INTRODUCTION TO BATTERIES AND CHARGING SYSTEMS

SURE POWER INDUSTRIES, INC.

BY RALPH E. SCHEIDLER

INTRODUCTION

Charging systems and battery maintenance should be the least of all the troubles encountered in RV, Marine, Truck and Industrial electrical systems. Yet it is often the GREATEST source of trouble —— dangerous trouble!

WHY?

The laws of physics are simple but explicit. Follow these principles and there will be very little trouble. Break the smallest of these principles and the whole system suffers.

IT'S THE LAW !!

The purpose of this booklet is to outline these simple laws in an easily understood and concise manner. We want to inform and possibly eliminate the mystery of the battery and charging system for the layman and providing a review for the electrician.

Since D.C. electricity has similar operating characteristics to a pressure water system, the water analogy approach shall be used.

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ANALOGICAL DEFINITIONS OF COMMON ELECTRICAL TERMS

SECTION 1.0

A simple method of understanding DC basic theory is to use a pressurized water system analogy. Fundamentally, electrical current will not flow unless there is voltage (or electrical pressure). For water to flow in a pressurized system you need water–pressure or pounds per square inch. The following chart lists the analogical similarities of both terminologies.

Electrical Term	Definition	Pressurized Water System Analogical Terms
Volt	Electrical Pressure	Pounds per Square Inch
Amp (Ampere Current)	Quantity of flow per unit of time	Gallons per Minute
Resistance (Ohms)	Restriction to flow`	Pipe Size, Nozzle or Valve
Conductor	Wire	Pipe, tubing, etc.
Semi–Conductor (diode)	Allows Current flow in one direction	Check Valve
Alternator, Generator, Charger	Creates the Electrical Pressure	Pump with a Maximum Pressure and Capacity Rating
Voltage Regulator		Pressure Regulator
Battery		Pressure Tank Accumulator
Ampere–Hour (A.H.)	Amount of amps flowing x Number of hours used	Gallons per minute x time

Within this analogy and using the terminology of this chart, we can say that electrical current is equal to the flow of water, and voltage is equal to the pressure. The alternator pumps current (water) into the batteries (storage tanks). The current then flows through wires (pipe) to the accessories needing power. Let us now focus on the physical properties of this analogy.

THE BATTERY

SECTION 2.0

The battery is a fantastic but greatly misunderstood source of portable power. It is an electrical power accumulator that stores a specific amount of electrical energy, the amount being dependent on its electrical size, or capacity. As a water pressure tank can supply a certain amount of gallons per minute for a period of time depending on its size, so a battery may deliver a certain amount of amperes for a period of time depending on its size. This is called the ampere–hour (A.H.) capacity of a battery.

Example: a 100 A.H. battery (in good condition) can deliver 5 amps for 20 hours. Remember, however, that similar to a water tank losing pressure as it empties without the pump running, so the voltage of a battery lowers as it delivers amps without the alternator running. Below a certain pressure, products like dishwashers and lawn sprin - klers won't work properly. Similarly, as voltage drops in a battery, lights dim, pumps slow, and refrigerators stop, even though there are amps (gallons) still in the battery. As a conservative rule of thumb, lead acid batteries can deliver approximately one–half their rated A.H. capacity before the voltage falls to a possible problem level.

A.H. CAPACITY AMPS LOAD = HOURS OF OPERATION AT NOMINAL VOLTAGE

SECTION 2.1

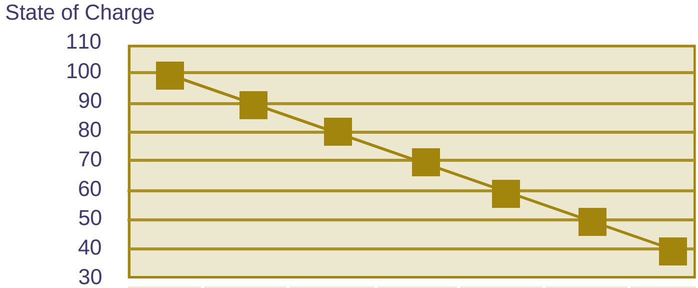
A battery is a very efficient device. If 10 A.H.'s are used, 10 A.H. returned to the battery by recharging will bring the battery back to a state of full charge. This is just like a pressure tank where 10 gals. per min. was used for 10 minutes. One hundred gallons would have been used, so 100 gallons would refill the tank again.

