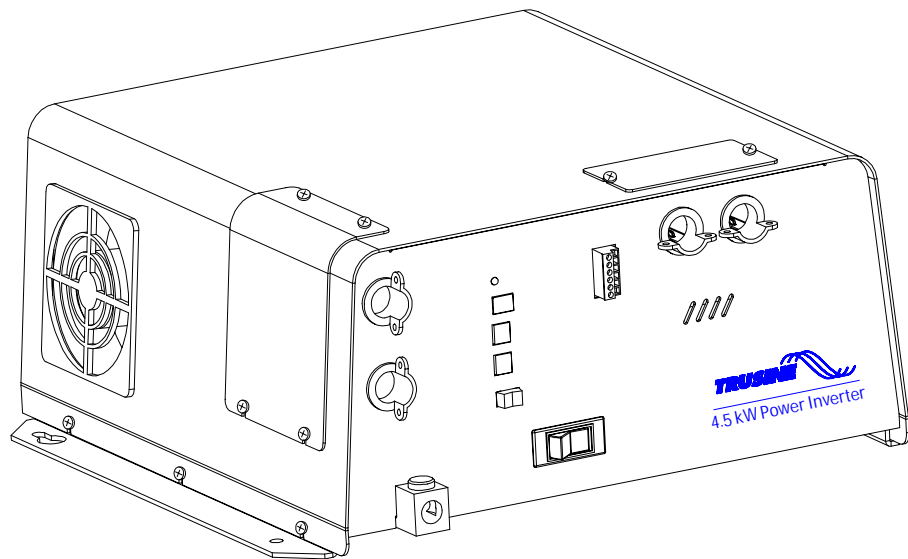


# TruSine 4500

## 4.5 kW Inverter/Charger System



Models

TSC24-4500

TSC24-4500D

Owner's Manual D98771 Rev B

**Notes**

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**Introduction**

Thank you for purchasing a Vanner TruSine inverter system. We are confident that you will be satisfied with its performance and its many features. With proper installation and care, you can look forward to years of service from this high performance product.

This document will describe the operation, technical specifications and installation procedures for the TruSine Inverter/Charger System. If you require additional information please contact your dealer, or contact us directly at the location shown on the cover of this manual.

**1 System Features and Specifications**

**1.1 General Description**

The TruSine system consists of a 4500 watt DC to AC true sine wave inverter, a 100 amp 24 volt battery charger, an automatic AC transfer switch, and a microprocessor based controller with data communications capability. A key feature of this system is the optional TSR-2 TruSine Remote Control Panel operator's interface which utilizes a high speed "data highway" to connect one or more TSR-2 units to the inverter.

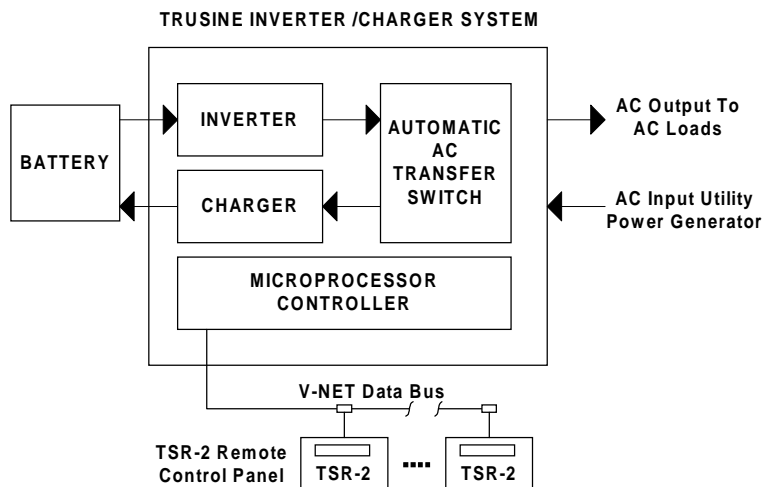


Figure 1 - System Diagram

**1.2 System Features**

**• Inverter**

The inverter consists of two sine wave inverters built into one unit. A "low power" high efficiency 70 watt inverter supplies power for the small loads. The "high power" 4,500 watt main inverter supplies power when AC loads over 70 watts are applied. Designed for maximum efficiency this system conserves battery power when only small loads are present. To further conserve battery power the Load Demand feature allows the inverter to 'go to sleep' if AC loads fall below a selected value. Load Demand may be disabled if very small AC loads must be operated.

The inverter develops up to 4,500 watts of continuous power. Using TruSine® technology, a very high quality pure sine wave is produced. Total harmonic distortion (THD) is less than 2.0 percent.

- **Battery Charger with Automatic Power Management**

A high efficiency 100 amp multi-stage battery charger allows fully automatic charging of flooded and gel lead acid battery banks. The efficient 0.85PF, compared to typical 0.59PF on triac type chargers, allows full charger output from a 30 amp aux AC source. The system's Bulk - Absorption - Float charge cycle quickly charges and maintains the charge on the battery bank. An Equalization charge cycle is provided for flooded lead acid battery maintenance.

Automatic Power Management (APM) monitors the Aux AC Input amps and will reduce the battery charger output as needed to keep the Aux AC Input amps below the preset APM Limit.

- **Automatic AC Power Transfer Switch with Solar Mode**

An automatic AC transfer switch provides system output power sourced from the Aux AC Input (generator or utility) or sourced from the battery, via the inverter. Solar Mode allows the inverter to operate on battery power while shore power is present.

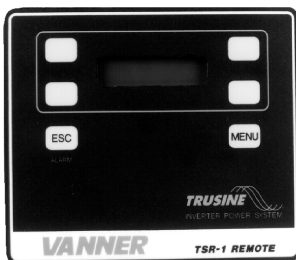
- **Gen Start**

The Gen Start feature provides a start/stop signal to control a generator used for recharging the batteries. The start/stop signal consists of a contact closure to start the generator based on battery voltage and stop the generator based on battery charging amps.

- **System Control**

The TruSine contains a System ON/OFF Switch to turn the system ON and OFF. A control microprocessor provides a variety of protection interlocks, system fault detection/reporting/recovery, storage of system data parameters, and high speed data communications to the optional TSR-2 Remote Control Panel. System protection functions include over load, over temperature, and high and low battery voltage. Use the ON/OFF Switch to reset the system after shutdown for a system fault. The optional TSR-2 Remote Control Panel provides a system status display and allows detailed control of individual system functions.

- **TSR-2 TruSine Remote Control Panel (Optional)**



The optional TSR-2 Remote Control Panel / Programming Panel is an operator interface which connects to the TruSine Inverter/Charger via a 6-conductor data bus and allows system operation near the inverter or from remote areas. Multiple TSR-2 Remotes may be connected for optimum flexibility. The TSR-2 contains an alphanumeric LCD display and functional keypad making it easy to use. System status messages are displayed, faults are reported, system functions may be enabled/disabled or turned ON/OFF, system setpoints may be examined and changed.

Figure 2: TSR-1 and TSR-2 Control Panels

Earlier production TSR Remotes, the TSR-1, are identical to the TSR-2 except contain early software used with TruSine inverter/charger model TSC24-4000D. The TSR-1 will work with TruSine 4500 models but cannot access the GenStart and other new features of the TruSine 4500. The TSR-1 may be upgraded to TSR-2 status by changing software to part number A88769-A or newer. TSR-2 software is displayed upon startup and also is identified in the General Information Menu step 52. TSR-1 software is identified in the System Info menu.

**1.3 Specifications**

	<b>Model TSC24-4500</b>	<b>Model TSC24-4500D</b>
<b>AC OUTPUT</b>		
Voltage (RMS)	120 VAC $\pm$ 3% adjustable	120/240 VAC $\pm$ 3% adjustable
Frequency	60 Hz $\pm$ 0.5%	60 Hz $\pm$ 0.5%
AC Waveform	Sine Wave	Sine Wave
Total Harmonic Distortion (THD)	Less than 2.0%	Less than 2.0%
Power Factor Allowed	-1 to 1	-1 to 1
Continuous Output Rating @ 25°C		
L1 to Neutral	4500 watts (37.5 amps)	2,250 watts (18.8 amps)
L2 to Neutral	N/A	2,250 watts (18.8 amps)
L1 to L2	N/A	4,500 watts (18.8 amps)
Surge Capacity @ 25°C (3 sec.)	10,000 watts	10,000 watts
<b>DC INPUT:</b>		
Operating Range (24 Volt Nominal)	21 to 34 Volts	21 to 34 Volts
No Load, Inverter ON	1.8 amps	1.8 amps
No Load, Search Mode	0.46 amps	0.46 amps
Full power	210 amps	210 amps
<b>INVERTER EFFICIENCY</b>		
15 watts	62.8%	63.1%
30 watts	72.6%	71.2%
60 watts	62.6%	75.2%
100 watts	72.3%	71.7%
400 watts	88.5%	88.3%
1100 watts	91.3%	92.2%
1500 watts	90.6%	90.7%
2000 watts	89.4%	89.50%
3200 watts	86.2%	86.7%
3900 watts	83.7%	84.1%
4600 watts	79.7%	82.5%
<b>AC INPUT</b>		
Voltage (adjustable)	120 Volts nominal $\pm$ 10%	120/240 Volts $\pm$ 10%, 3wire 1Ø
Frequency	60 Hz $\pm$ 12.5% (52.5 to 67.5)	60 Hz $\pm$ 12.5% (52.5 to 67.5)
<b>AC TRANSFER SWITCH</b>		
Power Rating	30 amps @ 120 VAC	30 amps @ 240 VAC
Transfer Time	Less than 40 milliseconds	Less than 40 milliseconds
<b>BATTERY CHARGER</b>		
Charger Output Current maximum	100 amps	100 amps
AC Input Current maximum	30 amps (0.85PF @ rated output)	15 amps per leg (same)
<b>SYSTEM</b>		
Ambient Operating Temperature	-40 to+40°C (-40 to+104°F)	-40 to+40°C (-40 to+104°F)
Cooling Exhaust Fan	Thermostatically controlled	Thermostatically controlled
Mounting	Wall or Shelf	Wall or Shelf
Dimensions (wall mtd position)	17.5"H x 19"W x 8.5"D	17.5"H x 19"W x 8.5"D
Weight	83 pounds	83 pounds
TSR-2 Remote DC power draw	0.11 amps	0.11 amps

