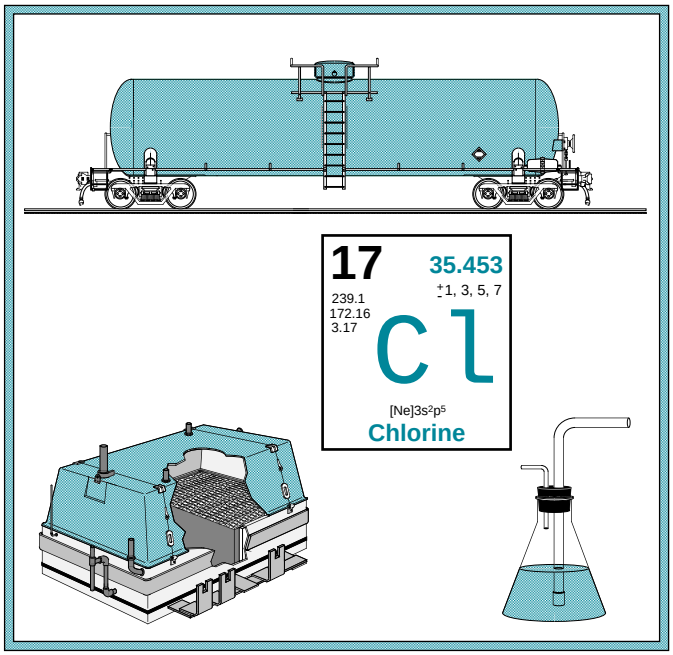
OxyChem Chlorine Handbook



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Foreword

This handbook outlines the methods for handling, storing, and using chlorine. It also includes information on the manufacture and physical properties of chlorine.

Additional information and contacts can be found on the internet at www.oxychem.com

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History and Growth of Chlorine

The earliest annals of chemistry mention chlorine compounds. In 77 A.D., Pliny the Elder published one of the first practical collections of chemical reactions. His formula for gold purification generated chlorine as a by-product in the form of hydrogen chloride. But more than 800 years passed before written records showed that the Arabs had learned to react chlorine with water to produce hydrochloric acid.

Around 1200 A. D., alchemists discovered that a mixture of hydrochloric and nitric acids dissolved gold. This procedure generates chlorine, but there is no record that a heavy greenish gas was evolved. In 1630, Belgian Jean Baptiste van Helmont wrote of a "salt gas" that we know contained chlorine, but it wasn't until 1774 that Swedish apothecary, Carl Wilhelm Scheele, generated, collected, and studied chlorine as an end in itself.

Even Scheele's discovery was nearly accidental. He collected chlorine out of simple curiosity. Perhaps he too would have treated the gas casually if he hadn't, on some impulse, placed some leaves and flowers into a bottle of chlorine. Within minutes the plants had turned white, and man had the first historical record of the bleaching action of chlorine.

Scheele's discovery came when both modern chemistry and the industrial revolution were taking their first halting steps down paths that would soon change the course of history. Antoine Lavoisier, the father of modern chemistry, took note of Scheele's work and quickly became embroiled in a controversy over whether chlorine was an element or a compound. Meanwhile, textile producers in the French town of Javelle heard of the bleaching action of this gas, and in 1789 bubbled it through a potash solution producing *eau de Javelle, Javelle Water,* the first commercial liquid chlorine bleach.

The eruption of the French Revolution cut short the intellectual ferment begun by Lavoisier and his followers. Lavoisier himself was guillotined in 1793, but his chemistry had crossed the English Channel. Once again, scientific curiosity paralleled commercial necessity. Humphry Davy, the English father of electrolysis, demonstrated that chlorine was an element with properties useful to Britain's rapidly expanding textile and paper industries.

In the 1830's Michael Faraday, Davy's lab assistant, produced a definitive work on both the electrolytic generation of chlorine and the ease of its liquefaction. In 1851, Charles Watt obtained the first English patent for an electrolytic chlorine production cell.

Through the 1880's and 1890's producers in Germany, England, Canada, and the United States refined chlorine technology. Around 1890, German producers learned that, while wet liquid chlorine was almost impossible to package, removal of all water allowed safe shipment in ordinary iron or steel pressure vessels.

By the early 1900's, chlorine was produced in mercury and diaphragm electrolytic cells and shipped in liquid form as a matter of course. A modern chlorine industry had formed. By 1913, the first permanent liquid chlorine water purification system had been installed in Philadelphia. The following year, Altoona, Pennsylvania, became the first city to treat sewage with liquid chlorine.

World War I brought added impetus to North American chlorine production. Submarine warfare practically eliminated imports of chemicals from Europe at a time when markets for many chemicals, including chlorine, were growing rapidly. By the end of the war, the United States had a large and firmly entrenched domestic chlorine industry.

In the 1930's, the world's chemical industry erupted in a period of extraordinary growth that still continues. Bleaching properties of chlorine became just one of its major uses. Its disinfecting properties remained vital to health, but became a minor market for a chemical that would soon affect almost every human activity.

Today, we use chlorine as a raw material in the manufacture of polyvinyl chloride, a plastic used in fabricating flooring, pipe, wallpaper, clothing, furniture, and a wide range of household products. . We treat our illnesses with complex drugs and spray our crops with insecticides, herbicides, and fungicides which contain chlorine as part of their basic structure. Chlorinated chemicals also enable us to refrigerate and freeze our food, cool our homes, offices and cars, and even insulate our buildings from the heat and cold.

One of the most important uses of chlorine is helping produce chemicals that contain no chlorine at all. Chlorine and chlorine chemicals help promote reactions that produce chemicals for antifreeze, textile lubricants, fabric softeners, book-binding pastes, solvents for lacquers, brake fluids, polyester fibers, and a host of other products.

Production Process

The basic raw material for the process, salt, comes from either mines or underground wells. Mined salt is dissolved with water to form raw brine. In other cases, water is pumped into salt deposits, forming brine in the earth that is tapped and drawn off from the resulting brine well.

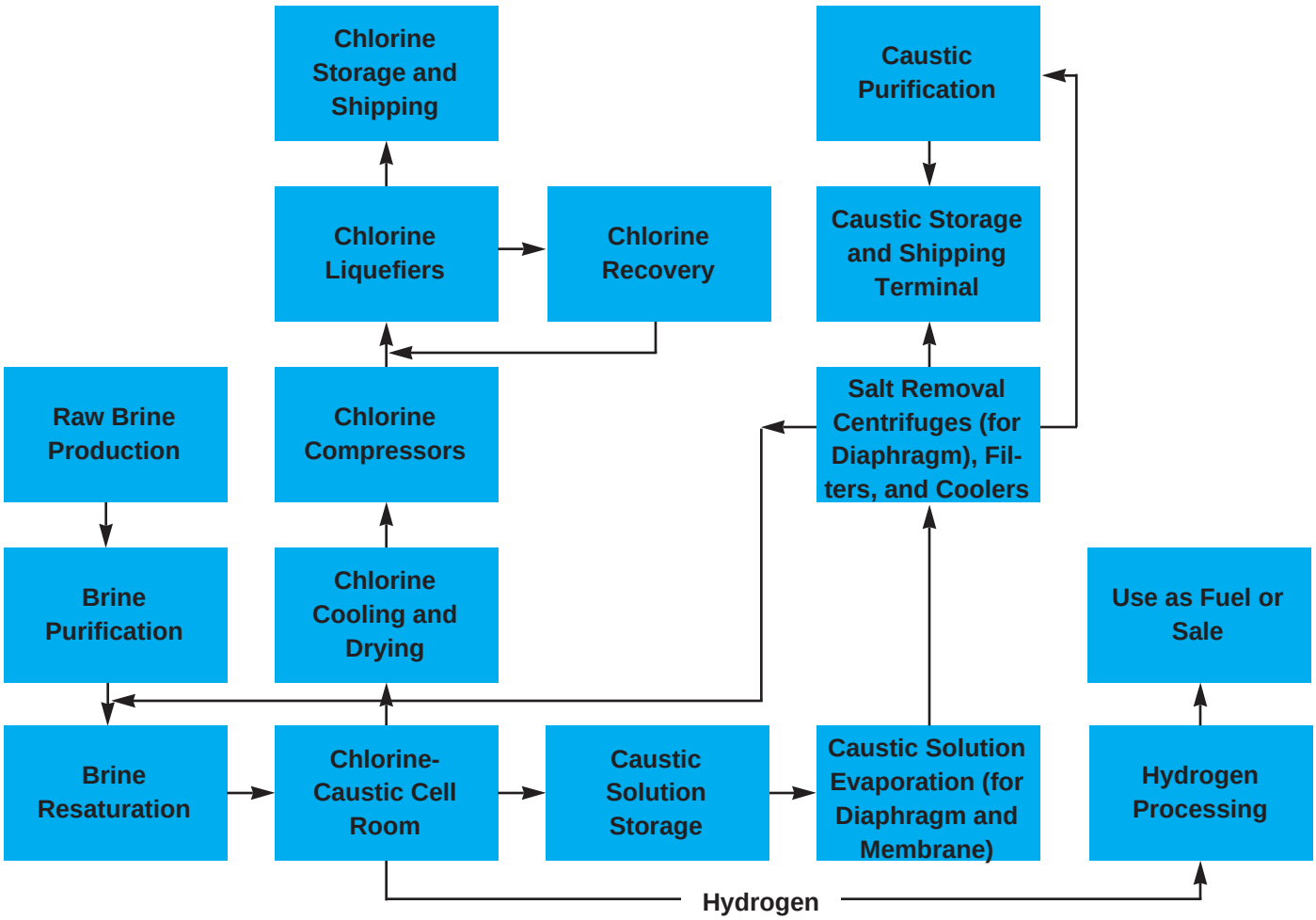
Raw brine contains impurities that interfere with chlorine-caustic production. They are removed by chemical treatment, settling, and filtration. The purified brine is pumped to the cell room. The cell room contains one of three types of electrolytic cells for decomposing brine into chlorine, caustic soda, and hydrogen. These three cell types are diaphragm, membrane, or mercury cells.

The chlorine that leaves the cell is hot and wet, and therefore very corrosive. It must be cooled and dried before it can be processed in ordinary steel equipment. In addition, the chlorine stream is contaminated with air, hydrogen, and some carbon dioxide (due to small amounts of carbon bearing chemicals in the brine).

Once the chlorine stream is cooled and dried, compressors and refrigeration machines are used to liquefy the gas. Chlorine is most easily handled as a liquid in specially designed pressure containers.

Any gaseous contaminants in the chlorine stream are removed. Small amounts of chlorine mixed with them are nearly completely recovered. The recovered chlorine is then returned to the liquefaction process.

Chlorine Process



Characteristics

Chlorine, at ordinary conditions of temperature and pressure, is a greenish-yellow gas with a pungent and irritating odor. Since chlorine is very active chemically, it is found in nature only in combination with other elements. Sodium chloride, for example, is widely and abundantly distributed in nature and constitutes the chief source of chlorine. Because gaseous chlorine is approximately two-and-one-half times as heavy as air, it is slow to diffuse into the air. It tends to accumulate in low places.

Gaseous chlorine can be liquefied by the application of pressure at reduced temperatures to form a clear, amber-colored liquid. Liquid chlorine is approximately one-and-one-half times as heavy as water.

In the presence of moisture, both gaseous and liquid chlorine are extremely corrosive to common metals of construction. At low pressures, wet chlorine can be handled in equipment made of glass, chemical stoneware, titanium, and certain plastics. Installations employing wet chlorine require special care and recommendations can be made only after a thorough and careful investigation. Platinum, tantalum, and titanium are some of the metals resistant to moist chlorine.

Dry chlorine, both gaseous and liquid, can be handled safely in equipment fabricated from iron, steel, certain stainless steels, Monel metal, nickel, copper, brass, bronze, and lead. These metals are not aggressively attacked by dry chlorine but the slightest trace of moisture will cause severe corrosion. However, dry chlorine attacks metals at elevated temperatures. Chlorine reacts with carbon steel at elevated temperatures. Operations above 250°F should be avoided.

Since chlorine boils at about -30°F, under certain conditions it can embrittle ordinary carbon steels. If temperatures below -20°F are expected to occur, special carbon steels, or other materials of construction should be considered.

Chlorine is an excellent oxidizing agent which accounts for its widespread use as a bleaching agent. Liquid and gaseous chlorine are nonflammable and will not support combustion in the normal sense. However, chlorine will support the combustion of certain materials under special conditions.

Dry chlorine has an extremely high affinity for moisture. Regardless of the environmental conditions of temperature and humidity, all open ends of chlorine pipelines should be sealed with rubber stoppers or some type of moisture-tight closure when not in use. An open end of a chlorine delivery line will, within a time interval of only a few minutes, pick up sufficient moisture from the atmosphere to cause severe corrosion.

Chlorine Containers

Chlorine is supplied in packages of varying sizes according to the requirements of the customer. Cylinders of 100 pounds or 150 pounds capacity are available to customers needing small quantities. Ton containers (2000 lbs. net) can be supplied to consumers requiring intermediate tonnage. Containers of these sizes are supplied by independent distributors (Repackagers) and not by OxyChem.

Additionally, chlorine cargo tank trucks of 15 to 20 tons capacity are in limited use and only available from certain Repackagers.

Receipt of chlorine by tank car requires special handling and compliance with the Department of Transportation (DOT) Hazardous Materials Regulations, CFR Title 49, Tank cars are supplied by OxyChem and are available in 90 ton capacities. 55 ton tank cars are in limited use and will be phased out of service after 2002.

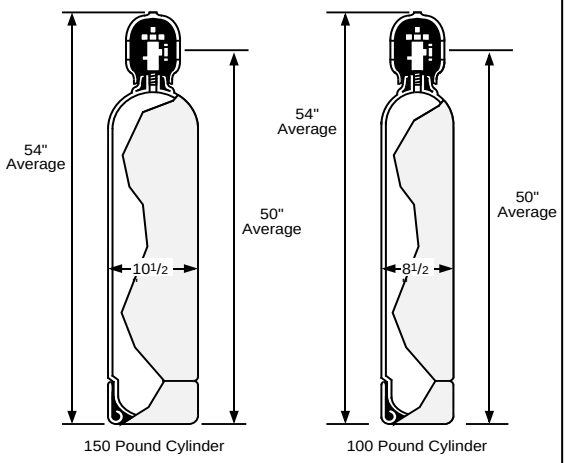
All chlorine containers and fittings are of a type approved by The Chlorine Institute, Inc. and must comply with the specifications and regulations of the DOT. Most Repackagers maintain facilities for the inspection, cleaning, testing, and filling of these containers.

Cylinders

Liquid chlorine cylinders are seamless steel construction. Cross-sectional drawings of 100-pound and 150-pound cylinders are shown in Figure 1. Cylinders are fitted with valves in compliance with the specifications and regulations of the DOT and approved by The Chlorine Institute, Inc. The US DOT (or Canadian equivalent) specification number, serial number, identifying symbol, original tare weight, inspector's official mark, and date of hydrostatic is stamped on the metal near the cylinder neck. Usually the owner's name or symbol is stamped or embossed in the same area. To mar or deface these markings is illegal.

Each cylinder is fitted with a cap to protect the valve mechanism. It must be kept in place whenever the cylinder is not in actual service. A cross-sectional drawing of a chlorine cylinder valve is shown in Figure 2.

