EXHIBIT L

The Chlorine Institute, Inc.

Pamphlet 5

Bulk Storage of Liquid Chlorine

Edition 7

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1. INTRODUCTION

1.1 Scope

This pamphlet is intended to apply to the design, construction, location, installation and inspection of liquid chlorine storage systems. The recommendations are based on storage in horizontal, cylindrical tanks. Some recommendations in this pamphlet may apply to small process tanks, both horizontal and vertical. The recommendations may have to be modified to meet local requirements. General information on safe handling is not included; prospective designers and operators of such facilities must be familiar with such information and are referred to the chlorine supplier and material referenced.

It is recognized that storage facilities built prior to the publication of this edition of this pamphlet may be operating successfully without adhering to all recommendations contained herein. Operators of such facilities should evaluate discrepancies and validate that they do not pose disproportionate risks to safe operation or the environment. Continued operation without adhering to all aspects of this pamphlet is generally acceptable provided that:

- Previous successful long-term operation, coupled with periodic hazard evaluations, show that risks to safe operations and the environment is sufficiently low.
- The system does not violate applicable codes or regulations.
- Consideration is given to modifying the system to meet recommendations contained in this edition of the pamphlet when redesign or replacement projects are planned.

1.2 Chlorine Institute Stewardship Program

The Chlorine Institute, Inc. exists to support the chlor-alkali industry and serve the public by fostering continuous improvements to safety and the protection of human health and the environment connected with the production, distribution and use of chlorine, sodium and potassium hydroxides, and sodium hypochlorite; and the distribution and use of hydrogen chloride. This support extends to giving continued attention to the security of chlorine handling operations.

Chlorine Institute members are committed to adopting CI's safety and stewardship initiatives, including pamphlets, checklists, and incident sharing, that will assist members in achieving measurable improvement. For more information on the Institute's stewardship program, visit CI's website at www.chlorineinstitute.org.

1.3 Definitions

In this pamphlet, the following meanings apply unless otherwise noted:

ANSI	American National Standard Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing & Materials
CGA	Compressed Gas Association

chlorine	dry chlorine (either gas or liquid)
Code	see ASME Code (10.2)
design pressure	the most severe condition of coincident pressure and temperature expected in normal operation. See UG-21 of the Code.
DOT	U.S. Department of Transportation
ERW	electric-resistance welded
gas padding	the addition of clean, dry, oil-free, compressed air, nitrogen or chlorine in order to increase system pressure. Air or nitrogen must be dried to a dew point of -40°F (-40°C) or below measured at the operating pressure.
gas purge	the use of clean, dry, oil-free, compressed air or nitrogen in order to displace chlorine, moisture or other contaminants from a tank or system. Air or nitrogen must be dried to a dew point of -40°F (-40°C) or below measured at the operating pressure.
Institute	The Chlorine Institute, Inc.
kPa	kilopascals (gage reading)
MAWP	maximum allowable working pressure at the top of the vessel at the designated coincident temperature for that pressure. See UG-98 of the Code.
OSHA	Occupational Safety and Health Administration, U.S. Department of Labor
psig	pounds per square inch gage
set pressure	the pressure measured at the valve inlet, where a pressure relief device is set for the start-to discharge
subcool	extent to which a liquid is cooled below its flashing temperature at the applicable pressure
tanks	stationary chlorine storage containers
TC	Transport Canada
ton	two thousand pounds
vapor tight pressure	the pressure, measured at the inlet of a closed valve or pressure relief device below which no fluid flow is detected at the downstream side of the seat.

1.4 Disclaimer

The information in this pamphlet is drawn from sources believed to be reliable. The Institute and its members, jointly and severally, make no guarantee and assume no liability in connection with any of this information. Moreover, it should not be assumed that every acceptable procedure is included or that special circumstances may not warrant modified or additional procedure. The user should be aware that changing technology or regulations may require a change in the recommendations herein.

Appropriate steps should be taken to insure that the information is current when used. These recommendations should not be confused with federal, state, provincial, municipal or insurance requirements, or with national safety codes.

1.5 Regulatory & Insurance Requirements

The location, capacity, design, maintenance and operation of chlorine storage installations may be subject to federal, state, provincial or local regulations and to insurance company requirements. Owners and designers should verify that installations will fully comply with all applicable requirements.

1.6 Approval

The Institute's Storage and Transport Committee approved Edition 7 of this pamphlet on May 26, 2005.

1.7 Revisions

Suggestions for revision should be directed to the Secretary of the Institute.

1.8 Reproduction

The contents of this pamphlet are not to be copied for publication, in whole or in part, without prior Institute permission.

2. CHLORINE STORAGE CAPACITY

2.1 General

The capacity of liquid chlorine storage tanks at producer and consumer locations should be kept to a minimum. The number of tanks should be the minimum which will satisfy operation, inspection, inventory and transportation requirements.

2.2 Storage Capacity

The total liquid chlorine storage is the sum of inventory in fixed storage and in transportation equipment. The total liquid storage capacity, and the number and sizing of the storage tanks, should be based on the following:

$ Local risk assessment

$ The relative merits of fixed storage versus inventory in transportation equipment

$ For batch transfers, the need for two tanks at the consuming site to deliver a continuous supply

$ The need for periodic out-of-service tank inspection

$ The relative merits of tank size versus system complexity and number of potential leak points inherent in multiple tanks or multiple transfer designs

$ Shipping logistics (trucks, tank cars, and barges)

$ Regulations that may influence the size and number of storage tanks (For instance, the Coast Guard requires chlorine barge loading to be done from weighed shore side chlorine storage tanks. Ideally, these tanks should be large enough to handle one barge tank. The goal is to minimize the number of transfers per barge tank.)

$ The size of the shipping container (If a storage tank is to receive and hold the total contents of a shipping container, consideration should be given to sizing the tank to 120 percent of the container size.)

$ The methods used to load and unload a storage tank (If a tank receives and discharges chlorine in a semi-continuous mode, the size should be based on providing an adequate volume to allow controls to keep the tank inventory within design limits.)

2.3 <u>Tank Car and Tank Motor Vehicle Sizes</u>

Rail tank cars commonly have chlorine capacities of 55 tons (49,900 kg), 85 tons (77,100 kg) or 90 tons (86,646 kg).

In North America, most tank motor vehicle trucks have chlorine capacities of 16 to 22 tons (14,500 kg to 20,000 kg).

2.4 <u>Chlorine Barge Sizes</u>

Two styles of chlorine barges are in common use in North America; these are the inland and ocean service barges.

Most inland service chlorine barges are of the open type with four independent, cylindrical, uninsulated pressure tanks mounted longitudinally. The common barge capacities are 1100 tons (997 Mkg), 4 tanks at 275 tons each and 1200 tons (1080 Mkg), 4 tanks at 300 tons each.

A different barge is utilized for ocean chlorine service, principally on the west coast. These are flush deck barges with two, three or four independent chlorine tanks mounted on the deck. Each tank has a nominal capacity of 300 tons (270 Mkg).

2.5 <u>Using Shipping Units for Fixed Storage</u>

Chlorine shipping tanks built in accordance with ASME and Coast Guard regulations for chlorine barges may be converted to stationary tanks.

Chlorine tank cars manufactured to DOT standards are not ASME vessels. Conversion of tank cars to fixed storage containers is not recommended. Existing conversions should be reviewed for replacement.

Although not recommended for conversion to fixed storage, chlorine tank cars built in compliance with Specification DOT (or TC) 105J500W are acceptable and commonly used as on-track storage (10.1.1).

Permanent installation of chlorine ton containers as stationary tanks is not acceptable because they are not equipped with pressure relief valves and are not ASME vessels.

3. TANK LOCATION

3.1 Location Considerations

Chlorine storage tanks should be located in separate, clearly-defined areas that can be isolated in emergencies and are accessible to emergency personnel. The chlorine storage area should be protected by barriers or separated from other processes or materials which might damage the storage tanks. A separation consistent with acceptable loss prevention practice is recommended. The location should be chosen to minimize the possibility of external corrosion and the possibility of damage by vehicles, fire or explosion. The direction of prevailing winds should be considered in order to minimize the impact of leaking chlorine.

To help prevent damage to chlorine storage tanks, they should be located away from property boundaries where visibility from outside the plant is limited. Barriers around tanks should also be considered as means to prevent damage to storage tanks.

3.2 Lighting

Special attention must be given to lighting in the area of storage tanks. Even if night operations are not contemplated, effective lighting should be installed as an aid in dealing with possible night emergencies. Emergency lighting should be available in case of power failure.

4. TANK DESIGN AND CONSTRUCTION

4.1 Process Considerations

4.1.1 Volume

The capacity considerations discussed in Section 2.0 are stated in terms of tons (short) of liquid chlorine. The density of liquid chlorine decreases considerably with increasing temperature. The volume of the storage tank(s) must therefore provide adequate room for expansion.

The chlorine tank volume shall be at least 192.2 U.S. gallons for each ton of chlorine stored. (Using this guideline, a tank that is fitted with a relief device set at 225 PSIG and allowed to warm up to a temperature of 122F will not relieve and will only be approximately 95% full of liquid.) Tanks should never be filled beyond its rated tonnage.

4.1.2 Pressure

Vessel design pressure should be at least 120% of the maximum expected operating pressure and in any case, not less than 225 psig (1551 kPa). If air or inert gas padding is contemplated, allowance must be made for the increased pressure that may develop.

For small installations, or at any site where a tank will remain isolated for extended periods, consideration should be given to a design pressure of 375 psig (2586 kPa). The higher design pressure will allow isolation of a tank filled and padded in accord with Institute Drawing 201 (10.1.13).

All tanks should be rated for full vacuum.

4.2 <u>Mechanical Considerations</u>

4.2.1 General

Except as specifically noted, tanks should be designed, constructed, inspected, tested and marked in accordance with parts UW and UCS of the Code. Construction shall be such that the maximum allowable working pressure shall be limited by the shell or head, not by minor parts. All longitudinal and circumferential seams should be located to clear openings and their reinforcing pads.

All tanks for chlorine service shall be fabricated of appropriate materials in accordance with the Code. With the exception of the nozzle to vessel joint, all joints shall be double-welded (or equivalent) butt joints, and shall be 100% radiographed in accordance with Section V of the Code (10.2.1). The weld joint connecting nozzles to the tank shall be full penetration welded extending through the entire thickness of the vessel wall or nozzle wall. The weld seam of ERW pipe, if used for nozzles, shall be fully radiographed. The vessel shall then be heat treated as outlined in Section 4.2.4. With exception of longitudinal welds, nozzles equal to or less than 10 inches may be ultrasonically tested in accordance with Section V of the Code in place of radiography.

4.2.2 Material Specifications

New tanks, including manway covers, shall be fabricated from normalized carbon steel complying with the current edition of ASTM Specification A516, Grade 70 or ASTM Specification A612, Grade B for service conditions not lower than -40°F (-40°C). Tank plate material and the welded plate specimens shall meet the Charpy V-Notch test requirements of the current edition of ASTM A20 at a minimum temperature of -40°F (-40°C).

4.2.3 Thickness

The wall thickness of tanks should be at least 1/8-inch (3.18 mm) greater than that required by the design formula in the Code to allow for corrosion.

4.2.4 Post-Weld Heat Treatment

Fabricated tanks shall be post-weld heat treated. The procedure shall meet the requirements of the current edition of the Code. In addition, the maximum temperature in the PWHT process shall not exceed 1250°F (677°C).

4.3 <u>Exterior Corrosion</u>

Exterior corrosion due to moisture condensation can be a serious problem. Tank design should be such as to minimize the collection of condensation. Particular attention should be paid to the area around the supports and nozzles.

4.4 <u>Supports</u>

Common industrial practice is for horizontal tanks to be supported by two saddles. Support designs must satisfy ASME Code requirements. These saddles should be designed and spaced to prevent excessive stress on the shell. If seismic considerations are a local concern, the structural design of the tank, nozzles, saddles, foundations, piping, and associated supports must be such that appropriate system ductility is maintained under design external forces, thereby preventing leakage.

The design of the supports should minimize the possibility of moisture accumulation between the tank and saddles. Provisions should be made to permit thermal contraction and expansion of the tank. Adequate restraints should be provided to minimize uplift and lateral movement resulting from flooding, explosion, earthquake, etc. If more than two saddles are used, special attention should be paid to avoiding misalignment, expansion, differential settling and moisture accumulation.

Where failure of weigh elements or scales installed under the storage tank will allow the tank to drop, safety piers must be provided (5.6). These safety piers are designed to minimize the fall of the tank to a fraction of an inch. Safety pier design should accommodate normal tank movement during product transfer operations so as not to interfere with the function of the scales.

4.5 Insulation and Painting

Tank insulation is not required; however, it may be useful to reduce effects of extremely high or low ambient temperatures. If used, tank insulation should be chlorine-resistant and fire-resistant material. To prevent corrosion of the shell, insulated tanks should have an appropriate exterior painting system. The outside of the insulation should be sealed and weatherproofed. Uninsulated tanks should have a reflective (white) surface maintained in good condition.

4.6 Tank Openings

In general, openings should be in the top of the tank and should be flanged nozzles. Minimum flange size should be 1-inch nominal. Shut-off valves should be considered for all openings. A manway not less than 18-inch inside diameter must be included.

In special cases, it may be deemed appropriate to locate tank nozzles on the sides or bottom of the storage tank. In these special situations, the possibility of chlorine spillage must be dealt with during the design and operation of the system. Utilization of protective devices for the specific nozzle in question, remote operating shut-off valves, storage area isolation barriers, maintenance and inspection procedures, and special tank supports must be given consideration if openings are to be utilized anywhere other than on the top of the tank.

5. TANK APPURTENANCES

5.1 Pressure Relief Devices

5.1.1 General

All storage tanks within the scope of this pamphlet must be protected from over-pressure in accordance with the Code. To ensure continuous operation all storage tanks should be equipped with two relief devices. Each one of the relief devices should be sized to provide the total relief requirement. (For large atmospheric storage tanks multiple relief devices may be required to provide adequate relief.) Piping must be arranged so that one of the relief devices always provides protection for the tank. This can be accomplished by using a three way valve or a mechanically linked set of valves. Valves installed between the vessel and the pressure relieving devices shall have a port area that is at least equal to the inlet area of the relieving device.

Local regulations may require pressure relief devices to be ASME certified. See relief device recommendations contained in Pamphlet 6 (10.1.2). If the inlet of the relief valve selected requires protection by either a breaking pin assembly or a rupture disc, then the space between the pin or disc and the pressure relief valve shall be equipped with pressure indication or suitable telltale indicator. This arrangement permits detection of breaking pin operation or diaphragm leakage.

Consideration should be given to collecting relief device vent discharges. Some issues with collection include the following:

  $ Pressure relief devices not vented to atmosphere should be designed to insure the vent system does not impede the vent flow.

  $ The potential for corrosion in the discharge side of pressure relief devices not vented to atmosphere must be taken into account.

If discharges are not collected, appropriate safeguards should be taken to minimize the possibility of a pressure relief device actually venting to the atmosphere. Such safeguards should include:

  $ An assessment of the probability of the pressure approaching the pressure relief device setting.

  $ Systems designed to prevent overfilling and to monitor pressure.

  $ A means for reducing the pressure through non-atmospheric venting.

5.1.2 Flow Capacity

In order to determine the minimum required flow rate capacity of the relief system, several factors must be considered in the design. The most conservative, technically feasible scenario for the tank should be considered when determining the size criteria for the valve. Sizing scenarios and factors to consider include:

$ volumetric fill rates, including accidental filling created by reverse flows

$ pressure relief device piping arrangement and the possibility of simultaneous discharges into a single collection system

$ tank insulation

$ proximity of the tank to sources of fire and effect of external fire

$ internal and external heat sources (e.g. tracing, insulation)

$ chemical reactions

$ insurance carrier requirements

$ regulatory or site specific requirements

$ liquid thermal expansion

$ reduction in flow out of the tank

$ composition change

$ momentum surge

The design should take all aspects into consideration and use good engineering practices to select a scenario for the proper flow capacity calculations. In the event a fire cannot reasonably be ruled out, the fire scenario must be considered.

