INSTRUCTIONS FOR

TRI-METRIC ™

BATTERY MONITOR

May 8, 1996

PART 2: SUPPLEMENTARY INSTRUCTIONS FOR SEVEN TriMetric DATA MONITORING FUNCTIONS.

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A: Introduction:

These supplementary instructions describe the operation of the 7 additional data monitoring functions, (and 48 volt option) beyond the basic TriMetric functions: "volts" "amps" and "amp-hours". None of this needs to be read by the persons interested in just these basic three. In fact the TriMetric has been designed so that these may be ignored by those not needing these functions.

We intend to revise these instructions periodically to make them clearer and more useful. Comments or suggestions on these instructions are welcome and they will influence future revisions. Likewise, suggestions about meter operation are also welcome, and could also be incorporated into the TriMetric design. We expect to respond to user input to periodically make improvements to the TriMetric monitor to make it even more useful to our customers.

To most effectively use these supplementary instructions you should first:

1. Install the TriMetric according to the installation instructions and be sure it is working correctly.

2. Understand the regular operation of the TriMetric, including how to program the volts and amps setpoints, the shunt size, and efficiency factor settings. You should understand how the TriMetric uses these voltage and current settings to determine that the "charged" lamp should be lighted.

B: Summary Description of the seven data monitoring functions

NOTE: Section C describes how to access these functions.

This is a brief description of each function. Each one will be described later, in its own section in precise detail. (See section D) Each also has a *reset function,* and some have a *program* mode--description of each of these will be reserved for the later, precise description. All of these functions operate at all times while the meter is powered--you are just choosing which you would like to view.

"d 0" This is the present "blank" display, which appears between "amp-hours" and "volts" display. *With this choice, the TriMetric works just like the older model TriMetric, and it is the mode that by default is chosen when the TriMetric is first powered up. Use to darken the meter, if desired, and reduce current consumption to the minimum of about 16 milliamps. (However the maximum current draw of the TriMetric with fully lighted display, is only about 32 ma.)*

"d 1": **Displays how long ago (in hours and tenths) that the batteries reached a full charge**: *As explained in the regular instructions, the "charged" lamp tells you that the batteries have reached approximately full charge at some time since it has been manually reset. This display tells you exactly how long ago it happened. Batteries should be recharged before this number becomes too high. There are two choices about exactly which time to record. (See detailed information)*

"d 2": Displays how many amp-hours have been withdrawn from the battery system over its lifetime. (*Counts down only discharge current--does not count charging current) It works somewhat like a car odometer to tell how much service the batteries have seen, and also to tell when battery maintenance should occur, such as battery equalization, which should be carried out after a certain number of A-hr have been withdrawn Reads to one million amp-hours. This data stays if power is disconnected (except at most the last 3.2 hours.) The RESET button resets this number to 0 (after flashing 3 times).*

"d 3": **Displays the calculated** (charge) **battery efficiency for the batteries for one discharge/charge cycle**. *This is the ratio of total amp-hours discharged to total amp-hours to charge, for one discharge/charge cycle. This can be occasionally used to check that the battery system is operating at expected efficiency. This function requires more understanding than some of the other functions to use effectively. The detailed description explains exactly how the meter makes this measurement so you know exactly what has been measured.*

"d 4": **Displays the total discharge amount** (not counting charging amount) **of amp-hours removed from the battery since the last "discharge/charge" cycle began**. *This is the same number as "d 2" above, except it is for just one discharge/charge cycle. Batteries should be recharged before this number becomes too large--for two reasons (1) The batteries should receive a full charge after they've been used a lot, for their own benefit, and (2)When this number becomes much greater than the "net" amp hours, the "amp-hour" reading will begin to lose synchronization with the battery, and therefore become less reliable as a measurement of battery state-of-charge. Fully charging at this point will regain synchronization with the battery.*

"d 5": Shows the **minimum net amp-hours**. *Shows how deeply the battery was discharged since this number was last manually reset. Lead acid batteries (for example) should not be over discharged. (Resetting the "charged" light does not reset this) The RESET button resets this to the present value of net amp-hours, after 3 flashes of the data.*

"d 6": Shows the **minimum battery voltage** which occurred since last reset. *If this number goes too low, it indicates possible harm to the batteries. The RESET button resets this to the present value of volts, after 3 flashes of the data.*

