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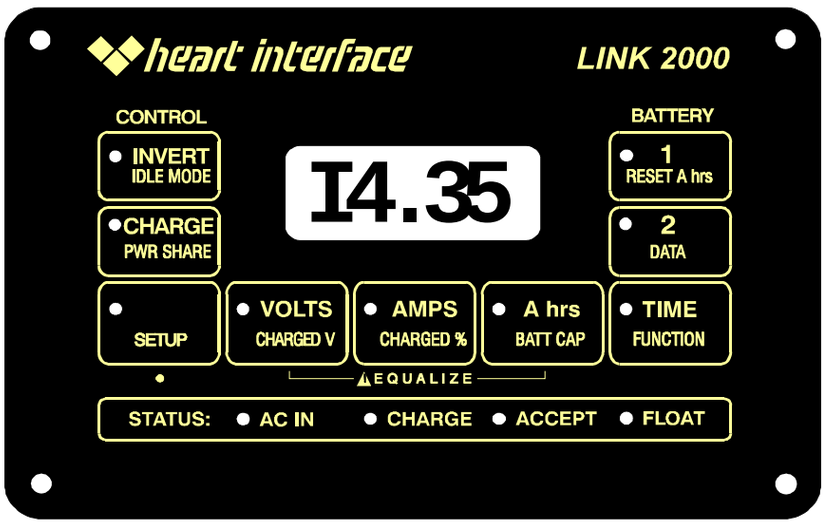
OWNERS MANUAL
LINK 2000

INVERTER CONTROLLER AND DUAL BATTERY MONITOR



INSTALLERS!!! THIS DOCUMENT IS IMPORTANT FOR OPERATION, PLEASE LEAVE IT WITH THE OWNER!!!

THIS MANUAL APPLIES TO LINK 2000 METERS WITH SERIAL NUMBERS ABOVE 8500 AND LINK 2000R METERS WITH SERIAL NUMBER ABOVE 5000

The **LINK 2000** is an integrated battery monitor and inverter/charger control. It displays the critical information necessary for 12V or 24V DC system battery management and allows precise control of critical inverter and charger features. The Link 2000R comes with an additional manual describing the Ideal Regulator option. The **LINK 2000** may be used as a stand-alone battery monitor or with the following ***HEART INTERFACE*** inverter/chargers:

FREEDOM 10, 15, 20, 25, and 30

☞FAST START: For installation details skip to the Required Reading section on page 34. Please read manual prior to using.

All warranty issues must be resolved through Heart Interface Corp. Please do not return to the retailer, or route warranty issues through the retailer.

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SPECIFICATIONS

<u>Power to Link 2000</u>	
Power Supply Voltage	9-40 Volts DC (Not for use with 32V Systems)
Power Supply Current	28mA (Typical; Backlight adds 1 to 18mA)
<u>Measurements</u>	
Voltage Range	8.5-50 Volts DC
Voltage Resolution	0.05 Volts DC
Voltage Accuracy	± 0.10 Volts DC at full scale.
Current Range	± 500 Amps DC
Current Resolution	0.1 Amp DC (From 0 to ± 42.0 Amps)
	1 Amp DC (From ± 42 to ± 500 Amps)
Current Accuracy	± 0.1 Amp DC at full scale low range
	± 1 Amp DC at full scale high range
Current Shunt	± 0.25% Ratio 50mV @ 500 Amps
Amp Hour Range	± 9,999 Amp Hours
Amp Hour Accuracy	≃ Time of Measurement x Current Error
Time Remaining Range	255 Hours maximum
Charger Voltage Regulation	± 0.2 Volts DC
Cut out size:	4.75" x 2.75"
Panel size:	5.75" x 3.75"
Weight:	Meter 9 oz.; Shunt 20 oz.
TC2+2 Compatibility:	Link 2000's: serial numbers greater than 6400.
	Link 2000*R*'s: serial numbers greater than 3900.

INTRODUCTION AND SPECIAL NOTES

Congratulations! You have purchased a powerful instrumentation and control system. In order to understand, use, and install it, PLEASE read this manual!! It is as short as possible and provides important information. Please contact us with suggested improvements to the manual. For installation, operation, or warranty questions please call Heart Interface.

The following Important Special Notes contain cautions and special considerations that must be considered during the installation of the **LINK 2000**. Failure to read and follow these special notes can lead to damage of the **LINK 2000**, the inverter, or other electrical equipment.

☞ The Helping Hand is used to draw your attention to very important sections of this manual or to indicate items that may need to be changed through the **SET UP** routine. Please take the time to read these sections.

1) DO NOT DISCONNECT THE NEGATIVE BATTERY CABLE TO THE FREEDOM WITH THE INVERTER OR CHARGER TURNED ON! WHEN INSTALLING, CONNECT THE INVERTER CABLES BEFORE PLUGGING THE REMOTE CABLE INTO THE LINK 2000. UNPLUG THE REMOTE CABLE BEFORE THE FREEDOM INVERTER IS DISCONNECTED FROM THE BATTERY.

2) Turn the ON/OFF switch located on the inverter to the OFF position .

3) When used in a mixed voltage (12V & 24V) system, Battery #1 is the battery that the **LINK 2000** uses for voltage regulation. Make sure it is the battery that is used by the Inverter/Charger, or with the alternator regulator option it must be the battery being charged by the alternator. See Functions Mode F11 on page 13.

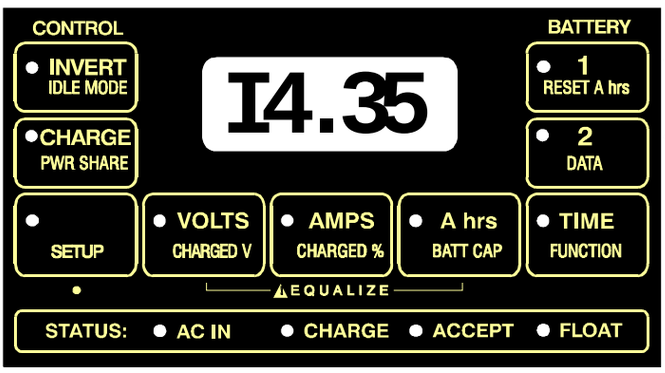
☞ **All warranty issues must be resolved through Heart Interface. Please do not return to, or route warranty issues through the retailer, dealer, or installer.**

BASIC BATTERY FACTS

1) One Amp-hour (Ahr) is 1 Amp for one hour, or 2 Amps for 1/2 hour, or 4 Amps for 1/4 hour, etc.
2) A liquid battery is generally considered completely discharged when the battery voltage reaches 10.5 volts for a 12 volt battery.
3) Batteries for cycling service are normally rated with 1) a 20 hour discharge rate which means, for example, a 100 Ahr battery will sustain 5 amps for 20 hours, and 2) a reserve capacity stated in minutes for a 25 Amp discharge rate.
4) Our Mid-Capacity Rule says that discharge below 50% shortens battery life and charging more than 85% takes too long with an engine driven charging system. So, 35% of the battery capacity is all that is normally available.

MONITOR FUNCTIONS

Please also refer to the one page summary of features in center of this manual.
The small blue legends indicate Set Up functions described later.



BATTERY SELECT

The battery to be monitored is selected by pressing the #1 or #2 switch. A Green LED indicates which battery is selected. ("Battery" may be a "bank" of batteries.)

VOLTS

When the **VOLTS** switch is pressed, the voltage of the selected battery is displayed. The measurement range is from 8.5V to 50V. The resolution is 0.05Volts. See Page 2 for power supply specification.

AMPS

When the **AMPS** switch is pressed, the current flowing into or out of the selected battery is displayed. Amps being consumed are displayed as a negative number. Charging amps are displayed as a positive number (no sign). The resolution below 42 Amps is 0.1 amps. Above 42 Amps the resolution is 1 Amp The range is from -500A to 500A. Over-range is indicated by OL.

Ahrs

When the **Ahrs** switch is pressed, the Amp-Hours (Ahrs) consumed from the battery is displayed as a negative number. During discharge the negative number will grow as Ahrs are consumed and the meter counts down. During charging, the number of Ahrs consumed will decrease as the meter counts back up toward zero. The range is $\pm$ 9,999Ahrs.

If the battery continues to be charged after the meter counts back up to zero, overcharge Ahrs are accumulated and displayed as a positive number. If there is an accumulated positive number in the display when discharging begins, the meter automatically resets to zero and begins counting down. See Over-Charge Amp-hours on Page 16.

The meter also automatically resets to zero after a discharge/charge cycle that satisfies the conditions for a recalculation of the Charge Efficiency Factor (CEF). In other words, if the battery is discharged 10% and then recharged until the charged parameters have been met, the Amp-hours consumed display is reset to zero.

TIME

When the **TIME** switch is pressed, the time which the load can continue to be run is displayed. The display is in hours with 0.1 hours resolution. The unit may be set up to calculate the time remaining based on the instantaneous current, or a rolling average of the last 4, 16, or 32 minutes. The time remaining function also takes into account the magnitude of the discharge current. (See Pages 24-27) The maximum time remaining is 255 hours. If you see this display, it means that the current being consumed could be supplied for more than 255 hours. During charging, current is a positive (unsigned) number and the Time

remaining display reads C C C.

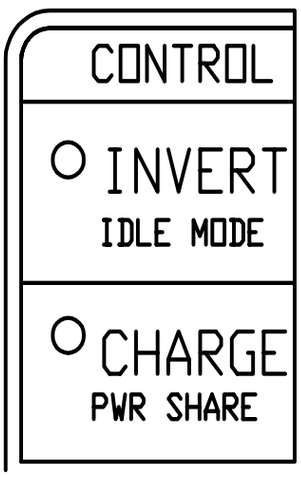
☞ For the **TIME** function to operate correctly you must enter your BATTERY CAPACITY through the **SET UP** routine (see Page 9). You must also set up the correct PEUKERT'S EXPONENT (see Page 13). It is also affected by your selection of DISCHARGE FLOOR (see page 14)

Caution: The **TIME** display is an estimate of how long your battery can sustain a load. Wild variations in battery current, battery condition, erroneously declared battery capacity, Peukert's exponent, temperature, or discharge floor, and prior charge and discharge history may affect the accuracy of this estimate. Please use this display only as a guide. The **LINK 2000** provides you with several important battery parameters. Using all of them, i.e. Voltage, Current, Amp-Hours consumed, and Time remaining, allows you to know about the state-of-charge of your battery. Do not rely on a single value to determine battery status or performance.

LO BAT

When 50% of the declared capacity of either Battery #1 or #2 is consumed, LO BAT flashes in the upper left hand corner of the display. (This indicator is affected by both the declared battery capacity and the discharge floor setting).

INVERTER/CHARGER FUNCTIONS



INVERT

When the **INVERT** switch is pressed, the inverter is enabled and the Green LED is lit. The inverter will only provide output if it is hooked up to the battery and there is no external AC power available. The inverter ON indicator does not indicate actual operation, only that the inverter is enabled. The initial power up condition is with the inverter turned OFF.

CHARGE

When the **CHARGE** switch is pressed, the charging function of the Freedom inverter/charger is enabled. The Green LED is lit when the charger is enabled. The initial power up condition is with the charger enabled. The charger will only provide output if it is hooked up to a battery and an external source of AC power is present (shore power or generator).

