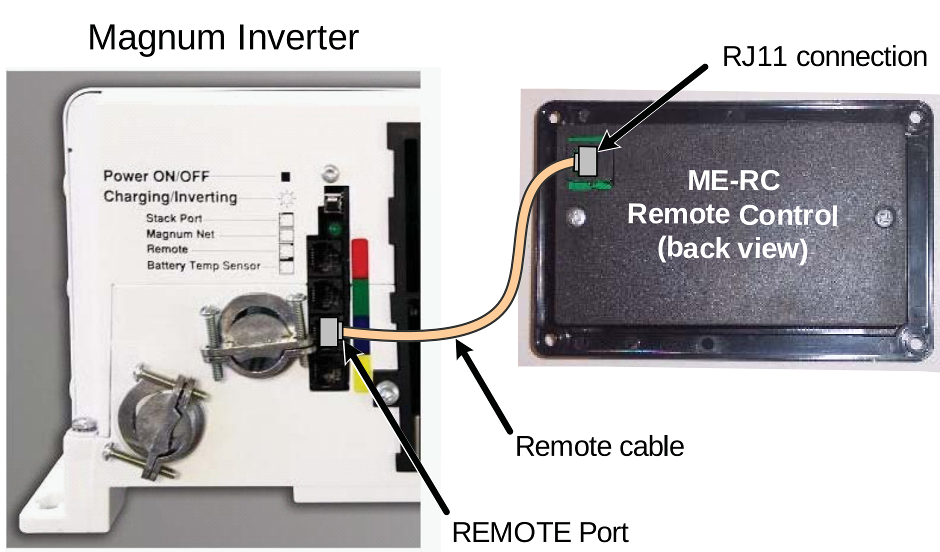


Figure 2-2, Remote Control Connections

3.0 Setup

When the remote is connected to a Magnum inverter/charger, the settings in the remote control determine the inverter/charger operating parameters. The default settings in the remote control (see Table 3-4, Inverter/Charger Default Settings) are adequate for most installations, however you have the option to change some of the operating parameters if required. This section will show you how to navigate the remote, give you an understanding of the function of each adjustable setting and help you decide what setting should be used.

3.1 Navigating the Remote's Menu

The ME-RC has an internal structure that provides menu items and adjustable settings that provide the ability to configure your inverter/charger to your specific parameters.

Info: See figure *4-1, Inverter/Charger Menu Map* for a complete map of the inverter/charger menu items and adjustable settings.

Familiarize yourself with the items on the front panel which are used to find, adjust and save the desired setting. They are:

- **LCD Display -** The bottom line of the LCD display shows the menu items, adjustable settings or the meters display information.

Info: The bottom line of the LCD display returns to the Home Screen to show DC voltage and current (see *Figure 3-1*) after 2 minutes - if no buttons have been pressed.

- **Menu Pushbuttons (x5) -** These five menus allow simple access to the menu items that can help with configuring, monitoring and troubleshooting your inverter/charger system.
- **Rotary SELECT Knob -** This knob allows you to quickly scroll through and select various menu items and settings after pressing a menu pushbutton. This knob also is used to "save" a setting once it is displayed on the LCD screen.

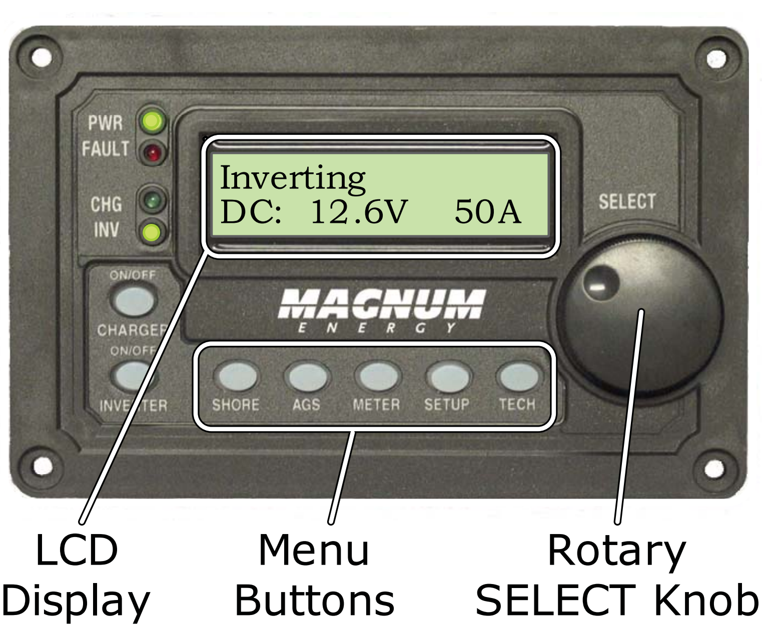
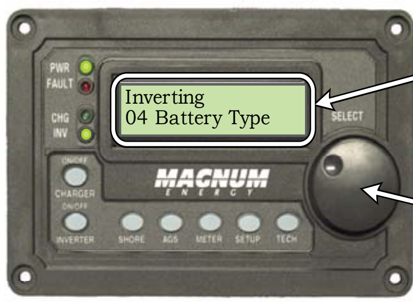


Figure 3-1, Front Panel Set-up Features

1. Press the SETUP Menu button.

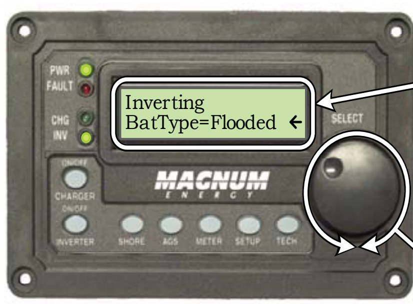
Bottom line shows a menu item.

2. Turn the SELECT knob to the desired menu item.



When the bottom line shows the desired menu item -

3. Press the SELECT knob.



Bottom line shows current setting* (indicated by a ←).

*[if this setting is correct, press the SELECT knob to continue to the next menu item].

4. Turn the SELECT knob to the desired setting.

When the bottom line shows the desired setting -

5. Press the SELECT knob to "save" this desired setting.

Figure 3-2, SETUP Menu Navigation

3.2 Menu Pushbuttons and Menu Items

The five menu pushbuttons (**SHORE**, **AGS**, **METER**, **SETUP** or **TECH**) allow the inverter/charger system to be configured to your specific preferences. These menus also allow you to access menu items that can help with monitoring and troubleshooting your system.

Read this section to help understand the function of each Menu pushbutton and the configurable settings - to determine if they should be changed to optimize the operation of the inverter/charger.

3.2.1 SHORE Menu

This menu pushbutton gives a quick means of changing your Shore Max setting to coordinate with the circuit breaker rating from the incoming AC source.

- **SHORE: Shore Max** - This selection ensures the inverter AC loads receive the maximum current available from the utility or generator power. Whenever the utility or generator is connected to the inverter (thru AC HOT 1), the current used to power the AC loads and to charge the batteries is monitored. When the total current used to power the AC loads and charge the batteries begins to approach the *Shore Max* setting, the current that was used for charging the batteries will automatically be reduced. This ensures the AC loads have all the available current when needed.

Default setting: Shore Max = 30A

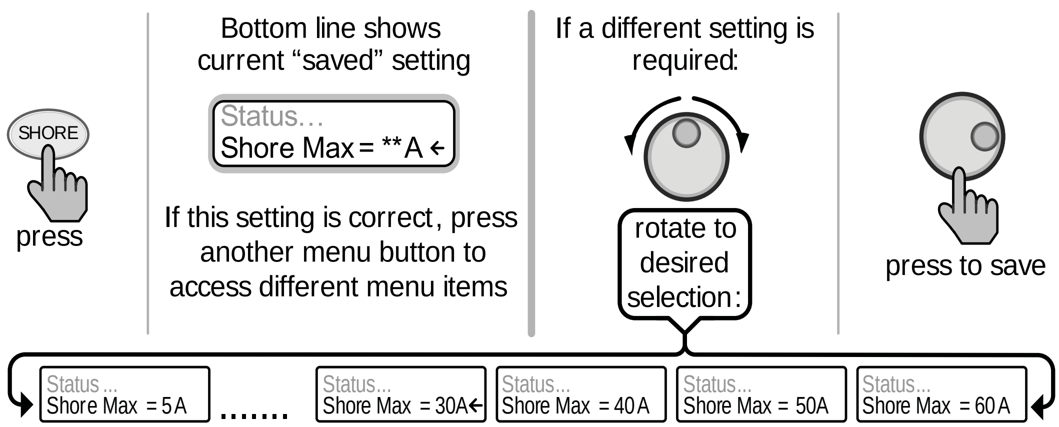


Figure 3-3, SHORE: Shore Max Selections

Where to set: Set the *Shore Max* setting to match the current rating of the utility power or generator's circuit breaker. If using multiple AC sources (utility and generator) through an AC transfer switch, adjust this setting to the smaller AC breaker size. This setting is very dependent on the stability of the AC source. If using a generator, factors such as altitude and output voltage regulation may require a lower setting than the generator's breaker size. For best performance, lower this setting to 1/3 its rated capacity and gradually increase while ensuring the voltage level stays above the *SETUP: 06 VAC Dropout* setting.

Caution: The Shore Max setting does not limit the current to the inverter loads. If the current from the loads on the output of the inverter are greater than the circuit breaker rating on the incoming AC source, you may experience nuisance tripping on this breaker.

3.2.2 AGS Menu

The AGS menu pushbutton allows the optional Auto Generator Start (AGS) controller (if installed and networked) to be configured to your specific system preferences and check status of the AGS.

Refer to the ***ME-AGS Owner's Manual*** (part number: 64-0005) for detailed information on the Magnum Energy Auto Generator Start (ME-AGS) and this menu.

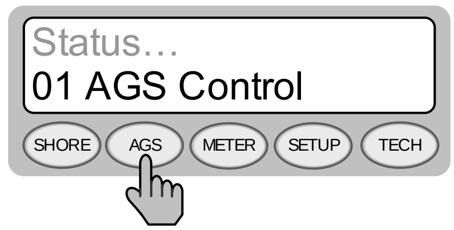


Figure 3-4, AGS Menu Display

3.2.3 METER Menu

Pressing the METER menu pushbutton gives you access to different meters, which helps determine the status of the inverter/charger and battery system.

- **METER: 01 INV/CHG Meter** - This menu provides the DC voltage and current while either inverting or charging.

The DC: V (Volts) display provides the voltage from the batteries connected to the inverter. The DC: V accuracy is ±1.5% with a 0.1 VDC resolution.

While inverting, the DC: A (Amps) display shows the battery current used by the inverter. If you are charging, the DC A (amps) display shows the amount of current delivered to the batteries. The accuracy of this display below 1 amp AC (~10 amps DC @ 12VDC) is not detected. When the current into or out of the batteries is greater than 1 amp AC, the display accuracy is ±20%.

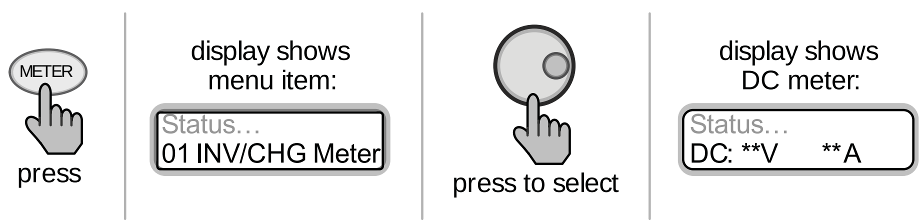


Figure 3-5, METER: 01 INV/CHG Meter Display

- **METER: 02 Battery Meter** - This menu allows the optional Battery Monitor (if installed) to be configured to your specific system preferences and display the status of the battery system; refer to the ***ME-BMK Owner's Manual*** (part number 64-0013) for detailed information on the Magnum Energy Battery Monitor Kit (ME-BMK) and this menu.

3.2.4 SETUP Menu

Pressing the SETUP menu pushbutton provides access to the menu items and settings that allow the inverter/charger to be configured. Read each menu item to determine if any setting requires adjustment to meet your requirements.

- **SETUP: 01 Search Watts** - Allows you to turn off the Search Watts feature or adjust the power level to determine when the search watts feature becomes active. The power level range selection is 5W to 50W. If this feature is not needed, select *Search=Off*. When search is turned off, the inverter continuously provides full AC voltage to the loads.

Default setting: *Search= 5W.*

Info: When the Search Watts feature is active, "Searching" appears on the top line of the LCD display and the green 'INV' LED will slowly flash.

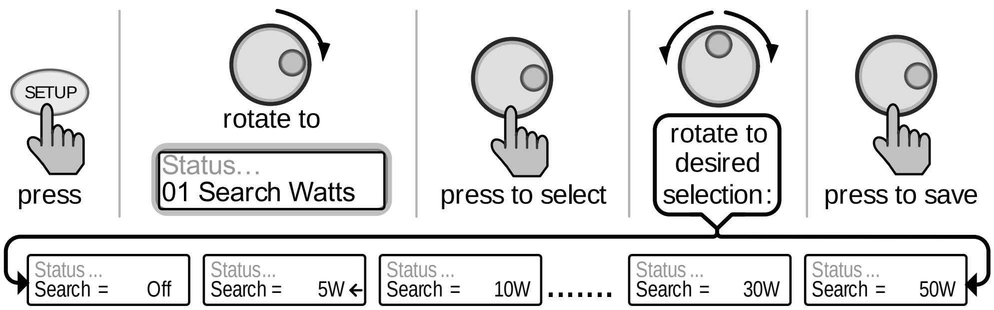


Figure 3-6, SETUP: 01 Search Watts Selections

What is the "Search Watts" feature? This feature is used to help save battery power by reducing the inverter's output to search pulses when there is no detectable load. If someone turns on a load greater than the wattage level setting while the inverter is "searching", the inverter will start "inverting" to provide full voltage on its output.

Should I use the "Search Watts" feature? If the inverter can spend a great deal of time "searching" (to reduce the power drain on your batteries) and you can tolerate small loads (less than 5 watts) from being on, then the search mode feature should be used. However, if you require some small load (digital clocks, satellite receivers, answering machines, etc.) to always be on, then this feature should be turned off (*Search = Off*).

I want to use the Search Watts feature, how do I determine where to set it? The search watts setting should be adjusted to the same power level (or the next lower setting) of the smallest load that you want to run. If you don't know the wattage of the smallest load you want to run, turn the load on and decrease the *Search Watts* setting until the load comes on and stays on.

Example: You have reviewed all the loads you want to run and determined that the smallest load is a 30 watt light, then set the *Search = 30W.* Whenever you turn on any load (because all the loads are greater than 30 watts), the inverter will stop "searching" and start "inverting" to deliver power to the load.

Note: Even though the search feature is on, some connected equipment may draw enough current even while in the "off" position to keep the inverter in the "inverting mode".

- **SETUP: 02 LowBattCutOut -** The Low Battery Cut-Out (LBCO) setting is used to set the DC voltage level that turns off the inverter to help protect the batteries from over-discharge damage. Selections are from 9.0 VDC to 12.2 VDC (12-volt inverter models), 18.0 VDC to 24.4 VDC (24-volt inverter models), or 36.0 to 48.8 (48-volt inverter models). If the battery voltage drops below the LBCO selected set-point continuously for more than 1 minute, the fault LED will come on, the inverter will turn off, and the display will show a 'Low Battery' status. If the battery voltage falls below 8.5 volts (12-volt models), 17.0 volts (24-volt models), or 34.0 (48-volt models); the fault LED and 'Low Battery' status will be immediate.

Default settings: LBCO = 10.0 VDC (12-volt models), 20.0 VDC (24-volt models) or 40.0 VDC (48-volt models).

Info: The inverter will automatically begin to start inverting when the DC voltage increases to ≥ 12.5 VDC (12-volt models), ≥ 25.0 VDC (24-volt models) or ≥ 50.0 VDC (48-volt models). If AC power is available and connected to the inverter's input, the inverter will automatically clear the 'Low Battery' fault, pass the input AC power to the output and begin charging the batteries.

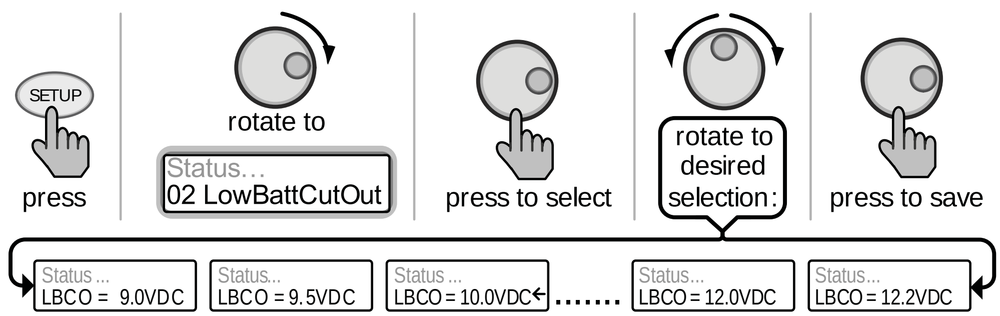


Figure 3-7, SETUP: 02 LowBattCutOut Selections (12-volt shown)

Where do I set the LBCO setting? If you want to cycle the batteries slightly - but don't want to discharge them more than 20%*, then the LBCO setting should be set from 11.5 to 12.2 VDC (12-volt models), 23.0 to 24.4 VDC (24-volt models) or 46.0 to 48.8 (48-volt models). In some applications, such as installed in an off-grid home or doing a lot of dry-camping in your RV, you may want to cycle down to 50%* by setting the LBCO from 10.0 to 11.4 VDC (12-volt models), 20.0 to 22.8 VDC (24-volt models) or 40.0 to 45.6 VDC (48-volt models). In extreme circumstances, you have the ability to discharge the batteries to 80%* by setting the LBCO to 9.0 or 9.5 VDC (12-volt models), 18.0 or 19.0 VDC (24-volt models), or 36.0 or 38.0 VDC (48-volt models) before recharging.

* These discharge percentage are rough estimates; for accurate battery monitoring, a battery monitor such as Magnum's ME-BMK is required.

Info: The higher the LBCO setting, the less the inverter will discharge the batteries; which should allow the batteries to have a longer life. The downside to a higher LBCO setting is that you need to charge more often to prevent the inverter from shutting down.

Info: If there is an ME-AGS installed, the *AGS: 04 Start Volts* setting should be ≥1.0 volts higher than the LBCO setting – this is to prevent the inverter from shutting down before the generator comes on.

- **SETUP: 03 Batt AmpHrs** - Used to select the approximate capacity of the battery bank connected to the inverter. This setting determines the time the battery charger is in the Absorb Charging stage (i.e. Absorption Time). See Table 3-1 to correlate the battery capacity to the Absorption Time; selections are in 200 AmpHrs increments from 200 - 1600 AmpHrs.

Default setting: Batt AmpHrs= 400

Table 3-1, Battery AmpHrs to Absorb Charging Time

Battery AmpHrs	Absorb Charging Time
Batt AmpHrs = 200	60 minutes
Batt AmpHrs = 400	90 minutes
Batt AmpHrs = 600	120 minutes
Batt AmpHrs = 800	150 minutes
Batt AmpHrs = 1000	180 minutes
Batt AmpHrs = 1200*	210 minutes
Batt AmpHrs = 1400*	240 minutes
Batt AmpHrs = 1600*	270 minutes

* these settings are active only on newer inverter revisions.

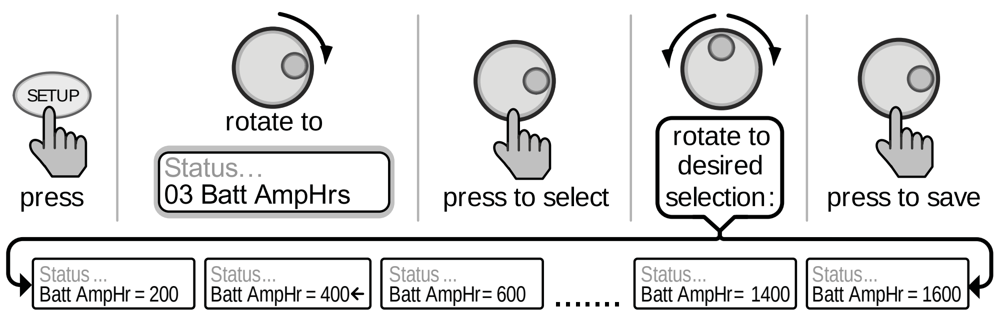


Figure 3-8, SETUP: 03 Batt Amphrs Selections

Where do I set the Battery Amp-Hour setting? Select the same setting or the next highest setting based on the 20-hour Amp-Hour (AH) capacity of your battery bank.

How do I determine my Battery Amp-Hour capacity? The inverter requires deep cycle batteries, which are specifically made for continuous use. Deep cycle batteries are rated either by a) amp-hours or b) reserve capacity in minutes.

a) Amp-hour (AH) capacity is a measurement of how many amps a battery can deliver for a specified length of time (usually 20 hours) until the voltage achieves 1.75 VDC / cell at 80°F (typically 10.5 vdc for a 12-volt battery).

b) Reserve Capacity (RC) is a measure of how many minutes a battery can deliver a certain amount of current (usually 25 amps) and maintain a voltage above 1.75 VDC/cell at 80°F. If using the 25 amps rate, the 20-hour Amp-Hour (AH) capacity can be estimated by multiplying "minutes reserve capacity" by 50%.

Table 3-2 below provides an estimated 20-hour Amp-Hour capacity based on the group/code size, physical size and voltage of the battery. If you are not sure of your battery's 20-hour AH rating, consult your battery manufacturer/ dealer or use the table below to obtain an estimate.

Table 3-2, Battery Size to Battery Amp-Hours (estimated)

Group / Code Size	Physical Size (L" x W" X H")	Battery Voltage	Battery AHrs (20-hour rate)
GC-2 (Golf Cart)	10 3/8 x 7 13/16 x 10 5/8	6V	220 AmpHrs
L16	11 11/16 x 7 x 16 11/16	6V	375 AmpHrs
Group 22	9 1/2 x 6 7/8 x 8 5/16	12V	55 AmpHrs
Group 24	10 1/4 x 6 13/16 x 8 7/8	12V	70 AmpHrs
Group 27	12 1/16 x 6 13/16 x 8 7/8	12V	95 AmpHrs
Group 31	13 x 6 13/18 x 9 7/16	12V	110 AmpHrs
4D	20 3/4 x 8 3/4 x 9 7/8	12V	200 AmpHrs
8D	20 3/4 x 11 1/8 x 9 7/8	12V	250 AmpHrs

Once you've determined the Amp-hour capacity of each battery, review how your batteries are connected (parallel or series) to determine the total amp-hour capacity of the battery bank:

Parallel connection – batteries connected in parallel (positive to positive, negative to negative) increase the amp-hour capacity of the battery bank, but the voltage remains the same.

For example: You have a 12-volt battery bank with three 12-volt batteries that are rated at 125 Amp-Hours (AH) each. Each of the positive terminals are connected together and each of the negative terminals are connected together, which means they are connected in parallel. The amp-hours of each battery connected in parallel are added together (125 AH + 125 AH + 125 AH = 375 AH), but the voltage of the battery bank stays the same (12 VDC).

Series connection - batteries connected in series (positive to negative) increase the voltage of the battery bank, but the amp-hour rate remains the same.

For example: You have a 12-volt battery bank with two 6-volt batteries that are rated at 220 amp-hours. The positive terminal of the first battery is connected to the negative terminal of the second battery, which means these batteries are connected in series. Since the two 6-volt batteries are connected in series, the voltage of the batteries are added together to produce 12-volts (6 VDC + 6 VDC = 12 VDC), but the amp-hour capacity of the battery bank does not change (220 AH).

In battery banks where you have batteries connected in series and in parallel –the rules are the same. The batteries connected in series are referred to as a "series string" and the amp-hour capacity doesn't change. Each "series string" is connected together in parallel to increase the amp-hour capacity. Add the amp-hour capacity of each "series string" connected in parallel to determine the total amp-hour capacity of the battery bank.

• **SETUP: 04 Battery Type** - Used to select the battery type, which determines the battery charge profile and ensures the batteries are receiving the proper charge voltage. Selections are GEL (for Gel batteries), Flooded (for liquid lead acid batteries), AGM 1 (for Lifeline AGM batteries) and AGM 2 (for East Penn/Deka/Discover/Trojan AGM batteries). The charging voltages vary depending on the battery type selected; see Table 3-3.

Default setting: BattType = Flooded

The voltage settings shown in Table 3-3 are based on the Battery Temperature Sensor (BTS) being disconnected or at a temperature of 77° F (25° C). If the BTS is connected, the actual charge voltages will increase if the temperature around the BTS is below 77° F (25° C) and decrease if higher than 77° F (25° C). This ensures the batteries receive correct charging even if they become cold or hot.

Table 3-3, Battery Type to Charge Voltages

Battery Type	Inverter Voltage	Absorption Voltage	Float Voltage	Equalization Voltage
GEL	12 VDC	14.1 VDC	13.6 VDC	14.1 VDC***
	24 VDC	28.2 VDC	27.2 VDC	28.2 VDC***
	48 VDC	56.4 VDC	54.4 VDC	56.4 VDC***
Flooded	12 VDC	14.6 VDC	13.4 VDC	15.5 VDC
	24 VDC	29.2 VDC	26.8 VDC	31.0 VDC
	48 VDC	58.4 VDC	53.6 VDC	62.0 VDC
AGM 1*	12 VDC	14.3 VDC	13.1 VDC	15.0 VDC
	24 VDC	28.6 VDC	26.2 VDC	30.0 VDC
	48 VDC	57.2 VDC	52.4 VDC	60.0 VDC
AGM 2**	12 VDC	14.5 VDC	13.5 VDC	14.5 VDC***
	24 VDC	29.0 VDC	27.0 VDC	29.0 VDC***
	48 VDC	58.0 VDC	54.0 VDC	58.0 VDC***

* specifications for Concord (Lifeline Series).
** specifications for East Penn / Deka / Discover/ Trojan.
*** voltage same as absorption voltage - to prevent equalization.

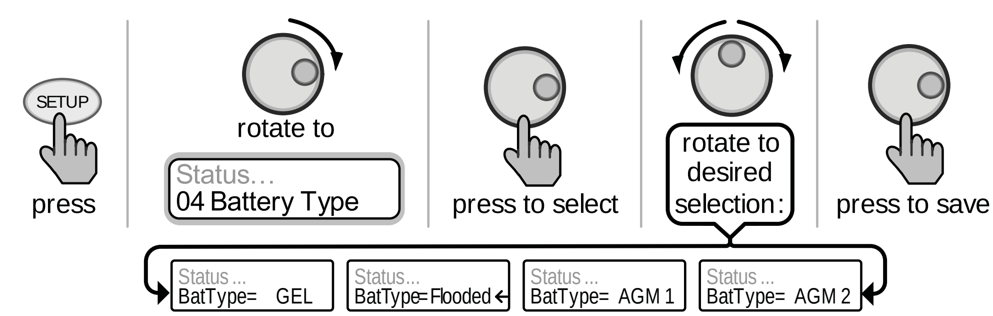


Figure 3-9, SETUP: 04 Battery Type Selections

- **SETUP: 05 Charge Rate -** Used to set the maximum charge rate allowed to charge the batteries during bulk, absorption, float and equalize charging. Selections are 'Max Charge = 0%' up to 'Max Charge = 100%. The *Max Charge = 0%* setting is available to help minimize charging while continuing to allow pass-thru power. The rest of the selections are provided to limit the charge rate on the battery bank - to help prevent battery overheating caused by charging at too high a charge rate.

The *Max Charge* selections are provided as a percentage of the inverter/charger's maximum charging capability. Refer to label on the side of the inverter or the operator's manual for the inverter/charger to determine its maximum charge rate. Once you find this maximum charge rate, determine the percentage needed to limit the charge rate to your battery-bank.

For example, if the maximum charge rate of your inverter/charger is 100 amps and you need to limit the charge rate to 50 amps, choose the *Max Charge = 50%* selection (50 amps = 50% of 100 amps).

Default setting: Max Charge = 80%

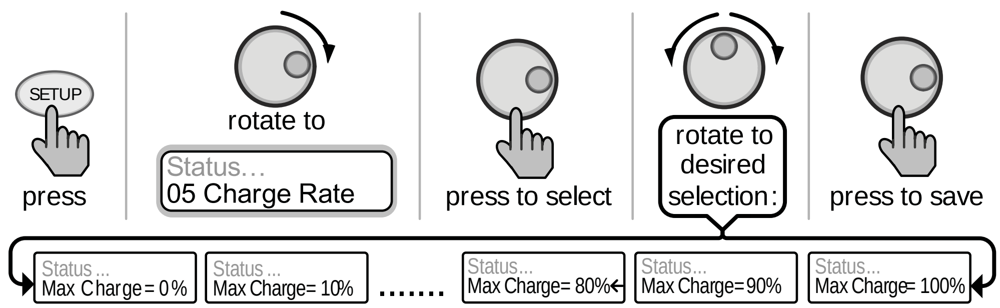


Figure 3-10, SETUP: 05 Charge Rate Selections

Info: If the Max Charge rate is set to 0%, the topology of the Magnum Inverter - when connected to an AC source - will over-ride the 0% setting and start charging if the battery voltage is <7 VDC (12 VDC models), <14 VDC (24-volt models) or <28 VDC (48-volt models).

How do I determine where to set my maximum charge rate? The maximum charge rate is generally set to a C/5* rate (C = the total amp-hour capacity of the battery bank). The C/5 rate is usually used when the objective is to charge the batteries as quickly as possible (i.e. 400 Amp-Hours ÷ 5 = 80 amp maximum charge rate). A lower rate such as C/20* or C/10* is recommended in installations where batteries are charged for long periods of time (i.e. plugged into shorepower for long periods or in a back-up power application).

Some GEL and AGM batteries can be charged at a higher charge rate - check with the battery manufacturer.

Info: If <u>multiple inverter/charger's</u> are used on a single battery bank, you must ensure that the <u>total</u> charge rate from all inverter/chargers is limited to the maximum charge rate needed for your battery bank. The Max Charge rate only limits the charging on each inverter/charger individually, not on all inverter/chargers.

* C/5, C/10, or C/20 rate - Charge rates are commonly expressed as a ratio of the total amp-hour (AH) capacity of the battery bank. For example, with a 400 AH battery bank (C = 400), the C/5 charge rate is 80 A (400/5 = 80 A).

- **SETUP: 06 VAC Dropout** - Used to select the minimum AC voltage that must be present on the input before the inverter/charger switches from inverter to charger mode. For example: If this setting is set to *Dropout = 60 VAC*, then the AC input voltage must be above 60 Volts before the inverter will allow switch from inverter mode to charge mode.

This setting also determines the minimum AC voltage threshold where the inverter/charger transfers from the AC input (utility/shore or generator) and begin inverting. This protects AC loads from utility outages. For example: If this setting is set to *Dropout = 60 VAC*, when the AC input voltage drops to 60 volts, the inverter will switch from charge mode to inverter mode. Selections are *Dropout = 60 VAC* to *Dropout = 100 VAC.*

Default setting: Dropout = 80 VAC

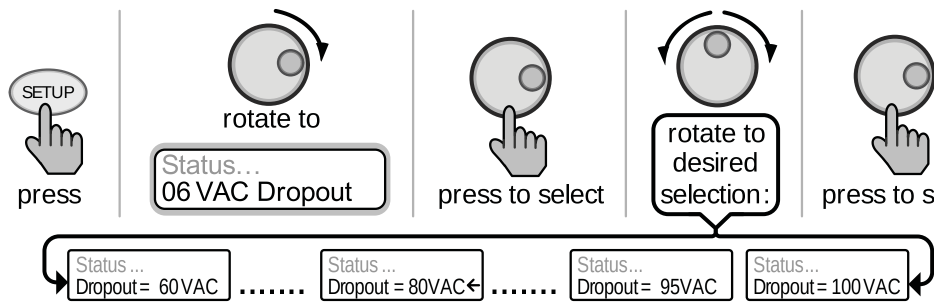


Figure 3-11, SETUP: 06 VAC Dropout Selections

Where do I set my VAC Dropout? It depends on the application and what you are using as the AC source. The settings not only look at the incoming voltage to determine when to transfer, but also determines the response sensitivity to incoming voltage fluctuations.

Use a VAC Dropout setting above 80 VAC (>80 VAC) when the AC source is well regulated and operating devices that are sensitive to voltage fluctuations. These settings are intolerant of voltage fluctuations and provide a quicker transfer. The transfer time from charge mode to inverter mode is about 16 milliseconds when using these settings (*Dropout = 85 VAC* to *Dropout = 100 VAC*).

Use the 80 VAC or lower setting (≤80 VAC) when the AC source may have significant fluctuations in RMS voltage. These settings are highly recommended if using a generator for charging. The transfer time from charge mode to inverter mode is about 22 milliseconds when using these settings (*Dropout = 60 VAC* to *Dropout = 80 VAC*).

- **SETUP: 07 Power Saver** - This setting allows you to turn off the Power Saver™ feature or select the time (from 1 minute to 60 minutes) that determines how often the display goes into Power Saver mode.

Default setting: PwrSave = 15min

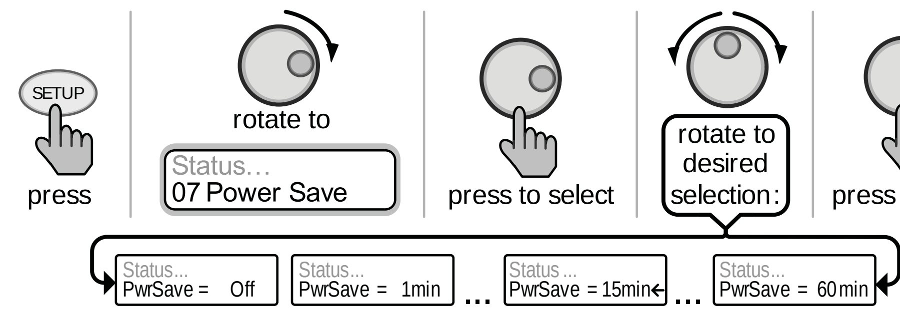


Figure 3-12, SETUP: 07 Power Saver Selections

What is the power saver feature? The Power Saver feature causes the LCD back-light and LED's on the remote display to turn off to conserve energy. The remote goes into Power Saver mode if there hasn't been a pushbutton press or fault message for a period of time (this time is determined by the *SETUP: 07 Power Save* setting). Whenever the remote goes into the Power Saver mode, the LCD backlight and LED's can be reactivated by pressing any menu pushbutton*. If you have a fault during the Power Saver mode, the LCD backlight and Fault LED will come on and stay on as long as the fault is detected.

If you want the LCD backlight and LED's to always be on, you will need to turn the Power Saver feature off by selecting *PwrSave = Off*.

* Even though you can press any menu pushbutton, do not press the ON/OFF INVERTER or ON/OFF CHARGER pushbutton to reactivate the remote's backlight and LED's - this will cause the charger or inverter to change the operating status. Instead, press the METER pushbutton; it does not change the inverter or charger status.

- **SETUP: 08 Scrn Contrast** - Used to adjust the contrast of the LCD screen for the best looking display based on the current lighting conditions and viewing angle.

Default setting: Contrast = 32

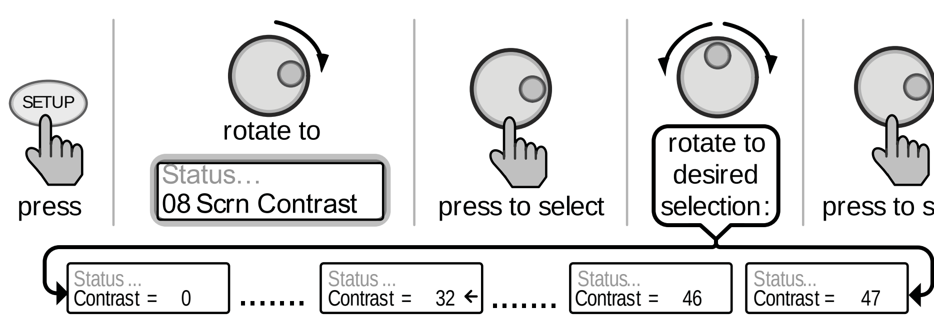


Figure 3-13, SETUP: 08 Scrn Contrast Selections

3.2.5 TECH Menu

The TECH menu pushbutton provides access to selections that are used to assist service technicians in troubleshooting. It provides access to system information along with a selection that allows all system settings to be returned to the original factory default values.

TECH: 01 Temperatures – This "read only" menu displays temperature readings of the battery temperature sensor (if connected), the transformer, the FET's (Field Effect Transistors) and a networked AGS (if installed).

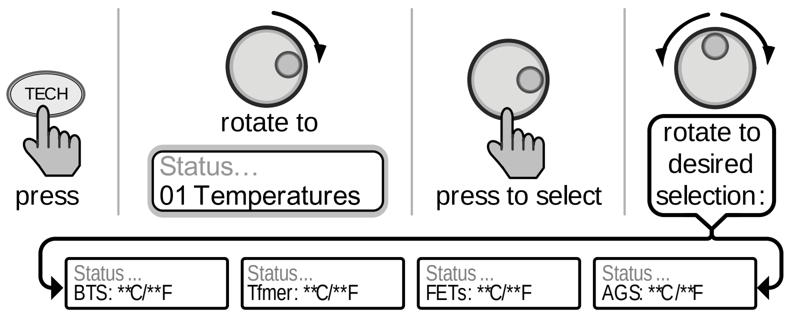


Figure 3-14, TECH: 01 Temperatures Display

TECH: 02 Revisions – This "read only" menu displays the firmware revision level of the inverter, remote and any optional accessory (i.e. AGS) that is installed and networked.

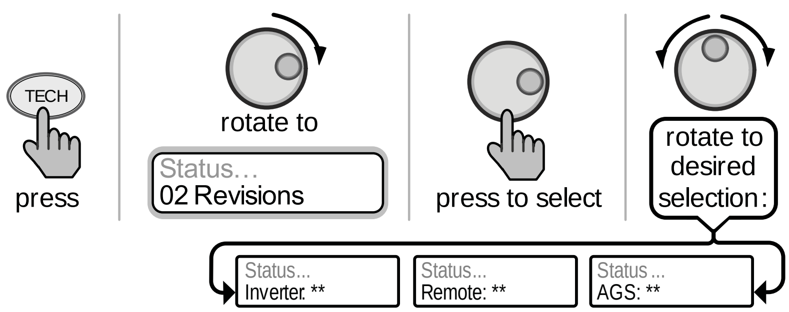


Figure 3-15, TECH: 02 Revisions Display

TECH: 03 Inv Model – This "read only" menu displays the model number of the connected inverter.

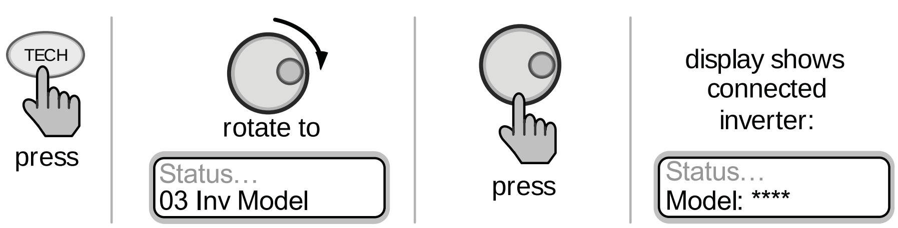


Figure 3-16, TECH: 03 Inv Model Display

Info: If "Model: UNKNOWN" is displayed, then the remote is connected to a newer released inverter; all menu selections and features in the remote control will function normally.

- **TECH: 04 Load Defaults** - This menu restores all settings on the inverter/charger and any settings on accessories that are networked and controlled by the inverter (i.e. ME-AGS) to the factory default settings. To restore, press and hold the Rotary SELECT knob for 5 seconds. After the default settings have been restored, the display will show DEFAULTS LOADED. The inverter/charger factory defaults are listed in Table 3-4.

Info: For detailed information on the factory default settings for any networked accessory; refer to the owner's manual for that accessory.

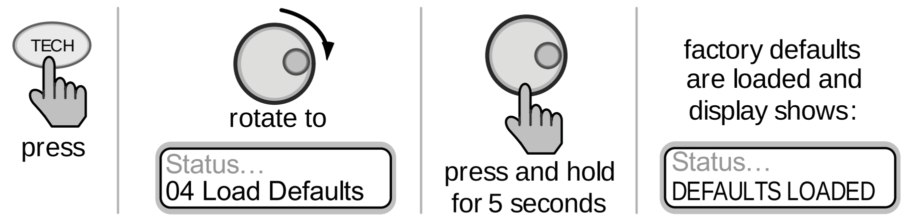


Figure 3-17, TECH: 04 Load Defaults Selection

Table 3-4, Inverter/Charger Default Settings

Menu Items		Default Settings
SHORE Pushbutton		Shore Max = 30A*
SETUP Pushbutton	01 Search Watts	Search = 5W
	02 LowBattCutOut	LBCO = 10.0 VDC (12-volt models), 20.0 VDC (24-volt models) or 40.0 VDC (48-volt models)
	03 Batt AmpHrs	Batt Amphrs = 400 AmpHrs (Absorb Time = 90 minutes)
	04 Battery Type	BatType = Flooded
	05 Charge Rate	Max Charge = 80%
	06 VAC Dropout	Dropout = 80VAC
	07 Power Save	PwrSave = 15min
	08 Scrn Contrast	Contrast = 32*

***** All adjustable inverter/charger settings in the ME-RC (except for *Shore Max* or *Contrast*, which revert back to the default setting) are saved in non-volatile memory and will be preserved until changed even if all power to the remote or inverter is lost.

Caution: An accessory that is networked to the inverter may have settings that revert back to default if all power to the inverter is lost. Refer to the owners manual for the accessory in question to determine if any setting in the accessory is affected.

4.0 Menu Map: ME-RC Remote Control

The following figure is a complete overview of the inverter/charger settings and info displays available in the ME-RC; this should help with menu navigation.

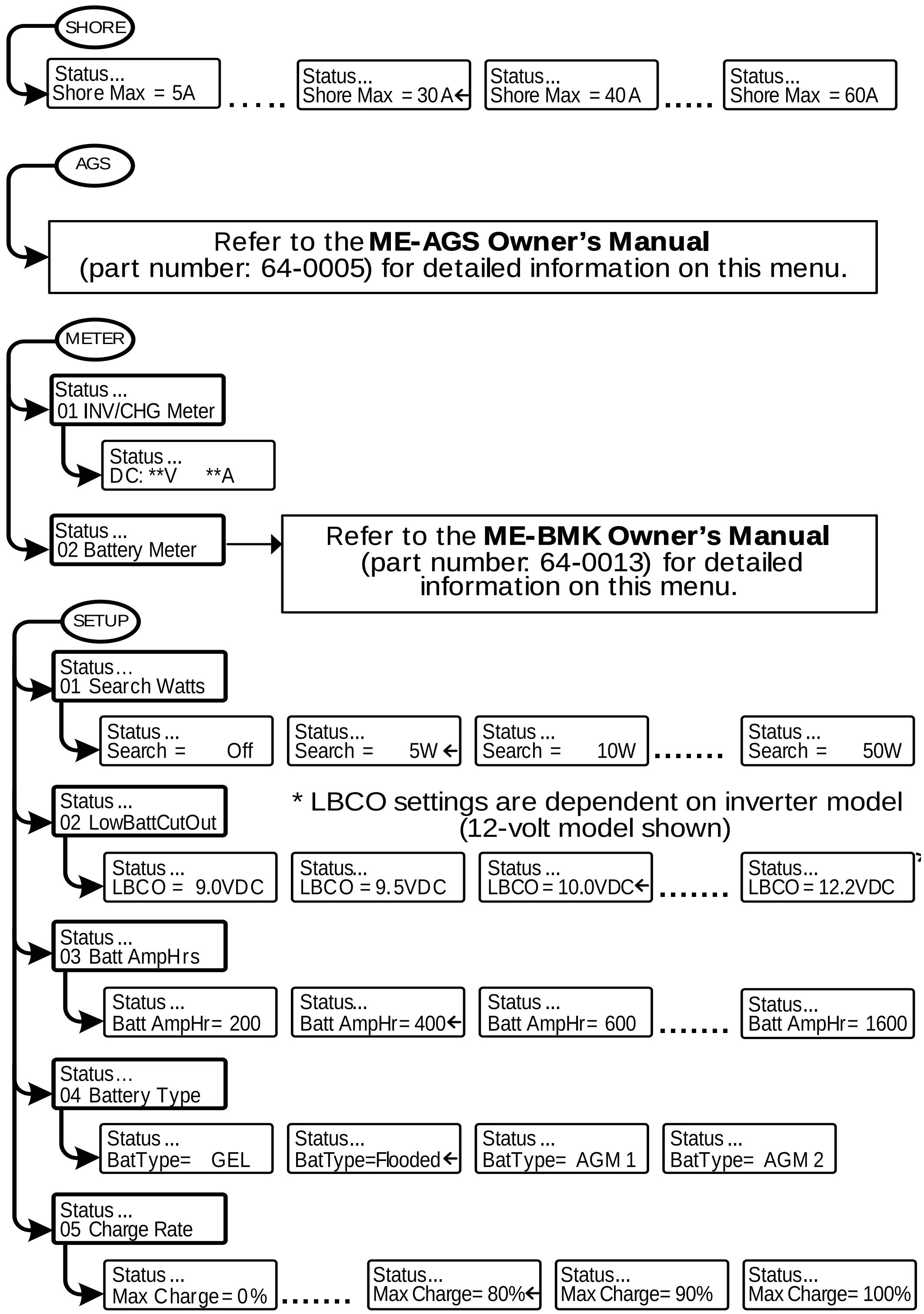


Figure 4-1, Inverter/Charger Menu Map

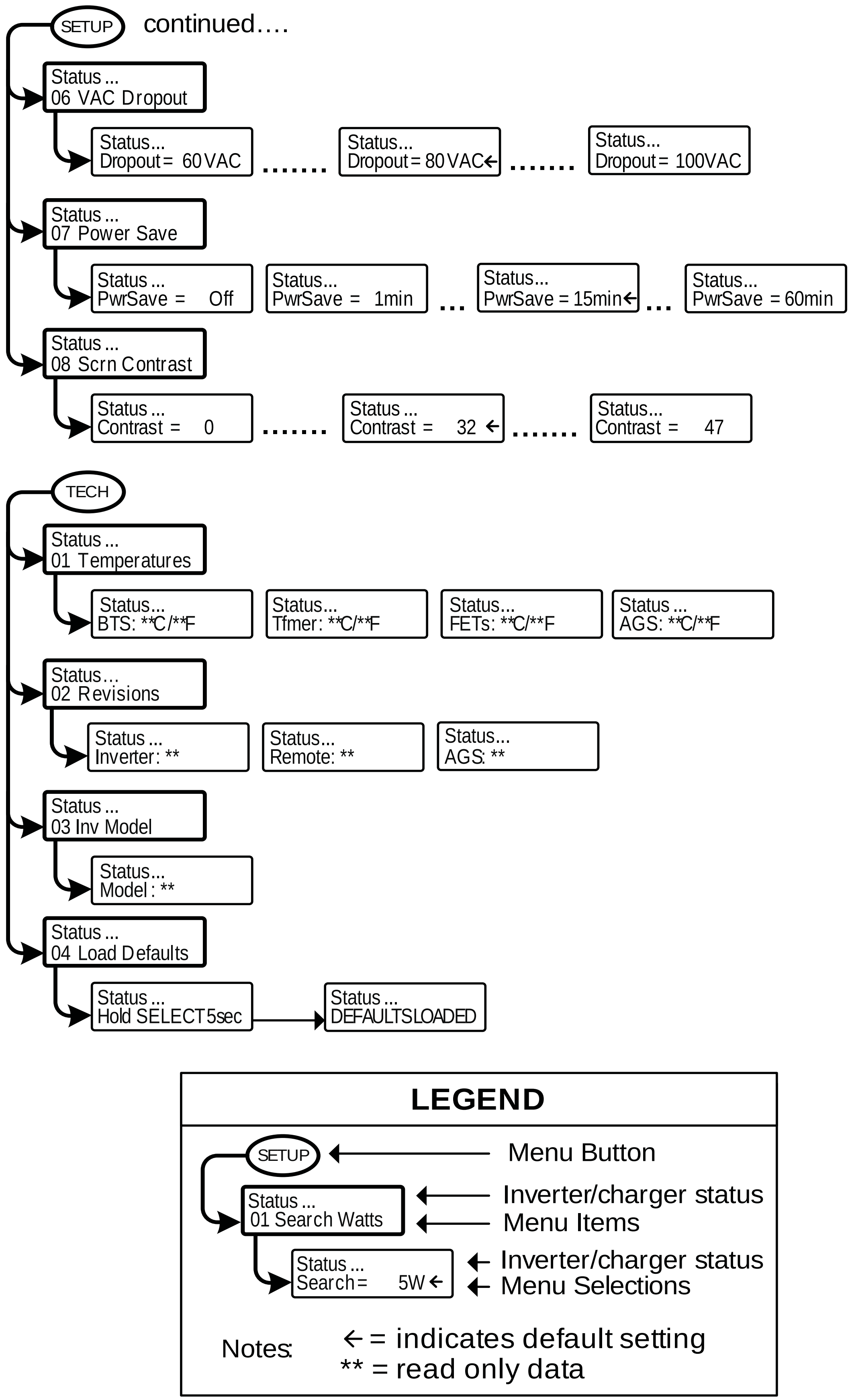


Figure 4-1, Inverter/Charger Menu Map (continued)

5.0 Operation

This section explains how to operate the inverter/charger. It also helps to explain the operational status determined by the LED indicators and LCD display.

5.1 Front Panel

The ME-RC front panel contains LEDs and a LCD display for viewing system status; pushbuttons to control system operation; and a Rotary Knob that allows an easy way to select and find system information.

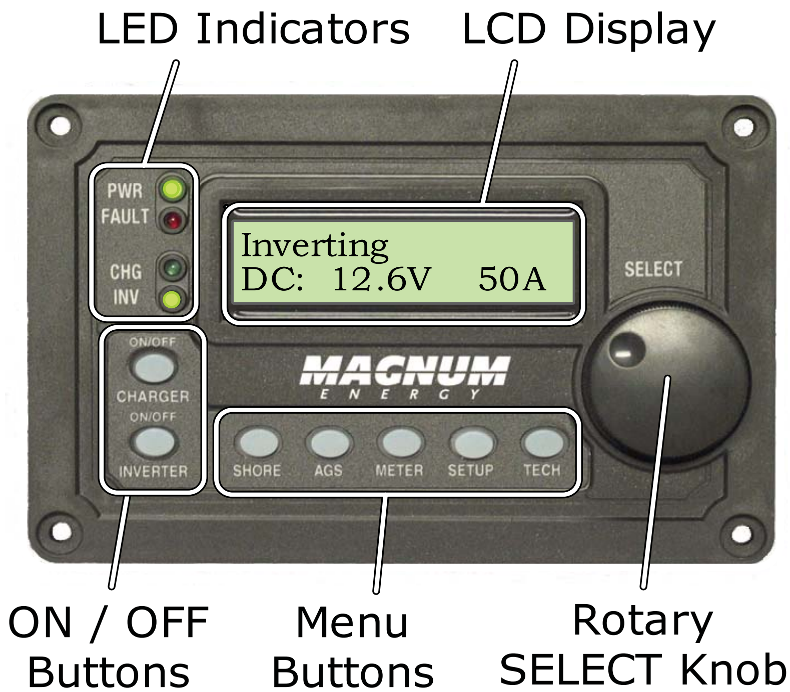


Figure 5-1, ME-RC Front Panel Controls and Indicators

5.1.1 LED Indicators

There are four LED's indicators on the front panel that light solid or blink to indicate the inverter/charger's status. When the remote is first powered-up, all the LED's come on as it goes through a self-test. Once the self-test is complete, the LED's along with the LCD provide the operating status of the inverter/charger. See section 5.3.4 for the LED Indicator Guide.

5.1.2 LCD Display

The LCD display is used for setting up the system operation as well as viewing the current operating status or any fault condition. This display has two lines of alphanumeric characters and features a back-light that can be set to turn off to conserve power. The top line provides the inverter/charger status, which is detailed in this section. The bottom line displays battery information while using the METER menu, system troubleshooting information while in the TECH menu and menu items that can be configured for your specific system operation while in the SETUP menu. This display automatically powers up with the current system status on the top line and the Home Screen (detailing the inverter's DC voltage and current as shown in figure 5-1) on the bottom line.

5.1.3 ON / OFF Pushbuttons

- ON/OFF INVERTER: This pushbutton toggles the inverter function on and off. The green "INV" LED turns on and off with the pushbutton.

- ON/OFF CHARGER: This pushbutton toggles the charger function on and off whenever the charger is actively charging. The green "CHG" LED turns on and off with this pushbutton. This pushbutton is also used to initiate an equalize charge; for more information on using this equalize charge feature, see section 5.2.2 and the Equalizing Mode information page 26.

5.1.4 Menu Pushbuttons

These five menu pushbuttons provide quick access to menu items that can help with configuring, monitoring and troubleshooting your inverter /charger system.

- SHORE: This pushbutton allows you to set the appropriate breaker size for the incoming utility/shore power and is used to control the amount of AC amps the battery charger uses from the HOT 1 IN input; see section 3.2.1 for more detailed information.

- AGS: This pushbutton allows the networked Auto Generator Start (AGS) controller (if connected) to be configured to specific system preferences and check status of the AGS. Refer to the ***ME-AGS Owner's Manual*** (part number: 64-0005) for detailed information on this menu.

- METER: This pushbutton provides meter information on the inverter/charger system; see section 3.2.3 for more detailed information.

- SETUP: This pushbutton allows the inverter/charger to be configured to your specific system preferences; see section 3.2.4 for more detailed information.

- TECH: This pushbutton allows you to access menu selections that can help service personnel with troubleshooting and also allows the factory default setting to be restored; see section 3.2.5 for more detailed information.

5.1.5 Rotary SELECT Knob

The Rotary 'SELECT' knob is similar to a dash radio knob and used to easily view and select various menu items and settings displayed in the LCD screen. Turn the rotary knob clockwise and counterclockwise to view the different menu items and available charger and inverter settings. Push or "SELECT" the rotary knob to enter a menu item or to "save" a setting once they are displayed on the LCD screen.

Info: All adjustable inverter/charger settings in the ME-RC (except for *Shore Max* and *Contrast* - which revert back to default) are saved in non-volatile memory and will be preserved until changed - even if all power to the remote or inverter is lost.

Caution: An accessory that is networked to the inverter may have settings that revert back to default if all power to the inverter is lost. Refer to the operation manual for the particular accessory to determine if any setting for the accessory is affected.

5.2 Operating the Inverter/Charger

5.2.1 Inverter Mode

Turning the inverter on: Press the ON/OFF INVERTER pushbutton to activate the inverter function. The inverter will either be actively "inverting" by using power from the batteries to power the AC loads (see figure 5-4); or will be "searching" for a load by using very little power from the batteries - if in search mode (see figure 5-3). The green 'INV' LED will be on when the inverter is actively inverting and the green 'INV' LED will flash while searching.

Turning the inverter off: While the inverter is actively "inverting" or "searching", the ON/OFF INVERTER pushbutton can be pressed to switch the inverter function off and this will turn the green 'INV' LED off (see figure 5-2).

Inverter Standby: The inverter is in standby when the inverter is active (green 'INV' LED is on) and an external AC power (utility/shore or generator) is passing through the inverter to power the AC loads. During normal operation, the AC loads will be powered by the external AC power, however, if a blackout or brownout condition occurs, the inverter senses these conditions, transfers to inverter mode and powers the AC loads connected to the inverter.

Caution: If you have critical loads and in Inverter Standby, do not press the ON/OFF INVERTER pushbutton to turn the inverter function off. If the green 'INV' LED is off, inverter power will NOT be available to run your critical loads if the external AC power is interrupted.

5.2.2 Charger mode

Turning the charger on: The charger will automatically be activated and begin to charge your batteries when acceptable AC power (utility/shore or generator) is connected to the input (HOT IN 1) of the inverter. When the charger is ON, it produces DC voltage and current to charge your batteries. The CHG LED will be on when the charger is ON and actively charging. While charging the display will show Bulk, Absorption, Float or Full Charge (see figures 5-5 thru 5-9).

Charger Standby: While the charger is actively charging, the ON/OFF CHARGER pushbutton can be pressed to switch the charger to "Charger Standby". While the charger is in Charger Standby, the incoming AC is still available on the inverter's output, but the charger is not allowed to charge. The display will show 'Charger Standby' and the CHG LED will flash when the charger is in standby mode, (see figure 5-10).

Info: To resume charging, momentarily press the ON/OFF CHARGER button; or disconnect/reconnect AC power to the inverter's input.

Equalize charging: Equalizing is a "controlled overcharge" performed after the batteries have been fully charged. It helps to mix the battery electrolyte (to reverse the buildup of stratification) and also helps to remove sulfates that may have built up on the plates. These conditions, if left unchecked will reduce the overall capacity of the battery.

Warning: Do not perform an equalization charge without reading and following all safety precautions pertaining to charging/equalization as noted in this manual and any equalization information in the inverter's manual.

To enable the equalization charge; see figure 5-11 and follow all related information on page 26.

5.3 System Status Messages

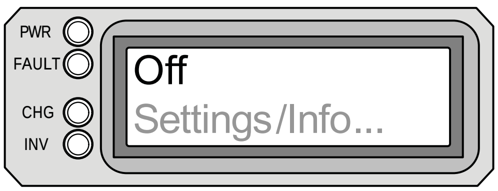
The remote control uses the top line of the LCD display to show the inverter/ chargers current operation by displaying a status message. This section will show the inverter/ charger's operating modes and the available status messages under each mode. Use these status messages along with the Status LED's to determine the inverter/charger's current operating status and to help troubleshoot the system if a fault occurs.

There are three operating modes of the inverter/charger:

- Inverter Mode
- Charger Mode
- Fault Mode

5.3.1 Inverter Mode Messages

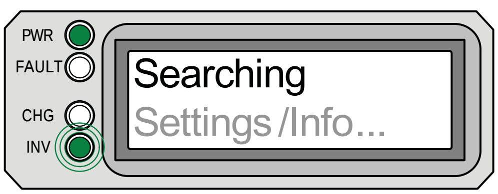
The inverter/charger will be in the Inverter Mode when AC power (shorepower/utility or generator) is not available or unacceptable to the inverter/charger's input. The Inverter Mode messages are Off, Searching and Inverting.



Off appears on the LCD; all LED's are off.

Figure 5-2, Off Mode

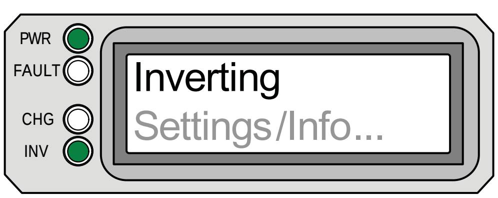
- **Off** – This message tells you that there is no AC available on the inverter's AC output. The inverter function is off and there is no utility/shore or generator power AC sensed on its input.



Searching appears on the LCD. The PWR (green) LED is on solid and the INV (green) LED slowly flashes. The FAULT (red) and CHG (green) LED's are off.

Figure 5-3, Searching Mode

- **Searching** – The inverter is in the Search mode, which means the AC loads on the inverter output are less than the *SETUP: 01 Search Watts* setting. The search mode function is used to reduce the inverter draw from the battery and may be turned off at any time if you want full inverter output voltage available at all times (see the SETUP: 01 section).



Inverting appears on the LCD. The PWR (green) and INV (green) LED's are on solid. The FAULT (red) and CHG LED's are off.

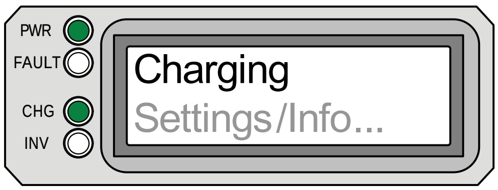
Figure 5-4, Inverting Mode

- **Inverting** - The inverter is providing AC voltage on its output by inverting power from the batteries.

5.3.2 Charger Mode Messages

When AC power (utility or generator) is connected to the inverter/charger, it begins to monitor the AC input for acceptable voltage. Once the AC input is accepted, the AC transfer relay (inside the inverter) closes and charger mode begins. There are several charger mode messages; view the top line of the LCD display and the corresponding message in this section to determine and understand the particular charger mode.

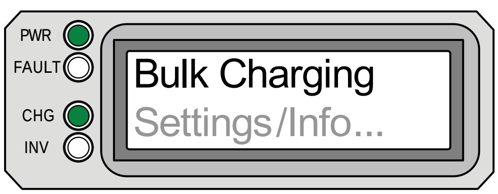
Info: The AC input becomes acceptable after a minimum 10 second delay and when the voltage is greater than the *SETUP: 06 VAC Dropout* setting.



Charging appears on LCD; PWR (green) and CHG (green) LED's are on solid; FAULT (red) LED is off and INV (green) LED could be on or off.

Figure 5-5, Charging Mode

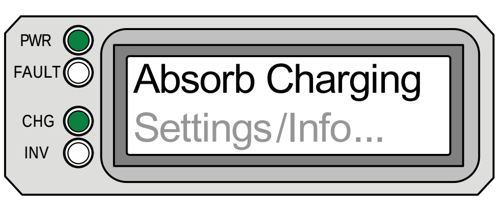
- **Charging** – Once the charger mode has been enabled, the unit will wait and display "Charging". During this wait time the DC voltage is being sampled to determine the charge routine. If the DC voltage is ≤12.9 VDC (12-volt models), ≤25.8 VDC (24-volt models) or ≤51.6 VDC (48-volt models); the charger will initiate "Bulk Charging". If the DC voltage is greater than 12.9 VDC (12-volt models), 25.8 VDC (24-volt models) or 51.6 VDC (48-volt models) the charger will go to "Float Charging".



Bulk Charging appears on LCD; PWR (green) is on solid and CHG (green) LED is typically on solid, but may blink slowly; FAULT (red) LED is off; INV (green) LED could be on or off.

Figure 5-6, Bulk Charging Mode

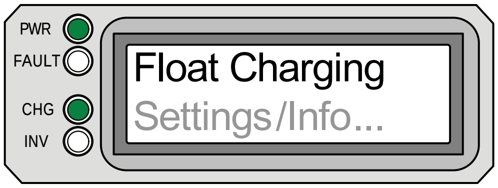
- **Bulk Charging** – The battery charger is delivering maximum current (determined by the *SETUP: 05 Charge Rate* setting) to the batteries. The charger will remain in bulk charge until the absorb voltage (determined by the *SETUP: 04 Battery Type* setting) is achieved.



Absorb Charging appears on LCD; PWR (green) is on solid and CHG (green) LED is typically on solid, but may blink slowly; FAULT (red) LED is off and INV (green) LED could be on or off.

Figure 5-7, Absorb Charging Mode

- **Absorb Charging** - The absorb charge state is the constant voltage stage and begins when the absorb voltage is reached (determined by the *SETUP: 04 Battery Type* setting) while bulk charging. During this stage, the DC charging current decreases in order to maintain the absorb voltage setting. This charge stage continues until the Absorb Charging time (determined by the *SETUP: 03 Battery AmpHrs* setting) is finished.

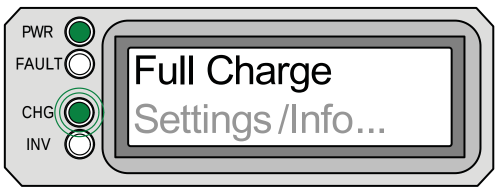


Float Charging appears on LCD; PWR (green) LED is on solid and CHG (green) LED is typically on solid, but may blink slowly; FAULT (red) LED is off and INV (green) LED could be on or off.

Figure 5-8, Float Charging Mode

- **Float Charging** – At the end of the Absorb Charging time, the charger reduces the charge voltage and tries to maintain the batteries at the float charge voltage setting; which is determined by the *SETUP: 04 Battery Type* setting as shown in Table 3-3, Battery Type to Battery Charge Voltages.

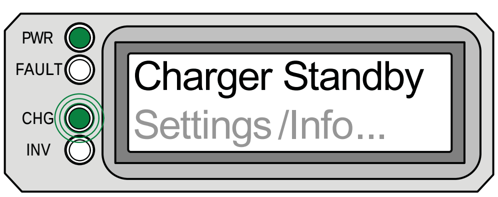
Info: If the battery voltage falls ≤12.1 VDC (12-volt models), ≤24.2 VDC (24-volt models) or ≤48.4 VDC (48-volt models); the unit will begin bulk charging.



Full Charge appears on LCD; PWR (green) LED is on solid and CHG (green) LED blinks slowly; FAULT (red) LED is off and INV (green) LED could be on or off.

Figure 5-9, Full Charge Mode

- **Full Charge** – This status indicates that you have entered the Battery Saver™ mode. This mode maintains the batteries without overcharging, thus preventing excessive loss of water in flooded batteries or drying out of GEL/AGM batteries. After 4 hours "Float Charging", the charger will turn off and "Full Charge" is displayed (charger is now in Battery Saver™ mode). If the battery voltage drops to ≤12.6 (12-volt models), ≤25.2 (24-volt models) or ≤50.4 (48-volt models); the charger will automatically initiate another 4 hours "Float Charging". This cycle helps to ensure the batteries are monitored and maintained; and continues as long as AC power is continuously connected to the AC input.

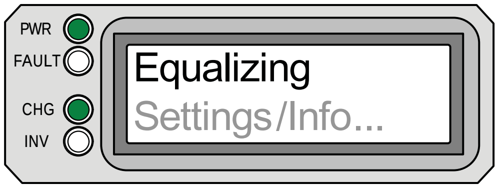


Charger Standby appears on LCD; PWR (green) LED is on solid and CHG (green) LED slowly blinks; FAULT (red) LED is off and INV (green) LED could be on or off.

Figure 5-10, Charger Standby Mode

- **Charger Standby** - This means the charger has been disabled to prevent any charging, but the AC power (from shore/utility or generator) to the AC input is still available on the AC output. This display is shown when the ON/OFF CHARGER pushbutton is pressed while the AC power is passing thru the inverter/charger.

Info: To enable charging again, press the ON/OFF CHARGER pushbutton. When the charger is again enabled, the charger will continue in the charge mode it left and the CHG (green) LED will come on solid.



Equalizing appears on LCD; PWR (green) and CHG (green) LED's are on solid; FAULT (red) LED is off and INV (green) LED could be on or off.

Figure 5-11, Equalizing Mode

Equalizing - The battery charger is delivering the equalize voltage to the batteries; see Table 3-3, *Battery Type to Battery Charge Voltages* to determine the equalize voltage for your battery type.

Equalize charging can be enabled by the ON/OFF CHARGER pushbutton - if the *SETUP: 04 Battery Type* selection allows. Equalization charging can only be enabled while the charger is in float charge or in Battery Saver mode. To turn on equalize charging, ensure the LCD display reads "Float Charging" or "Full Charge", then press and hold the ON/OFF CHARGER pushbutton down (about 5 seconds) until the LCD screen displays "Equalizing".

The equalize charge will continue for 4 hours and then automatically stop and return to "Float Charging". The equalize charge can be manually stopped by pressing and holding the ON/OFF CHARGER pushbutton down (about 5 seconds) until the LCD screen displays "Float Charging".

During equalize charge stage the batteries will begin gassing and bubbling vigorously which consumes water; ensure each cell has adequate distilled water levels prior to equalizing and add water as needed after equalizing.

How often should I equalize? Some experts recommend that heavily used batteries should be equalized periodically, ranging anywhere from once a month to once or twice per year. Other experts only recommend equalizing when the cells have a low specific gravity or when the difference between any individual cell has a specific gravity reading greater than .015 after being fully charged.

How long should I equalize? While the batteries are gassing, monitor the specific gravity readings every hour; when the specific gravity readings no longer increase, the equalization charge is complete and should be stopped.

Warning: Equalizing produces hydrogen and oxygen gas. Ensure the battery compartment has adequate ventilation in order to dissipate this gas to avoid explosions.

Caution: Ensure you batteries can be equalized - only equalize your batteries if permitted by your battery manufacturer or dealer. Performing an equalize charge on batteries other than liquid lead acid or certain AGM types could permanently damage them. Refer to your battery manufacturer/dealer for instructions on how to properly equalize your batteries.

Caution: Ensure the DC loads will not be damaged by the higher voltage applied to the batteries during the equalize charge. If in doubt, disconnect the DC loads to prevent damage.

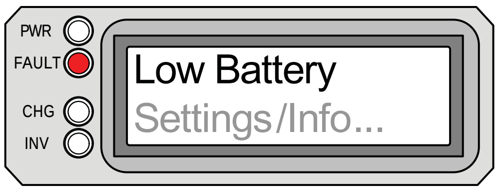
Info: Equalization charging is not available if GEL or AGM 2 is selected under the *SETUP: 04 Battery Type* menu.

5.3.3 Fault Mode Messages

The fault LED comes on and a fault status is displayed when an abnormal condition is detected. View the LCD display and the information in this section to determine and correct the issue.

Info: Many of the faults will automatically restart when the fault is cleared. Some faults will require a manual restart; this requires the ON/OFF INVERTER pushbutton on the remote to be pressed and released. Finally, if the fault is unable to clear, an inverter reset may be required - see section 6.2 to perform an inverter reset.

5.3.3.1 System Fault messages - These fault messages are usually caused by some external issue that directly affects the inverter/charger system.

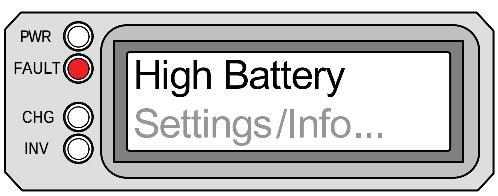


Low Battery appears on the LCD and the FAULT (red) LED is on. The PWR (green), CHG (green) and INV (green) LED's are off.

Figure 5-12, Low Battery Fault

- **Low Battery** – The inverter turned off to help prevent the batteries from being over-discharged. This message is displayed and the FAULT (red) LED illuminates when the battery voltage drops below the *SETUP: 02 LowBattCutOut* (LBCO) setting for more than 1 minute. The inverter will automatically restart and resume operation when the battery voltage rises to ≥12.5 VDC (12-volt models), ≥25.0 VDC (24-volt models), or ≥50.0 VDC (48-volt models).

Remedy: This fault will also automatically restart if AC power (such as utility/shore power or a generator) is connected to the inverter/charger's input and battery charging begins.



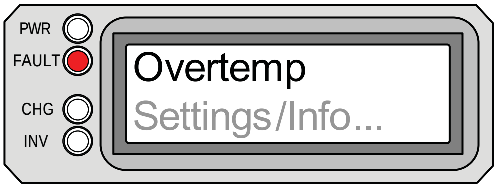
High Battery appears on the LCD and the FAULT (red) LED is on. The PWR (green), CHG (green) and INV (green) LED's are off.

Figure 5-13, High Battery Fault

- **High Battery** – The inverter has turned off because the battery voltage is at a very high level. This fault message is displayed and the FAULT (red) LED will be on when the battery voltage is above the High Battery Cut-Out (HBCO) value. This fault will automatically restart and resume operation when the battery voltage drops 0.3 VDC (12-volt models), 0.6 VDC (24-volt models), or 1.2 VDC (48-volt models) below the HBCO value.

Info: The HBCO value is dependent on your inverter revision and model. Normally, the HBCO value for the ME/MM/RD Series inverters is 16 VDC (12-volt models) or 32 VDC (24-volt models); and the HBCO value for the MS/MMS Series inverters is 17 VDC (12-volt models), 34 VDC (24-volt models), or 68 VDC (48-volt models).

Remedy: This fault usually only occurs when an external DC charging source is charging the inverter's battery bank. Turn off any other additional charging source to allow the DC voltage level to drop.

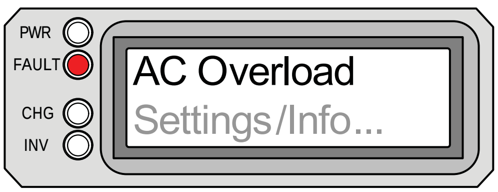


Overtemp appears on the LCD and the FAULT (red) LED is on. The PWR (green), CHG (green) and INV (green) LED's are off.

Figure 5-14, Overtemp Fault

- **Overtemp** – This fault message indicates the inverter/charger has shut down because the internal power components (FET's and/or Transformer) have exceeded their safe temperature operating range. When the unit has cooled down, it will automatically restart and continue operation.

Remedy: If the fault occurs while inverting, reduce the load on the inverter; if it occurs while charging, turn down the charge rate. If this fault happens often, ensure the inverter is not in a hot area, has proper ventilation and the cooling fans inside the inverter are working.

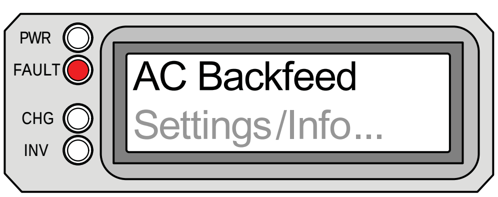


AC Overload appears on the LCD and the FAULT (red) LED is on. The PWR (green), CHG (green) and INV (green) LED's are off.

Figure 5-15, AC Overload Fault

- **AC Overload** - This fault message displays when the AC load on the inverter/charger's output has exceeded the inverters AC current protection limits. If the overload condition lasts for less than 10 seconds, the unit will automatically restart and resume operation. However, if the overload occurs more than 10 seconds, the unit will shut down and will require a manual restart.

Remedy: This fault usually occurs because the connected AC loads are larger than inverter's output capacity, there is a wiring short on the output or the output wires are incorrectly wired. Once the AC loads are reduced or the output wiring is corrected; the inverter can be restarted after a manual restart has been accomplished.

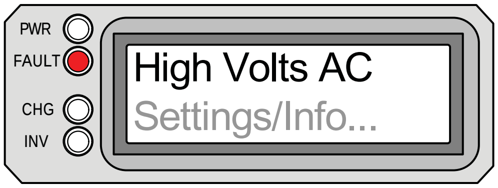


AC Backfeed appears on the LCD and the FAULT (red) LED is on. The PWR (green), CHG (green) and INV (green) LED's are off.

Figure 5-16, AC Backfeed Fault

- **AC Backfeed -** This fault message causes the inverter to shutdown because AC voltage from an external AC source has been detected on the inverters AC output. When the unit shutdowns because of this fault condition, an inverter reset will be required to resume operation (see section 6.2 to reset the inverter).

Remedy: This fault usually occurs because the AC output wiring is connected to (or able to be connected to) the incoming AC source. When this fault happens, all system wiring should be re-checked to ensure the incoming hot and/or neutral wires are not able to be connected to the AC output.

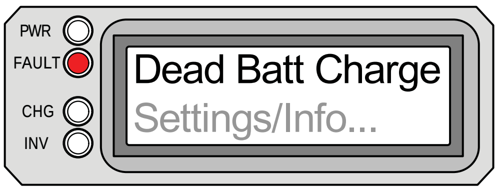


High Volts AC appears on the LCD and the FAULT (red) LED is on. The PWR (green), CHG (green) and INV (green) LED's are off.

Figure 5-17, High Volts AC Fault

- **High Volts AC** - This fault causes the charger to be disabled because a very high AC voltage (>150 VAC) has been detected on the AC input.

Remedy: Remove all AC power from the inverter's AC input to automatically restart this fault; ensure only 120VAC power is connected to the inverter's AC input.

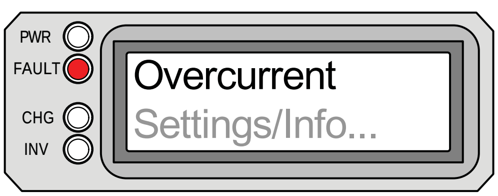


Dead Battery Charge appears on the LCD and the FAULT (red) LED is on. The PWR (green), CHG (green) and INV (green) LED's are off.

Figure 5-18, Dead Battery Charge Fault

- **Dead Battery Charge** – This fault has detected a very discharged battery bank or a battery bank that is disconnected from the inverter. The unit is attempting to enter the charge mode, but has detected less than 7 volts (12-volt models), 14 volts (for 24-volt models) or 28 volts (for 48-volt models) on the battery bank. This fault will continue until current is able to flow into the battery from the battery charger. Once this happens, the fault will automatically restart.

Remedy: Check the DC voltage on the inverter's DC terminals and compare it with the DC voltage on the battery bank, these two voltages should be very close (<0.5 VDC difference). If not, check to ensure all connections are tight and the fuse/circuit breaker between the inverter and battery bank is good.

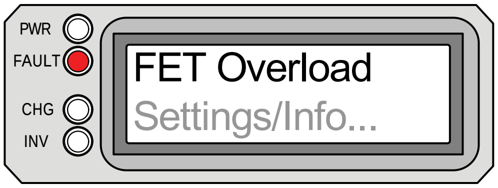


Overcurrent appears on the LCD and the FAULT (red) LED is on. The PWR (green), CHG (green) and INV (green) LED's are off.

Figure 5-19, Overcurrent Fault

- **Overcurrent** - This fault causes the inverter to shutdown to protect internal power components and may be caused by an excessive AC load. If the overload condition lasts for less than 3 seconds, the unit will automatically restart and resume operation. However, if the overcurrent condition occurs more than 10 seconds, the unit will shut down and will require a manual restart.

Remedy: This fault usually occurs because the connected AC loads are larger than the inverter's output capacity, there is a wiring short on the AC output or the wires are incorrectly wired. Once the AC loads are reduced or the output wiring is corrected; manually restart the inverter to resume operation. If this fault condition continues after all these recommendation, perform a inverter reset (see section 6.2).

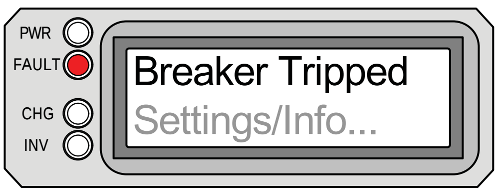


FET Overload appears on the LCD and the FAULT (red) LED is on. The PWR (green), CHG (green) and INV (green) LED's are off.

Figure 5-20, FET Overload Fault

- **FET Overload -** This fault message indicates the inverter/charger has shut down because the internal FET's (Field Effect Transistor's) have quickly exceeded a safe operating temperature. When the FET's have cooled, the unit will require a manual restart to resume operation.

Remedy: If the fault continues to occur, disconnect all the inverter's AC output wires and reset the inverter (see section 6.2). If this fault does not clear after doing a reset, the inverter may require service.



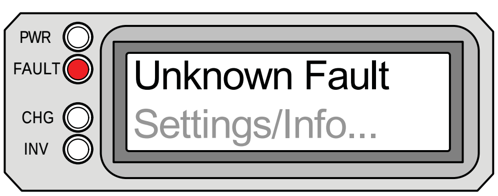
Breaker Tripped appears on the LCD and the FAULT (red) LED is on. The PWR (green), CHG (green) and INV (green) LED's are off.

Figure 5-21, Breaker Tripped Fault

- **Breaker Tripped** - The inverter has detected that the AC input breaker on the inverter/charger has opened due to excess current flow thru the inverter to the AC loads.

Remedy: After reducing the AC loads, push in the inverter's AC input circuit breaker to reset and resume operation.

Info: While in charger mode, the inverter's AC input breaker could nuisance trip if the loads on the inverter's AC HOT OUT 1 exceed the current rating of this circuit breaker.

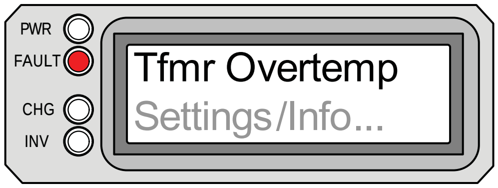


Unknown Fault appears on the LCD and the FAULT (red) LED is on. The PWR (green), CHG (green) and INV (green) LED's are off.

Figure 5-22, Unknown Fault

- **Unknown Fault** - This fault message displays when the inverter/charger has sent a fault code that cannot be determined by the remote.

