OPERATOR MANUAL FOR

402 Series High Voltage

POWER SUPPLY

Document: 83487001 Rev K

TDK-LAMBDA AMERICAS

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ONE YEAR WARRANTY

TDK-Lambda Americas, Inc. (405 Essex Road, Neptune, N.J. 07753), warrants that the unit is free from defects in material or workmanship for a period of ONE YEAR from the date of initial shipment. TDK-Lambda Americas Inc. will service and, at its option, repair or replace parts which prove to be defective. This will be done free of charge during the stated warranty period. This warranty excludes defects resulting from misuse, unauthorized modification, operation outside the environmental or safety specifications of the power supply, or improper site preparation or maintenance. The customer shall contact TDK-Lambda Americas Inc., for warranty service or repair as described in the RETURNING EQUIPMENT section. The customer shall prepay shipping charges. If the unit is covered under the foregoing warranty, then TDK-Lambda Americas Inc. shall pay the return shipping charges.

The "WARRANTY", "CLAIM FOR DAMAGE IN SHIPMENT", and "RETURNING EQUIPMENT" information applies to equipment purchased directly from TDK-Lambda Americas Inc. End users receiving equipment from a third party should consult the appropriate service organization for assistance with these issues.

THIS LIMITED WARRANTY IS IN LIEU OF, AND TDK-LAMBDA AMERICAS INC. DISCLAIMS AND EXCLUDES, ALL OTHER WARRANTIES, STATUTORY, EXPRESS OR IMPLIED, INCLUDING, WITHOUT LIMITATION, ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE, OR OF CONFORMITY TO MODELS OR SAMPLES.

CERTIFICATION

All test and measuring equipment used by TDK-Lambda Americas Inc. for Final Acceptance Testing are traceable to primary standards certified by the National Institute of Standards and Technology.

LETHAL VOLTAGES PRESENT!

All power supplies contain hazardous voltage and energy. The power supply must only be operated by qualified personnel who have read this operator's manual and are familiar with the operation, hazards and application of the power supply. Proper care and judgment must always be observed.

1. Before connecting input AC power, ensure all covers are in place and securely fastened. Ensure the required safety ground to chassis is installed and sufficient cooling is supplied.
2. Proper grounding from the input AC power is required to reduce the risk of electric shock, and to comply with safety agency and code requirements.
3. Use extreme caution when connecting input AC power. Only apply the input voltage specified on the rating label.
4. Use extreme caution when connecting any high voltage cables. Never handle any output cables when the power supply is operating.
5. After a power supply is switched OFF, its output section will retain a charge which may be lethal. Allow sufficient time for self-discharge before handling anything connected to the output. The discharge time specified in the Safety Notes does *NOT* include extra time required to discharge the energy stored in the user's load.
6. When user serviceable fuses are present, always replace fuses with the same type and Volt/Amp rating.
7. Never attempt to operate the power supply in any manner not described in this manual.
8. Never remove DANGER or WARNING labels from the power supply. Replace lost or damaged labels immediately. Contact TDK-Lambda Americas Customer Service for replacement labels.
9. The power supply may be serviced only by TDK-Lambda Americas Inc. factory qualified service personnel. Breaking the warranty seal will void the warranty. Prior to opening the power supply, contact TDK-Lambda Americas Inc. Customer Service for a written Service Waiver and a replacement warranty seal.

TDK-Lambda

MANUFACTURER'S PRODUCT DECLARATION

INTENDED PURPOSE (USE)

The Power Supplies described by this manual are defined by TDK-Lambda Americas Inc. as a component for use in the composition of an apparatus as defined in Article 1 (1) of the EMC Directive (89/336/EEC). These products, as individual components, do not perform in themselves a direct function for the user of the end product. They are not intended to be placed on the market with a direct function to a final user! As such, the products described by this manual are not subject to the provisions of the EMC Directive (89/336/EEC, with amendment 92/31/EEC).

The products described by this manual are intended for incorporation into a final product by a professional assembler. It is the responsibility of the assembler to ensure that the final apparatus or system incorporating our products complies with all relevant EMC standards for that final product.

OPERATING ENVIRONMENT

The operating environment as defined by TDK-Lambda Americas Inc., for the products described by this manual is stated as follows:

The Power Supplies described by this manual are intended for use in a protected industrial environment or in proximity to industrial power installations. These locations are often referred to as industrial locations containing establishments that are not connected to the low voltage public mains network.

Industrial locations are characterized by the existence of one or more of the following conditions:

1) industrial, scientific and medical (ISM) apparatus are present;
2) heavy inductive or capacitive loads are frequently switched;
3) currents and associated magnetic fields are high;
4) location supplied by their own transformer.

These components are not intended for connection to a public mains network, but are intended to be connected to a power network supplied from a high or medium-voltage transformer dedicated for the supply of an installation feeding manufacturing or similar operations. They are suitable for use in all establishments other than domestic and those directly connected to a low voltage power supply network which supplies buildings used for domestic purposes.

ELECTRICAL STANDARDS

All company primary standards are either certified or are traceable to certification by the National Institute of Standards and Technology.

CLAIM FOR DAMAGE IN SHIPMENT

This instrument received comprehensive mechanical and electrical inspection before shipment. Immediately upon receipt from the carrier, and before operation, this instrument should be inspected visually for damage caused in shipment. If such inspection reveals damage in any way, a claim should be filed with the carrier. A full report of damage should be obtained by the claim agent and this report should be forwarded to us. We will then provide a disposition of the equipment and arrange for repair or replacement.

When referring to this equipment, always include the model and serial numbers.

The "WARRANTY", "CLAIM FOR DAMAGE IN SHIPMENT", and "RETURNING EQUIPMENT" information applies to equipment purchased directly from TDK-Lambda Americas Inc. End users receiving equipment from a third party should consult the appropriate service organization for assistance with these issues.

RETURNING EQUIPMENT

Before returning any equipment to the factory, the following steps shall be taken.

1. Notify TDK-Lambda Americas Inc. at (732) 795-4100 or follow the instructions at https://rma.us.lambda.tdk.com/phv/Neptune_RMA. Give a full description of the difficulty including the model and serial number of the unit in question. Upon receipt of this information, we will assign a Return Material Authorization (RMA) number and provide shipping instructions.
2. The customer shall prepay shipping charges. Equipment returned to us must be packed in a manner to reach us without damage. The shipping container must be marked with the RMA number in an area approximate to the shipping label with numbers that are easy to read. All returned units that do not show the RMA number on the outside of the container will be refused.

   If the equipment is repaired within the warranty agreement, than TDK-Lambda Americas Inc. shall pay for the return shipping to the customer.
3. For non-warranty repairs, we will submit a cost estimate for your approval prior to proceeding. The customer shall pay return shipping charges.

MECHANICAL INSTALLATION

Most power supplies are heavy and, when rack mounted, they should be supported by rails along the sides of the supply from front to rear. The rails must adequately support the unit and not block airflow. Do not support the power supply from the front panel only.

TDK-Lambda

Description of symbols used in product labeling

SYMBOL	PUBLICATION	DESCRIPTION
	EC Council Directive 93/68/EEC	European Community Conformity Assessment Product Mark
	IEC 348	Attention, consult Accompanying documents
	IEC 60417-1-5036	Dangerous voltage
	IEC 60417-1-5019	Protective earth (e.g. power line earth ground)
	IEC 60417-1-5017	Functional earth (e.g. chassis ground)
	IEC 60417-1-5134	Electrostatic Discharge (ESD) Sensitive Device

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1. GENERAL INFORMATION

1.1. User Manual Content

This User's Manual contains the operating instructions, installation instructions and specifications for the ALE 402 series high voltage power supply. The instructions refer to standard power supply models, and include checkout, installation, and operation of the 402 series. Suggestions and requirements for connecting AC power, load cables and signal cables are given. Various operating modes and programming modes are described.

The model 402 is just one model in a broad family of HV power supplies covering the power range from 500J/sec to 30kJ/sec in a single package, and to 1MW and beyond in parallel systems. For more information please visit our web site at
https://www.us.lambda.tdk.com/products/high-voltage-power/

NOTE

This manual contains information, instructions and diagrams which apply to standard constructions. If special features or modifications have been installed, the instructions specific to that modification are contained in Addenda and take precedence if conflicts exist. Please take care to refer to the correct information for your unit.

1.2. Introduction

TDK-Lambda Americas ALE model 402 are state of the art switch mode high voltage power supplies, designed to rapidly and efficiently charge capacitors in laser systems, modulators, pulse forming networks, and a broad range of pulse generator circuits, without the need for a series current limiting resistor. They can also be used in many continuous DC applications including beam power for RF devices such as magnetrons, gyrotrons, klystrons and electron beam loads.

The 402 series utilize a high frequency IGBT based series resonant inverter topology which operates as a constant current source. This makes the supply perfect for rapidly charging capacitors which represent a challenging load for conventional HV DC supplies using multiplier designs.

The 402 series is available with a choice of three different front panel configurations designed to suit different applications and end uses. All models feature the same comprehensive remote control interface which is detailed in Section 6.2.

The 402L Model is fully instrumented with front panel meters displaying output voltage and current, status LEDs, a key switch for OFF, LOCAL or REMOTE operation, HV ON/OFF push-button switches, and a 10 Turn output voltage control. The rear panel features external interlock, inhibit, remote control and slave (parallel operation) control connections.

The 402S Model can only be operated by remote control and features only status LEDs and a power switch on the front panel. The "S" Models have been designed to operate as a slave unit to the "L" Models or in systems where local control is not a requirement. As many 402 supplies as required, can be connected in parallel to provide greater output power.

The 402OEM features a blank aluminum front panel and can only be operated by remote control.

1.3. 402 Overview

1.3.1. Features

- 4kJ/sec capacitor charging power, 4kW in continuous DC applications.
- Output voltages from 0-1kV to 0-50kV.
- Rep rates from single shot to kilohertz.
- Local or remote operation (L Model) with comprehensive control interface.
- Cost effective blank front panel version for OEM applications.
- Constant current topology for rapid efficient charging.
- Parallel operation (master/slave) for high power applications.
- Compact Air Cooled design.
- Passive Power Factor Correction reduces RMS current draw.

1.3.2. Benefits

- Lightweight switch mode design.
- Rack mount chassis configuration.
- Low stored energy provides greater safety.
- Constant current design requires no lossy current limit resistance.
- Immunity to external EMI.

1.3.3. Applications

- Charging capacitors and capacitor banks.
- Powering pulse forming networks/modulators.
- Powering lasers: Excimer, flash lamp pumped dye, Yag, CO_2, etc.
- Continuous power for RF tubes – magnetron, gyrotron, TWT, klystron etc.
- Electron beam applications.
- DC power source for pulsed hard-tube and solid state modulators.

1.4. Capacitor Charging Technology

Capacitor charging applications require a power supply designed specifically for the task. The 402 series supplies allow capacitors to be charged in pulse forming networks and modulators in a very fast, efficient and controllable manner.

The units are compact high power constant current sources that can linearly and rapidly charge a capacitive load to high voltage. Once the load capacitor is charged to the programmed voltage, the supply will switch over to a voltage regulation mode and maintain the load voltage at the programmed level, until the load is discharged.

The flexible design of the 402 allows the unit to be ordered with (L model) or without (S and OEM model) the front panel controls and meters. Front panel controls are ideal in applications where local control and read backs are necessary, such as R&D, laboratory use and diagnostics. All front panel controls and indicator signals are available at the rear panel remote control connector regardless which panel option (L, S, or OEM) is selected.

The unit is self-contained, requiring only AC power and appropriate controls. Several units may be connected in parallel for higher power operation. There is no theoretical limit to the number of units that may be paralleled. Typically one master unit and one or more slave or OEM units may be used to obtain as much output power as necessary. The 402 is also ideally suited to charge reservoir capacitors in resonant charging circuits where high rep rates (several kilohertz) are required, such as in metal vapor lasers or solid-state modulators.

1.5. Continuous DC Operation

Although the 402 series has been designed for capacitor charging applications, they can also be used as a continuous DC High Power Source for RF tubes such as klystrons, TWTs, or other DC loads such as DC-DC converters. The DC option must be specified when ordering, and the supply will be factory setup and tested with a continuous DC load. When 402 supplies are operated in continuous DC applications it is often necessary to add an external capacitor between the load and ground to improve the ripple performance of the unit. Our online Application Note 505 describes operating capacitor charging supplies in DC applications, and gives guidance in determining the size of any additional external filter capacitance required. App Note 505 can be found at:

https://product.tdk.com/en/products/power/tec_data/ps_ale.html

Consult the factory before connecting parallel units in continuous DC applications.

1.6. Additional Features:

- Internal contactor and fuses for AC disconnect and protection
- Standard AC power and control connectors
- Documentation Manual Including -
  Installation, check out, suggested remote interfaces and control circuits
- 10 ft (3m). Output cable is standard, other lengths are optional.

1.7. Safety Precautions

All 402 power supplies are designed to minimize the risk of fire or shock hazard. This instrument received comprehensive mechanical and electrical inspection prior to shipment. Nevertheless, certain safety precautions must be observed. Only TECHNICALLY QUALIFIED SERVICE PERSONNEL familiar with the principles of electrical safety should operate this supply. The power supply SHOULD NOT BE EXPOSED TO WATER OR MOISTURE OR DUSTY ENVIRONMENTS. Electrical safety must be maintained at all times.

Lethal voltages are developed within the power supply's enclosure and at the output cable. Therefore, the cover may not be removed by the user (see Warranty in preamble section for variance). Also, the large capacitors in the supply may store power even after the AC input line is removed. ALLOW AT LEAST 40 SECONDS DISCHARGE TIME between removing the AC input line and opening the cover. ALSO, ALLOW AT LEAST 40 SECONDS between switching the AC power off and switching it on again.

1.7.1. This product is designed for Indoor use.

1.7.2. This product is designed for pollution degree 2.

1.7.3. This product is designed for Transient Overvoltage Category II

1.7.4. Ensure all covers are in place and securely fastened before switching ON the AC power.

1.7.5. Proper grounding from the input AC power is required to reduce the risk of electric shock. Ensure that the AC Protective Earth Ground connection has at least the same gauge wire as the supply leads shown in Table 2.

1.7.6. Use extreme caution when connecting AC input power, and never apply the incorrect input voltage, refer to ratings label.

1.7.7. Use extreme caution when connecting the high voltage output cable to the load.

1.7.8. Ensure all load capacitors are completely discharged prior to connection. Never handle the output cable when the power supply is operating.

1.7.9. Never attempt to operate the power supply in any manner not described in this manual.

1.7.10. Never remove DANGER and WARNING labels from the power supply. Replace lost or damaged labels immediately.

1.7.11. The power supply should only be serviced by factory authorized personnel.

1.7.12. No user maintenance is required.

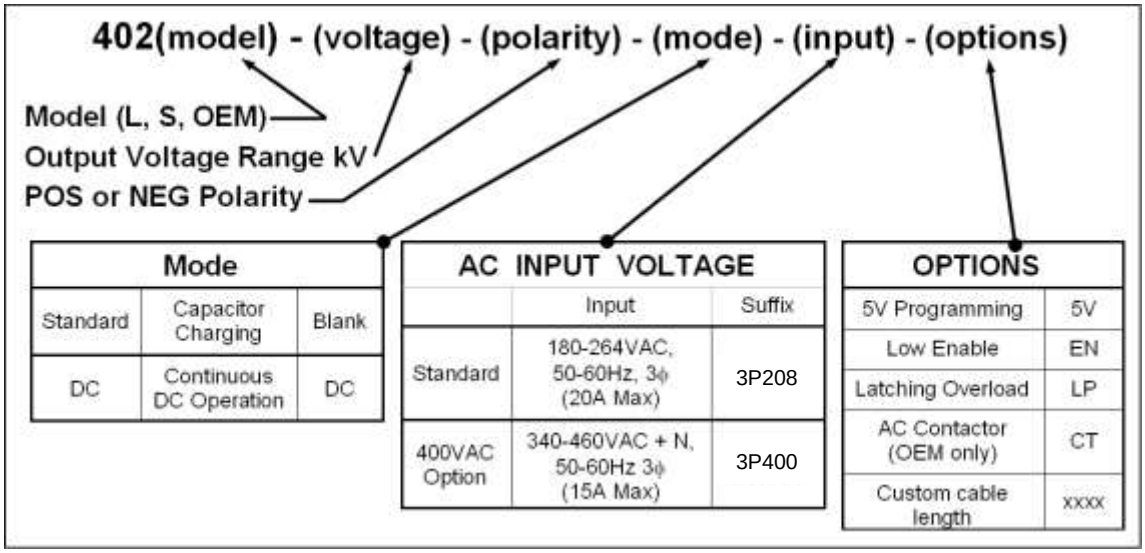
1.8. Model Number Format

The model numbering system for the 402 Series power supply includes symbols for features and options. They are separated by dashes.

Examples are: 402L-10KV-POS-3P208, 402S-1KV-NEG-DC-3P400.

The 402 is available with three front panel configurations, the L, S, and OEM. The choice of panel configuration is dependent upon the installation and system requirements. See section 5 for further details.

Table 1 shows a partial listing of the model description format for the 402 Power Supply family. For additional options, the customer may contact the Sales Department at TDK-Lambda Americas. Special options are typically shown as a four-digit suffix to the model number.



Mode		
Standard	Capacitor Charging	Blank
DC	Continuous DC Operation	DC

AC INPUT VOLTAGE		
	Input	Suffix
Standard	180-264VAC, 50-60Hz, 3ϕ (20A Max)	3P208
400VAC Option	340-460VAC + N, 50-60Hz 3ϕ (15A Max)	3P400

OPTIONS	
5V Programming	5V
Low Enable	EN
Latching Overload	LP
AC Contactor (OEM only)	CT
Custom cable length	xxxx

Table 1 402 Model Description Format .

2. SPECIFICATION

2.1. Average Charging Power	4,000 Joules/sec ($\frac{1}{2}CV^2$ x Rep Rate)
2.2. Peak Charging Power	5,000 Joules/sec ($\frac{1}{2}CV^2 / t_{charge}$)
2.3. Average DC Power	4,000 Watts
2.4. Output Voltage Range	1, 2, 4, 5, 10, 15, 20, 30, 40, 50kV, variable from 10-100% of rated. Other voltages on request, please contact the factory.
2.5. Polarity	Available as fixed Positive or Negative. Please specify at time of ordering
2.6. HV Output Cable	1-39kV Models - DS2124 Coaxial cable with proprietary HV connector
	40-50kV Models - DS2214 Coaxial cable with proprietary HV connector
2.7. HV Insulating Medium	Shell Diala or equivalent insulating oil
2.8. AC Input Voltage	200-240VAC (180-264), 3Ø or380-440VAC (340-460), 3Ø + N, 50-60Hz Please specify at time of ordering
2.9. AC Input Current	20A/15A
2.10. AC Connector	UL/CSA approved terminal block. 3Ø + GND for 200-240VAC, 3Ø + N + GND for 380-440VAC
2.11. AC Line Contactor	UL/CSA approved AC line contactor (standard on 402L and 402S, option for 402OEM)
2.12. Power Factor	Passive PFC pf = 0.85 at full load and nominal AC line
2.13. Efficiency	Better than 85% at full load
2.14. Front Panel	402L - Voltage Control, Voltage & Current Meters, Status Indicators
	402S - On/Off Switch, Status Indicators
	402-OEM - Blank front panel
2.15. Stability	0.2% per hour after 1 hour warmup
2.16. Temperature Coefficient	100ppm per °C typical
2.17. Stored Energy	Less than 0.5J all models
2.18. Pulse to Pulse Repeatability	±2% to 1000Hz, consult factory for higher rep rates
2.19. Dimensions - inches (mm)	19 (483) W x 7 (178) H x 17 (432) D
2.20. Weight - lbs (kg)	65 (30)
2.21. Ambient Temperature	Storage: -40 to +85°C. Operating: -20 to +45°C
2.22. Altitude	Storage: 40,000ft (12,000m), Operating: 9,900ft (3,000m)
2.23. Humidity	10-90%, non-condensing
2.24. Protection	Open/short circuits, Overloads, Arcs, Overtemp, Overvoltage, Safety Interlock
2.25. Remote Control (all models)	Via 25-pin D-sub connector on rear of unit, Signals include, Vprogram (0-10V), HV Enable/Reset, Inhibit, Summary Fault, Load Fault, Vanalog, Vpeak
2.26. Accessories	10ft HV cable, operating manual

2.27. Options	EN - Low Enable. Replaces standard high enable
	5V - 0-5V Analog programming. Replaces standard 0-10V programming.
	LP - Latching Overload Protection, requires HV reset after overload fault
	DC - Continuous DC operation
	CT - AC line contactor (option for 402OEM only, standard on 402L and 402S)
	Double terminated HV cable, and mating bulkhead connector
2.28. Ordering Info	Model - XXkV - POS (or NEG) - YYYVAC - ZZ (options)
2.29. Ordering Examples	402L-10KV-POS-3P208, 402S-1KV-NEG-DC-3P400
All specifications subject to change without notice	

3. OUT OF BOX INSPECTION

3.1. Visual Inspection

Prior to shipment, this instrument was inspected and found to be free of mechanical and electrical defects. As soon as the unit is unpacked, inspect for any damage that may have occurred in transit. Verify the following:

a) Check the operation of the front panel control (knob should rotate smoothly).
b) Confirm that there are no dents or scratches on the panel surfaces.
c) Check front panel meters and LEDs for any broken or cracked lenses.

If any damage is found, follow the instructions in Section 3.3.

3.2. Electrical Inspection

Before the power supply is installed in a system, verify that no internal damage occurred during shipping. A set of simple preliminary electrical test can be performed if desired. These tests are described below.

NOTE
The sequences described are for L model supplies with local controls, for S and OEM models the corresponding signals must be applied and monitored through the remote control interface.

3.2.1. Test 1

Purpose: Verify general logic operation, generate maximum output current, and check overload protection circuits. With AC power "OFF" and disconnected, short the HV output by connecting the center conductor of the output cable to its return shield (braid). This dead short will allow the unit to generate full output current at zero voltage.

1. Set the output voltage control to zero. Connect AC power to the unit. Turn "ON" the AC power front panel switch.
2. Turn the front panel key switch to the LOCAL position (if applicable). Press the HV "ON" button and turn up the HV control until the power supply is generating output current into the dead short. The current meter will indicate max. Current. The voltage meter will read zero and the power supply will intermittently turn on and off indicating the "overload" condition. The unit should continue to indefinitely cycle in this mode with a 1 second period. (The power supply will go into overload when max. current is drawn for more than half a second).
3. Turn off the HV and AC power switches.

This test indicates the inverter section is generating maximum current and the logic and overload circuitry works correctly.

3.2.2. Test 2

Purpose: Verify that the power supply generates maximum rated voltage, and the regulation and feedback circuits are functioning.

1. With AC power OFF and disconnected, connect an appropriate load capacitor to the power supply output cable. Select the capacitor size so the charge time is several milliseconds or more.
2. Prepare to charge the capacitor. NOTE: Operating a 402 power supply into an open circuit (no load operation) will instantly damage the power supply's HV output diodes. Make sure the load (capacitor) is connected and the HV output cable is securely inserted and connected.