For the fire sizing scenario, the following formulas for minimum flow are taken from CGA Pamphlet S-1.3, Part 3 (10.4.1).

Uninsulated Tank

The minimum required flow capacity of the pressure relief device(s) should be calculated using the formula:

$$Q_a = 0.3\ G_u A^{0.82}$$

$ Symbols above are defined as follows:

Q_a = required flow capacity in cubic feet per minute of air at standard conditions (60°F and 1 atmosphere)

G_u = gas factor for uninsulated container, see below

A = total outside surface of the container in square feet

The 0.3 or 30% factor in the above formula assumes that the chlorine storage tank is suitably isolated from possible envelopment in a fire or is equipped with a suitable water spray or fire extinguishing system.

Insulated Tank

Where the entire insulation system can be shown to be effective at 1200°F, the minimum required flow capacity of the pressure relief device(s) should be calculated using the formula:

$Q_a = G_i U A^{0.82}$

$ Symbols above are defined as follows:

G_i = factor for insulated container, see below

A = total outside surface of the container (square feet)

U = total thermal conductance of the container insulating material at 1200°F, Btu/hr-ft^2-F.

thermal conductance = thermal conductivity in Btu-in/hr-ft^2-F divided by thickness of insulation in inches

Values for G_u and G_i

For chlorine at the design pressure of 225 psig, with a corresponding flow rating pressure of the valve at 270 psig, the value of G_i is 6.7 and the value of G_u is 54.3 (Table 1 of 10.4.1).

When flow rating pressures lower than 270 psig are used, the values of G_i and G_u are on the safe side and may be used as shown or calculated as indicated below. For higher flow rating pressures than shown, values of G_i and G_u must be calculated from the following formulas:

$$G_u = \frac{633,000}{LC}\left[\frac{ZT}{M}\right]^{1/2}$$

$$G_i = \frac{73.4 \times (1200 - t)}{LC}\left[\frac{ZT}{M}\right]^{1/2}$$

$ Symbols above are defined as follows:

L = latent heat at flowing conditions in Btu per pound

C = constant for gas or vapor related to ratio of specific heats ($k = Cp/Cv$) at 60°F and 14.7 psia (Table 4 of 10.4.1)

Z = compressibility factor at flowing conditions

T = temperature in °R (Rankine) of gas at pressure at flowing conditions (t + 460)

M = molecular weight of gas

t = temperature in °F of gas at pressure at flowing conditions

When compressibility factor "Z" is not known, 1.0 is a safe value of "Z" to use. When gas constant "C" is not known, 315 is a safe value of "C" to use.

5.2 Operating Valves

Valves should be suitable for chlorine service at the most severe combination of temperatures and pressures expected. Valves mounted directly to tank nozzles should be flanged body construction with class 300 ANSI minimum rating (10.1.2).

5.3 Emergency Shut-Off Devices

To prevent loss of the contents in case of line rupture, installation of emergency shut-off devices on liquid lines should be considered.

5.4 Inventory Measurement

Over filling may result in excessive hydrostatic pressure and consequent loss of chlorine through the pressure relief device(s). Reliable means must be provided for determining the amount of chlorine in a tank at any time. Weight-measuring devices are preferred for this purpose because they are reliable, not affected by changing density and do not require an additional opening in the tank. Weight measuring devices may be required by government regulations. If level indicating devices are used, redundancy is required to assure reliability. Gage glasses should not be used.

5.5 Pressure Measurement

A pressure sensing device, which can be isolated from the tank by a shut-off valve, should be installed on every storage tank.

5.6 Piping

For general piping recommendations, see ASME B31.3 (10.2.4) and Pamphlet 6 (10.1.2). Piping from stationary supports to the chlorine storage tanks must be designed to provide sufficient flexibility to permit effective operation of weighing devices and to avoid pipe rupture in the event the tank falls from its primary support to the safety pier referred to in Section 4.4. Forces such as thermal expansion, impact, seismic and hydraulic should be considered.

6. SPILL CONTAINMENT

6.1 Design

All new stationary chlorine storage tanks should be installed in a diked area. The diked area should have a sloping floor leading to a sump. Specific procedures should be provided for emptying rainwater from the diked area. The diked area, including the sump, should be designed to hold the contents of 110% of the largest storage tank, but not so large as to provide excess surface area for vaporization. It should be recognized that diking alone does not provide full containment, due to the high vapor pressure of chlorine. Emergency procedures should be developed for disposal or recovery of spilled chlorine.

In many existing storage tank installations, diked areas were not provided based on historical data which validated chlorine storage tank reliability. These installations should be considered for retrofitting based on risk analysis and logistics. If retrofitting is not practical, spill mitigation must be addressed in plant emergency plans.

The severity of a leak/spill is reduced by lowering the pressure of the system. It is important to have a place to vent the vessel gas pressure, such as a scrubber system, gaseous chlorine process/user, or a low pressure tank. Some operations have a low pressure tank for emergency pressure reduction from liquid pipelines or tank pads.

6.2 Housekeeping

The area around liquid chlorine storage tanks and containments should be designed for adequate emergency clearances and good housekeeping. The area under and around the storage tanks should be kept clear of debris, materials, and vegetation.

6.3 Emergency Response

Operators of chlorine storage facilities must develop an emergency plan. Reference is made to Pamphlet 64 (10.1.5).

7. CHLORINE TRANSFER

7.1 Selection of Transfer Method

Selection of the appropriate method of transfer of liquid chlorine from storage tanks must take into consideration the safety, process, and environmental aspects during normal, start-up/shutdown and emergency circumstances. A review of these considerations will usually determine the final selection or combination of methods of transfer.

In addition to the primary transfer method, installation of a backup means of removing liquid should be considered such as a spare dip pipe.

CAUTION: Emptying a tank by vaporization of liquid at low temperatures may concentrate NCl_3 to dangerous levels.

7.2 Methods of Transfer

Methods generally involve one or a combination of the following:

$ use of chlorine vapor pressure in the storage tank to discharge liquid via a dip pipe

$ padding the chlorine storage tank with a dry, compressed gas (e.g. air, nitrogen or chlorine)

$ transfer of liquid chlorine to a separate tank; then, transfer it again using a pump specially designed for liquid chlorine

$ a special case of a bottom or side suction to an external pump specially designed for liquid chlorine (4.6)

$ use of a specially designed, submerged liquid chlorine pump installed inside (via top opening) the liquid chlorine storage tank

7.3 Transfer Using Vapor Pressure

For some applications the vapor pressure of liquid chlorine in a storage tank will be sufficient to transfer liquid chlorine via a dip pipe to the delivery points.

A problem may develop with this method in the winter months from insufficient vapor pressure due to low temperature in outdoor installations (Figure 9.1of The Chlorine Manual (10.1.1)). Advantages of this transfer method are that processes that cannot tolerate air or nitrogen do not risk being contaminated and the vapor can be recovered as a liquid or gas.

7.4 Transfer by Gas Padding

Gas padding of chlorine storage tanks to remove liquid chlorine via a dip pipe is one of the most common methods of transfer used. The gas used must be dry, oil free and non-reactive with chlorine. Typically compressed dry air, nitrogen, or chlorine are utilized for this method. Pad gas solubility in chlorine and flow through of pad gas to consuming processes should be considered.

Compressed nitrogen may be produced from a commercially designed liquid nitrogen evaporation unit. Air is usually provided by installing a compression and drying system that will furnish adequate volume at a pressure above the chlorine tank pressure. A separate and independent air/nitrogen system should be considered for padding. This will minimize the possibility of getting chlorine back into air or nitrogen systems (especially instrument air systems). When pad systems are not independent, automatic backflow prevention systems, check valves and high/low pressure alarms should be used to prevent the back flow of chlorine. The materials of construction used in the padding supply system should be reviewed to assess their stability with chlorine.

Chlorine gas is sometimes used in padding storage tanks. Chlorine gas is furnished by recompression of chlorine vapors from other storage tanks, or from vaporization of liquid chlorine. When using chlorine gas recompression, care must be taken that vent gases which might contain contaminants (hydrogen, moisture, or organics) do not accumulate in the storage system. Care should be taken in specifying the chlorine compressor system for this method. It should be noted that the addition of chlorine vapor to a tank containing cold chlorine could cause partial condensation of the vapor. Extra precautions must be taken to prevent over filling the tank.

7.5 Transfer by Pumping

Whether one chooses to use internal vertical or external pumps, consideration must be given to the following:

Minimum pump flow requirements shall be provided by recycle.

NPSH (net positive suction head) availability must exceed NPSH requirements for all operating conditions.

The pumping system should include high and low inventory alarms on the supply tank and low pressure alarm on the pump discharge.

The pump should be interlocked to shut down on low supply level or low discharge pressure.

Pump materials of construction must be compatible with dry liquid chlorine at all temperatures expected.

If NPSH is provided by subcooling, tanks should be insulated.

In a submerged pump installation, seal gas should be dry, oil-free and inert with chlorine. At a minimum, the seal chamber should be a double-packed type with seal gas pressure at least 10 psig over tank pressure. Consideration should be given to a backup seal gas system in case of failure of the main source.

Careful attention should be given to the pump assembly, its construction and the potential for plugging.

Alternate means should be provided for emptying the tank for routine maintenance or emergency shutdown.

Interlocks to shut down pumps upon high temperature and/or vibration should be considered.

For sealless pumps, careful consideration should be given to bearing selection and internal flow. Chlorine has minimal lubrication properties and internal flashing is undesirable.

Special attention should be given to the selection of materials at potential wear points or where excessive temperatures could occur.

8. COMMISSIONING AND MAINTENANCE

8.1 Initial Hydrostatic Test and Visual Inspection

For new installations, testing shall comply with national and local codes. Code hydrostatic testing is required. The vessel must have its mill scale removed; then be cleaned, degreased and dried. At the site, the vessel interior and exterior must be inspected to ensure that no corrosion or physical damage has occurred during shipping.

Additional field pressure testing should be considered based upon the owner's experience. The maintenance and drying procedures in Section 8.3 should be followed.

8.2 Inspection and Documentation

Safe storage of chlorine requires systematic inspection, documentation and maintenance so defects may be detected and corrected before they can lead to an emergency situation. In addition to compliance with all applicable requirements of municipal, state, or federal governments and insurance companies, the inspection and maintenance practices discussed below are recommended as a minimum.

If operating records indicate an upset has ever occurred which could have allowed excessive moisture to enter the tank, the tank should be emptied and an internal inspection made. Institute Pamphlet 100 (10.1.11) contains guidelines for determining excessive moisture levels.

8.2.1 Visual Exterior Inspection

The tank should undergo a visual exterior inspection for corrosion or signs of leakage every two years. Particular attention should be placed on nozzle welds. Spot removal of insulation is suggested at vulnerable areas such as nozzles and tank bottoms.

8.2.2 External In-Service Inspection

The tank wall thickness should be checked at pre-designated areas and logged every two years.

8.2.3 Out-of-Service Inspection

At regular intervals, not to exceed six years, tanks should be visually inspected internally. Detailed records of the inspection are necessary. Review and analysis of the records may dictate the inspection frequency should be adjusted. Wall thickness must be checked and logged. The tank shall be inspected by a certified pressure vessel inspector.

The interior of the tank should be inspected for dirt, corrosion, cracking or pitting, especially at the welds. Surface irregularities will show up more clearly if a flashlight beam is directed parallel to the surface being inspected. If pitting or corrosion is found to extend deeper into the tank wall than the tank's corrosion allowance, repairs must be made and evaluated before the vessel is returned to service.

Company policy may dictate a hydrostatic test as part of out-of-service inspections.

8.3 Maintenance and Test Procedures

Detailed written procedures should be prepared by the owner for all phases of cleaning, washing, testing, repairs, drying and recommissioning the tank. The following sections are designed as aids in preparing those procedures. The owner should also be aware of and follow applicable government regulations for worker's safety and environmental concerns.

8.3.1 Preparation for Water Wash or Hydrostatic Testing

All liquid chlorine should be transferred from the tank into the process or other acceptable storage. Install a dry gas purge into the tank through one of the piping connections, and allow the effluent gas to pass through to a waste gas absorption or recovery system. Connect the purge stream and the vent in an appropriate configuration to allow the entire vessel to be swept. Pressure cycling could be used as an alternative. The procedure should ensure that all connecting piping and valves that will be included in the maintenance are also cleared. Periodically, test the vent stream to check when it is free of chlorine. Shut off the gas purge and allow the tank to come to atmospheric pressure.

If the tank is mounted on a weighing device, it will be convenient to calibrate the device while the tank is completely empty.

Proper safety procedures have to be developed and implemented before disconnecting piping or instrumentation that has or could contain chlorine. See Section 8.3.3 for vessel entry guidelines.

If the vessel is to be hydrostatically tested, remove the gas purge and connect a water line to one or more tank openings. Hook up a temporary overflow line on the top of the vessel. The overflow line should include a valve. Route the temporary overflow line to a waste neutralization process. It may be necessary to have a caustic solution, containers, and test equipment to properly neutralize the liquid effluent for disposal. The temporary overflow should be connected to the neutralization process such that the gas that is displaced by the water is scrubbed of any residual chlorine. If the vessel is equipped with a bottom nozzle, connect a valve and temporary line from this opening as well and route to the waste neutralization process.

A calibrated pressure gage suitable for the test should be installed. All other piping and instrumentation should be removed from the vessel and blind flanges installed. Piping, valves, and instrumentation that are removed from the vessel should be protected from the atmosphere so as not to absorb moisture.

Fill the tank with water as quickly as possible. Do not interrupt the fill process or leave the tank partially full as selective corrosion will occur at the liquid interface. Allow the water to overflow for a period of time into the neutralization process to ensure that all the gas is out of the vessel and that the water effluent is chlorine free. If the vessel is extremely dirty and suspected of having residue, it may be advantageous to induct a weak caustic solution into the water injection going into the tank.

If the tank is to be washed but not hydrostatically tested, it is possible to use slip blinds instead of removing the piping and instrumentation. This is normally less labor intensive, and the piping and valves are less likely to be exposed to the atmosphere.

8.3.2 Hydrostatic Test Procedure

When the vessel is full of water and gas free, shut off the flow of water to the vessel and close the valve on the overflow line. Disconnect the water line and install a test pump. Apply hydrostatic pressure at the maximum allowable working pressure stamped on the tank. In certain situations as required by company policy or repair codes, one and a half (1 1/2) times the maximum allowable working pressure may be applied. Close all the valves and allow the tank to stand. There should be negligible pressure drop indicated on the gage after 30 minutes, as any significant pressure drop would indicate weakness of the tank or the presence of leaks.

If the tank is mounted on a weighing device, it will be convenient to calibrate the device while the tank is full of water.

8.3.3 Vessel Entry

It may be necessary at times to enter the tank for inspection purposes or for maintenance. Extreme caution must be used. A vessel entry procedure must be developed in accordance with the latest revision of OSHA requirements for confined space entry.

8.3.4 Repairs

Weld repairs will be made per the guidelines and requirements presented in nationally recognized repair codes and local ordinances (e.g. National Board Inspection Code and API-510) (10.3.1 and 10.3.2). A hydrostatic test may be necessary to comply with code repairs or company policy. Repairs should be well documented. Follow-up investigation should be done to determine the need for the repair and operating or physical adjustments made to minimize the need for future repairs. If insulation was removed, do not reinstall until vessel has been inspected and checked for leaks.