## 2 DESCRIPTION OF OPERATION

### 2.1 Inverter

The System ON/OFF Switch, located on the front panel, allows the user to turn the system ON and OFF and to reset the system after a fault. The inverter will always begin operation in the large inverter “high power” mode. If the AC load is less than 70 watts the inverter will automatically switch to the “low power” high efficiency small inverter after 5 seconds. The optional TSR-2 Remote Control Panel allows the inverter to be disabled (turned OFF) while allowing the other system functions (charger, transfer switch) to continue to operate.

The Inverter AC Output Circuit Breaker is a 2 pole, 20 amp breaker marked “O/I” located below the System ON/OFF Switch. The breaker protects the Inverter AC output and Battery Charger AC input against a severe overload. This breaker does not protect AC Passthrough Power. If the breaker trips during inverter operation, the system must be reset. Do this by turning the System ON/OFF Switch OFF and back ON. Do not use the AC Output Circuit Breaker as an ON/OFF switch.

#### Protective Interlocks

Auto-restart	After shutting down for any of the following fault conditions the inverter will <u>try</u> to restart itself every 5 minutes. The inverter will restart if the fault condition is no longer present.
Manual restart	Manually restart the system by resetting the inverter after the fault conditions is removed. Reset the inverter by turning the System ON/OFF Switch OFF and then ON.
Low Battery	The inverter continually monitors battery voltage. If battery voltage falls below the Low Battery Shutdown setpoint the inverter will shut OFF. Auto-restart will restart the inverter after battery voltage rises above the Low Battery Warning setpoint.
High Battery	The inverter will shut OFF if battery voltage rises above the High Battery setpoint.
Over Temperature	The inverter will shut OFF if internal temperature sensors detect a high temperature condition that would damage the inverter. While operating in Solar Mode a high temp shutdown will transfer back to shore power until the over-temperature condition clears.
Over Load -	If a short circuit or an overload is applied to the inverter’s output the inverter will shut down.

Additional details regarding protective interlocks are found in the Alarm Menu in section 3.

#### Load Demand

The TruSine Inverter’s Load Demand Mode is an energy-saving feature. Load Demand allows the inverter to go to sleep when the AC load is below the ‘Enter Load Demand’ (watts) setpoint for 5 seconds. While in Load Demand (asleep) the inverter produces only pulses of AC which are used to search for an AC load. When the inverter senses an AC load greater than the ‘Exit Load Demand’ (watts) setpoint, the inverter will turn fully ON. The Load Demand feature significantly reduces the DC amps drawn from the battery while the AC load is below the Load Demand enter and exit setpoints.

The inverter will not enter Load Demand from the High Power mode. The inverter will only enter Load Demand from the 70 watt small inverter Low Power mode.

The ‘Enter Load Demand’ and ‘Exit Load Demand’ setpoint values may be adjusted to suit the AC loads by using the optional TSR-2 Remote Control. The Load Demand feature may be turned OFF by selecting Load Demand enabled/DISABLED. This is recommended if very small AC loads under 5 watts, such as clocks or LCD displays, must be operated.

### 2.2 Battery Charger

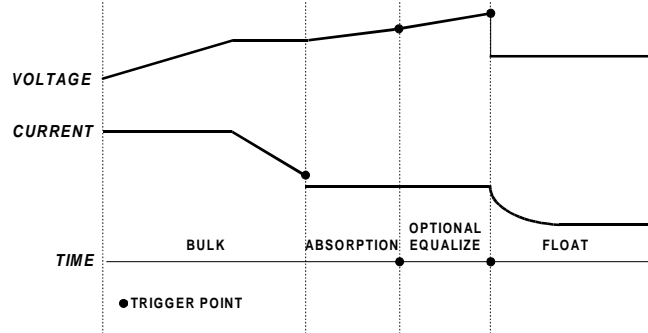
The battery charger’s advanced design incorporates an automatic, multi-stage charger. This design enables

the unit to automatically charge batteries which maintains the battery's integrity and reduces the likelihood of premature battery failure. The battery charger is designed to be used with lead-acid type batteries including sealed and gel types, but not for nickel-cadmium (Ni-Cad) or nickel-iron types.

**Battery Charging Sequence**

Stage 1: Bulk Charge Stage

The charger always starts in the Bulk Charge Stage each time shore power becomes present and/or each time the charger is turned ON. In Bulk Charge the system charges at the 'Bulk Charge Amps' setpoint until battery voltage rises to the 'Bulk Charge Voltage' setpoint. Then the voltage is held at that setpoint until charging amps have fallen to 5 amps above the 'Battery Absorption Amps' setpoint. This ends the Bulk Charge Stage and begins the Absorption Charge Stage. The charger will not enter the Bulk Stage again until shore power is reapplied, or until the charger or the system is turned ON again.



Stage 2: Absorption Charge Stage

The Absorption Charge Stage provides a controlled “overcharging” of the battery which is necessary to bring the battery up to full charge. The battery is charged at the 'Absorption Charge Amps' until one of following three conditions occur which signals the end of the Absorption Stage;

- Time: The Absorption Maximum Time setpoint is reached
- Time: The Absorption Charge Stage has reached ½ of the duration of the Bulk Charge Stage.
- Voltage: Battery voltage reaches the 'Absorption Voltage' setpoint

Stage 2A Equalize Charge Cycle

When Equalize Mode is ENABLED, one Equalize Charge Cycle will follow the Absorption Charge Stage. The Equalize Cycle will last for the 'Equalize Time' setpoint. Equalize Mode will automatically switch to DISABLED at the end of the Equalize Charge Cycle. During the Equalize Cycle the battery is charged at the 'Absorption Charge Amps' setpoint and the Equalize Voltage setpoint.

The Equalize Charge Cycle provides a deliberate overcharging of the battery to remove sulfate which accumulates on the battery plates through normal use. Equalizing returns battery cells to equal performance levels which improves battery performance and extends battery life. Consult the battery manufacturer for their recommendation regarding equalize voltages how often the Equalize Cycle should be performed.

**CAUTION**

**Do not equalize sealed (valve regulated lead acid or gel) batteries!** Consult battery manufacturer for equalizing guidelines. Do not equalize more often than approximately once a month. Check battery fluids after equalizing is complete, as gassing will occur. Use Equalize Mode only while batteries are well ventilated!

Stage 3: Float Charge Stage - Maintenance Mode

In the Float Stage the charging voltage is reduced to the 'Float Charge Voltage' setpoint and charging current is limited to the 'Absorption Charge Amps' setpoint. The charger will remain in the Float Stage until shore power is reapplied, or until the charger or system is turned OFF and then ON again.

**Charging Setpoints**

The TruSine's battery charger factory setpoints are for wet batteries. Do not use the factory setpoints for gel batteries. If gel batteries are used, consult the battery manufacturer for charging recommendations. Setpoints for typical gel batteries are listed and may be used if specific recommendations are not available from the gel battery manufacturer.

Caution: Do not operate DC loads, such as DC lights, pumps, etc., during battery charging. The loads may cause overcharging by preventing the charging stages from reaching their 'trigger points' or may cause the battery to run down even though the charger is ON.

Battery Charger Factory Setpoints (Factory Setpoints are for wet batteries, 4 size 8-D minimum.)

All Charging Setpoints are Password Protected in the TSR-2 Remote Control	Guideline	Setpoint Range	Factory Setpoint (for Wet Battery)	Typical setpoint for Gel Battery
Bulk Charge Volts		26.0 - 32.0	28.4 VDC	28.1 VDC
Bulk Charge Amps	20% C Rate	0 - 100	100 Amps	20% C Rate
Absorption Charge Volts		28.0 - 34.0	30.0 VDC	28.2 VDC
Absorption Charge Amps	5% C Rate minimum	10 - 50	50 Amps	5% C Rate minimum
Absorption Maximum Time		10 - 255	10 Minutes	10 minutes
Float Charge Volts		26.0 - 30.0	26.4 VDC	27.2 VDC
Equalize Volts	Wet only	26.0 - 34.0	31.0 VDC	Not used
Equalize Maximum Time	Wet only	5 - 30	15 Minutes	Not used

Battery 'C Rate' is equal to battery Amp Hour capacity.