3. Turn the voltage control on the front panel all the way down to zero (counter clockwise), apply AC power and press the HV ON button. By turning up the HV control knob the capacitor will charge to the voltage indicated on the front panel voltmeter. The power supply may be turned all the way up to its max. output voltage provided the load capacitor is sufficiently rated.
4. By turning the voltage control down or depressing the HV OFF button, the capacitor will slowly "bleed" down through the internal voltage divider resistors used for regulation feedback. Use an external discharge wand to ensure the capacitor is fully discharged.

Test #2 indicates the HV section is working correctly. Tests 1 and 2 generally indicate the unit is functioning as designed. Although 100% power had not been generated, these two tests give greater than 90% confidence that the unit is not damaged.

If any inconsistency from the above test procedure is noted, do not hesitate to call TDK-Lambda Americas Customer Service for assistance.

3.3. Contacting TDK-Lambda Americas Customer Service

When contacting customer service locate the product description, part number and serial number from the label located on the rear of the unit, and have this information available.

Phone: (732) 795-4100 E-mail: hp.service@us.tdk-lambda.com
Fax: (732) 922-9334

Customer Service, or an approved Service Center, should be contacted if:

- The power supply is mechanically or electrically damaged.
- The power supply requires on-site calibration, or replacement warning decals.
- The customer has questions about a special application that is not described in this manual.

Normally, the customer may *NOT* open any chassis covers that have a warranty seal. Breaking a seal will void the warranty.

At the discretion of TDK-Lambda Americas, the customer may be granted permission to break the warranty seal and open the chassis covers. Customer Service shall confirm the permission by sending a replacement seal. Once the unit has been serviced, the customer shall close the cover and apply the replacement seal adjacent to (not on top of) the broken seal.

3.4. Returning Defective Units

If a unit needs to be returned to the factory for repair, the factory must first assign an RMA number. Please complete and send the online RMA request form at https://rma.us.lambda.tdk.com/phv/Neptune_RMA and an RMA number will be assigned. Follow the return instructions on the form or at https://rma.us.lambda.tdk.com/phv/Neptune_RMA_Instructions .

4. INSTALLATION

4.1. 19-Inch Rack Mounting

This power supply is intended for mounting in a conventional 19-inch equipment rack. It's 7 inch height makes it a "4U" size instrument. The rack should enclose the sides, top and back to protect the operator from electrical shock and protect the supply from environmental contamination.

Never install the 402 so its weight is supported only by the front panel screws!

The 402 must never be installed without support in the back or sides of the unit. The 402 should be mounted on support rails or chassis slides –such as General Devices CTS-124- or on a suitable shelf or supports inside the rack.

4.2. Ventilation Requirements

This instrument is fan cooled. Sufficient space must be allocated so that a free flow of cooling air can reach the back and sides of the instrument when it is in operation. Ensure these clearances are met for adequate air flow:

- 4 inches (10 cm) rear
- 1 inch (2.5 cm) on each side.

Cooling air enters through the rear of the unit, and is forced out of the side panels. This power supply should not be operated with its cover removed since the cover directs the flow from the internal fan.

When operating in an enclosed system, care must be taken to ensure the ambient inlet air to the power supply does not exceed the maximum operating temperature of 45°C. This may require addition of a system heat exchanger.

4.3. Orientation

The power supply must be operated in a level horizontal orientation. More than a quarter of an inch (6.25mm) difference in height in any direction could potentially cause an arcing condition in the high voltage tank and should be avoided.

4.4. AC Power Connection

For 200-240VAC models, the maximum voltage allowed between any two AC input terminals is 264VAC. For 380-440VAC models, the maximum voltage allowed between any two AC input terminals is 460VAC. If this voltage is exceeded, catastrophic damage will result, that is not covered by TDK-Lambda Americas standard warranty.

The customer's AC power line connects to the 402 via a UL/CSA approved 5 position terminal block on the rear panel of the unit (see Figure 1). Only use a power cable with the correct voltage and current rating (see Table 2). The ground wire must be equal to or larger than the recommended gauge. Secure grounding of the input AC power is required to reduce the risk of electric shock. The metal chassis of the power supply is grounded through the earth wire at the input AC power terminal block. Use extreme caution when connecting input AC power and never apply the incorrect input power.

An external switch or circuit breaker with the following parameters must be used as means of disconnection:

a) Rated voltage not less than maximum rated voltage of the power supply

b) Rated current not less than 150% of the power supply rated current

The switch or circuit breaker must be located in proximity to the power supply and within easy access of the operator. The switch or circuit breaker must be marked as disconnecting device for the equipment.

The Protective Earth Ground ⏚ must be connected before applying AC Line Power to the 402.

Connect the three lines of the input power to the L1, L2, L3 terminals and the earth ground to the terminal marked with the ground symbol (⏚). No neutral connection is required for the 200-240VAC configuration. For models with the 380-440VAC input configuration (340-460VAC) the neutral wire must be connected to terminal marked N. The power connections are not phase rotation sensitive, so any phase can be connected to any of the AC inputs.

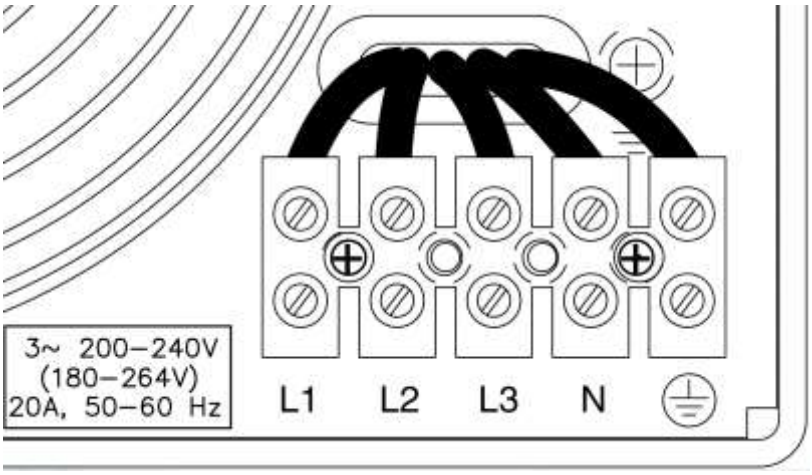


Figure 1 AC Input Terminal Block

If the power supply was purchased with the 400VAC input configuration, in addition to the three phases, the neutral wire must be connected to terminal marked N. Failure to connect the Neutral wire in a 400VAC unit may result in damage to the supply.

AC INPUT VOLTAGE	MODE	RECCOMENDED AC INPUT CABLE SIZE & RATING
200-240VAC (180-264VAC), 50-60 Hz, 3ϕ	Cap Charging	6mm²/10 AWG, 600V
	Continuous DC	6mm²/10 AWG, 600V
380-440VAC (340-460VAC), 50-60 Hz, 3ϕ	Cap Charging	6mm²/10 AWG, 600V
	Continuous DC	6mm²/10 AWG, 600V

Table 2 Recommended AC Input Cable

The AC input rating is marked on the rear terminal of the power supply. The rating is also part of the unit's model description shown in Table 1.

4.5. Connecting the High Voltage Output

Ensure that the power supply is off and disconnected from the AC input power and that all load capacitors are discharged and shorted to ground before making any connections. Never handle the HV cable while the supply is operating. Never operate the supply without a load capacitor connected.

Before connecting the HV output cable, inspect the cable and check for signs of damage.

Always use the HV connector and cable provided with the power supply or an equivalent substitute provided by TDK-Lambda Americas. Fully insert the connector end of the HV cable and tighten the locking nut only "hand tight".

When operating above 20kV or 200Hz rep rate, silicone grease (such as Dow Corning DC-4) must be applied to the HV cable before insertion into the HV connector. The grease is used to displace air in the connector and reduce long-term corona effects. A cable greasing procedure is available for download from the TDK-Lambda Americas web site.

The load ground must be connected to the chassis ground through a separate safety ground cable with a minimum wire size of 10 AWG in addition to the HV output cable shield (see Figure 2).

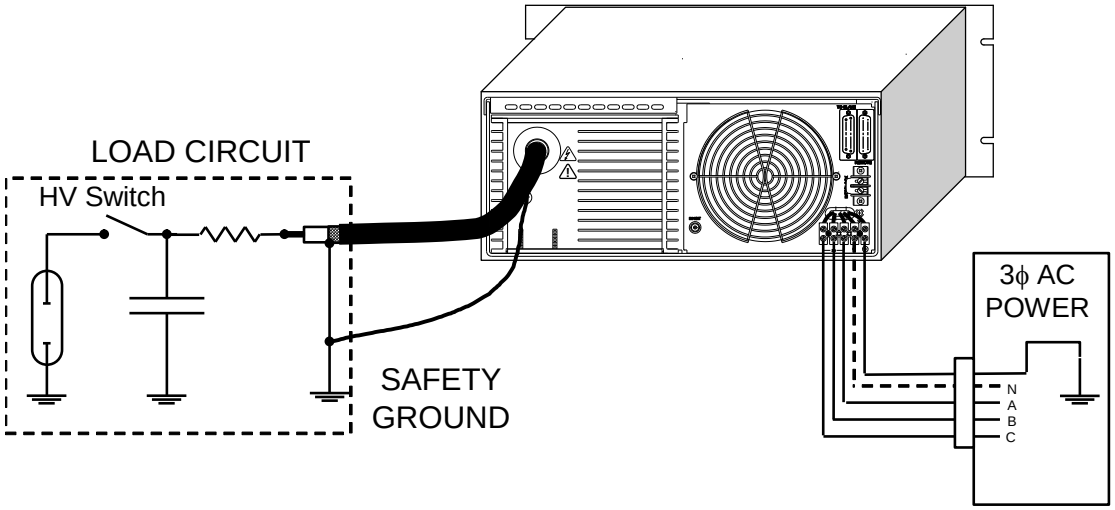


Figure 2 Typical Load Circuit Connection

Some peak current will flow out of the power supply during discharge and return through the HV return and system chassis. This current comes from voltage reversal in underdamped systems and from normal discharge of filter and cable capacitance. The path for this current should not parallel control signal returns since the resulting voltages could interfere with normal system operation.

Currents due to voltage reversal, particularly at high repetition rates can damage the power supply. Generally, a resistor in series with the HV output can be added to limit this current to an acceptable level, but an additional clamp diode may also be required.

Refer to Application Note 517 (available from the factory or https://product.tdk.com/en/products/power/tec_data/ps_ale.html) for more detailed information.

Dress the high voltage cable to create a gentle curve ensuring there are no sharp bends as this will tend to reduce the cable's insulation strength. Strain relieve the load end of the high voltage cable to prevent breaking of, or damage to the center conductor. Keep the HV cables as distant as possible from the input power and the control signals.

To connect the HV cable to the load it is necessary to remove the cable jacket, shield, and any semiconducting layer (if applicable) that remains on the cable insulation after removing the shield.

The cable outer jacket should be removed to reveal the cable shield. At least 12” or 300mm of outer jacket should be removed for suitable voltage hold-off. The exposed shield should be trimmed to an appropriate length and terminated with a ground connection.

For models shipped with DS2214 HV cable (>40kV rated voltage), after the shield is removed, the black semiconducting layer is exposed. This layer should be very carefully removed using a sharp craft knife, and a peeling action. Once the semiconducting layer is removed, the exposed EPR insulation should be cleaned with IPA or an equivalent solvent. If any of the semiconducting layer remains on the HV cable insulation it may cause the cable termination to fail.

For models shipped with the DS2124 HV cable (<40kV rated voltage), there is no semiconducting layer to be removed from the cable insulation, however the exposed polythene cable insulation should be cleaned with IPA.

5. CONTROLS, INDICATORS, CONNECTORS

5.1. Front Panel Layout (L Model)

The 402L series power supply is equipped with a fully instrumented front panel featuring output voltage control, voltage and current metering, and comprehensive status LEDs, along with local/remote mode keyswitch, and power on switch. The 402L can be operated locally from the front panel or remotely via the control connector located on the rear panel (see Section 6.2). Front panel layout of the 402L power supply is shown in Figure 3 below.

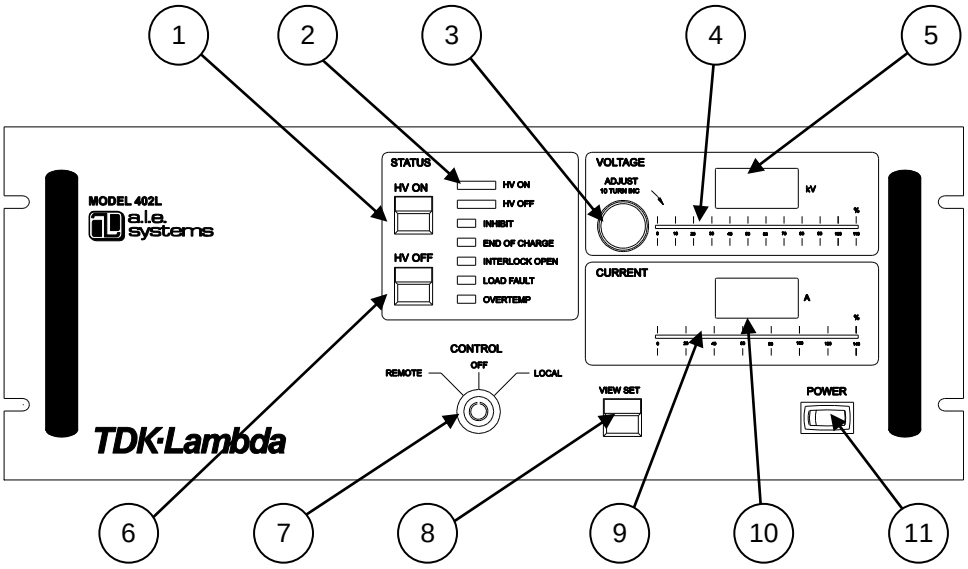


Figure 3 402L Front Panel Controls and Indicators

REF	DESCRIPTION	NOTE	SECTION
1	HV ON Push Button	Turns on HV output	5.2
2	Status LEDs	Indicates status of supply and presence of any faults	5.3
3	Local Voltage Set	10 turn pot for setting output voltage in local mode	5.4
4	Voltage bar graph	Analog bar graph showing output voltage (%)	5.5
5	Voltage Display	Digital display of output or set voltage	5.6
6	HV OFF Push Button	Turn off HV output	5.7
7	Off/Local/Remote Key	Switches control between remote, local, and off modes	5.8
8	View set push button	Push to view the output voltage set point in local mode	5.9
9	Current bar graph	Analog bar graph showing average output current (%)	5.10
10	Current Display	Digital display of average output current	5.11
11	Power switch	Turns on/off power to auxiliary circuits	5.12

Table 3 Front Panel Controls and Indicator Functions (L Model)

The front panel controls/indicators are described in detail in the following sections.

5.2. HV ON Push Button (Ref 1)

DO NOT DEPRESS THE HV ON PUSH-BUTTON UNLESS A SUITABLE CAPACITIVE LOAD IS CONNECTED TO THE POWER SUPPLY'S OUTPUT CABLE, AND THE LOAD IS CORRECTLY GROUNDED.

The HV On push button is a momentary switch that when depressed turns on HV output in local mode (keyswitch in local position) only if there are no faults present within the supply. If faults are present when the HV On button is pushed the supply **will not turn on**, and both the HV ON and HV Off LEDs will illuminate. When both the HV On and HV Off LEDS are illuminated together this indicates a Summary Fault. If the keyswitch is in the remote position the HV ON push button has no function.

5.3. Status LEDs (Ref 2)

There are 6 status LEDs on the front panel, indicating the state of the HV Output circuit and various fault detection circuits in the control system.

5.3.1. HV ON LED

The HV ON LED indicates that the HV output circuit is enabled and the supply will deliver output current if it is not inhibited by an external inhibit input. If the HV ON and HV OFF LEDs are illuminated together this indicates a Summary Fault. HV ON LED is active in local and remote modes.

5.3.2. HV OFF LED

The HV OFF LED indicates that the HV output circuit is disabled and the supply cannot deliver output current. If the HV OFF and HV ON LEDs are illuminated together this indicates a Summary Fault. HV OFF LED is active in local and remote modes.

5.3.3. Inhibit LED

If the Inhibit LED is illuminated it indicates the presence of an active inhibit signal, and the supply will not deliver charging current after the HV ON button is pushed. Inhibit is applied either via the rear panel mounted BNC connector or either inhibit input via the remote control connector. Inhibit LED is active in local and remote modes.

5.3.4. END OF CHARGE LED

The END OF CHARGE or EOC LED indicates that the load or output voltage has reached the programmed voltage. EOC LED is active in local and remote modes.

5.3.5. Interlock Open LED

The interlock open LED illuminates if the safety interlock circuit is not closed. The power supply cannot be turned on if the interlock loop is open. If the interlock loop is opened when the unit is running (ie when HV in ON), the unit will turn off with a latching fault, requiring an HV ON/OFF/ON reset cycle before it can be restarted. Interlock Open LED is active in local and remote modes.

5.3.6. Load Fault LED

The load fault LED indicates the presence of a fault in the load circuit due to a short circuit large external capacitor, or an output Overvoltage. An output Overvoltage condition will cause a latching fault requiring an HV ON/OFF/ON reset cycle before it can be restarted. Load Fault LED is active in local and remote modes.

5.3.7. **Overtemp LED**

The overtemp LED indicates an inverter over temperature condition internal to the supply. The temp fault will clear once the temperature is below the fault threshold, but the unit will not restart without a reset cycle. Overtemp LED is active in local and remote modes.

5.4. Local Voltage Set (Ref 3)

The local voltage set control is an analog 10-turn potentiometer for adjusting the output voltage from zero to full rated output. This control will only operate in local mode. If the supply is operated in remote mode the local voltage set control has no effect.

5.5. Voltage bar graph (Ref 4)

The voltage bar graph is a 'quick view' analog percentage indication of the voltage measured at the power supply output. Bar graph is active in local and remote modes.

5.6. Voltage Display (Ref 5)

The Voltage Display is a 4 digit LED indicator showing the voltage measured at the power supply output. This display momentarily shows the output program voltage after the View Set button is depressed. Voltage Display is active in local and remote modes.

5.7. HV OFF Push Button (Ref 6)

The HV OFF push button is a momentary switch that when depressed turns off HV output. If the power supply shuts off with a summary fault (indicated by HV ON and HV OFF LEDs both illuminated), then this condition can be reset by pushing the HV OFF, HV ON, HV OFF button sequence. If the supply is operated in remote mode the HV OFF push button will still function.

5.8. Off/Local/Remote Keyswitch (Ref 7)

DO NOT MOVE THE KEYSWITCH POSITION FROM OFF TO LOCAL OR REMOTE UNLESS A SUITABLE CAPACITIVE LOAD IS CONNECTED TO THE POWER SUPPLY'S OUTPUT CABLE, AND THE LOAD IS CORRECTLY GROUNDED.

The Off/Local/Remote Keyswitch switches the 402L power supply operating modes between OFF, LOCAL, and REMOTE. The key can be removed in the OFF position to prevent unauthorized use. If the switch is in the LOCAL position the supply will operate from the front panel. In the remote position the supply can only be operated via the remote control interface. An L model supply can simulate an S or OEM model with the key in the remote position.

5.9. View set push button (Ref 8)

The view set push button changes the reading on the digital voltage display from the power supply output voltage, to the programmed voltage set on the local voltage set potentiometer. After pushing this button the set voltage is displayed for approximately 3 seconds.

5.10. Current bar graph (Ref 9)

The current bar graph is a 'quick view' analog percentage indication of the average current delivered by the supply. Bar graph is active in local and remote modes.

5.11. Current Display (Ref 10)

The Current Display is a 4 digit LED indicator showing the average current delivered by the power supply output. Current display is active in local and remote modes.

5.12. Power switch (Ref 11)

The power switch connects AC input power to the control circuitry and causes the internal AC contactor to close if the interlock loop is closed.

5.13. Front Panel Layout (S Model)

The 402S series power supply is equipped with a partially instrumented front panel featuring status LEDs, and a power on switch. The 402S can only be operated remotely via the control connector located on the rear panel (see Section 6.2).

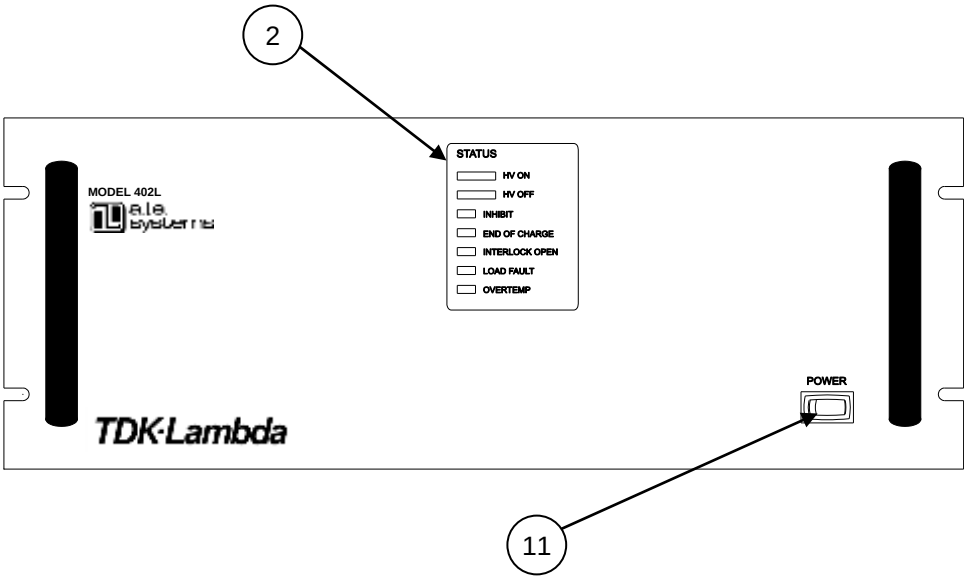


Figure 4 Front Panel Controls and Indicators (S Model)

REF	DESCRIPTION	NOTE	SECTION
2	Status LEDs	Indicates status of supply and presence of any faults	5.3
11	Power switch	Turns on/off power to auxiliary circuits	5.12

Table 4 Front Panel Controls and Indicators (S Model)

A description of the function of the LEDs and the power switch are given in sections 5.3 and 5.12 respectively.

5.14. Front Panel Layout (OEM Model)

The 402OEM front panel is completely blank and features no indicators or switches.

5.15. Rear Panel Layout (L Models)

All of the interconnect and HV connections for the 402L are located on the power supply rear panel. Figure 5 shows the rear panel layout and location of the various connectors.

