Guideline for Transportation of Dry Chlorine Gas Through Pipeline within Industrial Zone

March, 2019

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Disclaimer:

This document is only a guideline prepared for ensuring safe transportation of Dry Chlorine gas through pipelines. These guidelines do not provide any exemption from obtaining clearances under Environmental Act, Rules and other Regulations notified by the government from time to time.

PREFACE

Chlor Alkali industry produces Chlorine in the ratio of 0.89 tons to each ton of caustic lye. Chlorine being a hazardous material, it requires and demands safe handling and utmost care.

Dry Chlorine Gas transportation through pipeline has been widely practiced within plant premises for several decades – the manufacturing industry has developed a well-established design, operational methodology, checks and balances, etc. However, Chlorine transportation in liquid state through pipelines, particularly over long distances and cross fences, is still not prevalent, though widely practiced in the US, Europe, China, etc.

Chlorine and Hydrogen are bottled and transported in containers/cylinders. Chlorine consumers are more widespread and scattered. Presently Chlorine is transported in ton containers, often over long distances and traversing all types of terrain. However, for customers who regularly consume large volumes, it is highly beneficial to transport dry Chlorine gas through pipelines; it is safer and economical in the long run.

There was a need felt for developing guidelines for transportation of dry Chlorine through pipelines over long distances.

In response to requests from the industry, the Department of Chemicals and Petrochemicals (DCPC), Ministry of Chemicals and Fertilizers, Government of India took an initiative to develop guidelines for transportation of dry chlorine through pipelines outside the manufacturers' premises and constituted an Expert Committee headed by the Chief Controller of Explosives, Petroleum and Explosives Safety Organisation for the purpose. The Director (Chemicals) was nominated as Member Secretary of the Committee. Representatives from the Ministry of Environment, Forest and Climate Change (MoEF&CC), Central Pollution Control Board (CPCB), industry and Alkali Manufacturers Association of India (AMAI) were appointed Members.

The Expert Committee took up the task of developing a document for the Indian industry as there is no reference guideline presently available. In developing this comprehensive guideline document, the Committee has relied on the Chlorine Institute's pamphlet on Chlorine pipelines and the Euro Chlor document on transportation of dry Chlorine gas by pipelines. The US and Europe have large volumes of Chlorine transported over long distances by pipelines for many years. The Expert Committee has attempted to address the peculiarities of the Indian conditions in this document.

This Guideline Document is intended to serve as a supplement to the provisions of the Manufacture, Storage and Import of Hazardous Chemical (MSIHC) Rules, 1989 in order to address the specific requirements of transportation of chlorine through pipelines outside the factory limits.

New Delhi

March, 2019

ACKNOWLEDGEMENT

The Expert Committee gratefully acknowledges the assistance received from The Chlorine Institute and Euro Chlor in the preparation of this document. The contents of this document are largely based on the following documents:

- The Chlorine Institute Pamphlet 60 (7th Edition) on Chlorine pipelines
- Euro Chlor document number GEST 73/25 (11th edition) on Transport of Dry Chlorine by Pipelines.

The information contained in the above documents were invaluable inputs for this publication.

The Expert Committee records its appreciation for the support provided by thyssenrupp Industrial Solutions (India) Pvt. Ltd. in sharing their expertise and preparing the draft guideline.

The Expert Committee expresses its gratitude to the following organisations whose support has enabled it to undertake a study tour to the chlorine pipeline site in Germany:

- Euro Chlor for facilitating a visit to the chlorine pipeline facility in Germany
- Akzo Nobel Industrial Chemicals GmbH – Caustic Soda Plant (now Nouryon Industrial Chemicals), Bitterfeld, Germany, for hosting a visit to their chlorine pipeline site
- ChemiPark, Bitterfeld-Wolfen, Germany for hosting a visit to their Chemicals Park and interacting with the visiting team
- thyssenkrupp Uhde Chlorine Engineers GmbH, Dortmund, Germany for sharing their experiences of liquid chlorine transfer through pipeline, presenting case studies and introducing their new electrolysis technology
- Alkali Manufacturers Association of India (AMAI) for coordinating the visit

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1. INTRODUCTION

1.1 SCOPE

- This document provides guidelines for the design, construction, operation and maintenance of Carbon Steel pipelines that transport dry Chlorine gas. The guidelines are applicable to pipelines that terminate outside the Chlorine producers' premises or cross premises not owned by the producer or consumer of Chlorine. However, this guideline may not be applicable for pipelines entirely within a plant; these are provided by the Chlor-Alkali technology supplier and/ or Chlorine plant designer.
- It is recognized that pipelines built prior to the publication of this edition of this document may be operating successfully without adhering to all guidelines contained herein. Designers of such facilities should evaluate discrepancies and validate to ensure they do not pose disproportionate risks to safe operation or the environment. Continued operation without adhering to all aspects of this document is generally acceptable provided
    1. Previous, successful, long-term operation, coupled with periodic hazard evaluations, show that risks to safe operation and the environment are sufficiently low
    2. The system does not violate applicable codes or regulations
    3. Consideration is given to modifying the system to meet guideline contained in this document when redesign or replacement projects are planned.