Remedy: Call the Technical Support department at Magnum Energy for assistance to help determine and understand the actual fault status.



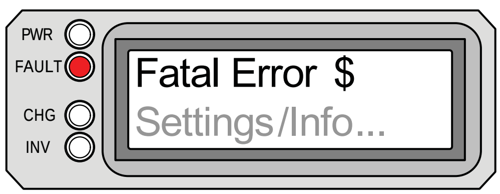
Tfmr Overtemp appears on the LCD and the FAULT (red) LED is on. The PWR (green), CHG (green) and INV (green) LED's are off.

Figure 5-23, Tfmr Overtemp Fault

- **Tfmr Overtemp** - This fault message is displayed when the TCO (Temperature Cut-Out) opens and causes the inverter to shutdown to protect the internal power transformer from damage. When the TCO has cooled down, the inverter will automatically restart and resume operation.

Remedy: If the fault occurs while inverting, reduce the load on the inverter; if it occurs while charging, turn down the charge rate. If this fault occurs often, ensure the inverter is in a cool location, has adequate ventilation and the internal cooling fans are operational.

5.3.3.2 Remote Fault Message – The remote control may not be functioning correctly and can also display a fault condition. Refer to the following fault message to help troubleshoot the remote.



Fatal Error $ appears on the LCD and the FAULT (red) LED is on. The PWR (green), CHG (green) and INV (green) LED's are normally off.

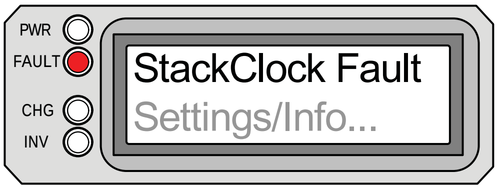
Figure 5-24, Fatal Error $ Fault

- **Fatal Error $** - This fault message indicates that the remote's internal data addressing was unrecognizable; similar to a computer lock-up.

Remedy: Reset the remote by disconnecting the remote communications cable from the inverter for 5 seconds and then reconnect (see figure 2-2). If the fault continues after resetting the remote, the remote requires service at an authorized service facility.

Info: The bottom line may not display correct information while the Fatal Error $ fault condition is displayed; ignore any remote display information during a Fatal Error $ fault.

5.3.3.3 Stacking Fault Messages – A fault condition may occur when two inverters are stacked together - using the stacking interface to provide 120/240VAC output - that is not possible on a single inverter installation. Refer to the following fault messages to help troubleshoot the inverters.



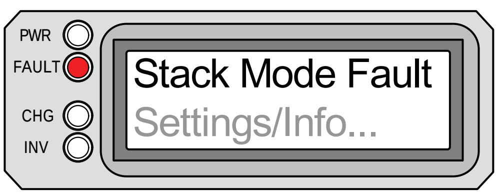
StackClock Fault appears on the LCD and the FAULT (red) LED is on. The PWR (green), CHG (green) and INV (green) LED's are off.

Figure 5-25, StackClock Fault

- **StackClock Fault** - There is a stacker cable problem; or 2. One inverter is losing synchronization with the other inverter.

Remedy: 1. Ensure you are using a Magnum Stacking Cable (this is not a telephone/data cable, this is a custom made cable). 2. Inspect the stacker cable and reconnect at both ends (listen and make sure you hear an audible "click" from the connectors at both inverters).

This fault has been known to occur when a Magnum Energy accessory is plugged into the Stack Port, but the installation is not using multiple inverters in a stacked configuration. If this occurs, perform an inverter reset (see section 6.2).

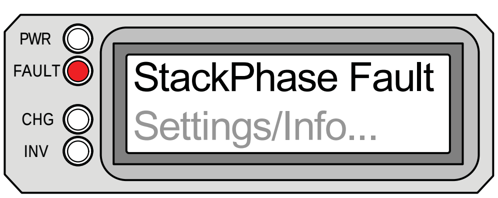


Stack Mode Fault appears on the LCD and the FAULT (red) LED is on. The PWR (green), CHG (green) and INV (green) LED's are off.

Figure 5-26, Stack Mode Fault

- **Stack Mode Fault -** This unit has detected a problem with the "other" stacked inverter, check that unit for a fault condition.

Remedy: This fault will automatically clear when the fault with the other inverter is corrected.



StackPhase Fault appears on the LCD and the FAULT (red) LED is on. The PWR (green), CHG (green) and INV (green) LED's are off.

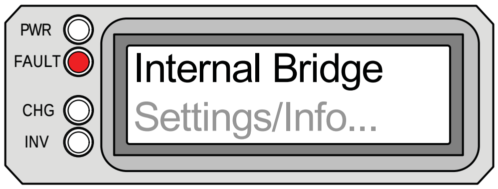
Figure 5-27, StackPhase Fault

- **StackPhase Fault -** 1. The AC input wiring is incorrect; or 2. One phase was lost from the AC input source; or 3. One of the inverter's internal transfer relay is bad; or 4. The inverter's AC input circuit breaker may be open.

Remedy: If this fault doesn't clear after checking these four recommendations; perform an inverter reset (see section 6.2).

5.3.3.4 Internal Fault Messages - The inverter continually monitors several internal components. If an condition inside the inverter occurs that does not allow proper operation, the inverter will shutdown to help protect itself. To clear these "internal" type of faults, the inverter will require an inverter reset.

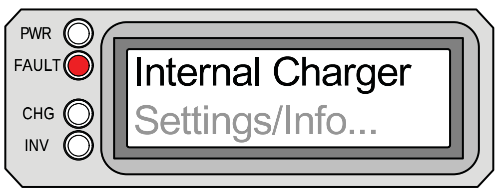
Remedy: Perform an inverter reset; see section 6-2. After the re-setting the inverter, press the ON/OFF INVERTER pushbutton to turn the inverter on and verify the fault has cleared. If the "internal" fault remains, the inverter will require repair at a service facility.



Internal Bridge appears on the LCD and the FAULT (red) LED is on. The PWR (green), CHG (green) and INV (green) LED's are off.

Figure 5-28, Internal Bridge Fault

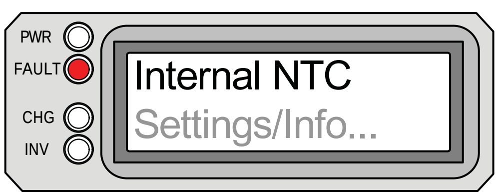
- **Internal Bridge** – This fault message displays and the inverter shuts down because the internal power-bridge protection circuit has been activated.



Internal Charger appears on the LCD and the FAULT (red) LED is on. The PWR (green), CHG (green) and INV (green) LED's are off.

Figure 5-29, Internal Charger Fault

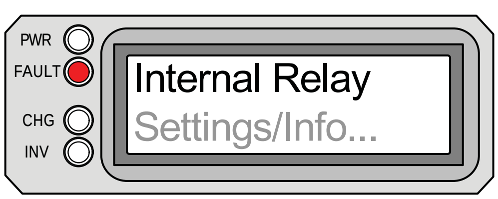
- **Internal Charger** - This fault message displays and the inverter shuts down because the internal charger protection circuit has been activated.



Internal NTC appears on the LCD and the FAULT (red) LED is on. The PWR (green), CHG (green) and INV (green) LED's are off.

Figure 5-30, Internal NTC Fault

- **Internal NTC** - This fault message displays and the inverter shuts down because the internal NTC (temperature sensor) circuit has been activated.



Internal Relay appears on the LCD and the FAULT (red) LED is on. The PWR (green), CHG (green) and INV (green) LED's are off.

Figure 5-31, Internal Relay Fault

- **Internal Relay** - This fault message displays and the inverter shuts down because the internal AC transfer relay protection circuit has been activated.

5.3.4 LED Indicator Guide

The remote provides the following LED's; use them along with the LCD display to determine the operating status.

Table 5-1, LED Indicator Guide

LED	Status	Meaning
PWR (green)	OFF	1. Remote is in Power Saver mode - press METER pushbutton to activate LED's; or 2. No power to remote (check remote cable or power to inverter); or 3. No AC power from inverter, shore or generator at inverter's AC output terminals.
	ON	AC power is available from inverter, shore or generator at the inverter's AC output terminals.
FAULT (red)	OFF	Normal operation.
	ON	A fault condition has been detected, check the LCD display to find and correct the cause.
CHG (green)	OFF	1. Remote is in Power Saver mode - press the METER pushbutton to activate LED's; or 2. Charger off - no utility or AC generator present.
	ON	Bulk, Absorb, Float or Equalize charge mode (see the LCD display to determine charge status).
	BLINKING (faster than 1/sec)	Utility or AC generator power is detected on the inverter's AC input. The LCD display will <u>not</u> show a charging status.
	BLINKING (slower than 1/sec)	Battery Saver mode - the charger is monitoring and maintaining the batteries. The LCD display will show "Full Charge".
		Charger Standby - the ON/OFF CHARGER pushbutton was pressed to disable the charger. The LCD display will show "Charger Standby".
	BLINKING (faster than 1/sec)	Charger Back-off - the internal temperature is getting hot so the charger is automatically reducing the charge rate to maintain temperature. The LCD display will show a charging status.
	BLINKING (every other sec)	Low AC Input Voltage - the input AC voltage is below 85 VAC. The charger has been automatically disabled to help stabilize incoming AC voltage.
INV (green)	OFF	1. Remote is in Power Saver mode - press the METER pushbutton to activate LED's; or 2. Inverter is disabled.
	ON	Inverter is enabled - 1. Supplying AC power on the output; or 2. In standby (if both INV and CHG LED's are on); the inverter will automatically supply AC power to the loads if shore or generator power is lost.
	BLINKING	Inverter is in search mode (the AC load is below the *SETUP: 01 Search Watts* setting).

6.0 Troubleshooting

The remote may not function correctly, use the following table to help find a solution.

Table 6-1, Remote Control Troubleshooting Guide

Symptom	Possible Cause	Solution
Display shows unrecognizable letters or symbols.	Static electricity may have been discharged into the LCD display	**Reset remote**: disconnect remote communications cable from inverter for 5 seconds and reconnect (see figure 2-2).
Display shows "fatal error" or "illegal address".	The remote's internal data addressing was unrecognizable.	**Reset remote**: disconnect remote communications cable from inverter for 5 seconds and reconnect (see figure 2-2).
LCD text display is locked-up, pushing any pushbutton has no response - may show "revision" or "connecting".	RJ11 connections on communication cable are not making a good connection	**Reset remote**: 1) disconnect remote cable from inverter for 5 seconds and reconnect; 2) check RJ11 cable connection on back of remote (see figure 2-2). Important: ensure the RJ11 connector is pushed into the correct port; you should feel/ hear "click" when the connection is made.
	Remote not getting sufficient power from inverter.	Ensure inverter batteries are connected and inverter is operating correctly; inverter should be able to invert and power AC loads from batteries (ensure no AC power is connected to the inverter AC inputs).
LEDs and backlight are off.	Remote is in Power Saver mode.	Press METER pushbutton to reactivate remote (or defeat Power saver mode).
Remote is non-functional (no lights, no text on LCD display and no response when pressing any pushbutton).	Communication cable bad or not correctly connected to remote port on inverter.	Check communications cable from inverter to remote; ensure: 1) it is connected to the REMOTE port, 2) the correct communications cable is used (a 4-conductor telephone cable may be substituted to determine if cable is good).
	Inverter is not connected to batteries.	Ensure inverter batteries are connected and inverter is operating correctly without any AC power connected (can invert and power AC loads from batteries).

6.0 Troubleshooting

6.1 Troubleshooting Tips -

6.1.1 Inverter problems:

- Inverter turned on, green led on inverter blinking, no output: Inverter is in search mode. Either defeat search mode - if not needed - or turn on loads greater than the Search Watts setting.

6.1.2 Charger problems:

- **Unit won't transfer to charge mode with AC applied:** Is charge (CHG) LED on remote blinking? If not, then the charger does not recognize the incoming AC being within acceptable limits. Measure the input AC voltage, it should be 120VAC +/ 20 VAC; also check that VAC dropout setting on the remote is 80 VAC or less. If the CHG LED is blinking, the transfer relay should be closing within 20 seconds, and begin charging. If the LED is on solid, the relay should be closed, and the charger should begin charging.

- **Transfer relay closes then opens and continues to cycle:** AC voltage is too low, or has transients that drop the AC voltage momentarily. Change the VAC Dropout setting to 80 VAC or 60 VAC and check for improvements. If the cycling continues, back off the *Charge Rate* from 100% to 50%.

This cycling may also be caused if the AC output of the inverter is connected to the inverter's AC input, check for proper input and output AC wiring.

- **Charger not charging even though charge LED is on steady and the unit says "Charging":** Full charge rates are not obtained in "Charging" mode, only after this mode changes to "Bulk Charging", "Absorb Charging" or "Float Charging" modes.

- **Charger not charging even though charge LED is on steady and the unit says "Bulk Charging" (or "Absorb Charging"):** Check the DC amps meter, and DC voltmeter on the ME-RC display, it should be 80% or more of rated charge current if the battery voltage is under 14.0 VDC (28.0 VDC on 24-volt models or 48.0 VDC for 48-volt models). If not, check the *Charge Rate* setting and verify the setting is 80% or greater. Still low charge rate? Check the *Shore Amps* setting to verify setting. If no AC loads are being "passed thru" the inverter, the S*hore Amps* setting must be 15 amps (25 amps for 3kW unit) or greater, to receive full charge rate.

- **Charger says "Float Charging" not "Bulk Charging" when the AC is first plugged in:** Check DC voltmeter on the ME-RC display, if the battery is over 13.0 VDC (26.0 VDC for a 24-volt unit or 52.0 VDC for 48-volt models) then the battery was already charged and the charger automatically goes to "Float Charging" to keep from overcharging the batteries.

- **Charge amps are lower than expected, or is 0 amps DC:** Measure input AC voltage and increase if the input voltage is under 90 VAC. The charge rate is reduced to try and keep the input voltage above 90 VAC; also check the *Shore Max* and *Charger Rate* settings to determine if the current is being limited.

- **Charger output voltage is higher than expected:** Check the Battery Temperature Sensor (BTS) temperature. If the BTS is installed, the charge voltage settings will increase if the temperature around the BTS is below 77° F (25° C) and decrease if the temperature around the BTS is higher than 77° F (25° C).

6.2 Performing an Inverter Reset

If the remote shows an 'internal' fault or the inverter needs to be reset; press and hold the Power ON/OFF pushbutton (see figure 6-1) for at least fifteen (15) seconds until the Charging/Inverting LED comes on and flashes rapidly to indicate the inverter has reset. Once the rapid flashing has begun, release the Power ON/OFF pushbutton. After the inverter reset is completed, check the remote display to verify that the fault has cleared.

Some older inverter models do not allow an inverter reset, if the inverter reset fails, you will need to power-down the inverter using the procedure below. In either case, if an "internal fault" does not clear, the inverter will require repair at an authorized service facility.

Info: The Power ON/OFF pushbutton is a small momentary type switch which operates by lightly pressing and releasing.

Info: All adjustable inverter/charger settings in the ME-RC (except for the *SHORE: Shore Max* and *SETUP: 08 Scrn Contrast* settings - which revert back to default) are saved in non-volatile memory and are preserved until changed - even if an inverter reset is performed or if all power to the remote or inverter is removed.

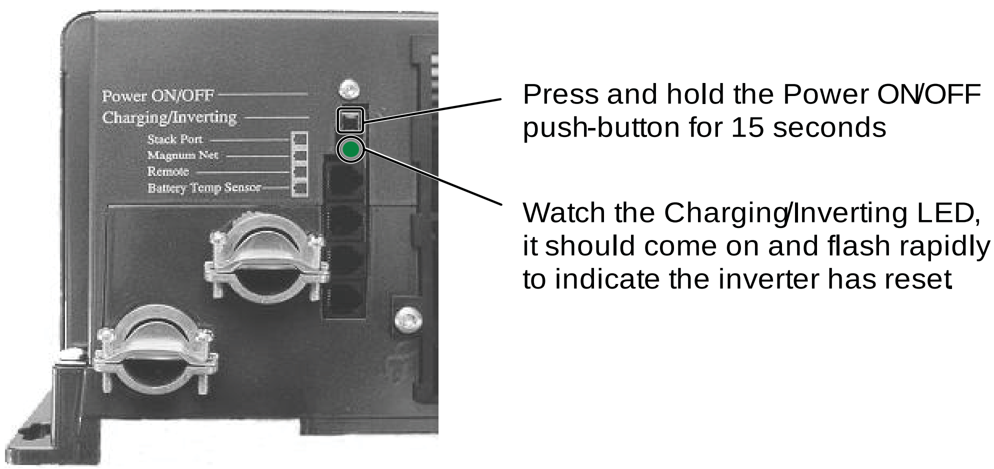


Figure 6-1, Performing an Inverter Reset

6.3 Powering-down the Inverter

Perform the following steps to power-down the inverter:

1. Remove all AC power (utility or generator power) to the inverter.
2. Disconnect the positive battery cable to the inverter.
3. Ensure the inverter and remote control are disconnected from all AC and DC power (the remote display will be blank).

After the inverter has been disconnected from all power for 30 seconds, re-connect the positive battery cable and resume operation.

Info: There may be a momentary spark when the positive battery cable is connected to the inverter's terminal; this is normal and indicates that the inverter's internal capacitors are being charged.

7.0 Limited Warranty

Magnum Energy, Inc., warrants the ME-RC remote control to be free from defects in material and workmanship that result in product failure during normal usage, according to the following terms and conditions:

1. The limited warranty for this product extends for a maximum of 24 months from the product's original date of purchase; or for the same period as the connected Magnum Energy inverter if the inverter and remote are newly installed at the same time up to a maximum of 36 months.

2. The limited warranty extends to the original purchaser of the product and is not assignable or transferable to any subsequent purchaser.

3. During the limited warranty period, Magnum Energy will repair, or replace at Magnum Energy's option, any defective parts, or any parts that will not properly operate for their intended use with factory new or rebuilt replacement items if such repair or replacement is needed because of product malfunction or failure during normal usage. The limited warranty does not cover defects in appearance, cosmetic, decorative or structural parts or any non-operative parts. Magnum Energy's limit of liability under the limited warranty shall be the actual cash value of the product at the time the original purchaser returns the product for repair, determined by the price paid by the original purchaser. Magnum Energy shall not be liable for any other losses or damages.

4. Upon request from Magnum Energy, the original purchaser must prove the product's original date of purchase by a dated bill of sale, itemized receipt.

5. The original purchaser shall return the product prepaid to Magnum Energy in Everett, WA. After the completion of service under this limited warranty, Magnum Energy will return the product prepaid to the original purchaser via a Magnum-selected non-expedited surface freight within the contiguous United States and Canada; this excludes Alaska and Hawaii.

6. If Magnum repairs or replaces a product, its warranty continues for the remaining portion of the original warranty period or 90 days from the date of the return shipment to the original purchaser, whichever is greater. All replaced products and parts removed from repaired products become the property of Magnum Energy.

7. This limited warranty is voided if:

- the product has been modified without authorization,
- the serial number has been altered or removed,
- the product has been damaged through abuse, neglect, accident, high voltage or corrosion.
- the product was not installed and operated according to the owner's manual.

BEFORE RETURNING ANY UNIT, CONTACT MAGNUM ENERGY FOR A RETURN MATERIAL AUTHORIZATION (RMA) NUMBER.

MAGNUM
ENERGY

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PN: 64-0003 Rev 3

Minarik Automation & Control

USER'S MANUAL

DC Series

Pulse-Width Modulated,
Adjustable Speed Drives
for DC Brush Motors

Models:
DC16-12/24
DC60-12/24
DC60-36/48

The Minarik DC Series drives are chassis drives that accept a DC input voltage and output a DC power voltage to control the speed of a low voltage motor. The speed may be controlled with a potentiometer or an external voltage signal.

Standard Features:

- Provides smooth variable capability for mobile equipment.
- Maintains variable speed control as batteries discharge.
- Adjustable min speed, max speed, IR compensation, current limit, and accel.
- Inhibit terminal permits optional start-stop without breaking battery lines.
- Speed potentiometer included.
- Increases range or running time of battery operated equipment through high efficiency.
- Power LED gives a visual indication when power is applied to the drive.
- Jumper reconnectable for low or high voltage.

Printed in the United States of America.

Safety Warnings

- This symbol ⚠ denotes an important safety tip or warning. **Please read these instructions carefully** before performing any of the procedures contained in this manual.

- **DO NOT INSTALL, REMOVE, OR REWIRE THIS EQUIPMENT WITH POWER APPLIED.** Minarik assumes the qualified technician is intimate with the dangers involving batteries, especially lead-acid type. This manual presupposes that you have taken all the necessary precautions to prevent a potentially fatal accident involving such batteries, and have followed all standard electrical precautions.

- Reduce the chance of an electrical fire, shock, or explosion by proper grounding, over-current protection, thermal protection, and enclosure. Follow sound maintenance procedures.

⚠ **It is possible for a drive to run at full speed as a result of a component failure.** Minarik strongly recommends the installation of a master switch in the main power input to stop the drive in an emergency.

This drive is isolated from earth ground. Avoid direct contact with the printed circuit board or with circuit elements to prevent the risk of serious injury or fatality. Use a non-metallic screwdriver for adjusting the calibration trimpots. Use approved personal protective equipment and insulated tools if working on this drive with power applied.

Contents

Illustrations

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Specifications

Model	Max. Armature Current (Amps DC)	Max. Armature Voltage[3] (VDC)	DC Voltage Input Range (VDC)
DC16-12/24	16 [1]	12 or 24 [2]	10–32
DC60-12/24	60	12 or 24 [2]	10–32
DC60-36/48	60	36 or 48 [2]	32–50

Acceleration Time Range	0.5 – 10 seconds
Deceleration Time	0.5 seconds
Analog Input Voltage Range (signal must be isolated; S1 to S2)	0 – 10 VDC
Input Impedance (S1 to S2)	200KΩ
Speed Regulation (% of base speed)	1%
Speed Range	80:1
Form Factor	1.01
Ambient Operating Temperature Range	10°C – 40°C
Weight	
DC16-12/24	1.7 lbs.
DC60-12/24	3.6 lbs.
DC60-36/48	3.6 lbs.

1 At 40°C ambient. No additional heat sink is necessary.

2 Or up to 95% of available battery voltage.

3 The lower maximum armature voltage is selectable by connecting a jumper to pins 2 and 3 of JP501 (see page 8).

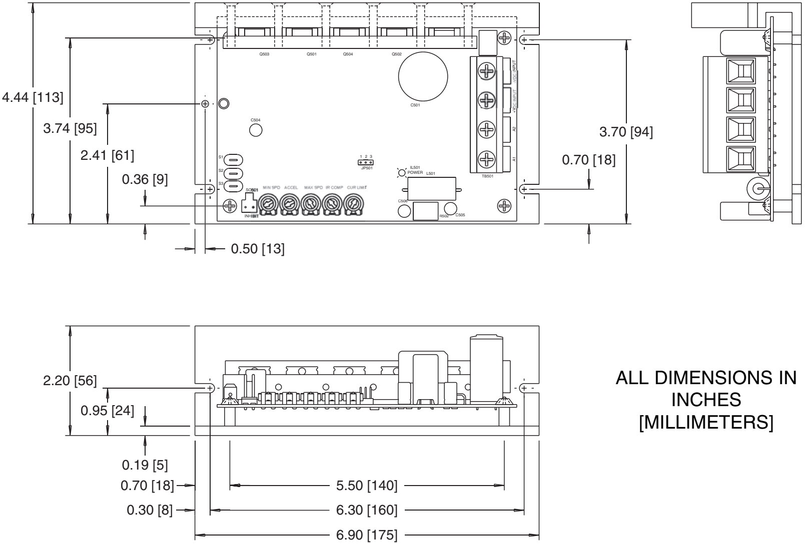

Figure 1. DC16-12/24 Dimensions

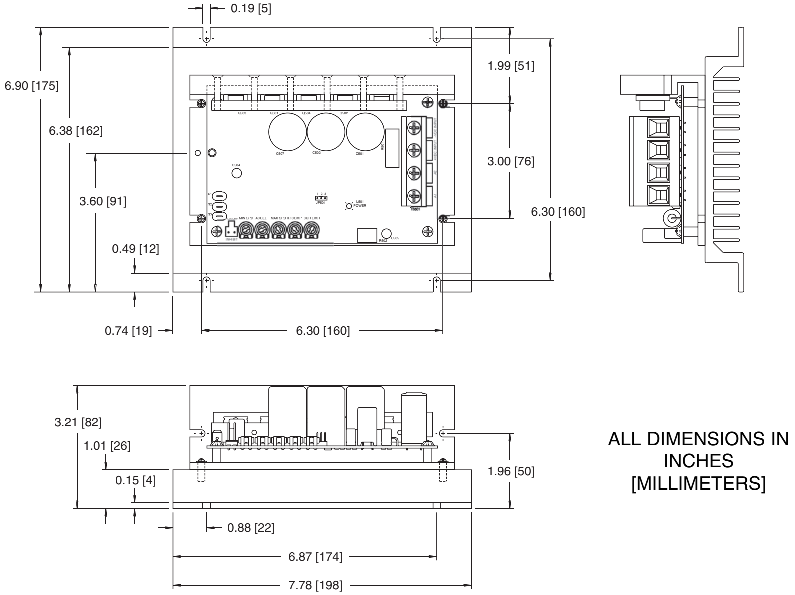

Figure 2. DC-12/24 and DC60-36/48 Dimensions

Installation

Mounting

Warning

Do not install, rewire, or remove this control with input power applied. Doing so may cause fire or serious injury. Make sure you have read and understood the Safety Warnings on page i before attempting installation.

- Drive components are sensitive to electrostatic fields. Avoid contact with the circuit board directly. Hold drive by the chassis only.
- Protect the drive from dirt, moisture, and accidental contact.
- Provide sufficient room for access to the terminal block and calibration trimpots.
- Mount the drive away from other heat sources. Operate the drive within the specified ambient operating temperature range.
- Prevent loose connections by avoiding excessive vibration of the drive.
- Mount drive with its board in either a horizontal or vertical plane. Six 0.19 in. (5 mm) wide slots in the chassis accept #8 pan head screws. Fasten either the large base or the narrow flange of the chassis to the subplate.

Wiring

Warning

Do not install, remove, or rewire this equipment with power applied. Failure to heed this warning may result in fire, explosion, or serious injury.

This drive is isolated from earth ground. To prevent the risk of injury or fatality, avoid direct contact with the printed circuit board or with circuit elements.

Do not disconnect any of the motor leads from the drive unless power is removed. Opening any one motor lead may destroy the drive.

This drive is not diode-protected from reverse battery voltage. You must assure that POS (+) is wired to +VDC IN and NEG (–) is wired to –VDC IN.

Use 18 AWG wire for speed adjust potentiometer wiring.

- Size the DC voltage input and motor wire according to the following chart:

Table 1. Wire Gauge/Length Chart

Armature Current (amps)	Wire Gauge (AWG)	Maximum Wire Length (feet)
0 – 19	14	8
20 – 32	10	10
60	8	10

Shielding guidelines

⚠ Warning

Under no circumstances should power and logic leads be bundled together. Induced voltage can cause unpredictable behavior in any electronic device, including motor controls.

As a general rule, Minarik recommends shielding of all conductors.

If it is not practical to shield power conductors, Minarik recommends shielding all logic-level leads. If shielding of logic level leads is not practical, the user should twist all logic leads with themselves to minimize induced noise.

It may be necessary to earth ground the shielded cable. If noise is produced by devices other than the drive, ground the shield at the drive end. If noise is generated by a device on the drive, ground the shield at the end away from the drive. Do not ground both ends of the shield.

If the drive continues to pick up noise after grounding the shield mount the drive in a less noisy environment.

Logic wires from other input devices, such as motion controllers and PLL velocity controllers, must be separated from power lines in the same manner as the logic I/O on this drive.

Heat sinking

DC60-12/24 and DC60-36/48 drives are pre-mounted on heat sink part number 223-0434. For optimum heat transfer, mount the drive with heatsink fins standing vertically as shown in Figure 3 below.

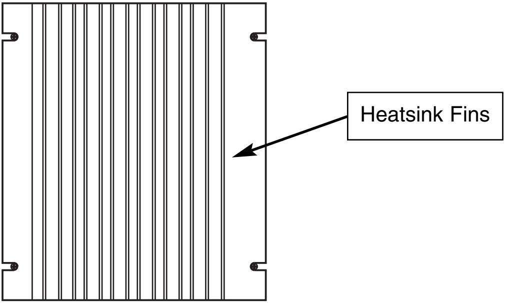

Figure 3. Heatsink mounting

Fuse / Circuit breaker protection

All Minarik drives should be protected by a fuse or circuit breaker. Use a fast acting fuse or circuit breaker rated for approximately 200% of the maximum armature current and armature voltage. Connect the fuse or circuit breaker to the VDC+ IN side of the DC voltage input.

Jumper 501 (JP501)

Minarik DC series drives are shipped with JP501 open (no jumper applied). This allows you to use 24 VDC motors with the DC16-12/24 and DC60-12/24, or 48 VDC motors with the DC60-36/48. To use lower voltage DC motors (12 VDC or 36 VDC, respectively) jumper pins 2 and 3 with the jumper provided. See Figure 4 for the location of JP501.

DC16-12/24 = 16 Amp 12/24 VDC
DC60-12/24 = 60 Amp 12/24 VDC
DC60-36/48 = 60 Amp 36/48 VDC

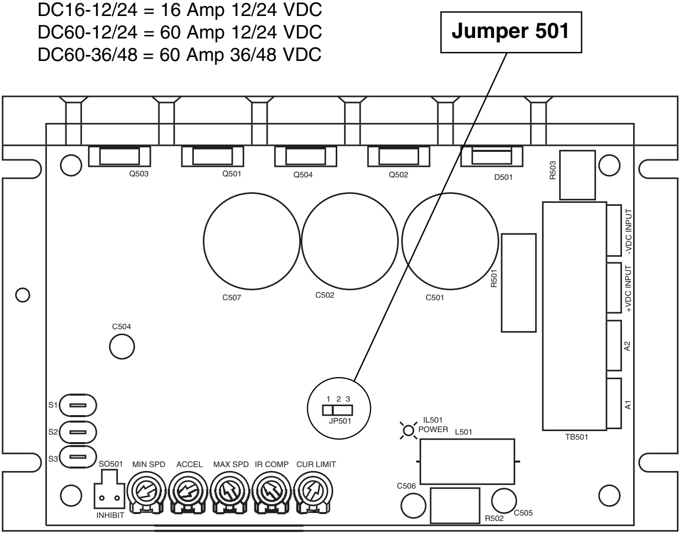

Figure 4. Jumper 501 (JP501)

Speed adjust potentiometer

> ⚠ **Warning**
>
> Be sure that the potentiometer tabs do not make contact with the potentiometer enclosure. Grounding the input will cause damage to the drive.

Mount the speed adjust potentiometer through a 0.38 in. (10 mm) hole with the hardware provided (see Figure 5 on Page 10). Install the circular insulating disk between the panel and the 10K ohm speed adjust potentiometer.

Twist the speed adjust potentiometer wire to avoid picking up unwanted electrical noise. If speed adjust potentiometer wires are longer than 18 in. (457 mm), use shielded cable. Keep speed adjust potentiometer wires separate from power leads (L1, L2, A1, A2).

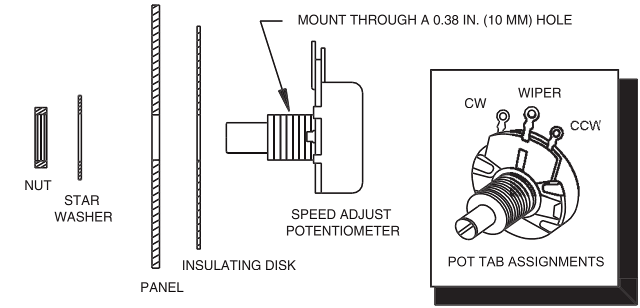

Figure 5. Speed Adjust Potentiometer

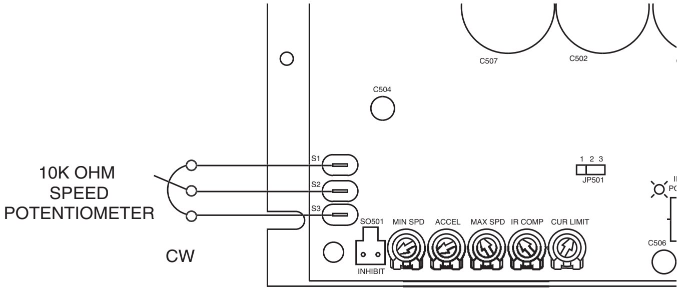

Figure 6. Speed Adjust Potentiometer Connections

Connections

> ⚠ **Warning**
>
> **Do not connect this equipment with power applied.** Failure to heed this directive may result in fire or serious injury.
>
> **Minarik strongly recommends the installation of a master power switch in the voltage input line, as shown in Figure 7, page 13.** The switch contacts should be rated at a minimum of 200% of motor nameplate current and 150% of the input voltage.

Power, fuse and motor connections

Connect the power input leads, an external line fuse and a motor to the drive's printed circuit board (PCB) as shown in Figure 7, page 13.

Motor

Minarik drives supply motor voltage from A1 and A2 terminals. It is assumed throughout this manual that, when A1 is positive with respect to A2, the motor will rotate clockwise (CW) while looking at the output shaft protruding from the front of the motor. If this is opposite of the desired rotation, simply reverse the wiring of A1 and A2.

Connect a DC motor to PCB terminals A1 and A2 as shown in Figure 7, page 13. **Ensure that the motor voltage rating is consistent with the drive's output voltage.**

Power input

Warning

This drive is not diode-protected from reverse battery voltage. You must assure that POS (+) is wired to +VDC IN and NEG (–) is wired to –VDC IN.

Connect the DC power leads to terminals + VDC IN and - VDC IN, or to a single-throw, single-pole master power switch as shown in Figure 7, page 13 (recommended).

Fuse

Wire a power input fuse between the stop switch (if installed) and the + VDC IN terminal on the circuit board. The fuse should be rated at 150% of input voltage and 150 - 200% of maximum motor nameplate current.

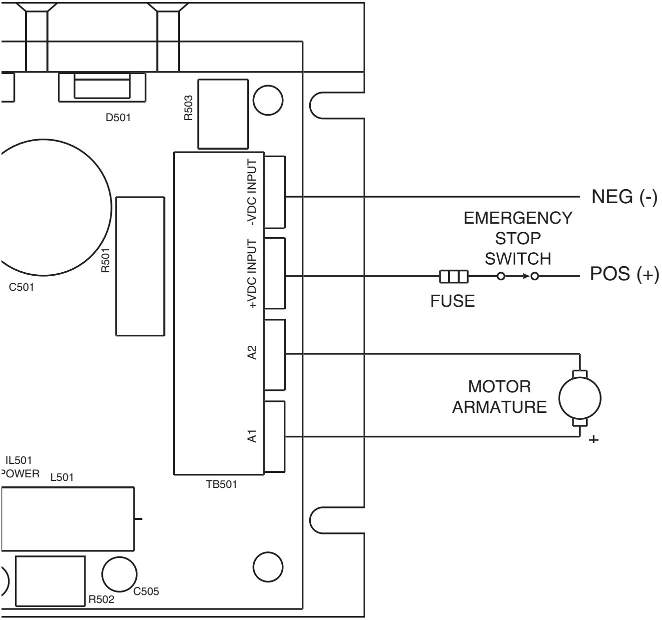

Figure 7. Power, Fuse and Motor Armature Connections

Voltage follower

Instead of using a speed adjust potentiometer, the drive may be wired to follow an isolated (floating, or differential) 0–10 VDC signal that is isolated from earth ground (Figure 8). Connect the signal input (+) to S2. Connect the signal common (–) to S1. Make no connection to S3. A potentiometer can be used to scale the analog input voltage.

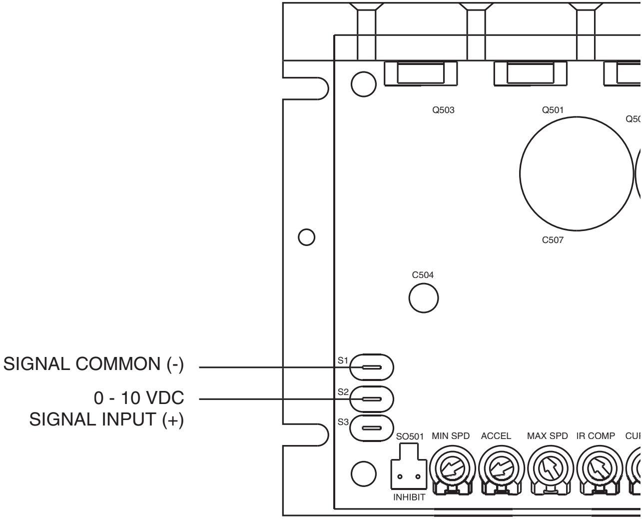

Figure 8. Voltage Follower Connections

Operation

Warning

Dangerous voltages exist on the drive when it is powered, and up to 30 seconds after power is removed and the motor stops. BE ALERT. High voltages can cause serious or fatal injury. For your safety, use personal protective equipment (PPE) when operating this drive.

Before applying power

- Verify that no conductive material is present on the printed circuit board.

- Ensure that all jumpers are properly set.

Startup and shutdown

To start the drive:

1. Turn the speed adjust potentiometer full counterclockwise (CCW), or set the voltage signal to zero.
2. Apply DC voltage input.
3. Slowly advance the speed adjust potentiometer clockwise (CW), or increase the voltage signal. The motor slowly accelerates as the potentiometer is turned CW or the voltage signal is increased. Continue until the desired speed is reached.
4. Remove DC voltage input from the drive to coast the motor to a stop.

If the motor or drive does not perform as described, disconnect the DC voltage input immediately. Refer to the Troubleshooting section (page 33) for further assistance.

Starting and stopping methods

> **Warning!**
>
> Decelerating to minimum speed or coasting to a stop is recommended for frequent starts and stops. Do not use any of these methods for emergency stopping. They may not stop a drive that is malfunctioning. Removing DC line power is the only acceptable method for emergency stopping.
>
> For this reason, **Minarik strongly recommends installing an emergency stop switch** (see figure 7, page 13).

Frequent decelerating to minimum speed produces high torque. This may cause damage to motors, especially gearmotors that are not properly sized for the application.

Automatic restart upon power restoration

All drives automatically run to set speed when power is applied.

Line starting and line stopping

Line starting and line stopping (applying and removing DC voltage input) is recommended for infrequent starting and stopping of a drive only. When DC voltage input is applied to the drive, the motor accelerates to the speed set by the speed adjust potentiometer. When DC voltage input is removed, the motor coasts to a stop.

Decelerating to minimum speed

A single pole, single throw switch may be used to decelerate a motor to minimum speed (see Figure 9). Close the switch between S1 and S2 to decelerate the motor from set speed to minimum speed. Open the switch to accelerate the motor from minimum speed to set speed. The ACCEL trimpot setting determines the rate at which the motor accelerates.

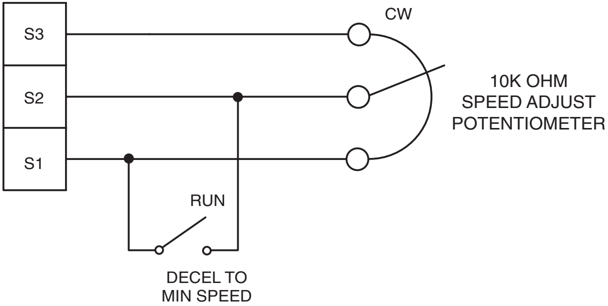

Figure 9. Run/Decelerate to Minimum Speed Switch

Inhibit terminals

Short the INHIBIT terminals to coast the motor to zero speed (see Figure 10 for INHIBIT terminal location). Reopen the INHIBIT terminals to accelerate the motor to set speed.

Twist inhibit wires and separate them from other power-carrying wires or sources of electrical noise. Use shielded cable if the inhibit wires are longer than 18 inches (46 cm). If shielded cable is used, ground only one end of the shield to earth ground. Do not ground both ends of the shield. See Shielding Guidelines, page 6.

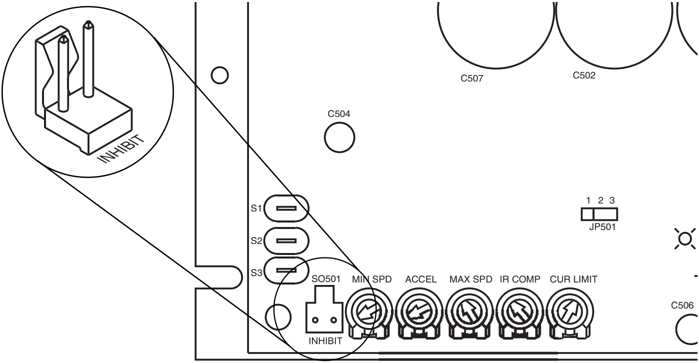

Figure 10. Inhibit Terminals

Power LED (IL501)

The power LED (IL501) lights whenever DC line voltage is applied to the drive. See Figure 11 below for the power LED location.

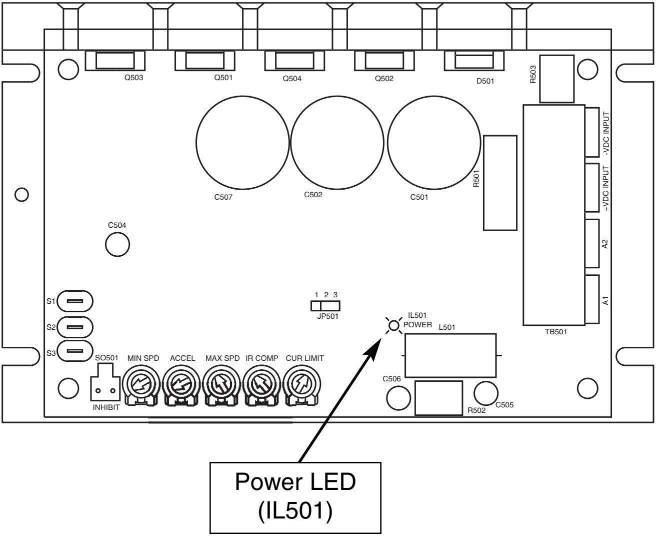

Figure 11. Power LED

Calibration

Warning

Dangerous voltages exist on the drive when it is powered, and up to 30 seconds after power is removed and the motor stops. When possible, disconnect the voltage input from the drive before adjusting the trimpots. If the trimpots must be adjusted with power applied, use insulated tools and the appropriate personal protection equipment. BE ALERT. High voltages can cause serious or fatal injury.

Each drive is factory calibrated to its maximum armature voltage and current rating. Readjust the calibration trimpot settings to accommodate a motor with a lower armature voltage and current rating.

All adjustments increase with clockwise rotation (CW), and decrease with counter-clockwise rotation (CCW). Use a non-metallic screwdriver for calibration. Each trimpot is identified on the printed circuit board (see Figure 12).

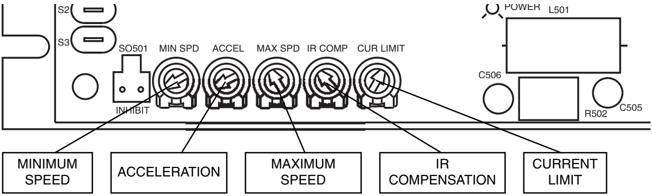

Figure 12. Calibration Trimpot Layout

MINIMUM SPEED (MIN SPD)

The MIN SPD setting determines the motor speed when the speed adjust potentiometer is turned full CCW. It is factory set for zero speed.

To calibrate MIN SPD:

1. Set the MAX SPD trimpot to full CW.
2. Set the MIN SPD trimpot to full CCW.
3. Turn the main speed adjust potentiometer to full CCW. If an input voltage is used instead of a speed adjust potentiometer, set the input signal to minimum.
4. Adjust the MIN SPD trimpot until the desired minimum motor speed is reached.

MAXIMUM SPEED (MAX SPD)

The MAX SPD setting determines the motor speed when the speed adjust potentiometer is turned full CW. It is factory set for maximum rated speed.

To calibrate MAX SPD:

1. Set the MAX SPD trimpot full CCW.
2. Apply power to the drive and turn the speed adjust potentiometer full CW. If an input voltage signal is used instead of a speed adjust pot, set the input signal to maximum.
3. Adjust the MAX SPD trimpot until the desired maximum motor speed is reached.

ACCELERATION (ACCEL)

The ACCEL setting determines the time the motor takes to accelerate to a higher speed. See ***Specifications*** on page 1 for approximate acceleration times. The ACCEL setting is factory set to its minimum value (full CCW).

To calibrate ACCEL:

1. Set the ACCEL trimpot full CCW.
2. Apply power to the drive and turn the main speed adjust potentiometer full CW. If an input voltage signal is used instead of a speed adjust pot, set the input signal to maximum. Note the time that the drive takes to accelerate to the desired speed.
3. Adjust the ACCEL trimpot until the desired acceleration time is reached. Turn the ACCEL trimpot CW to increase the acceleration time, and CCW to decrease the acceleration time.

IR COMPENSATION (IR COMP)

The IR COMP setting determines the degree to which motor speed is held constant as the motor load changes. It is factory set for optimum motor regulation.

Use the following procedure to recalibrate the IR COMP setting :

1. Set the IR COMP trimpot to minimum (full CCW).
2. Rotate the speed adjust potentiometer until the motor runs at midspeed without load (for example, 900 RPM for an 1800 RPM motor). A hand held tachometer may be used to measure motor speed.
3. Load the motor armature to its full load armature current rating. The motor should slow down.
4. While keeping the load on the motor, rotate the IR COMP trimpot until the motor runs at the speed measured in step 2. If the motor oscillates (overcompensation), the IR COMP trimpot may be set too high (CW). Turn the IR COMP trimpot CCW to stabilize the motor.
5. Unload the motor.

CURRENT LIMIT (CUR LIMIT)

Warning

CURRENT LIMIT should be set to 120% of motor nameplate current rating. Continuous operation beyond this setting may damage the motor. If you intend to operate beyond the rating, contact your Minarik representative.

The CURRENT LIMIT setting determines the maximum armature current output of the drive.

Recalibrate the CUR LIMIT setting when a lower current limit is required. Refer to the CUR LIMIT settings in Figure 13, page 26, or recalibrate using the following procedure:

1. With the power disconnected from the control, connect a DC ammeter in series with the armature.
2. Set the CUR LIMIT trimpot to minimum (full CCW).
3. Set the speed adjust potentiometer to maximum (full CW).
4. Carefully lock the motor armature. Be sure that the motor is firmly mounted.
5. Apply line power. The motor should be stopped.
6. Slowly adjust the CUR LIMIT trimpot CW slowly until the armature current is 120% of motor rated armature current.
7. Set the speed adjust potentiometer, or input voltage to minimum.
8. Remove the power from the drive and unlock the motor shaft.
9. Remove the ammeter in series with the motor armature if it is no longer needed and re-apply power to the drive.

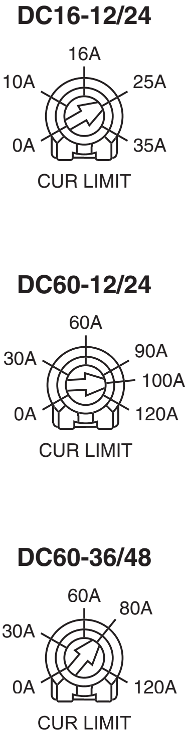

Figure 13. Approximate CUR LIMIT Settings

Application Notes

Multiple fixed speeds

Replace the speed adjust potentiometer with series resistors with a total series resistance of 10K ohms (Figure 14). Add a single pole, multi-position switch with the correct number of positions for the desired number of fixed speeds.

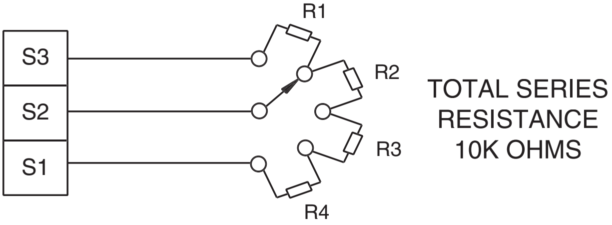

Figure 14. Multiple Fixed Speeds

Adjustable speeds using potentiometers in series

Replace the speed adjust potentiometer with a single pole, multi-position switch, and two or more potentiometers in series, with a total series resistance of 10K ohms. Figure 15 shows a connection for fixed high and low speed adjust potentiometers.

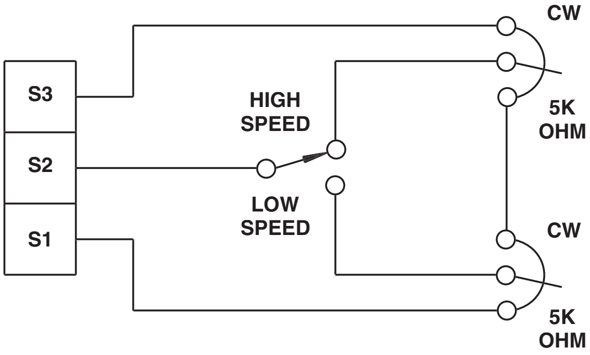

Figure 15. Adjustable Fixed Speeds Using Potentiometers in Series

Independent adjustable speeds

Replace the speed adjust potentiometer with a single pole, multi-position switch, and two or more potentiometers in parallel, with a total parallel resistance of 10K ohms. Figure 16 shows the connection of two independent speed adjust potentiometers that can be mounted at two separate operating stations.

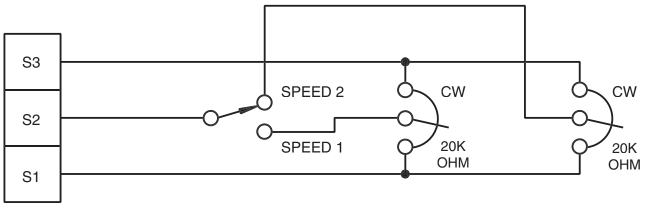

Figure 16. Independent Adjustable Speeds

RUN/JOG switch

Using a RUN/JOG switch is recommended in applications where quick stopping is not needed and frequent jogging is required. Use a single pole, two position switch for the RUN/JOG switch, and a normally closed, momentary operated pushbutton for the JOG pushbutton (see Figure 17). When the RUN/JOG switch is set to JOG, the motor decelerates to minimum speed. Press the JOG pushbutton to jog the motor. Return the RUN/JOG switch to RUN for normal operation.

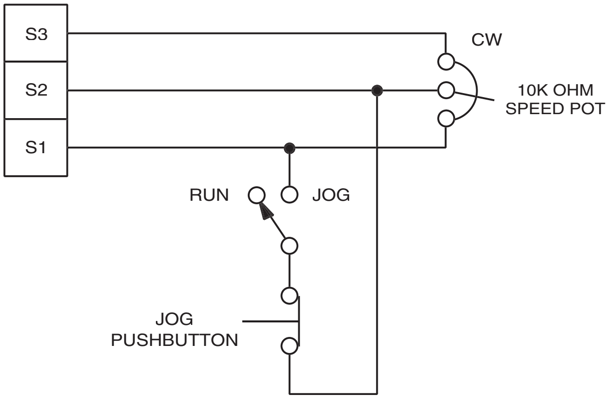

Figure 17. RUN/JOG Switch Connection to Speed Adjust Potentiometer

Reversing

Warning

Do not operate the control outside the recommended input ±10%.

Relays may be used in place of a switch, but a neutral position must be provided to prevent plug reversing (see Figure 18, page 32). DO NOT CHANGE DIRECTIONS WHILE THE MOTOR IS STILL RUNNING. Plug reversing the motor (not allowing the motor to come to a stop before reversing) will cause excessively high currents to flow in the armature circuit, which can damage the control and/or motor and is not recommended.

CAUTION

Motor and battery wire must be a minimum of 12 ga. and a maximum of 6 ga.

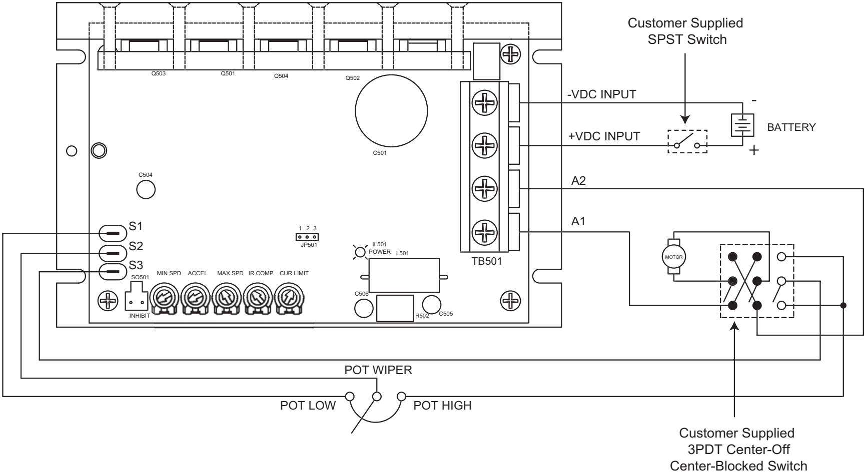

Figure 18. Reversing hookup diagram

Troubleshooting

> **Warning**
>
> Dangerous voltages exist on the drive when it is powered, and up to 30 seconds after power is removed and the motor stops. When possible, disconnect the drive while troubleshooting. High voltages can cause serious or fatal injury.

Before troubleshooting

Perform the following steps before starting any procedure in this section:

1. Disconnect DC voltage input from the drive.
2. Check the drive closely for damaged components.
3. Check that no conductive or other foreign material has become lodged on the printed circuit board.
4. Verify that all connections are correct and in good condition.
5. Verify that there are no short circuits or grounded connections.
6. Check that the drive's rated armature voltage and current is consistent with the motor ratings.

For additional assistance, contact your local Minarik distributor, or the factory direct:

Phone: (800) MINARIK or (800) 646-2745

Fax: (800) 394-6334

Symptom	Possible Causes	Suggested Solutions
Line fuse blows	1. Line fuses are the wrong size. 2. Motor cable or armature is shorted to ground. 3. Nuisance tripping caused by a combination of ambient conditions and high-current spikes.	1. Check that line fuses are the correct size. 2. Check motor cable and armature for shorts. 3. Add a blower to cool the drive components; decrease CUR LIMIT settings, or resize motor and drive for actual load demand, or check for incorrectly aligned mechanical components for “jams”. See page 25 for information on adjusting the CUR LIMIT trimpot.
Line fuse does not blow, but the motor does not run	1. Speed adjust pot or reference voltage is set to zero speed. 2. Speed adjust pot or reference voltage connections are open. 3. Drive is overloaded. 4. Drive is not receiving DC line voltage.	1. Increase speed adjust pot or reference voltage setting. 2. Check that the speed adjust pot or reference voltage connections are not open. 3. Verify that the motor is not jammed. Increase CURR LIMIT setting. 4. Apply DC line voltage to +VDC and -VDC.

Symptom	Possible Causes	Suggested Solutions
Line fuse does not blow, but the motor does not run (cont.)	5. Motor is not connected.	5. Connect motor to A1 and A2.
Motor runs too fast at maximum speed setting	1. MIN SPD and MAX SPD settings are too high.	1. Recalibrate MIN SPD and MAX SPD.
Motor runs too slow or too fast	1. MIN SPD and MAX SPD are not calibrated.	1. Recalibrate MIN SPD and MAX SPD
Motor will not reach the desired speed.	1. MAX SPD setting is too low. 2. IR COMP setting is too low. 3. Motor is overloaded.	1. Increase MAX SPD setting. 2. Increase IR COMP setting. 3. Check motor load. Resize the motor and drive if necessary.
Motor pulsates or surges under load.	1. IR COMP is set too high. 2. Control is in current limit mode.	1. Adjust the IR COMP setting slightly CCW until the motor speed stabilizes. 2. Check that motor and drive are of sufficient horsepower and amperage.

Notes

Unconditional Warranty

A. Warranty - Minarik Corporation (referred to as “the Corporation”) warrants that its products will be free from defects in workmanship and material for twelve (12) months or 3,000 hours, whichever comes first, from date of manufacture thereof. Within this warranty period, the Corporation will repair or replace, at its sole discretion, such products that are returned to Minarik Corporation, 901 East Thompson Avenue, Glendale, CA 91201-2011 USA.

This warranty applies only to standard catalog products, and does not apply to specials. Any returns for special controls will be evaluated on a case-by-case basis. The Corporation is not responsible for removal, installation, or any other incidental expenses incurred in shipping the product to and from the repair point.

B. Disclaimer - The provisions of Paragraph A are the Corporation’s sole obligation and exclude all other warranties of merchantability for use, express or implied. The Corporation further disclaims any responsibility whatsoever to the customer or to any other person for injury to the person or damage or loss of property of value caused by any product that has been subject to misuse, negligence, or accident, or misapplied or modified by unauthorized persons or improperly installed.

C. Limitations of Liability - In the event of any claim for breech of any of the Corporation’s obligations, whether express or implied, and particularly of any other claim or breech of warranty contained in Paragraph A, or of any other warranties, express or implied, or claim of liability that might, despite Paragraph B, be decided against the Corporation by lawful authority, the Corporation shall under no circumstances be liable for any consequential damages, losses, or expense arising in connection with the use of, or inability to use, the Corporation’s product for any purpose whatsoever.

An adjustment made under warranty does not void the warranty, nor does it imply an extension of the original 12-month warranty period. Products serviced and/or parts replaced on a no-charge basis during the warranty period carry the unexpired portion of the original warranty only.

If for any reason any of the foregoing provisions shall be ineffective, the Corporation’s liability for damages arising out of its manufacture or sale of equipment, or use thereof, whether such liability is based on warranty, contract, negligence, strict liability in tort, or otherwise, shall not in any event exceed the full purchase price of such equipment.

Any action against the Corporation based upon any liability or obligation arising hereunder or under any law applicable to the sale of equipment or the use thereof, must be commenced within one year after the cause of such action arises.

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OutBack Power Systems™

FLEXmax™ 60
FLEXmax™ 80

Maximum Power Point Tracking Charge Controller

User's Manual

Installation and Programming

Warranty Summary

Dear OutBack Customer,

Thank you for your purchase of OutBack products. We make every effort to assure our power conversion products will give you long and reliable service for your renewable energy system.

As with any manufactured device, repairs might be needed due to damage, inappropriate use, or unintentional defect. Please note the following guidelines regarding warranty service of OutBack products:

- Any and all warranty repairs must conform to the terms of the warranty.
- All OutBack equipment must be installed according to their accompanying instructions and manuals with specified over-current protection in order to maintain their warranties.
- The customer must return the component(s) to OutBack, securely packaged, properly addressed, and shipping paid. We recommend insuring your package when shipping. Packages that are not securely packaged can sustain additional damage not covered by the warranty or can void warranty repairs.
- There is no allowance or reimbursement for an installer's or user's labor or travel time required to disconnect, service, or reinstall the damaged component(s).
- OutBack will ship the repaired or replacement component(s) prepaid to addresses in the continental United States, where applicable. Shipments outside the U.S. will be sent freight collect.
- In the event of a product malfunction, OutBack cannot bear any responsibility for consequential losses, expenses, or damage to other components.
- Please read the full warranty at the end of this manual for more information.

The OutBack Power Systems FLEXmax 80 and FLEXmax 60 Maximum Power Point Tracking Charge Controllers are ETL listed in North America to UL1741 (Inverters, Converters, Controllers, and Interconnection System Equipment for Use with Distributed Energy Resources). It is also in compliance with European Union standards EN 61000-6-1 and EN 61000-6-3 (see page 91).

About OutBack Power Systems

OutBack Power Systems is a leader in advanced energy conversion technology. Our products include true sine wave inverter/chargers, a maximum power point charge controller, system communication components, as well as breaker panels, breakers, accessories, and assembled systems.

Notice of Copyright

Disclaimer

UNLESS SPECIFICALLY AGREED TO IN WRITING, OUTBACK POWER SYSTEMS:
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(b) ASSUMES NO RESPONSIBILITY OR LIABILITY FOR LOSS OR DAMAGE, WHETHER DIRECT, INDIRECT, CONSEQUENTIAL OR INCIDENTAL, WHICH MIGHT ARISE OUT OF THE USE OF SUCH INFORMATION. THE USE OF ANY SUCH INFORMATION WILL BE ENTIRELY AT THE USER'S RISK.

Date and Revision

April 2008 REV A

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SCOPE

This manual provides safety guidelines and installation information for the FLEXmax 60 and FLEXmax 80 Charge Controller Maximum Power Point Tracking Charge Controllers. It does not provide information about specific brands of solar panels and supplies limited information on batteries. Contact the supplier or manufacturer of the solar panels or batteries for further information.

INTRODUCTION

The FLEXmax 60 and FLEXmax 80 Maximum Power Point Tracking Charge Controllers *

The OutBack Maximum Power Point Tracking Charge Controllers offer an efficient, safe, multi-stage recharging process that prolongs battery life and assures peak performance from a solar array. Each Charge Controller allows customized battery recharging. The Charge Controller features include:

- 80 amps maximum continuous output current up to 40° C without thermal derating for the FLEXmax 80 and 60 amps for the FLEXmax 60
- Engineered to work with 12, 24, 36, 48, and 60VDC battery voltages
- Backlit LCD display screen with 80 characters (4 lines, 20 characters per line)
- Last 128 days of operational data are logged for review
- Voltage step-down capability allowing a higher PV array voltage configuration
- Manual and auto-equalize cycle

The following are the maximum recommended wattage for the most common solar arrays under Standard Test Conditions (1000 watts per square meter to solar panel at 25° C or 77° F):

- 12VDC battery systems—up to 1250 watts (FLEXmax 80) or 800 watts (FLEXmax 60) of solar panels
- 24VDC battery systems—up to 2500 watts (FLEXmax 80) or 1600 watts (FLEXmax 60) of solar panels
- 36VDC battery systems—up to 3750 watts (FLEXmax 80) or 1200 watts (FLEXmax 60) of solar panels
- 48VDC battery systems—up to 5000 watts (FLEXmax 80) or 3200 watts (FLEXmax 60) of solar panels
- 60VDC battery systems—up to 6250 watts (FLEXmax 60) or 4000 watts (FLEXmax 60) of solar panels

Each Charge Controller also features Continuous Maximum Power Point Tracking (MPPT), which seeks out the maximum power available from a solar array and uses it to recharge the batteries. Without this feature, the solar array does not operate at the ideal operating voltage and can only recharge at the level of the battery voltage itself. Each Charge Controller continuously tracks the array's maximum operating power.

This manual covers the wiring, installation, and use of the Charge Controllers, including explanations of all the menus displayed on the LCD screen. Each Charge Controller is designed to seamlessly integrate with other OutBack components and can be remotely monitored and configured (up to 1000 feet) by the optional OutBack Power Systems MATE display (version 4.0.4 or greater).

FIRMWARE

This manual covers Charge Controller firmware version 001.009.001

*For simplicity's sake, both the FLEXmax 60 and FLEXmax 80 will be referred to in this manual as "Charge Controller or by the abbreviation "CC."

OUTBACK CHARGE CONTROLLER INSTALLATION GUIDELINES AND SAFETY INSTRUCTIONS

This product is intended to be installed as part of a permanently grounded electrical system as shown in the system configuration sections (see pages 12-15) of this manual. The following important restrictions apply *unless superseded by local or national codes*:

- The negative battery conductor should be bonded to the grounding system at only *one* point in the system. If a GFP is present, the battery negative and ground are not bonded together directly but are connected together by the GFP device when it is on. All negative conductor connections must be kept separate from the grounding conductor connections.
- With the exception of certain telcom applications, the Charge Controller should *never* be positive grounded (see page 61, Applications Notes).
- The Charge Controller equipment ground is marked with this symbol: 
- If damaged or malfunctioning, the Charge Controller should only be disassembled and repaired by a qualified service center. Please contact your renewable energy dealer/installer for assistance. Incorrect reassembly risks malfunction, electric shock or fire.
- *The Charge Controller is designed for indoor installation or installation inside a weatherproof enclosure. It must not be exposed to rain and should be installed out of direct sunlight.*

For routine, user-approved maintenance:

- Turn off all circuit breakers, including those to the solar modules, and related electrical connections before cleaning the air vents.

Standards and Requirements

All installations must comply with national and local electrical codes; professional installation is recommended. NEC requires ground protection for all residential PV installations

DC and Battery-Related Installation Requirements:

- All DC cables must meet local and national codes.
- Shut off all DC breakers before connecting any wiring.
- Torque all the Charge Controller's wire lugs and ground terminals to 35 inch-pounds (4 Nm).
- Copper wiring must be rated at 75° C or higher.
- Use up to 2 AWG (33.6 mm^2) to reduce losses and ensure high performance of Charge Controller (smaller cables can reduce performance and possibly damage the unit).
- Keep cables together (e.g., using a tie-wrap) as much as possible.
- Ensure both cables pass through the *same* knockout and conduit fittings to allow the inductive currents to cancel.
- DC battery over-current protection must be used as part of the installation. OutBack offers both breakers and fuses for overcurrent protection.

WARNING - WORKING IN THE VICINITY OF A LEAD ACID BATTERY IS DANGEROUS.

BATTERIES GENERATE EXPLOSIVE GASES DURING NORMAL OPERATION. Design the battery enclosure to prevent accumulation and concentration of hydrogen gas in "pockets" at the top of the enclosure. Vent the battery compartment from the highest point to the outside. A sloped lid can also be used to direct the flow of hydrogen to the vent opening.

CAUTION - To reduce risk of injury, charge only deep-cycle lead acid, lead antimony, lead calcium, gel cell or absorbed glass mat type rechargeable batteries. Other types of batteries may burst, causing personal injury and damage. *Never* charge a frozen battery.

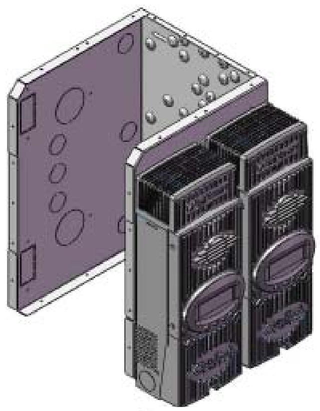
PERSONAL PRECAUTIONS DURING INSTALLATION

- Someone should be within range of your voice to come to your aid if needed.
- Keep plenty of fresh water and soap nearby in case battery acid contacts skin, clothing, or eyes.
- Wear complete eye protection. Avoid touching eyes while working near batteries. Wash your hands with soap and warm water when done.
- If battery acid contacts skin or clothing, wash immediately with soap and water. If acid enters an eye, flood the eye with running cool water at once for at least 15 minutes and get medical attention immediately following.
- Baking soda neutralizes lead acid battery electrolyte. Keep a supply on hand in the area of the batteries.
- NEVER smoke or allow a spark or flame in vicinity of a battery or generator.
- Be extra cautious to reduce the risk of dropping a metal tool onto batteries. It could short-circuit the batteries or other electrical parts that can result in fire or explosion.
- Remove personal metal items such as rings, bracelets, necklaces, and watches when working with a battery or other electrical current. A battery can produce a short circuit current high enough to weld a ring or the like to metal, causing severe burns.

FLEXmax™ 80

FLEXmax™ 60

1. Installing the Charge Controller

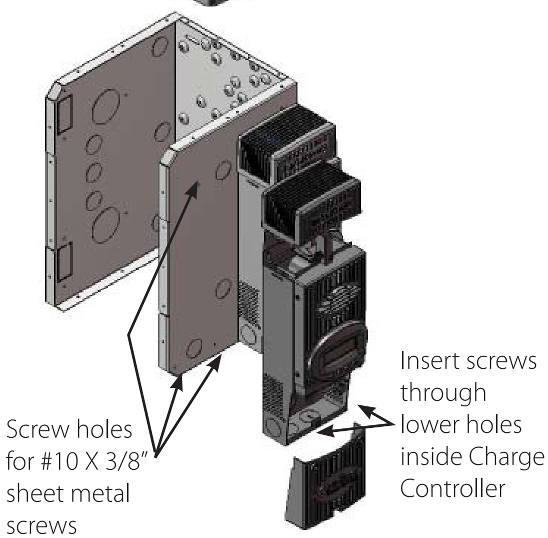


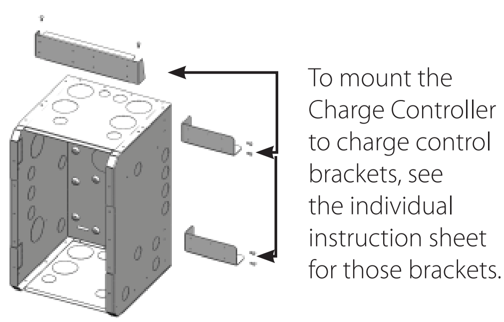
The Charge Controller is designed to attach directly to OutBack's FLEXware 500 DC and FLEXware 1000 DC enclosures (FLEXware 500 shown) or attach to its own charge control brackets (FW-CCB, FW-CCB2, and FW-CCB2T).

NOTE: Install the Charge Controller in an upright position out of direct sunlight.

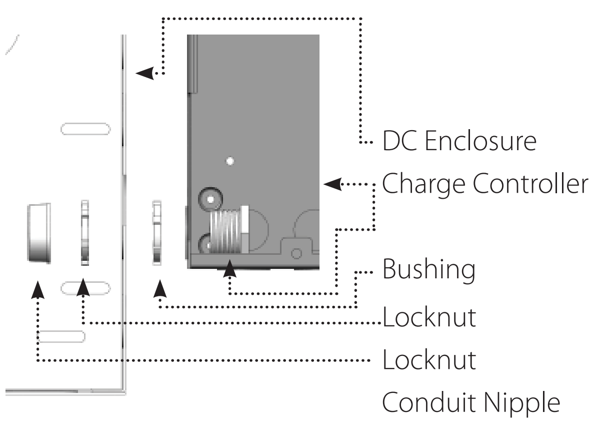
To mount directly to a FLEXware DC enclosure:

- Remove the fan cover and bottom cover from the Charge Controller.
- Insert a #10 X 3/8" sheet metal screw in the top hole on the side of the DC enclosure. This will act as a hanging screw for the keyhole slot at the top center of the Charge Controller.
- Hang the Charge Controller on the top screw and line up its bottom two screw holes with the holes on the enclosure.
- Insert a #10 X 3/8" sheet metal screw through each hole and tighten against the enclosure (screws are included with each DC enclosure).
- Keep the cover off until wiring is completed.





The Conduit Nipple Assembly creates a sealed pass-through from the Charge Controller to the enclosure



Mounting to Plywood

Use 1 5/8" wood screws to secure the Charge Controller at the top slotted holes and other interior lower holes as needed, making sure the unit is straight and level.

2. Determining Wire Sizes

Open Circuit Voltage/Wire and Disconnect Size

Maximum Open Circuit Voltage (VOC)

- VOC is the *unloaded* voltage generated by the solar array.
  - Greater than 145VDC → Charge Controller suspends operation to protect components
  - 150DC → max open circuit voltage with the coldest environment

NOTE: Although the Charge Controller shuts down at a voltage greater than 145VDC, it can withstand up to 150VDC from the array; anything higher than 150VDC will damage the Charge Controller).

- As every brand of panel is different, be sure to know the manufacturer's specifications.
- Weather conditions vary and will affect panel voltage.
  - Hot weather: lower open circuit voltage/lower maximum power point voltage
  - Cold weather: higher open circuit voltage/higher maximum power point voltage
  - Allow for ambient temperature correction using the following table:

25° to 10° C (77° to 50° F)	multiply VOC by 1.06
9° to 0° C (49° to 32° F)	multiply VOC by 1.10
-1° to -10° C (31° to 14° F)	multiply VOC by 1.13
-11° to -20° C (13° to -4° F)	multiply VOC by 1.17
-21° to -40° C (-5° to -40° F)	multiply VOC by 1.25

- **Check the PV array voltage before connecting it to the Charge Controller (see page 76)**

Wire and Disconnect Sizing

FLEXmax 80

- The output current limit of the FLEXmax 80 is 80 amps
- Use a minimum of 4 AWG (21.15 mm^2) wire for the output between the FLEXmax 80 and the battery bus bar conductors
- Install OutBack OBB-80-150VDC-PNL breakers for disconnect and overcurrent protection
- The largest PV array that can connect to a Charge Controller must have a rated short-circuit current of 64 amps or less under STC (Standard Test Conditions).

FLEXmax 60

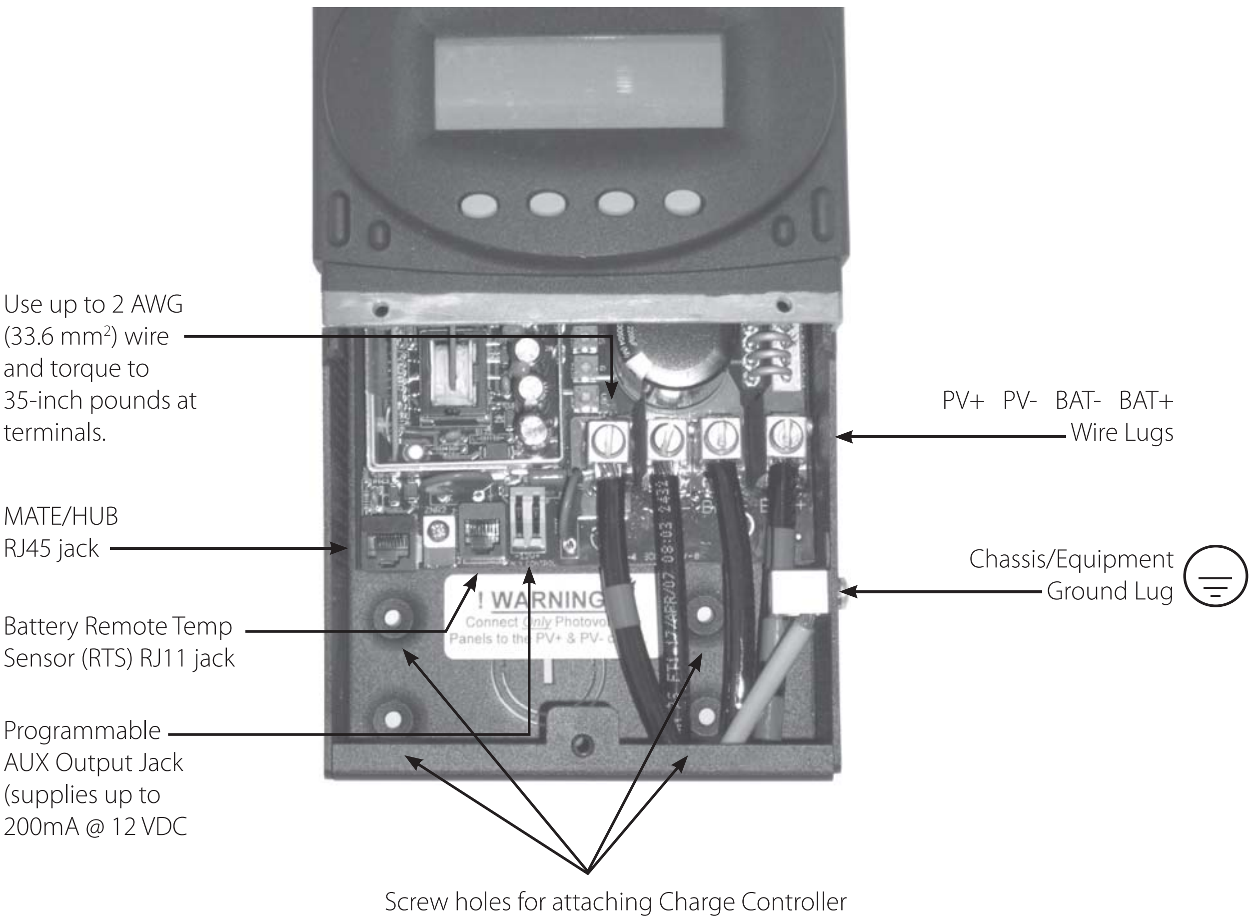
- The output current limit of the FLEXmax 60 is 60 amps
- Use a minimum of 6 AWG (13.3 mm^2) wire for the output between the FLEXmax 60 and the battery bus bar conductors
- Install OutBack OBB-60-150VDC-PNL or OBB-80-150VDC-PNL breakers for disconnect and overcurrent protection
- The largest PV array that can connect to a Charge Controller must have a rated short-circuit current of 48 amps or less under STC (Standard Test Conditions).

NOTE: Input conductors and circuit breakers must be rated at 1.56 times the short-circuit current of the PV array. OutBack 100% duty continuous breakers only need to be rated at 1.25 times the short-circuit current.

- Please see the wire Distance Chart and complete Wire and Disconnect Sizing on pages 78-81 for other suitable conductor/wire sizing.

3. Charge Controller Wiring Connections

Figure 1 Charge Controller wiring compartment



The PV (-) and BAT (-) terminals are connected internally. Only one negative wire may be needed to connect to the (-) wire lugs if the PV - and BAT- conductors are bonded at the negative bus bar. See Figures 2 and 3 for sample wiring diagrams. *See Wire and Disconnect Sizing on page 80 for suitable conductor/wire sizing.*

NOTES:

- Each Charge Controller requires its own PV array. DO NOT PARALLEL Charge Controller PV+ and PV- TERMINALS ON THE SAME ARRAY!

- An optional battery Remote Temperature Sensor (RTS) is recommended for accurate battery recharging (only one RTS is needed for multiple OutBack Series Inverter/Chargers and Charge Controller units when an OutBack HUB and a MATE are parts of the system). When one RTS is used, it must be connected to the component plugged into the Port 1 of the HUB.

