THE CHLORINE INSTITUTE

Pamphlet 9

Chlorine Vaporizing Systems

Edition 7

A LEGACY OF SAFETY STEWARDSHIP since 1924

July 2011

Table of Contents

1. INTRODUCTION

1.1 SCOPE

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

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

1.2 CHLORINE INSTITUTE STEWARDSHIP PROGRAM

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

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

1.3 DEFINITIONS AND ACRONYMS

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

ASME	American Society of Mechanical Engineers
ASTM	American Society of Testing and Materials
Chlorine	dry chlorine (either gas or liquid)
Code	refers to the ASME Code
container	any vessel fixed or movable for the purpose of holding chlorine
cylinder	a shipping container with capacity not exceeding 150 lbs (68 kg) of chlorine that is authorized by regulation for the transportation of chlorine
design pressure	same meaning as in the Code
$FeCl_3$	ferric chloride
gas padding	the addition of clean, dry, oil-free, compressed air, nitrogen or chlorine in order to increase system pressure

gas purge	the use of clean, dry, oil-free compressed air or nitrogen, dried to a dew point of -40°F (-40°C) measured at the operating pressure
Inconel®	a registered trademark of Special Metals Corporation
Institute	The Chlorine Institute
kPa	kilopascal(s)
Monel®	a registered trademark of Special Metals Corporation
NCl_3	nitrogen trichloride
psig	pounds per square inch gauge
ton container	a shipping container with a typical capacity of 2,000 lbs (907 kg) of chlorine that is authorized by regulation for the transportation of chlorine

1.4 DISCLAIMER

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

1.5 REGULATORY, INSURANCE REQUIREMENTS AND MANUFACTURERS RECOMMENDATIONS

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

1.6 APPROVAL

The Health, Environment, Safety and Security Issue Team approved Edition 7 of this pamphlet on July 8, 2011.

1.7 REVISIONS

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

1.7.1 Significant Revisions in Current Edition

There are no significant revisions to Edition 7 of this pamphlet.

1.8 <u>REPRODUCTION</u>

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

2. GENERAL

2.1 <u>CHLORINE SUPPLY</u>

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

2.2 <u>DETERMINING THE NEED FOR A VAPORIZER</u>

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

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

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

2.3 <u>LIQUID CHLORINE SUPPLY</u>

By withdrawing chlorine from its container as a liquid and using a vaporizer to convert it to a gas, flow rates can be greatly increased. Liquid chlorine is commonly supplied to vaporizers from tank cars, ton containers or storage tanks. Liquid chlorine rates can be increased by manifolding ton containers. Refer to CI Drawing 183 (*9.1*) and CI Pamphlet 1 (*9.1*).

Liquid chlorine must be available at a pressure well above the pressure at which the gas is intended to be used. Whenever liquid chlorine is supplied to the vaporizer from a shipping or storage container, the pressure necessary to sustain liquid flow is provided by the pressure in the container. If the pressure of the tank car, cargo tank or storage tank is too low for user requirements, gas padding or other methods of elevating the liquid pressure are necessary. For padding recommendations, see CI Pamphlets 5, 49 and 66 (*9.1*). Pumping of liquid chlorine into vaporizers requires special engineering considerations. Cylinders and ton containers should not be padded with gas.

2.4 Operating Principle

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

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

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

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

Other process criteria may require safety systems that could cause shut off of the liquid lines, such as recommended shutoff valves for bulk transport unloading, see CI Pamphlet 57 (*9.1*). Automated shutdown instrumentation and/or procedures should be provided for the vaporizer in case the liquid feed automated shutoff valves close. Emergency shutdown procedures should follow the guidelines found in Section 7.3.