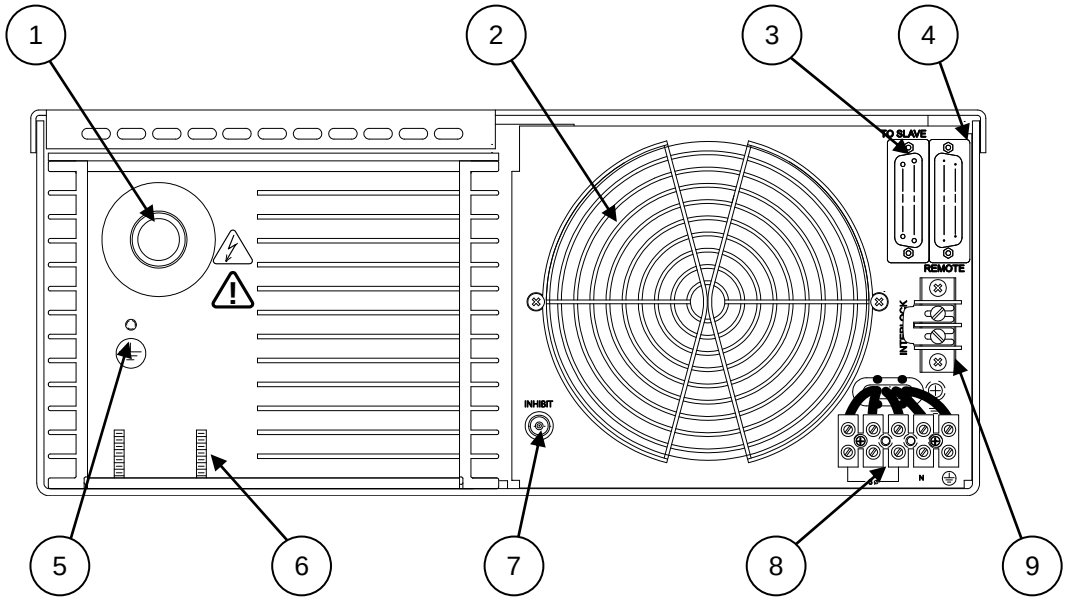


Figure 5 402L Rear Panel Connections

REF	DESCRIPTION	NOTE	SECTION
1	HV Output	HV Output connector, mates with supplied cable via proprietary connector	5.15.1
2	Cooling fan	Main AC cooling fan. Leave 4" clearance	5.15.2
3	Slave Interface	25pin male sub-D type plug for control of slave supplies in a parallel system (AMPHENOL 17BDFRA25P)	5.15.3
4	Remote Interface	25pin sub-D type receptacle for remote control of supply in remote mode (AMPHENOL 17BDFRA25S)	5.15.4
5	GND stud	10-32 UNC ground stud	5.15.5
6	GND stud	M5 ground stud (2 positions)	5.15.6
7	Inhibit input	BNC input to allow inhibit of output current	5.15.7
8	AC Input	5 position terminal block for AC input power	5.15.8
9	Interlock	Terminal for connection to interlock circuit. Contacts are isolated from ground and require dry contact closure for supply to operate.	5.15.9

Table 5 402L Rear panel Functions

The function of each item in Table 5 is described in the following sections.

5.15.1. HV Output Connector (Ref 1)

Connector socket for mating HV cable supplied with unit. The connector should be kept clean and free from debris at all times. If supply is operated at 20kV or 200Hz rep rate or above the cable should be greased to ensure corona free operation. The cable connector should only be hand tightened, never use a wrench or apply excessive force.

5.15.2. Cooling Fan (Ref 2)

Allow at least 4 inches of clearance and do not obstruct clear air flow around the fan. Air is pulled into the unit by the fan, and exhausts at the front of the side panels.

5.15.3. **Slave Connector (Ref 3)**

A 25 pin D-sub female connector that allows connection to a slave supply for increased power operation.

5.15.4. **Remote Connector (Ref 4)**

A 25 pin D-sub male connector that allows remote operation and monitoring of all power supply functions when the unit is operated in REMOTE mode.

5.15.5. **Safety Ground (Ref 5)**

10-32UNC threaded safety ground stud installed in HV tank. Should be used for additional safety ground cable between supply and load circuit.

5.15.6. **Safety Ground (Ref 6)**

M5 threaded safety ground stud installed in HV tank. Should be used for additional safety ground cable between supply and load circuit.

5.15.7. **INHIBIT BNC (Ref 7)**

The inhibit BNC input is a standard BNC socket that allows an external connection to a pulse generator or control system and gives the user control of the power supply output current. A logic 1 (10-15V) input will inhibit the supply (shuts off the output current) and a logic 0 (ground or open) allows the supply to operate.

5.15.8. **AC Input Terminal (Ref 8)**

Main AC input power terminal block see section 4.4 for further details. For 200-240VAC connect three phases and ground. For 380-440VAC option connect three phases, Neutral and Ground. AC input is not phase rotation sensitive.

5.15.9. **Interlock Terminal strip (Ref 9)**

Provides an external dry contact connection for the customer to allow interlock functions to be controlled. The interlock terminals should be connected to any safety interlock circuitry in the power supply installation. When the interlock is open the AC line contactor disconnects the AC line from the power circuitry. The power supply is shipped with a factory installed shorting link across the interlock terminals.

NOTE

The Interlock terminals are chassis referenced 24VAC circuits and should never be connected to ground.

5.16. Rear Panel Layout (S and OEM Models)

The 402S/OEM rear panel is similar to the 402L except these is no SLAVE or INHIBIT BNC connector. If a number of units are to be connected in parallel, a daisy chain type ribbon cable should be used to connect the supplies together. See section 6.4 for more details.

Note:

The numbers in Figure 6 refer to Table 5.

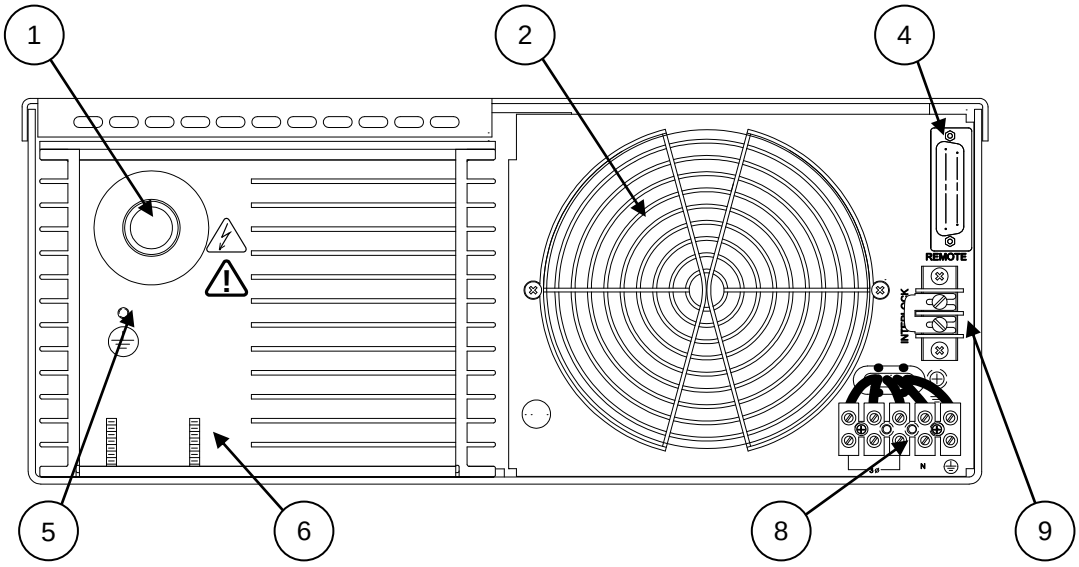


Figure 6 402S Rear Panel

5.17. Remote Control Connector Pin Diagram

Figure 7 shows a summary of the remote control signals on the connector labeled 4 in Figure 5 and Figure 6. The connector is a 25-pin sub D-type receptacle (female).

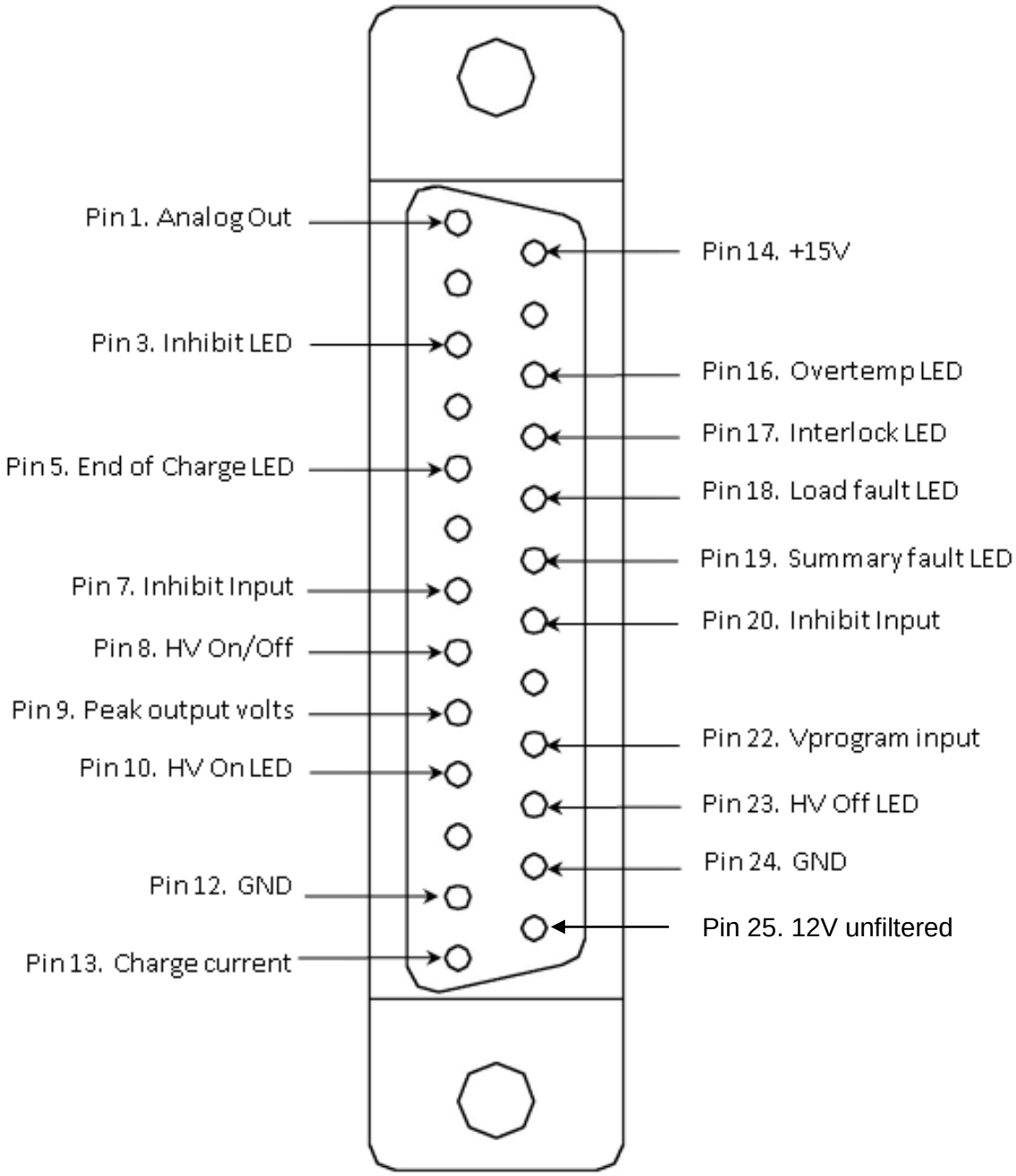


Figure 7 Remote Interface Connector and Signals

6. OPERATING INSTRUCTIONS

The 402 power supply is designed for operation in two modes. The first mode is local, where the power supply can be controlled from the front panel. Local operation is only possible with the L model supply. The second mode is remote, where control signals are passed via the 25pin remote connector. Remote operation is possible with all 402 model power supplies (L, S, or OEM).

6.1. Local Operation (402L only)

The model 402L has full front panel instrumentation and controls for use in laboratory, prototype or OEM systems. The front panel controls include power on/off, remote/local and HV on/off switches, output voltage adjust, view set switch, digital voltage and current meters, quick reference bar graphs and status indicators. An internal AC contactor is included which is controlled by the front panel power switch and the interlock terminals located on the rear of the unit. A BNC connector is provided on the rear panel for easily connecting a pulsed INHIBIT signal when operating from the front panel. The model 402L can be operated as a "master" unit in parallel with several model 402S or OEM "slave" units for increased output power. Refer to Section 6.4 "Paralleling Units".

Before operating the power supply ensure a load capacitor is connected between the power supply output, and the other terminal of the capacitor is connected to ground or the appropriate point in the load circuit. Failure to correctly connect a capacitive load prior to operating the power supply may result in damage.

HIGH VOLTAGES MAY POTENTIALLY EXIST FROM THIS POINT FORWARD.

The power supply should be connected to 3 phase AC power as described in section 4.4. The interlock terminals should be closed either with the supplied shorting link or by an isolated external dry contact. Follow the steps below;

1. Ensure the output voltage potentiometer is turned fully counter clockwise.
2. Turn on the AC power switch, the cooling fan should start and the front panel indicators will illuminate.
3. Turn the control key to the local position.
4. Push the View Set button and turn the Voltage potentiometer until the required load voltage is displayed. The view set mode stays active for approximately 3 seconds before the voltage display reverts to the output voltage mode.
5. Push the HV ON button. The load will charge to the preset voltage and once this voltage is reached the End of Charge LED will illuminate. The supply will maintain this voltage until the HV OFF button is pushed, or the load capacitor is discharged via the HV switch.

After the load has been discharged the external Inhibit function can be used to shut down the power supply output current which aids in the HV switch recovery. Application of an inhibit signal will typically shut down the output current in approximately 15microseconds.

To turn OFF the power supply depress the HV OFF button, or use the Inhibit input to shut off the output current but leave the supply in the HV ON condition. Opening the interlock terminals will also cause the power supply to turn off. In this case the unit can only be turned back on after the interlock has been closed and the HAV ON button depressed followed by the HV OFF button to RESET the fault. Any other fault occurring in the internal protection circuitry will interrupt the power supply's operation causing it to turn OFF. For a full explanation of each control and indicator refer to Section 5.

6.2. Remote Operation (All models)

All 402 models are easily controlled through the 25 pin sub D-type remote interface connector located on the rear panel. The minimum required signals for remote control operation are; HV ON/OFF, Vprogram and GND. The remaining signals are provided for status monitoring and fault diagnosis, or more sophisticated control methodologies. The function each signal is shown in Table 6, with a schematic showing a suggested remote interface circuit shown in Figure 8.

Pin	Signal Name	I/O	Description
1	Analog Out	O	0-10V (±1%) Analog of output voltage waveform. Impedance 1kΩ. If the 5V option is installed the voltage level is 0-5V.
3	Inhibit LED	O	Open collector through 100Ω. Low impedance when inhibit signal applied. See Note 1.
5	End of Charge LED	O	Open collector through 100Ω. Low impedance when power supply reaches End of Charge. See Note 1.
7	Inhibit Input	I	5-15V Inhibits unit, open or ground allows operation. Input impedance >10kΩ
8	HV ON/OFF	I	15V=On, ground or open =Off. Also used to reset latching faults by cycling from On to Off. Input impedance >1MΩ. If the EN option is installed 15V=Off, Ground or open = On
9	Peak output volts	O	0-10V (±1%) Peak detector of output voltage waveform. Can be used to drive a meter displaying peak charging voltage. Impedance 10k kΩ. If the 5V option is installed the voltage level is 0-5V.
10	HV ON LED	O	Open collector through 100□Ω. Low impedance when HV output is enabled. See Note 1.
12	GND		Control circuit return. Also chassis/earth ground.
13	Charge current	O	Uncalibrated Analog of output current waveform. Impedance 10kΩ
14	+15V	O	+15V through 100 kΩ
16	Overtemp LED	O	Open collector through 100Ω. Low impedance when inverter over temperature condition occurs. See Note 1.
17	Interlock LED	O	Open collector through 100Ω. Low impedance when external interlock circuit is open. See Note 1.
18	Load fault LED	O	Open collector through 100Ω. Low impedance when load fault condition occurs. Load fault is normally a non-latching fault and will self-reset after approximately 500ms (for models without LP option), unless caused by an output overvoltage where the supply will latch off. See Note 1.
19	Summary Fault LED	O	Open collector through 100Ω. Low impedance indicated a summary fault condition. Summary fault is a logical or of Overvoltage, Overtemp, AC Line, and Open Interlock conditions. See Note 1.
20	$\overline{\text{Inhibit Input}}$	I	0V Inhibits unit, 15V or open allows operation. Input impedance >10 kΩ
22	Vprogram	I	0-10V = 0-100% of rated output voltage. Input impedance >1MΩ. If the 5V option is installed the voltage level is 0-5V.
23	HV OFF LED	O	Open collector through 100Ω. Low impedance when HV output is off/disabled. See Note 1.
24	GND		Control circuit return. Also chassis/earth ground.

Table 6 402 Remote Interface Description

Note 1 – For 402L or 402S models, the front panel LEDs are driven by open collector drivers that are common to the remote control interface indicator signals. A pullup resistor is not required to sense the remote interface voltage on these signals. The user should expect the Active logic level (low) to be between 2 and 4V. If an external pullup resistor is added, the Active logic level (low) voltage will be higher.

For 402-OEM models, a pullup resistor is required to sense voltage levels at these outputs.

For applications that require logic level inputs the use of an opto-isolation device is recommended.

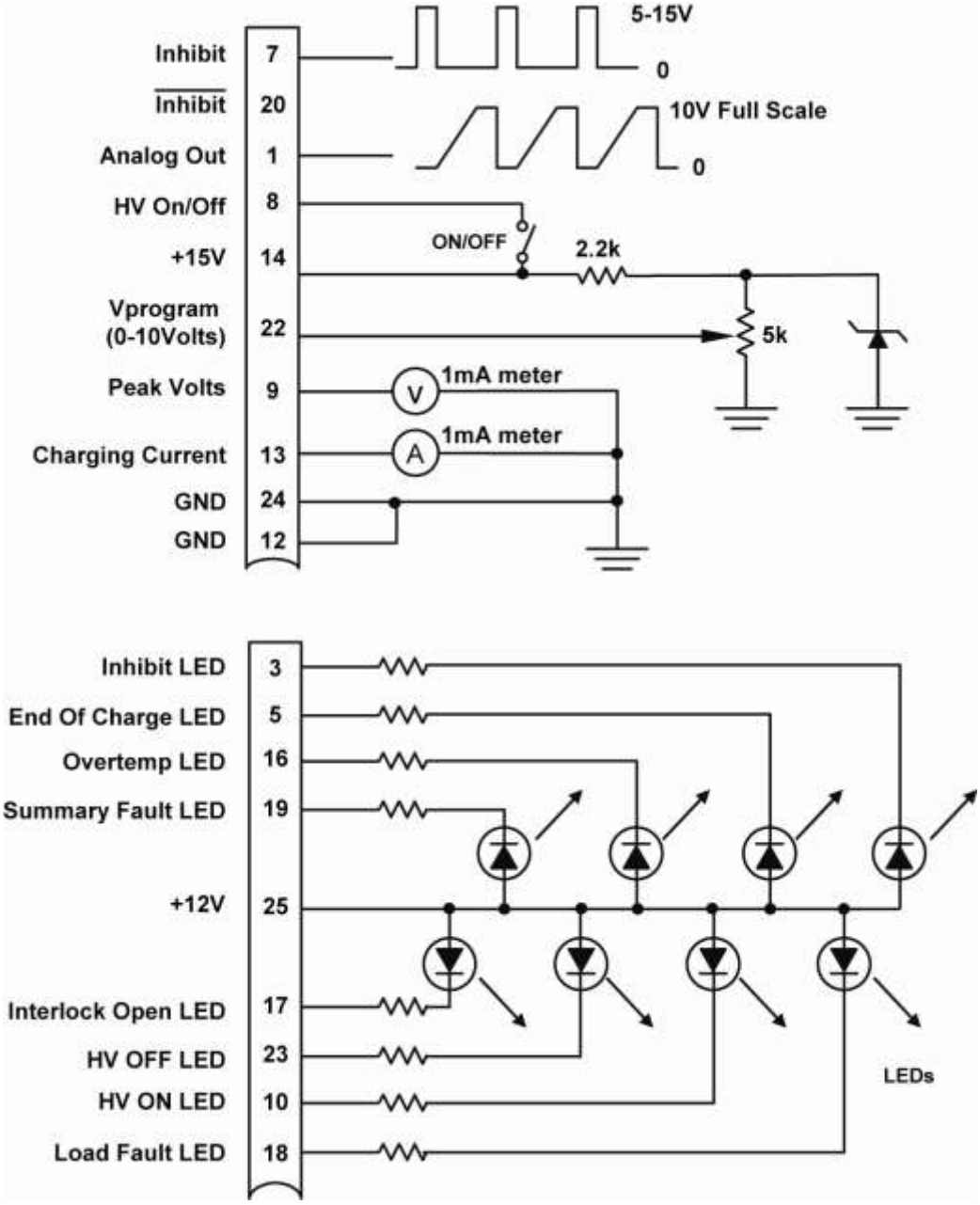


Figure 8 Suggested external remote interface circuit

A detailed description of each remote control signal is given in the following sub-sections.

6.2.1. **Analog Out**

Pin 1. Analog of output voltage waveform as measured at the output terminals of the power supply. Signal is 0-10V +/-1% (0-5V if 5V option installed).

6.2.2. **Inhibit LED**

Pin 3. Open collector Active Low output indicating presence of an external Inhibit signal. Max rated voltage - 60V, 100Ω series resistance.

6.2.3. **End Of Charge (EOC) LED**

Pin 5. Open collector Active Low output indicating power supply output voltage has reached the programmed voltage or end of charge cycle. Max rated voltage - 60V, 100Ω series resistance.

6.2.4. **Inhibit Input**

Pin 7. 5-15V Inhibits unit (shuts off output current), open or ground allows operation. Input impedance >10kΩ. Signal can be used to aid load switch recovery.

6.2.5. **HV ON/OFF**

Pin 8. +15V = HV ON, ground or open = HV OFF. Also used to reset latching faults by cycling from ON to OFF. Input impedance > 1MΩ. If EN option is installed +15V = OFF, Open or Ground = ON.

6.2.6. **Peak Output Volts**

Pin 9. Peak detector of Analog output voltage waveform. Can be used to drive a meter displaying peak charging voltage. Signal is 0-10V +/-1% (0-5V if 5V option installed).

6.2.7. **HV ON LED**

Pin 10. Open collector Active Low output indicating power supply output is ON/Enabled. Max rated voltage - 60V, 100Ω series resistance. If both the HV ON and HV OFF signals are both active at the same time, this indicates a Summary Fault.

6.2.8. **Ground**

Pin 12. Control circuit return. Also chassis/earth ground.

6.2.9. **Charge current**

Pin 13. Analog of output current waveform. Signal is not calibrated.

6.2.10. **+15V Output**

Pin 14. +15V through 100Ω, maximum current is 20mA.

6.2.11. **Overtemp LED**

Pin 16. Open collector Active Low output indicating an inverter overtemperature condition has occurred. Once temperature has returned to normal levels this fault will clear, but the power supply will not restart without a Reset Cycle. Max rated voltage - 60V, 100Ω series resistance.

6.2.12. **Interlock LED**

Pin 17. Open collector Active Low output indicating the external interlock circuit is open. Max rated voltage - 60V, 100Ω series resistance.

6.2.13. **Load Fault LED**

Pin 18. Open collector Active Low output indicating a load fault condition. Load fault is a non-latching fault and will self reset after approximately 500ms (for models without LP option).

Load fault is caused by an output overvoltage condition (110% of rated voltage) or an output short circuit/large capacitor (load charges for 500ms without reaching programmed voltage). Max rated voltage - 60V, 100Ω series resistance.

6.2.14. **Summary Fault LED**

Pin 19. Open collector Active Low output indicating a summary fault condition. Summary fault is a logical OR of Overvoltage, Overtemp, AC Line, and Open Interlock conditions. Summary Fault is also indicated by both HV ON and HV OFF LEDs/indicators illuminating at the same time. Max rated voltage - 60V, 100Ω series resistance.