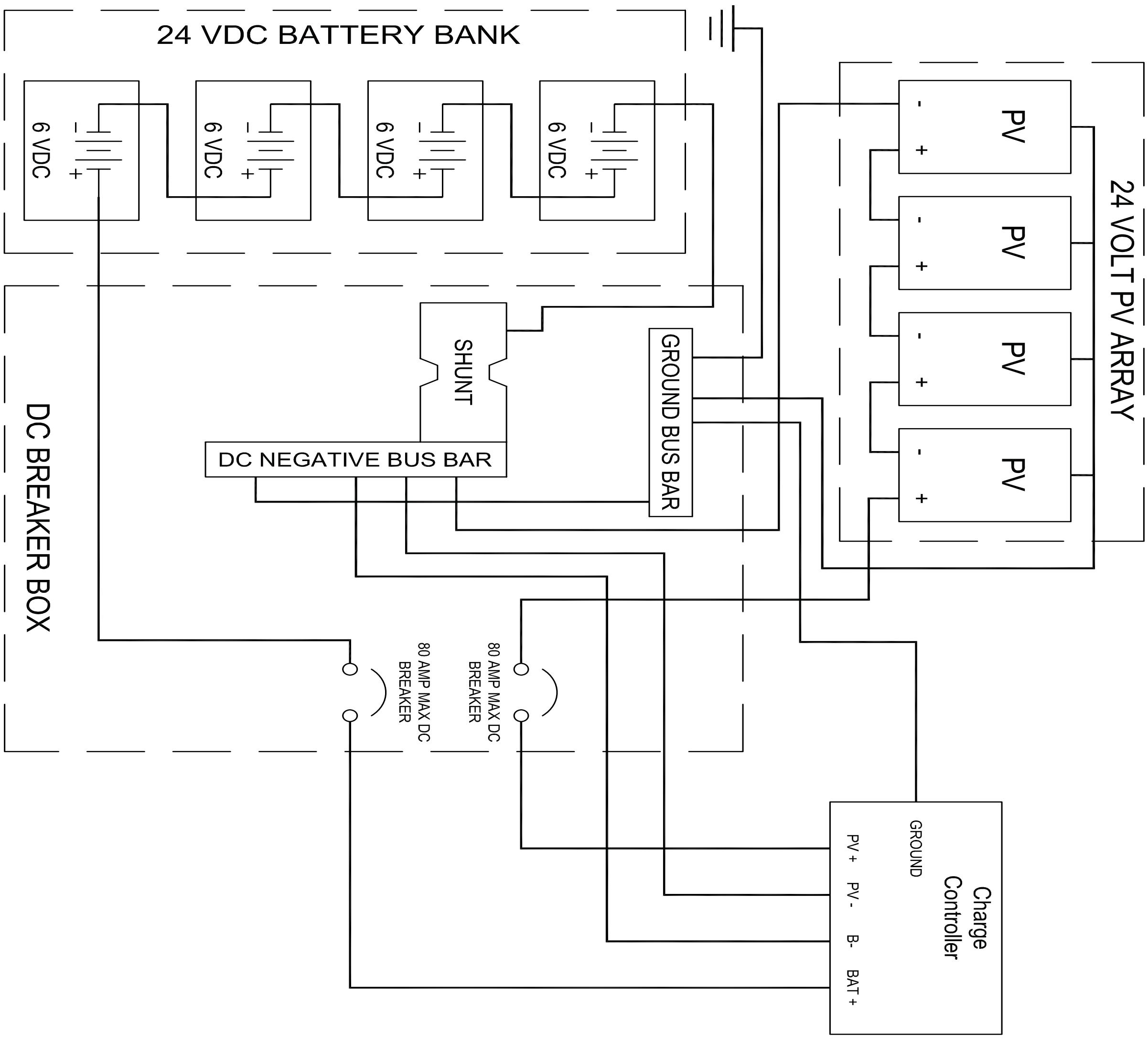


Figure 2 Single Charge Controller wiring diagram with 24 volt PV array

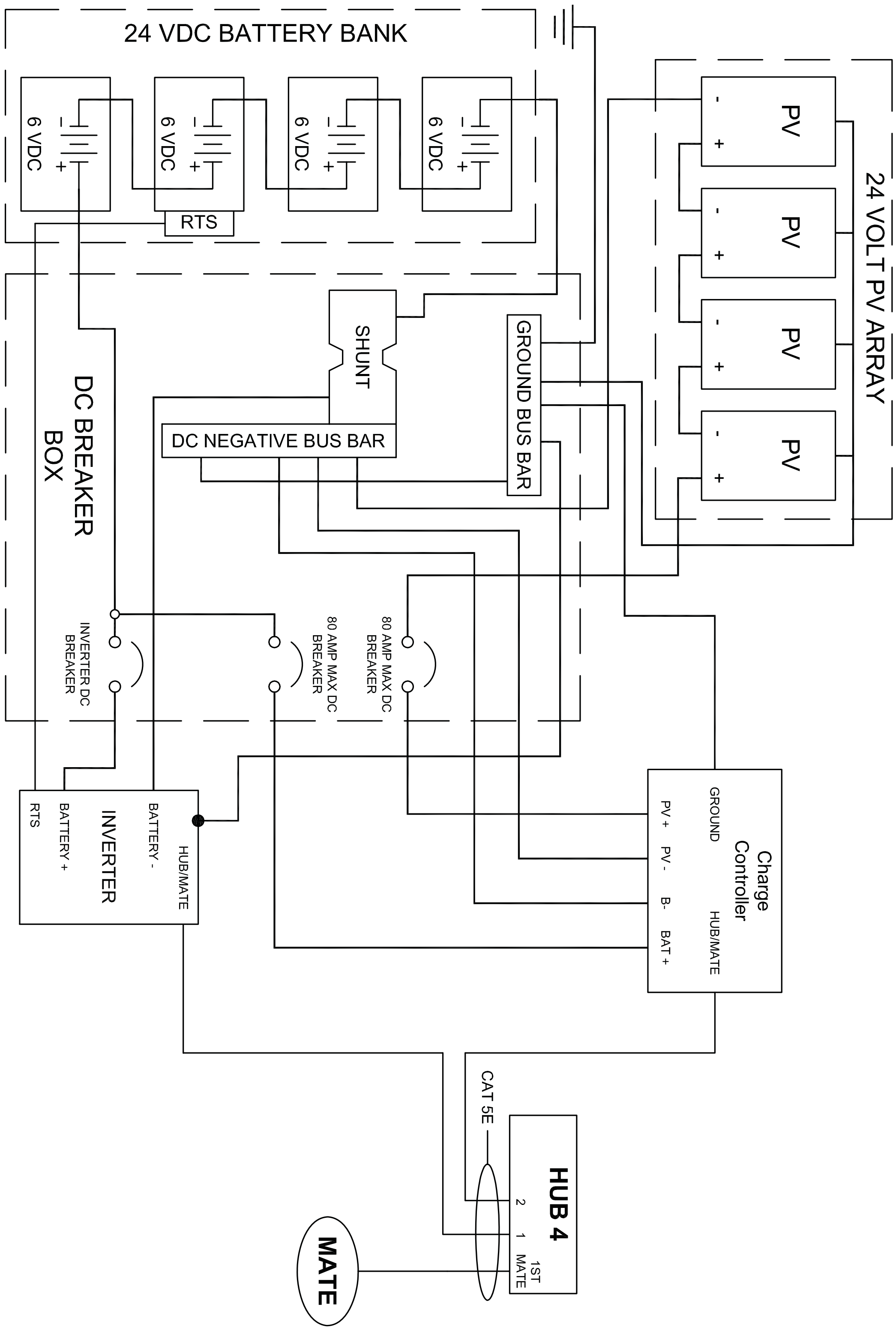


Figure 3 Charge Controller Wiring Diagram with an FX, HUB 4, and an RTS

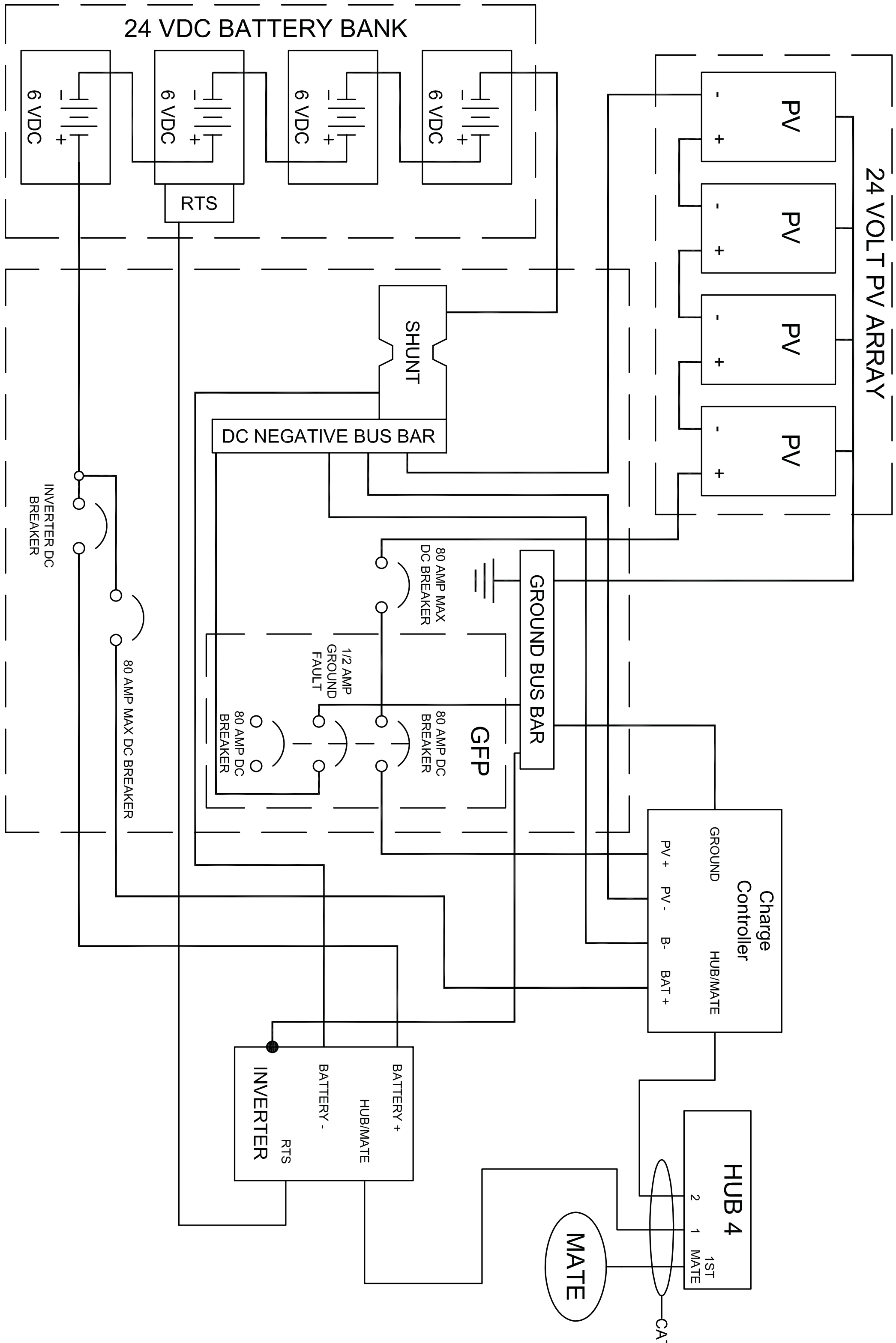
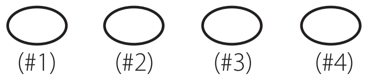
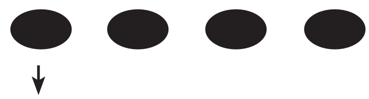


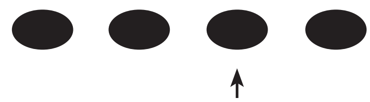
Figure 4 Charge Controller with PV array ground fault protection wiring digram.

How to Read the Charge Controller Screen Diagrams

Soft keys: 

Solid black indicates key is to be pressed: 

Down arrow will lead to the next screen: 

Up arrow points to one or more keys that will change a value: 

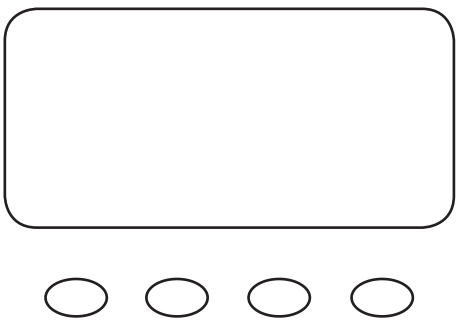
The keys correspond to any text immediately above them.

4. Powering Up

The Charge Controller power-up sequence first activates the unit and the *SELECT VERSION* screen (to determine a choice of English, Espanola, or Australian settings). A *SYSTEM VOLTAGE* screen soon follows. However, when it auto-detects the system's battery voltage, in some instances the Charge Controller might not reflect the correct system voltage (e.g., if a 36VDC system falls to a voltage range that could be misread as a 24VDC system). The *SYSTEM VOLTAGE* screens allow the user to adjust the Charge Controller to the correct voltage.

NOTE: Be sure the PV input and battery breakers are off before starting the power-up sequence.

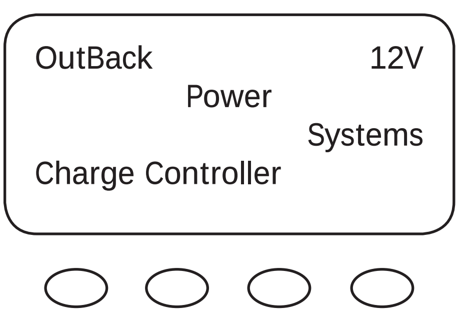
OFF SCREEN (this screen is initially blank at power up)



With the PV array and battery breakers off, turn on the battery breaker.

NOTE: The battery voltage must be at least 10.5V or higher to power up the Charge Controller. If the screen reads *Low Battery Voltage*, please see the Troubleshooting Guide on page 73.

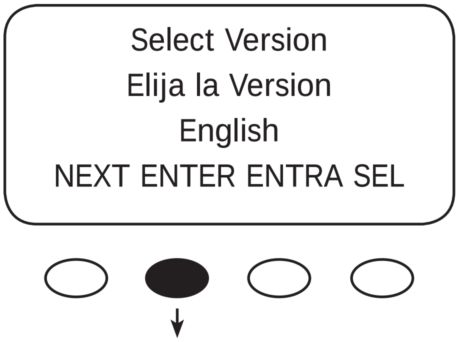
Power Up Screen



The Charge Controller will show the system battery voltage in the upper right corner of the screen. The *Select Version* screen appears next.

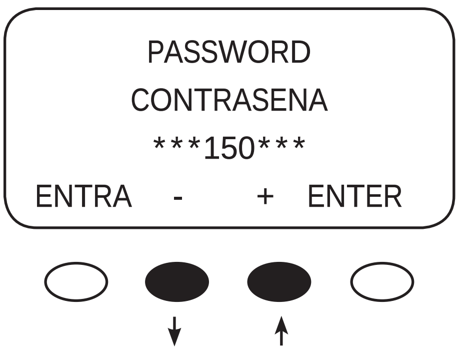
NOTE:

- The Charge Controller's default setting is for a 12 VDC battery.
- Change the setting after powering up the Charge Controller if a different battery voltage is used.
- The PV array voltage—which must not exceed 150 VDC open circuit—is automatically detected.



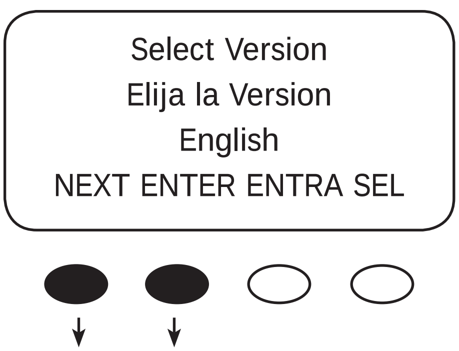
The Charge Controller screens are offered in English (standard screens) and Spanish. For Australian users, some of the charging values are of different voltages and the Charge Controller accommodates these. By pressing the **<NEXT>** soft key, the user can choose English, Australia, or Espanola versions of the screens. After pressing the **<NEXT>** soft key, a password must be entered before selecting the screen version.

Password Screen

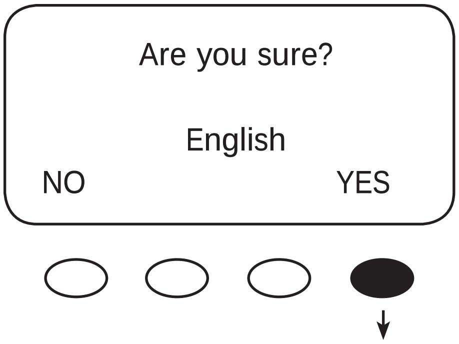


Press the " – " soft key until the password 141 shows on the screen. Press the **<ENTER>** soft key to return to the *Select Version* screen.

NOTE: 141 is the password for all OutBack products.

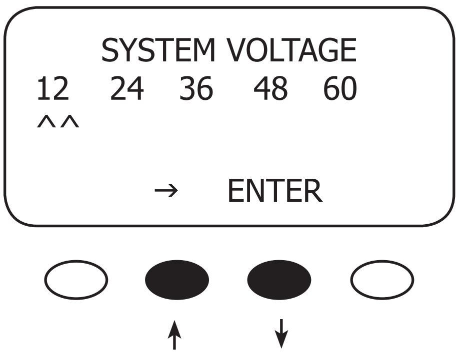


Press the **<NEXT>** to choose the desired screen version. Press the **<ENTER>** soft key to view the version confirmation screen.



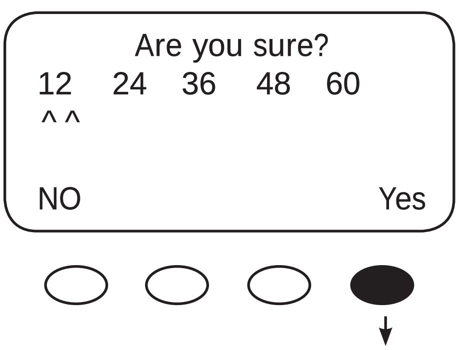
Press the **<YES>** soft key to confirm your choice or **<NO>** to return to the *SELECT VERSION* screen.

System Voltage Screen



The Charge Controller auto detects the system's battery voltage. To confirm this voltage, press the **<ENTER>** soft key. If incorrect, press the "→" soft key to select a battery voltage. The Charge Controller's default values are based on a 12VDC system. Selecting a higher voltage system will change all the default values (e.g., the values will double with a 24VDC system, triple with a 36 VDC system, etc.). "^^" indicates the chosen voltage. The Charge Controller will automatically accept the selected battery voltage if left unattended for 5 minutes in this screen. After choosing the voltage, press the **<ENTER>** soft key to proceed.

Verification Screen

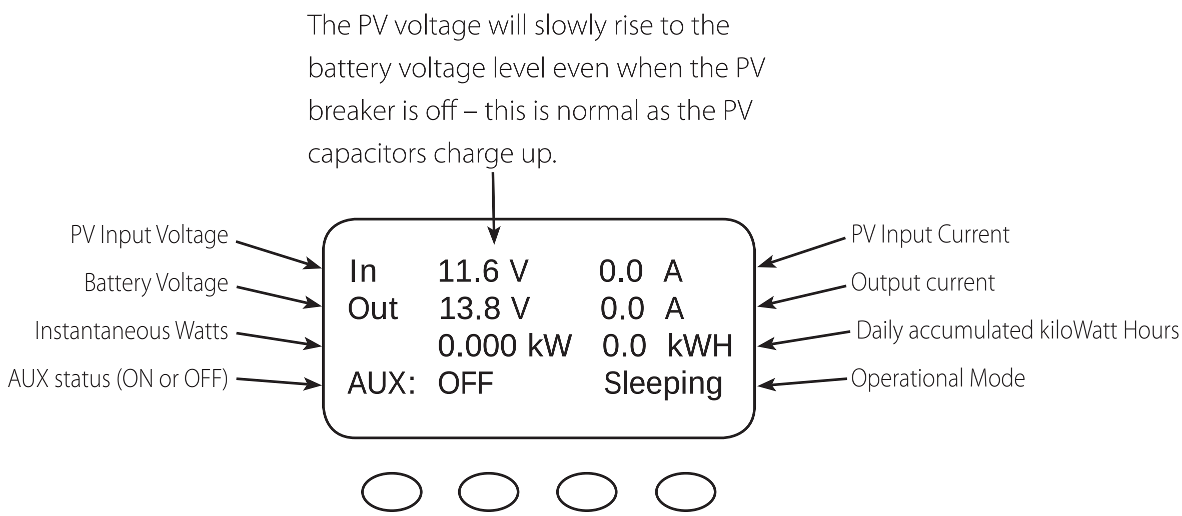


Press the **<YES>** soft key to proceed if the selected battery voltage is correct. If incorrect, press **<NO>** to re-enter the correct voltage. The **<YES>** soft key will open the STATUS screen.

NOTE: Repeating the Powering Up sequence resets the Charge Controller Charge Controller to its factory default settings (see page 77).

5. Status Screen

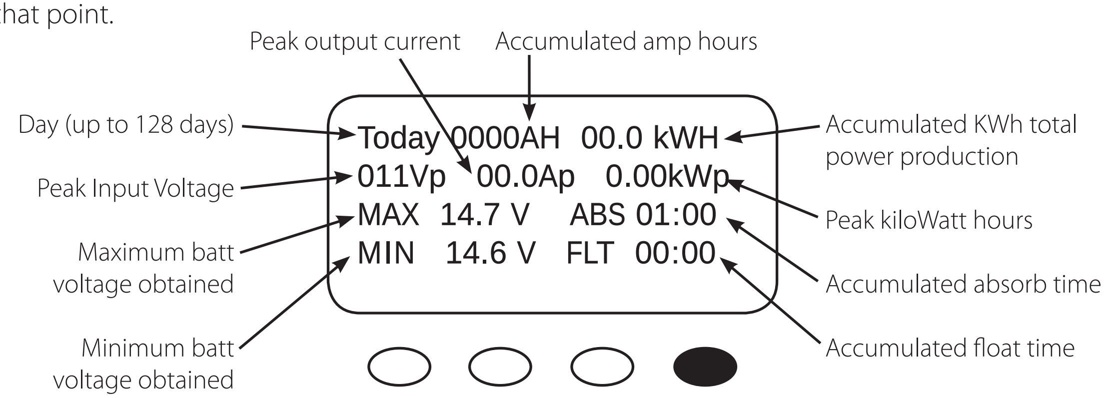
The *STATUS* Screen displays system information. See page 63 for detailed information of the different Operational Modes. The optional OutBack MATE displays CC (Charge Controller) STATUS screens for convenient distant viewing from the installation location of the Charge Controller. Please see pages 66-68 to view the Charge Controller screens displayed on the MATE.



NOTE:
- Pressing the first soft key opens the MAIN Menu screen.
- Pressing second soft key opens the End of the Day summary menu/logging.

6. End of Day Summary Screen

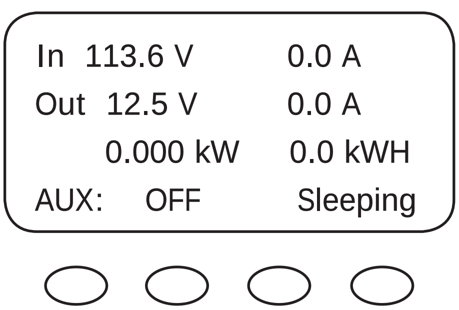
The *End of Day* summary screen appears after one hour of continuous sleeping. This screen can be opened anytime by pressing the second soft key while in the STATUS screen, providing a summary up to that point.



NOTE:

- Pressing the first soft key opens the STATUS screen.
- Pressing the second soft key brings up the CLEAR LOG screen.
- Pressing the third soft key shows the previous day's summary; continually pressing this soft key will bring up additional past summaries up to 128 days.
- Pressing the fourth soft key will bring up summary for the 128th day back.

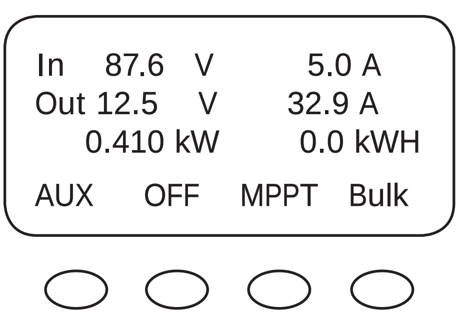
7. Recharging Using the PV Array



Turn the PV input breaker on. The Charge Controller automatically detects the PV input voltage.

(***NOTE:*** If PV voltage registers "000V" when the breaker is on, please check the polarity of the PV wires.)

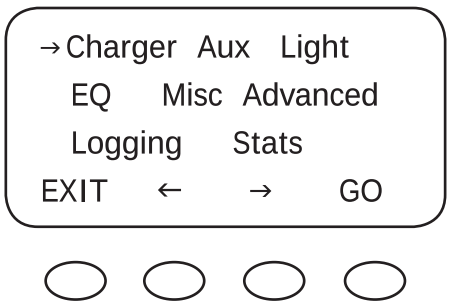
The Charge Controller enters a "Wakeup" stage, transitions to "Tracking" and prepares to charge the batteries by tracking the maximum power point of the solar array.



During the Charge Controller's initial tracking, the input source (e.g., solar) is gradually loaded from the open circuit voltage (VOC) to one-half of the VOC. Within this range, the Charge Controller seeks the maximum power point. When the Charge Controller goes into Re-Cal, Auto Restart, Wakeup, or RSTRT (restart) modes, among other conditions, it performs an initial tracking.

8. Accessing the MAIN Menu

The *MAIN* Menu allows the user to adjust and calibrate the Charge Controller for maximum performance. From the *STATUS* screen, press the first soft key on the left to open the *MAIN* Menu screen.



Press **<←>** or **<→>** to move the "→" to the left of the desired screen. The arrow allows access to any screen to its right.

Press the **<GO>** soft key after aligning the arrow in front of the selected menu choice.

Pressing the **<EXIT>** soft key in the *MAIN* Menu returns to the *STATUS* screen.

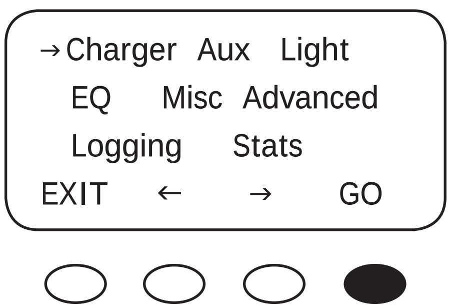
From the *MAIN* Menu, a user can choose among the following Charge Controller functions by aligning the arrow:

- **Charger—CHARGER SETUP**
  - Adjusts the Current Limit, Absorb, and Float recharging voltage set points
- **Aux—AUX OUTPUT CONTROL**
  - Secondary control circuit for a vent fan, error alarm, and other system-related additions
- **Light—BACKLIGHT CONTROL**
  - Adjusts the backlighting of LCD screen and soft key buttons
- **EQ—BATTERY EQUALIZE**
  - Activates battery equalization recharging (manually or automatically)
- **Misc—MISCELLANEOUS**
  - Additional settings and service information
- **Advanced —ADVANCE MENU**
  - Optimizing/fine-tuning the Charge Controller (these are advanced Menus that should be left alone until the user has a good working knowledge of the Charge Controller and its operations)
- **Logging—DATA LOGGING**
  - Displays recorded power production information
- **STATS—Statistics**
  - Displays recorded peak system information and cumulative kilowatt hours and amp hours

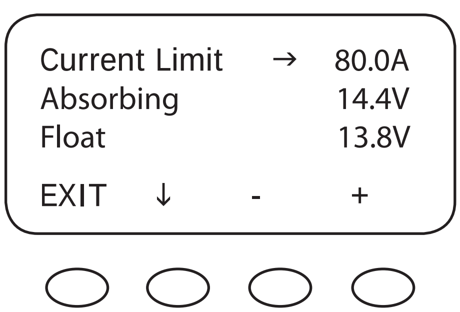
7. Charger Set-Up

This screen allows changes to the Charge Controller's recharging voltage set points—Current Limit, Absorb and Float (for an explanation of battery charging, see pages 83-84):

- The presently selected numerical value will have an arrow " → " to the left of it.
- Pressing **<↓>** selects the value to be changed.
- You *may* need to re-enter the password to change these settings.
- The default charger output current limit setting is 80 amps for the FM80 and 60 amps for the FM60. This setting is adjustable from 5-80 amps. An appropriate breaker must be used between the battery and the Charge Controller.
- Change Absorbing and Float set points using this screen if the battery manufacturer's recommendations are different than the default values. Otherwise, see page 8 for suggested recharging voltage set points.



From the MAIN screen, press **<←>** or **<→>** to move the "→" to the left of the *Charger* function and then press the **<GO>** soft key. This will open the Charger Set-Up screen.

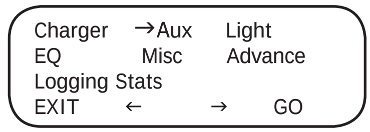


NOTE: If a battery remote temperature sensor (RTS) is used, set the ABSORB and FLOAT setting voltage based on a 25°C / 77°F setting. These are typically the manufacturer's set points (always consult the battery manufacturer's recommendations). RTS compensated voltage values can be viewed in the Advanced menu screen under the RTS Compensation heading. If an RTS is not in use, please see the Non-Battery Temperature Compensated System values (page 85) and adjust the ABSORB/FLOAT values accordingly.

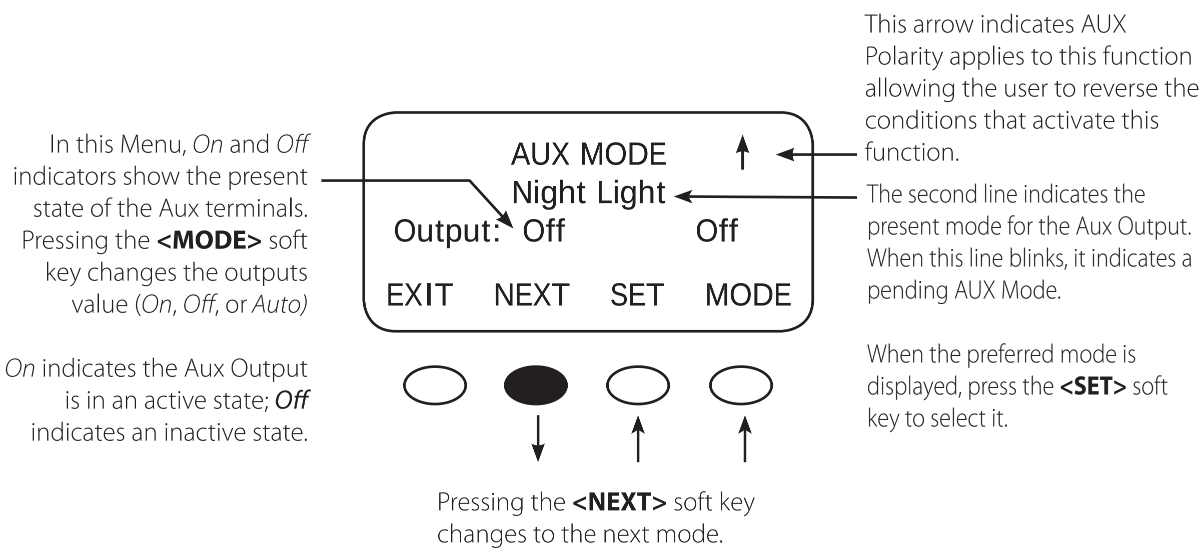
8. AUX Mode and Its Functions

The AUX is a secondary control circuit—essentially, a small power supply that provides a 12VDC (up to 200 milliamps) output current. It is either active (12VDC on) or inactive (0VDC). Most AUX modes or functions are designed for specialized applications and are infrequently used.

- To access the AUX MODE from the MAIN Menu, press the **< → >** soft key until the arrow is in front of the Aux selection (see next page).



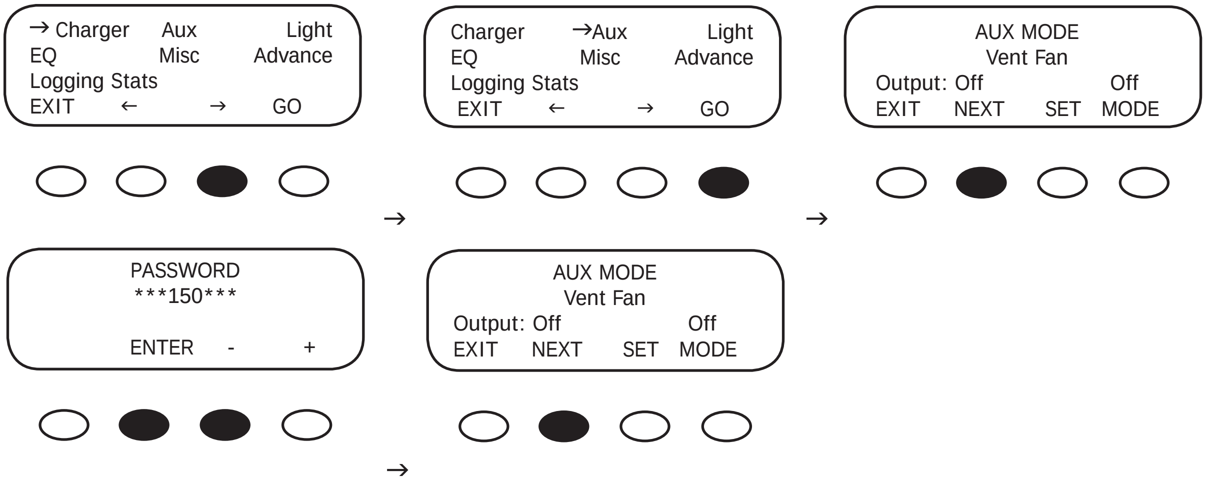
- A 200 milliamps or less, 12VDC/2.4W device can be wired directly to the AUX terminal; higher output DC loads require a 12VDC coil relay—also rated up to 200 milliamps or less for the DC coil—which itself is connected to the AUX output. An internal, re-settable Positive Temperature Co-efficient (PTC) fuse protects the AUX internal components from overcurrent or a short circuit.
- For certain AUX control applications the use of a solid state relay is preferred. This is particularly beneficial with applications such as the Diversion mode where fast switching (often called PWM control) allows a more constant battery voltage to be maintained. Both DC and AC load switching solid state relays are widely available from many sources. Eurotherm and Power-IO are two suggested solid state relay manufacturers.
- Only one AUX MODE can operate at a time (*even if other modes have been preset*).
- See Figure 5, page 36, for an AUX set-up wiring diagram example.



TERMS

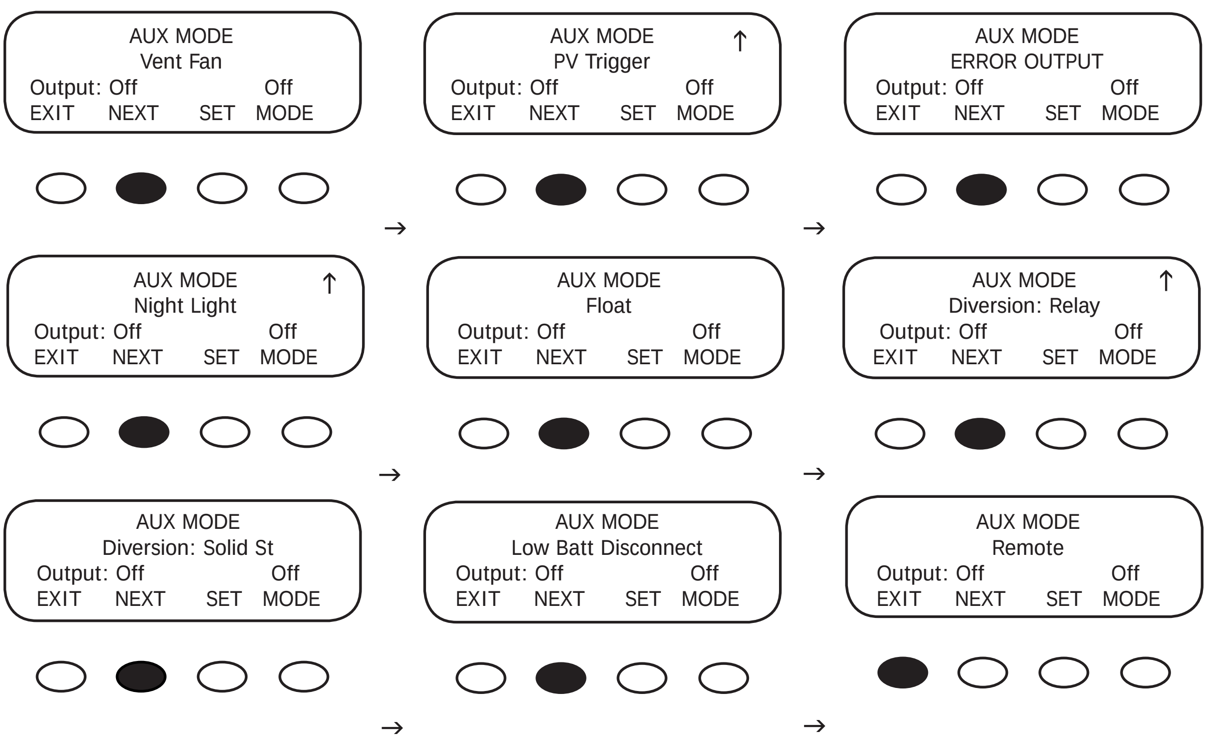
- AUX MODE: what is displayed on the Menu
- Aux Output: 12VDC is either available or unavailable at the Aux Terminal
- Aux Terminal: the jack to which a relay is wired

AUX MODE Menu Path



To access the AUX Output Menu:

- Press the first soft key once from the STATUS Menu to open the MAIN Menu.
- Press either of the arrow soft keys until the "→" is to the left of *Aux*.
- Press the **<GO>** soft key. If more than ten minutes have passed since any activity, the PASSWORD screen becomes active, requiring the user to input the 141 PASSWORD and press **< ENTER>**.
- Pressing the **<NEXT>** soft key scrolls through the AUX functions.
- The most commonly used AUX modes are *Vent Fan, Low Battery Disconnect* and *Diversion*.



AUX modes in order of appearance on the Charge Controller display:

- *Vent Fan* • *PV Trigger* • *Error Output* • *Night Light* • *Float* • *Diversion Relay*
- *Diversion Solid State* • *Low Battery Disconnect* • *Remote*

NOTE: All AUX functions can be manually activated in *On*, *Off*, or *Auto* mode. In *Auto* mode, the function will automatically activate when a user-determined value is met and deactivate or shut down when other conditions described here, such as a certain amount of time passing, occur.

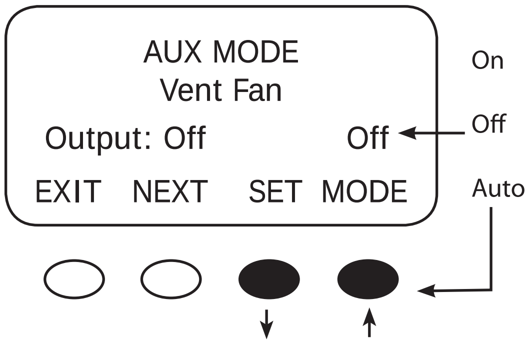
When an AUX MODE is in AUTO, 12VDC is available at the AUX terminals and a condition, such as a voltage set point, is met. Other modes can be programmed in lieu of the specific ones listed here, but the *Vent Fan* mode is most easily changed (e.g., to activate an alarm instead of a fan). Here are the default AUX modes:

- Vent Fan— when the *Vent Fan* voltage set point is exceeded, the vent fan will run for at least 15 seconds (the fan helps remove hydrogen from battery enclosure), even if the set point is exceeded for only a few seconds due to a surge. If the set point is exceeded for longer than 15 seconds, the fan will stay on until the voltage drops below the set point. It then takes 15 seconds before the fan shuts off. This is an optional external fan and not to be confused with the Charge Controller's internal, thermally activated fan which cools the unit.
- PV Trigger*—activates an alarm or relay (that disconnects the array); when the PV input exceeds the user-determined voltage set point (to avoid damage, do not go over 150VDC), the PV Trigger disconnects after a minimal adjustable amount of *Hold Time*.
- Error Output—useful for monitoring remote sites, switches to the *Off* state if the Charge Controller has not charged the batteries for 26 hours or more (not an audible alarm, only displayed as a printed message on Charge Controller AUX Menu) or the battery voltage has fallen below a user-determined set point for 10 continuous minutes. In the No Error state, the AUX output is on.
- Night Light*—after the PV voltage is below a threshold voltage for a user-determined time period, a user-provided light illuminates as long as the Charge Controller remains sleeping or as determined by the user-established time limit.
- Float—powers a load if the Charge Controller is producing power in the *Float* stage
- Diversion Relay*—diverts excess power away from batteries when a wind or hydro generator is connected directly to the batteries.
- Diversion Solid St—same as *Diversion Relay*, but applies when a solid state relay is used rather than a mechanical relay
- Low Batt Disconnect—activates/deactivates the AUX load(s) when a user-determined voltage and time levels are reached.
- Remote—allows OutBack MATE control of the AUX MODE (see MATE manual for details).

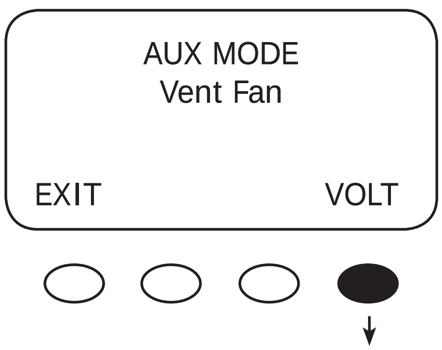
* These functions support AUX polarity.

9. Programming the AUX MODES

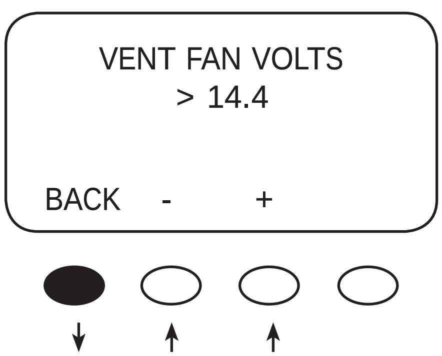
VENT FAN



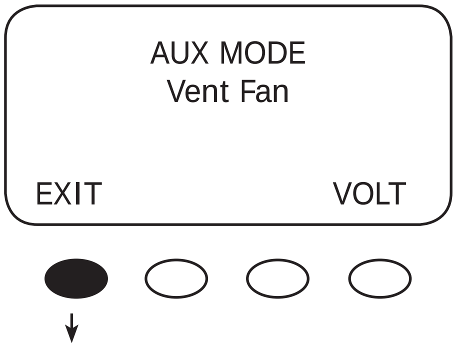
Press the **<MODE>** soft key to manually activate or deactivate (*On* or *Off*) the *Vent Fan*; if set to *Auto*, the *Vent Fan* will turn on when a user-determined voltage is met. Press the **<SET>** soft key to view the *Vent Fan* screen. To view other screens, continue to press the **<NEXT>** soft key.



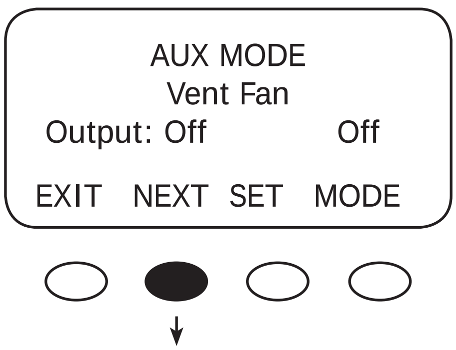
The *Vent Fan* helps remove hydrogen from the battery box. The ventilation fan referred to here is not the same as the Charge Controller cooling fan. Press the **<VOLT>** soft key to determine the battery voltage that will activate the AUX MODE and start the fan.



Adjust the voltage level using the **< - >** and **< + >** soft keys. Press the **<BACK>** soft key to return to the *Vent Fan* screen.

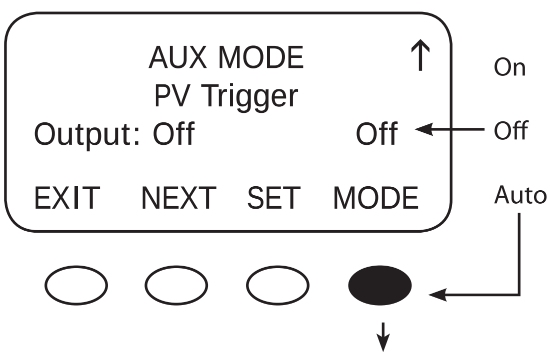


Press the **<EXIT>** soft key return to the main *Vent Fan* screen.

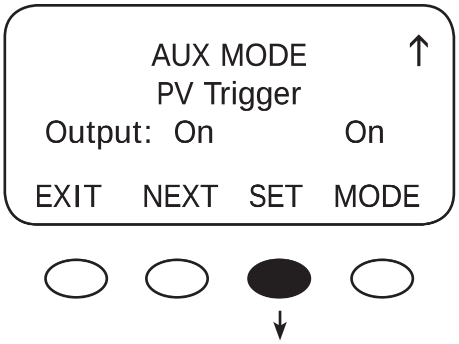


Press the **<NEXT>** sot key to view the *PV Trigger* screen

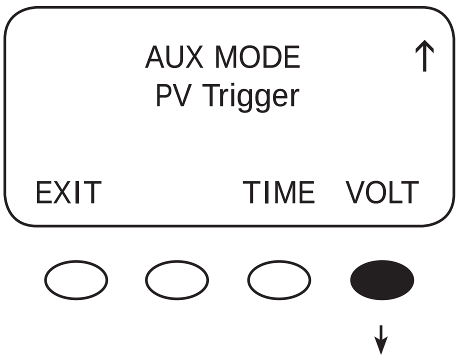
PV TRIGGER



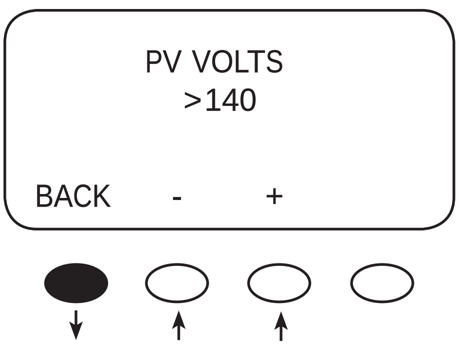
When the PV input exceeds the user-determined VOLT set point, the *AUX MODE PV Trigger* activates in Auto Mode. Press the **<MODE>** soft key to establish another *PV Trigger* mode (*On*, *Off*, or *Auto*).



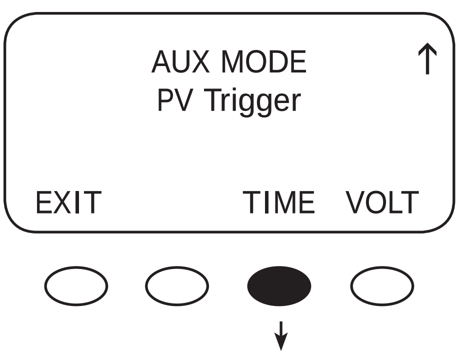
Press the **<SET>** soft key to open the *PV Trigger's TIME* and *VOLT*(age) set menus.



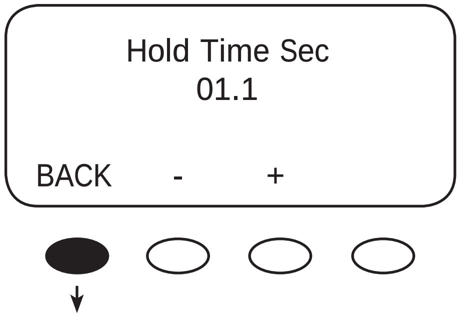
To adjust the voltage, press the **<VOLT>** soft key.



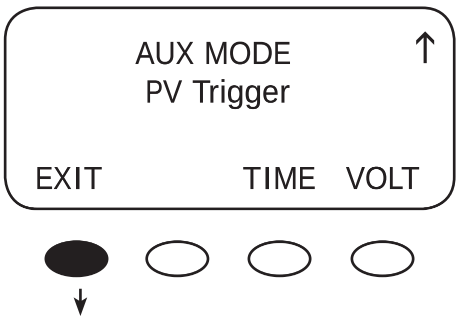
Adjust the voltage within a range of 20V-145V by pressing the **< - >** or **< + >** soft key. When finished, press the **<BACK>** soft key to return to the *PV Trigger* screen



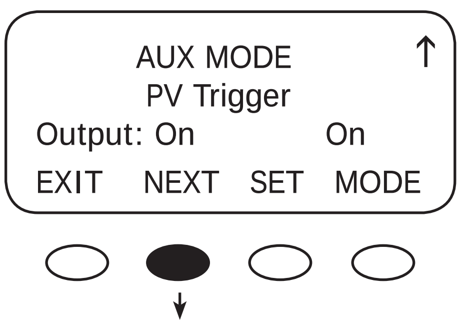
To adjust the minimum amount of time the PV voltage must remain high before deactivating the *AUX MODE*, press the **<TIME>** soft key.



Press the **< - >** or **< + >** soft key to adjust the Hold Time, then press the **<BACK>** soft key to return to the *PV Trigger* screen. In this example, the *AUX MODE* will remain active for 1.1 seconds after the PV voltage is below the *PV Trigger* voltage before deactivating the *PV Trigger* and reconnecting to the array.

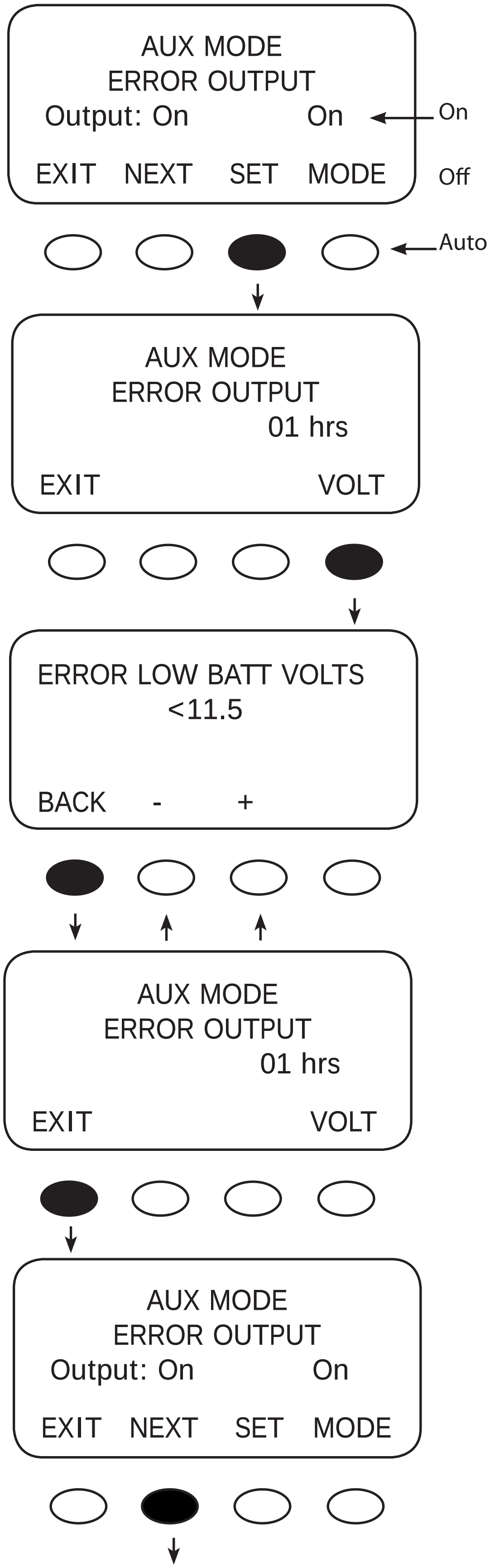


Press the **<EXIT>** soft key to return to the initial PV Trigger screen



Press the **<NEXT>** soft key to view the *ERROR OUTPUT* screen.

ERROR OUTPUT



The *ERROR OUTPUT* default state is *On*, meaning 12 VDC is present at the AUX terminal. If the Charge Controller has not charged the batteries for 26 hours or more continuously, the inaudible *ERROR OUTPUT* goes into an *Off* state. The *ERROR OUTPUT* is intended for remote locations to signal (e.g., a telecommunication signal to a computer) when the Charge Controller has not charged the battery for 26 hours or more. Press the **<SET>** soft key to advance to the *ERROR OUTPUT* volt screen.

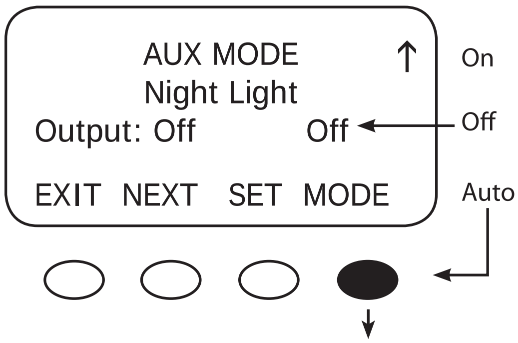
The *ERROR OUTPUT* screen displays the number of hours the Charge Controller has not been producing any power (the number of hours in *Sleep Mode*). Press the **<VOLT>** soft key to adjust the *ERROR LOW BATT VOLTS* screen.

User-determined value—not less than 10V—will trigger an alarm or, through a user-supplied modem, send a signal from a remote installation indicating the battery charge has reached this value. This informs the user of a low battery problem. Use the **< - >** and **< + >** soft keys to change this value. Press the **<BACK>** soft key to return to the *AUX MODE ERROR OUTPUT* screen.

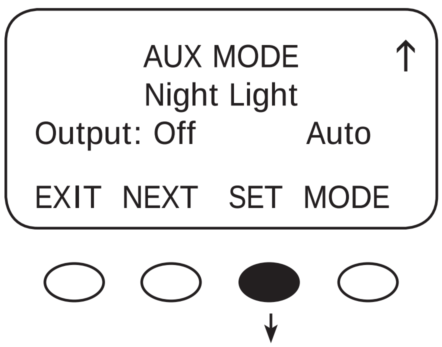
Press the **<EXIT>** soft key to bring up the original *ERROR OUTPUT* screen.

Press the **<NEXT>** soft key to view the *Night Light* screen.

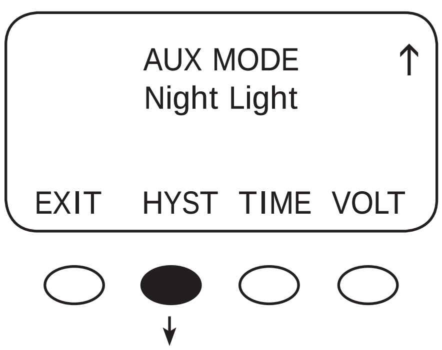
NIGHT LIGHT



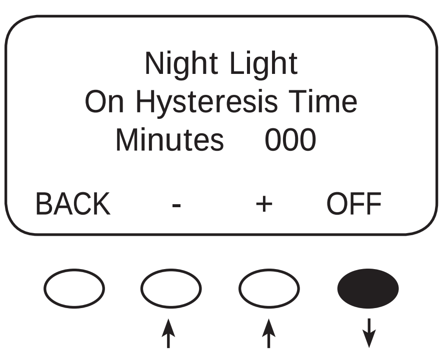
The *Night Light* illuminates a user provided low-wattage light when the PV voltage falls below a user-determined voltage. *Off* is the default value. Press the **<MODE>** soft key to change the *Night Light* MODE (*Off, On*, or *Auto*).



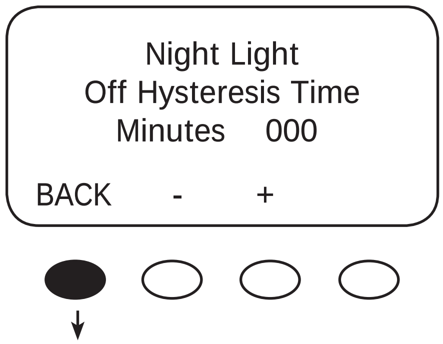
This example shows *Auto MODE* selected. Press the **<SET>** soft key to open the Hysteresis and PV Voltage screens.



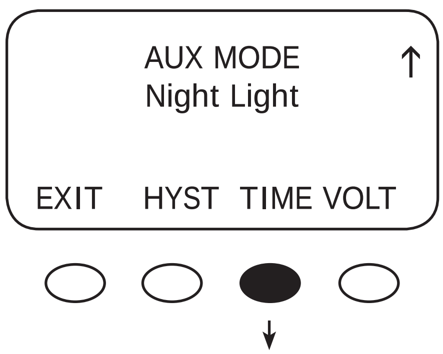
Press the **<HYST>** soft key to open the *On Hysteresis Time* screen.



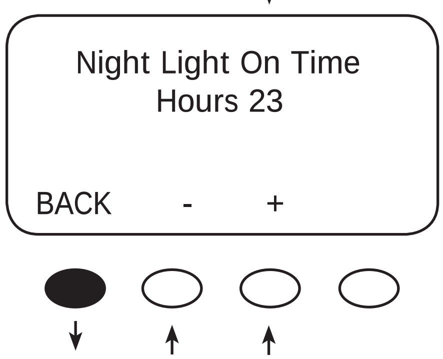
Use the **< - >** and **< + >** soft keys to adjust the time required for the PV input voltage to be below the threshold voltage before the *Night Light* is enabled. Press the **<OFF>** soft key to view the *Off Hysteresis Time* screen.



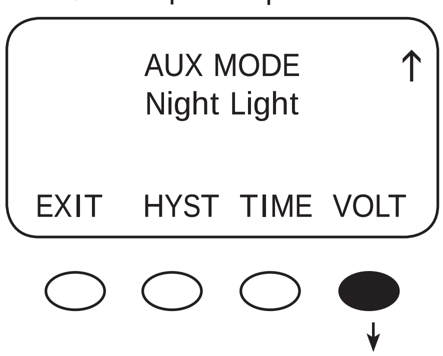
Use the **< - >** and **< + >** soft keys to adjust the time required for the PV input voltage to be above the thresh-old voltage before the *Night Light* is disabled. Press the **<BACK>** soft key twice to return to the *Night Light* screen.



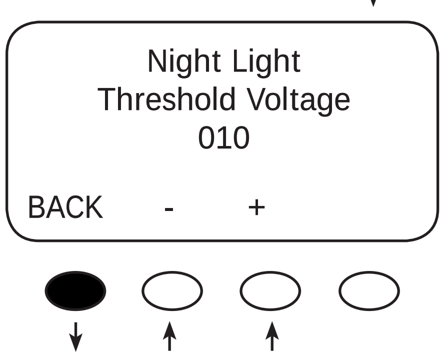
Press the **<TIME>** soft key to adjust the length of time the *Night Light* remains on. If the time is set to 0, the *Night Light* remains on until the off condition is met.



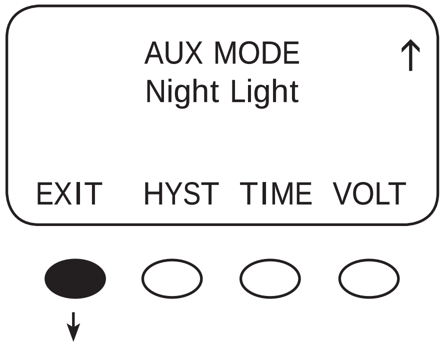
Use the **< - >** and **< + >** soft keys to adjust the number of hours the *Night Light* remains on. Press the **<BACK>** soft key to return to the previous *Night Light* screen.



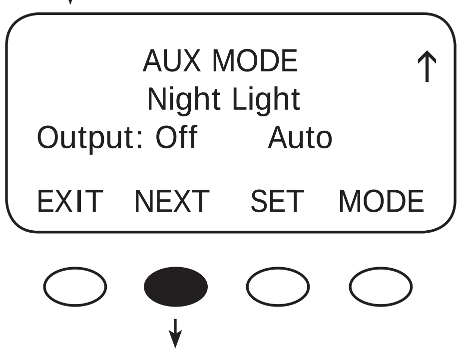
Press the **<VOLT>** soft key.



Press the **< - >** or **< + >** soft keys to adjust the *Threshold Voltage* value. When finished, press the **<BACK>** soft key to return to the *Night Light* screen.

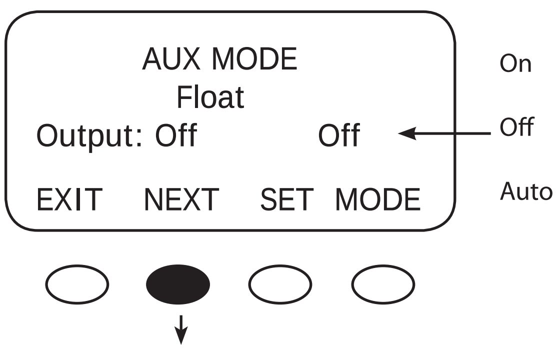


Press the **<EXIT>** soft key to return to the *Night Light AUX* mode.



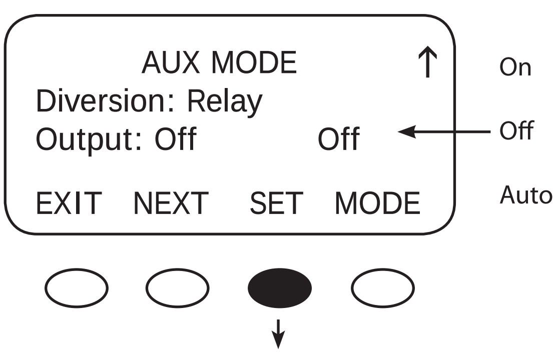
Press the **<NEXT>** soft key ro view the *AUX Float* screen.

FLOAT



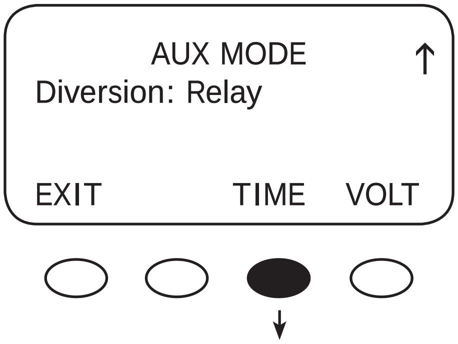
The *AUX MODE* is active when the Charge Controller is in *Float* and producing power. Press the **<NEXT>** soft key to advance to the *Diversion* screen.

RELAY

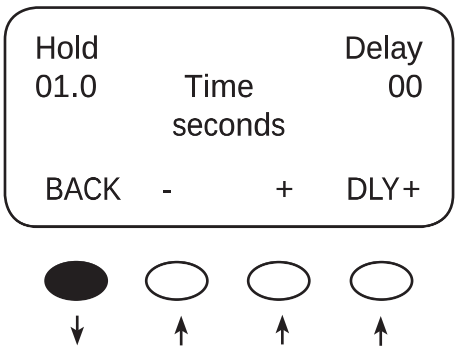


When external DC sources (wind, hydro) are directly connected to a battery bank, any excess power should be sent to a diversion load, such as a heating element, via a mechanical or solid state relay. In *Diversion*, which features *Relay* and *Solid State* screens, the user programs set points—from -5.0 volts to 5.0 volts relative to the Absorb, Float and EQ voltages—to activate the *AUX MODE*. With wind or hydro generator applications, keep the Charge Controller's diversion voltage slightly above its Absorb and Float voltages for efficient functioning.

This is primarily an off-grid function. Pressing the **<MODE>** soft key displays *Auto* and *On* modes in addition to *Off*. Pressing the **<SET>** soft key displays the *Diversion: Relay TIME* and *VOLT* screen.

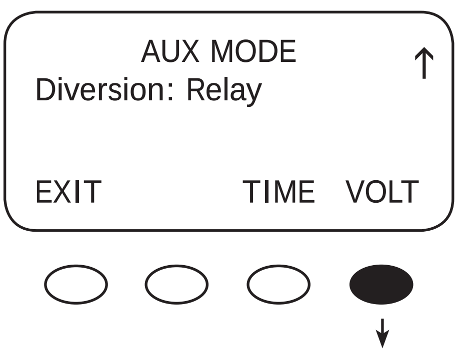


Press the **<TIME>** soft key to advance to the *Time* screen which allows the user to adjust the minimum time the *AUX MODE* is active after the battery voltage falls below the Hysteresis voltage.

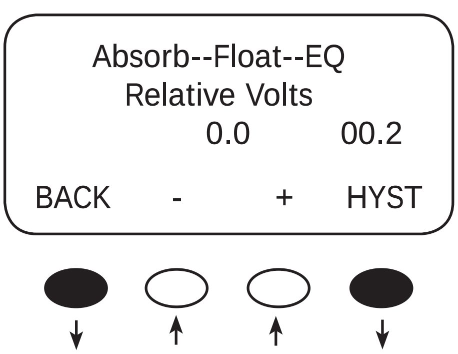


Hold Time shows how long the *AUX MODE* stays active after the battery voltage has fallen below the HYST (Hysteresis) set point. The user can adjust the *Hold Time* from 0.1 to 25 seconds.

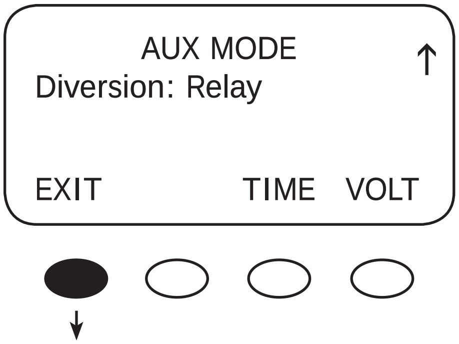
The *Delay Time* shows how long the battery voltage must be above the *Relative Volts* before the *AUX MODE* is activated. It can be adjusted from 0 to 24 seconds, *but is rarely required*. Pressing the <BACK> soft key returns to the *AUX MODE* Diversion: *Relay TIME* and *VOLT* screen.



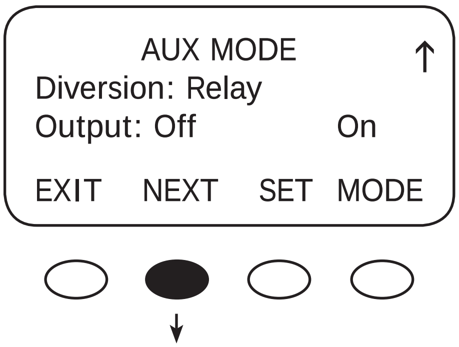
Press the **<VOLT>** soft key.



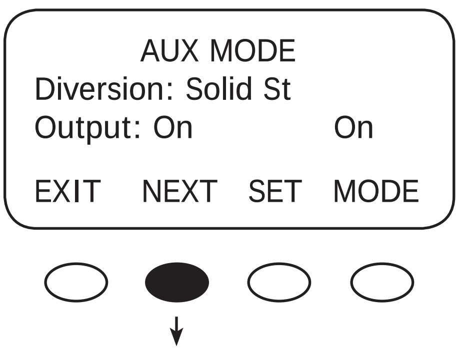
Use this screen to establish the set points for starting and ending the AUX MODE relative to the *Absorb*, *Float*, and *EQ* voltages. The **< - >** and **< + >** soft keys set the *Diversion* set points. The **<HYST>** (Hysteresis) set point establishes when the *AUX MODE* becomes inactive after the battery voltage falls below the *Relative Volts* voltage minus the HYST value. After establishing these values, press the **<BACK>** soft key to return to the *Diversion: Relay TIME* and *VOLT* screen.



Press the **<EXIT>** soft key.

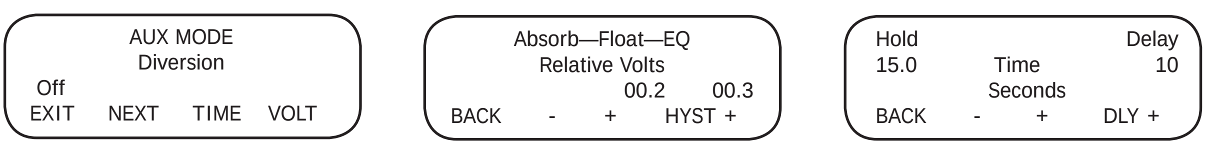


If a *Solid State Relay* is used, press the **<NEXT>** soft key to access the *Diversion Solid St* screen.



To adjust the time and voltage when a solid state relay is used, press the **<TIME>** and **<VOLT>** soft keys respectively and follow the same steps as for the *Diversion:Relay* screen. Note the values are displayed as percentages when a solid state relay is used. When any adjustments are completed, return to the *Diversion: Solid St* screen and press the **<NEXT>** soft key to view the *AUX MODE Low Batt Disconnect* screen.

Example of Diversion



Each recharging state—*Absorb, Float*, or *EQ*—has a recharging voltage set point. The *Diversion* AUX MODE can be active (*On*) when the battery voltage is raised above one of these set points for a certain amount of time or inactive (*Off*) when it falls below. The user can determine these voltages and times. In the example above, when the RE source (wind or hydro) raises the battery voltage 00.2v above the chosen set point for a *Delay* time of 10 seconds—the AUX Output will be active. When the battery voltage falls 00.3v below the HYST voltage set point for a Hold time of 15 sec – the AUX Output will be inactive (*Off*). See Figure 5, next page, for Diversion Load and AUX Wiring Set-Up.

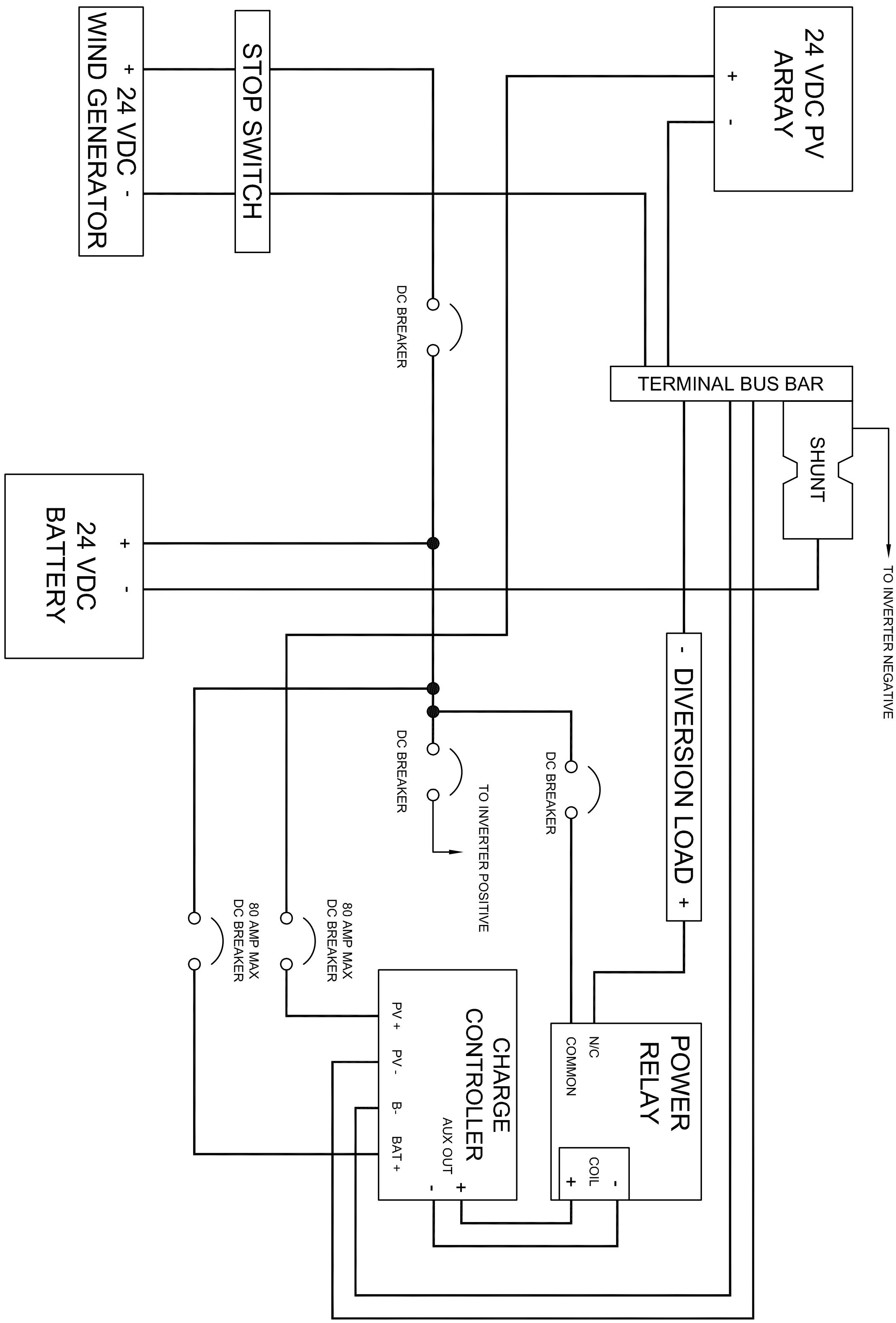
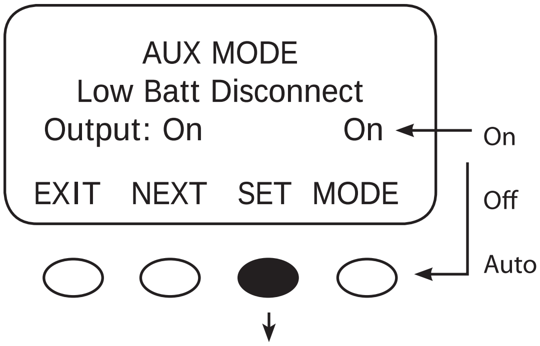
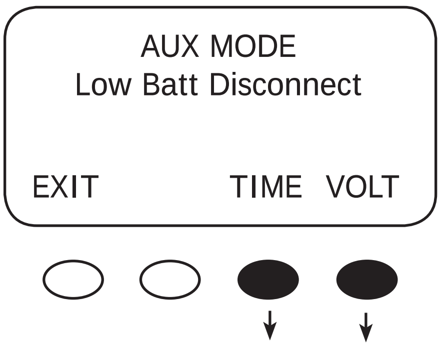


Figure 5 Diversion Load and AUX Wiring Set-Up Illustrated

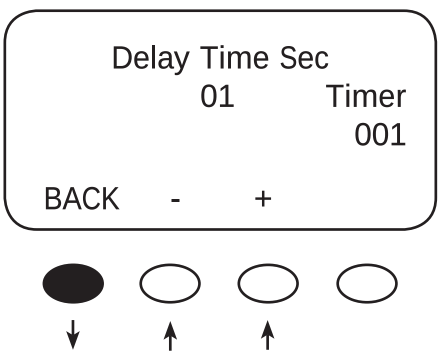
LOW BATTERY DISCONNECT



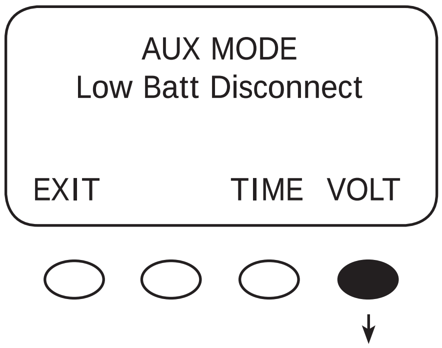
When the battery voltage falls below the disconnect volts, the *AUX connected loads only* are disconnected; the AUX *connected loads only* are connected when the battery voltage rises above the reconnect volts. To adjust these set points, press the **<TIME>** and **<VOLT>** soft keys.



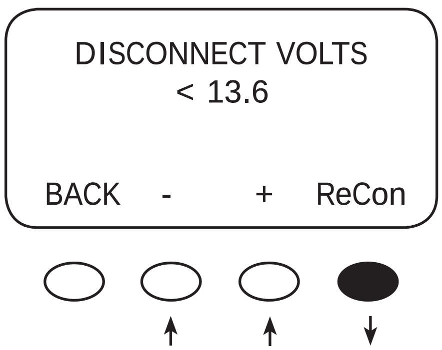
Press the **<TIME>** and **<VOLT>** soft keys to adjust the set points.



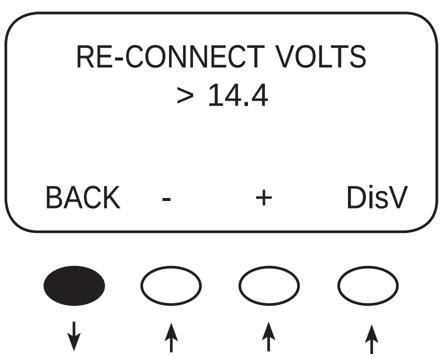
Press either the **< - >** or **< + >** soft key to adjust the delay time. This is the time period the Charge Controller waits before either activating or deactivating the *AUX MODE* when either the disconnect or reconnect voltages are reached. When the low voltage occurs, the timer shows the seconds remaining before disconnecting. When the reconnect voltage is reached, the timer shows the user-determined time before connecting. Press the **<BACK>** soft key to return to the *Low Batt Disconnect* screen.



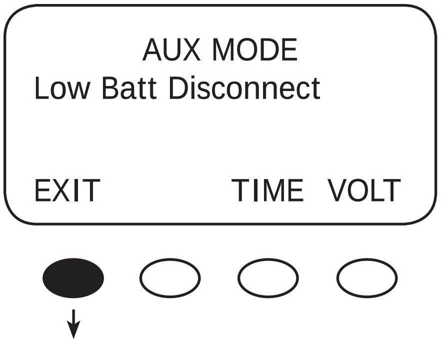
In the *Low Batt Disconnect* screen, press the **<VOLT>** soft key to adjust the battery voltage disconnects set point.



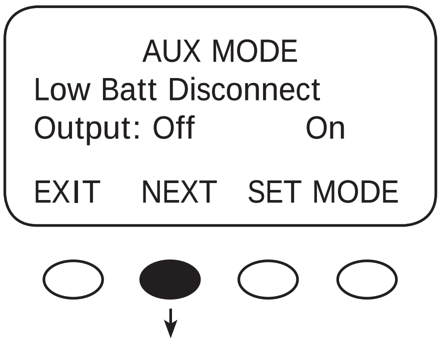
Press either the **< - >** or the **< + >** soft key to adjust the disconnect voltage. Press the **<ReCon>** soft key to open the *RE-CONNECT VOLTS* screen.



Press either the **< - >** or the **< + >** soft key to adjust the *RE-CONNECT VOLTS* value. The AUX Output activates when the voltage goes above this setting after the timer has counted back to zero. Press the **<BACK>** soft key to return to the *Low Batt Disconnect* screen. Press the **<DisV>** soft key to return to the *Disconnect Volts* screen.

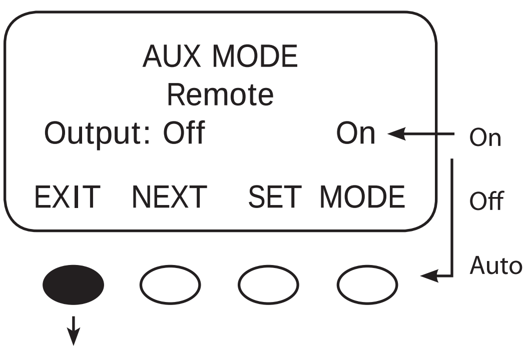


Press the **<EXIT>** soft key.

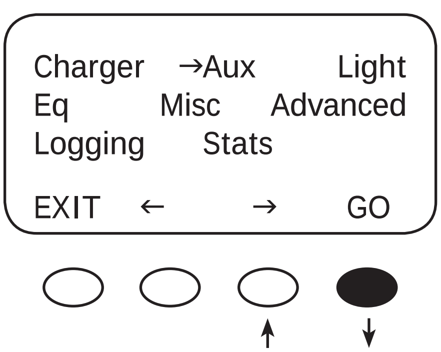


Press the **<NEXT>** soft key to view the *Remote* screen.

REMOTE

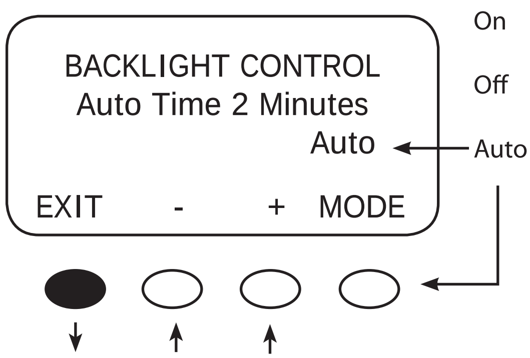


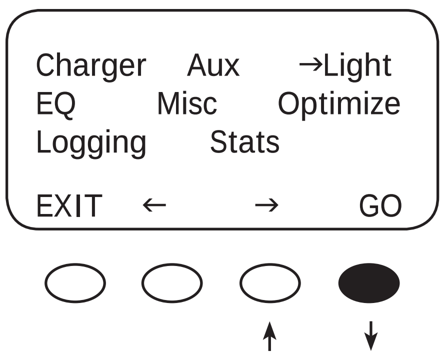
In Remote *AUX MODE,* the OutBack MATE can control the Charge Controller's AUX MODE. Press the **<EXIT>** soft key *twice* to return to the *MAIN* Menu screen.



Press the **<→>** soft key to move the "→" to the *Light* option. When the → is in front of *Light*, press the **<GO>** soft key.

10. Backlight





Auto (default) leaves backlight and soft keys on for up to nine minutes whenever any soft key is pressed (pressing any soft key when the LCD is *not* lighted does not change any settings). Minutes are adjustable using the **<->** and **< + >** soft keys.

On or *Off* states are also available.

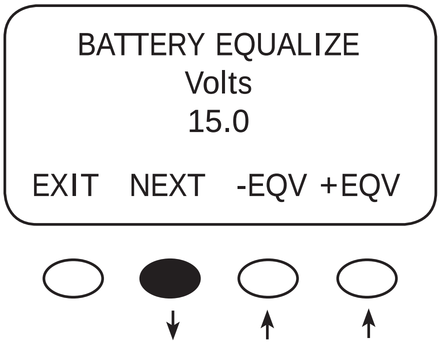
Press the **<EXIT>** soft key twice to return to the *MAIN* Menu screen

Press the **<→>** soft key to move the " → " to the *EQ* option. When the → is to the left of *EQ*, press the **<GO>** soft key.

