# MANUFACTURING EQUIPMENT
# PURCHASE SPECIFICATION

NEXTEER AUTOMOTIVE

**TITLE:** SOLID STATE INVERTER FOR INDUCTION EQUIPMENT **NUMBER:** SD-1004
**ISSUED BY:** Ronald P. Hoppe **DATE:** 11/22/95 **APPROVED BY:** 27SEP12
**REVISION:** C **DATE:** 09/13/12 **SHEET:** 1 of 16

## I. SCOPE

A. The intent of this specification is to outline the basis for standardization in the design and build of induction-inverter equipment. This will facilitate common maintenance, re-tooling, and will provide trouble-free production operation that will assure the quality and reliability of Nexteer Automotive's products. It is not intended to inhibit design or progress of new technology in the "Induction or Machine Tool" Industry.

## II. SAGINAW ELECTRIC SUPPLY

A. Plant power is 460-volt, 3-phase, 60-Hertz. Over / under voltage is + 10%, -5%. Unless otherwise specified for non U.S. installations.

B. The inverter shall be capable of withstanding voltage spikes and the electrical noise in the line that may occur (in addition to over and under voltage conditions) without damage to components or personnel (typical harmonic noise found in industrial power lines is: 5th harmonic = 20%, 7th harmonic = 14%, 11th harmonic = 9%, 13th harmonic = 7%, etc.

## III. CABINETS

A. All cabinets shall be of NEMA-12 construction.

B. All interlock switches for hinged doors and access panels shall be the defeatable type (can be manually energized for troubleshooting but are auto re-set when doors are closed).

C. High-voltage lights shall be provided to indicate when each phase of line power is being supplied to the inverter.

D. "DANGER -- HIGH VOLTAGE" warning signs shall be permanently attached to each door.

E. Manual grounding probes shall be provided for each cabinet section and shall be adequate for "ungrounded" systems. They shall have a hooked end suitable for leaving the probe in contact with the component to prevent charge build-up while maintenance is being performed. The grounding probe shall be mounted on the outside of the cabinet with an interlock switch, such that probe removal is required before door can be opened. In all cases, a permanently-mounted engraved plastic tag describing the grounding procedure shall be furnished adjacent to each probe in a conspicuous place.

F. A drain plug at the bottom of the cabinet in a convenient location is required. A sloped bottom floor to drain any water leakage toward the plug is desirable.

G. It is desirable to maintain the physical arrangement of components inside the cubicles in a "modular" design. An example is:

1. Control section
2. Power input section
3. Rectifier section
4. Inverter section

I. The component layout shall be designed for front access only so that the inverter could be positioned against a wall in a plant layout that requires it. However, screw-on rear-access panels shall be provided on all cabinets for convenience during maintenance.

## IV. LIMIT CIRCUITS, SENSORS, AND LIGHTS

The following limit circuits, sensors, and lights shall be furnished at a minimum. The vendor should list any other items (not covered here) that will be furnished. Unless otherwise specified, all fault-indicator lights shall be mounted on outside of panel door.

A. Monitor Load Tuning Capacitor: The vendor shall provide a limit circuit to sense the capacitor voltage in the heat station. This limit (and control) circuit shall limit the voltage within the capacitor's rating under all inverter operating conditions. This limit shall be adjustable from maximum capacitor value to some lower value.

B. Monitor and Limit Inverter Output Current: The inverter shall have an adjustable current-limit circuit to limit inverter output current at a maximum of 20% over the current rating. This should be factory set at 10% over rating.

C. If the internal current of the inverter can be different than the output current, then a limit circuit shall be provided to limit the internal current in the same manner as for output current.

D. All SCR's, IGBT's, mosfet's and diodes shall be protected from over-voltage.

E. A circuit to continually monitor gate-firing and SCR "turn-on" and "turn-off" shall be provided. This circuit shall indicate which SCR's are not operating properly.

F. A circuit shall be provided to indicate low-voltage fault on the D.C. bus.

G. The above faults shall seal in, requiring a "fault re-set" button to be pressed to turn off fault lights before inverter can be re-started. If the inverter can continue to operate at a limit without damage, then the lights shall still "seal" on so the operator is aware that the inverter is or was operating against a limit. Where multiple components are involved, individual pilot lights are required to indicate which device is defective.