1.2 ABBREVIATIONS USED AND DEFINITIONS

AMAI	Alkali Manufacturers Association of India
ASME	American Society of Mechanical Engineers
ANSI	American National Standards Institute, Inc
API	American Petroleum Institute
BIS	Bureau of Indian Standards
CI	The Chlorine Institute
CCoE	Chief Controller of Explosives
CPCB	Central Pollution Control Board
DCPC	Department of Chemicals & Petrochemicals, GOI
DCS	Distributed Control System
Dry Air or Nitrogen	Air or Nitrogen dried to a dew point of (-)40° C or below measured at the operating pressure
EIA	Environmental Impact Assessment study
Euro Chlor	European Association representing producers of chlorine and its primary derivatives
ESD	Emergency Shutdown System
HAZAN	Hazard Analysis study
HAZOP	Hazard and Operability study
HAZID	Hazard Identification study
HDD	Horizontal Directional Drilling system
OSHA	Occupational Safety and Health Administration, U.S. Department of Labor
Operator	Chlorine Producer and Chlorine Consumer
PESO	Petroleum and Explosives Safety Organization
PTFE	Polytetrafluoroethylene
QRA	Quantitative Risk Analysis study
RA	Risk Analysis study
SCADA	Supervisory Control and Data Acquisition system
SIL	Safety Integrity Level study

1.3 APPROVAL

The Expert Committee has approved this Edition of the document on Transportation of Dry Chlorine Gas through Pipeline within Industrial Zone in its final meeting held on 1st March 2019 in New Delhi.

1.4 REVISIONS

This guideline may be taken up for reaffirmation once every two years.

However, changes /revisions can be undertaken as and when necessary.

Suggestions for revisions should be addressed to:

The Chief Controller of Explosives,
Petroleum and Explosives Safety Organisation,
Government of India,
CGO Complex, Seminay Hills
Nagpur 440 006
Maharashtra
Email: explosives@explosives.gov.in

2. GENERAL

2.1 BASIC CONSIDERATION

Chlorine is essential in the chemical industry and consequently there is a need for Chlorine to be produced, stored, transported and used. Chlorine can be transported safely by a long distance pipeline, either in the gas or liquid phase, provided the appropriate design and operating conditions is satisfied. All precautions should be taken such that, in a pipeline designed for the transport of dry Chlorine gas, nothing should lead to the formation of liquid or condensate. Specific precautions required for the same is described in this document.

- **GAS AND LIQUID PHASE CHANGES**

  Phase changes are generally most difficult to handle during start-up. Suitable steps must be taken in design and operation to ensure adequate control of the process temperature and pressure. It is essential that a study of operating conditions be thoroughly carried out, because unusual equipment design and pressure ratings may be required to address the potential for condensing in the pipeline.

  Dry Chlorine vapour introduced into a pipeline may expand, cool, and partially condense. When this happens, sudden pressure swings may occur in the line pressure. A phase change can also be caused by pipeline cooling due to ambient conditions. For pipelines exposed to ambient conditions lower than the process temperature, regulated electric heat tracing and/or insulation should be considered. Changes in ambient conditions can also cause a phase change.

  Pressure reduction points, such as pressure control or regulating valves are the most likely locations for phase changes in a pipeline. In gas pipelines the refrigeration effect of expanding Chlorine gas may cause a portion of the gas to condense into the liquid phase.

- **DESIGN CONSIDERATION**

  Suitable consideration of the consequences of a leak and suitable means of minimizing or handling leaks must be undertaken in the early stages of design.

- **DIAMETER OF PIPE LINE AND FLUID VELOCITY**

  It is preferred to select pipeline diameter so as to have gas velocity less than 20 m/s. This also depends on the length of the pipe line and pressure drop across the pipe

line. Possibility of condensation of gas due to pressure drop to be reviewed while selecting the pipeline diameter.

- **PIPE WALL THICKNESS**

  The minimum nominal wall thickness for pipeline shall be as per ASME B31.8.

  Higher thickness may be used if required to reduce stresses or for providing stability during installation and service.

2.2 ROUTING

While choosing a route for a pipeline, special consideration must be given to environmentally sensitive areas and avoid populated area. Minimise the public access as much as possible while routing a pipeline. Consideration should also be given to potential pipeline damage due to adjacent pipelines, soil conditions, traffic, vandalism, and other factors along the route. These considerations are especially important when the pipeline traverses ground not under direct control of either the producer or the consumer. Each case has to be treated appropriately and suitable studies to be conducted on case by case basis.