2.5 Vaporizer Sources

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

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

2.6 INSTALLATION CONSIDERATIONS

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

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

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

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

3. DESIGN

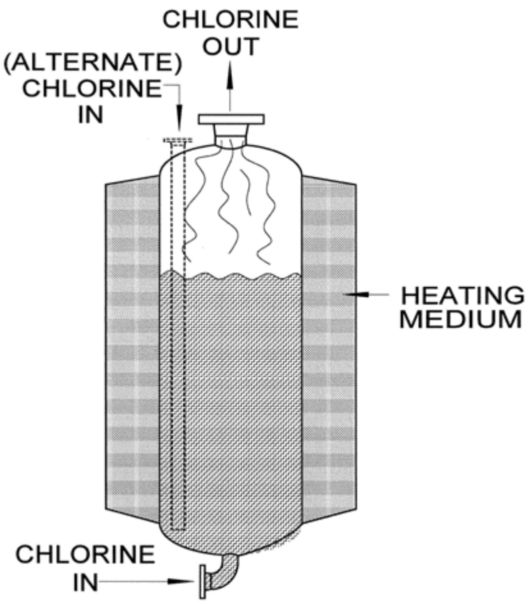
3.1 SELECTION

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

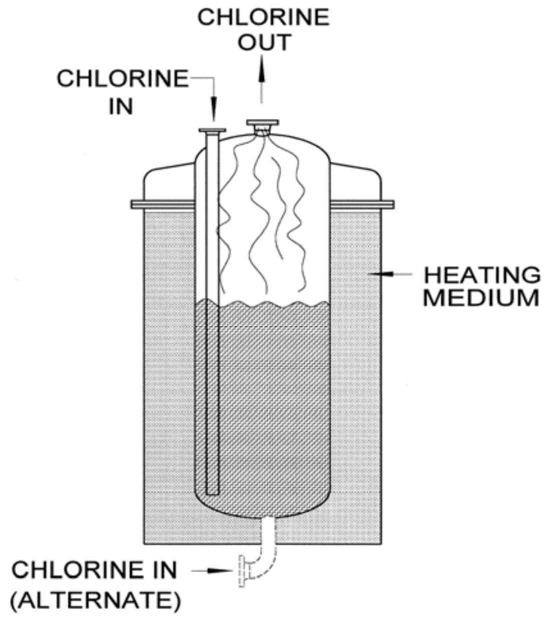
3.2 TYPES OF VAPORIZERS

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

Jacketed Shell



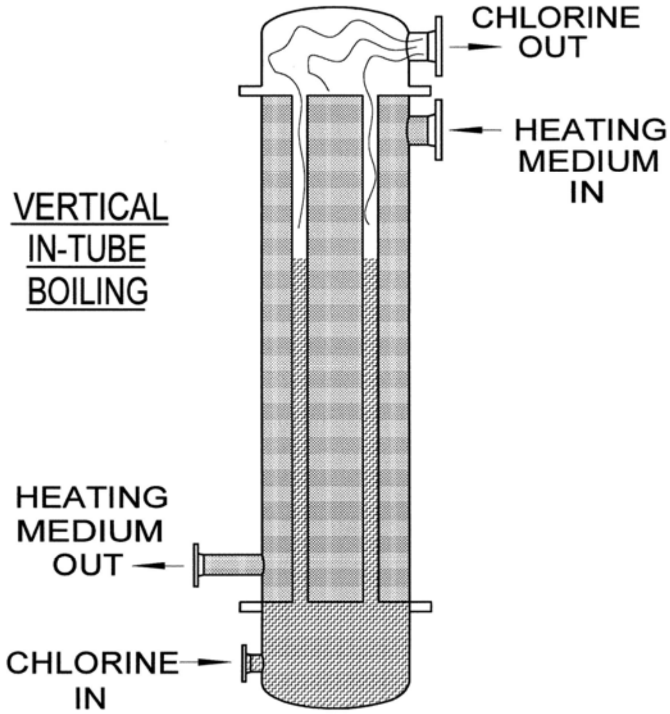
FIXED JACKETED SHELL



REMOVABLE JACKETED SHELL

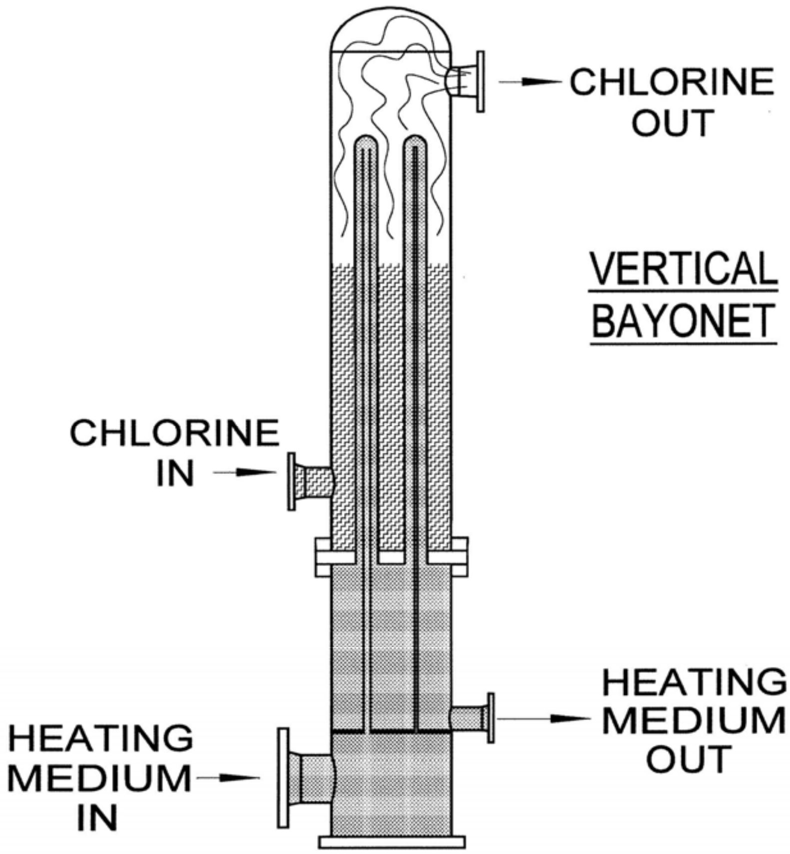
- simple construction
- easiest to maintain and operate
- less susceptible to $FeCl_3$ plugging
- less susceptible to NCl_3 build-up
- allows for heavy wall thickness which reduces chances of leakage
- easier to dry than tube type
- capacity limited by relatively small heat transfer surface area
- a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

Vertical In-Tube Boiling (Chlorine on Tube Side)



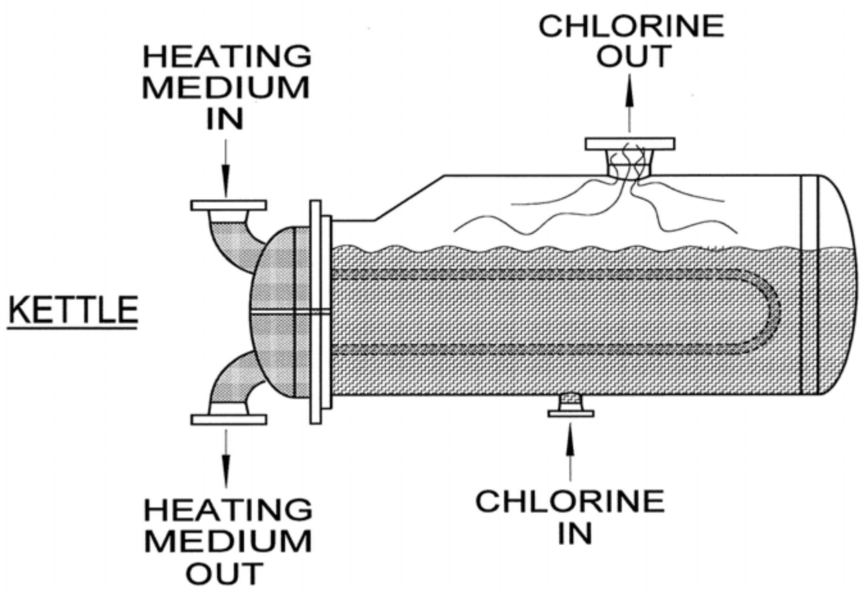
- high capacity due to large heat transfer surface area
- violent boiling increases heat transfer up to a point (flux limited)
- least susceptible to NCl_3 build-up
- smallest chlorine volume required for heat transfer area
- superheat available
- easy to clean
- most susceptible to $FeCl_3$ plugging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

Vertical Bayonet (Chlorine on Shell Side)



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

Horizontal Kettle (Reboiler Type)



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

3.3 DESIGN CONSIDERATIONS

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

- Flooding

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

- Liquid Disengagement

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

- Reliquefaction

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

- Fouling

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

- Freeze-up

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

3.4 METHODS OF HEATING

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

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

- an external heat exchanger with a pump circulating hot water through the vaporizer water jacket or tube section

- an electric immersion heater in the water jacket with water added to the system to make up water lost due to evaporation
- steam injected into the water jacket with an overflow for accumulated condensate

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

3.5 TEMPERATURE

High Temperature

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

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

Low Temperature

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

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

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

3.6 MATERIALS OF CONSTRUCTION

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

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

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

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

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

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

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

3.7 FABRICATION

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

3.8 POST-WELD HEAT TREATMENT

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

3.9 CORROSION ALLOWANCE

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

3.10 EFFECT OF GAS PADDING

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

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

4. CONTROLS AND INDICATORS

4.1 General

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

All electric components and wiring on a chlorine vaporizer system should conform to the National Electrical Code (*9.3*).