MARINE AND RV OPERATING TIP

When utility power is available, any loads normally supplied by the inverter are automatically transferred to utility power through the internal transfer switch. When utility power is not available the loads run on stored energy in the battery. If you have a load such as an electric space heater running on a circuit that is automatically transferred, you run the risk of deeply discharging your battery if there is a utility blackout. To avoid this, turn the inverter function OFF when leaving the boat or RV unattended. Leaving the charger function ON will insure a full battery when you return.

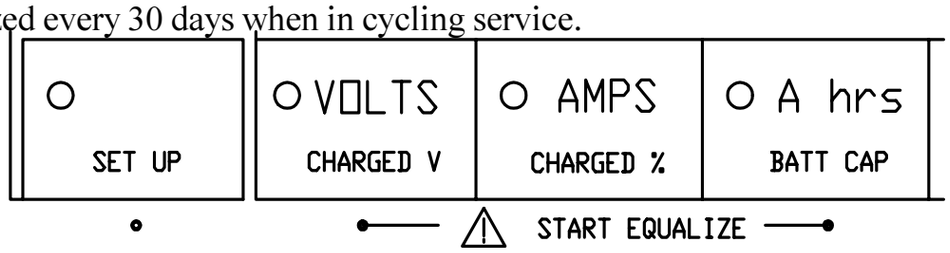
STATUS LINE

There are four LED status indicators to show the presence of AC power and the charger's cycle state.

AC IN: Green LED on when AC is present.
CHARGE: Red LED on when charger is in Charge mode.
Flashes Red when charger is in Equalize mode.
ACCEPT: Orange LED on when charger is in Acceptance mode.
FLOAT: Green LED on when charger is in Float mode.

STARTING AND STOPPING EQUALIZE

The Equalize Cycle conditions the battery with a controlled overcharge to remove Lead Sulfate that is not removed during normal charging. Liquid batteries should be Equalized every 30 days when in cycling service.



CAUTION!!! Turn off voltage sensitive DC loads before equalizing battery!!!
DC Voltage from the charger may go to 17 VDC (34 V for 24 V system) during equalizing !!!

Charge batteries fully before equalizing. To start the Equalize Cycle, first be sure that the Charger is ON, then press the **SET UP BUTTON** for five seconds until the LED begins to flash. Now press both the **VOLTS** and the **AHRS BUTTONS** simultaneously. Hold them both down for five seconds, until the Red CHARGE LED begins to flash, and the "E" in the display goes away.

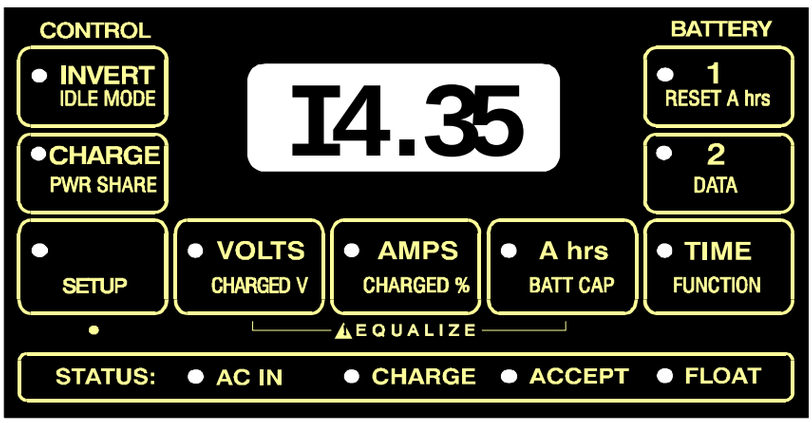
To terminate the Equalize Cycle and force the charger into the Float mode, repeat the same procedure as above. The cycle automatically terminates after eight hours, or if AC power is interrupted.

☞ Equalizing causes the battery to gas. You should check your battery electrolyte before and after equalization. Do not overfill before equalization as the electrolyte may expand enough to cause it to flow over the tops. You should be present during this type of charging. Make sure there is adequate ventilation. Leave the filler caps on or cover the tops with a folded paper towel. Terminate the cycle if a battery starts to overflow or overheat.

Gelled batteries are not normally equalized. However, if they have been severely discharged, it may be the only way to get them to begin to accept a charge. The voltage is limited to the Accept charging level but the cycle lasts for 8 hours. Be sure that the battery TYPE # is set to #1 or #2 before using this cycle on gelled batteries (or #3 for AGM type batteries).

Note: Equalizing voltages for Type #1, #2, and #3 batteries is limited to the acceptance voltage for the respective battery type.

SET UP



☞ The **LINK 2000** has been set up with default values chosen to work with a typical system. Normally the only values that must be changed are:

1) Battery capacity (Page 9)
2) Ambient Temperature (F03 Page 11)
3) Battery type (liquid or gel) (F02 Page 11).
4) Peukert's exponent (F08 Page 13).

The **SET UP BUTTON** is used to access the functions in small blue text below each button's primary function. It is also used for certain advanced functions described later. To set up a value, or function:

1) Select the battery to be set up by pressing Battery #1 or #2, (or Invert, or Charge, when setting up Idle Mode or Pwr Share).
2) Hold down the **SET UP BUTTON** until the green LED flashes at one second intervals.
3) Release the **SET UP BUTTON** and press and hold the function to be set up. The LED of the function being set up will also begin to flash at 1 second intervals. The present value of the function will appear in the display.
4) After 3 seconds, with the button pressed, the display will begin scrolling. When the desired value appears, release the button. If the button continues to be held down, the display will increment to the end of its range, roll over to its minimum value, and continue to scroll. You may also "bump" a value by repeatedly pressing the button.

You may set up additional values, or functions, as long as the **SET UP** LED continues to flash. When the **SET UP** LED stops flashing all values that were changed during the set up routine will be stored in nonvolatile memory.

SUMMARY OF FACTORY DEFAULT VALUES

INVERTER/CHARGER CONTROL

Standby	= 4 Watts (5 Watts in Series 458 units)
Power Sharing	= 30 Amps ("OFF" for Freedom 25)

MONITORING FUNCTIONS

Charged Voltage	= 13.2 Volts for 12 Volt systems
	= 26.4 Volts for 24 Volt systems
Charged Current %	= 2% (of battery capacity)
Battery Capacity	= 200 Ahrs
CEF (Charge Efficiency Factor)	= 87% for Liquid Acid
	= 90% for other cell types
Ambient Temp.	= 70°F
Type	= #0 Liquid
Peukert's Exponent	= 1.25

INVERTER SET UP

IDLE MODE: The default value is 4 Watts. This means it takes a 4 Watt AC load to turn the inverter on from its low power idle mode. Setting a value of 0 Watts means the inverter is always on. The low power idle current is about 0.25 Amps. When idle mode is set to 0W the current consumption goes up to about 0.9 Amps. Range = 0W, 4W, 6W, 15W. (0-15 Watts in 5 Watt steps in Series 458 units.)

SET UP EXAMPLE: To set the IDLE MODE to 0 Watts; first select the **INVERT** on, then press the **SET UP BUTTON** until the Green LED begins to flash. Now, press and hold the **IDLE MODE BUTTON.** The present value will appear. The display will scroll after 3 seconds. Hold the button down until 0 appears. Release the button. The new value will remain in the display for about 5 seconds. When the display reverts to the normal monitoring function the new value is stored in nonvolatile memory. To see if the new value has been successfully stored, repeat the set up procedure but do not scroll to a new value.

PWR SHARE: The default value is 30Amps (or OFF for Freedom 25). The power sharing feature automatically reduces the charger output, and therefore the AC power consumption, if the load passing through the inverter's automatic transfer switch exceeds the set up value. This load management feature helps prevent AC supply breakers from tripping when boats or RVs are plugged into AC power and the charger, water heater, and perhaps other loads all come on at once. In "Off Grid" applications the auxiliary generator often has several jobs; water pumping, running the washing machine, or heavy power tools, in addition to supplemental battery charging. With Power Sharing, when a heavy load turns on, it reduces charger output to help supply the heavy load. The ranges below are for units with serial #'s greater than 100,000:
Freedom 10, 15 & 20 Range = 5,15,20,30A; Freedom 25 & 30 Range = 5, 20, 30A, OFF;
Freedom 10E & 20E Range = 2, 5, 10, 15A; Freedom 25E Range = 2, 10, 15A, OFF

For Freedom serial numbers below 100,000 use this table to interpret the display.

Model	**F10**	**F10**	**F10E**	**F10E**	**F20**	**F20**	**F25**	**F25**
Serial#	**≤70759**	**≥70760**	**≤71746**	**≥71747**	**≤70699**	**≥70700**	**≤70801**	**≥70802**
Display	**Amps**	**Amps**	**Amps**	**Amps**	**Amps**	**Amps**	**Amps**	**Amps**
0	30	30	15	15	30	30	OFF	OFF
1	20	20	10	10	20	20	50	30
2	15	15	7.5	7.5	15	15	30	20
3	10	5	5	2	10	5	20	5

For Series 458 units, the range is 0-50 Amps, settable in 5 Amp steps.

ANOTHER SET UP EXAMPLE: To set **PWR SHARE** to 20 Amps on a F10 Model with a serial number below 100,000; First select the **CHARGE** on, then press the **SET UP BUTTON** until the Green LED begins to flash. Now, press and hold, the **PWR SHARE BUTTON.** The present value will appear. The display will scroll after 3 seconds. Hold the button down until 1 appears. (See table above.) Release the button. The new value will remain in the display for about 5 seconds. When the display reverts to the normal monitoring function the new value is stored in nonvolatile memory.

MONITOR SET UP

Normally the only **MONITOR SET UP** parameter that must be changed is **BATT CAP** . (See bottom of this page.) Please read the section on selecting charged parameters (page 21-22) before changing **CHARGED V** or **CHARGED %** default values. (See FUNC SET-UP on page 10 for other system values that may need to be changed.)

Setting the following parameters only affects the operation of the monitor, meaning that changing the Charged V parameter does not change the voltage set point of the charger in the **FREEDOM** inverter / charger. It only sets the point at which the monitor considers the battery full. To change the charging voltage during the Acceptance and Float cycles use Ambient Temp. Set up routine. Note also that when the **FREEDOM** is the charging source, the **Charged %** is always 2%.

SELECT BATTERY #1 OR #2: To set up a battery parameter, press the button for the battery you wish to set up. The LED will light. Do this first as set up changes are only made to the selected battery.

CHARGED V: The ability to set up a Charged Voltage above which the monitor considers the battery full allows it to be used with any charging system, or battery chemistry. The default Charged Voltage is 13.2 Volts for 12 Volt systems and 26.4 Volts for 24 Volt systems. The **LINK 2000** automatically selects the correct value based on the voltage it senses. (If the Alternative Energy function F05 is ON, the default value is 13.5 Volts or 27.0 Volts. See **FUNC SET-UP**, page 12, for details.)

To change **CHARGED V** follow the same procedure as described previously: Select the battery to be set up. Press **SET UP** until the LED begins to flash. Then release the button, and press **CHARGED V** until the desired Voltage appears and then release the button. The new Charged Voltage is stored in nonvolatile memory. If the Charged Voltage is inappropriate for the sensed battery voltage, Error E14 is displayed. See Error codes. Be sure to read the section on selecting correct charged parameters (Page 21-22) before changing the Charged Voltage.