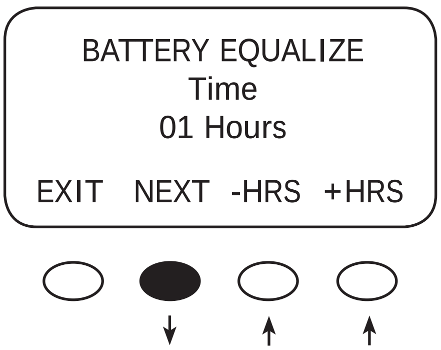
11. EQ—Battery Equalize

The intent of an equalization charge is to bring all battery cells to an equal voltage. Sealed batteries should not be equalized unless specifically instructed by the manufacturer. Shut off or minimize all loads on the battery. When equalizing, be sure the EQ voltage will not damage any still energized DC load. If possible, ensure the EQ cycle starts and stops the same day it is initiated or unnecessary battery gassing will occur.

- Occasional equalization extends the life of flooded electrolyte batteries.
- Proceed with caution! A vent fan is recommended in enclosed spaces.
- The Charge Controller allows the user to set voltages and times of equalization process.
- Both manual and auto modes are available.
- EQ voltage is *not* battery temperature compensated.
- *Always check the electrolyte level in the batteries before and after equalizing.*

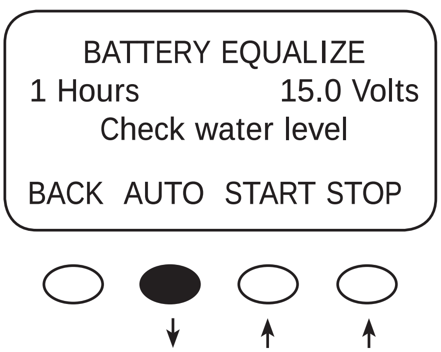


Press either the **< –EQV>** or **<+EQV >** soft key to change the EQ voltage, following your battery manufacturer's recommendations. Note that the factory default EQ voltage is set low, the same as the factory default Absorb voltage. Press the **<NEXT>** soft key to view the *BATTERY EQUALIZE Time* screen.



Press either the **<-HRS>** or **<+HRS>** soft key to set the desired equalization time, up to a seven hour maximum, always following your battery manufacturer's recommendations. Press the **<NEXT>** soft key to view the battery equalization start screen.

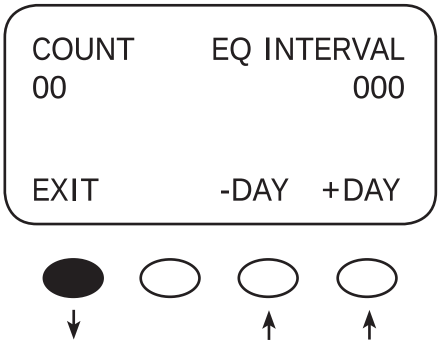
Manual Mode (default mode)



- Press the **<START>** soft key to manually begin an equalization cycle. To stop the cycle, press the **<STOP>** soft key.
- *EQ-MPPT* display indicates the Charge Controller is trying to reach the target equalize set point.
- Equalize time *EQ 0:00* in Hours:Minutes displays after the equalize set point is reached.
- The incomplete equalization cycle continues into the next day unless the Charge Controller is powered off or manually stopped. The remaining EQ time can be viewed in the *Stats* menu.
- EQ cycle terminates when EQ time period is reached.
- After equalizing, an *EQ DONE* message displayed and a *Float* cycle begins. This message remains displayed until a soft key is pressed.

Press the **<AUTO>** soft key to view the auto equalization screen.

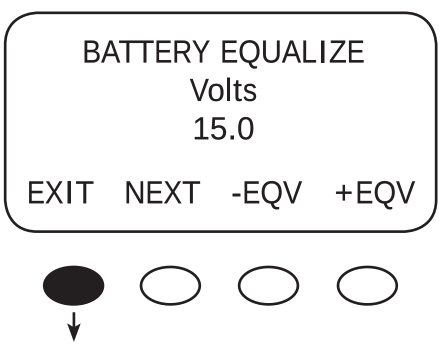
AUTO MODE



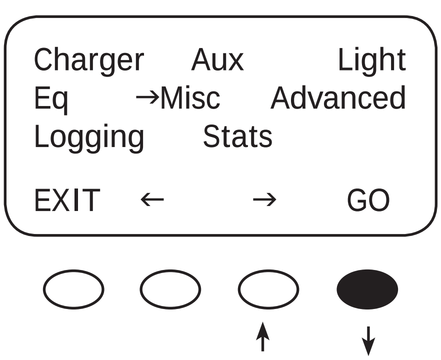
Use the **<-DAY>** and **<+DAY>** soft keys to preset the interval day to initiate an automatic equalization cycle. The *EQ INTERVAL* displays the number of days in the interval between cycles and *COUNT* displays how many days of the interval have passed. To view the *MAIN EQ* screens, press the **<EXIT>** soft key.

NOTE:

- *Auto Mode* initiates when a preset interval day (1-250 days) is reached.
- The default equalize interval (EQ INTERVAL) setting is 000 day leaving the auto eq disabled.
- EQ-MPPT display indicates the Charge Controller is trying to reach the target equalize set point.
- The equalize time *EQ 0:00* in Hours:Minutes displays after the equalize set point is reached.
- An incomplete equalization cycle continues into the next day unless the Charge Controller is powered off or manually stopped. The remaining *EQ* time can be viewed in the Stats Menu.
- The *COUNT* value will be cleared to 000 when an *EQ* is started, manually stopped, or Charge Controller has been powered off.
- After recharging, an *EQ DONE* message displays and a *Float* cycle begins. EQ DONE is displayed until (1) any soft key is pressed or (2) a new day occurs for systems using an OutBack MATE.



Press the first soft key twice to return to the *MAIN* Menu.



Press the **<→>** soft key until the → is in front of **Misc**. Press the **<GO>** soft key to view the *Misc* screen.

12. MISC—Miscellaneous

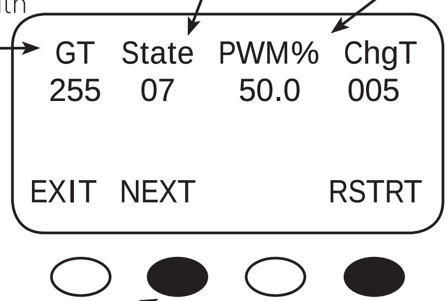
The MISCELLANEOUS screens display extra settings and technical information, some of which is useful for OutBack Power Systems Technical Services.

The Grid Tie (GT) value is sent from G-series inverter through the MATE and HUB for Grid Tie control communications. GT means The Charge Controller is in grid tie mode and communicating with the GT Series Inverter.

Each MPPT operation is a state. This number is useful for OutBack troubleshooting.

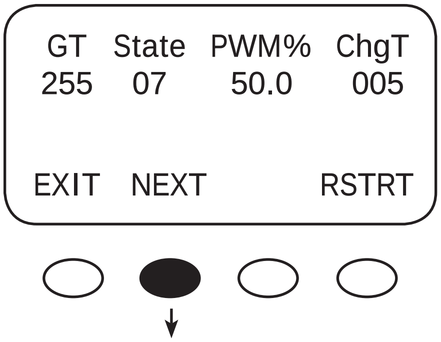
This is the duty cycle of the converter. At 50%, the PV terminals would be twice the battery voltage.

The Bulk/Absorb charge timer counts up to the Absorb time limit.

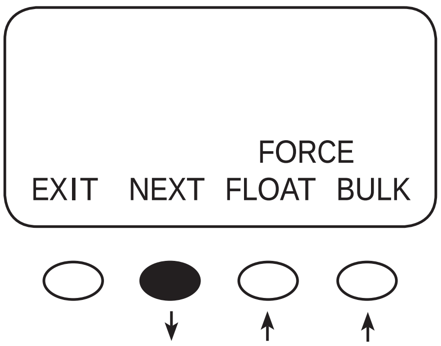


Press **NEXT** to Continue to the Force Bulk/Float Screen.

RSTRT forces the Charge Controller to restart or wake-up from 5-minute (default) long Snoozing mode. Restart and wakeup are mainly service features.



Press the **<NEXT>** soft key to view the *FORCE FLOAT*, or *BULK* screen.



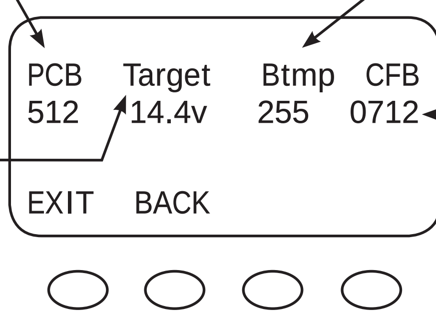
Pressing the **<FLOAT>** or **<BULK>** soft key forces the Charge Controller to that specific recharging cycle and returns to the *STATUS* screen. Forcing a *FLOAT* or *BULK* recharge will end an *EQ* cycle. Press the **<NEXT>** soft key to view the third *MISCELLANEOUS* screen.

- Force FLOAT = float cycle
- Force BULK = bulk cycle

This is the assigned number representing the temperature of the internal components to control the cooling fan. The lower the number, the higher the temperature. 25° C is approximately a value of 525.

Btmp is a battery temperature sensor reference value used to compensate the charging voltage. This is an arbitrary number between 0 and 255 and is not the actual temperature. An 'X' next to this value indicates a Global external RTS is being used (system with a HUB and MATE).

The target voltage the controller is trying to reach.



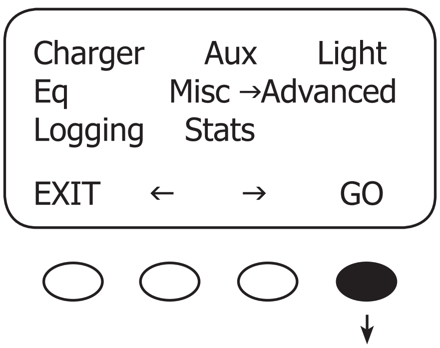
The output value of the internal current sensor is used to calculate output amps, watts, and track the Maximum Power Point of the array.

Press the **<EXIT>** soft key twice to return to the MAIN MENU.

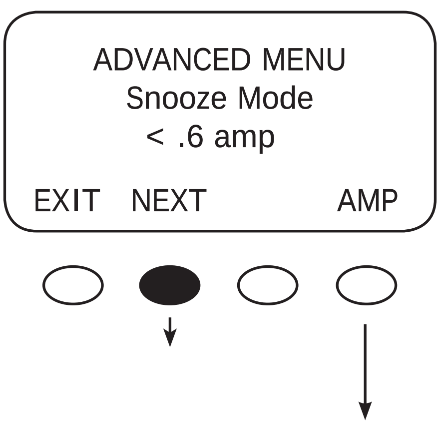
13. Advanced

The ADVANCED MENU allows fine-tuning of the Charge Controller operations including *Snooze* periods and Maximum Power Point limits. In order of appearance, the following modes occur in the ADVANCED Menu selections:

• *Snooze Mode* • *Wakeup* • *MPPT Mode* • *Park Mpp* • *Mpp Range Limit % Voc*
• *Absorb Time* • *Rebulk Voltage* • *Vbatt Calibration* • *RTS Compensation* • *Auto Restart*
• *Aux Polarity* • *Reset to Defaults?*

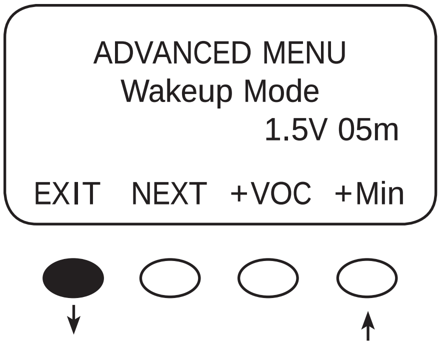


From the MAIN Menu, choose *Advanced* and press the **<GO>** soft key.

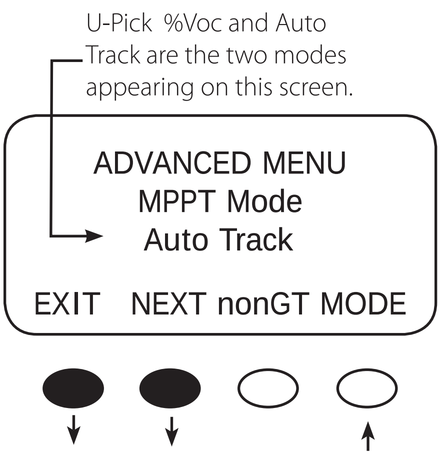


Snoozing occurs if the recharging current does not reach the user-selected cutoff current set point as shown in this screen. Press the **<AMP>** soft key to adjust the amp setting. Press the **<NEXT>** soft key for the *Wakeup Mode* screen.

Amp Values
0.2
0.4
0.6
0.8
1.0



Wakeup Mode selects how often the Charge Controller does a "Wakeup" during "Snoozing" periods. Since environmental conditions impact the open circuit voltage (Voc) of an array, a user selectable Voc rise in value will allow the controller to "wakeup" sooner or later based on the last measured Voc value. A selectable delay time in minutes will also allow the controller to "Wakeup" sooner or later if the measured Voc did not meet the user selectable Voc rise in value. Before changing these values, monitor your system for a week or so using the factory defaults and then gradually adjust the set points. If they're set too high, the Charge Controller might not wake up soon or often enough, which means a loss of power production. Note: +VOC ranges from 1.5V up to 9.5V. +MIN ranges from 5 up to 15 minutes. Press the **<NEXT>** soft key to go to the *MPPT Mode* screen.

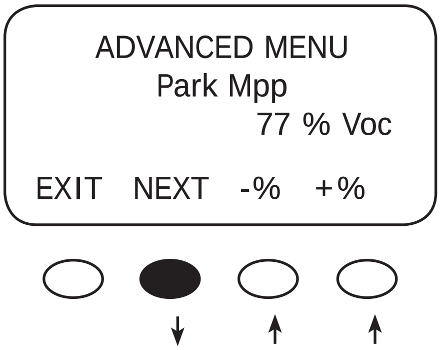


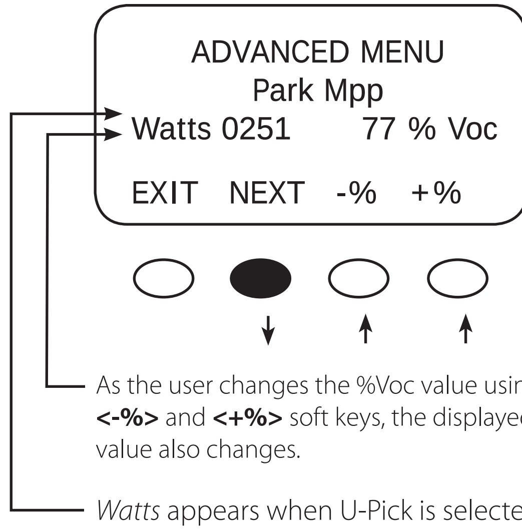
This screen allows the user to choose one of these modes:

- *Auto Track MPPT Mode* (the default and preferred mode) automatically tracks the PV upon wakeup and then tracks the MPP of the array. If the Auto Restart is set to 1 or 2, the Charge Controller awakes every 1.5 hours and does an initial tracking.
- *U-Pick % (Voc) MPPT* mode operates the PV voltage at a user-selected percentage of the Voc. This percentage is displayed in the *Park Mpp % Voc* screen along with the current output wattage. The wattage value changes as the user adjusts the Voc percentage, allowing the user to lock-in the most advantageous percentage value. *U-Pick %* acquires a new VOC value every 1.5 hours if Auto Restart is set to 1 or 2.

Press the **<MODE>** soft key to choose an MPPT mode. If you have an OutBack G-series inverter system with a HUB and MATE, press the **<nonGT>** soft key to activate the charge controller's grid-tie mode.

Press the **<NEXT>** soft key to view the *Park Mpp* screen.

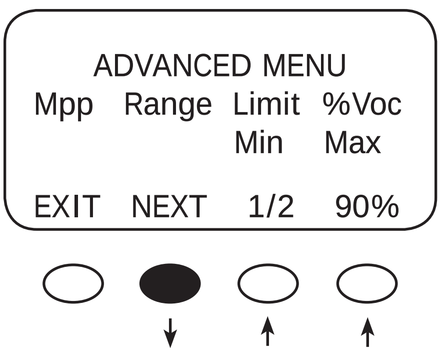




As the user changes the %Voc value using the **<-%>** and **<+%>** soft keys, the displayed Watts value also changes.

Watts appears when U-Pick is selected.

Press the **<NEXT>** soft key to view the *Park Mpp* screen.



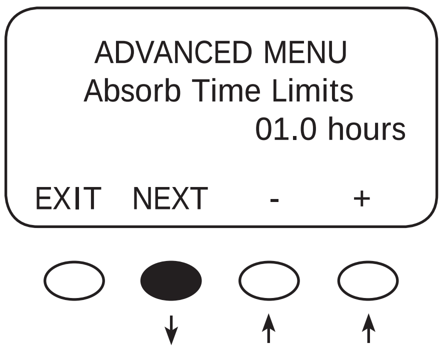
Use ½ value for high input arrays to speed up initial tracking.

U-Pick % (Voc) MPPT mode operates the PV voltage at a user-selected percentage of the VOC which is displayed in the *Park Mpp % Voc* screen. Press the **<NEXT>** soft key to view the *Mpp Range Limit %* screen.

The *Mpp Range Limit % Voc* adjusts the upper Mpp limit of the VOC. The default Charge Controller MPP voltage limit is set at 90% of the VOC and is normally left alone for an array. Setting *min* to *1/2* reduces the initial tracking time on a high input voltage array and also tracks one-half the VOC voltage.

The MPP adjustable Charge Controller limits are 80%, 85%, 90%, and 99% of the VOC. The *min* range limit setting may be set to *FULL* if something other than a PV array is connected to the input of the Charge Controller, such as a micro-hydro generator (see page 58), but the VOC cannot exceed 150 VDC at any time. Press the **<min>** or **<max>** soft key to adjust the MPP range limit. When done, press the **<NEXT>** soft key to view the *Absorb Time* screen.

14. Charging-Related Screens



In the *Absorb Time Limits* screen, the user can set the duration the Charge Controller stays in the *Absorb* recharge cycle.

- *Absorb Time* is adjustable from 0 to 24 hours (consult your battery manufacturer's recommendations).
- A *Bulk* cycle starts each morning (see chart next page). The charge timer (ChgT) is preset to zero.
- The *ChgT* counts up to the Absorb Time Limit after the Absorb voltage is reached.
- If the system cannot maintain the Absorb voltage set point during the *Absorb* cycle, the timer will stop counting up.
- If the battery voltage is greater than or equal to 12.4V, 24.8V, 37.2V, 49.6V 62.0V and less than the absorb voltage, the *ChgT* timer does not change.
- If the battery voltage is less than 12.4 V, 24.8V, 37.2V, 49.6V or 62.0V, the *ChgT* timer counts down to zero in minutes—for every minute elapsed, one minute is subtracted from the timer.
- If the battery voltage is less than 12.0V, 24.0V, 36.0V, 48.0V or 60.0V, the *ChgT* timer counts down to zero at twice as fast—for every minute elapsed, two minutes is subtracted from the timer.
- If the battery voltage is less than 11.6V, 23.2V, 34.8V, 46.6V, or 58.0V, the *ChgT* timer counts to zero four times as fast—for every minute elapsed, four minutes is subtracted from the timer.
- When the *Absorb Time Limit* is reached, the Charge Controller goes into *Float* stage and may briefly display *Charged* then *Float*. When the battery voltage drops below the float voltage set point, the Charge Controller recharges to maintain this set point, employing the *F(Float)-MPPT* function.

To adjust the *Absorb Time* limit, press either the **< + >** or **< ->** soft key. When finished, press the **<NEXT>** soft key to view the next screen.

Charge Controller Multi-Stage Battery Charging

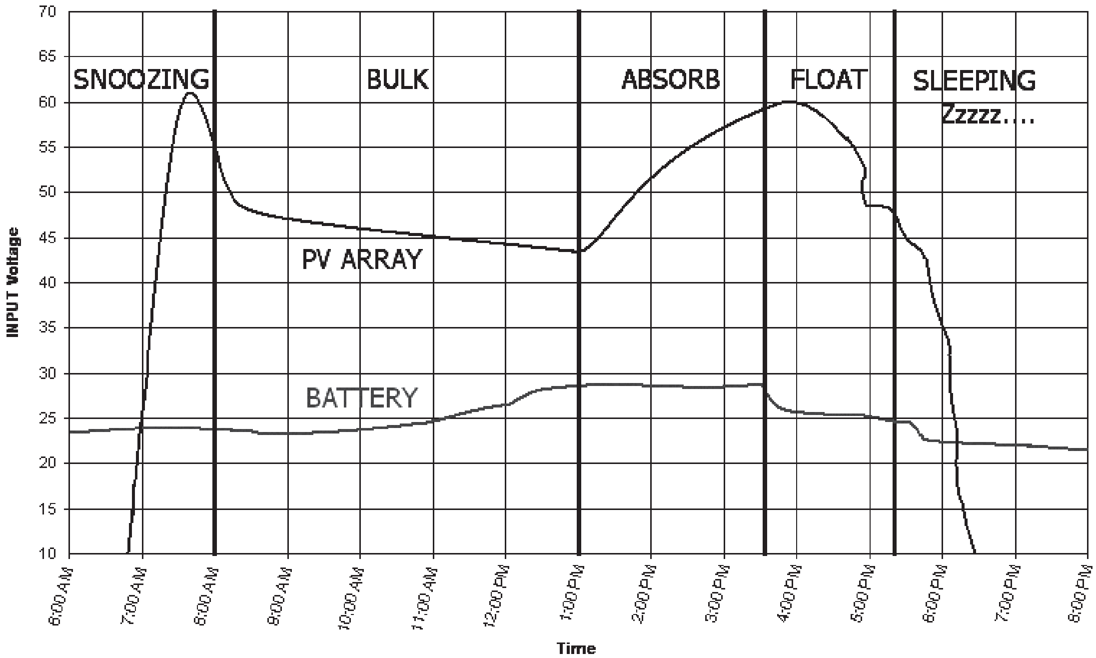
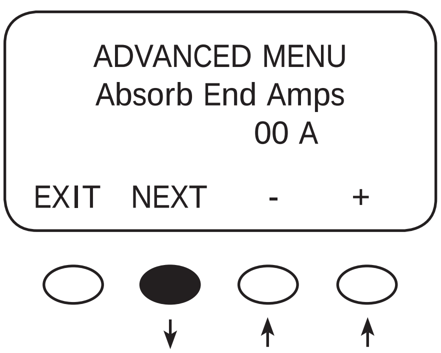
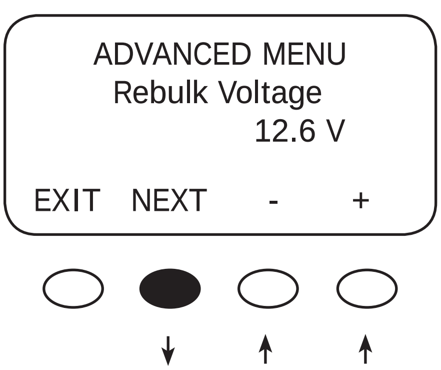


Figure 6 NOTE: In *BULK*, the Charge Controller will charge as long as necessary to complete the cycle, regardless of the timer's set points

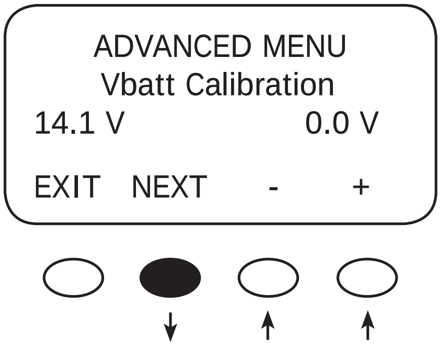


An *Absorb* charge cycle normally ends when a battery voltage is maintained at the *Absorb* set point for the user-determined time period. Use the **< ->** or **< + >** soft keys to adjust the *Absorb End Amps* to an optimal value (the default value is 00). While the battery voltage is at or above the Absorb target and the *Absorb End Amps* value is reached for a time delay of 15 seconds, the Charge Controller will switch to the Float stage regardless of the charger time minutes as shown in the *Misc* menu under *ChgT*. The charger timer will be cleared. This is an optional set point and is used for few installations.

When finished with any adjustments, press the **<NEXT>** soft key to view the *Rebulk Voltage* screen.

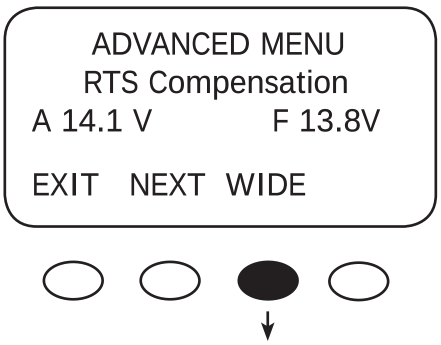


In *Float,* if the battery voltage falls below the *ReBulk Voltage* set point for at least 90 seconds, the Charge Controller will automatically reinitiate a *Bulk* charge cycle. The default is set to 6 volts, a very low value that will disable this function. The *Rebulk Voltage* value can be adjusted by pressing the **< - >** or **< + >** soft keys. Press the **<NEXT>** soft key to view the *Vbatt Calibration* screen.



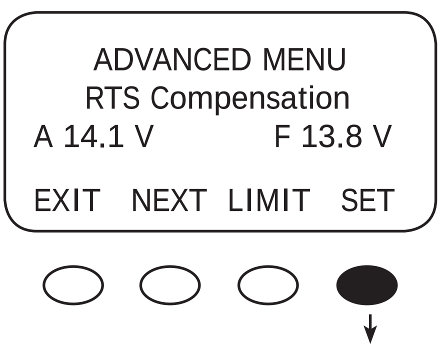
A quality calibrated voltmeter will provide even more accurate Charge Controller battery readings if an undesirable voltage drop occurs. When measuring battery voltage, ensure a good connection is made to the four wire lugs. Check the battery temperature compensation voltages if the voltages are much different than you expect from the charger setup *Absorb* and *Float* voltage settings. Use the **<->** and **<+>** soft keys to match the readings from the voltmeter (use of appropriate wire gauge will minimize voltage drop). When finished, press the **<NEXT>** soft key to view the *RTS Compensation* screen.

RTS Compensation*

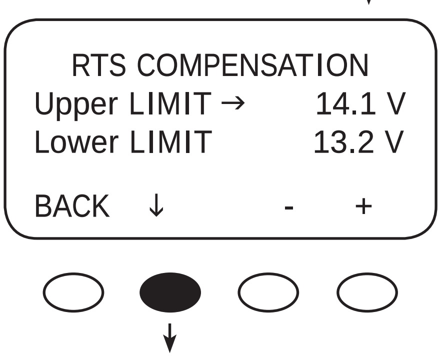


During cold weather, a battery often requires a higher recharging voltage. Lower quality inverters might not accommodate these higher voltages and can shut down during recharging, cutting off power to their loads. The Charge Controller allows the user to lower the compensated voltage in the Absorb cycle so these inverters will remain operating. Also, some batteries have an absolute voltage limit that should not be exceeded and the WIDE/LMIT option allows the user to control this during recharging. WIDE allows the *RTS* full control over recharging; *LIMIT* sets the ceiling and floor voltages for the RTS.

During hot weather, the *LIMIT* feature set point assures recharging will continue at a high enough voltage rather than dropping too low in reaction to a higher ambient temperature. This assures the recharging voltage adequately charges, but should be monitored according to the battery manufacturer's recommendations.

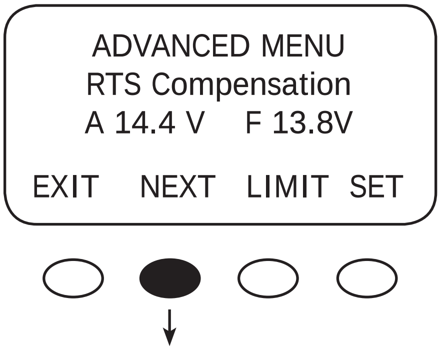


The *RTS* default compensated voltages apply if the *WIDE/LIMIT* option is set to *WIDE*. To change these values, press the **<WIDE>** soft key to bring up the next screen which allows user-determined limits. Press the <**SET**> soft key to adjust these values.



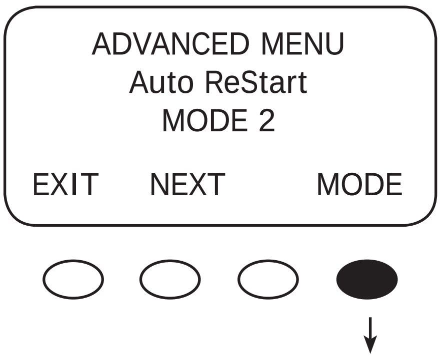
Press the **< ↓ >** soft key to choose the limit value you want to adjust. Press the **< - >** and **< + >** soft keys to adjust the chosen value(s). When finished, press the **<BACK>** soft key to return to the *RTS Compensation* screen.

*Optional OutBack RTS ***must*** be installed

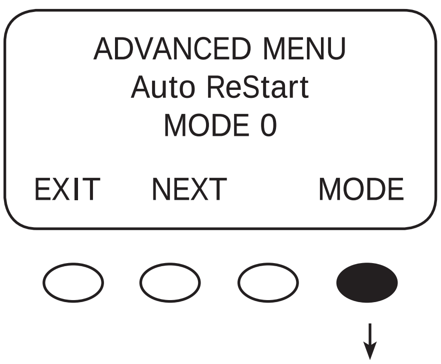


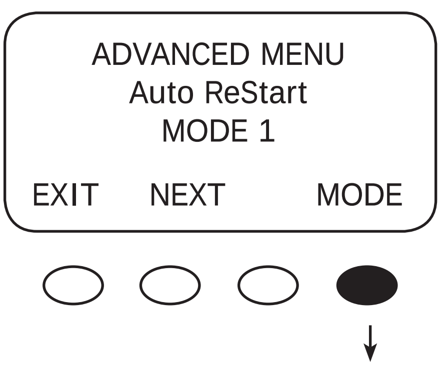
Press the **<NEXT>** soft key to view the *Auto Restart* screen.

AUTO RESTART

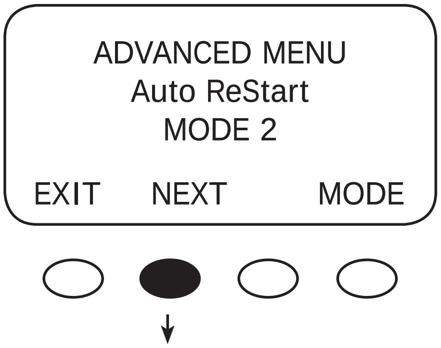


Pressing the fourth soft key selects among the three Charge Controller *Auto ReStart* modes: 0 (default), 1, and 2. *Auto ReStart* allows the Charge Controller to perform internal recalibrations.

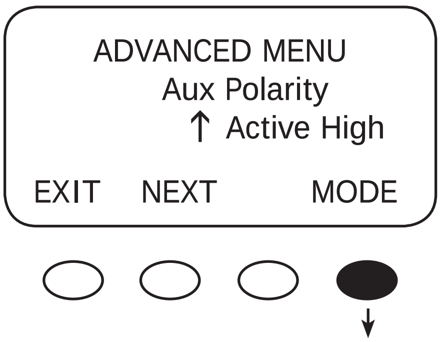




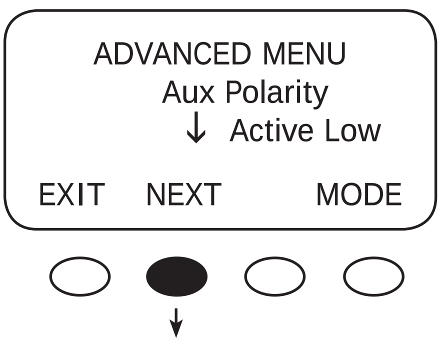
- *Mode 0— Auto ReStart* mode is disabled; the Charge Controller recharges continuously from an available source and never *Restarts.* Mode 0 would be chosen to avoid spinning a microhydro generator every 1.5 hours.
- *Mode 1*—once every 1.5 hours, when the Charge Controller is in *Bulk*, it will briefly *Restart* and initiate a full panel tracking. This will not reset any counters or charging stages or statistics.
- *Mode 2— Auto ReStar*t every 1.5 hours; in *Bulk, Absorb*, and *Float* modes, it will briefly *Restart* and initiate a full panel tracking. This will not reset any counters or charging stages or statistics.



From the *Auto Restart MODE 2* screen, press the **<NEXT>** soft key to view the *Aux Polarity* screen.

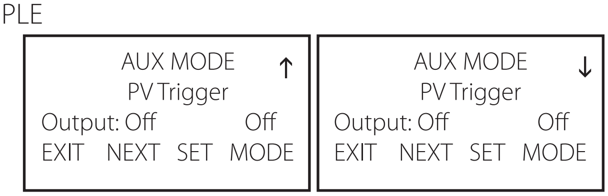


When the AUX function is ON, 12 volts is present at the AUX terminal; when it's OFF, 0 volts are present at the terminal. *Aux Polarity* allows the user to reverse the availability of this voltage for the *Night Light*, *PV Trigger,* or *Diversion Relay* functions. In *Active High*, the user establishes certain conditions for these functions. Pressing the **<MODE>** soft key brings up the *Active Low* screen which allows the user to reverse these conditions.

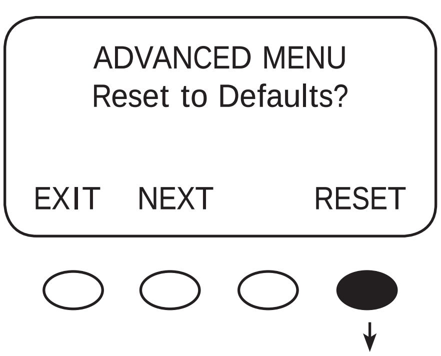


In the *Active Low* zero voltage will be available for a function that in *Active High* would normally have voltage. When one of the three functions— *Night Light*, *PV Trigger,* or *Diversion Relay*—has been chosen as the AUX function, an arrow in the right hand corner of the screen will reflect the *Aux Polarity* state. An arrow pointing up means *Active High* while an arrow pointing down means ***Active Low***. Press the **<NEXT>** soft key to view the *Reset to Defaults?* screen.

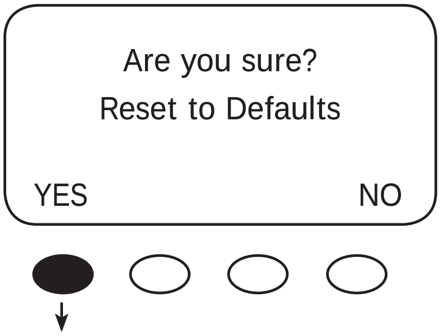
EXAMPLE



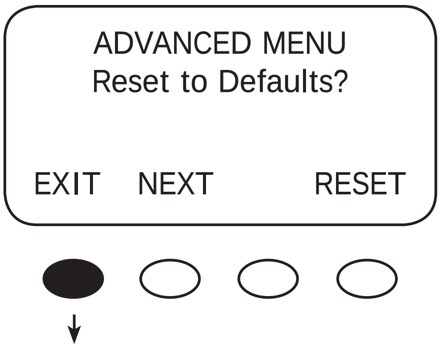
PV Trigger Active High *PV Trigger Active Low*



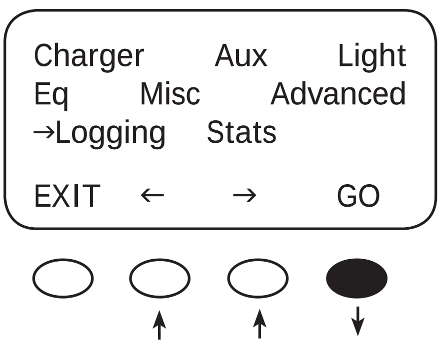
In this screen, a user can press the **<RESET>** soft key to return the Charge Controller to the factory default settings.
(If you do not need to reset, press the **<EXIT>** soft key to return to the *STATUS* screen.)



Pressing the **<YES>** soft key brings up a *Reset to Defaults* screen momentarily before returning to the *Reset to Defaults?* screen

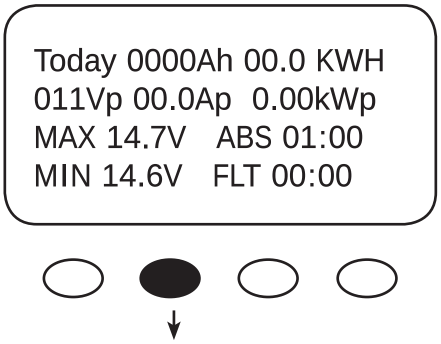


Press the **<EXIT>** key twice to return to the MAIN Menu screen.

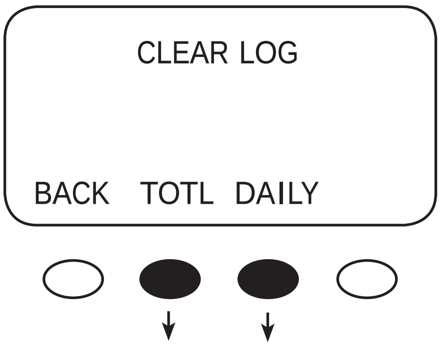


From the *MAIN* Menu, press the **<→>** soft key to move the arrow next to the *Logging* function and then press the **<GO>** soft key. This leads to the *End of the Day Summary* screen, which is a log of the daily statistics and can be viewed at any time.

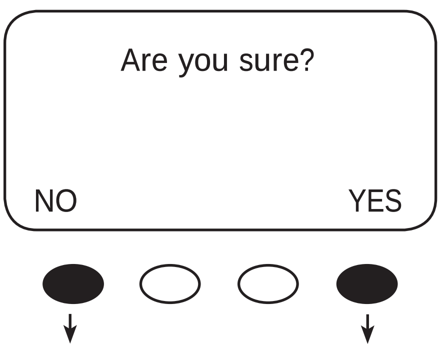
15. Logging



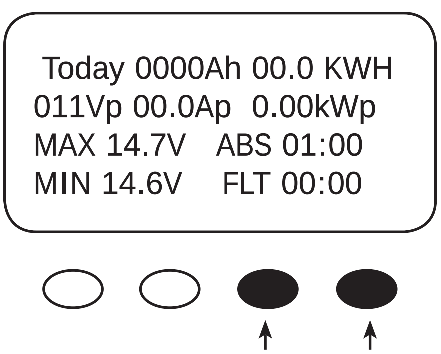
A user can clear either the daily or accumulated statistics of the Charge Controller by pressing the second button from the left in this screen. This will bring up the *CLEAR LOG* screen.



The *CLEAR LOG* screen offers the option of clearing up to 128 days of accumulated statistics or the total in the secondary *STATS* screen (page 56). Press and hold either the **<TOTL>** (total) or **<DAILY >**key to clear those specific statistics.



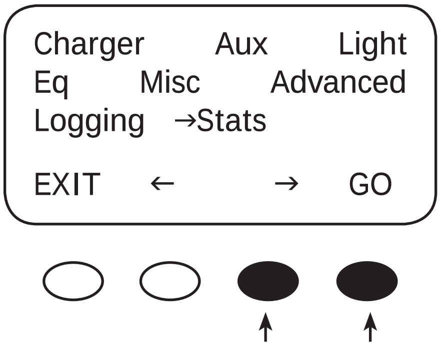
The *Are you sure?* screen appears. Pressing the **<YES>** soft key returns to the *CLEAR LOG* screen; pressing the **<NO>** soft key returns to the *Logging* screen.



Pressing the third and fourth soft keys changes the displayed day's statistics, by moving either forward or backward within the 128 days of available statistics that are viewable.

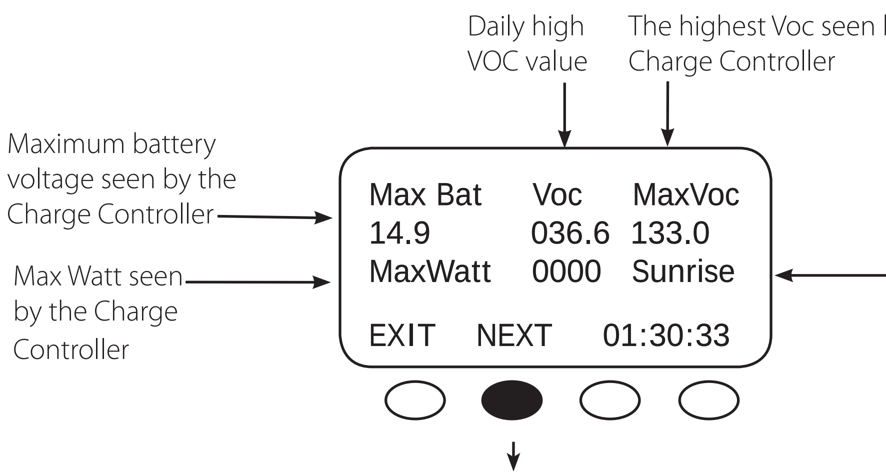
NOTE: If two or more Charge Controllers are used in the same system and are started up or cleared on different days, their numeric dates will not be the same. This can lead to some misunderstandings when looking back and comparing data between the two or more units. A user looking back at day 12 on both units would find very different results.

16. Stats



From the MAIN Menu, press the **<→>** soft key to move the arrow next to the Stats function and then press the **<GO>** soft key

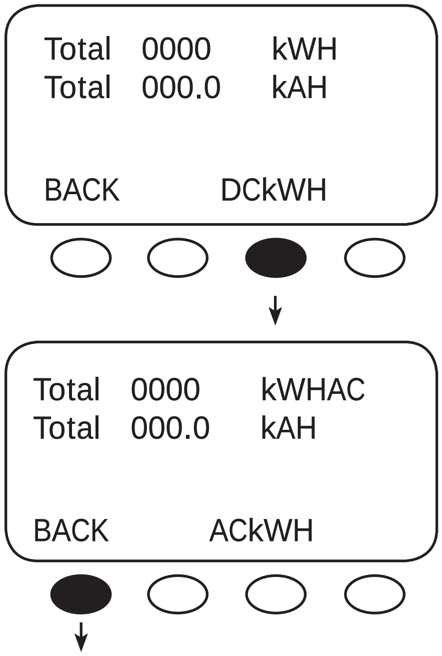
The *STATS* screen displays additional voltage and time information.



In a stand alone Charge Controller—one that is not connected to a MATE—Sunrise shows how long ago the Charge Controller woke up for the first time each day and when the daily and total logged values were updated and cleared from the STATUS screen. If the Charge Controller is connected to a MATE, the logging occurs at midinght.

Press the **<NEXT>** soft to view the second *STATS* screen.

Secondary STATS screen



The *Secondary Stats* screen shows the total accumulated DC and AC kilowatt hours and kiloamp hours of the Charge Controller.

Pressing the **<DCkWH>** soft key switches the screen between DC kilowatt hours and AC kilowatt hours

- *DCkWH* shows the DC kilowatthours and should be used in a non-grid-tied system
- A*CkWH* is used with a grid-tied system. This measure is based on a 90% inverter efficiency (1 kWH DC= 0.9 kWH AC)

Pressing the first soft key three times returns to the *MAIN* Menu screen.

17. Micro-Hydro and Fuel Cell Applications

The Charge Controller is designed to work with solar arrays. Although it will work with micro-hydro turbines and fuel cell, OutBack Power Systems can only offer limited technical support for these applications because there is too much variance in micro-hydro and fuel cell generator specifications. When used for micro-hydro or fuel cell applications, the Charge Controller warranty will be honored only if the manufacturer and turbine model have been approved by OutBack Power Systems. Please check with one of the following manufacturers or OutBack Power Systems before employing the Charge Controller with these applications:

- Harris Hydroelectric
  (831) 425-7652
  www.harrishydro.com

- Alternative Power & Machine
  (541) 476-8916
  www.apmhydro.com

- Energy System & Design
  (506) 433-3151
  www.microhydropower.com

The Charge Controller is not compatible with wind turbine applications and OutBack cannot warranty its use in these applications.

MICRO-HYDRO AND FUEL CELL SYSTEMS PERFORMANCE OPTIMIZATION

Micro-hydro and fuel cell systems are different than PV systems, whose VOC output is more subject to change due to weather and time of day. A PV system normally finds its Maximum Power Point voltage between 50-90% of its VOC. A micro-hydro or fuel cell system's MPP voltage can be outside of this range.

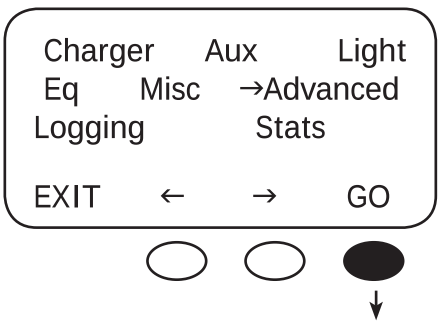
The Charge Controller allows a user to experiment and find more appropriate set points to best capture the MPP voltage using *U-Pick* mode. Otherwise, *Auto Track* begins tracking the VOC and works its way down until the optimum percentage of input voltage yields the MPP voltage. If *U-Pick % Voc* is chosen, the MPP is calculated by whatever value is found in *Park Mpp,* even if it's not the optimal value for determining the MPP voltage. For this reason, OutBack normally suggests leaving the system in *Auto Sweep* mode.

18. Advanced Menu (Micro-Hydro and Fuel Cell Applications)

Mpp Range Limit % (Auto Track Mode only)

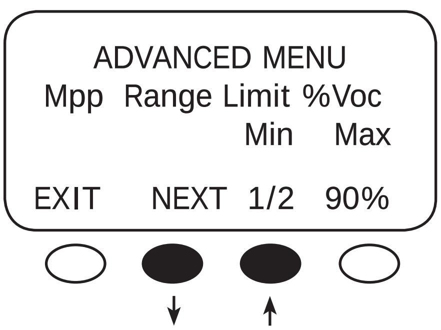
The Charge Controller searches for the MPP voltage by tracking the input voltage up to one half (default) of the Voc, which is based on values appropriate for a solar array. Micro-hydro and fuel cell systems can require a broader range, normally on the lower end. Adjusting the lower limit, expressed as *1/2* on the display screen, for *FULL* allows the Charge Controller to track the input voltage close to the battery voltage instead of 1/2 (or 50%) of the Voc.

This adjustment only affects the initial tracking at the beginning of the day and any subsequent trackings caused by Auto-Restart or any forced restart of the Charge Controller.

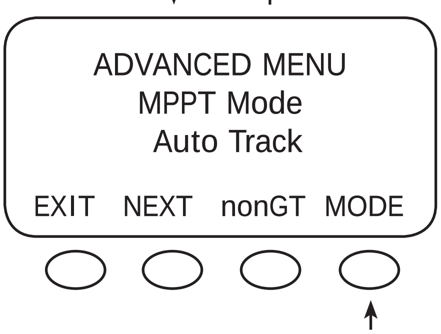


To adjust the Lower Mpp Range Limit:

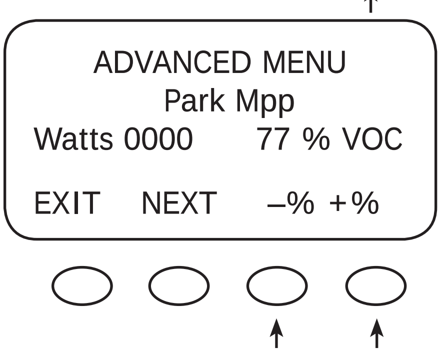
From the *MAIN* Menu, with the arrow in front of *Advanced,* press the **<GO>** soft key.



In the ADVANCED MENU screen, press the **<NEXT>** soft key until the *Mpp Range Limit % Voc* screen appears. Press the **<1/2>** soft key until *FULL* appears. When finished, press the **<NEXT>** soft key until the *MPPT Mode* screen appears.



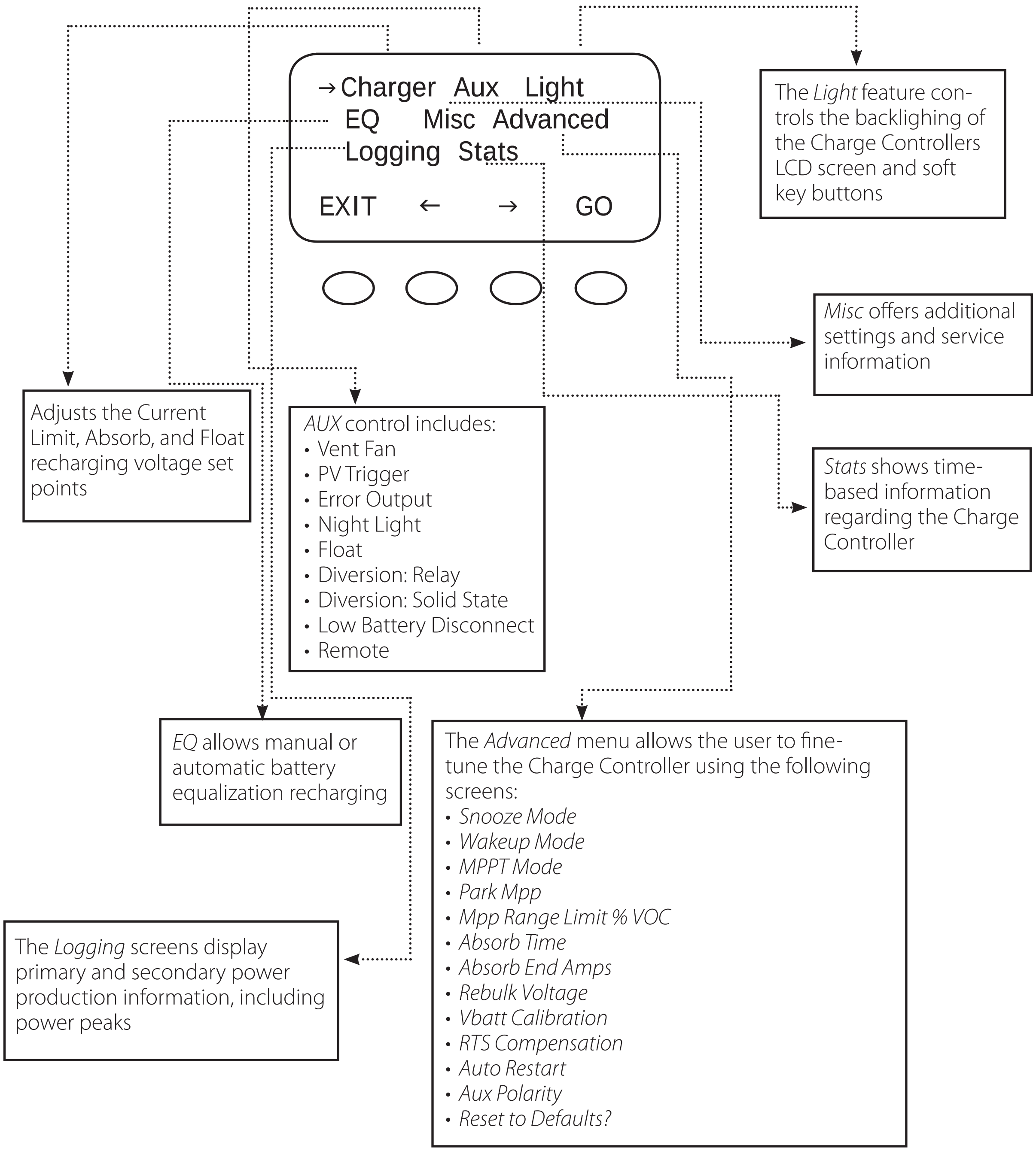
To pick between *Auto Track* or *U-Pick % MPPT* Mode and determine the Charge Controller's operating Voc percentage, press the **<MODE>** soft key to interchange between the two modes. Re-entering the password might be required. After choosing a mode, press the **<NEXT>** soft key in the *ADVANCED MENU* to view the *Park Mpp* screen (only applicable for *U-Pick* mode).



Press the **<-VOC>** or **<+VOC>** soft key to select one of the percentage values; *U-Pick* always uses the *Park Mpp* value.

19. Abbreviated Menu Map

Much of the Charge Controller activity takes place around the *MAIN* screen. From this screen, the user can access other screens to both observe system activiy and make adjustments to certain critical functions.



20. Application Notes

OutBack Power System GTFX/GVFX Grid-tie settings

In a GTFX/GVFX Series Inverter/Charger, Charge Controller, HUB, and MATE installation set the Charge Controller to GT mode in the ADVANCED MENU. GT mode allows the GTFX/GVFX to manage the Charge Controller float setting ensuring the Charge Controller is always keeping the battery above the sell voltage of the GTFX/GVFX.

Grid-tie applications (non-OutBack inverter/chargers)

When selling electricity back to the grid, keep the inverter Sell/Float voltage below the Charge Controller float voltage. Appropriate values: 0.5 Volts difference for 24V battery system or 1.0 volt difference for 48V battery systems.

Positive grounded systems

Telcom applications frequently require a positive grounded system. The Charge Controller switches the POSITIVE PV and battery leads. Keep these separate. If code allows, ground ONLY the battery positive lead in this case. Do not connect the Charge Controller's battery plus to the PV plus input while the Charge Controller is running. The OutBack HUB cannot be used in a positive grounded system.

21. Charge Controller EFFICIENCY vs. INPUT POWER GRAPH

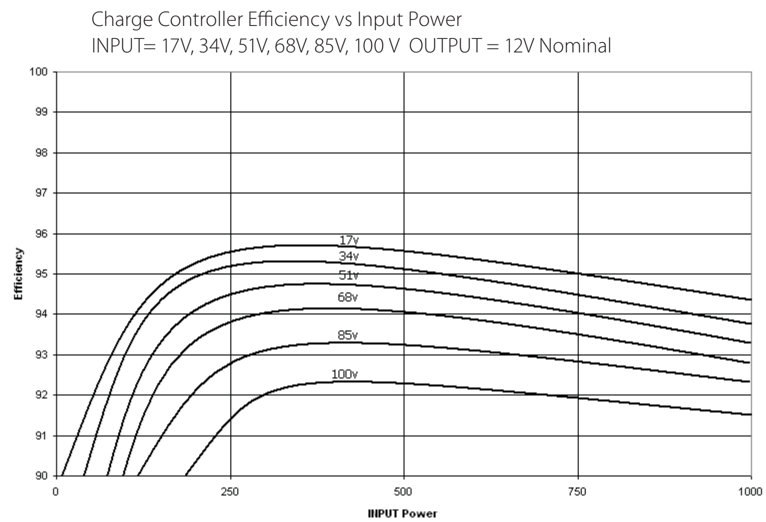


Figure 7 12V Battery System Efficiency Curve

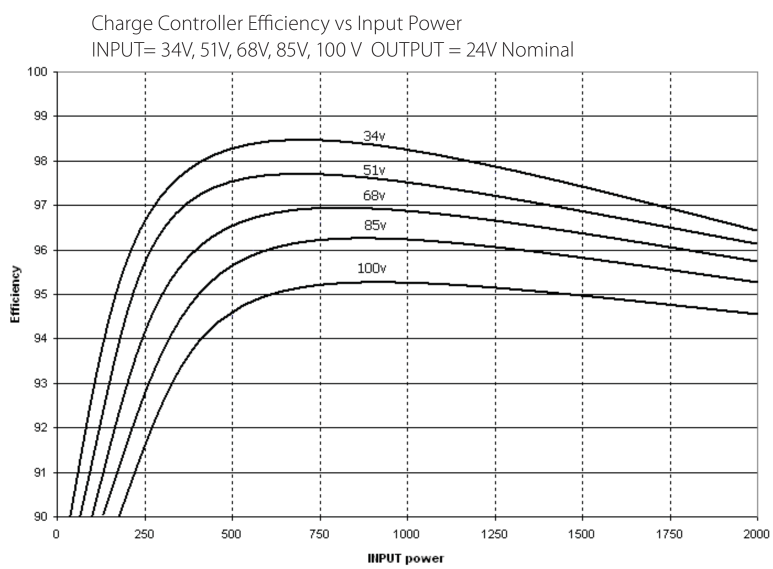


Figure 8 24V Battery System Efficiency Curve

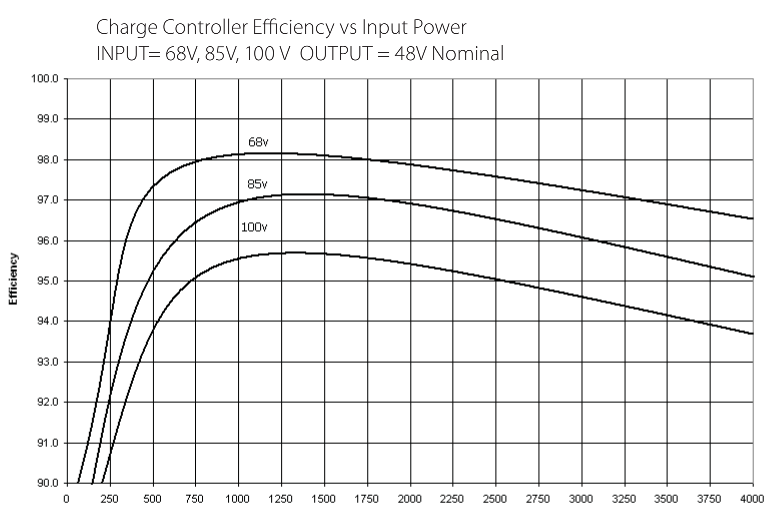


Figure 9 48V Battery System Efficiency Curve

22. Understanding the Various Operational Modes

The Charge Controller modes of operation will change occasionally during the day based on the PV array output and the battery system state of charge. The Charge Controller operating modes are displayed at the bottom right hand corner of the STATUS screen.

Absorbing The Charge Controller is in the Absorb (constant voltage) charge stage, regulating the battery voltage at the Absorb voltage set point (modified by battery temperature compensation if installed). During this cycle, the *ChgT* counter in the Misc menu is counting up towards the user defined *Absorb Time Limit*. If the system cannot regulate the battery voltage at the *Absorb* voltage set point, then the Charge Controller reverts back to the *Bulk* charge stage, display *MPPT Bulk,* and the *ChgT* counter may start counting down towards zero minutes or until the *Absorb* target is met. See page 49 for more information.

AutoStart (Auto Re-Start) Mode 1—Once every 1.5 hours in Bulk cycle and in Mode 2, once every 1.5 hours in the *Bulk, Absorb* and *Float* recharging modes, the Charge Controller will start over from sleeping and re-track (full track) and re-calibrate the current sensor. Mode 0 is disabled completely. (See *Stats* menu). Note: If enabled, *AutoStart* also occurs during the *MPPT EQ* cycle.

BatTmpErr The battery temperature sensor is shorted or damaged. The charging voltage will not be temperature compensated and the cooling fan will continuously operate.

BatTooHot The battery temperature sensor has detected a battery temperature of over 50°C. The Charge Controller will stop charging the battery and wait for the battery to cool below 50°C.

Charged There is an external DC source other than solar keeping the battery above the *Float* voltage set point-- the Charge Controller will stop charging. The display may also appear when the charge cycle is transitioning from *Absorbing* (upper target voltage) to *Floating* (lower target voltage).

EQ 0:00 This is the time elapsed in hours and minutes since the *Equalization* voltage set point was met. If the *EQ* voltage set point is not maintained, the controller will revert back – the EQ timer will pause until the batteries are regulated at the *EQ* voltage set point again. The paused time can be viewed in the *Stats* menu.

EQ Done Once the set *EQ* time (between 1 and 7 hours) has successfully completed, *EQ Done* will be displayed either until a button is pressed, or the next morning's wakeup. The Charge Controller will transition to *Float* cycle at the end of the completed *EQ* cycle.

EX-Absorb There is an external DC source other than solar keeping the battery above the *Absorb* voltage set point. The Charge Controller will stop charging.

Floating The Charge Controller is in the Float (constant voltage) charge stage and is regulating the battery at the *Float* voltage set point (modified by battery temperature compensation, if installed). If the system cannot maintain the *Float* voltage set point, (e.g. AC and/or DC loads are on), the Charge Controller will employ the *MPPT* function, display *MPPT Float*, and try its best to regulate the batteries to the *Float* voltage set point.

GT Mode In a system with an OutBack FX Grid-Tie Series Inverter(s), HUB *and* MATE, the Charge Controller will display *GT Mode* if and only if the inverter is in *Sell* mode *and* the Charge Controller is in *Bulk (MPPT BULK*) or *Float (MPPT FLOAT)* cycle. This is also a good indicator for establishing proper Grid-Tie mode communication between the FX G-Series Inverter(s) and Charge Controller. *GT* must be selected in the *MPPT Mode Advanced* menu in order to be viewed.

High VOC This indicates the PV array's open circuit voltage is too high for the controller to safely operate. This should only occur with systems using 72 VDC nominal PV arrays in very cold temperatures (below 5° F / -15° C). The controller will automatically restart operation once the PV array's open circuit voltage falls to a safe level (145 VDC or lower). The amount of time required before starting operation is dependent on the module type, ambient temperature, and the amount of sunlight directly on the PV array. Normally, the controller starts in the morning within a few minutes of the PV array being in direct sunlight.

Low Light / Snoozing During the initial tracking *(see Wakeup and Tracking)*, if it is determined to be too late (or too early) in the day, the Charge Controller will display *Low Light* for a few seconds and then display *Snoozing* for 5 minutes (default). This reduces energy usage and unnecessary powering of the Charge Controller. This message is also displayed in extremely cloudy weather.

MPPT Bulk The Charge Controller is in *Maximum Power Point Tracking* mode trying to regulate the battery voltage towards the *Absorb* voltage set point. If the Charge Controller transitioned from *Absorbing* to *MPPT Bulk*, the *Charge Timer (ChgT)* counter may start counting down towards zero minutes or until the *Absorb* target is met. See page 49 for more information.

MPPT Float The Charge Controller is in *Maximum Power Point Tracking* mode trying to regulate the battery voltage towards the *Float* voltage set point. Note: *Charge Timer (ChgT)* is inactive in the *Float* state.

MPPT EQ The *equalization cycle* has started and the Charge Controller is trying to regulate at the *Equalization* voltage set point. *EQ* is ***not*** battery temperature compensated. During an equalization cycle, *EQ 0:00* will be displayed along with the *EQ* time in hours and minutes. The AC/DC loads should be turned off/minimized and the battery charged so the Charge Controller can quickly reach the *EQ* voltage set point. Otherwise, the Charge Controller may not reach or maintain the *EQ* cycle.

New VOC The Charge Controller is acquiring a new open circuit panel voltage (VOC).

OvrCurrent If more than 6A flowing *from* the battery or more than 100A flowing *to* the battery. To reinitiate power production, press "RSTRT" in the "Misc" menu.

Over Temp (Very rare) Either the Charge Controller is too hot or its internal temperature sensor is shorted. If this message appears, carefully check if the Charge Controller's heat sink is extremely hot. The heat generated by the Charge Controller, and therefore its losses, is proportional to input voltage times output current. To help control its operating temperature, avoid installing the Charge Controller in direct sunlight

Re-Cal There are certain abnormal conditions that can confuse the current measuring method in the Charge Controller. When and if one happens, the Charge Controller will temporarily stop and re-calibrate. This may happen because of negative current, i.e., current flowing from the battery, or a tripped PV breaker. A new VOC is also acquired during a Re-Cal.

Sleeping The PV voltage is two volts less than the battery voltage. This may also appear during the day when the Charge Controller is transitioning between certain states, or due to other conditions.

SysError (Very rare) System Error indicates an internal non-volatile memory error. The unit will stop operating when this message is displayed. Call the factory if you see this message (360-435-6030).

Tracking In *Auto-Sweep MPPT* mode, the Charge Controller is doing an initial tracking of the panel voltage from VOC towards battery voltage after wakeup. This display also appears when the controller transitions from a target set point (*Absorbing/ Floating/EQ 0:00*) to the MPPT state (*MPPT Bulk/ MPPT Float/ MPPT EQ*).

Unloaded The battery terminals abruptly unload. *Unloaded* is also displayed if the battery breaker trips while MPPTing or the battery voltage is set too low.

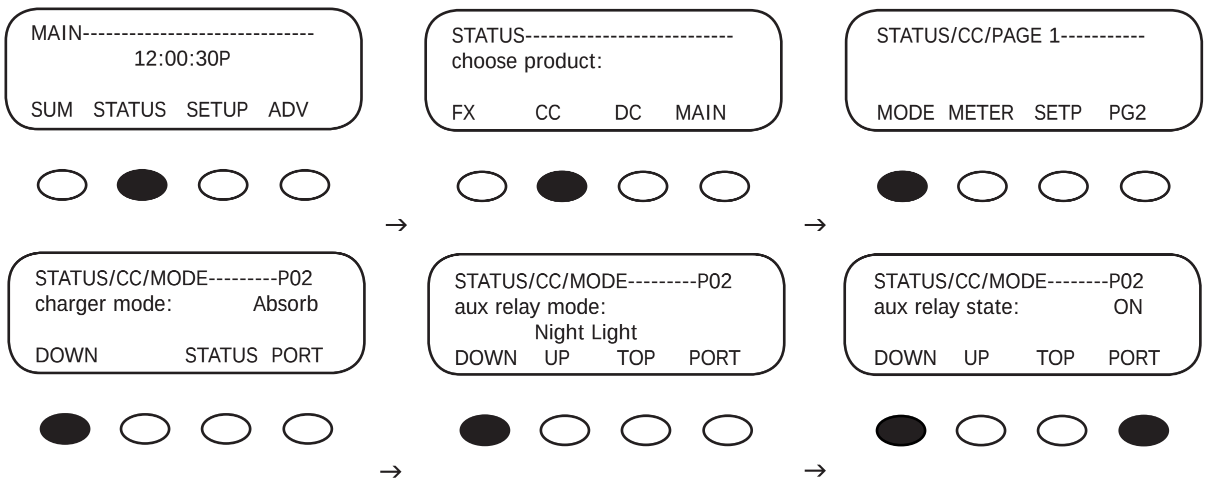
Wakeup As the PV open circuit voltage (VOC) rises above the battery system voltage by two volts, the Charge Controller prepares to deliver power to the batteries. During this period, the Charge Controller is calculating the pulse width modulation (PWM) duty cycles, turning on power supply voltages in the proper sequences, and making internal calibrations. At wakeup, the Charge Controller closes its relays and then starts tracking the input voltage (the "initial" tracking) towards the battery voltage. At dawn and dusk this may happen many times until there is (or is not) enough power from the PV array to keep going. Wakeup is also a time when the Charge Controller acquires a new VOC.

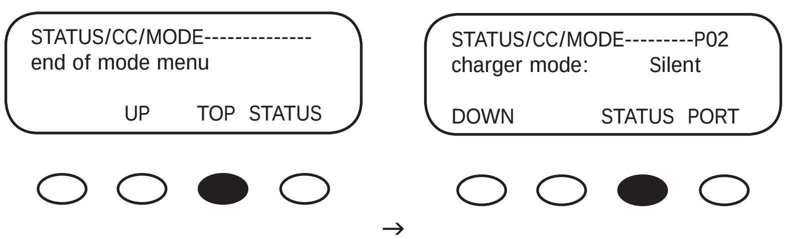
Zzzzz... At night (after 3 hours of continuous Sleeping) the Charge Controller will display *Zzzzz...* until the next wakeup. At the next wakeup, (usually the next morning), the daily statistics of a single Charge Controller, (AmpHours, KWh, etc.), will accumulate into the total statistics and then the displayed daily statistics and *End of Day* summary will clear. A *Bulk* charge will automatically initiate at the next Wakeup. A Charge Controller combined with a HUB and a MATE will log at midnight.

23. MATE-Displayed Charge Controller Screens

Status Mode Screens

The Charge Controller STATUS MODE Screens displayed on the optional OutBack MATE (Rev 4.0.4 or greater) include MODE, METER, and SET (SETPOINT). In STATUS Mode, these functions can be viewed by the MATE, but not changed. Please see the *MATE Installation and User Manual* for more information.



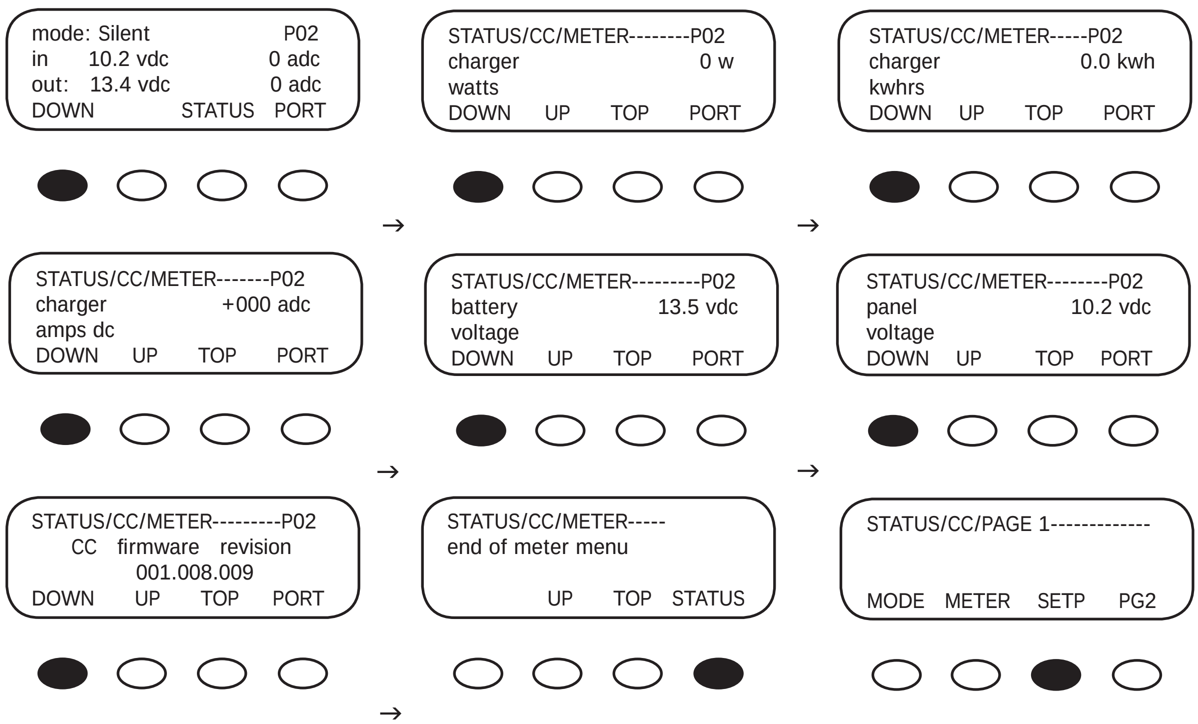


Press the **<STATUS>** soft key to return to the *STATUS* menu. Then press **<METER>** to view the *CC METER* screens.

Charge Controller MODE Screens

- *charger mode:* displays one of five charging stages (Bulk, Absorption, Float, Silent, or Equalization)
- *aux relay mode:* displays one of nine Charge Controller AUX modes (*Vent Fan, PV Trigger, ERROR OUT-PUT, Night Light, FLoat, Diversion: Relay, Diversion: Solid St, Low Batt(ery) Disconnect, Remote*)
- *aux relay state:* indicates if the AUX is *ON* or *OFF*

MATE-Displayed Charge Controller Status Meter Screens

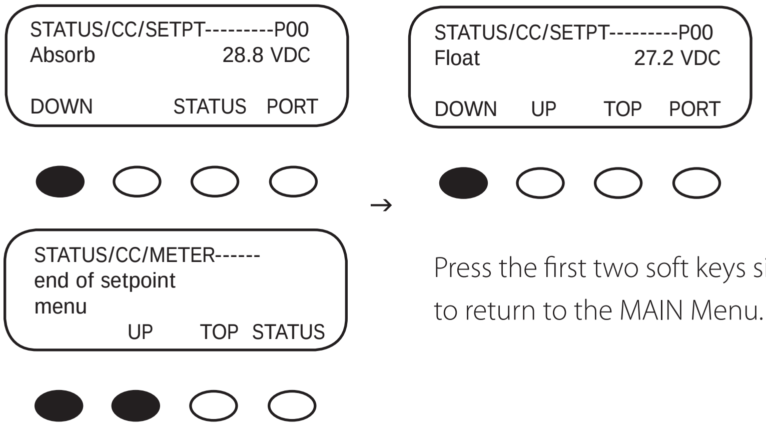


Press <**SETP**> to view the SETPOINT screens

FLEXmax METER Screens

- *mode/pv/in/bat/out:* displays the charger mode, the PV array voltage, the incoming PV amps, the battery voltage, and the outgoing amps to the battery
- *charger watts:* charger output measured in watts
- *charger kwhrs:* kilowatt hours produced today by the Charge Controller
- *charger amps dc:* the amount of amperage the Charge Controller is sending to the battery
- *battery voltage:* current battery voltage
- *panel voltage:* current voltage from the PV array

MATE-Displayed Charge Controller STATUS SETPT (SET POINT) Screen



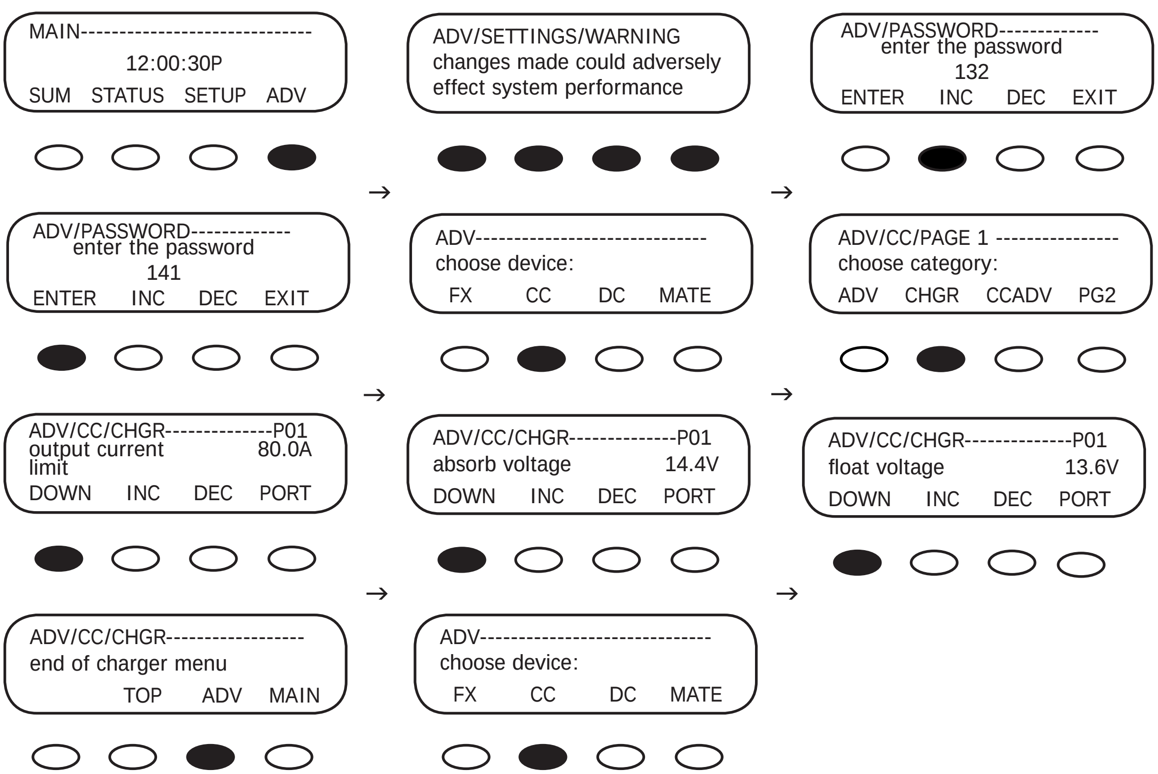
Press the first two soft keys simultaneously to return to the MAIN Menu.

CC SETP(OINT) Screens

- *Absorb:* displays the voltage that initiates and maintains the Absorb cycle
- *Float:* displays the voltage that begins the Float cycle and is maintained during this cycle

MATE-Displayed Charge Controller Advanced Screens

The Charge Controller Advanced Screens displayed on the optional OutBack MATE include CHGR (CHARGER), CCADV (ADVANCED), EQ, AND AUX. The *Advanced* screens allow the user to change various values and set points.