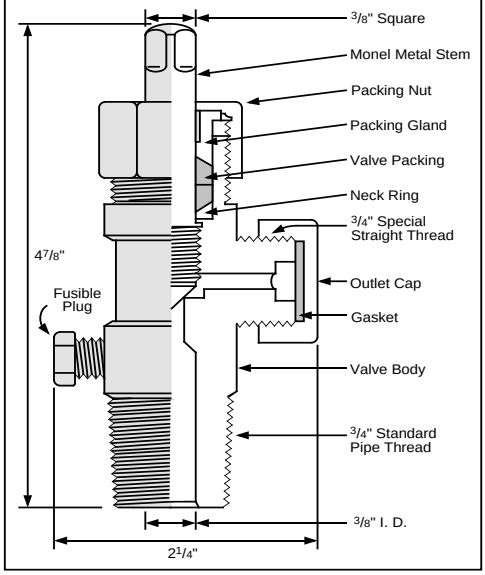
Figure 1 - Cylinder



Dimensions of Cylinders

Capacity lbs	Tare Weight lbs	Total Height inches	Outside Diameter inches
100	63 -115	39.5 - 59"	8.25 - 0.75"
150	85 -140	53.0 - 56"	10.25 - 10.75"

Figure 2 - Cylinder Valve



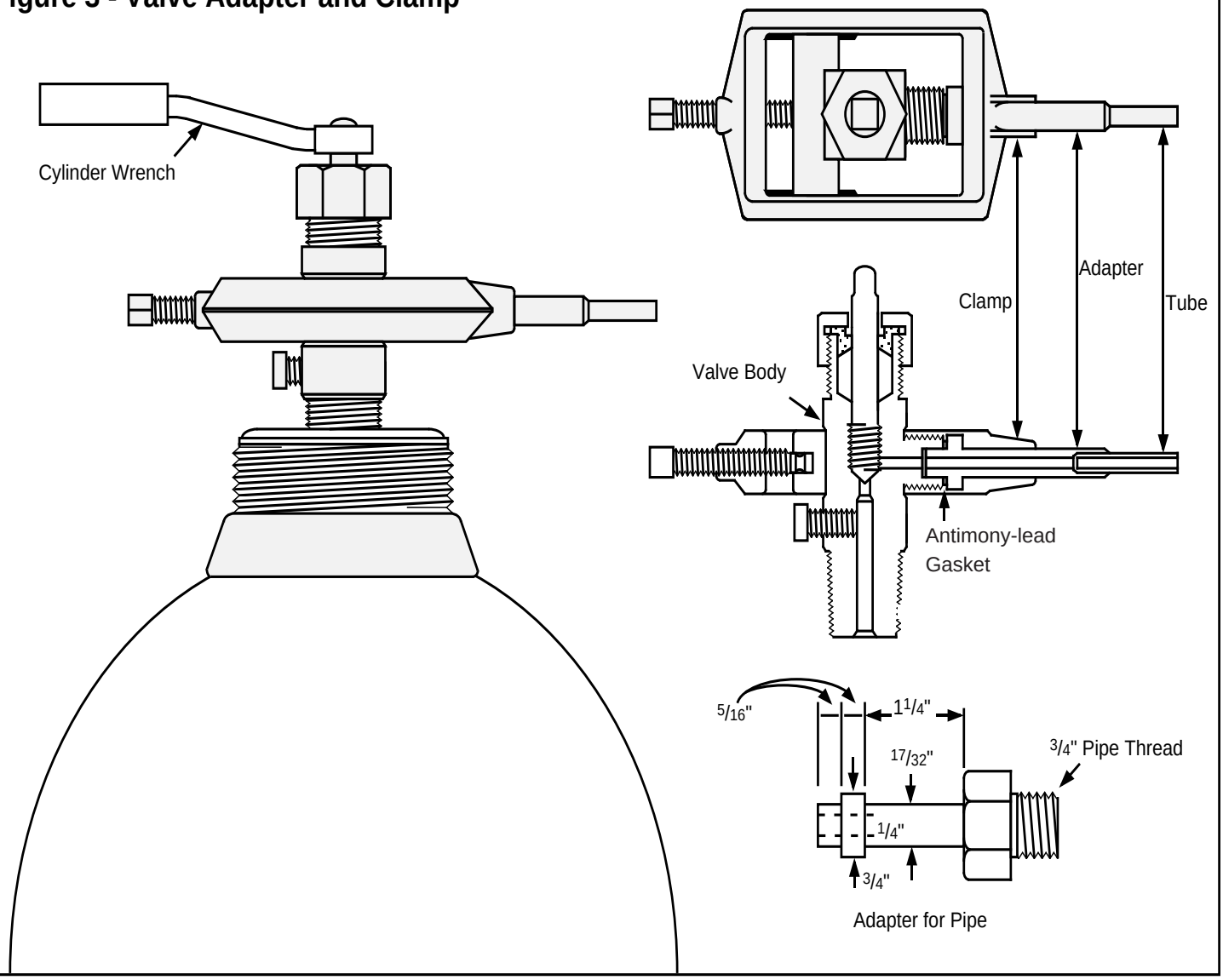
The outlet threads of a chlorine cylinder valve are not standard pipe threads. For this reason, a special clamp and adapter, as shown in Figure 3, is suggested. The use of the clamp and adapter affords greater convenience for the consumer and protects the cylinder valve from excessive wear.

The chlorine cylinder valve is equipped with a fusible metal plug which is a safety device designed to melt at about 158°F. This safety plug protects the chlorine cylinder against excessive pressure, by melting and allowing the contents of the cylinder to escape when exposed to high temperature. The fusible metal plug is located below the valve seat and cannot be controlled by the valve. The fusible metal plug should not be tampered with under any circumstances.

No wrench other than the one shown in Figure 3 should be used to open or close chlorine cylinder valves. Use of another wrench may damage the valve stem and make the valve difficult to close.

Storage of Cylinders

Figure 3 - Valve Adapter and Clamp



Store cylinders of liquid chlorine in a cool place away from steam pipes or other sources of heat.

Store cylinders, full or empty, with their valve outlet caps and valve protective caps in place.

Store all cylinders of liquid chlorine in a location which is protected from direct sunlight and from dampness.

Do not store cylinders where it is possible for leaking vapors to enter a ventilating system.

Store all cylinders in a vertical position.

Store cylinders so that the oldest shipments of cylinders are used first. Valve packing may harden with prolonged storage, causing leaks when the cylinders are used.

Storage areas should be kept clean so that accumulated trash does not present a fire hazard.

Handling and Use of Cylinders

It is illegal to ship a leaking chlorine cylinder or a chlorine containing cylinder which has been exposed to fire. Consult your chlorine supplier for advice under such circumstances.

If a chlorine cylinder or its valve is found out of order, notify the distributor from whom the chlorine was purchased, giving the cylinder number and the nature of the damage.

Handle all chlorine cylinders with extreme care. Do not drop cylinders or allow them to strike any object with force. Do not apply heat to chlorine cylinders or their valves.

Operate chlorine cylinder valves only with the wrenches shown in Figure 3. Under no circumstances use a pipe wrench or any wrench longer than six inches. Always use the correct special clamps and adapters as shown in Figure 3.

Use valves, gauges, regulators, and fittings which have been approved for chlorine service. Ordinary devices are not suitable.

The cylinder must be in an upright position to remove chlorine as a gas. If liquid chlorine is to be withdrawn from a cylinder, the cylinder must be inverted and clamped securely on a rack set at an angle of about 60° to the horizontal.

Use flexible connections between cylinders and piping systems (Figure 4). Copper tubing capable of withstanding pressures up to 400 pounds per square inch is satisfactory for dry chlorine.

Close valves on chlorine cylinders when chlorine is not being withdrawn in order to prevent moist air or foreign substances from entering the cylinder. It is dangerous to allow any chlorine cylinder, which has emptied its contents into water or another liquid, to remain connected with the process line. In such cases liquid could be sucked back into the cylinder causing danger to the operator and damage to the cylinder.

Replace outlet cap and valve protective cap as soon as the cylinder is disconnected.

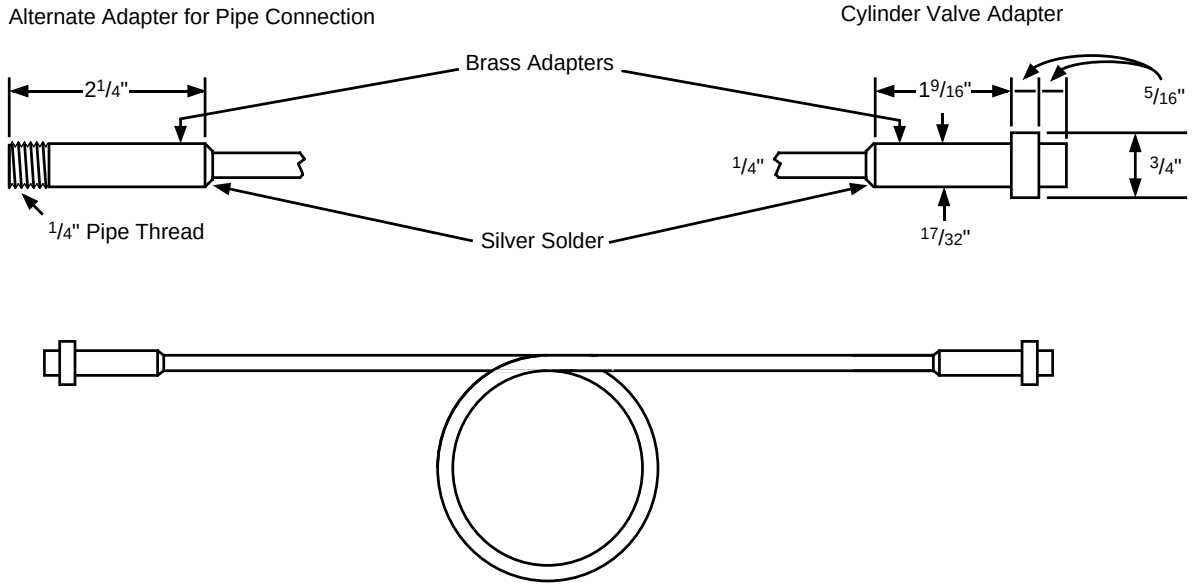
Do not alter or repair chlorine cylinders or their valves.

Leaks around the valve stem are usually corrected by tightening the packing nut in a clockwise direction. All threads on all chlorine valves are right-hand threads.

Provide suitable hand trucks for moving cylinders. These should be properly balanced and have a clamp support at least two-thirds of the way up the cylinder. If chlorine cylinders are to be lifted, provide a suitable sling. Do not use a chain, rope, or magnetic device. Do not lift cylinders by their valve protective caps because they are not designed for this purpose.

To monitor the consumption of chlorine at any given time, place the cylinder on a scale. The difference in weight between measurements will equal the quantity consumed.

Figure 4 - Flexible Tubing Connector for Ton Containers and Cylinders



Ton Containers

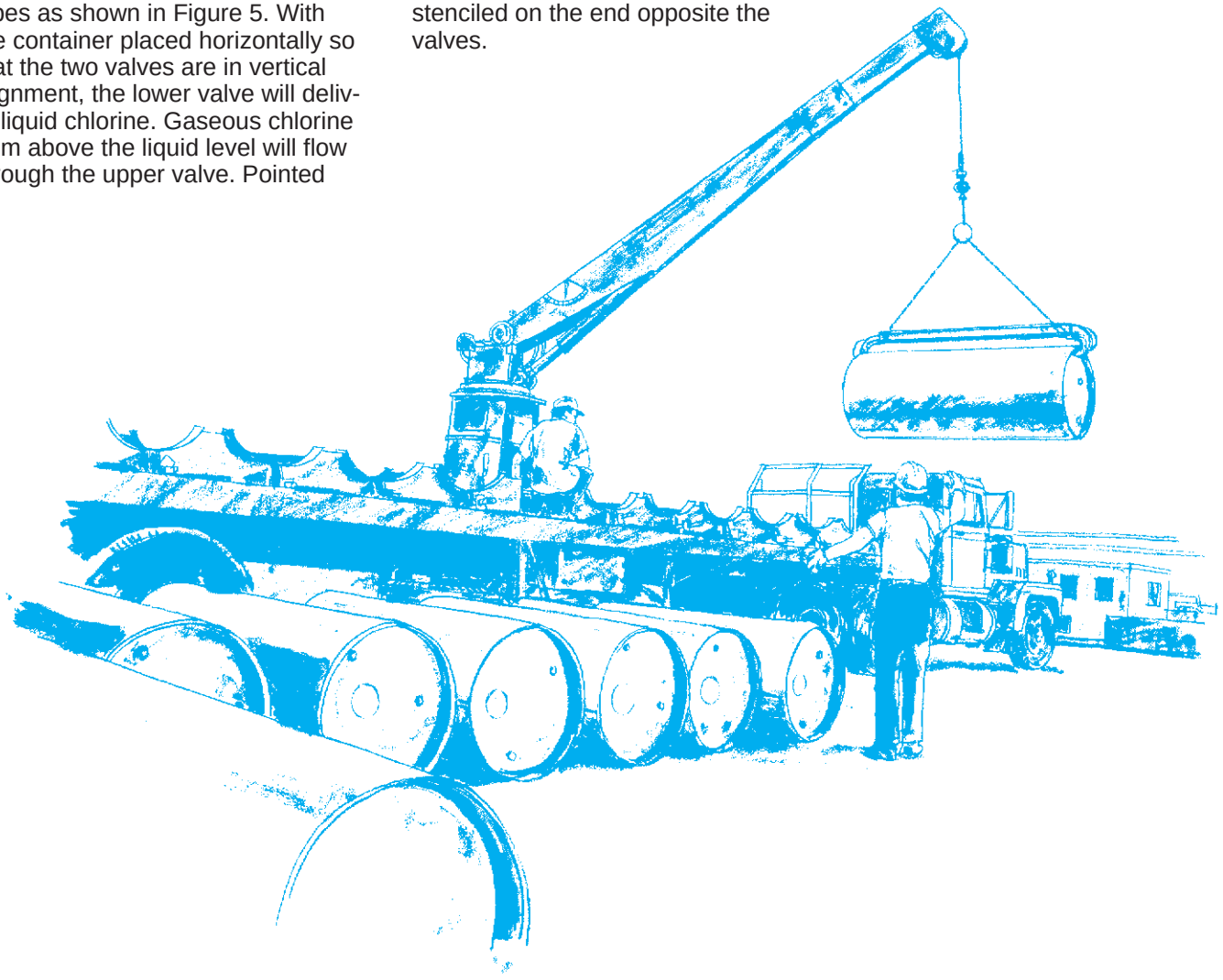
The ton containers for liquid chlorine are constructed of steel. Like the cylinders, they are fitted with valves approved by The Chlorine Institute, Inc. and in compliance with the specifications and regulations of the DOT.

The average ton container (Figure 5) is about 30 inches in outside diameter and about 82 inches in length. Average tare weight is about 1500 pounds, average gross weight is about 3500 pounds, leaving 2000 pounds net weight.

Each end of a ton container is concave. The sides are crimped inward over the ends to form chimes that provide suitable grips for hooks used in handling. Each container is equipped with two valves, both of which are located at the same end, near the center. The valves are connected to eduction pipes as shown in Figure 5. With the container placed horizontally so that the two valves are in vertical alignment, the lower valve will deliver liquid chlorine. Gaseous chlorine from above the liquid level will flow through the upper valve. Pointed arrows on the valve end of a ton container indicate the position of the two valves. These arrows are visible when the protective bonnet is in place, allowing proper positioning of a ton container before removing the bonnet. There are six fusible metal plugs in each ton container, three on each end. The fusible metal in these plugs melts at about 158°F. The melting plug prevents build up of excessive pressure when exposed to high temperature. The fusible metal plugs should not be tampered with under any circumstances. The container number, dates of hydrostatic tests, and water capacity are stamped in the metal of an unpainted portion of the chime at the valve end of each ton container. To mar or deface these markings is illegal.The tare weight of each ton container is stenciled on the end opposite the valves.