H. All limit circuits shall be "fail-safe".

## V. REGULATION MODES

The inverter shall regulate output power in Voltage, Current, or Kilowatts from 15% to 100% of rated power:

## VI. POWER OUTPUT

A. Under constant line and load conditions, and after controls have warmed up and stabilized, the output power regulation should be within ± ½ % of set value (power pot set anywhere from 15% to 100% power).

B. Under varying line conditions (line voltage + 10% to -5%), the output power regulation shall be within ±1% of set point (power pot set anywhere from 15% to 100% power).

C. If the vendor's unit will not comply with these specifications, vendor should detail in the quote how effective the power regulation is and under what range of operating conditions.

## VII. INVERTER TESTS

The inverter shall pass the following tests on the vendor's floor during final run-off:

A. Shorted Inverter Output: The inverter must be able to repeatedly withstand a "crowbar" test (dead short across output) and shut down without damage. The inverter shall be incapable of re-starting until the short is removed.

B. Shorted Heat-Station Output: if the vendor is furnishing an output station (load-matching transformer, capacitors, and enclosure) with the inverter the test in IX.A. shall be repeated with the short across the secondary of the

transformer. This test (IX.B.) is to verify that the response time of the circuit-sensing shorted output will shut the inverter down in time to save output station components.

C. Line Disturbance: When a short circuit (such as in IX.A. or IX.B.) occurs, the inverter shall not create a disturbance on the input power lines that will affect other equipment in the plant. The disturbance shall not exceed a 10% variation from normal line conditions when the inverter is running at full nameplate power (also see XIII.D. of this specification).

D. Ground Detection: The inverter shall consistently shut down when any portion of the output circuit is grounded, and the inverter shall be disabled from re-starting until the ground condition is removed. No damage shall occur to any components during this test.

E. Frequency Tuning Range: Dummy loads shall be connected to the inverter to demonstrate the inverter will run at 100% of rated (nameplate) power throughout the frequency-tuning range. The vendor shall specify in the quote the frequency-tuning range of the inverter.

F. Varying Load "Q": The inverter shall be able to run into any normal induction load. Dummy loads simulating Q of 1.5 and up shall be demonstrated at run-off.

G. Ramp-Up and Ramp-Down Times: The "ramp-up" time (0% to 100% power) and "ramp-down" time (100% to 0% power) shall not exceed 70 milliseconds and shall be repeatable within ±5% for any given load. This shall be demonstrated with an oscilloscope trace.

H. Phase Loss on Input Line: The vendor shall demonstrate that the inverter shall be able to withstand a phase loss (during inverter operation at 75% to 100% power rating) without incurring damage. This test can be set up by fusing one input leg with a lower-rated fuse than the other two legs and slowly increasing the inverter power control.

I. Tune-Up of Unknown Load: The vendor shall connect a dummy load and demonstrate tuning procedure to develop 100% rated power. This shall be accomplished in 30 minutes or less.

J. Fault-Protection Circuits: All limit circuits, safety circuits, and protection circuits shall be demonstrated to be working properly.

K. ON / OFF Cycling Test: In addition to the vendor's normal "burn-in" test of applying constant power over a selected period of time, the inverter shall also be

connected to a dummy load and cycled on and off repeatedly at full power for a period of two (2) seconds OFF..

L. Input Line Phase Ground Test: If the vendor has provided a monitor circuit to check for a grounded phase on the input line, this test shall be run to verify that the circuit is functioning properly (see Section X. G. of this document).

## VIII. INVERTER PROTECTION CIRCUITS

The following inverter protection circuits shall be furnished:

A. Inlet cooling-water temperature high.

B. Cooling-water flow low or equivalent

C. Cooling-water temperature high -- each internal cooling loop (these sensors shall be mounted on last component in each parallel water pat).

D. Phase loss, input line.

E. Input line phase ground. If a ground on an input-line phase (either intermittent or sustained) will be detrimental to the inverter, this circuit shall be furnished.

F. Load-fault circuits:

1. Inverter output grounded.
2. Inverter output shorted.
3. Inverter output open.

G. Re-set button for faults.

H. All circuits shall be fail-safe, shall seal in, and shall be resettable only after fault is removed

I. Inverter-run faults:

1. Inverter operating at voltage limit.
2. Inverter operating at current limit.
3. Inverter operating at power limit
4. Inverter operating at frequency limit.