24. Charge Controller Advanced Menu

ADV/CC/ADVANCED--------P01
snooze now
< 0.6 amp
DOWN INC DEC PORT

→

ADV/CC/ADVANCED--------P01
wakeup mode
VOC change 1.5 V
DOWN INC DEC PORT

→

ADV/CC/ADVANCED--------P01
wakeup mode
time 5 minutes
DOWN INC DEC PORT

ADV/CC/ADVANCED--------P01
MPPT mode
auto track
DOWN INC DEC PORT

→

ADV/CC/ADVANCED--------P01
grid tie mode
non GT
DOWN INC DEC PORT

→

ADV/CC/ADVANCED--------P01
park MPP 77.0
DOWN INC DEC PORT

ADV/CC/ADVANCED------P01
Mpp range limit %VOC
minimum 1/2
DOWN INC DEC PORT

→

ADV/CC/ADVANCED------P01
Mpp range limit %VOC
maximum 90%
DOWN INC DEC PORT

→

ADV/CC/ADVANCED------P01
absorb time
1.0 hours
DOWN INC DEC PORT

ADV/CC/ADVANCED------P01
absorb end amps
0 A
DOWN INC DEC PORT

→

ADV/CC/ADVANCED------P01
rebulk voltage
12.4 vdc
DOWN INC DEC PORT

→

ADV/CC/ADVANCED------P01
vbatt calibration
13.3 vdc 0.0 V
DOWN INC DEC PORT

ADV/CC/ADVANCED------P01
RTS compensation
wide
DOWN INC DEC PORT

→

ADV/CC/ADVANCED------P01
RTS comp limit
upper limit 14.1 vdc
DOWN INC DEC PORT

→

ADV/CC/ADVANCED------P01
RTS comp limit
lower limit 13.2 vdc
DOWN INC DEC PORT

ADV/CC/ADVANCED------P01
auto restart
mode 2
DOWN INC DEC PORT

→

ADV/CC/ADVANCED------P01
AUX output polarity
active high
DOWN INC DEC PORT

→

ADV/CC/ADVANCED------P01
reset CC to factory defaults
DOWN NO YES PORT

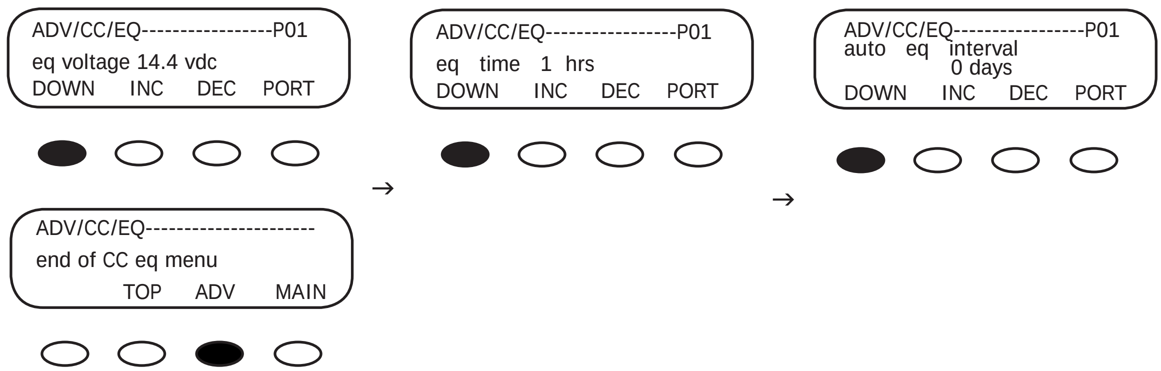
ADV/CC/ADVANCED---------
end CC advanced menu
TOP ADV MAIN

ADV-----------------------------
choose device:
FX CC DC MATE

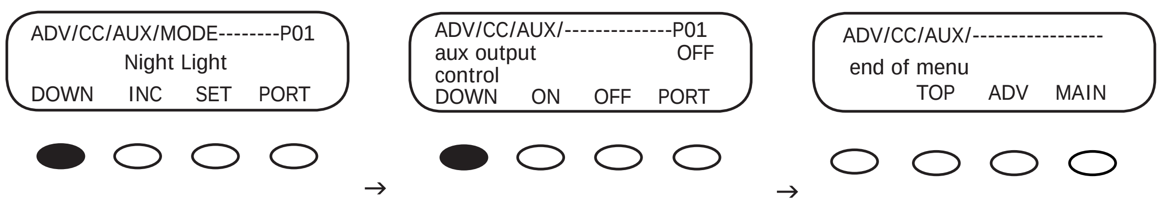
ADV/CC/PAGE 1 ----------------
choose category:
ADV CHGR CCADV PG2

ADV/CC/PAGE2----------------
choose category:
PG1 EQ AUX MAIN

Charge Controller EQ Screens

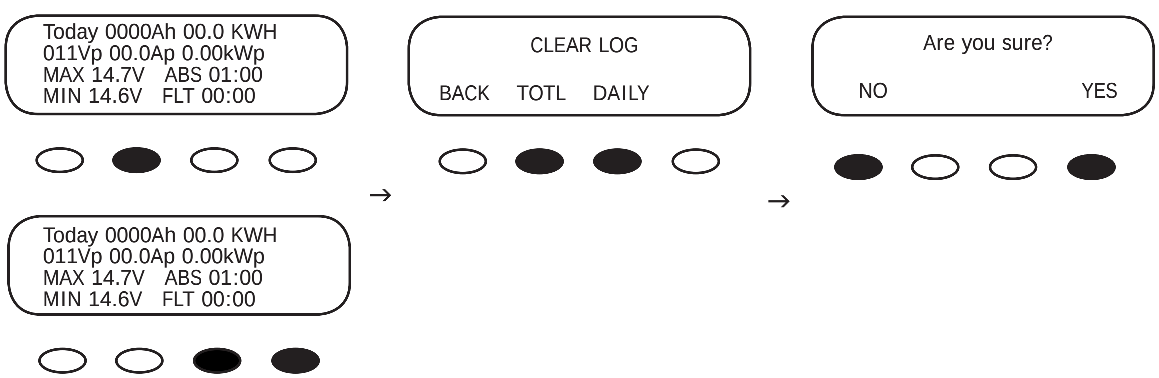


Charge Controller AUX Screens

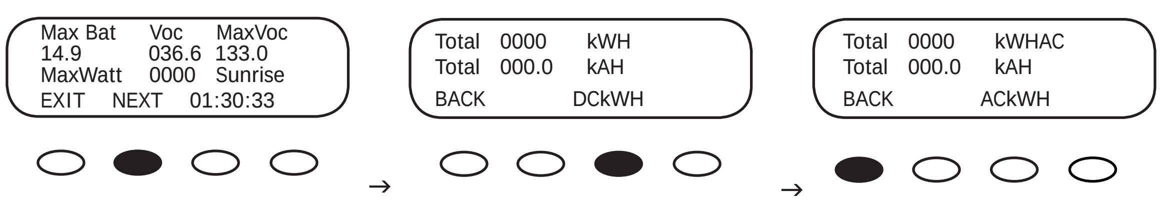


Charge Controller Displayed Screens

Charge Controller LOGGING Screens



Charge Controller STATS Screens



25. ABBREVIATED *CHARGER SET-UP*

OutBack 12V
Power
Systems
Charge Controller

Select Version
EliJa la Version
USA
NEXT ENTER ENTRA SEL

PASSWORD
CONTRASENA
150
ENTRA - + ENTER

Select Version
EliJa la Version
English
NEXT ENTER ENTRA SEL

ARE YOU SURE
USA
NO YES

SYSTEM VOLTAGE
12 24 36 48 60
^^
→ ENTER

Are you sure?
12 24 36 48 60
^^
NO YES

In 11.6 V 0.0 A
Out 14.1 V 0.0 A
0.000kW 0.0 kWH
Aux: OFF Zzzzz............

MAIN MENU

Charger Aux Light
EQ Misc Advanced
Logging Stats
EXIT ← → GO

Current Limit → 80.0 A
Absorbing 14.4 V
Float 13.8 V
EXIT ↓ - +

PUSH TWICE

→Charger Aux Light
EQ Misc Advanced
Logging Stats
EXIT ← → GO

PUSH THE ARROW KEY AND THEN PUSH GO

Charger →Aux Light
EQ Misc Advanced
Logging Stats
EXIT ← → GO

AUX MODES

AUX MODE
Vent Fan
Output: Off
EXIT NEXT SET MODE

PRESS MODE KEY FOR OFF, ON, and AUTO

AUX MODE ↑
PV Trigger
Output: Off Off
EXIT NEXT SET MODE

PRESS MODE KEY FOR OFF, ON, and AUTO

AUX MODE
ERROR OUTPUT
Output: Off Off
EXIT NEXT SET MODE

PRESS MODE KEY FOR OFF, ON, and AUTO

AUX MODE ↑
Night Light
Output: Off Off
EXIT NEXT SET MODE

PRESS MODE KEY FOR OFF, ON, and AUTO

AUX MODE
Float
Output: Off Off
EXIT NEXT SET MODE

PRESS MODE KEY FOR OFF, ON, and AUTO

AUX MODE ↑
Diversion: Relay
Output: Off Off
EXIT NEXT SET MODE

PRESS MODE KEY FOR OFF, ON, and AUTO

AUX MODE
Diversion: Solid St
Output: Off Off
EXIT NEXT SET MODE

PRESS MODE KEY FOR OFF, ON, and AUTO

AUX MODE
Low Bat Disconnect
Output: Off Off
EXIT NEXT SET MODE

PRESS MODE KEY FOR OFF, ON, and AUTO

AUX MODE
Remote
Output: Off Off
EXIT NEXT SET MODE

PUSH TWICE PRESS MODE KEY FOR OFF, ON, and AUTO

Charger Aux →Light
EQ Misc Advanced
Logging Stats
EXIT ← → GO

PUSH THE ARROW KEY AND THEN PUSH GO

BACKLIGHT CONTROL
On
EXIT MODE

PUSH TWICE PRESS MODE KEY FOR OFF, ON, and AUTO

Charger Aux Light
→EQ Misc Advanced
Logging Stats
EXIT ← → GO

PUSH THE ARROW KEY AND THEN PUSH GO

BATTERY EQUALIZE
Volts
14.4
EXIT NEXT -EQV +EQV

BATTERY EQUALIZE
TIME
1 Hours
BACK NEXT - HRS +HRS

BATTERY EQUALIZE
1 Hours 14.4 Volts
Check water level
BACK AUTO START STOP

COUNT EQ INTERVAL
000 000
EXIT -DAY +DAY

PUSH THREE TIMES

Charger Aux Light
EQ→Misc Advanced
Logging Stats
EXIT ← → GO

PUSH THE ARROW KEY AND THEN PUSH GO

GT State PWM% ChgT
255 00 98.0 0000
EXIT NEXT RETRY

FORCE
EXIT NEXT FLOAT BULK

PCB Target Btmp CFB
514 14.4v 255 0000
EXIT BACK

PUSH TWICE

Charger Aux Light
EQ Misc→Advanced
Logging Stats
EXIT ← → GO

PUSH THE ARROW KEY AND THEN PUSH GO

ADVANCED MENU
Snooze Mode
< .6 Amp
EXIT NEXT +AMP

ADVANCED MENU
Wakeup Mode
1.5V 05m
EXIT NEXT +VOC +Min

ADVANCED MENU
MPPT Mode
Auto Track
EXIT NEXT nonGT MODE

ADVANCED MENU
Park Mpp
77% VOC
EXIT NEXT +VOC +Min

ADVANCED MENU
Mpp Range Limit %Voc
Min Max
EXIT NEXT 1/2 90%

ADVANCED MENU
Absorb Time
01.0 hours
EXIT NEXT - +

ADVANCED MENU
Absorb End Amps
00 A
EXIT NEXT - +

ADVANCED MENU
Rebulk Voltage
12.4V
EXIT NEXT - +

ADVANCED MENU
Vbatt Calibration
14.9V 0.0V
EXIT NEXT -V +V

ADVANCED MENU
RTS Compensation
A 14.4V F 13.6V
EXIT NEXT WIDE

ADVANCED MENU
Auto Restart
MODE 2
EXIT NEXT MODE

ADVANCED MENU
Aux Polarity
↑ Active High
EXIT NEXT MODE

ADVANCED MENU
Reset to Defaults?
EXIT NEXT RESET

PUSH TWICE

Charger Aux Light
EQ Misc Advanced
→Logging Stats
EXIT ← → GO

PUSH THE ARROW KEY AND THEN PUSH GO

Today 0000AH 00.0kWH
012Vp 00.0Ap 0.00KWp
MAX 14.9V ABS 00:00
MIN 14.8V FLT 00:00

PUSH ONCE

In 11.6 V 0.0 A
Out 14.1 V 0.0 A
0.000kW 0.0 kWH
Aux: OFF Zzzzz............

Charger Aux Light
EQ Misc Advanced
Logging → Stats
EXIT ← → GO

PUSH THE ARROW KEY AND THEN PUSH GO

Max Bat Voc MaxVoc
15.0 000.0 030.4
MaxWatt 0000 Sunrise
EXIT NEXT 00:31:50

Total 0307 kWH
Total 000.0 kAH
BACK DCkWH

TO VIEW SOFTWARE REVISION

Charger Aux Light
EQ Misc →Advanced
Logging Stats
EXIT ← → GO

PUSH AND HOLD THE FIRST SOFT KEY

REVISION
001.008.009

EXTENDED PLAYMODE

→ Charger Aux Light
EQ Misc Advanced
Logging Stats
EXIT ← → GO

PRESS AND HOLD THE FIRST KEY AND THEN PRESS AND HOLD THE THIRD KEY. RELEASE THE THIRD KEY AND PRESS AGAIN TO TOGGLE THE EXTENDED PLAYMODE ON AND OFF.

X on

X off

26. Troubleshooting Guide

Be sure to check out the OutBack customer and user forum at www.outbackpower.com/forum/ for more Charge Controller information.

Charge Controller does not boot/power-up (blank LCD)

- Check the battery connection and polarity.
  - Reverse polarity or an improper connection will cause power-up issues.
- Check the battery breaker.
  - Ensure that the battery breaker is sized appropriately.
- A battery voltage below 10.5VDC may not power up the Charge Controller (measure the battery-side of wire lugs).
- If the Charge Controller still does not power up, call the factory for additional support.

Charge Controller is always SLEEPING

- If the battery voltage is at or above the ABSORB voltage set point (compensated ABSORB voltage), the Charge Controller will not wake up.
- The PV voltage has to be at least two volts greater than the battery voltage for the initial wakeup.
- Check the PV array breaker (or fuse).
- Confirm the PV array breaker (or fuse) is sized appropriately.
- Which State (in MISC Menu) is it at? Is it transitioning between 00 and 01? Is it in GT mode and connected to a MATE?
  - GT mode is only applicable with a HUB 4 or HUB 10 installations with a grid-tie compatible MATE.
- Does the PV array voltage on the display rise with the PV breaker OFF, but reads 000 with the PV breaker on?
  - If so, the PV array polarity connection on the Charge Controller maybe reversed or the PV lines could be shorted.
- Does the PV voltage still read 000 with the PV breaker off after a minute?
  - Call the factory for support.
- Have you checked the short circuit current of the PV array?
  - Use a multi-meter to determine if a short circuit current is detected. The short circuit current test will not harm the array.

Charge Controller not producing expected power

- Clouds, partial shading, or dirty panels can cause poor performance.
- The lower current limit set point in the *Charger* menu will yield a loss of power or poor performance symptoms.

- Are the batteries charged? Is the Charge Controller in the *Absorbing* or *Float* stage? If either case is true, the Charge Controller will produce enough power to regulate the voltage at the *ABSORB* or *FLOAT* set point voltage, therefore, requiring less power in these modes.
- What is the short circuit current of the PV array? Use a multi-meter to determine if a short circuit current is as expected. There might be a loose PV array connection.
- If the PV array voltage is close to the battery voltage, the panels could be warm/hot causing the Maximum Power Point to be at or lower than the battery voltage.
- Is it in *U-Pick* mode?

Charge Controller is not equalizing

- Has the *EQ* cycle been initiated?
  - In the EQ Menu, press START to begin process. When the EQ cycle has been initiated, *EQ-MPPT* will be displayed.
- The EQ cycle has been initiated, but the battery is not equalizing.
  - The *EQ* cycle will begin when the target *EQ* set point voltage has been reached. A small array or cloudy weather will delay the *EQ* cycle. Accordingly, running too many AC and/or DC loads will delay the *EQ* cycle, too.
- An EQ set point that is too high relative to the battery voltage will delay the *EQ* cycle.
- If the PV array voltage is close to the battery voltage, the panels could be warm/hot causing the Maximum Power Point to be at or lower than the battery voltage which can delay the *EQ* cycle.

Charge Controller Battery Temperature Compensated Voltage

- Only the OutBack RTS (remote temperature sensor) can be used with the Charge Controller.
- The battery voltage can rise above the *ABSORBING* and *FLOAT* voltage set points if the battery temperature is < 77°F or fall below the *ABSORBING* and *FLOAT* voltage if the battery temperature is > 77°F.
- Why does the Charge Controller show *BatTmpErr* on the *STATUS* screen?
  - The RTS is faulty or damaged. Disconnect the RTS from the RTS jack to resume normal operation.

Charge Controller Internal Fan

- The internal fan will only run when the internal temperature has reached approximately 112°F. The fan will continue running until the internal temperature is less than 104°F.

Charge Controller is beeping

- When the Charge Controller is in *Extended Play* mode, the array is very hot, and the MPP is close to the battery voltage, or the nominal PV voltage is higher than the nominal battery voltage, beeping can occur. To disable the *Extended Play* feature, go to the MAIN Menu and press and hold the #1 soft key until the Charge Controller's software version appears on the screen. Continue pressing the #1 soft key and press the #3 soft key at the same time until *X Off* displays on the screen. To reactivate *Extended Play*, repeat these steps and hold the #3 soft key until *X On* displays. *Extended Play* is meant to optimize the performance of a hot array, but isn't critical to efficient Charge Controller operations.

To enable/open the FLEXmax SELECT VERSION screens:

- Turn off the DC and array breakers
- Press and hold the first and third soft keys
- Turn on the battery breaker
- Follow the SELECT VERSION screen instructions from the beginning of the manual
- Rebooting the Charge Controller *like this* will return all the values and set points to the factory defaults.

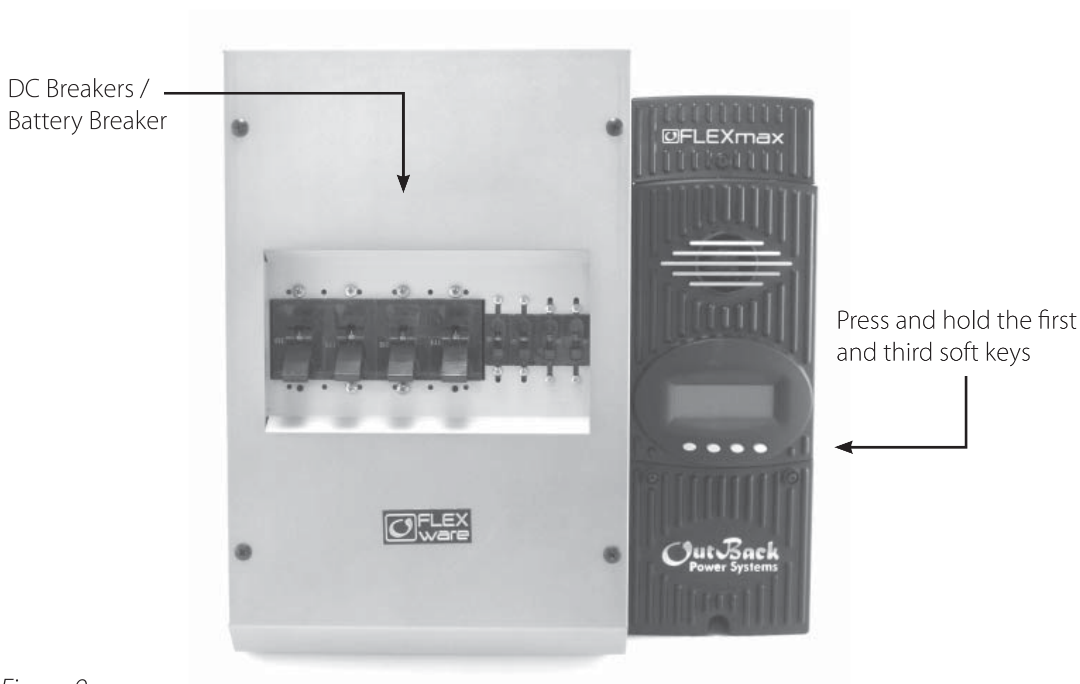


Figure 9

27. Typical Array Sizing Guide

Below is a list of recommended array sizing for the Charge Controller for various nominal voltage batteries:

Nominal Battery Voltage	**Recommended Array Size** (in watts, Standard Test Conditions)	
	FLEXmax 80	**FLEXmax 60**
12V	1250W	800W
24V	2500W	1600W
36V	3750W	2400W
48V	5000W	3200W
60V	6250W	4000W

The Charge Controller PV MPPT Charge Controller is capable of an input open circuit voltage (VOC) of up to 150 VDC. Cooler climates can cause the VOC to rise above the panel VOC rating. In climates that observe temperatures less than approximately 5° F, a VOC greater than 125 VDC is **not** recommended.

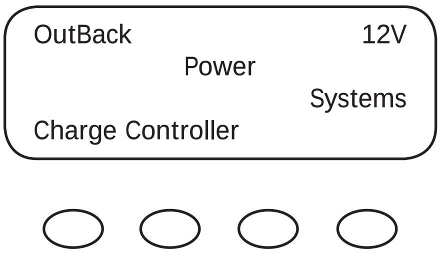
When sizing an array, it is recommended that the nominal array voltage be higher than the nominal battery voltage. Below is a list of recommended nominal array sizing:

Nominal Battery Voltage	Nominal Array Voltage (recommended)
12V	24V (or higher)*
24V	36V (or higher)*
36V	48V (or higher)*
48V	60 V (or higher)*
60V	60V (low temp is less than 5°F) or 72V (low temp is greater than 5°F)

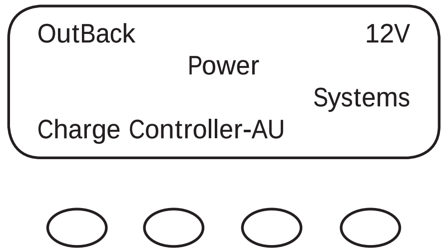
* When sizing an array to charge controller with a distance of 70 feet or greater, OutBack recommends the nominal array voltage be slightly higher than the *recommended* nominal array voltage. Example: A 36VDC nominal array recharging a 12V nominal battery with an array to charge controller distance of about 70 feet or greater. Sizing the nominal array voltage higher than the nominal battery voltage ensures that the Maximum Power Point is always above the battery voltage. The Maximum Power Point will decrease as the panels warm up, thus lowering the output of the array. The Charge Controller Charge Controller will not be able to boost the output if the Maximum Power Point of the array is at or lower than the battery voltage.

28. STANDARD vs. AUSTRALIAN DEFAULT SETTINGS

The Australian version Charge Controller has a few default settings that differ from the Standard version default settings. However, there are no differences in performance and efficiency between the two versions. The Standard and Australian version can be identified as follows:



Standard Version



Australian Version

Below are a few default setting differences between the Standard and Australian version.

Settings	**Standard**		**Australian**	
Charger	Absorb	Float	Absorb	Float
12V	4.4V	13.6V	14.4V	13.8V
24V	28.8V	27.2V	28.8V	27.6V
36V	43.2V	40.8V	43.2V	41.4V
48V	57.6V	54.4V	57.6V	55.2V
60V	72.0V	68.0V	72.0V	69.0V

Equalize	**Equalize Volts**	**Equalize Volts**
12V	14.4	14.7
24V	28.8	29.4
36V	43.2	44.1
48V	57.6	58.8
60V	72.0	73.5
Equalize Time	01 Hours	03 Hours

29. Wire Distance Chart

To meet NEC compliance (North America), the largest PV array that can be connected to a FLEXmax 80 must have a rated short-circuit current of 64 amps or less and 48 amps or less for a FLEXmax 60. The following charts show the maximum distance of various gauge two-conductor copper wire from the PV array to the Charge Controller with a 1.5% maximum voltage drop. Temperature and conduit fill corrections may be required. Using a higher voltage PV array with a low voltage battery system allows you to use a much smaller wire size or go up to 5 times as far with the same gauge wire.

FLEXmax 60 and FLEXmax 80 (The figures below assume THWN 75^0 C two-conductor copper wire and allow for a 1.5% voltage drop)

12V PV ARRAY (16v Vmp)

AMPS / WIRE GAUGE →	#8	#6	#4	#3	#2	#1	#1/0	#2/0	#3/0	#4/0
10	15	24	39	49	62	78	98	124	157	197
20	8	12	19	24	31	39	49	62	78	99
30	5	8	13	16	21	26	33	41	52	66
40	4	6	10	12	15	19	25	31	39	49
50	**3**	5	8	10	12	16	20	25	31	39
60	**3**	**4**	6	8	10	13	16	21	26	33
70	**2**	**3**	6	7	9	11	14	18	22	28
80	**2**	**3**	**5**	6	8	10	12	16	20	25

24V PV ARRAY (32v Vmp)

AMPS / WIRE GAUGE →	#8	#6	#4	#3	#2	#1	#1/0	#2/0	#3/0	#4/0
10	31	49	78	98	124	156	197	248	313	395
20	15	24	39	49	62	78	98	124	157	197
30	10	16	26	33	41	52	66	83	104	132
40	8	12	19	24	31	39	49	62	78	99
50	**6**	10	16	20	25	31	39	50	63	79
60	**5**	**8**	13	16	21	26	33	41	52	66
70	**4**	**7**	11	14	18	22	28	35	45	56
80	**4**	**6**	**10**	12	15	19	25	31	39	49

36V PV ARRAY (48v Vmp)

AMPS / WIRE GAUGE →	#8	#6	#4	#3	#2	#1	#1/0	#2/0	#3/0	#4/0
10	46	73	117	147	186	234	295	372	470	592
20	23	37	58	73	93	117	148	186	235	296
30	15	24	39	49	62	78	98	124	157	197
40	12	18	29	37	46	58	74	93	117	148
50	**9**	15	23	29	37	47	59	74	94	118
60	**8**	**12**	19	24	31	39	49	62	78	99
70	**7**	**10**	17	21	27	33	42	53	67	85
80	**6**	**9**	**15**	18	23	29	37	47	59	74

METRIC

- #8…8.37mm^2
- #6…13.30mm^2
- #4…21.15mm^2
- #3…26.7mm^2
- #2…33.6mm^2
- #1/0…53.5mm^2
- #2/0…67.4mm^2
- #4/0…107mm^2

NOTE: Numbers in bold might not meet NEC requirements

48V PV ARRAY (64v Vmp)

AMPS / WIRE GAUGE →	#8	#6	#4	#3	#2	#1	#1/0	#2/0	#3/0	#4/0
10	62	98	156	196	247	312	393	496	627	789
20	31	49	78	98	124	156	197	248	313	395
30	21	33	52	65	82	104	131	165	209	263
40	15	24	39	49	62	78	98	124	157	197
50	**12**	20	31	39	49	62	79	99	125	158
60	**10**	**16**	26	33	41	52	66	83	104	132
70	**9**	**14**	22	28	35	45	56	71	90	113
80	**8**	**12**	**19**	24	31	39	49	62	78	99

60V PV ARRAY (80v Vmp)

AMPS / WIRE GAUGE →	#8	#6	#4	#3	#2	#1	#1/0	#2/0	#3/0	#4/0
10	77	122	195	245	309	390	492	620	783	987
20	39	61	97	122	155	195	246	310	392	493
30	26	41	65	82	103	130	164	207	261	329
40	19	31	49	61	77	97	123	155	196	247
50	**15**	24	39	49	62	78	98	124	157	197
60	**13**	**20**	32	41	52	65	82	103	131	164
70	**11**	**17**	28	35	44	56	70	89	112	141
80	**10**	**15**	**24**	31	39	49	61	78	98	123

72V PV ARRAY (96v Vmp)

AMPS / WIRE GAUGE →	#8	#6	#4	#3	#2	#1	#1/0	#2/0	#3/0	#4/0
10	93	147	234	294	371	468	590	745	940	1184
20	46	73	117	147	186	234	295	372	470	592
30	31	49	78	98	124	156	197	248	313	395
40	23	37	58	73	93	117	148	186	235	296
50	**19**	29	47	59	74	94	118	149	188	237
60	**15**	**24**	39	49	62	78	98	124	157	197
70	**13**	**21**	33	42	53	67	84	106	134	169
80	**12**	**18**	**29**	37	46	58	74	93	117	148

NOTE: Numbers in bold might not meet NEC requirements

METRIC

#8…8.37mm^2

#6…13.30mm^2

#4…21.15mm^2

#3…26.7mm^2

#2…33.6mm^2

#1/0…53.5mm^2

#2/0…67.4mm^2

#4/0…107mm^2

30. WIRE AND DISCONNECT SIZING

FLEXmax 80

The Charge Controller is a buck type converter with the following properties:

- 80 amp DC output current limit (default setting)
- Listed to operate continuously at 80 amps (40°C/104° F)

With an 80 amp Charge Controller output current limit and PV array output higher than 80 amps offers little, if any, current boosting or Maximum Power Point Tracking advantage; in effect, any excess power beyond 80 amps is lost.

For NEC* compliance and the Charge Controller's 80 amp output rating / MPPT capabilities, the largest PV array input *must not exceed* a rated short-circuit current of 64 amps.

Battery Side of the Controller

- All OutBack Power circuit breakers (OBB-XX) are 100% continuous-rated type breakers
- The conductors connected to the breakers must have a 125% safety factor applied (i.e., an 80 amp breaker must have a 100-amp conductor connected when used at its full 80-amp rating)

PV Side of the Controller

- UL* requires a 125% safety multiplier (before NEC calculations)
- NEC* requires a 125% safety multiplier (after UL calculations).
- The 156% safety multiplier is specific in the NEC* to PV applications only – this "dual" 125% multiplier is used because a PV array can produce above its rated output in some conditions.

NEC Compliance

- When the 156% safety multiplier is applied, the resulting conductor amperage required is still 100-amps (1.56 X 64A) and an 80 amp breaker may be used (100% continuous duty rated breaker).
- When a PV array is configured for a higher nominal input voltage (such as 72V PV array), the PV input conductor can be sized smaller depending on the step-down ratio and the maximum short circuit current available.

NOTE: The input breaker must also be sized smaller; it cannot be the normal 80 amp with conductor smaller than #4 AWG. (21.1mm^2)

* North America

WIRE AND DISCONNECT SIZING

FLEXmax60

The MX60 has a 60 amp current output limit (default) and is listed to operate continuously at 60 amps depending on the nominal PV array voltage and the nominal battery voltage. There is no 80% de-rating as required by the NEC* for fuses, conductors, and most circuit breakers.

The MX60 is a buck type converter and cannot boost the output current when the PV array peak power point voltage is at or below the battery voltage as may happen on hot days in 24 VDC PV and a 24 VDC battery system or a 48 VDC PV and a 48 VDC battery system.

To meet minimum NEC requirements (NEC 310.15, 690.8, 9), the output conductor should have an ampacity of 75 amps after any temperature and conduit fill corrections. This would normally indicate that the output conductors be 6 AWG (5.83 mm), but a larger size may be required if there are temperature and/or conduit fill corrections required. With an output conductor rated at 75 amps (1.25 X the continuous output current), the OutBack OBB-60 breaker—rated for continuous 100% duty at 60 amps —can be used to provide the code-required disconnect and output circuit over current protection.

The PV array output connected to the MX60 input may be as high 60 amps, but at this current level, there is very little (if any) current boosting or maximum power-point tracking due to the 60-amp output current limit. Additionally, the input current may exceed 60 amps on bright sunny days and any excess power would be lost. The size and ampacity of the input conductors must be selected to handle 1.56 times the short-circuit current of the PV array. Any disconnect or circuit breaker connected to the input conductors must also be rated at 1.56** times the short-circuit current for the PV array unless the breaker is rated for 100% duty in its enclosure. If that is the case, the circuit breaker may be rated at 1.25 times the PV array short-circuit current. OutBack OBB-XX breakers are 100% duty rated breakers.

In terms of NEC compliance and the MX60's 60-amp output rating, the largest PV array it can connect to should have a rated short-circuit current of 48 amps. This meets NEC requirements and allows the MX60 to perform maximum power-point tracking functions. The following charts show maximum distance in feet of various gauge two-conductor copper wire from the PV array to the MX60 with a 1.5% maximum voltage drop. Temperature and conduit fill corrections may be required.

*When NEC does not apply, see local code requirements.

31. WIRING COMPARTMENT

The wiring terminals and compartment of the Charge Controller Charge Controller are fully compliant with all NEC and UL requirements. *The following summary is specific for North American applications where NEC and UL standards govern installations.*

Recommended Conductor and Breaker Sizes for the Charge Controller

Output Rating at 80 amps

If the output current of the Charge Controller is expected to reach the maximum output level of 80 amps:

- #3 or #2 AWG conductor must be used with an 80 amp breaker (100% continuous duty rated breaker)
- The minimum recommended battery conductor is #3* AWG
- The maximum recommended battery conductor is #2** AWG

METRIC
#4…21.15mm^2
#3…26.7mm^2
#2…33.6mm^2

* #3 AWG conductor can be installed through the side, back or bottom knockouts
** #2 AWG conductor must be installed on the side or back knockout to meet the specific UL requirements for wire bending room standards

- 1" conduit knockout is approved for up to three #2 AWG conductors
- For short conduit runs (less than 24"), a higher conduit fill is acceptable* —three #2 AWG wires

Please reference the NEC Appendix "C" in the back of the book. You must refer to the table representing the type of conduit you will be using to find the maximum number of conductors allowed within the conduit you will be using.

Output Rating less than 64 amps

If the output current of the Charge Controller is expected to be less than 64 amps:

- An 80 amp breaker and #4 AWG conductors can be used on the battery side.
- The PV array short circuit current must be less than 48 amps and the #4 conductor will be acceptable with an 80 amp breaker.

32. Charge Controller MULTI-STAGE BATTERY CHARGING

The Charge Controller charge controller is a sophisticated, multi-stage battery charger that uses several regulation stages to allow fast recharging of the battery system while ensuring a long battery life. This process can be used with both sealed and non-sealed batteries. The Charge Controller has a preset recharging voltage set points (Absorb & Float) for the selected nominal battery voltage, however, always follow the battery manufacturer's recommended charging regulation voltages. The Charge Controller charging regulation stages correspond to the chart in Figure 10.

Charge Controller Multi-Stage Battery Charging

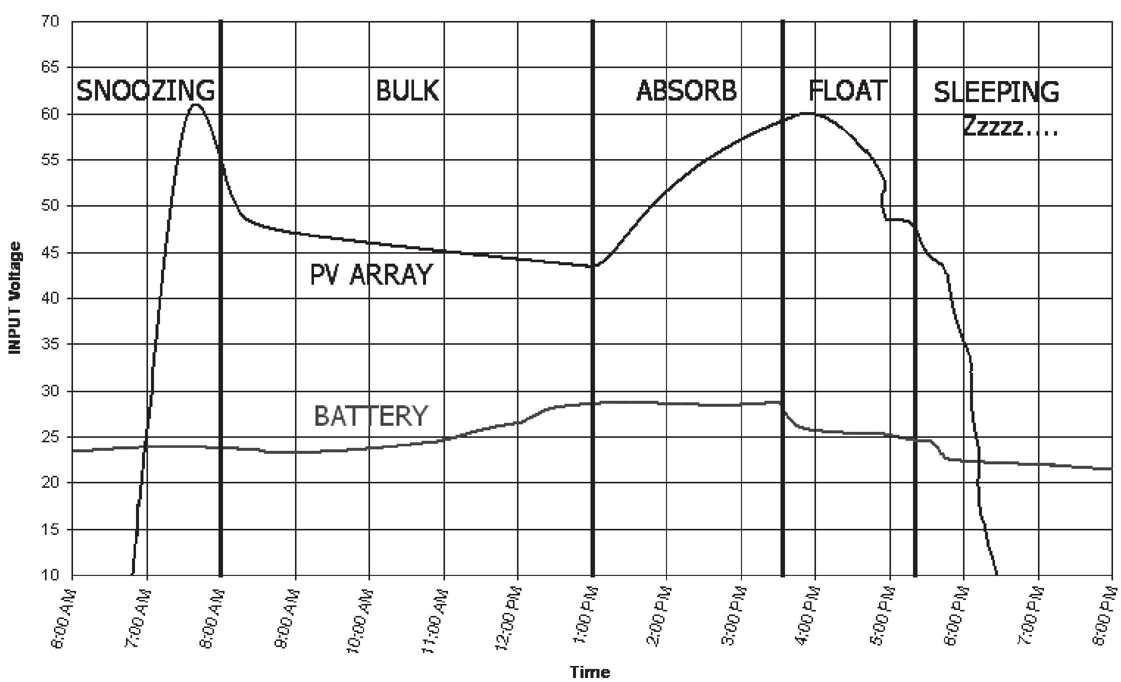


Figure 10

NOTE: In BULK, the Charge Controller will charge as long as necessary to complete the cycle, regardless of the timer's set points.

BULK cycle provides the maximum power to the battery –the voltage increases while recharging.

A Bulk cycle is automatically initiated when the battery voltage is below the *Absorb* and *Float** recharge voltage set points. The *Bulk* cycle will continue until the *Absorb* voltage set point is achieved. *MPPT Bulk* is displayed on the screen.

ABSORBING cycle limits the amount of power going to the battery—the voltage is held constant.

The *Absorb* cycle will continue for the duration of the *Bulk* cycle or until the 2 hour (default) *Absorb* time limit is reached. For example, if a *Bulk* cycle takes 1 hour to reach the *Absorb* voltage set point, then the *Absorb* cycle will continue for 1 hour as well. However, if a Bulk cycle takes 3 hours to reach the *Absorb* voltage set point, then the *Absorb* cycle will continue for 2 hours only. A *Bulk* cycle will be re-initiated if the battery voltage is not sustained at the *Absorb* voltage set point. *Absorbing* is displayed on the screen at this time.

FLOAT cycle reduces the recharging voltage to prevent overcharging of the batteries.

A *Float* cycle follows after the *Absorb* cycle is completed; *Float* is displayed on the screen. The Charge Controller **will not** re-initiate another *Bulk* cycle if the *Float* voltage set point is not sustained*. FMPPT is displayed. However, it will continue to recharge the battery until the *Float* voltage set point is reached.

* A *Bulk* cycle can be auto-initiated if the battery voltage falls below the *Float* voltage set point and the *Re-Bulk* voltage option is set.

33. BATTERY TEMPERATURE COMPENSATED VOLTAGE SET POINT

The temperature of a battery has an impact on the recharging process—in higher ambient temperatures, the regulation set points (*Absorb* and *Float*) need to be reduced to prevent overcharging of the batteries. In lower ambient temperature conditions, the voltage regulation set points need to be increased to ensure complete recharging of the batteries.

The default charger settings of the Charge Controller are based on typical lead acid battery systems. *Always ensure the Absorb and Float voltage regulation set points are set to the recommended battery manufacturer's recharging regulation voltages.*

Non-Battery Temperature Compensated System

If a battery remote temperature sensor is not available the *Absorb* and *Float* voltage regulation set points can be adjusted for the expected weather conditions. The following table shows the appropriate adjustments for both *Absorb* and *Float* voltage regulation set points for weather conditions above or below 77˚F / 25 C

EXPECTED TEMPERATURE	ADJUST SET POINT	12V	24V	48V
Average = 95˚F / 35˚C	Subtract	0.30V	0.60V	1.20V
Average = 86˚F / 30˚C	Subtract	0.15V	0.30V	0.60V
Average = 68 F / 20˚C	Add	0.15V	0.3 V	0.60V
Average = 59˚F / 15˚C	Add	0.30V	0.60V	1.20V

Battery Temperature Compensated System

A battery remote temperature sensor (RTS) will **automatically** compensate the *Absorb* and Float voltage **relative** to the *Absorb* and *Float* set points in the *Charger* menu. Please reference page 49 of this manual for adjusting the upper and lower battery compensated limits.

Battery temperature compensation with other slopes

The Charge Controller uses a 5mV per degree C per cell (2V) compensation slope required by UL. For other slopes, you may be able to pick a different battery voltage and change the charger *Absorb* and *Float* voltage settings to achieve a more or less aggressive slope. If going lower in voltage, reduce the *Float* voltage first, since the *Absorb* voltage will not be adjustable below the *Float* voltage setting. If going higher in voltage, increase the *Absorb* setting first before raising the *Float* voltage above the present setting. Here is a table of Charge Controller compensation based on system voltage for reference:

12V system	-30mV/degree C
24V system	-60mV/degree C
36V system	-90mV/degree C
48V system	-120mV/degree C
60V system	-150mV/degree C

34. SUGGESTED BATTERY CHARGER SET POINTS

The battery manufacturer should provide you with specific instructions on the following maintenance and voltage set point limits for the specific batteries. The following information can be used when the manufacturer's information is not available.

SEALED LEAD ACID – AGM / GEL	12V	24V	48V
ABSORB voltage set point	14.4V	28.8V	57.6V
FLOAT voltage set point	13.4V	26.8V	53.6V

NON-SEALED LEAD ACID	12V	24V	48V
ABSORB voltage set point	14.8V	29.6V	59.2V
FLOAT voltage set point	13.8V	27.6V	55.2V

NOTE: Higher settings can be used with non-sealed batteries, but water consumption will be greater and excessive temperatures when recharging may occur.

Battery Voltage and State of Charge

A battery's voltage can be used as a guideline to estimate the amount of power stored in the battery that is available for use. When referencing the battery voltage on the display, be sure the battery is not under significant recharging or heavy loads. Otherwise, the DC voltage is not reflective of the battery state of cycle. Often the best time to check the battery voltage is in the morning (pre-charging) or at night (post-charging), with the battery disconnected from charging sources and loads and a rest for at least three hours.

Operation of a battery below 50% state of cycle will adversely affect the long term health of the battery system and will result in premature failure. Keeping the battery above the 50% level and recharging it completely once a month will ensure proper operation and good performance.

STATE OF CHARGE

Nominal Battery Voltage	Charged	Good (~75%)	Average (~50%)	Low (~25%)	Discharged
12V	over 12.6V	12.3V	12.0V	11.7V	under 11.4V
24V	over 25.2V	24.6V	24.0V	23.4V	under 22.8V
48V	over 50.4V	49.2V	48.0V	46.8V	under 45.6V
60V	over 63.0V	61.5V	60.0V	58.5V	under 57.0V

35. CALLING THE FACTORY FOR ASSISTANCE

When calling OutBack Power for product assistance, please have the following information ready:

- Charge Controller Serial number and software version (the software version can be viewed by pressing the #1 soft key on the STATUS screen and then pressing a second time and holding the soft key down).
- The nominal PV array and battery voltage.
- The PV array operating voltage and battery current and any Status screen operational mode displays, such as *MPPT BULK, MPPT FLOAT, Absorbing*, or *Floating*.

36. SPECIFICATIONS

Output Current Rating, FLEXmax 80	80 amps continuous @ 40°C ambient
Output Current Rating, FLEXmax 60	60 amps continuous @ 40°C ambient
Default Battery System Voltage	12, 24, 36, 48 or 60VDC (adjustable)
PV open circuit voltage	150VDC Maximum (ETL Rating for UL1741 Standard); operational max = 145VDC temperature corrected VOC
Standby power consumption	Less than 1 watt typical
Recharging regulation methods	Five stage—Bulk, Absorption, Battery Full, Float, and Equalization
Voltage regulation set points	13-80VDC
Temperature compensation	With optional RTS sensor 5 millivolts °C per 2V cell
Voltage step down capability	Down convert from any PV array voltage within PV VOC limits of 145VDC to any battery system voltage. Examples: 72V array to 24V; 60V array to 48V
Digital Display	4 line 20 character per line backlit LCD display
Remote Interface	RJ45 modular connector Cat 5 cable 8 wire
Operating Temperature Range*	-40° to 60°C de-rated above 40°C
Environmental Rating	Indoor type 1
Conduit knockouts	One 1″ on the back; one 1″ on the left side; two 1″ on the bottom
Warranty	Five years parts and labor
Dimensions	FLEXmax 80–16.25″H x 5.75″W x 4″D Boxed–21″H x 10.5″W x 9.75″D FLEXmax 60–13.5″H x 5.75″W x 4″D Boxed–18″H x 11″W x 8″D
Weight	FLEXmax 80–12.20 lbs; Boxed–15.75 lbs FLEXmax 60–11.6 lbs; Boxes–14 lbs
Options	Remote Temperature Sensor (RTS), HUB 4, HUB 10, MATE, MATE2
Menu Languages	English and Spanish

*The Charge Controller automatically limits the current if the temperature rises above the allowable limit.

FIVE YEAR LIMITED WARRANTY INFORMATION

FLEXmax Products

OutBack Power Systems, Inc. ("OutBack") provides a five year (5) limited warranty ("Warranty") against defects in materials and workmanship for its FLEXmax products ("Products") if installed in fixed location applications.

For this Warranty to be valid, the Product purchaser must complete and submit the applicable Product registration card within ninety (90) days of the eligible Product's first retail sale. This Warranty applies to the original OutBack Product purchaser, and is transferable only if the Product remains installed in the original use location. The warranty does not apply to any Product or Product part that has been modified or damaged by the following:

- Installation or Removal;
- Alteration or Disassembly;
- Normal Wear and Tear;
- Accident or Abuse;
- Corrosion;
- Lightning;
- Repair or service provided by an unauthorized repair facility;
- Operation contrary to manufacturer product instructions;
- Fire, Floods or Acts of God;
- Shipping or Transportation;
- Incidental or consequential damage caused by other components of the power system;
- Any product whose serial number has been altered, defaced or removed; or
- Any other event not foreseeable by OutBack.

OutBack's liability for any defective Product, or any Product part, shall be limited to the repair or replacement of the Product, at OutBack's discretion. OutBack does not warrant or guarantee workmanship performed by any person or firm installing its Products. This Warranty does not cover the costs of installation, removal, shipping (except as described below), or reinstallation of Products.

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To request warranty service, you must contact OutBack Technical Services at (360) 435-6030 or support@outbackpower.com within the effective warranty period. If warranty service is required, OutBack will issue a Return Material Authorization (RMA) number. A request for an RMA number requires all of the following information:

1. Proof-of-purchase in the form of a copy of the original Product purchase invoice or receipt confirming the Product model number and serial number;
2. Description of the problem; and
3. Shipping address for the repaired or replacement equipment.

After receiving the RMA number, pack the Product(s) authorized for return, along with a copy of the original purchase invoice and warranty certificate, in the original Product shipping container(s) or packaging providing equivalent protection and mark the outside clearly with the RMA number. The sender must prepay all shipping charges, and insure the shipment, or accept the risk of loss or damage during shipment. OutBack is not responsible for shipping damage caused by improperly packaged Products, the repairs this damage might require, or the costs of these repairs. If, upon receipt of the Product, OutBack determines the Product is defective and that the defect is covered under the terms of this Warranty, OutBack will then and only then ship a repaired or replacement Product to the purchaser freight prepaid, non-expedited, using a carrier of OutBack's choice within the continental United States, where applicable

Shipments to other locations will be made freight collect. The warranty period of any repaired or replacement Product is twelve (12) months from the date of shipment from OutBack, or the remainder of the initial warranty term, which ever is greater.

THIS LIMITED WARRANTY IS THE EXCLUSIVE WARRANTY APPLICABLE TO OUTBACK PRODUCTS. OUTBACK EXPRESSLY DISCLAIMS ANY OTHER EXPRESS OR IMPLIED WARRANTIES OF ITS PRODUCTS, INCLUDING BUT NOT LIMITED TO ANY IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE. OUTBACK ALSO EXPRESSLY LIMITS ITS LIABILITY IN THE EVENT OF A PRODUCT DEFECT TO REPAIR OR REPLACEMENT IN ACCORDANCE WITH THE TERMS OF THIS LIMITED WARRANTY AND EXCLUDES ALL LIABILITY FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES, INCLUDING WITHOUT LIMITATION ANY LIABILITY FOR PRODUCTS NOT BEING AVAILABLE FOR USE OR LOST REVENUES OR PROFITS, EVEN IF IT IS MADE AWARE OF SUCH POTENTIAL DAMAGES. SOME STATES (OR JURISDICTIONS) MAY NOT ALLOW THE EXCLUSION OR LIMITATION OF WARRANTIES OR DAMAGES, SO THE ABOVE EXCLUSIONS OR LIMITATIONS MAY NOT APPLY TO YOU.

Revision.2007-10-02

FLEXmax™ 60
FLEXmax™ 80

Limited Warranty Registration

Complete this form to request a Limited Warranty, and return it to:

Outback Power Systems Inc.
19009 62nd Ave. NE
Arlington, WA 98223

NOTE: A Limited Warranty Certificate will only be issued if this Registration Card is received by OutBack within 90 days of the date of the first retail sale of the eligible Product. Please submit a copy (not the original) of the Product purchase invoice, which confirms the date and location of purchase, the price paid, and the Product Model and Serial Number.

Five Year Limited FLEXmax Warranty Registration

System Owner

Name: ______________________ Country: ______________________
Address: ______________________ Telephone Number: ______________________
City, State, Zip Code: ______________________ E-mail ______________________

Product

Product Model Number: ______________________ Sold by: ______________________
Product Serial Number: ______________________ Purchase Date: ______________________
Optional Extended Warranty* Coverage? (circle one): Yes No

Please circle the three most important factors affecting your purchase decision:

- Price
- Product Reputation
- Product Features
- Reputation of OutBack Power Systems
- Value

System

System Install/Commission Date: ______________ Number of FLEXmax Products in System: __________
FLEXmax Charging Source(i.e. Solar): ______________ System Array Size: ______________
System Array Nominal Voltage: ______________ Type of PV Modules: ______________
DC Input Wiring Size and Length: ______________ System Battery Bank Size (Amp Hours): __________
Type of Batteries: ______________

Installer

Installer: ______________________ Contractor Number: ______________________
Installer Address: ______________________ Installer City, State, Zip: ______________________
Installer E-mail: ______________________

*Extended Warranty
OutBack Power Systems offers an optional five(5) year extension to the standard five(5) year Limited Warranty in North America for the Charge Controller product. To request a 5-year Limited Warranty extension for a total effective warranty coverage period of ten(10) years; include a check or money order in the amount of $250USD payable to OutBack Power Systems, Inc. along with your Warranty Registration.

Revision.2007-10-02

EU DECLARATION OF CONFORMITY

According to ISO / IEC Guide 22 and EN 45014

Product Type: Photovoltaic Charge Controller
Product Model Number: Charge Controller

This product complies with the following EU directives:
Electromagnetic Compatibility 89/336/EEC, "Council Directive of 3 May 1989

On the approximation of the laws of member States relating to Electromagnetic compatibility"

Low Voltage Directive 73/23/EEC, "Council Directive of 19 February 1973 on the harmonization of the laws of Member States relating to electrical equipment for use within certain voltage limits"

The compliance of the above mentioned product with the directives and the following essential requirements is hereby confirmed:
Emissions Immunity Safety
EN 61000-6-3 (2001) EN 61000-6-1 (2001) EN 60335-1 Battery Chargers
EN 60335-2-29Battery Chargers

All associated technical files are located in the Engineering Department at OutBack Power Systems Inc., Arlington, Washington, USA.

As the manufacturer, we declare under our sole responsibility that the above-mentioned product complies with the above-named directives.

OutBack Power Systems™
19009 62nd Ave. NE
Arlington, WA. 98223 USA
(360) 435-6030

OWNER'S SYSTEM INFORMATION

Date of Purchase: ______________________________

Vendor: ______________________________

Date of Installation: ______________________________

Installer: ______________________________

Installer Contact Information: ______________________________

Charge Controller Serial Number: ______________________________

Battery Voltage: ______________________________

PV Voltage: ______________________________

PV Module Type and Manufacturer: ______________________________

Array Wattage: ______________________________

NOTES: ______________________________

____

Power Systems™

Corporate Office
19009 62nd Avenue NE
Arlington, WA USA
Phone: (+1) 360-435-6030

European Sales Office
C/ Castelló, 17
08830 - Sant Boi de Llobregat
BARCELONA, España
Phone: +34.93.654.9568

www.outbackpower.com

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solar electricity

170 WATT

MULTI-PURPOSE MODULE

NE-170U1

MULTI-PURPOSE 170 WATT MODULE FROM THE WORLD'S TRUSTED SOURCE FOR SOLAR.

Using breakthrough technology, made possible by nearly 50 years of proprietary research and development, Sharp's NE-170U1 solar module incorporates an advanced surface texturing process to increase light absorption and improve efficiency. Common applications include commercial and residential grid-tied roof systems as well as ground mounted arrays. Designed to withstand rigorous operating conditions, this module offers high power output per square foot of solar array.

Multi-purpose module ideal for ground mounted solar systems and the preferred solution for landowners.

ENGINEERING EXCELLENCE

High module efficiency for an outstanding balance of size and weight to power and performance.

DURABLE

Tempered glass, EVA lamination and weatherproof backskin provide long-life and enhanced cell performance.

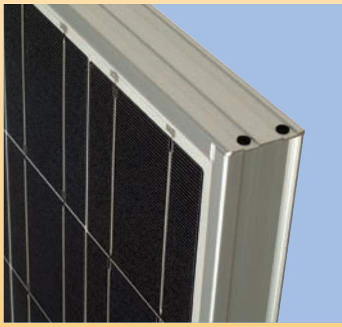
RELIABLE

25-year limited warranty on power output.

HIGH PERFORMANCE

This module uses an advanced surface texturing process to increase light absorption and improve efficiency.

Sharp multi-purpose modules offer industry-leading performance for a variety of applications.



Improved Frame Technology

SHARP: THE NAME TO TRUST

When you choose Sharp, you get more than well-engineered products. You also get Sharp's proven reliability, outstanding customer service and the assurance of our 25-year limited warranty. A global leader in solar electricity, Sharp powers more homes and businesses than any other solar manufacturer worldwide.

BECOME POWERFUL

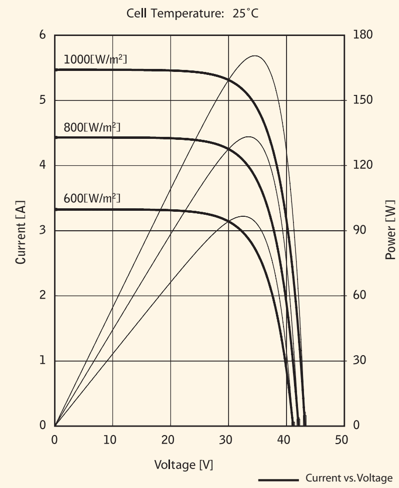
170 WATT

NE-170U1

ELECTRICAL CHARACTERISTICS	
Maximum Power (Pmax)*	170 W
Tolerance of Pmax	+10%/-5%
Type of Cell	Polycrystalline silicon
Cell Configuration	72 in series
Open Circuit Voltage (Voc)	43.2 V
Maximum Power Voltage (Vpm)	34.8 V
Short Circuit Current (Isc)	5.47 A
Maximum Power Current (Ipm)	4.90 A
Module Efficiency (%)	13.10%
Maximum System (DC) Voltage	600 V
Series Fuse Rating	10 A
NOCT	47.5°C
Temperature Coefficient (Pmax)	-0.485%/°C
Temperature Coefficient (Voc)	-0.36%/°C
Temperature Coefficient (Isc)	0.053%/°C

*Measured at (STC) Standard Test Conditions: 25°C, 1 kW/m², AM 1.5

IV CURVES



Current, Power vs. Voltage Characteristics

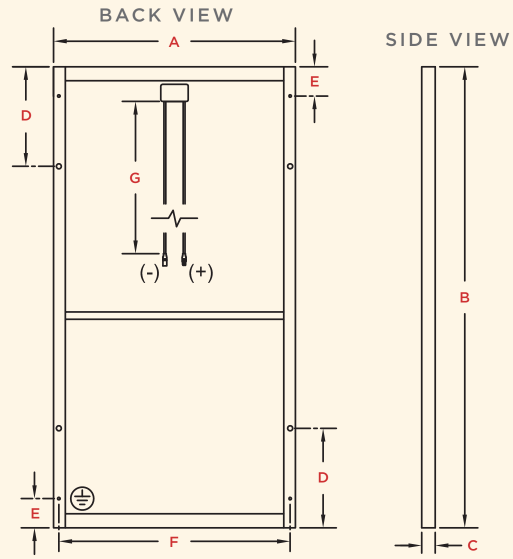
MECHANICAL CHARACTERISTICS	
Dimensions (A x B x C below)	32.5” x 62.0” x 1.8”/826 x 1575 x 46 mm
Cable Length (G)	43.3”/1100 mm
Type of Output Terminal	Lead Wire with MC Connector
Weight	35.3 lbs / 16.0 kg
Max Load	50 psf (2400 Pascals)

QUALIFICATIONS	
UL Listed	UL 1703
Fire Rating	Class C

WARRANTY

25-year limited warranty
Contact Sharp for complete warranty information

DIMENSIONS



A	B	C	D	E
32.5”/826 mm	62.0”/1575 mm	1.8”/46 mm	13.4”/340 mm	3.9”/100 mm

F	G
31.1”/790 mm	43.3”/1100 mm

Contact Sharp for tolerance specifications

SHARP

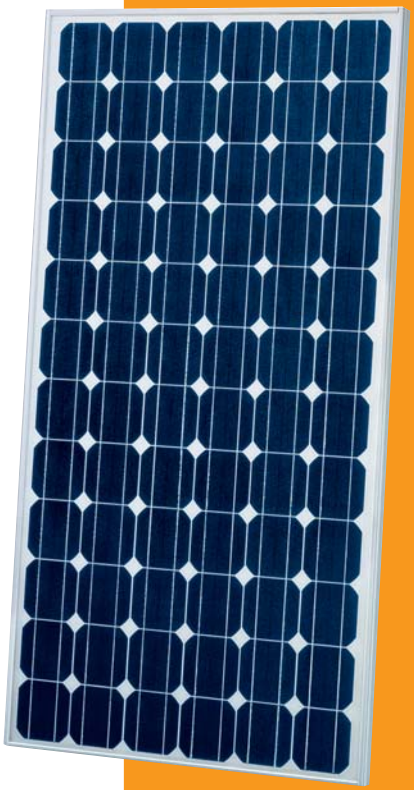
SHARP ELECTRONICS CORPORATION
5901 Bolsa Avenue, Huntington Beach, CA 92647
1-800-SOLAR-06 • Email: sharpsolar@sharpusa.com
www.sharpusa.com/solar

08F-013 • VP-06-08

SHARP

MULTI-PURPOSE MODULE

NT-185U1

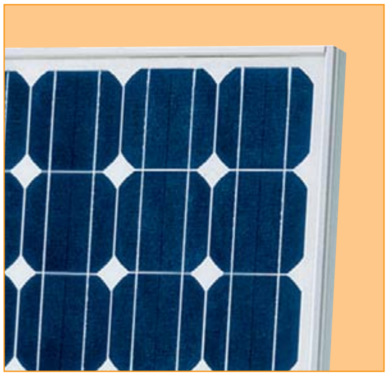


185 WATT

BIG POWER. REVOLUTIONARY DESIGN.

SINGLE CRYSTAL SILICON PHOTOVOLTAIC MODULE WITH 185W MAXIMUM POWER

This single crystal 185 watt module features 17.1% encapsulated cell efficiency and 14.2% module efficiency—the highest efficiency commercially available. Using breakthrough technology perfected by Sharp's nearly 45 years of research and development, these modules use a textured cell surface to reduce reflection of sunlight, and BSF (Black Surface Field) structure to improve conversion efficiency. An anti-reflective coating provides a uniform blue color and increases the absorption of light in all weather conditions. Common applications include office buildings, cabins, solar power stations, solar villages, radio relay stations, beacons, and traffic lights. Ideal for grid-connected systems and designed to withstand rigorous operating conditions, Sharp's NT-185U1 modules offer the maximum usable power per square foot of solar array.



Solder-coated grid results in high fill factor performance under low light conditions.

Sharp multi-purpose modules offer industry-leading performance for a variety of applications.

FEATURES

- **High-power module (185W) using 125mm square single crystal silicon solar cells with 14.22% module conversion efficiency**
- **Bypass diode minimizes the power drop caused by shade**
- **Textured cell surface to reduce the reflected sunlight and BSF (Black Surface Field) structure to improve cell conversion efficiency: 17.13%**
- **White tempered glass, EVA resin, and a weatherproof film, plus aluminum frame for extended outdoor use**
- **Nominal 24VDC output, perfect for grid-connected systems**
- **UL Listings: UL 1703, cUL**
- **Sharp modules are manufactured in ISO 9001 certified facilities**
- **25-year limited warranty on power output (see dealer for details)**

NT-185U1

MULTI-PURPOSE MODULE

185 WATT

ELECTRICAL CHARACTERISTICS

Cell	Single crystal silicon
No. of Cells and Connections	72 in series
Open Circuit Voltage (Voc)	44.9V
Maximum Power Voltage (Vpm)	36.2V
Short Circuit Current (Isc)	5.75A
Maximum Power Current (Ipm)	5.11A
Maximum Power (Pm)*	185W
Minimum Power (Pm)*	166.5W
Encapsulated Solar Cell Efficiency (ηc)	17.13%
Module Efficiency (ηm)	14.22%
PTC Rating (W)**	163.30
Maximum System Voltage	600VDC
Series Fuse Rating	10A
Type of Output Terminal	Lead Wire with MC Connector

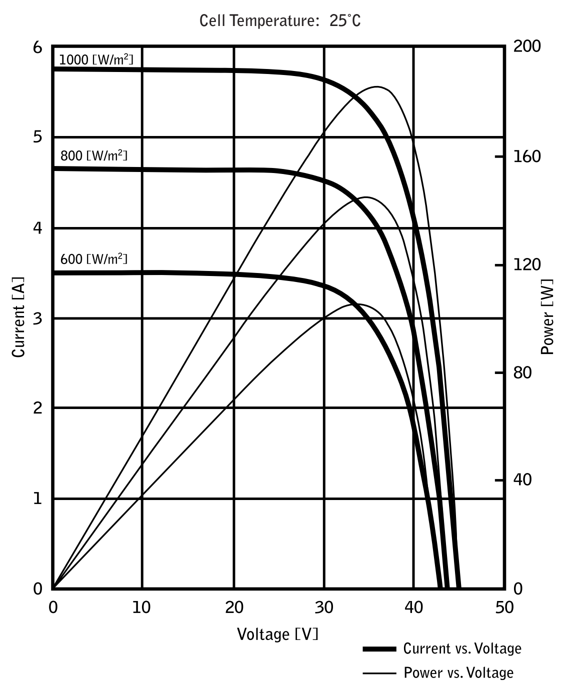
MECHANICAL CHARACTERISTICS

Dimensions (A x B x C below)	62.01 x 32.52 x 1.81" / 1575 x 826 x 46mm
Weight	37.485lbs / 17.0kg
Packing Configuration	2 pcs per carton
Size of Carton	66.93 x 38.19 x 5.12" / 1700 x 970 x 130mm
Loading Capacity (20 ft container)	168 pcs (84 cartons)
Loading Capacity (40 ft container)	392 pcs (196 cartons)

ABSOLUTE MAXIMUM RATINGS

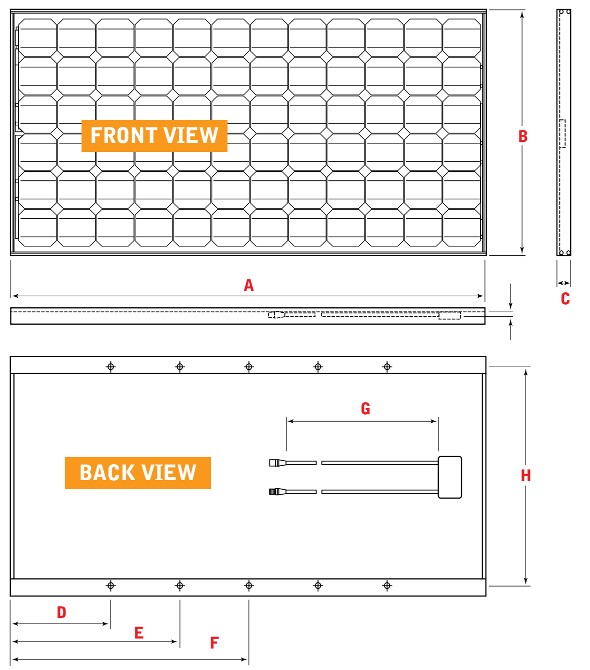
Operating Temperature	-40 to 194˚F / -40 to +90˚C
Storage Temperature	-40 to 194˚F / -40 to +90˚C
Dielectric Isolation Voltage	2200 VDC max.

IV CURVES



Current, Power vs. Voltage Characteristics

DIMENSIONS



D	E	F	G	H
7.3"/185.5mm	19.42"/485.5mm	30.93"/785.5mm	51.2" +/- 2"/1300mm+/-50mm	30.43"/773mm

Specifications are subject to change without notice.

* (STC) Standard Test Conditions: 25°C, 1 kW/m², AM 1.5
** (PTC) Pacific Test Conditions: 20°C, 1 kW/m², AM 1.5, 1 m/s wind speed

In the absence of confirmation by product manuals, Sharp takes no responsibility for any defects that may occur in equipment using any Sharp devices.
Contact Sharp to obtain the latest product manuals before using any Sharp device.

SHARP

Sharp Electronics Corporation • 5901 Bolsa Avenue, Huntington Beach, CA 92647
Tel:1-800-SOLAR-06 • E-mail: sharpsolar@sharpusa.com • www.sharpusa.com/solar

Cover photo: Solar installation by Pacific Power Management, Auburn CA SSD-185-904

TECHNICAL MANUAL

For

Sun Xtender® Batteries

Manufactured by:

Concorde Battery Corporation
2009 San Bernardino Road
West Covina, CA 91790
Phone 626-813-1234
Fax 626-813-1235
www.sunxtender.com

Document No. 6-0100
Revision A
October 22, 2008

RECORD OF REVISIONS

Revision	Date
Initial Release	8/26/08
A	10/22/08

SAFETY SUMMARY

DANGER OF EXPLODING BATTERIES

Lead acid batteries can produce explosive mixtures of hydrogen and oxygen. Take the following precautions:

- Never install batteries in an airtight or sealed enclosure and make sure installation is adequately ventilated.
- Charge batteries in accordance with the instructions given in this manual.
- Keep all sparks, flames and cigarettes away from batteries.
- Connect cables tightly to the terminals to avoid sparks.
- Wear proper eye and face protection when installing and servicing batteries.

DANGER OF CHEMICAL BURNS

Lead acid batteries contain sulphuric acid electrolyte which can cause severe burns to body tissue. Take the following precautions:

- Avoid contact of the electrolyte with skin, eyes or clothing.
- Never remove or damage vent valves.
- In the event of an accident, flush with water and call a physician immediately.

DANGER OF BURNS IF TERMINALS ARE SHORTED

Lead acid batteries are capable of delivering high currents if the external terminals are short circuited. The resulting heat can cause severe burns and is a potential fire hazard. Take the following precautions:

- Do not place metal objects across battery terminals.
- Remove all metallic items such as watches, bracelets and rings when installing or servicing batteries.
- Wear insulating gloves when installing or servicing batteries.
- Use insulating tools when installing or servicing batteries.

DANGER OF THERMAL RUNAWAY

Thermal runaway is a condition in which the battery temperature increases rapidly resulting in extreme overheating of the battery. Under rare conditions, the battery can melt, catch on fire, or even explode. Thermal runaway can only occur if the battery is at high ambient temperature and/or the charging voltage is set too high. Take the following precautions:

- Charge batteries in accordance with the instructions given in this manual.
- Do not install batteries near heat sources or in direct sunlight that may artificially elevate their temperature.
- Provide adequate air circulation around the batteries to prevent heat build up.

Table of Contents

CHAPTER 1 - INTRODUCTION

1.1 Company Background

Concorde Battery Corporation was founded in 1977 and is a manufacturer of premium quality lead acid batteries. Originally, Concorde's main product emphasis was dry charged and gelled electrolyte lead acid batteries. In 1985, Concorde developed its valve regulated, absorbent glass mat [AGM] technology for use in aircraft applications. The success of this technology in the aviation market has been outstanding. Concorde is now the largest manufacturer of valve regulated lead acid batteries for both commercial and military aircraft.

In 1986, Concorde further developed the AGM technology for deep cycle applications. This development effort provided higher energy density (higher capacity) and better cycle life than its gelled electrolyte battery. Concorde soon discontinued the gel product line and concentrated all engineering developments on the AGM product line. In 1987, Concorde began supplying the photovoltaic (PV) industry with our deep cycle AGM batteries. Over the years it has been our design expertise, quality and customer focus that has made Concorde a leader in providing the best battery available for the PV and Renewable Energy markets. Concorde is committed to the proposition that the customer deserves the best performing and highest quality product. Our batteries are tailored to the application rather than make the designer/user settle for what is available. It is this commitment – to meet the needs of the customer – that sets Concorde apart.

1.2 Overview of Sun Xtender® AGM Technology

Sun Xtender® AGM batteries are valve-regulated, recombinant gas, absorbed electrolyte, lead acid batteries. The cells are sealed with a pressure relief valve that prevents gases within the battery from escaping. The positive and negative plates are sandwiched between layers of glass mat consisting of a blend of glass micro fibers of varying length and diameter. This blend features superior wicking characteristics and promotes maximum retention of the electrolyte. An envelope of micro porous polyethylene surrounds each wrap of glass mat to further protect the plates from shorting. Electrolyte is absorbed and held in place by the capillary action between the fluid and the glass mat fibers. The mat is over 90% saturated with the electrolyte. By design it is not totally saturated with electrolyte, a portion is filled with gas. This void space provides the channels by which oxygen travels from the positive to the negative plates during charging. When the oxygen gas reaches the negative plate, it reacts with lead to form lead oxide and water. This reaction at the negative plate suppresses the generation of hydrogen that otherwise would come off the negative plate. In this manner, virtually all of the gas is "recombined" inside the cell, eliminating the need to add water, resulting in "maintenance free" operation. Furthermore, since the acid electrolyte is fully absorbed in the AGM separator, the battery is nonspillable even when turned upside down.

1.3 About this Manual

This manual is intended to provide the customer with technical information for selecting, installing, operating, and servicing Sun Xtender® AGM batteries. The next Chapter provides a detailed description of the product, its design features and materials of construction. Concorde is very proud of this innovative product line and we think you will share our enthusiasm. Chapter 3 provides a comparison of Sun Xtender® with other lead acid technologies: flooded-electrolyte batteries, gelled-electrolyte batteries, and AGM batteries from other manufacturers. Chapter 4 presents an overview of the battery specifications for the Sun Xtender® product line; detailed specifications for each model are published separately. Chapter 5 provides instructions for storing, operating and servicing Sun Xtender® AGM batteries. Chapter 6 gives an application guide and Chapter 7 gives important safety information. Further technical information can be found in the Appendices. If you have additional questions beyond what is covered in this manual, please contact Concorde Battery Corporation or any of our distributors.

CHAPTER 2 - BATTERY CONSTRUCTION

2.1 Component Description

Refer to the battery pictorial in Section 2.2 showing a cut away view of the cell and a summary of the features and benefits. A more detailed description of the battery's construction is given below.

GRIDS - The negative grid is made of pure lead calcium alloy. The positive grid is extra thick and is made from a proprietary, pure lead-tin-calcium alloy with special grain refiners. These features improve corrosion resistance of the grid and gives the battery excellent cycling capability and float life.

PLATES – The grids are pasted on state-of-the-art pasting machines to give the highest quality plates with tightly controlled weight and thickness specifications. The lead oxide paste used to make the positive plates is our high density formula. With time and use, the active material tends to soften and give less discharge capacity. The high density paste formula retards the active material softening and extends battery life.

ABSORBENT GLASS MAT [AGM] SEPARATOR – The AGM is a premium blend of glass micro fibers having an optimum ratio of fine and extra fine fiber sizes. This blend features superior wicking characteristics and promotes maximum retention of the electrolyte. The AGM layer is squeezed to an optimum level of compression during assembly to provide sufficient contact with the surface of the plate over the life of the battery. This compression also promotes retention of the active material if the battery is exposed to shock or vibration conditions.

POLYETHYLENE ENVELOPE – Concorde is only manufacturer that envelopes the AGM separator with a thin layer of microporous polyethylene. The microporous layer is wrapped around the glass-matted plate and then sealed along the sides to eliminate the possibility of shorts at the edges of the plate (a common failure mode). The microporous polyethylene is more durable and puncture resistant than the AGM material alone and significantly reduces the occurrence of plate to plate shorts.

INTERCELL CONNECTIONS - Massive "over the partition" fusion welds are used which increase the strength of the intercell connection. This minimizes the possibility of open welds and provides a low resistance connection between cells. Other manufacturers use "through the partition" spot welded construction that inserts a weak point into the assembly because of the small cross section area and the difficulty of making a reliable weld and leak proof construction.

HIGH IMPACT, REINFORCED CONTAINER & COVER – The battery container and cover are made of a thick walled polypropylene copolymer. This material provides excellent impact resistance at extreme low temperatures and minimizes bulging at high temperatures.

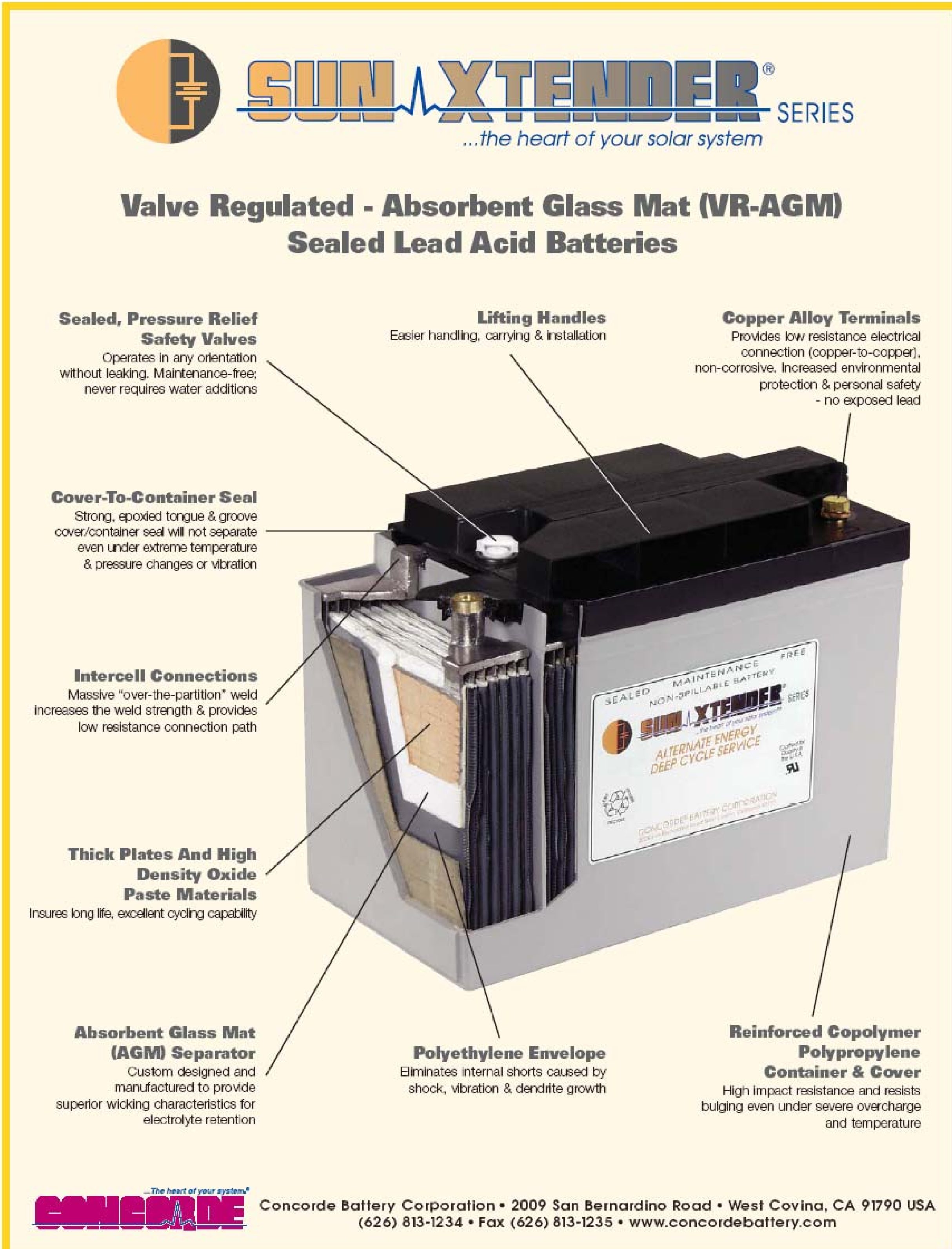
COVER-TO-CONTAINER SEAL - The batteries use an epoxied tongue and groove seal between the cover and container. Most other manufacturers heat seal their cover to the container. The epoxied tongue and groove is a far stronger seal and will not separate in high or low temperature extreme applications.

PRESSURE RELIEF SAFETY VALVE - Each cell in the battery employs a pressure relief safety valve. The valve is designed to release excess pressure that builds up over time to vent the small quantity of gasses that do not recombine inside of the battery. Once the pressure is released, the valve automatically re-seals. The gasses that escape are mainly oxygen and some hydrogen, and these gasses rapidly dissipate into the atmosphere.

TERMINALS - Sun Xtender® AGM batteries employ copper alloy (i.e., silicon bronze) terminals providing an improved low resistance electrical connection. The copper alloy terminals are non corrosive. Additionally, the copper alloy terminals offer increased environmental protection and personal safety in comparison to commonly used lead terminals. The terminals on most Sun Xtender® AGM batteries are recessed below the top of the battery cover. This prevents short circuiting across the battery terminals. Refer to the pictorial in Section 2.3 to see a detailed view of the various terminal designs that are available.

HANDLES – Lifting handles are incorporated into most Sun Xtender® AGM batteries. This provides easier handling for lifting, carrying and installation.

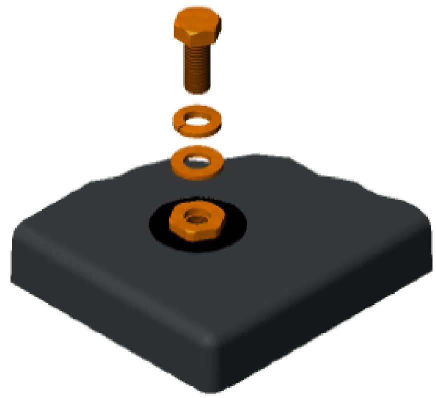
2.2 Battery with Cut Away View



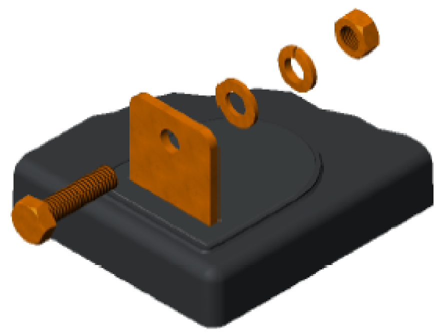
2.3 Terminal Types

Sun Xtender Battery Terminal Types

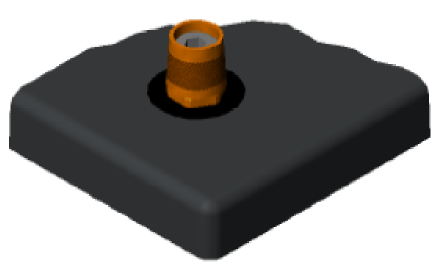
Copper Alloy Corrosion Free Connections for Maximum Conductivity



M8 Threaded Insert (Copper Alloy)
M6 Threaded Insert for PVX-340T & PVX-420T only



L-Blade Terminal (Solid Copper)
M8 Hardware



"A" - SAE Automotive Post (Copper Alloy)
Available as a separate kit, or installed at the factory
Kit Part Number: 6918

CHAPTER 3 - TECHNOLOGY COMPARISON

3.1 Sun Xtender® versus Flooded Batteries

Flooded-electrolyte lead acid batteries have been around since 1859 and tend to be less expensive than AGM or Gel batteries. However, they have major deficiencies compared to AGM or Gel batteries. For instance, deep cycle flooded lead acid batteries contain antimony in the grid alloy which causes a high rate of self discharge and rapid water loss due to gassing reactions. The escape of hydrogen and oxygen from the battery represents a serious safety hazard if the gasses are not ventilated properly. In flooded batteries, replacing the antimony lead alloy with calcium lead alloy reduces the amount of gassing and water loss, but the cycle life is much lower and they are no longer considered deep cycle batteries.

Electrolyte stratification can occur in all types of flooded batteries. As the battery is discharged and charged, the concentration of acid becomes higher at the bottom of the cell and becomes lower at the top of the cell. The low acid concentration reduces capacity at the top of the plates, and the high acid concentration accelerates corrosion at the bottom of the plates and shortens the battery life. Although stratification can be minimized by raising the charging voltage so that the increased gassing agitates the electrolyte, this will accelerate the water loss and watering frequency.

One other difference is that flooded batteries can not tolerate freezing temperatures when in the discharged state, whereas AGM batteries are not damaged by freezing temperatures. The following table provides a side by side comparison of Sun Xtender® AGM and flooded deep cycle batteries.

Characteristic	Sun Xtender® AGM Battery	Flooded Deep Cycle Battery
Self Discharge	1 to 3% per month – remains stable over life.	5-10% per month when new – increases drastically with age due to antimony contamination of the negative plate.
Water Addition	Never.	Frequent – increases dramatically with age due to antimony contamination of the negative plate.
Hydrogen Gas Emissions	Negligible unless severely overcharged.	Significant volume is generated and must be ventilated to prevent explosion.
Electrolyte Spillage	Non-spillable in all orientations – electrolyte is retained in AGM separator.	Spills when tilted, inverted, or cracked.
Electrolyte Stratification	No stratification occurs.	Stratification occurs when operated at low charging voltages or in taller batteries.
Tolerance to freezing temperatures	No damage when frozen.	Battery destroyed when frozen.

3.2 Sun Xtender® versus Gel Batteries

Gel batteries have been commercially available since the early 1970's and are still offered by some manufacturers. Concorde manufactured gel batteries for many years before developing the AGM technology and, therefore, is aware of inherent deficiencies associated with gel batteries.

The gel product employs a highly viscous, semisolid mixture of silica gel and dilute sulfuric acid in a colloidal suspension as an electrolyte. The electrolyte is difficult to keep homogeneous and the solid silica can separate from the acid, creating a "flooded" battery. Handling and vibration exposure are operational factors that can cause the silica and acid mixture to separate as there is no chemical bond. In high temperature environments, the semisolid electrolyte develops cracks and voids that reduce contact between the plates and causes the battery to lose capacity. This same effect gradually occurs even at normal room temperatures.

By contrast, AGM batteries employ a glass micro fiber mat separator that holds the liquid electrolyte like a sponge. Shrinkage of the separator does not occur as the battery ages and the electrolyte remains in direct contact with the plates. The electrolyte remains immobilized even when the battery is exposed to severe vibration, so electrolyte spillage or leakage is prevented.