8.3.5 Drying

Before the vessel can be returned to chlorine service it must be thoroughly dried. A means should be developed to assure that all pooled or standing water is removed from the tank. A dry purge gas should be used for drying. The gas should have a dew point of -40°F (-40°C) or lower, measured at operating pressure. For the gas purge to properly dry the entire tank interior, the gas must sweep over the entire vessel surface, including the nozzles. Pressure cycling could be used as an alternative. A means should be developed to ensure that all the nozzles are properly dried. There are different methods to do this. One method is to have coupling connections installed on the blind flanges used on the nozzles. An inexpensive bleed valve can be installed temporarily in the coupling to allow passage of the purge gas. Alternatively, a split gasket can be installed between the tank nozzle and the blind. A split gasket can be made from inexpensive gasket material by cutting a portion of the gasket out so there will be a leak path across the flange face. Heating the purge gas will aid considerably in the drying process. The temperature should be limited based on the equipment and insulation type, but 200°F (93°C) is typically an acceptable temperature. The purge gas flow should be started at high volume rates to sweep the moisture out of the tank and then reduced just prior to dew point measurement. The vessel should be dried until gas streams leaving all vent points have a dew point within 2°F (1°C) of the entering purge gas dew point. The purge rates should have been at a minimum for two or more hours when the dew point is taken.
After the tank is dried, it will be advantageous to leave a small purge of dried air on the vessel while the slip blinds or flange blinds are removed and the piping reinstalled with new gaskets. This purge will keep moist atmospheric air from getting back into the vessel. This

should be done with dry air. Install all tested and inspected appurtenances and reconnect pipe. It will be necessary to dry the vessel again when the final piping has been installed. If insulation was removed at piping, tank or instrument connections, do not reinstall insulation until the vessel and piping are leak checked.

8.4 Preparation for Service

After final drying, increase the tank pressure to operating pressure using the purge gas. Check all connections with a water soap solution for leaks. Depressurize the vessel and then introduce chlorine gas to achieve a chlorine air mixture. Using dry air or nitrogen, increase the tank pressure to operating pressure or 100 psig, whichever is greater?

Check all connections with an aqua ammonia solution for leaks. All tanks, piping, valves and instruments should be leak checked. See Pamphlet 6 for leak checking procedure details (10.1.2).

If possible, leave the tank uninsulated until after the tank is fully in service to enable further leak checking. The insulation should only be installed at this time if the bare fixtures will ice up due to operating conditions or extreme ambient temperatures.

The vessel is now ready to be put into service. As the vessel is being put into service, continue to perform leak checks until the vessel reaches its normal operating pressure and temperature.

9. INSPECTION AND TEST OF APPURTENANCES

9.1 Pressure Relief Device

All pressure relief devices should be inspected, cleaned and tested at regular intervals, in accordance with an established maintenance program. The frequency of these procedures is dependent on various factors, but the primary goal is safety. Immediately after removal from the tank, every pressure relief device should be tested for vapor tightness and set pressure. This is to be done prior to the device being cleaned, disassembled or reworked. If the pressure relief device fails to test properly, a detailed investigation should be carried out. The investigation should include valve design, calibration, maintenance practices, and inspection frequency.

The pressure relief valve supplier should be consulted as necessary to insure that maintenance procedures are kept current.

9.2 Valves and Internal Piping

Internal piping should be inspected during the scheduled tank inspection (8.2). This could be a convenient time to inspect other piping and valves in the tank system, provided caution is used to prevent moisture from entering other parts of the system.

9.3 Inventory Measurement Equipment

It is very important to ensure the continued accuracy of the inventory measurement devices. All devices, including redundant ones, should be serviced in strict accord with applicable regulations, owner's procedures and manufacturer's recommendations.

9.4 Critical Systems

All critical instruments, alarms and fail safe devices should be part of a reliability test program. A reliability test program requires regular inspection to guarantee that all critical devices will function when required and identify those components that no longer function. The frequency of the inspection depends on many factors. The basic premise is to have the inspection frequency higher than the expected failure frequency of the device. Increased reliability of the systems is achieved by review of the test records to upgrade the devices (design, materials, etc.) and adjust the frequency schedule.

10. REFRIGERATED LIQUID CHLORINE STORAGE

10.1 Choosing Refrigerated Storage

Refrigerated storage systems are not commonly used in North America due to their complexity and expense. These systems should only be considered by large chlorine producers with the expertise and manpower required to maintain and operate them.

Some reasons a chlorine producer may select refrigerated include:

- Much larger spherical storage tanks can be used due to the tank design.
- Refrigerated chlorine's vapor pressure is reduced. This limits the initial flash of chlorine should the vessel fail catastrophically.
- Venting requirements are significantly reduced due to the lower pressures.

10.2 Differences from non-refrigerated storage

Listed below are some of the major design differences between refrigerated storage systems and non-refrigerated storage systems. This list does not contain all the possible differences and is simply meant to aid the user in initial design considerations.

- Due to decreased chlorine vapor pressures at reduced temperatures chlorine is typically maintained near atmospheric pressure. This allows lower vessel pressure ratings.
- To maintain chlorine near atmospheric pressure, pressure and/or temperature control is required. Independent systems to control and/or relieve pressure to contain the chlorine should be installed.
- Due to decreased pressures, padding cannot normally be used to transfer chlorine. Because of NPSH limits, bottom outlet valves are sometimes used to allow pumping. Vertical pumps can be used but become impractical on large storage spheres due to long shaft requirements.

- Due to the decreased temperature in refrigerated storage, the volume requirements for liquid chlorine, is decreased. The chlorine tank volume shall be at least 168.7 U.S. gallons for each ton of chlorine stored. (Using this guideline, a tank that is fitted with a relief device set at 25 PSIG and allowed to warm up to a temperature of 15F will not relieve and will only be approximately 95% full of liquid). Tanks should never be filled beyond their rated tonnage.

- When sizing relief devices, modified versions of the equations in Section 5.2 should be considered that credit for the fact that large storage tanks cannot be completely engulfed in a fire.

- When designing refrigeration systems, reactions between chlorine and refrigerants should be considered. Equipment design and process operations should minimize the potential for catastrophic events to occur.

- When double walled vessels are used, the space between the walls should be monitored and maintained to prevent corrosion and leaks.

- Low temperature steel is used for the vessel material of construction

- Proper coating and insulation is required

11. REFERENCES

11.1 INSTITUTE PUBLICATIONS

11.1.1 *Chlorine Manual*, ed. 6; Pamphlet 1; The Chlorine Institute: Arlington, VA, **1997**.

11.1.2 *Piping Systems for Dry Chlorine*, ed. 14; Pamphlet 6; The Chlorine Institute: Arlington, VA, **1998**.

11.1.3 *Maintenance Instructions for Chlorine Institute Standard Pressure Relief Devices, Type 12JQ*, ed. 11; Pamphlet 39; The Chlorine Institute: Arlington, VA, **2001**.

11.1.4 *Maintenance Instructions for Chlorine Institute Standard Safety Valves, Type 4JQ*, ed. 5; Pamphlet 41; The Chlorine Institute: Arlington, VA, **2001**.

11.1.5 *Emergency Response Plans for Chlorine Facilities*, ed. 5; Pamphlet 64; The Chlorine Institute: Arlington, VA, **2000**.

11.1.6 *Atmospheric Monitoring Equipment for Chlorine*, ed. 7; Pamphlet 73; The Chlorine Institute: Arlington, VA, **2003**.

11.1.7 *Estimating the Area Affected by a Chlorine Release*, ed. 4; Pamphlet 74; The Chlorine Institute: Arlington, VA, **2004**.

11.1.8 *Respiratory Protection Guidelines for Chlor-Alkali Operations*, ed. 2; Pamphlet 75; The Chlorine Institute: Arlington, VA, **1993**.

11.1.9 *Recommendations to Chlor-Alkali Manufacturing Facilities for the Prevention of Chlorine Releases*, ed. 4; Pamphlet 86; The Chlorine Institute: Arlington, VA, **2001**.

11.1.10 *Dry Chlorine: Definitions and Analytical Issues*, ed. 3; Pamphlet 100; The Chlorine Institute: Arlington, VA **2002**.

11.1.11 *Safe Handling of Chlorine Containing Nitrogen Trichloride*, ed. 1; Pamphlet 152; The Chlorine Institute: Arlington, VA, **1998**.

11.1.12 *Padding Pressure Limits for Chlorine Tank Cars*, Drawing; DWG 201-2; The Chlorine Institute: Arlington, VA, **1991**.

11.2 ASME CODES

11.2.1 *Nondestructive Examination, Section V*, ASME Boiler and Pressure Vessel Code; ANSI/ASME BPV-V; The American Society of Mechanical Engineers: New York, NY, **2004**.

11.2.2 *Rules for Construction of Pressure Vessels, Section VIII - Division 1*, ASME Boiler and Pressure Vessel Code; ANSI/ASME BPV-VIII-I; The American Society of Mechanical Engineers: New York, NY, **2004**.

11.2.3 *Welding and Brazing Qualification, Section IX*, ASME Boiler and Pressure Vessel Code; ANSI/ASME BPV-IX; The American Society of Mechanical Engineers: New York, NY, **2004**.

11.2.4 *Process Piping*; ASME B31.3; an ANSI standard, The American Society of Mechanical Engineers: New York, NY, **2004**.

11.3 OTHER CODES

11.3.1 *National Board Inspection Code*, Manual for Boilers and Pressure Vessel Inspectors; ANSI/NB-23; National Board of Boiler and Pressure Vessel Inspectors: Columbus, OH, **2004**.

11.3.2 *Pressure Vessel Inspection Code: Maintenance Inspection, Rating, Repairs and Alteration*; ANSI/API 510; American Petroleum Institute: Washington, DC, **2003**.

11.4 OTHER PUBLICATIONS

11.4.1 *Pressure Relief Device Standards - Part 3 - Stationary Storage Containers for Compressed Gases*; Pamphlet CGA S-1.3; Compressed Gas Association: Arlington, VA, **2003**.

APPENDIX A

CHECKLIST

This checklist is designed to emphasize major topics for someone who has already read and understood the pamphlet. Taking recommendations from this list without understanding related topics can lead to inappropriate conclusions.

Place a check mark (T) in the appropriate box below:

Yes	No	N/A			
☐	☐	☐	1.	Chlorine inventory minimized and the complexity of the system reduced.	{2}
☐	☐	☐	2.	Storage located in a separate, protected, clearly defined area that can be accessed by emergency personnel.	{3}
☐	☐	☐	3.	Tank volumes are sufficiently large to allow for liquid expansion.	{4.1.1}
☐	☐	☐	4.	Tank design pressure is at least 120% of the maximum expected operating pressure and not less than 225 psig (1551 kPa).	{4.1.2}
☐	☐	☐	5.	The tank is designed, constructed, inspected, tested and marked in accordance with parts UW and UCS of the Code.	{4.2.1}
☐	☐	☐	6.	Tank materials are suitable for expected temperatures.	{4.2.3}
☐	☐	☐	7.	Tank thickness includes at least a 1/8" corrosion allowance.	{4.2.3}
☐	☐	☐	8.	Exterior corrosion has been addressed with a proper coating system.	{4.3}
☐	☐	☐	9.	Supports are suitable for thermal expansion, external forces and local seismic conditions.	{4.4}
☐	☐	☐	10.	Tank is protected from over pressure with dual relief devices sized for the most conservative, technically feasible scenario.	{5.1}
☐	☐	☐	11.	Relief device vent discharges are appropriately safeguarded. Proper consideration has been given to collecting relief device vents.	{5.1}
☐	☐	☐	12.	The tank inventory can be measured to prevent overfilling.	{5.4}
☐	☐	☐	13.	Emergency procedures and spill containment provisions have been developed to reduce the impact of spilled chlorine.	{6}
☐	☐	☐	14.	Appropriate methods of transfer have been selected.	{7}
☐	☐	☐	15.	Potential for NCl_3 concentration has been recognized.	{7}

❑	❑	❑	16.	A procedure is in place to properly maintain the system and to document and correct defects before they can lead to an emergency situation. {8}
❑	❑	❑	17.	The tank has been cleaned, dried and properly prepared for accepting chlorine. {8}
❑	❑	❑	18.	Pressure relief devices are inspected, cleaned and tested at regular intervals.{9}
❑	❑	❑	19.	For refrigerated liquid chlorine storage, the complexities and differences from pressurized storage are understood by personnel designing, installing and maintaining the system? {10.1}
❑	❑	❑	20.	For refrigerated liquid chlorine storage, controls are in place to maintain the temperature/pressure of the system and back-up systems are in place in case of primary refrigeration system or control failures? {10.2}

REMINDER:

Users of this checklist should document exceptions to the recommendations contained in this pamphlet.

THE CHLORINE INSTITUTE, INC.

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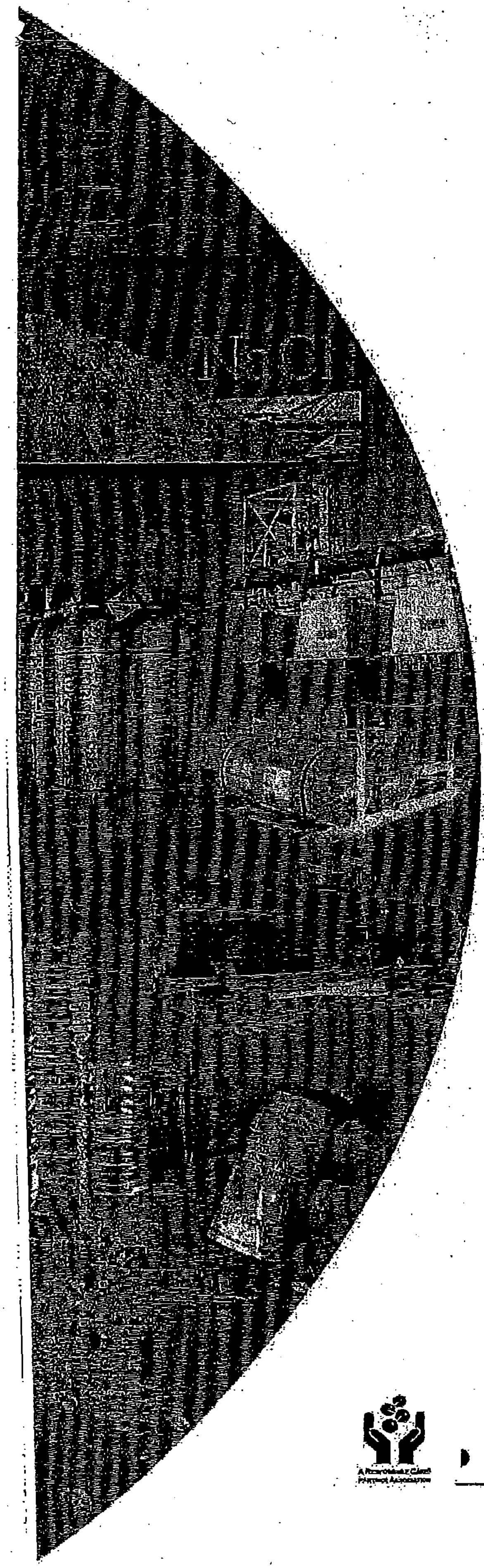


THE CHLORINE INSTITUTE, INC.

Pamphlet 9

Chlorine Vaporizing Systems

A LEGACY OF SAFETY STEWARDSHIP since 1924

Edition 6 October 2002

Table of Contents

1. INTRODUCTION

1.1 SCOPE

This pamphlet is intended to assist in the selection, design, safe operation and maintenance of chlorine vaporizer systems. It is limited to those who receive liquid chlorine in cylinders, ton containers, cargo tanks or tank cars and who will vaporize liquid for ultimate use of the chlorine as a gas. It is not intended for chlorine processing systems such as reboilers and complex distribution systems.

Chlorine vaporizer systems can be purchased from equipment manufacturers or designed and built by the user. The design and operations of specific chlorine vaporizer systems may vary slightly, but should follow the guidelines contained in this pamphlet. This pamphlet neither endorses nor excludes any products of equipment manufacturers.

1.2 RESPONSIBLE CARE®

Members of the Chlorine Institute pledge to follow the elements of a responsible care program such as the American Chemistry Council or the Canadian Chemical Producers' Association (CCPA) responsible care initiatives. The Chlorine Institute is a Partner Association in the American Chemistry Council Responsible Care ® initiative and is committed to the support of a continuing industry effort to ensure the responsible management of chemicals. This pamphlet demonstrates support of these principles.