The law for the battery is simple…but exact. Obey the law, and the battery will give long and faithful service. But like any other law, break it and the result is problems. The law is this: **THE BATTERY MUST ALWAYS BE RECHARGED AT THE PROPER VOLTAGE**; it must be maintained at **FULL** charge at all times. Recharging should always be as soon after the battery is used as possible, preferably within a few days. Overcharge the battery and it will be damaged from overheating and burning. Undercharge the battery and it will be damaged as seriously as overcharging. The lead sulfate that is formed on the plate as the result of the chemical action that takes place during discharge will harden over a short period of time if the battery is not recharged properly, and will result in a condition known as a sulfated battery. This sulfation will cause…among other problems…an inability of the battery to receive a complete charge from a properly regulated source, such as an alternator or a converter. The capacity of the sulfated battery will be reduced and if undercharging continues will soon become worthless. Also, a discharged or undercharged battery may freeze. Low water level is another cause of sulfated plates.

SECTION 2.2

The law of the effect of temperature on battery operation is often overlooked. A battery has 100% of its rated capacity at 80^{0} F. At 32^{0} F the same battery has 65% of its capacity and at 0^{0} F has only 40%.

Temperature Effect on DC Batteries
Percent of Charge



Temp F	80^{0} F	68^{0} F	56^{0} F	44^{0} F	32^{0} F	16^{0} F	0^{0} F
	100	90	80	70	60	50	40

This means that a 70 AH fully charged battery has only 45AHs available at 32^{0} F and 28 AHs at 0^{0} F. A half charged battery only has 46% of its capacity at 80^{0} or 32 AHs; it has a bare 22AHs available at 32^{0}, and a near unusable 15 AHs at 0^{0}. As if this is not bad enough, the temperature problem is compounded when the battery is used to crank the engine. Given an engine whose cranking power requirement at 80^{0} using 10W–30 oil is 100%, the power requirement for that same engine at 32^{0} is 155% and at 0^{0} is 210%!

If SAE 20 oil is used, that 0° figure is 250%. An engine that requires 2½ times the power to crank must be cranked by a battery that now has only 28AHs available…that is if none of its charge was used last night for lights or other needs. This points out very vividly one reason why the starting battery should NEVER be used for anything other than the normal operation of the vehicle.

The above figures apply to standard lead acid batteries. The low maintenance and maintenance free types of batteries now appearing on the market have different characteristics than standard types.

THE SIMPLE CHARGING SYSTEM (USING THE WATER ANALOGY)

SECTION 3.0

3.1 The *PUMP* creates the *PRESSURE* in the system. The *ALTERNATOR* creates the *VOLTAGE* in the system.

3.2 The regulator controls the *PUMP* to a specific *PRESSURE.* The regulator controls the *ALTERNATOR* to a specific *VOLTAGE.*

The regulator does not turn off the alternator when the battery is charged, but causes it to produce a constant electrical pressure, or voltage. This is **ALL** that the regulator does!

