Thermal Equipment Corporation

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SAFETY & MAINTENANCE

Thermal Equipment Corporation (TEC) builds the highest quality Autoclave Systems available and has set the standard for Aerospace Autoclave Systems for over 50 years. There are other manufactures who offer economy type Autoclave Systems, but none can match the quality and experience offered by TEC.

Thermal Equipment Corporation has always emphasized the need for safety in the operation of Autoclaves, with many years of experience in manufacturing and servicing of this equipment. With our concern for safety, we have come across many pieces of equipment which we have found to be operationally unsafe. It is our desire to assist you with developing a plan to prevent any of the potential hazards associated with improper maintenance or operation.

Attached are safety recommendations, inspection procedures, and potential modifications presented to assist you in maintaining the highest standards possible on all equipment manufactured by Thermal Equipment Corporation. We further suggest that these recommendations be implemented on equipment not manufactured by Thermal Equipment Corporation.

Please note that Thermal Equipment Corporation (TEC) provides an extensive line of spare parts and services and we take pride in the quality of workmanship by our highly experienced technicians. In addition, TEC has extensive experience servicing and refurbishing all Autoclave systems no matter who the original manufacturer. TEC would be pleased to provide a quote for an on-site inspection, evaluation or upgrades.

If you have any questions or need assistance to determine the safest operation of your equipment, please feel free to contact Thermal Equipment Corporation.

Sincerely,

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Thermal Equipment Corporation

Autoclave Safety Requirements / Recommendations

VESSEL

It has come to TEC's attention that many users and operators of pressure equipment do not properly service and inspect their pressure vessels. These vessels contain a tremendous amount of energy and should be operated and serviced with caution.

The following items should be installed and inspected for correct function:

SAFETY VALVES

At least one mechanical relief valve per ASME requirements should be installed. Some pressure vessels utilize two (2) relief valves to either work in tandem or redundancy. It should be capable of relieving 30% more than the flow from all sources of pressurization. The safety valves should be tested and calibrated by an ASME approved supplier every year.

RUPTURE DISK

Autoclaves may be equipped with a rupture disk in addition to the relief valve. The rupture disk should be checked against possible inlet flow versus discharge flow capability.

As a general recommendation, we suggest that rupture disks be replaced every year. The replacement of the rupture disks prevents accidental failure due to corrosion and/or fatigue which could cause the loss of the load in the Autoclave.

Rupture disks can prove to be very helpful in preventing damage usually caused by malfunctioning safety valves and inlet valves or by fires in the Autoclave.

PRESSURE VESSEL SAFETY

One area of great concern is lack of maintenance. The care and inspection of the pressure vessel and pressure retaining parts of the Autoclave system will be addressed separately in the following sections.

DOOR CLOSURE MAINTENANCE

Autoclave closures are typically the Breech-lock type. The Breech-lock closure consists of a rotating locking ring and mating lugs, which are connected to the head of the door, and to the front of the vessel. The closure should be inspected as follows:

1) Whenever the operator actuates and locks the door, it is their responsibility to confirm that the door is properly locked and aligned. Operators should be instructed in the correct procedure, which will confirm the relative position of all closure components. Problems have been observed in some door closure designs that incorporate excessive clearance becoming off-set to one side which dramatically reduces the engagement area of the wedges. This problem can be solved with the addition of wear plates that are installed inside the closure. Wear plates reduce the tolerances between the locking ring, shell flange and head flange. They should be added to all Breech-lock type closures that are designed with excessive clearance. TEC's current closure design maintains minimal clearance with close tolerances, eliminating the need for the addition of wear plates.

2) All wedges and sliding surfaces of the closures should be inspected on a monthly interval for damage, excessive wear and missing wedges. If the wedges on the vessel are in excess of 10 years old or negligence has caused the wedges to become excessively worn, the taper angle may be increased so that they are no longer static. In other words, hydraulic pressure is required on the locking assembly to maintain vessel closure. In the event that excessive wear angle, damage, galling or chafing is noticed, an ASME qualified repair agency, such as Thermal Equipment Corporation, should be notified immediately.

WARNING:

The following procedures supersede all other procedures published or otherwise recommended by TEC. Closure systems should be individually inspected and all grease or lubricant should be removed and replaced with only a very thin film of the following approved materials:

"Jet-Lube SS 30" Colloidal Copper Anti-seize
High temperature, High compressive load lubricant

The above-recommended products should be applied sparingly. Any excess lubricant should be removed. The back-up ring should be greased with a moly- based grease or equivalent product.

