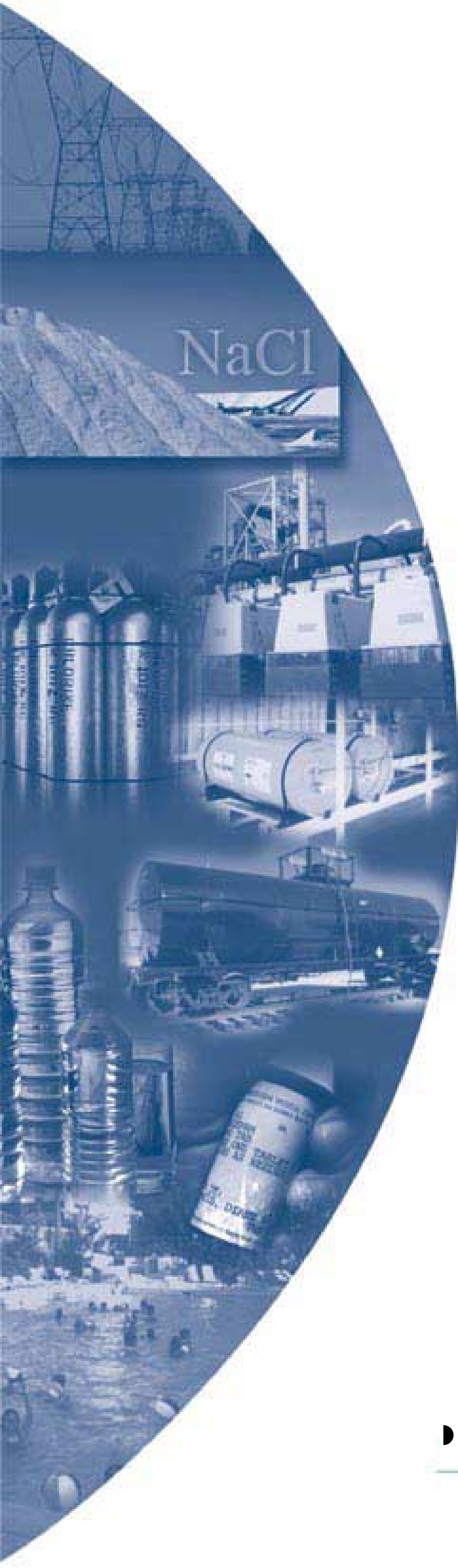

THE CHLORINE INSTITUTE, INC.

Pamphlet 5

Bulk Storage of Liquid Chlorine

Edition 7

A LEGACY OF SAFETY STEWARDSHIP since 1924

October 2005

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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 Tank Car and Tank Motor Vehicle Sizes

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 Chlorine Barge Sizes

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 Using Shipping Units for Fixed Storage

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 Mechanical Considerations

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 Exterior Corrosion

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 Supports

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 ($k = C_p/C_v$) 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 1 2 JQ*, 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.

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