4.2 Controls and Indicators for All Vaporizer Types

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

4.2.1 Automatic Gas Valve

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

4.2.2 Pressure Reducing Valve

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

4.2.3 Pressure Relief Valve

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

4.2.4 Superheat

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

4.2.5 Temperature/Pressure Indicator

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

4.2.6 Flow Control

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

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

4.2.7 Heating Medium Temperature

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

4.2.8 Heating Medium Pressure

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

4.2.9 Protection Against Reverse Flow

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

4.2.10 Reserve Container

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

4.2.11 Exit Water Temperature

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

4.2.12 Liquid Expansion Chamber

An expansion chamber is one device which prevents overpressure and possible hydrostatic rupture due to thermal expansion of liquid chlorine trapped between closed valves. Recommended configurations and use conditions for expansion chambers are referenced in CI Drawing 136 (*9.1*).

4.2.13 Alarm

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

4.3 STEAM-HEATED VAPORIZERS

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

4.3.1 Steam pressure

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

4.3.2 Pressure Relief Valve

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

4.3.3 Air Vent

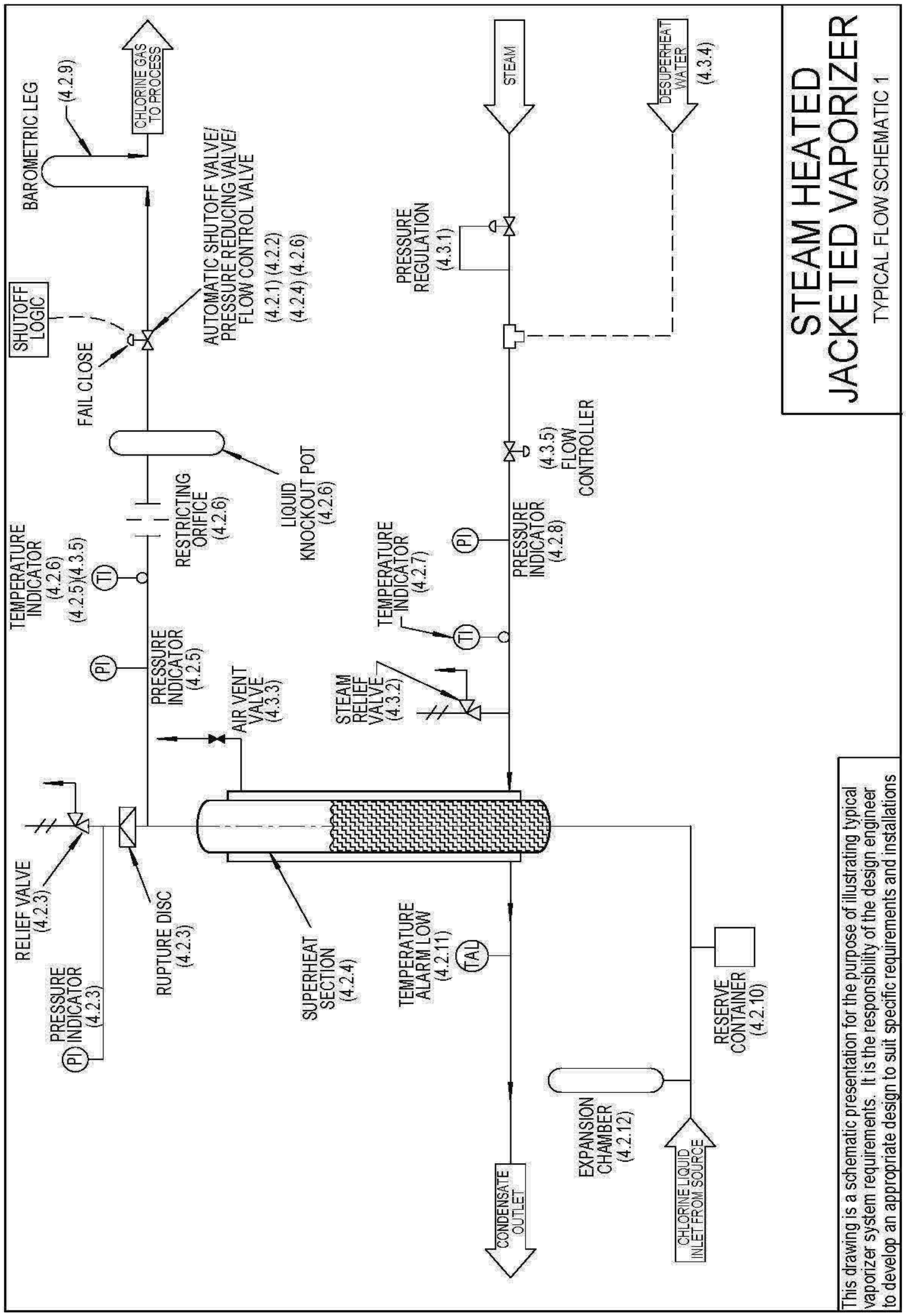
An air discharge vent valve on steam heated jacketed vaporizers is needed.