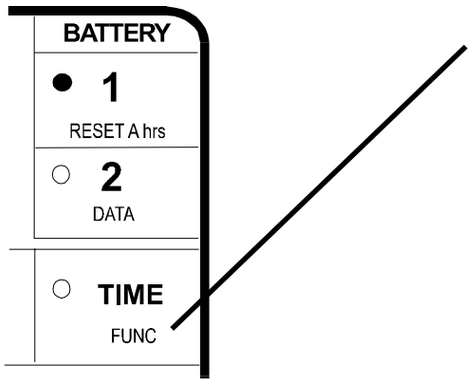
CHARGED %: The default value is 2%. This means that the charging current (Amps) flowing into the battery must fall below 2% of the declared battery capacity before the meter considers the battery full. For example, using the default values of 2% and 200 Ahrs means the current must fall below: 4 Amps = 2% x 200 Ahrs.

Before changing the **CHARGED %** from either of these values, be absolutely sure you understand the section on selecting charged parameters (Page 21-22). Set up and storage to nonvolatile memory is the same as for the function above.

☞ **BATT CAP:** The default value is 200 Ahrs . The battery capacity must be set up if it varies significantly (10-20%) from the default. The battery capacity is used in the calculation to determine when the battery is full and in the **TIME** remaining function.

To change the battery capacity, press **SET UP** until the LED begins to flash then release the button. Now press **BATT CAP**. Scroll until the desired battery capacity is in the display. If you are unsure of your battery capacity you may first test it as described on Page 17. The battery capacity is stored in nonvolatile memory. If you change to a different capacity battery you must change this number. Range = 20-2000 Ahrs in 20Ahr increments.

FUNCTIONS SET UP



FUNC: The **FUNC** (Function) mode is used to set up special functions or features that are not commonly changed. They might be thought of as internal software switches that allows selection of special functions, or values, that once set, are seldom changed.

☞ Normally the only Functions that must be changed are F02 Battery Type, F03 Ambient Battery Temperature, and F08 Peukert's Exponent. (See page 9 for how to set battery capacity.)

The set up process for functions is slightly different because the **FUNC** button is used first to scroll to the function to be set up, and then to scroll through the values for that function. To access the **FUNC** mode:

1) Press and hold the **SET UP** button until the green LED begins to slow flash, then release the button.
2) Now press the (blue) **FUNC** button. The letters **F0I** will appear in the display and the **FUNC** LED will begin flashing, indicating you are in the **FUNC** mode.
3) Scroll to the function to be set up by holding down the **FUNC** button.
4) Release the **FUNC** button and wait for the current value of the function you have selected to appear in the display. This will take about 3 seconds.
5) Press the **FUNC** button now and the display will scroll through the range of values. Stop scrolling when the value you wish appears in the display.
6) If you wish to continue to set up other functions, press the **SET UP** button until the green LED by the **FUNC** button stops flashing. You may now choose any blue key to continue setting up the **LINK 2000.** If you press the **FUNC** button again the process will begin at the next function after the one you last set up. Whatever functions you have set up will become active when the display reverts to its normal mode.

FUNCTIONS TABLE

F01 - AVERAGE PERIOD FOR TIME REMAINING CALCULATION

0 = INSTANTANEOUS (DEFAULT)
1 = 4 MINUTE AVERAGE
2 = 16 MINUTE AVERAGE
3 = 32 MINUTE AVERAGE

There are four averaging periods that the **LINK 2000** can use to calculate the time of operation remaining. You may select present consumption level (instantaneous), a four minute rolling average, a sixteen minute, or a 32 minute rolling average. Which method is best for you depends on your installation. Most installations will find the instantaneous or the four minute average appropriate.

Operating Tip: Use the longest period of time you can to insure long term load variations are considered. If you want instant feedback, use the instantaneous display (no averaging) "0" display.

☞ F02 - BATTERY TYPE

0 = LIQUID CELL (DEFAULT) **1 = GEL CELL (STANDARD)**
2 = GEL CELL (FAST CHARGE) **3= AGM (Absorbed Glass Mat)**

This function (Default: Type #0, standard liquid cells) sets the appropriate charge and float voltages for the **FREEDOM** charger (see table below) and sets an appropriate Peukert exponent. Gel cell owners may use Type 1 or Type 2, but should consult with the battery manufacturer prior to using the more aggressive charging regimen described by Type 2. Type 3 sets Acceptance and Float voltages suited to AGM type batteries.

☞ F03 - *VIEW* OR *SET* AMBIENT BATTERY TEMPERATURE

THIS FUNCTION DEPENDS ON THE SETTING OF F14, PAGE 14.

IF F14 IS ON, F03 *VIEWS* THE PRESENT BATTERY TEMP. (^{O}F.)

If F14 is **ON**, charging voltage of the Freedom charger and the Ideal Regulator (if using a Link 2000R) is based on the **TEMPERATURE COMPENSATION TABLE** below . This function is only available on *Freedom* inverter/chargers with serial numbers >150,000 with ***TC2+2*** capability, or, Series 458 units with temperature probe. The temperature is displayed until another button is pressed on the Link.

IF F14 IS OFF, F03 *SETS* A DECLARED BATTERY TEMP. (^{O}F.)

DEFAULT = 70F **RANGE = 30-120F** **STEP = 10F**

The default value for ambient temperature is 70^{0}F. The ambient temperature of the battery may be set up to select the appropriate Charge and Float Voltages for the charger. The temperature may be selected in 10^{0}F increments. The set up procedure is the same as previously described.

Setting up a different value should only be done if the battery is at a temperature significantly different from 70^{0}F **when they are being charged from the FREEDOM**. If the batteries are located in a hot engine room, but are not normally charged from the **FREEDOM** when the engine is running, do not adjust the temperature to the engine room level. High temperatures are destructive to batteries. If your batteries are regularly subjected to temperatures above 100^{0}F you should relocate them or supply forced fresh air ventilation.

☞ **Caution! Do not adjust to extremes unless the battery is normally at that temperature. Destructive over or under charging may occur. Multiply values by 2 for 24 Volt systems. Voltages are typical, charger regulation ± 0.2 Volts DC.**

TEMPERATURE COMPENSATION TABLE

TEMP		TYPE 0 Liquid		TYPE 1 Gel 1 (Std)		TYPE 2 Gel 2 (Fast)		TYPE 3 AGM	
^{0}F	^{0}C	ACCEPT	FLOAT	ACCEPT	FLOAT	ACCEPT	FLOAT	ACCEPT	FLOAT
120	49	12.5	12.5	13.0	13.0	13.0	13.0	12.9	12.9
110	43	13.6	12.7	13.5	13.0	14.0	13.4	13.9	12.9
100	38	13.8	12.9	13.7	13.2	14.1	13.5	14.0	13.0
90	32	14.0	13.1	13.8	13.3	14.2	13.6	14.1	13.1
80	27	14.2	13.3	14.0	13.5	14.3	13.7	14.2	13.2
70	21	14.4	13.5	14.1	13.6	14.4	13.8	14.3	13.3
60	16	14.6	13.7	14.3	13.8	14.5	13.9	14.4	13.4
50	10	14.8	13.9	14.4	13.9	14.6	14.0	14.5	13.5
40	5	15.0	14.1	14.6	14.1	14.7	14.1	14.6	13.6
30	-1	15.2	14.3	14.7	14.2	14.8	14.2	14.7	13.7

Freedom units produced prior to serial #100,000 have temperature compensation only for warm or cool environments. The temperature setup sets the voltages as per below:

TEMP	TYPE0 (Liquid)			TYPE1(Gel 1)		
	Accept	Float	Equalize	Accept	Float	Equalize
Above 80^0F	13.9	13.3	15.8	14.1	13.8	14.1
Below 80^0F	14.4	13.5	16.3	14.4	13.8	14.4

F04 - TOGGLE DISPLAY BETWEEN AHR AND KWHR

DEFAULT OFF = AHR DISPLAY MODE

ON = AHR/KWHR ALTERNATING DISPLAY MODE

When this function is selected the **Ahr** display alternates between the normal Amp-hour mode and the Kilowatt-hour counter that the **LINK 2000** uses to determine if 100% of the energy consumed from the battery has been returned. A recalculation of the CEF is not permitted unless this counter is greater than 0.00 KWhr. This counter counts down during discharge and the Kilowatt-hours consumed are displayed with a negative number. During charging it counts back up with 100% efficiency. Not allowing a recalculation of the CEF and an Ahr reset, until a positive number is in the counter, insures that there will not be a premature reset. See Page 21 for conditions required for a recalculation of the CEF and and Ahr reset.

F05 - ALTERNATIVE ENERGY MODE

DEFAULT: OFF

ON = USE ALTERNATIVE ENERGY DEFAULTS

Turn this mode on if your **Link 2000** is used in Alternative Energy Systems. This function 1) reduces the time necessary to satisfy the charged parameters from 5 minutes to 1 minute; 2) sets Batt #2 discharge floor to 100%; 3) Prevents Batt #2 from doing Ahr resets; 4) changes Charged V parameter to 13.5 V (27 V). If you're using a semi-mechanical photovoltaic controller, we strongly suggest you also consider changing Charged Current to 4%.

F06 - MANUALLY SET CEF (NOT RECOMMENDED)

DEFAULT OFF = AUTO RECALCULATION OF CEF

DISPLAY = A87 OR A90 (DEPENDS ON BATTERY TYPE)

RANGE = 65-99 STEP = 1

Allows manual set up of CEF (Charge Efficiency Factor). Default display `A87` or `A90` (depending on battery type selected, see F02) indicates automatic CEF recalculation feature. Returning to `A87` or `A90` from a user CEF restores the automatic CEF feature. If a user set up CEF has been selected it will appear as a `U##` (`U` preceding a number) in the **DATA** mode. See Page 15. A different CEF may be set up for each battery, only the selected battery's CEF will be changed.

F07 - SET TEMPERATURE COEFFICIENT

DEFAULT = 0.5 RANGE = 0.1 - 0.9 STEP = 0.1

This factor compensates for capacity change with temperature. Typical value 0.5% Capacity/^{0}C. This coefficient must be supplied by the battery manufacturer. The default value is typical for lead acid liquid or gelled batteries. Normally this value is not changed.

☞F08 - SET PEUKERT'S EXPONENT

DEFAULT = 1.25 RANGE = 1.00 - 1.50 STEP = 0.01

Sets the exponent for Peukert's equation. A setting of 1.00 defeats Peukert's calculation. See Page 24-27 for a discussion of Peukert's equation and typical values for various batteries. Properly setting Peukert's exponent insures a more accurate display of time remaining and percent remaining.

F09 - AHR OR RATE COMPENSATED % REMAINING MODE

DEFAULT OFF = AHR DISPLAY MODE

ON = RATE COMPENSATED PERCENT REMAINING MODE

Changes the **Ahrs** function to % Remaining mode, which displays the selected battery's rate compensated state-of-charge as a percentage of the declared capacity. A full battery is displayed as `Pi00` and a 50% charged battery is displayed as `P050`. When in this mode, the battery capacity and Peukert exponent must be accurately set up.

This option is not available when F04 or F05 is ON.

