The widespread use of chlorine and the accompanying demand for authoritative information on recognized principles of chlorine handling resulted in the publication of the first *Chlorine Manual* by the Chlorine Institute in 1947. The second, third and fourth editions were published in 1954, 1959 and 1969 respectively. This fifth edition reflects updated experience involving the safe handling of chlorine and the many changes in pertinent regulations.

This manual contains information available to the Institute based on experience with materials, equipment and practices that contribute to the safe handling, storage, shipment and use of chlorine. Important properties of chlorine are included as well as methods of dealing with potential emergencies. Brief information is included on the manufacture of chlorine. The reference section will serve readers who would like more detailed information about matters on which the text, of necessity, is brief. Where questions remain, such as to details of protective provisions or procedures, the user should consult the producer or supplier of his chlorine or chlorine handling equipment or he should consult the Institute.

The information in this *Chlorine Manual* is drawn from sources believed to be reliable. Safety suggestions are based on the accident prevention experience of members of The Chlorine Institute, Inc. The Institute and its members make no guarantee, jointly or severally, in connection with the information or safety suggestions herein. Moreover, it should not be assumed that every acceptable safety procedure is included or that abnormal or unusual circumstances may not warrant or require modified or additional procedures. The user should be aware that changing technology or regulations may require a change in the recommendations herein. Appropriate steps should be taken to assure that the information is current. These suggestions should not be confused with federal, state, provincial or municipal regulations nor with national safety codes or insurance requirements.

THE CHLORINE INSTITUTE, INC.

Organized in 1924, the Institute is a non-profit association dedicated to the promotion of occupational and environmental safety in all aspects of chlorine production, transportation, and handling.

FIFTH EDITION

The Chlorine Institute, Inc.
2001 L Street, NW
Washington, D.C. 20036

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DANGER! Chlorine is a hazardous chemical that can cause severe injury or death if released to the atmosphere. To avoid injury when working with chlorine—

- **ALWAYS** carry or have immediately available an approved, escape-type respirator.
- Check operating condition of self contained breathing apparatus and Chlorine Institute Emergency Kits (if provided) on a scheduled basis.
- Develop a healthy respect for chlorine. Read this manual and other pertinent Institute publications.

In Case of an Accident—

1. Move victim cross wind to an area clear of chlorine. Use appropriate respiratory equipment for rescue! Don't become another victim!
2. If breathing has apparently ceased, start artificial respiration immediately. If the victim is breathing, keep him in a comfortable position, calm and warm.
3. If heart has stopped. start cardiopulmonary resuscitation.
4. If trained personnel are available, administer oxygen.
5. Summon medical assistance as soon as possible. For detailed information see Section 6 of this manual.

BE PREPARED FOR AN EMERGENCY!

AVOIDING AN ACCIDENTAL RELEASE

The risk of chlorine releases can be minimized by adhering to the following:

- Equipment Design and Construction

  Chlorine handling systems should be designed by engineers familiar with chlorine. Knowledgeable persons should approve design drawings and should inspect equipment installations before connecting to a chlorine supply. The Institute's Pamphlet 6, Piping Systems For Dry Chlorine, (Ref. 10.5.2.2) serves as a guide for handling dry chlorine.

- Equipment Maintenance

  Periodic inspections by knowledgeable persons should be made to assure that the equipment is used appropriately and that the system is kept in suitable operating condition.

- Safety Programs

  Every installation should have an on-going safety program. Periodic training sessions and safety inspections should be conducted. Special attention should be paid to the appropriateness of emergency procedures and to equipment to be used in an emergency. Additional information on safety programs is available from the Institute and from chlorine suppliers.

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1. GENERAL INFORMATION

1.1 **CHLORINE MANUFACTURE**

Most chlorine is manufactured electrolytically by the diaphragm cell process, the mercury cell process or the membrane cell process. The diaphragm cell process is predominant in North America. In each process a salt solution is electrolyzed by the action of direct electric current which converts chloride ions to elemental chlorine.

In the diaphragm cell process, using sodium chloride as feed, chlorine is produced at the positive electrode (anode) and sodium hydroxide (caustic soda) and hydrogen are produced at the negative electrode (cathode). In order to prevent the reaction of caustic soda with the chlorine, the anode and cathode chambers are separated by a porous diaphragm. Chlorine is removed from the gas space while the brine flows through the diaphragm from the anode chamber to the cathode chamber. Chlorine is further processed to yield a dry liquefied product. In the cathode chamber hydrogen is removed from the gas space and a dilute solution of caustic soda and salt is removed as a liquid. This "cell liquor" is concentrated to produce commercial caustic soda.

In the mercury cell process a flowing stream of mercury serves as the cathode. Chlorine is removed from the gas space and elemental sodium is formed at the cathode. The sodium amalgamates with the mercury. The sodium amalgam then flows to a decomposer where it is reacted with purified water to produce caustic soda and hydrogen. The regenerated mercury is recycled back to the cell.

The membrane cell differs from the diaphragm cell in that the membrane allows passage of only positively charged ions (i.e., Na^+ or H_3O^+). Hydroxide ions are formed at the cathode, and sodium ions move from the anolyte compartment through the membrane. This permits direct production of higher strength caustic solutions. Since chloride ions do not diffuse through the membrane, a relatively chloride free caustic is produced.

Chlorine also is produced in a number of other ways, for example, by electrolysis of potassium chloride brine with co-production of potassium hydroxide; by electrolysis of molten sodium or magnesium chloride to make elemental sodium or magnesium metal; by electrolysis of hydrochloric acid; and by non-electrolytic processes.

1.2 **CHLORINE IN TRANSPORTATION**

1.2.1 **General**

Chlorine is normally shipped as a liquefied compressed gas. All containers used in the transportation of chlorine, as well as all modes of their transportation, are controlled by regulations. It is the responsibility of each person shipping or transporting chlorine to know and to comply with all applicable regulations.

1.2.2 **United States**

In the United States chlorine in commerce is regulated principally by the Department of Transportation (DOT) and is classified a non-flammable gas. For land transportation and for carriage of containers by water DOT regulations appear in Title 49 Code of Federal Regulations (CFR) (Ref. 10.2.2.2). DOT regulations covering tank barges appear in Title 46 CFR (Ref. 10.2.2.1.) Many states have adopted regulations substantially the same as DOT regulations. In addition there may be local requirements.

1.2.3 **Canada**

In Canada chlorine is classified as a corrosive gas. Regulations are issued by the Canadian Transport Commission (CTC) (Ref. 10.2.1.1) for rail transportation. Regulations for all modes are issued by Transport Canada (Ref. 10.2.1.2). In addition, the Canadian Transport Commission has issued General Order 0-35 pertaining to chlorine tank car unloading facilities (Ref. 10.2.1.3). Many Canadian regulations are consistent with U.S. regulations but it must not be assumed that this is always the case.

1.2.4 **International**

For international shipments it is important to establish in advance that shipping containers and shipping papers are acceptable. The United Nations has applicable regulations. For example, they control the marine mode through the International Maritime Organization (IMO).

1.3 **OTHER REGULATORY ASPECTS**

In common with other industries, U.S. chlorine manufacturers, packagers and most consumers are subject to the workplace regulations issued by the Department of Labor (DOL), Title 29 CFR Occupational Safety and Health Administration (OSHA) (Ref. 10.7.2) and environmental regulations issued by the Environmental Protection Agency (EPA), Title 40 CFR (Ref. 10.7.3). When used as a disinfectant (water or waste treatment), chlorine is considered to be a fungicide and is subject to EPA regulations issued under the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) (Ref. 10.7.3). In addition, state or local requirements may apply. Similar regulations apply in many other countries.

Various numbering systems of chemicals apply in certain regulatory programs. For chlorine, the following are pertinent:

- For transportation, chlorine's UN designation is UN1017.
- The Chemical Abstracts Service number is CAS 7782-50-5.
- The RTECS number assigned in the US by the National Institute for Occupational Safety and Health is F02100000.

1.4 CHEMICAL AND PHYSICAL PROPERTIES

Chlorine is one of the chemical elements and is one of the halogens. Neither the gas nor the liquid is explosive or flammable; both react chemically with many substances. Chlorine is only slightly soluble in water. The gas has a characteristic odor and greenish yellow color and is about two and one-half times as heavy as air. Thus, if it escapes from a container or system, it will tend to seek the lowest level in the building or area in which the leak occurs.

Liquid chlorine is amber in color and is about one and one-half times as heavy as water. At atmospheric pressure, it boils at about -29°F(-34°C) and freezes at about -150°F (-101°C). One volume of liquid chlorine, when vaporized, yields about 460 volumes of gas.

Although dry chlorine (gas or liquid) does not react with (corrode) many metals, it is very reactive (strongly corrosive) when moisture is present. See 9.3.3.2.

1.5 TERMINOLOGY

1.5.1 Chlorine

The chemical element in whatever state or condition it may exist under the conditions being considered.

1.5.2 Liquid Chlorine

The element, chlorine, in the liquid state. Note: The term "liquid chlorine" sometimes is used to describe a hypochlorite solution often employed for swimming pool sanitation. This is a misuse of the term and is to be discouraged.

1.5.3 Chlorine Gas

The element, chlorine, in the gaseous state.

1.5.4. Dry Chlorine

Chlorine, liquid or gaseous, containing no more than 150 ppm water (by weight). Note: The term "dry chlorine" sometimes is used to describe a dry compound (usually calcium hypochlorite or the chloroisocyanurates) often employed for swimming pool sanitation. This is a misuse of the term and is to be discouraged.

1.5.5 Moist Chlorine

Chlorine, liquid or gaseous, containing more than 150 ppm water (by weight).

1.5.6 Wet Chlorine

Synonymous with moist chlorine.

1.5.7 Saturated Chlorine Gas

Chlorine gas in such condition that the removal of any heat will cause some portion of it to condense to a liquid. This term is not to be confused with wet or moist chlorine.

1.5.8 Saturated Chlorine Liquid

Chlorine liquid in such condition that the addition of any heat will cause some portion of the chlorine to vaporize to a gas. This term is not to be confused with wet or moist chlorine.

1.5.9 Chlorine Solution (Chlorine Water)

A solution of chlorine in water (for solubility of chlorine in water see Fig. 9.3). Note: The term "chlorine solution" is sometimes used to describe hypochlorite solutions. This is a misuse of the term and is to be discouraged.

1.5.10 Liquid Bleach

A solution of hypochlorite, usually sodium hypochlorite. This term rather than "liquid chlorine" should be used to describe a liquid hypochlorite product. See 1.5.2.

1.5.11 Container

In this publication, any container authorized by an applicable regulatory body for the transport of chlorine. It does not include pipelines or stationary storage tanks specifically designed and installed for storage.

1.6 HEALTH HAZARDS

Chlorine gas is primarily a respiratory irritant. In sufficient concentration, the gas irritates the mucous membranes, the respiratory system and the skin. In extreme cases difficulty in breathing may increase to the point where death can occur from suffocation.

The characteristic, penetrating odor of chlorine gas usually gives warning of its presence in the air. Its greenish yellow color makes it visible at high concentrations.

Liquid chlorine in contact with skin or eyes will cause burns. See 6.

1.7 OTHER HAZARDS

1.7.1 Fire

Chlorine is neither explosive nor flammable; however, chlorine will support combustion.

1.7.2 Chemical Action

Chlorine has a very strong chemical affinity for many substances. It will react with many inorganic and organic compounds, usually with the evolution of heat. At elevated temperatures it reacts vigorously with many metals. See 9.3.

1.7.3 Corrosive Action

At ordinary temperatures, dry chlorine, either liquid or gas, does not corrode steel. In the presence of moisture, however, highly corrosive conditions exist as a result of the formation of hydrochloric and hypochlorous acids. Precautions should be taken to keep chlorine and chlorine equipment free from moisture. Piping, valves and containers should be closed or capped when not in use to keep atmospheric moisture out of the system. If water is used on a chlorine leak the resulting corrosive conditions will make the leak worse.

1.7.4 Volumetric Expansion

The volume of liquid chlorine increases considerably with increasing temperature. Precautions should be taken to avoid hydrostatic rupture of containers or other equipment filled with liquid chlorine.

1.8 CONTAINERS

1.8.1 Container Specifications

Chlorine shipping containers other than barges must comply with the authorized, numbered specification under which they have been fabricated. New containers must be fabricated according to current specifications. Older containers may be continued in service in accord with applicable regulations. Plans and specifications for construction of barges must be approved by the U.S. Coast Guard, the Canadian Coast Guard or both if the barge is to be operated in the U.S. and in Canada.

1.8.2 Container Types

- **Cylinders.** Fabricated to DOT (or CTC) specification 3A480 or 3AA480. See 2. Cylinders conforming with some older specifications may still be used. "Lecture bottles" 3E1800 and sample cylinders 3BN480 also are authorized; these need not have a pressure relief device.
- **Ton Containers.** Fabricated to DOT (or CTC) specification 106A500X. See 2. This is a multi-unit tank car tank specification. Ton containers conforming with older specifications may still be used.
- **Tank-Multi-Unit (TMU) Cars.** Specially built railroad cars with cradles to carry 15 one-ton containers. The TMU car is nearly obsolete and will not be considered further in this manual.
- **Tank Cars.** Railroad tank cars fabricated to DOT (or CTC) specification 105A500W. See 3.2. Cars built to some older specifications may still be used.
- **Tank Motor Vehicles.** Tank trailers complying with DOT specification MC 331. See 3.3. Trailers conforming to ICC specification MC 330 may still be used.
- **Tank Barges.** Barges containing chlorine tanks, usually four. See 3.5.

1.8.3 Container Similarities

All containers are similar in the following aspects:

- They are constructed of steel.
- They are inspected and pressure tested at regular intervals as required by applicable regulations.
- They are equipped with one or more pressure (or safety) relief devices.
- They are marked, labeled and placarded as required by applicable regulations.
- The weight of chlorine that is loaded into a container may not exceed 125% of the weight of water at 60°F (15.6°C) that the container will hold. For this purpose, the weight in air of a U.S. gallon of water is taken to be 8.32828 lb (3.77764 kg). The percentage, 125%, is called the filling density.

2. CYLINDERS AND TON CONTAINERS

2.1 CONTAINER DESCRIPTIONS

2.1.1 General

Cylinders and ton containers have many similarities in the way in which they are handled, and many users of cylinders also use ton containers. Therefore, they are considered together in this section. It is important that the terms "cylinder," "ton cylinder," or "drum" not be used to describe the ton container. Emergency equipment for handling ton containers is different from that used for cylinders and much confusion can be avoided if the proper terms are used.

2.1.2 **Cylinders**

Chlorine cylinders are of seamless construction with a capacity of from 1 to 150 lb (0.45 to 68 kg); those of 100 lb and 150 lb (45.4 and 68 kg) capacity predominate. Approximate dimensions and weights of common cylinders are shown in Table 2.1. Cylinders are the foot-ring type, bumped-bottom type or double-bottom type (Fig. 2.1). Chlorine cylinders are not permitted to be fabricated with more than one opening, the valve connection at the top. A steel valve protective housing is provided to cover the valve.

The DOT or CTC specification number, serial number, identifying symbol, inspector's official mark and date of hydrostatic test must be stamped on the metal near the cylinder neck. It is illegal to mar or deface these markings. The tare weight is stamped in the same area. Tare weight means weight of cylinder and valve but not the valve protective housing.

2.1.3 **Ton Containers**

Ton containers are welded tanks having a capacity of 1 short ton, 2000 lb (907 kg) and a loaded weight of as much as 3700 lb (1678 kg) (Fig. 2.2). Approximate dimensions and weights are shown in Table 2.1. The heads are convex inward and forge welded to the barrel. The sides are crimped inward at each end to form chimes which provide a substantial grip for lifting beams. The container valves are protected by a removable steel valve protective housing. (A few containers of different design are in service.)

The DOT or CTC specification number, the material and cladding material if any, the owner's or the builder's identifying symbol and serial number, the inspector's mark, the test date(s), and the water capacity must all be stamped into the chime at the valve end. It is illegal to mar or deface these markings. Instead of being stamped in the metal, this information may be stamped on a brass plate secured to the tank head opposite the valve end. In addition to the above required markings, the tare weight sometimes is stamped either on the chime or on the brass plate. Tare weight means weight of the container with valves and fusible plugs but not the valve protective housing.