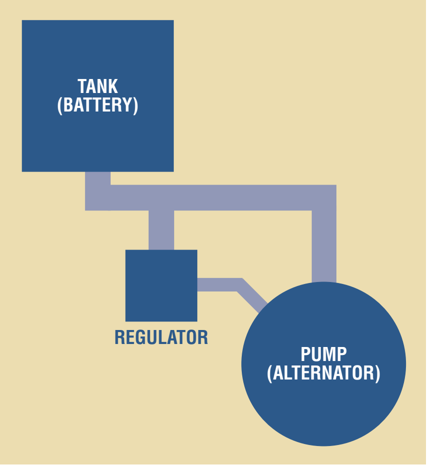


Figure 1

3.3 Liquid flow (GPM) is controlled by the *PRESSURE* in the *TANK.* Current flow (AMPS) is controlled by the *VOLTAGE* in the *BATTERY.*

If the pressure at the pump is regulated at 14.5 pounds per sq. inch, water will flow into the tank until it also reaches 14.5 pounds per sq. inch, at which time the flow will stop. The amount of flow at any given time is determined by the pressure difference between the tank and pump. If the pressure difference is 10 lbs., the flow will be at a higher rate than when the difference is only 5 lbs. The battery, then, is an electrical pressure tank and the current flow in the circuit is determined by its electrical pressure (state of charge). Current flow stops when the pressure or voltage is the same at both ends. Therefore, in a properly regulated circuit, the amount of current flow is determined by the *BATTERY,* not the regulator. Note: It is possible to have voltage in the circuit without amps flowing, but it is **NOT POSSIBLE** to have amps without volts. Current cannot flow without pressure.

3.4 The maximum flow produced is controlled by the *PUMP,* size of *PIPE,* etc. The maximum current produced is controlled by the *ALTERNATOR,* size of *WIRE,* etc.

If the pressure in the tank is so low that it could receive 100 gallons/minute at the regulated pressure, but the pump could only produce 60 gallons/minute, the 60 gallons/minute would be the maximum flow that could be produced. If the pipe or fittings could handle only 30 gallons/minute at that pressure, then 30 gallons/minute is the maximum flow that can be produced. If the battery was so low that it would receive 100 amps at the regulated voltage (electrical pressure), but the alternator has a capacity of 60 amps, then 60 amps is the maximum amount of current that can be supplied. If the wire or connector or any other circuit component is too small and can handle only 30 amps at the regulated 14.5 volts of electrical pressure, then 30 amps is all the current that this circuit can produce. The circuit is said to have too much resistance. Recharging this battery from an alternator will take twice as long using #10 wire as it would if #8 wire is used.

THE MULTI–BATTERY PROBLEM

SECTION 4.0

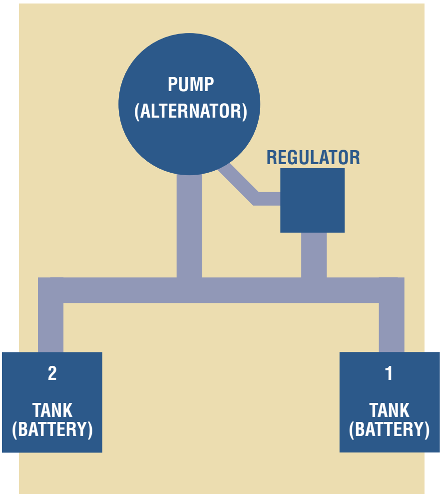


Figure 2

4.1 To the same system we add one more *TANK.* To the same system we add one more *BATTERY.* When the system is fully charged, the *PRESSURE* is the same throughout the circuit; at both *TANKS,* at the regulator, at the *PUMP,* and in the *PIPE.* When the system is fully charged, the *VOLTAGE* is the same throughout the circuit; at both *BATTERIES,* at the regulator, at the *ALTERNATOR,* and in the *WIRES.*

4.2 When the pump is not operating and current is used for #2 *TANK, PRESSURE* will be lowered in #1 *TANK* also. When the *ALTERNATOR* is not operating and current is used from #2 *BATTERY, VOLTAGE* will be lowered in #1 *BATTERY* also.