"d 7": Shows the **maximum battery voltage** which occurred since last reset. *Checks that the charging system voltage is set properly. Or when equalizing check maximum voltage attained by batteries The RESET button resets this to the present value of volts, after 3 flashes of the data.*

"d 8": Shows **Filtered amps** . *Displays the same value as the regular "amps" display except that value here is filtered by a long time constant. Therefore, it is a very "sluggish" version of what is shown in the "amps" display.. This is the "amps" value that is used for determining that the batteries have reached "full charge". The amount of filtering (sluggishness) is adjustable by the program mode. Primarily useful with charging systems that slowly switch the charging source on and off as the batteries begin to attain a full charge, which otherwise can't use the "charged" indicator of the TriMetric. (The user can program any of four values of time constant: 0, .5, 2 or 8 minutes.) Also useful for viewing an average charge current for a wind or solar source that is varying somewhat rapidly up and down, due to changing wind, or clouds.*

"d 9": *Possible future or custom function. Call us with your suggestion or need*. However at present this display temporarily shows **total charging amount** (not counting discharge) **of amp-hours put into the battery since the last "discharge/charge" cycle began**. The battery efficiency ("d 3") is obtained by dividing the number shown in "d 4" by this number. The *reset function* for "d 9" may be used to preset all programmed values to original factory values..

C: General information about accessing and using these functions

How these functions are accessed: After power is first turned on to the meter, pushing "select" button allows the user to toggle between volts, amps, amp-hours and a "blank" display, and then back to volts again. The new meter allows any <u>one</u> of the preceding 7 displays to *substitute* for the "blank" display, if desired, so that the user may toggle between "volts", "amps", "amp-hours" and one of the display options shown.

How the display looks: Each of the display option above periodically flashes, for example, a "d 6" alternating with 0 .4 seconds of displayed "d 6" data (in this case minimum battery voltage), followed again by the "d 6". This serves to remind the user which display option has been selected. The only exception is that "d 0" (the "dark" display) is dark all the time.

How to select a different display option: If the meter currently is showing one "d #" display, and you wish to switch to another:

Step 1: Place the unit in the "blank", low power mode (if this is currently selected) or, alternatively, show the data function which has the display that alternates with the "d #".

Step 2:Push and hold down the "select" button a few seconds until "d " appears with flashing number in the display, and then release the button.

Step 3: Now push the "reset" button and the flashing number will change. Push successively (or hold) the reset button until the new desired display number appears. Then push "select" momentarily to get to the new display. This new display will now substitute for the "blank" display until you follow this procedure again.

Each of the display modes described above has its own reset function and many have a program mode. As mentioned above, the function of the various program modes and reset functions is described in detail below, where each display function is described in detail.

How to enter the program modes: Program modes are entered the same as the basic program modes described in PART 1 of the instructions. Not every display function has a program mode--but the ones that do are entered as follows: First push "select" to display the mode "d #" whose program mode you wish to access. Then push and hold down the "select" button and while holding push "reset". Verify that you are in "program" mode by observing 3 flashing lamps. If no program mode exists, this will not happen.

Performing reset functions: The present functions of the "reset" button while the normal "volts", "amps" and "amp hours" are displayed is exactly the same as before. (I.e., the "charged" lamp is reset) However, now in addition, every new display mode has its own "reset" function as well--(they are *not* all the same.) Since it is difficult to remember what each reset function does, (for these new display modes only,) when the reset button is pushed it blinks the appropriate display *four times* before actually performing the reset, to remind the user of what the reset does. So you must remember to hold the button for four flashes --plus a little longer, to actually perform the reset function. This prevents you from accidentally resetting something you didn't intend to. If you are not sure what the reset function does, it is safe to push it and allow the display to flash a couple of times to see what it is supposed to reset.

Important information on flashing decimal points when using new functions: The previous TriMetric could display numbers from 0.01 to 999. This newer TriMetric has the capability of displaying numbers (for example, amp-hours) much higher than before, from 0.01 up to 999,000. When you see a **flashing decimal point,** this means you must multiply the number you see by 1000. **For example, if the display shows 1.02 amp-hours, and the decimal point is flashing, this means "1020 amp-hours"**:

D: Detailed description of each data monitoring function.