The ton container valve is the same as the cylinder valve except that it has a larger discharge port and no fusible metal plug. A cross section of the ton container valve is shown in Figure 6. The outlet threads of a ton container valve are not standard pipe threads. For that reason, a special clamp and adapter shown in Figure 3, are suggested.

The use of the clamp and adapter affords greater convenience for the consumer and protects the ton container valve from excessive wear.



Storage of Ton Containers

Only the wrench shown in Figure 3 is to be used to open or close a ton container valve. Clamps, adapters, and valve wrenches are available from your chlorine distributor.

A suitable hoist equipped with a lifting beam as shown in Figure 7 is required to remove or replace the containers.

Storage

Store ton containers of liquid chlorine in a cool place, away from steam pipes or other sources of heat.

Store all ton containers, full or empty, with their valve outlet caps and valve protective bonnets in place.

Store all ton containers of liquid chlorine in a location which is protected from direct sunlight and from dampness.

Do not store ton containers of liquid chlorine near flammable materials.

Store ton containers where it is not possible for leaking vapors to enter a ventilating system.

Store ton containers in a horizontal position on a level rack. Keep them on the same level. Do not stack ton cylinders to avoid the possibility of the one at the bottom developing a leak and being difficult to remove.

Figure 5 - Ton Container

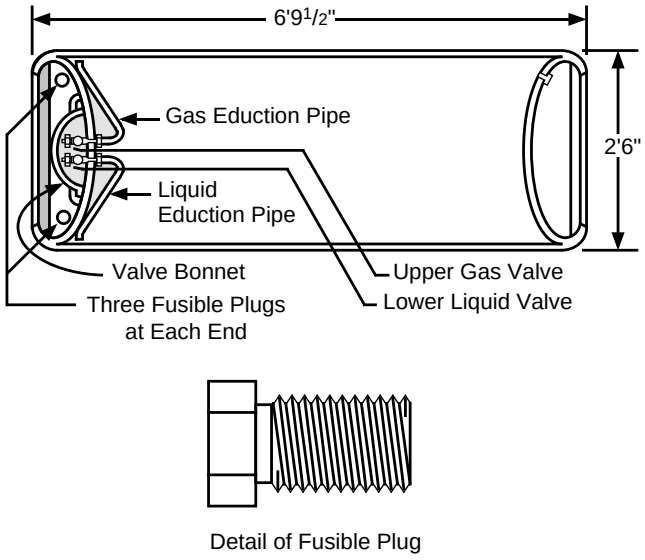


Figure 6 - Ton Container Valve

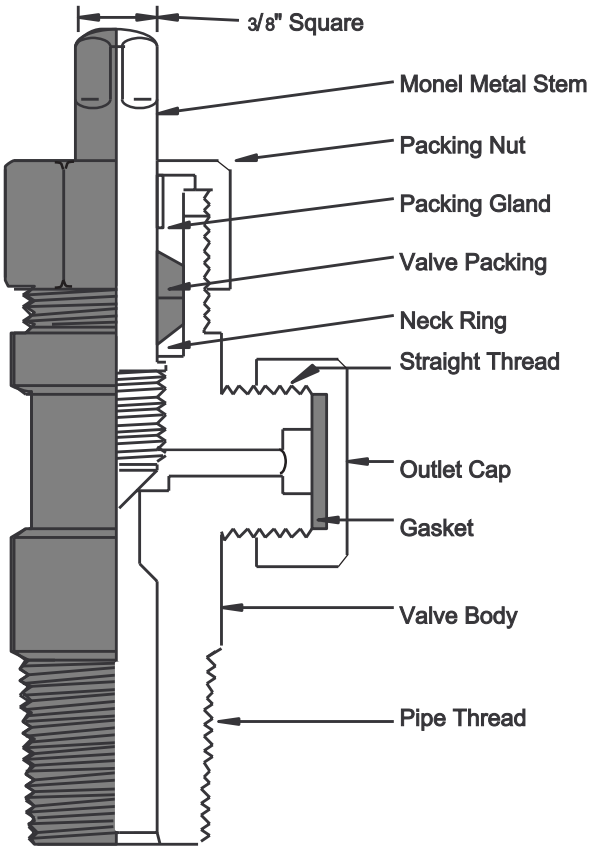
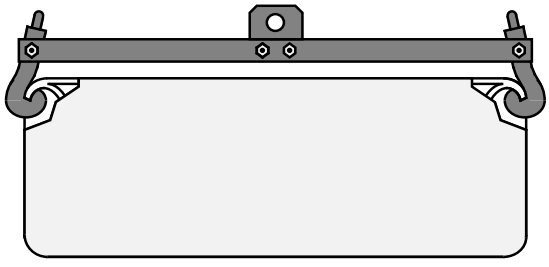


Figure 7 - Ton Container Lifting Beam



Handling and Use of Ton Containers

Shipping a leaking chlorine container or one, partially or fully loaded, which has been exposed to fire is illegal. Consult your distributor for advice under such circumstances.

If a ton container or its valves are found out of order, notify the distributor from whom the chlorine was purchased, giving the container number and nature of the damage.

Handle all chlorine ton containers with extreme care. Do not drop ton containers or allow them to strike any object with force. Do not apply heat to ton containers or their valves.

Ton container valves should be operated only with wrenches as shown in Figure 3. Under no circumstances use a pipe wrench or any wrench longer than six inches. Always use special clamps and adapters. (See Figure 3.)

Use valves, gauges, regulators, and fittings which have been approved for chlorine service. Ordinary devices are not suitable.

Use flexible connections between ton containers and piping systems. (See Figure 4.) Copper tubing capable of withstanding pressures of 400 pounds per square inch is satisfactory for dry chlorine. A typical installation is shown in Figure 8.

Use the lower valve to withdraw liquid chlorine and the upper valve to remove chlorine gas.

Close valves on ton containers when chlorine is not being withdrawn to prevent moist air or foreign substances from entering the container. It is dangerous to allow any chlorine container, which has emptied its contents into water or other liquid, to remain connected with the process line. In such cases, liquid could be sucked back into the container causing danger to the operator and damage to the container.

Replace outlet caps and valve protective bonnets as soon as the containers are disconnected.

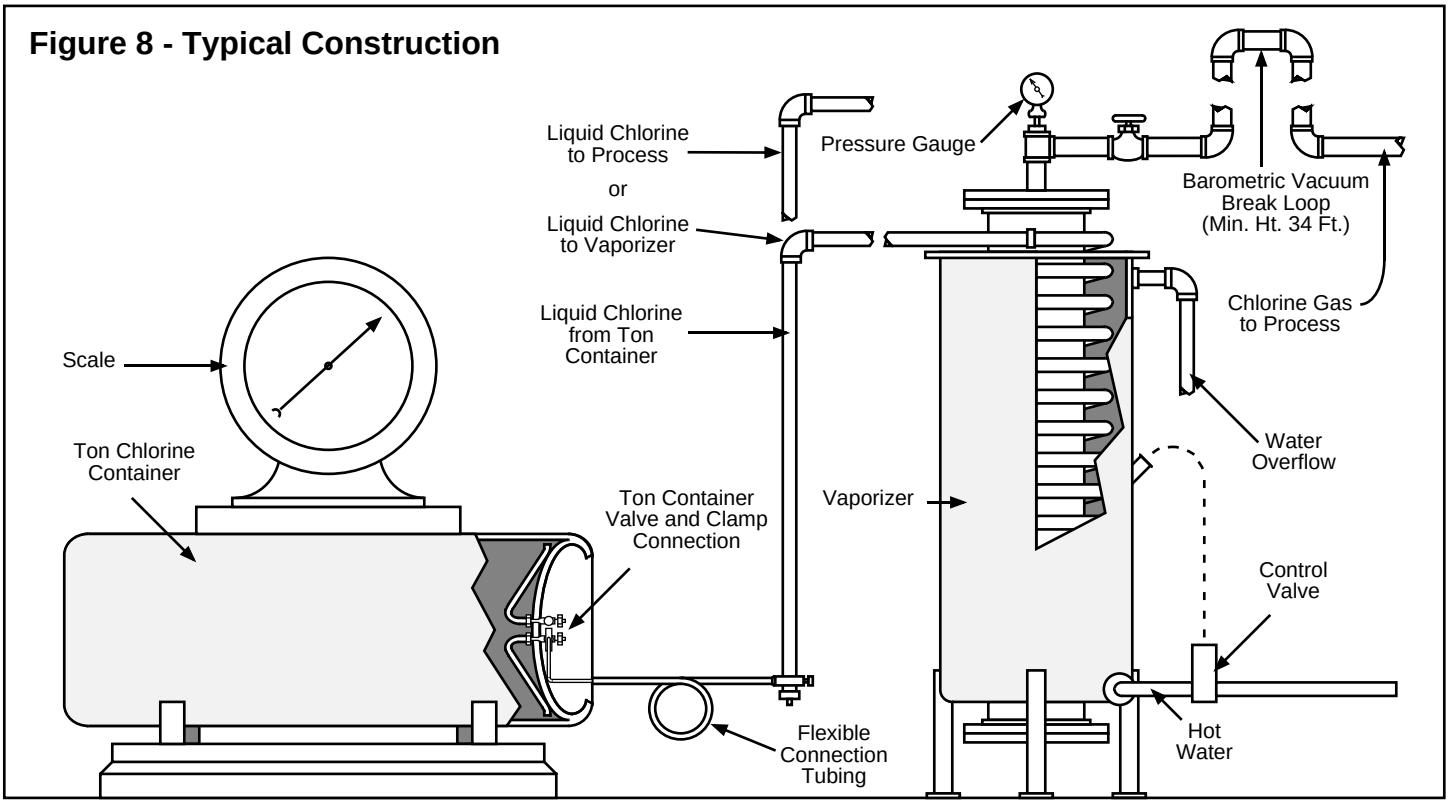
Always have an attendant present when chlorine is being withdrawn from a ton container.

Do not alter or repair ton containers or their valves.

Leaks around the valve stem usually can be corrected by tightening the packing nut in a clockwise direction. All threads on all chlorine valves are right-hand threads.

Place a ton container on a scale as its contents are removed to determine the quantity of chlorine in the container at any time.

Figure 8 - Typical Construction



Tank Cars

OxyChem's large fleet of tank cars comply with all specifications and regulations of the DOT. Liquid chlorine is supplied in tank cars with capacities of 55 tons and 90 tons.

The tank of most tank cars is of fusion welded steel construction, built according to DOT specifications 105A300W and 105A500W. The tank is provided with a thick covering of insulating material which in turn is protected by a steel jacket. The only opening in the tank is in the dome which contains all of the valves on the tank. (See Figures 9 and 10.)

The two angle valves parallel to the length of the tank car deliver liquid chlorine. The liquid valves are connected to eduction pipes which are equipped with excess-flow valves. The excess-flow valves are designed to stop the flow of liquid chlorine if the delivery rate exceeds 7,000 pounds/hour for a 55 ton capacity car or 15,000 pounds/hour for a 90 ton car. The angle valve must be fully opened to allow the excess-flow valve to function in case of a ruptured delivery line. (See Figure 11.)

The two angle valves at right angles to the longitudinal axis of the tank car will deliver gaseous chlorine or they can be used to apply dry air or nitrogen padding.

Average Dimensions of Tank Cars

Capacity Tons	Length (between striking plates)	Height (to valve connection)	Overall Height	Overall Width
55	42'8"	12'9"	14'6"	10'2"
90	45'8"	13'6"	14'10"	10'6"

The safety valve is located at the center of the dome, (Figure 9, Valve Number 5). On DOT 105A300W tanks, it is designed to initially relieve at a pressure of 225 psig. Following the initial relief, the valve functions as a regular spring loaded valve set at 213 psig. On a 105A500W tank, the safety valve is designed to initially relieve at a pressure of 375 psig and then it operates as a regular spring loaded valve set to discharge at 360 psig. Safety valves on chlorine tank cars must never be disturbed or tampered with under any circumstances.

The outlet of each angle valve on a tank car has one-inch standard tapered female pipe threads. This outlet is protected by a one-inch pipe plug which must be kept in place whenever the valve is not in use.

Each time a tank car is returned to OxyChem, it is subjected to a rigorous inspection. Any damaged tank car is immediately removed from service until such time as repairs can be made.

When the angle valves are removed, they are dismantled, completely reconditioned, and subjected to a static test at a pressure far greater than a normal working pressure. The excess-flow valves are inspected and cleaned at the same time. Safety valves are removed, reconditioned, and tested every two years.

Figure 9 - Standard Arrangement of Valves on Single Unit Tank Car

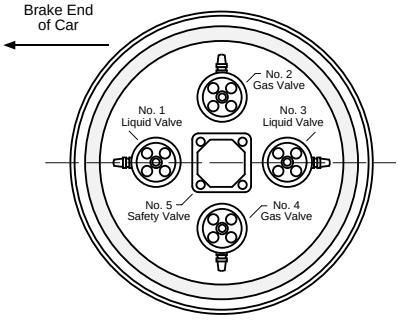
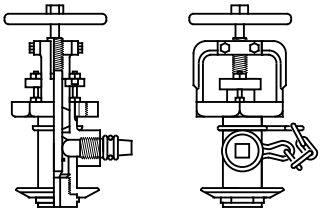
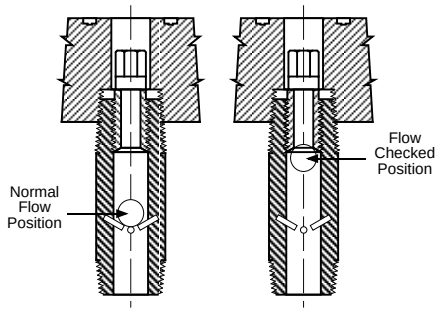


Figure 10 - Single-Unit Tank Car Valve



Note: Figures 9 and 10 show typical installation for the ACF angle valve.

Figure 11 - Excess Flow Valve with Removable Seat

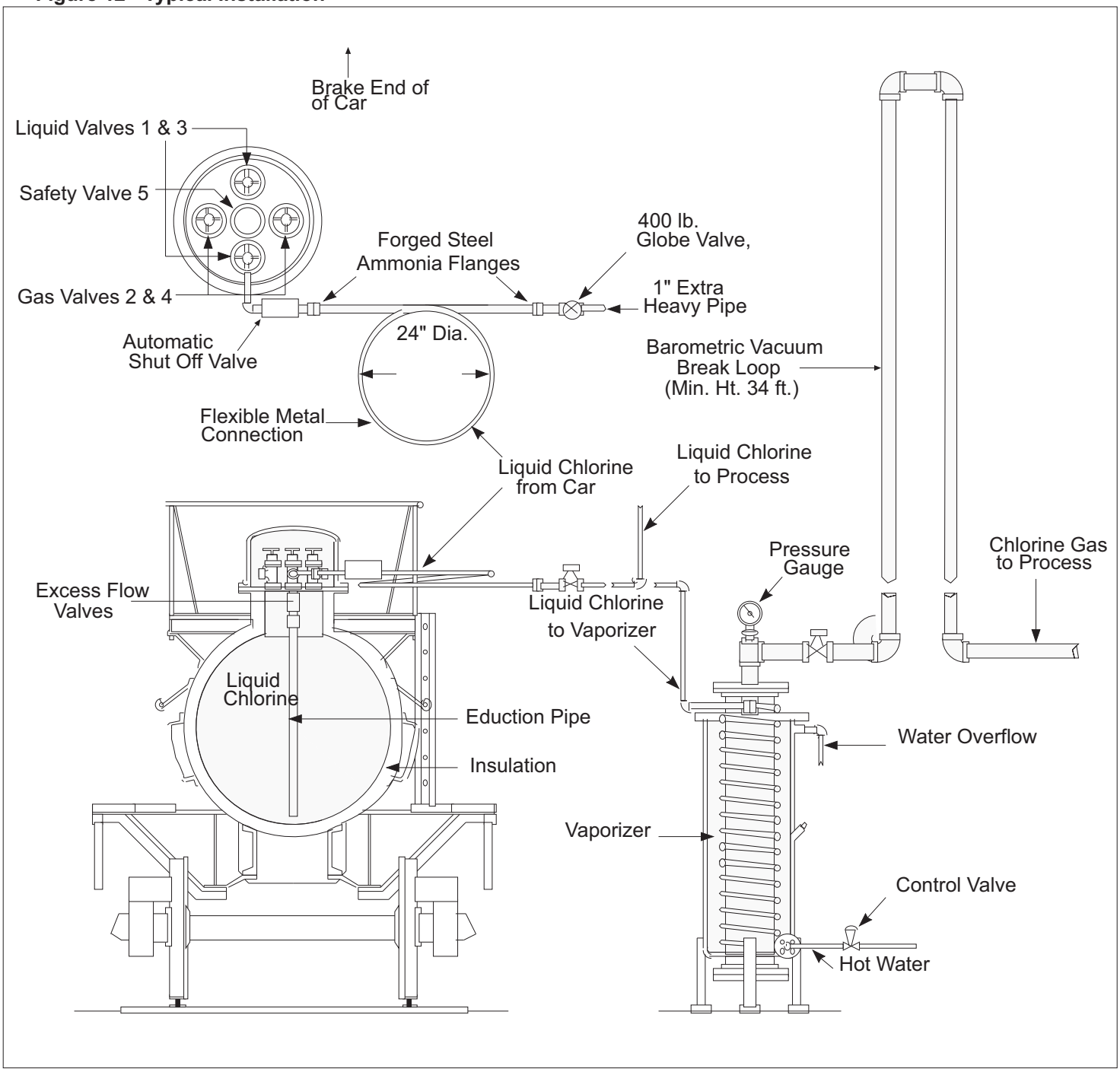


Handling and Use of Tank Cars

Single-unit tank cars must be unloaded only on the consumer's protected private track.