1.3 DEFINITIONS

In this pamphlet, the following meanings apply unless otherwise noted:

ASME	American Society of Mechanical Engineers
chlorine	dry chlorine (either gas or liquid)
Code	refers to the ASME Code
container	any vessel fixed or movable for the purpose of holding chlorine
cylinder	a shipping container with capacity not exceeding 150 lbs (68kg) of chlorine that is authorized by regulation for the transportation of chlorine
design pressure	same meaning as in the Code
$FeCl_3$	ferric chloride
gas padding	the addition of clean, dry, oil free, compressed air, nitrogen or chlorine in order to increase system pressure
gas purge	the use of clean, dry, oil-free compressed air or nitrogen, dried to a dew point of -40°F (-40°C) measured at the operating pressure

Inconel	a registered trademark of Inco Alloys International, Inc.
Institute	The Chlorine Institute, Inc.
kPa	kilopascal(s)
Monel	a registered trademark of Inco Alloys International, Inc.
NCl_3	nitrogen trichloride
psig	pounds per square inch gage
ton container	a shipping container with a typical capacity of 2000 lbs (907 kg) of chlorine that is authorized by regulation for the transportation of chlorine

1.4 DISCLAIMER

The information in this pamphlet is drawn from sources believed to be reliable. The Institute and its members, jointly and severally, make no guarantee and assume no liability in connection with any of this information. Moreover, it should not be assumed that every acceptable procedure is included or that special circumstances may not warrant modified or additional procedure. The user should be aware that changing technology or regulations may require a change in the recommendations herein. Appropriate steps should be taken to insure that the information is current when used. These recommendations should not be confused with federal, state, provincial, municipal or insurance requirements, or with national safety codes.

1.5 REGULATORY, INSURANCE REQUIREMENTS AND MANUFACTURERS RECOMMENDATIONS

The location, capacity, design, maintenance, and operation of chlorine vaporizer installations may be subject to federal, local, state, or provincial regulations, fire and building codes, insurance company requirements, and manufacturer's recommendations. Owners and designers should verify that installations will fully comply with all applicable requirements.

1.6 APPROVAL

The Institute's Storage and Transport Committee approved Edition 6 of this pamphlet at a meeting held on September 25, 2002.

1.7 REVISIONS

Suggestions for revision should be directed to the Secretary of the Institute.

1.8 REPRODUCTION

The contents of this pamphlet are not to be copied for publication, in whole or in part, without prior Institute permission.

2. GENERAL

2.1 CHLORINE SUPPLY

Chlorine in commerce is shipped in liquid form but in many applications it is utilized in vapor form because of process requirements and because of greater handling ease. It is common practice to withdraw vapor directly from tank cars, cargo tanks, cylinders and ton containers, relying upon natural heat transfer to produce the necessary rate of liquid vaporization. The vaporization capacity of these containers is limited, however and it is frequently necessary for larger users to install special vaporizing systems. Such equipment is referred to either as a "chlorine vaporizer" or a "chlorine evaporator" but in this pamphlet the term "vaporizer" is used.

2.2 DETERMINING THE NEED FOR A VAPORIZER

Chlorine gas can be vaporized directly from cylinders and ton containers. The maximum dependable, continuous discharge rate of chlorine gas from a cylinder is about 1-1.5 lb/day/°F (0.25 - 0.38 kg/day/°C). This discharge rate assumes an ambient temperature of at least 60°F (15°C) and natural air circulation. The maximum dependable discharge rate for a ton container under similar conditions is about 6-8 lb/day/°F (1.5 - 2 kg/day/°C). The flow is limited by heat transfer from the atmosphere to the container. For short periods these average flows can be greatly exceeded while the chlorine in the container cools to the saturation temperature of the delivery pressure. Direct heating of a chlorine container should not be done. If more gaseous chlorine is required than can be vaporized due to natural heat transfer, a vaporizer is required.

Cylinders or ton containers can be manifolded together to give greater gas flows. When manifolding is contemplated, provision must be made to insure that all vessels connected to the manifold are at the same temperature. This prevents chlorine from a warm cylinder from flowing to, liquefying in, and thus possibly overfilling the colder cylinder.

Vaporizers are recommended for higher continuous chlorine gas feed rates when it is not practical to manifold the gas lines of the required number of containers, or when the chlorine liquid supply originates from chlorine tank cars, tank trucks or storage tanks.

2.3 LIQUID CHLORINE SUPPLY

By withdrawing chlorine from its container as a liquid and using a vaporizer to convert it to a gas, flow rates can be greatly increased. Liquid chlorine is commonly supplied to vaporizers from tank cars, ton containers or storage tanks. Liquid chlorine rates can be increased by manifolding ton containers. Refer to Drawing 183 (9.1.11) and Pamphlet 1 (9.1.1).

Liquid chlorine must be available at a pressure well above the pressure at which the gas is intended to be used. Whenever liquid chlorine is supplied to the vaporizer from a shipping or storage container, the pressure necessary to sustain liquid flow is provided by the pressure in the container. If the pressure of the tank car, cargo tank or storage tank is too low for user requirements, gas padding or other methods of elevating the liquid pressure are necessary. For padding recommendations, see Pamphlets 5, 49 and

66 (9.1). Pumping of liquid chlorine into vaporizers requires special engineering considerations.

Cylinders and ton containers should not be padded with gas.

2.4 OPERATING PRINCIPLE

Liquid chlorine is transferred to a chamber (heat exchanger) where it is caused to boil (vaporize) by the controlled application of heat. Heat is generally supplied by steam or hot water. Chlorine gas is withdrawn from above the pool of boiling liquid and delivered to the point of use.

Vaporizer systems should be designed so that the rate of vaporization self adjusts to the process demand. Typically, chlorine flow is set by the user's gas demand. As demand increases, pressure in the vaporizer and the line between the vaporizer and user drops, allowing an increased liquid chlorine flow rate into the vaporizer. This increased flow increases the liquid level in the vaporizer. This submerges more of the vaporizer heat transfer surface in liquid chlorine. Since the rate of vaporization is a function of the surface area below the liquid level, the vaporization rate increases until equilibrium is established to match the demand. If demand increases beyond the vaporizer capacity, liquid chlorine will be entrained in the outlet vapor.

When demand drops, the pressure in the gas line increases. When it increases to a pressure above the liquid supply pressure, liquid chlorine is pushed out of the vaporizer, back to the supply source. The reduction in exposed heat transfer surface reduces vaporization and a lower equilibrium rate is established.

The use of automated valves or check valves on liquid lines to the chlorine vaporizer can lead to situations that impede the intended back flow. The valves could shut off and thereby prevent free flow of liquid back to the supply source. If pumps are used, it is necessary to provide a controlled constant pressure supply to the vaporizer with a high capacity bypass back to the liquid source. If liquid is trapped in the vaporizer, or reverse flow is restricted, the relief valve setting can be exceeded.

Other process criteria may require safety systems that could cause shut off of the liquid lines, such as recommended shut off valves for bulk transport unloading, see Pamphlet 57 (9.1.6). Automated shut down instrumentation and/or procedures should be provided for the vaporizer in case the liquid feed automated shut off valves close. Emergency shutdown procedures should follow the guidelines found in Section 7.3.

2.5 VAPORIZER SOURCES

Chlorine vaporizers are available commercially. They differ in design details and in heat source. Individual suppliers generally offer a number of models spanning a wide capacity range. Some chlorine consumers custom design their own units. Whether a unit is purchased or custom designed, the vaporizer and its auxiliaries should contain the features outlined in this pamphlet.

Chlorine producers' technical service staffs and the vaporizer manufacturer can be excellent sources of information on vaporizer design and operation.

2.6 INSTALLATION CONSIDERATIONS

When selecting a location for a vaporizer, consideration must be given to the needs of the user, the type of container from which the chlorine is supplied, and the necessary safety requirements. Chlorine vaporizer systems should be located in separate clearly defined areas which can be isolated in emergencies and are accessible to emergency personnel. The chlorine vaporizing area should be protected by barriers and isolated from other processes or materials which might damage the vaporizer. The location should be chosen to minimize the possibility of external corrosion by acid gases or liquids, and the possibility of damage by vehicles, fire or explosion.

Always review the piping design to insure adequate chlorine liquid supply. In unpadded containers, the source pressure is solely a function of temperature. Flashing in the feed line will substantially limit capacity of the system. Elevation differences between the supply source and vaporizer can reduce pressure to the flash point.

The capacity of the feed pipe to back flow liquid when the load is reduced must also be checked. Insufficient capacity will result in over pressurizing the vaporizer and possible venting through the relief valve..

Because of potential flashing, degassing and back flow issues, it is preferable to minimize the length of the liquid lines by locating the vaporizer as close as possible to the liquid chlorine source. Each situation should be reviewed to select the best solution.

3. DESIGN

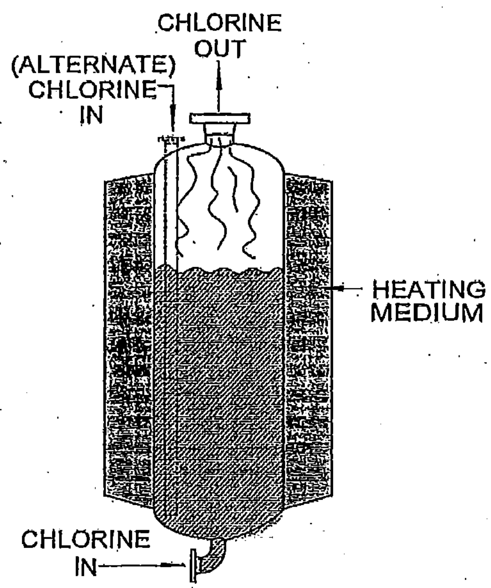
3.1 SELECTION

This section covers some of the possible vaporizer designs. It particularly considers those factors necessary to ensure safe operation. When selecting a specific vaporizer, factors such as capacity, heat source, installation location, controls, and user requirements must be considered.

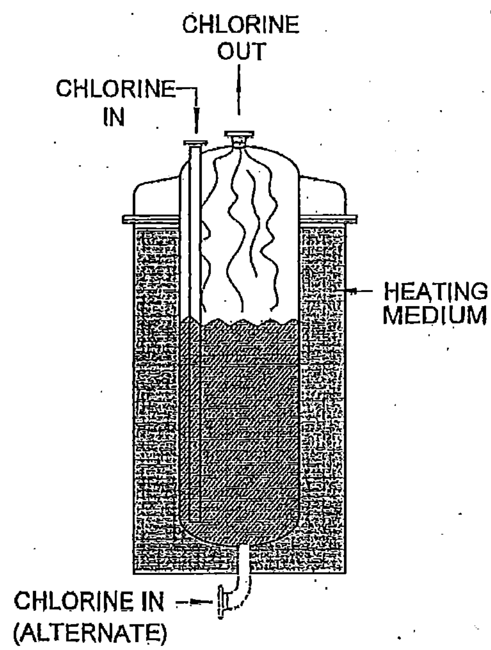
3.2 TYPES OF VAPORIZERS

There are four main types of chlorine vaporizers in use. The following are comparative advantages and disadvantages:

Jacketed Shell



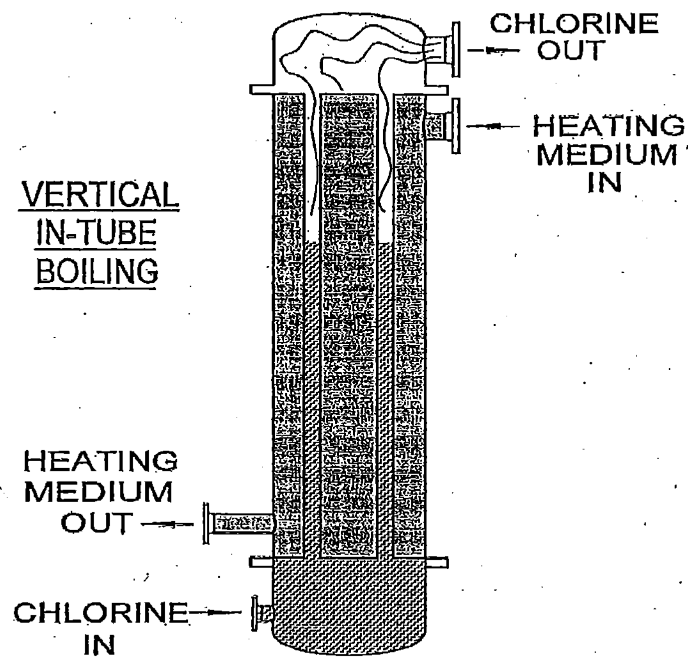
FIXED JACKETED SHELL



REMOVABLE JACKETED SHELL

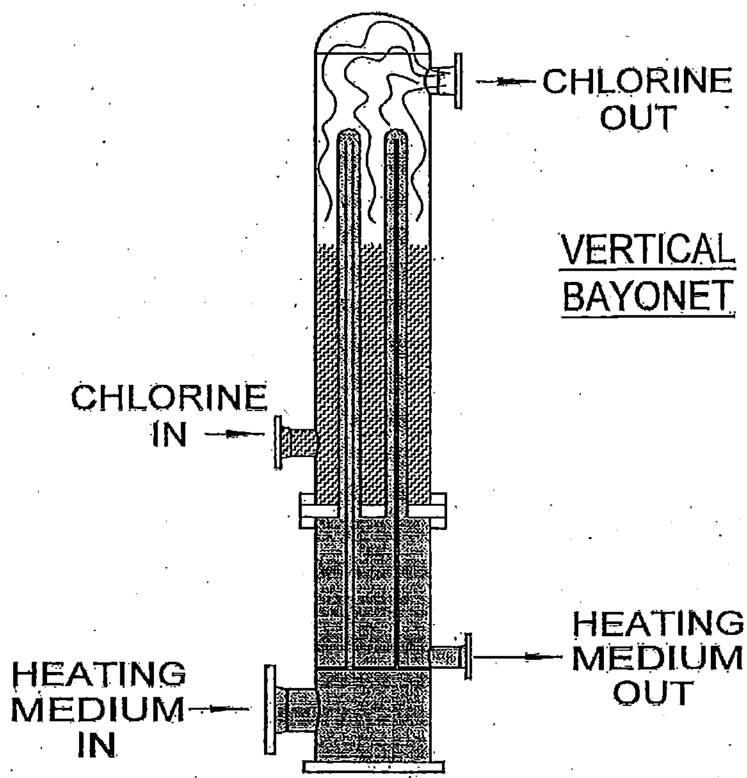
- simple construction
- easiest to maintain and operate
- less susceptible to $FeCl_3$ plugging
- less susceptible to NCl_3 build-up
- allows for heavy wall thickness which reduces chances of leakage
- easier to dry than tube type
- capacity limited by relatively small heat transfer surface area
- a large chlorine volume
- relatively less superheat available
- fixed-jacketed designs are difficult to inspect on the heating medium side
- least susceptible to water freeze-up

Vertical In-Tube Boiling (Chlorine on Tube Side)



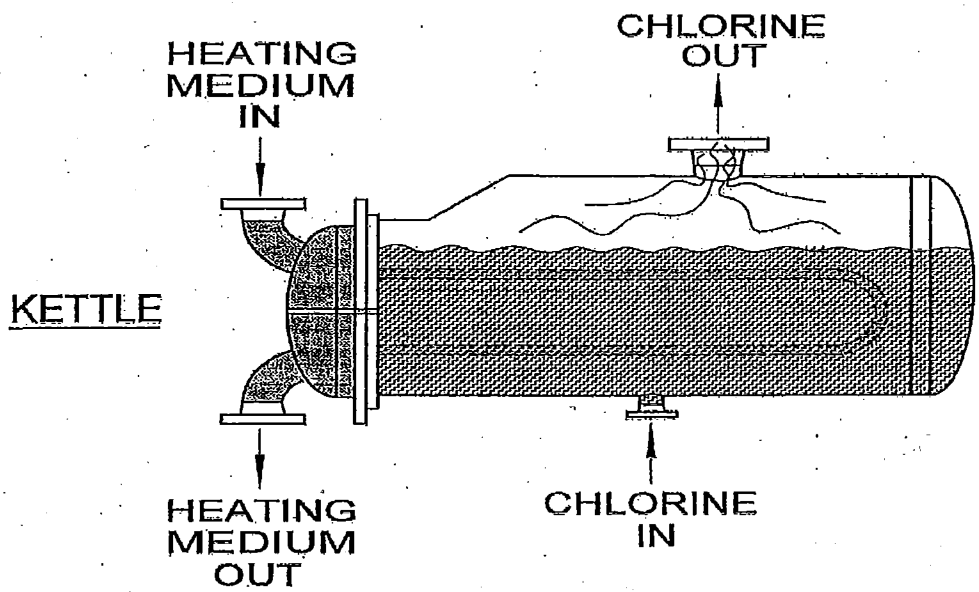
- high capacity due to large heat transfer surface area
- violent boiling increases heat transfer up to a point (flux limited)
- least susceptible to NCl_3 build-up
- smallest chlorine volume required for heat transfer area
- superheat available
- easy to clean
- most susceptible to $FeCl_3$ plugging
- most complex construction
- most susceptible to liquid entrainment
- must allow for thermal expansion of tubes
- most susceptible to leaks due to double quantity of tube joints and thermal stress
- susceptible to water freeze-up

Vertical Bayonet (Chlorine on Shell Side)



- maximum superheat available
- high capacity due to large heat transfer surface area
- less susceptible to water freeze-up
- violent boiling increases heat transfer
- less susceptible to NCl_3 build-up
- small chlorine volume required for heat transfer
- least susceptible to liquid entrainment
- difficult to visually inspect chlorine side of tubes if not on square pitch
- complex construction
- more susceptible to leaks due to large number of tubes
- more susceptible to $FeCl_3$ plugging

Horizontal Kettle (Reboiler Type)



- Highest capacity due to large heat transfer area
- most susceptible to NCl_3 build-up
- most susceptible to $FeCl_3$ build-up
- superheat not available
- more plant space required
- very susceptible to water freeze-up
- least responsive to process changes
- largest chlorine volume
- u-tube distortion due to large thermal gradients
- difficult to visually inspect, clean and maintain shell side
- more susceptible to flooding and liquid entrainment
- more susceptible to leaks due to large number of tubes

3.3 DESIGN CONSIDERATIONS

Chlorine vaporizers should be designed to deliver chlorine in excess of the peak load demanded by the process. This includes consideration of the following:

- Flooding

  Load variations should not cause flooding of liquid chlorine into the chlorine gas line (5.2).