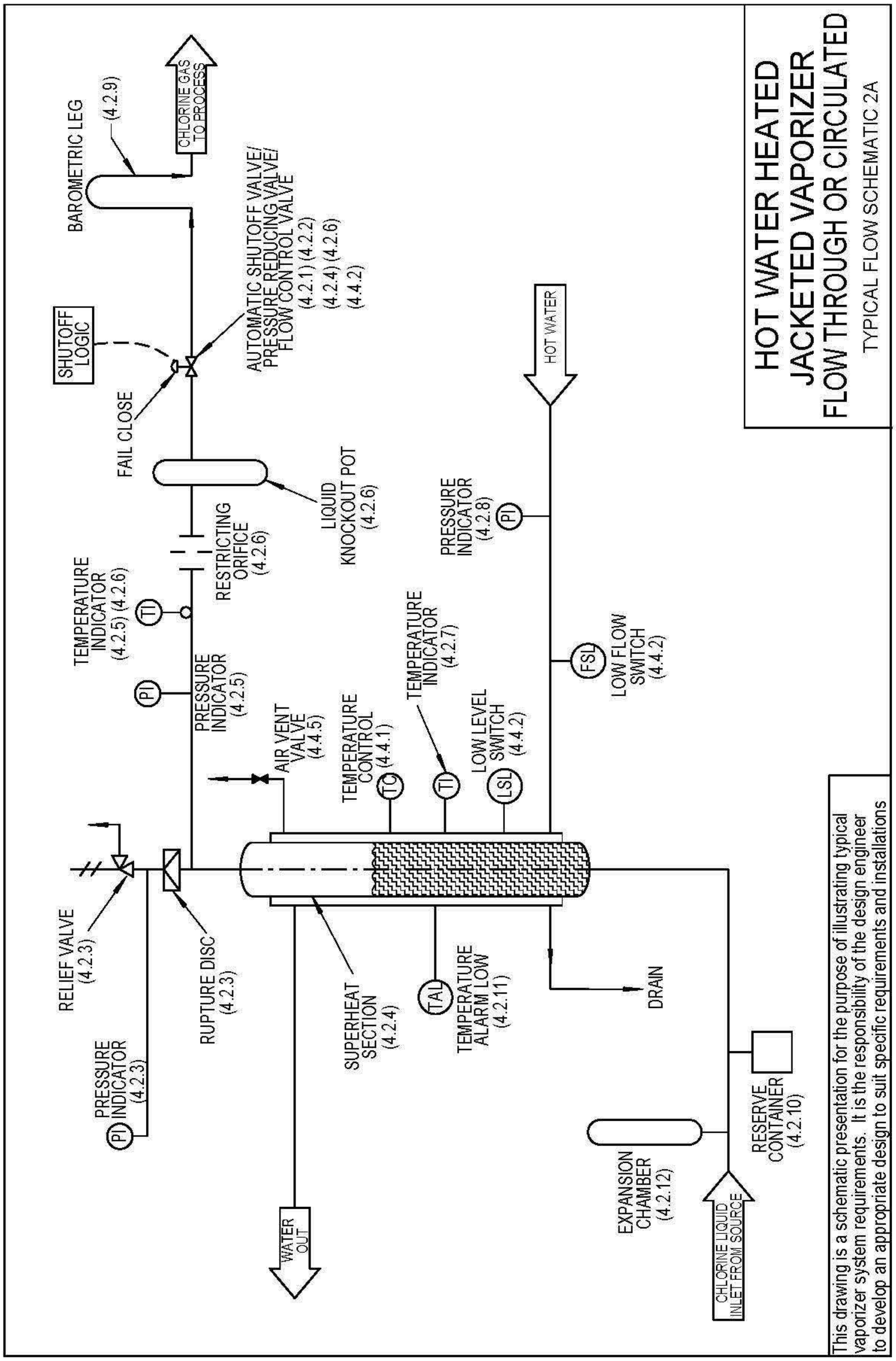
4.3.4 Desuperheat

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

4.3.5 Steam Flow Control

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


STEAM HEATED
JACKETED VAPORIZER
TYPICAL FLOW SCHEMATIC 1
BAROMETRIC LEG (4.2.9)
CHLORINE GAS TO PROCESS
SHUTOFF LOGIC
FAIL CLOSE
AUTOMATIC SHUTOFF VALVE/ PRESSURE REDUCING VALVE/ FLOW CONTROL VALVE (4.2.1) (4.2.2) (4.2.4) (4.2.6)
LIQUID KNOCKOUT POT (4.2.6)
RESTRICTING ORIFICE (4.2.6)
TEMPERATURE INDICATOR (4.2.6) (4.2.5)(4.3.5)
TI
PI
PRESSURE INDICATOR (4.2.5)
AIR VENT VALVE (4.3.3)
RELIEF VALVE (4.2.3)
PRESSURE INDICATOR (4.2.3)
RUPTURE DISC (4.2.3)
SUPERHEAT SECTION (4.2.4)
STEAM
PRESSURE REGULATION (4.3.1)
DESUPERHEAT WATER (4.3.4)
(4.3.5) FLOW CONTROLLER
PRESSURE INDICATOR (4.2.8)
TEMPERATURE INDICATOR (4.2.7)
STEAM RELIEF VALVE (4.3.2)
TEMPERATURE ALARM LOW (4.2.11)
TAL
RESERVE CONTAINER (4.2.10)
EXPANSION CHAMBER (4.2.12)
CONDENSATE OUTLET
CHLORINE LIQUID INLET FROM SOURCE
This drawing is a schematic presentation for the purpose of illustrating typical vaporizer system requirements. It is the responsibility of the design engineer to develop an appropriate design to suit specific requirements and installations



