

# BOGART ENGINEERING

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## Information on Shunts

**How a shunt works:** A shunt is necessary in order to measure amps and amp-hours with the TriMetric battery monitor. A shunt is an accurate, very low resistance resistor which is placed "in line" with the wire carrying the current to be measured. With the TriMetric, it is usually placed in the negative wire from the battery bank, such that *all* the current going into the battery (charging) or out (discharging) must pass through it. Connected in this way it will be set up to monitor "net" amp-hours in and out of the battery. (It also could be placed in series with the negative wire coming from a solar array--or other charging source--in which case it would measure only the solar array current, if that were desired--to show total solar "amp hours" production.) The shunt needs to be placed near the batteries; since these wires carry very high currents the wires from the batteries must be kept short to minimize electrical losses.

**Shunt resistance:** When current flows through the shunt, a small voltage is developed across the shunt which is proportional to the current flow. The TriMetric battery monitor accurately measures this very low voltage and converts it to the "amps" reading on the meter. The resistance, which is the ratio between the voltage across the shunt and the current flowing through it, is a constant for any particular shunt--and is one of its important parameters. For most substances, resistance is usually described in "ohms", however for some reason shunts are described by the voltage drop that occurs with a certain current: for example: "50 millivolts at 500 amperes." However the meter only cares about the ratio--which is the resistance--so a 500Amp/50 millivolt shunt is equivalent, from the TriMetric's view, to a 250Amp/25 millivolt shunt. They both have a resistance of 0.1 milliohm, or one ten thousandth of an ohm.

**Kelvin connections:** Shunts have four connections: two of them are the large bolts that carry the large battery current that is to be measured. There are also two smaller screws, called "Kelvin connections" that the meter connects to in order to sense the voltage drop. These are needed because otherwise large errors of measurement would occur because the voltages picked up by the meter are extremely small--often smaller than the voltage drop along the large battery cables in that carry the large current. The Kelvin terminals define two points along the current path that define the exact shunt resistance.

**Setting up the TriMetric for correct shunt:** There is a choice of two different shunts, depending on the size of your system. As mentioned below, the more common, larger one is required if your system has more than 70 amps charging or discharging. The TriMetric is designed to use either the larger 500 Amp/50 millivolt (0.1 milliohm) or smaller 100 Amp/100 millivolt (1.0 milliohm) shunt. The latter shunt delivers 10 times the voltage for a given current flow through the shunt, so the meter can show an extra digit of current resolution (down to 0.01 amp) compared with the 500 Amp/50 millivolt shunt, which displays a minimum current of 0.1 amp. To make the TriMetric read "amps" and "amp-hours" correctly, you must tell the TriMetric which shunt is being used. This is done by programming either an "L" (low) or "H" (high) in one of the program modes. ("L" for the 100A/100 mV shunt, and "H" for the 500 A/50 mV shunt.) There is provision both in TriMetrics and PentaMetric for selecting this..

**Shunt maximum current capability:** The other important characteristic of a shunt is how much maximum current may safely flow through it. The higher the current that flows through it the greater the temperature rise of the shunt. In fact, (just as in any resistor) the temperature rise is proportional to the square of the current passing through it--so the heat becomes rather rapidly hotter as the current is increased. A shunt may operate safely up to 145° C. Beyond that, the alloy it is made from--called manganin, (which is a material which has the unusual and desirable property that it does not change resistance when it changes temperature) can undergo permanent changes of resistance. If it gets still hotter, it could even burn up. Interestingly, the shunt manufacturers seem to be rather vague (or is it "optimistic?") about this rating. One might expect that a shunt with a "100 amp/100 millivolt" rating would be able to safely pass 100 amps--however this is frequently a wrong assumption! Some shunts supposedly rated for 200% or 300% normal will overheat at those maximums. For this reason, we have measured the current carrying capability of some shunts. The 100 amp/100 mv shunts have been measured with number #4 wire connected to the shunt, and the 500 amp/50 mv shunts are measured with #0000 wire connected. (This is significant, because the wire serves as a means of removing some heat from the shunt. It is realistic since it is necessary to connect the shunt to a large wire to adequately carry the current.) The temperature at the hottest place on the shunt is monitored, and a safe but reasonably large current is put through the shunt. The amount of

temperature rise is measured. We then compute the current in amperes which will yield a 105°C rise. If the ambient temperature is 40° C, (103° F) a rise of 105°C will yield a final temperature of 145°C. If actual temperature is lower, more current may be safe--and vice versa. For temperatures different from 40°C, you may use this formula below in Note 1 to determine maximum current.

**MKB-500-50:** Manufactured by Deltec

**Resistance:** "500 Amp at 50 millivolts", or 0.1 milliohm.

**Max. steady state current, amps: (Note 1):** 410 Amperes

**Thermal time constant (Note2):** 18 minutes

**Overload current:** If normally operated at less than 300 amps, it will take overloads to 500 amps for durations of less than 5 minutes.

**Physical characteristics:** Has a plastic base 3.25 x 1.75 in. with two mounting holes .205 "dia, 1.25" apart o.c. 1.75 inches overall height. High current connections are made to two bolts (3/8"-16) which are 1.50 in. apart (o.c).

**MKA-100-100:** "mini shunt" Manufactured by Deltec

**Resistance:** "100 Amp at 100 millivolts" or 1.0 milliohm.

**Max. steady state current, amps: (Note 1):** 75 Amps

**Thermal time constant:(Note2):** 30 seconds

**Overload current:** If normally operated at less than 50 amps, it will take overloads to 100 amps for durations of up to 8 seconds.

**Physical characteristics:** Has plastic base 2.00 x 1.25 inches, with two mounting holes .205 "dia, .875 apart o.c. Overall height 1.7 inches. High current connections are made to two bolts (1/4"-28) which are 1.00" apart.

**WO2-100-100:** Manufactured by Deltec

**Resistance:** "100 Amp at 100 Millivolts" or 1.0 milliohm.

**Max. steady state current, amps (Note 1):** 95 amperes

**Thermal time constant (Note2):** 2 minutes.

**Overload current:** If normally operated at less than 50 amps, it will take overloads to 120 amps for durations of up to 1 minute.

**Physical characteristics:** It has *no* base--dimensions 5-3/4 x 3/4 x 3/8 inches. High current connections are made to two 11/32" dia. bolt holes, which are 4-15/16" apart (o.c.)

NOTE1: All currents shown are for 40°C (103°F) maximum ambient temperature (still air) for maximum shunt temperature of 145°C. For other temperatures *T* you may use the formula

$$I_{\text{act}} = I_{40} \sqrt{\frac{145 - T}{105}}$$

*I*<sub>act</sub> = Maximum current at temperature *T* (other than 40°C.)

*I*<sub>40</sub> = Maximum current as shown above (for 40°C).

*T* = Ambient temperature of shunt degrees *Celsius*.

NOTE2: **Thermal response time:** The thermal time constant is a measure of how fast the temperature rises when the current is switched on. It is useful for determining permissible overloads and how long they may continue. (The time constant is defined as the amount of time required for the temperature to climb to 63% of its "steady state" value.) Measurements made on "500 A" shunts used 1 ft. #0000 wire bolted to shunt. "100 A" shunts used 1 ft. #4 wire bolted to shunt.