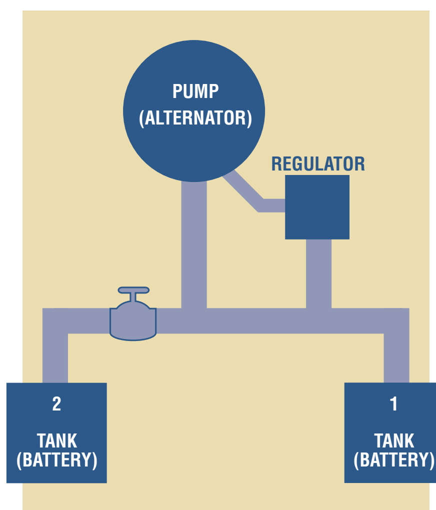


Figure 3

4.3 To correct this situation, a *VALVE* in *TANK* line #2 may be installed so that flow may be blocked from #1 *TANK* when #2 is being used. To correct this situation, a *SWITCH* in battery line #2 may be installed so that circuit flow may be blocked from #1 battery when #2 is being used (See figure 3).

However, when #2 TANK has been run low, and the valve or switch is activated, #1 TANK can now rapidly equalize into #2 TANK because of the PRESSURE difference and no control of current. However, when #2 BATTERY has been run low, and the valve or switch is activated, #1 BATTERY can now violently equalize into # 2 TANK because of the large VOLTAGE difference and no control of current. If #2 TANK needs 150 GPM, then that amount can flow. If #2 BATTERY needs 150 amps, then that amount can flow. Another problem is that within seconds after the valve or switch reconnects the two systems, not only do we have an uncontrolled current flow, but now both TANKS or BATTERIES have nearly equalized with each other and both systems are in a state of at least partial discharge.

(More on this in Section 6.0)

THE SOLUTION

SECTION 5.0

5.1 To eliminate the above problems, isolate the two *TANKS* or *BATTERIES* by simply installing two *CHECK VALVES* or *DIODES,* one in each line.

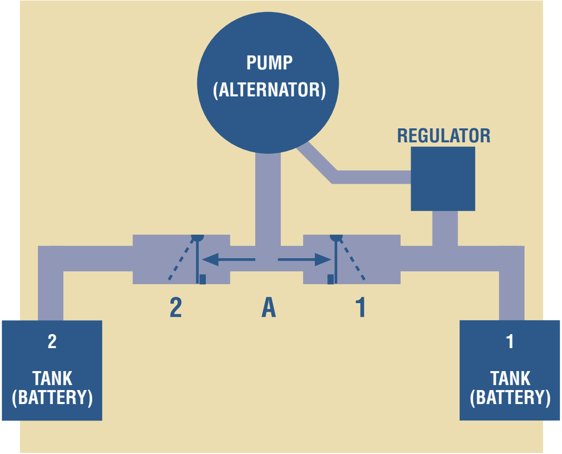


Figure 4

5.2 Both *TANKS* will receive current from the *PUMP* and the *PRESSURE* will still equalize throughout the system while the *PUMP* is in operation. Both *BATTERIES* will receive current from the *ALTERNATOR* and the *VOLTAGE* will still equalize throughout the system while the *ALTERNATOR* is in operation.

5.3 Now when current is used from *TANK* #2, the #1 *CHECK VALVE* stops current flow from *TANK #1*, since current can only flow in one direction, and that is from the *PUMP.* Now when current is used from *BATTERY* #2, the #1 *DIODE (VALVE)* stops current flow from *BATTERY* #1, since current can only flow in one direction, and that is from the *ALTERNATOR.*

5.4 When the *PUMP* is started, an absolutely controlled current flow goes to *TANK* #2 and a different amount of controlled charge or flow will, at the same time, go to *TANK* #1, since each *TANK* controls the amount of current that flows into it, (See point 3.3), by its own *PRESSURE.* When the *ALTERNATOR* is started an absolutely controlled current flow goes to *BATTERY* #2, and a different amount of controlled charge or flow will, at the same time, go to *BATTERY* #1, since each *BATTERY* controls the amount of current that flows into it, (See point 3.3), by its own *VOLTAGE.*

