CONSARC
An Inductotherm Group Company

PROPOSAL NO.

13025/D

For

MEGGITT

Covering

Four (4)
8-ft Vacuum & Atmospheric Heat Treat Furnaces

for

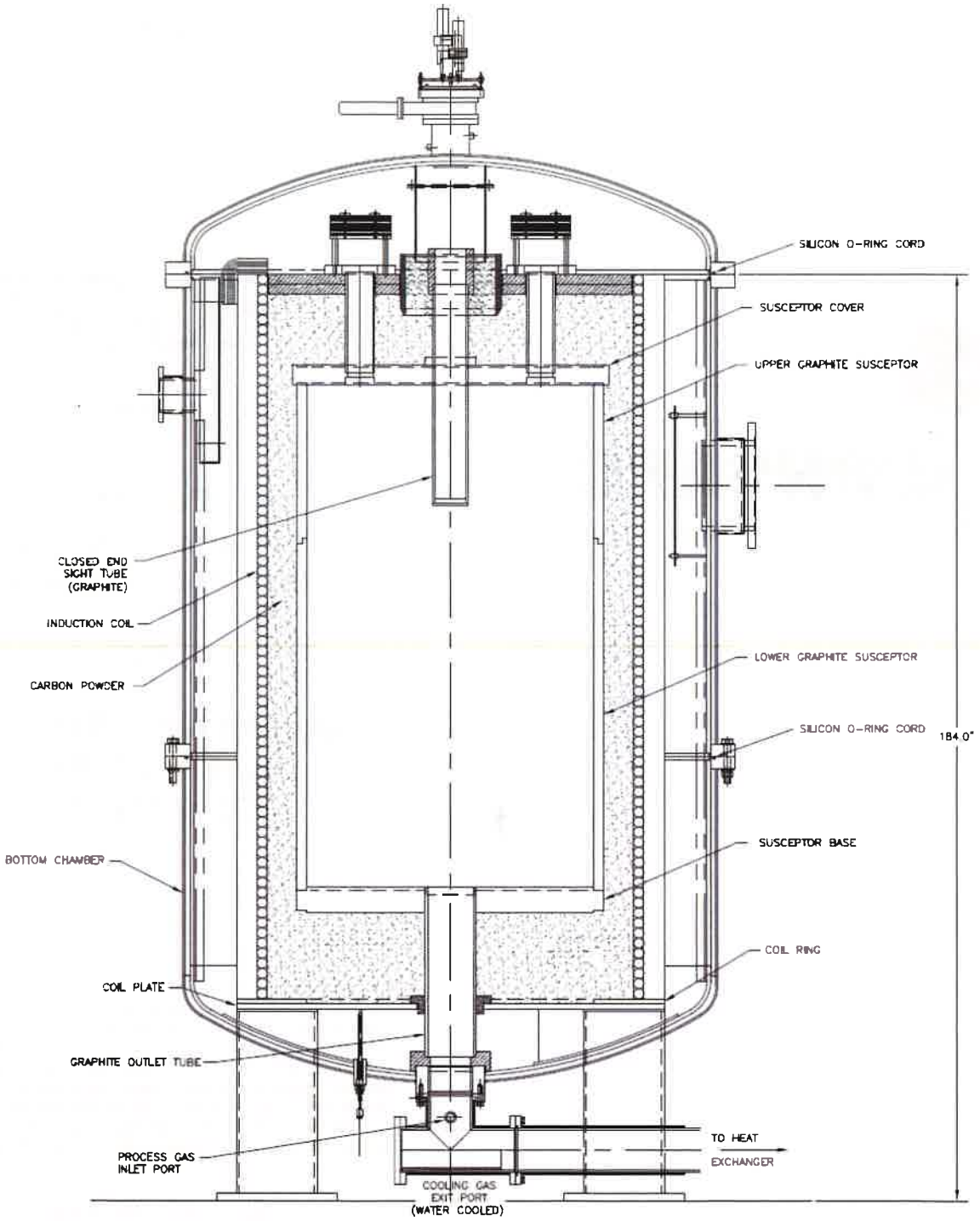
Meggitt Aircraft Braking Systems (MABS)
Coventry, UK.