Pipeline shall be located and routed considering following aspects:

a. Pipeline should be installed in the notified industrial area / SEZ / Industrial zone located in PCPIRs
b. Pipeline hydraulic requirement
c. EIA, RA and QRA study for the pipeline
d. HAZOP, HAZID study and HAZAN Study for the pipeline
e. Approachability, water table, flood level and natural drainage
f. Habitation
g. Availability of electric power

The route for Chlorine pipe line should:

a. Provide the shortest and least complicated design, minimizing the Chlorine inventory in the line, while maintaining the ability to satisfactorily accommodate thermal movement
b. Provide the maximum protection to the pipeline from all risk of external damage (mechanical, corrosive, fire or explosion, etc.), whether such risk exists at the time of installation of the pipeline or is brought about by subsequent installations; potential

risks created by the proximity of other pipelines or high voltage electric cables should be controlled

c. Avoid, whenever possible, any risk of the normal line temperature being affected by an external source of high heat output, such as adjacent steam pipelines, pipelines containing flammable gases or liquids, etc. and if a high temperature risk exists the Chlorine line should be protected (physical isolation, fire resistant barrier, fire resistant insulation, etc.)
d. Allow sufficient access for inspection even though permanent facilities are not necessary
e. Consider potential risks from natural disasters like earthquake, flooding, storm, etc.

Marking visible at distance or colour-coding of pipes is recommended, particularly on pipe racks or pipe bridges where immediate access is not possible.

If the pipeline is above ground, it should be protected from any risk of mechanical damage such as falling objects, collisions, etc.

If the pipeline is laid in a pipe trench, it must be provided with sufficient support, together with drain provisions to remove water or possible corrosive liquids from the trench. The trench should also permit access for inspection of the pipeline. Any crossing which is unstable or susceptible to earth movement like land sliding, underground buried pipeline is not preferred.

It is recommended not to consider Chlorine pipeline for Seismic zone IV and V

3. BASIC DESIGN AND INSTALLATION

3.1 GENERAL DESIGN CONSIDERATIONS

The material selected for pipeline shall be suitable for handling of dry Chlorine gas. Possibility of condensation of Chlorine gas shall be considered while selecting the material for pipe line. For the minimum specifications for materials used in dry Chlorine gas service refer Annexure II – Piping Specification. Design specifications need to be determined based on the potential range of operating conditions of the pipeline system including start-ups, abnormal operating conditions, shutdowns, and system evacuation. In selecting materials careful consideration should be given to the minimum temperature to which any part of the system may be subjected. Additional cold service charpy testing as per ASME Code may be required if API Specification 5L piping is used. It should be noted that the boiling point of Chlorine at atmospheric pressure is -34°C. This is the temperature a pipeline may be subjected to when a liquid Chlorine pipeline is vented to atmospheric pressure. Refer Annexure I – Chlorine vapour pressure curve[1].

The maximum recommended temperature of any section of a carbon steel pipeline should not exceed 120°C in order to avoid Chlorine-Iron fire.

The designer should review and consider applicable regulations.

Points to be considered while design and operation of dry Chlorine gas pipeline system are as follows:

a. The pipeline to be designed in a manner that ensures adequate safety under all condition likely to be encountered during installation, testing, commissioning and operating conditions
b. The operating pressure to be considered which is technically achievable
c. The minimum ambient temperature and corresponding Chlorine vapour pressure shall be taken into account while defining the operating pressure in pipeline to avoid the condensation of gas. Associated hazard due to the same to be studied while designing and laying the pipeline. During winter the operating pressure and temperature are adjusted in such a way that no condensation is accrued due to low ambient temperature. For above ground pipeline, operating pressure should be $\leq$3 bar.g and for underground pipeline, operating pressure should be $\leq$5 bar.g.
d. Requirement of insulation / electrical heat tracing to be reviewed in order to avoid condensation / liquefaction of Chlorine. In case heat tracing to be provided, ensure

[1] From Chlorine Institute Pamphlet number 1

that at no point metal temperature shall exceed 120°C. For underground buried pipeline avoid insulation and heat tracing

e. If insulation to be provided, the material shall be non-flammable, chemically inert to Chlorine, totally sealed against ingress of moisture, protected against mechanical damage. Aluminium cladding shall not be used over the insulation as it is reactive with Chlorine, Galvanised Iron sheet / Stainless steel sheet / Cementing cladding to be chosen. The bare pipeline shall be coated with anti-corrosive painting before application of insulation

f. Design Pressure:
   - While estimating the wall thickness, following condition shall be taken into consideration;