HOT WATER HEATED
JACKETED VAPORIZER
FLOW THROUGH OR CIRCULATED
TYPICAL FLOW SCHEMATIC 2A
This drawing is a schematic presentation for the purpose of illustrating typical vaporizer system requirements. It is the responsibility of the design engineer to develop an appropriate design to suit specific requirements and installations
CHLORINE GAS TO PROCESS
BAROMETRIC LEG (4.2.9)
SHUTOFF LOGIC
FAIL CLOSE
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LIQUID KNOCKOUT POT (4.2.6)
RESTRICTING ORIFICE (4.2.6)
TEMPERATURE INDICATOR (4.2.5) (4.2.6)
PRESSURE INDICATOR (4.2.5)
AIR VENT VALVE (4.4.5)
TEMPERATURE CONTROL (4.4.1)
TEMPERATURE INDICATOR (4.2.7)
LOW LEVEL SWITCH (4.4.2)
LOW FLOW SWITCH (4.4.2)
PRESSURE INDICATOR (4.2.8)
HOT WATER
RELIEF VALVE (4.2.3)
RUPTURE DISC (4.2.3)
PRESSURE INDICATOR (4.2.3)
SUPERHEAT SECTION (4.2.4)
TEMPERATURE ALARM LOW (4.2.11)
DRAIN
WATER OUT
EXPANSION CHAMBER (4.2.12)
RESERVE CONTAINER (4.2.10)
CHLORINE LIQUID INLET FROM SOURCE
PI
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TAL
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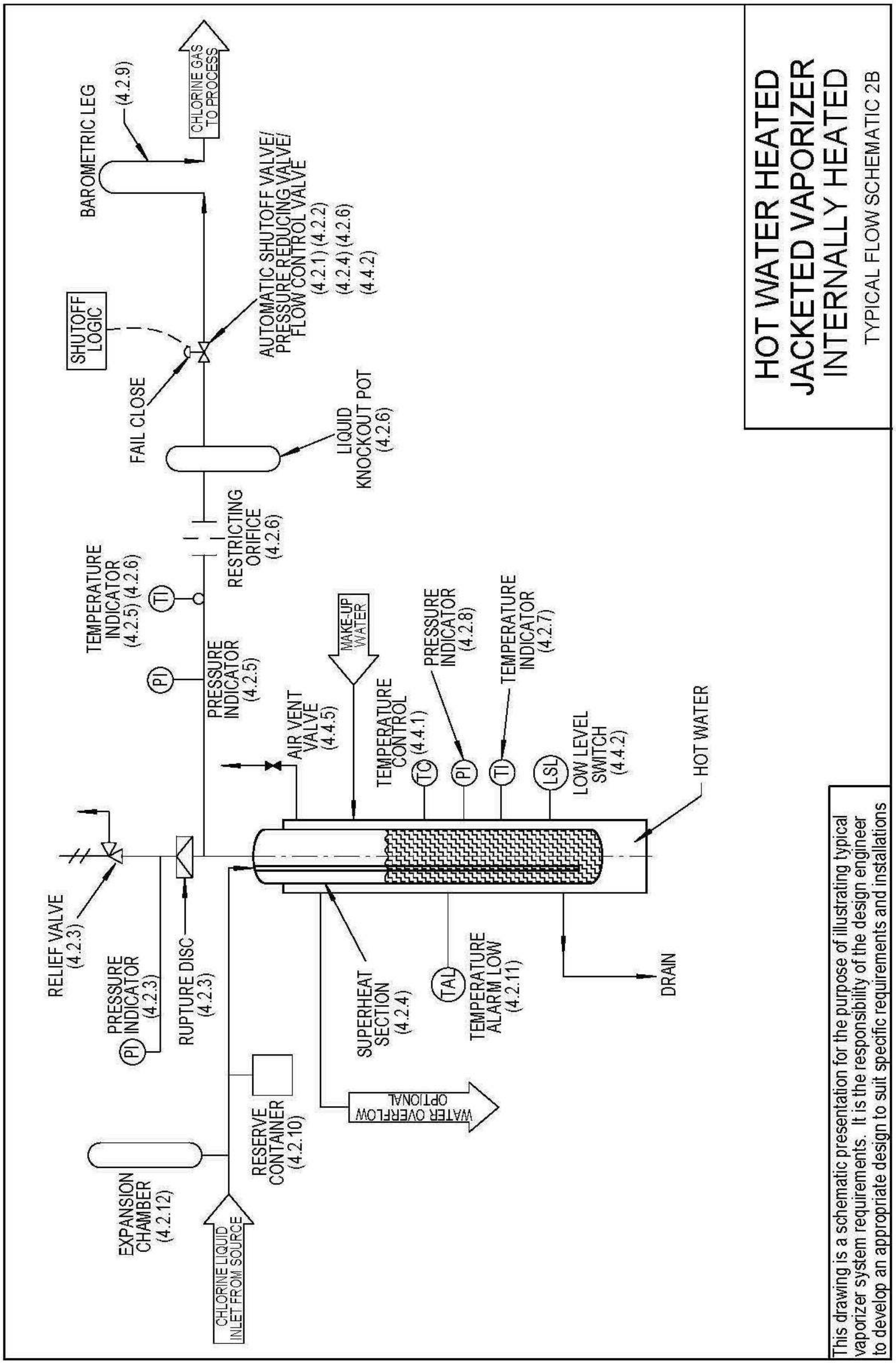
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JACKETED VAPORIZER
INTERNALLY HEATED
TYPICAL FLOW SCHEMATIC 2B
BAROMETRIC LEG
(4.2.9)
CHLORINE GAS TO PROCESS
SHUTOFF LOGIC
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AUTOMATIC SHUTOFF VALVE/ PRESSURE REDUCING VALVE/ FLOW CONTROL VALVE
(4.2.1) (4.2.2)
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LIQUID KNOCKOUT POT
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PRESSURE INDICATOR
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MAKE-UP WATER
AIR VENT VALVE
(4.4.5)
TEMPERATURE CONTROL
(4.4.1)
TC
PRESSURE INDICATOR
(4.2.8)
TEMPERATURE INDICATOR
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LSL
LOW LEVEL SWITCH
(4.4.2)
HOT WATER
RELIEF VALVE
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PRESSURE INDICATOR
(4.2.3)
RUPTURE DISC
(4.2.3)
SUPERHEAT SECTION
(4.2.4)
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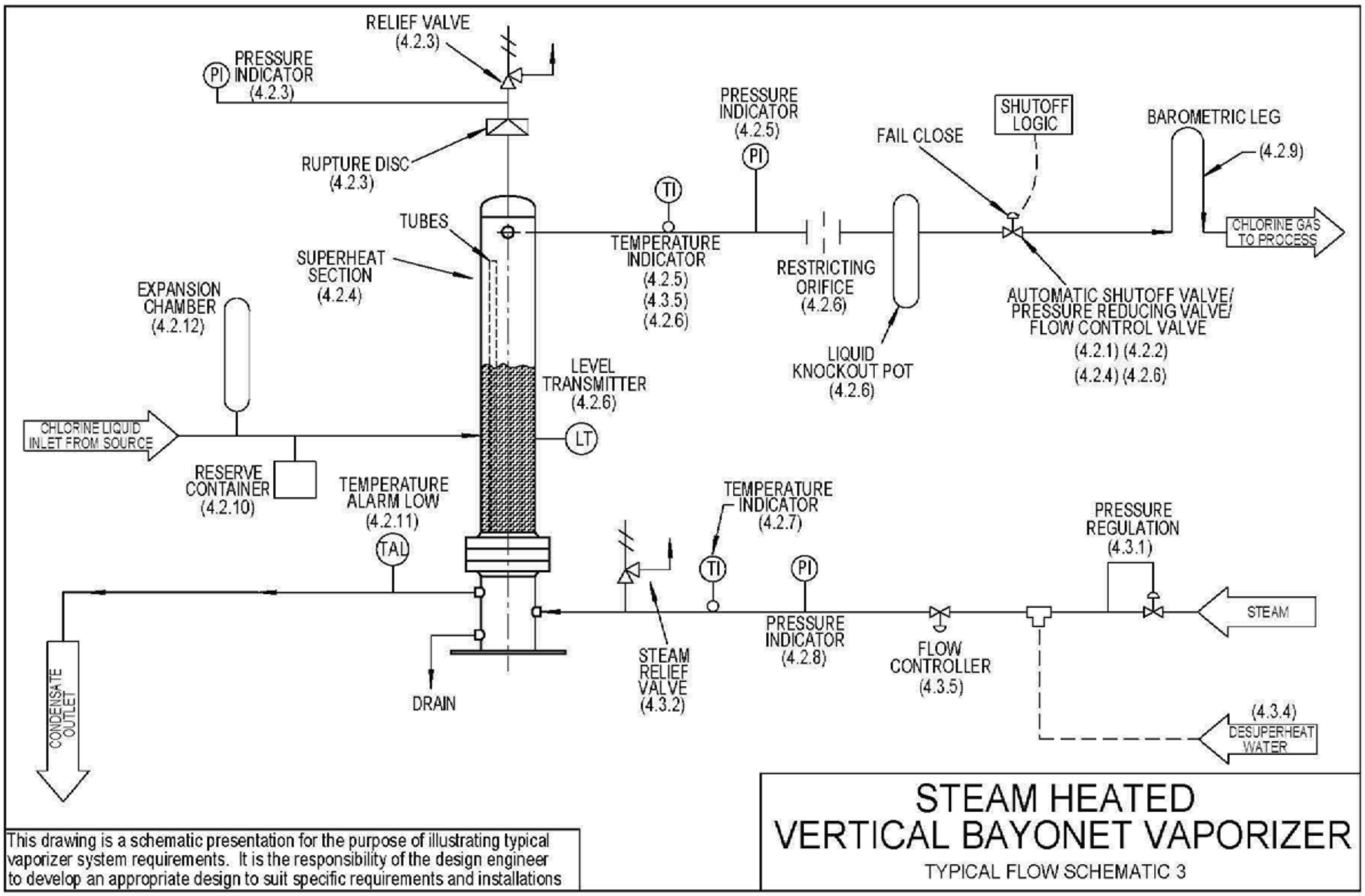
TEMPERATURE ALARM LOW
(4.2.11)
DRAIN
EXPANSION CHAMBER
(4.2.12)
RESERVE CONTAINER
(4.2.10)
WATER OVERFLOW OPTIONAL
CHLORINE LIQUID INLET FROM SOURCE
This drawing is a schematic presentation for the purpose of illustrating typical vaporizer system requirements. It is the responsibility of the design engineer to develop an appropriate design to suit specific requirements and installations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RUPTURE DISC (4.2.3)
TUBES
SUPERHEAT SECTION (4.2.4)
EXPANSION CHAMBER (4.2.12)
CHLORINE LIQUID INLET FROM SOURCE
RESERVE CONTAINER (4.2.10)
TEMPERATURE ALARM LOW (4.2.11)
TAL
CONDENSATE OUTLET
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TEMPERATURE INDICATOR (4.2.5) (4.3.5) (4.2.6)
PRESSURE INDICATOR (4.2.5)
RESTRICTING ORIFICE (4.2.6)
LEVEL TRANSMITTER (4.2.6)
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LIQUID KNOCKOUT POT (4.2.6)
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BAROMETRIC LEG
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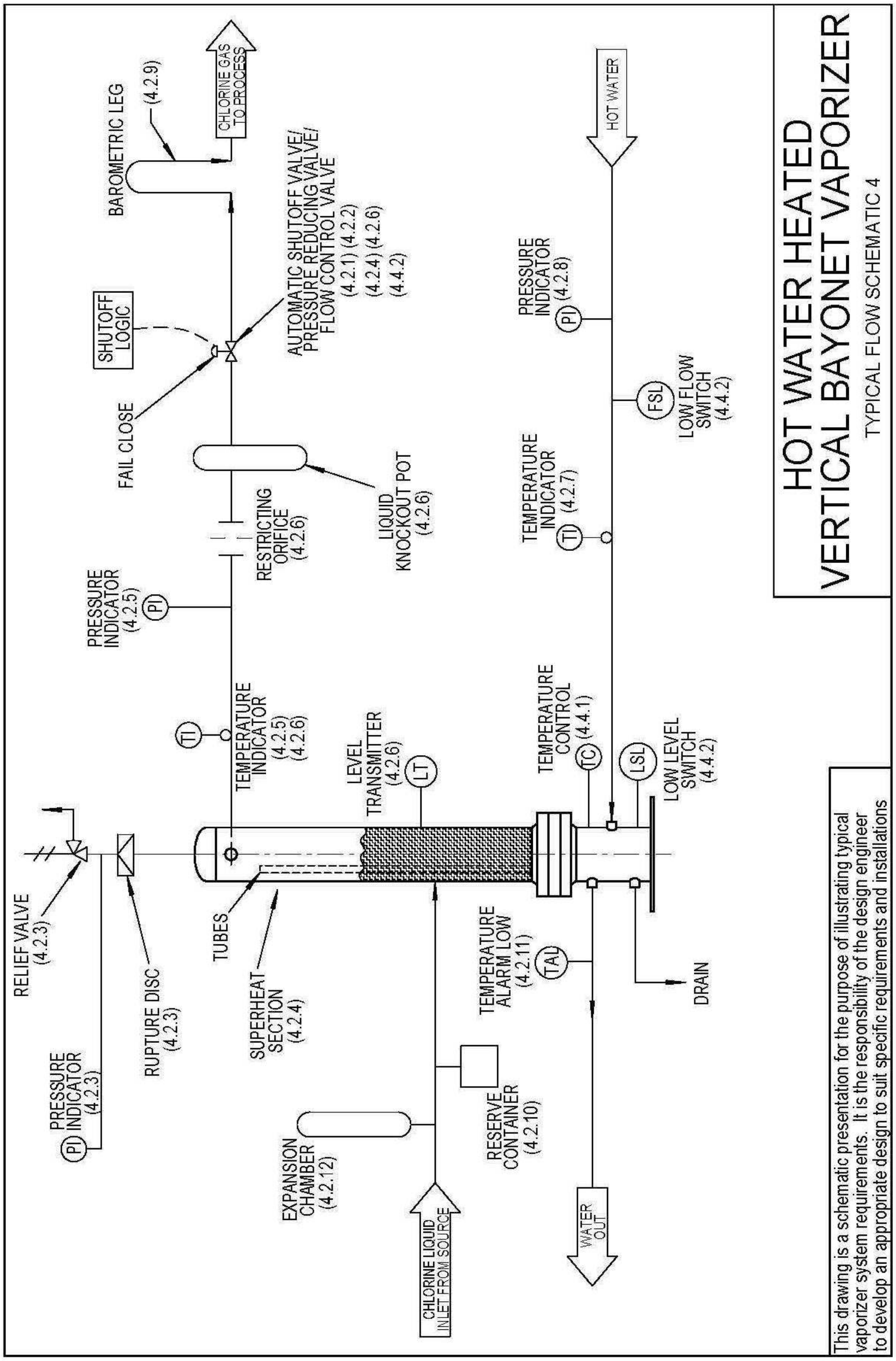
CHLORINE GAS TO PROCESS
TEMPERATURE INDICATOR (4.2.7)
STEAM RELIEF VALVE (4.3.2)
PRESSURE INDICATOR (4.2.8)
FLOW CONTROLLER (4.3.5)
PRESSURE REGULATION (4.3.1)
STEAM
(4.3.4)
DESUPERHEAT WATER
This drawing is a schematic presentation for the purpose of illustrating typical vaporizer system requirements. It is the responsibility of the design engineer to develop an appropriate design to suit specific requirements and installations
STEAM HEATED
VERTICAL BAYONET VAPORIZER
TYPICAL FLOW SCHEMATIC 3