Since it is easier to fill a container with a liquid than a semi-solid, AGM batteries require less space between battery plates. The closer plate spacing gives the AGM battery a lower internal resistance, making it more charge efficient and giving better power performance on discharge, especially at low temperatures.

Gel batteries are also more sensitive to charging voltage. If the charging voltage is not controlled within a very tight range relative to the battery's temperature, the life of the battery will be adversely affected. For example, one manufacturer of gel batteries claims that if the charging voltage is 0.7V higher than the recommended level, the cycle life will be reduced by 60 percent. The reason for this effect is the limited oxygen recombination capability of gelled batteries. Sun Xtender® AGM batteries are more forgiving in overcharge conditions and their ability to recombine the hydrogen and oxygen gases back into water is more efficient. With Sun Xtender® AGM batteries, tests have shown that increasing the charging voltage 1.0V above the recommended charging voltage results in only a 23% reduction in the cycle life.

The charge acceptance of gel batteries is also less than that of Sun Xtender® AGM batteries. This means it takes longer to recharge gel batteries. As an example, tests have shown that when discharged to 50% of rated capacity (fairly common in a PV system), gel batteries took twice as long to reach full charge as compared to Sun Xtender® AGM batteries.

The following table provides a side by side comparison of Sun Xtender® AGM and gel batteries:

Characteristic	Sun Xtender® AGM Battery	Gel Batteries
Electrolyte Stability	Excellent – AGM acts like a flexible sponge.	Prone to solid / liquid separation leading to spillage / spewage of acid and premature failure. Electrolyte looses contact with plates due to cracks and voids as the battery ages, especially at higher ambient temperatures.
High Rate Performance	Excellent due to low internal impedance.	Inferior. Plate spacing must be greater to allow for gel passage during filling. Gel adds to impedance, especially at low temperatures.
Sensitivity to Charging Voltage Levels	Moderately sensitive. Life is somewhat reduced if charged outside of recommended charge voltage levels.	Very Sensitive. Life is greatly reduced if charged outside of recommended charge voltage levels.
Charge Acceptance Rate	Excellent. Battery can be fully charged in 2 hours if high inrush current is available.	Inferior. Must limit in rush current and charge time is at least twice as long to reach full charge.

3.3 Sun Xtender® versus other AGM Batteries

Sun Xtender® AGM batteries have been specifically designed for true deep cycle, long service life capability in adverse temperature and handling conditions. Concorde uses extra thick positive plates, high density paste, thick AGM separator layers encased within a microporous polyethylene envelope, thick walled containers with epoxy-sealed covers. A side by side comparison of Sun Xtender® AGM batteries with typical AGM batteries from other manufacturers is provided in the following table:

Characteristic	Sun Xtender® AGM Battery	Other AGM Batteries
Positive Grids	Extra thick grids (typically 0.095" or greater) and extra thick plates (typically 0.105" or greater), for long cycle and float life.	Thinner grids, typically 0.045 to 0.060".
Pasted Plates	High density positive paste for long cycle life.	Lower density, resulting in lower cycle life.
AGM Separator	Extra thick for maximum electrolyte reserve. Premium grade of AGM with extra fine fibers for long life.	Thinner material used. Inferior grade of AGM without the extra fine fiber content.
Microporous polyethylene separators	Envelopes the positive plate to prevent shorting due to shock, vibration and dendrites	Not present, AGM is the only separator protecting the plates.
Intercell connections	Massive over the partition connectors provide a robust, leak proof connection with low voltage loss.	Inferior through the partition welds have less cross sectional area, provide weaker structural connection, and are leak prone.
Battery Terminals	Copper alloy – low electrical resistance and no exposed lead.	Lead alloy - higher in electrical resistance and user is exposed to lead. contamination
Container	Thick wall for rigid support of cell elements and high compression of AGM separator.	Thinner walls, less support of cell elements and lower compression of AGM separator.
Cover Seal	Cover is epoxied to container – high strength bond for reliable operation at temperature extremes.	Cover is heat sealed (melted) to container – prone to separation and leakage at temperature extremes.

CHAPTER 4 - BATTERY SPECIFICATIONS

4.1 Battery Models

The Sun Xtender® Series consists of batteries ranging in capacity from 34 to 915 ampere hours (rated at the 24 hour rate). A variety of 2-volt, 6-volt and 12-volt models are available. Refer to the battery specification sheet (published separately) for a complete listing of the mechanical and electrical specifications for each battery model.

4.2 Terminals

Standard Terminals**:** Batteries with a “T” at the end of the part number incorporate M6 or M8 (copper alloy) threaded insert terminals. Batteries with an “L” at the end of the part number incorporate “L” Blade (solid copper) terminals. All batteries are supplied with silicon bronze bolts, nuts, and washers required for installation.

Optional (Copper Alloy) Terminal Installed at the Factory: Batteries with a “T” at the end of the part number (except PVX-340T & PVX-420T) are available with an optional factory installed SAE automotive type terminal by adding the “A” suffix to the end of the part number. For example, order PVX-1040TA instead of PVX-1040T.

Optional (Copper Alloy) Terminal Kit: Kits can be ordered for “After Factory” customer conversions of “T” type batteries (except PVX-340T & PVX-420T) by ordering P/N 6918 for the “A” SAE automotive post kit. Kit includes terminals and installation bolts required for installation.

Terminal Torque Values**:** M6 use 35 in-lbs / 4.0 nm. M8 use 70 in-lbs / 7.9 nm.

4.3 Handles

All batteries include built in lifting handles except the PVX-490T and PVX-560T.

4.4 Definition of Ratings

Capacity ratings are after 15 cycles per BCI specifications and are stated at 77°F (25°C) to 1.75 volts per cell.

4.5 Temperature Range

Storage: -55°C (-67°F) to 50°C (122°F). Operating: -40°C (-40°F) to 71°C (160°F).

4.6 UL Recognition

All Sun Xtender® AGM batteries meet the requirements of UL® 1989 (Standby Battery) and are UL recognized under UL File Number MH-17983.

4.7 Shipping Classification

Sun Xtender® AGM batteries have been tested and determined to be in compliance with the vibration and pressure differential tests in accordance with DOT 49 CFR 173.159(d) and Special Provision A67 of the International Air Transport Association (IATA) Dangerous Goods regulations. As such, they are classified as a “NONSPILLABLE BATTERY” and can be shipped as non-hazardous material by any means. To comply with DOT shipping regulations, the battery must be packaged to protect against short circuits and the battery and outer packaging must be plainly and durably marked “NONSPILLABLE” or “NONSPILLABLE BATTERY”.

CHAPTER 5 - COMMISSIONING AND SERVICING INSTRUCTIONS

5.1 Storage

Sun Xtender® Batteries are charged at the factory and are ready for installation when they are received. Batteries may be stored prior to installation for up to 2 years, provided they are boost charged as described below. Batteries should be stored in the coolest environment available, preferably not exceeding 20°C (68°F). The higher the temperature, the faster the battery will self-discharge and require boost charging. See Appendix C for data on storage time versus temperature.

While in storage, batteries should be boost charged every 90 days or when the open circuit voltage (OCV) drops to 2.08 volts per cell (12.5 volts for a 12 volt battery). This OCV corresponds to approximately 65% state of charge. Boost charge batteries using a constant voltage charger set at 2.40 to 2.45 volts per cell (14.4 to 14.7 volts for a 12 volt battery) at a temperature of 20°C (68°F). If the temperature is above 20°C (68°F), compensate the charge voltage by subtracting 0.04V/cell for every 10°C difference (0.24V for a 12 volt battery). If the temperature is below 20°C (68°F), compensate the charge voltage by adding 0.04V/cell for every 10°C difference. The boost charge should be applied until the charging current falls below 0.5 percent of the battery's 24 hour rated capacity (0.5 amps for a 100 Ah battery). The time it takes for boost charging can be estimated from the following equation, based on the battery state of charge (SOC), rated capacity, and rated output of the charger:

Time to Reach Full Charge = [(1-SOC)/100) x Rated Capacity (Ah) ÷ Rated Output of Charger (Amp)] + 2 hours.

For example, when boosting a 104 Ah battery at 50% SOC using a 15A charger, the charging time can be estimated as follows:

Time to Reach Full Charge = [(1-50/100) x 104 Ah ÷ 15A]+ 2 hours = 5.5 hours.

5.2 Installation

Be sure there is adequate ventilation in the area where the batteries are to be installed (see Chapter 7). Connect batteries using cabling that is sized for the maximum load of the system. The voltage drop on the cables during charging should not exceed 0.2 volts at full output. Protect the battery terminals from shorting during installation.

Batteries may be connected in series (voltage adds, capacity stays the same), in parallel (capacity adds, voltage stays the same), or a combination of series and parallel (voltage and capacity adds). Each of these connection options are illustrated in Figures 5-1 through 5-3, respectively.

Always use batteries of the same size and condition in multi-battery installations. When replacing batteries, it is best to replace the entire set of batteries so they remain balanced.

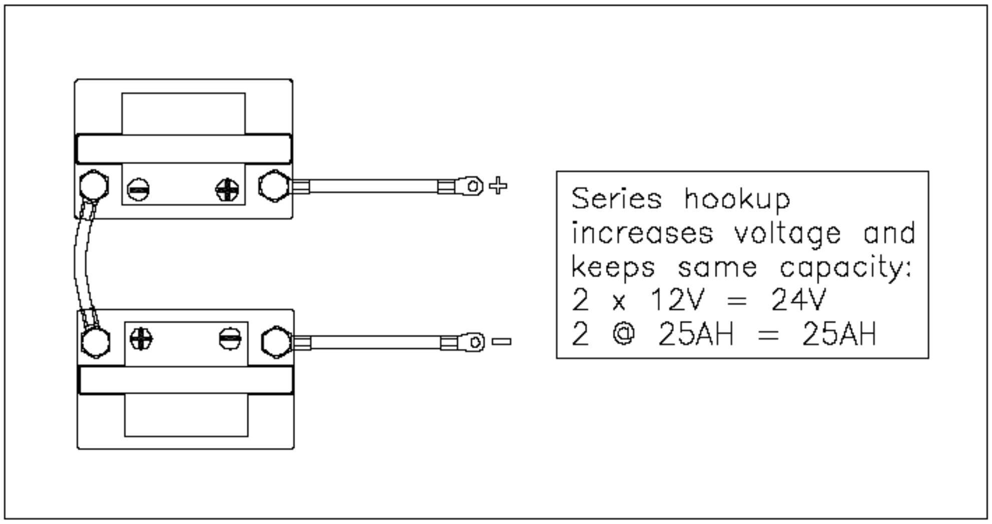


Figure 5-1. Series Connection

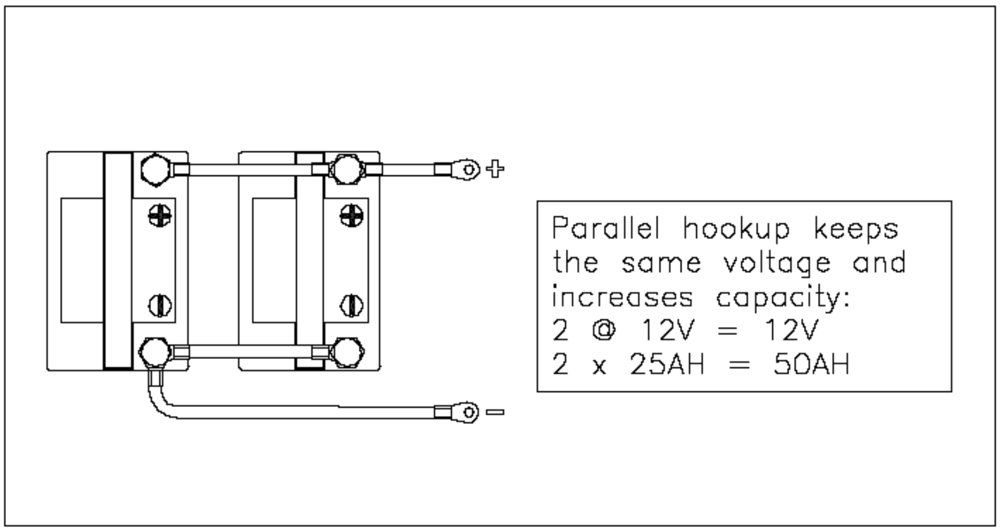


Figure 5-2. Parallel Connection

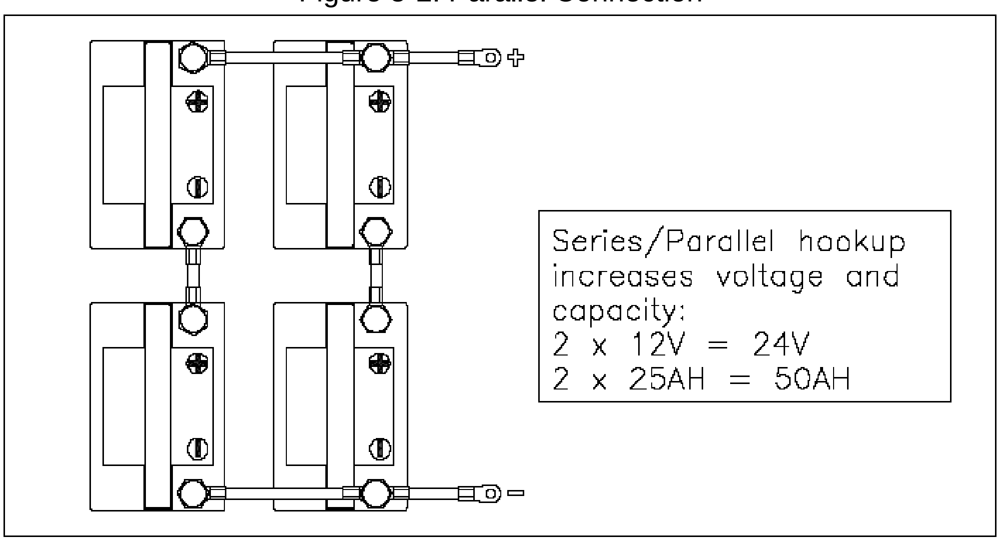


Figure 5-3. Series/Parallel Connection

5.3 Discharging

Discharge data for Sun Xtender® AGM batteries are given in Appendix C. In general, batteries should be sized such that the rated capacity is at least twice the capacity required by the load. For example, if 100 Ah is required on average, select at least a 200Ah battery. This approach will limit the average depth of discharge to 50% and will dramatically extend the life of the battery (see chart of Cycle Life versus Depth of Discharge in Appendix C).

5.4 Charging

Charging Sun Xtender® AGM batteries is a matter of replacing the energy removed during discharge plus a little extra to make up for charging inefficiency. The amount of energy necessary for complete recharge depends on the depth of discharge, rate of recharge, and temperature. Typically, between 102% and 110% of the discharged ampere-hours must be returned for full recharge.

The most efficient method of charging Sun Xtender® AGM batteries is to use a 3 stage charging profile. In the first stage, a constant current is applied until the voltage reaches a pre-set limit. The first stage is often called the ***Bulk*** charging stage. In the second stage, the voltage is held constant at the same pre-set limit until the charging current tapers to a very low value, at which point the battery is fully charged. The second stage is often called the ***Absorption*** charging stage. A voltage limit of 2.40 ± 0.01 volts per cell (14.40 volts ± 0.06 volts for a 12 volt battery) should be used when the battery temperature is 25°C (77°F). The battery is fully charged when the current drops below 0.5% of the battery's rated capacity (0.5A for a 100Ah battery). In the third stage, the charging voltage is reduced to a lower value that minimizes the amount of overcharge, while maintaining the battery at 100% state of charge. This third stage is often called the ***Float*** charging stage. A float voltage of 2.21 ± 0.1 volt (13.25 ± 0.06 volts for a 12 volt battery) should be used when the battery temperature is 25°C (77°F). The charging voltages at other temperatures can be determined from the following equations:

VPC(Absorption) = $0.00004T^2 - 0.006T + 2.525$ (where T = °C)
VPC (Float) = $0.00004T^2 - 0.006T + 2.335$ (where T = °C), but not less than 2.20 volts per cell.

Chargers should have a current limit of at least 0.2C. Due to the low impedance design, Sun Xtender® batteries can tolerate in-rush current levels as high as 5C (5 times the 24 hour capacity rating). The time to reach full charge at temperatures in the range of 20-30°C (68 to 86°F) can be estimated from the following equation:

Time to Reach Full Charge = [(DOD/100) x Rated Capacity (Ah) ÷ Rated Output of Charger (Amp)] + 2 hours.

For example, charging a 100Ah battery at 50% DOD with a 25A charger would take
[(50/100) x 100 ÷ 25] + 2 = 4 hours to reach full charge. With a 10A charger it would take [(50/100) x 100 ÷ 10] + 2 = 7 hours.

Note that this formula is approximate and the full charge state should be verified using the criteria given above (current drops below 0.5% of rated capacity). If the recharge does not return 102 to 110% of the discharged capacity, the battery's state of charge will gradually "walk down" as it is cycled leading to premature failure. Therefore, it is important to verify that the battery is not being undercharged.

5.5 Conditioning

Conditioning should only be done when the battery is showing symptoms of capacity loss due to extended time in a partial or low state of charge condition. This could be caused, for example, by low output of a solar powered charger due to a week of cloudy skies.

In the event conditioning is necessary, go through the normal charge cycle to bring the battery to full charge. The conditioning charge should then be applied by charging for 8 hours using the voltage given in the following equation:

VPC (Conditioning) = $0.00004T^2 - 0.006T + 2.725$ (where T = °C).

At 25°C, the conditioning voltage is 2.60 VPC (15.6 volts for a 12 volt battery). By using the temperature-compensated voltage, calculated from the above equation, batteries that are not in controlled temperature environments may be conditioned without bringing them to room temperature.

5.6 Deep Discharge Recovery

Batteries that have been in storage for long periods of time without boost charging, or have been kept deeply discharged for an extended time, may need to be charged at constant current instead of constant voltage to restore capacity. The following procedure is effective if the batteries are not too badly sulfated. **WARNING: This procedure should only be done in a well ventilated area because a significant amount of hydrogen gases may be released from the battery.**

1. Stabilize the battery at 20-30°C (68-86°F) for at least 24 hours.
2. Charge at a constant current of 5% of rated (24 hour) capacity until the voltage reaches 2.60 VPC (15.6 volts for a 12 volt battery), then continue charging at this rate for an additional 4 hours. Note that the charging voltage may get as high as 3.0 volts per cell, so the power supply must be capable of outputting this level to maintain constant current. This constant current charge may take 16 to 20 hours.

CAUTION: If the battery becomes hot (above 55°C/130°F) during this charge, stop the current and allow the battery to cool to room temperature before continuing the charge.

NOTE: The above procedure should be performed by an experienced battery maintenance facility utilizing the proper charging and test equipment. Concorde recommends the use of our Model CA1550 charger/analyzer. For more information regarding Concorde's test equipment go to: **www.concordebattery.com/accessories.php.**

5.7 Recycling

Batteries that have reached the end of their service life should be returned to a local or regional collection center for recycling. All local regulations and ordinances must be followed. Never discard Sun Xtender® AGM batteries in the trash or in a landfill. The recycle rate of lead acid batteries is close to 100% and this is very good for the environment!

CHAPTER 6 – APPLICATION GUIDE

The following section contains guidelines for sizing a battery system that should provide a reliable energy storage system for stand alone Renewable Energy systems. The primary emphasis is for photovoltaic (PV) systems but other renewable energy source systems would have similar requirements.

6.1 Load Calculations

DC Loads

To calculate the *DC Ampere Hours per Day* required to power the system:

DC Load Amps = 1000 x kW ÷ DC System Voltage

Total Daily Load [AH] = DC Load Amps x No. of Operating Hours per Day

> Example:
> For a 0.12 kW DC load at 48 VDC,
> DC Load Amps = 1000 x 0.12kW ÷ 48VDC = 2.5A.
> Total Daily Load = 2.5A x 24 Hours/Day = 60 AH/Day.

For variable DC Loads, establish the duty cycle based on percentages of the daily operations.

(P1% of day at xx Amps) + (P2% of day at yy Amps) + Etc = Total AH Consumed/Day

> Example:
> A system operates at 5A for 70% of the day and 10A for 30% of the day:
> Total Daily Load = (70% X 5A X 24 Hrs) + (30% X 10A X 24 Hrs)
> Total Daily Load = 84 AH + 72 AH = 156 AH/Day.

AC Loads

When an inverter is used to power 120 or 240 VAC appliances, such as pumps, refrigerators, lighting, etc., the AC voltage must be converted to the Battery's DC voltage and the efficiency of the inverter must be considered.

If the inverter AC voltage is 120 VAC and the battery DC voltage is 24 VDC, then the conversion factor is 5.0. For every AC amp drawn there will be 5 times as many DC amps required. Also, the inverter's conversion efficiency from DC to AC is not 100%. There is an internal loss in the inverter which is normally about 10% to 15%. See inverter/charger manufacturer's data for efficiency specifications.

> Example:
> For a 2.4 kW AC Load at 120VAC with a 48VDC battery and Inverter operating at 90% efficiency,
> AC Load = 1000 x 2.4 kW ÷ 120 VAC = 20 Amps @ 120 VAC
> DC Load = 20 Amps AC X 120/48 ÷ 0.90 = 55.6 Amps DC
> Total Daily Load = 55.6 A x 24 Hours/Day = 1,334 AH/Day

Note: When sizing the battery for non continuous loads, or for larger loads for short periods of time per day, it may not be possible to use the 20, 24 or 120 hr. rate of discharge for the battery's capacity. When discharged at different rates, a battery's capacity will vary. The higher the rate of discharge, the lower the capacity of the battery will be. More detailed calculations are required in these cases.

6.2 Days of Autonomy

As everybody knows, the sun does not shine with equal intensity every day, nor does it shine at night and during inclement weather. Cloud cover, rain, snow, etc. diminish the daily insolation (*Insolation* is the amount of solar energy delivered to the earth's surface, measured in W/m^2 or kWh/m^2/day. A storage factor must be employed to allow the photovoltaic battery system to operate reliably throughout these periods.

In addition, it is desired to obtain the best service life of the battery by limiting its average daily depth of discharge. This storage factor is commonly referred to as "Number of Days of Battery Autonomy". The number of days is established by evaluating the peak hours of sun per day for the lowest insolation month of the year with the solar array oriented for maximum output during that month.

The minimum number of days that should be considered is 5 days of storage for even the sunniest locations on earth. In these high sun locations there will be days when the sun is obscured and the battery's average depth of discharge should not be more than 20% per day. The recommended days of autonomous storage are shown in the following table:

Table 6-1.

Recommended Days of Storage	
kWh/m^2/day	Days of Autonomy
4.5+	5
3.5 to 4.5	6
2.7 to 3.5	7
2.0 to 2.7	8
< 2.0	10 or more

6.3 Temperature Considerations

The temperature of the battery is a major factor in sizing a PV system. Battery capacity is reduced in cold temperatures and the battery life is shortened in high temperatures.

It should be realized that the temperature of the battery itself and ambient temperature can be vastly different. While ambient temperatures can change very quickly, battery temperature change is much slower. This is due to the large thermal mass of the battery. It takes time for the battery to absorb temperature and it takes time for the battery to relinquish temperature.

The battery's temperature is normally the average temperature for the past 24 hours plus or minus a few degrees. In many systems it can be difficult or impossible to heat or cool the battery and we must take ambient temperature into consideration. A battery that is required to operate continuously at -18ºC (0º F.) will provide about 60% of its capacity. This same battery operated continuously in a 35º C (95º F.) environment will see its life expectancy cut in half.

The earth is a great heat sink which provides enormous insulation in high or low temperatures. By burying the battery in the ground we can increase its capacity at cold ambient temperatures and increase the life of the battery at high ambient temperatures. The battery with only 60% of its capacity at -18ºC (0º F) can be brought up to 85% to 90% capacity by burying it. With life cut in half at 35ºC (95ºF), burying the battery can bring it back to near normal life expectancy.

6.4 Battery Sizing

The battery capacity for a PV system can be calculated using the following formula:

Capacity (AH) = Total Daily Load x Days of Autonomy x Design Factor

The Design Factor depends on the battery's average temperature during the coldest time of the year, as discussed above. The following table provides recommended Design Factors at various temperatures.

Table 6-2.

Lowest Battery Temperature Averaged over 24 Hours		Design Factor
Degrees C	Degrees F	
25 or above	77 or above	1.25
20 to 24	68 to 76	1.39
10 to 19	50 to 67	1.43
0 to 9	32 to 49	1.60
-10 to -1	14 to 31	1.84
-20 to -11	-4 to 13	2.23
-30 to -21	-22 to -5	2.84
-40 to -31	-40 to -23	4.17

<u>Example:</u>

For a 48VDC system, Total Daily Load of 30AH, 5 Days of Autonomy, and -8°C is the lowest average temperature, the required battery capacity is as follows:

Battery Capacity = 30 x 5 x 1.84 = 276AH. This requirement could be satisfied with a PVX-2580L, which has a C/120 rating of 305AH. Four of these batteries in series gives 4 x 12VDC = 48VDC.

CHAPTER 7 - SAFETY INFORMATION

There are four main safety hazards associated with the use of any valve regulated lead acid (VRLA) battery. These hazards are: a) Release of ignitable gas, b) Exposure to acid, c) Shorting of terminals, d) Thermal runaway. This chapter provides a description of each of these hazards and means to mitigate them.

7.1 Release of Ignitable Gasses

All lead acid batteries, including VRLA batteries, produce hydrogen and oxygen gases during normal charging. Even though VRLA batteries are designed to recombine these gases internally, the recombination efficiency is less than 100%. Small amounts of hydrogen and oxygen are released from the pressure relief valve during charging. Normally, the hydrogen gas dissipates very rapidly and never reaches a concentration level that is hazardous. However, if the battery is installed in an enclosure with minimal airflow, the concentration of hydrogen could build up to a high enough concentration to be of concern. Hydrogen can ignite at concentrations as low as 4% in air. **For this reason, never install a Sun Xtender® AGM battery in a sealed or an airtight container.**

7.2 Exposure to Acid

All lead acid batteries contain sulfuric acid in the electrolyte, which can cause chemical burns to body tissue. Although Sun Xtender® AGM batteries are classified as Nonspillable, exposure to the electrolyte is possible under extreme conditions (e.g., if the battery is cracked open or crushed**). In the event that electrolyte is displaced from the battery, avoid contact with the skin, eyes and clothing. In the event of an accident, flush with water and call a physician immediately.**

7.3 Shorting of Terminals

Sun Xtender® AGM batteries have very low internal impedance and therefore are capable of delivering high currents if the external terminals are short circuited. The resulting heat can cause severe burns and is a potential fire hazard. Accidentally placing metal objects across the terminals can result in severe skin burns. **It is a good practice to remove all metallic items such as watches, bracelets and rings when installing or servicing batteries. As a further precaution, insulating gloves should be worn and only insulated tools should be used when installing or servicing batteries.**

7.4 Thermal Runaway

Thermal runaway is a condition in which the battery temperature increases rapidly resulting in extreme overheating of the battery. Under rare conditions, the battery can melt, catch on fire, or even explode. Thermal runaway can only occur if the battery is at high ambient temperature and/or the charging voltage is set too high. As the battery accepts current, its internal temperature rises. The rise in temperature reduces the battery impedance, causing it to accept more current. The higher current further heats the battery, and so on, causing the battery temperature to “runaway”. An upper limit will eventually be reached when the electrolyte starts to boil, but once the electrolyte has boiled away, the temperature can climb even further to the point of plastic meltdown and possible fire.

As of this writing, Concorde does not know of any Sun Xtender® AGM batteries that have failed due to thermal runaway. **To preclude the possibility of thermal runway, the charging instructions of Chapter 4 should be carefully followed, especially if the battery will be subjected to high ambient temperatures. Batteries should not be installed near heat sources or in direct sunlight that may artificially elevate their temperature. Also, there should be adequate air circulation around the batteries to prevent heat build-up.**

APPENDIX A – GLOSSARY OF BATTERY TERMS

AGM - Stands for Absorbed Glass Mat. This is the separator system used in all Sun Xtender® AGM batteries.

Active Material - Electrode material which produces electricity during its chemical conversion. In the positive plate it is lead dioxide. In the negative plate, it is sponge lead.

Ampere - Unit of electrical current Abbreviated as amps or A.
Amps = Watts/Volts or A = W/V.

Ampere Hour (Ah) - The capacity of a storage battery is measured in ampere hours. One ampere hour is defined as a current flow of one ampere for a period of one hour. Five ampere hours means a current flow of one ampere for five hours, a current flow of 2 1/2 ampere for 2 hours, or any multiple of current and time that will result in five. This relationship can be expressed as follows:
Capacity (Ampere hours)= I*T, where I is the current (in amperes) and T is the time (in hours). The capacity of a storage battery is based on a given discharge rate, since the capacity will vary with the rate of discharge.

Battery - Two or more chemical cells electrically connected together to produce electric energy. Common usage permits this designation to be applied also to a single cell used independently.

Boost Charge - A charge applied to a battery which is already near a state of full charge, usually of short duration.

C/X Rate - Discharge rate in amperes that will take X hours to fully discharge the battery. C/1 = 1-hour rate, C/120 = 120-hour rate, C/0.5 = ½-hour rate (normally written as 2C).

Capacity - The quantity of electricity delivered by a battery under specified conditions, usually expressed in ampere hours.

Capacity, Rated - A designation by the battery manufacturer which defines the performance of a new battery at a defined rate of discharge. For Sun Xtender® AGM batteries, the rated capacity is based on the 24 hour rate.

Capacity, Residual - Capacity remaining at particular point in time after any set of operating conditions, usually at a partial state of charge condition.

Case - The battery box which contains the cells and associated internal connectors.

Cell - An electrochemical device composed of positive and negative plates, separator, and electrolyte which is capable of storing electrical energy. When encased in a container and fitted with terminals, it is the basic building block of the battery.

Cell Reversal - Reversing of polarity within a cell in a multi cell battery due to over discharge.

Charge - The conversion of electrical energy from an external source, into chemical energy within a cell or battery.

Charge Rate - The rate at which current is applied to a cell or battery to restore its capacity.

Charge Retention - The ability of a charged cell or battery to resist self discharge.

Charge, State of - Ratio of the amount of capacity remaining in a battery to the capacity when fully charged. A battery at 25% state of charge has 25% capacity remaining versus what it could give if fully charged.

Charger - Device capable of supplying electrical energy to a battery.

Charging - The process of converting electrical energy to stored chemical energy. The opposite of discharging.

Charging Efficiency - Ratio of the Ampere hours delivered on discharge to the Ampere hours needed to fully charge a battery.

Conditioning - A special constant current charge process used to restore a battery's capacity after extended storage periods or deep discharge exposure. Also known as reconditioning.

Connector - An electrically conductive bar or cable which joins individual cells together in a battery.

Constant Current (CC) Charge - Charging technique where the output current of the charge source is held constant. Warning! This procedure may damage the battery if performed on a repetitive basis.

Constant Voltage (CV) Charge - Charging technique where the output voltage of the charge source is held constant and the current is limited only by the resistance of the battery and / or the capacity of the charge source. Also known as Constant Potential (CP) charge.

Container - The bottom portion of the cell container (excluding the cover).

Coulometer - Electrochemical or electronic device, capable of integrating current and time to tally ampere-hours. Used for charge control.

Counter EMF - Voltage of a cell or battery opposing the voltage of the charging source.

Current - The rate of flow of electricity. The movement of electrons along a conductor. It is comparable to the flow of a stream of water. The unit of measurement is an ampere.

Current Density - The amount of electric current passing through a given cross-sectional area of a conductor in amperes per square inch, i.e: the ratio of the current in amperes to the cross-sectional area of the conductor.

Cut Off Voltage - Battery voltage reached at the termination of a discharge. Also known as end point voltage or EPV.

Cycle - One sequence of discharge and charge.

Cycle Life - The total number of charge/discharge cycles before the battery reaches end of life (generally 80% of rated capacity).

Deep Discharge - Withdrawal of more than 80% of the rated capacity.

Depth Of Discharge - The portion of the capacity taken out during a discharge, expressed as a percent of rated capacity.

Discharge - The conversion of the chemical energy of a cell or battery into electrical energy and withdrawal of the electrical energy into a load.

Discharge rate - The rate of current flow from battery, generally expressed in amperes.

Duty Cycle - The conditions and usage to which a battery is subjected during operation, consisting of discharge, charge, and rest periods.

Electrode - Conducting body in which active materials are placed and through which current enters or leaves cell.

Electrolyte - In a lead acid battery, the electrolyte is sulfuric acid diluted with water. It is a conductor and is also a supplier of hydrogen and sulfate ions for the reaction.

Electromotive Force (EMF) - Potential causing electricity to flow in a closed circuit. Measured in volts.

End Of Discharge Voltage - The voltage of the battery at the termination of a discharge but before the discharge is stopped. See End Point Voltage (EPV).

End Of Life - The stage at which the battery fails to deliver acceptable capacity (typically 80% of nameplate rating).

End Point Voltage - Voltage at which point the rated discharge capacity had been delivered at a specified rate of discharge. Also used to specify voltage below which the connected equipment will not operate or below which operation is not recommended. Sometimes called cutoff voltage or voltage end point.

Energy - Output capability, expressed as capacity times voltage, or Watt hours (Whr).

Energy Conversion - The change from chemical to electrical energy within the cell, or the reverse.

Energy Density - The ratio of battery energy to either the weight (Wh/lb or Wh/kg) or the volume (Wh/L or Wh/cu.in.).

Environmental Conditions - External circumstances to which a cell or battery may be subjected, such as ambient temperature, humidity, shock, and vibration.

Equalization Charge - A maintenance procedure consisting of a sustained overcharge used to correct cell imbalance.

Fast charging - Rapid return of energy to a battery at the C rate or higher.

Float charge - A method of maintaining a battery in a charged condition by continuous, long term, constant voltage charging at level sufficient to balance self-discharge.

Flooded cell - A cell design which incorporates an excess amount of electrolyte, also see Vented Cell.

Gassing - The evolution of gas from one or more of the electrode plates in a cell. Gassing commonly results from local action (self discharge) or from the electrolysis of water in the electrolyte during charging.

High Rate Discharge - Withdrawal of large amounts of current for short intervals of time from a battery, usually at a rate that will completely discharge a cell or battery in less than 1 hour.

Internal Impedance - Same as Internal Resistance.

Internal Resistance - The opposition or resistance to the flow of a direct electric current within a cell or battery; the sum of the ionic and electronic resistance of the cell components. Its value varies with the current, state of charge, temperature, and age. With an extremely heavy load, such as an engine starter, the cell voltage may drop significantly. This voltage drop is due to the internal resistance of the cell. A cell that is partly discharged has a higher internal resistance than a fully charged cell, hence it will have a greater voltage drop under the same load. This change in internal resistance is due to the accumulation of lead sulfate in the plates.

Ion - Part of a molecule or group of atoms, positively or negatively charged, which transports electricity through the electrolyte.

Lead Acid - Terms used in conjunction with a battery that utilizes lead and lead dioxide as the active plate materials in a diluted electrolyte solution of sulfuric acid and water.

Lead Dioxide - A higher oxide of lead present in charged positive plates and frequently referred to as lead peroxide (PbO_2).

Lead Sulfate - A lead salt formed by the action of sulfuric acid on lead oxide during paste mixing and formation. It is also formed electrochemically when a battery is discharged.

Life - The duration of satisfactory performance, measured as usage in years or as the number of charge/discharge cycles.

Low Rate Discharge - Withdrawal of small amounts of current for long periods of time from a battery.

Migration - Directed movement of an ion of the electrolyte under the influence of an electric field.

Monobloc - A battery assembly that contains multiple cells connected in series or parallel and housed in a single container.

Negative Electrode - See Negative Plate.

Negative Plate - The plate which has an electrical potential below that of the other plate during normal cell operation. Positive current flows to the negative plate during discharge.

Nominal Voltage - Equivalent to the number of cells in series in a battery times 2 volts per cell. A 6 cell battery has a nominal voltage of 12 volts.

Open Circuit Voltage - The voltage of a battery when it is not delivering or receiving power, and has been at rest long enough to reach a steady state (normally, at least 4 hours).

Overcharge - The forcing of current through a cell after all the active material has been converted to the charged state. In other words, charging continued after 100% state of charge is achieved. The result will be the decomposition of water in the electrolyte into hydrogen and oxygen gas, heat generation, and corrosion of the positive electrode.

Oxygen recombination - The process by which oxygen generated at the positive plate during charge reacts with the pure lead material of the negative plate and in the presence of sulfuric acid reforms water.

Parallel connection - Voltage stays the same, discharge rate and AH capacity are additive.

Plate - A grid or framework that gives mechanical support to the active materials of a cell. The combination is termed a pasted plate.

Polarity - The electrical term used to denote the voltage relationship to a reference potential (+).

Positive Electrode - See Positive Plate.

Positive Plate - The plate which has an electrical potential higher than that of the other plate during normal cell operation. Positive current flows from the positive plate during discharge.

Power - Rate at which energy is released or consumed (expressed in watts).

Power Efficiency - The proportion, expressed in percent, of energy recovered from a storage system, i.e: output power divided by input power.

Rated Capacity - See Capacity, Rated

Rechargeable Secondary Cell or Battery - A cell or battery which can be recharged many times after being discharged without appreciable depreciation of capacity.

Recombination - See Oxygen recombination.

Resealable - In a cell, pertains to a safety vent valve which is capable of closing after each pressure release, in contrast to the non resealable vent cap.

Reversible Reaction - A chemical change which takes place in either direction, as in the reversible reaction for charging or discharging a secondary battery.

Sealed Cells - Cells that are free from routine maintenance and can be operated without regard to position.

Secondary Battery - A system which is capable of repeated use by employing chemical reactions that are reversible, i.e., the discharged energy may be restored by supplying electrical current to recharge the cell.

Self Discharge - The decrease in the state of charge of a cell or a battery, over a period of time, due to internal electrochemical losses.

Separator - An insulating sheet or other device employed in a storage battery to prevent metallic contact between plates of opposite polarity within a cell.

Series Connection - Voltage of the system is cumulative. Capacity stays the same.

Shelf Life - The period of time (measured from date of manufacture) at a specified storage temperature after which the cell or battery needs to be boost charged so it does not suffer permanent capacity loss.

Specific Energy - The energy storage ability of a battery on a weight basis, usually expressed in watt hours per pound (or kilogram); sometimes given on a volume basis in watt hours per cubic foot (or liter).

Starved Cell - A cell containing little or no free fluid electrolyte solution; this enables gases to reach electrode surfaces readily, and permits relative high rates of recombination.

State Of Charge (SOC) - The available ampere hours in a battery at any given time relative to its full charge capacity.

Sulfation - Refers to the formation of hard lead sulfate crystals in the plates that are difficult, if not impossible, to reconvert to active material.

Temperature, Ambient - The average temperature of the battery's surroundings.

Temperature, Cell - The average temperature of the battery's internal components.

Terminal - An electrical conductor used in a battery to make electrical connection to external circuits for charging and discharging.

Trickle Charging - Method of charging in which the battery is either continuously or intermittently connected to a constant current charging source to maintain the battery in a fully charged condition. Not recommended for use with Sun Xtender® AGM batteries.

Vent Valve - A normally closed check valve located in a cell which allows the controlled escape of gases when the internal pressure exceeds its rated value.

Venting - A release of gas either controlled (through a vent) or accidental from a battery cell.

Volt - Unit of electromotive force, voltage or potential. The volt is the voltage between two points of a conductor carrying a constant current of one ampere, when the power dissipated between these points is one watt.

Voltage Limit - The upper limit of the charge voltage that is applied to the battery.

APPENDIX B – FREQUENTLY ASKED QUESTIONS (FAQ'S)

What does AGM stand for?
It stands for Absorbed Glass Mat, the type of separator used in all Sun Xtender® AGM batteries.

What is the difference between AGM batteries and Gel batteries?
Both AGM and Gel batteries utilize oxygen recombination and pressure relief valves to minimize water loss and allow maintenance-free operation. That is where the similarities end. AGM batteries have the advantage of being mountable in any orientation without capacity loss, have lower internal impedance to support high load currents, and have better capacity at low temperatures. Gel batteries must be mounted upright to prevent air pockets from forming that will burn out the plates. They have inferior performance at high discharge rates and low temperatures. Refer to Chapter 3 for further details.

Why should I choose Sun Xtender® AGM batteries?
Concorde has been supplying Sun Xtender® AGM batteries to the Renewable Energy Storage/ Solar Energy / Photovoltaic (PV) Industries for over 20 years, providing excellent performance, reliability and life. Applications include installations for telecommunications, village power, medical refrigeration, remote home, supervisory control & data acquisition, cathodic protection, telemetry, residential homes, aids to navigation [sea & air], lighting, and many more uses. With this long history and wide variety of successful applications, prospective customers are assured that Sun Xtender® AGM batteries have proven themselves over and over again.

What depth of discharge should be used when sizing a battery?
To get the best cycle life, the average depth of discharge should be as low as possible. Concorde recommends the average depth of discharge be no greater than 50% of the battery's 24 hour rating.

What is the maximum number of batteries that can be connected in parallel?
In general, the number of batteries in parallel should be limited to four (4). It may be difficult to keep the batteries in balance beyond this number, unless a special charging system is employed.

Can Sun Xtender® AGM batteries be installed in sealed containers?
NO! Do not install Sun Xtender® AGM batteries in a sealed box or enclosure. During charging, hydrogen gas can be released and must be ventilated to prevent the possibility of ignition and/or explosion.

What is the best way to charge my battery?
Charge with a 3 stage charger that compensates the voltage setting as the battery temperature changes. See Chapter 5 for further information.

What is the best charge voltage setting for outdoor applications if temperature sensing is not available?
NONE! Charging voltage varies widely depending on the battery's temperature and there is no single voltage that will work over a wide temperature range. Batteries will fail prematurely if this is attempted.

How can I tell if my battery is fully charged?
For a battery at room temperature, it can be considered fully charged when the charging current falls below 0.5A per 100Ah of rated capacity. The open circuit voltage (after at least 4 hours of rest) will be 2.17 volts per cell or higher (13.0 volts for a 12-volt battery), regardless of the battery temperature.

How do I know when it is time to replace my battery?
Replace the battery when it no longer is capable of supporting the discharge load for the minimum required run time.

APPENDIX C – CHARTS AND GRAPHS

Battery Load Voltage vs. DOD

Below are listed the one hour, 8 hour, 24 hour and 120 hour load voltages during the discharge cycle from full charge to 100% discharge to 1.75V/cell or 10.5V (6 cells) at 25°C (77°F).

DOD (%)	1 hr. Rate	8 hr. Rate	24 hr. Rate	120 hr. Rate
10	12.23	12.62	12.74	12.79
20	12.16	12.51	12.59	12.69
30	12.07	12.39	12.45	12.55
40	11.96	12.25	12.30	12.40
50	11.83	12.11	12.15	12.22
60	11.70	11.96	12.00	12.08
70	11.55	11.79	11.83	11.90
80	11.38	11.59	11.63	11.70
90	11.15	11.32	11.36	11.43
100	10.50	10.50	10.50	10.50

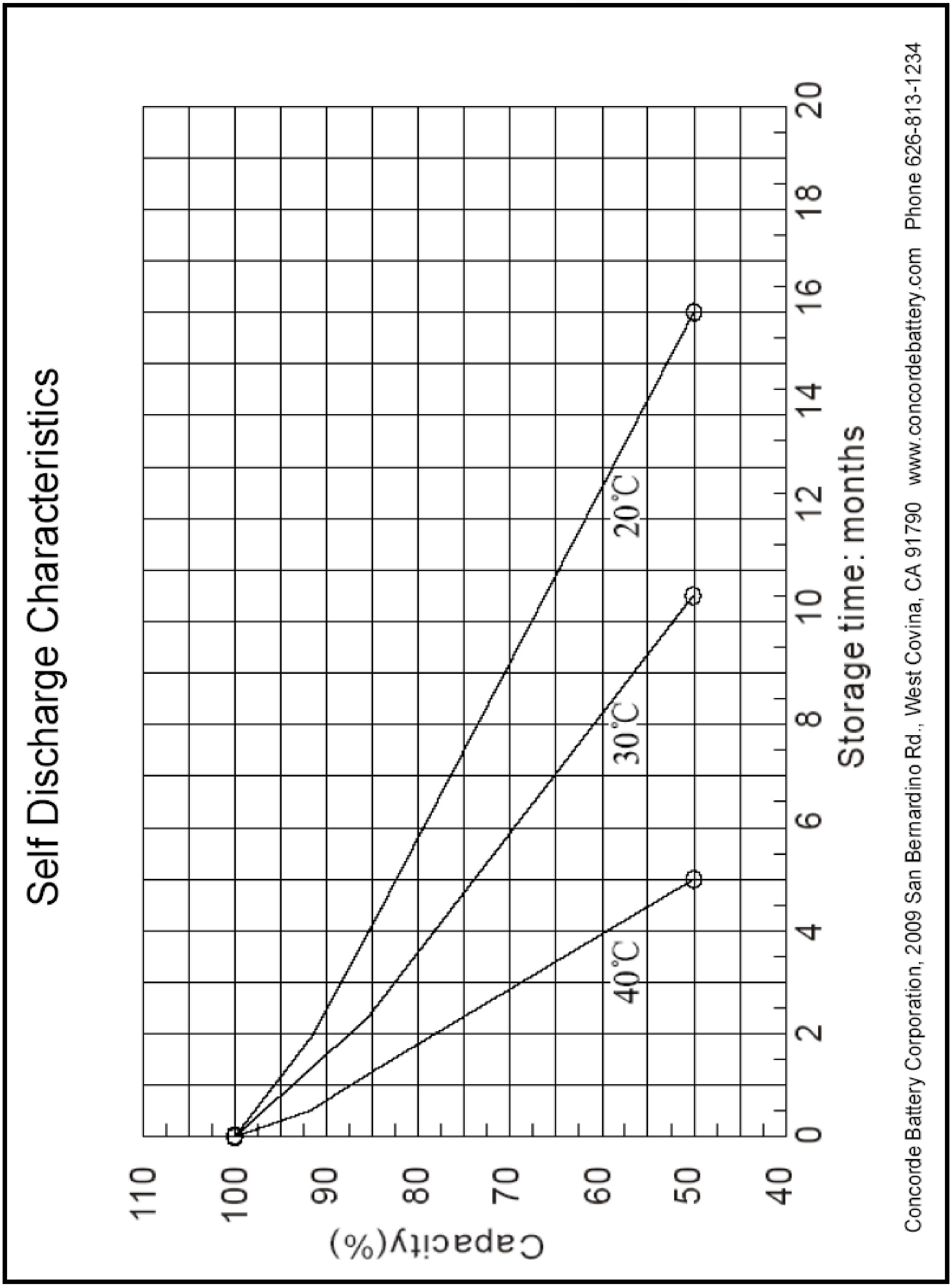
Please note that these voltages are averages and will vary slightly from battery to battery even of the same rating. They are, however, a good indicator of state of charge and can be used when setting low voltage alarms or disconnects for a Concorde AGM battery. Other battery types or manufacturers voltage vs. DOD may be substantially different. The data is for newer batteries with relatively few cycles. An older battery will measure a lower voltage for a given DOD.

SOC (%) vs. OCV

An easy method to estimate the State of Charge (SOC) of the battery is by measuring its Open Circuit Voltage (OCV). This measurement should be made after the battery has been at rest for a minimum of four hours with the battery shut off from its charging source and load. The voltage is listed as Volts/cell and for a 12V (6 cell) battery at 25°C (77°F).

State of Charge (%)	OCV per cell	OCV per 12V battery
100	2.17 or greater	13.0 or greater
75	2.10	12.6
50	2.03	12.2
25	1.97	11.8
0	1.90 or less	11.4 or less

These voltage levels are approximate and give an indication of the state of charge of a battery at rest. As the battery ages these voltage measurements will be lower.


Self Discharge Characteristics
Capacity(%)
110
100
90
80
70
60
50
40
0
2
4
6
8
10
12
14
16
18
20
Storage time: months
20°C
30°C
40°C
Concorde Battery Corporation, 2009 San Bernardino Rd., West Covina, CA 91790 www.concordebattery.com Phone 626-813-1234

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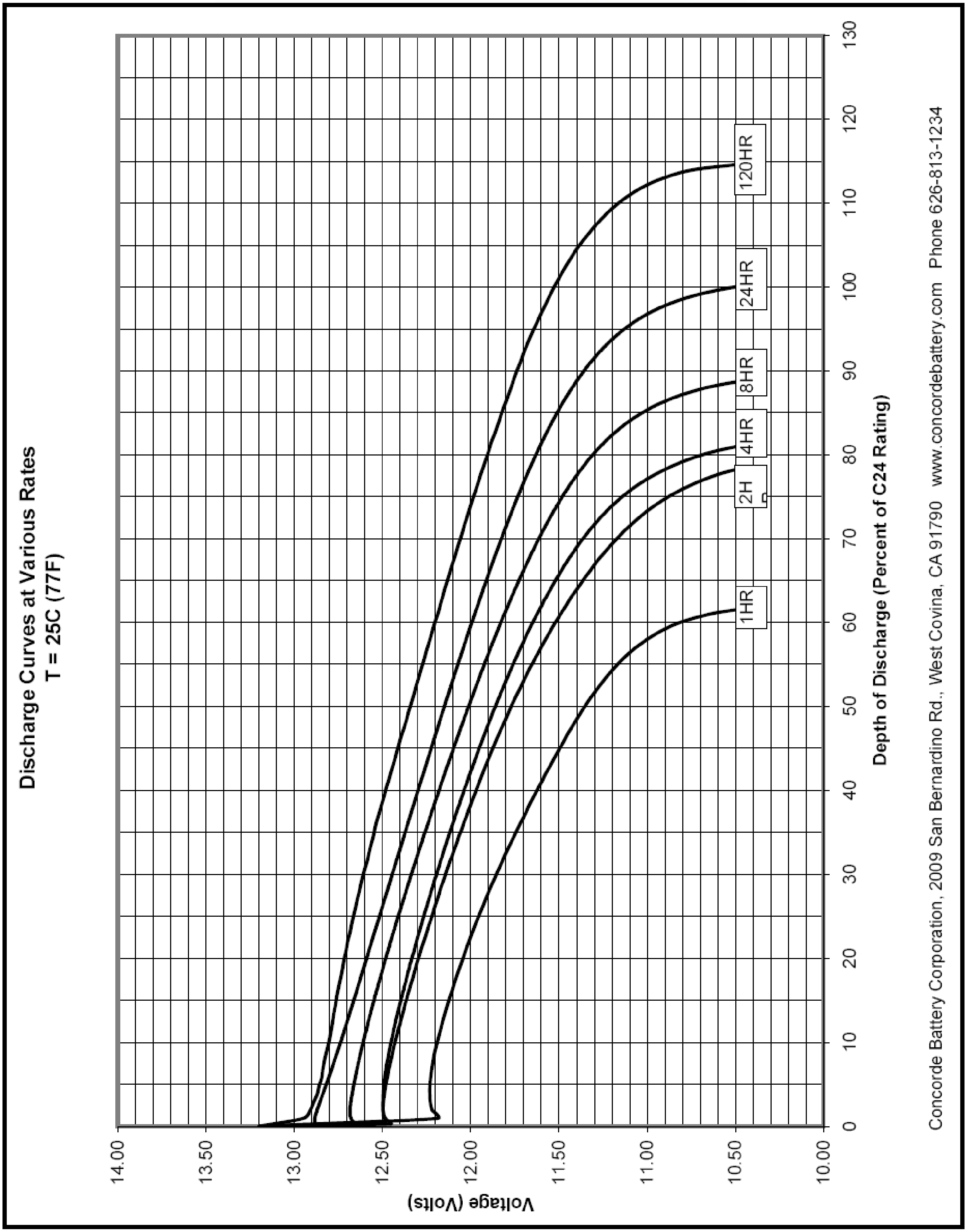

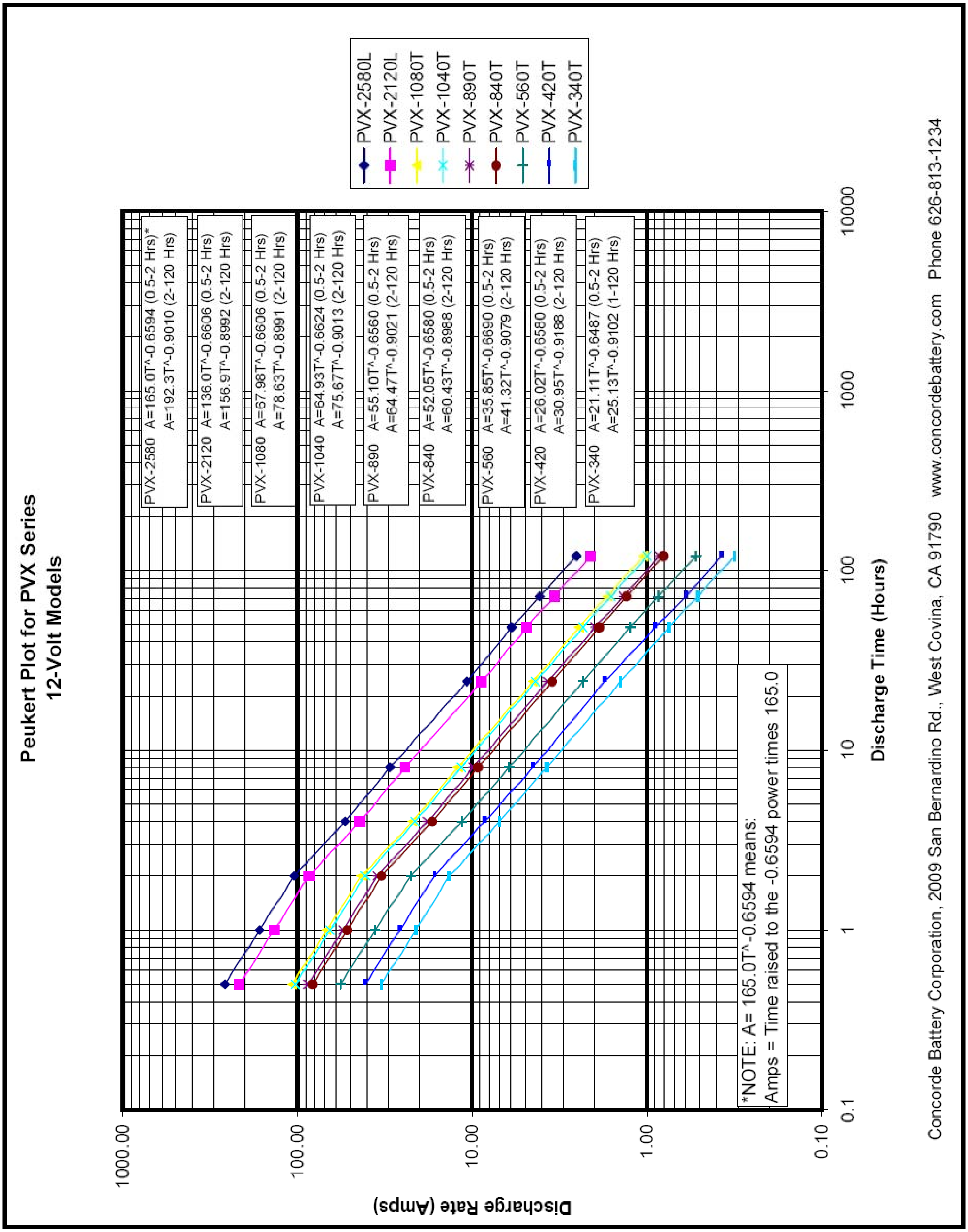
Peukert Plot for PVX Series
12-Volt Models
PVX-2580 A=165.0T^-0.6594 (0.5-2 Hrs)*
A=192.3T^-0.9010 (2-120 Hrs)
PVX-2120 A=136.0T^-0.6606 (0.5-2 Hrs)
A=156.9T^-0.8992 (2-120 Hrs)
PVX-1080 A=67.98T^-0.6606 (0.5-2 Hrs)
A=78.63T^-0.8991 (2-120 Hrs)
PVX-1040 A=64.93T^-0.6624 (0.5-2 Hrs)
A=75.67T^-0.9013 (2-120 Hrs)
PVX-890 A=55.10T^-0.6560 (0.5-2 Hrs)
A=64.47T^-0.9021 (2-120 Hrs)
PVX-840 A=52.05T^-0.6580 (0.5-2 Hrs)
A=60.43T^-0.8988 (2-120 Hrs)
PVX-560 A=35.85T^-0.6690 (0.5-2 Hrs)
A=41.32T^-0.9079 (2-120 Hrs)
PVX-420 A=26.02T^-0.6580 (0.5-2 Hrs)
A=30.95T^-0.9188 (2-120 Hrs)
PVX-340 A=21.11T^-0.6487 (0.5-2 Hrs)
A=25.13T^-0.9102 (1-120 Hrs)
PVX-2580L
PVX-2120L
PVX-1080T
PVX-1040T
PVX-890T
PVX-840T
PVX-560T
PVX-420T
PVX-340T
*NOTE: A= 165.0T^-0.6594 means:
Amps = Time raised to the -0.6594 power times 165.0
1000.00
100.00
10.00
1.00
0.10
Discharge Rate (Amps)
0.1
1
10
100
1000
10000
Discharge Time (Hours)
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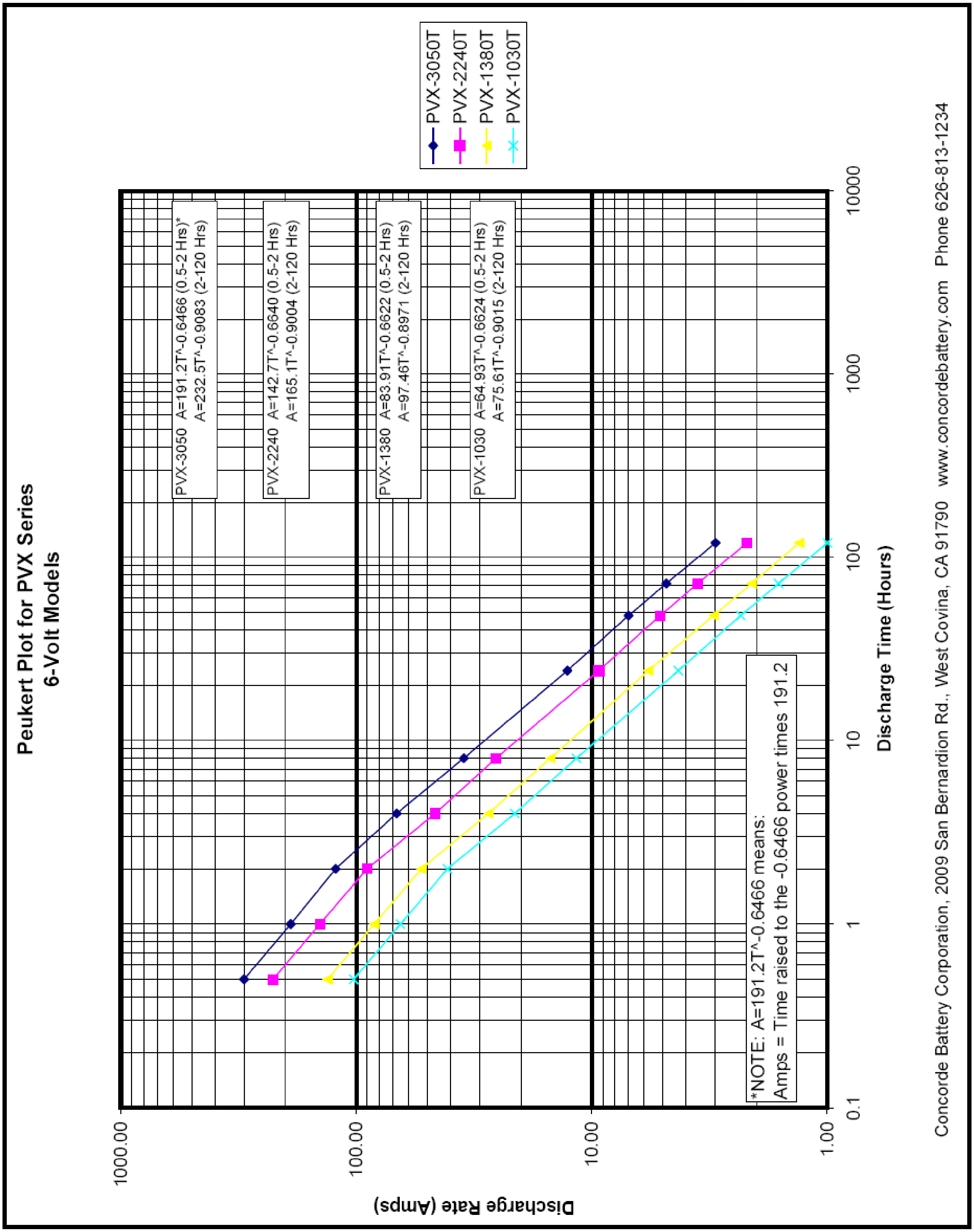
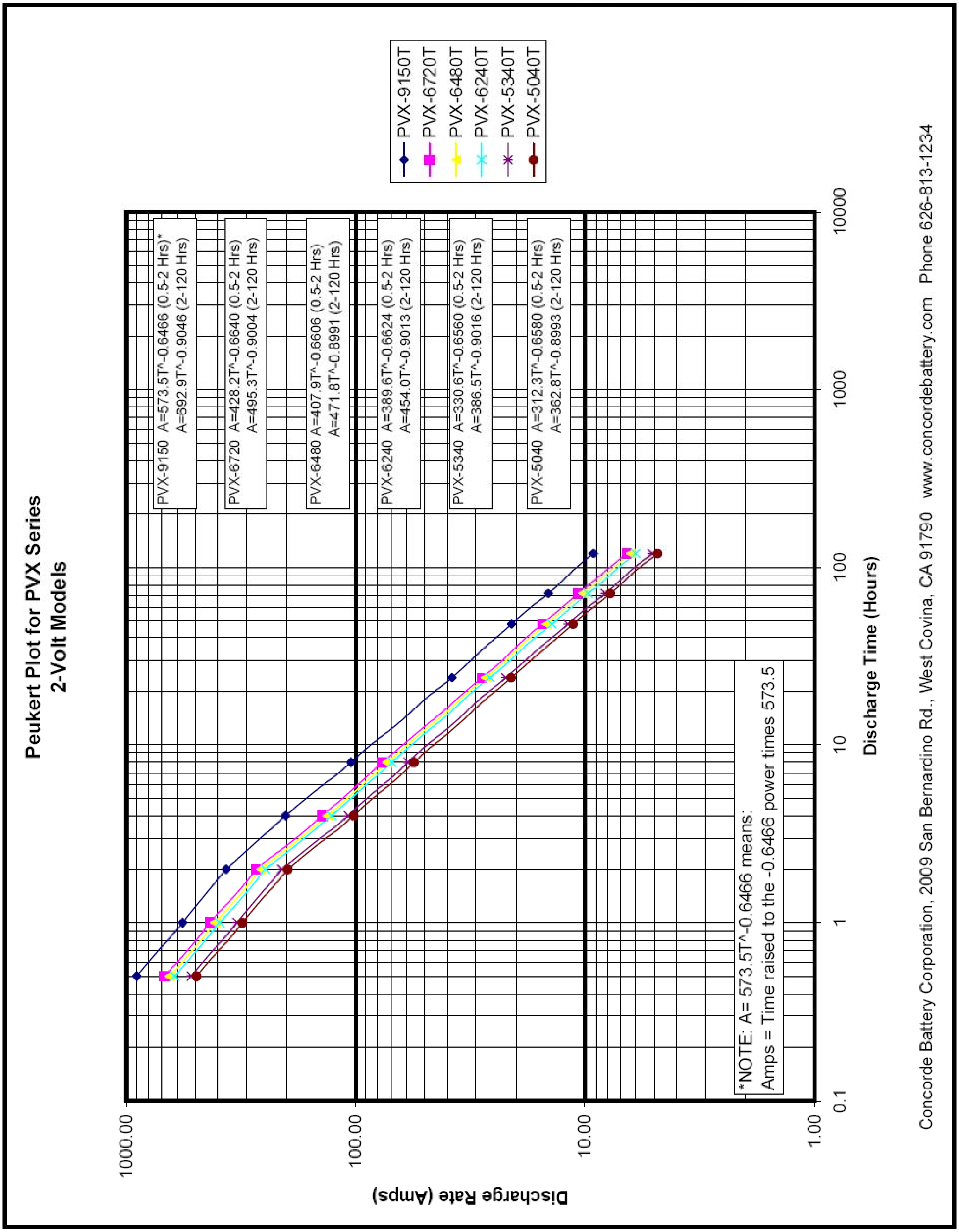
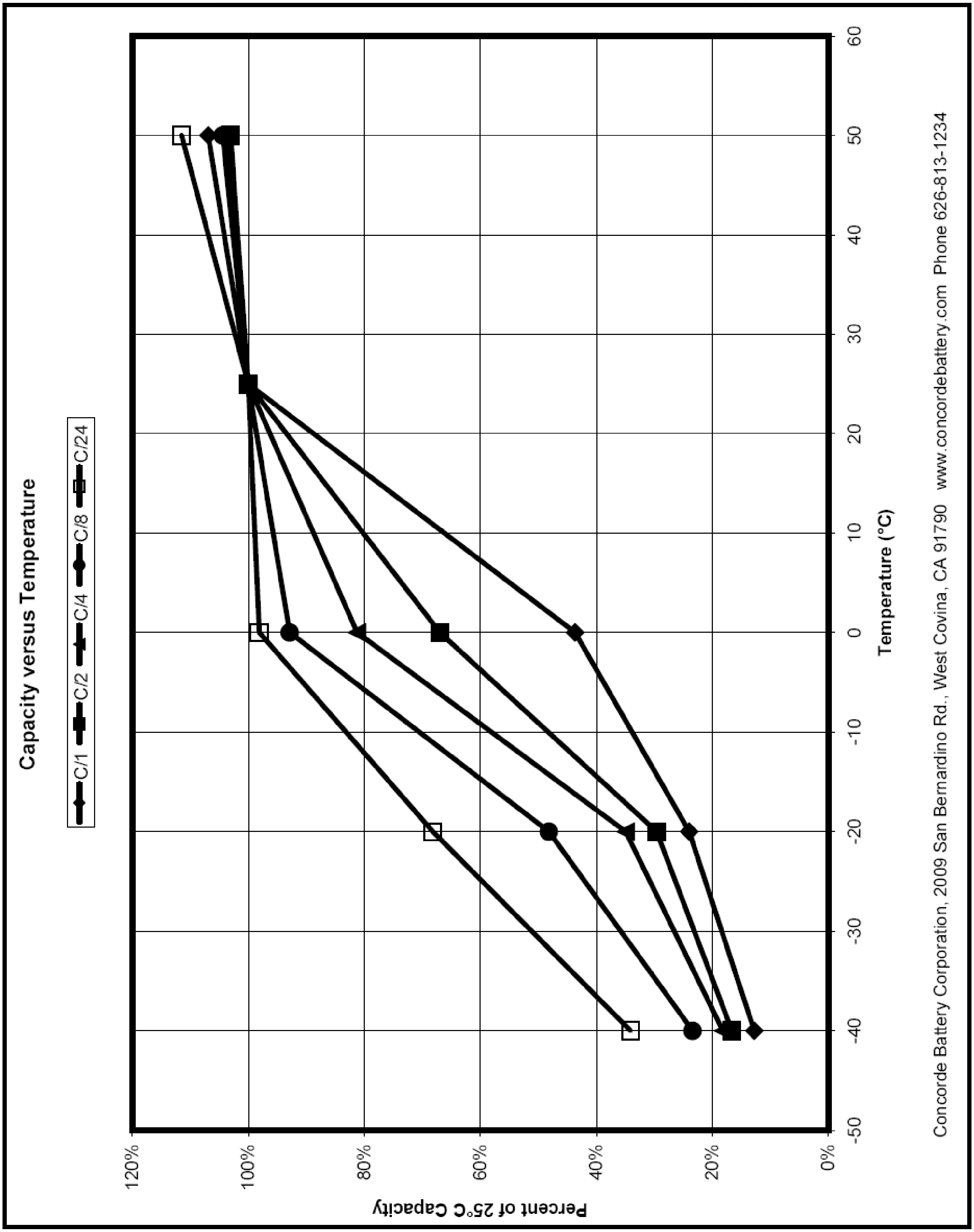
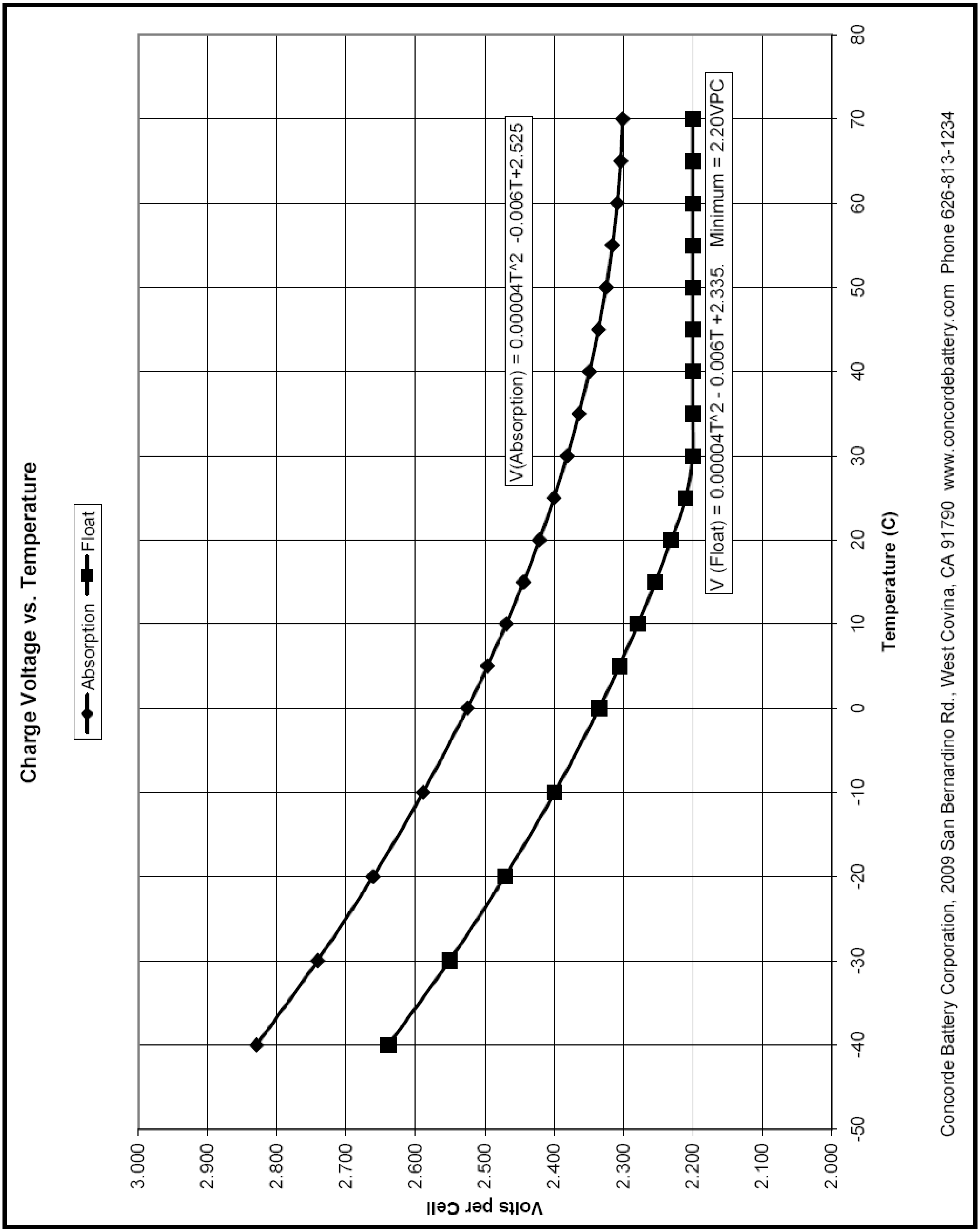



Peukert Plot for PVX Series
2-Volt Models
PVX-9150 A=573.5T^-0.6466 (0.5-2 Hrs)*
A=692.9T^-0.9046 (2-120 Hrs)
PVX-6720 A=428.2T^-0.6640 (0.5-2 Hrs)
A=495.3T^-0.9004 (2-120 Hrs)
PVX-6480 A=407.9T^-0.6606 (0.5-2 Hrs)
A=471.8T^-0.8991 (2-120 Hrs)
PVX-6240 A=389.6T^-0.6624 (0.5-2 Hrs)
A=454.0T^-0.9013 (2-120 Hrs)
PVX-5340 A=330.6T^-0.6560 (0.5-2 Hrs)
A=386.5T^-0.9016 (2-120 Hrs)
PVX-5040 A=312.3T^-0.6580 (0.5-2 Hrs)
A=362.8T^-0.8993 (2-120 Hrs)
PVX-9150T
PVX-6720T
PVX-6480T
PVX-6240T
PVX-5340T
PVX-5040T
*NOTE: A= 573.5T^-0.6466 means:
Amps = Time raised to the -0.6466 power times 573.5
Discharge Rate (Amps)
1000.00
100.00
10.00
1.00
Discharge Time (Hours)
0.1
1
10
100
1000
10000
Concorde Battery Corporation, 2009 San Bernardino Rd., West Covina, CA 91790 www.concordebattery.com Phone 626-813-1234



Capacity versus Temperature
C/1
C/2
C/4
C/8
C/24
Percent of 25°C Capacity
120%
100%
80%
60%
40%
20%
0%
Temperature (°C)
-50
-40
-30
-20
-10
0
10
20
30
40
50
60
Concorde Battery Corporation, 2009 San Bernardino Rd., West Covina, CA 91790 www.concordebattery.com Phone 626-813-1234


Charge Voltage vs. Temperature
Absorption
Float
V(Absorption) = 0.000004T^2 -0.006T+2.525
V (Float) = 0.00004T^2 - 0.006T +2.335. Minimum = 2.20VPC
Volts per Cell
Temperature (C)
3.000
2.900
2.800
2.700
2.600
2.500
2.400
2.300
2.200
2.100
2.000
-50
-40
-30
-20
-10
0
10
20
30
40
50
60
70
80
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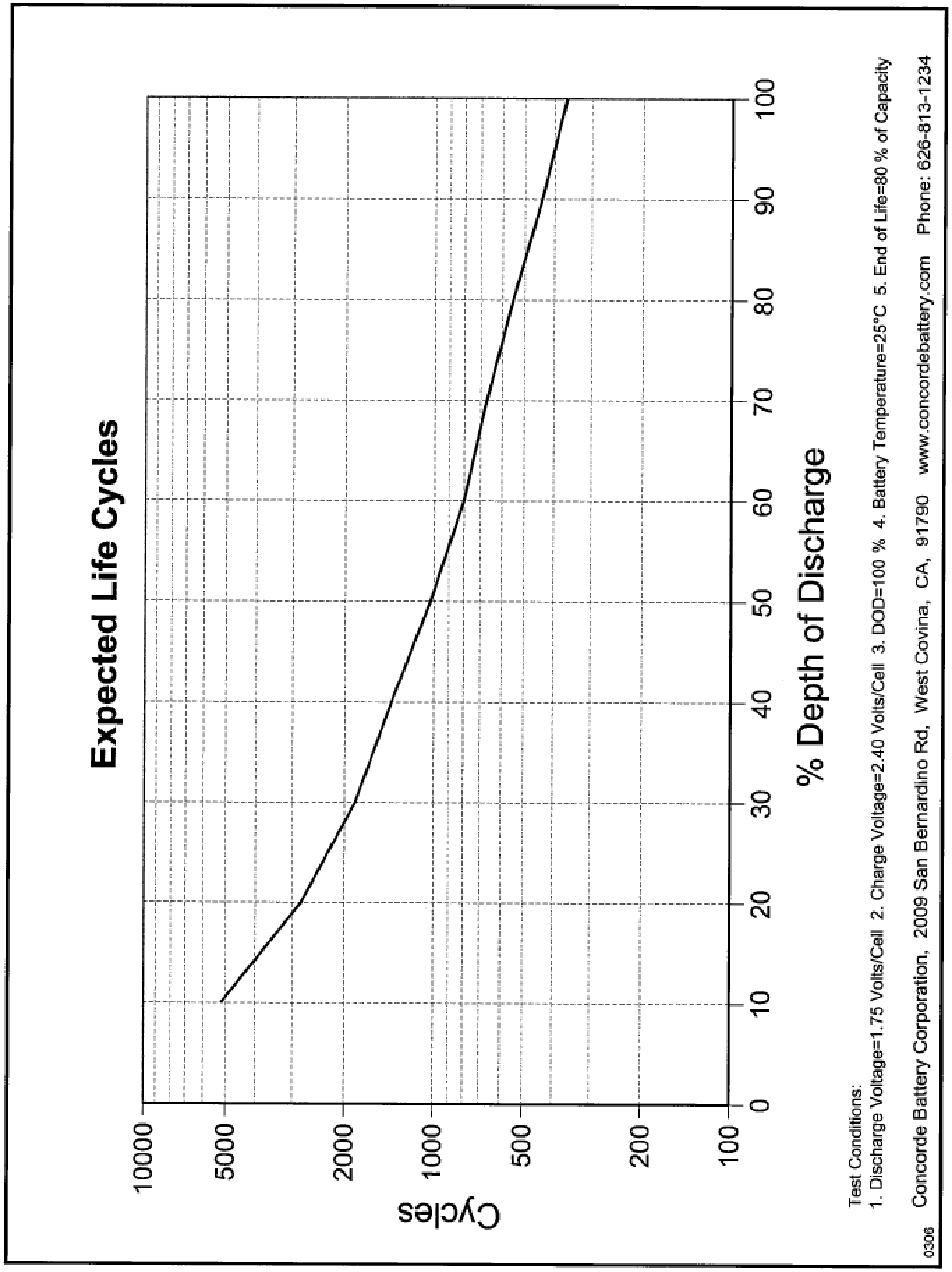

TRISTAR

Solar System Controller

Installation and Operation Manual

Solar Battery Charging

Load Control

Diversion Charge Control

MORNINGSTAR corporation

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www.morningstarcorp.com

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continued...

Table of Contents *continued*

IMPORTANT SAFETY INSTRUCTIONS SAVE THESE INSTRUCTIONS:

This manual contains important safety, installation and operating instructions for the TriStar solar controller.

The following symbols are used throughout this manual to indicate potentially dangerous conditions or important safety instructions.

WARNING: Indicates a potentially dangerous condition. Use extreme caution when performing this task.

CAUTION: Indicates a critical procedure for safe and proper operation of the controller.

NOTE: Indicates a procedure or function that is important to the safe and proper operation of the controller.

General Safety Information

- Read all the instructions and cautions in the manual before starting the installation.
- There are no user serviceable parts in the TriStar. Do not disassemble or attempt to repair the controller.
- Disconnect all sources of power to the controller before installing or adjusting the TriStar. Ensure that both the battery and the solar power have been disconnected before opening the access cover.
- There are no fuses or disconnects in the TriStar. Power must be removed externally.
- Do not allow water to enter the controller.
- Confirm that the power wires are tightened to the correct torque to avoid excessive heating from a loose connection.
- Ensure the enclosure is properly grounded with copper conductors.
- The grounding terminal is located in the wiring compartment and is identified by the symbol below that is stamped into the enclosure.

Ground Symbol

Battery Safety

- Be very careful when working with large lead-acid batteries. Wear eye protection and have fresh water available in case there is contact with the battery acid.
- Remove rings and jewelry when working with batteries.
- Use insulated tools and avoid placing metal objects in the work area.

continued...