     Maximum Operating Pressure + margin as per ASME B31.8 for design pressure + 1.5 mm Corrosion Allowance.
   - For dry Chlorine gas pipeline complete pipeline system should be designed for minimum pressure of 1.5 times maximum operating pressure.
   - In case possibility of condensation of Chlorine gas in pipeline, pipeline should be designed for a maximum operating pressure equivalent to vapour pressure of Chlorine at the maximum operating temperature chosen.
   - It is recommended to consider minimum 26 bar.g for pipeline design, even if calculated pressure from the above case is less than 26 bar.g

g. Design temperature of Chlorine pipeline to be considered based on maximum temperature being attained and minimum temperature possible in system. In case possibility of condensation of Chlorine in pipeline, the pipeline shall be designed for minimum temperature of -40°C

h. Adequate control of pressure and temperature to be ensured at producer's end

i. Evacuation plan for the quantity of Chlorine contained in the pipeline system

j. Material of construction for pipeline, valves, instruments suitable for handling the dry Chlorine gas. The metal used for the flanges, nuts, bolts shall be of same characteristics as that of pipeline

k. Minimum corrosion allowance of 1.5 mm should be considered.

l. Type of manual isolation valve and control valve suitable for handling the Chlorine

m. Pipelines may be installed above ground or below ground. The entire system should be evaluated to determine the preferred method

n. Consider isolation valve at producer end and at consumer end. If offsite isolation valves are required by risk modelling studies like QRA study, etc., they should be located and protected to prevent access by unauthorized persons. Preferably,

isolation valves should be located within an industrial site. It is imperative to also ensure that the evacuation system is available for the Chlorine inventory between the onsite isolation and offsite isolation valves

o. Intermediate flange is not recommended in order to avoid the leakage point
p. Site survey from public safety point of view
q. The pipeline should be protected from all risks of external fire or explosion, whether such risk exists at the time of installation of the pipeline or is brought about by subsequent installations
r. Suitable consideration of the consequences of a leak and suitable means of minimizing or handling leaks must be undertaken in the early stages of design
s. In case line is routed above ground, it is preferred to have Chlorine detector at regular intervals less than 60m distance away in order to monitor the pipeline leakage
t. Leak detection system like optical fibre can be considered for underground pipeline
u. For underground pipeline it is preferred to consider earth excavation monitoring system like “Perimeter Intrusion Detection System (PIDS)” to avoid uncontrolled excavation and damage of line due to excavation
v. Chlorine transfer equipment:
    - For gaseous Chlorine, the choice of compressor for feeding the pipeline system is a function of the characteristics required (throughput, operating pressure, maximum pressure). A non-return system should be installed on the downstream side of the compressor and particular attention must be paid to its reliability, the choice of an automatic valve is recommended
    - If the gas supply comes from vaporization of liquid Chlorine, and if the working pressure is high enough, it is possible to work without any additional transfer equipment
w. If two parallel Chlorine pipe lines need to be run then the gap between the two pipelines to be maintained as per good engineering practice or as per maintenance requirement, applicable for both underground and above ground pipe lines
x. All valves used for Chlorine service should be Euro Chlor designed and Euro Chlor certified valves.

3.2 INSTALLATION AND CONSTRUCTION

3.2.1 Design Considerations

Pipelines may be installed above or below ground. The entire system should be evaluated to determine the preferred method.

For gaseous Chlorine, a buried pipeline should be considered where operating conditions do not necessitate either heat tracing or thermal insulation to avoid risk of condensation; this means only in circumstances where the pipeline is operated at a sufficiently low pressure.

- It is easier to monitor an aboveground system, but overall safety considerations may indicate an underground pipeline is preferred. Underground piping should be installed in a dedicated concrete casing with sand fill or buried at a level below the normal frost line and not less than that required by regulation. Consideration should be given to burying the line deeper to prevent accidental impact and also allow for warning indicators to be buried/fixed above the pipeline. Refer Annexure – II & III for typical pipeline cross section.
- Special attention should be given to protecting the pipe from corrosion, especially at points where buried lines enter and leave the ground. Thick walls should be considered on Chlorine pipelines to allow for corrosion and provide mechanical strength. Use of thick walled pipe allows the pipeline to be used beyond the normal life of plant process piping. Pipeline should be designed for a life of minimum 25 years.
- Provision must be made to evacuate the Chlorine gas in the pipeline to a safe location. This includes an absorption system at producer and consumer ends of the pipeline. Capacity of Chlorine absorption unit to be decided based on capacity of Chlorine inventory to be evacuated and time required to evacuate the inventory, based on risk modelling studies like QRA study, etc.
- Where necessary to cross right-of-way, roadway, railway tracks, highway or waterway (river, drain/ channel [Nala] & Canal), the pipeline must be designed with sufficient protections such as height above grade to preclude vehicular damage or be installed below ground. When crossing navigable waterways, the pipeline should be buried well below the bottom so the line cannot be impacted by passing vessels or dredging activities. Open cut, Auger boring or HDD method can be used for such crossings.
- Underground piping can suffer third party damage due to poor excavation techniques. The design should consider means to reduce any major damage to the pipeline. Underground excavation monitoring system to be established.
- Design techniques that have been used should include increased depth of cover, increasing wall thickness, and concrete coating of the pipe.