F10 - ALTERNATOR CURRENT LIMIT

DEFAULT = 100 RANGE = 30 - 220 AMPS, OFF

STEP = 10 AMPS

This function is only used with the Alternator Regulator Model (Link 2000R). It sets a safety current limit for the alternator. This limits the maximum amount of current that the alternator can ever deliver which in turn reduces heat and wear on belts and bearings. The OFF position turns alternator current limiting off.

F11 - BATTERY #2 USED FOR CONTROL

DEFAULT ON = BATTERY #2 USED FOR CONTROL

OFF = BATTERY #2 IS NOT USED FOR CONTROL.

This function is used to defeat Battery #2 as a part of the charger control function of the **FREEDOM** inverter (also alternator control in the Link 2000R). This is necessary for systems that have both 12V and 24V batteries. Battery #1 must be the battery that is used by the **FREEDOM**. You may also wish to use this function if the main house battery (Bank 1) is substantially larger than a separate engine battery (Bank 2) that is also monitored by the **LINK 2000**. This will prevent the **LINK 2000** from making a premature transition to float based on the smaller engine battery meeting the charged parameters substantially before the house battery.

☞ **NOTE: This function is not changed in a reset to factory default values. If you wish to change this function you must use the set up routine to change it.**

F12 - BACKLIGHTING INTENSITY CONTROL

DEFAULT = 130 RANGE = 0 - 240 STEP = 10

This function may be used to increase or decrease the intensity of the backlighting for the display.

F13 SET DISCHARGE FLOOR

DEFAULT: 100% RANGE: 50% - 100% STEP = 5%

When this option is activated, you may set a discharge floor for each battery bank. When the discharge floor is set to 50%, the Time Remaining display reports time remaining until the battery reaches the 50% discharged level. You may set the discharge floor from 50% to 100% in 5% increments. When the Settable Discharge Floor is 100%, time remaining to 100% discharge is displayed. You may set a discharge floor for each battery. The settable floor is applied to the battery selected (BAT1 or BAT2) at the time you enter this function. You may wish to set a higher discharge floor, such as 50%, for an engine starting bank and a deeper floor, such as 75%, for a deep cycling house bank.

F14 - ACTIVE TEMPERATURE COMPENSATION ON, OFF

DEFAULT: OFF RANGE: OFF, ON

When this function is **ON**, the Link 2000 / Link 2000R uses the actual battery temperature reported to the *Freedom* inverter/charger by a Heart ***TC2+2*** unit, or Series 458 unit with temperature probe. If the Heart ***TC2+2*** (or 458 with probe) is not reporting a valid temperature to the *Freedom* inverter/charger, the Link 2000 will use the battery temperature declared by F03 (**Default: 70 F)** to set charging voltages. Remember: Charging voltages are controlled by Battery Type *and* temperature settings.

F15 - SPECIAL FUNCTION FOR DIAGNOSTIC USE.

DEFAULT ON = INVERTER CONTROL

OFF = ASCII OUTPUT

CAUTION!! LEAVE THIS FUNCTION ON. TURNING IT OFF DISABLES COMMUNICATION. TO BE USED FOR SERVICE DIAGNOSTIC PURPOSES ONLY.

SUMMARY OF SOFTWARE DEFAULTS

	Function	Name	Default	Options
	F01	Averaging Period	0	4, 16, 32 Minutes
**	F02	Battery Type	Lead Acid	Gel cell , AGM
**	F03	View or set ambient Temperature	70 degrees F	See text
	F04	View Ahr or KWhr	OFF (Ahr)	ON (KWhr)
	F05	Alternative Energy mode	Off	Solar cell (see text)
	F06	Peukert's Exponent	Auto	See text
	F07	Temp Coefficient	0.5	0.1 to 0.9
**	F08	Puekert's Exponent	1.25	1.00 to 1.50 (see text)
	F09	% remaining time display	Off (Ahr mode)	On (% remaining)
	F10	Alternator Current limit	100 Amps	30 to 220 amps, off
	F11	Battery #2 used for control	On (Yes)	Off
	F12	Backlighting intensity	130	0 to 240
	F13	Settable discharge floor	100%	50% to 100%
	F14	Active Temp Compensation	Off	On
	F15	Manufacturer Reserved	On	Do not change

** Item that should be confirmed or changed at installation to insure proper operation

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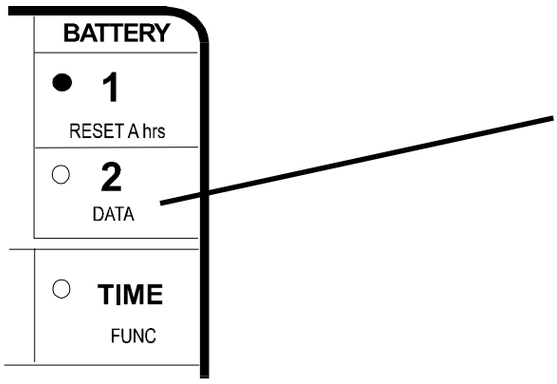
DATA MODE



DATA: The **DATA** mode is used to recall key historical information about the battery (battery banks).

To access the **DATA** mode:
1) Select Battery #1 or #2 to review its data.
2) Press and hold the **SET UP** button until the green LED begins to flash then release the button.
3) Now press the (blue) **DATA** button, each time you press the **DATA** button a new piece of data is displayed. You may also hold the button down to scroll through the following data:

CEF (Displayed as EXX): The Charging Efficiency Factor (CEF) is displayed. A display of E99 indicates a 99% CEF. This number sets the rate at which Amp-hours are counted back up during charging. This is an Amp-hour CEF, not KWhr efficiency. The Default setting is 87% for Type 0 (Liquid) batteries, 90% for Types 1 & 2 (Gelled) and Type 3 AGM batteries. **NOTE:** If the CEF display has a "u" in front of it, this means the CEF has been selected by the user. See Function F06 for details. The CEF of a battery typically remains fairly constant until end of life. A sudden drop in the CEF indicates time to equalize, a battery failing, or a charging problem.

#CEF Recalculations (Displayed as +I999): This is the number of times that the battery has been discharged more than 10% and then recharged until the Charged Parameters have been met. May be considered as the number of charge/discharge cycles the meter has recorded since its last **RESET** to factory defaults. This is useful to evaluate the cycling performance of your battery system.

Deepest Discharge (Displayed as -i999): Shows the deepest discharge in Amp-hours recorded by the meter since its last **RESET** to factory defaults. Very deep discharges indicate battery abuse.

Average Discharge (Displayed as i999): The running average of all discharges as an Amp-hour value since last **RESET** to factory defaults. The average discharge level should normally be no more than about 50% of declared capacity.

HOW TO USE the link CONTROL PANEL

BATTERY MANAGEMENT PHILOSOPHY: Recharge When the Battery is 50% Discharged!

The **LINK 2000** is a guide to the battery's state of charge. Our Mid-Capacity Rule says you should begin charging when your **LINK 2000** shows that 50% of battery capacity has been consumed. In Marine and RV systems, which are trying to minimize charging time with an engine driven alternator or generator driven charger, the battery is normally charged only to the 85% level. This means only 35% of the battery capacity is actually available for use. The Mid-Capacity rule is a very conservative approach to battery use. Occasionally discharging a battery more deeply is perfectly acceptable. The Mid-Capacity rule is intended as a design and operating guideline to provide optimal battery life and ensure the most energy output from the battery over its life, not a law which must be obeyed without exception.

We recommend synchronizing your **LINK 2000** to the 100% charged level of the battery. You should begin recharging when 50% of the your battery capacity has been consumed. **When recharging from an engine driven alternator or generator supplied battery charger you do not have to charge until the meter reads 0 Amp-hours consumed.** You may cease charging when the **LINK 2000** is displaying that 15% of the battery capacity is still consumed. See example below. When you plug back into AC power, or when your Alternative Energy production exceeds demand, the remaining Amp-hours consumed will be replaced.

MANAGING A TWO BATTERY SYSTEM

With a two battery system we recommend using battery #1 until you consume 50% of its capacity, then switch to battery #2 and use 50% of it. When both batteries are 50% discharged it is time to charge. You should never leave either battery partially discharged for more than a few days.

Suppose you have two 200 Ahr batteries for a total system capacity of 400 Ahrs and you have synchronized your **LINK 2000** to 100% charged batteries. . You would use battery #1 until the **LINK 2000** showed that you had used 50% (the display would show -100Ahrs). You would then use battery #2 until you had used 50% of it (-100Ahrs). At this point charge both batteries up to about the 85% level (-30 Ahrs on each). If you have other reasons to continue running the engine or plug back into AC power you may continue charging until the meter reads zero.

OVERCHARGE AMP-HOURS

If the battery is 100% charged, and the **LINK 2000** is in sync with the batteries, overcharge Ahrs are displayed as positive. Some accumulation of overcharge Ahrs is normal and harmless with systems continuously connected to a charger. For example: A 100 Ahr battery at the Float voltage, will normally have less than .1 A flowing into it. This means that a maximum of 2.4 Ahrs of overcharge would accumulate in a 24 hour period. If your battery system is larger there will be proportionately more current flow and positive Ahr accumulation.

If the charging system is a constant voltage type set at 14.2 volts, as much as one Amp of current may be flowing all the time after the battery has reached the charged parameters. The battery will be gassing and you will see an accumulation of a large number of Ahrs each day. This is a clear indication that you are destroying your battery by overcharging. Check your **LINK**

2000 before turning off a charging source to see that you have not accumulated too many overcharge Ahrs. When discharging begins, overcharge Ahrs are erased and the **LINK 2000** resets to zero.

Systems that have a Conditioning or Equalization cycle will accumulate a few overcharge Ahrs during equalization. This is normal and ensures that the **LINK 2000** stays in sync with the battery state of charge.

BATTERY CAPACITY TESTING

Your **LINK 2000** can be used to conduct periodic capacity tests that tell you the actual amount of energy your batteries can store. A capacity test should start with a battery that has been properly charged and conditioned. The objective is to find the maximum available capacity.

Deep cycle battery capacity is usually based on a 20 hour discharge rate. A 100 Ahr battery will provide 5 amps for 20 hours. At discharge rates above 5 amps, the battery will not supply 100 Ahr. For example: If you are drawing 100 amps out of the battery it will last less than one half hour. This was discovered in 1897 by a scientist named Peukert and is discussed in detail later. You can see the effect in the following table listing approximate capacities at different discharge rates.

CAPACITY AT VARIOUS DISCHARGE RATES
(percentage of 20 hour rate)

Hours to Discharge	Capacity (percent of rating)
20	100%
10	89%
5	78%
3	66%
1	45%

To test battery capacity, turn on a load that draws approximately 5% of the declared battery capacity. Measure the current using the Amps function of the **LINK 2000**. The load should be constant, such as incandescent lighting. When the battery voltage reaches 10.5 volts, hopefully about 20 hours later, turn off the load and look at the Ahrs display on your **LINK 2000.** The number displayed is the capacity at the test current. If less than 20 hours passed before the battery voltage fell to 10.5V you can still determine the capacity with some arithmetic. For example: Assume a 12V battery rated at 100 Ahr. Apply a 5 amp load. Suppose it only took 10 hours for the voltage to reach 10.50 volts. The **LINK 2000** would display -50 Ahr. This is the 10 hour capacity. Dividing 50 by 89% (10 hour rate) from the table above, you determine that the actual 20 hour capacity is 56 Amp-hours. You could repeat the test at 5% of the tested capacity (2.8A) to verify the actual capacity.