- Carefully read the battery manuals before installing and connecting the controller.
- Be very careful not to short circuit the cables connected to the battery.
- Have someone nearby to assist in case of an accident.
- Explosive battery gasses can be present during charging. Be certain there is enough ventilation to release the gasses.
- Never smoke in the battery area.
- If battery acid comes into contact with the skin, wash with soap and water. If the acid contacts the eye, flood with fresh water and get medical attention.
- Be sure the battery electrolyte level is correct before starting charging. Do not attempt to charge a frozen battery.
- Recycle the battery when it is replaced.

1.0 TriStar Description

The TriStar is a technically advanced solar system controller. There are three operating modes programmed into each TriStar. This manual describes solar battery charging, and specific load control or diversion charge control instructions are inserted where required.

This manual will help you to become familiar with the TriStar's features and capabilities. Some of these follow:

- **UL Listed (UL 1741) and cUL Listed (CSA-C22.2 No. 107.1)**
- **Complies with the US National Electric Code**
- **Complies with EMC and LVD standards for CE marking**
- **Rated for 12, 24, 48 volt systems, and 45 or 60 amps current**
- **Fully protected with automatic and manual recovery**
- **Seven standard charging or load programs selected with DIP switches**
- **Adjustability by means of an RS-232 connection with PC software**
- **Continuous self-testing with fault notification**
- **LED indications and pushbutton functions**
- **Terminals sized for 35mm^2 (2 AWG) wire**
- **Includes battery voltage sense terminals**
- **Digital meter options (mounted to TriStar or remote)**
- **Optional remote battery temperature sensor**
- **5-year warranty** ***(see Section 10.0)***

1.1 Versions and Ratings

There are two standard versions of TriStar controllers:

TriStar-45:
Rated for maximum 45 amps continuous current
(solar, load or diversion load)
Rated for 12, 24, 48 Vdc systems

TriStar-60:
Rated for maximum 60 amps continuous current
(solar, load or diversion load)
Rated for 12, 24, 48 Vdc systems

To comply with the National Electric Code (NEC), the current rating of the controller for solar charging must be equal or greater than 125% of the solar array's short circuit current output (Isc). Therefore, the maximum allowable solar array input to the TriStar controller for compliance with the NEC is:

TS-45: 36 amps Isc

TS-60: 48 amps Isc

1.2 Operating Modes

There are three distinct and independent operating modes programmed into each TriStar. Only one mode of operation can be selected for an individual TriStar. If a system requires a charging controller and a load controller, two TriStars must be used.

Solar battery charging
The energy output of a solar array is used for recharging the system battery. The TriStar manages the charging process to be efficient and to maximize the life of the battery. Charging includes a bulk charging stage, PWM absorption, float and equalization.

Load control
When set for load control, the TriStar powers loads from the battery, and protects the battery from over-discharge with a current compensated LVD (low voltage load disconnect).

Diversion charge control
In diversion mode, the TriStar will manage battery charging by diverting energy from the battery to a dedicated diversion load. The energy source is typically wind or hydro.

1.3 Adjustability

Eight DIP switches permit the following parameters to be adjusted at the installation site:

DIP switch	Solar Battery Charging
1	Battery charge control mode
2-3	Select battery voltage
4-6	Standard battery charging programs
7	Manual or automatic equalization
8	PWM charging or on-off charging

DIP switch	Load Control
1	DC load control mode
2-3	Select battery voltage
4-6	Standard low voltage disconnects and reconnects
7	not used for load control
8	not used for load control

DIP switch	Diversion Charge Control
1	DC load control mode
2-3	Select battery voltage
4-6	Standard diversion charge control programs
7	Select diversion charge control mode
8	Manual or automatic equalization

In addition to the DIP switches, the TriStar provides for additional adjustments using a PC program. An RS-232 connection between the TriStar and a personal computer will enable extensive adjustments using PC software from Morningstar's website.

1.4 General Use

NOTE: This manual describes solar battery charging. Specific instructions for the load control and diversion charge control modes are provided as notes throughout this manual.

The TriStar is suitable for a wide range of solar applications including homes, telecom and industrial power needs.

TriStar controllers are configured for negative ground systems. There are no parts in the controller's negative leg. The enclosure can be grounded using the ground terminal in the wiring compartment.

The TriStar is protected from faults electronically with automatic recovery. There are no fuses or mechanical parts inside the TriStar to reset or change.

Solar overloads up to 130% of rated current will be tapered down instead of disconnecting the solar. Over-temperature conditions will also taper the solar input to lower levels to avoid a disconnect.

The NEC requires overcurrent protection externally in the system *(see Section 2.3 step 6)*. There are no system disconnects inside the TriStar enclosure.

Any number of TriStars can be connected in parallel to increase solar charging current. TriStars can be paralleled ONLY in the battery charging mode. DO NOT parallel TriStars in the load mode, as this can damage the controller or load.

The TriStar enclosure is rated for indoor use. The controller is protected by conformal coated circuit boards, stainless steel hardware, anodized aluminum, and a powder coated enclosure, but it is not rated for corrosive environments or water entry.

The construction of the TriStar is 100% solid state.

Battery charging is by a series PWM constant current charging, with bulk charging, PWM absorption, float and equalization stages.

The TriStar will accurately measure time over long intervals to manage events such as automatic equalizations or battery service notification.

Day and night conditions are detected by the TriStar, and no blocking diodes are used in the power path.

LED's, a pushbutton, and optional digital meters provide both status information and various manual operations.

The date of manufacture can be found on the two bar code labels. One label is on the back of the TriStar, and the other is in the wiring compartment. The year and week of manufacture are the first four digits of the serial number. For example:

year	week	serial #
03	36	0087

1.5 Safety and Regulatory Information

☞ ***NOTE: This section contains important information for safety and regulatory requirements.***

The TriStar controller is intended for installation by a qualified technician according to electrical rules of each country in which the product will be installed.

TriStar controllers comply with the following EMC standards:

- Immunity: EN61000-6-2:1999
- Emissions: EN55022:1994 with A1 and A3 Class B1
- Safety: EN60335-1 and EN60335-2-29 (battery chargers)

A means shall be provided to ensure all pole disconnection from the power supply. This disconnection shall be incorporated in the fixed wiring.

Using the TriStar grounding terminal (in the wiring compartment), a permanent and reliable means for grounding shall be provided. The clamping of the earthing shall be secured against accidental loosening.

The entry openings to the TriStar wiring compartment shall be protected with conduit or with a bushing.

FCC requirements:
This device complies with Part 15 of the FCC rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Changes or modifications not expressly approved by Morningstar for compliance could void the user's authority to operate the equipment.

Note: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communication. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment on and off, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

This Class B digital apparatus complies with Canadian ICES-003.

Cet appareil numerique de la classe B est conforme a la norme NMB-003 du Canada.

1.6 Options Available

Three optional components can be added to the standard TriStar controller at any time.

Remote Temperature Sensor (RTS)
If the temperature of the system battery varies more than 5˚C (9˚F) during the year, temperature compensated charging should be considered. Because the battery's chemical reactions change with temperature, it can be important to adjust charging to account for the temperature effects. The RTS will measure the battery temperature, and the TriStar uses this input to adjust the charging as required.

The battery charging will be corrected for temperature as follows:

- 12 V battery – 0.030 Volts per ˚C (–0.017V per ˚F)
- 24 V battery – 0.060 Volts per ˚C (–0.033V per ˚F)
- 48 V battery – 0.120 Volts per ˚C (–0.067V per ˚F)

The RTS should be used only for battery charging and diversion control. Do not use the RTS for load control. The charging parameters that are adjusted for temperature include:

- PWM regulation
- Equalization
- Float
- High Voltage Disconnect

See Installation, Step 4, for connecting the RTS to the TriStar.

Digital Meter Displays
Two digital meters can be added to the TriStar at any time during or after installation. One version is mounted on the controller (TS-M), the other is suitable for remote locations (TS-RM). The manual for installation and operation of the meter displays is included with the meter.

The display is a 2x16 LCD meter with backlighting. Four pushbuttons are used to scroll through the displays and to execute manual functions.

There are a series of display screens that provide information such as:

- operating information and data
- operating bar charts (voltage and current)
- alarms and faults
- diagnostics
- settings

In addition, there are various manual functions built into the meter. For example, the meter can be used to reset Ah data or start/stop equalizations.

One of 5 languages can be selected for the meter.

2.0 TriStar Installation

The installation instructions describe solar battery charging. Specific instructions for the load control and diversion modes are provided as notes.

2.1 General Information

The mounting location is important to the performance and operating life of the controller. The environment must be dry and protected as noted below. The controller may be installed in a ventilated enclosure with sealed batteries, but never in a sealed battery enclosure or with vented batteries.

If the solar array exceeds the current rating of the controller, multiple TriStars can be installed in parallel. Additional parallel controllers can also be added in the future. The load controllers cannot be used in parallel. To parallel diversion controllers, refer to Morningstar's website.

If solar charging and load control are both required, two separate controllers must be used.

2.2 Installation Overview

The installation is straightforward, but it is important that each step is done correctly and safely. A mistake can lead to dangerous voltage and current levels. Be sure to carefully follow each instruction in Section 2.3 and observe all cautions and warnings.

The following diagrams provide an overview of the connections and the proper order.

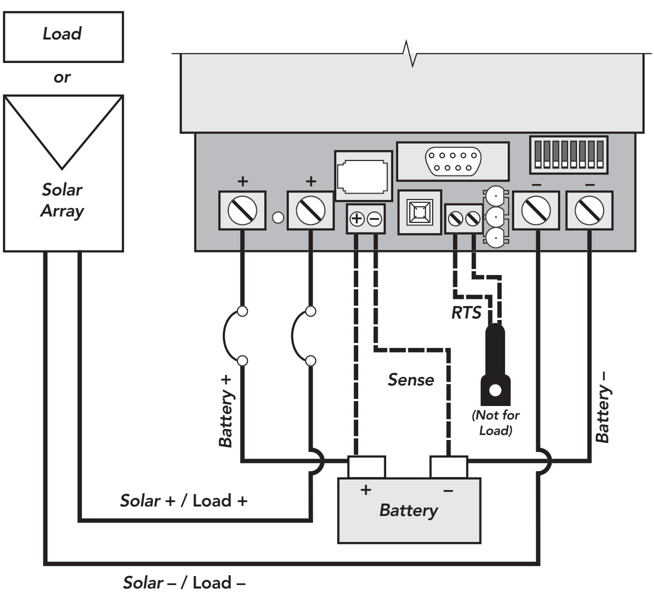


Figure 2.2a Installation Wiring for Solar Charging and Load Control

Step	Solar Charging and Load Control
1.	Remove the access cover
2.	Mount the TriStar using the enclosed template.
3.	Adjust the 8 switches in the DIP switch. Each switch must be in the correct position.
4.	Attach the RTS if battery charging will be temperature compensated (not for load control).
5.	Connect battery voltage sense wires (recommended).
6.	Connect the battery power wires to the TriStar. Then connect the solar array wires (or load).
7.	Connect a computer to the TriStar if making adjustments with PC software.
8.	Replace the cover.

Steps #3 and #6 are required for all installations.

Steps #4, #5, and #7 are optional.

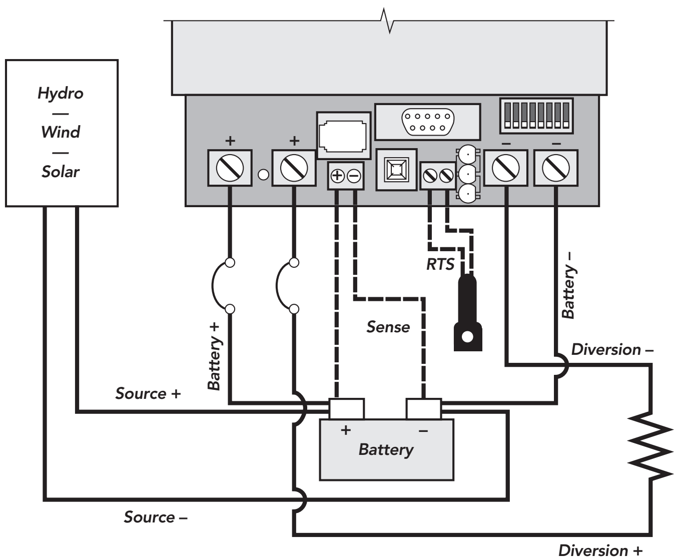


Figure 2.2b Installation Wiring for Diversion Charge Control

Step	Diversion Charge Control
1.	Remove the access cover
2.	Mount the TriStar using the enclosed template.
3.	Adjust the 8 switches in the DIP switch. Each switch must be in the correct position.
4.	Attach the RTS if battery charging will be temperature compensated.
5.	Connect battery voltage sense wires (recommended).
6.	Connect the battery power wires to the TriStar. Then connect the diversion load wires.

continued...

Step Diversion Charge Control *(continued)*

7. Connect a computer to the TriStar if making adjustments with PC software.
8. Replace the cover.

Steps #3 and #6 are required for all installations.

Steps #4, #5, and #7 are optional.

2.3 Installation Steps

The TriStar controller must be installed properly and in accordance with the local and national electrical codes. It is also important that the installation be done safely, correctly and completely to realize all the benefits that the TriStar can provide for your solar system.

Refer to Sections 4.0 and 9.0 for information about the TriStar's standard battery charging programs and general charging needs for different battery types. Refer to Section 5.0 for load control information, and Section 6.0 for diversion.

Recommended tools:

- wire cutter
- wire stripper
- slotted screw drivers
- phillips screwdrivers
- torque wrench (to 50 in-lb)
- flashlight

Before starting the installation, review these safety notes:

- Do not exceed a battery voltage of 48V nominal (24 cells). Do not use a battery less than 12V (6 cells).
- Do not connect a solar input greater than a nominal 48V array for battery charging. Never exceed a Voc (open-circuit voltage) of 125V.
- Charge only 12, 24, or 48 volt lead-acid batteries when using the standard battery charging programs in the TriStar.
- Verify the nominal charging voltage is the same as the nominal battery voltage.
- Do not install a TriStar in a sealed compartment with batteries.
- Never open the TriStar access cover unless both the solar and battery power has been disconnected.
- Never allow the solar array to be connected to the TriStar with the battery disconnected. This can be a dangerous condition with high open-circuit solar voltages present at the terminals.

Follow the installation steps in order: #1 through #8

Step 1 - Remove the Cover

Remove the 4 screws in the front cover. Lift the cover until the top edge clears the heat sink, and set it aside. If an LCD meter display is attached to the cover, disconnect the RJ-11 connector at the meter for access.

CAUTION: Do not remove the cover if power is present at any of the terminals. Verify that all power sources to the controller are disconnected.

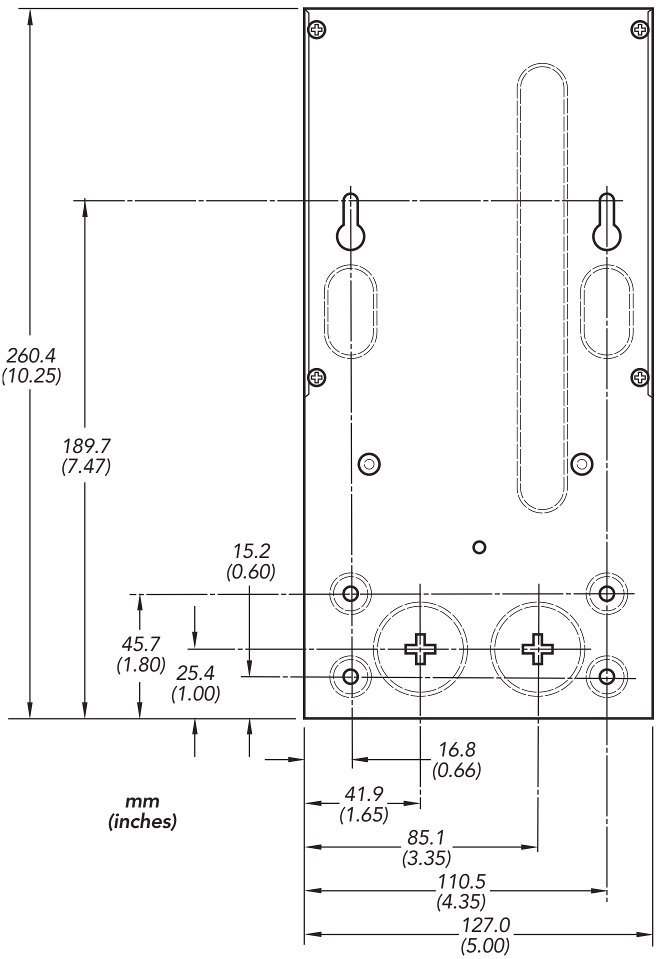


Figure 2.3 - Step 2 Mounting Dimensions

Step 2 - Mounting

Locate the TriStar on a wall protected from direct sun, high temperatures, and water. Do not install in a confined area where battery gasses can accumulate.

NOTE: When mounting the TriStar, make sure the air flow around the controller and heat sink is not obstructed. There should be open space above and below the heat sink, and at least 75 mm (3 inches) clearance around the heat sink to allow free air flow for cooling.

Before starting the installation, place the TriStar on the wall where it will be mounted and determine where the wires will enter the controller (bottom, side, back). Remove the appropriate knockouts before mounting the controller. The knockouts are sized for 1 inch and 1.25 inch conduit.

continued...

Step 2 - Mounting *(continued)*

Refer to Figure 2.3-2. Use the template provided in the shipping carton for locating the mounting holes and for stripping the wires. Use two of the #10 screws provided for the two keyhole slots. Leave the screw heads protruding enough to lock inside the keyhole slots (about 3.8 mm / 0.150 inch). Mount the controller and pull it down to lock the screws into the slots. Use the remaining two screws to fasten the controller to the wall.

Provide for strain relief for the bottom knockouts if conduit will not be used. Avoid excessive pulling forces on the terminals from the wires.

Step 3 - Adjust the DIP Switches

An 8-position DIP switch is used to set-up the controller for its intended use. All major functions can be set with the DIP switches. *See Section 7.0 for additional custom settings using PC software.*

NOTE: The instructions below are for solar battery charging. Refer to Appendix 1 for Load Control DIP switch settings, and Appendix 2 for Diversion Charge Control DIP switch settings.

The DIP switches are located behind the negative power terminals. Each switch is numbered. The solar battery charging functions that can be adjusted with the DIP switches follow:

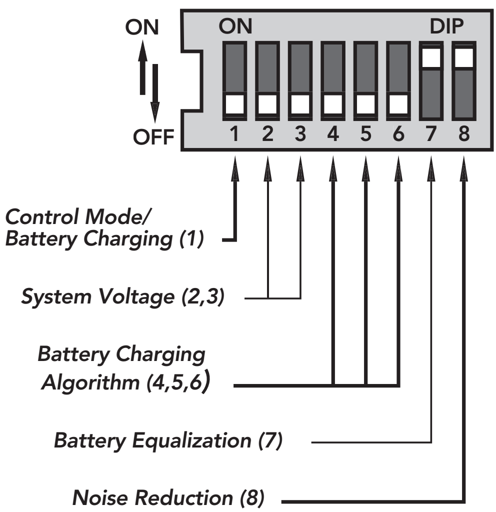


Figure 2.3 - Step 3 DIP Switch Functions

As shown in the diagram, all the positions are in the "OFF" position except switch numbers 7 and 8, which are in the "ON" position.

NOTE: The DIP switches should be changed only when there is no power to the controller. Turn off disconnect switches and remove all power to the controller before changing a DIP switch. A fault will be indicated if a switch is changed while the controller is powered.

CAUTION: The TriStar is shipped with all the switches in the "OFF" position. Each switch position must be confirmed during installation. A wrong setting could cause damage to the battery or other system components.

The DIP switch settings described below are for **Solar Battery Charging only**. Load and Diversion switch settings can be found in Appendixes 1 and 2.

The DIP switches are shipped in the OFF position. With the switches in the OFF position, the following functions are present:

Switch	Function
1	Battery charge mode
2, 3	Auto voltage select
4, 5, 6	Lowest battery charging voltage
7	Manual equalization
8	Normal PWM charging mode

To configure your TriStar for the battery charging and control you require, follow the DIP switch adjustments described below. To change a switch from OFF to ON, slide the switch up toward the top of the controller. Make sure each switch is fully in the ON or OFF position.

DIP Switch Number 1 - Control Mode: Solar Battery Charging

Control	Switch 1
Charging	Off
Load	On

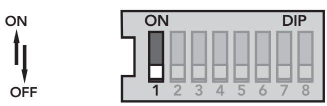


Figure 2.3 - Step 3   DIP Switch #1

For the Solar Battery Charging control mode, leave the DIP switch in the OFF position as shown.

DIP Switches Number 2,3 - System Voltage:

Voltage	Switch 2	Switch 3
Auto	Off	Off
12	Off	On
24	On	Off
48	On	On

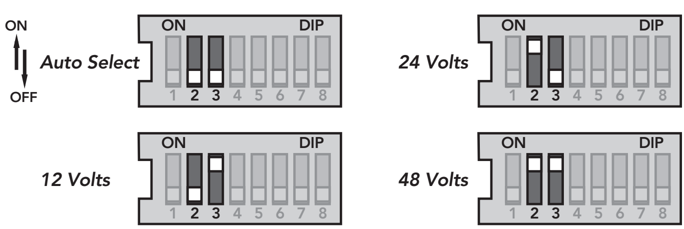


Figure 2.3 - Step 3 DIP Switches # 2,3

The auto voltage selection occurs when the battery is connected and the TriStar starts-up. There should be no loads on the battery that might cause a discharged battery to indicate a lower system voltage.

The DIP switch selectable voltages are for 12V, 24V or 48V lead-acid batteries. Although the "auto voltage" selection is very dependable, it is recommended to use the DIP switches to secure the correct system voltage.

DIP Switches Number 4,5,6 - Battery Charging Algorithm:

Battery Type	PWM	Switch 4	Switch 5	Switch 6
1	14.0	Off	Off	Off
2	14.15	Off	Off	On
3	14.35	Off	On	Off
4	14.4	Off	On	On
5	14.6	On	Off	Off
6	14.8	On	Off	On
7	15.0	On	On	Off
8	Custom	On	On	On

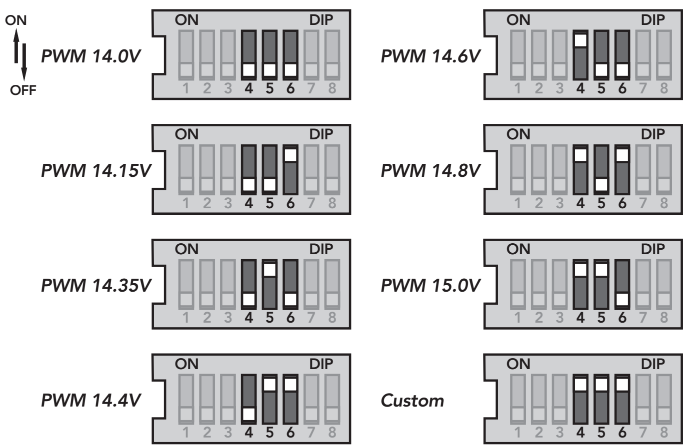


Figure 2.3 - Step 3 DIP Switch # 4,5,6

Select one of the 7 standard battery charging algorithms, or select the "custom" DIP switch for special custom settings using the PC software.

Refer to Section 9.0 of this manual for battery charging information. The 7 standard charging algorithms above are described in Section 4.2 - Standard Battery Charging Programs.

DIP Switch Number 7 - Battery Equalization:

Equalize	Switch 7
Manual	Off
Auto	On

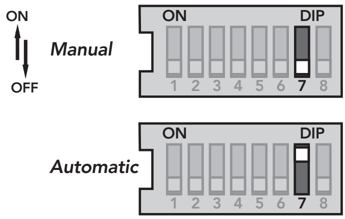


Figure 2.3 - Step 3 DIP Switch # 7

In the Auto Equalization mode (switch #7 On), battery equalization will automatically start and stop according to the battery program selected by the DIP switches 4,5,6 above. *See Section 4.0 for detailed information about each standard battery algorithm and the equalization.*

In the Manual Equalization mode (switch #7 Off), equalization will occur only when manually started with the pushbutton. Automatic starting of equalization is disabled. The equalization will automatically stop per the battery algorithm selected.

In both cases (auto and manual mode), the pushbutton can be used to start and stop battery equalization.

DIP Switch Number 8 - Noise Reduction:

Charging	Switch 8
PWM	Off
On-Off	On

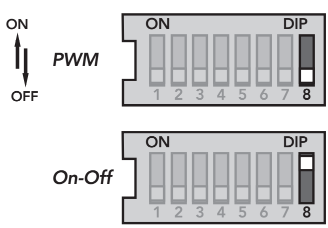


Figure 2.3 - Step 3 DIP Switch # 8

The PWM battery charging algorithm is standard for all Morningstar charge controllers. However, in cases where the PWM regulation causes noise interference with loads (e.g. some types of telecom equipment or radios), the TriStar can be converted to an On-Off method of solar charge regulation.

It should be noted that the On-Off solar charge regulation is much less effective than PWM. Any noise problem should be suppressed in other ways, and only if no other solution is possible should the TriStar be changed to an On-Off charger.

LOAD CONTROL

DIP switch settings are in Appendix 1.

DIVERSION CHARGE CONTROL

DIP switch settings are in Appendix 2.

☞ ***NOTE: Confirm all dip-switch settings before going to the next installation steps.***

Step 4 - Remote Temperature Sensor (RTS)

For solar battery charging and diversion load control, a remote temperature sensor (RTS) is recommended for effective temperature compensated charging. This remote temperature probe should not be installed for dc load control.

The optional Morningstar RTS is connected to the 2-position terminal located between the pushbutton and the LED's. *See the diagram below:*

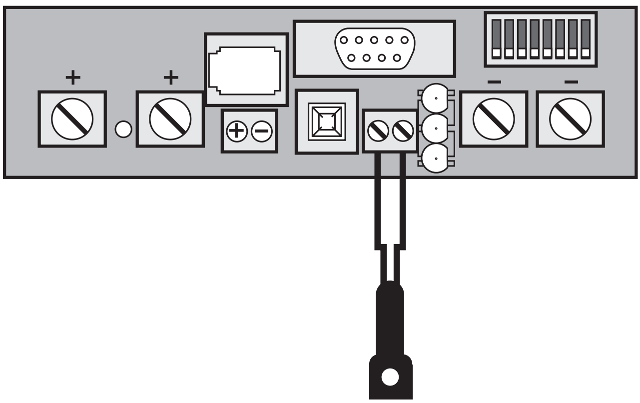


Figure 2.3 - Step 4 RTS Connection

The RTS is supplied with 10 meters (33 ft) of 0.34 mm^2 (22 AWG) cable. There is no polarity, so either wire (+ or –) can be connected to either screw terminal. The RTS cable may be pulled through the conduit with the power wires. Tighten the connector screws with 0.56 Nm (5 in-lb) of torque.

Refer to the installation instructions provided with the RTS.

☞ ***NOTE: Never place the temperature sensor inside a battery cell. Both the RTS and the battery will be damaged.***

Step 5 - Battery Voltage Sense Connection

A battery voltage sense connection is not required to operate your TriStar controller, but it is recommended for best performance in all charging and load control modes. The battery voltage sense wires carry almost no current, so the voltage sense input avoids the large voltage drops that can occur in the battery power conductors. The voltage sense connection allows the controller to measure the actual battery voltage under all conditions.

In addition, if a TriStar meter will be added to the controller, the battery voltage sense will ensure that the voltage and diagnostic displays are very accurate.

The two battery voltage sense wires are connected to the TriStar at the 2-position terminal located between the pushbutton and the positive (+) terminal lug. *See the diagram below:*

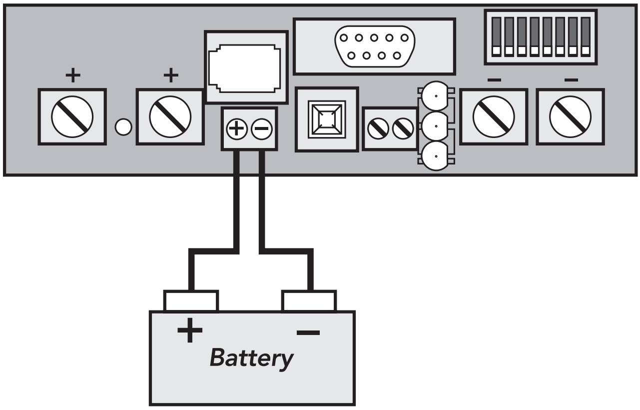


Figure 2.3 - Step 5 Battery Sense Connection

The two voltage sense wires (not provided with the controller) should be cut to length as required to connect the battery to the voltage sense terminal. The wire size can be from 1.0 to 0.25 mm^2 (16 to 24 AWG). It is recommended to twist the wires together every few feet (twisted pair), but this is not required. The voltage sense wires may be pulled through the conduit with the power wires. Tighten the connector screws with 0.56 Nm (5 in-lb) of torque.

The maximum length allowed for each battery voltage sense wire is 30 meters (98 ft).

The battery sense terminal has polarity. Be careful to connect the battery positive (+) terminal to the voltage sense positive (+) terminal. No damage will occur if the polarity is reversed, but many functions of the controller can be affected. If a TriStar meter is installed, check the "TriStar Settings" to confirm the Voltage Sense and the RTS (if installed) are both present and "seen" by the controller. The PC software can also be used to confirm the voltage sense is working correctly.

Do not connect the voltage sense wires to the RTS terminal. This may cause an alarm. Review the installation diagram for the correct battery voltage sense connection.

Note that the battery voltage sense connection does not power (start-up) the controller.

Step 6 - System Wiring and Power-Up

To comply with the NEC, the TriStar must be installed using wiring methods in accordance with the latest edition of the National Electric Code, NFPA 70.

Wire Size

The four large power terminals are sized for 35 - 2.5 mm^2 (2-14 AWG) wire. The terminals are rated for copper and aluminum conductors.

continued...

Wire Size *(continued)*

Good system design generally requires large conductor wires for the solar and battery connections that limit voltage drop losses to 3% or less. The following table provides the maximum wire length (1-way distance / 2-wire pair) for connecting the battery, solar array or load to the TriStar with a maximum 3% voltage drop.

Wire Size	60 Amps	45 Amps	30 Amps	15 Amps
95 mm^2 (3/0 AWG)	12.86 m (42.2 ft.)	17.15 m (56.3 ft.)	25.72 m (84.4 ft.)	51.44 m (168.8 ft.)
70 mm^2 (2/0 AWG)	10.19 m (33.4 ft.)	13.58 m (44.6 ft.)	20.38 m (66.8 ft.)	40.75 m (133.7 ft.)
50 mm^2 (1/0 AWG)	8.10 m (26.6 ft.)	10.80 m (35.4 ft.)	16.21 m (53.1 ft.)	32.41 m (106.3 ft.)
35 mm^2 (2 AWG)	5.12 m (16.8 ft.)	6.83 m (22.4 ft.)	10.24 m (33.6 ft.)	20.48 m (67.2 ft.)
25 mm^2 (4 AWG)	3.21 m (10.5 ft.)	4.27 m (14.0 ft.)	6.41 m (21.0 ft.)	12.82 m (42.1 ft.)
16 mm2 (6 AWG)	2.02 m (6.6 ft.)	2.69 m (8.8 ft.)	4.04 m (13.2 ft.)	8.07 m (26.5 ft.)
10 mm^2 (8 AWG)	1.27 m (4.2 ft.)	1.70 m (5.6 ft.)	2.54 m (8.3 ft.)	5.09 m (16.7 ft.)
6 mm^2 (10 AWG)		1.06 m (3.5 ft.)	1.60 m (5.2 ft.)	3.19 m (10.5 ft.)
4 mm^2 (12 AWG)			1.00 m (3.3 ft.)	2.01 m (6.6 ft.)
2.5 mm^2 (14 AWG)				1.26 m (4.1 ft.)

Table 2.3-6a Maximum 1-Way Wire Distance (12 Volts)

Notes:

- The specified wire length is for a pair of conductors from the solar, load or battery source to the controller (1-way distance).
- Figures are in meters (m) and feet (ft).
- For 24 volt systems, multiply the 1-way length in the table by 2.
- For 48 volt systems, multiply the 1-way length in the table by 4.

Minimum Overcurrent Device Ratings

To comply with NEC requirements, overcurrent protection must be provided externally in the system. The NEC requires that each overcurrent device is never operated at more than 80% of its rating. The minimum overcurrent device ratings for TriStar controllers are as follows:

- TriStar-45 60 amps
- TriStar-60 75 amps
- Voltage rating 125 Vdc
- UL Listed for dc circuits

The NEC requires that manually operated disconnect switches or circuit breakers must be provided for connections between the TriStar and the battery. If the overcurrent devices being used are not manually operated disconnects, then manual disconnect switches must be added. These manual switches must be rated the same as the overcurrent devices noted above.

- *Refer to the NEC for more information.*

Minimum Wire Size

The NEC requires that the wires carrying the system current never exceed 80% of the conductors' current rating. The table below provides the minimum size of copper wire allowed by NEC for the TS-45 and TS-60 versions. Wire types rated for 75˚C and 90˚C are included.

Minimum wire sizes for ambient temperatures to 45˚C are provided in the table below:

TS-45	75C Wire	90C Wire	TS-60	75C Wire	90C Wire
≤ **45C**	16 mm^2 (6 AWG)	10 mm^2 (8 AWG)	≤ **45C**	25 mm^2 (4 AWG)	16 mm^2 (6 AWG)

Table 2.3-6b Minimum Wire Size

Both copper and aluminum conductors can be used with a TriStar controller. If aluminum wire is used, the minimum size of the aluminum conductor must be one wire size larger than the minimum wire size specified in the table above.

Ground Connection

Use the grounding terminal in the wiring compartment to connect a copper wire to an earth ground or similar grounding point. The grounding terminal is identified by the ground symbol shown below that is stamped into the enclosure:

Ground Symbol

The minimum size of the copper grounding wire:

- TS-45   6 mm^2 (10 AWG)
- TS-60   10 mm^2 (8 AWG)

Connect the Power Wires

First, confirm that the DIP switch #1 is correct for the operating mode intended.

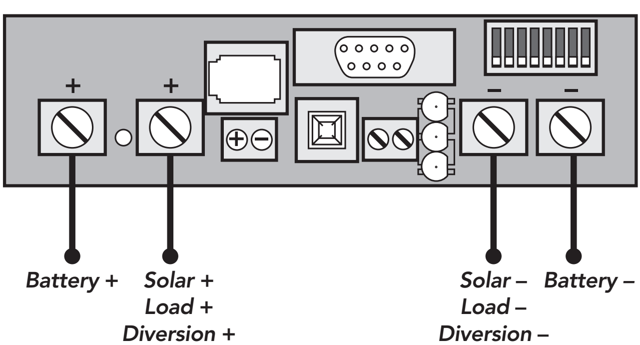


Figure 2.3 - Step 6 Power Wire Connections

CAUTION: The solar PV array can produce open-circuit voltages over 100 Vdc when in sunlight. Verify that the solar input breaker has been opened (disconnected) before installing the system wires (if the controller is in the solar charging mode).

Using the diagram on the previous page, connect the four power conductors in the following steps:

1. Confirm that the input and output disconnect switches are both turned off before connecting the power wires to the controller. There are no disconnect switches inside the TriStar.
2. Provide for strain relief if the bottom knockouts are used and conduit is not used.
3. Pull the wires into the wiring compartment. The temperature probe wires and battery voltage sense wires can be inside the conduit with the power conductors.
4. Connect the Battery + (positive) wire to the Battery + terminal.
5. Connect the Battery – (negative) wire to the Battery – terminal.
6. Connect the Solar + wire (positive) to the Solar + terminal. (or Load + / Diversion +)
7. Connect the Solar – (negative) wire to the Solar – terminal. (or Load – / Diversion –)

The CE certification requires that the battery conductors, the battery voltage sense wires, and the remote temperature sensor shall not be accessible without the use of a tool and are protected in the battery compartment.

Do not bend the power wires up toward the access cover. If a TS-M meter is used now or in the future, these large wires can damage the meter assembly when the access cover is attached to the controller.

Torque each of the four power terminals to 5.65 Nm (50 in-lbs).

Power-Up

- Confirm that the solar (or load) and battery polarities are correct.
- Turn the battery disconnect on first. Observe the LED's to confirm a successful start-up. (LED's blink Green - Yellow - Red in one cycle)
- Note that a battery must be connected to the TriStar to start and operate the controller. The controller will not operate from a solar input only.
- Turn the solar (or load) disconnect on.

Step 7 - RS-232 Adjustments

The TriStar must be powered from the battery to enable use of the RS-232 / PC computer connection. *Refer to Section 7.0 for using the RS-232 and Morningstar's PC software to change setpoints or confirm the installation settings.*

Step 8 - Finish Installation

Inspect for tools and loose wires that may have been left inside the enclosure.

Check the power conductors to make sure they are located in the lower part of the wiring compartment and will not interfere with the cover or the optional meter assembly.

NOTE: If the power conductors are bent upwards and touch the meter assembly (TS-M option), pressing the cover down on the wires can damage the meter.

Carefully place the cover back on the controller and install the 4 cover screws.

Closely observe the system behavior and battery charging for 2 to 4 weeks to confirm the installation is correct and the system is operating as expected.

3.0 TriStar Operation

The TriStar operation is fully automatic. After the installation is completed, there are few operator tasks to perform. However, the operator should be familiar with the basic operation and care of the TriStar as described below.

3.1 Operator's Tasks

- Use the pushbutton as needed *(see 3.2 below)*
- Check the LED's for status and faults *(see 3.3 below)*
- Support recovery from a fault as required *(see 3.4 below)*
- Routine inspection and maintenance *(see 3.5 below)*

If a TriStar digital meter is installed, please refer to the meter manual.

3.2 Pushbutton

In the battery charging mode (both solar and diversion), the following functions can be enabled with the pushbutton (located on the front cover):

PUSH: Reset from an error or fault.

PUSH: Reset the battery service indication if this has been activated with the PC software. A new service period will be started, and the flashing LED's will stop blinking. If the battery service is performed before the LED's begin blinking, the pushbutton must be pushed at the time when the LED's are blinking to reset the service interval and stop the blinking.

PUSH AND HOLD 5 SECONDS: Begin battery equalization manually. This will begin equalization in either the manual or automatic equalization mode. The equalization will automatically stop per the battery type selected *(see Section 4.4)*.

PUSH AND HOLD 5 SECONDS: Stop an equalization that is in progress. This will be effective in either the manual or automatic mode. The equalization will be terminated.

Note that if two or more TriStars are charging in parallel, the equalization cycles may start on different days for various reasons (such as one controller is disconnected and restarted). If this happens, the pushbutton on each controller can be used to manually start and then stop an equalization, and this will reset the equalizations to the same schedule.

LOAD CONTROL

PUSH: Reset from an error or fault.

PUSH AND HOLD 5 SECONDS: After a low voltage disconnect (LVD) of the load, the pushbutton can be used to reconnect the loads again. The loads will remain on for 10 minutes, and will then disconnect again. The pushbutton can be used to override the LVD without limit.

NOTE: The purpose of the LVD is to protect the battery. Repeated overrides of an LVD can deeply discharge the battery and may damage the battery.

3.3 LED Indications

Valuable information can be provided by the three LED’s in the front cover. Although there are many different LED indications, they have similar patterns to make it easier to interpret each LED display. Consider as three groups of indications: General Transitions // Battery or Load Status // Faults.

LED Display Explanation:

G = green LED is lit
Y = yellow LED is lit
R = red LED is lit
G/Y = Green and Yellow are both lit at the same time
G/Y - R = Green & Yellow both lit, then Red is lit alone
Sequencing (faults) has the LED pattern repeating until the fault is cleared

1. General Transitions:

• Controller start-up	G - Y - R (one cycle)
• Pushbutton transitions	blink all 3 LED’s 2 times
• Battery service is required	all 3 LED’s blinking until service is reset

2. Battery Status

• General state-of-charge	*see battery SOC indications below*
• PWM absorption	G blinking (1/2 second on / 1/2 second off)
• Equalization state	G fast blink (2 to 3 times per second)
• Float state	G slow blink (1 second on / 1 second off)

Battery State-of-Charge LED Indications (when battery is charging):

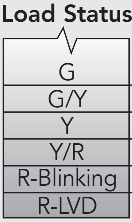
• G on	80% to 95% SOC
• G/Y on	60% to 80% SOC
• Y on	35% to 60% SOC
• Y/R on	0% to 35% SOC
• R on	battery is discharging

Refer to the Specifications (Section 11.0) for the State-of-Charge voltages. Another LED chart is provided at the end of this manual (Appendix 3) for easier reference.

Note that because these State-of-Charge LED displays are for all battery types and system designs, they are only approximate indications of the battery charge state.

LOAD CONTROL

2. Load Status



	12V	24V	48V
LVD+	0.60V	1.20V	2.40V
LVD+	0.45V	0.90V	1.80V
LVD+	0.30V	0.60V	1.20V
LVD+	0.15V	0.30V	0.60V
LVD			

The load status LED’s are determined by the LVD voltage plus the specified transition voltages. As the battery voltage rises or falls, each voltage transition will cause a change in the LED’s.

3. Faults & Alarms

• Short circuit - solar/load	R/G - Y sequencing
• Overload - solar/load	R/Y - G sequencing
• Over-temperature	R - Y sequencing
• High voltage disconnect	R - G sequencing
• Reverse polarity - battery	no LED's are lighted
• Reverse polarity - solar	No fault indication
• DIP switch fault	R - Y - G sequencing
• Self-test faults	R - Y - G sequencing
• Temperature probe (RTS)	R/Y - G/Y sequencing
• Battery voltage sense	R/Y - G/Y sequencing

3.4 Protections and Fault Recovery

The TriStar protections and automatic recovery are important elements of the operating system. The system operator should be familiar with the causes of faults, controller protections, and any actions that may be required.

Some basic fault conditions are reviewed below:

Short circuit:
(R/G-Y sequencing) When a short circuit occurs, the FET switches are opened in micro-seconds. The FETs will probably open before other protective devices in the system can react, so the short circuit may remain in the system. The TriStar will try to reconnect the FETs two times. If the short circuit remains, the LED's will continue sequencing.

After the short in the system is repaired, there are two ways to restart the controller:

- Power should have been disconnected to repair the short. When power is restored, the TriStar does a normal start-up and will reconnect the solar input or load.
- The pushbutton can also be used to reconnect the FET switches (if there is battery power to the TriStar).

☞ ***NOTE: There will always be a 10 second delay between attempts to reconnect the FET switches. Even if power is disconnected, the TriStar will wait for the remainder of the 10 seconds when the power is restored.***

Solar overload:
(R/Y-G sequencing) If the solar input exceeds 100% of the controller's current rating, the controller will reduce the average current below the TriStar's rating. The controller is capable of managing up to 130% of the rated solar input.

When 130% rated current is exceeded, the solar will be disconnected and a fault will be indicated. The input FET switches will remain open for 10 seconds. Then the switches are closed again and charging resumes. These cycles can continue without limit.

The current overload is reduced to the "equivalent heating" of the rated current input. For example, a 72A solar array (120% overload) will PWM down to 50A, which is equivalent to the heating from a normal 60A solar input.

LOAD CONTROL

Load overload:
(R/Y-G sequencing) If the load current exceeds 100% of the controller's rating, the controller will disconnect the load. The greater the overload, the faster the controller will disconnect. A small overload could take a few minutes to disconnect.

The TriStar will attempt to reconnect the load two times. Each attempt is at least 10 seconds apart. If the overload remains after 2 attempts, the load will remain disconnected. The overload must be corrected and the controller restarted. The pushbutton can also be used to reconnect the load.

DIVERSION CHARGE CONTROL

Diversion overload:
(R/Y-G sequencing) If the current to the diversion load exceeds the TriStar rating, the controller will attempt to reduce the load. If the overload is too large, the TriStar will disconnect the diversion load. The controller will continue attempts to reconnect the load.

If the overload LED's are sequencing, the diversion load is too large for the controller. The size of the load must be reduced.

Reversed polarity:
If the battery polarity is reversed, there will be no power to the controller and no LED's will light. If the solar is reversed, the controller detects nighttime and there will be no LED indication and no charging. If the load is reversed, loads with polarity will be damaged. Be very careful to connect loads to the controller with correct polarity. *See Section 5.4*.

DIP switch fault:
(R-Y-G sequencing) If a DIP switch is changed while there is power to the controller, the LED's will begin sequencing and the FET switches will open. The controller must be restarted to clear the fault.

Solar high temperature:
(R-Y sequencing) When the heatsink temperature limit is reached, the TriStar will begin reducing the solar input current to prevent more heating. If the controller continues heating to a higher temperature, the solar input will then be disconnected. The solar will be reconnected at the lower temperature *(see Section 11.0)*.

LOAD CONTROL

Load high temperature:
(R-Y sequencing) When the heatsink temperature limit is reached (90˚C / 194˚F), the TriStar will disconnect the load. The load will be reconnected at the lower temperature setting (70˚C / 158˚F).

DIVERSION CHARGE CONTROL

Diversion high temperature:
(R-Y sequencing) When the heat sink temperature reaches 80˚C, the TriStar will change to an on-off regulation mode to reduce the temperature. If the temperature reaches 90˚C, the load will be disconnected. The load is reconnected at 70˚C.

Solar high voltage disconnect (HVD):
(R-G sequencing) If the battery voltage continues increasing beyond normal operating limits, the controller will disconnect the solar input (unless the FET switches cannot open due to a failure). *See Section 11.0 for the disconnect and reconnect values.*

LOAD CONTROL

Load HVD:
(R-G sequencing) In the Load Control mode, the HVD can only be enabled using the PC software. At the battery voltage value selected in the software, the TriStar will disconnect the load. At the selected lower voltage, the load will be reconnected.

DIVERSION CHARGE CONTROL

Diversion HVD:
(R-G sequencing) HVD will be the same value as used for Solar charging. In the Diversion mode, an HVD condition will be indicated with the LEDs, but there is no disconnect.

Battery removal voltage spike:
(no LED indication) Disconnecting the battery before the solar input is disconnected can cause a large solar open-circuit voltage spike to enter the system. The TriStar protects against these voltage spikes, but it is best to disconnect the solar input before the battery.

Very low battery voltage:
(LED's are all off) Below 9 volts the controller will go into brownout. The controller shuts down. When the battery voltage rises, the controller will restart. In the Load Control mode, the TriStar will recover in the LVD state.

Remote temperature sensor (RTS) failure:
(R/Y-G/Y) If a fault in the RTS (such as a short circuit, open circuit, loose terminal) occurs after the RTS has been working, the LED's will indicate a failure and the solar input is disconnected. However, if the controller is restarted with a failed RTS, the controller may not detect that the RTS is connected, and the LED's will not indicate a problem. A TriStar meter or the PC software can be used to determine if the RTS is working properly.

Battery voltage sense failure:
(R/Y-G/Y) If a fault in the battery sense connection (such as a short circuit, open circuit, loose terminal) occurs after the battery sense has been working, the LED's will indicate a failure. However, if the controller is restarted with the failure still present in the battery sense, the controller may not detect that the battery sense is connected, and the LED's will not indicate a problem. A TriStar meter or the PC software can be used to determine if the battery sense is working properly.

3.5 Inspection and Maintenance

The TriStar does not require routine maintenance. The following inspections are recommended two times per year for best long-term performance.

1. Confirm the battery charging is correct for the battery type being used. Observe the battery voltage during PWM absorption charging (green LED

blinking 1/2 second on / 1/2 second off). Adjust for temperature compensation if an RTS is used *(see Table 4.3)*.

For load and diversion modes, confirm that the operation is correct for the system as configured.

2. Confirm the controller is securely mounted in a clean and dry environment.
3. Confirm that the air flow around the controller is not blocked. Clean the heat sink of any dirt or debris.
4. Inspect for dirt, nests and corrosion, and clean as required.

4.0 Solar Battery Charging

4.1 PWM Battery Charging

PWM (Pulse Width Modulation) battery charging is the most efficient and effective method for recharging a battery in a solar system. *Refer to "Why PWM?" on Morningstar's website for more information.*

Selecting the best method for charging your battery together with a good maintenance program will ensure a healthy battery and long service life. Although the TriStar's battery charging is fully automatic, the following information is important to know for getting the best performance from your TriStar controller and battery.

4.1.1 Four Stages of Solar Charging

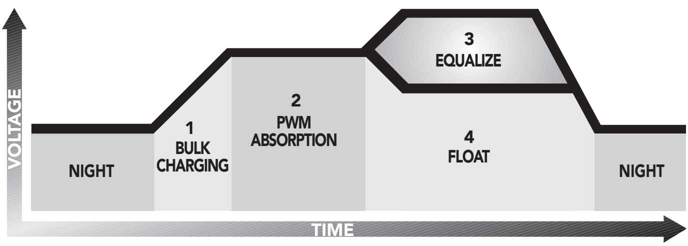


Figure 4.1.1 Solar Charging Stages

1. **Bulk Charging:** In this stage, the battery will accept all the current provided by the solar system. The LED's will display an indication of the battery charge state as the battery is being recharged.
2. **PWM Absorption:** When the battery reaches the regulation voltage, the PWM begins to hold the voltage constant. This is to avoid over-heating and over-gassing the battery. The current will taper down to safe levels as the battery becomes more fully charged. The green LED will blink once per second. *See Section 4.2.*
3. **Equalization:** Many batteries benefit from a periodic boost charge to stir the electrolyte, level the cell voltages, and complete the chemical reactions. The green LED will blink rapidly 2-3 times per second. *See Section 4.4.*
4. **Float:** When the battery is fully recharged, the charging voltage is reduced to prevent further heating or gassing of the battery. The green LED will blink slowly once every 2 seconds. *See Section 4.5.*

4.1.2 Battery Charging Notes

The TriStar manages many different charging conditions and system configurations. Some useful functions to know follow below.

Solar Overload: Enhanced radiation or "edge of cloud effect" conditions can generate more current than the controller's rating. The TriStar will reduce this overload up to 130% of rated current by regulating the current to safe levels. If the current from the solar array exceeds 130%, the controller will interrupt charging *(see Section 3.4)*.

Battery Voltage Sense: Connecting a pair of voltage sense wires from the controller to the battery is recommended. This allows a precise battery voltage input to the controller and more accurate battery charging. *See Section 4.3 for more information.*

Temperature Compensation: All charging setpoints are based on 25˚C (77˚F). If the battery temperature varies by 5˚C, the charging will change by 0.15 volts for a 12 volt battery. This is a substantial change in the charging of the battery, and a remote temperature sensor is recommended to adjust charging to the actual battery temperature. *See Section 4.3 for more information.*

Day-Night Detection: The TriStar will automatically detect day and night conditions. Any functions that require measuring time or starting at dawn, for example, will be automatic.

PWM Noise: In some installations, the PWM charging may cause audible noise in certain equipment. If this occurs, the PWM can be changed to “On-Off” solar charging to reduce the noise. This requires DIP switch number 8 to be turned On. However, it is strongly recommended to try to remedy the noise problem with grounding or filtering first, because the benefits from PWM battery charging are significant.

Battery Types: The TriStar’s standard battery charging programs are suitable for a wide range of lead-acid battery types. These standard programs are reviewed in the following Section 4.2. A general review of battery types and their charging needs is provided in Section 9.0.

4.0

4.2 Standard Battery Charging Programs

The TriStar provides 7 standard battery charging algorithms (programs) that are selected with the DIP switches *(see Step 3 in Installation)*. These standard algorithms are suitable for lead-acid batteries ranging from sealed (gel, AGM, maintenance free) to flooded to L-16 cells. In addition, an 8th DIP switch provides for custom setpoints using the PC software.

The table below summarizes the major parameters of the standard charging algorithms. Note that all the voltages are for 12V systems (24V = 2X, 48V = 4X).

All values are 25°C (77°F).

DIP Switches (4-5-6)	A. Battery Type	B. PWM Absorp. Voltage	C. Float Voltage	D. Equal. Voltage	E. Time in Equal. (hours)	F. Equalize Interval (days)	G. Max Equal. Cycle (hours)
off-off-off	1 - Sealed	14.0	13.4	none	–	–	–
off-off-on	2 - Sealed	14.15	13.4	14.2	1	28	1
off-on-off	3 - Sealed	14.35	13.4	14.4	2	28	2
off-on-on	4 - Flooded	14.4	13.4	15.1	3	28	4
on-off-off	5 - Flooded	14.6	13.4	15.3	3	28	5
on-off-on	6 - Flooded	14.8	13.4	15.3	3	28	5
on-on-off	7 - L-16	15.0	13.4	15.3	3	14	5
on-on-on	8 - Custom		Custom			Custom	

Table 4.2 Standard Battery Charging Programs

A. **Battery Type** - These are generic lead-acid battery types. *See Section 9.0 for more information about battery types and appropriate solar charging.*

B. **PWM Voltage**–This is the PWM Absorption stage with constant voltage charging. The "PWM voltage" is the maximum battery voltage that will be held constant. As the battery becomes more charged, the charging current tapers down until the battery is fully charged.

C. **Float Voltage**–When the battery is fully charged, the charging voltage will be reduced to 13.4 volts for all battery types. The float voltage and transition values are adjustable with the PC software. *See Section 4.5 for more details.*

D. **Equalization Voltage**–During an equalization cycle, the charging voltage will be held constant at this voltage.

E. **Time in Equalization**–The charging at the selected equalization voltage will continue for this number of hours. This may take more than one day to complete. *See Section 4.4.*

F. **Equalization Interval**–Equalizations are typically done once a month. Most of the cycles are 28 days so the equalization will begin on the same day of the week. Each new cycle will be reset as the equalization starts so that a 28 day period will be maintained.

G. **Maximum Equalization Cycle**–If the solar array output cannot reach the equalization voltage, the equalization will terminate after this many hours to avoid over gassing or heating the battery. If the battery requires more time in equalization, the manual pushbutton can be used to continue for one or more additional equalization cycles.

These 7 standard battery charging algorithms will perform well for the majority of solar systems. However, for systems with specific needs beyond these standard values, any or all of these values can be adjusted using the PC software. *See Section 7.0.*

4.3 Temperature Effects & Battery Voltage Sense

4.3.1 Remote Temperature Sensor (RTS)

The RTS is used for temperature compensated battery charging. As the battery gets warmer, the gassing increases. As the battery gets colder, it becomes more resistant to charging. Depending on how much the battery temperature varies, it may be important to adjust the charging for temperature changes.

There are three battery charging parameters that are affected by temperature:

PWM Absorption
This is the most important part of charging that is affected by temperature because the charging may go into PWM absorption almost every day. If the battery temperature is colder, the charging will begin to regulate too soon and the battery may not be recharged with a limited solar resource. If the battery temperature rises, the battery may heat and gas too much.

Equalization
A colder battery will lose part of the benefit of the equalization. A warmer battery may heat and gas too much.

Float
Float is less affected by temperature changes, but it may also undercharge or gas too much depending on how much the temperature changes.

The RTS corrects the three charging setpoints noted above by the following values:

- 12 volt battery: –0.030 volts per ˚C (–0.017 volts per ˚F)
- 24 volt battery: –0.060 volts per ˚C (–0.033 volts per ˚F)
- 48 volt battery: –0.120 volts per ˚C (–0.067 volts per ˚F)

Variations in battery temperature can affect charging, battery capacity, and battery life. The greater the range of battery temperatures, the greater the impact on the battery. For example, if the temperature falls to 10˚C (50˚F) this 15˚C (27˚F) change in temperature will change the PWM, equalization and float setpoints by 1.80V in a 48V system.

If a remote temperature sensor is not used and the temperatures near the battery are stable and predictable, the PWM absorption setting can be adjusted using the PC software per the following table:

Temperature	12 Volt	24 Volt	48 Volt
40°C / 104°F	– 0.45 V	– 0.90 V	– 1.80 V
35°C / 95°F	– 0.30 V	– 0.60 V	– 1.20 V
30°C / 86°F	– 0.15 V	– 0.30 V	– 0.60 V
25°C / 77°F	0 V	0 V	0 V
20°C / 68°F	+ 0.15 V	+ 0.30 V	+ 0.60 V
15°C / 59°F	+ 0.30 V	+ 0.60 V	+ 1.20 V
10°C / 50°F	+ 0.45 V	+ 0.90 V	+ 1.80 V
5°C / 41°F	+ 0.60 V	+ 1.20 V	+ 2.40 V
0°C / 32°F	+ 0.75 V	+ 1.50 V	+ 3.00 V
– 5°C / 23°F	+ 0.90 V	+ 1.80 V	+ 3.60 V
– 10°C / 14°F	+ 1.05 V	+ 2.10 V	+ 4.20 V
– 15°C / 5°F	+ 1.20 V	+ 2.40 V	+ 4.80 V

Table 4.3 Temperature Compensation

The need for temperature compensation depends on the temperature variations, battery type, how the system is used, and other factors. If the battery appears to be gassing too much or not charging enough, an RTS can be added at any time after the system has been installed. *See Section 2.3 - Step 4 for installation instructions.*

The TriStar will recognize the RTS when the controller is started (powered-up).

4.3.2 Battery Voltage Sense

There can be voltage drops typically up to 3% in the power cables connecting the battery to the TriStar. If battery voltage sense wires are not used, the controller will read a higher voltage at the controller’s terminals than the actual battery voltage while charging the battery.

Although limited to 3% as the generally accepted wiring standard, this can result in a 0.43 voltage drop for 14.4V charging (or 1.72V for a 48 volt nominal system).

continued...

4.3.2 Battery Voltage Sense *(continued)*

These voltage drops will cause some undercharging of the battery. The controller will begin PWM absorption, or limit equalization, at a lower battery voltage because the controller measures a higher voltage at the controller's terminals than is the actual battery voltage. For example, if the controller is programmed to start PWM absorption at 14.4V, when the controller "sees" 14.4V at its battery terminals, the true battery voltage would only be 14.1V if there is a 0.3V drop between the controller and battery.

Two sense wires, sized from 1.0 to 0.25 mm^2 (16 to 24 AWG), can be used for battery voltage sense. Because these wires carry no current, the voltage at the TriStar will be identical to the battery voltage. A 2-position terminal is used for the connection

Note that the battery sense wires will not power the controller, and the sense wires will not compensate for losses in the power wires between the controller and the battery. The battery sense wires are used to improve the accuracy of the battery charging.

See Section 2.3 - Step 5 for instructions how to connect the battery sense wires.

4.4 Equalization

Routine equalization cycles are often vital to the performance and life of a battery — particularly in a solar system. During battery discharge, sulfuric acid is consumed and soft lead sulfate crystals form on the plates. If the battery remains in a partially discharged condition, the soft crystals will turn into hard crystals over time. This process, called "lead sulfation," causes the crystals to become harder over time and more difficult to convert back to soft active materials.

Sulfation from chronic undercharging of the battery is the leading cause of battery failures in solar systems. In addition to reducing the battery capacity, sulfate build-up is the most common cause of buckling plates and cracked grids. Deep cycle batteries are particularly susceptible to lead sulfation.

Normal charging of the battery can convert the sulfate back to the soft active material if the battery is fully recharged. However, a solar battery is seldom completely recharged, so the soft lead sulfate crystals harden over a period of time. Only a long controlled overcharge, or equalization, at a higher voltage can reverse the hardening sulfate crystals.

In addition to slowing or preventing lead sulfation, there are also other benefits from equalizations of the solar system battery. These include:

Balance the individual cell voltages.
Over time, individual cell voltages can drift apart due to slight differences in the cells. For example, in a 12 cell (24V) battery, one cell is less efficient in recharging to a final battery voltage of 28.8 volts (2.4 V/c). Over time, that cell only reaches 1.85 volts, while the other 11 cells charge to 2.45 volts per cell. The overall battery voltage is 28.8V, but the individual cells are higher or lower due to cell drift. Equalization cycles help to bring all the cells to the same voltage.

Mix the electrolyte.
In flooded batteries, especially tall cells, the heavier acid will fall to the bottom of the cell over time. This stratification of the electrolyte causes loss of capacity and corrosion of the lower portion of the plates. Gassing of the

electrolyte from a controlled overcharging (equalization) will stir and remix the acid into the battery electrolyte.

NOTE: Excessive overcharging and gassing too vigorously can damage the battery plates and cause shedding of active material from the plates. An equalization that is too high or for too long can be damaging. Review the requirements for the particular battery being used in your system.

4.4.1 Standard Equalization Programs

Both automatic and manual equalizations can be performed using either the standard charging programs *(see 4.2)* or a custom program *(see 7.0)*.

Manual Equalization
The TriStar is shipped with the DIP switch set for manual equalization only. This is to avoid an unexpected or unwanted automatic equalization. In the manual mode, the pushbutton is used to both start or stop a manual equalization. Hold the pushbutton down for 5 seconds to start or stop an equalization (depending on whether an equalization is in progress or not).

The LED's will confirm the transition (all 3 LED's blink 2 times). When the battery charging enters into equalization, the Green LED will start fast blinking 2-3 times per second.

There are no limits to how many times the pushbutton can be used to start and stop equalizations. Equalizations will be terminated automatically per the charging program selected if the pushbutton is not used to manually stop the equalization.

Automatic Equalization
If the equalization DIP switch is moved to the ON position *(see 2.3 - Step 3)*, the equalizations will begin automatically per the charging program selected. Other than starting, the automatic and manual equalizations are the same and follow the standard charging program selected. The pushbutton can be used to start and stop equalizations in both the manual and automatic mode.

4.4.2 Typical Equalizations

The automatic equalizations will occur every 28 days (except L-16 cells at 14 days). When an equalization begins (auto or manual), the battery charging voltage increases up to the equalization voltage (Veq). The battery will remain at Veq for the time specified in the selected charging program *(see table in 4.2)*.

If the time to reach Veq is too long, the maximum equalization cycle time will end the equalization. A second manual equalization cycle can be started with the pushbutton if needed.

If the equalization cannot be completed in one day, it will continue the next day or days until finished. After an equalization is completed, charging will return to PWM absorption.

4.4.3 Preparation for Equalization

First, confirm that all your loads are rated for the equalization voltage. Consider that at 0˚C (32˚F) the equalization voltage will reach 16.05V in a 12V

continued...

4.4.3 Preparation for Equalization *(continued)*

a 12V system (64.2V in a 48V system) with a temperature sensor installed. Disconnect any loads at risk.

If Hydrocaps are used, be sure to remove them before starting an equalization. Replace the Hydrocaps with standard battery cell caps. The Hydrocaps can get very hot during an equalization. Also, if Hydrocaps are used, the equalization should be set for manual only (DIP switch #7 is Off).

After the equalization is finished, add distilled water to each cell to replace gassing losses. Check that the battery plates are covered.

4.4.4 When to Equalize

The ideal frequency of equalizations depends on the battery type (lead-calcium, lead-antimony, etc.), the depth of discharging, battery age, temperature, and other factors.

One very broad guide is to equalize flooded batteries every 1 to 3 months or every 5 to 10 deep discharges. Some batteries, such as the L-16 group, will need more frequent equalizations.

The difference between the highest cell and lowest cell in a battery can also indicate the need for an equalization. Either the specific gravity or the cell voltage can be measured. The battery manufacturer can recommend the specific gravity or voltage values for your particular battery.

4.4.5 "Equalize" a Sealed Battery?

The standard battery charging table *(see Section 4.2)* shows two sealed batteries with an "equalization" cycle. This is only a 0.05 volt (12V battery) boost cycle to level individual cells. This is not an equalization, and will not vent gas from sealed batteries that require up to 14.4V charging (12V battery). This "boost" charge for sealed cells allows for adjustability with the PC software.

Many VRLA batteries, including AGM and gel, have increased charging requirements up to 14.4V (12V battery). The 0.05V boost shown in the table (Section 4.2) is less than the accuracy range of most charge controllers. Alternatively, for these two sealed battery charging programs you may prefer to consider the PWM absorption stage to be 14.2V and 14.4V (12V battery).

The 14.0, 14.2, and 14.4 volt standard charging programs should be suitable for most sealed batteries. If not optimum for your battery, the PC software can be used to adjust these values. *Refer to Section 9.0 for more information about charging sealed batteries.*

4.5 Float

When a battery becomes fully charged, dropping down to the float stage will provide a very low rate of maintenance charging while reducing the heating and gassing of a fully charged battery. When the battery is fully recharged, there can be no more chemical reactions and all the charging current is turned into heat and gassing.

The purpose of float is to protect the battery from long-term overcharge. From the PWM absorption stage, charging is dropped to the float voltage. This is typically 13.4V, and is adjustable with the PC software.

The transition to float is based on the previous 24 hour history. Factors include the battery voltage, the state of charge the night before, the battery type, and the PWM duty cycle and stability of the duty cycle. The battery will be charged for part of the day until the transition to float.

If there are loads for various periods of time during float, the TriStar will cancel float and return to bulk charge.

Float is temperature compensated.

5.0 Load Control

This section describes the user selectable load control settings (5.1) and the low voltage load disconnect (LVD) warning indications (5.2). Load information and general cautions are provided in the remaining sections.

5.1 Load Control Settings

The primary purpose of a low voltage load disconnect function (LVD) is to protect the system battery from deep discharges that could damage the battery.

In the Load Control mode, the TriStar provides for seven standard LVD settings that are selected by the DIP switches. These are described in the table below. Custom LVD settings are possible using the PC software *(see Section 7.0)*.

DIP Switch	12V LVD	24V LVD	48V LVD	Battery SOC%	12V LVD_R	24V LVD_R	48V LVD_R
off-off-off	11.1	22.2	44.4	8	12.6	25.2	50.4
off-off-on	11.3	22.6	45.2	12	12.8	25.6	51.2
off-on-off	11.5	23.0	46.0	18	13.0	26.0	52.0
off-on-on	11.7	23.4	46.8	23	13.2	26.4	52.8
on-off-off	11.9	23.8	47.6	35	13.4	26.8	53.6
on-off-on	12.1	24.2	48.4	55	13.6	27.2	54.4
on-on-off	12.3	24.6	49.2	75	13.8	27.6	55.2
on-on-on		Custom		Custom		Custom	

Table 5.1

The table above describes the standard selectable LVD battery voltages for 12, 24 and 48 volt systems. The LVD_R values are the load reconnect setpoints. The "Battery SOC %" provides a general battery state-of-charge figure for each LVD setting. The actual battery SOC can vary considerably depending on the battery condition, discharge rates, and other specifics of the system.

☞ ***NOTE: The lowest LVD settings are intended for applications such as telecom that only disconnect the load as a last resort. These lower LVD settings will deeply discharge the battery and should not be used for systems that may go into LVD more than once a year.***

The LVD values in the table above are current compensated. Under load, the battery voltage will be reduced in proportion to the current draw by the load. A short-term large load could cause a premature LVD without the current compensation. The LVD values in the table above are adjusted lower per the following table:

	TS-45	TS-60
12V	–15 mV per amp	–10 mV per amp
24V	–30 mV per amp	–20 mV per amp
48V	–60 mV per amp	–40 mV per amp

As an example, consider a 24V system using a TriStar-60 with a 30 amp load.

The LVD will be reduced by 0.02V (per the table above) times 30 amps. This equals –0.6V. A DIP-switch selected LVD of 23.4V would be reduced to 22.8V in this example.

Note that the LEDs are linked to the LVD setting, so the LEDs are also current compensated.

After an LVD, the load reconnect voltages are 0.25 volts per battery cell higher than the LVD (for example, in a 12V system the LVD_R would be 1.5 volts above LVD). Battery voltages can rise quickly after an LVD, typically from 1.0 to 1.3 volts or more (12V system). The LVD_R value must be high enough to avoid cycling in and out of LVD.

5.2 LVD Warning

When the battery is discharging and the green LED changes to the next state (G-Y LEDs on), there are four remaining transitions to LVD *(refer to the LED indications in Section 3.3)*. Each of these LED displays will serve as a warning of an approaching LVD. The final warning is a blinking red LED state.

The amount of time from the initial G-Y display until the load disconnect will depend on many factors. These include:

- The rate of discharge.
- The health of the battery
- The LVD setting

For a “typical” system with a healthy battery and an LVD setting of about 11.7 volts, there could be approximately 10 hours per LED transition. The LVD would occur about 40 hours from the first G-Y display (under constant load with no charging).

Another significant factor affecting the warning time is the LVD voltage setpoint. Lower LVD voltage settings may result in the battery discharging 70% or 80% of its capacity. In this case, the battery’s very low charge state will result in the voltage dropping much faster. At the lowest LVD settings, there could be as little as 2 or 3 hours of warning between LED transitions for a healthy battery.

The amount of time it takes to transition through the LEDs to LVD can vary greatly for different systems. It may be worthwhile to measure the time it takes for your system to transition from one LED state to the next. Do this under “typical” discharging loads.

This will provide a good reference for how long it will take for your system to reach LVD. It can also provide a benchmark for judging the health of your battery over time.

5.3 Inductive Loads (Motors)

For dc motors and other inductive loads, it is strongly recommended to install a diode near the controller. Inductive loads can generate large voltage spikes that might damage the controller’s lightning protection devices.

The diode should be installed near the controller, and in the orientation shown in the diagram on the next page:

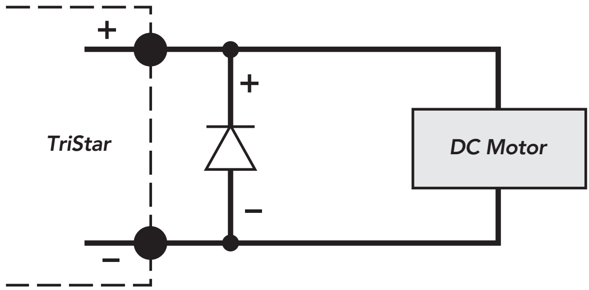


Figure 5.3 Diode Protection

The specifications for the diode follow:
- a power diode
- rated equal or greater than 80 volts
- rated equal or greater than 45 amps (TS-45) or 60 amps (TS-60)

For large inductive loads, a heat sink for the diode may be necessary.

5.4 General Load Control Notes

In addition to the inductive loads discussed above, there are a few other load issues that require attention:

5.4.1 Inverters

Inverters should never be connected to the TriStar.

5.4.2 Parallel TriStars

Two or more TriStars should never be put in parallel for a large load. The controllers cannot share the load.

5.4.3 Reverse Polarity

If the battery is correctly connected (LEDs are on), the load should be connected very carefully with regard to polarity (+ / –).

If the polarity is reversed, the controller cannot detect this. There are no indications.

Loads without polarity will not be affected.

Loads with polarity can be damaged. It is possible that the TriStar will go into short circuit protection before the load is damaged. If the LEDs indicate a "short", be certain to check for both shorts and reversed polarity connections.

If the controller does not go into short circuit protection, the loads with polarity will be damaged.

CAUTION: Carefully verify the polarity (+ and –) of the load connections before applying power to the controller.

6.0 Diversion Charge Control

The TriStar's third mode of operation is diversion load battery charge control. As the battery becomes fully charged, the TriStar will divert excess current from the battery to a dedicated diversion load. This diversion load must be large enough to absorb all the excess energy, but not too large to cause a controller overload condition.

6.1 Diversion Charge Control

In the diversion mode, the TriStar will use PWM charging regulation to divert excess current to an external load. As the battery becomes fully charged, the FET switches are closed for longer periods of time to direct more current to the diversion load.

As the battery charges, the diversion duty cycle will increase. When fully charged, all the source energy will flow into the diversion load if there are no other loads. The generating source is typically a wind or hydro generator. Some solar systems also use diversion to heat water rather than open the solar array and lose the energy.

The most important factor for successful diversion charge control is the correct sizing of the diversion load. If too large, the controller's protections may open the FET switches and stop diverting current from the battery. This condition can damage the battery.

If you are not confident and certain about the installation, a professional installation by your dealer is recommended.

6.2 Diversion Current Ratings

The maximum diversion load current capability for the two TriStar versions is 45 amps (TS-45) and 60 amps (TS-60). The diversion loads must be sized so that the peak load current cannot exceed these maximum ratings.

See section 6.4 below for selecting and sizing the diversion loads.

The total current for all combined charging sources (wind, hydro, solar) should be equal or less than two-thirds of the controller's current rating: 30A (TS-45) and 40A (TS-60). This limit will provide a required margin for high winds and high water flow rates as well as a margin for error in the rating and selection of the diversion load. This protects against an overload and a safety disconnect in the TriStar controller, which would leave the battery charging unregulated.

CAUTION: If the TriStar's rating is exceeded and the controller disconnects the diversion load, Morningstar will not be responsible for any damage resulting to the system battery or other system components. Refer to Morningstar's Limited Warranty in Section 10.0.

6.3 Standard Diversion Battery Charging Programs

The TriStar provides 7 standard diversion charging algorithms (programs) that are selected with the DIP switches. An 8th algorithm can be used for custom setpoints using the PC software.

The table below summarizes the major parameters of the standard diversion battery charging algorithms. Note that all the voltages are for 12V systems (24V = 2X, 48V = 4X).

All values are 25°C (77°F).

DIP Switches (4-5-6)	A. PWM Absorp. Voltage	B. Float Voltage	C. Time Until Float (hours)	D. Equalization Voltage	E. Time in Equal. (hours)	F. Equalize Interval (days)	G. Max. Equalize Cycle (hours)
off-off-off	13.7	13.5	3	14.0	3	28	3
off-off-on	13.9	13.7	3	14.2	3	28	3
off-on-off	14.1	13.9	4	14.4	3	28	4
off-on-on	14.3	14.1	4	14.6	4	28	4
on-off-off	14.5	14.3	4	14.8	4	28	5
on-off-on	14.7	14.5	4	15.0	4	28	5
on-on-off	14.9	14.7	4	15.2	4	28	5
on-on-on		Custom		Custom		Custom	

Table 6.3 Standard Diversion Charging Programs

A. **PWM Absorption Voltage** - This is the PWM Absorption stage with constant voltage charging. The PWM absorption voltage is the maximum battery voltage that will be held constant.

B. **Float Voltage** - When the battery is fully charged, the charging voltage will be reduced by 0.2 volts for all diversion settings. The float voltage and transition values are adjustable with the PC software.

C. **Time Until Float** - This is the cumulative time in PWM before the battery voltage is reduced to the float voltage. If loads are present during the PWM absorption, the time to transition into float will be extended.

D. **Equalization Voltage** - During an equalization cycle, the charging voltage will be held constant at this voltage. Equalizations are manual, and can be selected for automatic *(See Section 4.4.1)*.

E. **Time in Equalization** - Charging at the selected equalization voltage will continue for this number of hours.

F. **Equalization Interval** - Equalizations are typically done once a month. The cycles are 28 days so the equalization will begin on the same day of the week. Each new cycle will be reset as the equalization starts so that a 28 day period will be maintained.

G. **Maximum Equalization Cycle** - If the battery voltage cannot reach the equalization voltage, the equalization will terminate after this number of hours to avoid over gassing or heating the battery. If the battery requires more time in equalization, the manual pushbutton can be used to continue for one or more additional equalization cycles.

6.3.1 Battery Charging References

The diversion load battery charging is similar to conventional solar charging. Refer to the following sections in this manual for additional battery charging information.

4.1 Four stages of charging (applies to diversion)

4.3 Temperature Effects and Battery Voltage Sense

4.4 Equalization
4.5 Float
9.0 Battery Information

6.4 Selecting the Diversion Load

It is critical that the diversion load be sized correctly. If the load is too small, it cannot divert enough power from the source (wind, hydro, etc). The battery will continue charging and could be overcharged.

If the diversion load is too large, it will draw more current than the rating of the TriStar. The controller's overload protection may disconnect the diversion load, and this will result in all of the source current going to the battery.

CAUTION: The diversion load must be able to absorb the full power output of the source, but the load must never exceed the current rating of the TriStar controller. Otherwise, the battery can be overcharged and damaged.

6.4.1 Suitable Loads for Diversion

Water heating elements are commonly used for diversion load systems. These heating elements are reliable and widely available. Heating elements are also easy to replace, and the ratings are stable.

NOTE: Do not use light bulbs, motors, or other electrical devices for diversion loads. These loads will fail or cause the TriStar to disconnect the load. Only heating elements should be used.

Water heating elements are typically 120 volts. Elements rated for 12, 24 and 48 volts are also available, but more difficult to source. The derating for 120 volt heating elements is discussed in 6.4.3 below.

6.4.2 Definition of Terms

Maximum Source Current:
This is the maximum current output of all the energy sources (hydro, wind, solar, etc.) added together. This current will be diverted through the TriStar to the diversion load.

Maximum Battery Voltage:
This maximum voltage is the PWM regulation voltage selected with the DIP switches, plus the increase with an equalization, plus the increase due to lower temperatures. The highest battery voltage is commonly 15, 30 and 60 volts for 12-, 24- and 48-volt systems.

Peak Load Current:
At the maximum battery voltage, this is the current the diversion load will draw. This peak load current must not exceed the TriStar's rating.

NOTE: Because the battery can supply any size load, the peak load current is not limited by the source (hydro or wind rating). The diversion load's power rating is the critical specification for reliable battery charging.

6.4.3 Load Power Ratings

The power rating of the diversion load will depend on the voltage of the battery being charged. If the heating element is not rated for the same voltage as the diversion system, the power rating of the load must be adjusted to the diversion system's voltage.

The manufacturers typically rate the heating elements for power at a specified voltage. The peak load current at the load's rated voltage will be the power divided by the rated voltage (I = P / V). For example: 2000W / 120V = 16.7 amps of current.

If the load is being used at a voltage less than the load's rated voltage, the power can be calculated by the ratio of the voltages squared. For example, a 120 volt 1000 watt heating element being used at 60 volts:

1000W x $(60/120)^2$ = 250 watts

The 1000W element will only dissipate 250W when being used at 60 volts.

NOTE: The loads (heating elements) can be used at the manufacturer's voltage rating, or at a lower voltage. Do not use the load at a higher voltage than the load's rating.

6.4.4 Maximum Diversion Load

The diversion load should never exceed the TriStar's current rating (45A or 60A). Note that the load is not limited by the source (wind, hydro), and will draw its rated current from the battery.

The following table specifies the absolute maximum diversion loads that can be used with each TriStar version. These loads (heating elements) are rated for the same voltage as the system voltage.

Nominal Voltage	TriStar-45	TriStar-60
48V	2700W at 60V	3600W at 60V
24V	1350W at 30V	1800W at 30V
12V	675W at 15V	900W at 15V

These maximum power ratings are translated to the equivalent at 120 volts in the following table. If using heating elements rated for 120 volts, the power ratings of all the elements can be simply added up and the sum compared with this table and no further math is required.

Nominal Voltage	TriStar-45	TriStar-60
48V	10,800W at 120V	14,400W at 120V
24V	21,600W at 120V	28,800W at 120V
12V	43,200W at 120V	57,600W at 120V

To illustrate the same point from the opposite perspective, a heating element rated for 120 volts will draw reduced load current as indicated by the following table. A standard 2,000 watt / 120 Vac heating element is used as the reference.

Voltage	Power	Current
120V	2000 W	16.7 A
60V (48V nominal)	500 W	8.3 A
30V (24V nominal)	125 W	4.2 A
15V (12V nominal)	31 W	2.1 A

Whether using dc rated loads (the first table) or 120V elements, the total diversion load current must not exceed the current rating of the TriStar.

6.4.5 Minimum Diversion Load

The diversion load must be large enough to divert all the current produced by the source (wind, hydro, etc.). This value is the maximum battery voltage times the maximum source current.

For example, if a hydro source can generate up to 30 amps of current in a nominal 48 volt system (60V maximum), the minimum diversion load size = 60V x 30A = 1,800 watts (for loads rated at 60 volts).

General Sizing Example

Consider a 24V system with a wind turbine that is rated to generate 35A of current. A TriStar-45 will not provide the 150% diversion load margin, and the TS-45 is only rated for 30A of source current. The TS-45 will not provide enough margin for wind gusts and overloads, so a TS-60 should be used.