3) In addition to visual inspection, the closure mechanism should be examined by an authorized, third party, inspection agency utilizing magnetic particle examination. This inspection should be completed every one (1) to two (2) years as part of a critical safety inspection. Magnetic particle examination should be conducted on all lugs, welds and components of the closure assembly. TEC specializes in providing this service as a turnkey project including preparation and supervision of the inspection agency.

   In the event that a problem is noticed, repair should be executed by a qualified ASME agency, such as Thermal Equipment Corporation. Any welding on the pressure vessel will require pre-approval and an ASME "R-1" report to indicate that the repairs and inspections have been made, as required.

OVER PRESSURE SWITCH

All Autoclaves should be fitted with a mechanical overpressure switch which senses Autoclave internal pressure. The overpressure switch should be integrated into the control system to disable the pressure inlet valve and force the Autoclave exhaust valve to the open position. It should also be integrated into the alarm circuitry.

The overpressure switch should be checked and calibrated once a year. In addition, the overpressure sensor line should be disconnected from the control panel and back-flushed (100 PSI air) annually. Problems have been reported of plugged sensor lines causing the vessel to over pressurize.

PRESSURIZATION SOURCE

TEC strongly suggests that all Autoclaves be pressurized with either nitrogen, carbon dioxide, or other inert gases to prevent the risk of a fire in the Autoclave.

It has come to our attention that Autoclaves pressurized with nitrogen or other inert gases are being used as ovens prior to pressurization for the processing of thermoplastics. When thermoplastics or similar products are processed, the Autoclave should be pre-purged with inert gas prior to the heating cycle to help reduce the risk of fires. Slightly pressurizing the Autoclave and then venting it several times can accomplish this.

CAM-ROLLER MAINTENANCE AND INSPECTION

All breech-lock type closures are fitted with positioning rollers that maintain the concentricity of the locking ring to the shell flange. These should be inspected annually to confirm that the locking ring is concentric with the shell flange. Failure or absence of concentricity can allow the locking ring to become un-centered causing a problem similar to a misaligned door. Cam-rollers should be inspected concurrently with door adjustment and door centering procedures. They should also be inspected each time the Autoclave door closure is serviced.

VESSEL AND NOZZLE MAINTENANCE

An inspection of the vessel shell and nozzles should be conducted in order to search for signs of cracking, surface pits, damage or any abnormal indication. The vessel should also be inspected for signs of high surface operating temperatures demonstrable by peeled or blistered paint, which is caused by localized deterioration or damage to the insulation. If an area is noted, the insulation should be inspected and repaired immediately. In the event that it is necessary to continue operation, this is acceptable as long as the mean metal temperature of the pressure vessel, material or part does not exceed the temperature stated on the nameplate and personnel are protected from the hot location from possible contact.

DOOR INTERLOCK ASSEMBLY

Many Autoclaves have been observed with either improper or non-functional manual door bolt lock assemblies. The function of the door bolt lock assembly is to prevent the door actuation mechanism from being operated while there is pressure in the vessel. The door bolt lock assembly should be fitted in such a manner that, when retracted, it directly opens a valve into the vessel to confirm vessel pressure. The door bolt function engages the locking ring assembly to prevent it from being rotated unless the bolt is retracted. The door bolt should be fitted with two (2) micro-switches, one to disable the hydraulics in the event that the door bolt is not fully opened. The second switch provides an electrical interlock for the pressure inlet and exhaust valves. The bolt assembly must also be fitted with a pneumatic cylinder which locks the door bolt lock in the locked position when the pressure in the Autoclave is above 2-8 PSI.

A lack of maintenance and inspections can cause the door bolt lock, when retracted, not to actuate the valve, which directly accesses the work space. This can provide the false impression that the Autoclave is at 0 PSI when in fact it may still contain residual pressure. When actuating the door bolt lock assembly, the operator should be able to visually check the operation of the valve to the Autoclave. This is done by observing if the ball valve or plug valve is open.

The door bolt valve should be located so that, if actuated, any residual pressure in the Autoclave would not be directed toward the eyes of the operator. The door bolt lock assembly should be designed to withstand the force without damage of the hydraulic or mechanical actuation devices. Other features that should be interlocked electronically are as follows:

1) When activated, the door bolt "closed" micro-switch should disable and force the pressurization valves closed.