HOT WATER HEATED
VERTICAL BAYONET VAPORIZER
TYPICAL FLOW SCHEMATIC 4
This drawing is a schematic presentation for the purpose of illustrating typical vaporizer system requirements. It is the responsibility of the design engineer to develop an appropriate design to suit specific requirements and installations
BAROMETRIC LEG (4.2.9)
CHLORINE GAS TO PROCESS
SHUTOFF LOGIC
FAIL CLOSE
AUTOMATIC SHUTOFF VALVE/ PRESSURE REDUCING VALVE/ FLOW CONTROL VALVE (4.2.1) (4.2.2) (4.2.4) (4.2.6) (4.4.2)
LIQUID KNOCKOUT POT (4.2.6)
RESTRICTING ORIFICE (4.2.6)
PRESSURE INDICATOR (4.2.5) PI
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LEVEL TRANSMITTER (4.2.6) LT
RELIEF VALVE (4.2.3)
RUPTURE DISC (4.2.3)
PRESSURE INDICATOR (4.2.3) PI
TUBES
SUPERHEAT SECTION (4.2.4)
EXPANSION CHAMBER (4.2.12)
CHLORINE LIQUID INLET FROM SOURCE
RESERVE CONTAINER (4.2.10)
TEMPERATURE ALARM LOW (4.2.11) TAL
WATER OUT
DRAIN
TEMPERATURE CONTROL (4.4.1) TC
LSL LOW LEVEL SWITCH (4.4.2)
TEMPERATURE INDICATOR (4.2.7) TI
PRESSURE INDICATOR (4.2.8) PI
FSL LOW FLOW SWITCH (4.4.2)
HOT WATER