J. If the conditions of over and under AC line voltage will be detrimental to the inverter, the vendor shall state what these problems will be and what circuit protection will be furnished for this condition.

## IX. SAFETY CIRCUITS

A. When any door is opened on the inverter, input power shall be de-energized and charged components discharged per National Electric Code (also see Section III. B. of this specification).

B. The vendor shall specify what ground-detection circuits he will furnish on the inverter to meet the requirements of the National Electric Code.

C. Control voltage and 480 voltage (or higher) shall be isolated and, preferably, both will not be present in the same cubicle. Where this is not possible, the exposed 480-voltage points shall be covered with insulating shields per Nexteer's specifications.

D. The vendor shall describe the method of disconnecting input-line power to the inverter (in addition to the main disconnect to circuit breaker).

E. The inverter shall have a "disable high-frequency power" interlock circuit that can be set from a remote point to disable the inverter during a set-up and other maintenance operations.

## X. INVERTER OUTPUT METERS

All meters shall be red-lined in OVERLOADED areas of inverter operation. Also, labels are required on all meters that read in % to indicate the actual electrical quantity that 100 is equal to. These labels shall be white-black-white plastic and be secured with drive screws.

A. Output voltage -- 0% to 150% volts (red-lined over 110% volts).

B. Output current -- 0% to 150% amps (red-lined over 110% amps).

C. Output power -- 0% to 150% KW (red-lined over 110% KW).

D. Output-frequency meter.

E. Capacitor volts -- 0% to 150% volts (red-lined over 110% volts). This meter required only on series-tuned inverters.

F. Solid-state equivalent is acceptable with prior Process Engineering approval.

## XI. INVERTER DESIGN

A. The inverter should have "soft-start" and "soft-stop" circuit design.

B. In the event of inverter SCR failure (direct short in bridge), the incoming 3-phase line current shall be inherently limited.

C. The inverter shall not generate noise or surges back into Nexteer Automotive's power lines. It is preferable to use a 3-phase isolation transformer on the front end of the inverter.

## XII. HIGH-FREQUENCY OUTPUT

A. The vendor shall specify the size, number, and type of cables required to connect the output station to the inverter. Vendor shall also specify full-load voltage and current in these cables.

B. If cable terminations are made outside the inverter, vendor shall supply split micarta cable-clamp plated (sealed with RTV silicone rubber at installation) to maintain NEMA-12 sealing. These clamp plates shall be designed for use at the top to bottom of the high-frequency output, and a gasketed solid cover plate shall be installed on the unused opening.

C. If cable terminations are made outside the inverter, then a cover shall be furnished to guard the exposed bus connections. Split micarta cable-clamp plates shall be furnished in the covers to protect the cable insulation and to provide support (stress-relief) on the terminations. The points where the high-frequency output bus passes through the inverter cabinet should be enclosed with micarta plates and sealed with RTV silicone rubber. The unused high-frequency output opening (top or bottom) shall be plugged with a gasketed solid cover plate.

D. "DANGER -- HIGH VOLTAGE" warning signs shall be installed on the inverter cabinet near the high-frequency output and on each access door.

## XIII. INVERTER POWER DISTRIBUTION AND INTERLOCKS

A. The 120-volt single-phase power for the inverter control circuits shall be supplied from a vendor-furnished 480-volt / 120-volt control transformer (not the lighting power supply). The primary and secondary of this transformer shall be fused.

B. The control system for the induction-heating fixture or machine is to serve as the master control, and all other systems (inverter, load conveyors, etc.) are to be considered sub-systems.

C. The inverter shall have the following minimum input and output interlocks, using relay, analog, or digital-signal interfacing. All of the following interlocks shall be wired to a common "user's terminal block". Each wire and terminal screw shall be numbered and will correspond to the wire and terminal numbers on that schematic. All interlocks (output and input) shall be discussed at time of quote. Also, one of the schematic drawings shall be dedicated to describing the interlocks that follow (see XVII, Appendix C, Sheet 14).