2) The door bolt lock system should be inspected every 30 days. When retracted, the door bolt lock assembly should override and force the Autoclave vent valve to the open position. In addition to the door bolt lock assembly, pressure switches should be connected to the pressure vessel thereby disabling all hydraulic or mechanical means of unlocking the vessel if pressure is above 0.5 PSI. It must be stressed to the operator that the electronic pressure switches do not relieve his responsibility for confirming zero pressure or the absence of flow from the door interlock. Pressure switches are not accurate enough to prevent the vessel from being unlocked with slight amounts of pressure remaining. In several incidents, operators did not monitor the door bolt lock for flow and simply relied on the pressure switches. Due to the oversight, the vessels were opened when approximately 1-2 PSI was present. If damage is discovered, the locking mechanism should be repaired immediately. Damage due to excessive force is usually limited to the hydraulic door actuation assemblies and hinge assemblies.

   TEC recommends that all door bolt assemblies be provided with two (2) locking sectors. This will insure that the locking ring does not under lock or over lock.

PRESSURIZATION SYSTEMS

Several problems have been observed with liquid nitrogen, LN2 vaporizers, liquid nitrogen injection systems and C02 systems.

Liquid nitrogen and C02 vaporization systems should all be fitted with low temperature cut off valves. These valves should be electro-pneumatic or electrically operated ball valves of the cryogenic type. Many LN2 systems have been supplied by various gas suppliers around the country utilizing solenoid valves for the safety shut-off valves. This type of valve has been known to freeze open on occasion causing catastrophic results. Over time, they become susceptible to wear and jamming and must be replaced. In addition, they are very susceptible to moisture and to contamination, which can occur during service. Replace these valves with cryogenic ball valves in a double block configuration (i.e., 2 valves with a relief valve installed in between). A manual ball valve should always serve as a back-up to all cryogenic valves.

The vaporization system should be fitted with two (2) thermocouple sensors mounted in the gas supply stream to the Autoclave.

The thermocouple sensors need to be interlocked in the control system, forcing the ball valves closed in the event of low temperature and under temperature detection. The type of controllers should be down scale burn out and should be tested and inspected every six months. The controllers can be integrated to the PLC control system or by an independent limit controller.

While not as common as inert gas pressurization, some vessels use direct injection utilizing the vessel heat at the vaporization source. The interlocks and safety requirements are very similar to the external vaporizer systems. For direct cryogenic injected vessels, a double ball valve configuration is the recommended replacement for solenoid valves. Several problems have occurred with valve shafts twisting due to when the maintenance personnel over-torque the packing. The vessels should be fitted with two (2) thermocouple sensors mounted in the bottom of the vessel.

The thermocouple sensors need to be interlocked in the control system, forcing the ball valves closed in the event of low temperature and under temperature detection. The type of controllers should be down scale burn out and should be tested and inspected every six months. The controllers can be integrated to the PLC control system or by an independent limit controller.

VESSEL CORROSION INSPECTION

Several Autoclaves have been observed with excessive vessel pitting. Usually this is caused by persistent leaks in cooling coils which have not been properly monitored. To compound the issue, the insulation at the bottom of the vessel can take a significant amount of time to dry out resulting in additional corrosion even though the source of the leak had been resolved. This vessel pitting and corrosion has never been attributed to vessel failures in Aerospace applications. As a precaution, vessels should be inspected for minimum thickness every five years. This inspection is typically limited to the bottom portion of the vessel between 5:00 and 7:00 where water would stagnate. An approved authorized, third party, inspection agency should conduct this inspection ultrasonically.

VESSEL MODIFICATIONS, ALTERATIONS & REPAIRS

It is perfectly acceptable, and in accordance with ASME regulations, to install nozzles, to make repairs including structural welding or surface welding, to modify and to alter pressure vessels. These modifications or repairs MUST be performed by an appropriately ASME registered agency such as Thermal Equipment Corporation. It is critical that the appropriate ASME reports and/or inspections be completed at the time of the work.

The user or any non-ASME approved organization should not weld, cut, add to or alter the pressure vessel in any way.

ELECTRIC DISTRIBUTION SYSTEMS

All Autoclaves will include a Motor Control Center (MCC) for distribution of the electrical power for motors, heaters and control voltage transformer. The MCC will typically include circuit breakers, feeder breakers, contactors, starters and motor overload protection relays. It is strongly suggested that the complete assembly be inspected on an annual basis. This includes all connections and component condition. Many companies utilize an Infrared camera to help locate hot spots and trouble areas. All connections including both the line and load side should be checked for proper torque. The contacts on both starters and contactors should be inspected for condition including pitting and welded contacts. Appropriate safety gear must be worn and appropriate practices should be exercised when working with this type of electrical equipment including, but not limited to, Lock-Out-Tag-Out.