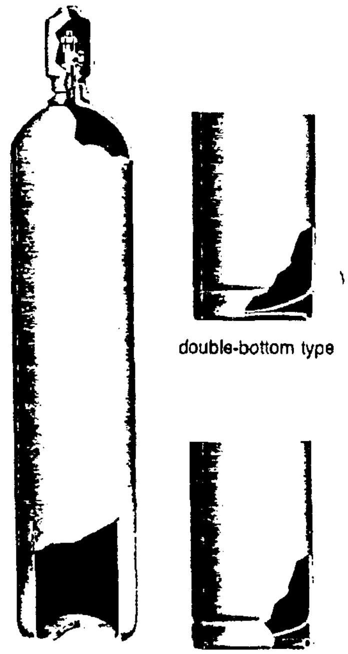

Figure 2.1
Chlorine Cylinders

Figure 2.2
Chlorine Ton Container

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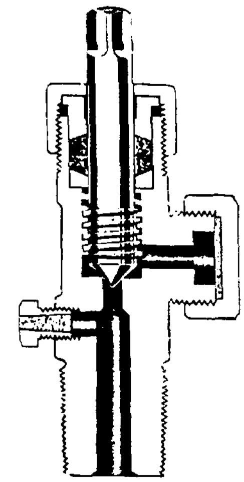


Figure 2.3
Standard Cylinder Valve

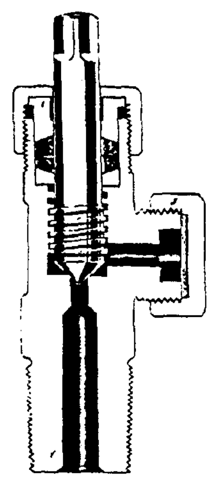


Figure 2.4
Standard Ton Container Valve

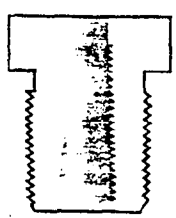


Figure 2.5
Standard Fusible Plug for Ton Containers

2.2 CONTAINER VALVES

2.2.1 Cylinders

There is a standard cylinder valve (Fig. 2.3) (Ref. 10.4.1.7). The valve outlet threads are not standard pipe threads but are special straight threads (designated as 1.030"-14NGO-RH-EXT). See 2.8.5 for details on recommended connections. Cylinder valves are equipped with a pressure relief device. See 2.3.1.

2.2.2 Ton Containers

Each ton container is equipped with two identical valves near the center of one end. These valves are standard ton container valves (Fig. 2.4) (Ref. 10.4.1.7). They differ from the standard cylinder valve only in that they have no fusible metal plug and have a larger internal passage. Each valve connects with an internal eduction pipe (Fig. 2.2).

2.3 PRESSURE RELIEF DEVICES

2.3.1 Cylinders

Cylinder valves are equipped with a fusible metal pressure relief device. Most valves have a threaded plug containing the fusible metal screwed into a tapped hole in the valve body, below the valve seat. (A few have fusible metal cast directly into a threaded hole in the valve body.) The fusible metal is designed to yield or melt between 158°F and 165°F (70°C and 74°C) to relieve pressure and prevent rupture of the container in case of fire or other exposure to high temperature.

2.3.2 Ton Containers

All ton containers are equipped with fusible metal pressure relief devices (Fig. 2.5). Most have six fusible metal plugs, three in each end, spaced 120° apart. The fusible metal is designed to yield or melt between 158°F and 165°F (70°C and 74°C) to relieve pressure and prevent rupture of the container in case of fire or other exposure to high temperature.

2.4 CONTAINER SHIPPING

2.4.1 Cylinders

Cylinders may be shipped by truck, rail or water. Truck shipments may be truckload or less-than-truckload (LTL) lots. Suitable restraints are necessary to prevent cylinders from shifting during transportation.

2.4.2 Ton Containers

Most ton containers are shipped by private carrier trucks. Such trucks should have suitable holddown devices or chocks with chains to prevent the containers from shifting during transportation. Trucks are sometimes

TABLE 2.1
CONTAINER DIMENSIONS AND WEIGHTS

Capacity lb	(kg)	Tare Weight lb	(kg)	Outside Diameter in	(mm)	Overall Height (1) or Length in	(mm)
100	45	63–115	29–52	8¼–10¾	210–273	39½–59	1003–1499
150	68	85–140	39–64	10¼–10¾	260–273	53–56	1346–1422
2000	907	1300–1650	590–748	30	762	79¾–82½	2026–2096

Note: (1) Height to top of valve protective housing; height to center line of valve outlet is about 3½" (89 mm) less.

equipped with a crane and lifting beam to facilitate loading and unloading.

2.5 CONTAINER LABELING AND PLACARDING

Containers in transportation must be suitably labeled and placarded as required by regulations (Ref. 10.3.2.1).

2.6 CONTAINER HANDLING

2.6.1 General

Chlorine containers must be handled with care. When not connected, container valve protective housings should be in place. Containers should not be dropped and no object should be allowed to strike them with force. It is convenient to load and unload containers from a truck to a dock at truck bed height. If such a dock is not provided a hydraulic tail gate can be used. Containers should be secured to prevent them from rolling off (Ref. 10.3.2.4).

2.6.2 Cylinders

Cylinders can be moved about in a plant area using a properly balanced hand truck. The truck should have a clamp or chain two-thirds of the way up the cylinder wall to hold the cylinder in place. If cylinders must be elevated by hoist a specially designed cradle or carrier should be used and not a sling or magnetic device. Cylinders must not be lifted by the valve protective housing because the neck ring to which the housing is attached is not designed to carry the weight of the cylinder.

2.6.3 Ton Containers

Ton containers are best moved using a monorail or crane with a lifting beam (Fig. 2.6) (Ref. 10.3.2.5). They can be rolled on rails or roller conveyors provided for the purpose. If a fork lift truck is used the ton container must be adequately restrained to prevent it from falling off, particularly when the truck changes direction. The fork lift truck must have adequate capacity to lift the ton container.

2.7 CONTAINER STORAGE

Containers may be stored indoors or outdoors. If stored indoors, the storage area should comply with the provisions of 7.1 and 7.2. If stored outdoors, the storage area should be clean so that accumulated trash does not present a fire hazard. Containers should not be stored near elevators or ventilating systems because dangerous concentrations of gas may spread rapidly if a leak occurs.

All containers should be stored to minimize external corrosion. If standing water can collect, suitable platforms or supports should be provided. Provisions should be made to permit routine inspection of all containers. Containers should not be stored where they can drop or where heavy objects can fall on them or where vehicles can strike them. Subsurface storage areas should be avoided. Access by unauthorized persons should be controlled.

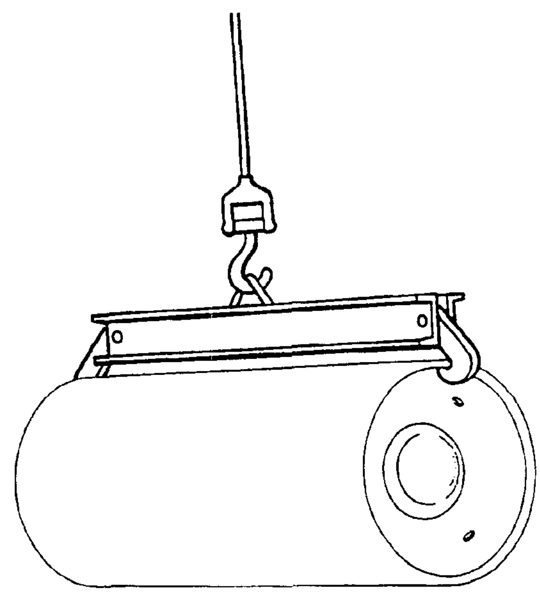


Figure 2.6
Lifting Beam for Handling Chlorine Ton Containers

Exposure of containers to flame, intense radiant heat or to steam lines must be avoided. If the metal in the vicinity of the fusible plug reaches about 158°F (70°C) the plug will melt and chlorine will escape.

Intense local heat will increase corrosion of the steel walls; if the steel approaches 483°F (251°C) it will ignite.

Full and empty containers should be stored separately. Even though a container is empty, the valve outlet cap(s) and the valve protective housing should be in place. Cylinders should be stored in an upright position. Ton containers should be stored on their sides above the ground or floor on steel or concrete supports.

Chlorine containers should be segregated from other compressed gas containers (eg. anhydrous ammonia) and hydrocarbon chemicals.

Easy access to all containers is important in the event of a leak.

2.8 CONTAINER USE

2.8.1 General

Containers should be used in the order in which they are received. Before connecting or disconnecting a container the operator should make sure that all safety and emergency equipment is available and operable.

Containers and valves must not be modified, altered or repaired by other than the owner. It is illegal to refill a container without the owner's permission.

2.8.2 Gas Discharge

Cylinders are normally secured in the upright position and deliver chlorine gas.

Ton containers chocked in a horizontal position and with the valves in a vertical line (Fig. 2.3) deliver gas from the upper valve and liquid from the lower valve. The direction in which the valve outlets face varies geographically (Ref. 10.4.1.1). The flow of chlorine gas from a container depends on the internal pressure which, in turn, depends on the temperature of the liquid chlorine. In order to withdraw gas, liquid must vaporize. Unless enough external heat is available, the temperature of the chlorine will be reduced and consequently the pressure in the container will fall. At low withdrawal rates sufficient heat can usually be obtained from the surrounding air so the pressure in the container will remain constant and uniform flow can be maintained. At high withdrawal rates, however, the temperature and pressure within the container will fall because of the cooling effect of vaporization and the rate of flow will gradually diminish.

In humid conditions, condensation will form on the outside of the container. At excessive withdrawal rates, the liquid will be cooled to such an extent that frost will form on the outside of the container. The insulating effect of the frost causes further decrease in the rate of discharge. Discharge rates will fall off as the container empties because there is progressively less area of container wall in contact with the remaining liquid chlorine. Discharge rates may be increased by circulating room temperature air around the container with a fan. **Never place a container in a bath of water or apply direct heat.**

Since the discharge rate is affected by ambient temperature, humidity and air circulation, as well as the pressure required by the equipment connected to the container, results vary widely. The dependable, continuous discharge rate of chlorine gas from a cylinder is about 1 3/4 lb/hr (0.8 kg/hr). This assumes an ambient temperature of 70°F (21°C) and natural air circulation. It further assumes that the gage pressure against which the cylinder is discharging is about 35 psi (241 kPa). The discharge rate for a ton container under similar conditions is about 15 lb/hr (6.8 kg/hr). For short periods the rates may be greatly exceeded.

If the gas discharge rate from a single container will not meet requirements, two or more can be connected to a manifold and discharged simultaneously, or a vaporizer (evaporator) can be used. See 7.6. When discharging through a manifold all containers should be at the same temperature to prevent transfer of gas from a warm container to a cool container.

2.8.3 Liquid Discharge

For special use, cylinders can be inverted to deliver liquid chlorine. In such cases appropriate racks should be used.

Liquid chlorine is delivered from the lower valve of a ton container. Very high liquid withdrawal rates can be obtained. The rate depends on the temperature of the chlorine in the container and on the back pressure. The dependable continuous discharge rate of liquid chlorine under normal temperature conditions and against a gage pressure of 35 psi (241 kPa) is at least 400 lb/hr (181 kg/hr) for ton containers.

Connection of multiple ton containers simultaneously discharging liquid to a manifold should not be attempted without first considering the possibility of liquid chlorine feeding from a higher pressure ton container into one of lower pressure. In general this may be prevented by equalizing pressures through the gas valves. It is not sufficient to depend on ton containers reaching the same pressure merely by storing them in the same working area. Piping evacuation procedures should be established so chlorine is not trapped in the system. Ref. 10.5.2.11.

2.8.4 **Weighing**

Because chlorine in a container is a compressed, liquefied gas, the pressure in a container depends on the temperature of the chlorine (Fig. 9.1). The pressure does not indicate the amount of chlorine in the container. Container contents can be determined accurately only by weight. The use of scales that continuously indicate the weight of the container as the contents are being withdrawn is recommended. The amount of chlorine remaining is determined either by direct scale reading or by comparing the present weight with the latest stamped tare weight.

2.8.5 **Connections**

A flexible connection must be used between the container and the piping system. Copper tubing suitable for a minimum gage pressure of 500 psi (3450 kPa) is recommended. Recommended adaptors use tubing with an outside diameter of 1/4 inch or 3/8 inch. Tubing suitable for brazing (Copper No. 120) in annealed state should be chosen. ASTM Specifications B 68, B 75 and B 88 are suitable provided the material furnished is of the proper dimensions. As alternates, 1/2 inch non-metallic hoses are acceptable flexible connections if they meet specific manufacturers criteria. The connection should be regularly inspected. It should be replaced whenever there is sign of deterioration but, in any event, at intervals no less than annually.

The yoke and adaptor (CGA Connection 820) is the standard connection to the container valve outlet (Fig. 2.7). A flat gasket on the face of the valve is part of the connection. The union connection (CGA Connection 660) is used for special limited applications (Ref. 10.4.2.5). If used, the threads on the connector must match the valve outlet threads. Valve outlet threads are not standard taper pipe threads.

A new gasket should be used each time a connection is made no matter what connector is used. If the system is to remain in operation while containers are being connected or disconnected, auxiliary container valves must be used. These should be located at the container end of the connector to minimize the escape of gas and the entrance of atmospheric moisture.

2.8.6 **Opening Valves**

The container valve is opened by turning the valve stem in a counter-clockwise direction. One full turn of the stem permits maximum discharge. Special 3/8" square box wrenches are available for turning the valve stem. A wrench no longer than 8" (200 mm) should be used. The wrench can be chained near the use point so that it is always available. Once the valve is opened, the wrench can be left in place so that the valve can be closed quickly. Usually the valve can be opened by striking the end of the wrench with the heel of the hand. If the valve is unduly difficult to operate, the packing nut may be loosened as much as 1/2 turn and then retightened after the valve is opened or closed. If this does not succeed, do not use extra force—call your supplier. Once connections have been made, pressurize the system, shut off the chlorine supply valve and test for leaks. If no leaks exist, start continuous flow.

2.8.7 **Disconnecting Containers**

As soon as a container is empty, the valve should be closed. Prior to disconnecting, a means of removing the chlorine trapped in the flexible connecting line must be provided. This can be accomplished by purging the line with dry air (-40°F (-40°C) or lower dew point) or nitrogen, applying a vacuum, or installing an auxiliary valve close to the container valve. Approved escape-type respirators should be on the operator's person when disconnecting the container. The container should be cautiously disconnected since there may be chlorine gas in the lines. The outlet cap should be applied promptly and the valve protective housing should be replaced.

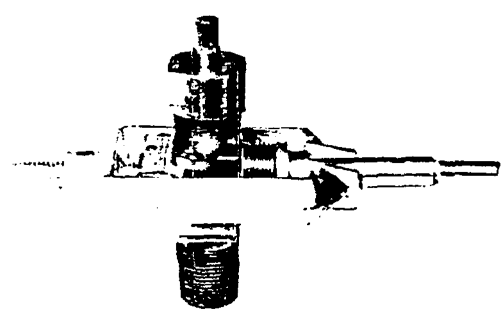


Figure 2.7
Yoke and Adapter Type Connection

The open end of the disconnected line should be capped promptly to keep atmospheric moisture out of the system.

3. BULK SHIPPING CONTAINERS

3.1 GENERAL

Chlorine is shipped in bulk in tank cars, tank motor vehicles, portable tanks and barge tanks. It may also be transferred in bulk by pipeline.

Tank car, as used here, does not include the TMU (tank-multi-unit) car discussed in 1.8.2.

3.2 TANK CARS

3.2.1 General

The following is generalized information on chlorine tank cars. For detailed information, including tank car dimensions, see Pamphlet 66 (Ref. 10.3.2.3).

3.2.2 Specifications

The common tank cars (Fig. 3.1) for chlorine are nominally of 55 or 90 tons capacity but 16-, 30-, and 85-ton cars are authorized and in use. By regulation, tanks may not be loaded in excess of these nominal weights.

Chlorine tank cars must comply with all of the following (Paragraphs *a* through *d* appear in 49 CFR 179.102-2. Similar text appears in CTC Regulations at 79.102-2. Paragraph *e* appears in 49 CFR 173.314 (c) note 12. The equivalent CTC Regulation is 73.314 (c) note 12.):

a. Chlorine tanks must be constructed in compliance with Specification DOT (or CTC) 105A500W. Tank cars must be operated and the jackets stenciled either DOT (or CTC) 105A300W or DOT (or CTC) 105A500W. Tanks must be equipped with the safety relief device required by the stenciled specification.
b. Interior pipes of liquid discharge valves must be equipped with excess-flow valves of approved design.