- Vents and drains outside the supplier's or consumer's property should be avoided if possible. Vents, drains, or other small protrusions from main lines that must be installed should be protected from potential damage or tampering.
- Consideration should be given to underground line marking tapes to notify excavators of the existence of an underground line and/or SCADA fiber-optic alarm cable installed above the pipeline. (Refer Part V of Chapter III under Petroleum Rules, 2002).
- "Double walled pipe" or "Pipe in Pipe" construction to be considered for situations such as pipe section running above ground in populated area, casings under roads, railways crossing etc. In cases where double walled pipe is used, steps should be taken to prevent moisture accumulation in the annular space. In such case annular space to be padded with Dry Air or Nitrogen gas. Annular space pressure shall be monitored continuously in producer and consumer DCS.
- All pipelines should be well supported and supports should be capable of withstanding hydraulic forces that can result from starting and stopping flow.
- Leak detection systems are required. Consideration should be given to install an automated leak detection system on Chlorine pipelines. This could be something as simple as measuring mass flow on each end of the line or a leak detection system which employs both pressure analysis, temperature analysis and mass balance to verify the line is not leaking or Chlorine detection system at every 60 m for above ground portion or fibre-optic measuring method.
- Underground pipeline shall be provided with sufficient support, together with drain provisions to remove rain- and drain-water, or possible corrosive liquids from the trench. The trench should also permit access for inspection of the pipeline.

3.2.2 Welding

The welding of carbon steel pipelines must be performed in accordance with written welding procedures that have been qualified under Section IX of the ASME Code (11.4.2) or Section VI of API 1104 (11.5.1). Welders must be certified for each procedure. The welding has to be inspected by a third party.

If required by ASME B31.8, welds must be preheated and/or stress relieved.

3.2.3 Inspection and Test of Welds

Visual inspection of all welds is required. Non-destructive testing procedures must be used in accordance with ASME B31.8. This procedure includes radiography, dye penetrate, or other test methods recognized by ASME.

All butt welds are to be 100% radiographed. A combination of radiography and/or dye penetrate testing procedures should be used for all welds depending on the weld configuration. The weld area and pipe should be thoroughly cleaned after dye penetrate testing.

Radiographic techniques will identify many types of weld defects but are not fully effective for all weld configurations. Dye penetrate testing will sometimes locate weld defects including some not identified by radiographic techniques.

3.3 INSULATION AND LINE PROTECTION

3.3.1 Aboveground Piping – Insulation/Heat Tracing

The necessity to keep the Chlorine pipe line contents at the intended phase is the primary consideration in determining the need to insulate a system. Insulated pipes should have an appropriate exterior painting system similar to an uninsulated pipe. A reflective outer jacketing should be considered when covering insulated piping. This would reduce heat pick-up from ambient sources. Recommended insulation is polyurethane foam or foam glass block protected by an adequate outer fire resistant weather barrier.

3.3.2 Aboveground Piping – Fire / Heat Protection

Where the risks for elevated temperatures exist, including fire or any other undesirable heat source (e.g. hot vent streams, adjacent steam lines or combustible materials), the Chlorine line should be protected. The designer may consider physical isolation from other pipes in the pipe rack, erection of a fire resistant barrier between the lines, or insulation of the Chlorine line. Insulation in this case should be fire retardant material such as foam glass with a fire resistant barrier on the outside.

3.3.3 Buried Lines – External Protection

All new buried pipelines, as well as repairs to existing lines, must be coated and wrapped. All buried pipelines must be evaluated to determine the need and adequacy of cathodic protection. Special precautions to be taken where high voltage electrical cables are present. Any change to conditions along the route may require modifications to the external protection of the pipeline.

3.3.4 Electrical Isolation

Pipeline shall be installed such that the buried pipelines are not in electrical contact with any foreign piping system or other metallic structures. This shall not preclude the use of electrical bonds where necessary. In case any shorting is observed, suitable additional corrosion protection measures should be considered

Insulating devices shall be protected against induced voltage due to lightening or ground fault at nearby high-voltage electrical cable. Such protection can be achieved by providing surge diverter or grounding cell across insulating joints or other suitable grounding technique, etc.

3.4 HEAT TRACING OF CHLORINE GAS PIPELINE

According to operating pressures, the length of the pipeline and other ambient conditions, heat tracing and thermal insulation can be used to avoid condensation of the gaseous Chlorine. All precautions must then be taken to ensure the permanent availability of the heating system as long as the pipe is in operation and to avoid any localised overheating to prevent local corrosion or Chlorine-Iron fire.