"d 0" This is the present **"blank" display,** as explained above.

d 0 Program mode*:* This is the "normal" TriMetric program mode: which allows selection of shunt size, and efficiency factor. See regular (PART 1, section D) instructions.

d 0 reset mode*:* The reset button turns of the "charged" lamp (see PART 1 instructions).

"d 1": **Displays how long ago (in hours and tenths) that the batteries reached a full charge**.: This displays how many hours (and tenths) ago the batteries were "fully charged" as determined by the voltage/current criteria which light the "charged" light for the TriMetric. (The method the meter uses to determine this is described in the regular PART 1 instructions). The maximum time is 6550 hours, (displayed as 6.55 with flashing decimal point) after which the numbers will roll over to 0 again, which is about 9 months. However, this data *will reset back to zero* if power is disconnected from the meter). This is essentially a timer that is reset at the time the batteries are "charged". However, there are two options for the user which determine the precise "charged" event that resets this timer. With one option, (the "Last" or "L" option, which is the factory default) the time shown will be literally the most recent time that the battery met the "charged" criteria. With the other option (called "F" or "First") the meter records the *first* time that the criteria were met *after* the battery was partially discharged--typically the first time that it happened in the day. It then ignores any subsequent "charged" condition, unless the batteries are first significantly discharged again and then recharged. ("Significantly discharged" means that the total number of net amp hours went below the number programmed in "d 4".)- With this second option, if the sun keeps shining brightly, and keeps the batteries at full charge for two hours, say, only the initial time is retained. If this "First" option is selected, it is also important to realize that the "partial discharge" criterion must be properly programmed, as described both in section d 3 and d 4, which defines the depth of discharge (in amp-hours) that qualify as "partial discharge", so you should read these too.

Which option one chooses will depend on the purpose. The simplest to understand is the "L" option, which literally shows the last time that the meter was charged. However, using the "F" option with a solar array charging source allows one to see how early in the day the array succeeds in charging the batteries. If it charges them by 12:00, for example, one could assume that there is a lot of extra energy available to use, whereas if the time is late in the afternoon, the array is just succeeding in meeting the day's requirements of energy.

d 1 Program Mode: The program mode allows the user to select the "First" or Last mode, as described above, by selecting either "F" or "L". Remember that if "F" is chosen, one must also properly program the "partial discharge" amp-hours. See program mode for "d 4".

d 1 Reset: The reset button with this display resets the "charged" lamp. (It is necessary to hold the rest button long enough to flash the "charged" lamp a little more than 3 times before it actually resets)

"d 2": Displays how many amp-hours have been withdrawn from the battery system over its lifetime. This number starts at 0 when manually reset (see "reset", below, for this function), which would usually be at the time of initial installation of the batteries. Every time the current is negative (charge is leaving the battery) the display counts "amp-hours" down. It analogous to a car odometer to tell how much service the batteries have seen. When the batteries are replaced, the number can be noted to evaluate performance of the batteries and the level of care which they received. In case of power interruption to the meter you will only lose a maximum of 3.2 hours of this data--because this data is automatically stored every 3.2 hours. So if power should be temporarily disconnected from the meter, the number showing here will usually be slightly less than before, representing the value that was present when it was last stored into permanent memory, and will continue from that number. This number can be displayed to -999,000 amp hours, which is longer than most batteries would be expected to last. (Should it ever reach this high it should be reset--since it does not, as of this edition of instruction, just roll over to zero by itself after 999,999.)

Often battery life of "deep cycle" batteries is rated by the number of discharge cycles it will undergo without failure--however this always assumes a fairly complete discharge during each cycle. The life of deep cycle batteries is increased if the discharge depth is less--in fact the number of cycles of life is inversely related to the depth of discharge of each cycle--so if one discharges only half the amount during each "cycle" the battery will last about twice as many cycles. This is really just another way of saying that the battery life is related to the number of amp-hours removed.

Another use for this function is to serve as guide as to when to equalize the batteries, or provide other maintenance, such as watering the batteries. Battery equalization should be performed after a certain number of total amp-hours used.

d2 Program Mode: None.

d2 Reset: This resets the number displayed in "d2" to 0. "000" will flash in the display 3 times (to warn the user of what's going to happen) before this actually takes place.