### Automatic Power Management (APM)

A key feature of the battery charger operation is Automatic Power Management (APM). This feature monitors the Aux AC input amps and will reduce the battery charger output as necessary to keep the Aux AC input amps under the APM setpoint. The APM circuit will not limit power to the passthrough AC loads. If the passthrough AC loads exceed the APM setpoint the battery charger output will be reduced to zero.

Adjust the "APM Limit" setpoint to match the circuit breaker at the Aux AC source. This will reduce the chance of tripping the source's circuit breaker due to battery charging.

On model TSC24-4500D (240VAC) the APM feature monitors L1 and L2. APM decisions are based on the heavier loaded line.

Example: With the APM Limit on a TSR24-4500D set at 15 amps, L1 loaded to 15 amps and L2 has no load, then the APM will allow no power to go to charging. If the load on L1 is reduced to 10 amps then the charger will be allowed to use 5 amps.

### 2.3 Automatic Transfer Switch with Solar Mode

The Automatic Transfer Switch consists of electro-mechanical relays controlled by circuits which monitor Aux AC input voltage, Aux AC Input frequency and battery voltage.

In the normal mode of operation, Solar Mode OFF, the Automatic Transfer Switch will automatically accept 'in-tolerance' Aux AC input power whenever it is available within tolerance for the 'AC Line Stabilization' time delay. The Aux AC input power will be used to operate the battery charger and to passthrough to operate AC loads. Upon loss of 'in-tolerance' Aux AC input power, the transfer switch will automatically transfer the AC loads back to inverter power. Transfer time is approximately 40 milliseconds (0.040 seconds). The 0.040 second transfer time allows all but the most sensitive loads to transfer from inverter power to shore power and back without interruption.

The Transfer Switch will function properly as long as the System ON/OFF switch is ON even while the Inverter is disabled, while the Battery Charger is disabled or while the batteries are disconnected from the system.

The Transfer Switch switches both hot and neutral. For safety purposes the inverter output neutral is connected to the inverter chassis ground only when the system is in inverter mode. This is a requirement of the National Electric Code for all systems of this type that *neutral should be connected to ground only at the source of AC power*, which is the inverter when in inverter mode. When Aux AC input (shore power, or generator) is available, the Transfer Switch system breaks the connection between neutral and inverter chassis ground. The neutral-to-ground connection for passthrough power is then expected to be provided by the Aux AC input source. This transfer scheme presents no problems for a properly installed system. The installer should verify that all AC circuits connected to the inverter AC output are an insulated neutral type as required by the National Electrical Code (NEC) article 551.

### Solar Mode

Turn Solar Mode ON in applications where it is preferred to operate on battery power while 'in tolerance' Aux AC input (shore power) is available. With Solar Mode ON, the inverter will operate on battery power while Aux AC input is available until battery voltage falls below the Low Battery Warning setpoint. Then the system will

accept Aux AC input, the batteries will be Bulk charged and the system will switch to inverter again.

### 2.4 Gen Start

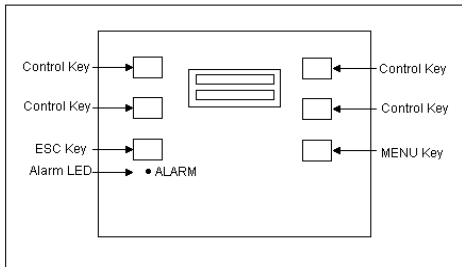
The Gen Start feature is designed for use in installations having a generator to provide Aux AC input power for battery charging. The Gen Start feature provides a contact closure to signal the generator to start when battery voltage falls below the 'Gen Start Volts' setpoint. The Gen Start contacts open when bulk charging amps fall below the 'Gen Stop Amps' setpoint. Bulk charging amps are sampled every 4 minutes, therefore the minimum generator ON time is 4 minutes. The contacts are NEC Class 2, rated 2 amps at 12 or 24 VDC.

Gen Stop Amps should be set higher than the Absorption Charge Amps setpoint.

Caution: The battery charging process will be affected if 24VDC loads are being powered during battery charging. The increased charger output, required to power those loads, may keep the charger from reaching the 'Gen Stop Amps' setpoint.

## 3 TSR-2 Remote Control Panel (optional)

### 3.1 General Description



The TSR-2 TruSine Remote Control Panel is an optional display/keypad module that allows the installer to adjust the system operation factory setpoints and allows the user to monitor and control in detail the TruSine Inverter/Charger operation. The TSR-2 connects to the inverter at the V-NET Port. One or more control panels may be installed to provide the necessary level of system control and flexibility. The TruSine Inverter/Charger System setpoints will not change after removal of the TSR-2 Remote.

TSR-2 Control Panel

The TSR-2 TruSine Remote Control Panel contains a 32 character (two 16 character lines) liquid crystal display (LCD), a red Alarm LED indicator, and a functional keypad. A menu scheme is used to allow the operator to select and control system functions, and to display information. In the event of a system fault the Alarm LED will illuminate and a fault message will be displayed. The TSR-2 Remote connects to the inverter's V-Net Port via a 6 conductor modular data communication cable. The unit is supplied with a 25' long cable with a 6-pin RJ-11 connector at each end.

Early production TSR-1 Remotes, used with earlier model Vanner inverter/chargers, are identical to the TSR-2 but will need the software upgraded to A88769-A to access the GenStart and other new features in the TruSine 4500 Inverter/Charger. TSR-2 software is identified in the General Information Menu step 52. TSR-1 software is identified in System Information step 53 for the TSC24-4000D.

### 3.2 Adjustable Factory Setpoints for the TruSine 4500

The following chart lists the Factory Setpoints for all System functions which may be adjusted, Enabled/Disabled, or turned ON/OFF using the optional TSR-2 Remote Control. (Software A88769-A)

Inverter/Charger Model		TSC24-4500		TSC24-4500D	
Non-Password Protected Function		Adj. Range	Factory Setpoint	Adjustment Range	Factory Setpoint
Basic Control	Inverter	Same	Same	Enabled/Disabled	Enabled
	Load Demand	Same	Same	Enabled/Disabled	Enabled
	Enter Load Demand	Same	Same	0 – 70	20 Watts
	Exit Load Demand	Same	Same	0 – 255	40 Watts
	Charger	Same	Same	Enabled/Disabled	Enabled
	Equalize Cycle	Same	Same	Enabled/Disabled	Disabled
	APM Limit Amps	Same	30 Amps	0 – 60	30 Amps
<b>Password Protected Function</b>					
Inverter	Inverter Output Voltage	110 - 125	120 VAC	110 – 125	120 VAC /phase
	Low Battery Warning Voltage	Same	Same	20.0 - 25.0	22.0 VDC
	Low Bat. Shutdown Voltage	Same	Same	20.0 - 22.0	21.0 VDC
	High Bat. Shutdown Voltage	Same	Same	25.0 - 34.0	34.0 VDC
Battery Charger	Bulk Charge Voltage	Same	Same	26.0 - 32.0	28.4 VDC
	Bulk Charge Amps	Same	Same	0 – 100	100 Amps
	Absorption Charge Voltage	Same	Same	28.0 - 34.0	30.0 VDC
	Absorption Charge Amps	Same	Same	10 – 50	50 Amps
	Absorption Maximum Time	Same	Same	10 – 255	10 Minutes
	Float Charge Voltage	Same	Same	26.0 - 30.0	26.4 VDC
	Equalize Voltage	Same	Same	26.0 - 34.0	31.0 VDC
	Equalize Maximum Time	Same	Same	5 – 30	15 Minutes
	Battery Temp Compensation	Same	Same	On - OFF	OFF
	Battery Temp Coefficient	Same	Same	0 – 25.5	4.0 mV/°C/Cell
Gen	Gen Start Mode	Same	Same	ON/OFF	ON
	Gen Start Batt Voltage	Same	Same	20.0 - 25.0	22.0 VDC
	Gen Stop Charging Amps	same	Same	0 – 50	10 Amps
Trans Switch	AC Line Stabilization Time	Same	Same	10 – 120	10 seconds
	Solar Mode	Same	Same	ON/OFF	OFF
ID	(address) Look for inverters?			Yes - No	No
	Inverter Address (*see Note)	Same	Same	1 – 10	1
	Remote Address	Same	Same	1 – 10	1

\*Note - Inverter Address, Step 92, applies only to systems having multiple inverters and multiple TSR-2 Remotes. Do not change Inverter Address from 1 in a single inverter system. The TSR-2 will immediately stop responding if Inverter Address is changed. Use Demo Mode to change Step 92 'Inverter Address' back to 1.

### 3.3 Operation

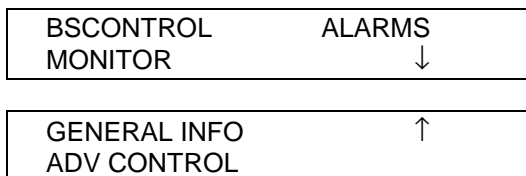
The TSR-2 Remote Control Panel contains: a Menu button; an Escape button; a two-line display; four control buttons located at the corners of the two-line display; and an Alarm indicator light. The two-line display will contain information that will instruct the operator to take action based on display characters at each “corner” of the display. For example, if the display has an ‘up arrow’ in the left position of the upper display line, press the upper left control button to step up in the menu sequence. Likewise, a ‘down arrow’ would instruct you to press the corresponding control button to move down in the menu sequence. For data values, press the control button corresponding a displayed +(plus sign) or – (minus sign) to increase or decrease the data value. System functions are turned ON or OFF by selecting ‘ENABLED’ or ‘DISABLED’ from the display. Capital letters indicate the selected status.