If an electrical heating system is used, it should be equipped with self-limiting/self-regulating heat tracing cables which shall be attached to, but insulated from, the Chlorine pipe to avoid localized hot spots. The elements should be armoured and externally protected against corrosion and the ingress of moisture. The heating power should be calculated as a function of the thermal losses and not as a function of the heat input required to re-vaporize any Chlorine which may have condensed in the pipe work. An independent high temperature safety system will be foreseen; several temperature sensors could be used along the pipeline for alarm.

Electrical heat tracing installation should be designed to avoid overheating by suitable calculation of the heat density, so that at any point the metal temperature should never exceed 120°C, taking into account the worst possible climatic conditions.

3.5 MATERIAL FOR THERMAL INSULATION

The insulation materials to be applied for thermal insulation of Chlorine pipeline should meet the following criteria:

- Chemically inert to Chlorine
- Not flammable or combustible

For dry Chlorine gas, following insulation materials are used satisfactorily:

- polyurethane foams
- foam glass

Except for insulation material with closed cells, vapour barriers must be utilized to prevent the accumulation of moisture on the insulation of any insulated pipe that operates at temperatures below ambient temperature.

For the cladding used to protect externally the insulation layer and to prevent as far as possible ingress of water, several materials can be used, according to the local environment (coated carbon steel, plastic, resin, fibre reinforced resin, etc.). A sufficient spacing should be foreseen between cladding and the liquid barrier to avoid damaging this one.

For double wall pipes, no insulation will be installed in the inner space.

3.6 THERMAL PIPE EXPANSION

Provision must be made for thermal pipe expansion in the system. It is recommended that aboveground pipelines be designed utilizing stress analysis. If drains or vents are present, these must be taken into account when designing for expansion.

3.7 PROTECTION AGAINST OVERPRESSURE OF THE GASEOUS CHLORINE

To protect against over pressuring the pipeline, a pressure interlock or a relief device must be installed. These relief devices (bursting discs, relief valves or a combination of both) should always be connected to an absorption system or a point of use in the liquefaction. Overpressure protection relief devises should be calibrated periodically and should be replaced every 10 years.

3.8 VALVE LOCATION

Regulations sometimes require the use of valves at locations along a pipeline to minimize the consequences from accidental discharge. In balancing this against environmental concerns for fugitive emissions, which can occur at each valve location, and the possibility of blocking in a section of line, it is recommended that valves may be located at both ends of a pipeline i.e., inside supplier's and customer's locations.

If offsite isolation valves are required by risk modelling studies like QRA study, etc., they should be located and protected to prevent access by unauthorized persons. Preferably,

isolation valves should be located within an industrial site and also ensured that the evacuation system is available for the Chlorine inventory between the onsite isolation and offsite isolation valves

Isolation valves may be closed manually, remotely and/or automatically when a leak is detected. For automated remotely activated valves, valve position should be monitored. Remote operated valves require an energy source to close and should be equipped for manual as well as automatic operation.

3.9 VENT AND DRAIN BRANCHES

The use of vent and drain branches in a Chlorine pipeline should be limited to the minimum number necessary for operation. Branches increase the risk of a leak and are difficult to insulate, allowing a location for corrosion to initiate.

Vents and drains should be located inside the producer's or consumer's plant site.

4. MARKING

4.1 LINE MARKERS

Underground pipelines should be provided with aboveground markers at public road crossings, at railway crossings with sufficient number along the pipeline so that its location is accurately known to reduce the possibility of damage or interference. Above ground pipelines should be provided with markers over long sections of the pipeline that are in areas accessible to the public. The markings may be made using a combination of pictorial representation and wordings. Pipeline marking shall be as per local regulation, if applicable.

4.2 LINE MARKER WORDING

The wording on the line marker should be "WARNING – CHLORINE GAS UNDER PRESSURE" and should include the name of the Producer and Consumer and contact details like telephone numbers where the third party can be reached at all times. The wordings should be in local state language, Hindi and English.

5. PREPARATION FOR USE

Information specific to preparing Chlorine pipelines for use is listed in this document.

5.1 PRESSURE TESTING

Chlorine Gas Piping

New, relocated or replaced Chlorine gas pipelines and modified sections of existing gas pipelines are to be pressure tested in accordance with ASME B 31.8 until all leaks have been located and eliminated. Process piping testing requirements should be applied as a minimum standard. There are two types of acceptable testing methods: hydrostatic testing and pneumatic testing. Following hydrostatic testing, it is essential that Chlorine pipeline systems be thoroughly dried prior to service.

Dry Air or Nitrogen may be used as a test medium. The operation of a Chlorine gas piping system, tested in this manner, may be limited to lower stress conditions. Care should be taken to limit personnel exposure while conducting tests with these media.