5.5 The maximum current that the *PUMP* can produce is limited by its own capacity. The maximum current that the *ALTERNATOR* can produce is limited by its own capacity. If, in the case of an alternator system, #1 battery wants 30 amps and #2 battery wants 50 amps…which is a total demand requirement of 80 amps…but the alternator has only a 60 amps capacity, the 60 amps is all that will be produced. So with this system the alternator is protected, the batteries are protected and the family is protected. The balanced circuit electronic Isolator is absolutely the **ONLY** way that proper isolation and control can be accomplished and every multi–battery problem solved. **IT'S THE LAW!**

5.6 Since the PRESSURE is the same everywhere in the circuit when the PUMP is operating, the PRESSURE sensing can be taken from either TANK circuit for the regulator. Since the VOLTAGE is the same everywhere in the circuit when the ALTERNATOR is operating, the VOLTAGE sensing can be taken from either BATTERY circuit, it is regulated at every part of the circuit. Proper water PRESSURE causes correct current flow to the TANK. Proper VOLTAGE causes correct current flow to the BATTERY.

MECHANICAL SWITCHES, RELAYS, SOLENOIDS, ETC.

SECTION 6.0

There are many switches, relays, solenoids, and other variations of switches on the market that claim to be battery isolation devices. This **CANNOT** be! **IT'S THE LAW!** These cannot isolate; they simply disconnect one battery from the other when *"OFF,"* but reconnect the batteries when turned *"ON".* In the *"ON"* position the full battery can discharge at an uncontrolled rate into the low battery. If the low battery is substantially lower than the other battery, this current can be so high that the wiring, plugs, and the switch contacts can overheat, creating a possible fire danger. Many switches on the market will have stuck contacts after only one such abuse…a serious situation when a family believes that the auxiliary battery is disconnected from the cranking battery and it in fact is not.

Another serious problem is when the engine is again stopped soon after starting. The two batteries have been connected long enough to cause the cranking battery to discharge into the auxiliary…a period of time that is measured in seconds…and now the vehicle will not restart. This is a common problem. If the auxiliary battery is low, the main battery *WILL* discharge into the low one and the engine may have to be operated for a considerable period of time before it may be safely turned off. Many an engine has failed to restart because of this problem.

The alternator is a rugged charging device; a vast improvement over the original DC generator. Yet it has one serious and instant enemy…excessive voltage surges, or spikes. These are *VOLTAGE* spikes (electrical pressure), not current surges. Some switch installations can cause voltage spikes under certain conditions which can and do cause instant destruction of the alternator.

Another point of law is that: if two or more batteries are to be connected and charged in parallel, they must be the same size and age. If not, one battery or the other may be damaged. Switches literally connect batteries in parallel. This condition does not exist when using the Sure Power Battery Isolator. The cranking battery may be a one year old 65AH battery and the auxiliary battery may be a new 200AH battery, and they will both charge properly.

Most of the switches on the market are far underrated for today's high output alternators, with the exception of the solenoid type. The solenoid used in this charging application has its own set of problems. They are not designed for a continuous charging current to be flowing through their copper to copper contacts. As a result of this misapplication, a high resistance builds up within the switch that does not allow the auxiliary battery to fully charge. The auxiliary battery then sulfates very quickly, and before long a battery that had the capacity to furnish power for an entire week or more without charge will be able to supply power for only a day or two. Many a battery has been wrongly blamed when the trouble was in the way that it was being charged.

A vehicle or a boat which represents thousands of dollars investment and is the most refined equipment ever offered for sale should never be equipped with one of these unsafe, misengineered (for this application) devices. Today's vehicles are equipped with the most efficient, safe, and reliable charging systems that have ever been available, incorporating all of the safety margin needed, and absolute control of the electrical system. Any device that is installed in the system **MUST NOT DO LESS**. This can only be accomplished with a **PROPERLY ENGINEERED** electronic isolation device! Any other way will fail!
IT'S THE LAW!