The TSR-2 Remote uses a menu approach to select desired system functions. When menu command messages are shown on the display, the operator may select the desired function by pressing the corresponding control button. Press the ESC (Escape) button at any time to step back one level. Press the MENU button at any time to return to the Main Menu.

The MAIN MENU and all submenus are structured as follows:

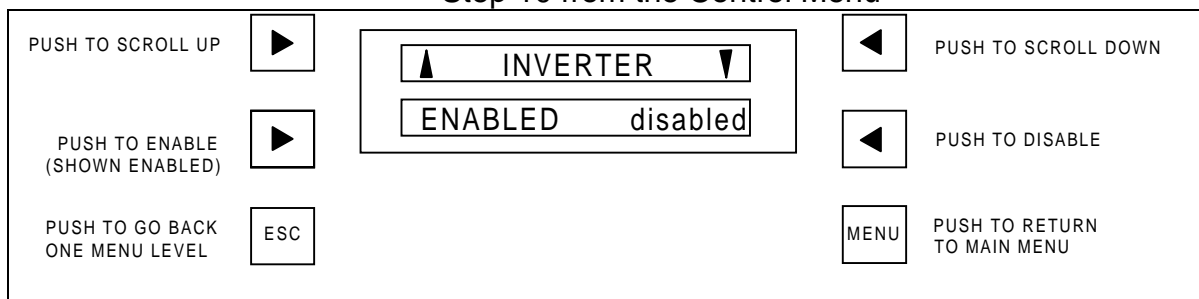
- MAIN MENU
  - BASIC CONTROL
  - MONITOR
    - AUTOSCAN (display)
    - MANUAL SCAN (display)
  - GENERAL INFO (display)
  - ADVANCED CONTROL
    - ADVANCED CONTROL
    - COMMUNICATIONS

The MAIN MENU is made up of the following two displays. Select the arrows to scroll up or down.



Select the BSCONTROL (BASIC CONTROL) submenu from the first display by pressing the upper left Control Button. The TSR-2 will then display the BASIC CONTROL submenu which is Step 10. The following figure shows Step 10 and describes how the buttons on the TSR-2 work while Step 10 is displayed.

Step 10 from the Control Menu



**Adjustable Contrast Control**

The TSR-2 Display has an adjustable contrast control. To increase intensity: hold down the lower left control button and press the upper right control button repeatedly until the desired level is obtained. To decrease intensity: hold down the lower left control button and press the lower right control button repeatedly until the desired contrast level is obtained.

**Demo Mode**

Use Demo Mode to become familiar with the TSR-2 menu sequences. The TSR-2 is placed in Demo Mode by connecting the Data Cable while both the Escape button and the Menu button are held down. Discontinue Demo Mode by disconnecting the data cable.

If someone accidentally changes the Inverter Address, Step 92, the TSR-2 immediately will stop responding. Use Demo Mode to reset Step 92 'Inverter Address' to 1. The Communication Addresses are the only settings selected in Demo Mode which carry back to normal operation.

**Placing changes into effect**

The only changes which go into effect without resetting the system are 'enabling or disabling' the inverter and

the charger. Changes to other system functions or setpoints will not go into effect until the system is reset. Reset the system by turning the System ON/OFF Switch, located on the front of the inverter, OFF for 5 seconds and then back ON. When changing setpoint values you must leave that screen before resetting the system.

The system also can be reset via the TSR-2. When changing inverter functions, disable/enable the inverter to reset the inverter. When changing charger functions, disable/enable the charger to reset the charger. Reset both if in doubt.

**Password**

Acceptance of factory setpoints or adjustments to setpoints should be made only by qualified personnel. If certain setpoints are incorrect then system performance degradation or external equipment damage could occur; i.e. battery damage due to improper charging, etc. The most sensitive system adjustments are located in the Advanced Control Menu which is password protected. The password for gaining access to the Advanced Control Menu consists of pressing the four Control Buttons in the following sequence: upper left, lower right, lower left, upper right.

**3.4 Menu Map**

Initial Display (Push any button to enter main menu.)  
 TSR-2  
 A88769-A

**MAIN MENU:**

<u>Ref. Step</u>	<u>Display</u>	<u>Function</u>	<u>Action</u>
1	BSCONTROL	Selects the BASIC CONTROL submenu	Go to Step 10
2	MONITOR	Selects the MONITOR display submenu	Go to Step 20
3	ALARMS	Selects the ALARMS display submenu	Go to Step 100
4	↓ Down Arrow	Scrolls down in the menu	Go to Step 5
5	GENERAL INFO	Selects the GENERAL INFO display submenu	Go to Step 50
6	ADV CONTROL	Selects the ADVANCED CONTROL submenus	Go to Step 60
7	↑ Up Arrow	Scrolls up in the menu	Go to Step 1

**BASIC CONTROL Menu:**

10	↑ Inverter ↓ ENABLED disabled	Allows inverter to operate automatically (ENABLED) or turns inverter OFF (DISABLED).	Controls inverter
11	↑ Load Demand ↓ ENABLED disabled	Allows Load Demand to operate automatically or turns Load Demand OFF (DISABLED).	Controls inverter
12	↑ Enter Load Dmd ↓ + XX Watts -	Selects the size of the AC load at which the inverter goes into Load Demand (asleep)	Controls inverter
13	↑ Exit Load Dmd ↓ + XX Watts -	Selects the size of the AC load at which the inverter turns fully ON (wakes up)	Controls inverter
14	↑Charger ↓ ENABLED disabled	Allows charger to operate automatically or turns the charger OFF (DISABLED)	Controls Charger
15	↑ Equalize Cycle ↓ ENABLED disabled	Allows Equalize Cycle to operate automatically or turns the Equalize Cycle OFF (DISABLED)	Controls Charger
16	↑ APM Limit ↓ + XX Amps AC -	Sets Automatic Power Management Amps	Controls Charger

**MONITOR Menu:**

20	AUTOSCAN	System status display	Go to Step 30
21	MANUAL SCAN	System status display	Go to Step 40

**AUTOSCAN Menu:**

30	Press ESC to quit.		Go to 31
31	Inverter/Charger/System SYSTEM STATUS	Displays inverter status message	Go to 32
32	APM Limit XX Amps AC	Displays APM setpoint	Go to 33
33	Aux AC Input ERROR	Displays if Aux AC Input is within voltage and frequency tolerance	Go to 34
34	System AC Volts XXX VAC	Displays Aux AC input volts or inverter AC output volts	Go to 35
35	System AC Amps XXX Amps AC	Displays Aux AC input amps or inverter AC output amps	Go to 36
36	Battery Volts XX.XX VDC	Displays battery voltage	Go to 37
37	Battery Status GOOD	Displays if battery is within operating range (within high and low battery setpoints)	Go to 38
38	Batt Temperature XXX ° C	Displays battery temperature if optional battery temperature sensor is installed	Go to 31

**MANUAL SCAN Menu:**

40	Inverter/Charger/System SYSTEM OFF↓	Displays inverter status message	Go to 41
41	APM Limit ↑ XX Amps AC ↓	Displays APM setpoint	Go to 42
42	Aux AC Input ↑ ERROR↓	Displays if Aux AC Input is within voltage and frequency tolerance	Go to 43
43	System AC Volts ↑ XXX VAC ↓	Displays Aux AC input volts or inverter AC output volts	Go to 44
44	System AC Amps ↑ XXX Amps AC ↓	Displays Aux AC input amps or inverter AC output amps	Go to 45
45	Battery Volts ↑ XX.XX VDC ↓	Displays battery voltage	Go to 46
46	Battery Status ↑ GOOD ↓	Displays if battery is within operating range (between high and low battery setpoints)	Go to 47
47	Batt Temperature	Displays battery temperature if optional	Go to 40



	+ XX ADC -		
76	↑ AbsorpChrgVolt ↓ + XX.XX VDC -	Adjusts Absorption Charge DC Volts setpoint	Go to Step 77
77	↑ AbsorpChrgAmps ↓ + XX ADC -	Adjusts Absorption Charge DC Amps setpoint	Go to Step 78
78	↑ Absorp MaxTime ↓ + XXX minutes -	Adjusts Absorption Charge maximum time duration setpoint	Go to Step 79
79	↑ FloatChrgVolts ↓ + XX.XX VDC -	Adjusts Float Charge DC Volts setpoint	Go to Step 80
80	↑ Equalize Volts ↓ + XX.XX VDC -	Adjusts Equalize Cycle DC Volts setpoint	Go to Step 81
81	↑ EqualizMaxTime ↓ + XX minutes -	Adjusts Equalize Cycle maximum time duration setpoint	Go to Step 82
82	↑ Batt Temp Comp ↓ ON off	Turns ON/OFF Battery Temperature Compensation for Battery Charger	Go to Step 83
83	↑ Batt Temp Coef ↓ + XX.XmV/°C/Cell -	Adjusts Battery Temperature Compensation Coefficient	Go to Step 84
84	↑ BattTempShutDn ↓ + XX°C -	Adjusts battery charger High Battery Temperature shutdown setpoint	Go to Step 85
85	↑ Gen Start Mode ↓ on OFF	Allows Gen Start to operate automatically (ON) or turns Gen Start OFF.	Go to Step 86
86	↑ GenStart Volts ↓ + XX.XX VDC -	Adjusts battery voltage setpoint at which the Gen Start contacts close	Go to Step 87
87	↑ Gen Stop Amps ↓ + XX ADC -	Adjusts Bulk Charging amps setpoint at which the Gen Start contacts open	Go to Step 88
88	↑ Aux AC Delay ↓ + XXX Seconds -	Sets time delay after Aux AC input power is present until AC transfer occurs	Go to Step 89
89	↑ Solar Mode ↓ on OFF	Allows inverter to operate in Solar Mode or turns Solar Mode OFF (DISABLED)	Go to Step 70