The diversion load should be sized for 52.5A (150% of the source current) up to 60A (the rating of the TriStar-60). If 55A is selected for the diversion load, the load must be capable of diverting 55A at 30V (maximum battery voltage). If a 30V heating element is used, it would be rated for 1,650 watts (or from 1,575W to 1,800W per the load range noted above).

If a 2,000 watt / 120 volt heating element is used, 13 of these elements in parallel will be required for the diversion load (4.2 amps per element [Table in 6.4.4] x 13 = 54.6 amps).

The minimum diversion load would be the source output (35A) times the voltage (30V). This would require a 1,050 watt heating element rated at 30 volts. Or if a 2,000W heater element rated for 120 volts is used, 9 heater elements will be required to draw the required minimum diversion load at 30 volts.

6.5 NEC Requirements

To comply with NEC 690.72 (B), the following requirements will apply when the TriStar is being used as a diversion charge controller in a photovoltaic system.

6.5.1 Second Independent Means

If the TriStar is the only means of regulating the battery charging in a diversion charging mode, then a second independent means to prevent overcharging the battery must be added to the system. The second means can be another TriStar, or a different means of regulating the charging.

6.5.2 150 Percent Rating

The current rating of the diversion load must be at least 150% of the TriStar source current rating. *Refer to Section 6.2 (Diversion Current Rating).* The maximum allowable current ratings for both TriStar versions are summarized below:

	Max. Input Current	Max. Diversion Load Rating
TS-45	30 A	45 A
TS-60	40 A	60 A

CAUTION: The NEC requirement that the diversion load must be sized at least 150% of the controller rating does NOT mean the diversion load can exceed the maximum current rating of the TriStar. NEVER size a diversion load that can draw more than the 45 amps or 60 amps maximum rating of the TriStar controllers.

6.6 Additional Information

Visit Morningstar's website (www.morningstarcorp.com) for additional diversion charge control information. The website provides expanded technical support for more complex diversion load systems.

7.0 Custom Settings with PC Software

An RS-232 connection between the TriStar and an external personal computer (PC) allows many setpoints and operating parameters to be easily adjusted. The adjustments can be simply a small change to one setpoint, or could include extensive changes for a fully customized battery charging or load control program.

CAUTION: Only qualified service personnel should change operating parameters with the PC software. There are minimal safeguards to protect from mistakes. Morningstar is not responsible for any damage resulting from custom settings.

Consult Morningstar's website for the latest TriStar PC software and instructions.

7.1 Connection to a Computer

An RS-232 cable with DB9 connectors (9 pins in 2 rows) will be required.

If the computer will be used to change battery charging or load control setpoints, verify that DIP switches 4, 5, 6 are in the custom position (On, On, On) before connecting the TriStar to a computer. The custom position is required to change setpoints. *See Section 2.3 - Step 3.* Disconnect power before changing DIP switches.

7.2 Using the PC Software

Download the TriStar PC software from Morningstar's website. Follow the instructions on the website for installing the software on your computer.

Open the TriStar PC software. This software will make the connection with the TriStar via the RS-232 cable. The TriStar must be powered by the battery or a power supply to complete the connection. If there is a conflict between the TriStar and PC comm ports, the software will provide instructions to resolve the problem.

7.3 Changing Setpoints

Follow the instructions in the PC software.

CAUTION: There are few limits to the changes that can be made. It is the responsibility of the operator to be certain all changes are appropriate. Any damage resulting to the controller or the system from TriStar setpoint adjustments will not be covered under warranty.

If you are not certain about each of the changes you are making, the software provides for returning to the factory default settings.

7.4 Finish

Confirm that the changes made to the TriStar are as you intended. It is advisable to make a record of the changes for future reference. Observe the system behavior and battery charging for a few weeks to verify that the system is operating correctly and as you intended.

Exit the software. The PC/TriStar connection can either be disconnected or left in place.

8.0 Self-Testing / Diagnostics

The TriStar performs a continuous self-test to monitor controller and system operation. Detected problems are classified as either faults or alarms. Typically, faults are problems that stop the normal operation of the controller and require immediate attention. Alarms indicate an abnormal condition, but will not stop the controller's operation.

If a problem is detected, the TriStar will alert the user to an existing fault or alarm. In this situation, the LED indicators will flash a particular sequence. Section 3.3 references these sequences with their associated faults and alarms. Flashing LED sequences can indicate conditions ranging from a simple battery service reminder to an existing short circuit in the system. It is recommended that the user become familiar with the LED indications and their meanings.

If a TriStar meter option has been added, more detailed information concerning faults and alarms will be available. Menus provide text displays of the specific fault as well as indicating on the standard display screens when a problem exists. *Consult the meter manual for further details.*

General Troubleshooting

TriStar is not powering up
- Confirm that all circuit breakers and switches in the system are closed
- Check all fuses
- Check for loose wiring connections and wiring continuity
- Verify that the battery voltage is not below 9Vdc *(brownout: section 3.4)*
- Verify that the battery power connection is not reversed polarity

Flashing/Sequencing LEDs
- *Reference Section 3.3 for a list of LED indications and their corresponding faults/alarms*

Self-Test Indication (R - Y - G sequencing)
- Self-testing will also detect various system wiring faults outside the TriStar
- Check for both TriStar faults and external system wiring problems

The RTS or Battery Sense is not working properly
- R/Y – G/Y sequencing LEDs indicates an RTS or Sense fault
- Check for a reverse polarity connection on the sense leads
- Verify that the RTS and Sense connections are wired to the correct terminals
- Check for shorts and continuity in the cables
- Verify that good electrical contact is made at the terminals
- Note that if the TriStar is restarted with an RTS or Sense fault present, it will not detect the RTS or Sense connection and the LED indication will stop

Troubleshooting Solar Charging

- Over-charging or under-charging the battery
- DIP switch settings may be wrong
- RTS is not correcting for high or low temperatures
- Over-temperature condition is reducing the charging current (heat sink cooling may be blocked — indicated with LED's)
- Voltage drop between TriStar and battery is too high *(connect the battery voltage sense — see Section 2.3 Step 5)*

- Battery charging requires temperature compensation (connect a remote temperature sensor)
- Load is too large and is discharging the battery

Not charging the battery
- DIP switch settings may be wrong (check each switch position carefully)
- TriStar has detected a fault *(indicated by sequencing LEDS, refer to Section 3.3)*
- Solar circuit breaker or disconnect is open
- Reversed polarity connections at the solar terminals (TriStar will not detect the solar array)
- Short circuit in the solar array has eliminated part of the array output
- Solar array is not providing enough current (low sun or fault in the array)
- Battery is failing and cannot hold a charge

Troubleshooting Load Control

No power to the load
- DIP switch settings may be wrong (check each switch position carefully)
- Controller is in LVD (check the LEDs)
- Load circuit breaker or disconnect may be open
- Check the load cables for continuity and good connection
- An over-temperature condition may have caused the load to be disconnected

Troubleshooting Diversion Control

- Diversion load is too small so PWM reaches 99%
- Diversion load is burned out so PWM reaches 99%
- Diversion load is too large so TriStar faults on overcurrent
- An overtemperature condition may have caused the load to be disconnected
- The RTS is not correcting for high or low temperatures
- Voltage drops between the TriStar and battery are too high

Still having problems? Point your web browser to http://www.morningstarcorp.com for technical support documents, FAQ's, or to request technical support.

9.0 Battery Information

The standard battery charging programs in the TriStar controller, as described in Section 4.2, are typical charging algorithms for three battery types:

- sealed (VRLA)
- flooded (vented)
- L-16 group

Other battery chemistries such as NiCad, or special voltages such as 36V, can be charged using a custom charging algorithm modified with the PC software. Only the standard TriStar battery charging programs will be discussed here.

CAUTION: Never attempt to charge a primary (non-rechargeable) battery.

All charging voltages noted below will be for 12V batteries at 25˚C.

9.1 Sealed Batteries

The general class of sealed batteries suitable for solar systems are called VRLA (Valve Regulated Lead-Acid) batteries. The two main characteristics of VRLA batteries are electrolyte immobilization and oxygen recombination. As the battery recharges, gassing is limited and is recombined to minimize the loss of water.

The two types of VRLA batteries most often used in solar are AGM and Gel.

AGM:
Absorbed Glass Mat batteries are still considered to be a "wet cell" because the electrolyte is retained in fiberglass mats between the plates. Some newer AGM battery designs recommend constant voltage charging to 2.45 volts/cell (14.7V). For cycling applications, charging to 14.4V or 14.5V is often recommended.

AGM batteries are better suited to low discharge applications than daily cycling. These batteries should not be equalized since gassing can be vented which causes the battery to dry out. There is also a potential for thermal runaway if the battery gets too hot, and this will destroy the battery. AGM batteries are affected by heat, and can lose 50% of their service life for every 8˚C (15˚F) over 25˚C (77˚F).

It is very important not to exceed the gas recombination capabilities of the AGM. The optimum charging temperature range is from 5 to 35˚C (40 to 95˚F).

Gel:
Gel batteries have characteristics similar to AGM, except a silica additive immobilizes the electrolyte to prevent leakage from the case. And like AGM, it is important to never exceed the manufacturer's maximum charging voltages. Typically, a gel battery is recharged in cycling applications from 14.1V to 14.4V. The gel design is very sensitive to overcharging.

For both AGM and Gel batteries, the goal is for 100% recombination of gasses so that no water is lost from the battery. True equalizations are never done, but a small boost charge may be needed to balance the individual cell voltages.

Other Sealed Batteries:
Automotive and "maintenance-free" batteries are also sealed. However, these are not discussed here because they have very poor lifetimes in solar cycling applications.

☞ ***NOTE: Consult the battery manufacturer for the recommended solar charging settings for the battery being used.***

9.2 Flooded Batteries

Flooded (vented) batteries are preferred for larger cycling solar systems. The advantages of flooded batteries include:

- ability to add water to the cells
- deep cycle capability
- vigorous recharging and equalization
- long operating life

In cycling applications, flooded batteries benefit from vigorous charging and equalization cycles with significant gassing. Without this gassing, the heavier electrolyte will sink to the bottom of the cell and lead to stratification. This is especially true with tall cells. Hydrocaps can be used to limit the gassing water loss.

Note that a 4% mixture of hydrogen in air is explosive if ignited. Make certain the battery area is well ventilated.

Typical equalization voltages for flooded batteries are from 15.3 volts to 16 volts. However, a solar system is limited to what the solar array can provide. If the equalization voltage is too high, the array I-V curve may go over the "knee" and sharply reduce the charging current.

Lead-Calcium:
Calcium batteries charge at lower voltages (14.2 to 14.4 typically) and have strong advantages in constant voltage or float applications. Water loss can be only 1/10th of antimony cells. However, calcium plates are not as suitable for cycling applications.

Lead-Selenium:
These batteries are similar to calcium with low internal losses and very low water consumption throughout their life. Selenium plates also have poor cycling life.

Lead-Antimony:
Antimony cells are rugged and provide long service life with deep discharge capability. However, these batteries self-discharge much faster and the self-discharging increases up to five times the initial rate as the battery ages. Charging the antimony battery is typically from 14.4V to 15.0V, with a 120% equalization overcharge. While the water loss is low when the battery is new, it will increase by five times over the life of the battery.

There are also combinations of plate chemistries that offer beneficial tradeoffs. For example, low antimony and selenium plates can offer fairly good cycling performance, long life, and reduced watering needs.

☞ ***NOTE: Consult the battery manufacturer for the recommended solar charging settings for the battery being used.***

9.3 L-16 Cells

One particular type of flooded battery, the L-16 group, is often used in larger solar systems. The L-16 offers good deep-cycle performance, long life, and low cost.

The L-16 battery has some special charging requirements in a solar system. A study found that nearly half of the L-16 battery capacity can be lost if the regulation voltage is too low and the time between finish-charges is too long. One standard charging program in the TriStar is specifically for L-16 batteries, and it provides for higher charging voltages and more frequent equalizations. Additional equalizations can also be done manually with the pushbutton.

A good reference for charging L-16 batteries is a Sandia National Labs report (year 2000) titled "PV Hybrid Battery Tests on L-16 Batteries." Website: www.sandia.gov/pv.

☞ ***NOTE: The best charging algorithm for flooded, deep-cycle batteries depends on the normal depth-of-discharge, how often the battery is cycled, and the plate chemistry. Consult the battery manufacturer for the recommended solar charging settings for the battery being used.***

10.0 Warranty

LIMITED WARRANTY
The TriStar-45 and TriStar-60 controllers are warranted to be free from defects in material and workmanship for a period of FIVE (5) years from the date of shipment to the original end user. Morningstar will, at its option, repair or replace any such defective products.

CLAIM PROCEDURE
Before requesting warranty service, check the Operator's Manual to be certain that there is a fault with the controller. Return the defective product to your authorized Morningstar distributor with shipping charges prepaid. Provide proof of date and place of purchase.

To obtain service under this warranty, the returned products must include the model, serial number and detailed reason for the failure, the panel type, array size, type of batteries and system loads. This information is critical to a rapid disposition of your warranty claim.

Morningstar will pay the return shipping charges if the repairs are covered by the warranty.

WARRANTY EXCLUSIONS AND LIMITATIONS
This warranty does not apply under the following conditions:

- Damage by accident, negligence, abuse or improper use.
- PV or load currents exceeding the ratings of the product.
- Unauthorized product modification or attempted repair
- Damage occurring during shipment

THE WARRANTY AND REMEDIES SET FORTH ABOVE ARE EXCLUSIVE AND IN LIEU OF ALL OTHERS, EXPRESS OR IMPLIED. MORNINGSTAR SPECIFICALLY DISCLAIMS ANY AND ALL IMPLIED WARRANTIES, INCLUDING, WITHOUT LIMITATION, WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. No Morningstar distributor, agent or employee is authorized to make any modification or extension to this warranty.

MORNINGSTAR IS NOT RESPONSIBLE FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES OF ANY KIND, INCLUDING BUT NOT LIMITED TO LOST PROFITS, DOWNTIME, GOODWILL OR DAMAGE TO EQUIPMENT OR PROPERTY.

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Email: info@morningstarcorp.com
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11.0 Technical Specifications

ELECTRICAL

• System voltage ratings	12, 24, 48 Vdc
• Current ratings — **Battery Charge Control**	
TS-45:	45 A
TS-60:	60 A
• Current ratings — **Load Control**	
TS-45:	45 A
TS-60:	60 A
• Current ratings — **Diversion Charge Control**	
TS-45:	45 A diversion load
TS-60:	60 A diversion load
• Accuracy	12/24V: ≤ 0.1 % ± 50 mV 48V: ≤ 0.1 % ± 100 mV
• Min. voltage to operate	9 V
• Max. solar array Voc	125 V
• Max. operating voltage	68 V
• Self-consumption	less than 20 mA
• High temp shutdown	95°C disconnect solar 90°C disconnect load / diversion load 70°C reconnect solar / load / diversion load
• Solar high voltage disconnect	highest equalization + 0.2V
HVD reconnect	13.0V
• Transient surge protection:	
pulse power rating	4500 watts
response	< 5 nanosec

BATTERY CHARGING / RTS

• Charge algorithm:	PMW, constant voltage
• Temp comp. coefficient	–5mV/°C/cell (25°C ref)
• Temp comp. range:	–30°C to +80°C
• Temp comp. setpoints	PWM, float, equalize, HVD (with RTS option)

BATTERY CHARGING STATUS LED's

G	13.3 to PWM
G/Y	13.0 to 13.3 V
Y	12.65 to 13.0 V
Y/R	12.0 to 12.65 V
R	0 to 12.0 V

Note: Multiply x 2 for 24V systems, x 4 for 48V systems

Note: The LED indications are for charging a battery. When discharging, the LED's will typically be Y/R or R.

MECHANICAL

• Dimensions (mm/inch)	H: 260.4 mm / 10.25 inch W: 127.0 mm / 5.0 inch D: 71.0 mm / 2.8 inch
• Weight (kg/lb)	1.6 kg / 3.5 lb
• Power terminals:	compression connector lug
largest wire	35 mm^2 / 2 AWG
smallest wire	2.5 mm^2 / 14 AWG
• Terminal wire slot	8.2 mm / 0.324 in wide 9.4 mm / 0.37 in high
• Knockout sizes	1 and 1.25 inch
• Torque terminals	5.65 Nm / 50 in-lb
• RTS / Sense terminals:	
wire sizes	1.0 to 0.25 mm^2 / 16 to 24 AWG
torque	0.40 Nm / 3.5 in-lb

ENVIRONMENTAL

• Ambient temperature	–40 to +45°C
• Storage temperature	–55 to +85°C
• Humidity	100% (NC)
• Enclosure	Type 1 (Indoor & vented), powder coated steel

Specifications subject to change without notice.
Designed in the U.S.A.
Assembled in Taiwan.

CE

MS-ZMAN-TS01-A (MAY 03)

11.0

Appendix 1 — Load Control DIP Switch Settings

The **Load Control** functions that can be adjusted with the DIP switches follow:

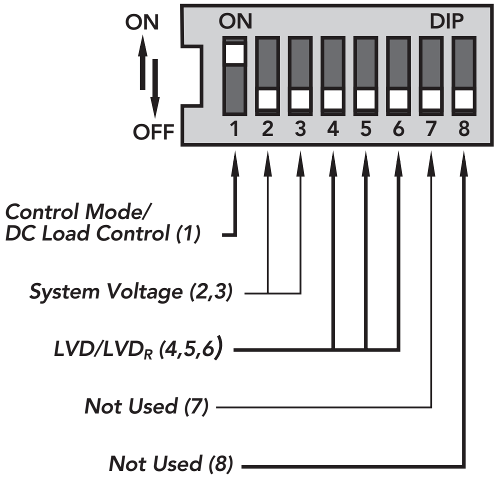

Figure 2.3 - Step 3 (Load) DIP Switch Functions

As shown in the diagram, all the positions are in the "OFF" position except switch number 1, which is in the "ON" position.

NOTE: The DIP switches should be changed only when there is no power to the controller. Turn off disconnect switches and remove power to the controller before changing a DIP switch. A fault will be indicated if a switch is changed with the controller powered.

CAUTION: The TriStar is shipped with all the switches in the "OFF" position. Each switch position must be confirmed during installation. A wrong setting could cause damage to the load or other system components.

The DIP switch settings described below are for **Load Control** only.

The DIP switches are shipped in the OFF position. With switches 2-8 in the OFF position, the following functions are present:

Switch	Function
1	Must be "ON" for Load Control
2, 3	Auto voltage select
4, 5, 6	Lowest LVD = 11.1V
7	Not used (selects diversion mode)
8	Not used

To configure your TriStar for the Load Control you require, follow the DIP switch adjustments described below. To change a switch from OFF to ON, slide the switch up toward the top of the controller. Make sure each switch is fully in the ON or OFF position.

DIP Switch Number 1 - Control Mode: Load Control

Control	Switch 1
Charging	Off
Load	On

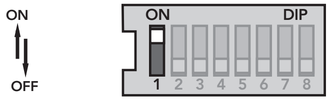

Figure 2.3 - Step 3 DIP Switch #1

For the Load Control mode, move the DIP switch to the ON position as shown.

DIP Switches Number 2,3 - System Voltage:

Voltage	Switch 2	Switch 3
Auto	Off	Off
12	Off	On
24	On	Off
48	On	On

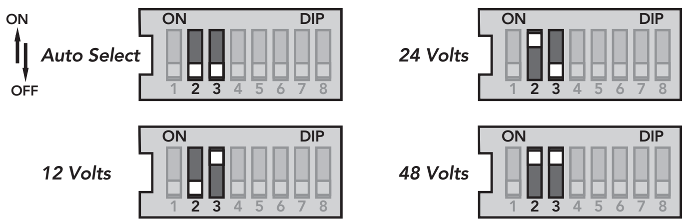

Figure 2.3 - Step 3 DIP Switches # 2,3

The auto voltage selection occurs when the battery is connected and the TriStar starts-up. There should be no loads on the battery that might cause a discharged battery to indicate a lower system voltage.

The DIP switch selectable voltages are for 12V, 24V or 48V lead-acid batteries. Although the "auto voltage" selection is very dependable, it is recommended to use the DIP switches to secure the correct system voltage.

DIP Switches Number 4,5,6 - Load Control Algorithm:

LVD	Switch 4	Switch 5	Switch 6
11.1	Off	Off	Off
11.3	Off	Off	On
11.5	Off	On	Off
11.7	Off	On	On
11.9	On	Off	Off
12.1	On	Off	On
12.3	On	On	Off
Custom	On	On	On

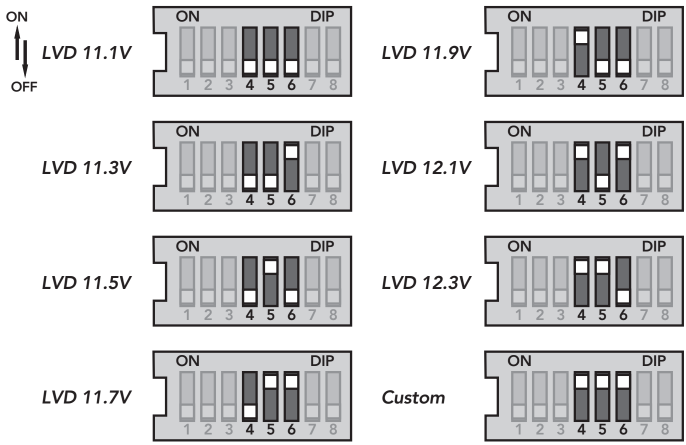

Figure 2.3 - Step 3 DIP Switch # 4,5,6

Select one of the 7 standard load control algorithms, or select the "custom" DIP switch for special custom settings using the PC software.

Refer to Section 5.1 for the 7 standard LVD settings, LVD_R reconnect settings, and current compensation values.

DIP Switch Number 7 - Must be OFF:

Switch 7
Off

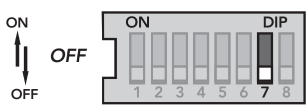

Figure 2.3 - Step 3 DIP Switch # 7

In the Load Control mode, DIP switch #7 must be in the OFF position.

DIP Switch Number 8 - Must be OFF:

Switch 8
Off

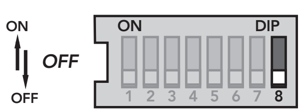

Figure 2.3 - Step 3 DIP Switch # 8

In the Load Control mode, DIP switch #8 must be in the OFF position.

☞ ***NOTE: Confirm all dip-switch settings before going to the next installation steps.***

Appendix 2 - Diversion Charge Control DIP Switch Settings

The **Diversion Charge Control** functions that can be adjusted with the DIP switches follow:

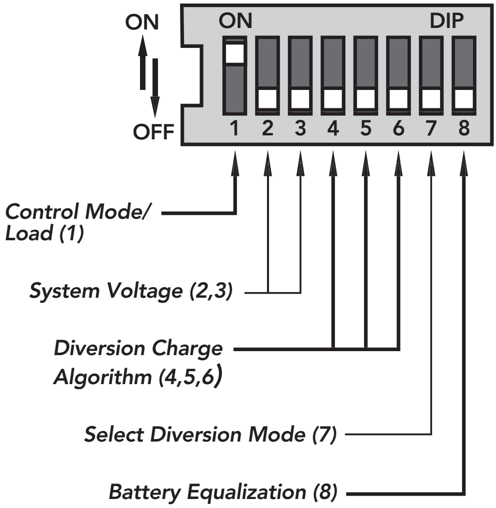

Figure 2.3 - Step 3 (Diversion) DIP Switch Functions

As shown in the diagram, all the positions are in the "OFF" position except switch number 1, which is in the "ON" position.

NOTE: The DIP switches should be changed only when there is no power to the controller. Turn off disconnect switches and remove all power to the controller before changing a DIP switch. A fault will be indicated if a switch is changed with the controller powered.

CAUTION: The TriStar is shipped with all the switches in the "OFF" position. Each switch position must be confirmed during installation. A wrong setting could cause damage to the battery or other system components.

The DIP switch settings described below are for **Diversion Charge Control** only.

The DIP switches are shipped in the OFF position. With switches 2-8 in the OFF position, the following functions are present:

Switch	Function
1	Must be "ON" (load control)
2, 3	Auto voltage select
4, 5, 6	Lowest battery charging voltage
7	Must turn "ON" to select Diversion
8	Manual Equalization

Appendices

To configure your TriStar for the diversion battery charging and control you require, follow the DIP switch adjustments described below. To change a switch from OFF to ON, slide the switch up toward the top of the controller. Make sure each switch is fully in the ON or OFF position.

DIP Switch Number 1 - Control Mode: Solar Battery Charging

Control	Switch 1
Charging	Off
Load	On

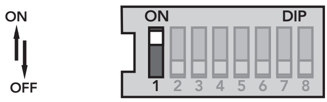

Figure 2.3 - Step 3 DIP Switch #1

For the Diversion Charge Control mode, move the DIP switch to the ON position as shown.

DIP Switches Number 2,3 - System Voltage:

Voltage	Switch 2	Switch 3
Auto	Off	Off
12	Off	On
24	On	Off
48	On	On

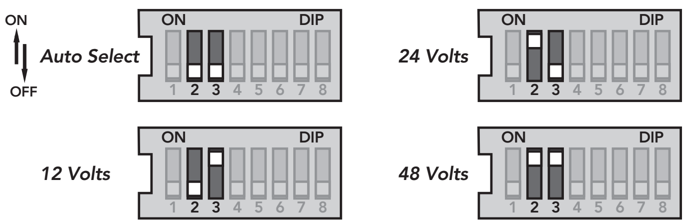

Figure 2.3 - Step 3 DIP Switches # 2,3

The auto voltage selection occurs when the battery is connected and the TriStar starts-up. There should be no loads on the battery that might cause a discharged battery to indicate a lower system voltage.

The DIP switch default voltages are for 12V, 24V or 48V lead-acid batteries. Although the "auto voltage" selection is very dependable, it is recommended to use the DIP switches to secure the correct system voltage.

DIP Switches Number 4,5,6 - Diversion Charge Control:

Battery Type	PWM	Switch 4	Switch 5	Switch 6
1	13.7	Off	Off	Off
2	13.9	Off	Off	On
3	14.1	Off	On	Off
4	14.3	Off	On	On
5	14.5	On	Off	Off
6	14.7	On	Off	On
7	14.9	On	On	Off
8	Custom	On	On	On

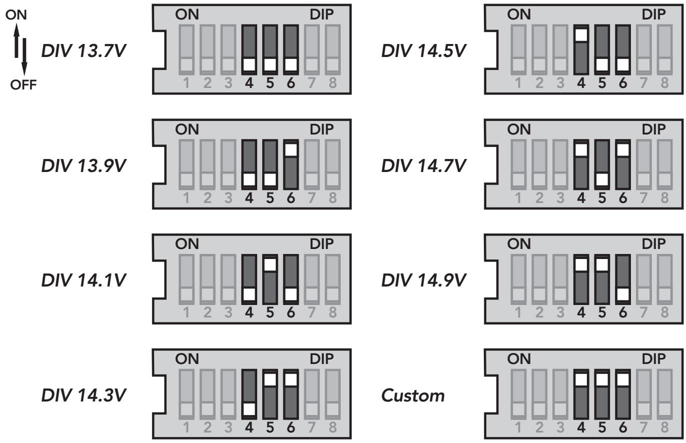

Figure 2.3 - Step 3 DIP Switches # 4,5,6

Select one of the 7 standard diversion charging algorithms, or select the "custom" DIP switch for special custom settings using the PC software.

Refer to Section 6.3 for information describing the 7 standard diversion charging algorithms. Refer to Section 9.0 of this manual for battery charging information.

DIP Switch Number 7 - Select Diversion:

Switch 7
On

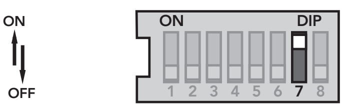

Figure 2.3 - Step 3 DIP Switch # 7

In the Diversion Charge Control mode, DIP switch #7 must be in the ON position.

DIP Switch Number 8 - Battery Equalization:

Equalize	Switch 8
Manual	Off
Auto	On

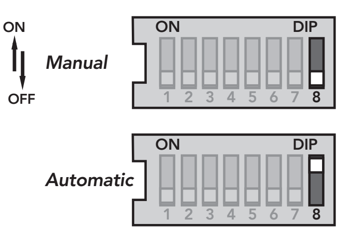

Figure 2.3 - Step 3 DIP Switch # 8

In the Auto Equalization mode (switch #8 On), battery equalization will automatically start and stop according to the battery program selected by the DIP switches 4,5,6 above. See Section 6.0 for detailed information about each standard diversion battery charging algorithm and equalization.

In the Manual Equalization mode (switch #8 Off), equalization will occur only when manually started with the pushbutton. Automatic starting of equalization is disabled. The equalization will automatically stop per the battery algorithm selection.

In both cases (auto and manual mode), the pushbutton can be used to start and stop battery equalization.

☞ ***NOTE: Confirm all dip-switch settings before going to the next installation steps.***

Appendix 3 - LED Indications

LED Display Explanation:

G = green LED is lit
Y = yellow LED is lit
R = red LED is lit
G/Y = Green and Yellow are both lit at the same time
G/Y - R = Green & Yellow both lit, then Red is lit alone
Sequencing (faults) has the LED pattern repeating until the fault is cleared

1. General Transitions:

• Controller start-up	G - Y - R (one cycle)
• Pushbutton transitions	blink all 3 LED's 2 times
• Battery service is required	all 3 LED's blinking until service is reset

2. Battery Status

• General state-of-charge	*see battery SOC indications below*
• PWM absorption	G blinking (1/2 second on / 1/2 second off)
• Equalization state	G fast blink (2 to 3 times per second)
• Float state	G slow blink (1 second on / 1 second off)

Battery State-of-Charge LED Indications (when battery is charging):

• G on	80% to 95% SOC
• G/Y on	60% to 80% SOC
• Y on	35% to 60% SOC
• Y/R on	0% to 35% SOC
• R on	battery is discharging

LOAD CONTROL

2. Load Status

LED	Transition	12V	24V	48V
G				
G/Y	LVD+	0.60V	1.20V	2.40V
Y	LVD+	0.45V	0.90V	1.80V
Y/R	LVD+	0.30V	0.60V	1.20V
R-Blinking	LVD+	0.15V	0.30V	0.60V
R-LVD	LVD			

The load status LED's are determined by the LVD voltage plus the specified transition voltages. As the battery voltage rises or falls, each voltage transition will cause a change in the LED's.

3. Faults & Alarms

• Short circuit - solar/load	R/G - Y sequencing
• Overload - solar/load	R/Y - G sequencing
• Over-temperature	R - Y sequencing
• High voltage disconnect	R - G sequencing
• Reverse polarity - battery	no LED's are lighted
• Reverse polarity - solar	No fault indication
• DIP switch fault	R - Y - G sequencing
• Self-test faults	R - Y - G sequencing
• Temperature probe (RTS)	R/Y - G/Y sequencing
• Battery voltage sense	R/Y - G/Y sequencing

ATTACHMENT E

EXCEL SPREADSHEETS

Page Trowbridge Ranch Landfill SVE Systems
Calculation of Average Monthly Insolation Conditions - Tucson

	Average Daily Insolation[1] - Horizontal Surface - Tucson					Full Sun-Hours Equivalent[3]		
	Langleys[2]				Watt-Hours / M[2]	Horizontal Surface[4]	Fixed:+15,-15,+15[4]	Fixed:+15,-15,+15[5]
Month	**2007**	**2006**	**2005**	**3 YR Ave**	**3 YR Ave**	**Tucson**	**Tucson**	**3 YR Ave**
Jan	300	323	257	293	3,411	3.4	5.9	5.92
Feb	398	381	295	358	4,164	4.4	6.4	6.06
Mar	538	439	474	484	5,625	5.6	6.6	6.63
Apr	645	608	603	619	7,195	7.1	7.5	7.60
May	**704**	**728**	**658**	**697**	**8,102**	**7.9**	**7.8**	**8.00**
Jun	736	652	681	690	8,021	8.1	7.8	7.72
Jul	584	565	596	582	6,765	7.1	6.9	6.57
Aug	**521**	**516**	**544**	**527**	**6,129**	**6.7**	**6.9**	**6.31**
Sep	509	478	497	495	5,753	6.0	6.6	6.33
Oct	428	417	423	423	4,916	5.0	6.8	6.69
Nov	333	372	347	351	4,078	3.8	6.2	6.65
Dec	288	297	286	290	3,377	3.2	5.6	5.91

1. "http://ag.arizona.edu/azmet/data/" for Tucson

2. "X" watt-hours / M^2 * 0.0860 = "Y" Langleys
   1 Langley = 11.63 Watt-Hours / M^2

3. Sun-Hour Equivalent = 1000 Watt-Hours/M^2
4. NREL data for Tucson (WBAN No. 23160).
5. AZMET data (horizontal surface) adjusted for respective solar panel mounting device using NREL data ratios as proportionality factors, expressed as full sun-hours equiv.

PAGE TROWBRIDGE RANCH LANDFILL

Month	Parameter		5:00 AM	6:00 AM	7:00 AM	8:00 AM	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM	3:00 PM	4:00 PM	5:00 PM	6:00 PM	7:00 PM	8:00 PM	9:00 PM	10:00 PM	11:00 PM	12:00 PM	TOTALS
Jan	Solar Power Available to Charge Controllers (W)[1]	Absorb Current	0	0	19	907	1,857	2,658	3,109	3,289	3,347	2,664	2,008	1,332	84	0	0	0	0	0	0	0	21,374
	Solar Power Output from Charge Controllers (W)[2]	Limit	1	1	20	879	1,895	2,574	3,010	3,185	3,241	2,580	1,945	1,291	82	1	1	1	1	1	1	1	20,710
	Current Output from Charge Controllers (A)[3]	125	0.0	0.0	0.8	34.9	72.4	96.8	113.7	119.8	121.2	96.3	73.1	50.8	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Net Current to (+) / from (-) Battery Array (A)[4]		0.0	0.0	0.8	34.9	72.4	30.3	30.6	36.7	38.0	13.2	-10.1	-32.3	-79.9	-83.1	-41.5	0.0	0.0	0.0	0.0	0.0	
	Battery Array Charge / Discharge Time (H)[5]		48662	48820	1783	26	12	31	30	25	24	77	104	29	10	10	22	46662	48503	48503	48504	48504	
	Battery Array Charge, 448 AH Min at 24 H (AH)[6]		658	658	659	689	755	783	811	845	880	893	883	850	767	681	637	637	637	637	637	658	
	Battery Array State of Charge (% of 24 H Rating)[7]		73%	73%	74%	77%	84%	87%	91%	94%	98%	100%	99%	95%	86%	76%	71%	71%	71%	71%	71%	73%	
	Battery Array Voltage at Rest, 26.7 V Max @ >25C / 25.2 V Min (V)[8]	Absorb Voltage	25.2	25.2	25.2	25.3	25.6	25.7	25.8	25.9	25.9	26.0	26.0	25.8	25.5	25.2	25.1	25.1	25.1	25.1	25.1	25.2	
	Battery Array Running Voltage Change from Rest (V)[9]	Setpoint	0.00	0.00	0.00	0.82	1.01	0.78	0.79	0.83	0.84	0.62	-0.57	-0.80	-1.04	-1.05	-0.86	0.00	0.00	0.00	0.00	0.00	
	Load Voltage (24.2 V Min) or Charge Voltage[10]	28.7	25.2	25.2	25.2	26.2	26.6	26.5	26.6	26.7	26.6	26.6	25.4	25.0	24.5	24.2	24.2	25.1	25.1	25.1	25.1	25.2	
	Blowers Operating Time (H)		0	0	0	0	0	0.8	1	1	1	1	1	1	1	1	0.5	0	0	0	0	0	9.3
Feb	Solar Power Available to Charge Controllers (W)[1]	Absorb Current	0	0	172	1,090	2,109	2,785	2,820	3,223	2,933	2,566	2,074	1,298	474	0	0	0	0	0	0	0	21,544
	Solar Power Output from Charge Controllers (W)[2]	Limit	1	1	167	1,056	2,043	2,697	2,731	3,121	2,840	2,485	2,008	1,257	460	1	1	1	1	1	1	1	20,875
	Current Output from Charge Controllers (A)[3]	120	0.0	0.0	6.6	40.9	77.7	101.4	103.5	117.9	106.4	93.4	75.9	49.6	18.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Net Current to (+) / from (-) Battery Array (A)[4]		0.0	0.0	6.6	40.9	61.1	18.2	20.4	34.8	23.2	10.3	-7.3	-33.6	-64.7	-83.1	-41.5	0.0	0.0	0.0	0.0	0.0	
	Battery Array Charge / Discharge Time (H)[5]		48769	48931	166	22	14	54	48	26	41	102	149	27	13	10	22	46612	48453	48453	48454	48454	
	Battery Array Charge, 448 AH Min at 24 H (AH)[6]		672	672	678	715	770	787	806	838	859	869	862	827	761	674	631	631	631	631	631	672	
	Battery Array State of Charge (% of 24 H Rating)[7]		75%	75%	76%	80%	86%	88%	90%	93%	96%	97%	96%	92%	85%	75%	70%	70%	70%	70%	70%	75%	
	Battery Array Voltage at Rest, 26.6 V Max @ >25C / 25.2 V Min (V)[8]	Absorb Voltage	25.3	25.3	25.3	25.4	25.6	25.7	25.8	25.9	25.9	25.9	25.9	25.8	25.5	25.2	25.1	25.1	25.1	25.1	25.1	25.2	
	Battery Array Running Voltage Change from Rest (V)[9]	Setpoint	0.00	0.00	0.51	0.86	0.96	0.68	0.70	0.82	0.73	0.57	-0.52	-0.81	-0.98	-1.05	-0.86	0.00	0.00	0.00	0.00	0.00	
	Load Voltage (24.2 V Min) or Charge Voltage[10]	28.6	25.3	25.3	25.8	26.3	26.6	26.4	26.5	26.7	26.6	26.5	25.4	24.9	24.5	24.2	24.2	25.1	25.1	25.1	25.1	25.2	
	Blowers Operating Time (H)		0	0	0	0	0.2	1	1	1	1	1	1	1	1	1	0.5	0	0	0	0	0	9.7
Mar	Solar Power Available to Charge Controllers (W)[1]	Absorb Current	0	12	511	1,308	2,137	2,752	3,013	3,208	3,116	2,653	2,129	1,519	809	0	0	0	0	0	0	0	23,167
	Solar Power Output from Charge Controllers (W)[2]	Limit	1	13	496	1,268	2,070	2,665	2,918	3,106	3,018	2,569	2,062	1,471	784	1	1	1	1	1	1	1	22,446
	Current Output from Charge Controllers (A)[3]	120	0.0	0.5	19.6	48.7	78.4	100.2	110.5	116.8	112.8	96.1	77.5	57.7	31.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Net Current to (+) / from (-) Battery Array (A)[4]		0.0	0.5	19.6	48.7	53.4	17.0	27.4	33.6	29.6	12.9	-5.7	-25.4	-52.0	-83.1	-66.5	0.0	0.0	0.0	0.0	0.0	
	Battery Array Charge / Discharge Time (H)[5]		48769	2957	50	18	16	58	34	27	31	79	198	37	17	10	13	46519	48628	48628	48629	48629	
	Battery Array Charge, 448 AH Min at 24 H (AH)[6]		672	672	690	734	783	798	823	855	882	894	889	863	809	723	654	654	654	654	654	672	
	Battery Array State of Charge (% of 24 H Rating)[7]		75%	75%	77%	82%	87%	89%	92%	95%	98%	100%	99%	96%	90%	81%	73%	73%	73%	73%	73%	75%	
	Battery Array Voltage at Rest, 26.6 V Max @ >25C / 25.2 V Min (V)[8]	Absorb Voltage	25.3	25.3	25.3	25.5	25.7	25.7	25.8	25.9	26.0	26.0	26.0	25.9	25.7	25.4	25.1	25.1	25.1	25.1	25.1	25.2	
	Battery Array Running Voltage Change from Rest (V)[9]	Setpoint	0.00	0.00	0.69	0.90	0.92	0.66	0.76	0.81	0.78	0.61	-0.48	-0.75	-0.92	-1.05	-0.98	0.00	0.00	0.00	0.00	0.00	
	Load Voltage (24.2 V Min) or Charge Voltage[10]	28.6	25.3	25.3	26.0	26.4	26.6	26.4	26.6	26.8	26.7	26.6	25.5	25.1	24.8	24.3	24.2	25.1	25.1	25.1	25.1	25.2	
	Blowers Operating Time (H)		0	0	0	0	0.3	1	1	1	1	1	1	1	1	1	0.8	0	0	0	0	0	10.1
Apr	Solar Power Available to Charge Controllers (W)[1]	Absorb Current	0	234	977	1,760	2,492	3,026	3,260	3,235	3,062	2,748	2,258	1,612	902	83	0	0	0	0	0	0	25,650
	Solar Power Output from Charge Controllers (W)[2]	Limit	1	228	947	1,705	2,413	2,930	3,157	3,133	2,965	2,661	2,186	1,562	874	81	1	1	1	1	1	1	24,849
	Current Output from Charge Controllers (A)[3]	120	0.0	9.0	36.6	64.9	90.7	111.9	119.0	117.3	110.6	100.0	81.8	59.9	34.6	3.3	0.0	0.0	0.0	0.0	0.0	0.0	
	Net Current to (+) / from (-) Battery Array (A)[4]		0.0	9.0	36.6	64.9	7.5	28.7	35.8	34.1	27.4	16.9	-1.3	-23.2	-48.5	-79.9	-74.8	0.0	0.0	0.0	0.0	0.0	
	Battery Array Charge / Discharge Time (H)[5]		48769	118	25	13	144	33	25	27	34	59	1000	41	18	10	11	46615	48797	48798	48798	48798	
	Battery Array Charge, 448 AH Min at 24 H (AH)[6]		672	680	713	772	779	805	838	870	895	911	909	886	836	754	676	676	676	676	676	672	
	Battery Array State of Charge (% of 24 H Rating)[7]		75%	76%	80%	86%	87%	90%	94%	97%	100%	102%	102%	99%	93%	84%	75%	75%	75%	75%	75%	75%	
	Battery Array Voltage at Rest, 26.4 V Max @ >25C / 24.2 V Min (V)[8]	Absorb Voltage	25.3	25.3	25.4	25.6	25.7	25.8	25.9	26.0	26.0	26.1	26.0	26.0	25.8	25.5	25.2	25.2	25.2	25.2	25.2	25.2	
	Battery Array Running Voltage Change from Rest (V)[9]	Setpoint	0.00	0.55	0.83	0.98	0.52	0.77	0.82	0.81	0.61	0.66	0.00	-0.73	-0.90	-1.04	-1.02	0.00	0.00	0.00	0.00	0.00	
	Load Voltage (24.2 V Min) or Charge Voltage[10]	28.4	25.3	25.9	26.3	26.6	26.2	26.5	26.7	26.8	26.6	26.7	26.0	25.2	24.9	24.5	24.2	25.2	25.2	25.2	25.2	25.2	
	Blowers Operating Time (H)		0	0	0	0	1	1	1	1	1	1	1	1	1	1	0.9	0	0	0	0	0	10.9
May	Solar Power Available to Charge Controllers (W)[1]	Absorb Current	7	460	1,155	1,837	2,466	2,827	3,148	3,234	3,105	2,814	2,238	1,509	953	166	0	0	0	0	0	0	25,918
	Solar Power Output from Charge Controllers (W)[2]	Limit	7	446	1,119	1,779	2,388	2,737	3,048	3,131	3,007	2,725	2,167	1,462	924	161	1	1	1	1	1	1	25,109
	Current Output from Charge Controllers (A)[3]	120	0.3	17.7	43.2	67.8	89.8	104.8	115.4	117.7	112.5	102.0	81;3	56.3	36.8	6.5	0.0	0.0	0.0	0.0	0.0	0.0	
	Net Current to (+) / from (-) Battery Array (A)[4]		0.3	17.7	43.2	67.8	6.7	21.6	32.3	34.6	29.3	18.9	-1.9	-26.9	-46.4	-76.7	-66.5	0.0	0.0	0.0	0.0	0.0	
	Battery Array Charge / Discharge Time (H)[5]		5252	56	21	13	165	45	29	26	32	52	662	35	19	11	13	46622	48731	48731	48731	48732	
	Battery Array Charge, 448 AH Min at 24 H (AH)[6]		644	659	698	760	766	786	815	847	875	892	890	863	816	736	667	667	667	667	667	644	
	Battery Array State of Charge (% of 24 H Rating)[7]		72%	74%	78%	85%	86%	88%	91%	95%	98%	100%	99%	96%	91%	82%	74%	74%	74%	74%	74%	72%	
	Battery Array Voltage at Rest, 26.2 V Max @ >25C / 24.2 V Min (V)[8]	Absorb Voltage	25.2	25.2	25.4	25.6	25.6	25.7	25.8	25.9	25.9	26.0	26.0	25.9	25.7	25.4	25.2	25.2	25.2	25.2	25.2	25.1	
	Battery Array Running Voltage Change from Rest (V)[9]	Setpoint	0.00	0.67	0.87	0.99	0.51	0.71	0.80	0.81	0.78	0.68	0.00	-0.76	-0.89	-1.02	-0.98	0.00	0.00	0.00	0.00	0.00	
	Load Voltage (24.2 V Min) or Charge Voltage[10]	28.2	25.2	25.9	26.2	26.6	26.1	26.4	26.6	26.7	26.7	26.7	26.0	25.1	24.8	24.4	24.2	25.2	25.2	25.2	25.2	25.1	
	Blowers Operating Time (H)		0	0	0	0	1	1	1	1	1	1	1	1	1	1	0.8	0	0	0	0	0	10.8
Jun	Solar Power Available to Charge Controllers (W)[1]	Absorb Current	21	458	1,067	1,649	2,198	2,603	2,842	3,008	2,777	2,506	2,065	1,554	963	496	0	0	0	0	0	0	24,209
	Solar Power Output from Charge Controllers (W)[2]	Limit	21	444	1,034	1,597	2,129	2,521	2,753	2,913	2,690	2,426	2,000	1,505	933	482	1	1	1	1	1	1	23,454
	Current Output from Charge Controllers (A)[3]	120	0.9	17.6	39.7	60.7	80.0	99.8	104.4	110.0	101.0	91.5	75.7	59.5	37.3	19.5	0.0	0.0	0.0	0.0	0.0	0.0	
	Net Current to (+) / from (-) Battery Array (A)[4]		0.9	17.6	39.7	60.7	-3.2	16.7	21.2	26.8	17.8	8.4	-7.4	-23.7	-45.9	-63.7	-58.2	0.0	0.0	0.0	0.0	0.0	
	Battery Array Charge / Discharge Time (H)[5]		1620	56	23	14	372	59	46	35	55	128	146	40	19	13	15	46599	48628	48628	48628	48629	
	Battery Array Charge, 448 AH Min at 24 H (AH)[6]		672	687	723	779	776	790	810	834	851	859	851	827	780	714	654	654	654	654	654	672	
	Battery Array State of Charge (% of 24 H Rating)[7]		75%	77%	81%	87%	87%	88%	90%	93%	95%	96%	95%	92%	87%	80%	73%	73%	73%	73%	73%	75%	
	Battery Array Voltage at Rest, 26.0 V Max @ >25C / 24.2 V Min (V)[8]	Absorb Voltage	25.3	25.3	25.5	25.7	25.7	25.7	25.8	25.9	25.8	25.9	25.8	25.8	25.6	25.4	25.1	25.1	25.1	25.1	25.1	25.2	
	Battery Array Running Voltage Change from Rest (V)[9]	Setpoint	0.00	0.67	0.85	0.96	-0.41	0.66	0.71	0.76	0.67	0.54	-0.52	-0.73	-0.88	-0.97	-0.95	0.00	0.00	0.00	0.00	0.00	
	Load Voltage (24.2 V Min) or Charge Voltage[10]	28.0	25.3	26.0	26.3	26.6	25.2	26.4	26.5	26.6	26.5	26.4	25.3	25.0	24.7	24.4	24.2	25.1	25.1	25.1	25.1	25.2	
	Blowers Operating Time (H)		0	0	0	0	1	1	1	1	1	1	1	1	1	1	0.7	0	0	0	0	0	10.7
Jul	Solar Power Available to Charge Controllers (W)[1]	Absorb Current	3	318	822	1,425	1,886	2,364	2,603	2,644	2,443	2,116	1,647	1,172	784	388	0	0	0	0	0	0	20,614
	Solar Power Output from Charge Controllers (W)[2]	Limit	4	309	797	1,381	1,827	2,289	2,521	2,560	2,366	2,050	1,595	1,135	760	376	1	1	1	1	1	1	19,975
	Current Output from Charge Controllers (A)[3]	120	0.2	12.2	30.7	52.7	68.9	86.0	96.4	96.9	89.4	78.0	63.1	45.4	30.8	15.4	0.0	0.0	0.0	0.0	0.0	0.0	
	Net Current to (+) / from (-) Battery Array (A)[4]		0.2	12.2	30.7	52.7	43.9	2.9	13.2	13.8	6.2	-5.1	-20.1	-37.7	-52.4	-51.1	0.0	0.0	0.0	0.0	0.0	0.0	
	Battery Array Charge / Discharge Time (H)[5]		11002	84	30	17	20	421	77	74	178	220	48	24	17	17	46725	48680	48681	48681	48681	48681	
	Battery Array Charge, 448 AH Min at 24 H (AH)[6]		672	683	710	758	799	801	813	826	832	827	806	768	713	660	660	660	660	661	661	672	
	Battery Array State of Charge (% of 24 H Rating)[7]		75%	76%	79%	85%	89%	89%	91%	92%	93%	92%	90%	86%	80%	74%	74%	74%	74%	74%	74%	75%	
	Battery Array Voltage at Rest, 26.0 V Max @ >25C / 24.2 V Min (V)[8]	Absorb Voltage	25.3	25.3	25.4	25.6	25.7	25.8	25.8	25.8	25.8	25.8	25.7	25.5	25.3	25.2	25.2	25.2	25.2	25.2	25.2	25.2	
	Battery Array Running Voltage Change from Rest (V)[9]	Setpoint	0.00	0.60	0.79	0.92	0.87	0.40	0.62	0.62	0.50	-0.47	-0.70	-0.84	-0.92	-0.91	0.00	0.00	0.00	0.00	0.00	0.00	
	Load Voltage (24.2 V Min) or Charge Voltage[10]	28.0	25.3	25.9	26.2	26.5	26.6	26.1	26.4	26.5	26.3	25.3	25.0	24.7	24.4	24.2	25.2	25.2	25.2	25.2	25.2	25.2	
	Blowers Operating Time (H)		0	0	0	0	0.3	1	1	1	1	1	1	1	1	0.8	0	0	0	0	0	0	9.1
Aug	Solar Power Available to Charge Controllers (W)[1]	Absorb Current	0	185	755	1,365	1,922	2,363	2,649	2,632	2,318	2,039	1,832	1,297	785	78	0	0	0	0	0	0	20,219
	Solar Power Output from Charge Controllers (W)[2]	Limit	1	180	732	1,322	1,862	2,289	2,565	2,549	2,245	1,975	1,774	1,256	760	76	1	1	1	1	1	1	19,592
	Current Output from Charge Controllers (A)[3]	100	0.0	7.1	28.4	50.5	70.3	86.1	98.2	96.5	84.9	76.7	70.4	50.1	30.7	3.1	0.0	0.0	0.0	0.0	0.0	0.0	
	Net Current to (+) / from (-) Battery Array (A)[4]		0.0	7.1	28.4	50.5	45.4	2.9	15.0	13.3	1.7	-6.4	-12.8	-33.0	-52.4	-55.1	0.0	0.0	0.0	0.0	0.0	0.0	
	Battery Array Charge / Discharge Time (H)[5]		48769	153	33	17	20	416	67	76	730	172	80	28	17	16	46656	48654	48654	48654	48654	48655	
	Battery Array Charge, 448 AH Min at 24 H (AH)[6]		672	678	704	750	791	794	808	820	821	815	802	768	714	657	657	657	657	657	657	672	
	Battery Array State of Charge (% of 24 H Rating)[7]		75%	76%	79%	84%	88%	89%	90%	91%	92%	91%	90%	86%	80%	73%	73%	73%	73%	73%	73%	75%	
	Battery Array Voltage at Rest, 26.1 V Max @ >25C / 24.2 V Min (V)[8]	Absorb Voltage	25.3	25.3	25.4	25.6	25.7	25.7	25.8	25.8	25.7	25.7	25.7	25.5	25.4	25.1	25.1	25.1	25.1	25.1	25.1	25.2	
	Battery Array Running Voltage Change from Rest (V)[9]	Setpoint	0.00	0.52	0.77	0.91	0.88	0.40	0.64	0.62	0.00	-0.50	-0.61	-0.80	-0.92	-0.93	0.00	0.00	0.00	0.00	0.00	0.00	
	Load Voltage (24.2 V Min) or Charge Voltage[10]	28.1	25.3	25.8	26.2	26.5	26.6	26.1	26.4	26.4	25.7	25.2	25.1	24.7	24.4	24.2	25.1	25.1	25.1	25.1	25.1	25.2	
	Blowers Operating Time (H)		0	0	0	0	0.3	1	1	1	1	1	1	1	1	0.7	0	0	0	0	0	0	9.0
Sep	Solar Power Available to Charge Controllers (W)[1]	Absorb Current	0	78	706	1,465	2,065	2,622	2,725	2,721	2,531	2,231	1,768	1,137	487	11	0	0	0	0	0	0	20,545
	Solar Power Output from Charge Controllers (W)[2]	Limit	1	76	684	1,419	2,000	2,540	2,639	2,635	2,451	2,160	1,713	1,101	472	11	1	1	1	1	1	1	19,908
	Current Output from Charge Controllers (A)[3]	110	0.0	3.0	26.7	54.4	75.7	95.5	100.2	99.7	92.5	82.1	66.5	44.0	19.1	0.5	0.0	0.0	0.0	0.0	0.0	0.0	
	Net Current to (+) / from (-) Battery Array (A)[4]		0.0	3.0	26.7	54.4	50.7	12.4	17.1	16.5	9.4	-1.1	-16.7	-39.2	-64.0	-57.7	0.0	0.0	0.0	0.0	0.0	0.0	
	Battery Array Charge / Discharge Time (H)[5]		48662	397	35	16	17	83	58	60	113	1216	59	23	13	15	46551	48576	48576	48577	48577	48577	
	Battery Array Charge, 448 AH Min at 24 H (AH)[6]		658	661	684	734	780	792	807	822	831	830	813	773	707	647	647	647	647	647	647	658	
	Battery Array State of Charge (% of 24 H Rating)[7]		73%	74%	76%	82%	87%	88%	90%	92%	93%	93%	91%	86%	79%	72%	72%	72%	72%	72%	72%	73%	
	Battery Array Voltage at Rest, 26.1 V Max @ >25C / 24.2 V Min (V)[8]	Absorb Voltage	25.2	25.2	25.3	25.5	25.7	25.7	25.8	25.8	25.8	25.8	25.7	25.6	25.3	25.1	25.1	25.1	25.1	25.1	25.1	25.2	
	Battery Array Running Voltage Change from Rest (V)[9]	Setpoint	0.00	0.40	0.76	0.93	0.91	0.61	0.66	0.66	0.56	0.00	-0.66	-0.84	-0.97	-0.94	0.00	0.00	0.00	0.00	0.00	0.00	
	Load Voltage (24.2 V Min) or Charge Voltage[10]	28.1	25.2	25.6	26.1	26.4	26.6	26.3	26.4	26.5	26.3	25.8	25.0	24.7	24.4	24.2	25.1	25.1	25.1	25.1	25.1	25.2	
	Blowers Operating Time (H)		0	0	0	0	0.3	1	1	1	1	1	1	1	1	0.7	0	0	0	0	0	0	9.0
Oct	Solar Power Available to Charge Controllers (W)[1]	Absorb Current	0	9	665	1,598	2,358	2,936	3,382	3,154	2,854	2,440	1,853	1,147	77	0	0	0	0	0	0	0	22,473
	Solar Power Output from Charge Controllers (W)[2]	Limit	1	10	644	1,548	2,283	2,843	3,275	3,055	2,764	2,363	1,794	1,111	76	1	1	1	1	1	1	1	21,773
	Current Output from Charge Controllers (A)[3]	120	0.0	0.4	25.5	59.3	86.1	106.9	120.0	114.2	103.1	89.1	67.7	43.9	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Net Current to (+) / from (-) Battery Array (A)[4]		0.0	0.4	25.5	59.3	44.6	23.8	36.8	31.1	19.9	5.9	-15.4	-39.2	-80.1	-83.1	0.0	0.0	0.0	0.0	0.0	0.0	
	Battery Array Charge / Discharge Time (H)[5]		48769	3873	37	15	20	40	25	30	49	188	65	23	10	10	46531	48780	48780	48780	48781	48781	
	Battery Array Charge, 448 AH Min at 24 H (AH)[6]		672	672	695	748	789	811	845	874	893	898	883	843	760	673	673	673	673	673	674	672	
	Battery Array State of Charge (% of 24 H Rating)[7]		75%	75%	78%	84%	88%	91%	94%	98%	100%	100%	99%	94%	85%	75%	75%	75%	75%	75%	75%	75%	
	Battery Array Voltage at Rest, 26.3 V Max @ >25C / 24.2 V Min (V)[8]	Absorb Voltage	25.3	25.3	25.4	25.6	25.7	25.8	25.9	26.0	26.0	26.0	26.0	25.8	25.5	25.2	25.2	25.2	25.2	25.2	25.2	25.2	
	Battery Array Running Voltage Change from Rest (V)[9]	Setpoint	0.00	0.00	0.75	0.95	0.88	0.73	0.83	0.79	0.54	0.49	-0.65	-0.84	-1.04	-1.05	0.00	0.00	0.00	0.00	0.00	0.00	
	Load Voltage (24.2 V Min) or Charge Voltage[10]	28.3	25.3	25.3	26.1	26.5	26.6	26.5	26.7	26.8	26.5	26.5	25.3	25.0	24.5	24.2	25.2	25.2	25.2	25.2	25.2	25.2	
	Blowers Operating Time (H)		0	0	0	0	0.5	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	9.5
Nov	Solar Power Available to Charge Controllers (W)[1]	Absorb Current	0	0	344	1,350	2,310	3,038	3,405	3,546	3,411	2,671	1,897	988	0	0	0	0	0	0	0	0	22,960
	Solar Power Output from Charge Controllers (W)[2]	Limit	1	1	334	1,307	2,237	2,942	3,297	3,434	3,303	2,586	1,838	958	1	1	1	1	1	1	1	1	22,245
	Current Output from Charge Controllers (A)[3]	130	0.0	0.0	13.3	50.5	84.9	110.6	124.5	128.5	122.8	96.7	69.2	37.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Net Current to (+) / from (-) Battery Array (A)[4]		0.0	0.0	13.3	50.5	60.0	27.5	41.3	45.3	39.6	13.6	-14.0	-45.5	-83.1	-83.1	0.0	0.0	0.0	0.0	0.0	0.0	
	Battery Array Charge / Discharge Time (H)[5]		48662	48820	77	17	14	34	22	20	23	75	72	20	10	10	46672	48922	48922	48922	48922	48923	
	Battery Array Charge, 448 AH Min at 24 H (AH)[6]		658	658	670	715	770	795	833	875	912	925	911	864	778	692	692	692	692	692	692	658	
	Battery Array State of Charge (% of 24 H Rating)[7]		73%	73%	75%	80%	86%	89%	93%	98%	102%	103%	102%	96%	87%	77%	77%	77%	77%	77%	77%	73%	
	Battery Array Voltage at Rest, 26.4 V Max @ >25C / 24.2 V Min (V)[8]	Absorb Voltage	25.2	25.2	25.3	25.4	25.6	25.7	25.9	26.0	26.1	26.1	26.1	25.9	25.6	25.3	25.3	25.3	25.3	25.3	25.3	25.2	
	Battery Array Running Voltage Change from Rest (V)[9]	Setpoint	0.00	0.00	0.62	0.91	0.95	0.76	0.86	0.88	0.69	0.47	-0.63	-0.88	-1.05	-1.05	0.00	0.00	0.00	0.00	0.00	0.00	
	Load Voltage (24.2 V Min) or Charge Voltage[10]	28.4	25.2	25.2	25.9	26.3	26.6	26.5	26.7	26.9	26.7	26.6	25.4	25.0	24.5	24.2	25.3	25.3	25.3	25.3	25.3	25.2	
	Blowers Operating Time (H)		0	0	0	0	0.3	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	9.3
Dec	Solar Power Available to Charge Controllers (W)[1]	Absorb Current	0	0	70	1,015	2,113	2,879	3,319	3,549	3,268	2,630	1,819	721	0	0	0	0	0	0	0	0	21,382
	Solar Power Output from Charge Controllers (W)[2]	Limit	1	1	69	983	2,046	2,788	3,214	3,436	3,164	2,547	1,762	699	1	1	1	1	1	1	1	1	20,718
	Current Output from Charge Controllers (A)[3]	130	0.0	0.0	2.7	38.4	78.1	104.6	121.7	128.9	117.8	95.0	66.1	27.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Net Current to (+) / from (-) Battery Array (A)[4]		0.0	0.0	2.7	38.4	78.1	21.4	38.6	45.7	34.6	11.8	-17.0	-55.5	-83.1	-66.5	0.0	0.0	0.0	0.0	0.0	0.0	
	Battery Array Charge / Discharge Time (H)[5]		48662	48820	443	24	11	45	23	19	26	87	58	16	10	13	46701	48810	48810	48811	48811	48811	
	Battery Array Charge, 448 AH Min at 24 H (AH)[6]		658	658	660	695	766	785	821	863	895	906	890	833	747	677	677	677	677	677	677	658	
	Battery Array State of Charge (% of 24 H Rating)[7]		73%	73%	74%	78%	85%	88%	92%	96%	100%	101%	99%	93%	83%	76%	76%	76%	76%	76%	76%	73%	
	Battery Array Voltage at Rest, 26.6 V Max @ >25C / 24.2 V Min (V)[8]	Absorb Voltage	25.2	25.2	25.2	25.4	25.6	25.7	25.8	26.0	26.0	26.0	26.0	25.8	25.5	25.2	25.2	25.2	25.2	25.2	25.2	25.2	
	Battery Array Running Voltage Change from Rest (V)[9]	Setpoint	0.00	0.00	0.39	0.84	1.03	0.71	0.84	0.88	0.81	0.60	-0.66	-0.93	-1.05	-0.98	0.00	0.00	0.00	0.00	0.00	0.00	
	Load Voltage (24.2 V Min) or Charge Voltage[10]	28.6	25.2	25.2	25.6	26.2	26.6	26.4	26.7	26.9	26.8	26.6	25.3	24.8	24.4	24.2	25.2	25.2	25.2	25.2	25.2	25.2	
	Blowers Operating Time (H)		0	0	0	0	0	1	1	1	1	1	1	1	1	0.8	0	0	0	0	0	0	8.8

1. Fully derated, PV array output available, given PV panel ratings and NREL data for Tucson.
2. Accounts for power loss through charge controller plus 1 watt for controller operation.
3. Solar power output divided by charge controller output voltage (Load or Charge Voltage), as limited by Absorb Limit Current.
4. Current from charge controller to battery array less current to blower motors, accounting for amperage loss through motor controller.
5. Time duration required to fully charge or discharge battery array at given current to / from battery array.
6. Battery array charge capacity proportional to battery array voltage at rest and decreases / increases with current from / to battery array, accounting for current loss from load / charge voltage deviation from rest voltage.
7. Battery Array State of Charge (SOC) calculated from Battery Array Charge , 100% SOC at 224 AH * 4 (896 AH) at 26.0 volts
8. Battery Array Voltage at Rest calculated from Battery Array SOC, 22.8 volts at 0% SOC as base.
9. Running voltage change calculated from Battery Array Charge / Discharge Time (magnitude of current to / from battery array) - see Voltage Loss Chart.
10. Battery Array Voltage at Rest plus Battery Array Running Voltage Change from Rest, as limited by Absorb Voltage Setpoint.

Charge Controller Efficiency =	96.8%
SGS Blower Motor Current Draw =	60 A
SGD Blower Motor Current Draw =	19 A
Motor Controller Efficiency =	95.0%

USER GUIDE

1. Input desired values for SGS and SGD Blower Motor Current draws.
2. Check charge controller and motor controller efficiencies for proper values.
3. Objective is to assign time (hourly) durations for Blowers Operating Time such that Charge Voltage (blowers down) increases to Load Controller setpoint of 26.6 V, followed by Load Voltage (blowers running) decreasing to Load Controller setpoint of 24.2 V.
4. Check Battery Array Voltage at Rest for values that exceed indicated maximum value. Reduce any excessive values by setting Absorb Current Limit to lower value.
5. Check 12:00PM value of Battery Array Voltage at Rest for agreement with preceeding values (within 0.1 V). If not in agreement, then adjust this value and repeat step 3 until agreement is reached.

Month	Solar Panel Derate Factors						
	Internal Temp[1]	PV Module Rating	PV Module Mismatch	Diodes & Connections	DC Wiring	Soiling	Combined Derate Factor
Jan	0.91	0.98	0.98	0.995	0.98	0.96	0.81
Feb	0.89	0.98	0.98	0.995	0.98	0.96	0.80
Mar	0.88	0.98	0.98	0.995	0.98	0.96	0.79
Apr	0.85	0.98	0.98	0.995	0.98	0.96	0.76
May	**0.81**	**0.98**	**0.98**	**0.995**	**0.98**	**0.96**	**0.73**
Jun	0.79	0.98	0.98	0.995	0.98	0.96	0.71
Jul	0.79	0.98	0.98	0.995	0.98	0.96	0.71
Aug	**0.80**	**0.98**	**0.98**	**0.995**	**0.98**	**0.96**	**0.72**
Sep	0.81	0.98	0.98	0.995	0.98	0.96	0.73
Oct	0.84	0.98	0.98	0.995	0.98	0.96	0.76
Nov	0.86	0.98	0.98	0.995	0.98	0.96	0.78
Dec	0.91	0.98	0.98	0.995	0.98	0.96	0.81

1. Solar power output decreases by 0.5% for every 1C increase in panel temperature above 25C.

Month	Max Ave Ambient Air Temperature (F)- Tucson				Solar Panel Temp Above Ambient (C)[1]	Solar Panel Temp (C)
	2007	2006	2005	3 YR Ave		
Jan	61	69	67	66	25	44
Feb	70	73	65	69	26	47
Mar	78	71	71	73	27	50
Apr	83	83	81	82	28	56
May	**93**	**94**	**91**	**93**	**29**	**63**
Jun	100	102	99	100	30	68
Jul	99	100	102	100	30	68
Aug	**98**	**95**	**95**	**96**	**29**	**65**
Sep	95	91	96	94	28	62
Oct	87	84	85	85	27	57
Nov	80	79	78	79	26	52
Dec	62	65	70	66	25	44

1. Internal temperature of solar panel is typically 25 to 30C greater than prevailing ambient temperature..

Month	Voltage Losses - Maximum Solar Panel Output to MPPT Charge Controller						
	Max Panel Output	Internal Temp Loss	PV Module Rating	PV Module Mismatch	Diodes & Connections	DC Wiring	Available Panel Output
Jan	72.00	6.73	0.00	1.44	0.360	1.44	62.03
Feb	72.00	7.83	0.00	1.44	0.360	1.44	60.93
Mar	72.00	8.99	0.00	1.44	0.360	1.44	59.77
Apr	72.00	11.15	0.00	1.44	0.360	1.44	57.61
May	**72.00**	**13.57**	0.00	**1.44**	**0.360**	**1.44**	**55.19**
Jun	72.00	15.47	0.00	1.44	0.360	1.44	53.29
Jul	72.00	15.47	0.00	1.44	0.360	1.44	53.29
Aug	**72.00**	**14.24**	**0.00**	**1.44**	**0.360**	**1.44**	**54.52**
Sep	72.00	13.48	0.00	1.44	0.360	1.44	55.28
Oct	72.00	11.39	0.00	1.44	0.360	1.44	57.37
Nov	72.00	9.76	0.00	1.44	0.360	1.44	59.00
Dec	72.00	6.73	0.00	1.44	0.360	1.44	62.03

ATTACHMENT F

FIELD DATA SHEETS

PAGE-TROWBRIDGE RANCH LANDFILL INTERIM MEASURES

OPERATIONS AND MAINTENANCE FIELD DATA SHEET - QUARTERLY

Date:	Time:	Technician:	Technician:

PROCESS PARAMETERS - QUARTERLY

PROCESS PARAMETER	SVE-1	SVE-2	COMMENTS
Blower Motor Shaft Speed (rpm)[1]			
Blower Shaft Speed (rpm)[1]			
PROCESS PARAMETER	MW-2	MW-5	SGD-DP
PID Reading (ppmv)[4]			
	SGS-SP	SGD-SP	SGD-MP

Date:	Time:	Technician:	Technician:
PROCESS PARAMETER	MW-2	MW-5	SGD-DP
Wellhead Gas Pressure (in WC)[2,3]			

1. Record from tachometer.
2. Connect portable pressure or vacuum gauge to valve port.
3. Collect pressure data after at least 5 hours of operation.
4. Follow Section 6.2.1.

MAINTENANCE LOG AND OPERATIONS COMMENTS

PDB-1 belt drive alignment adjusted? (circle)	YES / NO	PDB-2 belt drive alignment adjusted? (circle)	YES / NO
PDB-1 belts replaced? (circle)	YES / NO	PDB-2 belts replaced? (circle)	YES / NO
PDB-1 gear oil replaced? (circle)	YES / NO	PDB-2 gear oil replaced? (circle)	YES / NO
PDB-1 shaft bearings greased? (circle)	YES / NO	PDB-2 shaft bearings greased? (circle)	YES / NO
Process piping leakage? (circle)	YES / NO		
Pressure gauges calibrated / zeroed? (circle)	YES / NO		
Solar arrays cleaned? (circle)	YES / NO		

PAGE-TROWBRIDGE RANCH LANDFILL INTERIM MEASURES
OPERATIONS AND MAINTENANCE FIELD DATA SHEET - WEEKLY / MONTHLY

Date:	Time:	Technician:	Technician:

PROCESS PARAMETERS - WEEKLY

PROCESS PARAMETER	WELL SGS / SVE-1	WELL SGD / SVE-2	COMMENTS
Operating Status (circle)	Extraction	Extraction / Injection	
Hour Meter Reading (hours)[1]			
Wellhead Gas Pressure (in WC)[2]			
KO Inlet Gas Pressure (in WC)[2]			
Pitot Tube Differential Pressure (in WC)[3]			
Blower Inlet Gas Pressure (in WC)[2]			
Blower Discharge Gas Pressure (in WC)[2]			
Wellhead PID Reading (ppmv)[4,12]			
KO Condensate Level (inches)[5]			
SGS Condensate Sump Level (inches)[6]		-	
PROCESS PARAMETER	**ACF-1 Inlet**	**ACF-2 Inlet**	**Stack**
Gas Pressure (in WC)[2]			-
PID Reading (ppmv)[4]			

PROCESS PARAMETERS - MONTHLY

SOIL GAS SAMPLING	WELL SGS	WELL SGD / SGD-DP	ACF-2 Inlet / Stack
Gas Sample Collected? (circle)[7,12,13]	YES / NO	WELL SGD / SGD-DP / NO	ACF-2 Inlet / Stack
Date of Last Sampling Event			

ELECTRICAL PARAMETERS - WEEKLY

ELECTRICAL PARAMETER	SVE-1	SVE-2	COMMENTS
Operational Mode (circle)[8]	Bulk / Absorb / Float	Bulk / Absorb / Float	
Absorb Duration Setpoint (hours)			
Bulk / Absorb Voltage Setpoint (V)			
Current Limit Setpoint (A)			
Instantaneous Input Voltage (V)[8]			
Instantaneous Input Current (A)[8]			
Instantaneous Output Voltage (V)[8]			
Instantaneous Output Current (A)[8]			
Instantaneous DC Power Ouput (W)[8]			
Daily Accumulated DC Power (KWH)[8]			
Peak Input Voltage (V)[9]			
Peak DC Power (KWH)[9]			
Maximum Output Voltage (V)[9]			
Minimum Output Voltage (V)[9]			
Peak Output Current (A)[9]			
Accumulated Current (AH)[9]			
Accumulated DC Power (KWH)[9]			
Accumulated Absorb Times (H)[9]			
Accumulated Float Times (H)[9]			
Instantaneous Motor Voltage (V)[10]			
Instantaneous Motor Input Current (A)[11]			

1. Record from meter on control panel.
2. Connect portable pressure or vacuum gauge to valve port.
3. Use digital differential manometer or flow meter indicator.
4. Follow Section 6.2.1.
5. Measure height of water column within sight glass.
6. Measure height of water column with gauge stick.
7. Follow Section 6.2.2.
8. Obtain from status screen of charge controller.
9. Obtain from end-of-day summary screen of charge controller.
10. Obtain from motor controller output terminal using voltmeter.
11. Obtain from ammeter on control panel.
12. Applies to Well SGD / SVE-2 only if in extraction mode.
13. Applies to SGD-DP only if SVE-2 is in injection mode.

MAINTENANCE LOG AND OPERATIONS COMMENTS

SVE-1 Pitot tube properly oriented? (circle)	YES / NO	SVE-2 Pitot tube properly oriented? (circle)	YES / NO
SVE-1 Pitot tube / connecting lines serviced? (circle)	YES / NO	SVE-2 Pitot tube / connecting lines serviced? (circle)	YES / NO
Condensate drained from bottom of ACF-1? (circle)	YES / NO	Condensate drained from bottom of ACF-2? (circle)	YES / NO
SVE-1 / PDB-1 operating condition?		SVE-2 / PDB-2 operating condition?	

PAGE-TROWBRIDGE RANCH LANDFILL INTERIM MEASURES

OPERATIONS LOGGED DATA SHEET

LOGGED DATA FROM SVE-1 CHARGE CONTROLLER						
Technician:	DATE					
ELECTRICAL PARAMETER						
Peak Input Voltage (V)[1]						
Peak DC Power (KWH)[1]						
Maximum Output Voltage (V)[1]						
Minimum Output Voltage (V)[1]						
Peak Output Current (A)[1]						
Accumulated Current (AH)[1]						
Accumulated DC Power (KWH)[1]						
Accumulated Absorb Times (H)[1]						
Accumulated Float Times (H)[1]						
LOGGED DATA FROM SVE-2 CHARGE CONTROLLER						
Technician:	DATE					
ELECTRICAL PARAMETER						
Peak Input Voltage (V)[1]						
Peak DC Power (KWH)[1]						
Maximum Output Voltage (V)[1]						
Minimum Output Voltage (V)[1]						
Peak Output Current (A)[1]						
Accumulated Current (AH)[1]						
Accumulated DC Power (KWH)[1]						
Accumulated Absorb Times (H)[1]						
Accumulated Float Times (H)[1]						

1. Obtain from end-of-day summary screen for indicated date.

PAGE-TROWBRIDGE RANCH LANDFILL INTERIM MEASURES
OPERATIONS AND MAINTENANCE FIELD DATA SHEET - WEEKLY / MONTHLY

Date:	Time:	Technician:	Technician:

PROCESS PARAMETERS - WEEKLY

PROCESS PARAMETER	WELL SGS / SVE-1	WELL SGD / SVE-2	COMMENTS
Operating Status (circle)	Extraction	Extraction / Injection	
Hour Meter Reading (hours)[1]			
Wellhead Gas Pressure (in WC)[2]			
KO Inlet Gas Pressure (in WC)[2]			
Pitot Tube Differential Pressure (in WC)[3]			
Blower Inlet Gas Pressure (in WC)[2]			
Blower Discharge Gas Pressure (in WC)[2]			
Wellhead PID Reading (ppmv)[4,12]			
KO Condensate Level (inches)[5]			
SGS Condensate Sump Level (inches)[6]		-	
PROCESS PARAMETER	**ACF-1 Inlet**	**ACF-2 Inlet**	**Stack**
Gas Pressure (in WC)[2]			-
PID Reading (ppmv)[4]			

PROCESS PARAMETERS - MONTHLY

SOIL GAS SAMPLING	WELL SGS	WELL SGD / SGD-DP	ACF-2 Inlet / Stack
Gas Sample Collected? (circle)[7,12,13]	YES / NO	WELL SGD / SGD-DP / NO	ACF-2 Inlet / Stack
Date of Last Sampling Event			

ELECTRICAL PARAMETERS - WEEKLY

ELECTRICAL PARAMETER	SVE-1	SVE-2	COMMENTS
Operational Mode (circle)[8]	Bulk / Absorb / Float	Bulk / Absorb / Float	
Absorb Duration Setpoint (hours)			
Bulk / Absorb Voltage Setpoint (V)			
Current Limit Setpoint (A)			
Instantaneous Input Voltage (V)[8]			
Instantaneous Input Current (A)[8]			
Instantaneous Output Voltage (V)[8]			
Instantaneous Output Current (A)[8]			
Instantaneous DC Power Ouput (W)[8]			
Daily Accumulated DC Power (KWH)[8]			
Peak Input Voltage (V)[9]			
Peak DC Power (KWH)[9]			
Maximum Output Voltage (V)[9]			
Minimum Output Voltage (V)[9]			
Peak Output Current (A)[9]			
Accumulated Current (AH)[9]			
Accumulated DC Power (KWH)[9]			
Accumulated Absorb Times (H)[9]			
Accumulated Float Times (H)[9]			
Instantaneous Motor Voltage (V)[10]			
Instantaneous Motor Input Current (A)[11]			

1. Record from meter on control panel.
2. Connect portable pressure or vacuum gauge to valve port.
3. Use digital differential manometer or flow meter indicator.
4. Follow Section 6.2.1.
5. Measure height of water column within sight glass.
6. Measure height of water column with gauge stick.
7. Follow Section 6.2.2.
8. Obtain from status screen of charge controller.
9. Obtain from end-of-day summary screen of charge controller.
10. Obtain from motor controller output terminal using voltmeter.
11. Obtain from ammeter on control panel.
12. Applies to Well SGD / SVE-2 only if in extraction mode.
13. Applies to SGD-DP only if SVE-2 is in injection mode.

MAINTENANCE LOG AND OPERATIONS COMMENTS

SVE-1 Pitot tube properly oriented? (circle)	YES / NO	SVE-2 Pitot tube properly oriented? (circle)	YES / NO
SVE-1 Pitot tube / connecting lines serviced? (circle)	YES / NO	SVE-2 Pitot tube / connecting lines serviced? (circle)	YES / NO
Condensate drained from bottom of ACF-1? (circle)	YES / NO	Condensate drained from bottom of ACF-2? (circle)	YES / NO

SVE-1 / PDB-1 operating condition?	SVE-2 / PDB-2 operating condition?

HYDRO GEO CHEM, INC.

Soil Vapor Sampling Form

Well ID: ____________

Project Name/Number: **PTRL 793400** Date: ____________________ Sampler: ____________

PURGE CALCULATION

Well Diameter ("a", in.): ______ Length of air column ("b", ft): _________ Well Volume: $b \bullet a^2 \bullet 0.0055 = c$: ______ ft^3

Sounder Diam. ("d", in.): _____ Length of air column ("e", ft): _______ Sounder Volume: $e \bullet d^2 \bullet 0.0055 = f$: ______ ft^3

Purge Volume: $[c+f] \bullet 5 = g$: ______ ft^3 Purge Rate ("h"): _______ ft^3/min Purge Time (g/h) = _______ min.

PURGE INFORMATION AND FIELD MEASUREMENTS

Time Started: __________________________ Time Completed: ______________________

Total Purge Time: ______________________ min. Total Purge Volume: ___________________ ft^3

Elapsed Time (Min)	PID/FID Reading (ppmV)	Notes

SAMPLING INFORMATION AND SAMPLE RECORD

Time Started: ______________ Time Completed: ______________ Sampling Method: ____________________.

Sample No.	Time	Container Type	Volume	Serial Number	Analysis Method	Start Pressure	End Pressure	Notes