- Liquid Disengagement

  Vaporizers should be designed to prevent liquid carryover in the gas stream. Entrained liquid should be separated from the chlorine gas before discharge to the process lines. Liquid can be formed as a result of an unpredicted temperature drop or from incomplete vaporization due to an excessive withdrawal rate from the vaporizer.

- Reliquefaction

  Chlorine can reliquefy in downstream piping. Superheating of the vapor in the heated section above the liquid surface of the vaporizer is sometimes utilized to minimize this possibility. Superheating may also be accomplished by lowering the gas pressure in the discharge line (with a pressure reducing valve) or by using a separate superheater. Line insulation and/or heat tracing may be necessary. The degree of superheat required is a function of the pipeline system configuration, routing, process needs, and ambient conditions. Generally a minimum superheat of 20°F (11°C) is considered to be the minimum required desirable.

- Fouling

  Liquid chlorine may contain traces of non-volatile impurities that can accumulate and reduce vaporizer capacity. Improper system operation that allows moisture to enter the vaporizer can cause corrosion and the corrosion by-products that may contribute to fouling (e.g. $FeCl_3$).

- Freeze-up

  The temperature of the chlorine in the vaporizer can be well below the freezing point of water. The design of the vaporizer should minimize the potential to damage the unit due to water/condensate freeze-up.

3.4 METHODS OF HEATING

Vaporizers are usually heated with hot water or steam. Other heat transfer fluids and direct electric heaters are also employed, but they require special considerations and are outside the scope of this pamphlet. Electric heaters can be used to heat water as an intermediate heat transfer fluid.

The hot water may be supplied by one of the following methods:

- an external heat exchanger with a pump circulating hot water through the vaporizer water jacket or tube section
- an electric immersion heater in the water jacket with water added to the system to make up water lost due to evaporation
- steam injected into the water jacket with an overflow for accumulated condensate

Direct steam-heated vaporizers should use low pressure steam (3.5).

3.5 TEMPERATURE

High Temperature

The maximum recommended operating temperature for vaporizers constructed of steel is 250°F (121°C) because the corrosion rate of steel by chlorine increases markedly above this temperature. Additionally, operating below 250°F (121°C) reduces the possibility of an iron chlorine reaction and resultant fire. In general, lower operating temperatures tend to increase equipment life. Higher temperatures lead to higher corrosion rates and should be compensated for in equipment design (refer to Section 5.2 for corrosion temperature recommendations). Consideration must also be given to the increased vapor pressure of the chlorine gas caused by higher temperatures. Although most operations are designed not to exceed these temperature limitations, high temperatures can occur as a result of malfunction. Means for maintaining temperature within the design limits are as follows:

- Hot water-heated vaporizers may have a vented heating jacket to prevent build up of pressure and the resultant higher temperature.
- If a regulator is used to reduce the steam supply pressure, a relief valve should be installed on the low pressure supply line to prevent overheating in the event the regulator fails. Steam should be de-superheated if stepped down from high pressure. It is desirable to maintain the steam pressure below the chlorine pressure. Relief valves should be set no higher than the heating medium side pressure rating.
- A high temperature alarm and automatic shut-off should be incorporated into steam-heated or unvented hot water systems. This is not required in water-heated systems vented to the atmosphere.

Low Temperature

The minimum metal temperature used in design shall be the lowest expected. This temperature may be dictated by operational upsets, auto-refrigeration or atmospheric temperature. In any case, consideration should be given to specifying a lower minimum metal design temperature of -40°F (-40°C) at the corresponding highest operating pressure expected at this low temperature on the chlorine side of the vaporizer.

The boiling point of chlorine is -29.15°F (-33.97°C) at atmospheric pressure. Chlorine boils at 32°F (0°C) at 38.8 psig (267.6 kPa). Operation of a chlorine vaporizer below this pressure will introduce the danger of freezing the water in the heating jacket or tubes. In normal operation, this condition may not occur, but persons operating vaporizers should be aware that it could. To avoid freezing, proper procedures should be followed during start-up and shutdown (7.2 and 7.3).

Freezing of water in vaporizers can be caused by many abnormal conditions such as heat source failure, steam condensate back up, failure to drain the water from water heated vaporizers during periods of non-use, and operation above vaporizer capacity. Low temperature will also contribute to liquid carry over and must be avoided. A low temperature alarm that will initiate automatic shut-off of the gas discharge valve should be incorporated into the vaporizer design to prevent liquid carry over (4.2 and 5.2).

3.6 MATERIALS OF CONSTRUCTION

Chlorine vaporizers are generally fabricated from carbon steel. Steel is resistant to chlorine provided no moisture or contaminants are present and the upper temperature limitation is not exceeded. Nickel, Monel, and Inconel are more corrosion resistant than steel and can be used at higher temperatures. Refer to Table 3-1 for standard materials of construction.

Some steels become brittle at low temperatures. If the lower design temperature limit is below -20°F (-29°C), grades of steel with sufficient impact resistance, as determined by Charpy impact testing or use of Code curves to gain impact exemption for material thickness and stress ratio, are required. No reduction in impact testing exemption temperature is allowed due to post-weld heat treatment requirements stated in Section 3.8. An alternate is the use of other materials found in Table 3-2. **Some carbon steels may require Charpy impact testing at temperatures greater than -20°F (-29°C) per Part UCS of the current edition of the Code.**

Table 3-1.
Standard Materials of Construction of Chlorine Vaporizing Systems

Product Forms	Steel	Nickel	Monel
Plate	A516 Gr 55, 60, 65 or 70	B162	B127
Pipe	A106 Gr B or A53 Type S Gr B	B161	B165
Forgings	A105	N/A	B164, B564
Fittings	A234 Gr WPB	B160, B366	B164, B366
Bolts	A193 Gr B7	N/A	N/A
Nuts	A194 Gr 2H	N/A	N/A
Tube	A179, A192	B161, B163	B163, B165

Table 3-2.
Materials of Construction for Low Temperature Vaporizing Systems

Product Forms	Steel	Nickel	Monel
Plate	A516 Gr 70 or A612 Gr B	B162	B127
Pipe	A333 seamless Gr 1 or 6	B161	B165
Forgings	A350 Gr LF2	N/A	B164, B564
Fittings	A350 Gr LF2 A420 Gr WPL6	B160, B366	B164, B366
Bolts	A320 Gr L7 A193 Gr B7M	N/A	N/A
Nuts	A194 Gr 4 or 7 A194 Gr 2HM	N/A	N/A
Tube	A334 seamless Gr 1 or 6	B161, B163	B163, B165

Listed ASTM specifications are those in effect at the time of publication.

3.7 FABRICATION

Vaporizers shall be designed, constructed, inspected, tested and marked in accordance with Section VIII Parts UG, UW, UCS and UNF of the Code. In addition to Code requirements, all chlorine side pressure retaining welded joints shall be full penetration. All chlorine side pressure retaining butt-welded joints shall be fully radiographed per the requirements of the current edition of the Code. Welding shall be done in accordance with the requirements of Section IX of the current edition of the Code. The chlorine side design pressure should not be less than 250 psig (1724 kPa).

3.8 POST-WELD HEAT TREATMENT

Fabricated carbon steel chlorine side pressure retaining parts of the vaporizer shall be post-weld heat treated. The procedure shall meet the requirements of the current edition of the Code.

3.9 CORROSION ALLOWANCE

The wall thickness of new chlorine side carbon steel vaporizer pressure containing parts (except transfer tubes) should be at least 1/8 inch (3.18 mm) greater than that required by the design formulas in the Code to allow for corrosion.

3.10 EFFECT OF GAS PADDING

Gas padding of the chlorine source vessel could result in higher pressure liquid chlorine being fed to the vaporizer. This could induce a higher boiling point and may lower the temperature difference between the heating medium and the liquid chlorine. The result is less heat transfer between the heating medium and the liquid chlorine which increases the potential for liquid carryover or flooding. The chlorine source vessel should be gas padded only when the pressure drops below that required by the process and its equipment. Gas padding should be limited to the minimum amount required. If gas padding is required, a continuous review is recommended to ensure that sufficient gas superheat is maintained and that an adequate margin remains between the operating pressure and the relief valve settings.

The use of dry pad gas is absolutely critical to avoid excessive corrosion due to moisture introduced into the chlorine. A dew point of -40°F (-40°C) or below measured at the operating pressure is required.

4. CONTROLS AND INDICATORS

4.1 GENERAL

Regardless of vaporizer type or capacity, controls and indicators should be provided that will allow safe, reliable and convenient operation of the vaporizer. The following paragraphs are referenced in the schematics included in this section. These schematics are intended to convey instrumentation philosophy only and are not design specific. For example, the vertical in-tube boiling and the kettle designs may require additional controls, not shown on the schematic.

All electric components and wiring on a chlorine vaporizer system should conform to the National Electrical Code (9.3.1).

4.2 CONTROLS AND INDICATORS FOR ALL VAPORIZER TYPES

The following controls and indicators apply to all vaporizer systems illustrated in the typical flow schematics found at the end of this section.

4.2.1 Automatic Gas Valve

An automatic valve in the exit gas line is required to prevent the discharge of chlorine gas if an improper condition exists. This valve should fail in a closed position.

4.2.2 Pressure Reducing Valve

A gas pressure reducing valve should be considered to provide some superheat to the chlorine exit gas stream and/or to stabilize the pressure at which the chlorine gas is supplied to the process. This valve may be provided with an automatic actuator to serve the function of the automatic shut-off valve mentioned above in Section 4.2.1.

4.2.3 Pressure Relief Valve

A pressure relief valve is required in the chlorine gas space between the vaporizer and any gas shut-off valve (5.2). If an inlet rupture disc is used in series with the relief valve, the space between must be fitted with a pressure gauge and/or pressure alarm. A non-fragmenting rupture disc should be used.

4.2.4 Superheat

Provision for superheating the exit gas stream should be considered. In some vaporizers the superheat is built into the vaporizer design. Some vaporizers require a separate superheater.

4.2.5 Temperature/Pressure Indicator

Chlorine gas temperature and pressure indicators are required. By comparing these readings with the vapor pressure curve, the amount of superheat can be determined.

4.2.6 Flow Control

A provision is required for limiting the chlorine gas flow to the capacity of the vaporizer to avoid liquid entrainment into the gas exit line. This may be accomplished by one or more of the following means:

- gas flow control (This may be a flow controller or a restricting orifice).
- gas temperature control and/or automatic low temperature shut-off
- high level cut-off in the vaporizer
- liquid knockout pot to collect entrainment This pot can be fitted with level indicators and automatic shut-off or a liquid leg return to the vaporizer.

4.2.7 Heating Medium Temperature

Provision for detecting high and/or low temperature in the heating medium with options for vaporizer shutdown should be considered.

4.2.8 Heating Medium Pressure

Provision for detecting high and/or low pressure in the heating medium in non-vented systems with options for vaporizer shutdown should be considered. For non-vented systems, a heating medium pressure relief valve shall be provided per Code requirements.

4.2.9 Protection Against Reverse Flow

Reverse-flow protection (barometric leg or other device) is required to prevent process material from flowing backwards into the vaporizer (5.2).

4.2.10 Reserve Container

A reserve container should be considered in the liquid feed line to the vaporizer to give some contingent storage of liquid to allow for time to change to another source of liquid feed.

4.2.11 Exit Water Temperature

Low water exit temperature alarm indicating possible freeze-up danger should be considered. This device should be located as near to the chlorine inlet as possible.

4.2.12 Liquid Expansion Chamber

An expansion chamber is one device which prevents over pressure and possible hydrostatic rupture due to thermal expansion of liquid chlorine trapped between closed valves. Recommended configurations and use conditions for expansion chambers are referenced in Drawing 136 (9.1.10).

4.2.13 Alarm

An alarm system in operating stations should be considered to give warning when critical improper conditions exist (not shown on schematics).

4.3 STEAM-HEATED VAPORIZERS

In addition to the controls and indicators listed in Section 4.2, the following apply to steam-heated vaporizers:

4.3.1 Steam pressure

Steam pressure regulation is required to avoid excess pressure in the steam/condensate sections of the vaporizer and in any separate superheater.

4.3.2 Pressure Relief Valve

If a steam regulating valve is used, a pressure relief valve is required between the regulator and the steam/condensate section of the vaporizer. The steam discharge of the pressure relief valve should be conveyed to a suitable location. Consideration should be given to setting the relief valve at 15 psig (corresponding to 250°F (121°C)) to avoid an over-temperature situation.