6.2.15. **Not Inhibit Input**

Pin 20. Logical Inverse of Inhibit input (Pin 7), 0V Inhibits unit, 15V or open allows operation. User should control supply with either the Inhibit or Not Inhibit signal, both signals should not be used together. Input impedance >10kΩ.

6.2.16. **Vprogram**

Pin 22. 0-10V Analog Input = 0-100% of rated output voltage (0-5V if 5V option is installed). Input impedance >1MΩ.

6.2.17. **HV Off LED**

Pin 23. Open collector Active Low output indicating HV output is off/disabled. Max rated voltage - 60V, 100Ω series resistance.

6.2.18. **Ground**

Pin 24. Control circuit return. Also chassis/earth ground.

6.3. Remote Control Sequence

Note

The logic levels in the description below are for a supply without EN option. If EN is installed the logic levels for HV ON/OFF should be reversed.

Before operating either a 402L, S, or OEM in remote mode it must first be connected to a master supply, or an appropriate external control system. To operate a model 402L in remote mode the front panel keyswitch must be in the REMOTE position.

It is suggested that the INHIBIT signal is used in addition HV ON/OFF signal to control the output current of the power supply during the normal charge/discharge cycle. The INHIBIT signal should be asserted (Pin 7=5-15V) prior to activating the HV ON signal.

Once HV ON has been set (Pin 8=15V), then INHIBIT can be removed (Pin 7=0V), and the supply will begin charging the load. A few tens of microseconds before the load switch is triggered to close, the INHIBIT signal should be asserted to turn-off the output current, and aid in switch recovery.

After the load is discharged, and the HV switch has recovered to an insulating state, INHIBIT can be removed and the load re-charged. A typical set of remote control waveforms illustrating this sequence is shown in Figure 9.

There is no need to turn HV ON and OFF during the normal charge discharge cycle, just use the INHIBIT signal to control the power supply. HV should be turned off (Pin 8=0V) as soon as the load circuit is no longer required to operate.

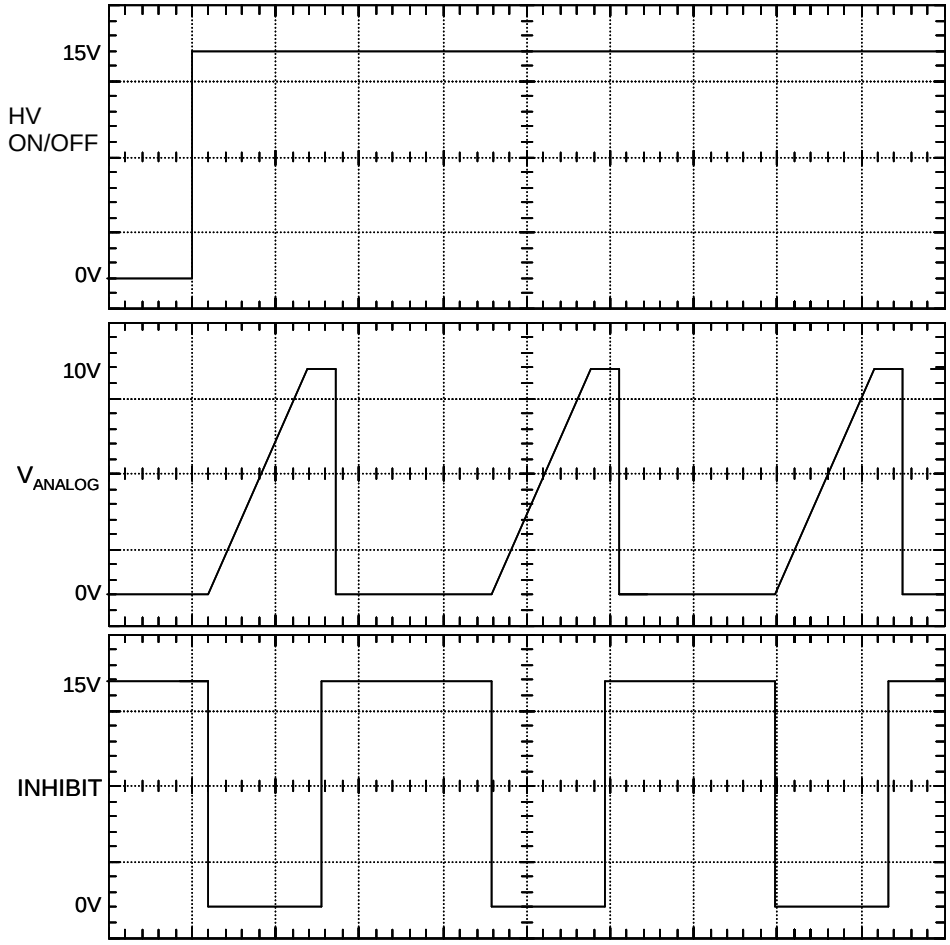


Figure 9 Typical remote Interface waveforms

The 402 supply can also be controlled without using the Inhibit signal (leaving Pin 7or 20 unconnected), and in this case the output current is immediately turned ON when the HV ON signal is activated assuming there are no faults present.

6.4. Parallel Operation

The 402 series capacitor charging power supplies are constant current sources, and can simply be connected in parallel for applications requiring increased power. Parallel supplies should have the same output voltage rating and programming options (if one unit has the 5V option, all others in parallel must have this option). Note that it is also possible to operate power supplies in parallel from different series (ie a model 402 in parallel with a model 802), but the user has to ensure the remote interface connections are compatible.

To operate more than one unit in parallel all that is required is a parallel control cable, and to connect the HV output cables together at the load. The output currents from the parallel supplies simply add together to increase the overall system current. Any model 402 supply, or any combination of units can be operated in parallel. If at least one model 402L is connected in a parallel system then the system can be operated without an external controller by using the 402L as a master supply in local mode.

If status, voltage, and current displays/measurements are required individually for each supply in a parallel system then the ‘daisy chain’ control cable is not appropriate, and each unit must be individually connected to a remote control system.

6.4.1. Parallel system comprising 402L supplies

If all of the parallel units are L model supplies then one unit should be operated as the master supply in either local or remote mode. The other parallel supplies can be connected to the SLAVE 25-pin D-sub connector on the master unit rear panel (refer to **Error! Reference source not found.**). The SLAVE control cable can be a pin-to-in ribbon or other cable that is ‘daisy chained’ to the REMOTE connector on each of the SLAVE supplies. Note: The master 402L supply in a parallel system only displays the status, voltage, and current output for that unit, not for the entire system. The slave supplies will also display the voltage and current only for that specific unit.

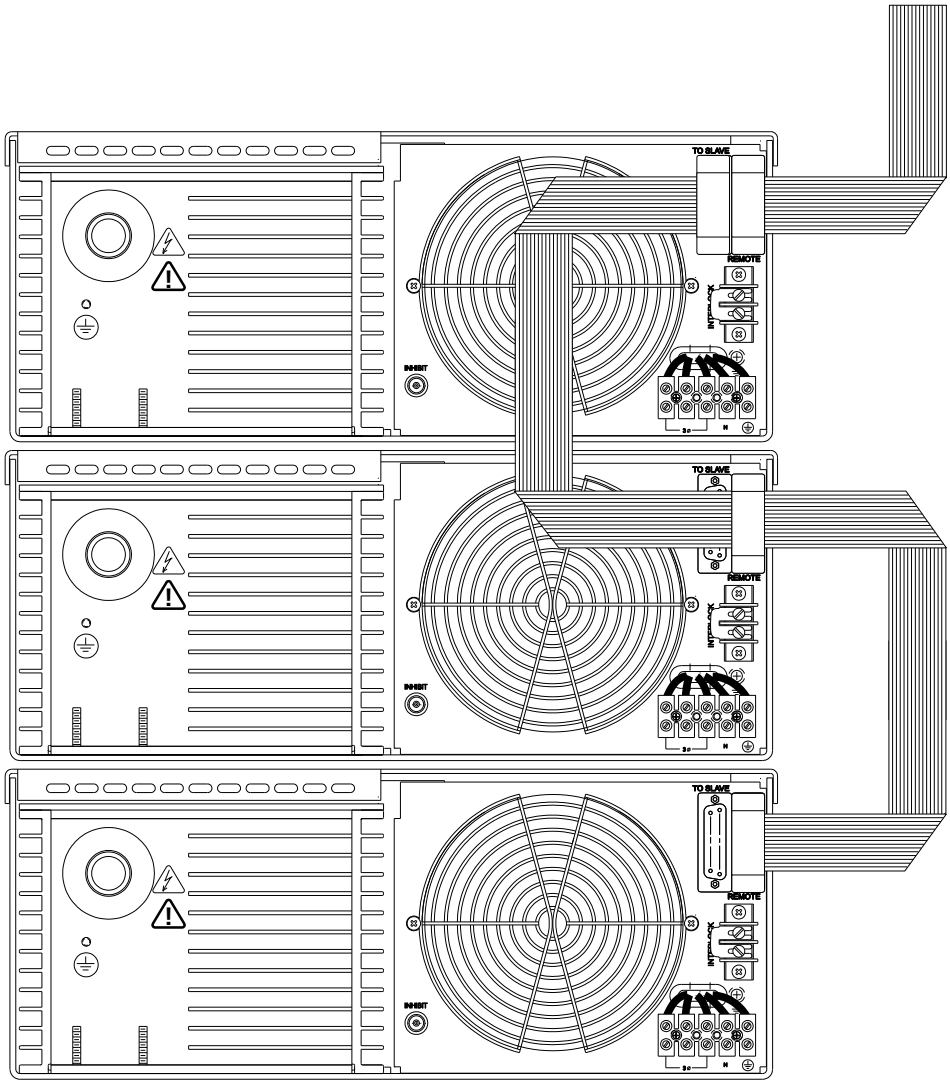


Figure 10 402L Parallel System Control Connections

6.4.2. **Parallel system comprising both 402L and 402S or OEM supplies**

For a system comprising both 402L and S/OEM units, a single L model should be operated as a master in either local or remote mode. The other parallel supplies can be connected to the SLAVE 25-pin D-sub connector on the master unit rear panel (refer to Figure 11). The SLAVE control cable can be a pin-to-pin ribbon or other cable that is ‘daisy chained’ to the REMOTE connector on each of the SLAVE supplies.

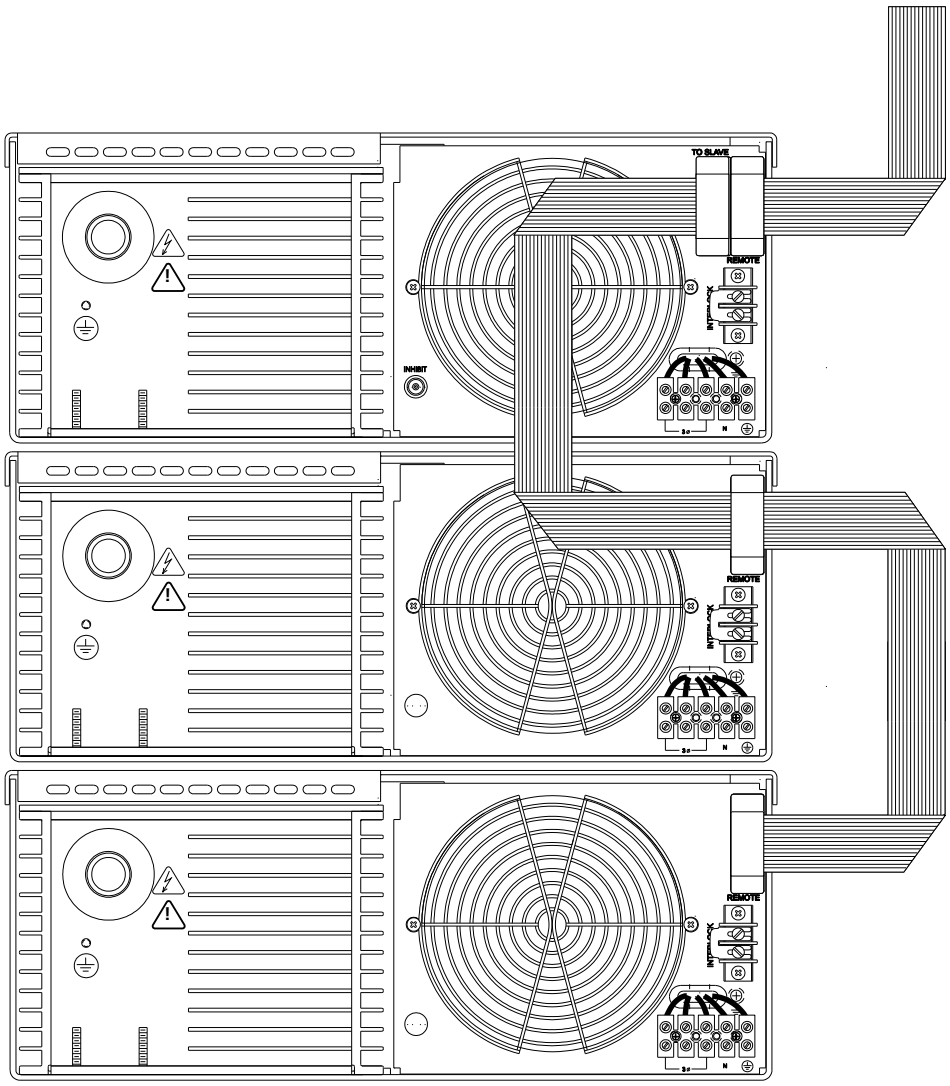


Figure 11 402L and 402S/OEM Parallel System control Connections

6.4.3. **Parallel system comprising 402S/OEM supplies**

A system comprising only model 402S/OEM supplies must be operated from an external control system. The control system should be connected using a pin-to-pin ribbon or other cable that is ‘daisy chained’ to the REMOTE connector on each of the 402S/OEM supplies in the system. A sketch is shown in Figure 12.

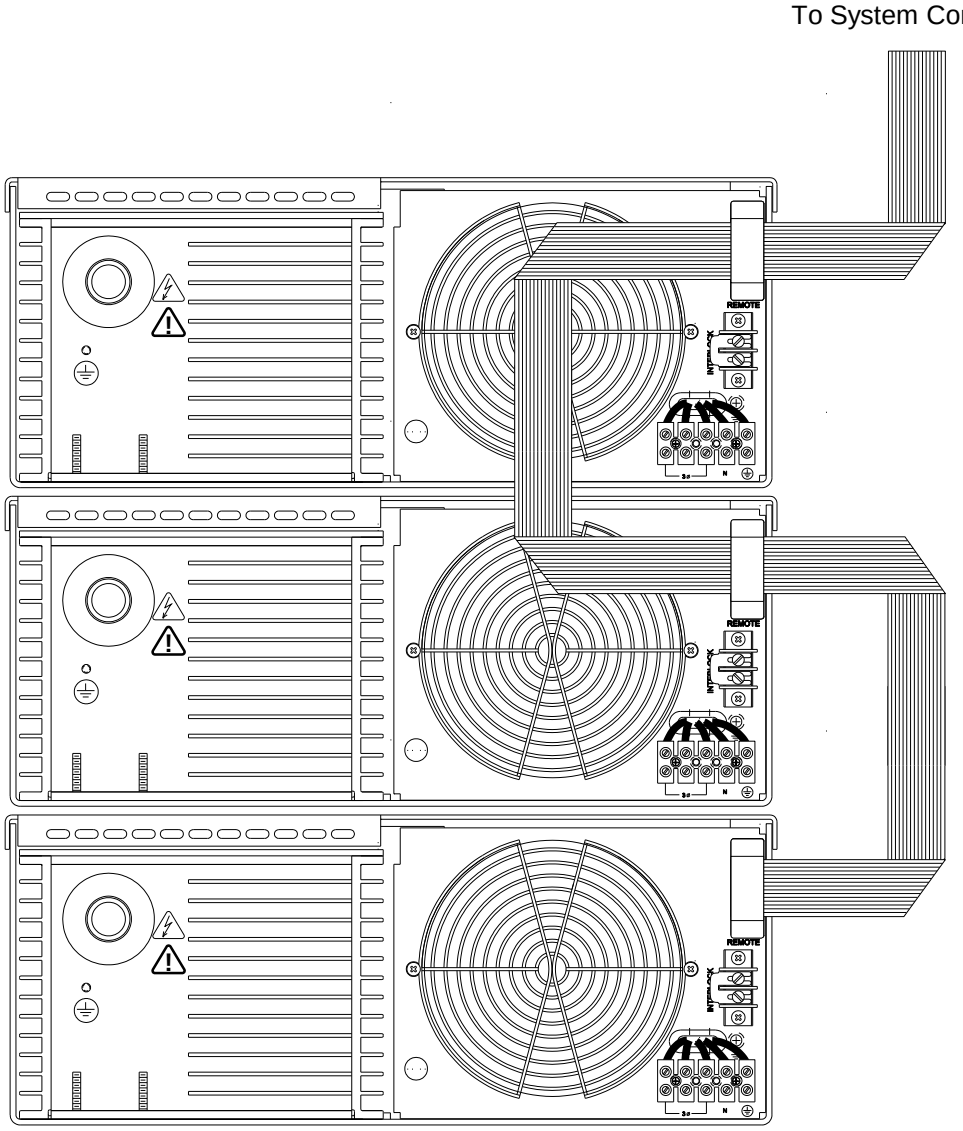


Figure 12 Parallel Operation Connections for 402S/OEM Supplies

Notes

7. APPLICATION NOTES

The 402 series power supplies are high voltage power sources and great care should be taken when connecting and operating these units. In order to aid installation and system design, a number of application notes have been produced to support the design engineer with certain load circuit component rating and selection. The latest versions of these application notes are available for download at the TDK-Lambda High Power web site (https://product.tdk.com/en/products/power/tec_data/ps_ale.html).

The following App Notes were available at the time this manual was produced. These documents are continually being improved and expanded, so always check for the latest revision on-line.

APP Note 500: Calculating Capacitor Charge Time

APP Note 502: Calculating AC Line Currents

APP Note 505: Charging units as Continuous Output DC Supplies

APP Note 507: Charging Large Load Capacitors

APP Note 509: What is Regulation and Repeatability?

APP Note 513: Power Factor Correction

APP Note 517: Protection against Voltage Reversal

If there are any other application issues or questions that are not covered in these Application Notes, or elsewhere in this manual, please do not hesitate to contact the factory and our team of experienced HV application engineers.

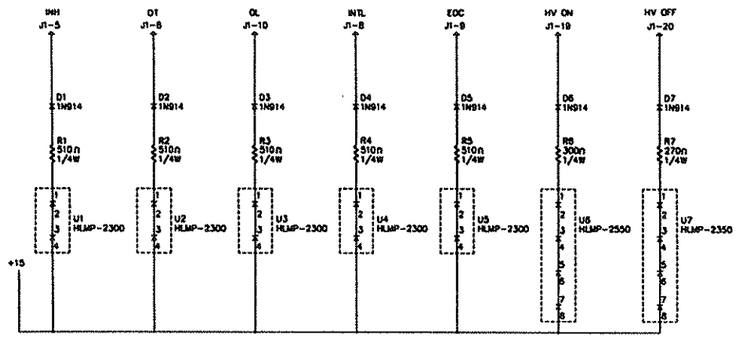
Contact the Factory – We are here to help!

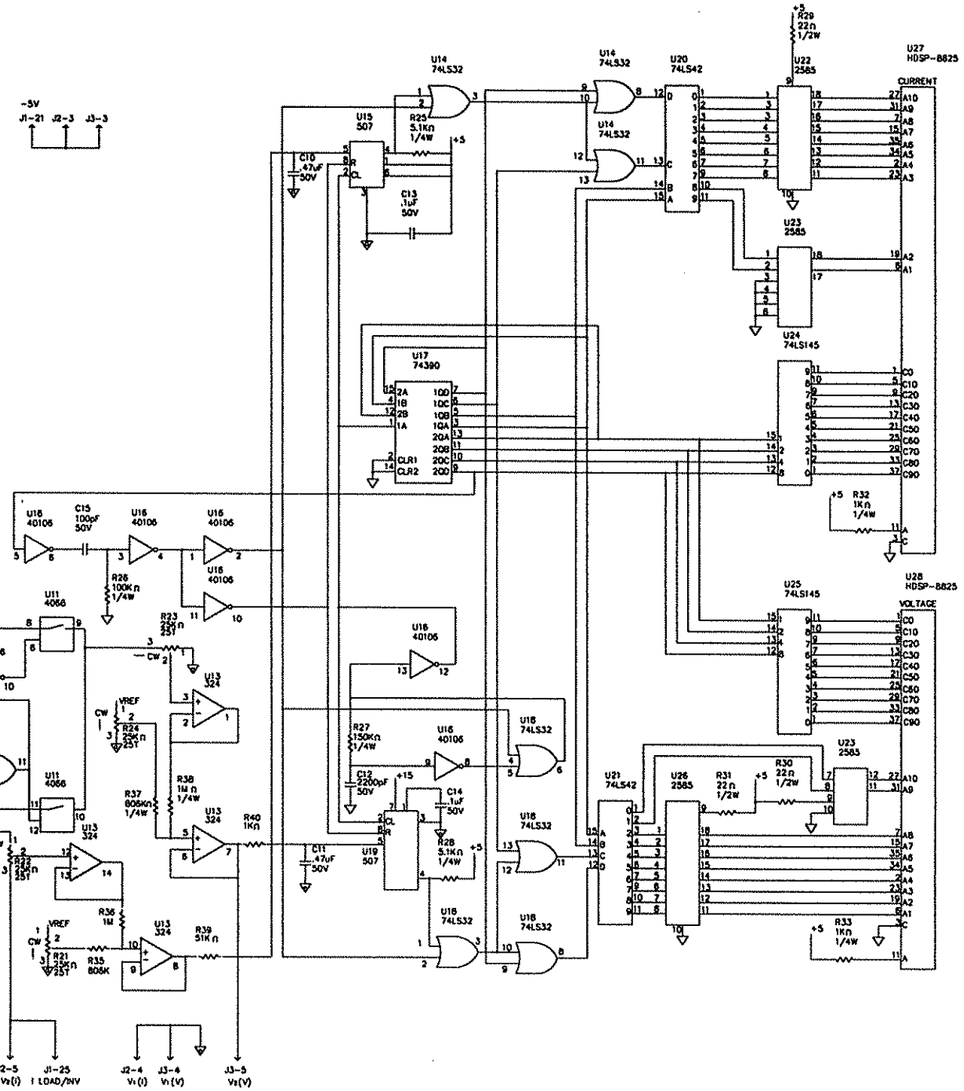
Tel: +1 732 795 4100

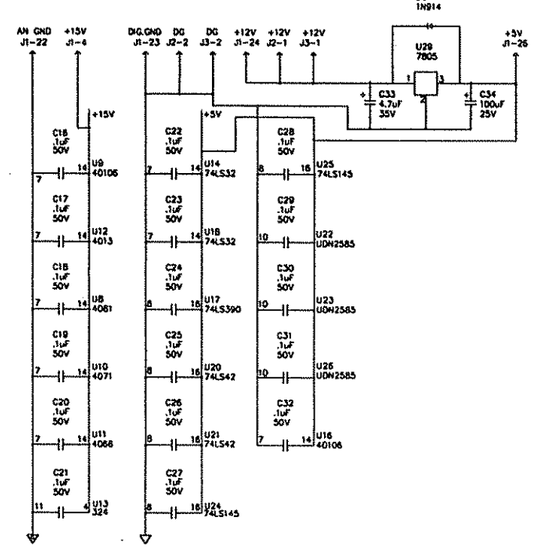
Fax: +1 732 922 9334

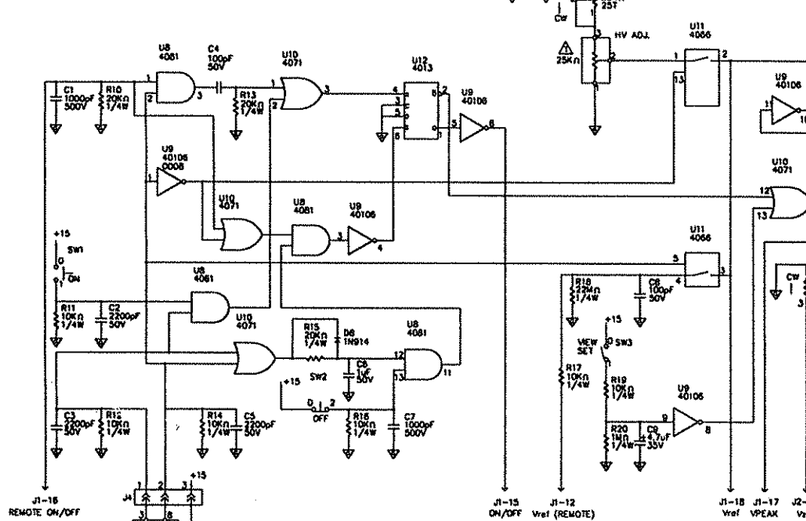
THIS IS A COMPUTER GENERATED DWG.
NO MANUAL REVISIONS ARE PERMITTED.