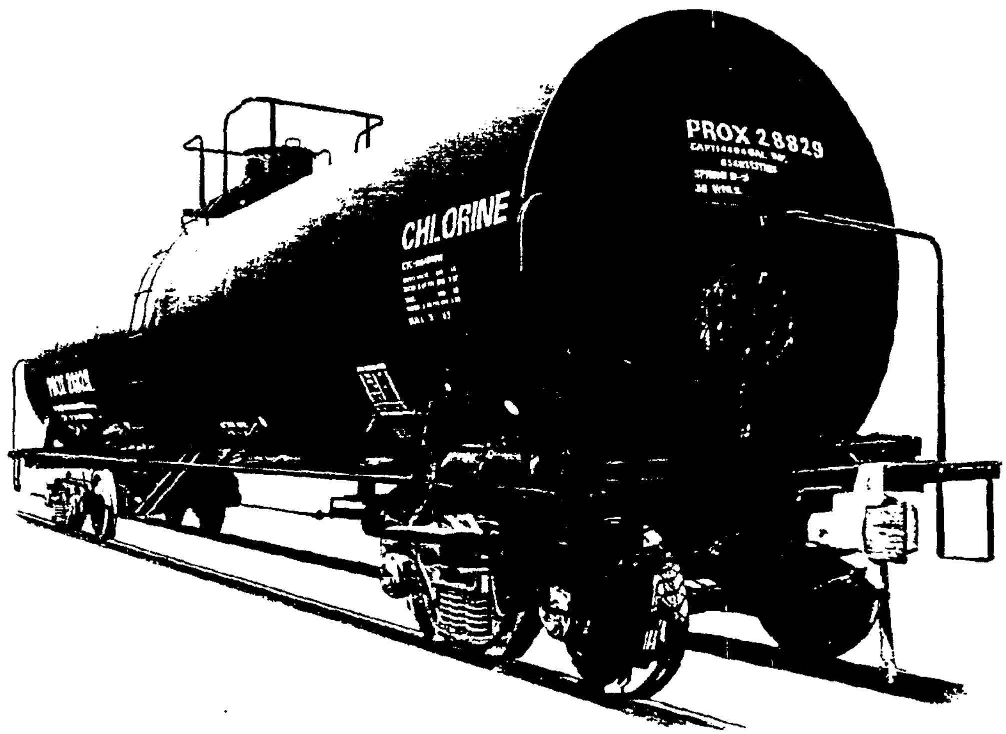


Figure 3.1
Chlorine Tank Car

c. Insulation must be 4 inches minimum thickness.
d. Tanks must be fabricated from approved carbon steels.
e. Existing tank cars not larger than 55-ton chlorine capacity built to ICC-105A300 or ICC-105A300W may be continued in service.

3.2.3 Manway Arrangement

3.2.3.1 **General.** Five fittings are mounted on the manway cover within the protective housing (Fig. 3.2). Four of these are angle valves and the fifth, located in the center, is a safety relief device designed to relieve if excessive pressure builds up in the tank.

3.2.3.2 **Angle Valves.** The Chlorine Institute Standard Angle Valve (Fig. 3.3) (Ref. 10.4.1.6) has a forged steel body and a Monel® stem and seat. The outlet is 1" female ANSI Standard taper pipe thread and is protected by a pipe plug. The two angle valves on the longitudinal center line of the tank car are for liquid discharge. The two valves on the transverse center line are connected to the vapor space.

3.2.3.3 **Excess-Flow Valves.** Under each liquid valve there is an excess-flow valve (Fig. 3.4). The excess-flow valve consists of a rising ball which closes the valve when the rate of flow exceeds a predetermined value. It does not respond to pressure in the car. It is designed to close automatically against the flow of liquid chlorine if the angle valve is broken off in transit. It may close if a catastrophic leak involving a broken connection occurs but it is not designed to act as an emergency shut-off device during the unloading process. The excess-flow valves have a maximum operating flow rate of 7000 lb/hr (3200 kg/hr), 11,000 lb/hr (5000 kg/hr), or 15,000 lb/hr (6800 kg/hr).

3.2.3.4 **Eduction Pipes.** Liquid chlorine is withdrawn through 1-1/4" eduction pipes (Fig. 3.2). (Bottom outlets are not permitted in chlorine cars.) The eduction pipes are attached to the excess-flow valves and extend to the bottom of the car. One or both eduction pipes may be used to unload the car.

3.2.3.5 **Safety Relief Device.** In the center of the manway cover is a spring loaded safety relief device (Fig. 3.5). In this section the term "safety relief device" is equivalent to "pressure relief device." The device is set to start-to-discharge at a gage pressure of 225 psi (1551 kPa) on cars stenciled 105A300W or at a gage pressure of 375 psi (2586 kPa) on cars stenciled 105A500W.

3.2.4 Unloading

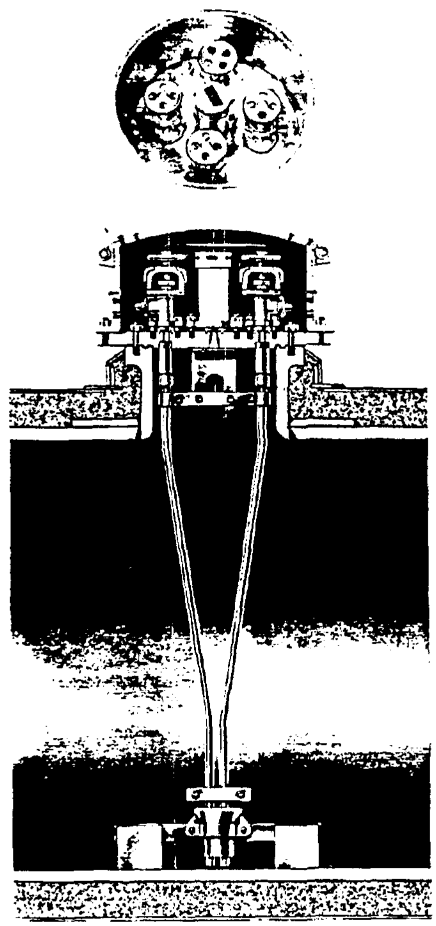
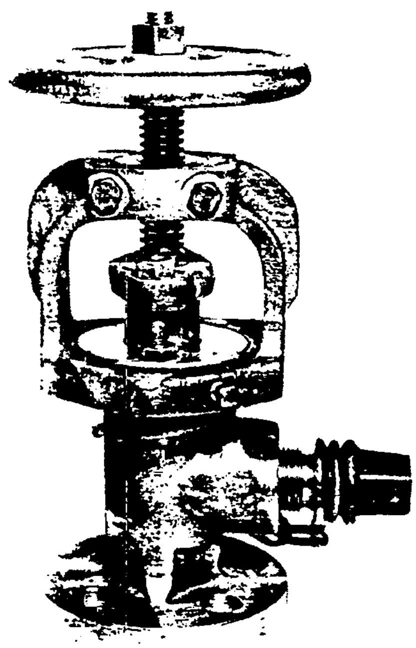


Figure 3.2
Valve Arrangement and Manway



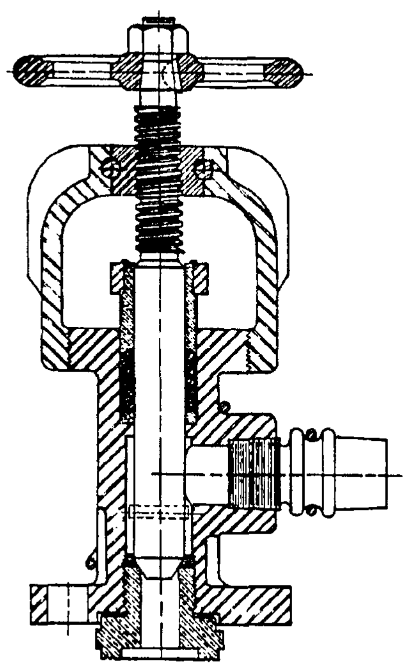


Figure 3.3
Standard Angle Valve

3.2.4.1 **Regulations.** In the U.S. DOT regulations which apply to the unloading of tank cars appear in 49 CFR 174.67. In Canada similar CTC regulations appear in Part 74 of "Regulations for the Transportation of Dangerous Commodities By Rail." In addition many regulations specific to chlorine tank car unloading appear in CTC General Order No. 0-35 (Ref. 10.2.1.3).

3.2.4.2 **Precautions.** The following are recommended; some are prescribed by applicable regulations:

a. Unloading operations, including connect and disconnect steps, should be performed by persons properly instructed in handling hazardous materials. During unloading, the operation should be monitored. See 3.2.4.5.

b. During all times when a tank car(s) is connected for unloading:

—Car brakes should be set and wheels chocked.

—Caution signs should be so placed on the track to give necessary warning to persons approaching the cars from the open end of a siding.

—Derail devices should be placed at open end(s) of siding not less than approximately one car length from the car(s) being unloaded, unless the car(s) is protected by a closed and locked switch.

c. Unloading area must be adequately illuminated during transfer operations.

d. Before unloading valves are opened, unloading connections should be securely attached to car connections and receiving piping.

e. All unloading valves should be closed whenever unloading is discontinued, whether car is disconnected or not.

f. Cars should not be allowed to stand with unloading connections attached after unloading is completed.

g. After the tank car is completely unloaded, all valves should be closed, the unloading connections removed and all other closures made tight.

h. The unloading area should be checked to make sure all safety equipment (self-contained breathing apparatus, emergency kits, if provided, eye wash fountains etc.) is in its proper place and operable.

i. An approved escape-type respirator or other breathing apparatus should be on the operator's person. A hard hat and chemical workers' goggles should be worn.

j. A suitable operating platform should be provided at the unloading point for easy access to the protective housing, for connection of lines and for operation of valves. For dimensions of tank cars, see Ref. 10.3.2.3

3.2.4.3 **Connections.** Unloading should be done through a suitable flexible connector to permit the rise of the tank car on its springs as it is unloaded. The Institute has drawings of a copper loop (Ref. 10.5.2.8) or a flexible Monel® metal hose (Ref. 10.5.2.9). Nipples for insertion in tank car angle valves should have clean, sharp threads. A non-reactive lubricating pipe dope should be used to prevent galling of the threads. It should be applied in such a manner as to prevent its entry into the piping. After the connections are tight, add chlorine to the system and test for leaks. See 4.4.

At times, due to opening the angle valve too rapidly or due to unusually high flow rates, the excess-flow valve will close. If this occurs, the angle valve should be closed and left closed until the metal ball in the excess-flow valve drops back into place. A click will be heard when the ball drops. While delivering chlorine the angle valve should be completely open. It should not be used to control flow.

3.2.4.4 **Pressurizing.** Liquid chlorine usually is unloaded by tank car pressure. The vapor pressure of the chlorine is frequently augmented by a "pad" of dry air or non reactive gas which often is applied by the producer but can be applied by the user. It is essential that air used for padding should be free from oil and foreign matter and should be dried to a dew point, measured at atmospheric pressure, of -40°F (-40°C) or below. (See Ref. 10.3.2.3 for a detailed discussion).

3.2.4.5 **Monitoring.** DOT Regulations require that "Throughout the entire period of unloading, and while car is connected to unloading device, the car must be attended by the unloader." The intent is to assure that the flow of chlorine from the tank car is carefully controlled and that the car can quickly be shut off should unloading difficulties develop.

3.2.4.6 **Disconnecting.** When a sharp drop in tank car pressure occurs, unloading is normally complete. The angle valve should be closed first and the discharge line emptied before closing other valves in the system and disconnecting the piping. It is desirable to discharge as much of the residual chlorine as possible to process. Chlorine lines may be purged with dry air or non-reactive gas to an absorption

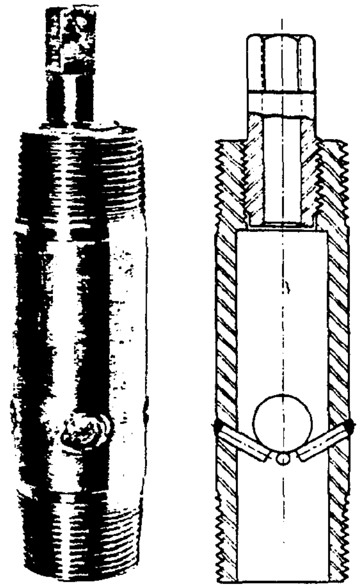


Figure 3.4
Excess-Flow Valve

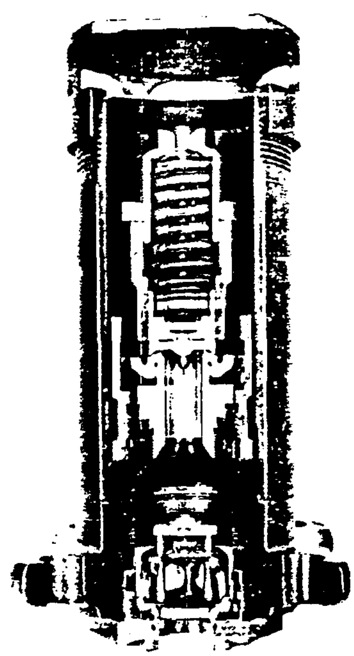


Figure 3.5
Standard Safety Relief Device

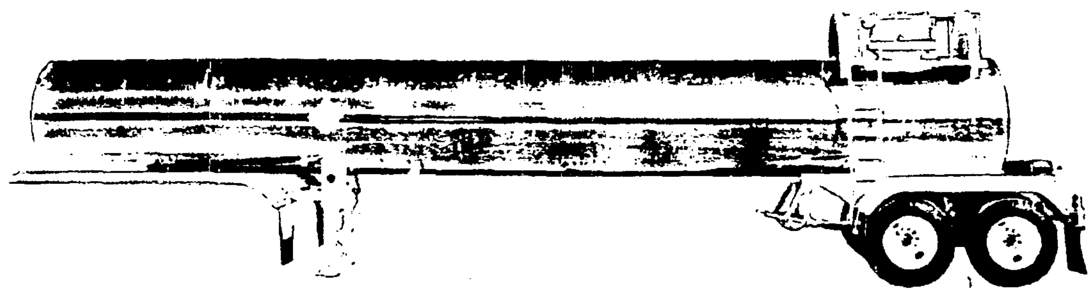


Figure 3.6
Chlorine Tank Truck

system before disconnecting.

After the unloading lines have been disconnected, the valve outlet plugs should be replaced immediately. This is essential to prevent corrosion of the threads by atmospheric moisture. After checking for leaks the protective housing cover must be closed. The open end of the chlorine unloading line also should be protected from atmospheric moisture with suitable closures.

3.2.5 Returning

The empty tank car should be turned over to the railroad with the proper shipping papers and placards.

3.3 TANK MOTOR VEHICLES

3.3.1 General

The following is generalized information on chlorine tank motor vehicles. For detailed information see Pamphlet 49 (Ref. 10.3.2.2). In North America they usually have a capacity ranging from 15 to 22 tons (13 600 kg to 20 000 kg) with certain exceptions (Fig. 3.6). DOT specifications apply only to the tank; such "cargo tanks" comply with Specification MC331 including the special requirements for chlorine, but tanks built to Specification MC 330 may be continued in service. See 49 CFR 178.337 for specification details.

3.3.2 Manway Arrangement

3.3.2.1 **General.** The manway arrangement is the same as that on chlorine tank cars (see 3.2.3.1) except that special excess-flow valves are required under the gas valves.

3.3.2.2 **Angle Valves.** The angle valves are the same as those on tank cars (see 3.2.3.2). Angle valves must be tested before installation to be leak free at a gage pressure not less than 225 psi (1552 kPa) using dry air or non reactive gas. Angle valves must be so tested once every 5 loadings or once a week whichever occurs first. Upon each loading they must be checked at a gage pressure of not less than 50 psi (345 kPa) to determine that they are in proper condition for transportation.

3.3.2.3 **Excess-Flow Valves.** Under each liquid angle valve there is an excess-flow valve with a maximum operating flow rate of 7000 lb/hr (3200 kg/hr). There are eduction pipes connected to the two liquid excess-flow valves as in a tank car.

In addition under each gas valve there is an excess-flow valve of different design; these valves have a removable basket so that the ball can be removed and the interior of the tank inspected.

3.3.2.4 **Safety Relief Device.** The safety relief device is the same type as that used on tank cars (see 3.2.3.5). On all tanks the start-to-discharge gage pressure is 225 psi (1551 kPa).

3.3.3 Unloading

No piping, hose, or other means of loading or unloading may be attached to any valve of a cargo tank containing chlorine except at the time of loading or unloading. Pipe connections of each angle valve must be closed with a screw plug chained or attached in some manner to prevent misplacement. Liquid chlorine pumps must not be installed on the tank motor vehicle. Contents of the tank vehicle must be unloaded at one unloading point.

3.3.3.1 **Precautions.** The engine must be shut off. Handbrakes must be set during loading and unloading. Wheel chocks must be in place. The tank motor vehicle must not be left unattended. The tank motor vehicle must not be moved, coupled, or uncoupled when loading or unloading connections are attached to the vehicle.

3.3.3.2 **Emergency Equipment.** Approved respiratory equipment must accompany the motor vehicle together with an emergency kit to control leaks in the manway fittings.

3.3.3.3 **Connections.** See discussion for tank cars, 3.2.4.3.

3.3.3.4 **Pressurizing.** See discussion for tank cars, 3.2.4.4.