When a tank car of chlorine is placed on a private siding for unloading, the brakes must be set and the wheels blocked. The following precautions are required by DOT Hazardous Materials Regulation, CFR Title 49, Paragraph 174.67, governing the transportation of hazardous materials: "Caution" signs must be placed in such a position on the track or car to warn persons approaching the car from

Figure 12 - Typical Installation



the open end or ends of the siding and must be left up until after the car is unloaded and disconnected from the discharge connection. Signs must be of metal, at least 12 by 15 inches in size and bear the words “STOP—Tank Car Connected” or “STOP—Men at Work.” The word “STOP” must be in letters at least 4 inches high and the other words in letters at least 2 inches high. The letters must be white on a blue background.

Tank cars must be protected by a derail at the switch end or ends of a siding.

Shipping a leaking or defective tank car containing any chlorine is illegal. If a tank car is defective, call your supplier. OxyChem’s 24 hour emergency number is 800/733-3665.

Use a flexible metal connection for unloading chlorine as outlined in The Chlorine Institute, Inc. Pamphlet No. 6, DWG No. 118. A typical installation is shown in the diagram in Figure 12.

Opening a liquid chlorine valve too rapidly could cause the excess-flow valve to function and stop the flow of liquid chlorine. The excess-flow valve can be unchecked by closing the chlorine valve completely and waiting until a noticeable click is heard, indicating that the metal ball has fallen back into place.

In many chlorine handling systems, additional pressure is necessary for unloading at a normal or accelerated rate. Under these conditions, dry air (dew point of -40°F) must be used.* A separate plant air drying system is needed for this operation.

Safe padding pressure limits are defined by the setting of the pressure relief valve and the temperature of the liquid chlorine. Padding pressure limits for chlorine tank cars can be found in the The Chlorine Institute, Inc., Drawing # 201.

For additional information on the handling and use of tank cars refer to The Chlorine Institute, Inc., Pamphlet # 66.

* Dry nitrogen may also be used in most cases.

Cargo Tank Trucks

DOT issued CFR Title 49, gives the MC331 specification for cargo tank trucks authorized for chlorine use in the United States and Canada.

Chlorine cargo tank trucks meeting DOT Specification MC331 or MC330 have an approximate capacity of 15 to 20 tons. The only opening in a chlorine cargo tank truck is in the dome which contains all of the required valves. The two angle valves parallel to the length of the tank will deliver liquid chlorine. The liquid valves are connected to eduction pipes which are equipped with excess-flow valves. The excess-flow valves are designed to stop the flow of liquid chlorine if the delivery rate exceeds 7,000 pounds per hour.

The two angle valves at right angles to the longitudinal axis of the tank will deliver gaseous chlorine. They are also equipped with excess-flow valves, but of a different design.

The outlet of each angle valve on a chlorine cargo tank truck has one-inch standard tapered female pipe threads. This outlet is protected by a one-inch pipe plug which should be kept in place whenever the valve is not in use.

The safety valve is located at the center of the dome, between the angle valves. It is designed to initially relieve at a pressure of 225 psig. Subsequent to relief, the valve functions as a regular spring loaded valve set at 213 psig.

Handling and Use of Chlorine Cargo Tank Trucks

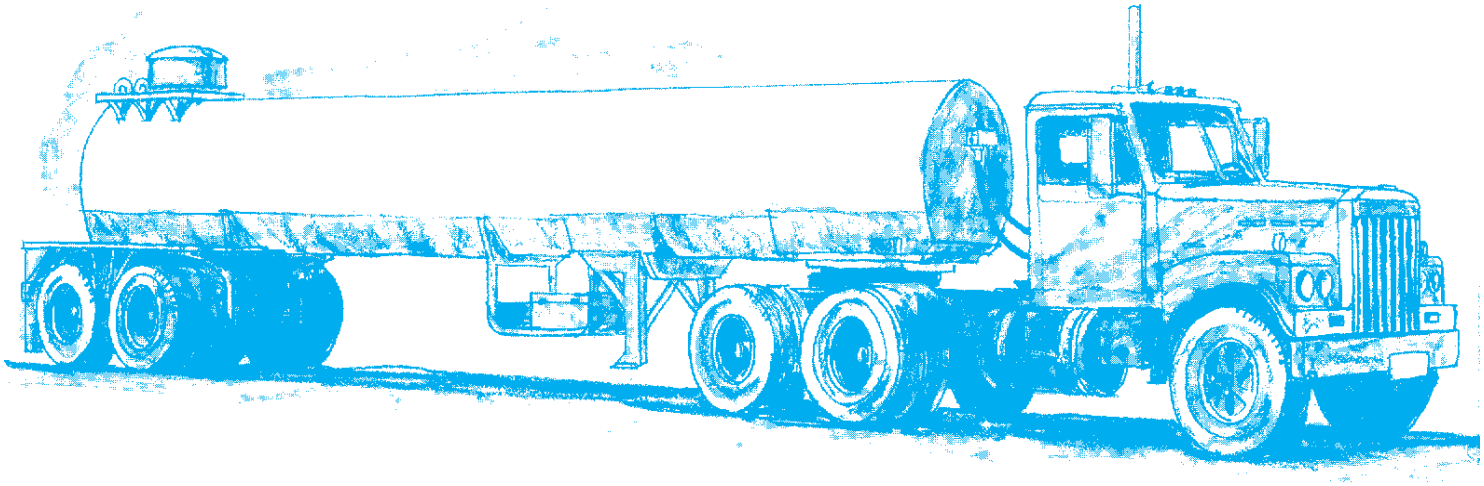
In general, chlorine can be shipped in cargo tank trucks only if the contents are to be unloaded at one unloading point. For this reason, Occidental Chemical will assist in any individual study or evaluation to determine if tank truck shipments of chlorine are feasible.

Tank Truck Unloading—Air Padding

In many chlorine handling systems, additional pressure is necessary for unloading at a normal or accelerated rate. Under these conditions, dry air (dew point of -40°F) must be used.* A separate plant air drying system is needed for this operation.

For additional information on chlorine tank motor vehicles, refer to The Chlorine Institute, Inc. Pamphlet No. 49.

* Dry nitrogen may also be used in most cases.



In general, pipelines for handling chlorine should be fabricated from extra-heavy, black-iron pipe. Joints must be welded or flanged. Fittings must be eliminated wherever possible.

Valves for chlorine service should be constructed of forged steel. Packing for these valves should be either PTFE or flexible graphite. For additional information on valves for chlorine service please consult The Chlorine Institute, Inc., Pamphlet # 6.

The use of valves in pipelines must balance minimizing accidental release and reducing fugitive emissions. Liquid chlorine has a high coefficient of thermal expansion. If liquid chlorine is trapped between two valves, high pressure may develop and lead to a rupture of the line or its fittings. Expansion chambers, installed at the highest point in the section may be needed. Expansion chambers are fabricated from extra-heavy pipe and have a capacity equal to at least 20 volume percent of the protected section of pipe.

For more information on piping systems, consult The Chlorine Institute, Inc., Pamphlets # 6 and 60.

Chlorine Vaporizer

When large amounts of gaseous chlorine are required for a specific process, it is advisable to remove the chlorine from the manufacturer's container as a liquid and pass it through a vaporizer to convert it to a gas. In this manner much more gaseous chlorine can be sent to process than would otherwise be possible. Rapid removal of gaseous chlorine from a container will cool the remaining liquid chlorine to a point where no chlorine vapor will flow into the process. The use of a vaporizer supplies sufficient heat to the liquid chlorine from an outside source so that the temperature of the chlorine supply remains relatively constant. Figure 8 shows a typical installation using a vaporizer to obtain gaseous chlorine from a ton container. Figure 12 shows a typical installation using a vaporizer to obtain gaseous chlorine from a single-unit tank car.

For more information on Chlorine Vaporizers, consult The Chlorine Institute, Inc. Pamphlet No. 9.

Pressure Drop in Liquid Chlorine Lines

Any liquid passing through a pipeline suffers a loss in pressure due to the resistance to flow offered by the pipeline. A further loss in pressure or head is experienced when the liquid is elevated. For every foot in elevation that liquid chlorine is raised, there is a loss in pressure of about 0.635 psi which should be added to the pressure losses due to the resistance of the piping.

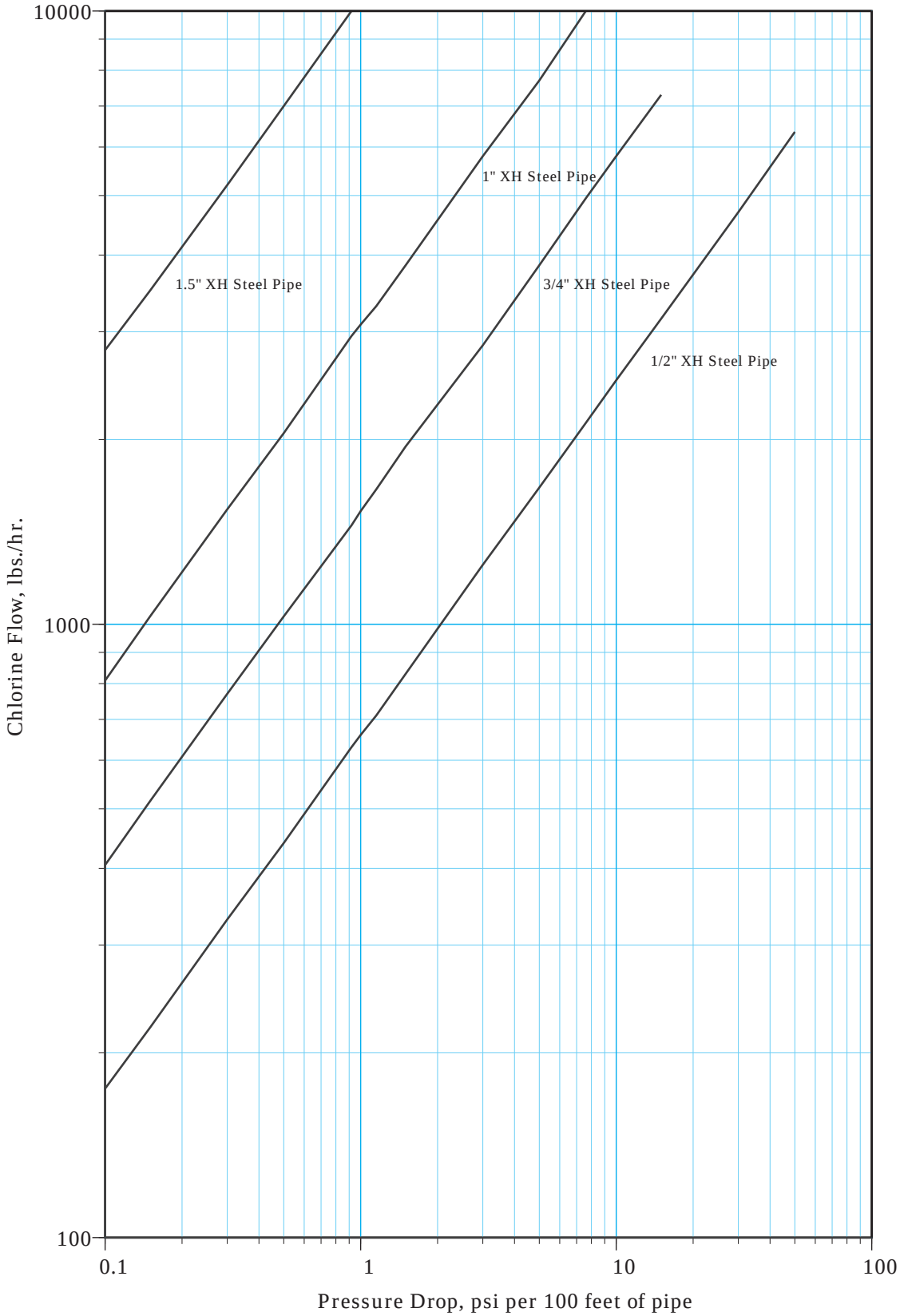
The graph on page 16 shows the calculated pressure drop for liquid chlorine flowing through SCH 80 pipe of various dimensions. When valves and fittings are included in the piping system the additional pressure loss can be readily computed by converting the friction loss in the valves and fittings to equivalent lengths of straight pipe. The data below are taken from Crane Company Technical Paper No. 409.

Equivalent Length of Pipe in Feet

Fitting	1"	3/4"	1/2"
Globe Valve (full open)	28.3	21.3	14.2
Angle Valve (full open)	12.0	9.0	6.0
Standard T (through the branch)	4.8	3.6	2.7
Long Radius Ell	1.6	1.2	0.9

Technical Data

Pressure Drop for Liquid Chlorine Flowing in New Steel Pipe



All personnel engaged in handling chlorine must be thoroughly instructed in the necessary precautions for the safe handling, storage, and use of chlorine. Carefully study everything in this manual.

Read the MSDS before use.

Chlorine is a chemical element. Neither the gas nor the liquid alone is explosive or flammable. Both react chemically with many substances, especially at elevated temperatures. The gas is greenish-yellow in color at high concentrations. It has a penetrating odor, and is two-and-one-half times as heavy as air. If it escapes from a container or system, it will seek the lowest level in the building or area in which the leak occurs. Training should include the use of safety equipment and first aid procedures.

EMPLOYEE PROTECTION

Do not breathe chlorine vapors. Chlorine irritates the mucous membranes, respiratory tract, and eyes. Smoking can aggravate the respiratory symptoms which result from chlorine exposure. Prolonged exposure to the gas causes coughing, gagging, and may result in pulmonary edema and death. Individuals with respiratory problems should consult a physician before working with chlorine.

Avoid contact with eyes, skin, and clothing. Gaseous chlorine hydrolyzes in the presence of moisture, forming hydrochloric acid, which irritates the eyes and skin. Liquid chlorine removes body heat, freezing exposed skin.