THE ELECTRONIC ISOLATOR

SECTION 7.0

The electronic Isolator must be engineered to include certain qualities. A properly engineered electronic Isolator will solve all of the problems in charging two or more batteries of the same voltage, but a misengineered unit will create a whole new set of problems. The prime requirements for an isolator are as follows:

7.1 It must have diode protection in each leg. There are some single diode models on the market that inject more problems in the circuit than any other device sold for this purpose.

7.2 It must have diodes heavy enough to handle today's high output alternators with safety margin to spare. Special diodes are manufactured for Sure Power to Sure Power specifications to accomplish this end. Since one battery in the system may require all of the alternator's output while the other(s) require none, the diode in each leg of the Isolator must be capable of carrying the maximum alternator current output.

7.3 A major enemy to an electronic device is heat. The alternator is able to take care of keeping its own diodes cool with the high volume air blast that passes over the diodes from the alternator's own fan. An Isolator must depend on the radiation from the heat sink fins plus whatever airflow it can get from the engine fan and from the air scooped while the vehicle is in motion. The heat sink must provide adequate radiation area to guarantee the proper control of temperature under the most severe condition that the alternator can create. Remember, the alternator produces the current (amps) which creates the heat. Sure Power heat sinks are especially made and anodized in order to meet these requirements. Heat sinking is a tremendous engineering study in itself…a fact that is seldom fully appreciated by the average person.

7.4 Shorts to ground are a serious problem. An Isolator can seldom be mounted on a perfectly flat surface and is almost always found mounted with the heat sink torsionally distorted to some degree. If the diodes are mechanically attached to the heat sink, the mica insulator washers may shear resulting in a short to the heatsink. If thicker washers are used then the heat block becomes so great that the diode will operate at a dangerously high temperature. Also, when diodes are mounted through the heat sink with terminals exposed underneath then dust, grease and water may provide an electrical path to ground in a short period of time. These problems can only be eliminated when the diodes are NOT mechanically attached to the heat sink. Sure Power products use a thermal–diffuser sub assembly that evenly transfers the heat into the heat sink by using a special material that thermally connects but electrically insulates the sub assembly from the heat sink.

The Sure Power Isolator System will assure a safety margin equal to or exceeding that of the alternator; it is an automatic guardian of all batteries; it will assure proper charge to each battery with minimum water consumption; it provides absolute isolation so that the cranking battery is always at full charge; and it will provide peace of mind while battery power is being used. The alternator is a high output charger that will safely recharge the low battery quickly. As long as there is fuel in the tank, there is a continuous supply of battery power available.

SECTION 8.0

Batteries are available in many types. Nickel cadmium (Ni–Cad), lead/calcium maintenance free (M–F), lead/low antimony (low maintenance, L–M), lead/antimony, 'deep cycle' lead/antimony and gel cells are among those found in marine, automotive and industrial use. Each type has particular voltage/current requirements for recharging. Use care and seek knowledgeable advice if more than one type is used in a system. Never mix battery types in a parallel bank. All batteries in the bank should be identical in type, size, age, and voltage charge requirements.

Auxiliary batteries for vehicles and boats should be designed for deep cycle use…that is, a continuous long discharge period followed by a complete recharge. Standard types and most of the currently available maintenance free batteries will not perform as expected. Consult the battery manufacturer and select the correct type for your application.

8.1 Having obtained the batteries, select the Isolator just as carefully. The Isolator must be rated[1] for at least the maximum available alternator output.

Ensure that the gauge (size) of wire used in the charging circuit is sufficient for the alternator output. See Section 3.4 and charts on page 15.

