

Thermal Equipment Corporation

Autoclave Safety Requirements / Recommendations

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VESSEL SAFETY

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.

It is the end user's responsibility to inspect the following items for correct function on a regular basis.

SAFETY VALVE

In accordance with the ASME requirements, at least one mechanical relief valve should be installed. 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

All autoclaves should be equipped with a rupture disk. The rupture disk should also be capable of relieving 30% more than the flow from all sources of pressurization. Rupture disks prove to be very helpful in preventing damage usually caused by malfunctioning safety valves and inlet valves or by fires in the autoclave.

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 part load in the autoclave.

PRESSURE VESSEL MAINTENANCE

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

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:

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- 1) Whenever the operator actuates and locks the door, it is the OPERATOR'S RESPONSIBILITY to confirm that the door is properly locked and aligned. Operators should be instructed in the correct start-up procedure, which will confirm the relative position of all closure components. Problems have been observed in doors becoming offset to one side, which dramatically reduces the engagement area of the wedges. This problem can be solved with the addition of wear plates installed inside the closure. Wear plates reduce the tolerances between the locking ring, shell flange and head flange. They should be added to all older breech-lock type closures. TEC's current design maintains low tolerances, eliminating the need for the additions of wear plates.
- 2) All wedges and sliding surfaces of the closures should be inspected on a monthly schedule 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 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:

SS 30 Colloidal Copper
Chesterton Antiseize

The above-recommended products should be applied sparingly and applied to the wedges only. 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, an ASME certified inspector should examine the closure mechanism every year. A non-destructive examination (NDE) should be conducted on all lugs, welds and components of the closure assembly.

In the event that a problem is noticed, repair should be executed by a qualified ASME agency. The repair should be performed such that the original design dimensions are maintained.

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SPLIT RING CLOSURE MAINTENANCE

The majority of hydroclaves are fitted with a split ring or segmented split ring closure. This type of closure is usually pinned together at each segment section. Pins on several older hydroclaves have shown excessive wear and elongation, a potential problem area if proper pin alignment does not exist. All sliding surfaces should be cleaned, greased and inspected. The hydroclaves should also be inspected for split ring angle. This angle should not exceed one degree from the coplanar.

OVER PRESSURE SWITCH

All autoclaves should be fitted with an overpressure device, which senses autoclave 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, thus reducing the risk of fire during the initial un-pressurized heating portion of the cycle. This can be done by slightly pressurizing the autoclave and then venting it several times. It also can be accomplished, if the pressurization inlet valve and vent valve do not share a common nozzle, by opening the vent valve and fill valve simultaneously.

CAMROLLER 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 of the camrollers or absence of concentricity can allow the locking ring to become uncentered causing a problem similar to a misaligned door. Camrollers should be inspected concurrently with door adjustment and door centering procedures.

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VESSEL AND NOZZLE MAINTENANCE

An annual 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. Every three years, the nozzles should be inspected by a non-destructive examination (NDE). This inspection can be limited to nozzles over 2 inches in diameter. 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. Continued autoclave operation, is only acceptable as long as the mean metal temperature of the pressure vessel material and nozzle does not exceed the maximum temperature stated on the ASME name plate and the hot location is protected from possible contact by personnel.

DOOR INTERLOCK ASSEMBLY

Door interlock assemblies should be inspected on a monthly schedule.

Many autoclaves have been observed with either improper or non-functional 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 opens a valve directly into the vessel. The door bolt assembly also engages the autoclave lock ring to prevent it from being rotated unless the bolt is retracted. The bolt should also be fitted with a micro switch to disable the hydraulics in the event that the door bolt is not fully retracted. The bolt should also be fitted with a pneumatic cylinder, which locks the door bolt assembly in the closed position when the pressure in the autoclave is above 1/4psig or 0.5psig.

A lack of maintenance and inspection can cause the door bolt lock, when retracted, not to actuate the valve, which directly accesses the workspace. When actuating the door bolt assembly, the operator should be able to visually check the operation of the valve to the autoclave. This is done either by observing if a ball valve or plug valve is open or by looking into the autoclave.

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 of the lock ring rotation hydraulic system, without damaging the hydraulic or mechanical actuation devices. Other features that should be interlocked electronically are as follows:

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

Thermal Equipment Corporation

- 2) The door bolt lock assembly, when retracted, should override and force the autoclave vent valve to the open position. In addition to the door bolt lock assembly, redundant 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 in the autoclave and the absence of flow from the door bolt interlock valve. 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 this oversight, the vessels were opened when approximately 1-2 psi was present. Damage due to excessive force is usually limited to the hydraulic door actuation assemblies and hinge assemblies. If damage is discovered, the locking mechanism should be repaired immediately.