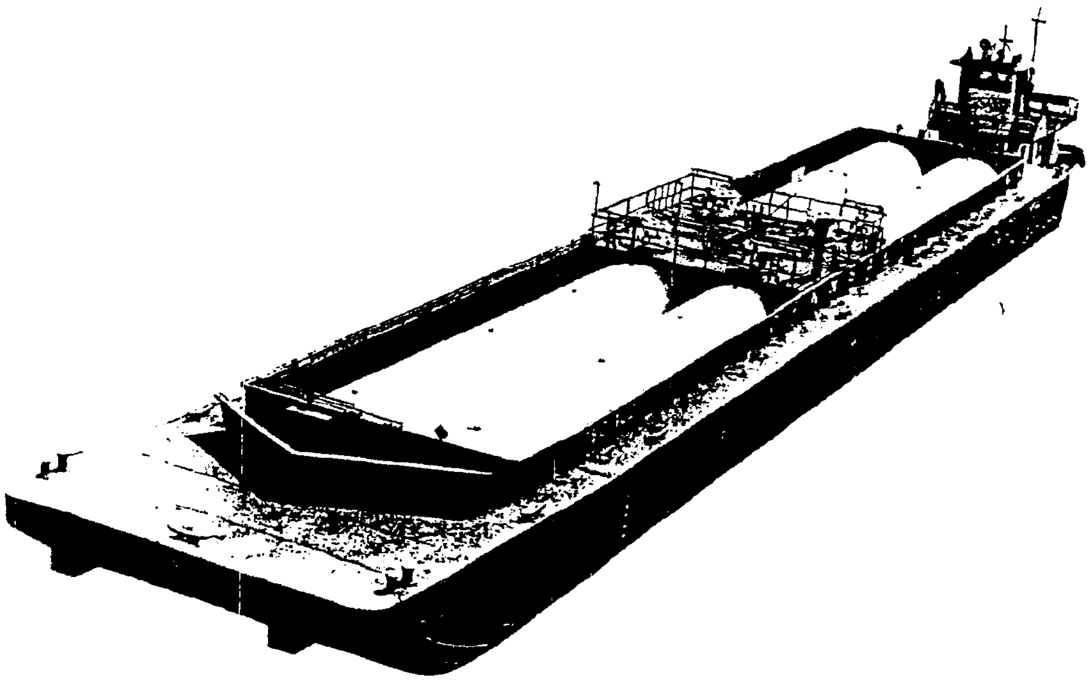


Figure 3.7
Chlorine Barge

3.3.3.5 **Disconnecting.** See discussion for tank cars, 3.2.4.6. The driver should recheck all features by a general visual inspection before starting the engine and departing.

3.4 PORTABLE TANKS

Tanks suitable for multi-modal transportation (road, rail and water) of chlorine have been built under the provisions of a DOT exemption.

3.5 TANK BARGES

3.5.1 General

The following is generalized information on chlorine tank barges. For detailed information see Pamphlet 79 (Ref. 10.5.2.7).

Two styles of chlorine barges are in common use in North America. Most inland chlorine barges are of the open-hopper type with four independent, cylindrical, uninsulated pressure tanks mounted longitudinally. The most common barge capacities are 600 tons (540 Mg), (4 tanks—150 tons each) and 1100 tons (997 Mg), (4 tanks—275 tons each). All openings in the tanks are required to be on the top. A typical barge is shown in Fig. 3.7. A different barge design is utilized for ocean service, principally on the west coast. These are flush deck barges, usually carrying caustic soda in the holds, with independent chlorine tanks mounted on the deck. Either two or four chlorine tanks are carried with nominal capacities of 300 tons (270 Mg) per tank.

Both the tanks and the barge are subject to DOT (US Coast Guard) approval in the US and to Canadian Coast Guard approval in Canada.

3.5.2 Manway Arrangement

3.5.2.1 **General.** Chlorine barge tanks may have one or more openings. The arrangement of the valves is not standardized. Depending on the tank capacity each tank has two or three safety relief valves and a varying number of angle valves.

3.5.2.2 **Angle Valves.** Inland chlorine barges usually have one-inch Chlorine Institute Standard Angle Valves. Some oceangoing chlorine barges are equipped with two-inch angle valves.

3.5.2.3 **Excess-Flow Valves.** Under each liquid valve there is an excess-flow valve. The excess-flow valve consists of a rising ball which closes the valves when the rate of flow exceeds a predetermined value. It does not respond to pressure in the tank. It is designed to close automatically against the flow of liquid chlorine if the angle valve is broken off in transit.

It may close if a catastrophic leak involving a broken connection occurs but it is not designed to serve as emergency shut-off device during the unloading process. Most excess-flow valves have a maximum operating flow rate of 15,000 lb/hr (6800 kg/hr) or 30,000 lb/hr (13 600 kg/hr). Under each gas valve there is an excess-flow valve of different design; these valves have a removable basket so that the ball can be removed and the interior of the tank inspected.

3.5.2.4 **Eduction Pipes.** Liquid chlorine is withdrawn through eduction pipes. (Bottom outlets are not permitted in chlorine barge tanks.) The eduction pipes are attached to the excess-flow valves and extend to the bottom of the tank. One or both eduction pipes may be used to unload the tank.

3.5.2.5 **Safety Relief Devices.** Depending on capacity, each barge tank has two or three safety relief devices. These are designated 4 JQ and are designed to start-to-discharge at a gage pressure of 300 psi (2070 kPa).

3.5.3 **Unloading**

3.5.3.1 **General.** Loading and unloading are subject, in the United States, to Coast Guard regulations. These regulations are found in Title 46 CFR Part 151. Special requirements for chlorine appear in 151.50-31 (Ref. 10.2.2.1). Both the Army Corps of Engineers and OSHA also have jurisdiction and must be consulted before the installation of facilities. There may be other requirements of other regulatory bodies. For unloading details see Pamphlet 79 (Ref. 10.5.2.7).

3.5.3.2 **Personnel Protection.** Personnel involved in cargo transfer operations must be equipped with proper personal protective equipment and adequately trained in its use.

4. EMERGENCY MEASURES

4.1 PREPAREDNESS

An emergency plan for chlorine is essential (Ref. 10.7.1.1 and 10.7.1.3). This should include a procedure for the training of personnel who could become involved and periodic drills to review the response. Assistance is available to help in emergencies, but the first action must be taken by the people on the scene.

The best source of assistance for the majority of chlorine consumers is the supplier. A first step in any emergency plan should be the conspicuous posting of the supplier's telephone number and the instruction to call that number for assistance. Help also is available in the U.S. from CHLOREP through CHEMTREC. In Canada, CANUTEC provides information and assistance. The CHEMTREC or CANUTEC numbers also should be posted. See 4.5.

4.2 ACTION

As soon as there is any indication of the presence of chlorine in the air, immediate steps should be taken to correct the condition.

Chlorine leaks always get worse if they are not promptly corrected. When a chlorine leak occurs, authorized, trained personnel equipped with suitable respiratory protection, should investigate and take action. Whenever possible, no person should work alone on a chlorine leak. All other persons should be kept away from the affected area until the leak has been stopped and the residual chlorine dispersed. If the emission is extensive, all persons in the path of the fumes should be evacuated by the proper authorities.

Potentially exposed persons should move to a point upwind of the leak. Because chlorine is heavier than air, higher elevations are preferable. To escape in the shortest time persons already in a contaminated area should move crosswind. When outdoors without respiratory protection, a wet handkerchief or cloth will reduce the effects of exposure.

If inside a building and evacuation seems to be impractical, all windows should be closed and air conditioners and air intake systems turned off and personnel should retreat to the highest point of the building on the side away from the release. When calling for advice or assistance the following information should be provided:

a. Company name, address, telephone number, and the name of the person(s) to contact for further information.
b. Description of the emergency.
c. Travel directions to the site.
d. Type and size of container involved.
e. Corrective measures being applied.
f. Other pertinent information i.e. weather conditions, injuries, etc.

If the leak is serious the local authorities must be notified to effect any necessary evacuation. In some instances, reporting releases to government authorities is required. See 5.6. Chlorine monitors and wind direction indicators can supply information to help determine whether personnel need to be evacuated and the evacuation route to be chosen.

All personnel at a location who are involved in the handling of chlorine, or could be involved in an emergency, should be trained in emergency procedures. In addition, periodic drills should be held.

4.3 FIRE

If fire is present or threatened, chlorine containers should be moved away from the fire. If a non-leaking container cannot be moved, it should be kept cool by playing water on it. If the container is leaking, water should not be used. Chlorine and water react, and acids are formed that will corrode the container and the leak quickly will get worse. However, where several containers are involved and some are leaking, it may be prudent to use water to prevent rupture of the non-leaking containers.

4.4 LEAKS

If ammonia vapor is directed at a leak, a white cloud will form indicating the source of the leak. Use a plastic squeeze bottle containing aqua ammonia. If a wash bottle is used the dip tube should be cut off so that squeezing the bottle directs vapor, not liquid, out of the nozzle. Avoid contact of aqua ammonia with brass or copper. Commercial 26° Baumé aqua ammonia should be used. If a leak occurs in equipment or piping, the chlorine supply should be shut off, the pressure relieved and necessary repairs made. If welding is needed, the system should be purged with dry air or nonreactive gas before processing. Welding should comply with all applicable codes.

Leaks around shipping container valve stems usually can be stopped by tightening the packing gland. If this does not stop the leak, the container valve should be closed. If simple corrective measures are not sufficient, the appropriate Chlorine Institute Emergency Kit should be applied and the chlorine supplier notified. See 4.8.

4.5 TRANSPORTATION EMERGENCIES

For emergencies involving the transportation of chlorine, the Chlorine Institute's CHLOREP, the Chlorine Emergency Plan, can provide assistance. This plan is activated through the CHEMTREC in the United States (toll free 800-424-9300) and CANUTEC in Canada (call collect 613-996-6666). For further information consult the Institute.

In the U.S., the CHEMTREC operator will contact the nearest CHLOREP participant and a member of the CHLOREP team will call to give immediate advice. If needed, he will dispatch a CHLOREP team to the site. In Canada, the CANUTEC operator will contact a CHLOREP team for the same purpose. These systems operate throughout the United States and Canada on a 24-hour basis.

If a chlorine leak develops in transit through a populated area, it generally is advisable to keep the vehicle or tank car moving until open country is reached in order to disperse the gas and minimize the hazards from its escape. Appropriate emergency measures then should be taken as quickly as possible. If a vehicle transporting chlorine cylinders or ton containers is wrecked and there is any possibility of fire, the containers should be removed from the vehicle. If any container is leaking, appropriate measures should be taken to stop or minimize the leak.

If a tank car or tank trailer is wrecked and chlorine is leaking, an appropriate downwind area should be evacuated. Clearing of track or highway should not be started until safe working conditions are established. See 4.3 for action to take if a fire occurs.

These additional specific actions may be taken to contain or reduce leaks:

a. If a container is leaking chlorine, turn it, if possible, so that gas instead of liquid escapes. The quantity of chlorine that escapes from a gas leak is about one-fifteenth the amount that escapes from a liquid leak through the same size hole.
b. If practical, reduce pressure in the container by removing the chlorine as gas (not as liquid) to process or a disposal system as described below.
c. It may be desirable to move the container to an isolated spot where it will do the least harm.
d. Apply the appropriate emergency kit device from the A, B, or C kit. See 4.8

A leaking chlorine container should not be immersed or thrown into a body of water; the leak will be aggravated and the container may float when still partially full of liquid chlorine allowing gas evolution at the surface.

Regulations prohibit shipment of a leaking chlorine container or a container which has been exposed to fire, whether full or partially full. It may be desirable in some instances to ship a defective chlorine container, such as one which has been exposed to fire or one on which an emergency device has been applied. In such cases special arrangements are required and the chlorine supplier should be consulted first.

4.6 DISPOSAL OF CHLORINE

If a leak occurs at a consuming location, it may be best to dispose of the chlorine through the regular consuming process or to run a temporary line to the consuming point. If the consuming process cannot handle chlorine under emergency conditions, a standby alkali absorption system should be considered. It must be recognized that systems consuming liquid chlorine at low rates will not significantly reduce pressure in the supply container. In order to reduce pressure in the supply container, chlorine must be removed as a gas at a rate high enough to cause cooling of the remaining liquid. See 2.8.2.

4.7 ABSORPTION SYSTEMS

A simple absorption system consists of a suitable tank capable of holding the required alkaline solution. The alkali should be stored in a form such that a solution can readily be prepared when needed. After the solution is prepared, the chlorine can be passed from the container into it through a connection weighted to hold the outlet under the surface; do not immerse the container. See Tables 4.1A and 4.1B for recommended solutions — (the recommended alkali quantities provide 20% excess). CAUTION: When absorbing chlorine in alkaline solutions, the heat of reaction is substantial. Caustic solutions can cause burns to personnel.

TABLE 4.1A
RECOMMENDED ALKALINE SOLUTIONS FOR ABSORPTION—U.S. UNITS

Chlorine Container Capacity	20 Weight % Caustic Soda Solution		10 Weight % Soda Ash Solution	
lb (net)	100% NaOH lb	Water gal	100% Na_2CO_3 lb	Water gal
100	135	65	359	390
150	203	98	538	585
2000	2708	1300	7176	7800

TABLE 4.1B
RECOMMENDED ALKALINE SOLUTIONS FOR ABSORPTION—METRIC UNITS

Chlorine Container Capacity	20 Weight % Caustic Soda Solution		10 Weight % Soda Ash Solution	
kg (net)	100% NaOH kg	Water liters	100% Na_2CO_3 kg	Water liters
45.4	61.5	246	163	1470
68	92	370	244	2200
907	1230	4920	3260	29,350

4.8 EMERGENCY KITS

Chlorine Institute Emergency Kits are designed to contain most leaks which may be encountered in chlorine shipping containers. They are designated:

—Kit A—for 100 lb and 150 lb cylinders (Fig. 4.1)
—Kit B—for ton containers
—Kit C—for tank cars, and tank trucks.

These kits operate on the principle of containing valve leaks by applying hoods and gaskets. For cylinders and ton containers patches are provided for sealing off a small hole in the side wall. Capping devices are provided for fusible plugs in ton containers. The kits contain step-by-step instructions for the use of the devices. The necessary tools are included, but respiratory protective devices and personal protective clothing are not included. (Ref. 10.7.1.5, 10.7.1.6 and 10.7.1.7.) Many chlorine consumers incorporate plans for the use of these kits in their emergency programs.

Further information on the utility, availability and purchase of kits, kit components

Figure 4.1
Chlorine Institute Emergency Kit A for Chlorine Cylinders

and audio visual training aids is available from the Institute.

It is the responsibility of the user to provide instruction in the use of kits and to maintain the kits. The chlorine supplier can provide assistance in these matters.

5. EMPLOYEE TRAINING AND SAFETY

5.1 EMPLOYEE TRAINING

Safety in handling chlorine depends, to a great extent, upon the effectiveness of employee training, proper safety instructions, intelligent supervision and the use of suitable equipment. It is the responsibility of supervisors to train employees how to use personal protective and other safety equipment. It is the responsibility of employees to properly use the equipment provided. Training classes for all employees should be conducted periodically to maintain a high degree of competence in handling procedures. Employees should be thoroughly informed of the hazards that may result from improper handling of chlorine. They should be trained to prevent leaks and thoroughly instructed regarding proper action to take in case leaks occur. Each employee should know what to do in an emergency and should be fully informed as to first aid measures. Only designated persons who have been suitably trained in advance should use specialized equipment for containing chlorine leaks.

Both U.S. and Canadian regulations have specific training requirements.

Employee education and training should include the following:

a. Instruction in the properties and physiological effects of chlorine. A Material Safety Data Sheet (MSDS) for chlorine is available from the Institute (Ref. 10.7.1.8).

b. Instruction and periodic drills regarding the locations, purpose, and use of chlorine emergency equipment, fire fighting equipment, fire alarms and shut-down equipment such as valves and switches.

c. Instruction and periodic drills in the use of emergency kits, such as the Chlorine Institute Emergency Kits A, B, or C, if they are part of the emergency equipment and planning at the location. Training should include the actual installation of kits on containers.

d. Instruction and periodic drills regarding locations, purpose, and use of personal protective equipment. Employees should be cautioned to consider the safety of other people in the area before undertaking operations which may require the wearing of respiratory protective equipment.

e. Instruction and periodic drills regarding the locations, purpose, and use of safety showers, eye baths, bubbler fountains or the closest source of water for use in emergencies.

f. Instruction and periodic drills of selected employees regarding the locations, purpose and use of specialized first aid equipment.

g. Instruction to report to the proper authority all equipment failures and chlorine or other leaks.

5.2 PERSONAL PROTECTIVE EQUIPMENT

5.2.1 Availability and Use

Severe exposure to chlorine can occur whenever chlorine is handled or used. Suitable protective equipment for emergency use should be available outside of chlorine rooms near the entrance, away from areas of likely contamination. If chlorine is used in widely separated locations, protective equipment should be available near each use point.

5.2.2 Respiratory Equipment

Every effort must be made to prevent chlorine releases from containers and process equipment. However, since this is not always possible, respiratory equipment should be selected based on careful evaluation of hazards and degree of potential exposure. For example, when tank cars, ton containers or cylinders are connected to or disconnected from plant piping, small releases of chlorine can occur. As a precautionary measure, respiratory protection is advisable during this operation.