RECOMMENDED WIRE & CABLE SIZES FOR CHARGING SYSTEMS

Alternator Output Maximum Amperes						Wire Size	
To 40	40-60	60-80	80-100	100-130	130-160	AWG	Metric mm^2
5(6.1)						14	(2.5)
7(2.5)	5(2)					12	(4)
12(4)	8(3)	6(2)				10	(6)
18(7)	12(5)	9(4)	8(2)			8	(10)
30(11)	20(8)	15(6)	12(5)	9(3)		6	(16)
45(18)	30(11)	23(8)	19(7)	14(5)	12(4)	4	(25)
	50(16)	38(12)	30(10)	24(7)	20(6)	2	(35)
		50(15)	40(12)	30(9)	25(8)	1	(50)
			48(15)	38(12)	30(10)	0	(70)
Maximum Distance of the Alternator to Battery in Feet (Meters)							

[1] Refer back to Section 7.0 and the Specification Chart on page 16

CHARTS

SECTION 9.0

Now that the batteries have been looked after, don't forget the equipment and accessories wired to them. Skimping on wire gauge here will waste power and result in poor performance or even cause damage to pumps, refrigerators, radios, marine electronics, etc. The charts on these pages show wire sizes for both a 10% voltage drop (most normal accessories) and a 3% voltage drop (sensitive electronics).

9.1

WIRE GAUGE for 10% Voltage Drop
12 Volt Systems (AWG)

	Wire to load in Feet								
Current (amps)	10	15	20	25	30	35	40	45	50
5	14	14	14	14	14	14	14	14	12
10	14	14	14	12	12	12	10	10	10
15	14	14	12	10	10	10	8	8	8
20	12	12	10	10	8	8	8	6	6
25	10	10	10	8	8	8	6	6	6

WIRE GAUGE For 3% Voltage Drop
12 Volt Systems (AWG)

Current (amps)	10	15	20	25	30	35	40	45	50
5	14	12	12	10	10	8	8	8	8
10	12	10	8	8	6	6	6	4	4
15	10	8	6	6	4	4	4	4	2
20	8	6	6	4	4	2	2	2	2
25	8	6	4	4	2	2	2	1	1

9.3

Wire Size Comparison between AWG (American Standard) and Euro Standard (mm²)

AWG	Euro Std mm^2	AWG in mm^2	AWG	Euro Std mm^2	AWG in mm^2
16	1.5	1.31	6	16.0	13.30
14	2.5	2.08	4	25.0	21.15
12	4.0	3.31	2	35.0	33.62
10	6.0	5.26	1	50.0	42.41
8	10.0	8.38	0	50.0	53.49
			00	70.0	67.43

ISOLATOR SPECIFICATIONS

SECTION 10.0

The specification chart below shows the current capabilities of each model series of Sure Power Multi–Battery Isolators. (Refer to Section 7.2). Note the heat sink radiation area of each isolator series in relation to the amp rating.

Model Rating max. cont. alternator(s) input	Model Series Example	Heat Sink Radiation Area cm^2 (sq.in.)
25	122	70 (11)
70	702,703	1096 (170)
95	952	1522 (236)
130	1302	2200 (341)
160	1602, 1603	3045 (472)
200	2002	3045 (472)
240	2402	4064 (630)
300	3002	5884 (912)
2x70 amp	2702, 2703	2200 (341)
2x120 amp	3202	4064 (630)

IMPORTANT: *Not heat sunk for continuous duty higher than model rating*

Sure Power Multi–Battery Isolators are designed and manufactured as described in order to perform at full model rating under all ‘real life’ conditions. Further information is available from the factory.

WHO WE ARE

In order that you may have a better idea as to who we are, and what we do, let us explain what Sure Power is all about.

Sure Power Industries is an engineering based firm that specializes in DC charging system controls. Our product line originated through the recognized need for such specialized controls. Our experience in the field has led to our expertise in the automotive, truck, bus, R.V. and marine marketplace. For this reason, wherever more than one charging source, battery bank, and/or system voltage is required, companies throughout the world look to Sure Power for their answers. Sure Power prides itself in being the only company worldwide that has designed and developed its total product line around solving these specific application problems.

Sure Power Industries would like to encourage you to look to us for your multi–voltage, multi–charging source, and/or multi–battery application answers. We know we can help.

For further information, contact Sure Power at (800) 845-6269, or visit us online at **www.surepower.com.**

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