"d 3": **Displays the battery** (charge) **efficiency for the batteries for one discharge/charge cycle**. This function is the most complicated one to understand, although also an interesting battery measure to the sophisticated user. Once determined, it may be used to program the "efficiency factor" setting in "d 0". It compares the total amp hours *discharged* in one charge/discharge cycle to the total amp-hours *charged* in that cycle. It then divides the result to give a number in percent, from 1-200. (The following discussion will assume that the "d 3" program mode has "E1" rather than "EC" programmed and "d5" has "C" programmed rather than "1". These options will be described in more detail later.) When power is first applied to the meter, the d3 display shows "-0-", which indicates that meter has no information yet on which it can make an efficiency calculation. As soon as the batteries first reach the "charged" setpoint the efficiency display indicates this by changing to "-1-". The TriMetric defines the beginning of a "discharge/charge" cycle *after* the batteries have been "charged" (i.e., the charged lamp has lighted) at the moment that the batteries *first* begin to discharge. (This is also the moment that the "amp hour" display is reset to 0). At this time, when the batteries first begin to discharge, the total amount of *charging* amp hours start to record in one accumulating counter, and the total amount of *discharging* amp hours starts recording in another. Next, the batteries must be partially discharged below an amount which has been defined as the minimum discharge amount (which is programmed in function "d 4" see "d 4" programming description) After this partial discharge, the efficiency display "d3" indicates this by changing to "-2-" The discharge/charge cycle ends as soon as the batteries are again recharged sufficiently so that the "charged" lamp is again lighted. At that moment the "amp-hour" number in the discharging counter (which is displayed in "d4") is divided by the "amp-hour" number in the charging counter (which is displayed in "d9") and displayed as the new efficiency value in "d 3". This value now stays in "d 3" until the next "discharge/charge" cycle occurs. However, if you wish, is also possible to have the TriMetric do not just *one* calculation as described above, but after the above calculation takes place to continue to continuously recalculate the efficiency as more and more "charging" current accumulates into the battery. This way it is possible to see how the efficiency decreases as even more charging takes place. To select this option you must program (in the "d 3" program mode) "EC" (Efficiency Continuous) instead of "E1" (Efficiency Once). Then "d3" efficiency recalculations will continue until the *beginning* of the next "discharge/charge" cycle--that is, until the first time that "discharging" again takes place. Incidentally, you can tell that the calculations are occurring continuously when the decimal point is *not* lighted in the efficiency display As soon as the number is not being recalculated, the decimal

point (at the rightmost position *while the efficiency is being displayed*) will light, to indicate that the number is at its final value.

For completeness we will describe two more options--however they will probably be useful only rarely (possibly never, and we may eliminate this feature if it is never used). If the "d 5" program item is set to "1" ("one cycle") instead of "C" ("continuous cycle") and if "d 3" is programmed for "E1" instead of "EC", just one "discharge/charge" cycle will be measured. The efficiency will be calculated for just one cycle and the result will stay forever in the "d3" until the "charged" lamp is reset. When the "charged" lamp is reset, the efficiency display will go back to "-0-" and go through "-1-" and "-2-" according to the process outlined above to measure another cycle, and then hold the efficiency data in "d3" and the "discharge" amp-hour data in "d5". The last option to be described occurs if in "d 5" the program item is set to "1" and the "d 3" is programmed instead for "EC", after the "charged" lamp is reset the sequence of events will be the same as described above in this paragraph, *except* that instead of making just one efficiency calculation the calculations will be made continuously forever as long as the reset "charged" light is not pushed again. It essentially keeps a running total of the ratio between amp-hours discharged divided by amp-hours charged continuously through all future discharge/charge cycles. Eventually, if left long enough, through enough cycles, it should converge to an "average" battery efficiency.