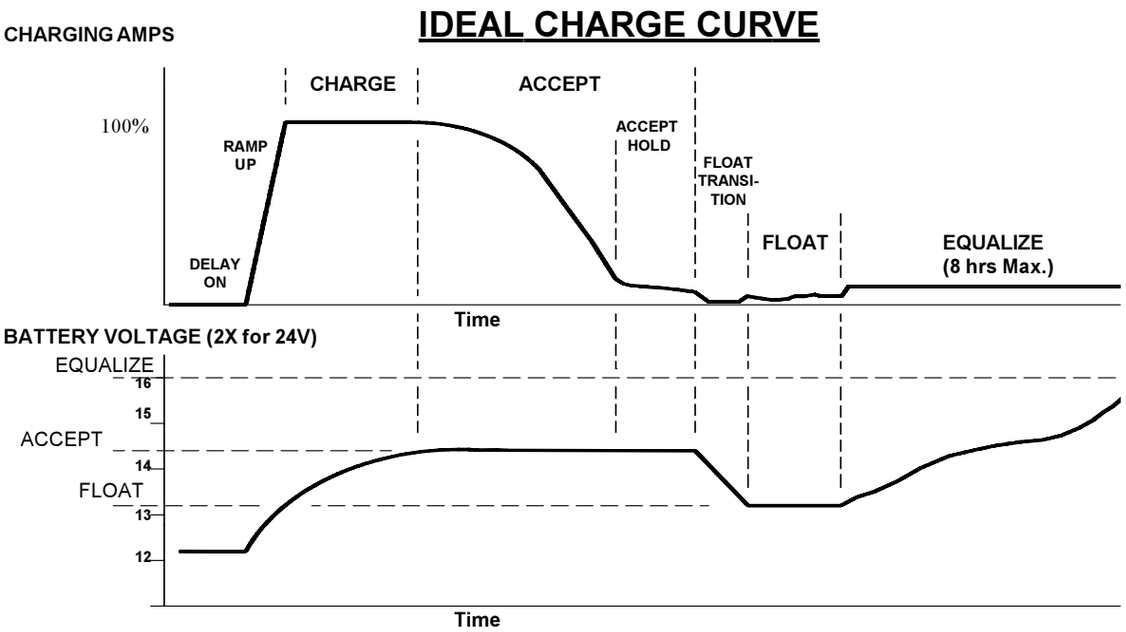
USING YOUR FREEDOM INVERTER TO TEST BATTERY CAPACITY

Your inverter makes testing the battery capacity easy. First fully charge (and equalize if necessary) the battery to be tested. Use a load like incandescent lights running on the inverter whose amperage consumption is 5% or less of the battery capacity. Let the load run until the inverter shuts down on low voltage (about 10.2V). Read the number of Amp-hours that have been consumed from the battery. If it is not close to the expected number use the procedure outlined above to estimate the capacity.

Caution! Be sure to completely recharge your battery after a discharge test.

IDEAL CHARGE CURVE

The **LINK 2000** transmits critical battery state of charge information to the **FREEDOM** inverter/charger. This enables the charger to conform to our proven **Ideal Charge Curve** with four basic cycles; **Charge, Accept, Float,** and **Equalize**. The **CHARGE** cycle supplies full charger output current until the battery reaches the Accept charging voltage (14.4V typ.). The **ACCEPT** cycle continues until the battery is accepting only a small amount of current. The battery is now full. During the **FLOAT** cycle the voltage is lowered to maintain the batteries, without water consumption, for long life. The **EQUALIZE** cycle allows for periodic "equalization" of liquid electrolyte batteries for maximum capacity and life. The batteries should be Equalized about every 30 days during deep cycling service.



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IDEAL CHARGING STATE TABLE

CYCLE	VOLTAGE	BATTERY CURRENT	CYCLE LIGHT
CHARGE	**12.0 - 14.4** (Rising)	Maximum Charger rating	**RED**
ACCEPT	**14.4** (Constant)	Falling	**ORANGE**
FLOAT	**13.5** (Constant)	Small (< 2% Capacity)	**GREEN**
EQUALIZE	**13.2 - 16.0** (Rising)	Constant until 16V	**SLOW FLASH RED**

THE FACTORY DEFAULT VALUES FOR CHARGING:

Battery capacity: = 200 Ahrs (800 Ahrs if F05 is ON)
Accept Voltage: = 14.4 Volts for 12 Volt systems (for wet cell batteries)
= 28.8 Volts for 24 Volt systems (for wet cell batteries)
Charged Current: = 2% (of battery capacity)
Float Voltage: 0.9V below the Accept Voltage for Liquid electrolyte batteries.
0.6V below the Accept Voltage for Gel 2 electrolyte batteries.
Ambient Temp: = 70^0F (See Temperature Compensation Table)

HOW TO TELL WHEN A BATTERY IS FULLY CHARGED?

(CHARGED BATTERY PARAMETERS)

MULTIPLE STAGE CHARGING SYSTEMS

If you are using the charger in the **FREEDOM**, the battery is charged when the system switches to the Float cycle. If another manufacturer's charging system is being used it should be adjusted so the transition from Acceptance Charging to Float will occur when the charging current, at the Acceptance Voltage (14.4 / 28.8V Typ.), drops to below 2% of the battery capacity. (See description on previous page about the Ideal Charge Curve.)

CONSTANT VOLTAGE CHARGING SYSTEMS

Constant voltage charging systems have restored as much charge to a battery as they can when the voltage reaches the maximum regulation point (typical 12V system is set at 13.8V) and the charging current drops to less than 1% of the battery capacity. (It can take more than 8 hours for a battery to reach this state of charge.) If you are using an engine driven charging system and trying to limit engine run time, you probably will charge only until the current drops to 5% or 10% of capacity. The **LINK 2000** should be synchronized to which ever of these charge levels is reached in normal operation.

USING SPECIFIC GRAVITY

Accurate battery current measurement is necessary to determine the charged parameters in the two previous methods. Specific gravity of the battery can also be used to determine the charge level of a battery. Regardless of the charging system used, a battery is charged when the specific gravity shows no increase for three hours, when measured at half hour intervals. Typical specific gravity @ 77^0F for a fully charged liquid electrolyte battery is 1.265 ± 0.050.

CHARGE EFFICIENCY FACTOR (CEF) AND HOW IT IS USED

The CEF determines the rate at which the Link 2000 counts back up during charging to compensate for the inefficiencies of the charging process. The CEF has a factory default value of 87%. That means the charger must return 1.15 Ahrs to the system for the battery to restore 1.0 Ahr.

The CEF is automatically recalculated (and averaged over the last few cycles) after every charge cycle if the battery has been discharged more than 10% of the declared battery capacity and the charged parameters for voltage and current (selected automatically or manually in the set up procedure) are met for 5 minutes (may vary by set up). Additionally, 100% of the KWhrs removed must be returned during charging .

Continual CEF compensation insures that the battery state of charge and the Link 2000 stay in sync. Monitoring the CEF over time helps as-

sess changes in performance of the battery or charging system.

SYNCHRONIZING YOUR LINK 2000 TO A CHARGED BATTERY

A charged battery has zero Ahrs removed. Synchronizing your **LINK 2000** to read zero when the battery is charged ensures that you always know the net number of Ahrs removed. The charged parameters on the previous page indicate when a charging system has put as much energy into a battery as it normally can and the battery can be considered charged.

Your LINK 2000 must be synchronized at this point !!!

TWO WAYS TO SYNCHRONIZE

There are two ways to synchronize your **LINK 2000** to a battery that has met the charged parameters:

1) Install the **LINK 2000** on a charged battery and it will automatically be in sync.

2) If the **LINK 2000** is installed on a partially charged battery, simply charge until the charged parameters are met. The **LINK 2000** will begin counting up and will display charging Ahrs as positive. When the battery is charged, turn off the charging source. After discharging begins the **LINK 2000** automatically resets to zero, starts counting down, and is in sync.

☞ **If the LINK 2000 should ever get out of sync with the battery state of charge it must be re-synchronized. The best way to do this is to be sure the battery is discharged at least 10% of the declared battery capacity and then recharge until the charged parameters are met. At this point the meter should automatically reset to zero.**

Remember, a battery should be fully charged, and float charged if possible, when leaving it for extended periods of time for best battery life. This will automatically ensure that the Link 2000 stays in sync. Some things that will cause the Link 2000 to not stay in sync are: 1) discharge cycle is less than 10% of battery capacity, 2) battery not fully charged to 100% , 3) charged voltage set too high for the charging system, 4) charged current % of battery capacity set too low for the charging system, 5) battery is never charged long enough for 100% charge.

MANUALLY RESETTING AHRS TO ZERO

If you want to manually reset your **LINK 2000** Ahrs display to zero:

1) First select the battery you wish to reset.
2) Press the **SET UP** button for five seconds, when the LED begins flashing, release the button.
3) Press and hold the **RESET Ahrs** button for three seconds (until the normal display returns) to reset the Ahrs of the selected battery to zero.

MANUALLY SELECTING THE CHARGED BATTERY PARAMETERS

DISCUSSION - HOW THE LINK 2000 USES THESE VALUES:

The **LINK 2000** allows the set up of specific charged parameters. The factory default values have been carefully chosen to work on most systems, including constant voltage and multiple step charging systems. The factory Charged Parameters are 13.2 Volts and 4 Amps (2% of the default battery capacity of 200Ahr). **This means when the battery is above 13.2 Volts and the current falls below 4 Amps, for five minutes, the LINK 2000 considers the battery full.**

The **LINK 2000** learns the Charge Efficiency Factor (CEF) of the battery based on the Charged Parameters. A CEF of greater than 100% is not allowed. To trigger a recalculation of the CEF, the battery must be discharged at least 10% of declared capacity. After this discharge, at least 100% of the energy (KWhrs) removed must be returned, and both the Charged Voltage and Charged Current % parameters must be met for 5 minutes for a recalculation of the CEF to occur. **Amp-hours consumed are automatically reset to zero after a recalculation of the CEF.** The new CEF is used during the next recharge cycle to determine the rate that the meter counts back up toward zero.

The battery must go through several cycles for the meter to learn the CEF. It will take several (at least six) cycles for the displayed CEF to reflect the actual CEF of the battery.

SHOULD YOU CHANGE THE CHARGED PARAMETERS?

Please consider changing only the battery capacity unless your system falls into one of the following categories:

1) Battery chemistry other than lead acid.

If you are using NiCad or other types of batteries you should change your Charged Parameters to the factory specification. NiCad systems would normally use 15.5 to 15.7 as the Charged Voltage. The Charged Current % can probably stay at 2% of declared battery capacity.

2) Charging normally ends before the current drops below 2% of battery capacity.

If the charging system is shut down before the charging current drops below 2%, the factory Charged Current % will have to be changed. Examples might include: Large solar arrays with controllers that shut off the array at a particular voltage and turn it back on at a lower voltage. Engine driven alternator or AC generators running large inverter/chargers that are normally shut down before the charging current falls below 2% of capacity.