Wash thoroughly after handling chlorine. Shower, using plenty of soap and water.

Safety Equipment

Use goggles, rubber gloves, rubber shoes, hard hat, and a NIOSH approved respirator with an acid gas cartridge where airborne concentrations are expected to exceed exposure limits or when symptoms have been observed that are indicative of overexposure. It is essential that each individual who may be exposed to chlorine carry, at all times, a respirator approved for chlorine use. For re-entry into an emergency area, self-contained breathing equipment must be used.

EQUIPMENT & EMERGENCY PROCEDURES

Ventilation

Provide adequate ventilation to reduce the accumulation of liquid or gaseous chlorine in low areas. In some cases, natural ventilation may be adequate; in others, artificial ventilation, such as forced air through a system of ducts, must be provided. A one to four minute rate of air change is required in an emergency. Precautions must be taken to avoid discharging chlorine into areas where it can cause damage or personal injury.

Eye Wash Fountains and Deluge Showers

Readily accessible eye wash fountains and deluge showers must be provided in strategic locations wherever chlorine is used. Personnel should test equipment each day before beginning work to ensure adequate water flow.

Emergency Respiratory Protection

Severe exposure to chlorine may occur wherever chlorine is handled or used. Therefore, self-contained positive pressure breathing apparatus, approved for emergency chlorine use, should be located strategically outside chlorine work areas near entrances and away from contamination. Such equipment shall have a rating of at least 30 minutes use, and be equipped with a low pressure warning bell. Any person entering a chlorine emergency area must be protected by this respiratory protective equipment.

Emergency Kits

In an emergency involving chlorine cylinders, ton containers, tank cars, or barges, kits are available which can be used to stop leaks. Chlorine emergency kits are maintained by producers and are located strategically throughout the United States and Canada. In addition, kits are available from other chlorine users and distributors, and the location of these kits can be found in The Chlorine Institute, Inc. Pamphlet No. 35, “Location of Chlorine Emergency Kits.” Obtain a copy and note the nearest source, or purchase kit(s) from an approved supplier.

OTHER EMERGENCY MEASURES

The Chlorine Institute, Inc. was formed over 50 years ago by chlorine producers to promote the safe use of chlorine and to standardize chlorine handling equipment. The Institute also sponsors a mutual assistance program in which trained teams respond to chlorine emergencies on a 24-hour-a-day, 7-day-a-week basis. In the United States, this response program is known as CHLOREP (Chlorine Emergency Plan). The United States is divided into 32 sectors with CHLOREP teams available from 49 plant sites (one to three plant sites in each sector).

CHLOREP is now affiliated with CHEMTREC (The Chemical Transportation Emergency Center) maintained by the Chemical Manufacturers Association (CMA) in Washington, D.C. Assistance can be summoned by calling either CHEMTREC (Toll free 1-800-424-9300) or the appropriate CHLOREP team.

Canada is divided into ten regions with teams available from 13 plant



sites as established by TEAP (Transportation Emergency Assistance Plan) of the Canadian Chemical Producers' Association. In Canada, assistance is available by calling either the TEAP regional number or the appropriate response team.

In both the United States and Canada, these teams provide assistance in any chlorine emergency whether a transportation incident or a problem at the point of usage. Chlorine users must have the telephone number of their response team(s) readily available for use in chlorine emergency situations.

Chlorine users must accept responsibility for taking all proper precautions to prevent accidents with chlorine. The fact that emergency assistance is available should not encourage carelessness in the use of this chemical.

HANDLING AND STORAGE

Store cylinders and ton containers in a dry, ventilated, fire resistant area separate from metals, organic, or inorganic chemicals. All valves must be kept tightly closed until containers are connected for unloading. Protect from heat and direct sunlight.

In Case of Fire

Chlorine itself will not burn, but it does act as an oxidizer and supports combustion, even in the absence of oxygen. Cool the affected containers with large amounts of water. Use any other extinguishing medium appropriate for the surrounding fire. All fires liberate toxic gases. Use self-contained breathing apparatus and full protective equipment.

Leaks

Do not apply water directly on a chlorine leak. Moisture hydrolyzes chlorine, forming hydrochloric acid which attacks the metal, thus enlarging the leak. If a container is leaking chlorine, position the container so that gas escapes instead of liquid. The quantity of escaping chlorine is significantly less from a gas leak than a liquid leak, since one volume of liquid is equal to about 460 volumes of gas. Evacuate the area and keep all personnel upwind of leaks, preferably on high ground. Secure self-contained breathing apparatus. Shut chlorine supply off at source.

Water Disposal

Absorb chlorine in an alkaline solution (caustic soda, soda ash, or hydrated lime) while maintaining an excess of base at all times (see below).* Destroy resulting hypochlorite by adding sodium sulfite or treating the basic hypochlorite at 122°-158°F (50°-70°C) in the presence of copper, nickel, or iron. Control pH at the discharge to sewer or the receiving water and comply with all applicable federal, state, and local regulations.

Recommended Alkaline Solutions for Absorbing Chlorine

Size of Chlorine Container (Pounds Net)	100% Caustic Soda		100% Soda Ash		100% Hydrated Lime	
	Pounds	Water (gallons)	Pounds	Water (gallons)	Pounds	Water (gallons)
100	125	60	300	200	115	125
150	188	90	450	300	175	188
2000	2500	1200	5980	4000	2325	2500

* Slurry must be continuously and vigorously agitated if chlorine is to be absorbed 100%.

FIRST AID

Exposure Symptoms

Liquid chlorine is a skin and eye irritant. Prolonged contact produces burns. Liquid chlorine slowly vaporizes to gas in the open atmosphere. At detectable odor levels, the gas will irritate the mucous membranes and respiratory tract. (Detectable odor levels range from 0.3 to 3.0 ppm depending on the individual.) With excessive exposure to chlorine, the individual exhibits excitement, accompanied by restlessness, sneezing, and copious salivation. In extreme cases, retching, pulmonary edema, and even death may occur.

There are no specific known antidotes for chlorine. Effective medical management is necessary for relief of symptoms with proper treatment. Complete recovery normally occurs.

Inhalation

If chlorine is inhaled, move the individual to fresh air. If breathing is difficult, have a trained person administer oxygen. If respiration stops, have a trained person administer artificial respiration.

Treatment for inhalation must precede first aid given to other body areas affected by exposure to chlorine.

Skin

In case of contact, immediately remove the contaminated clothing and shoes. Flush skin with plenty of water. Never attempt to neutralize the chlorine with chemicals. Salves and ointments should not be applied unless directed by a physician. Wash clothing before re-use. Discard contaminated nonrubber shoes. GET MEDICAL ATTENTION IMMEDIATELY

Eyes

In case of eye contact, immediately flush eyes with a directed stream of water (low pressure-high volume) for 15 minutes. Forcibly hold eyelids apart to ensure complete irrigation of all eye and lid tissues. An eye wash fountain is ideal for this type of treatment. GET MEDICAL ATTENTION IMMEDIATELY

Ingestion

Due to its physical properties, swallowing liquid chlorine is extremely unlikely. In such an instance, call a physician immediately.

Notes to Physician

Because there is no known antidote for chlorine gas inhalation, treatment is symptomatic. The effective and immediate relief of symptoms is the primary goal. Steroid therapy, if given early, has been reported effective in preventing pulmonary edema.

EMPLOYEE TRAINING FOR SAFE OPERATIONS

Safety in handling chlorine depends, to a great extent, upon the effectiveness of employee education, proper safety instructions, effective supervision, and the use of proper personal protective equipment.

Supervisory personnel are responsible for providing proper instruction and training of employees. Training for all employees should be conducted periodically, to reinforce correct methods and to maintain a high degree of competence in handling procedures. All new employees must be trained in handling and using chlorine before operating equipment. Employees should be thoroughly familiar with the hazards that may result from improper handling of chlorine. Each employee should know emergency and first aid measures, and how to use associated equipment.

As a minimum, employee training should include the following:

A) Instruction with periodic drills regarding the locations, purpose, limitations, and use of chlorine emergency kits, fire fighting equipment, fire alarms, and shutdown equipment such as valves and switches.

B) Instruction with periodic drills regarding the locations, purpose, limitations, and use of personal protective equipment, both normal and emergency.

C) Instruction with periodic drills regarding the locations, purpose, and use of safety showers, eye baths, or the closest source of water for use in emergencies.

D) Instruction with periodic drills for specified employees on each work shift/period regarding the locations, purpose, and use of emergency respiratory protection and first aid equipment.

E) Instruction on avoiding inhalation of chlorine gas and contact with the liquid. Emphasis should be placed on chlorine's effect on the human body at different exposure levels.

F) Instruction on procedures for reporting all equipment failures to the proper authority.

G) Instruction on procedures for conducting inspections before working with equipment, and periodically during operations. This instruction should include procedures for recognizing leaks and other potential problems.

H) Instruction on the proper actions to take when leaks occur and on procedures for evacuating affected areas.

Technical Data

Physical Properties of Chlorine

Atomic weight: 35.453
Boiling point: -34.05°C (-29.29°F)
Freezing point: -100.98°C (-149.76°F)
Critical temperature: 144.0°C (291.2°F)
Critical pressure: 7711 kPa (76.1 atm, 1118 psi)
Critical volume: $1.745 \times 10^{-3} m^3/kg$ (0.02796 cu ft/lb)
Heat of fusion at the melting point: 6405± 5 J/mol (38.86 Btu/lb)

Viscosity of Chlorine Gas at 1 Atm

°C	cp.
-30	0.0112
0	0.0126
100	0.0169
200	0.021
300	0.025

Thermal Conductivity of Chlorine Gas at 1 Atm

°C	Btu/(hr-ft-°F)
-30	0.0042
0	0.0048
100	0.0067
200	0.0086
300	0.0103

Thermal Conductivity of Liquid Chlorine

°C	Btu/(hr-ft-°F)
-100	0.1149
0	0.0847
100	0.0532
144	0.0230

Conversion of Units

Physical Quantity	Sl Unit	Conversion
Concentration	kilograms per cubic meter	1 kg/m^3 = 0.008345 lbs/gal
Density	kilograms per cubic meter	1 kg/m^3 = 0.062428 lbs/cu ft
Energy	joules per kilogram	1 J/kg = 0.000430 Btu/lb
Entropy	joules per kilogram-Kelvin	1 J/kg-°K = 0.000239 Btu/lb-°F
Pressure	Pascals (Newtons per square meter)	1 Pa = 0.000145 psi
		1 Pa = 9.86923×10^{-6} atm
Surface Tension	joules per square meter	1 J/m^2 = 0.068522 lb(force)/ft
		1 J/m^2 = 1000 $ergs/cm^2$
Temperature	Kelvin	°K = °C+273.15
		°C = (°F-32)/1.8
Thermal Conductivity	watts per meter-Kelvin	1 W/m-°K = 0.577797 Btu/(hr-ft-°F)
Viscosity	Pascal-second	1 Pa-s = 0.671969 lb/ft-sec
		1 Pa-s = 1000 centipoise
Volume	cubic meters per kilogram	1 m^3/kg = 16.0185 cu ft/lb

Thermodynamic Properties of Saturated Chlorine

(Base: h = 0, s = 0 for solid Cl_2 at 0°R)

Temp (°F)	Absolute Pressure (psi)	Volume (cu ft/lb)		Enthalpy (Btu/lb)			Entropy (Btu/lb-°R)		
		Liquid	Vapor	Liquid	Vaporization	Vapor	Liquid	Vaporization	Vapor
t	p	v_l	v_g	h_l	^3h	h_g	s_l	^3s	s_g
-130	0.51902	0.0093981	95.993	78.488	137.13	215.57	0.37472	0.41593	0.79065
-120	0.80251	0.0094727	63.930	80.890	135.72	216.61	0.38201	0.39956	0.78158
-110	1.2055	0.0095492	43.776	83.305	134.35	217.65	0.38901	0.38420	0.77322
-100	1.7643	0.0096277	30.738	85.697	133.00	218.69	0.39575	0.36976	0.76551
-90	2.5213	0.0097083	22.081	88.067	131.66	219.73	0.40225	0.35615	0.75840
-80	3.5258	0.0097911	16.193	90.420	130.34	220.76	0.40852	0.34328	0.75181
-70	4.8336	0.0098761	12.101	92.759	129.02	221.78	0.41459	0.33110	0.74570
-60	6.5073	0.0099636	9.1996	95.087	127.71	222.80	0.42048	0.31954	0.74003
-50	8.6157	0.010053	7.1037	97.406	126.40	223.81	0.42620	0.30854	0.73474
-40	11.234	0.010146	5.5642	99.719	125.08	224.80	0.43177	0.29805	0.72982
-30	14.443	0.010242	4.4156	102.02	123.76	225.79	0.43719	0.28802	0.72522
-29.29	14.696	0.010248	4.3457	102.19	123.66	225.86	0.43757	0.28732	0.72490
-20	18.329	0.010340	3.5462	104.33	122.41	226.75	0.44248	0.27842	0.72090
-10	22.984	0.010442	2.8793	106.64	121.05	227.70	0.44765	0.26920	0.71686
0	28.504	0.010547	2.3613	108.95	119.67	228.63	0.45271	0.26033	0.71305
10	34.987	0.010656	1.9544	111.27	118.26	229.53	0.45767	0.25179	0.70946
20	42.538	0.010768	1.6313	113.59	116.82	230.41	0.46252	0.24354	0.70606
30	51.265	0.010885	1.3722	115.92	115.34	231.26	0.46729	0.23555	0.70284
40	61.276	0.011006	1.1625	118.25	113.83	232.09	0.47196	0.22781	0.69978
50	72.684	0.011132	0.99128	120.59	112.28	232.88	0.47656	0.22029	0.69686
60	85.606	0.011263	0.85030	122.95	110.68	233.63	0.48109	0.21297	0.69406
70	100.15	0.011399	0.73335	125.32	109.02	234.35	0.48555	0.20583	0.69138
80	116.45	0.011541	0.63565	127.71	107.31	235.02	0.48994	0.19885	0.68879
90	134.63	0.011690	0.55346	130.11	105.54	235.65	0.49428	0.19200	0.68629
100	154.80	0.011846	0.48388	132.53	103.70	236.23	0.49857	0.18528	0.68385
110	177.09	0.012009	0.42462	134.98	101.78	236.76	0.50281	0.17866	0.68148
120	201.64	0.012181	0.37386	137.45	99.782	237.24	0.50702	0.17213	0.67915
130	228.57	0.012362	0.33014	139.96	97.685	237.65	0.51121	0.16565	0.67686
140	258.03	0.012554	0.29228	142.51	95.483	237.99	0.51537	0.15922	0.67459
150	290.14	0.012758	0.25934	145.09	93.162	238.26	0.51953	0.15280	0.67233
160	325.05	0.012975	0.23052	147.73	90.709	238.44	0.52368	0.14637	0.67006
170	362.91	0.013208	0.20520	150.43	88.105	238.54	0.52786	0.13991	0.66778
180	403.86	0.013458	0.18285	153.20	85.328	238.53	0.53206	0.13339	0.66545
190	448.07	0.013728	0.16301	156.06	82.354	238.41	0.53631	0.12676	0.66307
200	495.68	0.014023	0.14533	159.01	79.150	238.16	0.54063	0.11998	0.66061
210	546.88	0.014348	0.12947	162.07	75.677	237.75	0.54504	0.11300	0.65805
220	601.82	0.014710	0.11518	165.28	71.882	237.16	0.54958	0.10575	0.65534
230	660.70	0.015118	0.10221	168.66	67.696	236.36	0.55428	0.098155	0.65243
240	723.69	0.015587	0.090340	172.25	63.022	235.28	0.55919	0.090072	0.64926
250	790.99	0.016143	0.079352	176.13	57.713	233.84	0.56440	0.081322	0.64573
260	862.81	0.016827	0.069011	180.38	51.528	231.90	0.57004	0.071598	0.64164
270	939.35	0.017729	0.058995	185.19	44.007	229.20	0.57635	0.060310	0.63666
280	1020.8	0.019102	0.048647	191.04	33.987	225.03	0.58393	0.045948	0.62987
290	1107.5	0.022862	0.034207	200.80	14.060	214.86	0.59658	0.018756	0.61534
291.2	1118.37	0.027960	0.027960	207.77	00.000	207.77	0.60582	0.000000	0.60582

REF: Kapoor, R.M.; Martin, J.J.,Thermodynamic Properties of Chlorine,
Engineering Research Institute, University of Michigan, Ann Arbor, Michigan (1957).