ELECTRIC HEATING SYSTEMS

Electrically heated Autoclaves should be inspected approximately once a year. All contactors and silicon-controlled rectifier's (SCR's) should be inspected for proper functionality. On several occasions, contactors have partially hung up, leaving one or more legs of the heater energized when the contactor is not energized. This has also occurred with SCR's where they fail in the "ON" condition. Several systems have been observed with SCR control only on the heaters and did not include a contactor or other overriding device.

In the event of an SCR failure in the energized position uncontrollable heating would occur in the Autoclave. In this situation a manual power disconnect is the only remedy. This type of SCR failure can occur when the Autoclave is operating and even when it is not operating. A system failure of this type has never occurred in a TEC Autoclave due to the standard use of contactors. If you have an Autoclave manufactured by another vendor with SCR control only, we strongly suggest the addition of a contactor override on the SCR interlock to the safety and control systems.

All Autoclaves, whether gas or electrically heated, should be fitted with an independent over-temperature protection device with a manual reset. The over-temperature protection thermocouple should be mounted directly above the heater coil or elements in the Autoclave and interlocked to the main heater and SCR override contactors. It also should be connected to the alarm circuitry. The over temperature protection device is designed to disable the heater in the event of an over temperature condition. It should be of the upscale burn out configuration so that in the event of a loss of sensor, the heater will be disabled.

GAS FIRED SYSTEMS

Gas fired Autoclaves fabricated by TEC are extremely reliable and require little maintenance. The following suggestions provide the TEC customer with the best inspection procedure for maximum system reliability. It is suggested that a TEC qualified technician perform a complete inspection, evaluation and tuning of the heating system to help insure reliable operation and optimum performance.

INSPECTION

Once a year the following items should be inspected for function and performance:

1) In the event of an over temperature condition in the combustion chamber, the independent over-temperature device shuts down the combustion chamber. It should be set for a range of 1,200° F. to a maximum of 1,600° F.

2) High gas and low gas pressure switches should be inspected for function and performance. They both should terminate the combustion process and provide alarm indication.

3) The main gas supply, double block and bleed valves should be checked for leakage and proper function.

4) The pilot gas supply, double block valves should be checked for leakage and proper function

5) The low combustion air and dilution air pressure switches should terminate the combustion process. They should be inspected by field verification.

6) The UV scanner and programmer should be tested by simulating all alarms and flame indicators.

7) The condition of the blowers, gas train, combustion chamber internals, burner refractory and general condition and cleanliness of the combustion system should be inspected.

8) Motors and linkages should be inspected and greased as recommended by the manufacturer.

Suggested Combustion System Modifications:
On several occasions, inadvertent shut down or failure of the combustion mass (dilution) blower has caused damage to the combustion chambers due to overheating. The suggested modification, and TEC's standard practice, is to add an additional pressure switch to the combustion mass blower and to interlock it to the combustion control circuitry. This prevents inadvertent operation with the combustion mass blower disabled or a motor failure.

COMBUSTION HEATING COIL INSPECTION

Combustion heating coils typically have good operational longevity. The coils should be inspected annually for any leakage by pressurizing the vessel to approximately 15 PSI. After the vessel is pressurized to 15 PSI and stable at approximately 100 degrees F., all systems including the combustion chamber and fan motor should be secured and shut down. The combustion exhaust nozzle on the Autoclave should be inspected for any leakage of Autoclave pressure into the heating coil. Any leak that is large enough to be a concern can easily be heard.

In the event that a leak is noticed, it should be repaired only by a qualified ASME agency. Care should be taken when entering heating coil headers, especially when the vessel recently was in operation. Never enter the header when the vessel is pressurized as it is possible that there is a lack of oxygen. Personnel entering a heating coil header or combustion chamber should always receive adequate ventilation. In addition, all power sources to the equipment should be padlocked off utilizing appropriate "Lock out – Tag out" procedures.

FAN & FAN DRIVE SYSTEMS

All fan and fan drive components should be annually inspected and greased accordingly. Over greasing can cause bearing damage. Motor documentation provides manufacturer guidelines for greasing procedures.

Shaft seals and shaft drive assemblies, although not used on current TEC Autoclaves, have been the source of several incidents, none of which caused severe damage. Several thrust absorbing bearings on Autoclave shaft seal assemblies have failed causing the fan drive shaft to be displaced backwards from the Autoclave. This causes the fan to impinge on the sheet metal in the rear of the Autoclave and to result in system shut down due to an overload. The resulting damage to the internal sheet metal may cause extended down time. All fan shaft seal drive bearings, sheaves, guards, etc., should be inspected on an annual basis. Sheave guards and belt guards should never be left off after maintenance or be removed while the Autoclave is operating.