Remember, if charging is normally terminated when the current is a higher percentage of battery capacity, the battery is probably not being thoroughly charged. If the meter accumulates negative Ahrs, it is letting you know that you must periodically remove them by a complete charge or that you are not meeting the charged parameters.

RULES FOR CHANGING THE CHARGED BATTERY PARAMETERS

If you must change the Charged Parameters please use the following rules.

☞1) The Charged Voltage MUST be at least 0.1V BELOW the charging system voltage.

☞2) The Charged Current % times declared Battery Capacity MUST be GREATER than the minimum current the charging system maintains the battery at, or turns off at.

If the charged parameters are not correctly selected, the LINK 2000 will never recalculate the CEF. For example:

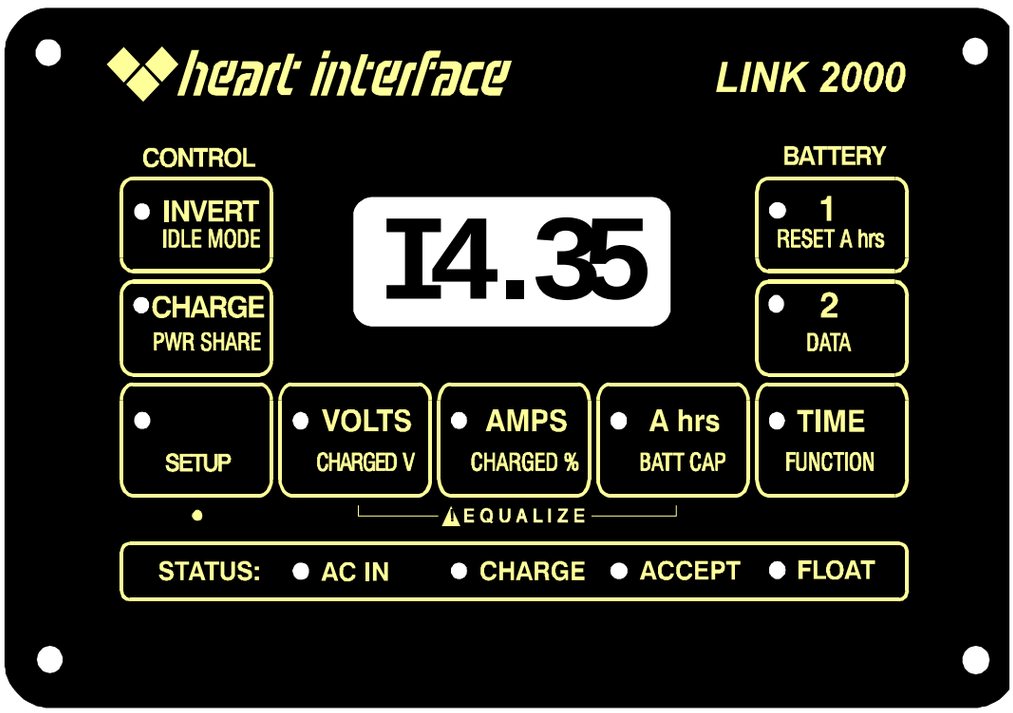
(1) If your charging system only reaches 13.8 (27.6) Volts, a Charged Voltage of 14.0 (28.0V) Volts will not work it is set too high and the Link 2000 will never know that the battery is charged. Lower the Charged Voltage. (Changing the Charged Voltage to 13.7 (27.5) Volts should work. See Monitor Set-up on page 9.)

(2) If the Charged Current % times the Battery Capacity is less than the current at which the charging system switches off, the Charged Current cannot be met and the Link 2000 will never know that the battery is charged. If the charging system shuts off when the current is 10 Amps, using the factory default value of 4 Amps (2% of 200 Ahrs), will not work. (Changing the Charged Current % to 6% would give a Charger Current of 12 Amps which would work fine. See Monitor Set-up on page 9.)

If you have a charging system that cannot satisfy the default values, the CEF will not be recalculated and the meter will use the default CEF of 87%. This will work fine in most systems. You may notice an accumulation of negative Ahrs. If so, set up appropriate charged parameters or resynchronize periodically. (See Synchronizing your Link 2000 to a charged battery on page 20.)

RESET / INFO FUNCTIONS

The drawing below shows the Reset / Info Functions layout. To access these press the **SET UP BUTTON** for ten seconds. The time is long to avoid unintentionally entering this mode. When the green LED begins to **flash quickly** (about 3 times per second) select the Advanced Function you wish by consulting this drawing. The display returns to the monitoring mode 5 seconds after the selected function button is released.



 # LOW BAT/ # OL: The number of Inverter Low Battery shut downs (since last reset) is displayed with a minus sign (negative number). The number of Inverter shut downs (since last reset) from other causes are displayed with no sign (positive number). The display alternates at three second intervals until the button is released.

SOFTWARE INFO: The revision number of the **LINK 2000** software is displayed.

FLASH ALL LEDS & SEGMENTS: This display test continues until the button is released.

RESET TO FACTORY DEFAULTS: When this button is held down for 5 seconds, all of the values set up for the selected battery are reset to the factory values. A 0 (zero) should appear briefly in the display (watch closely). **All historical data is lost!! Normally this would only be done if you are changing batteries.**

☞ **IMPORTANT NOTE! During a RESET TO FACTORY DEFAULTS any changes to the inverter/charger set up are also reset to the factory values IF the INVERT or CHARGE LEDs are on.**

☞ **IMPORTANT NOTE! Function F11 (Battery #2 used for control) is NOT reset during a RESET TO FACTORY DEFAULTS.**

HIGH DISCHARGE RATES & PEUKERT'S EQUATION

Peukert's Equation describes the effect of different discharge rates on battery capacity. As the discharge rate increases the available battery capacity decreases. The tables on pages 25, 26 & 27 have typical values of "*n*" for common batteries. Page 25 is a look-up table, pages 26 & 27 have "*n*" values for common batteries, and page 27 has the formula for calculating "*n*" for other batteries.

The **LINK 2000** uses Peukert's equation only for calculating the Time Remaining of operation function. The Amp hours display is always the actual number of Ahrs consumed. This means that if you rapidly discharge a battery, your time remaining number may show zero hours remaining before you see the total number of Ahrs of battery capacity consumed.

If battery **Type 0** is selected, the **initial Peukert exponent is set at 1.25**. This is a appropriate mid-range value for many common liquid cells. If any other battery type is selected, the **initial Peukert exponent is set at 1.11**. This is an appropriate mid-range value for many common gel and AGM cells. Please note that you may only declare *one* battery type using function F02. This is because we strongly recommend against mixing AGM, gel, and liquid electrolyte batteries in the same system. The selected Peukert exponent is applied to both battery banks. Set the exponent to the correct value for the bank which you use most often.

Making two discharge tests, one at a high discharge rate and one at a low rate, that bracket your normal range of operation, allows you to calculate an "*n*" that will describe this varying effect. The uses a default value of *"n"* equal to 1.25 which is typical for many batteries.

At some low to moderate discharge rate, typically a battery's 20 hour rate, the logarithmic effect of Peukert's Equation is greatly reduced. The effect of discharge rates smaller than this is nearly linear. Battery manufacturer specifications of battery capacity in Amp-hours is typically given at the 20 hour rate. From this description, if a battery is discharged at this rate for the period of time called out, you will be able to remove the rated capacity.

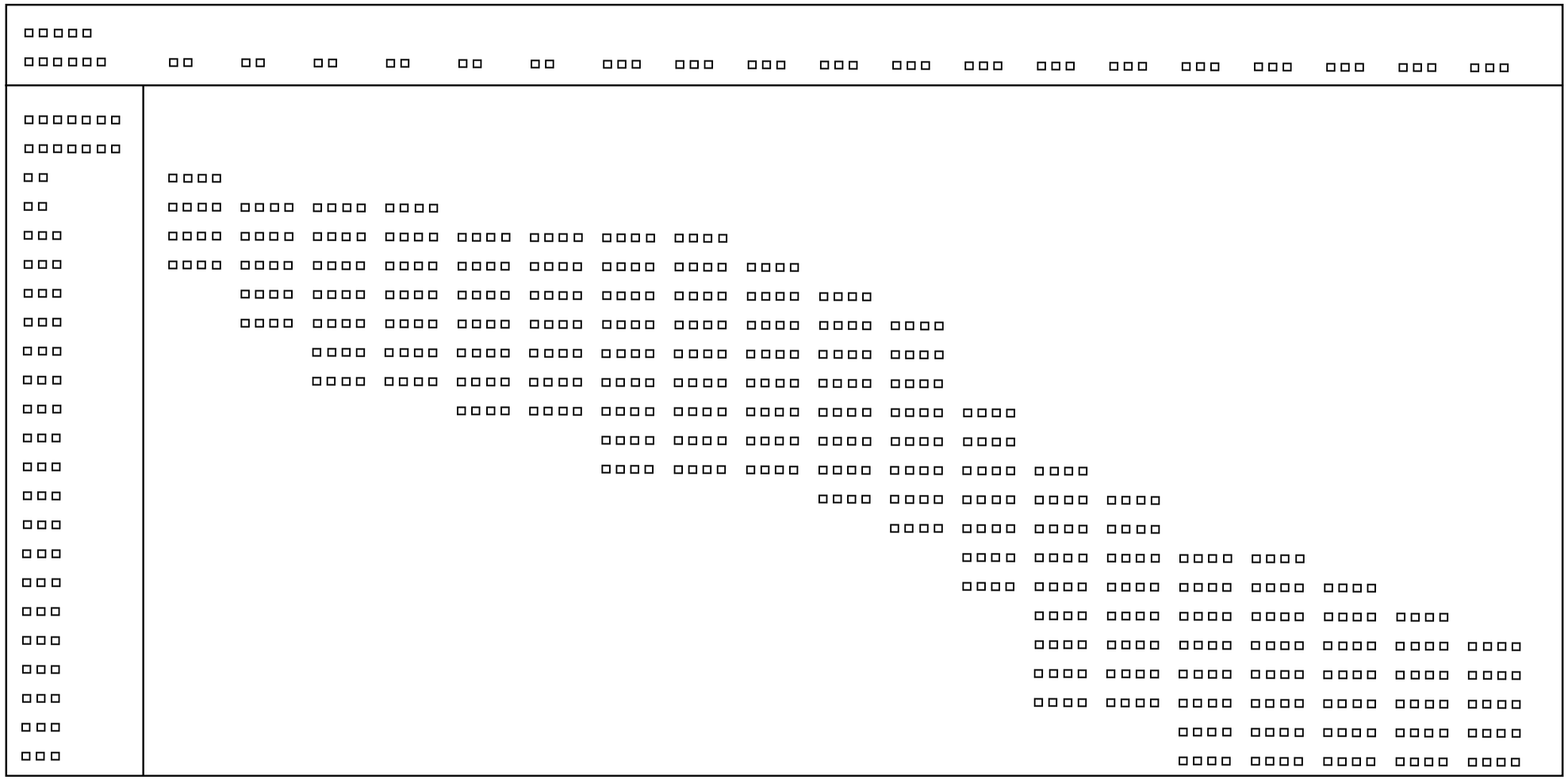
The equation for Peukert's Capacity (C_p) is:

$$C_p = I^n t \quad \text{where} \quad n = \frac{\log t_2 - \log t_1}{\log I_1 - \log I_2}$$

By doing two discharge tests and knowing I_1 & I_2 (discharge current in Amps of the two tests), and t_1 & t_2 (time in hours for the two tests) you can calculate *n* (the Peukert exponent). You will need a calculator that has a Log function to solve the equation above. You may also use the 20 hour discharge rate and the number of reserve minutes as the two discharges to solve Peukert's equation. See example on page 27. After you solve for your Peukert's exponent you may enter it using Function F08.