**COMMUNICATIONS Menu Used only for multiple inverter and/or multiple TSR-2 applications.**

90	Look for Inverters? yes NO	Starts automatic Remote configuration. The default setting is NO.	If yes, go to Step 91, If no go to Step 92
91	Remote Addr: 1 Inverter Addr: 1	Displays the addresses of the Remote(s) and the Inverter(s)	
92	↑ Inverter Addr: ↓ + 1 -	The Address of the system's first inverter is 1. Do not change. See Demo Mode if changed.	Go to Step 93
93	↑ Remote Addr: ↓ + 1 -	Sets the Remote address number. The remote address will match the inverter(s).	Go to Step 90

**ALARM Menu:**

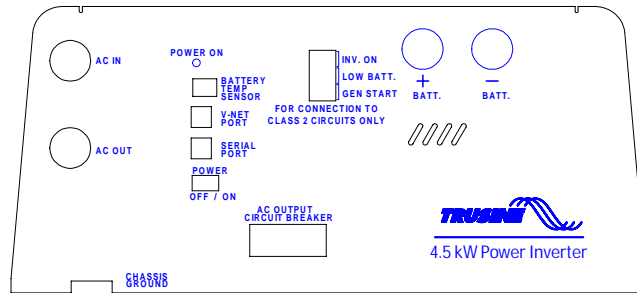
- |     |                                    |     |   |                 |
|-----|------------------------------------|-----|---|-----------------|
| 100 | ALARM<br>(message)                 | ↓   | If system faults exist the ALARM LED will be ON and Alarm message(s) will be displayed. | Go to next step |
| 101 | Getting Alarms<br>from Inverter... | (↓) | Press lower right control button to scroll through Alarm Messages.                      |                 |

Alarm Message Displayed

Description of Problem

- |                   |   |
|-------------------|---|
| 1. AC Input ERROR | There is no Aux AC input voltage or the Aux AC input is out of voltage or frequency tolerance limits.   |
| 2. Battery High   | Battery voltage is above High Battery Shutdown setpoint (will shut down system).  |
| 3. Battery Low    | Battery voltage is below Low Battery Warning setpoint and soon will reach Low Battery Shutdown setpoint.  |
| 4. Current Limit  | Inverter AC output amps are at the Maximum Current allowed. The AC voltage will be fall if load increases. Overload Shutdown will occur if voltage falls below tolerance for 3 seconds. |
| 5. Overload       | Inverter has shut down due to overload. High AC load caused inverter output voltage to fall below tolerance for three seconds.  |
| 6. Hardware Fault | Internal circuit failure or power brick high temperature (will shut down system).   |
| 7. Overheat       | 1) High internal temperature (transformer, triac plate or power brick). System shutdown will occur. 2) AC output circuit breaker tripped.   |

## 4 Front Panel Wiring Identification



Front Panel

All field wiring enters the TruSine housing through the front panel. This is the bottom surface when the unit is oriented in the wall mounted position.

### 4.1 AC Input & Output Wiring

The AC wiring compartment is located on the left side of the unit. The compartment contains a removable access cover and two cable clamps for the AC input and AC output wiring. Inside the compartment is a terminal strip for making AC input and AC output connections.

#### NOTE

The AC output voltage and the *required* Aux AC input voltage of Model **TSC24-4500** is 120 VAC, 60Hz.

The AC output voltage and the *required* Aux AC input voltage of Model **TSC24-4500D** is 120/240 VAC, 60Hz, single phase, 3 wire. L1 and L2 are 180 degrees out of phase and cannot be tied together. The unit may be damaged if the AC input power is not 180 degrees out of phase. Examples of unacceptable power are two phases from a three phase generator or power from two separate 120 volt generators.

### 4.2 DC (Battery) Wiring

A DC wiring compartment is located behind the wiring panel on the right side of the unit. The compartment contains a removable access cover and two cable clamps for the battery positive and battery negative cables. The inverter's battery cable terminal lugs can accommodate cable sizes up to 250 MCM.

### 4.3 System ON Indicator

The light emitting diode (LED) indicates that the System ON/OFF Switch is ON.

### 4.4 Battery Temperature Sensor Port

This is an RJ-11 (4-wire) jack for optional Battery Temperature Sensor.

### 4.5 V-NET Port / TSR-2 Remote Control Port

This is an RJ-11 (6-Wire) jack for communications with the optional TSR-2 Remote Control / Operator Interface Panel.

### 4.6 Serial Interface Port

This is an RJ-11 (6-Wire) jack for RS-232 serial communications.

### 4.7 Inverter Output Circuit Breaker

This 20-Amp circuit breaker provides over current protection for Inverter AC output and the Battery Charger AC input. This breaker does not protect the Aux AC passthrough power.

#### 4.8 System ON/OFF Switch

Use this rocker switch to turn the system ON and OFF and to reset the system. The System ON/OFF Switch does not interrupt Aux AC input power or DC input power to the system.

#### 4.9 Remote Signal Contacts

Three sets of contacts provide signals (continuity) for Remote Inverter ON/OFF indication, Remote Low Battery Warning indication and Gen Start control. Contacts are rated 2 amps for 12 or 24 volt, Class 2 circuits. Wiring connections are made through a 6 conductor plug-in terminal block. Screw pressure-clamp terminals accept up to 14 gauge wire.

## 5 INSTALLATION

### Unpacking the Inverter

Inspect the shipping container and equipment for loose or damaged parts. If any damage is found, immediately notify the freight carrier.

#### 5.1 Basic Guidelines

The wiring of your inverter installation should conform to the National Electric Code (NEC) and any other state or local codes in effect at the time of installation. These codes have been written for your protection and their requirements should be followed.

##### Mounting

Locate a secure, dry, flat horizontal or vertical surface large enough to mount the inverter. The location should be as close to the battery as possible without being in the same compartment and should provide adequate ventilation to maintain room temperature while the inverter is operating. The location must allow unobstructed cooling air flow at sides and bottom of the unit, and the location must be free from road spray, dripping water or other moisture contamination. A recommended minimum clearance of 4 inches (102 mm) should be maintained on all sides of the unit.

**WARNING:** Risk of fire or explosion. The inverter must not be mounted in fuel storage areas, battery compartments, or other areas hazardous locations requiring ignition protection.

##### NOTE

The wiring of your inverter installation should conform to the National Electric Code (NEC) and any other state or local codes in effect at the time of installation. Article 551 of the NEC requires any DC cable from a battery, which measures longer than 18 inches along its length, be protected by a fuse. Other codes may require each ungrounded output conductor from a storage battery, other than to the engine cranking motor, to have a manually reset trip-free circuit breaker or fuse within 72 inches of the battery as measured along the conductor.

#### 5.2 DC Wiring

##### Preliminary Considerations

1. **BE AWARE** that, as a large number of capacitors become charged upon completion of the DC circuit, **THERE WILL BE A LARGE SPARK** when the last battery connection is made. The spark is normal and will occur every time the batteries are connected.
2. The DC cables should be as short as possible. It is electrically more efficient to run the lower current AC wiring longer distances than the DC cables. (See DC Cable Sizing Chart for proper size.)
3. Route the DC positive and negative cables as close together as possible, and use cable ties to keep them together. This reduces some electromagnetic radiation that could interfere with some sensitive electronics.
3. On vehicle installations do not use the vehicle chassis as the DC negative conductor. Use a cable the same size as the DC positive to go directly from the inverter to the battery negative.
4. Route the AC and DC power wiring separately, and with as much physical separation as possible, from low voltage wiring such as audio and video signal wires.

5. DC power input cables which pass through steel or other ferrous metal walls need to pass through the same hole. If two holes are required, cut a slot connecting the two holes to prevent a transformer effect.
6. Do not allow wire fragments or metal shavings to fall into the DC wiring compartment or to enter the inverter in any way. Severe inverter damage will result which is not covered by the warranty.
7. Do not connect the inverter to the battery at this time. Final battery connections will be made after all installation issues have been inspected.
8. **WARNING:** A poorly made high current connection may result in risk of fire and personal injury.
9. **WARNING:** Be sure of the polarity of the DC input wiring. Reverse polarity may severely damage your inverter and is not covered under warranty. Risk of fire or explosion of batteries may occur due to very high currents.
10. A DC fuse is required to properly protect the inverter.
11. The table below shows the recommended minimum cable size which should be used. Wire sizing charts published in the NEC may allow a greater amp capacity than we recommend. We have sized the cable for a maximum voltage drop to maintain better performance of your inverter installation. The inverter's DC cable terminal lugs can accommodate cable sizes up to 250 MCM.