1. Outputs (from inverter to machine; See XVI, Appendix A, Sheet 12)

   a. Inverter Ready: All inverter faults are re-set, and high-frequency power can be enabled.

   b. High-Frequency Power Enabled: A signal to tell the machine that DC bus voltage is ON (see Section XI. E. of this specification).

   c. High-Frequency Power Disabled: A signal to tell the machine that the DC bus voltage is OFF.

   d. Heat On: The high-frequency power is ON (inverter bridge firing).

   e. Heat Off: The high-frequency power is turned OFF (inverter bridge not firing).

   f. KW and KW SEC: Analog signals from energy monitor (to be 0 to 10 volts).

   g. Meters: Analog signals are required from all the meter circuits for driving a remote meter panel. Also required are 0 to 10 volt analog signals from all the meter circuits for driving digital displays on remote equipment (drives A to D converters).

   h. Water Pump On: A contact from the motor-starter on the water system that says the water system is turned ON.

   i. Inverter Operating at Limit: A signal that tells the machine control that the inverter is operating against a limit (current, voltage, and frequency).

   j. Individual Faults: In most systems, any inverter fault, such as door open, current overload, shorted output, ground fault, ground probe interlock, etc., would drop out the inverter-ready light (on the machine) and the machine would shut down. The operator would have to go to the inverter to read the individual annunciation fault

lights to determine the problem. For some special system installations, where a machine control would incorporate a complete fault diagnosis from a location remote from the inverter, individual signals for each fault will be required.

2. Inputs (from machine to inverter; See XVII, Appendix B Sheet 13)
   a. Heat Level: Accept external signal from machine control to set power level (this is in addition to 10-turn power potentiometer on inverter control panel).
   b. Enable / Disable High-Frequency Power: Enable or disable high-frequency power (see Section XI. E. of this specification).
   c. Turn Heat ON / OFF: Turn high-frequency power ON and OFF.
   d. Start Water Pump: Starts water pump from a remote location.
   e. Stop Water Pump: Stops water pump from a remote location.

## XIV. MAINTENANCE ABILITY

Ease of maintenance will be a prime consideration in the evaluation of the vendor's inverter. It is very important to arrange the components inside the cabinet for accessibility, ease of troubleshooting by the average Electrician, and in a logical "flow-chart" arrangement that corresponds to the schematic layout as much as possible. Everything possible should be done to minimize the time required for diagnosis and component replacement.

A. Components shall be arranged so that any individual component, such as a printed circuit-board, temperature-sensor, SCR device, capacitor, etc., can be removed if defective without having to remove any other component first.

B. All components shall be labeled the same as on the schematic drawings. Labels shall remain in place when components are removed during service and not attached to the defective component. Labels shall be white-black-white laminated plastic and secured with drive screws.

C. All outlet hoses to be one (1) size larger than inlet hoses on each device, if possible. Inlet and outlet fittings shall be labeled "water in" and "water out".

D. Components shall be mounted on sub-plates and panels by tapping mounting holes directly in the sub-plates. Drilling through holes and using nuts on the back side of the panels is not allowed.

E. All power components shall be arranged in a logical, easily-recognizable arrangement, according to the schematic layout.

F. All control-logic boards and wiring shall be mounted in one location in a control section of the enclosure and isolated from high-voltage components, where possible.

G. Troubleshooting aids are an absolute necessity. Besides indicating lights for fault conditions and complete logical drawings for all circuits, the following are also required:

1. Flow-chart troubleshooting manuals that lead you, step by step, through the procedure shall be provided.
2. Oscilloscope hook-up instructions shall be for the use of a differential input module on the scope. Floating voltage on the oscilloscope case is dangerous and not allowed.
3. Oscilloscope traces of correct wave shapes under different conditions shall be included, as well as all voltages, resistance, and currents noted on circuit drawings adjacent to each test point. The inverter condition (at full power, zero power, etc.) at which the readings at the test points should be taken shall also be noted. Make and model number of scope used -- along with knob settings -- shall be listed for each trace.
4. All test points shall be clearly marked physically on the inverter and on the schematic drawings.
5. Each gate firing board shall be self-checking with LED indicating lights that will indicate a defective PC board. All other control boards shall also be self-checking with LED indication.
6. The inverter should have a test mode of operation whereby all of the control circuits, frequency control, gate-firing signals, etc., can be operated without the high voltage ON.

## XV. NAMEPLATE

The inverter shall have a permanently-attached nameplate on the outside of enclosure, near disconnects, with the following engraved (or stamped) information:

A. Manufacturer's name, address, and phone number.

B. Serial number and model number

C. Rated output data:
   1. Power (KW).
   2. Output voltage (at 100% power).
   3. Output current (amps at 100% power).
   4. Power factor of output.
   5. Duty factor.
   6. Frequency of output.