TABLE OF PEUKERT'S EXPONENT FOR VARIOUS BATTERY RATINGS

DIRECTIONS: FIND THE 20 HR RATING OF YOUR BATTERY ON THE HORIZONTAL AXIS. FIND THE RESERVE CAPACITY RATING ON THE VERTICAL AXIS. THE INTERSECTION IN THE TABLE GIVES THE "*N*" VALUE.



TYPICAL PEUKERT'S EXPONENTS

The following table contains values for the exponent *"n"* for various batteries and manufacturers. They are calculated from the 20 hour rating and the Reserve Minutes @ 25A as supplied by the manufacturer. Page 27 shows how the calculation is performed. You may choose a battery of similar size and construction as a guide in selecting *"n"* if your battery does not appear in this table, or you may calculate *"n"* as shown.

Typical Values for Peukert's Exponent *"n"*
Prevailer & SeaGel Batteries

Model	Volts	Res. Min.	20 Hr. Rating	*"n"*
8GGC	6	375	180	1.14
8GU1	12	140	43	1.20
8GU24	12	130	70	1.13
8GU27	12	167	86	1.12
8GU30H	12	188	95	1.12
84D	12	388	180	1.11
8G8D	12	500	225	1.10

Trojan Batteries

Model	Volts	Res. Min.	20 Hr. Rating	*"n"*
T-105	6	447	225	1.24
T-125	6	488	235	1.19
T-145	6	530	244	1.14
J250	6	535	250	1.17
J305	6	660	305	1.21
L16	6	760	350	1.28
24TM	12	135	85	1.23
27TM	12	160	105	1.28
30XHS	12	225	130	1.24
SCS225	12	225	130	1.24
EV8D	12	450	216	1.17

TYPICAL PEUKERT'S EXPONENTS

Surrette and Rolls Batteries

Model	Volts	Res. Min.	20 Hr. Rating	*"n"*
EHG-208	6	345	208	1.42
EIG-225	6	350	225	1.54*
EIG-262	6	395	262	1.72*
24/90	12	165	90	1.16
27/12M	12	190	112	1.23
30H/108	12	230	108	1.08
HT/4D	12	348	170	1.15
HT/8D	12	450	221	1.20

*Use Max allowed *"n"* of 1.50

CALCULATING PEUKERT'S EXPONENT

Example of using Reserve Minutes @ 25 Amps and the 20 hour rate to calculate "*n*".

First convert Reserve Minutes to hours, then find the discharge current at the 20 hour rating. Finally use a calculator to solve the arithmetic.

Trojan T-105:

Reserve Minutes = 447 min @ 25 Amps.

t_1 = 447 min = 447/60 = 7.45 hrs

I_1 = 25 Amps

20 Hour rating = 225 Ahr

t_2 = 20 hours

I_2 = 225 Amp-hours/20 hours = 11.25 Amps

$$n = \frac{\log t_2 - \log t_1}{\log I_1 - \log I_2} = \frac{\log 20 - \log 7.45}{\log 25 - \log 11.25} = \frac{1.301 - 0.872}{1.398 - 1.051} = 1.24$$

ERROR CODES AND TROUBLE SHOOTING

The following error codes are displayed when the **LINK 2000** detects a problem. The display alternates between the selected monitoring function and the Error Code. The Error Code continues to flash until the error is corrected. (Error codes same for all models.)

CODE	DEFINITION
E-1	**INVERTER HIGH DC/BATTERY VOLTAGE SHUTDOWN:** Battery Voltage has risen above 15.5V for 12V models or above 31V for 24V models. Check all charging sources.
E-2	**INVERTER LOW DC/BATTERY VOLTAGE SHUTDOWN:** Battery Voltage has dropped below 10.5V for 12V units or below 21V for 24V units.
E-3	**INVERTER OR CHARGER OVER TEMP SHUTDOWN:** Unit will reset automatically after it has cooled sufficiently. Be sure there is adequate ventilation around the unit.
E-4	**BATTERY OVERLOAD:** Caused by excessively discharged batteries, or a battery with a bad cell. See section in inverter owner's manual titled "Charging over-discharged batteries."
E-5	**AC BACKFEED:** AC power from an outside source has been fed to the AC output of the inverter. Potentially damaging to the unit!! Disconnect incoming AC power and correct immediately!! See a qualified technician if you do not know how to check for this condition.
E-6	**ELECTRONIC OVERLOAD:** Inverter overload caused by too large of a load or a short circuit on the output of the inverter. Reset by cycling the inverter OFF and ON or connecting incoming AC power.
E-7	**TRIAC CONTROL ERROR:** The Triac is used in the battery charging circuit in the FREEDOM series product. This error indicates that the Triac has overheated. Turn off charger and allow to cool. Be sure there is adequate ventilation around the unit.
E-8	**HIGH BATTERY VOLTAGE SHUTDOWN DURING CHARGING:** Check all charging sources (solar panels, alternators, other battery charges, etc.) for proper voltage. Reset by cycling the charger off and on.
E-9	**NOT USED:**

E-10 **LINK 2000 DEPOWERED:**
Displayed on power up and when power has been interrupted or dipped below the operating voltage of the LINK 2000. May be caused by voltage dips during engine starting if the meter is powered by starting battery.

E-11 **NOT USED:**

E-12 **BATTERY #1 VOLTAGE SENSE LEADS OPEN:**
Check the fuse and connections in the sense lead (Blue wire) to battery #1.

E-13 **BATTERY #2 VOLTAGE SENSE LEADS OPEN:**
Check the fuse and connections in the sense lead (Violet wire) to battery #2.

E-14 **INAPPROPRIATE CHARGED VOLTAGE SELECTED FOR THE SENSED VOLTAGE:**
Displayed if the Charged Voltage parameter is above 20V and sensed voltage is below 20V, or if the sensed voltage is above 20V and the Charged Voltage parameter is below 20V. Helps avoid an erroneous set up. See Charged V.

E-15 **INCOMING AC POLARITY REVERSED:**
Check incoming AC wiring for a reversed polarity (hot and neutral reversed). See a qualified technician if you do not know how to check for this condition.

CCC **INDICATES BATTERY IS BEING CHARGED. DISPLAYED WHEN TIME REMAINING IS SELECTED.**

Exx **CHARGE EFFICIENCY IN DATA DISPLAY**

LO BAT **MORE THAN 50% OF DECLARED CAPACITY OF BATTERY #1 OR #2 HAS BEEN CONSUMED. SEE PAGE 5.**

OL **METER READING OUT OF RANGE.**

Pxxx **INDICATES PERCENT OF CHARGE MODE SELECTED.**

Uxx **DESIGNATES USER SETUP CEF. SEE F06 PAGE 12.**

TO VERIFY CURRENT MEASUREMENT:
You may use a digital multimeter to verify that the current measurement is displayed correctly. Place at least a 20 to 30 amp load on the system. Use the multimeter to check the millivolt reading across the battery shunt. The shunt has a 500A 50mV rating, which means a load of 30 amps generates 3.0mV across the shunt. The reading at the shunt and at the point where the wires coming out of the meter join the shunt wiring should be the same, and when multiplied by 10 should equal the reading in the amps display of the Link 2000.

MICROPROCESSOR RESET PROCEDURE

The **LINK 2000** uses a microprocessor to perform all of its calculations and functions. We have worked very hard to insure a stable trouble-free product, however like all computer products the unit is sometimes susceptible to power supply dips or surges that can cause erratic behavior or memory errors. If you detect a problem please use the following procedure to reset the microprocessor, you may also need to reset the memory to the factor defaults as described on the next page. If you reset to factory defaults be sure and set up appropriate values for battery capacity, battery type, ambient temperature, and Peukert's exponent as previously described. Please read the entire instruction set before beginning the procedure.

TO RESET FROM A LOCKUP, ERRATIC DISPLAY, OR ERRATIC BEHAVIOR

1) Disconnect from shore power.

2) De-power the meter by removing the fuse from the red wire. If the red wire is jumpered to the blue or violet wires, remove the fuses in the appropriate wire to remove power to the unit. If your meter is an alternator regulator model you can de-power the meter by removing the gray ribbon cable from the monitor terminal board and reconnecting it.

3) Wait at least 30 seconds before reconnecting the fuse (or the ribbon cable). When the fuse is reconnected use a continuous motion. If the meter is intermittently powered and de-powered several times in a short period, the microprocessor may lockup.

4) Press the INVERT and CHARGE buttons so that their LED's are illuminated.

5) Restore shore power. After a few seconds you should see the AC STATUS light illuminate and the charge status lights come on indicating the CHARGE mode. (If the battery is full the CHARGE lite will only be on for a short time before the Accept LED comes on.)

6) Check to see that your battery capacity, battery type, ambient temperature, Peukert's exponent, charged voltage parameter, and any other values you might have previously set up are still correct. If they are, end here, if not change them to the appropriate values or follow the procedure on the next page for resetting to factory values.

RESETTING MEMORY TO FACTORY VALUES:

If some portions of the memory have been "corrupted" you should consider resetting to the factory default values and then changing any specific values you need to. This insures a "clean slate" for your new set up.

1) Follow the procedure outlined on the previous page to first reset the microprocessor.

2) Select Battery bank #1 on the **LINK 2000** to reset to factory values for Battery #1. To also reset Inverter and Charger functions to factory defaults be sure that the INVERT and CHARGE LEDs are lit.

3) Press and hold the **SET UP** button for approximately 10 seconds. After 5 seconds the **SET UP** LED will begin to flash slowly, continue to hold until the **SET UP** LED begins to flash quickly (about 3 times per second). Release the **SET UP** button, press and hold the **RESET AHRS** button (blue legend under **BATTERY #1 button).** After holding down the **RESET AHRS** button for about 5 seconds you should see a 0 (zero) appear in the display momentarily. If you do not see the zero, the meter did not reset and this step must be repeated.

4) Select Battery bank #2 on the **LINK 2000** to reset to factory values for Battery #2.

5) Repeat step 3.

6) Reprogram the necessary set up values such as battery type, capacity, ambient temperature, Peukert's exponent, Inverter/Charger parameters, etc..

SET UP & HISTORICAL DATA SUMMARY

The following table is a summary of the values that may be changed through set up or by accumulating historical data. The column on the right is provided to write down your set up values or historical data. Be sure and know these values before calling for customer service. Multiply Voltage values by two for 24 Volt systems.