4.4 HOT WATER-HEATED VAPORIZERS

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

4.4.1 Temperature Control

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

4.4.2 Low Water Detector

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

4.4.3 Corrosion Control

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

4.4.4 Maintain Water Fill

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

4.4.5 Vent Valve

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

5. SAFETY

5.1 GENERAL

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

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

5.2 PRECAUTIONS

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

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

Excess Pressure

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

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

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

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

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

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

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

Temperature Build-up

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

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

Flooding

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

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

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

Reverse Process Flow

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

Corrosion

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

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

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

5.3 <u>Nitrogen Trichloride</u>

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

5.4 <u>Leak Detection</u>

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

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

6. PREPARATION FOR USE

6.1 <u>General</u>

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

6.2 Cleaning

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

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

There are various cleaning techniques available, but there is no best method. The appropriate technique will depend on the nature of the system and the type of contamination. For any technique employed, the user must establish a written procedure. Each step of the cleaning procedure should be closely monitored. The procedure should include criteria for written acceptance of the effectiveness of the cleaning. Reference material for developing procedures can be found in CGA's Pamphlet G-4.1 (*9.3.3*).

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

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

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

Chlorine Institute Pamphlet 5 (*9.1*) includes detailed instructions on the water wash which can be used to rid the system of any organic contaminants. Care must be taken that the entire system is flushed and that a means is devised to dispose of any residue or solids. A detergent suitable to dissolve the oil or grease can be used. This must be followed by thorough flushing with water to remove the detergent. Some facilities utilize low pressure steam versus a water wash. It has the added advantage of raising the temperature of the vessel to aid in drying. The temperature should be limited based on the equipment and insulation type, but 200°F (93°C) is typically used.

For information on solvent cleaning and cleaning the liquid and gas piping systems refer to CI Pamphlet 6 (*9.1*).

6.3 Hydrostatic Testing

A hydrostatic test is necessary if weld repairs or alterations are made to the vessel. Owner-user policy may dictate a hydrostatic test during out-of-service inspections. Remove piping, valves, and instrumentation from the vaporizer and protect them from absorbing moisture from the atmosphere. Install a calibrated pressure gauge suitable for the test. Fill the vaporizer with water as quickly as possible to avoid corrosion at the liquid interface. When the vessel is full of water, shut off the flow and close the outlet valve. Disconnect the water line and install a test pump. Apply hydrostatic pressure as specified in the Code. Close the inlet valve and allow the vaporizer to stand. There should be negligible pressure drop indicated on the gauge after 30 minutes, as any significant pressure drop indicates the presence of leaks. Pressurized heating systems should be tested on the heating medium side in accordance with the current edition of the Code.

Recommended testing procedures for piping systems are covered in CI Pamphlet 6 (*9.1*). If insulation was removed at piping, tank or instrument connections, do not reinstall it until the vessel and piping are gas leak checked.

6.4 Drying

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

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

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

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

6.5 Leak Testing

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

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

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

Piping, valves, and instrumentation should be leak checked as detailed in CI Pamphlet 6 (*9.1*). If possible, leave the system uninsulated until it is fully in service to do further leak checking. The insulation would only be installed prior to this time if the bare fixtures will ice up due to operating conditions or ambient temperatures.