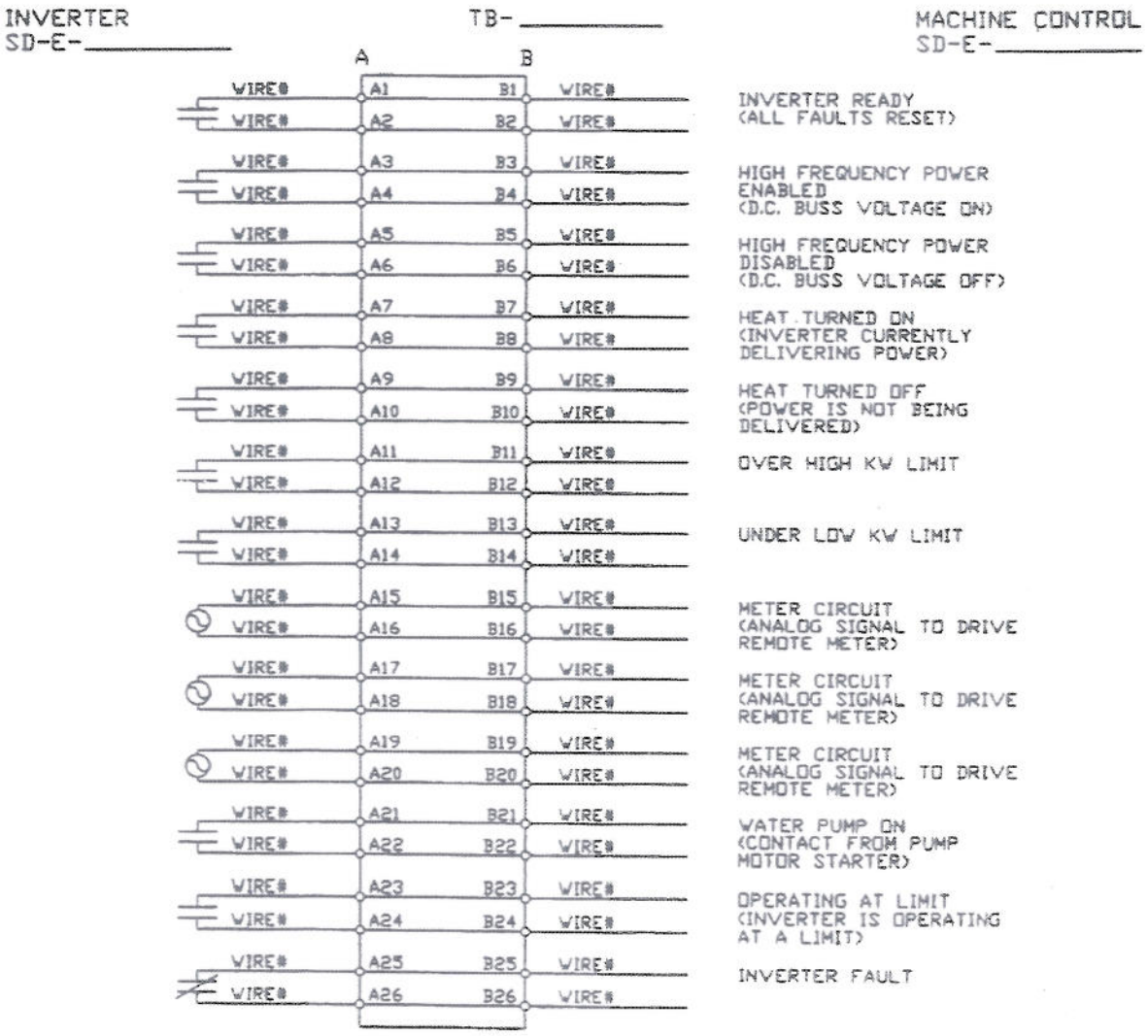
D. Rated input date:
   1. Input line current (amps at 100% power).
   2. Input voltage level, number of phases, and frequency.

E. Water data (at 100% power and maximum duty cycle):
   1. Maximum inlet water temperature
   2. Maximum water pressure (inlet).
   3. Minimum flow rate (GPM) required at maximum inlet temperature.
   4. Maximum allowable outlet water temperature (continuous).