5.2 CLEANING

The aqueous and abrasive cleaning methods are most commonly used on large pipelines. The solvent cleaning method is not normally used for cleaning Chlorine gas pipelines because of the need to address the environmental and industrial hygiene risks associated with most solvents. If moisture is introduced into a pipeline, all moisture absorbing gaskets and valve packing should be replaced. Consideration should be given to removing valves prior to introducing moisture.

The preferred method for removal of dirt, weld spatter, Chlorine, etc. from a Chlorine pipeline is with a pig. Pigging in the context of pipelines refers to the practice of using devices known as "pigs" to perform various maintenance operations. These operations include but are not limited to cleaning and inspecting the pipeline. In this system of cleaning a pig is forced through the pipeline by Dry Air or Nitrogen pressure.

If a pigging system will be used for cleaning or if a smart pig will be used for inspections, the following features should be included at a minimum. Additional features may be required for use of pigs or smart pigs:

- Radius of curvature must allow passage
- Pig catcher at one end and a launcher at the other

- Guide bars in piping tees

5.3 DRYING

Chlorine piping systems must always be dried before being placed in service. Even if water has not been purposely introduced into the system for hydrostatic testing or cleaning, drying is required because moisture may enter the system from the atmosphere or other sources. The purge gas flow should be started at high volume rates to sweep the moisture out of the piping system, and then reduced. The system should be dried until the entire vent gas streams leaving have a -40°C dew point, measured at normal system operating pressure, or reasonably close to the entering purge gas dew point.

The purge rates should be at an absolute minimum, allowing adequate time for the purge gas to reach equilibrium when the dew point is taken.

5.4 TESTING FOR LEAKS

Leak testing should be done once the piping system is completely assembled. The purpose of a leak test is to ensure all connections and components will not leak Chlorine when pressurized. Leak testing is not a substitute for pressure testing. If the system was not disassembled and reassembled as part of the pressure testing and drying process, the Nitrogen/Dry Air test (i.e. Step 1) may be omitted.

- Step 1

Pressurize the system to 110% of design pressure with Dry Air or Nitrogen. Use a soap solution to test for leaks at joints.

- Step 2

Introduce Chlorine gas into the system and raise the pressure to approximately 0.2 bar.g.

- Step 3

Test the system for leaks with aqua Ammonia. Care must be taken that Chlorine has diffused throughout the piping system before leak checking with Ammonia. The reaction of ammonia vapour with escaping Chlorine forms a dense white cloud. The most convenient way to use ammonia for this purpose is to direct the vapour from a plastic squeeze bottle containing 26 degree Baume' aqua (ammonia solution) at the suspected leak. Do not squirt liquid aqua ammonia on pipe fittings.

Never attempt to repair leaks by welding until all Chlorine has been purged from the system. When detectable leaks have been repaired, the line should be retested by

repeating Step 3. Any effort to detect the source of a leak should be carried out with full consideration for potential hazards. Appropriate protective equipment must be used.

- Step 4

Slowly increase the Chlorine pressure and continue to check for leaks at several intermediate pressures until the operating pressure is obtained. If leaks are detected, repairs should be made and step 4 continued until the operating pressure is achieved.

6. OPERATION AND MAINTENANCE GUIDELINES

6.1 GENERAL

The pipeline operator, the person who is operating the pipelines, must have procedures for the operation and maintenance of Chlorine pipelines. For new pipelines, the procedures must be prepared before the start of pipeline operation. Persons handling/ operating the pipeline must be trained.

The procedures must include start up, shutdown, normal operation, abnormal process operations, maintenance and inspection procedures, and address procedures to be used in case of emergencies.

The procedures must be reviewed and updated once per calendar year and kept at locations where operations and maintenance activities are conducted.

6.2 OPERATION GUIDELINES

6.2.1 Before placing a pipeline in service ensure the following:

a. Clean the line and ensure it is free of oil and grease. Chlorine will react vigorously with hydrocarbon-based lubricants.

b. Dry the line with oil-free Dry Air or Nitrogen.

c. Leak test of pipeline

d. Check on the quality of Chlorine introduced, especially the concentration of Hydrogen in Chlorine and moisture in Chlorine

e. Purge of the pipeline with Chlorine gas to eliminate all inert before putting it under pressure.

6.2.2 During Operation

a. The line should be maintained at conditions that ensure the proper state to avoid condensation at all times

b. Only dry Chlorine gas should be introduced into carbon steel pipelines

c. Operating data should be obtained and continuously evaluated to assure the integrity of the system

d. Proper precaution to be taken at producer end to avoid liquid Chlorine ingress into the gas line. A liquid Chlorine trap with temperature sensor can be considered immediate after evaporation of liquid Chlorine.