Technical Data

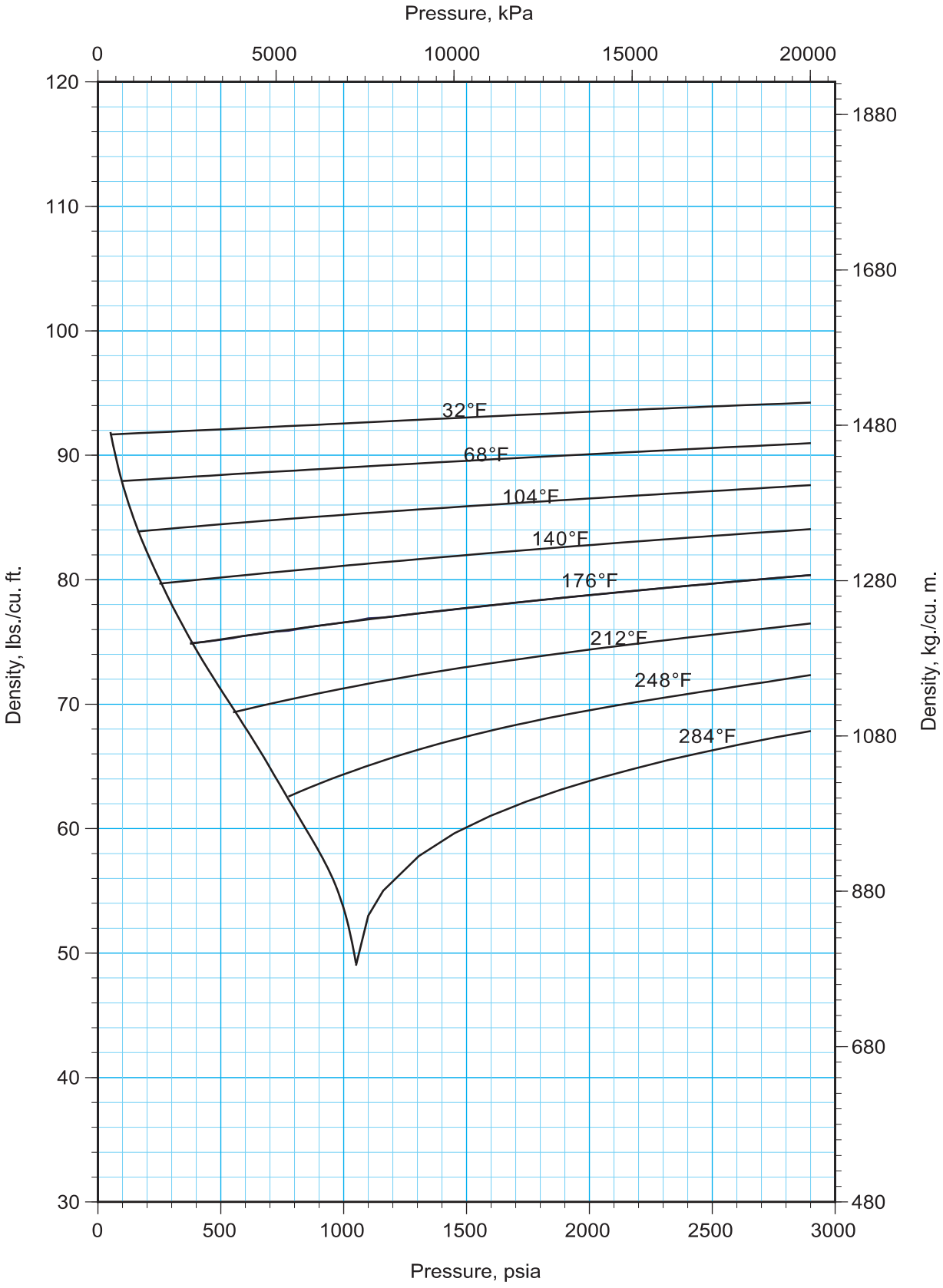
Thermodynamic Properties of Superheated Chlorine

v, volume (cu ft/lb); h, enthalpy (Btu/lb); s, entropy (Btu/lb-°R) Figures in parenthesis under the pressures are the saturation temperatures
Base: h = 0, s = 0 for solid Cl_2 at 0°R

Temp. (°F)	10 psi (-44.4°F)			14.696 psi (-29.3°F)			20 psi (-16.2°F)			25 psi (-6.1°F)		
t	v	h	s	v	h	s	v	h	s	v	h	s
0	6.8782	229.30	0.74326	4.6552	229.13	0.73226	3.3996	228.94	0.72338	2.7036	228.76	0.71689
25	7.2623	232.10	0.74919	4.9185	231.94	0.73822	3.5948	231.77	0.72937	2.8610	231.60	0.72291
50	7.6458	234.92	0.75488	5.1812	234.78	0.74392	3.7892	234.61	0.73510	3.0178	234.45	0.72866
75	8.0288	237.77	0.76033	5.4434	237.63	0.74939	3.9832	237.48	0.74058	3.1739	237.33	0.73416
100	8.4113	240.63	0.76556	5.7050	240.51	0.75464	4.1766	240.36	0.74585	3.3296	240.22	0.73945
125	8.7934	243.52	0.77060	5.9663	243.40	0.75969	4.3697	243.26	0.75092	3.4849	243.13	0.74453
150	9.1752	246.42	0.77546	6.2273	246.30	0.76456	4.5624	246.17	0.75580	3.6398	246.05	0.74942
175	9.5567	249.33	0.78015	6.4879	249.23	0.76926	4.7548	249.10	0.76051	3.7944	248.98	0.75414
200	9.9380	252.27	0.78468	6.7483	252.16	0.77380	4.9469	252.05	0.76506	3.9487	251.94	0.75870
225	10.319	255.21	0.78907	7.0084	255.12	0.77819	5.1388	255.00	0.76946	4.1028	254.90	0.76311
250	10.699	258.17	0.79331	7.2684	258.08	0.78245	5.3305	257.97	0.77372	4.2566	257.87	0.76738
275	11.080	261.15	0.79743	7.5281	261.06	0.78657	5.5220	260.96	0.77785	4.4103	260.86	0.77151
300	11.460	264.13	0.80142	7.7877	264.04	0.79057	5.7133	263.95	0.78175	4.5638	263.86	0.77553
325	11.841	267.12	0.80530	8.0472	267.04	0.79445	5.9045	266.95	0.78574	4.7172	266.86	0.77942
350	12.221	270.13	0.80907	8.3065	270.05	0.79822	6.0956	269.96	0.78952	4.8704	269.88	0.78320
375	12.601	273.14	0.81273	8.5656	273.06	0.80189	6.2865	272.98	0.79319	5.0235	272.90	0.78687
400	12.981	276.15	0.81629	8.8247	276.08	0.80545	6.4773	276.00	0.79676	5.1765	275.92	0.79045
Temp. (°F)	30 psi (2.4°F)			35 psi (10.0°F)			40 psi (16.8°F)			45 psi (23.0°F)		
t	v	h	s	v	h	s	v	h	s	v	h	s
25	2.3717	231.43	0.71759	2.0222	231.25	0.71306	1.7600	231.08	0.70910	1.5559	230.90	0.70558
50	2.5034	234.30	0.72336	2.1358	234.14	0.71885	1.8601	233.97	0.71492	1.6456	233.81	0.71142
75	2.6343	237.18	0.72889	2.2489	237.03	0.72440	1.9597	236.88	0.72048	1.7348	236.73	0.71701
100	2.7648	240.08	0.73419	2.3614	239.94	0.72972	2.0588	239.80	0.72582	1.8234	239.66	0.72236
125	2.8949	242.99	0.73928	2.4735	242.86	0.73483	2.1574	242.73	0.73094	1.9115	242.60	0.72750
150	3.0246	245.92	0.74419	2.5852	245.80	0.73974	2.2556	245.67	0.73588	1.9993	245.55	0.73245
175	3.1540	248.87	0.74892	2.6966	248.75	0.74449	2.3535	248.63	0.74063	2.0867	248.51	0.73721
200	3.2831	251.82	0.75349	2.8077	251.71	0.74906	2.4512	251.60	0.74522	2.1738	251.49	0.74181
225	3.4120	254.79	0.75791	2.9186	254.69	0.75349	2.5486	254.58	0.74965	2.2607	254.47	0.74625
250	3.5407	257.77	0.76218	3.0293	257.67	0.75777	2.6457	257.57	0.75394	2.3474	257.47	0.75055
275	3.6692	260.76	0.76632	3.1398	260.67	0.76192	2.7427	260.57	0.75810	2.4339	260.47	0.75471
300	3.7975	263.76	0.77034	3.2501	263.67	0.76594	2.8395	263.58	0.76213	2.5201	263.49	0.75875
325	3.9256	266.77	0.77424	3.3602	266.69	0.76985	2.9361	266.60	0.76603	2.6063	266.51	0.76266
350	4.0536	269.79	0.77802	3.4702	269.71	0.77364	3.0326	269.62	0.76983	2.6923	269.54	0.76646
375	4.1815	272.82	0.78170	3.5801	272.74	0.77732	3.1290	272.66	0.77352	2.7782	272.58	0.77015
400	4.3093	275.85	0.78528	3.6898	275.77	0.78090	3.2253	275.69	0.77710	2.8639	275.62	0.77374
Temp. (°F)	50 psi (29.6°F)			60 psi (38.8°F)			70 psi (47.7°F)			80 psi (55.8°F)		
t	v	h	s	v	h	s	v	h	s	v	h	s
50	1.4740	233.65	0.70827	1.2163	233.31	0.70276	1.0321	232.97	0.69803	—	—	—
75	1.5547	236.57	0.71388	1.2846	236.26	0.70841	1.0915	235.95	0.70373	0.9465	235.62	0.69961
100	1.6350	239.51	0.71925	1.3523	239.22	0.71382	1.1503	238.93	0.70917	0.9987	238.63	0.70510
125	1.7148	242.46	0.72441	1.4196	242.19	0.71901	1.2086	241.91	0.71440	1.0503	241.63	0.71035
150	1.7941	245.42	0.72936	1.4864	245.17	0.72399	1.2665	244.91	0.71941	1.1015	244.65	0.71540
175	1.8732	248.39	0.7314	1.5529	248.15	0.72879	1.3240	247.91	0.72423	1.1523	247.66	0.72025
200	1.9519	251.37	0.73875	1.6190	251.15	0.73342	1.3812	250.92	0.72888	1.2028	250.68	0.72492
225	2.0303	254.37	0.74320	1.6850	254.15	0.73789	1.4382	253.93	0.73337	1.2530	253.71	0.72942
250	2.1087	257.37	0.74751	1.7507	257.16	0.74221	1.4949	256.96	0.73771	1.3030	256.75	0.73378
275	2.1868	260.38	0.75168	1.8161	260.18	0.74640	1.5514	259.99	0.74191	1.3528	259.79	0.73799
300	2.2647	263.40	0.75572	1.8814	263.21	0.75045	1.6077	263.03	0.74597	1.4023	262.84	0.74207
325	2.3424	266.42	0.75964	1.9466	266.25	0.75438	1.6638	266.07	0.74991	1.4517	265.89	0.74602
350	2.4200	269.46	0.76344	2.0116	269.29	0.75820	1.7198	269.12	0.75374	1.5010	268.95	0.74986
375	2.4975	272.50	0.76714	2.0764	272.33	0.76190	1.7757	272.17	0.75745	1.5501	272.01	0.75358
400	2.5748	275.54	0.77073	2.1412	275.39	0.76550	1.8315	275.23	0.76106	1.5991	275.08	0.75720
Temp. (°F)	90 psi (63.1°F)			100 psi (69.9°F)			125 psi (84.8°F)			150 psi (97.7°F)		
t	v	h	s	v	h	s	v	h	s	v	h	s
75	0.83371	235.30	0.69592	0.74329	234.96	0.69258	—	—	—	—	—	—
100	0.88072	238.32	0.70146	0.78621	238.02	0.69816	0.61574	237.23	0.69100	0.50165	236.40	0.68493
125	0.92717	241.35	0.70675	0.82855	241.07	0.70349	0.65075	240.33	0.69643	0.53187	239.57	0.69048
150	0.97317	244.38	0.71182	0.87041	244.11	0.70859	0.68522	243.43	0.70162	0.56150	242.73	0.69576
175	1.01871	247.41	0.71670	0.91186	247.16	0.71349	0.71925	246.53	0.70659	0.59063	245.87	0.70081
200	1.0640	250.45	0.72139	0.95298	250.22	0.71821	0.75291	249.62	0.71137	0.61936	249.00	0.70566
225	1.1090	253.49	0.72592	0.99380	253.27	0.72275	0.78625	252.71	0.71597	0.64775	252.13	0.71031
250	1.1538	256.54	0.73029	1.03437	256.33	0.72714	0.81932	255.80	0.72040	0.67584	255.26	0.71479
275	1.1983	259.59	0.73452	1.07471	259.39	0.73139	0.85215	258.89	0.72468	0.70369	258.38	0.71912
300	1.2426	262.65	0.73861	1.11487	262.46	0.73549	0.88478	261.98	0.72883	0.73132	261.50	0.72329
325	1.2868	265.71	0.74257	1.15485	265.53	0.73947	0.91723	265.08	0.73283	0.75877	264.62	0.72734
350	1.3308	268.78	0.74642	1.19467	268.61	0.74333	0.94952	268.17	0.73672	0.76804	267.74	0.73125
375	1.3747	271.85	0.75015	1.23436	271.68	0.74707	0.98167	271.27	0.74049	0.81317	270.86	0.73504
400	1.4184	274.92	0.75378	1.27393	274.76	0.75071	1.0136	274.37	0.74414	0.84017	273.97	0.73872
Temp. (°F)	200 psi (119.4°F)			300 psi (152.9°F)			400 psi (179.1°F)			500 psi (200.9°F)		
t	v	h	s	v	h	s	v	h	s	v	h	s
150	0.40616	241.25	0.68610	0.24844	237.90	0.67098	—	—	—	—	—	—
175	0.42934	244.50	0.69133	0.26630	241.48	0.67674	—	—	—	—	—	—
200	0.45202	247.73	0.69633	0.28338	244.97	0.68213	0.19729	241.80	0.67069	—	—	—
225	0.47430	250.95	0.70111	0.29987	248.40	0.68723	0.21139	245.55	0.67627	0.15684	242.26	0.66655
250	0.49625	254.14	0.70570	0.31590	251.78	0.69209	0.22479	249.19	0.68149	0.16913	246.28	0.67231
275	0.51792	257.33	0.71011	0.33155	255.12	0.69672	0.23767	252.74	0.68641	0.18064	250.13	0.67764
300	0.53934	260.51	0.71437	0.34690	258.44	0.70116	0.25015	256.23	0.69109	0.19158	253.85	0.68262
325	0.56056	263.68	0.71847	0.36199	261.74	0.70543	0.26230	259.68	0.69555	0.20211	257.48	0.68733
350	0.58160	266.85	0.72245	0.37687	265.01	0.70954	0.27419	263.08	0.69982	0.21230	261.05	0.69180
375	0.60247	270.01	0.72329	0.39155	268.27	0.71350	0.28585	266.46	0.70393	0.22222	264.56	0.69608
400	0.62321	273.17	0.73002	0.40607	271.52	0.71734	0.29732	269.81	0.70788	0.23192	268.03	0.70017