Regarding the use of mechanical seals with pressurized oil systems, several incidents occurred when oil from the seal assembly leaked into the insulation and work space of the Autoclave.

These Autoclaves were pressurized with compressed air only. Subsequent combustion of the oil, damaged the work load and Autoclave internals. Operators must notify maintenance immediately if they observe oil in the vessel. Simply removing the oil that is visible may not eliminate the hazard. Oil saturation of the insulation is a fire hazard. If maintenance observes a loss of oil in the seal oil feed system and the oil is not discharging outside of the Autoclave, it probably has impregnated the Autoclave insulation and should be attended to immediately.

Modification of the external motor, belt and sheave system to the encapsulated motor and seal-less design has proven to be very cost effective. TEC's fan motor and water cooled carbon steel coil are encapsulated in a pressurized fan motor housing.

Fan hub and fan shaft is a tapered fit with the fan wheel and motor shaft dynamically balanced. This style of enclosure eliminates the need for external bearings and seals. This equates to dramatically increased reliability and near zero maintenance.

VACUUM SYSTEMS AND VACUUM SYSTEM COMPONENTS

All vacuum system components are either designed for full vessel pressure or have relief valve protection. This applies to all pipe work, valves, receivers or vessels located in the vacuum system. Several users have expressed concern about the potential toxicity of cure products collecting in vacuum systems. The safety department should review the chemicals and by-products that exist in the vacuum systems. In collaboration with the maintenance department, they should review safety procedures whenever in contact with the vacuum system.

VESSEL PURGING SYSTEMS

Oxygen monitoring and detection systems confirm whether sufficient oxygen is present to sustain life in the vessel. This feature is especially important when vessels are pressurized with nitrogen, carbon dioxide or other inert gases. Unfortunately, many users do not maintain the calibration of this equipment. The system should be calibrated on a six month interval per manufacturer's procedures. In the purge blower systems, it is completely acceptable to simply operate the main Autoclave fan motor for a period of approximately 3 to 5 minutes with the door fully open. Due to the installation characteristics this method may not be acceptable and a purge blower would be required. Some facilities use plant air as the purge source but this will require a significant amount of volume coupled with the problem of water and oil in the air lines. Any inert gases and volatiles must be adequately purged from the vessel prior to entering.

It is TEC's advice that ALL Autoclaves large enough to allow a person to enter should be provided with an appropriate purge system and oxygen analyzer. Please note that it is strongly recommended that all personnel entering the Autoclave also carry a portable analyzer. Portable or remote oxygen monitoring systems alert personnel when an oxygen deficiency exists. The analyzer systems should be inspected and calibrated per the manufacturer's recommendations.

The purge blower system should be inspected and tested on an annual basis as a minimum. This inspection should include an operational check of the purge blower motor and the isolation valve. TEC has been advised by our customers of several catastrophic failures of the purge systems. These failures typically involve compromised safety interlocks or operator error. There have been a few instances where the valve or valve positioner isolating the purge blower failed, causing the isolation valve to open with the Autoclave at pressure. Please note that this type of failure typically has catastrophic results and can include damage to the equipment as well as injury to personnel.

In an effort to provide the safest Autoclaves in the industry TEC includes a high flow, high pressure check valve in line with the isolation valve and the purge blower assembly. TEC has made this important safety feature part of our standard supply with a purge blower system for the past ten years. The check valves are a critical safety device and TEC suggests making this modification on all Autoclaves that have a purge blower if a check valve is not already present.

PERSON IN VESSEL ALARM SYSTEM

All vessels sufficiently large enough to allow personnel to enter should be fitted with an internal switch, cable or device interlocked with the alarm and control system. When this device is pulled or activated inside the vessel, the pressurization system is disabled, the heating system is disabled, the vent system is forced to the fully opened position and an alarm is activated. All operational and loading personnel should be fully briefed on the location of this device inside the vessel. All operators should be briefed on procedures in the event of activation. This system should be tested and confirmed operable every six months. Regardless of whether this alarm system is present, the operator is responsible to confirm that personnel do not remain in the vessel before closing and locking the door. It is very difficult to locate this alarm in a dark vessel that is fully loaded. It is the management' responsibility to enforce safety procedures.

TEC's control system is configured to flash the Autoclave lights during the door operation. As the Person in Autoclave cable runs the length of the Autoclave, this should provide sufficient time to access the cable. We also turn the lights for five (5) minutes on once we get the door closed signal.