6th May 2019

Confidential Information

1. GENERAL DESCRIPTION

The vacuum heat treatment furnace is designed for processing a 3,000 pound (1,360kg) charge of carbon furnace load in a 57" (1447mm) inner diameter by 100" (2540mm) inner height susceptor. The system is designed to inductively heat the charge under either vacuum to 2600°C or atmospheric pressure of inert gas to 2900°C.



Typical Hot Zone Assembly for Induction Heat Treat Furnace

Consarc works to continuously improve its products and this proposal includes several features that are important to MABS.

- The water in/out on the heat exchanger of the previous design will be modified with U-tubes at one end in order to supply a more robust design.
- The heat exchanger will be installed horizontally at floor level for ease of access and shall be mounted on wheels for removal during maintenance.
- The heat exchanger fan will be mounted at floor level for ease of access and maintenance.
- The distributed I/O will be constructed of Allen-Bradley equivalent, robust Turck hardware.
- All water circuits, chambers, components, etc. will be cleaned and flushed before connecting to the facility's water supply.
- Induction equipment (VIP Power Supplies, induction coils, power leads and bolt on shunts) will be manufactured in the UK by Inductotherm (Europe) Ltd who will also provide local aftersales services to MABS UK.
- Equivalent UK / European supplied components will be used for the furnace systems, where possible, to provide best possible aftersales support to MABS UK. Changes of component suppliers from previous Consarc furnaces and MABS specification will be discussed and mutually agreed between both parties.

The proposed system configuration is based on two vacuum & atmosphere heat treat furnaces sharing a common Inductotherm power supply, which heats one furnace at a time. Each furnace has its own induction heating coil plus controls, water, cooling, and vacuum subsystems.

All descriptions are per one furnace, excluding the Inductotherm VIP power supply. A total of four furnaces (vessels) are offered by Consarc.

The Inductotherm power supply system includes two VIP units (each VIP being switchable between a pair of furnaces) and four induction coil assemblies with power leads.

2. TECHNICAL PARAMETERS

PROCESS	:	Heat Treatment
Maximum Weight	:	3000 lb (1360kg) including jigs & fixtures
Hot Zone Dimensions	:	57" (1447mm) diameter x 100" (2540mm) high
Process Zone Dimensions	:	52" (1320mm) inner dia. x 80" (2032mm) high.
Operating Parameters:		
Heating Time (vacuum)	:	25°C to 2600°C in 24 hours.
Heating Time (inert atmosphere)	:	25°C to 2900°C in 24 hours
Heating Rate	:	100°C/hour above 1800°C
Temperature Uniformity	:	±50°C at 2900°C
Gas Cooling Time	:	2800°C to 50°C in 96 hours with recirculating nitrogen gas from 1100°C
Leak-Up Rate	:	1 torr/hour at room temperature and a base pressure < 1.0 torr.
Furnace Details:		
Maximum Temperature	:	2900°C
Power Supply	:	Inductotherm 600 kW VIP with furnace selector switch
Induction Coil Dimensions	:	73" (1854mm) inner diameter x 110" (2794mm) active length with 144" (3657mm) overall length.
Insulation Material	:	Lampblack, Cancarb Thermax N991UP thermal powder and graphite felt.
Heater Type	:	Graphite susceptor (NAC -673 grade)
Vacuum Pumping Subsystem	:	One – Kinney KT-500 rotary piston pump, 490cfm (840m^3/hr) nominal displacement.
Colour:		
Furnace Chamber	:	Single colour to Buyer specified RAL number.
Hand Rails and Ladders	:	RAL1003 (Signal yellow)
Control & Electrical Cabinets	:	RAL7035 (Light grey)
Ancillary Equipment	:	To manufacturer's standard finish (e.g. vacuum pumps, etc.)

3. SCOPE OF SUPPLY

3.1. Vacuum Vessel

The vacuum vessel and lid are water cooled, double walled carbon steel, ASME coded. It is designed for top loading in a vertical orientation. There is one 6" sight port and a platform with access ladder on the lid. It is prepared for vacuum operation and is designed in sections as described below:

- Lower Chamber – Cylindrical vessel with a dished end base and upper sealing flange.
- Lid – Dished end with sealing flange.