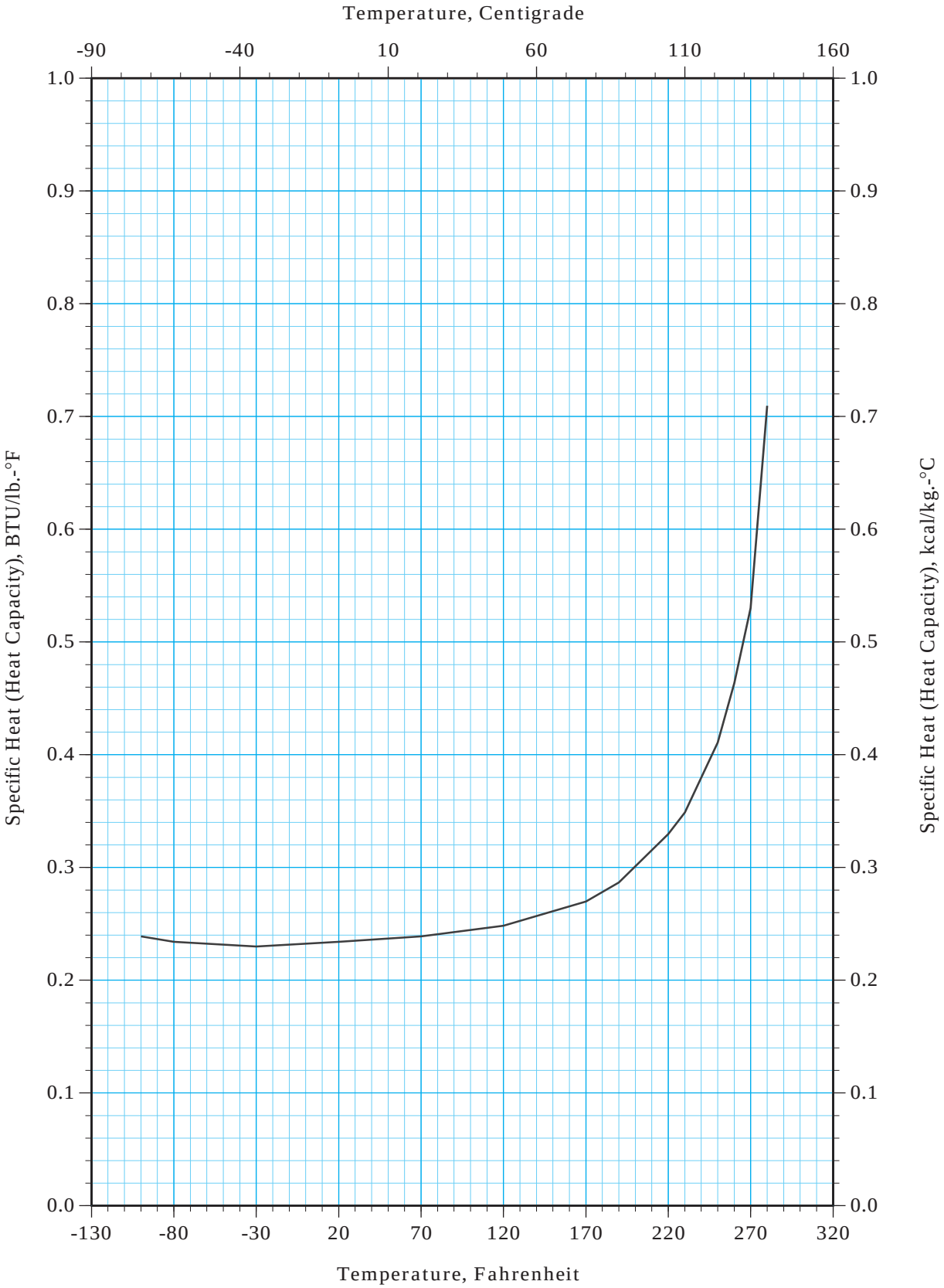
REF: Kapoor, R.M.; Martin, J.J.,Thermodynamic Properties of Chlorine,
Engineering Research Institute, University of Michigan, Ann Arbor, Michigan (1957).