Most chlorine releases are at low concentrations where the oxygen content in the air is greater than 19.5% and chemical cartridge respirators (up to 10 ppm) or canister gas masks (25 ppm, maximum) would offer adequate protection. However, without chlorine monitoring equipment sampling air in the vicinity of the leak, the use of pressure-demand self-contained breathing apparatus (SCBA), with full face piece, is required.

Fit testing and regular maintenance programs for respirator equipment are necessary.

Personal respirators for those regularly handling chlorine containers and chlorination equipment are advisable. SCBA should be stored in adjacent areas not likely to be contaminated by chlorine releases.

5.2.3 **Protective Clothing**

Protective clothing is not required for performing routine plant operations. (Ref. 10.7.1.9).

While not specific for chlorine, safety glasses or goggles, hard hats and safety shoes should be worn or available as dictated by plant practice.

5.3 TANK ENTRY

Workers entering tanks should be equipped with suitable personal respiratory and other protective equipment such as safety harness and life line. See 5.2. At least one other person should oversee operations from outside the tank at all times. Under no circumstances should a rescuer enter a tank to remove a victim of overexposure without proper respiratory protection, a safety harness and an attached life line. The free end of the line should be manned by an attendant located outside the tank. Another attendant should be immediately available to assist in the rescue if needed. The rescuer should be in view of the outside attendant at all times or in constant communication with him.

5.4 EXPOSURE MONITORING

The characteristic odor of chlorine makes its presence known at concentrations well below those which might injure persons exposed for brief periods. Because the odor of chlorine in itself is an inadequate indicator of concentration, it is essential that some quantitative measure of exposure be determined. This is necessary to insure that the health of workers is not impaired and to determine compliance with any applicable regulations. (In the U.S., the permissible exposure concentration is 1 ppm, expressed as a "ceiling" exposure level, in practice, as determined over a 15-minute sampling period.)

5.4.1 **Sampling Frequency**

It is impossible to generalize in the matter of sampling frequency but obviously it must be related to the degree of exposure. Where potential exists for exposure to concentrations of health significance a routine monitoring program should be established as determined by an industrial hygienist or other person trained and qualified in this area. The sampling method and interval should be such as to adequately characterize exposure potential associated with specific work areas and job assignments so that proper work practices and controls can be established and their maintenance assured.

5.4.2 **Sampling Methods**

Sampling can be characterized generally as either area sampling or personnel sampling. In the former case chlorine concentrations in a rather well defined work area are determined, whereas personnel sampling involves determination of actual chlorine concentrations in the vicinity of the worker's breathing zone. In either case, the duration of sampling can extend over the course of the entire work shift or for a short finite period, practically about 15 minutes. Care must be exercised in interpreting exposure data so that due consideration is taken of possible respirator use during the sampling period.

5.4.3 **Analytical Methods**

There exist a large variety and complexity of chemical and instrument methods for sampling, analyzing and documenting chlorine concentrations. The simplest systems are portable devices, (usually depending on color changes associated with increasing chlorine levels), and are particularly useful for spot-checking chlorine concentration at a worker's breathing zone or in a work area. The more sophisticated systems may include such features as electrochemical sensing devices, digital readout, continuous recording, data integration and alarms. Each has limitations, advantages and disadvantages and no one scheme is optimal under all circumstances. The choice depends in large measure on the specific purpose for which monitoring is intended and the circumstances of use (Ref. 10.7.1.2).

5.5 REGULATORY REQUIREMENTS

Many governmental agencies have adopted "right-to-know" regulations which impose strict liability on the part of employers to inform workers about hazardous materials in the workplace and safe handling methods. Use of a Material Safety Data Sheet (MSDS) is sometimes required and in any case is a useful training tool (Ref. 10.7.1.8).

5.6 REPORTING

Some governmental agencies have strict reporting requirements for chlorine emissions. Producers, transporters and users of chlorine should be aware of the "reportable quantity" and of all relevant requirements.

6. MEDICAL ASPECTS AND FIRST AID

6.1 HAZARDS TO HEALTH

6.1.1 General

Chlorine gas is primarily a respiratory irritant. It is so intensely irritating that low concentrations in air (well below 1 ppm) are readily detectable by the normal person. At low concentrations chlorine gas has an odor similar to household bleach. As the concentrations increase from the level of detection by smell so does symptomatology in the exposed individual. At chlorine concentrations above 5 ppm the gas is very irritating and it is unlikely that any person would remain in such an exposure for more than a very brief time unless he is trapped or unconscious.

6.1.2 Acute Toxicity

In concentrations near the threshold of smell, chlorine gas will, after several hours of exposure, cause mild irritation of the eyes and of the mucous membrane of the respiratory tract. As concentrations increase there is an increase in the irritating effect on the eyes, coughing mechanism and on the upper and lower respiratory tract with eventual difficulty in breathing. As the duration of exposure and/or the concentration increase, the affected individual may become apprehensive and restless with coughing accompanied by throat irritation, sneezing, and excess salivation. At higher levels there is vomiting associated with labored breathing. In extreme cases difficulty in breathing can progress to the point of death through suffocation.

Liquid chlorine in contact with the eyes or skin will cause local irritation and/or burns. All symptoms and signs result directly or indirectly from its direct irritating action. There are no known systemic effects.

6.1.3 Chronic Toxicity

Low concentrations of chlorine gas in the air may have minor irritating effects or may produce slight symptoms after several hours of exposure, but careful examination of persons repeatedly exposed to such conditions reportedly has shown no permanent physiological effect.

6.2 PREVENTIVE HEALTH MEASURES

6.2.1 Preplacement Physical Examinations

Most chlorine producers require a routine preplacement examination which consists of a complete history and physical examination, including chest x-ray (14" x 17") and baseline respiratory function studies (minimum FVC, FEV1). Specific reference to respiratory allergies, congenital or acquired pulmonary and/or cardiac disease is necessary. Chronic eye conditions (i.e. chronic conjunctivitis) should be ascertained. It should be determined that the employee can wear respiratory protection equipment.

Chlorine consumers should adopt a program suitable to their needs.

6.2.2 Personal Protective Equipment

Personal protective equipment is described in 5.2.

6.3 FIRST AID

This is the immediate temporary treatment given to an exposed individual before the services or recommendations of a physician are obtained. Prompt action is essential. Firmness and assurance will help to alleviate anxiety. Medical assistance must be obtained as soon as possible. Never give anything by mouth to an unconscious or convulsing person.

6.3.1 Inhalation

6.3.1.1 **Artificial Respiration.** If breathing has apparently ceased, the victim must be moved to fresh air. Artificial respiration by accepted means, including mouth-to-mouth, should be started immediately. If breathing has not ceased, the exposed individual should be placed in a comfortable position. In severe cases, the patient should lie down with the head and trunk elevated to a 45°—60° position. Slow, deep breathing should be encouraged. Trained personnel should administer oxygen as soon as possible. If the heart has stopped, CPR should be started by a trained person.

6.3.1.2 **Oxygen Administration.** Oxygen should be administered by first aid attendants trained in the use of the specific oxygen equipment. Suitable equipment for the administration of oxygen should be available either on site or at a nearby facility. Such equipment should be periodically tested. More sophisticated inhalation equipment is available in most emergency facilities.

6.3.2 Contact With Skin Or Mucous Membranes

If chlorine has contaminated the skin or clothing, the emergency shower should be used immediately. Contaminated clothing should be removed under the shower. Flush contaminated skin with copious amounts of running water for 15 minutes or longer. Do not attempt chemical neutralization or apply any salves or ointments to damaged skin. Refer to a physician if irritation persists after irrigation or if skin is broken or blistered.

6.3.3 Contact With The Eyes

If even minute quantities of chlorine enter the eyes, or if the eyes have been exposed to strong concentrations of chlorine, they should be flushed immediately with copious quantities of tepid running water or a direct stream of water for at least 15 minutes. Never attempt to neutralize with chemicals. The eyelids should be held apart during this period to ensure contact of water with all accessible tissue of the eyes and lids. Medical assistance must be obtained as soon as possible. If a physician is not immediately available, eye irrigation should be continued for a second 15-minute period. No oils, oily ointments or any medication should be applied unless ordered by a physician.

6.4 SUGGESTIONS TO PHYSICIANS

6.4.1 General Treatment

There is no known specific antidote for chlorine inhalation. Treatment for inhalation is symptomatic and supportive. It is important to start symptomatic treatment as soon as possible to obtain effective relief of symptoms. In case of mild exposure, the patient should be kept at rest until the respiratory symptoms subside. Sedation for apprehension or restlessness is indicated. See 6.4.3. Steroid therapy, if given early in severe inhalations, may be effective in preventing or alleviating pulmonary edema (medical decision). If steroids are used, a loading dose should be given promptly and the dose then gradually tapered off over a one- to two-week period, in keeping with clinical findings. The use of antibiotics should be considered to protect against secondary pulmonary infection (medical decision).

It is not unusual for individuals to vary in their reaction to inhalation of apparently similar amounts of chlorine. Those with respiratory allergies or chronic bronchial conditions will often have symptoms of dyspnea, sometimes with cough and wheezing, and/or fever, aches and purulent sputum the next day and perhaps persisting for several days. These individuals seem to be benefited by early administration of both steroids and antibiotics The same treatment may be beneficial to those with pre-existing respiratory infection.

The inhalation of any irritating gas may lead to delayed reactions such as pulmonary edema. Since physical exercise appears to have some relation with the incidence of a delayed reaction, it is recommended that any patient who has had a severe inhalation exposure should be kept at rest for a period of observation. The length of observation will depend on the clinical assessment of the exposed individual. Observation may be required up to several days after exposure. Excitement, apprehension and/or emotional distress may persist after a period of observation following a severe exposure.

6.4.2 Oxygen Therapy

The administration of oxygen to exposed individuals is an important treatment and should begin as soon as possible. See 6.3.1.2. It should be given only under guidance from qualified personnel suitably trained to use oxygen equipment according to medical recommendations. See 5.1.f. Oxygen can be given by mask from a portable system until more sophisticated equipment and expertise are available. In such cases, oxygen by mask or catheter should be administered. If available, it should be humidified and in concentrations of 60 to 100% and up to 6 liters per minute at atmospheric pressure. Inhalation of 100% oxygen should be intermittent and not exceed one hour before being interrupted and reinstated as the clinical indications require. Caution is required if there is coexisting peripheral circulatory collapse. The use of bronchodilators nebulized into the inspiratory air may be beneficial when spasm is present.

6.4.3 **Excitement Phenomenon**

This occurs as a result of central stimulation and emotional disturbance. Mild sedation with diazepam is usually effective. In severe cases heavier sedation may be employed with close supervision of respiratory function. Some patients may require special sedation the first night following overexposure.

6.4.4 **Specific Treatment**

Specific methods of therapy in each case will be dictated by the type and severity of the physiological disturbances.

7. ENGINEERING DESIGN AND MAINTENANCE

7.1 **STRUCTURES**

Any building to house chlorine equipment or containers should be designed and constructed to protect all elements of the chlorine system from fire hazards. If flammable materials are stored or processed in the same building a fire wall should be erected to separate the two areas. Fire-resistive construction is recommended.

Chlorine monitoring equipment which continuously samples the air and detects the presence of chlorine is available and should be considered in any storage or operating area where chlorine can be released. See 5.4.

At least two exists should be provided from each separate room or building in which chlorine is stored, handled or used. All exit doors should open outward.

7.2 **VENTILATION**

The building ventilation system should provide fresh air for normal operation and should take into consideration the possibility of a leak. In some cases natural ventilation may be adequate; in others, ventilation by means of a suitable exhaust fan should be provided. Provision should be made to completely change the air in less than four minutes in an emergency. Precautions must be taken to avoid discharging chlorine in such a manner as to cause damage or injury.

7.2.1 **Air Openings**

Chlorine gas is heavier than air and has a tendency to collect at floor level. The fan inlet should be located at or near floor level. An elevated fresh air inlet must be provided and should be located for adequate cross ventilation. Multiple fresh air inlets and fans may be necessary to exhaust air from some areas. Alternatively, it may be desirable to pressurize an installation with fresh air and to exhaust the contaminated air through an outlet at floor level.

7.2.2 **Fans**

Wall type fans may be used. Ducts may be necessary; if used such ducts should lead directly to the fan. Switches for all ventilating fans should be provided outside of chlorine rooms or buildings even when an inside switch is installed.

7.2.3 **Heating**

In cool weather chlorine storage rooms should be heated to 50°-60°F (10°-16°C), or warmer if it will facilitate gas discharge rates from the container. Rooms containing chlorinator feed equipment should be maintained at a normal indoor temperature of about 68°F (20°C).

7.3 **PIPING SYSTEMS FOR DRY CHLORINE**

Piping described in this section pertains only to fixed piping. For information on container unloading connections, see 2.8.5 and 3.2.4.3.

In general, steel piping is recommended for handling dry chlorine. Stainless steels of the 300 series have useful properties for low temperature service but can fail due to chloride stress corrosion cracking, particularly in the presence of moisture at ambient or elevated temperatures.

Recommendations for materials, pipe fittings and some miscellaneous equipment suitable for use with dry chlorine are available from the Institute (Ref. 10.5.2.2).

7.3.1 **Design and Installation**

7.3.1.1 **General.** Piping arrangements should be as short and simple as possible, preferably above ground. The number of screwed or flanged joints should be held to a minimum. Piping systems should be well supported and adequately sloped to allow drainage. Low spots should be avoided. Suitable allowance should be made for pipe expansion due to changes in temperature.

7.3.1.2 **Liquid Expansion.** Liquid chlorine has a high coefficient of thermal expansion. If liquid chlorine (containing no gas bubbles) is trapped between two valves, extremely high pressure can develop upon increase in the temperature of the chlorine. This pressure may lead to hydrostatic rupture of the line.

The effects of possible rupture must be considered in the design of any piping system and protection against hydrostatic pressure must be provided. This protection may be either a suitably designed, operated and maintained expansion chamber (Ref. 10.5.2.10) or a pressure relief valve or rupture disc discharging to a receiver or a safe area.

7.3.1.3 **Condensation.** Condensation or reliquefaction of chlorine may occur in chlorine gas lines which pass through areas where the temperature is below the temperature-pressure equilibrium indicated in the vapor pressure curve (Fig. 9.1). Condensation can usually be prevented by reducing the pressure with a pressure reducing valve. In some cases an external vaporizer with adequate capacity to provide sufficient superheat is needed. It is often necessary to insulate the lines and perhaps to heat trace them. Heat tracing chlorine lines is potentially hazardous and should be approached with great caution to preclude ignition of steel. See 7.9.1.

7.3.1.4 **Installation.** Joints in chlorine piping may be flanged, screwed or welded. If screwed joints are used extreme care should be taken to obtain clean, sharp threads. A thread lubricant compatible with chlorine should be used (Ref. 10.5.2.2).

7.3.1.5 **Suck Back.** When chlorine gas is being injected into a liquid, the liquid can be sucked back into the chlorine lines and into the container from which the chlorine is being fed. This can happen when chlorine flow ceases either by the supply source running empty and/or by the operator shutting off an improper valve.

Suck back has caused serious accidents and severe corrosion. Design of equipment should be such as to prevent its occurrence. Flow interlocks, vacuum breaking devices and barometric loops have all been used. A barometric loop is useful only when the chlorination vessel is at atmospheric pressure and the loop can extend at least 34 feet (10.4m) above the surface of the liquid.

7.3.2 Preparation Of Systems For Use

7.3.2.1 **Cleaning.** All portions of new piping systems must be cleaned before use because chlorine can react violently with cutting oil, grease, and other foreign materials. Each length of pipe must be thoroughly cleaned. New valves or other equipment received in an oily condition should be dismantled and cleaned before use.

- Fully hydrogenated hydrocarbons are effective solvents.
- Cleaning must not be done with hydrocarbons or alcohols because residual solvent may react with chlorine (Ref. 10.5.2.2).
- Excess exposure to all chlorinated solvents presents a toxic risk. Use the most effective combination of engineering controls, work practices and personal protection to insure minimum exposure to such solvents.

7.3.2.2 **Hydrostatic Testing.** Chlorine piping systems should be hydrostatically tested (Ref. 10.5.2.2). It is essential that the system be thoroughly dried prior to being put into service.

7.3.2.3 **Drying.** During construction moisture may enter the system from the atmosphere or other sources. For this reason piping must always be dried before use. This can be done by passing steam through the lines from the high end until the lines are thoroughly heated. While steaming, allow condensate and foreign matter to drain out. The steam supply then should be disconnected and all the pockets and low spots in the line drained. While the line is still warm, dry air or nonreactive gas (eg. nitrogen) having a dew point of -40 °F (-40 °C) or below should be blown through the line until it is dry; this may require an extended period of time.

If steam and dry air are not available, particular care must be taken in cleaning sections of pipe and other equipment before assembly, and careful inspection is necessary as construction proceeds. The final system should be purged with dry cylinder air or nitrogen to remove as much moisture as possible.