The chamber weight, without shunts fitted, shall not exceed 10 tons.

The main sealing flanges are fabricated in carbon steel. As the vessel body is carbon steel, magnetic shunts are supplied to prevent excessive heating of the vessel body through induction. The shunts are bolted onto the chamber to facilitate removal for furnace maintenance.

The vessel is supported by external support legs.

The vacuum vessel and lid will be manufactured in the UK / European Union or USA.

Typical Chamber Shunt Bolts

Typical Top Loading Induction Heat Treat Furnace

3.1.1. Lid

The lid is removable using the Buyer's overhead crane and has legs to protect the sealing surfaces from damage. The design will incorporate a balanced 3-point lift for manual attachment to the overhead crane, with cables weighing less than 20 lbs (9kg) and includes the following:

- Approximate dimensions of 4' (1219mm) high by 8' (2438mm) diameter.
- One 6" (150mm) diameter sight port with isolation gate valves, and sweep gas plenums.
    - One port located to visually align with top of susceptor centre exhaust stack.
    - Quartz sight port glass with O-ring groove on port flange.
    - Vacuum and inert gas lines to be ½" (25mm) minimum.
- Top platform and access ladder mounted on lid to access sight ports including cable support bracket and identification plate.
- Polarized lid for correct alignment of the sight port with the susceptor lid via 3 locating holes in the lid support legs
- Lid will have legs to protect it from damage when resting on the floor.
- Silicon O-ring seal is located on lid instead of the vessel in a dove tail groove.
- Water and gas lid connections will be double sealed, quick disconnect, that will be sized differently to prevent mismatched connections.

3.1.2. Vessel

The vessel is approximately 8' (2438mm) diameter and 15' (4572mm) tall for use with a graphite susceptor 61" (1549mm) outer diameter and 110" (2794mm) outer height and an induction coil with a 120" (3048mm) active section and 144" (3657mm) overall length. The susceptor will be surrounded circumferentially with lampblack. Cancarb Thermax N991UP Ultra-Pure thermal powder will be installed above and below the susceptor. Additionally, rigid graphite felt is fitted as a top layer above the susceptor to prevent blowing of the thermal powder during gas cooling.

Flanged ports will be fabricated into the vessel as per the furnace configuration to suit the thermocouple / pyrometer layout, configuration of power supply and services as follows:

- Emergency argon gas inlet.
- Vacuum exhaust port 15" (381mm) below vessel flange.
- One power port angled toward the lead connection of the induction coil.
- Two 2" (50mm) diameter spare ports 30" (762mm) down from flange, 90° apart.
- Two thermocouple pass-thru ports, 90° apart, near flange accommodating six thermocouples for each port with high temperature jacks inside vessel with braided stainless steel sleeve thermocouple extension cable.
- External support legs.
- The vessel flange is located 4" (100mm) above the floor. The top of the induction coil is located 1" (25mm) below this flange.
- Cooling water pressure to accommodate 85 psig (5.8 barg) in the power supply loop and 65 psig (4.5 barg) in the vessel jacket loop.
- Gas inlet/nitrogen re-circulation pipework connection flange in the centre of the base. Flange, cover plate, and all piping to be water cooled.

The leak-up rate of the above vessel under clean, dry and empty conditions will be ≤ 1.0 torr in 60 minutes at room temperature starting from a base pressure < 1.0 torr.

3.2. Inductotherm Corp. Power Supply Equipment (Priced Separately)

3.2.1. VIP Power Supply (Two VIP units offered)

Consarc is a member of the Inductotherm Group of companies. Inductotherm is a world leader in the design and manufacture of induction power supplies. The furnace will utilize an Inductotherm power supply that is sized for heating 3000 lb of carbon charge and fixtures at atmospheric pressure from 25°C to 2900°C in <24 hours and from 25°C to 2600°C in <24 hours at 10 - 20 torr with inert gas purge. A 600 kW Inductotherm VIP Vacuum Operation Power Supply is supplied with the system to serve two furnace.