We will probably eventually write a technical note on this subject, since there is quite a bit more to discuss about "battery efficiency". Meanwhile, there are two additional points we shall make here:

1. A meaningful description of "battery efficiency" depends on beginning and ending at precisely the same "state of charge" of the battery--and it is critical (and not so easy) to insure that this is the case. If at the beginning of the defined "discharge/charge" cycle the battery is in a *higher* state of charge compared to the defined end of the cycle, then the measured "efficiency" is going to be too high. (and vice versa) This can cause the value of "efficiency" to be calculated greater than 100% (which we know can't be true for a true cycle!) For this reason, the value when "E1" is selected above may be higher than true, especially if the batteries at the beginning of the cycle were at a high state of charge. The key to getting an accurate efficiency value is to insure that the beginning and ending state of charge is about the same. One way to approach this is to turn off the charger as soon as the "charged" lamp comes on--then begin the discharge/charge cycle for a reasonably deep discharge, and then recharge again (with the "E1" option selected in the program mode of "d3").

2. *For the technically knowledgeable:* There are two kinds of "battery efficiency" that shouldn't be confused. What is being measured here is "charge efficiency", or ratio of "charge out" to "charge in" which is not the overall or "true" battery efficiency. True efficiency is the ratio of total *energy* out to *energy* in, which also takes in to account the loss of voltage when discharging compared to charging, as well as the "charge" being measured here. True efficiency is often said to be about 80% for lead acid batteries--however the *charge* efficiency is quite a bit greater than that, since a lot of the loss of energy in a battery is due to the difference in "charging" voltage compared to "discharging" voltage. Charge efficiency for lead acid batteries, especially when the batteries are not highly charged (and therefore not gassing) appears to us to be high--and although this is quite unofficial yet (don't quote us until we do more measurements!) our observations suggest values in the 95% range. We invite observations of others who have measured this. In fact, it is because this number is reasonably close to 100% that "amp-hour" meters work as well as they do to track total battery charge.

d 3 Program Mode: As explained at length above, "E1" allows "efficiency" (d3) and "discharging amps", (d4) to be calculated just once after each manual reset of the "charged" lamp. Selecting "EC" allows these calculations to be continuously updated until discharging again begins.

d 3 Reset: Resets the "charged" lamp.

"d 4": **Displays the total amount of amp-hours discharged** (not counting charging) **from the battery since the last "discharge/charge" cycle began**. This is one of the two numbers that is used in the "battery efficiency" calculation, above (d 3). This number is reset to 0 after the batteries reach the "charged" criteria, just after the batteries *start discharging* again. From this time on it counts amp-hours down (more negative) whenever the batteries are being discharged. It continues to do so until after the batteries again reach the "charged" setpoint, and begin to discharge again after that. Batteries should be recharged before this number becomes too large--for two reasons (1) For their own benefit batteries should receive a full charge after they've been used a lot, (and "used a lot" means that the total charge removed is a lot), and (2)When this number becomes much greater than the "net" amp hours, the "amp-hour" reading will begin to lose synchronization with the battery, and therefore become less reliable as a measurement of battery state-of-charge. The "net" amp hours (i.e., the regular amp-hour display) must always be equal or less than the "d 4" number, since the "d 4" number and "net" amp hours are both driven down (negative) by discharging at the same rate, but only the "net" number goes positive when charging takes place. If the "net" is *much* less, it means that the battery has "traveled" up and down in its charge cycle quite a bit since it has been charged, (this "d 4" number is

measuring all this "down" travel). Fully charging at this point will be a good thing for the battery, and also regain synchronization of "net" amp hours with the battery

d4 program mode: This allows the user to define the minimum amount of net amp-hours that need to be removed from the battery before a cycle will qualify as a "discharge/charge" cycle. It affects the "d 3" function, and also the "d 1" function when the "F" option is programmed for that function. The number programmed (from 8-200) is the number down to which the "net" amp hours must reach to count as a "discharge/charge" cycle. Just program in the number from 8-200 which is desired. With solar arrays, if the typical usage during an evening is about 100 amp hours, one might want to set this for, say 10-50 amp hours, to use the "F" option with the "d1" function to see the first time in the day that the batteries were charged (refer to "d1" section for more information)

d 4 reset: Resets the "charged" lamp.