4.3.3 Air Vent

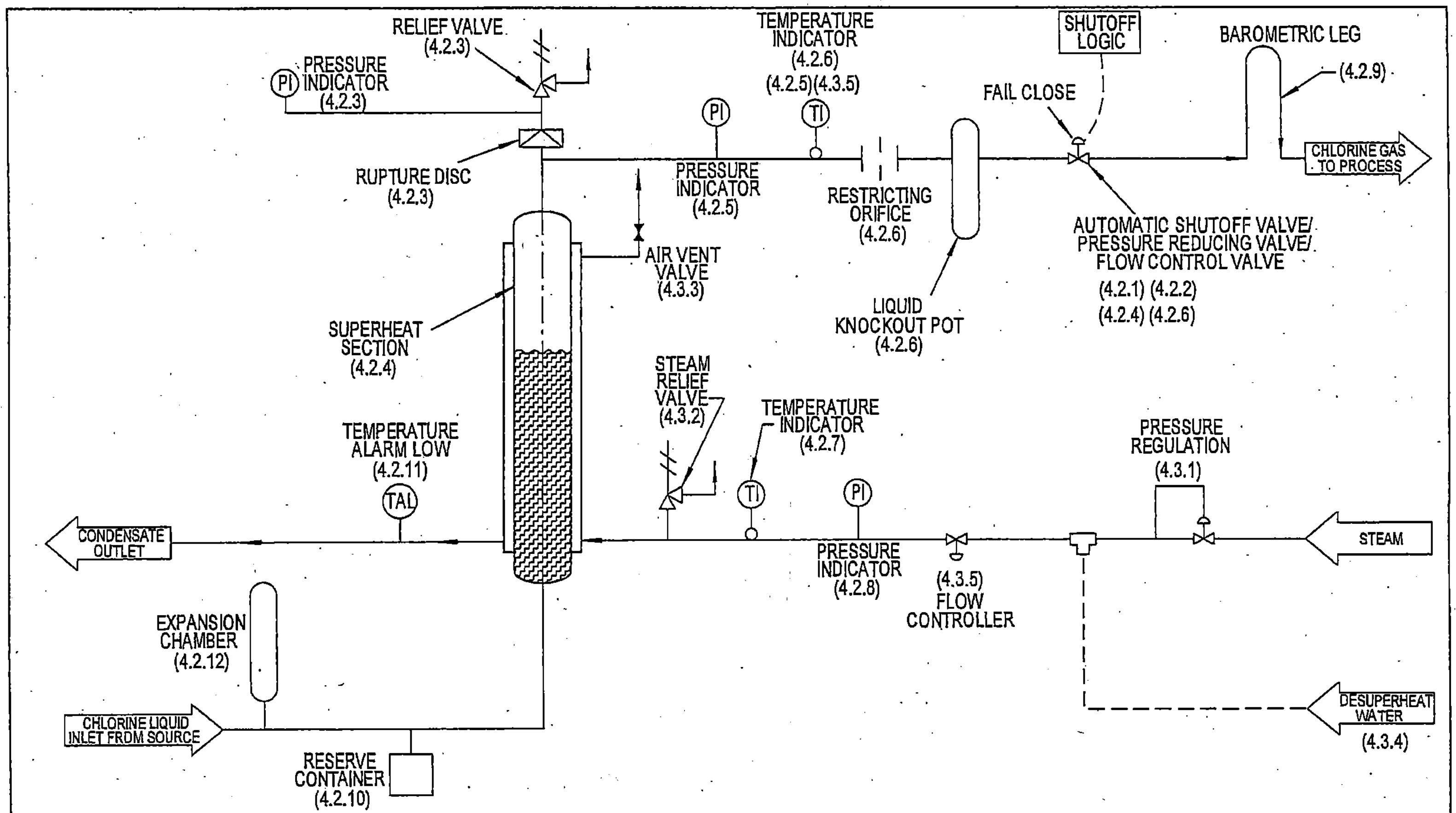
An air discharge vent valve on steam heated jacketed vaporizers is needed.

4.3.4 Desuperheat

Steam must be desuperheated to insure the feed to the vaporizer does not exceed the maximum design or operating temperature.

4.3.5 Steam Flow Control

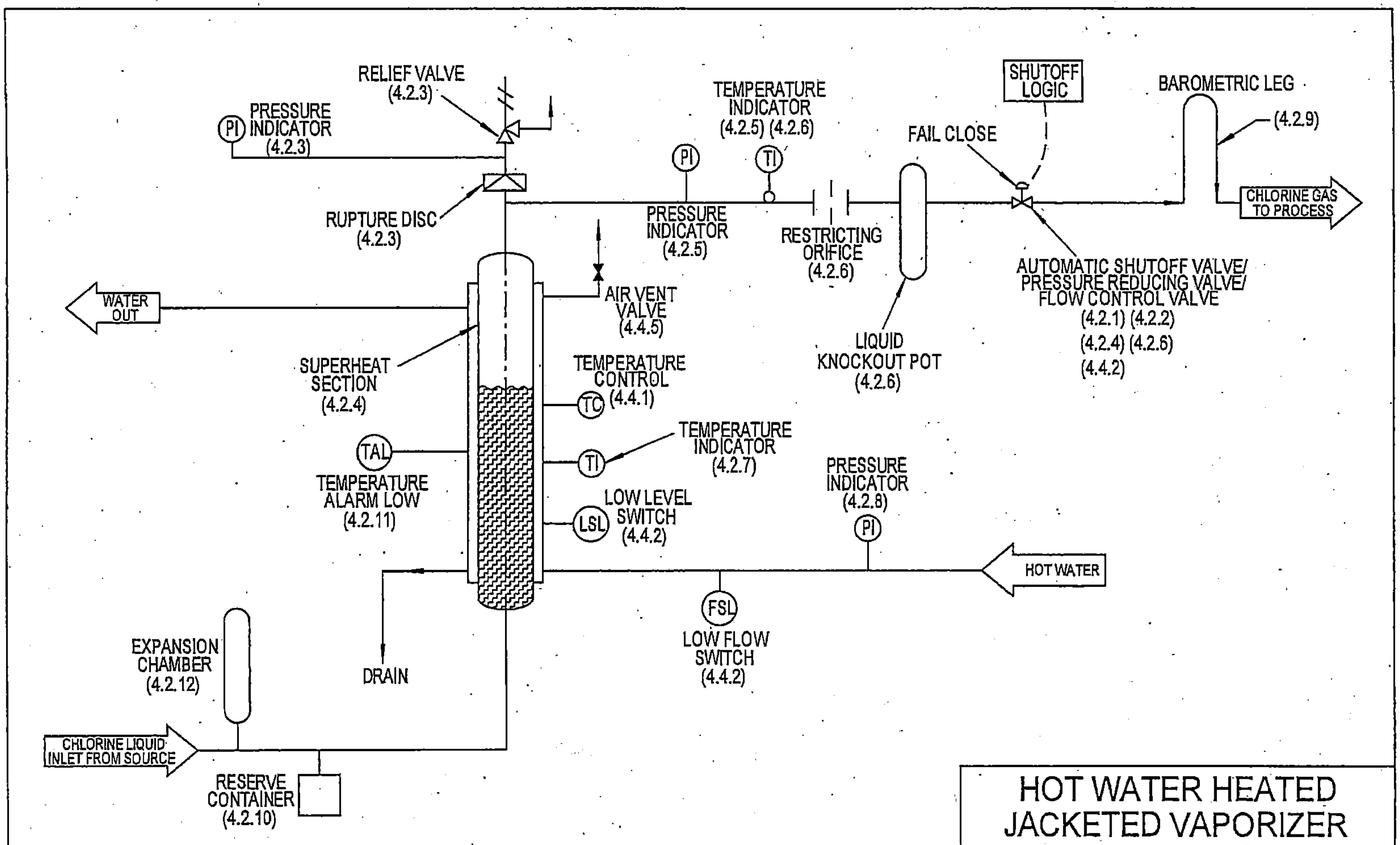
If a specific chlorine gas exit temperature is required, including chlorine superheat, then a steam flow controller can be utilized. The steam control valve should not be allowed to close off completely while there is liquid chlorine in the vaporizer.



This drawing is a schematic presentation for the purpose of illustrating typical vaporizer system requirements. It is the responsibility of the design engineer to develop an appropriate design to suit specific requirements and installations

STEAM HEATED JACKETED VAPORIZER

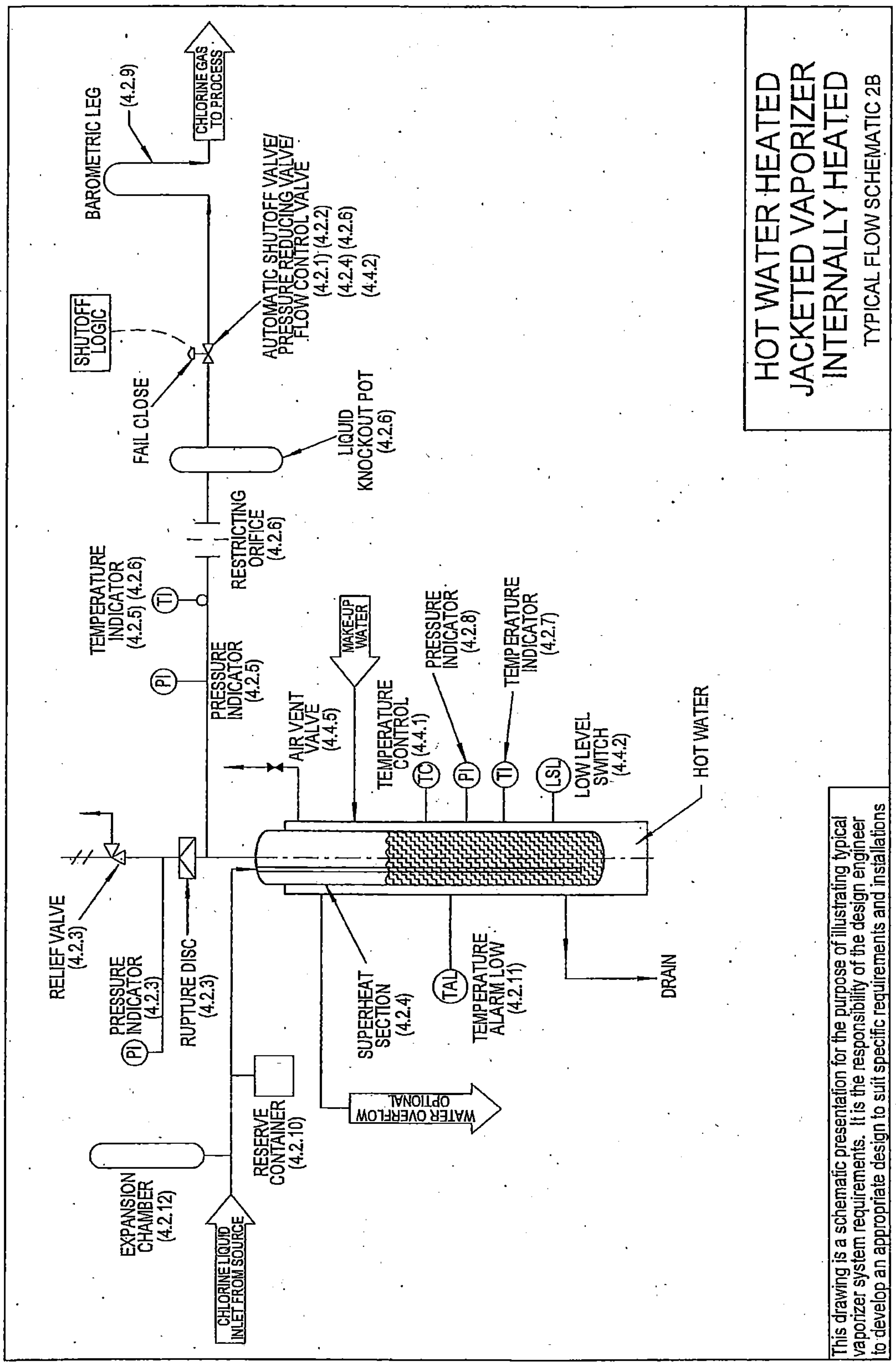
TYPICAL FLOW SCHEMATIC 1

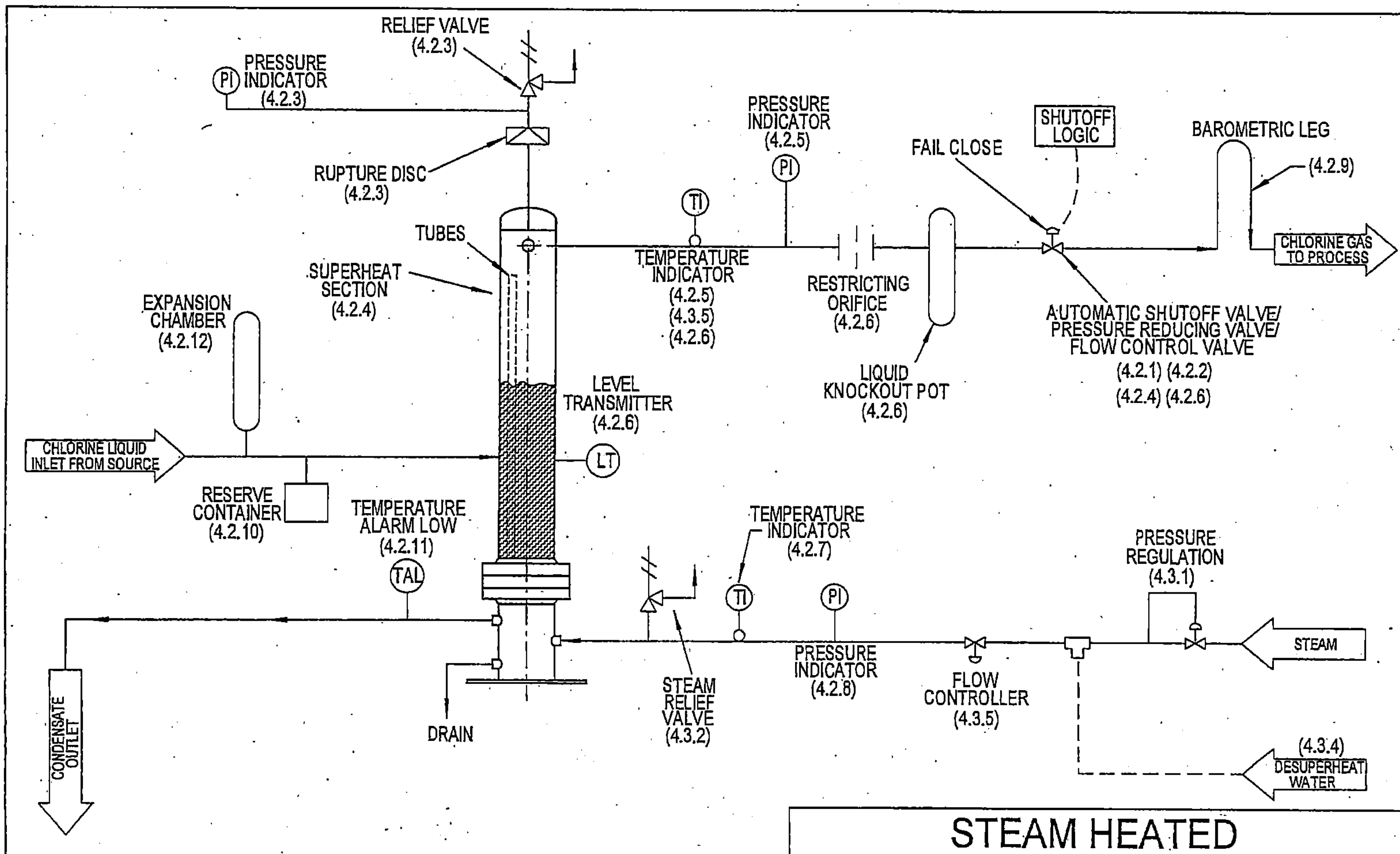


This drawing is a schematic presentation for the purpose of illustrating typical vaporizer system requirements. It is the responsibility of the design engineer to develop an appropriate design to suit specific requirements and installations