APPLICATION			LTR	E. C. D. NO.	BY	APP.
USED ON	NEXT ASSY.	QTY.				
402			01	ECO 353 3/91	JT	
802			02	CHANGE TO EMI FORMAT 10/19/94	SAdB	
			A	TG3 RELEASE 11/95	CB	









NOTES:

⚠ ITEMS TO BE MOUNTED ON FRONT PANEL ASSEMBLY.

REFERENCE DESIGNATIONS	
LATEST	NOT USED
C34	
D9	
J4	
R34	R9
U29	

SHEET 1 OF 1

MTL:	TOL: .X = ± .02" .XX = ± .01" .XXX = ± .005" FRAC. = ± 1/64" ANGLES = ± 1/2°	REL TO MFG. DATE: 11/13/95	ENG. CTL. DWN: TURCOTTE 4/90 DATE:	ELECTRONIC MEASUREMENTS, INC.
FIN: DO NOT SCALE DWG.	P/L: 488 SCALE: N/A	MFG DATE: 11/14/95 DOC. REL. DATE: 11/13/95 DO NOT SCALE DWG.	CHK: DATE: APP: DATE: APP: DATE:	TITLE: SCHEMATIC PCB A11 DISPLAY BD 802 STD DWG. NO. 01-000-610 REV. A

THIS IS A COMPUTER GENERATED DWG.
NO MANUAL REVISIONS ARE PERMITTED.

APPLICATION			LTR	E.C.O. NO.		BY	APP.
USED ON	NEXT ASSY.	QTY.					
402-OEM LV AC	003-0273		00	REL.ECO# 320	4/91	JT	
			01	ECO# 378	5/91	JT	
			A	TG 3 REL	12/15/94	CJS	
			B	ECO #16288	6/23/97	CJS	

NOTE:
SEE SHT 2 FOR CONTACTOR OPTION.
SEE SHT 3 FOR CIRCUIT BREAKER OPTION.

A1 REAR PANEL ASSY 26-587-005

A2 VNR BD 003-0206 01-000-609

MOUNTED OFF BOARD

A3 CONTROL BD 20-003-301 001-0219

A4 INVERTER ASSY 20-851-400 01-000-608

A5 AUXILIARY BD 20-799-000 01-000-612

A6 HIGH VOLTAGE ASSY

A8 FAN ASSY 003-0272

A7 FRONT PANEL BLANK 26-580-400

3ø
N
INTLK
CONTACTOR
REMOTE
BLK
RED
HV OUTPUT
GND
IFB
VFB
COAX 2
COAX 1
VNR SENSE CIRCUIT
VNR+
VNR-
VNR-/NEUT
JP1 FOR 400VAC
JP2 FOR 208VAC
JP3
C1 1500uF 450V
C2 1500uF 450V
L1
L2
12Ω,11W, 2X
200Ω
20K Ω 11W
.01uF 3KV
.01 3X
7815
+15
+35
-3V
GND
INTLK
+12

NOTES:

1. WIRES W1,13, AND 14 ARE NOT USED ON OPTION 2 ONLY. WIRE W11 IS USED ONLY ON OPTION 1 AND 2.
2. SEE FAMILY TREE (004-0018).

REFERENCE DESIGNATIONS	
HIGHEST	NOT USED
S1	
M1	
C2	
L2	
A8	
P16	P2
W23	W1,11-14,17,18
E2	

MTL: N/A	TOL: .X = ±.02" .XX = ±.01" .XXX = ±.005" FRAC. = ±1/64" ANGLES = ±1/2°	REL. TO MFG. ENG: DATE: 12/15/94 MFG: DATE: 12/15/94 DOC. REL: DATE: 12/15/94 APP: DATE: 12/15/94	ENG. CTL. DWN: DATE: J TURCOTTE 7/90 CHK: DATE: B.WEAVER 10/90	ELECTRONIC MEASUREMENTS, INC.
FIN: N/A	P/L: 487 SCALE: N/A DO NOT SCALE DWG.			TITLE: SCHEMATIC 402-OEM 200V AC SYSTEM
				DWG. NO. 01-487-003 REV. B

SHEET 1 OF 3

THIS IS A COMPUTER GENERATED DWG.
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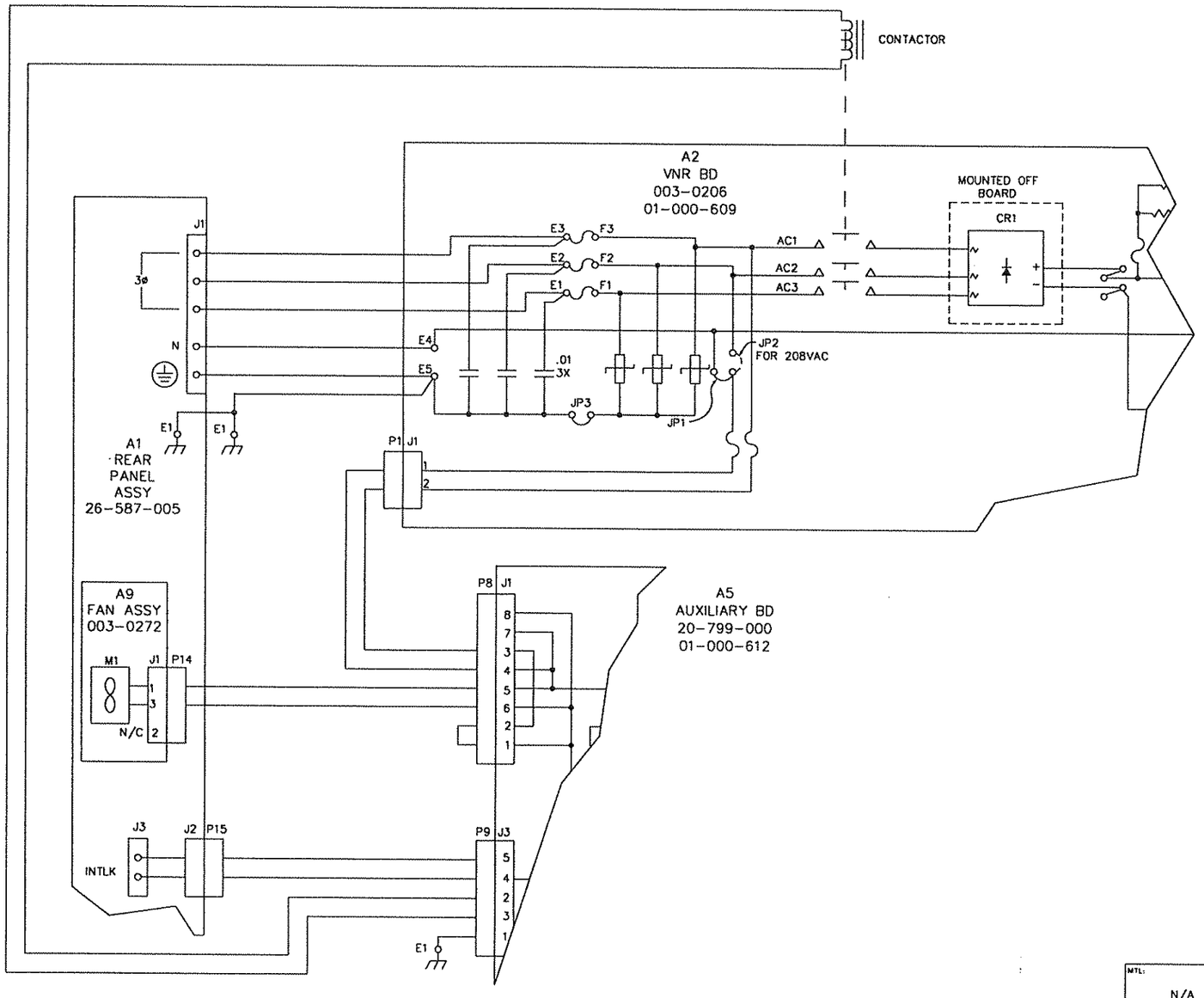
APPLICATION			LTR	E.C.O. NO.	BY	APP.
USED ON	NEXT ASSY.	QTY.				
				SEE SHEET 1		



OPTION 1

402 OEM VERSION WITH CONTACTOR

SHEET 2 OF 3

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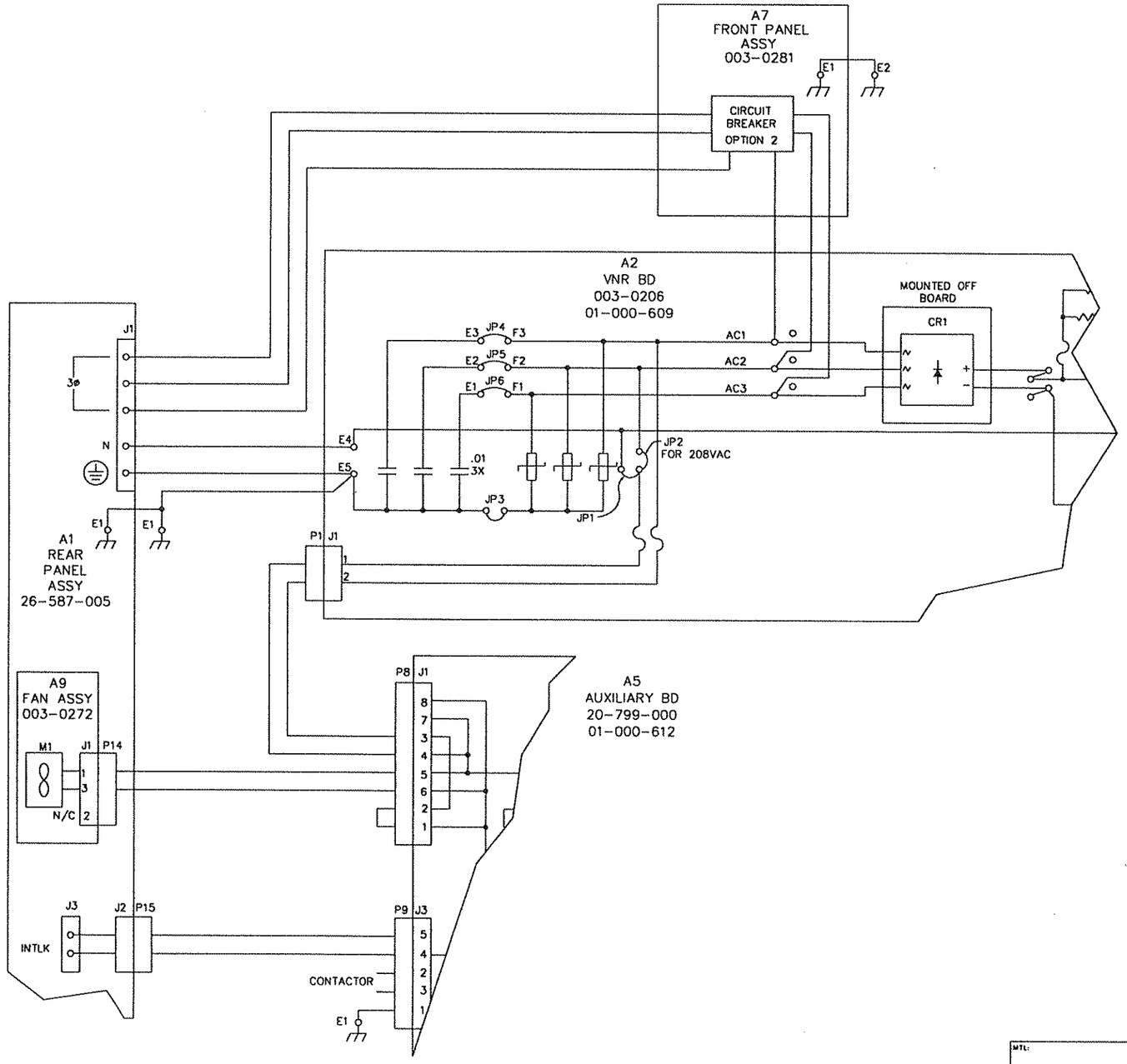
				DWG. NO. 01-487-003 REV. B

THIS IS A COMPUTER GENERATED DWG.
NO MANUAL REVISIONS ARE PERMITTED.

APPLICATION			LTR	E.C.O. NO.	BY	APP.
USED ON	NEXT ASSY.	QTY.		SEE SHEET 1		



OPTION 2

402 OEM VERSION WITH CIRCUIT BREAKER
AND WITHOUT FUSES.

SHEET 3 OF 3

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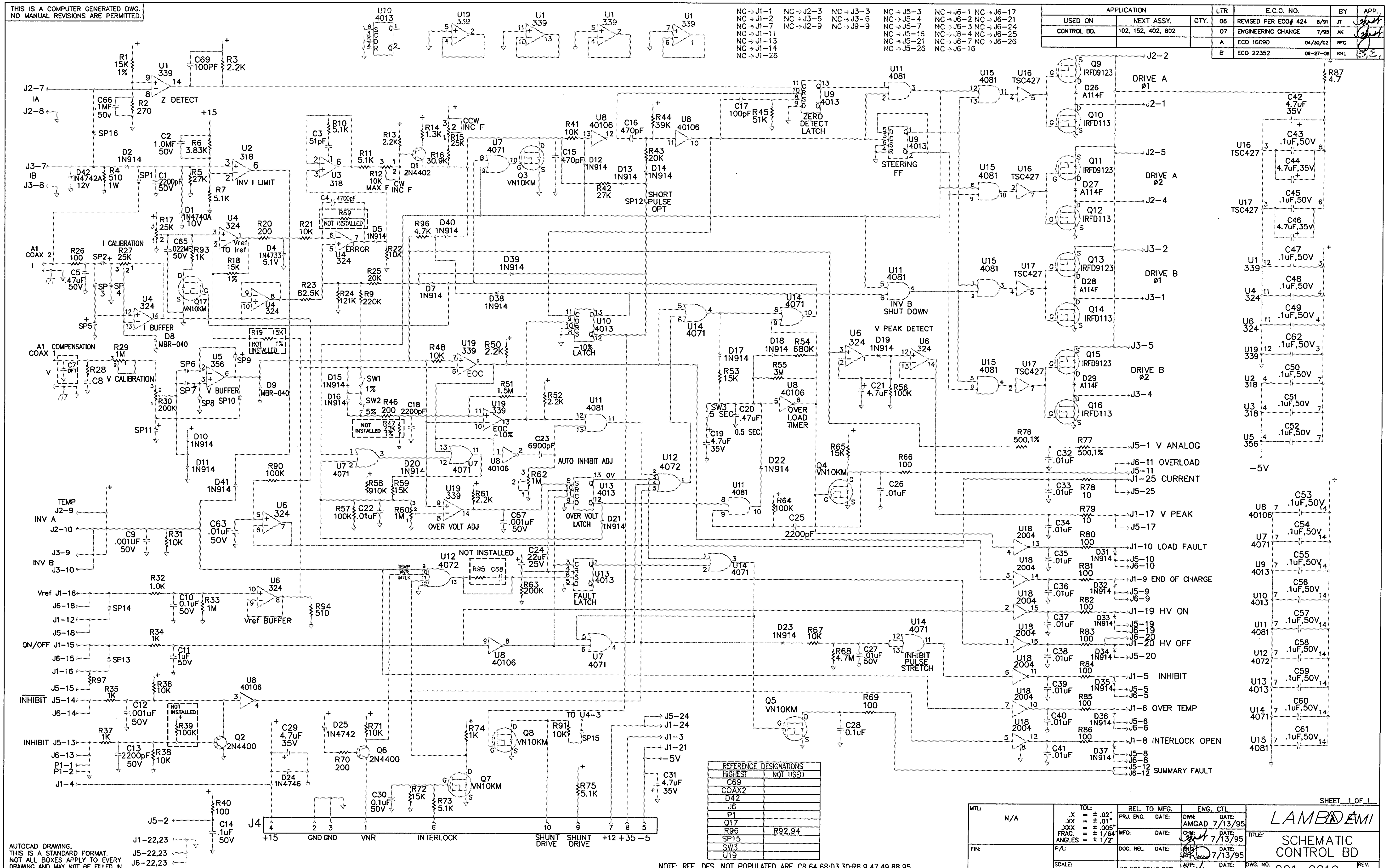
FIN: N/A	P/L: 487 SCALE: N/A	DO NOT SCALE DWG.		TITLE: SCHEMATIC 402-OEM 200VAC SYSTEM	
				DWG. NO. 01-487-003	REV. B



APPLICATION		
USED ON	NEXT ASSY.	QTY.
CONTROL BD.	102, 152, 402, 802	

LTR	E.C.O. NO.	BY	APP.
06	REVISED PER ECO# 424 8/91	JT	
07	ENGINEERING CHANGE 7/95	AK	
A	ECO 16090 04/30/02	RFC	
B	ECO 22352 09-27-06	KHL	

REFERENCE DESIGNATIONS	
HIGHEST	NOT USED
C69	
COAX2	
D42	
J6	
P1	
Q17	
R96	R92,94
SP15	
SW3	
U19	

NOTE: REF. DES. NOT POPULATED ARE C8,64,68;D3,30;R8,9,47,49,88,95.

SHEET 1 OF 1

MTL: N/A

TOL: .X = ± .02" .XX = ± .01" .XXX = ± .005" FRAC. = ± 1/64" ANGLES = ± 1/2°

REL. TO MFG. — PRJ. ENG. DATE: — MFG: DATE: — DOC. REL. DATE: — DO NOT SCALE DWG.

ENG. CTL. — DWN: AMGAD DATE: 7/13/95 — CHK: DATE: 7/13/95 — DATE: 7/13/95 — APP: DATE: 7/13/95

FIN: — P/L: — SCALE:

LAMBDA EMI

TITLE: SCHEMATIC CONTROL BD

DWG. NO. 001-0219 REV. B

THIS IS A COMPUTER GENERATED DWG.
NO MANUAL REVISIONS ARE PERMITTED.

APPLICATION			LTR	E.C.O. NO.		BY	APP.
USED ON	NEXT ASSY.	QTY.	1	INITIAL REL.	2/3/96	SE	
FINAL	802 L	REF.	A	TO 3 REL.	3/13/96	CJS	
			B	ECO #16266	8/11/97	CJS	

CONTACTOR

A2
VNR BD
003-0205
01-000-609

MOUNTED OFF BOARD
CR1

12Ω, 11W, 2X
200Ω
K1

VNR+
VNR-/NEUT
VNR-
20K Ω 11W
20K Ω 11W

L1 L2

C1 1500uF 450V
C2 1500uF 450V

JUMPER BRKT

JP2 FOR 208VAC
JP1 FOR 400VAC
JP3

A1
REAR PANEL ASSY
26-587-001

A6
HIGH VOLTAGE ASSY
HV OUTPUT
GND
IFB
VFB

A4
INVERTER ASSY
20-851-400
01-000-608

A5
AUXILIARY BD
20-799-000
01-000-612

7815

+15
+35
-3V
GND
INTLK
+12

A3
CONTROL BD
001-0219
20-003-301

VNR SENSE CIRCUIT

P/O J1
P/O P1

A9
FAN ASSY
003-0272

INTLK
INHIBIT
SLAVE
REMOTE

COAX 2
COAX 1

A11
DISPLAY BD ASSY
20-783-000
01-000-610

A12
DPM BD ASSY
20-003-601
01-000-611

A13
DPM BD ASSY
20-003-602
01-000-611

A14
KEYLOCK ASSY
003-0277

A7
FRONT PANEL ASSY
26-582-100

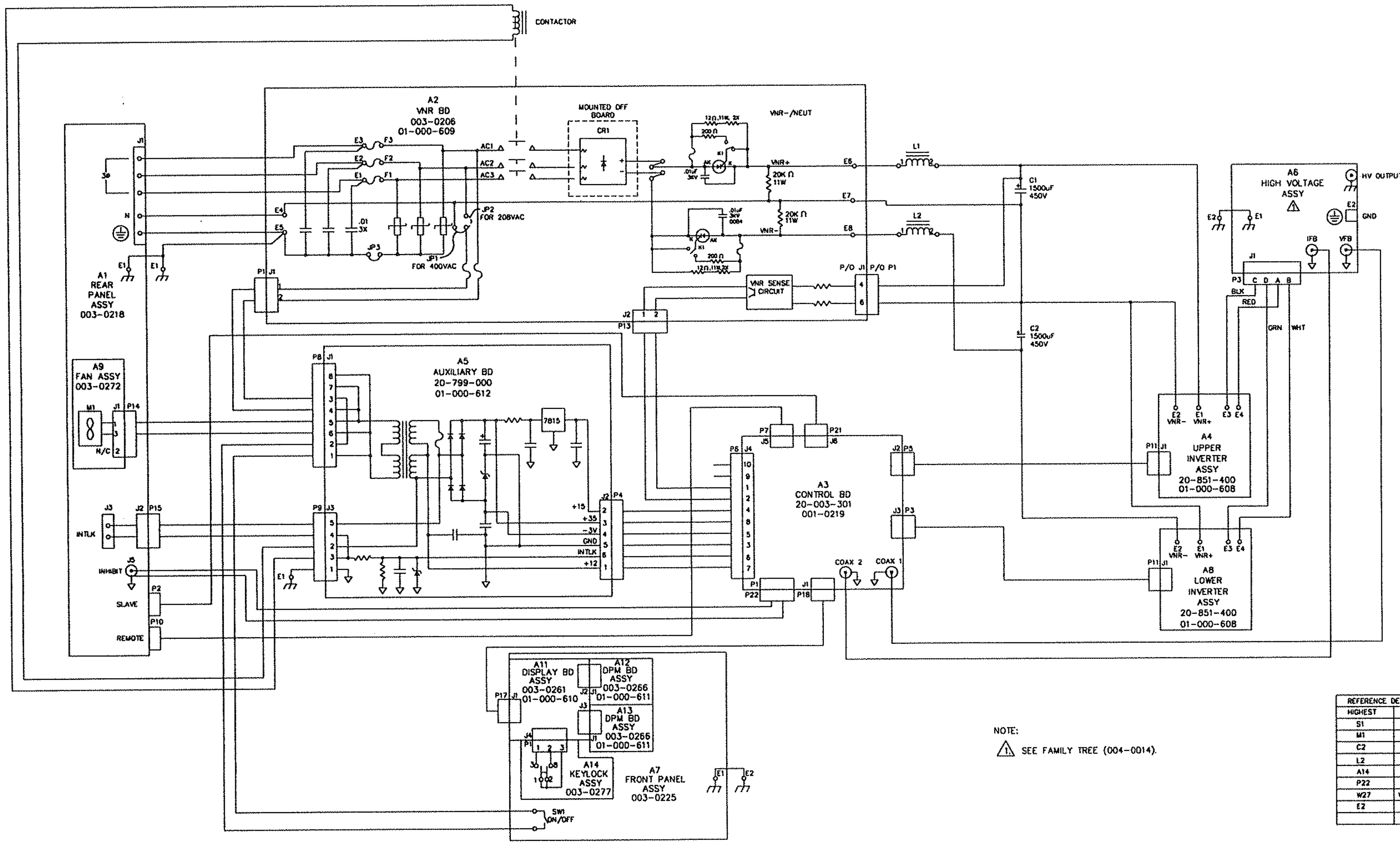
SW1
ON/OFF

REFERENCE DESIGNATIONS	
HIGHEST	NOT USED
S1	
M1	
C2	
L2	
A14	A8
P22	
E2	

MTL: N/A	TOL: .X = ± .01" .XX = ± .01" .XXX = ± .005" FRAC = ± 1/32 ANGLES = ± 1/2°	REL. TO MFG. DWN: DATE: 3/13/96	ENG. CTL. DWN: C.SEIBERT DATE: 3/13/96	ELECTRONIC MEASUREMENTS, INC.	SHEET 1 OF 1
PN: N/A	PA: 487	CHK: DATE: 3/13/96	APP: DATE: 3/13/96	TITLE: SCHEMATIC 402L 208V AC SYS	
SCALE: NONE	DO NOT SCALE DWG.	APP: DATE: 3/13/96	APP: DATE: 3/13/96	DWG NO: 01-487-009	REV: B

THIS IS A COMPUTER GENERATED DWG. NO MANUAL REVISIONS ARE PERMITTED.