TEC recommends that an additional locking sector be added to the lock ring so the door bolt interlock will close in only one position. This is to ensure that the locking ring does not under-lock or over-lock. This is TEC's current practice.

PRESSURIZATION SYSTEMS

Several problems have been observed with liquid nitrogen (LN₂), LN₂ vaporizers, LN₂ injection systems and carbon dioxide (CO₂) systems.

LN₂ and CO₂ 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.) They are approximately 99% reliable. 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.

For direct cryogenic injected vessels, a double cryogenic ball valve configuration is the recommended replacement for solenoid valves. Several problems have occurred with *Worcester* valves twisting due to maintenance personnel over-torquing the packing. We suggest that the *Worcester* valves be replaced with *TBV* valves. These vessels should be fitted with 2 thermocouple sensors mounted in the bottom of the vessel. The thermocouple sensors need to be interlocked to an independent controller that forces the ball valves closed in the event of low temperature or under temperature detection. The type of controller should be down scale burn out and should be tested and inspected every six months.

VESSEL CORROSION INSPECTION

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Several autoclaves have been observed with excessive vessel pitting. This is usually caused by persistent leaks in cooling coils, which have not been properly repaired and monitored. 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 o'clock and 7 o'clock where water would stagnate. An approved authorized inspection agency should conduct this inspection using ultrasonic examinations.

HYDROCLAVE CORROSION INSPECTION

The hydroclave vessel, piping and auxiliary equipment should be inspected for minimum thickness every year.

VESSEL MODIFICATIONS, ALTERATIONS & REPAIRS

It is perfectly acceptable to install nozzles, to make repairs including structural welding or surface welding, to modify, and to alter pressure vessels, as long as it is performed in accordance with ASME code regulations and by a certified code shop.

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

ELECTRIC HEATING SYSTEMS

Electrically heated autoclaves should be inspected approximately once a year. All contactors and 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. Several systems have been observed with SCR control only on the heaters and without any contactor or other overriding device. In the event of an SCR failure in the energized position, uncontrollable heating would occur in the autoclave. A manual disconnect is the only remedy. This SCR failure can occur when the autoclave is operating or not. A system failure of this type has never occurred in a TEC autoclave. 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 system.

All autoclaves should be fitted with an over temperature protection device. This over-temperature protection thermocouple should be mounted directly above the heater elements in the autoclave workspace and interlocked to the 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.

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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.

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 combustion chamber over-temperature device shuts down the combustion chamber. It should be set for a range of 1200 degrees F. to a maximum of 1600 degrees F. in autoclaves and a maximum of 2000 degrees F. for un-pressurized oven systems. The controller should be configured for upscale burnout in the event of a loss of sensor.
- 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 gas supply, double block, proof of closure switch and bleed valves should be checked for leakage and proper function.
- 4) The low combustion air pressure switch should terminate the combustion process. It can be inspected by field verification.
- 5) The UV scanner and programmer should be tested by simulating all alarms and flame indicators.
- 6) The condition of the blowers, gas train, internals and general cleanliness of the combustion system should be inspected.

Suggested Combustion System Modifications:

On several occasions, inadvertent shut down of the combustion mass blower has caused superficial surface damage to the combustion chambers due to overheating. The suggested modification (and our current 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. Details of this modification will be provided upon request.

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COMBUSTION HEATING COIL INSPECTION

Combustion heating coils typically have good operational longevity. The coils should be inspected annually for any leakage by operating the autoclave normally and 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 shut down. The combustion nozzle should be inspected for any leakage of autoclave pressure into the heating coil by listening inside the coil nozzles.

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 coils especially when the vessel is either pressurized or recently was in operation. It is possible that there may be a lack of oxygen. Personnel entering a heating coil or combustion chamber should receive adequate ventilation. In addition, all power sources to the equipment should be padlocked off.

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 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. 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 have occurred when oil from the seal assembly leaked into the insulation and workspace 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 and should be attended to immediately.

Modification of the shaft seal device assemblies to encapsulated motor and seal-less systems has proven to be very cost effective.

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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 absence of 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. Any inert gases will be adequately purged from the autoclave. Portable or remote oxygen monitoring systems alert personnel when an oxygen deficiency exists.

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 in 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's responsibility to institute and enforce safety procedures.