HOT WATER HEATED JACKETED VAPORIZER FLOW THROUGH OR CIRCULATED

TYPICAL FLOW SCHEMATIC 2A

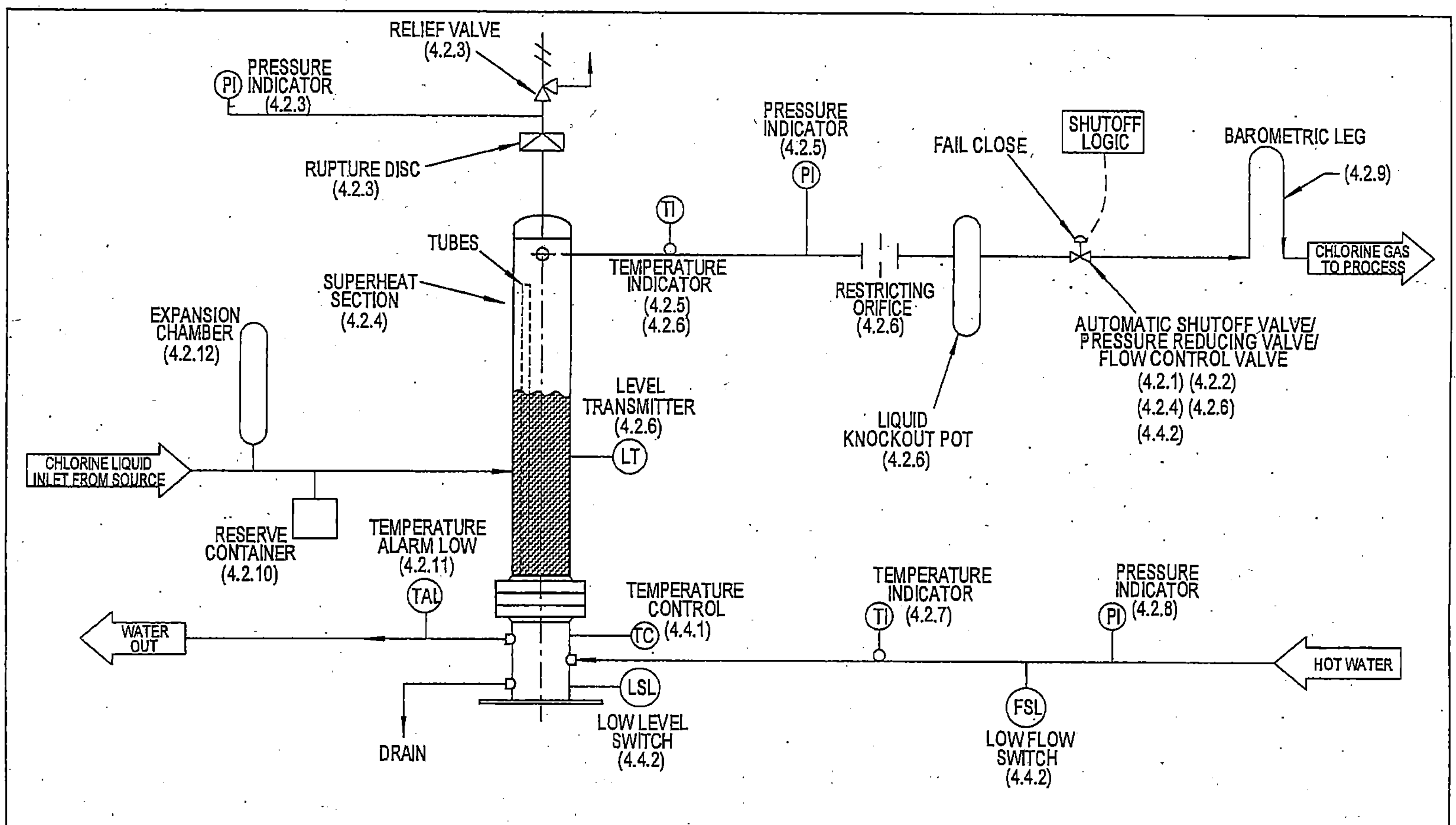

HOT WATER HEATED
JACKETED VAPORIZER
INTERNALLY HEATED
TYPICAL FLOW SCHEMATIC 2B
BAROMETRIC LEG
(4.2.9)
CHLORINE GAS TO PROCESS
SHUTOFF LOGIC
FAIL CLOSE
AUTOMATIC SHUTOFF VALVE/
PRESSURE REDUCING VALVE/
FLOW CONTROL VALVE
(4.2.1) (4.2.2)
(4.2.4) (4.2.6)
(4.4.2)
LIQUID KNOCKOUT POT
(4.2.6)
TEMPERATURE INDICATOR
(4.2.5) (4.2.6)
TI
RESTRICTING ORIFICE
(4.2.6)
PI
PRESSURE INDICATOR
(4.2.5)
MAKE-UP WATER
AIR VENT VALVE
(4.4.5)
TEMPERATURE CONTROL
(4.4.1)
TC
PRESSURE INDICATOR
(4.2.8)
PI
TEMPERATURE INDICATOR
(4.2.7)
TI
LSL
LOW LEVEL SWITCH
(4.4.2)
HOT WATER
RELIEF VALVE
(4.2.3)
PI
PRESSURE INDICATOR
(4.2.3)
RUPTURE DISC
(4.2.3)
SUPERHEAT SECTION
(4.2.4)
TAL
TEMPERATURE ALARM LOW
(4.2.11)
DRAIN
RESERVE CONTAINER
(4.2.10)
WATER OVERFLOW
OPTIONAL
EXPANSION CHAMBER
(4.2.12)
CHLORINE LIQUID INLET FROM SOURCE
This drawing is a schematic presentation for the purpose of illustrating typical vaporizer system requirements. It is the responsibility of the design engineer to develop an appropriate design to suit specific requirements and installations.



STEAM HEATED VERTICAL BAYONET VAPORIZER

TYPICAL FLOW SCHEMATIC 3

This drawing is a schematic presentation for the purpose of illustrating typical vaporizer system requirements. It is the responsibility of the design engineer to develop an appropriate design to suit specific requirements and installations



This drawing is a schematic presentation for the purpose of illustrating typical vaporizer system requirements. It is the responsibility of the design engineer to develop an appropriate design to suit specific requirements and installations

HOT WATER HEATED VERTICAL BAYONET VAPORIZER

TYPICAL FLOW SCHEMATIC 4

4.4 HOT WATER-HEATED VAPORIZERS

In addition to the controls and indicators listed in Section 4.2, the following apply to hot water-heated vaporizers:

4.4.1 Temperature Control

A hot water temperature controller in the jacket or tube section of the vaporizer is required.

4.4.2 Low Water Detector

A low water flow detector and/or a low water level detector to interrupt chlorine gas flow is required.

4.4.3 Corrosion Control

Sacrificial anodes can be used in the hot water section to counter the possibility of corrosion in the water system (not shown on schematics).

4.4.4 Maintain Water Fill

A water make-up system can be used in the water system to maintain fill (not shown on schematics).

4.4.5 Vent Valve

An air discharge vent valve should be considered on non-vented water heated jacketed vaporizers.

5. SAFETY

5.1 GENERAL

Other sections of this pamphlet deal with specifics which lead to improving the safety of maintaining and operating a chlorine vaporizer. This section summarizes measures which should be applied to minimize hazards, especially when abnormal operation occurs. The keys to overall safe operation of chlorine vaporizers are as follows:

- proper design, construction and controls (Sections 2, 3 and 4)
- proper operation (Sections 6 and 7)
- comprehensive training of personnel (all sections, especially 7.1)
- thorough maintenance and inspection of equipment (Sections 6 and 8).

5.2 PRECAUTIONS

To minimize potential hazards all chlorine vaporizers should be designed to cope with the following contingencies:

- excess pressure
- excess temperature
- flooding
- reverse process flow
- corrosion (internal and external)

Excess Pressure

Chlorine vaporizing systems must be equipped with pressure relief devices to protect the system against rupture. Pressure relief valves are the preferred relief device since they limit the amount of material released and then reseat. Pressure relief devices must be opened to the vessel while the vaporizer is in operation. The piping should not be flow restricted. Occasionally, a dual relief valve manifold with a three-way valve is used when inspection of a relief valve is required in continuous operations.

If a pressure relief valve is combined in series with a rupture disc or a breaking pin assembly, the section between these devices must be equipped with a pressure alarm or other suitable tell-tale device to detect a leaking rupture disc/breaking pin diaphragm. Local or state regulations may require the pressure relief valves be ASME certified. Pressure relief valves should be inspected and/or tested on a regularly scheduled basis.

The discharge from pressure relief devices should be vented to a receiver or a safe area. If a receiver is considered, use should be based upon the results of a risk analysis. Some receiver choices include vent scrubbers, low pressure receivers, or absorption systems.

Atmospheric venting of relief devices for vaporizers may be considered if appropriate safeguards are taken to minimize the possibility of a chlorine release to the atmosphere. Safeguards include:

- an assessment of the probability of the pressure approaching the pressure relief device setting
- an assessment of the probability that liquid will be trapped in the vaporizers with the heat source still applied

It should be noted that there is always the possibility of back flow if an absorption system is used to neutralize relief valve vents. To minimize this possibility, a barometric loop and inert gas purge system is recommended. When long vent lines are necessary, the required relief discharge flow should be considered in the design.

Chlorine vaporizer systems should be designed to allow unrestricted flow of liquid chlorine back to the supply source so that liquid is not trapped when the gas discharge valve is closed (2.4). The liquid chlorine inlet to the vaporizer should be designed to minimize trapping liquid chlorine.

Temperature Build-up

At elevated temperatures chlorine can react with its containment (steel) vessel. Precautions must be taken in the design and operation of vaporizers to insure that overheating cannot occur (3.5). These precautions should include the following:

- Protection from external fires
- No burning or welding on vessels or piping containing chlorine
- Limiting steam pressure to levels consistent with the vaporizer material of construction, and installing a de-superheating system to limit steam temperatures (4.3)
- Venting hot water systems to the atmosphere, or installing regulating devices to limit water temperatures on pressurized hot water systems (4.4)
- Guarding against thermostat failure or low water level in electrically-heated systems (4.2 and 4.4)

Flooding

Flooding is defined as the passage of liquid chlorine to the chlorine gas lines from the vaporizer. Safety procedures should be established to prevent this from occurring. Listed below are several causes of flooding:

- process demand exceeding vaporizer design rate
- inadequate heat supply
- high feed pressure to the vaporizer
- fouling of heat exchange surfaces

Flow control can be insufficient to limit the gas discharge rate from the vaporizer. Additional flooding protection can be achieved by installing a level chamber, a knockout pot with level switches, or a low temperature switch in the gas line downstream of the vaporizer and/or pressure reducing valve (4.2).

Reverse Process Flow

Reverse process flow (back flow or "suck back") can occur when the chlorine gas pressure is lower than the process side pressure. In systems where the point of application is at or near atmospheric pressure a barometric leg (of height suitable for the density of the process fluid) can aid in preventing reverse flow. Other devices such as vacuum breakers, low pressure switches and alarms, check valves, power operated control valves, and automatic back pressure regulators have been used where barometric legs are not practical. To be reliable, these devices must be adequately maintained and periodically tested. Chlorine gas introduced below the process fluid surface at the point of use requires particular care to prevent reverse flow of the process liquid into the vaporizer (4.2).

Corrosion

Failure of chlorine vaporizers can occur due to corrosion on the chlorine side, the heating medium side, or on the exterior. Each of these areas should be monitored closely.

The rate of corrosion on the chlorine side will not be serious if moisture or process fluids are not present, and if the temperatures for steel equipment are kept below approximately 250°F (121°C). Periodic inspection (and cleaning if necessary) and routine corrosion monitoring (with vessel thickness readings) will indicate corrosion trends (8.2).

In addition to corrosion on the chlorine side, vaporizers are also subject to corrosion from the heating medium side, and externally from the atmosphere. Corrosion should be monitored to ensure the integrity of the vaporizer is not compromised. Measures such as cathodic protection and exterior coatings may be effective.

5.3 Nitrogen Trichloride

The presence of nitrogen trichloride (NCl_3) in liquid chlorine is the suspected cause of explosions that have occurred, although infrequently in chlorine systems. Nitrogen trichloride may be formed in minute quantities during the production of chlorine by the reaction of chlorine with various nitrogen containing compounds. Evaporation of chlorine in a closed container (such as a vaporizer) may concentrate this compound because NCl_3 has a higher boiling point than chlorine. If sufficiently concentrated, NCl_3 can decompose spontaneously in an explosive fashion. Refer to the Institute Pamphlets 21 and 152 (9.1).

5.4 Leak Detection

When a chlorine leak occurs, protection of all personnel and the environment requires rapid leak identification, isolation and repair. Chlorine gas detectors with alarms are used in some plants for rapid detection and identification.

Adequate leak action procedures should be written and training done on a regular basis. Both approved escape and air supplied respirators must be available to those assigned to control and repair the leak. Several Institute pamphlets address this issue including Pamphlets 1, 64 and 86 (9.1).

6. PREPARATION FOR USE

6.1 General

Detailed written procedures should be provided and used by the owner for all phases of cleaning, washing, testing, and drying. The following sections are designed as aids in preparing those procedures. Additional assistance can be found by consulting Pamphlets 5 and 6 (9.1) as well as the vaporizer supplier's instructions. The owner should also be aware and follow applicable government regulations for workers' safety and environmental concerns.

6.2 CLEANING

Because chlorine may react violently with cutting oil, grease, and other foreign materials, it is important to clean all portions of chlorine vaporizing systems before use. Care must be taken in the cleaning process to remove all residues, because chlorine may also react vigorously with water and most solvents, including hydrocarbons and alcohols.

If the vaporizer was in operation, it is imperative that all chlorine be removed from the vaporizing system prior to opening the unit or introducing any moisture into the chlorine side of the chamber. Failure to do so will result in a safety risk and damage to the equipment.

There are various cleaning techniques available, but there is no best method. The appropriate technique will depend on the nature of the system and the type of contamination. For any technique employed, the user must establish a written procedure. Each step of the cleaning procedure should be closely monitored. The procedure should include criteria for written acceptance of the effectiveness of the cleaning. Reference material for developing procedures can be found in CGA' s Pamphlet G-4.1 *Cleaning Equipment for Oxygen Service* (9.3.4.).

Procedures should be in compliance with all federal, state and local regulations. The recommendations of the manufacturers of the cleaning product and the equipment to be cleaned should be followed as applicable.

Some method must be used for evaluating the effectiveness of the cleaning process. To the extent possible, an initial visual inspection should be made to look for gross contamination. For solvent and water washes any discoloration or visible particles in the spent liquid indicates contamination. Another industry practice is to shine a black light at the cleaned surface. Most oils and grease will fluoresce under this examination. Any fluorescence shall be taken to indicate contamination

Piping, valves, and instrumentation should be protected to prevent moisture absorption. If the vaporizer is to be washed only, it is possible to use slip blinds instead of removing these parts. This is normally less labor intensive. If it is intended to conduct a hydrostatic test, piping, valves, and instrumentation should be removed and protected from atmospheric moisture.

Pamphlet 5 (9.1.2) includes detailed instructions on the water wash which can be used to rid the system of any organic contaminants. Care must be taken that the entire system is flushed and that a means is devised to dispose of any residue or solids. A detergent suitable to dissolve the oil or grease can be used. This must be followed by thorough flushing with water to remove the detergent. Some facilities utilize low pressure steam versus a water wash. It has the added advantage of raising the temperature of the vessel to aid in drying. The temperature should be limited based on the equipment and insulation type, but 200°F (93°C) is typically used.

For information on solvent cleaning and cleaning the liquid and gas piping systems refer to Pamphlet 6 (9.1.3).

6.3 HYDROSTATIC TESTING

A hydrostatic test is necessary if weld repairs or alterations are made to the vessel. Owner-user policy may dictate a hydrostatic test during out-of-service inspections.

Remove piping, valves, and instrumentation from the vaporizer and protect them from absorbing moisture from the atmosphere. Install a calibrated pressure gauge suitable for the test. Fill the vaporizer with water as quickly as possible to avoid corrosion at the liquid interface. When the vessel is full of water, shut off the flow and close the outlet valve. Disconnect the water line and install a test pump. Apply hydrostatic pressure as specified in the Code. Close the inlet valve and allow the vaporizer to stand. There should be negligible pressure drop indicated on the gauge after 30 minutes, as any significant pressure drop indicates the presence of leaks.

Pressurized heating systems should be tested on the heating medium side in accordance with the current edition of the Code.

Recommended testing procedures for piping systems are covered in Pamphlet 6 (9.1.3). If insulation was removed at piping, tank or instrument connections, do not reinstall it until the vessel and piping are gas leak checked.

6.4 DRYING

The vaporizing system must always be dried before use since moisture could have entered the system during erection, cleaning, or hydrostatic testing. The following is a procedure for cleaning and pre-heating the system with steam followed by drying with dry air. Other methods, such as pulling a vacuum, may be used to achieve equivalent results.

Pass low pressure steam through the system. The steam temperature should be limited based on the equipment and insulation type. Allow condensate and foreign matter to drain out. When no further evidence of contamination is apparent at the open end and the entire system is hot, the steam supply should be disconnected. Drain all low spots to assure that all pooled or standing water is removed.

While the vessel is still hot (approximately 200°F (93°C)), blow in dry air or nitrogen having a dew point of at least -40°F (-40°C) as measured at the operating pressure. The gas purge flow should be started at a high volume rate to sweep out the moisture and then reduced. Continue the flow until the dew point of the vent gas stream is reasonably close to that of the entering gas. The rate should be at an absolute minimum long enough to reach equilibrium when the dew point is taken. Drying of the vaporizing system may require an extended period of time. It can be accelerated by utilizing the vaporizer heating medium.