APPLICATION			LTR	E.C.O. NO.	BY	APP.
USED ON	NEXT ASSY.	QTY.	00	REL. ECO# 320 4/91	JT	GFS
402L	003-0351		01	ECO# 378 5/91	JT	GFS
			A	ECO #16288 6/11/97	CJS	GFS



NOTE:

⚠ SEE FAMILY TREE (004-0014).

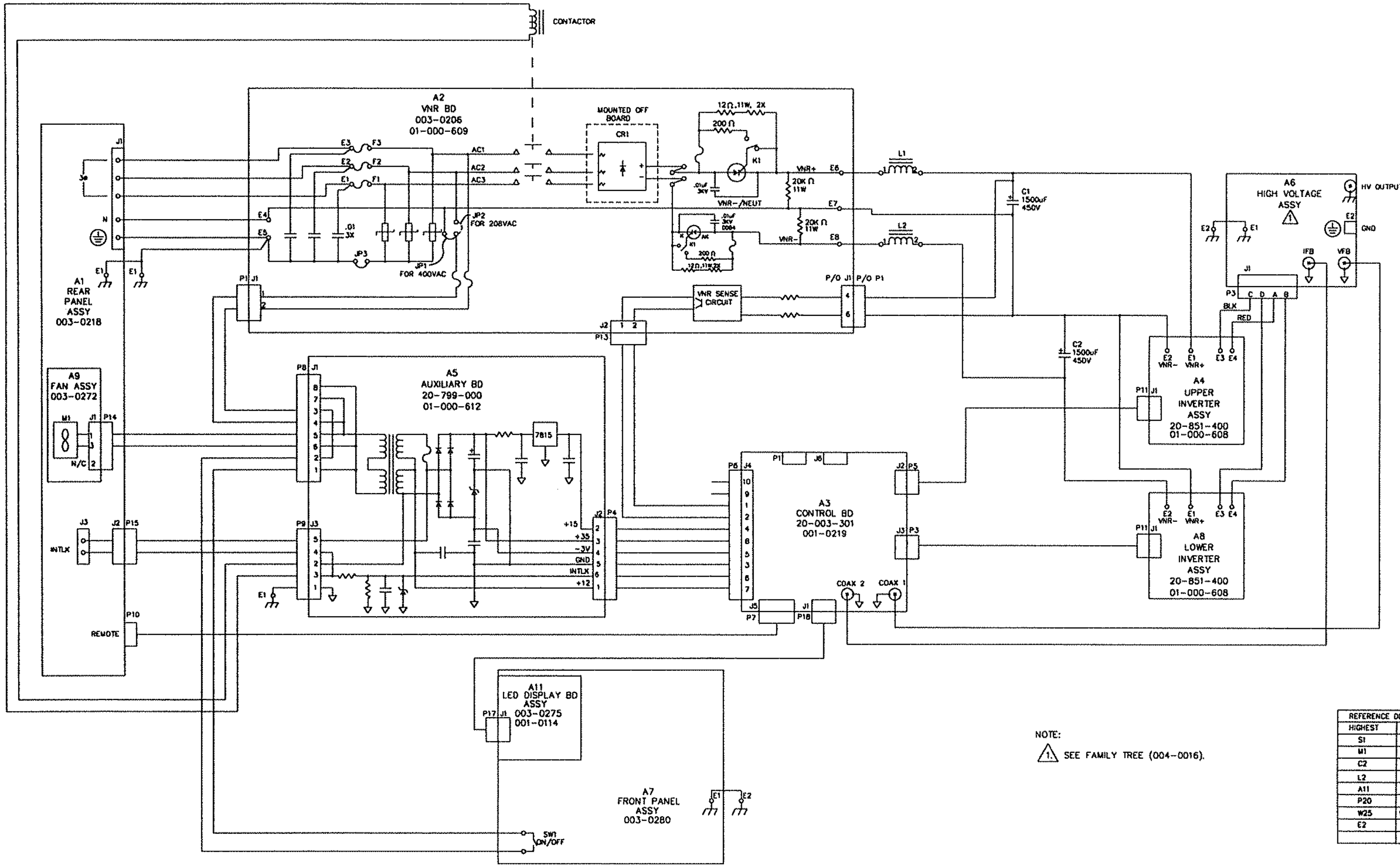
REFERENCE DESIGNATIONS	
HIGHEST	NOT USED
S1	
M1	
C2	
L2	
A14	A8
P22	
W27	W12,17,18,24
E2	

SHEET 1 OF 1

MTL. N/A	TOL: .X = ± .02" .XX = ± .01" .XXX = ± .005" FRAC. = ± 1/64 ANGLES = ± 1/2°	REL. TO MFG. ENG. DATE	ENG. CTL. DWN DATE B. WEAVER 12/90	ELECTRONIC MEASUREMENTS, INC.	
			CHK. DATE	TITLE: SCHEMATIC 402L 400VAC SYSTEM	
FIN. N/A	P/L 487	DOC. NO. DATE	DATE		
	SCALE N/A	DO NOT SCALE DWG	DATE	DWG NO. 001-0254	REV. A

THIS IS A COMPUTER GENERATED DWG.
NO MANUAL REVISIONS ARE PERMITTED.

APPLICATION			LTR	E.C.O. NO.	BY	APP.
USED ON	NEXT ASSY.	QTY.	00	REL. ECO# 320 5/91	JT	GFS
402 L	003-0352		01	ECO# 378 5/91	JT	GFS
			A	ECO #16288 6/11/97	CJS	GFS



NOTE:

1. SEE FAMILY TREE (004-0016).

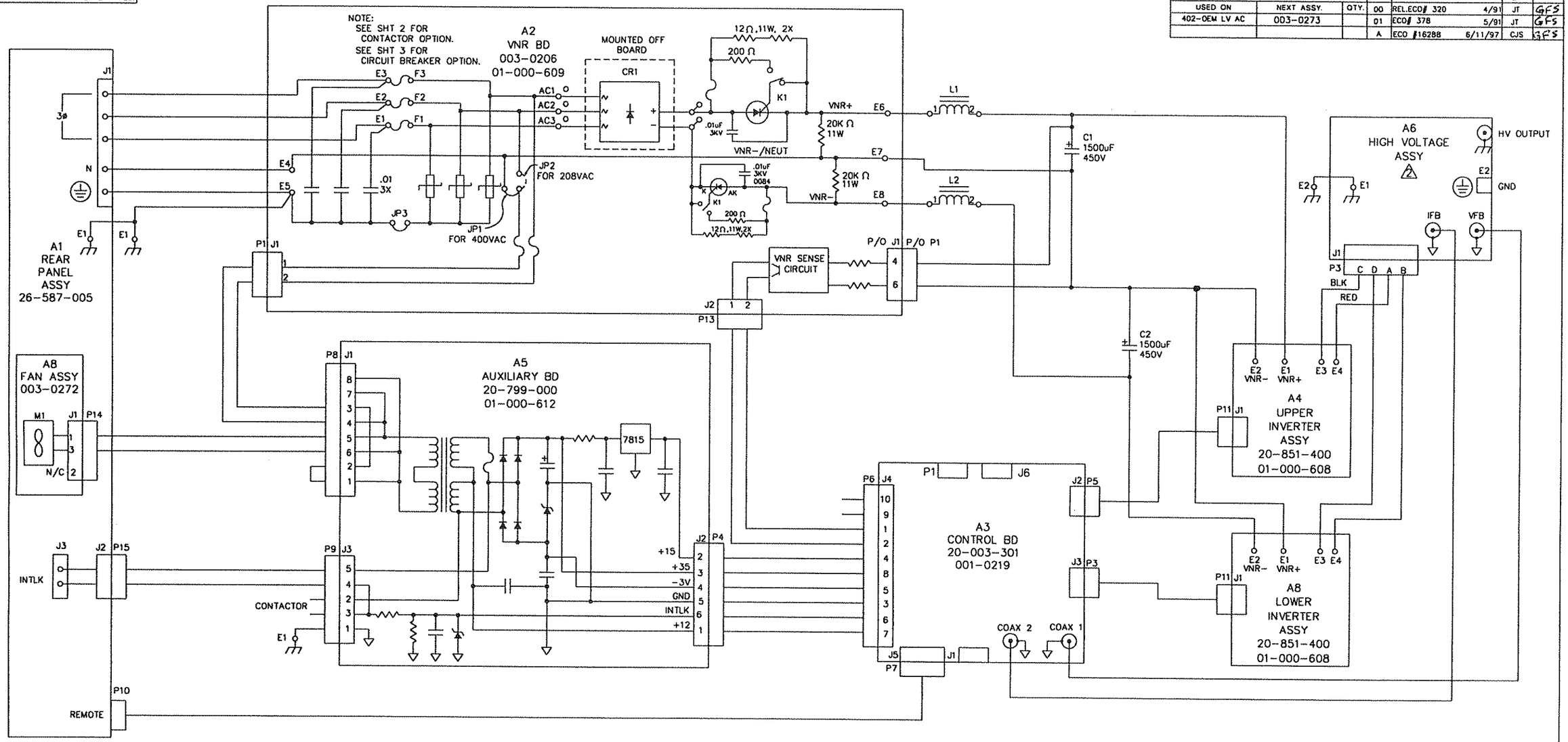
REFERENCE DESIGNATIONS	
HIGHEST	NOT USED
S1	
M1	
C2	
L2	
A11	A8
P20	P2
W25	W12,17,18,24
E2	

SHEET 1 OF 1

MTL. N/A	TOL: .X = ± .02" .XX = ± .01" .XXX = ± .005" FRAC. = ± 1/64 ANGLES = ± 1/2	REL. TO MFG.	ENG. CTL. DWN. R. WEAVER 12/90		ELECTRONIC MEASUREMENTS, INC.
FIN. N/A	P.A. 487	DOC. REL. GFS 6-25-97	CHK. GFS 6-25-97	TITLE: SCHEMATIC 402S 400V AC SYSTEM	
	SCALE N/A	DO NOT SCALE DWG.	GFS 6-25-97	DWG. NO. 001-0255	REV. A

THIS IS A COMPUTER GENERATED DWG.
NO MANUAL REVISIONS ARE PERMITTED.

APPLICATION			LTR	E.C.O. NO.	BY	APP.
USED ON	NEXT ASSY.	QTY.				
402-OEM LV AC	003-0273		00	REL.ECO# 320 4/91	JT	GFS
			01	ECO# 378 5/91	JT	GFS
			A	ECO #16288 6/11/97	CJS	GFS



NOTES:

⚠1 WIRES W1,13, AND 14 ARE NOT USED ON OPTION 2 ONLY. WIRE W11 IS USED ONLY ON OPTION 1 AND 2.

2. SEE FAMILY TREE (004-0018).

A7 FRONT PANEL BLANK 002-0226

REFERENCE DESIGNATIONS	
HIGHEST	NOT USED
S1	
M1	
C2	
L2	
A8	
P16	P2
W23	W1,11-14,17,18
E2	

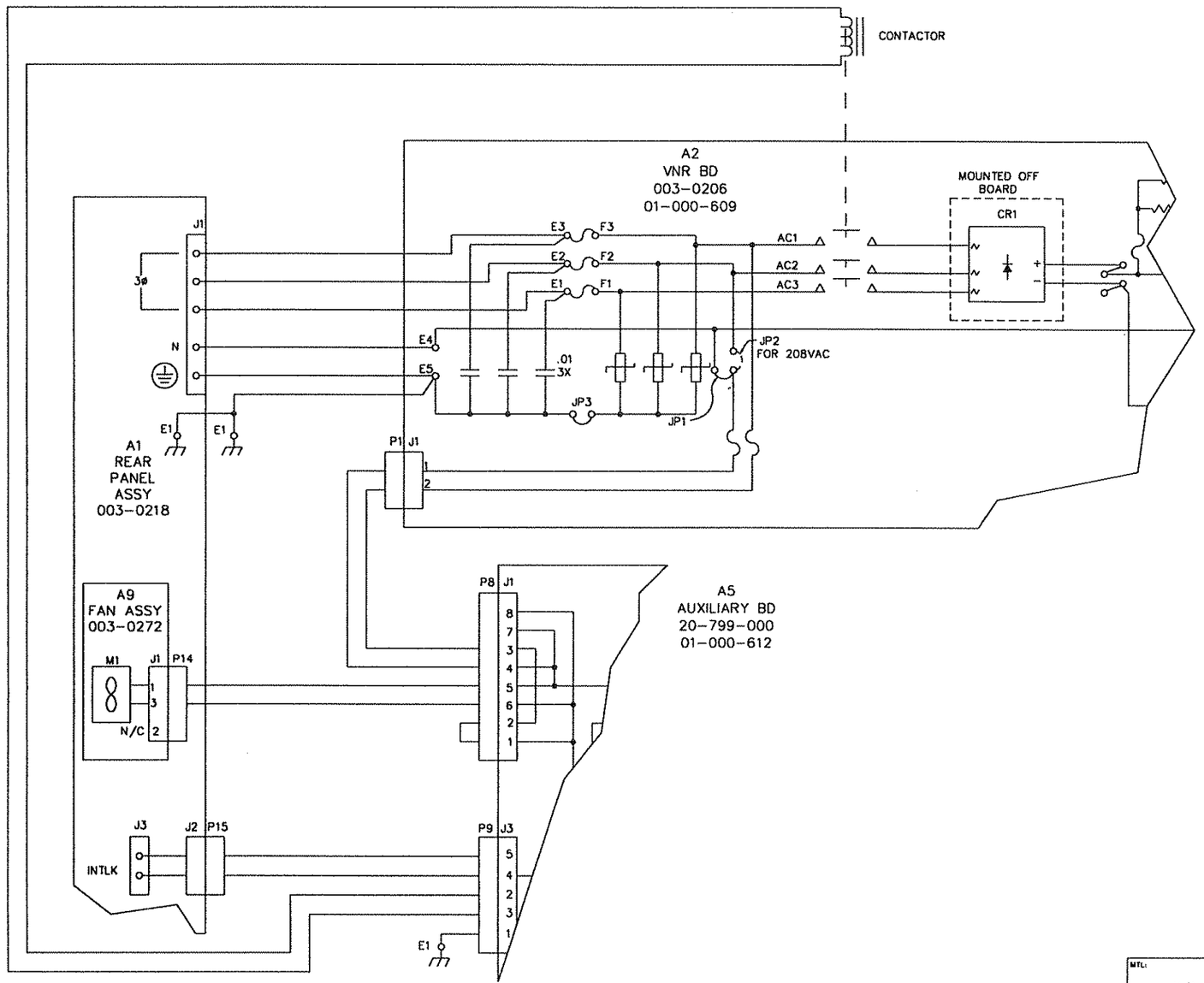
⚠1

MTL: N/A	TOL: .X = ± .02" .XX = ± .01" .XXX = ± .005" FRAC. = ± 1/64" ANGLES = ± 1/2"	REL. TO MFG. ENG. DATE: 6/24/97 MFG. DATE: 6/24/97	ENG. CTL. DWN: J TURCOTTE 7/90 CHK: B.WEAVER 10/90 ENG. DATE: 6/24/97 APP. DATE: GFS 6-23-97	ELECTRONIC MEASUREMENTS, INC.
FIN: N/A	P/L: 487	DOC. REL. DATE: GFS 6-23-97		TITLE: SCHEMATIC 402-OEM 400V AC SYSTEM
	SCALE: N/A	DO NOT SCALE DWG.		DWG. NO. 001-0256 REV. A

SHEET 1 OF 3

THIS IS A COMPUTER GENERATED DWG.
NO MANUAL REVISIONS ARE PERMITTED.

APPLICATION			LTR	E.C.O. NO.	BY	APP.
USED ON	NEXT ASSY.	QTY.				
				SEE SHEET 1		



OPTION 1

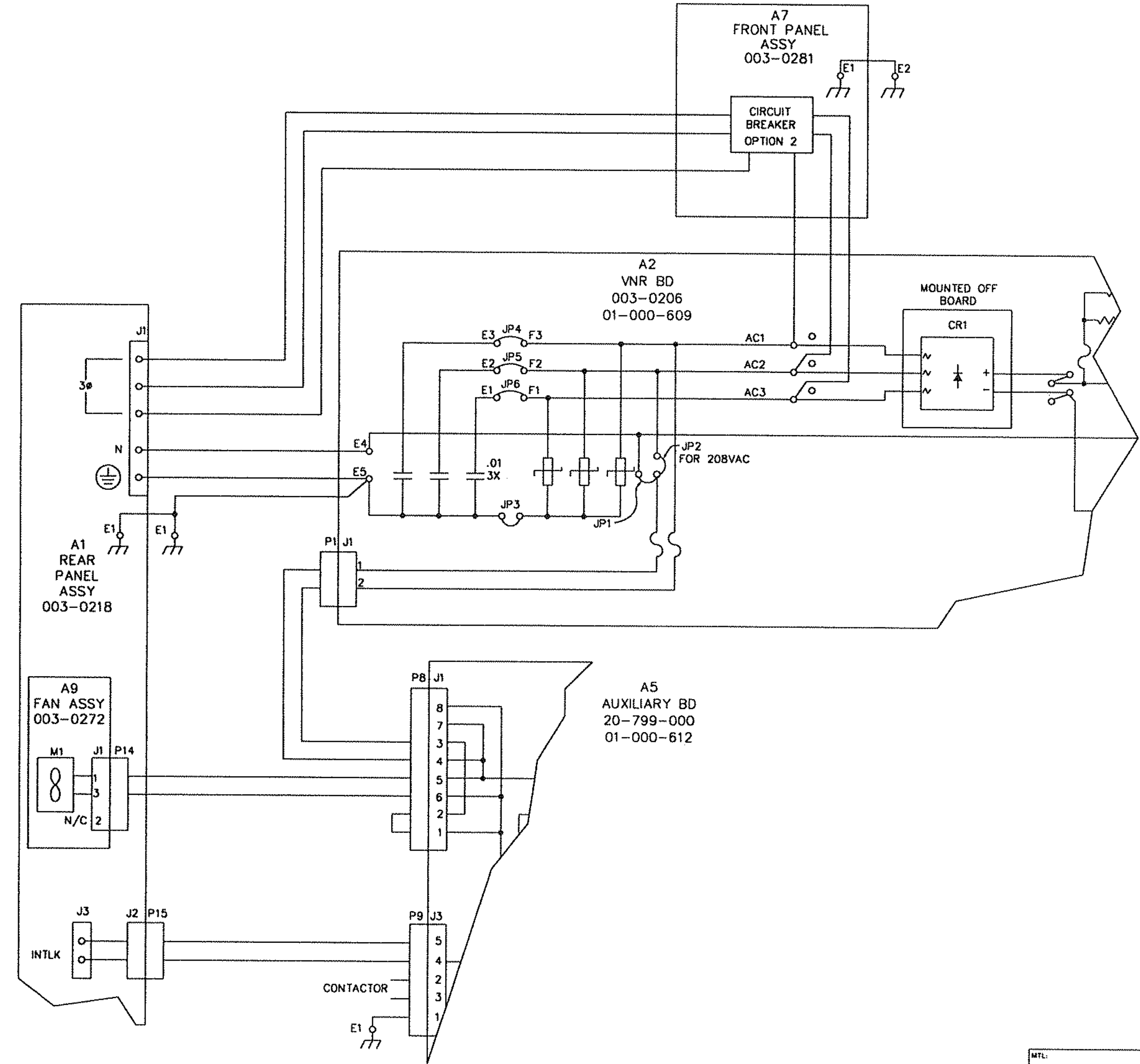
402 OEM VERSION WITH CONTACTOR

SHEET 2 OF 3

MTL: N/A	TOL: X = ± .02", XX = ± .01", XXX = ± .005", FRAC. = ± 1/64", ANGLES = ± 1/2°	REL. TO MFG. M. ENG. DATE: 6/24/97 PROD. DATE: 6/24/97	ENG. CTL. DWN: J TURCOTTE 7/90 DATE: CHK: DATE: 6-23-97	ELECTRONIC MEASUREMENTS, INC.
FIN: N/A	P/L: 487 SCALE: N/A	DOC. REL. DATE: 6-23-97 DO NOT SCALE DWG.	MFG. DATE: APP: DATE: 6-23-97	TITLE: SCHEMATIC 402-OEM 400V AC SYSTEM
				DWG. NO. 001-0256 REV. A

THIS IS A COMPUTER GENERATED DWG.
NO MANUAL REVISIONS ARE PERMITTED.