7.3.2.4 **Gas Testing.** After drying, the system should be pressurized with dry air or nonreactive gas and tested for leaks by application of soapy water to the outside of joints (Ref. 10.5.2.2). Chlorine gas may then be gradually introduced and the system further tested for leaks. *CAUTION:* Never attempt to repair leaks by welding until all chlorine has been purged from the system. When detectable leaks have been repaired, the line should be retested. See 4.4.

7.4 PIPING SYSTEMS FOR MOIST CHLORINE

Moist chlorine is very corrosive to all of the common construction metals. At low pressures moist chlorine can be handled in chemical stoneware, glass or porcelain equipment and by certain alloys. Hard rubber, unplasticized polyvinylchloride, glassfiber reinforced polyester, polyvinylidene chloride or fluoride (Kynar®) and fully halogenated fluorocarbon resins have been used successfully. All of these materials must be selected with great care. For higher pressures, combinations using resistant lining materials with the common metals for strength should be used. Titanium may be used with moist chlorine but must not be used with dry chlorine under any circumstances as it burns spontaneously on contact. Tantalum is inert to moist and dry chlorine at temperatures up to 300°F (148.9°C). Hastelloy® and Monel® are widely used. Platinum and silver have special applications. In general, operations involving moist chlorine require individual study. Chlorine and equipment suppliers can make recommendations only after careful study of all factors involved.

7.5 CHLORINATORS

Chlorine gas feeding equipment must be carefully selected. Vacuum operated equipment offers the safest operation for low capacities. For higher capacities a pressure-vacuum system may be required. Pressure piping and connections should be minimized to decrease the possibility of a leak. Equipment manufacturers can recommend optimum system design.

7.6 VAPORIZERS

High chlorination rate systems may need a chlorine vaporizer (evaporator). Vaporizers are usually water-jacketed or steam-heated. Careful attention must be given to the design and operation of such systems (Ref. 10.5.2.3).

7.7 STATIONARY STORAGE

Consumers receiving chlorine in barges require stationary storage installations. Consumers receiving chlorine in tank cars or trucks may require such facilities. The facilities must be specifically designed for the purpose and must be operated and periodically inspected in accord with recommended principles (Ref. 10.5.2.1).

7.8 WASTE DISPOSAL

If a chlorine consuming process involves the discharge of a waste containing chlorine, special processes may be required. All governmental regulations regarding health and safety or the pollution of natural resources must be followed.

7.9 EQUIPMENT MAINTENANCE

7.9.1 General

Cleaning and repair of tanks and other equipment should be under the direction of thoroughly trained personnel. All precautions pertaining to education, protective equipment and health and fire hazards should be reviewed and understood. Workmen should not attempt to repair chlorine piping or other equipment while it is in service. When a chlorine system is to be cleaned or repaired, tanks, piping and other equipment always should be thoroughly purged with dry air or nonreactive gas. This is especially important where cutting or welding operations are undertaken because iron and steel will ignite in chlorine near 483°F (251°C). If pipe sections are to be removed and flanges opened, the lower bolts should be loosened first and, although the lines have been purged, care should be exercized to avoid contact with any residual material that drips from the equipment. Immediate drying of a chlorine pipe or container into which water has been introduced or which has been opened for repairs or cleaning is essential to prevent corrosion.

7.9.2 Cleaning Piping And Other Equipment

If moisture enters a chlorine system, such as when connections are being made or broken at a chlorine container or while maintenance is being performed, ferric chloride will form. Ferric chloride appears as a bright yellow powder which soon picks up moisture. As it does, its color changes, ultimately appearing as a brown, viscous liquid. If it is heated it may appear as a reddish brown scale. Ferric chloride rapidly plugs chlorine lines and buildup of ferric chloride in vaporizers reduces their efficiency.

Steam or hot water rapidly dissolves ferric chloride. However lines or equipment so cleaned must be carefully dried before they are put back in service. Steam should not be used on plastic equipment unless it is known that the specific plastic material can stand the temperature.

7.9.3 Entering Tanks

Chlorine tank inspection, cleaning and repair, are discussed in Ref. 10.5.2.1. All piping to the tank should be disconnected and blanked before entering. See also 5.3.

8. ENVIRONMENTAL CONSIDERATIONS

8.1 GENERAL

Chlorine facilities should be designed and operated so that release of chlorine into the environment does not take place. However, accidental releases of chlorine may occur. The environmental effects of such releases must be considered. There may also be reporting obligations involved.

8.2 TYPES OF RELEASE

8.2.1 Continuous Release

Chlorine can be released from a point source over a period of time. An example of such a release is a leak through a faulty flanged joint. Such a leak will get worse until the condition is corrected. Until that time the downwind hazards will continue.

8.2.2 Slug Release

A slug release will occur if a vessel incurs a large puncture or ruptures. Large quantities of chlorine will be discharged in a short time. In the case of a puncture in the upper (vapor) portion of the vessel about one-fourth of the liquid (depending on the liquid temperature) will rapidly evaporate or "flash off." This will cool the remaining liquid to the atmospheric boiling point. The evaporation rate of the remaining liquid primarily depends on the heat input from the atmosphere.

In the case of a puncture in the liquid phase, liquid will be expelled through the hole until the liquid level drops to the lip of the opening. Most of the liquid expelled will "flash off" as it comes out of the tank, but some may spill on the ground. The evaporation rate of the spilled liquid depends on heat input from the ground and from the sun. Reducing the surface area of the spill will reduce the evaporation rate. The addition of water streams will provide additional heat and will increase the evaporation rate. See Ref. 10.7.1.3 for additional discussion.

8.3 AREA AFFECTED

Mathematical modeling has been done to estimate the dispersion characteristics of chlorine gas cloud from a release. See Ref. 10.7.1.3.

The area and exposure duration depend upon the total quantity released, the rate of release, the height of the release point, and weather conditions. These factors are difficult to evaluate in an emergency situation. Chlorine downwind can vary from barely detectable to high concentrations.

8.4 EFFECT OF CHLORINE ON THE ENVIRONMENT

8.4.1 Vegetation

Chlorine causes bleached spots on leafy plants due to attack on chlorophyll in the leaf. Mature leaves are most susceptible to chlorine injury. Usually the plant itself is not destroyed although yield or growth rate may be retarded.

8.4.2 Animals

The U.S. National Institute for Occupational Safety and Health 1980 "Registry of Toxic Effects of Chemical Substances" lists the following inhalation LC_{50}'s (concentration of chlorine in air lethal to 50% of the defined animal, exposed over the specified time period):

Human—840ppm/30 minutes
Rat—293ppm/60 minutes
Mouse—137ppm/60 minutes

For an unspecified species of mammal the lowest concentration of chlorine in air (other than LC_{50}) which has been reported to cause death in humans or animals is listed as 500ppm/5 minutes.

8.4.3 Aquatic Life

Chlorine is only slightly soluble in water and there would be little absorption from a cloud of chlorine gas. Many forms of aquatic life are adversely affected by chlorine in concentrations well below 0.1 ppm but harmful concentrations are unlikely unless chlorine is discharged directly into water.

9. TECHNICAL DATA

9.1 GENERAL

Chlorine has a characteristic penetrating and irritating odor. The gas is greenish yellow in color and the liquid is clear amber. The data on physical properties of chlorine as determined by different investigators show some variations. Values for physical properties below are taken from "Thermodynamic Properties of Chlorine in SI Units." Ref. 10.9.5.

9.2 ATOMIC AND MOLECULAR PROPERTIES

Atomic Symbol—Cl
Atomic Weight—35.453
Atomic Number—17
Molecular Weight—70.906

Elemental chlorine exists in the form of two naturally occurring isotopes with mass numbers of 35 and 37. Ordinary molecular chlorine consists of a mixture of about 76% chlorine 35 and 24% chlorine 37. There are also at least 13 artificially produced isotopes of chlorine.

9.3 CHEMICAL PROPERTIES

9.3.1 Flammability

Chlorine, gas or liquid, is non-explosive and non-flammable; however, like oxygen, it is an oxidizer and is capable of supporting combustion of certain substances. Many organic chemicals react readily with chlorine, sometimes violently.

9.3.2 Valence

Chlorine usually forms compounds with a valence of -1 but it can combine with a valence of +1, +2, +3, +4, +5 or +7.

9.3.3 Chemical Reactions

9.3.3.1 **Reactions With Water.** Chlorine is only slightly soluble in water. When it reacts with pure water, a weak solution of hydrochloric and hypochlorous acids is formed. Chlorine hydrate ($Cl_2 \cdot 8H_2O$) may crystallize below 49.3°F (9.6°C) at atmospheric pressure and at higher temperatures at increased pressures.

9.3.3.2 **Reactions With Metals.** The reaction rate of dry chlorine with most metals increases rapidly above a temperature which is characteristic for the metal. Below 250°F (121°C) iron, copper, steel, lead, nickel, platinum, silver and tantalum are resistant to dry chlorine, gas or liquid. At ordinary temperatures dry chlorine, gas or liquid, reacts with aluminum, arsenic, gold, mercury, selenium, tellurium, and tin. Titanium reacts violently with dry chlorine. At certain temperatures sodium and potassium burn in chlorine gas. Carbon steel ignites near 483°F (251°C) depending on its physical form. For piping recommendations see Ref. 10.5.2.2.

Moist chlorine, primarily because of the hydrochloric and hypochlorous acids formed through hydrolysis, is very corrosive to most common metals. Platinum, silver, tantalum and titanium are resistant.

9.3.3.3 **Reactions With Other Elements.** Chlorine unites under specific conditions with most of the elements; these reactions may be extremely rapid. At its boiling point chlorine reacts with sulfur. It does not react directly with oxygen or nitrogen; the oxides and nitrogen compounds are well known but can only be prepared by indirect methods. Mixtures of hydrogen and chlorine can react violently. Ignition limits depend on temperature, pressure and concentration. At 70°-80°F (21°-27°C) the ignition limits range from 3% to 93% by volume of hydrogen.

9.3.3.4 **Reactions With Inorganic Compounds.** The preparation of soda and lime bleaches (sodium and calcium hypochlorite) are typical reactions of chlorine with the alkali and alkaline earth metal hydroxides; the hypochlorites formed are powerful oxidizing agents. Because of its great affinity for hydrogen, chlorine removes hydrogen from some compounds such as the reaction with hydrogen sulfide to form hydrochloric acid and sulfur. Chlorine, as the hypochlorous ion, reacts with ammonium ions to form various mixtures of chloramines. At low pH the predominant chloramine formed is explosive nitrogen trichloride (NCl_3).

9.3.3.5 **Reactions With Organic Compounds.** Chlorine reacts with many organic compounds to form chlorinated derivatives. Hydrogen chloride is often formed as a by-product of the reaction. Some reactions can be extremely violent, especially those with hydrocarbons, alcohols and ethers. Proper methods must be followed, whether in laboratory or plant, when organic materials are reacted with chlorine.

9.4 PHYSICAL PROPERTIES

The following properties are for pure chlorine. "Standard conditions," where referenced, are 32°F (0°C) and an absolute pressure of 14.696 psi (101.325 kPa).

9.4.1 Boiling Point (Liquefying Point)

-29.15°F (-33.97°C)—The temperature at which liquid chlorine vaporizes under one atmosphere pressure (101.325 kPa).

9.4.2 Critical Properties

9.4.2.1 **Critical Density.** 35.77 lb/ft^3 (573.0 kg/m^3)—The mass of a unit volume of chlorine at the critical pressure and temperature.

9.4.2.2 **Critical Pressure.** 1157.0 psia (7977 kPa)—The vapor pressure of liquid chlorine at the critical temperature.

9.4.2.3 **Critical Temperature.** 290.75°F (143.75°C)—The temperature above which chlorine exists only as a gas no matter how great the pressure.

9.4.2.4 **Critical Volume.** 0.02795 ft^3/lb (0.001745 m^3/kg)—The volume of a unit mass of chlorine at the critical pressure and temperature.

9.4.3 Density

The mass of a unit volume of chlorine at specified conditions of temperature and pressure.

9.4.3.1 **Gas At Standard Conditions.** 0.2006 lb/ft^3 (3.213 kg/m^3).

9.4.3.2 **Saturated Gas At 32°F (0°C).** 0.7632 lb/ft^3 (12.23 kg/m^3). (Absolute pressure at 32°F (0°C) is 53.51 psi (368.9 kPa)).

9.4.3.3 **Saturated Liquid.** 91.56 lb/ft^3 (1467 kg/m^3) at 32°F (0°C); 88.76 lb/ft^3 (11.87 lb/gal; 1422 kg/m^3) at 60°F (15.6°C)—(Absolute pressure of liquid chlorine at 60°F is 86.58 psi (597.0 kPa)).

9.4.4 **Freezing Point**
See Melting Point, 9.4.7.

9.4.5 **Latent Heat Of Vaporization**
123.9 Btu/lb (288.1 kJ/kg) at the normal boiling point—The heat required to evaporate a unit weight of chlorine.

9.4.6 **Liquid-Gas Volume Relationship**
At standard conditions the weight of one volume of liquid chlorine equals the weight of 456.5 volumes of chlorine gas.

9.4.7 **Melting Point—Freezing Point**
-149.76°F (-100.98°C)—The temperature at which solid chlorine melts or liquid chlorine solidifies at one atmosphere.

9.4.8 **Solubility In Water**
The weight of chlorine which can be dissolved in a given amount of water at a given temperature when the total vapor pressure of chlorine and the water equals a designated value. See Fig. 9.3. At 60°F (15.6°C) and one atmosphere (101.325 kPa) it is 6.93 lbs/100 gals (8.30 kg/m^3).

9.4.9 **Specific Gravity**

9.4.9.1 **Gas.** 2.485—The ratio of the density of chlorine gas at standard conditions to the density of air under the same conditions. (Density of air, free of moisture, at standard conditions is 1.2929 kg/m^3.)

9.4.9.2 **Liquid.** 1.467 0/4°C—The ratio of the density of saturated liquid chlorine at 32°F (0°C) to the density of water at its maximum density.

9.4.10 **Specific Heat**
The heat required to raise the temperature of a unit weight of chlorine one degree.

9.4.10.1 **Saturated Gas At Constant Pressure (C_p).** 0.1244 Btu/lb·°F (0.521 kJ/kg·K) at 32°F (0°C); 0.1347 Btu/lb·°F (0.564 kJ/kg·K) at 77°F (25°C).

9.4.10.2 **Saturated Gas At Constant Volume (C_v).** 0.088 87 Btu/lb·°F (0.3721 kJ/kg·K) at 32°F (0°C); 0.093 03 Btu/lb·°F (0.3895 kJ/kg·K) at 77°F (25°C).

9.4.10.3 **Saturated Liquid.** 0.2264 Btu/lb·°F (0.948 kJ/kg·K) at 32°F (0°C); 0.2329 Btu/lb·°F (0.975 kJ/kg·K) at 77°F (25°C).

9.4.10.4 **Ratio.** Ratio of gas specific heat at constant pressure to gas specific heat at constant volume, Cp/Cv. 1.400 for saturated gas at 32°F (0°C); 1.448 for saturated gas at 77°F (25°C).

9.4.11 **Specific Volume**
The volume of a unit mass of chlorine at specified conditions of temperature and pressure.

9.4.11.1 **Gas At Standard Conditions.** 4.986 ft^3/lb (0.3113 m^3/kg).

9.4.11.2 **Saturated Gas At 32°F (0°C).** 1.310 ft^3/lb (0.08179 m^3/kg).