F. Cooling power supply with quench water is NOT permitted.

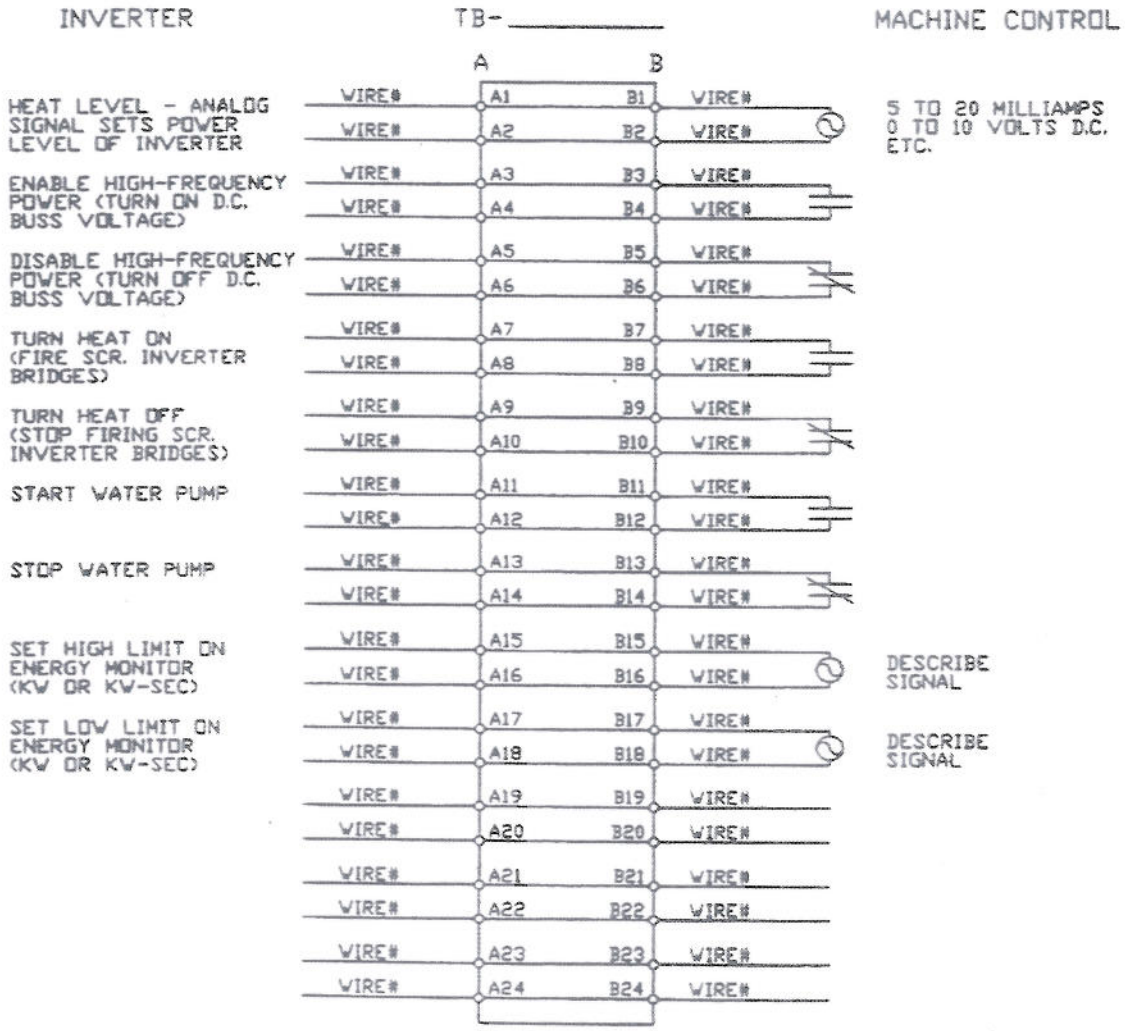
## XVI. APPENDIX A

SAMPLE CONTROL. INTERLOCK DRAWING
OUTPUTS



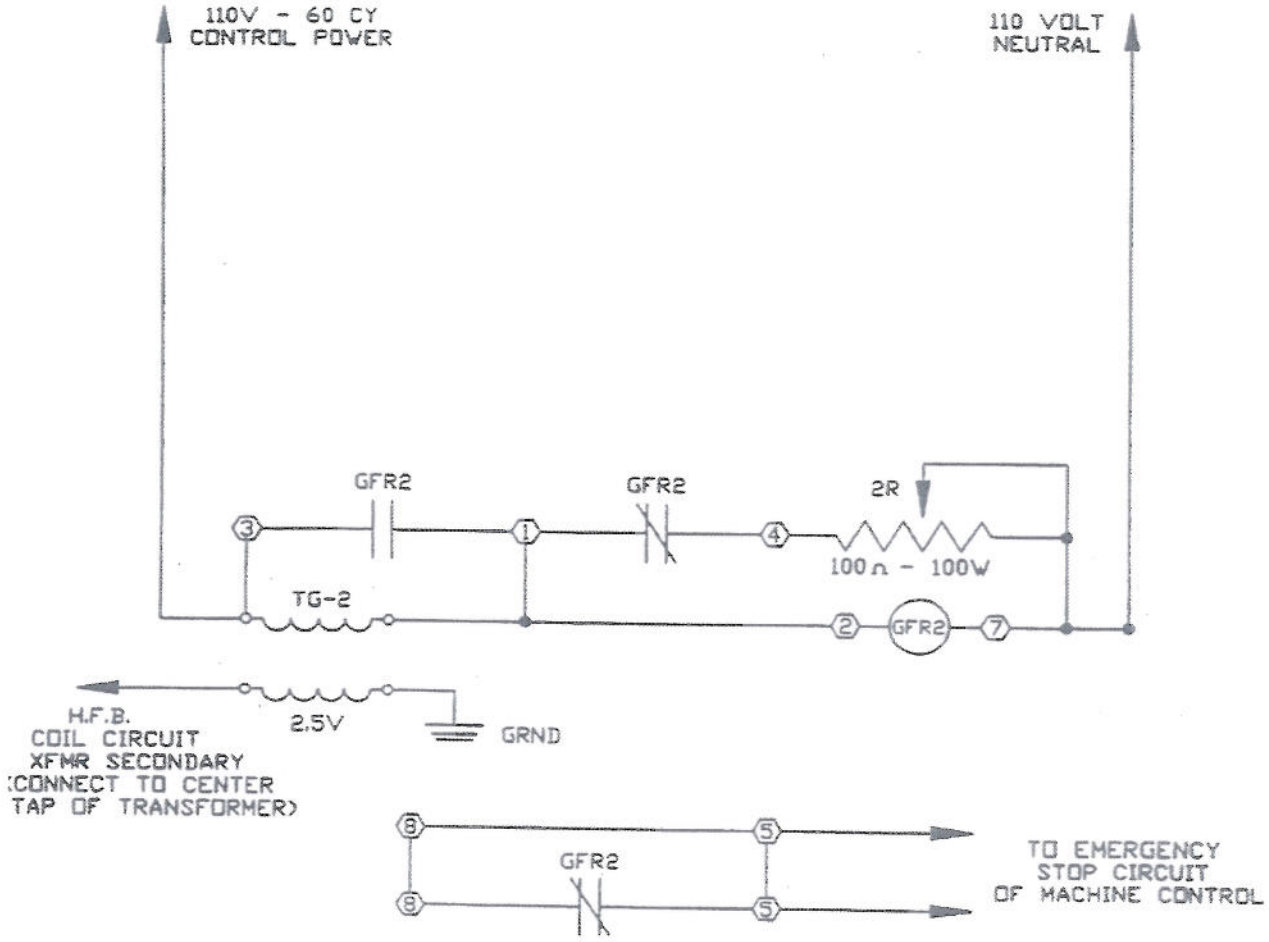
## XVII. APPENDIX B

SAMPLE CONTROL INTERLOCK DRAWING
INPUTS




TYPICAL DRAWING TO SHOW
INVERTER TO MACHINE CONTROL INTERLOCKS

## XVIII. APPENDIX C



## XIV. SPECIFICATION REVISION SHEET

| Revision Symbol | Revision Description | Date | Revised By |
|---|---|---|---|
| A | Complete rewrite | 4/18/98 | Ronald P. Hoppe |
| B | Retyped | 06/05/07 | Ronald P. Hoppe |
| C | Touch Up | 09/13/2012 | David Novak |