The primary power input to the VIP is 415V, 3phase, 50Hz. The VIP is provided with a furnace selector switch to enable sharing of the power supply between two vessels.

Access to the power supply subsystem is through front opening doors that are interlocked to provide intrinsically safe operation. The VIP unit includes an internal closed loop deionised water system, complete with circulation pump and water to water heat exchanger.

Typical Inductotherm VIP Power Supply

Located in full view of the face of the cabinet are typically the following indicators and controls:

- Frequency meter
- Kilowatt meter
- Furnace volt meter
- Circuit monitoring panel
- Power control knob
- ON-OFF pushbuttons

The VIP Power Supply is supplied with a 4-20 mA command control feature allowing the kW level to be controlled remotely via a Loop Controller in the control console

3.2.2. VIP Remote Control Panel (Two Panels offered)

The VIP controls and subsystem data are displayed on a touch-sensitive, flat-panel monitor that shall have the following functionality:

i. Inductotherm circuit monitor
ii. Power control dial
iii. Ground leak detector
iv. kW meter
v. Coil selector switch position indication
vi. Auto / Manual switch (selects control signal from dial or controllers)
vii. Power supply internal cooling loop temperature indication
viii. Induction coil return water temperatures indication (individual meters)
ix. Start/Stop functions

3.2.3. Induction Coil Assembly and Shunts (Four sets offered)

The induction heating coil is manufactured by Inductotherm. The high purity copper coil is wound into a single induction coil and designed to couple with a graphite susceptor as follows:

- Coil to be Insulated with Inducto-Flex for vacuum operation.
- G-10 material coil support posts.
- Ceramic grouted face and back side.
- 120" (3048mm) long active section.
- Coil to have cooling coils on each end.

Typical Inductotherm Coil Assembly With Ceramic Grout

Power shunts will be used to minimize vessel heating and will be bolted to the inside of the chamber wall. This approach will facilitate removal of the shunts for maintenance.

The induction coil is supplied with a set of water cooled power leads up to 25' (7600mm) in length. The furnace chamber power port will be designed to utilize grommet sealed leads.

The VIP power supply and associated induction equipment, coils, leads, etc. are manufactured in the UK by Inductotherm (Europe) Ltd, located 40 miles from the MABS UK facility in Coventry, England.

3.3. Sight Port

One (1) 6" sight port is mounted on the furnace lid and is complete with the following:

- GNB model G6PSOPWGWF water cooled gate valve.
- Inert sweep gas circuit.
- Open/closed actuation and position indication.
- Valve activation on main control panel and lid platform.
- Valve actuation on lid to have priority control over main panel actuation.

The sight port will have the capability for the sight glass to be removed and cleaned during furnace operation. Additionally, an inert sweep gas circuit is provided on the interior surface of the glass to minimize any condensation of volatiles on the glass. A 3-way valve with vacuum break and re-evacuation capability will be used.

3.4. Vacuum Subsystem

The vacuum pumping subsystem consists of one (1) Kinney KT-Custom Vacuum Pump Sets with the following components:

- Kinney KT-500 rotary piston pump, 490cfm (840m^3/hr) nominal displacement.
- The vacuum subsystem will have a dedicated Consarc filter, which incorporates Dollinger filter elements.
- An oil mist eliminator including isolation bellows, modified for heavy duty service.
- Automatic pump isolation valve.
- A KF port and manual ball valve to vacuum pump for leak checking.
- Expanded metal guards for hot piping.
- Vacuum pump control to include oil mist eliminator high backpressure alarm, high oil temperature alarm and low internal oil pressure alarm.

3.5. Internal Graphite and Insulation Hot Zone Assembly

3.5.1. Susceptor

The susceptor is manufactured using NAC -673 grade graphite supplied by Graphite Machining, Inc. The susceptor is constructed from interlocking blocks with ship lap down on the inner diameter side and shall have an inside dimension of 57" (1447mm) diameter by 100" (2540mm) high.