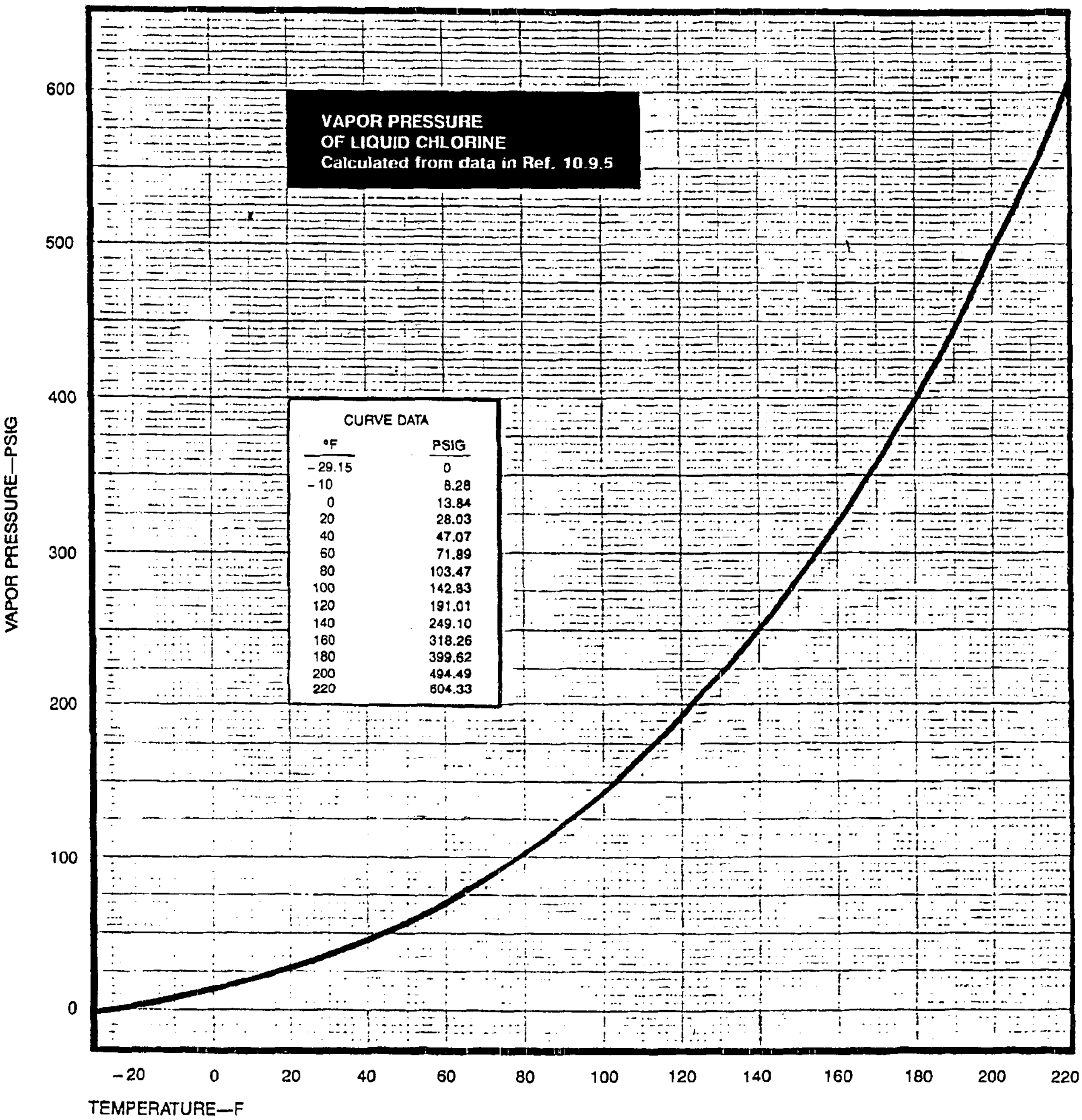
9.4.11.3 **Saturated Liquid at 32°F (0°C).** 0.01092 ft^3/lb (0.000 681 8 m^3/kg).

9.4.12 **Vapor Pressure**
The absolute pressure of chlorine gas above liquid chlorine when they are in equilibrium. 53.51 psi (368.9 kPa) at 32°F (0°C); 112.95 psi (778.8 kPa) at 77°F (25°C). See Fig. 9.1.

9.4.13 **Viscosity**
The measure of internal molecular friction when chlorine molecules are in motion.

9.4.13.1 **Saturated Gas.** 0.0125 centipoise (0.0125 mPa·s) at 32°F (0°C); 0.0132 centipoise (0.0132 mPa·s) at 60°F (15.6°C).

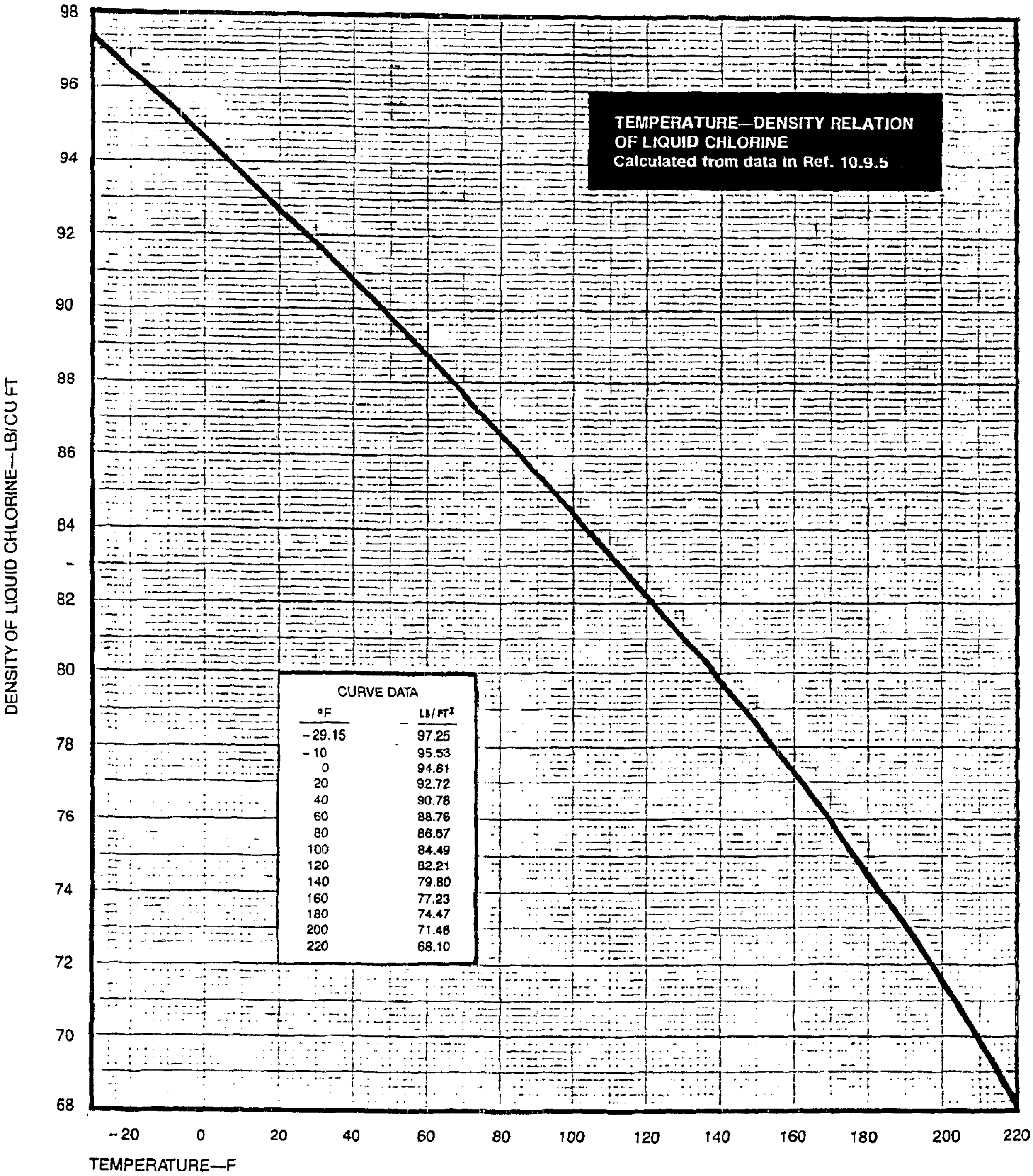
9.4.13.2 **Liquid.** 0.3863 centipoise (0.3863 mPa·s) at 32°F (0°C); 0.3538 centipoise (0.3538 mPa·s) at 60°F (15.6°C).



CURVE DATA

°F	PSIG
-29.15	0
-10	8.28
0	13.84
20	28.03
40	47.07
60	71.89
80	103.47
100	142.83
120	191.01
140	249.10
160	318.26
180	399.62
200	494.49
220	604.33

FIGURE 9.1



°F	LB/FT³
-29.15	97.25
-10	95.53
0	94.61
20	92.72
40	90.78
60	88.76
80	86.67
100	84.49
120	82.21
140	79.80
160	77.23
180	74.47
200	71.46
220	68.10

FIGURE 9.2

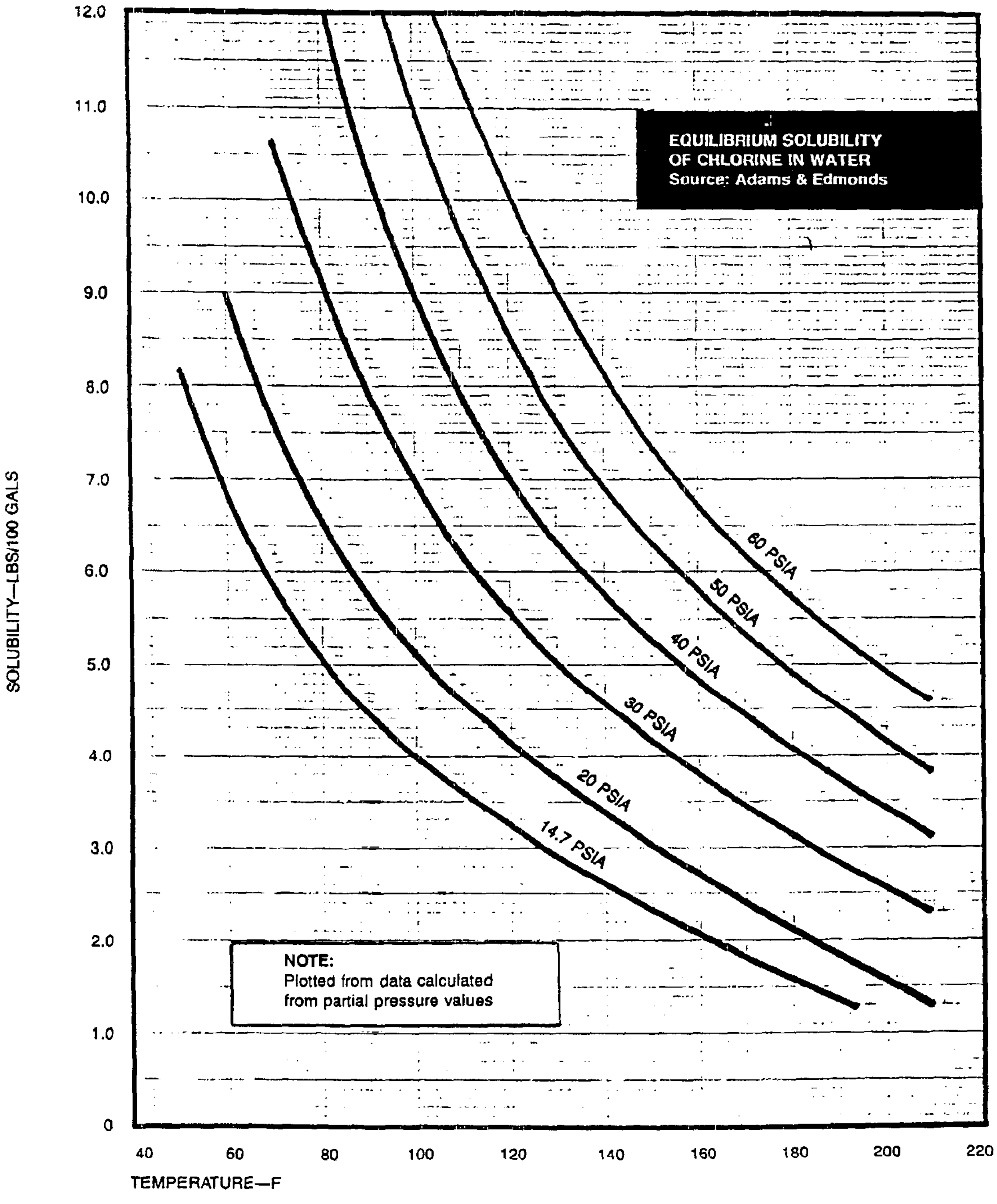


FIGURE 9.3

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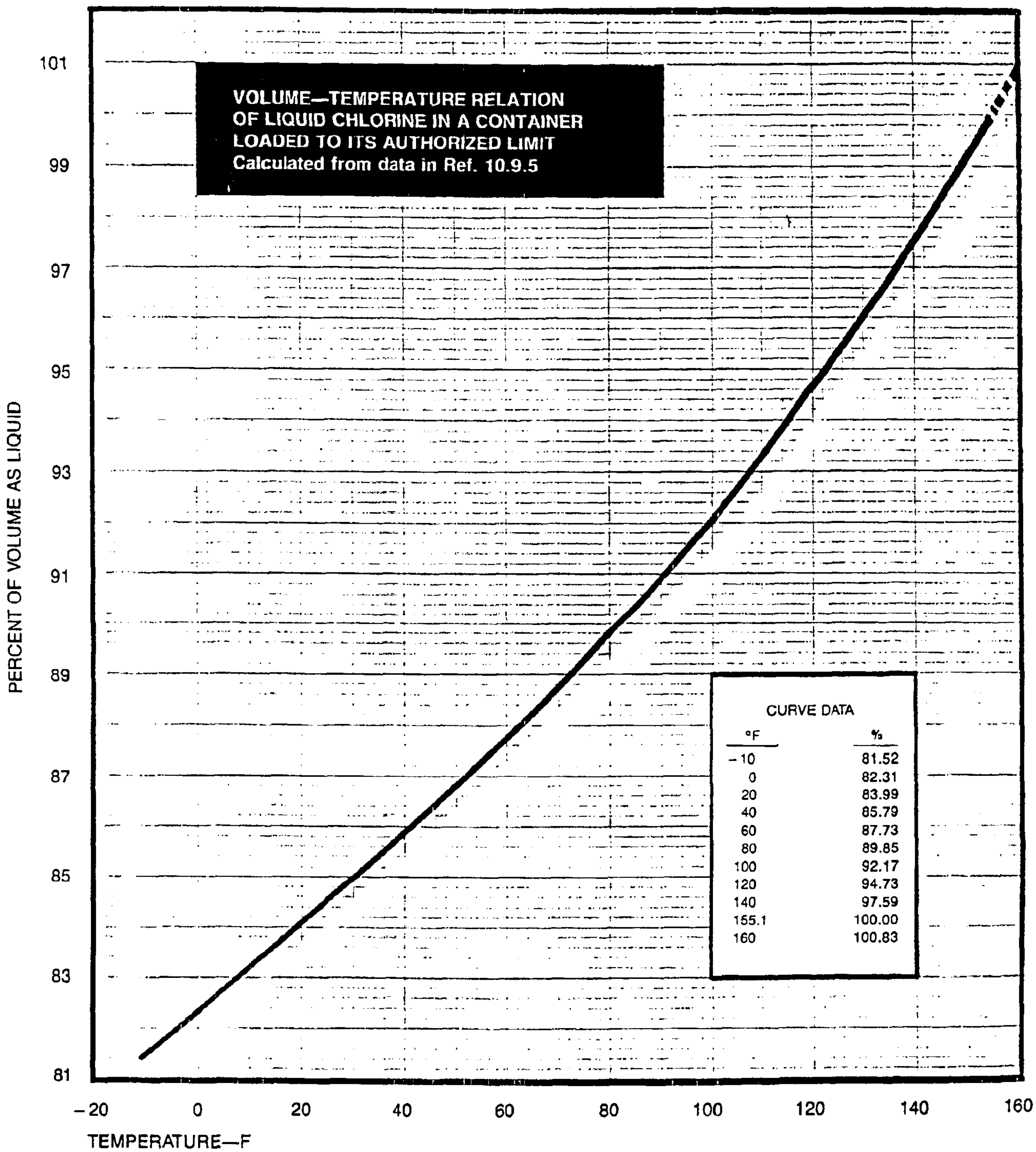

VOLUME—TEMPERATURE RELATION
OF LIQUID CHLORINE IN A CONTAINER
LOADED TO ITS AUTHORIZED LIMIT
Calculated from data in Ref. 10.9.5
PERCENT OF VOLUME AS LIQUID
101
99
97
95
93
91
89
87
85
83
81
– 20
0
20
40
60
80
100
120
140
160
TEMPERATURE—F
CURVE DATA
°F
%
– 10 81.52
0 82.31
20 83.99
40 85.79
60 87.73
80 89.85
100 92.17
120 94.73
140 97.59
155.1 100.00
160 100.83

FIGURE 9.4

10. SELECTED REFERENCES

Many of the following references are cited in the text. Such references are to the editions current at the date of publication of this Manual. The reader should be aware that changing technology or regulations may require a change in the references cited. Publication lists are available from the Institute and many of the other listed sources.

10.1 AVAILABILITY

10.1.1 Publications of the **American Society of Mechanical Engineers** are available from the Society at United Engineering Center, 345 East 47th Street, New York, NY 10017.

10.1.2 Publications of the **American Society for Testing and Materials** are available from the Society, 1916 Race Street, Philadelphia, PA 19103. Individual methods cited in these references are available from The Chlorine Institute.

10.1.3 Publications of the **American Water Works Association** can be obtained from the Association, 6666 West Quincy Avenue, Denver, CO 80235.

10.1.4 Publications of the **Association of American Railroads** can be obtained from the Association, 50 F St., N.W., Washington, D.C. 20001

10.1.5 Publications of **Canadian regulatory authorities** are available from Canadian Government Publishing Centre, Supply and Services Canada, Ottawa, Canada K1A 0S9.

10.1.6 Publications of **The Chlorine Institute, Inc.**, are available from the Institute, 2001 L Street, N.W., Washington, D.C. 20036. A Publications List will be sent on request.