APPLICATION			LTR	E.C.O. NO.	BY	APP.
USED ON	NEXT ASSY.	QTY.		SEE SHEET 1		



OPTION 2

402 OEM VERSION WITH CIRCUIT BREAKER
AND WITHOUT FUSES.

SHEET 3 OF 3

MTL: N/A	TOL: .X = ± .02" .XX = ± .01" .XXX = ± .005" FRAC. = ± 1/64" ANGLES = ± 1/2°	REL. TO MFG.	ENG. CTL. DWN: B. WEAVER DATE: 12/90	ELECTRONIC MEASUREMENTS, INC.
		ENG. DATE: 6/24/97	CHK: GFS DATE: 6-23-97	TITLE: SCHEMATIC 402-OEM 400VAC SYSTEM
		MFG. CS DATE: 6/24/97		
FIN: N/A	P/L: 487	DOC. REL. GFS DATE: 6-23-97	DATE: 6/24/97	
	SCALE: N/A	DO NOT SCALE DWG.	APP: GFS DATE: 6-23-97	DWG. NO. 001-0256 REV. A

SAFETY DATA SHEET

According to OSHA Hazard Communication Standard, 29 CFR 1910.1200

Shell Diala S2 ZX-A

Version	Revision Date:	SDS Number:	Print Date: 04/03/2020
3.2	04/02/2020	800001009714	Date of last issue: 12/06/2018

SECTION 1. IDENTIFICATION

Product name : Shell Diala S2 ZX-A

Product code : 001D8374

Manufacturer or supplier's details

Manufacturer/Supplier : **Shell Oil Products US**
PO Box 4427
Houston TX 77210-4427
USA

SDS Request : (+1) 877-276-7285

Customer Service :

Emergency telephone number

Spill Information : 877-504-9351

Health Information : 877-242-7400

Recommended use of the chemical and restrictions on use

Recommended use : Insulating oil.

SECTION 2. HAZARDS IDENTIFICATION

GHS classification in accordance with 29 CFR 1910.1200

Aspiration hazard : Category 1

Long-term (chronic) aquatic hazard : Category 3

GHS label elements

Hazard pictograms :

Signal word : Danger

Hazard statements : PHYSICAL HAZARDS:
Not classified as a physical hazard under GHS criteria.
HEALTH HAZARDS:
H304 May be fatal if swallowed and enters airways.
ENVIRONMENTAL HAZARDS:
H412 Harmful to aquatic life with long lasting effects.

Precautionary statements : **Prevention:**
P273 Avoid release to the environment.

Response:

P301 + P310 IF SWALLOWED: Immediately call a POISON CENTER/doctor.
P331 Do NOT induce vomiting.

Storage:

P405 Store locked up.

Disposal:

P501 Dispose of contents/ container to an approved waste disposal plant.

Hazardous components which must be listed on the label:
Contains Distillates (petroleum), hydrotreated light naphthenic.

Other hazards which do not result in classification

Prolonged or repeated skin contact without proper cleaning can clog the pores of the skin resulting in disorders such as oil acne/folliculitis.
Used oil may contain harmful impurities.
Not classified as flammable but will burn.
The classification of this material is based on OSHA HCS 2012 criteria.

SECTION 3. COMPOSITION/INFORMATION ON INGREDIENTS

Chemical nature : Highly refined mineral oils and additives.
The highly refined mineral oil contains <3% (w/w) DMSO-extract, according to IP346.

Hazardous components

Chemical name	Synonyms	CAS-No.	Concentration (% w/w)
Distillates (petroleum), hydrotreated light naphthenic	Distillates (petroleum), hydrotreated light naphthenic	64742-53-6	95 - 100
Butylated hydroxytoluene	2,6-di-tert-butyl-p-cresol	128-37-0	0.25 - 0.5

SECTION 4. FIRST-AID MEASURES

If inhaled : No treatment necessary under normal conditions of use.
If symptoms persist, obtain medical advice.

In case of skin contact : Remove contaminated clothing. Flush exposed area with water and follow by washing with soap if available.
If persistent irritation occurs, obtain medical attention.

In case of eye contact : Flush eye with copious quantities of water.
Remove contact lenses, if present and easy to do. Continue rinsing.
If persistent irritation occurs, obtain medical attention.

If swallowed : Call emergency number for your location / facility.
If swallowed, do not induce vomiting: transport to nearest

		medical facility for additional treatment. If vomiting occurs spontaneously, keep head below hips to prevent aspiration. If any of the following delayed signs and symptoms appear within the next 6 hours, transport to the nearest medical facility: fever greater than 101° F (38.3°C), shortness of breath, chest congestion or continued coughing or wheezing.
Most important symptoms and effects, both acute and delayed	:	If material enters lungs, signs and symptoms may include coughing, choking, wheezing, difficulty in breathing, chest congestion, shortness of breath, and/or fever. The onset of respiratory symptoms may be delayed for several hours after exposure. Defatting dermatitis signs and symptoms may include a burning sensation and/or a dried/cracked appearance. Ingestion may result in nausea, vomiting and/or diarrhoea.
Protection of first-aiders	:	When administering first aid, ensure that you are wearing the appropriate personal protective equipment according to the incident, injury and surroundings.
Indication of any immediate medical attention and special treatment needed	:	Potential for chemical pneumonitis. Call a doctor or poison control center for guidance.

SECTION 5. FIRE-FIGHTING MEASURES

Suitable extinguishing media	:	Foam, water spray or fog. Dry chemical powder, carbon dioxide, sand or earth may be used for small fires only.
Unsuitable extinguishing media	:	Do not use water in a jet.
Specific hazards during fire-fighting	:	Hazardous combustion products may include: A complex mixture of airborne solid and liquid particulates and gases (smoke). Carbon monoxide may be evolved if incomplete combustion occurs. Unidentified organic and inorganic compounds.
Specific extinguishing methods	:	Use extinguishing measures that are appropriate to local circumstances and the surrounding environment.
Special protective equipment for firefighters	:	Proper protective equipment including chemical resistant gloves are to be worn; chemical resistant suit is indicated if large contact with spilled product is expected. Self-Contained Breathing Apparatus must be worn when approaching a fire in a confined space. Select fire fighter's clothing approved to relevant Standards (e.g. Europe: EN469).

SECTION 6. ACCIDENTAL RELEASE MEASURES

Personal precautions, protec-	:	Avoid contact with skin and eyes.

tive equipment and emergency procedures

Environmental precautions	:	Local authorities should be advised if significant spillages cannot be contained.
Methods and materials for containment and cleaning up	:	Slippery when spilt. Avoid accidents, clean up immediately. Prevent from spreading by making a barrier with sand, earth or other containment material. Reclaim liquid directly or in an absorbent. Soak up residue with an absorbent such as clay, sand or other suitable material and dispose of properly.
Additional advice	:	For guidance on selection of personal protective equipment see Chapter 8 of this Safety Data Sheet. For guidance on disposal of spilled material see Chapter 13 of this Safety Data Sheet.

SECTION 7. HANDLING AND STORAGE

Technical measures	:	Use local exhaust ventilation if there is risk of inhalation of vapours, mists or aerosols. Use the information in this data sheet as input to a risk assessment of local circumstances to help determine appropriate controls for safe handling, storage and disposal of this material.
Advice on safe handling	:	Avoid prolonged or repeated contact with skin. Avoid inhaling vapour and/or mists. When handling product in drums, safety footwear should be worn and proper handling equipment should be used. Properly dispose of any contaminated rags or cleaning materials in order to prevent fires.
Avoidance of contact	:	Strong oxidising agents.
Product Transfer	:	Proper grounding and bonding procedures should be used during all bulk transfer operations to avoid static accumulation.
Further information on storage stability	:	Keep container tightly closed and in a cool, well-ventilated place. Use properly labeled and closable containers. Store at ambient temperature.
Packaging material	:	Suitable material: For containers or container linings, use mild steel or high density polyethylene. Unsuitable material: PVC.
Container Advice	:	Polyethylene containers should not be exposed to high temperatures because of possible risk of distortion.

SECTION 8. EXPOSURE CONTROLS AND PERSONAL PROTECTION

Components with workplace control parameters

Components	CAS-No.	Value type (Form of exposure)	Control parameters / Permissible concentration	Basis
Oil mist, mineral	Not Assigned	TWA (Mist)	5 mg/m3	OSHA Z-1
Oil mist, mineral		TWA (Inhalable particulate matter)	5 mg/m3	ACGIH
Butylated hydroxytoluene	128-37-0	TWA (Inhalable fraction and vapor)	2 mg/m3	ACGIH

Biological occupational exposure limits

No biological limit allocated.

Monitoring Methods

Monitoring of the concentration of substances in the breathing zone of workers or in the general workplace may be required to confirm compliance with an OEL and adequacy of exposure controls. For some substances biological monitoring may also be appropriate.
Validated exposure measurement methods should be applied by a competent person and samples analysed by an accredited laboratory.
Examples of sources of recommended exposure measurement methods are given below or contact the supplier. Further national methods may be available.

National Institute of Occupational Safety and Health (NIOSH), USA: Manual of Analytical Methods http://www.cdc.gov/niosh/

Occupational Safety and Health Administration (OSHA), USA: Sampling and Analytical Methods http://www.osha.gov/

Health and Safety Executive (HSE), UK: Methods for the Determination of Hazardous Substances http://www.hse.gov.uk/

Institut für Arbeitsschutz Deutschen Gesetzlichen Unfallversicherung (IFA) , Germany http://www.dguv.de/inhalt/index.jsp

L'Institut National de Recherche et de Securité, (INRS), France http://www.inrs.fr/accueil

Engineering measures : The level of protection and types of controls necessary will vary depending upon potential exposure conditions. Select controls based on a risk assessment of local circumstances. Appropriate measures include:
Adequate ventilation to control airborne concentrations.

Where material is heated, sprayed or mist formed, there is greater potential for airborne concentrations to be generated.

General Information:
Define procedures for safe handling and maintenance of

controls.
Educate and train workers in the hazards and control measures relevant to normal activities associated with this product.
Ensure appropriate selection, testing and maintenance of equipment used to control exposure, e.g. personal protective equipment, local exhaust ventilation.
Drain down system prior to equipment break-in or maintenance.
Retain drain downs in sealed storage pending disposal or subsequent recycle.
Always observe good personal hygiene measures, such as washing hands after handling the material and before eating, drinking, and/or smoking. Routinely wash work clothing and protective equipment to remove contaminants. Discard contaminated clothing and footwear that cannot be cleaned.
Practice good housekeeping.

Do not ingest. If swallowed, then seek immediate medical assistance

Personal protective equipment

Respiratory protection : No respiratory protection is ordinarily required under normal conditions of use.
In accordance with good industrial hygiene practices, precautions should be taken to avoid breathing of material.
If engineering controls do not maintain airborne concentrations to a level which is adequate to protect worker health, select respiratory protection equipment suitable for the specific conditions of use and meeting relevant legislation.
Check with respiratory protective equipment suppliers.
Where air-filtering respirators are suitable, select an appropriate combination of mask and filter.
Select a filter suitable for the combination of organic gases and vapours and particles [Type A/Type P boiling point >65°C (149°F)].

Hand protection
Remarks : Where hand contact with the product may occur the use of gloves approved to relevant standards (e.g. Europe: EN374, US: F739) made from the following materials may provide suitable chemical protection. PVC, neoprene or nitrile rubber gloves Suitability and durability of a glove is dependent on usage, e.g. frequency and duration of contact, chemical resistance of glove material, dexterity. Always seek advice from glove suppliers. Contaminated gloves should be replaced.
Personal hygiene is a key element of effective hand care. Gloves must only be worn on clean hands. After using gloves, hands should be washed and dried thoroughly. Application of a non-perfumed moisturizer is recommended.
For continuous contact we recommend gloves with breakthrough time of more than 240 minutes with preference for > 480 minutes where suitable gloves can be identified. For

short-term/splash protection we recommend the same but recognize that suitable gloves offering this level of protection may not be available and in this case a lower breakthrough time maybe acceptable so long as appropriate maintenance and replacement regimes are followed. Glove thickness is not a good predictor of glove resistance to a chemical as it is dependent on the exact composition of the glove material. Glove thickness should be typically greater than 0.35 mm depending on the glove make and model.

Eye protection : If material is handled such that it could be splashed into eyes, protective eyewear is recommended.

Skin and body protection : Skin protection is not ordinarily required beyond standard work clothes.
It is good practice to wear chemical resistant gloves.

Protective measures : Personal protective equipment (PPE) should meet recommended national standards. Check with PPE suppliers.

Thermal hazards : Not applicable

Environmental exposure controls

General advice : Local guidelines on emission limits for volatile substances must be observed for the discharge of exhaust air containing vapour.
Minimise release to the environment. An environmental assessment must be made to ensure compliance with local environmental legislation.
Information on accidental release measures are to be found in section 6.

SECTION 9. PHYSICAL AND CHEMICAL PROPERTIES

Appearance	:	Liquid at room temperature.
Colour	:	clear
Odour Threshold	:	Data not available
pH	:	Not applicable
pour point	:	<= -40 °C / <= -40 °F Method: ASTM D97
Initial boiling point and boiling range	:	> 280 °C / 536 °F estimated value(s)
Flash point	:	150 °C / 302 °F Method: ASTM D92 (COC)
Evaporation rate	:	Data not available

Flammability (solid, gas)	:	Data not available
Upper explosion limit / upper flammability limit	:	Typical 10 %(V)
Lower explosion limit / Lower flammability limit	:	Typical 1 %(V)
Vapour pressure	:	< 0.5 Pa (20 °C / 68 °F) estimated value(s)
Relative vapour density	:	> 1 estimated value(s)
Relative density	:	0.890 (15 °C / 59 °F)
Density	:	<= 910 kg/m3 (15.0 °C / 59.0 °F) Method: ASTM D1298
Solubility(ies)		
Water solubility	:	negligible
Solubility in other solvents	:	Data not available
Partition coefficient: n-octanol/water	:	log Pow: > 6 (based on information on similar products)
Auto-ignition temperature	:	> 320 °C / 608 °F
Decomposition temperature	:	Data not available
Viscosity		
Viscosity, dynamic	:	Data not available
Viscosity, kinematic	:	<= 76 mm2/s (0 °C / 32 °F) Method: ASTM D445 <= 3 mm2/s (100 °C / 212 °F) Method: ASTM D445 <= 12 mm2/s (40.0 °C / 104.0 °F) Method: ASTM D445
Explosive properties	:	Not classified
Oxidizing properties	:	Data not available
Conductivity	:	This material is not expected to be a static accumulator.

SECTION 10. STABILITY AND REACTIVITY

Reactivity	:	The product does not pose any further reactivity hazards in addition to those listed in the following sub-paragraph.
Chemical stability	:	Stable.
Possibility of hazardous reactions	:	Reacts with strong oxidising agents.
Conditions to avoid	:	Extremes of temperature and direct sunlight.
Incompatible materials	:	Strong oxidising agents.
Hazardous decomposition products	:	No decomposition if stored and applied as directed.

SECTION 11. TOXICOLOGICAL INFORMATION

Basis for assessment	:	Information given is based on data on the components and the toxicology of similar products.Unless indicated otherwise, the data presented is representative of the product as a whole, rather than for individual component(s).

Information on likely routes of exposure
Skin and eye contact are the primary routes of exposure although exposure may occur following accidental ingestion.

Acute toxicity

Product:

Acute oral toxicity	:	LD50 (rat): > 5,000 mg/kg Remarks: Low toxicity: Based on available data, the classification criteria are not met. Remarks: Aspiration into the lungs may cause chemical pneumonitis which can be fatal.
Acute inhalation toxicity	:	Remarks: Based on available data, the classification criteria are not met.
Acute dermal toxicity	:	LD50 (Rabbit): > 5,000 mg/kg Remarks: Low toxicity: Based on available data, the classification criteria are not met.

Skin corrosion/irritation

Product:

Remarks: Slightly irritating to skin., Prolonged or repeated skin contact without proper cleaning can clog the pores of the skin resulting in disorders such as oil acne/folliculitis., Based on available data, the classification criteria are not met.

Serious eye damage/eye irritation

Product:

Remarks: Slightly irritating to the eye., Based on available data, the classification criteria are not met.

Respiratory or skin sensitisation

Product:

Remarks: Not a skin sensitiser.
Based on available data, the classification criteria are not met.

Germ cell mutagenicity

Product:

: Remarks: Non mutagenic, Based on available data, the classification criteria are not met.

Carcinogenicity

Product:

Remarks: Not a carcinogen., Based on available data, the classification criteria are not met.

Remarks: Product contains mineral oils of types shown to be non-carcinogenic in animal skin-painting studies., Highly refined mineral oils are not classified as carcinogenic by the International Agency for Research on Cancer (IARC).

IARC	No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible or confirmed human carcinogen by IARC.
OSHA	No component of this product present at levels greater than or equal to 0.1% is on OSHA's list of regulated carcinogens.
NTP	No component of this product present at levels greater than or equal to 0.1% is identified as a known or anticipated carcinogen by NTP.

Reproductive toxicity

Product:

: Remarks: Not a developmental toxicant., Does not impair fertility., Based on available data, the classification criteria are not met.

STOT - single exposure

Product:

Remarks: Based on available data, the classification criteria are not met.

STOT - repeated exposure

Product:

Remarks: Based on available data, the classification criteria are not met.

Aspiration toxicity

Product:

Aspiration into the lungs when swallowed or vomited may cause chemical pneumonitis which can be fatal.

Further information

Product:

Remarks: Used oils may contain harmful impurities that have accumulated during use. The concentration of such impurities will depend on use and they may present risks to health and the environment on disposal., ALL used oil should be handled with caution and skin contact avoided as far as possible.

Remarks: Slightly irritating to respiratory system.

SECTION 12. ECOLOGICAL INFORMATION

Basis for assessment : Ecotoxicological data have not been determined specifically for this product.
Information given is based on a knowledge of the components and the ecotoxicology of similar products.
Unless indicated otherwise, the data presented is representative of the product as a whole, rather than for individual component(s).(LL/EL/IL50 expressed as the nominal amount of product required to prepare aqueous test extract).

Ecotoxicity

Product:

Toxicity to fish (Acute toxicity) :
Remarks: LL/EL/IL50 >10 <= 100 mg/l
Harmful

Toxicity to daphnia and other aquatic invertebrates (Acute toxicity) :
Remarks: LL/EL/IL50 >10 <= 100 mg/l
Harmful

Toxicity to algae (Acute toxicity) :
Remarks: LL/EL/IL50 >10 <= 100 mg/l
Harmful

Toxicity to fish (Chronic toxicity)	:	Remarks: Data not available
Toxicity to daphnia and other aquatic invertebrates (Chronic toxicity)	:	Remarks: Data not available
Toxicity to microorganisms (Acute toxicity)	:	Remarks: Data not available

Components:

Butylated hydroxytoluene:

M-Factor (Acute aquatic toxicity)	:	1

Persistence and degradability

Product:

Biodegradability	:	Remarks: Not readily biodegradable. Major constituents are inherently biodegradable, but contains components that may persist in the environment.

Bioaccumulative potential

Product:

Bioaccumulation	:	Remarks: Contains components with the potential to bioaccumulate.

Mobility in soil

Product:

Mobility	:	Remarks: Liquid under most environmental conditions. If it enters soil, it will adsorb to soil particles and will not be mobile. Remarks: Floats on water.

Other adverse effects

Product:

Additional ecological information	:	Does not have ozone depletion potential, photochemical ozone creation potential or global warming potential. Product is a mixture of non-volatile components, which will not be released to air in any significant quantities under normal conditions of use. Poorly soluble mixture. Causes physical fouling of aquatic organisms. Mineral oil does not cause chronic toxicity to aquatic organisms at concentrations less than 1 mg/l.

SECTION 13. DISPOSAL CONSIDERATIONS

Disposal methods

Waste from residues : Recover or recycle if possible.
It is the responsibility of the waste generator to determine the toxicity and physical properties of the material generated to determine the proper waste classification and disposal methods in compliance with applicable regulations.
Do not dispose into the environment, in drains or in water courses

Waste product should not be allowed to contaminate soil or ground water, or be disposed of into the environment.
Waste, spills or used product is dangerous waste.

Contaminated packaging : Dispose in accordance with prevailing regulations, preferably to a recognized collector or contractor. The competence of the collector or contractor should be established beforehand. Disposal should be in accordance with applicable regional, national, and local laws and regulations.

Local legislation

Remarks : Disposal should be in accordance with applicable regional, national, and local laws and regulations.

SECTION 14. TRANSPORT INFORMATION

National Regulations

US Department of Transportation Classification (49 CFR Parts 171-180)

Not regulated as a dangerous good

International Regulations

IATA-DGR
Not regulated as a dangerous good

IMDG-Code
Not regulated as a dangerous good

Transport in bulk according to Annex II of MARPOL 73/78 and the IBC Code

Not applicable for product as supplied. MARPOL Annex 1 rules apply for bulk shipments by sea.

Special precautions for user

Remarks : Special Precautions: Refer to Section 7, Handling & Storage, for special precautions which a user needs to be aware of or needs to comply with in connection with transport.

SECTION 15. REGULATORY INFORMATION

EPCRA - Emergency Planning and Community Right-to-Know Act

*: This material does not contain any components with a CERCLA RQ., Shell classifies this material as an "oil" under the CERCLA Petroleum Exclusion, therefore releases to the environment are not reportable under CERCLA.

SARA 304 Extremely Hazardous Substances Reportable Quantity

This material does not contain any components with a section 304 EHS RQ.

SARA 302 Extremely Hazardous Substances Threshold Planning Quantity

This material does not contain any components with a section 302 EHS TPQ.

SARA 311/312 Hazards : Aspiration hazard

SARA 313 : This material does not contain any chemical components with known CAS numbers that exceed the threshold (De Minimis) reporting levels established by SARA Title III, Section 313.

Clean Water Act

This product does not contain any Hazardous Chemicals listed under the U.S. CleanWater Act, Section 311, Table 117.3.

US State Regulations

Pennsylvania Right To Know

Distillates (petroleum), hydrotreated light naphthenic	64742-53-6

California Prop. 65

This product does not contain any chemicals known to State of California to cause cancer, birth defects, or any other reproductive harm.

California List of Hazardous Substances

Distillates (petroleum), hydrotreated light naphthenic	64742-53-6

Other regulations:

The regulatory information is not intended to be comprehensive. Other regulations may apply to this material.

The components of this product are reported in the following inventories:

EINECS : Notified with Restrictions.

TSCA : All components listed.

DSL : All components listed.