3.5.2. Susceptor Lid

The graphite susceptor lid is a single piece design including the following:

- One 7.25" (184mm) diameter hole in the centre for pyrometer tube.
- Two holes 6" (152mm) diameter, on 18" (457mm) radius.
- Two vent stacks approximately 18" (457mm) long to fit stack holes.

3.5.3. Susceptor Base

The graphite susceptor base shall be the same diameter as the susceptor outer diameter and is provided with a ½" (12mm) step on one side to mate with the susceptor inner diameter. The susceptor base includes the following:

- Centre gas inlet tube.
- One graphite 25" (635mm) diameter deflector plate.
- Stainless steel gaskets between susceptor base, supports, fence, and diffusers.

3.5.4. Insulation

The susceptor will be surrounded circumferentially with lampblack insulation. Cancarb Thermax N991UP Ultra-Pure thermal powder will be installed above and below the susceptor. Additionally, rigid graphite felt is fitted as a top layer above the susceptor to prevent blowing of the thermal powder during gas cooling.

3.6. Controls and Instrumentation

The control subsystem consists of an Allen-Bradley CompactLogix PLC subsystem, a Yokogawa (or alternatively Eurotherm) Loop Process Controller and Recorder, and an Allen-Bradley Panelview Plus Operator Interface terminal. The above instrumentation along with the vacuum graphic, control buttons and indicator lights are located on a front opening cabinet.

The instruments and controls are mounted on the opening panel for convenience of maintenance. The two section door is firmly interlocked by a single lockable door handle. The vacuum graphic on the right hand door demonstrates the vacuum subsystem and has indicating lights that characterize the working conditions of the vacuum pump and valves.

The Yokogawa (or alternatively Eurotherm) programmable loop controller / process recorder will have the functionality of the previous Consarc furnaces, but will not be an exact duplicate as these are no longer available. The loop controller will control the temperature of the furnace by using the temperature sensing equipment readings to control the output of the power supply.

3.7. Cooling Water Distribution System

Efficient cooling is essential for the safe, reliable operation of the installation. The water manifolds distribute cooling water, supplied by the MABS factory cooling loop, to areas of the vacuum furnace system exposed to thermal radiation, such as the vessel sections, bases, and penetrations. Other components such as the vacuum pump, VIP, etc. are also cooled as required.

The furnace will supplied with two separate water cooling loops:

1. VIP power supply, induction coils and gas cooling heat exchanger.
2. Steel components, such as the chamber, lid, etc.

Each cooling water loop consists of an inlet manifold, including a pressure gauge, with individual ball valves and nipples from the manifold, properly labelled for each circuit. The cooling water lines terminate at a closed return manifold that incorporates flow and temperature switches on critical circuits for process monitoring.

Typical Consarc Supply and Return Water Manifolds

3.8. Temperature Measurement – Hot Zone

The furnace hot zone temperature is measured and controlled with an Ircon pyrometer for data collection. At temperatures <1000°C a fixed power input profile is utilised for the initial ramp-up. Transition to pyrometer control is made >1000°C.

Pyrometer details to be mutually agreed during the engineering phase of the Contract.

3.9. Temperature Measurement – Internal Vessel

One – thermocouple pass through port is provided on the chamber for six type K thermocouple ceramic jacks with high temperature jacketed wire inside the vessel and terminated outside the control cabinets with type K standard size jacks.

Two – sheathed thermocouples with adjustable Conax fittings in the lower vessel port to measure susceptor support plate and lower cavity temperatures. Signals from theses thermocouples will be used high limit displays and adjustable alarms.

Thermocouple details to be mutually agreed during the engineering phase of the Contract.

3.10. Pressure Measurement

Coarse pressure, 0-760mm Hg, is measured using a Heise Model CM 6" dial gauge with dial actuation counter clockwise from 760mm on the right to 0mm vacuum on the left.

Low pressure and inert gas are measured using MKS vacuum pressure transducers.

3.11. Gas Panel

A gas panel is supplied with argon and nitrogen via separate flow lines including valves and pressure switches. The choice of either argon or nitrogen gas is selected from the control panel. The flow lines feed a panel with a common manifold for the purge gas, sight port sweep gas and backfill gas. An emergency argon gas flow circuit with manual by-pass is provided.