TruSine 4500 DC Cable and Fuse Sizing Chart		
Model Number	TSC24-4500 and TSC24-4500D	
	Distance from battery to inverter in feet (Length of cable is 2 times the distance.)	
Cable Size		
4/0	16	
250MCM	19	
Fuse	Bussmann ANL500	Vanner 03646
Fuse Holder	Bussmann 4164	Vanner 03637

**DC Wiring Installation**

The DC input terminals are located in the field wiring compartment located at the front right side of the unit and accessed from the top. The connections are compression terminals which require a stripped cable and are tightened by an Allen wrench. The positive and negative cables enter the compartment through separate strain reliefs located at the right front of the unit.

**WARNING**

Never make electrical connections "live". Make the connections to the inverter first and the battery last. Make certain the ON/OFF control switch on front of inverter is in the OFF position before connecting to the battery.

**NOTE**

Severe damage to the inverter will result, which is not covered under warranty, if wire fragments or other metal particles enter the inverter through the DC wiring compartment.

Procedure

- Step 1: Turn the inverter OFF and disconnect all AC and DC power to the wiring harness. Make sure power to the inverter wiring is disconnected. Verify that the inverter is turned OFF (the Inverter ON-OFF switch is in the OFF position).
- Step 2: Select a location for the unit. An ideal installation location has the following characteristics:
  - Close to the battery (usually within six feet).
  - Protected from the weather.
  - Well ventilated.
- Step 3: Route DC input cables. Route the negative and positive DC input cables from the inverter to the battery. If required, protect cables where they contact hard, sharp edges.
- Step 4: Install the in-line fuse. Install the in-line fuse in the red, positive DC input cable between the battery and inverter, within 18 in. of the battery or DC wiring bus system.
- Step 6: Connect the inverter to the battery.
  - A) Remove the cover plate on the DC cable compartment exposing the positive and negative Allen head terminal lugs.
  - B) Remove the two Allen screws from the terminal lugs.
  - C) Strip the positive and negative DC cable ends 3/4 in.

- D) Insert the black, negative (-) cable end through the strain relief and into the negative terminal lug. Be sure that all cable strands are completely in the lug.
  - E) Insert the Allen screw into the negative terminal block and tighten to 275 inch-pound.
  - F) Insert the red, positive (+) cable end through the strain relief and into the positive terminal lug. Be sure that all cable strands are completely in the lug.
  - G) Insert the Allen screw into the positive terminal block and tighten to 275 inch-pounds.
  - H) Tighten the two cable clamps.
  - I) Inspect the DC cable compartment to ensure that no foreign particles are present.
  - J) Replace the cover plate over the DC cable compartment.
  - K) Repeat steps E and G every 30 days.
- Step 7: Verify Installation. Verify all connections are tight and bright and the cables are secure.

## 5.3 AC Wiring

### Preliminary Considerations

#### 1. Output and Input Voltages

The AC output voltage and *required* Aux AC input voltage of Model **TSC24-4500** is 120 VAC, 60Hz.

The AC output voltage and *required* Aux AC input voltage of Model **TSC24-4500D** is 120/240 VAC, 60Hz, single phase, 3 wire. L1 and L2 are 180 degrees out of phase and cannot be tied together. The unit may be damaged if the AC input power is not 180 degrees out of phase. Examples of unacceptable power are two phases from a three phase generator or power from two separate 120 volt generators.

#### 2. AC Wire Size

To properly size the AC input and output wiring the installer must consider the inverter output capability, the inverter passthrough capability and the battery charger input requirement. The AC input/output terminal strip is a compression lug style which will accept up to #6 AWG wire.

Model TSC24-4500 – The 37.5 amp at 120 volt (4500 watt) inverter output capability requires #8 AWG wire minimum be used for the AC output. The AC transfer switch is rated 30 amps at 120 volts.

Use input wire up to #6 AWG sized to suit the AC input source. The AC output wire should be the same size as the AC input wire but not less than #8 AWG.

Model TSC24-4500D – The 18.75 amp at 240 volt (4500 watt) inverter output capability requires #12 AWG wire minimum be used for the AC output. The AC transfer switch is rated 30 amps at 240 volts.

Use input wire up to #10 AWG sized to suit the AC input source. The AC output wire should be the same size as the AC input wire but not less than #12 AWG.

#### 3. The AC Input and Output wiring compartment is accessed from the top left side of the unit. Field wires are brought in through two cable clamps to the terminal strip identifying the “AC Input” and “AC Output” terminals.

Model TSC24-4500 – The 120VAC Input and AC output terminals are labeled L1, N, and G.

Model TSC24-4500D – The 240VAC input and AC output terminals are labeled L1, L2, N and G.

#### 4. AC feedback will cause damage to the inverter! The power distribution circuits must be designed to prevent AC power from an external source (shore power or a generator) from feeding back into the inverter's AC output.

#### 5. The inverter AC output must be wired to a Ground Fault Circuit Interrupter (GFCI) to ensure a safe installation. Always maintain an isolated neutral downstream from the GFCI to prevent nuisance tripping.

#### 6. NEC ‘Branch Circuit Rated’ circuit breakers must be installed in all installations having Aux AC input.

#### 7. The CHASSIS BONDING LUG located on the front of the unit has been provided for safety to prevent possible shock hazards. Connect a #8 AWG minimum size wire to this terminal and then to chassis of the vehicle, the installation's grounding system, or to earth ground.

Failure to connect the chassis bonding lug to the chassis of the vehicle, the installation's grounding system, or to earth ground may result in a lethal shock hazard.

### AC Wiring Procedure

Step 1: Connect the AC output. Remove the cover of the AC wiring compartment to expose the AC

input/output terminal strip. Identify the lower terminals labeled “AC Output”. Insert the field wires through the lower strain relief into the AC wiring compartment. Tighten the strain relief. Connect the field wires to the proper AC output terminals.

- Step 2: Connect AC Input. Identify the terminal strip's upper terminals labeled “AC Input”. Insert the field wires through the upper strain relief into the AC wiring compartment. Tighten the strain relief. Connect the field wires to the proper AC input terminals. Replace the AC wiring compartment cover.
- Step 3: Connect Bonding Lug. Use a #8 AWG or larger copper conductor to connect the chassis bonding lug to the chassis of the vehicle, the installation's grounding system, or to earth ground.
- Step 4: Verify Installation. Verify all connections are tight and secure for maximum performance.

## 5.4 TSR-2 TruSine Remote Control Panel Installation

### Unpacking the Optional TSR-2 TruSine Remote Control Panel

Inspect the shipping container and equipment for loose, damaged, or missing parts. If any damage is found, immediately notify the freight carrier.

### Installing the TSR-2 TruSine Remote Control Panel

The TSR-2 TruSine Remote Control Panel may be located near the inverter or at a convenient remote location. The unit is supplied with a 25' long twisted data cable with a 6-pin RJ-11 connector at each end.

- Step 1: Locate a suitable clean dry location for installation. The TSR-2 front panel is 6½ wide x 5¼ high. The back housing is 5¾ wide x 4½ high x 1¾” deep with cable entry on the right side.
- Step 2: Route the data cable from the remote panel mounting area to the inverter.
- Step 3: Plug the data cable into the RJ-11 modular jack labeled “V-NET” on the front of the inverter.
- Step 4: Plug the data cable into the RJ-11 modular jack on right side of the TSR-2.
- Step 5: Mount the TSR-2 Remote Panel using four #8 screws (not included).

## 5.5 System Start-up and Testing

- Step 1: Completely install the TruSine 4500 Inverter/Charger following the system design considerations and instructions provided previously in this manual.
- Step 2: Place the System On/Off switch located on the front of the inverter in the OFF position.
- Step 3: Verify that the external GFCI breaker is reset and connect an AC load, such as a 100-Wattlight.
- Step 4: Turn ON the battery DC power to the inverter.
- Step 5: Turn ON the AC shore power (or generator) to supply the AC input power to the system.
- Step 6: Place the System On/Off switch located on the front of the inverter to the ON position.
- Step 7: The green Power On LED on the front of the inverter should come ON.
- Step 8: The TSR-2 TruSine Remote Control Panel (optional), if used, should display the main menu.
- Step 9: The AC output test light should be ON, indicating the presence of shore power and correct operation of the AC transfer switch.
- Step 10: Disconnect the AC shore power input. The AC output test light should immediately quickly blink once, indicating the transfer switch transferred the test light from shore power to inverter power.
- Step 11: At this point, apply AC loads up to 4,500 watts to verify full-power operation.
- Step 12: Apply shore power. After a delay the AC output test light should blink indicating the transfer of the load from inverter power to shore power.
- Step 13: Test the battery charger operation:

- A) Discharge the battery by placing the AC load on the system and operating the inverter, (remove shore power input).
- B) When the battery charge level is low, the inverter will turn off.
- C) Apply shore power and observe the battery charger operation. Connect an ammeter to the DC cables between the inverter and the battery to monitor the current (DC amps), and a volt meter to the battery to monitor the battery voltage. The battery charger will step through its sequence and stop in the float mode.