PARAMETER	DEFAULT VALUE	SET UP VALUE
B1 $V_{CHARGED}$	13.2 (13.5 IF F05 IS ON)	
B2 $V_{CHARGED}$	13.2 (13.5 IF F05 IS ON)	
B1 $AMPS_{CHARGED}$	2% (4% IF F05 IS ON)	
B2 $AMPS_{CHARGED}$	2% (4% IF F05 IS ON)	
B1 BAT CAPACITY	200 Ahrs (800 IF F05 IS ON)	
B2 BAT CAPACITY	200 Ahrs (800 IF F05 IS ON)	
AMBIENT TEMP (F03)	70^0F	
BATTERY TYPE (F02)	#0 LIQUID LEAD ACID	
POWER SHARE	30A (OFF in Freedom 25)	
STANDBY	4W	
B1 USER CEF (F06)	87% (90% FOR GELLED)	
B2 USER CEF (F06)	87% (90% FOR GELLED)	
TIME REMAINING (F01)	0=INSTANTANEOUS	
AHR OR KWHR (F04)	OFF = AHR	
ALT. ENERGY MODE (F05)	OFF	
TEMP. COEFFICIENT (F07)	0.5	
PEUKERT'S EXP. (F08)	1.25	
BATT #2 FOR CNTRL (F11)	ON=YES	
BACKLIGHTING (F12)	130	
DISCHARGE FLOOR (F13)	100%	
TEMP. COMP. (F14)	OFF	

HISTORICAL DATA	VALUE
B1 # of CEF RECALCS	
B2 # OF CEF RECALCS	
B1 AVG DEPTH OF DISCHARGE	
B2 AVG DEPTH OF DISCHARGE	
B1 DEEPEST DISCHARGE	
B2 DEEPEST DISCHARGE	
SOFTWARE REVISION	

LIMITED WARRANTY

This LINK METER is a joint venture of two Valley Forge Companies, Heart Interface Corp. and Cruising Equipment Co..

Cruising Equipment Co. manufactures LINK METERS for Heart Interface Corp.

Installation, operation, technical support, warranty and service issues should be directed to Heart Interface Corp..

DO NOT INSTALL OR ATTEMPT TO USE THIS PRODUCT UNTIL YOU HAVE READ THE OWNER'S MANUAL IN ITS ENTIRETY. IMPROPER INSTALLATION OR USAGE OF THIS DEVICE MAY BE HAZARDOUS AND MAY CAUSE DAMAGE TO OTHER ELECTRICAL EQUIPMENT.

Cruising Equipment Co. (CECO) warrants, to the original purchaser only, for a period of 30 months from the date of purchase, that LINK 2000, and LINK 2000R Meters (hereafter Meter) will be in good working order when properly installed and operated as described in this Manual.

If your Meter fails to perform or becomes defective under normal use and service, CECO, will, without charge, at CECO's place of business, within a reasonable time after delivery, repair, or at CECO's option, replace with a new or factory reconditioned part any part found defective, or at its further option, refund to you the entire purchase price.

In order to qualify and avail yourself of the warranty you must:

1. Contact :
   Heart Interface Corp. at 21440 68th Ave. So. Kent, WA 98032, (253) 872-7225 or
   Cruising Equipment Co. at 5245 Shilshole Ave. N.W., Seattle, WA 98107, (206) 782-8100;
2. Obtain warranty authorization from Heart or CECO;
3. Ship the Meter, charges prepaid, with proof of purchase within 30 months of its purchase.

This warranty is void and will not apply if:
1. Your Meter has been modified or repaired without written authorization from CECO:
2. The identification markings on your Meter have been altered or removed:
3. Your Meter has been damaged through abuse, neglect, exposure to sea spray, lighting strikes, high voltage, accident: or
4. Your Meter was not installed and operated according to the owner's manual or was operated under conditions more severe than those specified in the owners manual.

THE FOREGOING WARRANTY IS IN LIEU OF ALL OTHER WARRANTIES, INCLUDING THE WARRANTIES OF FITNESS FOR A PARTICULAR PURPOSE AND MERCHANTABILITY, EXPRESS OR IMPLIED, AND OF ALL OBLIGATIONS OR LIABILITIES ON THE PART OF CECO FOR DAMAGES, INCLUDING, BUT NOT LIMITED TO LOSS OF TIME, INCONVENIENCE, COMMERCIAL LOSS OR CONSEQUENTIAL DAMAGES, WHICH MAY ARISE OUT OF OR IN CONNECTION WITH THE USE OR PERFORMANCE OF THE METER.

Some states do not allow the exclusion or limitation of incidental or consequential damages, and some states do not allow limitations on how long and implied warranty lasts, so if the law of that state applies, the above limitation or exclusion may not apply to you. This warranty gives you specific legal rights and you may also have others which vary from state to state.

Shipping Policy: CECO will ship to any location in the United States or Canada, at its cost, via UPS surface or surface US mail, all warranty repairs. Shipment outside of the United States or Canada or by methods other that UPS surface or surface US mail will be at the expense of the customer.

REQUIRED READING !!!!!

Before wiring the LINK 2000, install the shunt as indicated.
All wiring should be done before installing the fuses.

GENERAL NOTES

1) Wiring to the **LINK 2000** should be #16 or #18 AWG. (Larger is OK, but not necessary.) Wiring should be per NEC or applicable standards.

2) The Shunt Sense Leads should be a twisted pair. Leads up to 1,000 feet long may be used if they are not run along with other noise producing conductors. Offset error should be less than 0.2 Amps.

☞ For the easiest installation you may wish to purchase our four twisted pair cable with the same color code as the meter. This cable may be run between the meter and the batteries to supply all needed signals. This cable is available from your dealer or from Heart Interface.

Note: You may make your own twisted pair wire by chucking up two wires in an electric drill motor and twisting them by running the drill motor until there is a twist every inch. A wrap of tape every 16" will keep the wires together and make them easier to pull through the raceway.

3) Caution! If your starter draws more than 500 amps see #5 below.

CAUTION!!!!

The output voltage of the shunt is very small. It is critical that all of the connections for the shunt sense leads have the highest possible integrity. Every effort must be made to prevent corrosion that might affect the sense leads.

4) Battery current is sensed with a shunt which is a very precise, small, resistance. It is inserted in series (in line) in the negative wire of the circuit you wish to measure. The current is measured by sensing the voltage drop across this resistance. The **LINK 2000** uses a 50 mV, 500 Amp shunt. When 500 Amps flows through the shunt, there is a 50 mV drop across it. Thus 10 Amps equals 1 mV or 1 Amp equals 0.1mV The display is scaled to read amps. If you wish to check this you will need a very accurate digital meter (Fluke 87 in 4 1/2 digit mode or better) if the current is below 30 Amps (3.0mV). Above 50 Amps most digital meters can be used for testing.

5) Note for Marine and RV installations: If starter current exceeds 500 amps, the starter negative must be connected to the battery side of the battery shunt so that starter current does not flow through it. The problem with this is that if the alternator is of the grounded case type its current will not be flowing through the shunt. The alternator ground must be isolated from the engine and run to the load side of the battery shunt to be able to measure the current going into the battery from the alternator. Isolated negative output

alternators are available and we strongly recommend them. With isolated negative output alternators, remember that instrumentation and other loads grounded directly to the engine block will not be measured unless their negatives are relocated to the load side of the Battery Shunt. Special high current shunts are also a solution and may be ordered from us. A separate engine starting battery whose negative is connected directly to the engine also solves the problem.

6) We have shown several wires connected to the load side of the battery shunt in the wiring diagram. If more than a few wires must be connected here, it is best to use a 2/0 jumper from the shunt to a good negative bus. We recommend that no more than two, or at a maximum three, connections per large bolt be made on the negative bus side of the shunt. The negative bus should be a solid copper or brass bar with many threaded screws under which the negatives for all of the loads may be secured. It should be fed with a conductor of sufficient size so that there is no appreciable voltage drop even under full load.

WIRE BY WIRE INSTALLATION

Be sure the shunt is installed before proceeding.

The **BLACK WIRE** (AGND) is the Analog Ground. It is the reference for all measurements. It must be connected on the BSHG (Grounded) side of the shunt. The BSHG side of the shunt is the side opposite of the negative battery terminals . It must have a good connection to one of the two #10 screws on the top of the battery shunt.

The **RED WIRE** (+12V) is the +12V supply. (In a 24V system supply with +24V.) The wiring diagram shows two options. The preferred option is to jumper together the RED and BLUE wires as shown. Wired this way, the meter cannot accidentally be de-powered. It has the disadvantage of always consuming a little bit of power from the #1 Battery. The meter consumes about 28mA (.028A). If left on all the time it would use about 0.7 Ahrs per day.

If the system is left on for long periods (long enough to significantly discharge the battery) with no charging sources then you should consider the option shown with the dotted line. In this case the RED wire is <u>not</u> jumped to the BLUE but supplied from the common of the battery switch. (Be sure to install the 2A fuse as near the battery switch as possible.) Whichever battery is selected is the battery that supplies the power. If the switch is turned off the meter is de-powered. To re-synchronize your meter you must fully charge the battery when it is put back into service.

The **WHITE WIRE** (LITE) supplies the display backlighting. It should be supplied from a switch that controls other instrument lighting. It may be connected to +12 V along with the RED wire if you wish the lighting to be on all the time. The backlighting consumes about 8mA (.008A). If left on all the time it would use less than 0.2Ahrs per day.

The **BLUE WIRE** (B1V) supplies Battery #1 Voltage for sensing. It should be supplied directly from Battery #1. Be sure to install the 2 Amp fuse shown in the drawing as near the battery as possible.

The **VIOLET WIRE** (B2V) supplies Battery #2 Voltage for sensing. It should be supplied directly from Battery #2. Be sure to install the 2 Amp fuse shown in the drawing.

☞ **Note: If only one battery is to be monitored connect the VIOLET wire to the BLUE wire.**

The **GREEN WIRE** (B1SHG) is connected to the SMALL SCREW ON THE GROUND SIDE, OR LOAD SIDE, of the battery #1 shunt (B1SHG). This wire must be located exactly as described to ensure accuracy of current measurements. The wires that run from the battery #1 shunt sense terminals to the GREEN AND ORANGE wires should be a twisted pair.

The **ORANGE WIRE** (B1SHB) is connected to the SMALL SCREW ON THE BATTERY SIDE of the battery #1 shunt (B1SHB). This wire should be located exactly as described to ensure accuracy in current measurements.

☞ **NOTE: If only one current input is used, connect the Green and Brown wires together and the Orange and Yellow wires together. This hookup will display the same current information for both the battery #1 and #2 selection.**

The **BROWN WIRE** (B2SHG) is connected to the SMALL SCREW ON THE GROUNDED, OR LOAD SIDE, of the battery #2 shunt (B2SHG). SEE ABOVE CAUTIONS.

The **YELLOW WIRE** (B2SHB) is connected to the SMALL SCREW ON THE BATTERY SIDE of the Battery #2 shunt (B2SHB). The YELLOW and BROWN wires should be a twisted pair. SEE ABOVE CAUTIONS.

THE INVERTER REMOTE CABLE

The only connection between the **FREEDOM** and the **LINK CONTROL PANEL** is a standard remote cable. There are three jacks on the back (bottom) of the inverter. Use the one labeled REMOTE. It is best to plug the remote cable into the **LINK 2000** after it is powered up. It is supplied with a 25' cable. You may purchase longer cords from any telephone supply company. You should limit its length to 50 feet. Do not run the remote cable in the same wireway as very noisy power conductors. This helps reduce noise interference problems.

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