10.1.7 Publications of the **Compressed Gas Association** are available from the Association, 1235 Jefferson Davis Highway, Arlington, VA 22202.

10.1.8 Publications of the **National Academy of Sciences** are available from the Printing and Publishing Office, National Academy of Sciences, 2101 Constitution Avenue, N.W., Washington, DC 20418.

10.1.9 Publications of the **National Fire Protection Association** are available from the Association, Batterymarch Park, Quincy, MA 02269.

10.1.10 Publications of the **National Safety Council** are available from the Council, 444 North Michigan Avenue, Chicago, IL 60611.

10.1.11 Most publications of the **U. S. Government** are available from the Superintendent of Documents, Government Printing Office, Washington, DC 20402.

10.1.12 Publications of the **Water Pollution Control Federation** are available from the Federation, 2626 Pennsylvania Avenue, N.W., Washington, DC 20037.

10.1.13 Publications of the **World Health Organization** are available from WHO's Distribution and Sales Service, 1211 Geneva 27, Switzerland, or through local booksellers.

10.2 TRANSPORTATION REGULATIONS

10.2.1 **Canadian Regulations**

10.2.1.1 Canadian Transport Commission (CTC) Regulations for the Transportation of Dangerous Commodities by Rail, revised periodically.

10.2.1.2 Transport Canada
Transportation of Dangerous Goods Regulations, revised periodically.

10.2.1.3 Canadian Transport Commission (CTC) General Order O-35 pertaining to chlorine tank car unloading facilities.

10.2.2 **US Department of Transportation**

10.2.2.1 Title 46, Code of Federal Regulations, Shipping.
Chapter 1—Coast Guard, Department of Transportation. Subchapter O. Certain Bulk Dangerous Commodities. Part 151—Unmanned Barges and Part 153—Safety Rules for Self Propelled Vessels Carrying Hazardous Liquids. U. S. Government Printing Office, revised periodically.

10.2.2.2 Title 49, Code of Federal Regulations, Transportation, Subchapter C, Hazardous Materials Regulations Parts 171—177; Shipping Container Specifications, Part 178; Specifications for Tank Cars, Part 179; and Subchapter D, Pipeline Safety, Parts 190-195, U. S. Government Printing Office, revised periodically.

10.3 OTHER TRANSPORTATION INFORMATION

10.3.1 **Association of American Railroads**

10.3.1.1 Specifications for Tank Cars, revised annually.

10.3.2 **The Chlorine Institute, Inc.**

10.3.2.1 Pamphlet 8. Chlorine Packaging Manual

10.3.2.2 Pamphlet 49. Handling Chlorine Tank Motor Vehicles

10.3.2.3 Pamphlet 66. Chlorine Tank Car Loading, Unloading, Air Padding, Hydrostatic Testing

10.3.2.4 Pamphlet 76. Guidelines for the Safe Motor Vehicular Transportation of Chlorine Containers

10.3.2.5 Dwg. 122. Ton Container Lifting Beam

10.4 CONTAINER AND VALVE MAINTENANCE

10.4.1. **The Chlorine Institute, Inc.**

10.4.1.1 Pamphlet 17. Cylinder and Ton Container Procedure for Chlorine Packaging

10.4.1.2 Pamphlet 39. Maintenance Instructions for Chlorine Institute Standard Safety Valves, Type 1 1/2 JQ

10.4.1.3 Pamphlet 40. Maintenance Instructions for Chlorine Institute Standard Angle Valve

10.4.1.4 Pamphlet 41. Maintenance Instructions for Chlorine Institute Standard Safety Valves, Type 4 JQ

10.4.1.5 Pamphlet 42. Maintenance Instructions for Chlorine Institute Standard Excess Flow Valves

10.4.1.6 Dwg. 104. Standard Chlorine Angle Valve Assembly

10.4.1.7 Dwg. 110. Valve for Chlorine Cylinders and Ton Containers—Assembly

10.4.2 **Compressed Gas Association, Inc.**

10.4.2.1 Handbook of Compressed Gases, Van Nostrand Reinhold, New York, NY

10.4.2.2 Pamphlet C-1. Methods for Hydrostatic Testing of Compressed Gas Cylinders

10.4.2.3 Pamphlet C-6. Standards for Visual Inspection of Compressed Gas Cylinders

10.4.2.4 Pamphlet P-1. Safe Handling of Compressed Gases in Containers

10.4.2.5 Pamphlet V-1. Compressed Gas Cylinder Valve Outlet and Inlet Connections (This pamphlet is also designated as ANSI B57.1 and CSA B96.)

10.5 ENGINEERING MATERIALS, EQUIPMENT AND OPERATIONS

10.5.1 **American Society Of Mechanical Engineers**

10.5.1.1 Rules for Construction of Pressure Vessels, Sections VIII, Division ASME Boiler and Pressure Vessel Code, ANSI/ASME BPV-VIII-1.

10.5.2 **The Chlorine Institute, Inc.**

10.5.2.1 Pamphlet 5. Non-Refrigerated Liquid Chlorine Storage

10.5.2.2 Pamphlet 6. Piping Systems for Dry Chlorine

10.5.2.3 Pamphlet 9. Operation of Chlorine Vaporizing Equipment

10.5.2.4 Pamphlet 66. Chlorine Tank Car Loading, Unloading, Air Padding, Hydrostatic Testing

10.5.2.5 Pamphlet 67. Safety Guidelines for the Manufacture of Chlorine

10.5.2.6 Pamphlet 78. Refrigerated Liquid Chlorine Storage

10.5.2.7 Pamphlet 79. Recommended Practices for Handling Chlorine Barges

10.5.2.8 Dwg. 118. Chlorine Tank Car Unloading Connections

10.5.2.9 Dwg. 135. Recommended Specifications for Chlorine Transfer Hose

10.5.2.10 Dwg. 136. Chlorine Expansion Chambers

10.5.2.11 Dwg. 183. Manifolding Ton Containers for Liquid Chlorine Withdrawal

10.5.3 **US Environmental Protection Agency**

10.5.3.1 US EPA Program Requirements Memorandum, 1978. (Available from the Institute as PRM 79-1.)

10.5.4 **National Fire Protection Association**
NF PA No. 49. Hazardous Chemicals Data

10.5.5 **National Safety Council**

10.5.5.1 Industrial Safety Data Sheet No. 207

10.5.5.2 Accident Prevention Manual for Industrial Operations

10.5.6 **Other**

10.5.6.1 Fawcett, Howard H. and Wood, William S., Safety and Accident Prevention in Chemical Operations, Interscience Publishers Division of John Wiley & Sons, NY, 1965.

10.5.6.2 Heinemann, G., Garrison, F. G. and Haber, P. A., Corrosion of Steel by Gaseous Chlorine, Effect of Time and Temperature, *I & EC*, 38, 497, 1946.

10.6 CHLORINE MANUFACTURE

10.6.1 Coulter, M. O., ed., Modern Chlor-Alkali Technology, Volume 1, Society of Chemical Industry, J. Wiley & Sons, Publishers, New York, NY, 1980.

10.6.2 Jackson, C., ed., Modern Chlor-Alkali Technology, Volume 2, Society of Chemical Industry, J. Wiley & Sons, Publishers, New York, NY, 1983.

10.6.3 Hardie, D. W. F., Electrolytic Manufacture of Chemicals from Salt, The Chlorine Institute, Inc., Oxford University Press, 1975.

10.6.4 Jeffery, Thomas, Danna, P. A., and Holden, H. Stuart, Editors, Chlorine Bicentennial Symposium. Electrochemical Society, Princeton, NJ, 1974.

10.6.5 Sconce, J. S. ed., Chlorine, Its Manufacture, Properties and Uses, ACS Monograph 154, Robert E. Krieger Publishing Co., Huntington, NY 1972.

10.7 EMERGENCIES, SAFETY AND RESPIRATORY PROTECTION

10.7.1 **The Chlorine Institute, Inc.**

AP00023210

10.7.1.1 Pamphlet 64, Emergency Control Planning Checklist for Chlorine Facilities
10.7.1.2 Pamphlet 73, Atmospheric Monitoring for Chlorine
10.7.1.3 Pamphlet 74, Calculating the Area Affected by Chlorine Releases
10.7.1.4 Pamphlet 75, Respiratory Protection Guidelines for Chlor-Alkali Operations
10.7.1.5 Instruction Booklet, Chlorine Institute Emergency Kit "A" for 100-lb and 150-lb Chlorine Cylinders
10.7.1.6 Instruction Booklet, Chlorine Institute Emergency Kit "B" for Chlorine Ton Containers
10.7.1.7 Instruction Booklet, Chlorine Institute Emergency Kit "C" for Chlorine Tank Cars and Tank Trucks
10.7.1.8 Material Safety Data Sheet—Chlorine
10.7.1.9 Pamphlet 65, Protective Clothing for Chlorine

10.7.2 **Department of Labor**
Title 29, Code of Federal Regulations, Labor, Subtitle B, Chapter XVII, Parts 1900 to 1999, Occupational Safety and Health Administration, U.S. Government Printing Office, Revised periodically.

10.7.3 **Environmental Protection Agency**
Title 40, Code of Federal Regulations, Protection of the Environment, Seven Volumes, U.S. Government Printing Office, Revised periodically.

10.7.4 **National Institute Of Occupational Safety And Health**
10.7.4.1 NIOSH Certified Equipment List, U.S. Government Printing Office, Revised periodically.
10.7.4.2 NIOSH Criteria for a Recommended Standard, Occupational Exposure to Chlorine, U.S. Government Printing Office, 1976.
10.7.4.3 NIOSH Technical Information Guide to Industrial Respiratory Protection, U.S. Government Printing Office, 1976.

10.8 MEDICAL AND TOXICOLOGICAL

10.8.1 **American Conference Of Governmental Industrial Hygienists**
Threshold Limit Values (ACGIH, 1014 Broadway, Cincinnati, OH 45202.)

10.8.2 **The Chlorine Institute, Inc.**
Pamphlet 63, First Aid and Medical Management of Chlorine Exposures

10.8.3 Kowitz, T. A., Reba, R. C., Parker, R. T. and Spicer, W. S., Effects of Chlorine Gas on Respiratory Function, *Arch. of Environmental Health*, 14,545, 1967.
10.8.4 Patty, F. A., Industrial Hygiene and Toxicology, Interscience Publishing Corp., New York, NY.
10.8.5 Weill, H., George, R., Schwartz, M., and Ziskind, M., Late Evaluation of Pulmonary Function after Acute Exposure to Chlorine Gas, *Am Review of Respiratory Diseases*, 29, 373, 1969.
10.8.6 Rotman, Harold H. et al, Effects of Low Concentrations of Chlorine on Pulmonary Function in Humans, *J. Am. Physiological Soc.*, 1120, 1983.
10.8.7 National Academy of Sciences, Medical and Biological Effects of Environmental Pollutants: Chlorine and Hydrogen Chloride, 1976.
10.8.8 World Health Organization, Environmental Health Criteria 21, Chlorine and Hydrogen Chloride, 1982.

10.9 PROPERTIES AND SPECIFICATIONS

10.9.1 Adams, F. W. and Edmonds, R. G., Absorption of Chlorine by Water in a Packed Tower, *I. & E. C.*, 29, 447, 1937.
10.9.2 Ambrose, D., Hall, D. J., Lee, D. A., Lewis, G. B., and Mash, C. J., The Vapour Pressure of Chlorine, *J. Chem. Thermodynamics*, 11, 1089, 1979. Also available from The Chlorine Institute.

10.9.3 **American Society For Testing And Materials**
10.9.3.1 ASTM-E410, Standard Method of Test for Moisture and Residue in Liquid Chlorine
10.9.3.2 ASTM-E412, Standard Method of Assay of Liquid Chlorine (Zinc Amalgam Method)
10.9.3.3 ASTM-E649, Standard Test Method for Bromine in Chlorine
10.9.3.4 ASTM-E806, Standard Test Method for the Determination of Carbon Tetrachloride and Chloroform in Liquid Chlorine by Direct Injection (Gas Chromatographic Procedure)
10.9.3.5 ASTM-D2022, Standard Methods of Sampling and Chemical Analysis of Chlorine-Containing Bleaches

10.9.4 **American Water Works Association**
AWWA Standard for Liquid Chlorine, B301-81.)

10.9.5 **The Chlorine Institute, Inc.**
Pamphlet 72, Thermodynamic Properties of Chlorine in SI Units

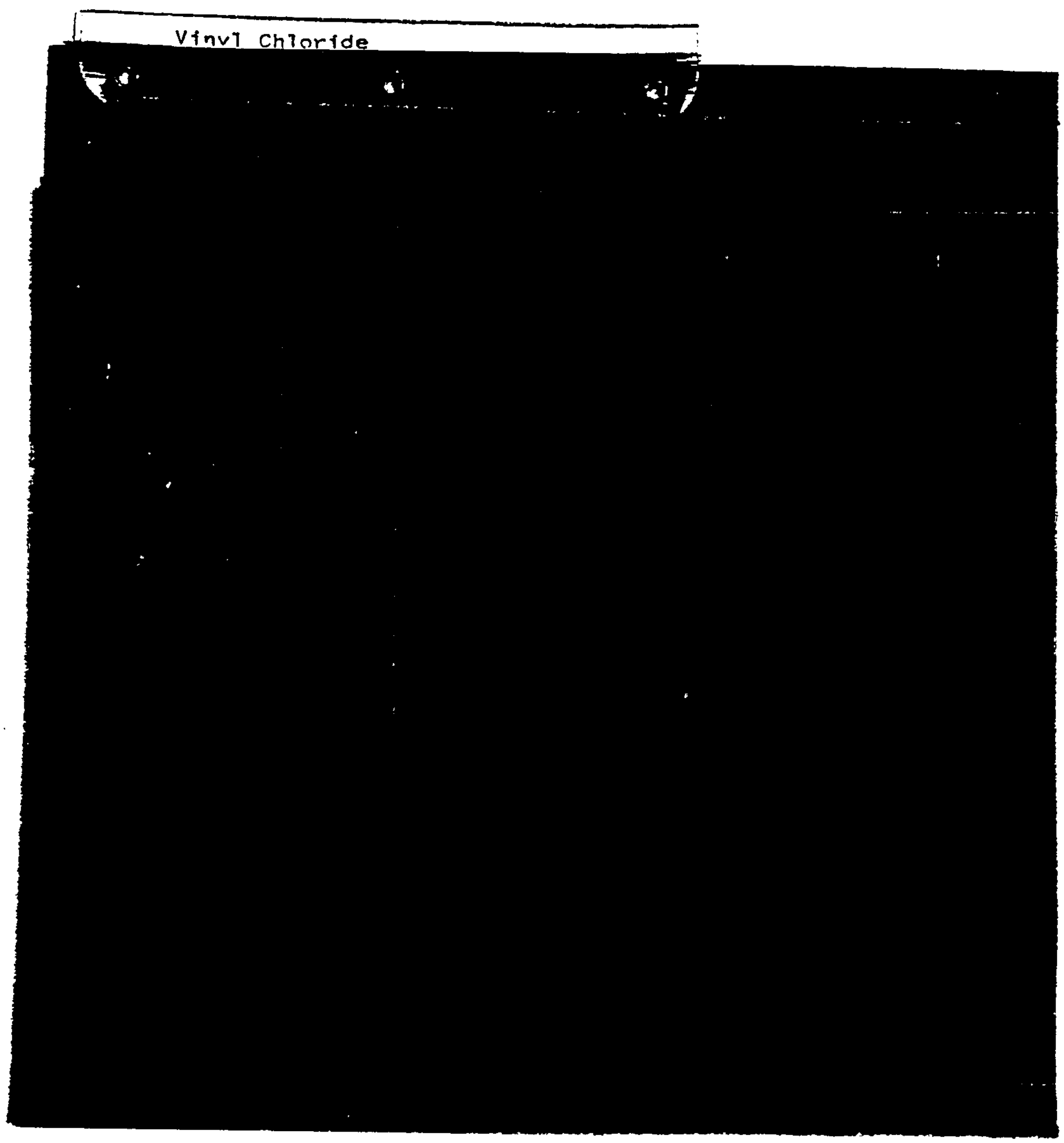
10.9.6 **Federal Specification, Chlorine Technical, Liquid,**
BB-C-120 C, 1980. Available from The Chlorine Institute.

10.9.7 **National Academy of Sciences/National Research Council**
10.9.7.1 Water Chemicals Codex, 1982.
10.9.7.2 Food Chemicals Codex II, 1972, First Supplement, 1974.

10.10 SANITARY USES OF CHLORINE

10.10.1 **American Water Works Association**
Water Chlorination, Principle and Practices Manual M20, 1973.

10.10.2 **Water Pollution Control Federation**
Operation of Wastewater Treatment Plants, Manual of Practice No. 11, 1976.
10.10.2.1 Chlorination of Wastewater, Manual of Practice No. 4, 1976.


Vinyl Chloride