Step 14: The system is now ready for operation.

## 6 GENERAL INFORMATION SECTION

### 6.1 Generic Inverter Description

In general, an inverter converts DC electrical power into AC power. This power can be used to operate various AC-driven appliances. Typical DC power sources include batteries that store electrical energy, power generated from a vehicle alternator or renewable energy sources such as photovoltaic (solar) panels.

The most common battery systems are 12 or 24 volt. Some systems, however, operate on higher voltages such as 32, 36, 48, or 120 volts. The most common inverter AC output power is 120 volts at a frequency of 60 Hz. Some inverters, however, are designed to produce 240 volts, or both 120 and 240 volts at 60 Hz. Because some countries use power of different voltage and frequency (e.g., 230 volts at 50 Hz), inverters are available to conform to these requirements.

The three available inverter types are distinguished by the type of AC output wave form they produce. This wave form affects the AC loads they operate. This section provides an overview of these inverter types, including the advantages and disadvantages associated with using each type.

#### *Sine Wave Inverter*

Sine wave inverters produce an AC output wave form like power produced by the electric utility companies and rotating generators. The sine wave inverter's wave form is characterized by the highest peak voltage and smooth voltage transitions (no square wave components). Such inverters are the most costly of the three inverter types because they contain additional electronics to produce the required wave form. A measure of the sine wave quality is *Total Harmonic Distortion* (THD), and is expressed in a percentage. The lower the THD the higher the quality of the sine wave power.

#### *Modified Sine Wave Inverter*

Modified sine wave inverters are sometimes called "quasi sine wave inverters" or "modified square wave inverters." Modified sine wave inverters generally cost more than square wave inverters because they contain additional electronic circuitry to produce true RMS regulated AC output. Modified sine wave inverters have higher AC peak voltages than square wave inverters, and automatically control the width of the AC output wave form to regulate the output voltage (pulse-width modulation). The shape of the modified sine wave inverter's wave form includes a square wave component. It is stepped in such a way, however, to closely approximate the true sine wave produced by the electric utility companies. Although this wave form has a higher peak voltage than do square wave inverters, its peak voltage is not as high as a pure sine wave. Therefore, AC loads containing power supplies might not always operate properly on the modified sine wave inverter.

#### *Square Wave Inverter*

The square wave inverter is a low cost device that produces a pure square wave AC power output. This AC power can be an accurate 60 Hz frequency if it is crystal controlled. It does not have the necessary peak voltage to properly operate many AC appliances that contain electronic power supplies (e.g., computers, TVs, and VCRs). The square wave is appropriate when operating AC loads such as resistive heating devices.

### 6.2 Inverter Sizing

Output Power Rating - Power output is an important consideration when purchasing an inverter. Power is defined as the rate that a device produces (or uses) electrical energy. This rate is measured in watts or kilowatts (one kilowatt equals 1,000 watts), or sometimes in voltamps. Voltamps are roughly equal to watts and

are obtained by multiplying volts times amps produced or used by a device

To properly determine an inverter size (in watts) for your application decide which AC loads you plan to operate. Inverter size is the sum of the wattages of the AC loads that you wish to run at the same time, plus a safety factor, say 10 to 20 percent.

Continuous Output Power - Continuous power is defined as the AC power in watts (or voltamps) an inverter can produce on a continuous basis. The ambient temperature can affect the continuous rating of the inverter, and is normally specified, e.g., 25° C. or 40°C.

Surge Output Power - Inverter power can also be rated in terms of surge power. Surge power is the short term duration of AC power that the inverter can produce. It is often specified as the watts (or voltamps) that can operate a resistive load for two or three seconds. Sometimes this is specified in AC amps because the inverter may allow output voltage to drop (which would reduce its wattage). Like continuous power, the surge rating is affected by ambient temperature.

Note - Regardless of an inverter's power ratings, an inverter's AC output capability is only as strong as the DC source. To achieve optimum performance an inverter must be installed with properly sized cable and have an ample DC supply. Recommended cable sizes are listed in the DC Cable and Fuse Chart. The following sections in this manual will cover the basic information required to properly size the inverter battery and the vehicle alternator. Keep in mind that if information in this manual directly conflicts with instructions from a specific battery or other equipment manufacturer, Vanner recommends that those manufacturer's recommendations be followed.

### 6.3 DC Power Consumption

An inverter takes in DC power, and produces AC power to operate AC loads. In general, we can see a direct relationship between DC input power and AC output power. This allows us to establish the following rule of thumb:

For 12 volt DC inverters:  $\text{Output Watts} \div 10 = \text{DC Input Amps}$ .

For 24 volt DC inverters:  $\text{Output Watts} \div 20 = \text{DC Input Amps}$ .

This rule of thumb can be used to estimate the minimum alternator size required for your application. It may also be used in calculating the minimum size battery required when operating from an alternator and battery combination; a photovoltaic panel and battery combination; or when operating from battery alone. The following examples should help to clarify the use of this rule of thumb.

#### Example A

What is the DC current draw of a 12 volt DC input inverter when it is operating a vacuum cleaner with a name plate rating of 6 amps at 120 volts AC?

The appliance rating is given in amperes, so we must first calculate the power it consumes. Then the rule of thumb can be used to find the DC input current of the inverter.

Output power = 120 volts x 6 amps = 720 watts, and  
DC input current =  $720 \div 10 = 72$  amps DC.

#### Example B

What is the DC current draw of a 24 volt DC input inverter when it is operating a toaster with a name plate rating of 1050 watts at 120 volts AC?

Since the appliance is rated in watts, the rule of thumb can be applied directly:

DC input current =  $1050 \div 20 = 52.5$  amps DC.

This information on estimating the DC input current requirement for an inverter will allow you to size an alternator or charging system to supply an inverter for continuous operation. This rule of thumb will be used later in the discussions on battery sizing.

## 6.4 Battery Terminology and Ratings

Batteries used for automotive applications generally are lead-acid storage batteries. They can be separated into two categories according to their use: engine cranking batteries and deep cycle batteries. The engine cranking battery is specifically designed to supply hundreds of amps for a short period of time to start an engine. Cranking an engine usually uses a small portion of the battery's total capacity and once the engine is running, the battery is quickly recharged by the engine's alternator. The deep cycle battery is specifically designed to deliver current for extended periods of time and can be almost totally discharged before recharging.

The "deep cycle" lead-acid battery is designed to withstand the deep discharge/recharge cycling that is typical of most inverter installations. These batteries are available in the "maintenance free" style where the electrolyte does not need to be checked or replenished and they also are available in the gelled electrolyte style or "Gel Cells". Deep cycle batteries are generally advertised for use in recreational vehicles or boats and are sometimes referred to as RV or marine batteries.

Battery Council International (BCI) is a voluntary industry organization which has helped to standardize battery ratings. Ratings in use at this date are:

CCA (Cold Cranking Amperes): Rating in amps a battery cold soaked at 0°F or -20°F will carry for 30 seconds and maintain a minimum terminal voltage of 7.2.

MCA (Marine Cranking Amperes): Rating in amps a battery cold soaked at 30°F will carry for 30 seconds and maintain a minimum terminal voltage of 7.2.

RC (Reserve Capacity): Rating in minutes a battery will carry a 25 amp load at 80°F and maintain a minimum terminal voltage of 10.5.

AH (Amp Hour): At the "20 Hour Rate", also called the C Rate, a battery having a 100 AH rating must carry a 5 amp load for 20 hours ( $100\text{AH} \div 20 \text{ hours} = 5 \text{ amps}$ ) and maintain a terminal voltage of 10.5 at 80°F. (Two 100AH 12volt batteries connected in series provides 100AH at 24 volts. Two 100 AH 12volt batteries connected in parallel provides 200 AH at 12 volts.).

CCA and MCA are used for sizing an engine cranking battery and have no bearing on a battery's cycling ability. RC is a rating given to cranking batteries to provide an idea of how long a vehicle could be driven if the vehicle charging system were to fail.

The most important and probably least understood battery capacity rating is the ampere-hour. One simple reason the AH rating is misunderstood is that a battery rated at 100 AH cannot always deliver 100 AH. The underlying reason is the efficiency with which the battery converts its chemical energy into electric energy. The AH capacity of a battery is affected in the following ways:

Discharge rate: A battery becomes less efficient as the discharge current increases. For example, a typical 100 AH battery is specified to be able to deliver 5 amps for a period of 20 hours. If the discharge current were increased to 25 amps, the capacity will be reduced to approximately 75 AH ( $25 \text{ amps} \times 3 \text{ hours} = 75 \text{ AH}$ ).

Operating temperature: A battery becomes less efficient at lower temperatures. Most battery manufacturers specify the battery AH capacity at 80° F. At a temperature of 32° F, the same battery will have only about 65% of its rated capacity even though it may be fully charged. At a temperature of 0° F, a battery's capacity will be reduced to about 40% of its rated capacity.

Battery age: As a battery is used, the active material on the battery plates will gradually deteriorate and become useless. As the battery gets older, there will be less and less useful material left on the plates and the operating time will become noticeably shorter. A battery will age faster (lose active material from its plates faster) if it is deeply discharged regularly, if it is left in a discharged state for extended periods of time, or if it is repeatedly overcharged.