Density of Liquid Chlorine

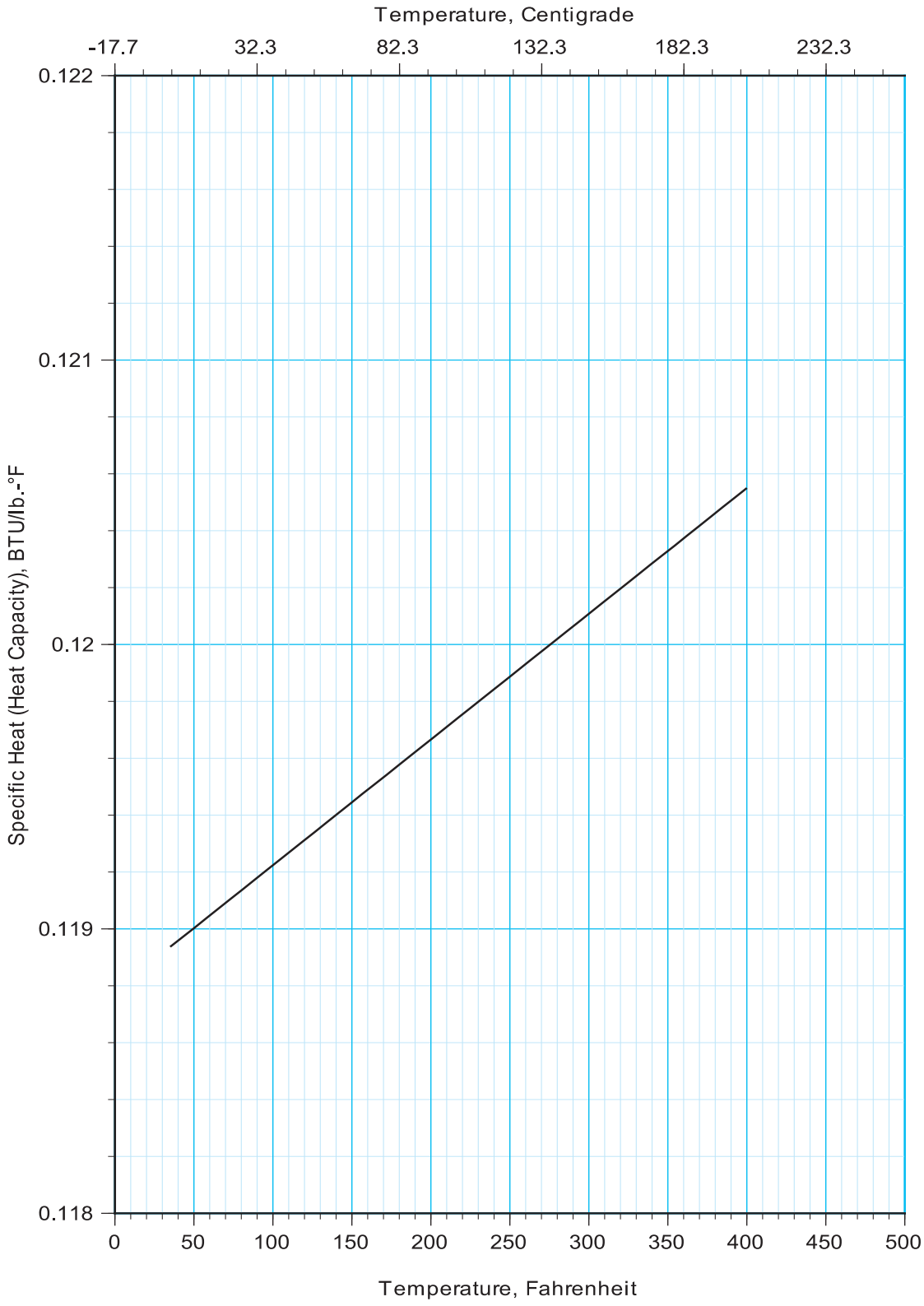


Technical Data

Specific Heat (Heat Capacity) of Liquid Chlorine

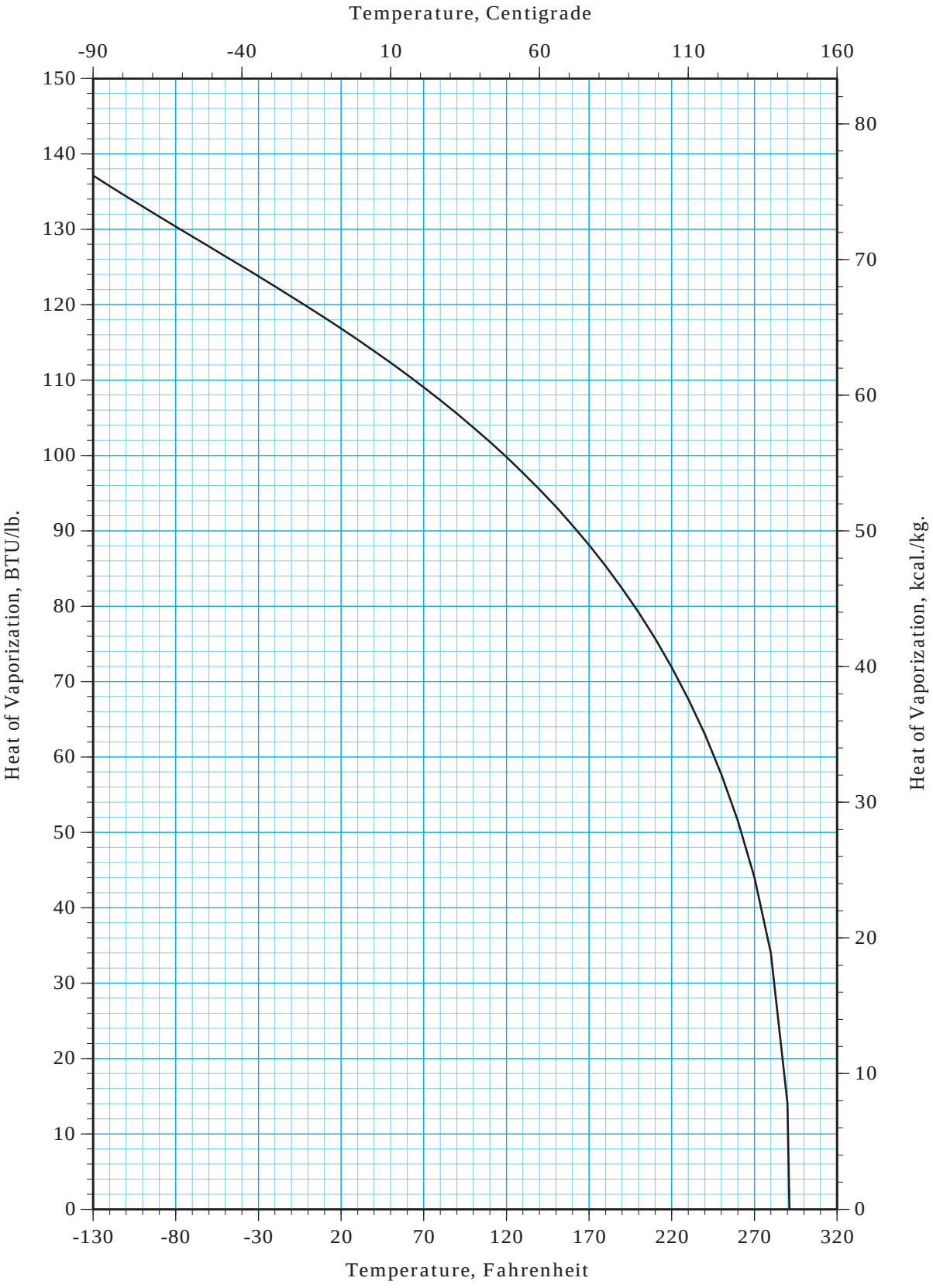


Specific Heat (Heat Capacity) of Chlorine Gas

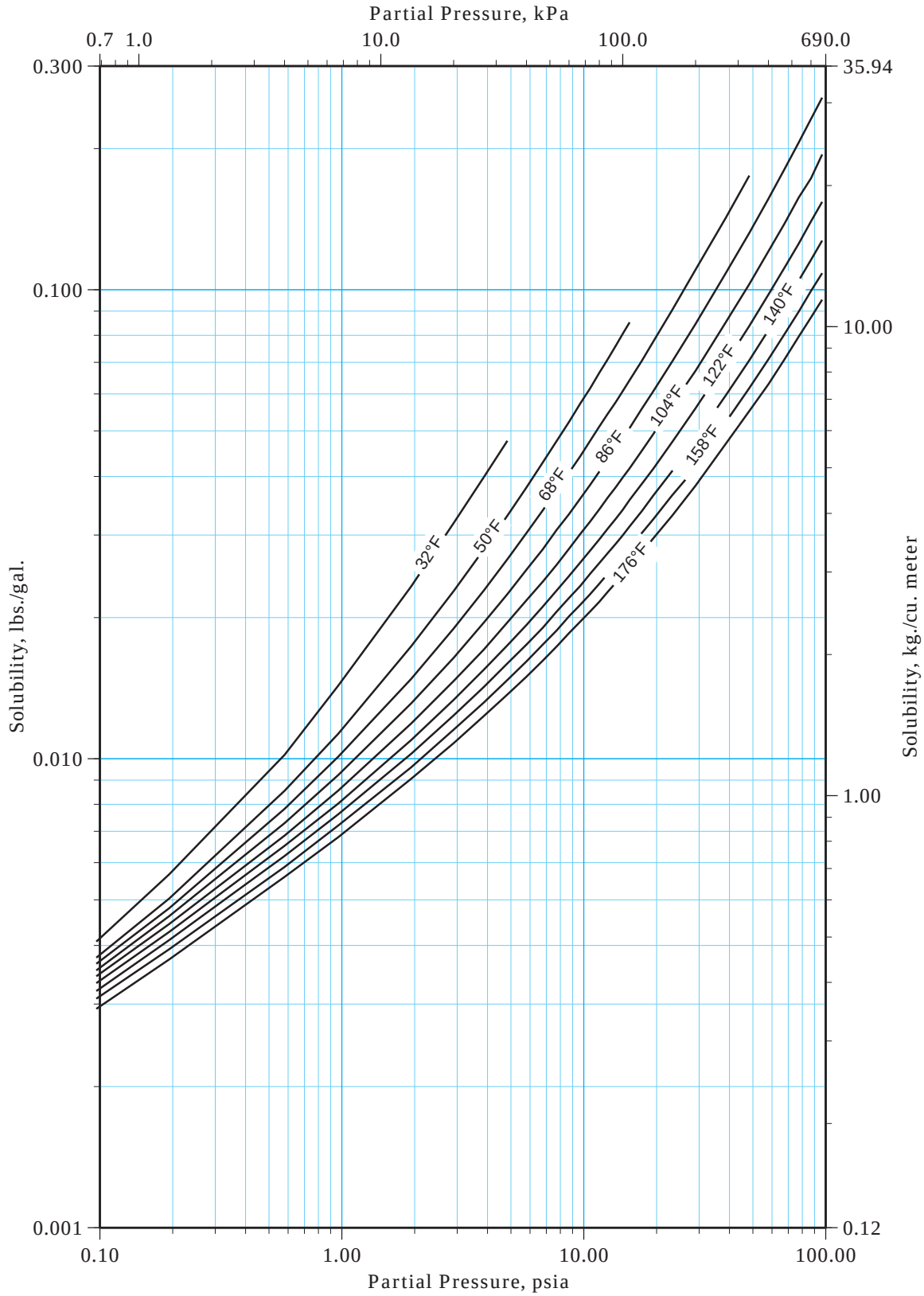


Technical Data

Latent Heat of Vaporization of Chlorine

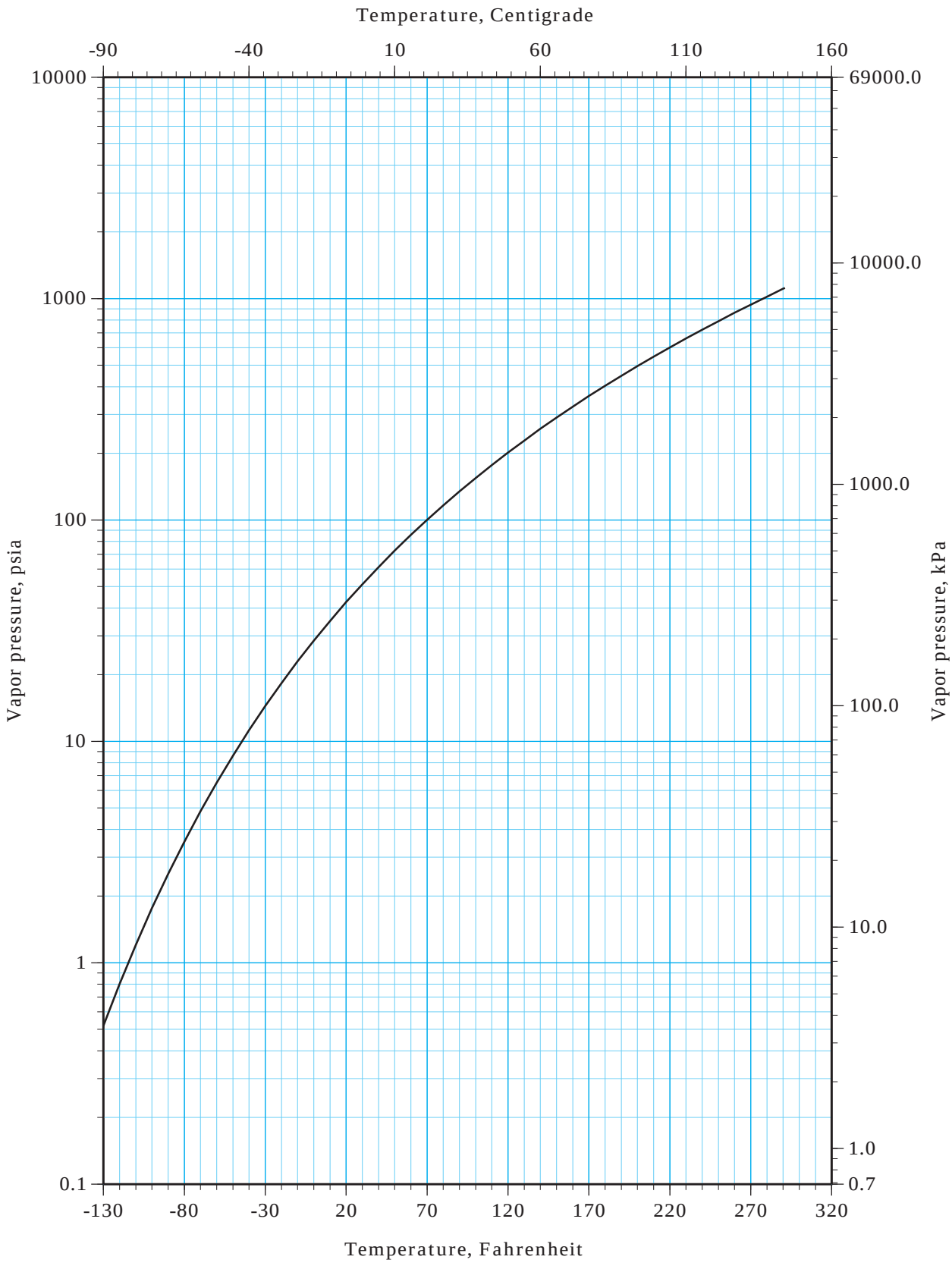


Solubility of Chlorine in Water

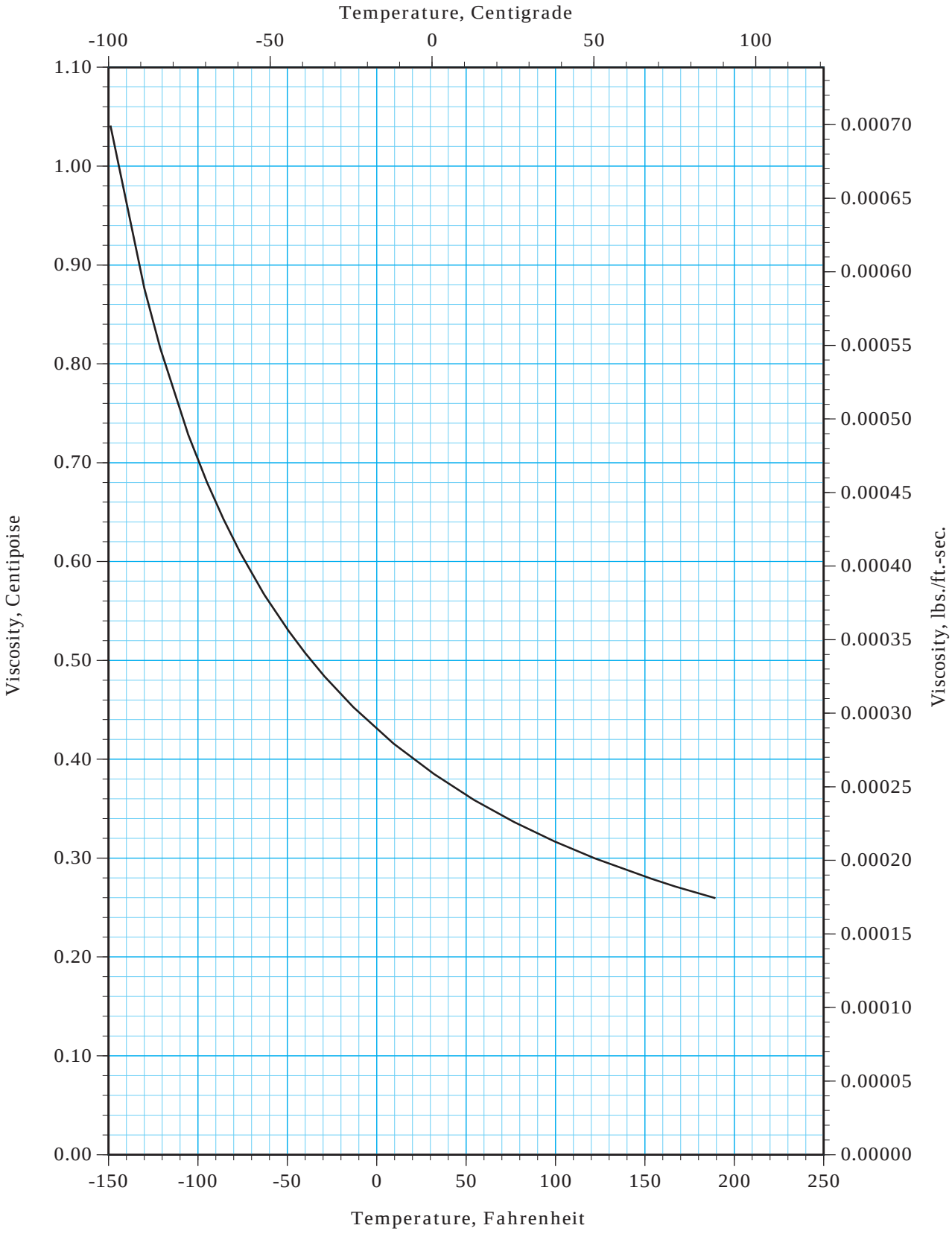


Technical Data

Vapor Pressure of Saturated Chlorine

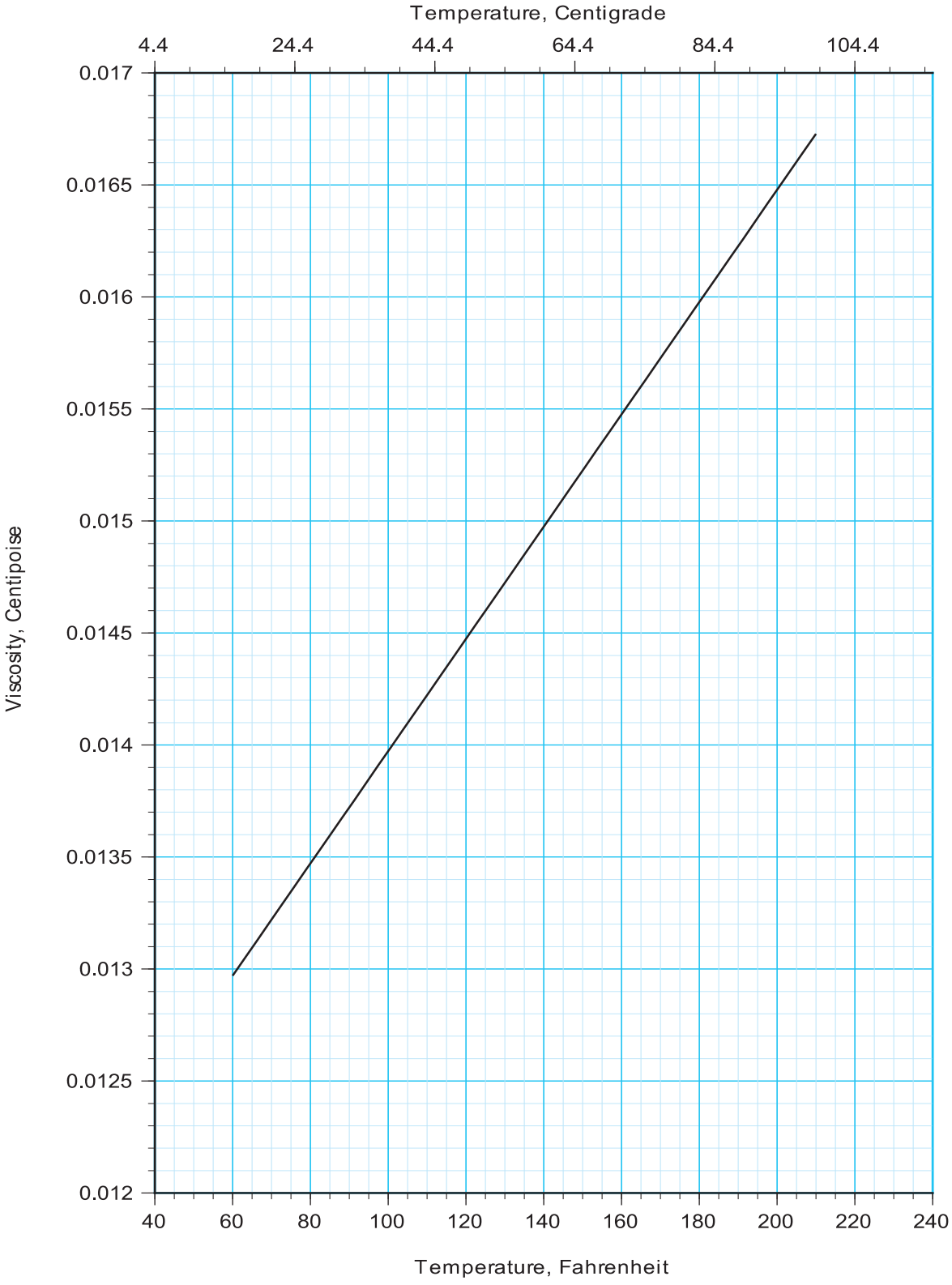


Viscosity of Liquid Chlorine

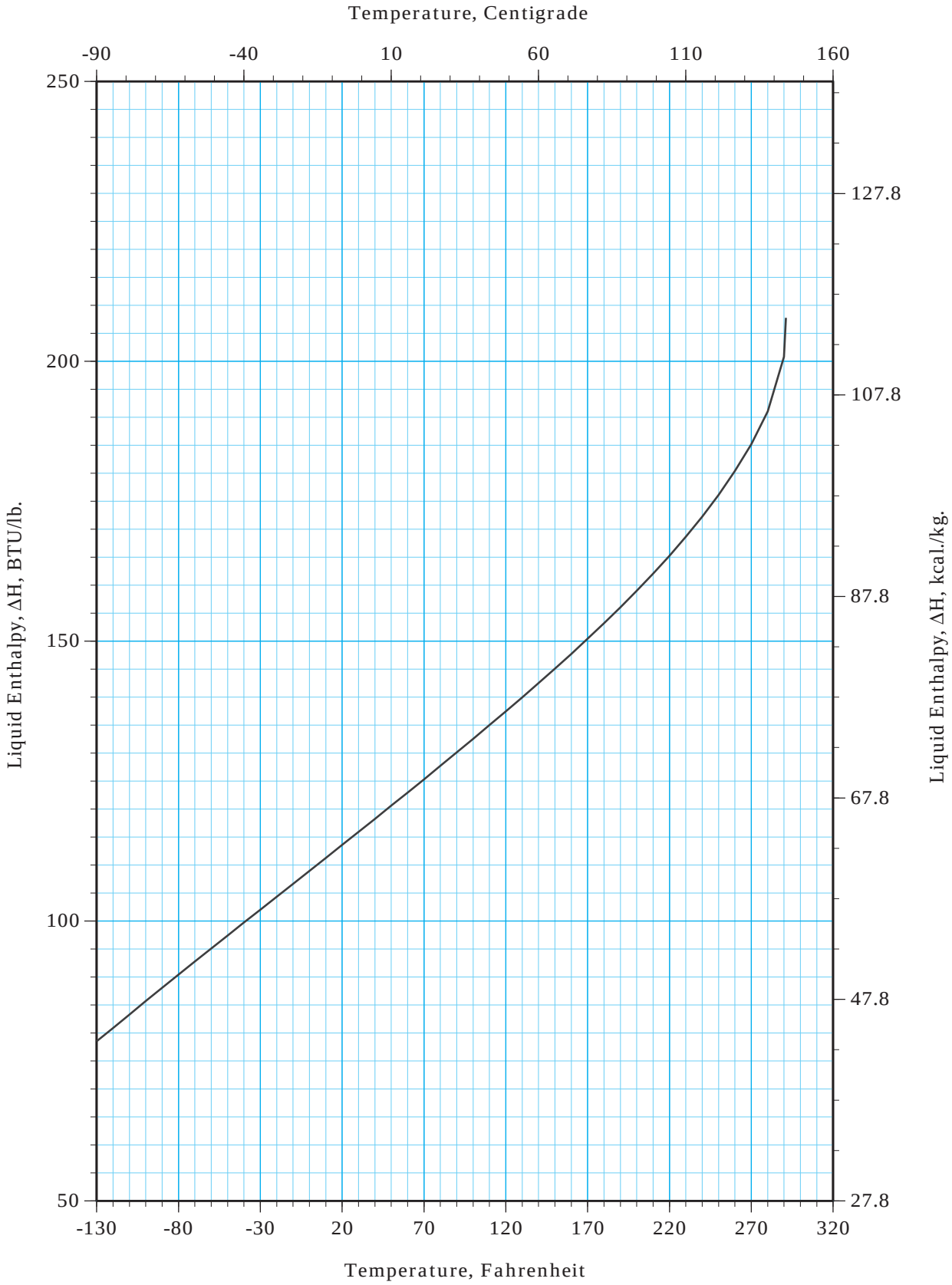


Technical Data

Viscosity of Chlorine Gas



Enthalpy of Liquid Chlorine



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