After the system is dry, install all tested and inspected valves and instrumentation and reconnect piping with new gaskets. It is advantageous to leave a small purge of dry air on the vessel during this process to keep moist atmospheric air from entering the system.

6.5 LEAK TESTING

After cleaning and drying, pressurize the system to 5 psig (34.5 kPa) with dry air or nitrogen. Test for leaks by applying soapy water to the outside of joints. Chlorine gas should then be introduced in small quantities and the system pressure gradually increased until it reaches the operating level. Any effort to detect the source of a leak should be carried out with full consideration for potential hazards and appropriate protective equipment must be used.

Check for leaks using aqua ammonia after a sufficient amount of time has expired to ensure chlorine has completely diffused through the system. The most convenient testing method is to direct the vapor from a plastic squeeze bottle containing a 26° Baumé aqua ammonia (ammonium hydroxide) solution at the suspected leak. The reaction of ammonia vapor with escaping chlorine results in the formation of a dense white cloud. Do not squirt liquid aqua ammonia on pipe fittings.

For large vaporizer systems, testing at higher pressures using dry air or nitrogen is recommended. This may be accomplished in a step-wise fashion up to system operating pressure. This high test pressure must be relieved to 5 psig (34.5 kPa) to permit chlorine addition and subsequent testing with chlorine and air. Never attempt to repair leaks by welding until all of the chlorine has been purged from the system. If detectable leaks have been repaired by welding, the item should be tested and dried as described in Section 6.3.

Piping, valves, and instrumentation should be leak checked as detailed in Pamphlet 6 (9.1.3). If possible, leave the system uninsulated until it is fully in service to do further leak checking. The insulation would only be installed prior to this time if the bare fixtures will ice up due to operating conditions or ambient temperatures.

The vessel is now ready to be put in service. To avoid leaks resulting from the expansion of joints, continue to perform leak checks until the system reaches its normal operating pressure and temperature.

7. OPERATION

7.1 GENERAL

Proper preparations should be made for safe start-up of a chlorine vaporizer. A comprehensive review of the system design, preventive maintenance schedules, and thoroughness of procedural training is required. All employees involved in operating vaporizers should be trained by someone knowledgeable in all aspects of vaporizer system operation and maintenance and in OSHA requirements (9.3.2). Thorough training of personnel should be conducted on the procedures for start-up, shutdown, and changing of supply source, along with emergency procedures necessary in each area. Insure that the appropriate emergency equipment is available and ready for use (9.1.7).

7.2 START-UP

Each vaporizer supplier's start-up procedures may differ slightly. Some vaporizers automatically control the sequence of steps necessary for start up. Review the vaporizer supplier's manual to become familiar with specific start-up requirements.

The following are general guidelines:

- Liquid chlorine must never be allowed to enter a vaporizer which is not properly heated. With all chlorine valves closed (fill the water jacket if the system is a hot water heated vaporizer) turn on the heat supply. Check controls to see that they are functioning properly. Make certain the vaporizer has reached the normal operating temperature.

- Slowly open the chlorine container valve. Rapid opening of valves in a tank car supply system may result in closing of excess flow valves (Refer to Pamphlet 66 (9.1.8). Then slowly open the other valves in the liquid line, progressively from the container valve to the vaporizer inlet. Once the vaporizer inlet valve has been opened, all valves in the liquid supply line must be left open until either the supply of liquid has been exhausted or the supply line and vaporizer are empty. The heat source must remain on.

- When the chlorine pressure reaches the operating level, slowly open the vaporizer discharge valve so that chlorine gas can flow to the process line.

- If a leak is discovered at any time close the valve nearest the leak, but between the chlorine container and the leak source, and depressurize the leak source.

- Never close both the liquid inlet and gas outlet valves on a vaporizer with chlorine in the equipment and the heat source still in service.

7.3 <u>SHUTDOWN</u>

Liquid chlorine must not be trapped in the vaporizing chamber when the vaporizer is shut down. Otherwise, the pressure would reach the vapor pressure of chlorine at the temperature of the heating medium. If this temperature is high enough, the relief valve may discharge. If the vaporizer were completely full of liquid, thermal expansion could cause the pressure relief system to discharge even with the heat source shut off.

The vaporizer may be shut down in two ways. Care should be taken to understand the chlorine consuming process before selecting the shutdown method.

7.3.1 Close Off the Liquid Supply

By closing off the liquid supply and maintaining heat, the remaining liquid is vaporized and discharged to the process. A rapid fall in vaporizer pressure indicates vaporization is completed and the gas withdrawal may be stopped. This method is effective only when the chlorine is being fed into a low pressure system or into a process that will continuously consume chlorine.

Care must be taken to not allow the process to back flow into the vaporizer (5.2).

To the maximum extent possible, transfer liquid back to the source. This will minimize the amount of nitrogen trichloride that could concentrate in the vaporizer when liquid is evaporated. Reference is made to 5.3.

7.3.2 Close Off the Vapor Discharge

By closing off the vapor discharge to the process with the heat supply uninterrupted, pressure buildup in the chamber will cause the remaining liquid to return to the chlorine container. In systems with large liquid frictional pressure drop in the supply line, it may be necessary to close the gas valve gradually while observing the chlorine pressure gauge on the vaporizer to avoid excessive pressure rise which would actuate pressure relief devices. Before the liquid chlorine valves are closed ensure that all the liquid has been removed from the vaporizer.

If cylinders or ton containers are the source of chlorine, ensure there is sufficient volume to receive the contents of the vaporizer without exceeding the allowable filling volume of the container(s).

Regardless of the shutdown method utilized all chlorine must be safely purged from the system prior to opening the system.

7.4 CHANGING CHLORINE SUPPLY

Chlorine tank cars and large supply tanks are commonly padded to a constant pressure. The internal pressure of a chlorine cylinder or a ton container depends on the temperature of the liquid chlorine which in turn depends on the surrounding temperature. Because of the variations in pressure of the liquid source, the changing of containers can result in changing chlorine supply pressure and temperature. This may cause one of the following hazardous conditions:

- flooding the vaporizer and/or a surge of chlorine into the process

  To avoid this, valves should be opened slowly whenever standby chlorine supplies are brought on line.

- transfer of chlorine from the vaporizer to a container resulting in overfilling

  To avoid this, the pressure of the chlorine in the standby container must be equal to or greater than that in the vaporizer at the time of changeover. To help attain this when cylinders or ton containers are being used, store the standby containers for several days at the same temperature as those being used.

- Reverse flow of process fluid in the vaporizer and, possibly, the container (5.2)

  Positive reverse flow prevention is required.

Users generally employ some system to determine when the supply container is nearly empty and must be switched or replaced. Some examples include monitoring chlorine use, weighing the container, or sensing vapor in the liquid supply line.

8. MAINTENANCE

8.1 GENERAL

Chlorine vaporizers require adequate and timely maintenance. Effective maintenance starts with frequent observation, and includes periodic inspection, cleaning as dictated, and disassembly for full inspection.

The frequency of cleaning and internal inspection of vaporizers is dependent on variables that include the quality of feed liquid, the introduction of moisture, a change in operating performance, and the time in operation.

A program for proof testing critical instrumentation should be followed.

8.2 FREQUENCY OF INSPECTIONS

The frequency of inspections for determining maintenance requirements can be divided into two categories: internal and external. These should include the complete system, not just the vaporizer vessel.

8.2.1 External Inspection

As part of the normal operating routines, checks should include the following as appropriate:

- gaskets and valves for leaks
- insulation for damage and signs of leaks
- proper function of steam traps
- proper function of all instruments
- condition of chlorine supply system
- coating condition
- general housekeeping of area to guarantee safe personnel entrance and escape

The vaporizing system should undergo an extensive documented visual inspection by the owner every year for corrosion or signs of leakage.

8.2.2 Internal Inspection

The frequency for the internal inspection of the vaporizing chamber shall be determined by considering the following variables:

- type of service
- the quality of the chlorine source
- the quality of pad gas

- changes in system performance
- the frequency of connects and disconnects
- the length of time in operation
- metal thickness measurements

It is imperative that all chlorine be removed from the vaporizing system prior to opening the unit or introducing any moisture into the chlorine side of the chamber. Failure to do so will result in a safety risk and damage to the equipment.

It is suggested that an initial internal inspection of the vaporizer chamber be performed after one year of service. Depending upon the results, the interval to the next inspection can be lengthened or shortened. Depending on chlorine quality delivered to the vaporizer, inspection intervals can vary from less than one year to greater than five years. If a moisture upset occurs, a full internal inspection is required as soon as possible. After assembly the unit should be prepared for use per Section 6.

The heating medium side of the vaporizer should be inspected on regular intervals based on local experience or manufacturer's recommendations. A full inspection includes a rigorous examination of heating medium side for pitting and general corrosion. Special attention should be made to all vessel connections.

Detailed records of all internal inspections and/or repairs must be kept.

8.3 CLEANING

The need for cleaning is indicated by a reduction in superheat of the chlorine gas or a reduction in the operating capacity of the vaporizer. Cleaning should be performed as recommended by the supplier of the vaporizer but general procedures are discussed in Section 6.2.

8.4 REPAIRS BY WELDING

Before welding, make sure that all piping and equipment is thoroughly purged of chlorine. The heat of welding may cause ignition of chlorine with steel. All welding, stress relieving, radiographing, hydrostatic testing, inspection and restamping must be performed in compliance with the current edition of the Code (9.3.3).

9. REFERENCES

9.1 INSTITUTE PUBLICATIONS

9.1.1 *Chlorine Manual*, ed. 6; Pamphlet 1; The Chlorine Institute: Arlington, VA, **1997**.

9.1.2 *Non-Refrigerated Liquid Chlorine Storage*, ed. 6; Pamphlet 5; The Chlorine Institute: Arlington, VA, **1998**.

9.1.3 *Piping Systems for Dry Chlorine*, ed. 14; Pamphlet 6; The Chlorine Institute: Arlington, VA, **1998**.

9.1.4 *Nitrogen Trichloride - A Collection of Reports and Papers*, ed. 4; Pamphlet 21; The Chlorine Institute: Arlington, VA, **1997**.

9.1.5 Handling Chlorine Tank Motor Vehicles, ed. 8; Pamphlet 49; The Chlorine Institute: Arlington, VA, **2001**.

9.1.6 *Emergency Shut-Off Facilities for Tank Car and Tank Truck Transfer of Chlorine*, ed. 3; Pamphlet 57; The Chlorine Institute: Arlington, VA, **1997**.

9.1.7 *Emergency Response Plans for Chlorine Facilities*, ed. 5; Pamphlet 64; The Chlorine Institute: Arlington, VA, **2000**.

9.1.8 *Recommended Practices for Handling Chlorine Tank Cars*, ed. 3; Pamphlet 66; The Chlorine Institute: Arlington, VA, **2001**.

9.1.9 *Recommendations to Chlor-Alkali Manufacturing Facilities for the Prevention of Chlorine Releases*, ed. 4; Pamphlet 86; The Chlorine Institute: Arlington, VA, **2001**.

9.1.10 *Chlorine Expansion Chambers*, Drawing; DWG 136-5; The Chlorine Institute: Arlington, VA, **1992**.

9.1.11 *Manifolding Ton Containers for Liquid Chlorine Withdrawal*, Drawing; DWG 183-3; The Chlorine Institute: Arlington, VA, **1994**.

9.2 ASME CODES

9.2.1 *Rules for Construction of Pressure Vessels, Section VIII - Division I*, ASME Boiler and Pressure Vessel Code; ANSI/ASME BPV-VIII-I; The American Society of Mechanical Engineers: New York, NY, (revised annually).

9.2.2 *Welding and Brazing Qualifications, Section IX*, ASME Boiler and Pressure Vessel Code; ANSI/ASME BPV-IX; The American Society of Mechanical Engineers: New York, NY, (revised annually).

9.2.3 *Chemical Plant and Petroleum Refinery Piping*, ASME Code for Pressure Piping; ANSI/ASME B31.3; The American Society of Mechanical Engineers: New York, NY, (revised annually).

9.3 MISCELLANEOUS

9.3.1 *National Electric Code*; NFPA 70; National Fire Protection Association: Quincy, MA, **2002**.

9.3.2 *Process Safety Management of Highly Hazardous Chemicals*. 29 CFR 1910.119. Department of Labor. U.S. Government Printing Office: Washington, DC, (revised annually).

9.3.3 *National Board Inspection Code,* Manual for Boilers and Pressure Vessel Inspectors; ANSI/NB-23; National Board of Boiler and Pressure Vessel Inspectors: Columbus, OH, **2001**.

9.3.4 *Cleaning Equipment for Oxygen Service*, ed. 4; Pamphlet G-4-1; Compressed Gas Association, Inc. Arlington, VA, **1996**.

For further assistance and information on items referenced, contact:

American Society of Mechanical Engineers
United Engineering Center
345 East 47th Street
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212-705-7740
1-800-843-2763 (publications)
http://www.asme.org

The Chlorine Institute, Inc.
1300 Wilson Boulevard
Arlington, VA 22209
703-741-5760
703-741-6068 (Fax)
http://www.CL2.com

Superintendent of Documents
Government Printing Office
Washington, DC 20402
202-512-1800 (sales)
http://www.access.gpo.gov

National Board of Boiler and Pressure
Vessel Inspectors
1055 Crupper Avenue
Columbus, OH 43229
614-888-8320
www.nationalboard.org

National Fire Protection Association
1 Batterymarch Park
Quincy, MA 02269-9101
617-770-3000
617-770-0700 (Fax)
www.nfpa.org

Compressed Gas Association
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Phone: 703-788-2700
Fax: 703-961-1831
http://www.cganet.com/

APPENDIX A

CHECKLIST

This checklist is designed to emphasize major topics for someone who has already read and understood the pamphlet. Taking recommendations from this list without understanding related topics can lead to inappropriate conclusions.

Place a check mark (_) in the appropriate box below:

Yes	No	N/A			
❑	❑	❑	1.	Does the vaporizer installation comply with regulatory and insurance requirements?	{1.5}
❑	❑	❑	2.	Is manifolding of ton containers in accordance with Drawing 183 and Pamphlet 1?	{2.3}
❑	❑	❑	3.	Is adequate liquid supply pressure available without padding?	{2.3}
❑	❑	❑	4.	If padding is used, does it comply with recommendations in Pamphlets 5, 49 and 66?	{2.3, 3.10}
❑	❑	❑	5.	Are automated shutdown instrumentation and/or procedures provided?	{2.4}
❑	❑	❑	6.	Does the location of the vaporizer system meet the Institute's recommendations?	{2.6}
❑	❑	❑	7.	Does the system capacity exceed peak process demands?	{3.3}
❑	❑	❑	8.	Does the lowest expected temperature meet the minimum metal temperature used in the design?	{3.5}
❑	❑	❑	9.	Are the materials of construction appropriate for the intended service?	{3.6}
❑	❑	❑	10.	Does the design and fabrication comply with the ASME Code?	{3.7}
❑	❑	❑	11.	Have chlorine side pressure-retaining, butt-welded joints been fully radiographed?	{3.7}
❑	❑	❑	12.	Has post-weld heat treatment been performed?	{3.8}
❑	❑	❑	13.	Has a corrosion allowance of 1/8 inch (3.18 mm) minimum been provided?	{3.9}
❑	❑	❑	14.	Has a detailed review of system controls and indicators been performed?	{4}
❑	❑	❑	15.	Has a detailed systems safety review been performed?	{5.2}
❑	❑	❑	16.	Do appropriate emergency response procedures and training programs exist?	{5.4}
❑	❑	❑	17.	Do detailed written procedures for cleaning, testing and drying exist?	{6.1}

❑	❑	❑	18.	Was the system properly cleaned, tested and dried prior to being placed in service? {6.2, 6.3, 6.4}
❑	❑	❑	19.	Was the system leak tested with gas prior to being placed in service?{6.5}
❑	❑	❑	20.	Have proper preparations been made for a safe start-up, operation and shutdown? {7}
❑	❑	❑	21.	Are inspection and maintenance procedures and schedules adequate? {8}

REMINDER

Users of this checklist should document exceptions to the recommendations contained in this pamphlet.