SECTION 16. OTHER INFORMATION

Further information

NFPA Rating (Health, Fire, Reactivity)	1, 1, 0

Full text of other abbreviations

ACGIH	:	USA. ACGIH Threshold Limit Values (TLV)
OSHA Z-1	:	USA. Occupational Exposure Limits (OSHA) - Table Z-1 Limits for Air Contaminants
ACGIH / TWA	:	8-hour, time-weighted average
OSHA Z-1 / TWA	:	8-hour time weighted average
Abbreviations and Acronyms	:	The standard abbreviations and acronyms used in this document can be looked up in reference literature (e.g. scientific dictionaries) and/or websites. ACGIH = American Conference of Governmental Industrial Hygienists ADR = European Agreement concerning the International Carriage of Dangerous Goods by Road AICS = Australian Inventory of Chemical Substances ASTM = American Society for Testing and Materials BEL = Biological exposure limits BTEX = Benzene, Toluene, Ethylbenzene, Xylenes CAS = Chemical Abstracts Service CEFIC = European Chemical Industry Council CLP = Classification Packaging and Labelling COC = Cleveland Open-Cup DIN = Deutsches Institut fur Normung DMEL = Derived Minimal Effect Level DNEL = Derived No Effect Level DSL = Canada Domestic Substance List EC = European Commission EC50 = Effective Concentration fifty ECETOC = European Center on Ecotoxicology and Toxicology Of Chemicals ECHA = European Chemicals Agency EINECS = The European Inventory of Existing Commercial Chemical Substances EL50 = Effective Loading fifty ENCS = Japanese Existing and New Chemical Substances Inventory EWC = European Waste Code GHS = Globally Harmonised System of Classification and Labelling of Chemicals IARC = International Agency for Research on Cancer IATA = International Air Transport Association IC50 = Inhibitory Concentration fifty IL50 = Inhibitory Level fifty IMDG = International Maritime Dangerous Goods INV = Chinese Chemicals Inventory IP346 = Institute of Petroleum test method N° 346 for the determination of polycyclic aromatics DMSO-extractables KECI = Korea Existing Chemicals Inventory LC50 = Lethal Concentration fifty LD50 = Lethal Dose fifty per cent. LL/EL/IL = Lethal Loading/Effective Loading/Inhibitory loading

LL50 = Lethal Loading fifty
MARPOL = International Convention for the Prevention of Pollution From Ships
NOEC/NOEL = No Observed Effect Concentration / No Observed Effect Level
OE_HPV = Occupational Exposure - High Production Volume
PBT = Persistent, Bioaccumulative and Toxic
PICCS = Philippine Inventory of Chemicals and Chemical Substances
PNEC = Predicted No Effect Concentration
REACH = Registration Evaluation And Authorisation Of Chemicals
RID = Regulations Relating to International Carriage of Dangerous Goods by Rail
SKIN_DES = Skin Designation
STEL = Short term exposure limit
TRA = Targeted Risk Assessment
TSCA = US Toxic Substances Control Act
TWA = Time-Weighted Average
vPvB = very Persistent and very Bioaccumulative

A vertical bar (|) in the left margin indicates an amendment from the previous version.

Sources of key data used to compile the Safety Data Sheet	:	The quoted data are from, but not limited to, one or more sources of information (e.g. toxicological data from Shell Health Services, material suppliers' data, CONCAWE, EU IUCLID date base, EC 1272 regulation, etc).
Revision Date	:	04/02/2020

The information provided in this Safety Data Sheet is correct to the best of our knowledge, information and belief at the date of its publication. The information given is designed only as a guidance for safe handling, use, processing, storage, transportation, disposal and release and is not to be considered a warranty or quality specification. The information relates only to the specific material designated and may not be valid for such material used in combination with any other materials or in any process, unless specified in the text.

US / EN

SAFETY DATA SHEET

SECTION 1 PRODUCT AND COMPANY IDENTIFICATION

PRODUCT

Product Name: **UNIVOLT N 61 B**
Product Description: Base Oil and Additives
Product Code: 201580102520, 730846-00, 97P847
Intended Use: Electrical insulating oils

COMPANY IDENTIFICATION

Supplier: **EXXON MOBIL CORPORATION**
22777 Springwoods Village Parkway
Spring, TX. 77389 USA

24 Hour Health Emergency	609-737-4411
Transportation Emergency Phone	800-424-9300 or 703-527-3887 CHEMTREC
Product Technical Information	800-662-4525
MSDS Internet Address	http://www.exxon.com, http://www.mobil.com

SECTION 2 HAZARDS IDENTIFICATION

This material is hazardous according to regulatory guidelines (see (M)SDS Section 15).

CLASSIFICATION:

Aspiration toxicant: Category 1.

LABEL:
Pictogram:

Signal Word: Danger

Hazard Statements:
H304: May be fatal if swallowed and enters airways.

Precautionary Statements:
P273: Avoid release to the environment.P301 + P310: IF SWALLOWED: Immediately call a POISON CENTER or doctor/physician. P331: Do NOT induce vomiting. P391: Collect spillage.P405: Store locked up.P501: Dispose of contents and container in accordance with local regulations.

Other hazard information:

HAZARD NOT OTHERWISE CLASSIFIED (HNOC): None as defined under 29 CFR 1910.1200.

PHYSICAL / CHEMICAL HAZARDS

No significant hazards.

HEALTH HAZARDS

Frequent or prolonged contact may defat and dry the skin, leading to discomfort and dermatitis. May be irritating to the eyes, nose, throat, and lungs.

ENVIRONMENTAL HAZARDS

Expected to be toxic to aquatic organisms. May cause long-term adverse effects in the aquatic environment.

NFPA Hazard ID:	Health:	1	Flammability:	1	Reactivity:	0
HMIS Hazard ID:	Health:	1*	Flammability:	1	Reactivity:	0

NOTE: This material should not be used for any other purpose than the intended use in Section 1 without expert advice. Health studies have shown that chemical exposure may cause potential human health risks which may vary from person to person.

SECTION 3 COMPOSITION / INFORMATION ON INGREDIENTS

This material is defined as a mixture.

Hazardous Substance(s) or Complex Substance(s) required for disclosure

Name	CAS#	Concentration*	GHS Hazard Codes
2,6-DI-TERT-BUTYL-P-CRESOL	128-37-0	1 - < 5%	H400(M factor 1), H410(M factor 1)
HYDROTREATED LIGHT NAPHTHENIC DISTILLATE (PETROLEUM)	64742-53-6	90 - < 100%	H304

* All concentrations are percent by weight unless material is a gas. Gas concentrations are in percent by volume.

As per paragraph (i) of 29 CFR 1910.1200, formulation is considered a trade secret and specific chemical identity and exact percentage (concentration) of composition may have been withheld. Specific chemical identity and exact percentage composition will be provided to health professionals, employees, or designated representatives in accordance with applicable provisions of paragraph (i).

SECTION 4 FIRST AID MEASURES

INHALATION

Remove from further exposure. For those providing assistance, avoid exposure to yourself or others. Use adequate respiratory protection. If respiratory irritation, dizziness, nausea, or unconsciousness occurs, seek immediate medical assistance. If breathing has stopped, assist ventilation with a mechanical device or use mouth-to-mouth resuscitation.

SKIN CONTACT

Wash contact areas with soap and water. Remove contaminated clothing. Launder contaminated clothing before reuse.

EYE CONTACT

Flush thoroughly with water. If irritation occurs, get medical assistance.

INGESTION

Seek immediate medical attention. Do not induce vomiting.

NOTE TO PHYSICIAN

If ingested, material may be aspirated into the lungs and cause chemical pneumonitis. Treat appropriately.

SECTION 5 FIRE FIGHTING MEASURES

EXTINGUISHING MEDIA

Appropriate Extinguishing Media: Use water fog, foam, dry chemical or carbon dioxide (CO2) to extinguish flames.

Inappropriate Extinguishing Media: Straight Streams of Water

FIRE FIGHTING

Fire Fighting Instructions: Evacuate area. Prevent runoff from fire control or dilution from entering streams, sewers, or drinking water supply. Firefighters should use standard protective equipment and in enclosed spaces, self-contained breathing apparatus (SCBA). Use water spray to cool fire exposed surfaces and to protect personnel.

Hazardous Combustion Products: Aldehydes, Oxides of carbon, Sulfur oxides, Smoke, Fume, Incomplete combustion products

FLAMMABILITY PROPERTIES

Flash Point [Method]: >145°C (293°F) [ASTM D-92]
Flammable Limits (Approximate volume % in air): LEL: N/D UEL: N/D
Autoignition Temperature: >315°C (599°F)

SECTION 6 ACCIDENTAL RELEASE MEASURES

NOTIFICATION PROCEDURES

In the event of a spill or accidental release, notify relevant authorities in accordance with all applicable regulations. US regulations require reporting releases of this material to the environment which exceed the applicable reportable quantity or oil spills which could reach any waterway including intermittent dry creeks. The National Response Center can be reached at (800)424-8802.

PROTECTIVE MEASURES

Avoid contact with spilled material. Warn or evacuate occupants in surrounding and downwind areas if required due to toxicity or flammability of the material. See Section 5 for fire fighting information. See the Hazard Identification Section for Significant Hazards. See Section 4 for First Aid Advice. See Section 8 for advice on the minimum requirements for personal protective equipment. Additional protective measures may be necessary, depending on the specific circumstances and/or the expert judgment of the emergency responders.

For emergency responders: Respiratory protection: respiratory protection will be necessary only in special cases, e.g., formation of mists. Half-face or full-face respirator with filter(s) for dust/organic vapor or Self Contained Breathing Apparatus (SCBA) can be used depending on the size of spill and potential level of

exposure. If the exposure cannot be completely characterized or an oxygen deficient atmosphere is possible or anticipated, SCBA is recommended. Work gloves that are resistant to hydrocarbons are recommended. Gloves made of polyvinyl acetate (PVA) are not water-resistant and are not suitable for emergency use. Chemical goggles are recommended if splashes or contact with eyes is possible. Small spills: normal antistatic work clothes are usually adequate. Large spills: full body suit of chemical resistant, antistatic material is recommended.

SPILL MANAGEMENT

Land Spill: Stop leak if you can do it without risk. Recover by pumping or with suitable absorbent.

Water Spill: Stop leak if you can do it without risk. Confine the spill immediately with booms. Warn other shipping. Remove from the surface by skimming or with suitable absorbents. Seek the advice of a specialist before using dispersants.

Water spill and land spill recommendations are based on the most likely spill scenario for this material; however, geographic conditions, wind, temperature, (and in the case of a water spill) wave and current direction and speed may greatly influence the appropriate action to be taken. For this reason, local experts should be consulted. Note: Local regulations may prescribe or limit action to be taken.

ENVIRONMENTAL PRECAUTIONS

Large Spills: Dike far ahead of liquid spill for later recovery and disposal. Prevent entry into waterways, sewers, basements or confined areas.

SECTION 7 HANDLING AND STORAGE

HANDLING

Avoid contact with skin. Prevent small spills and leakage to avoid slip hazard. Material can accumulate static charges which may cause an electrical spark (ignition source). When the material is handled in bulk, an electrical spark could ignite any flammable vapors from liquids or residues that may be present (e.g., during switch-loading operations). Use proper bonding and/or ground procedures. However, bonding and grounds may not eliminate the hazard from static accumulation. Consult local applicable standards for guidance. Additional references include American Petroleum Institute 2003 (Protection Against Ignitions Arising out of Static, Lightning and Stray Currents) or National Fire Protection Agency 77 (Recommended Practice on Static Electricity) or CENELEC CLC/TR 50404 (Electrostatics - Code of practice for the avoidance of hazards due to static electricity).

Static Accumulator: This material is a static accumulator.

STORAGE

The container choice, for example storage vessel, may effect static accumulation and dissipation. Do not store in open or unlabelled containers.

SECTION 8 EXPOSURE CONTROLS / PERSONAL PROTECTION

EXPOSURE LIMIT VALUES

Exposure limits/standards (Note: Exposure limits are not additive)

Substance Name	Form	Limit / Standard			NOTE	Source
2,6-DI-TERT-BUTYL-P-CRESOL	Inhalable fraction and	TWA	2 mg/m3		N/A	ACGIH

	vapor					
HYDROTREATED LIGHT NAPHTHENIC DISTILLATE (PETROLEUM)	Mist.	TWA	5 mg/m3		N/A	OSHA Z1
HYDROTREATED LIGHT NAPHTHENIC DISTILLATE (PETROLEUM)	Inhalable fraction.	TWA	5 mg/m3		N/A	ACGIH
HYDROTREATED LIGHT NAPHTHENIC DISTILLATE (PETROLEUM)	Mist.	TWA	5 mg/m3		N/A	ACGIH

Exposure limits/standards for materials that can be formed when handling this product: When mists/aerosols can occur the following are recommended: 5 mg/m³ - ACGIH TLV (inhalable fraction), 5 mg/m³ - OSHA PEL.

NOTE: Limits/standards shown for guidance only. Follow applicable regulations.

No biological limits allocated.

ENGINEERING CONTROLS

The level of protection and types of controls necessary will vary depending upon potential exposure conditions. Control measures to consider:

No special requirements under ordinary conditions of use and with adequate ventilation.

PERSONAL PROTECTION

Personal protective equipment selections vary based on potential exposure conditions such as applications, handling practices, concentration and ventilation. Information on the selection of protective equipment for use with this material, as provided below, is based upon intended, normal usage.

Respiratory Protection: If engineering controls do not maintain airborne contaminant concentrations at a level which is adequate to protect worker health, an approved respirator may be appropriate. Respirator selection, use, and maintenance must be in accordance with regulatory requirements, if applicable. Types of respirators to be considered for this material include:

No special requirements under ordinary conditions of use and with adequate ventilation.

For high airborne concentrations, use an approved supplied-air respirator, operated in positive pressure mode. Supplied air respirators with an escape bottle may be appropriate when oxygen levels are inadequate, gas/vapor warning properties are poor, or if air purifying filter capacity/rating may be exceeded.

Hand Protection: Any specific glove information provided is based on published literature and glove manufacturer data. Glove suitability and breakthrough time will differ depending on the specific use conditions. Contact the glove manufacturer for specific advice on glove selection and breakthrough times for your use conditions. Inspect and replace worn or damaged gloves. The types of gloves to be considered for this material include:

If prolonged or repeated contact is likely, chemical resistant gloves are recommended. If contact with forearms is likely, wear gauntlet style gloves.

Eye Protection: If contact is likely, safety glasses with side shields are recommended.

Skin and Body Protection: Any specific clothing information provided is based on published literature or manufacturer data. The types of clothing to be considered for this material include:

If prolonged or repeated contact is likely, chemical, and oil resistant clothing is recommended.

Specific Hygiene Measures: Always observe good personal hygiene measures, such as washing after handling the material and before eating, drinking, and/or smoking. Routinely wash work clothing and protective equipment to remove contaminants. Discard contaminated clothing and footwear that cannot be cleaned. Practice good housekeeping.

ENVIRONMENTAL CONTROLS

Comply with applicable environmental regulations limiting discharge to air, water and soil. Protect the environment by applying appropriate control measures to prevent or limit emissions.

SECTION 9 PHYSICAL AND CHEMICAL PROPERTIES

Note: Physical and chemical properties are provided for safety, health and environmental considerations only and may not fully represent product specifications. Contact the Supplier for additional information.

GENERAL INFORMATION

Physical State: Liquid
Color: Pale Yellow
Odor: Characteristic
Odor Threshold: N/D

IMPORTANT HEALTH, SAFETY, AND ENVIRONMENTAL INFORMATION

Relative Density (at 15 °C): 0.883
Flammability (Solid, Gas): N/A
Flash Point [Method]: >145°C (293°F) [ASTM D-92]
Flammable Limits (Approximate volume % in air): LEL: N/D UEL: N/D
Autoignition Temperature: >315°C (599°F)
Boiling Point / Range: N/A
Decomposition Temperature: N/D
Vapor Density (Air = 1): > 5 at 101 kPa [Estimated]
Vapor Pressure: < 0.013 kPa (0.1 mm Hg) at 20 °C [Estimated]
Evaporation Rate (n-butyl acetate = 1): N/D
pH: N/A
Log Pow (n-Octanol/Water Partition Coefficient): > 6.5 [Estimated]
Solubility in Water: Negligible
Viscosity: 8.18 cSt (8.18 mm2/sec) at 40 °C | 2.18 cSt (2.18 mm2/sec) at 100°C
Oxidizing Properties: See Hazards Identification Section.

OTHER INFORMATION

Freezing Point: N/D
Melting Point: -55°C (-67°F)
Pour Point: -40°C (-40°F)
DMSO Extract (mineral oil only), IP-346: < 3 %wt

SECTION 10 STABILITY AND REACTIVITY

REACTIVITY: See sub-sections below.

STABILITY: Material is stable under normal conditions.

CONDITIONS TO AVOID: Excessive heat. High energy sources of ignition.

MATERIALS TO AVOID: Strong oxidizers

HAZARDOUS DECOMPOSITION PRODUCTS: Material does not decompose at ambient temperatures.

POSSIBILITY OF HAZARDOUS REACTIONS: Hazardous polymerization will not occur.

SECTION 11 TOXICOLOGICAL INFORMATION

INFORMATION ON TOXICOLOGICAL EFFECTS

Hazard Class	Conclusion / Remarks
Inhalation	
Acute Toxicity: No end point data for material.	Minimally Toxic. Based on assessment of the components.
Irritation: No end point data for material.	Elevated temperatures or mechanical action may form vapors, mist, or fumes which may be irritating to the eyes, nose, throat, or lungs.
Ingestion	
Acute Toxicity: No end point data for material.	Minimally Toxic. Based on assessment of the components.
Skin	
Acute Toxicity: No end point data for material.	Minimally Toxic. Based on assessment of the components.
Skin Corrosion/Irritation: No end point data for material.	May dry the skin leading to discomfort and dermatitis. Based on assessment of the components.
Eye	
Serious Eye Damage/Irritation: No end point data for material.	May cause mild, short-lasting discomfort to eyes. Based on assessment of the components.
Sensitization	
Respiratory Sensitization: No end point data for material.	Not expected to be a respiratory sensitizer.
Skin Sensitization: No end point data for material.	Not expected to be a skin sensitizer. Based on assessment of the components.
Aspiration: Data available.	May be fatal if swallowed and enters airways. Based on physico-chemical properties of the material.
Germ Cell Mutagenicity: No end point data for material.	Not expected to be a germ cell mutagen. Based on assessment of the components.
Carcinogenicity: No end point data for material.	Not expected to cause cancer. Based on assessment of the components.
Reproductive Toxicity: No end point data for material.	Not expected to be a reproductive toxicant. Based on assessment of the components.
Lactation: No end point data for material.	Not expected to cause harm to breast-fed children.
Specific Target Organ Toxicity (STOT)	
Single Exposure: No end point data for material.	Not expected to cause organ damage from a single exposure.
Repeated Exposure: No end point data for material.	Not expected to cause organ damage from prolonged or repeated exposure. Based on assessment of the components.

TOXICITY FOR SUBSTANCES

NAME	ACUTE TOXICITY
2,6-DI-TERT-BUTYL-P-CRESOL	Oral Lethality: LD50 0.89 g/kg (Rat)

OTHER INFORMATION

For the product itself:

Prolonged and/or repeated skin contact with low viscosity materials may defat the skin resulting in possible irritation and dermatitis.
Small amounts of liquid aspirated into the lungs during ingestion or from vomiting may cause chemical pneumonitis or pulmonary edema.

Contains:

Base oil severely refined: Not carcinogenic in animal studies. Representative material passes IP-346, Modified Ames test, and/or other screening tests. Dermal and inhalation studies showed minimal effects; lung non-specific infiltration of immune cells, oil deposition and minimal granuloma formation. Not sensitizing in test animals.

The following ingredients are cited on the lists below: None.

--REGULATORY LISTS SEARCHED--

1 = NTP CARC	3 = IARC 1	5 = IARC 2B
2 = NTP SUS	4 = IARC 2A	6 = OSHA CARC

SECTION 12 ECOLOGICAL INFORMATION

The information given is based on data available for the material, the components of the material, and similar materials.

ECOTOXICITY

Material -- Expected to be toxic to aquatic organisms. May cause long-term adverse effects in the aquatic environment.

MOBILITY

Base oil component -- Low solubility and floats and is expected to migrate from water to the land. Expected to partition to sediment and wastewater solids.

PERSISTENCE AND DEGRADABILITY

Biodegradation:

Base oil component -- Expected to be inherently biodegradable

BIOACCUMULATION POTENTIAL

Base oil component -- Has the potential to bioaccumulate, however metabolism or physical properties may reduce the bioconcentration or limit bioavailability.

SECTION 13 DISPOSAL CONSIDERATIONS

Disposal recommendations based on material as supplied. Disposal must be in accordance with current applicable laws and regulations, and material characteristics at time of disposal.

DISPOSAL RECOMMENDATIONS

Product is suitable for burning in an enclosed controlled burner for fuel value or disposal by supervised incineration at very high temperatures to prevent formation of undesirable combustion products. Protect the environment. Dispose of used oil at designated sites. Minimize skin contact. Do not mix used oils with solvents, brake fluids or coolants.

REGULATORY DISPOSAL INFORMATION

RCRA Information: The unused product, in our opinion, is not specifically listed by the EPA as a hazardous waste (40 CFR, Part 261D), nor is it formulated to contain materials which are listed as hazardous wastes. It does not exhibit the hazardous characteristics of ignitability, corrosivity or reactivity and is not formulated with contaminants as determined by the Toxicity Characteristic Leaching Procedure (TCLP). However, used product may be regulated.

Empty Container Warning Empty Container Warning (where applicable): Empty containers may contain residue and can be dangerous. Do not attempt to refill or clean containers without proper instructions. Empty drums should be completely drained and safely stored until appropriately reconditioned or disposed. Empty containers should be taken for recycling, recovery, or disposal through suitably qualified or licensed contractor and in accordance with governmental regulations. DO NOT PRESSURISE, CUT, WELD, BRAZE, SOLDER, DRILL, GRIND, OR EXPOSE SUCH CONTAINERS TO HEAT, FLAME, SPARKS, STATIC ELECTRICITY, OR OTHER SOURCES OF IGNITION. THEY MAY EXPLODE AND CAUSE INJURY OR DEATH.

SECTION 14 TRANSPORT INFORMATION

LAND (DOT): Not Regulated for Land Transport

LAND (TDG): Not Regulated for Land Transport

SEA (IMDG): Not Regulated for Sea Transport according to IMDG-Code

Marine Pollutant: No

AIR (IATA): Not Regulated for Air Transport

SECTION 15 REGULATORY INFORMATION

OSHA HAZARD COMMUNICATION STANDARD: This material is considered hazardous in accordance with OSHA HazCom 2012, 29 CFR 1910.1200.

Listed or exempt from listing/notification on the following chemical inventories: AICS, DSL, ENCS, IECSC, KECI, PICCS, TSCA

EPCRA SECTION 302: This material contains no extremely hazardous substances.

SARA (311/312) REPORTABLE HAZARD CATEGORIES: Immediate Health. Delayed Health.

SARA (313) TOXIC RELEASE INVENTORY: This material contains no chemicals subject to the supplier notification requirements of the SARA 313 Toxic Release Program.

The following ingredients are cited on the lists below:

Chemical Name	CAS Number	List Citations
2,6-DI-TERT-BUTYL-P-CRESOL	128-37-0	1, 13, 16, 17, 18
HYDROTREATED LIGHT NAPHTHENIC DISTILLATE (PETROLEUM)	64742-53-6	1, 4, 13, 17, 18

--REGULATORY LISTS SEARCHED--

1 = ACGIH ALL	6 = TSCA 5a2	11 = CA P65 REPRO	16 = MN RTK
2 = ACGIH A1	7 = TSCA 5e	12 = CA RTK	17 = NJ RTK
3 = ACGIH A2	8 = TSCA 6	13 = IL RTK	18 = PA RTK
4 = OSHA Z	9 = TSCA 12b	14 = LA RTK	19 = RI RTK
5 = TSCA 4	10 = CA P65 CARC	15 = MI 293	

Code key: CARC=Carcinogen; REPRO=Reproductive

SECTION 16 OTHER INFORMATION

N/D = Not determined, N/A = Not applicable

KEY TO THE H-CODES CONTAINED IN SECTION 3 OF THIS DOCUMENT (for information only):
H304: May be fatal if swallowed and enters airways; Aspiration, Cat 1
H400: Very toxic to aquatic life; Acute Env Tox, Cat 1
H410: Very toxic to aquatic life with long lasting effects; Chronic Env Tox, Cat 1

THIS SAFETY DATA SHEET CONTAINS THE FOLLOWING REVISIONS:
Updates made in accordance with implementation of GHS requirements.

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DGN: 2011629XUS (548632)