Series and/or Parallel Connected Batteries: Up to this point we have spoken of the battery as if it were a single battery. In some cases this may be true, but in general, the battery may be made up of several individual batteries electrically connected together to form a "Bank" of batteries. Batteries can be connected in series, parallel, or a combination of series and parallel as long as all of the batteries in the bank are of equal ratings, are from the same manufacturer, and are the same age. Old and new batteries should never be mixed in the same battery bank. Mixed batteries will result in accelerated battery failure due to the unequal discharge and recharge rates.

A series connection is where two or more batteries are connected positive (+) to negative (-). The total voltage

of the battery bank is the sum of the voltage of each battery in the bank. For example, most large custom coaches require a 24 volt battery to crank the large diesel engine. The 24 volts is usually provided by connecting two 12 volt batteries in series, and sometimes by connecting four 6 volt batteries in series. The ratings of the series connected battery bank remain the same as the individual battery's rating. If the battery bank is made up of two 8D size batteries in series, each with a CCA of 1050 amps, 425 minutes RC, and amp-hour capacity of 200 AH, then these individual battery ratings are also the ratings of the entire 24 volt battery bank.

Parallel connected batteries are batteries which are connected positive to positive and negative to negative. They form a battery bank that has the same voltage as each individual battery. The ratings of a parallel connected battery bank, in general, are the sum of the individual batteries. For instance, if two 8D batteries are connected in parallel, and each battery has the ratings given in the paragraph above, then the ratings for the battery bank become 2100 CCA, 900 minutes RC, and approximately 400 amp-hours. Parallel connected batteries should be of the same voltage and rating to achieve optimum battery life and performance.

**6.5 Sizing the Inverter Battery**

Sizing a battery system for an inverter application can be a very tedious task if all the different variables, such as discharge rate, depth of discharge, and operating life time are included in the calculations. To simplify these calculations and get a reasonably correct battery size, we will assume: 1) A 50% depth of discharge for the purpose of obtaining a reasonable life time for a reasonable battery system cost, 2) there is no charge current into the battery system, 3) the batteries are in a fully charged state at the beginning of the discharge cycle, and 4) the DC current draw from the battery does not exceed 1/3 the C rate for any length of time.

Follow the steps listed below to find the AH capacity required for your application.

- Step 1: Make a list of each appliance, its power requirement in watts, and the amount of time in hours it will be operating between charging cycles. Note: If the appliance is rated in amperes (amps) instead of watts, multiply the amps by the voltage (120 or 240) to get watts.
- Step 2: Calculate the watt-hours required for each appliance by multiplying the power requirement by the operating time of that appliance.
- Step 3: Calculate the total watt-hours needed by adding together the watt-hours of each appliance.
- Step 4: Find the amp-hours consumed by dividing the total watt-hours found in step 3 by 10 for 12 volt DC systems or by 20 for 24 volt DC systems.
- Step 5: Multiply the amp-hours consumed by 2 (for 50% depth of discharge) to get the battery amp-hour capacity desired.

Example 1: Follow Steps 1 through 3 (above)

<u>Appliance</u>	<u>Power Rating</u>	<u>Operating Time</u>	<u>Watt-Hours Consumed</u>
TV, VCR, Stereo	225 watts	2.5 hours	563 watt-hours
Small Refrigerator	300	3.8	1,140
Microwave	800	0.3	240
TOTALS			1,943 watt-hours

Step 4: Amp-hours consumed = 1943 watt-hours ÷ 20 = 97.15 amp-hours for 24 a volt system.

Step 5: The minimum battery size for this application is 2 x 97.15 = 194.3 amp-hours.

**6.6 Battery and Charging System Considerations**

The Battery and DC Charging System is a very important part of your inverter installation responsible to supply all of the DC power required by the inverter. The system normally consists of the primary charger (engine alternator or photovoltaic array), a secondary charger, if used, the battery, and other equipment which may be used such as battery isolator diodes. The complexity of the system depends on the way the inverter is used. In some cases, such as utility or service vehicles, the system may be as simple as the engine alternator and the cranking battery which also powers the inverter. In most cases, additional equipment is needed to provide additional DC power and/or protection. These systems can be grouped into two categories, the single battery

and the dual battery systems.

In the single battery system, there is one battery which is shared for starting the engine and operating the inverter. This is a common practice in a service vehicle where the engine runs all the time and allows the alternator to provide continuous charging for the battery. In this case, the inverter can be connected directly to the engine cranking battery. The most important detail of this system is the alternator output rating. The continuous output of the alternator needs to be at least as much as the total DC current draw on the system. The total DC current draw must include the inverter, warning lights, radios, engine controls, and any other device connected to the DC system. Care should be used when operating this type of system while the engine is shut off. The inverter will shut itself OFF for low battery but most other DC loads will not. The vehicle battery may be drained too low to restart the engine.

The dual battery system uses two separate batteries, one for starting the engine and operating the vehicle's systems, and one for operating the inverter. The two batteries are usually referred to as the "cranking battery" and the "house or auxiliary battery" respectively. The two separate batteries are usually charged from the same source, the engine alternator, but are separated by a device called a battery isolator. The battery isolator allows DC current to flow from the alternator into each battery, but blocks current from flowing from one battery to the other. This is a must to protect the cranking battery in recreation vehicles, boats and other vehicles where the inverter needs to be operated when the engine (therefore the alternator) is not running.

## 6.7 Battery Charging Guidelines

### CAUTION

The following information on battery charger setup adjustments should be used as guidelines only. Vanner strongly recommends that you contact the manufacturer of your batteries to obtain the specific charging setup values for the type and model of battery you are using. This is due to the fact that battery charging parameters such as bulk, absorption, float and equalize voltages vary from one manufacturer to another, and that gel cell batteries have different parameters than wet lead acid batteries. An improperly adjusted battery charger may cause damage to your batteries!

The maximum charging current for a battery is usually equal to 20% of the battery's Amp hour capacity ("C") for lead acid batteries, and 50% of the battery's C for gel cell batteries. The C rate is numerically equal to the amp-hour capacity for the battery. For example, a 280 amp-hour battery has a C rate of 280 amps, and the maximum charge rate would be 56 amps DC. (Note that this is not the same as the battery's Cold Cranking Amp rating.) You should also take into consideration that if two batteries are connected in parallel their amp-hours add but if batteries are connected in series their amp-hours remain the same.

## 7 MAINTENANCE & TROUBLESHOOTING

### 7.1 Preventative Maintenance

There are no user serviceable components inside the TruSine Inverter/charger. For service refer to Vanner Power Group or other qualified service personnel.

Maintenance Items:

For continued reliability and safety, a monthly maintenance program should be implemented to include the following:

1. Check to insure that all AC and DC wiring is secure and connections are tight and corrosion free.
2. Check air ventilation openings for dust and other obstructions.
3. Examine receptacle, indicators and switches for cracks and breaks.

Trouble Shooting

Problem: The TSR-2 Remote Control Panel does not respond.

Check: Suspect Step 92 Inverter Address has been changed from 1. Change back to 1 using Demo

Mode. See TSR-2 Remote Control Panel operation.

## 8 Warranty

### NORTH AMERICAN LIMITED WARRANTY

Vanner Inc., doing business as The Vanner Power Group, referred to herein as Vanner, warrants that this product is free from defects in materials and workmanship for a period of two (2) years from date of installation or two and one half (2 1/2) years from date of manufacture, whichever is less if and only if the following requirements are complied with:

1. The product is installed and checked out properly according to all guidelines, instructions, and checkout procedures set forth in the product Installation and Operating Manual.
2. The installer records all checkout data required and completes, signs, and returns the warranty registration card to Vanner within ten (10) days after installation.
3. The product was purchased after January 1, 2000.

Vanner does not warrant its products against any and all defects when: defect is a result of material or workmanship not provided by Vanner; normal wear and tear, or defects caused by misuse or use in contrary to instructions supplied, neglect, accident, reversed polarity, unauthorized repairs and/or replacements.

All warranties of merchantability and fitness for a particular purpose: written or oral, expressed or implied, shall extend only for a period of two (2) years from date of installation or two and one half (2 1/2) years from date of manufacture, whichever is first. There are no other warranties that extend beyond those described on the face of this warranty. Some states do not allow limitation on how long an implied warranty lasts, so the above limitations may not apply to you.

Vanner does not undertake responsibility to any purchaser of its product for any undertaking, representation, or warranty made by any dealers or distributors selling its products beyond those herein expressed unless expressed in writing by an officer of Vanner.

Vanner does not assume responsibility for incidental or consequential damages, including, but not limited to, responsibility for loss of use of this product, removal or replacement labor, loss of time, inconvenience, expense for telephone calls, shipping expense, loss or damage to property, or loss of revenue. Some states do not allow the exclusion or limitation of incidental or consequential damages, so these limitations may not apply to you.

Vanner reserves the right to repair, replace, or allow credit for any material returned under this warranty. Any damage caused by the customer will be charged or deducted from the allowance.

All warranty work will be performed at Vanner's factory, or authorized repair facility utilizing a valid Warranty Authorization Number (WAN) prior to repair. Products shall be delivered to Vanner's facility, freight prepaid and fully insured. Products repaired under warranty, or replacement parts or products will be returned to North American location prepaid via same transportation means and level of service as received, unless directed otherwise. Prepaid freight policy does not apply to locations outside North America.

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