3.12. Gas Cooling Subsystem

The gas cooling subsystem allows nitrogen within the vessel to be circulated with a heat exchanger for fast cool down of the furnace.

This subsystem consists of:

- High temperature fan with variable frequency drive using temperature control loop from thermocouples at the heat exchanger inlet and outlet. Fan operation will be interlocked with cooling water flow to heat exchanger.
- Horizontally installed external gas to water heat exchanger with removable U-tube bundle.
- Water miser valve for heat exchanger, with by-pass circuit to allow a small flow to prevent water stagnation.
- Gas piping and isolation valve.

Typical Heat Exchanger and Gas Fan

The subsystem will be capable of cooling 3000 lbs (1360kg) of carbon from 2800°C to 50°C in 96 hours. The furnace will initially cool under static as conditions down to 1100°C before the cooling fan comes into operation and the gas is then recirculated through the heat exchanger.

3.13. Interlocks and Safety Devices

The furnace and associated ancillary equipment shall be manufactured in accordance with the appropriate European Electrical and Safety Standards. A design risk assessment will be conducted by Consarc prior to the issuing of a CE Certificate (Declaration of Conformity) for the furnace installations. The induction power supply equipment will be CE Certified by Inductotherm (Europe) Ltd.

Interlocks and safety devices provided with the furnace will include the following:

- All the vacuum valves installed in the system are fail-safe and will open or close to a safe condition in the event of a failure of the compressed air or electrical supply.
- A compressed air reservoir is provided to activate the pneumatic valves in the event of the compressed air supply failing.
- A temperature controller, sited inside the control cabinet, prevents air admittance of the furnace chamber above 260°C (or a lower pre-set temperature).
- Flow switches installed in the critical cooling water return lines, protect the system from over-heating. These devices will automatically shut down the system in the event of a restriction or temperature rise of the water supply.
- Safety critical cooling circuits are wired through safety relays.
- A pressure relief valve will be fitted to the water supply manifolds.
- A pressure relief valve will be fitted to the water return manifold on the chamber cooling loop.
- Emergency stop circuits with local E-Stop buttons will provided for operator safety and in accordance with UK regulations.

3.14. Specification Compliance

This proposal was prepared to conceptually comply with MABS "8-ft Vacuum & Atmospheric Heat Treat Furnace Specification, Revision E dated April 1, 2019" with the following notes:

- Some components may be obsolete and no longer available, in which case Consarc reserves the right to utilize comparable replacements.
- Induction equipment (VIP Power Supply, coils, power leads and bolt on shunts) will be manufactured in the UK by Inductotherm (Europe) Ltd who will also provide local aftersales services to MABS UK.
- Water flow switches to be IFM in place of Kobold.
- Optical pyrometer to be Ircon in place of BASF.
- Vacuum valves to be Bray.
- Equivalent UK / European supplied components will be used for the furnace systems, where possible, to provide best possible aftersales support to MABS UK. Changes of component suppliers from previous Consarc furnaces and MABS specification will be discussed and mutually agreed between both parties.
- The distributed I/O will be A-B compatible Turck hardware as previously discussed with MABSKY engineering.
- The installation is based on compliance with UK regulations. Conduit layout drawings will not be made, which is as per previous Consarc installations.
- References to CVI equipment/process requirements are excluded.
- Ownership of drawings will be the same as the previous projects with Consarc Contractual drawings will be supplied by Consarc on MABS title blocks.

3.15. General Notes

- All capacities, utilities and dimensions contained within this proposal should be considered approximate and preliminary.
- If the customer desires that a specific manufacturer's components or material be substituted for that encompassed by this proposal, Consarc reserves the right to charge the customer for all costs involved.
- Consarc shall not be held responsible for any mistakes in design or manufacture that is a direct result of erroneous information furnished by the customer.
- Consarc shall not be held responsible for any mistakes in design or manufacture that is a direct result of pertinent information being withheld by the customer.
- Consarc shall not be held responsible for delays in committed deliveries that may be directly attributed to lengthy drawing review times by the customer.