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

7. OPERATION

7.1 General

Proper preparations should be made for safe start-up of a chlorine vaporizer. A comprehensive review of the system design, preventive maintenance schedules, and thoroughness of procedural training is required. All employees involved in operating vaporizers should be trained by someone knowledgeable in all aspects of vaporizer system operation and maintenance and in OSHA requirements (PSM). Thorough training of personnel should be conducted on the procedures for start-up, shutdown, and changing of supply source, along with emergency procedures necessary in each area. Insure that the appropriate emergency equipment is available and ready for use (*9.1*).

7.2 Start-up

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

The following are general guidelines:

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

- Slowly open the chlorine container valve. Rapid opening of valves in a tank car supply system may result in closing of excess flow valves. Refer to CI Pamphlet 66 (*9.1*). Then slowly open the other valves in the liquid line, progressively from the container valve to the vaporizer inlet. Once the vaporizer inlet valve has been opened, all valves in the liquid supply line must be left open until either the supply of liquid has been exhausted or the supply line and vaporizer are empty. The heat source must remain on.
- When the chlorine pressure reaches the operating level, slowly open the vaporizer discharge valve so that chlorine gas can flow to the process line.
- If a leak is discovered at any time close the valve nearest the leak, but between the chlorine container and the leak source, and depressurize the leak source.
- Never close both the liquid inlet and gas outlet valves on a vaporizer with chlorine in the equipment and the heat source still in service.

7.3 SHUTDOWN

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

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

7.3.1 Close Off the Liquid Supply

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

Care must be taken to not allow the process to backflow into the vaporizer (Section 5.2). To the maximum extent possible, transfer liquid back to the source. This will minimize the amount of nitrogen trichloride that could concentrate in the vaporizer when liquid is evaporated (Section 5.3).

7.3.2 Close Off the Vapor Discharge

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

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

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

7.4 Changing Chlorine Supply

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

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

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

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

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

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

  Positive reverse flow prevention is required.

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

8. MAINTENANCE

8.1 General

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

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

A program for proof testing critical instrumentation should be followed.

8.2 FREQUENCY OF INSPECTIONS

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

8.2.1 External Inspection

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

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

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

8.2.2 Internal Inspection

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

- type of service
- the quality of the chlorine source
- the quality of pad gas
- changes in system performance
- the frequency of connects and disconnects
- the length of time in operation
- metal thickness measurements

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

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

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

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

8.3 CLEANING

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

8.4 REPAIRS BY WELDING

Before welding, make sure that all piping and equipment is thoroughly purged of chlorine. The heat of welding may cause ignition of chlorine with steel. All welding, stress relieving, radiographing, hydrostatic testing, inspection and restamping must be performed in compliance with the current edition of the Code (*9.2.3*).

9. REFERENCES

9.1 CHLORINE INSTITUTE REFERENCES

Pamphlet # & Drawing	Title
1	*Chlorine Basics* (*formerly The Chlorine Manual*), ed. 7; Pamphlet 1; The Chlorine Institute: Arlington, VA, **2008**.
5	*Non-Refrigerated Liquid Chlorine Storage*, ed. 7; Pamphlet 5; The Chlorine Institute: Arlington, VA, **2005**.
6	*Piping Systems for Dry Chlorine*, ed. 15; Pamphlet 6; The Chlorine Institute: Arlington, VA, **2005**.
21	*Nitrogen Trichloride - A Collection of Reports and Papers*, ed. 6; Pamphlet 21; The Chlorine Institute: Arlington, VA, **2010**.

Pamphlet # & Drawing	**Title**
49	*Recommended Practices for Handling Chlorine Bulk Highway Transports*, ed. 9; Pamphlet 49; The Chlorine Institute: Arlington, VA, **2009**.
57	*Emergency Shut-Off Systems for Bulk Transfer of Chlorine*, ed. 5-R1; Pamphlet 57; The Chlorine Institute: Arlington, VA, **2009**.
64	*Emergency Response Plans for Chlor-Alkali, Sodium Hypochlorite and Hydrogen Chloride Facilities*, ed. 6-R1; Pamphlet 64; The Chlorine Institute: Arlington, VA, **2008**.
66	*Recommended Practices for Handling Chlorine Tank Cars*, ed. 4-R1; Pamphlet 66; The Chlorine Institute: Arlington, VA, **2008**.
86	*Recommendations to Chlor-Alkali Manufacturing Facilities for the Prevention of Chlorine Releases*, ed. 5; Pamphlet 86; The Chlorine Institute: Arlington, VA, **2010**.
152	*Safe Handling of Chlorine Containing Nitrogen Trichloride*, ed. 2, Pamphlet 152, The Chlorine Institute: Arlington, VA, **2010**.
DWG 136-8	*Chlorine Expansion Chambers*, Drawing; DWG 136-5; The Chlorine Institute: Arlington, VA, **2007**.
DWG 183-3	*Manifolding Ton Containers for Liquid Chlorine Withdrawal*, Drawing; DWG 183-3; The Chlorine Institute: Arlington, VA, **1994**.

9.2 ASME CODES

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

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

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

9.3 MISCELLANEOUS

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

9.3.2 *National Board Inspection Code,* ANSI/NB 23; National Board of Boiler and Pressure Vessel Inspectors: Columbus, OH, **2007.**

9.3.3 *Cleaning Equipment for Oxygen Service*, ed. 6; Pamphlet G-4-1; Compressed Gas Association, Inc. Arlington, VA, **2009**.

For further assistance and information on items referenced, contact:

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PAMPHLET 9 CHECKLIST

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

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

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

Yes	No	N/A		
❒	❒	❒	14. Has a detailed review of system controls and indicators been performed?	{4}
❒	❒	❒	15. Has a detailed systems safety review been performed?	{5.2}
❒	❒	❒	16. Do appropriate emergency response procedures and training programs exist?	{5.4}
❒	❒	❒	17. Do detailed written procedures for cleaning, testing and drying exist?	{6.1}
❒	❒	❒	18. Was the system properly cleaned, tested and dried prior to being placed in service?	{6.2, 6.3, 6.4}
❒	❒	❒	19. Was the system leak tested with gas prior to being placed in service?	{6.5}
❒	❒	❒	20. Have proper preparations been made for a safe start-up, operation and shutdown?	{7}
❒	❒	❒	21. Are inspection and maintenance procedures and schedules adequate?	{8}

REMINDER:

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

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