"d 5" Shows the **minimum net amp-hours** which were reached since this number was last reset. *Shows how deeply the battery was discharged.* This just displays the lowest value of the "net amp hour" display since it was last reset using the reset button while this display is showing.

d 5 reset: This resets the "minimum net amp hour" display to the *present* value of "net" amp hours. This reset affects only this function--it does not reset anything else. It will flash "000" to hint that this is what will happen. However, it will not really go to "000", but rather the present value of net amp hours.

d 5 program: You may program two possibilities: **C** and **1**. This should usually be set to "C" If interested, you may read the section under "d 3" called: For completeness we will describe two more options to see what happens when it is set to "1". The "C" causes the efficiency data in d3, and cycle discharge data in d4 to be continually and automatically updated for every "charge/discharge" cycle that occurs. When set to "1", these data are calculated for just one discharge/charge cycle, and the data remains forever until the "reset" for the "charged" light is pushed, which initiates a new measurement cycle--after which the data is again remains until reset.

"d 6": Shows the **minimum battery voltage** which occurred since last reset. *If this number goes too low, it indicates possible harm to the batteries.*

d 6 reset: This reset causes the "minimum battery voltage" display to be reset to the *present* battery voltage. When it is pushed the present value of battery voltage will flash three times before resetting.

d 6 program: none

"d 7": Shows the **maximum battery voltage** which occurred since last reset. *Checks that the charging system voltage is set properly. Or when equalizing check maximum voltage attained by batteries..*

d 7 reset: This reset causes the "maximum battery voltage" display to be reset to the *present* battery voltage. When it is pushed the present value of battery voltage will flash three times before resetting to this value.

d 7 program: Selects between "12/24 volt mode and "48 volt" mode. This should be set to "**24**" when using the monitor for 12 or 24 volt systems. In this case the "volts" reading measures the actual voltage present of the TriMetric. It is only set to "**48**" with the special 48 volt adapter (Model TM-48A) which is designed to convert the TriMetric to 48 volt operation. When this is set to "48", the voltage shown on the TriMetric display is *two times* the actual voltage between the "G2" and "+m" terminals. (The adapter inserts a series resistor to drop the voltage to one-half to these points.) Alternatively, it is possible for a user to put a resistor (about 154K) in series from the desired voltage source and M+. (However, the meter must then be recalibrated to get "in spec" voltage accuracy.) Choosing "48" also alters the "charged voltage" option appropriate to 48 volt systems.

"d 8": Shows **Filtered amps** .*This is the "amps" number that is used for determining that the battery has attained full charge. Primarily useful with charging systems that slowly switch the charging source on and off as the batteries begin to attain a full charge, which otherwise can't use the "charged" indicator of the TriMetric. Displays the same value as the regular "amps" display except that value here is filtered by a long time constant. Therefore, it is a very "sluggish" version of what is shown in the "amps" display. The user can program any of four values of time constant:* **0**, **.5**, **2** *or* **8** *minutes.* The display shows this filtered value of amps, which is useful when setting up a charge controller to determine the value of "amps" that should be programmed in the "charged setpoint" to determine that the batteries are "charged". This display is also useful to see the average current input when observing the "amps" from a wind system, or solar panels when the current is varying somewhat due to changing wind, or clouds.

d 8 program: Select between time constants of **0**, **.5**, **2** *or* **8** minutes--which to be precise are about 1 second, 28 seconds, 112 seconds and 446 seconds. The exact definition of "time constant" is that if the actual "amps" changes abruptly from 10 to 0 amps,. it is the time required for the display to drop from 10 to 37% of 10, or 3.7 amps.

d 8 reset: Resets the "charged" lamp.

"d 9": **Presently not used.** *Possible future or custom function. Call us with your suggestion or need.* However at present this display temporarily shows **total charging amount** (not counting discharge) **of amp-hours put into the battery since the last "discharge/charge" cycle began**. The battery efficiency ("d 3") is obtained by dividing the number shown in "d 4" by this number. The *reset function* for "d 9" may be used to preset all programmed values to original factory values..

d 9 reset: Resets all values to factory values which are as follows: **V setpoint=14.4 volts**, with "**auto reset" on**. **Amps setpoint=35** amps. **"d0"**:Efficiency factor**=94%**, with **"H" shunt** (500Amp). **"d 1"= L** (last). **"d 3"=CE**, **"d4",** depth of discharge definition**=15** amp-hours, "**d 5"= C**.(continuous update) **"d7" =24** volt systesm. **"d9"** filtered amps time constant**=0**.