6.2.3 Removing Pipelines from Gaseous Chlorine Service

a. Special attention is required during transient phases and shut down operations

b. Reduce line pressure and flow to ensure that the gaseous state is maintained. The design must be such that Chlorine gas can be vented into a suitable installation (absorption unit or compression and liquefaction plant of adequate capacity). All equipment associated with the operation, therefore, should be suitable for the actual temperatures which will arise.

c. If line is to be emptied, isolate the pipeline. If works have to be performed on the pipeline, or if the duration of the shutdown is too long to guarantee a correct continuous surveillance, the electric heat tracing, if any, will be kept off, and the Chlorine in the pipeline will be replaced by Dry Air or Nitrogen, venting and purging towards absorption unit. This operation should be continued until the residual Chlorine content within the system permits its opening or dismantling without risk of corrosion or exposure of personnel to gas.

d. For a few hours' shutdown of a gaseous Chlorine pipeline, the internal pressure should be lowered; the pressure may not fall below atmosphere to avoid Air ingress but, whenever possible, stay below the Chlorine vapour pressure corresponding to the pipeline temperature, to prevent the risk of liquefaction; before restart, all efforts must be made to confirm the absence of any liquid phase Chlorine.

6.2.4 Purging

- Dry Air or Nitrogen of adequate quality, quantity and pressure should be permanently available. All precautions should be taken to avoid contamination by oils, grease or other contaminants that could react with Chlorine.
- The system will be designed to avoid back flow from Chlorine side to the Dry Air or Nitrogen gas network; this can be realised by dedicated purging system, if its pressure is at least 2 bar g higher than the maximum pipeline pressure, or a backflow protection.
- Purged gas should be passed through an absorption unit to remove Chlorine, before being vented to atmosphere.

6.3 MAINTENANCE GUIDELINES AND PRECAUTIONS

For all maintenance operations the pipeline shall be isolated upstream and downstream by the installation of blind flanges, or the removal of a spool piece provided for this

purpose. However, the pipeline should not be left open to moist atmosphere to prevent corrosion, the $FeCl_3$ layer will attract moisture and become corrosive liquid

6.3.1 Welding

Do not attempt to repair Chlorine piping by burning or welding until all Chlorine and traces of Chlorine-associated residues have been purged from the system. Burning or welding can cause carbon steel to react rapidly with Chlorine and even burst into flame. Hot work of any kind must not be performed on an in-service Chlorine pipeline. After hot work, lines should be cooled prior to introduction of Chlorine, Refer to Section 3.2 for welding guidelines.

6.3.2 Moisture

Every effort should be made to prevent the introduction of moisture into a dry Chlorine gas piping system. Pipelines not in service should be sealed, dried, and padded with Dry Air or Nitrogen. Wet Chlorine is very corrosive to carbon steel piping. “Moisture in Chlorine” analyser shall be installed to check moisture content in Chlorine gas.

6.3.3 Lubricants and Seals

All materials used as lubricants, greases, packing, seals and gaskets must be nonreactive with Chlorine. Chlorine will react vigorously with hydrocarbon based lubricants.

Fluorocarbon grease may be used as a gasket dope but care should be taken to ensure it will not degrade the gasket. Where thread dope is used, care must be taken to prevent the material from entering the piping system. Thread dopes may include PTFE tape, PTFE paste, white lead paste, litharge and glycerine. Special Chlorine compatible lubricants are used in the assembly of valves for Chlorine service.

6.3.4 Protective Coatings

The integrity of protective coatings on pipelines must be preserved. Corrosion under insulation may damage Chlorine piping, particularly if it is subjected to freeze-thaw cycles. Any damage to the coating should be promptly and completely repaired.

6.3.5 Valves

Each valve necessary for the safe operation of the system shall be inspected and operated in accordance with manufacturer’s instructions and applicable regulations.

7. INSPECTION, TESTING, AND MONITORING

7.1 GENERAL

Due to the characteristics of Chlorine, the guidelines listed below are in some cases more rigorous than those required by regulation. The producer / consumer shall have written procedures for inspection and surveillance. All activity must be documented to verify adherence to procedures as required by regulation.

List of critical activities with respect to pipeline inspection, testing and monitoring to be followed as per following table:

Sr. No.	Critical Process or Activity	Recommended time period
1	100% Radiography of pipeline	After erection / after any pipeline modification
2	Pneumatic Testing of pipeline	After erection of pipeline / after any modification / once in two year
3	Corrosion testing of pipeline or thickness checking	Once in a year
4	Pipeline cathodic protection record	Every month
5	Pipeline as built record review	Once in a year
6	Pipeline, valves visual survey	Once in a week
7	Dew point check record	Before start up / after maintenance
8	Insulation record / Electric heat tracing	Every month
9	External painting record	Every month
10	Underground trench inspection	Once in a week
11	Underground marking record	Once in 2 month
12	Instrument calibration like Cl_2 detector Flow meter, temperature transmitter, etc.	Every month Once in a year
13	Safety valve calibration	Once in a year
13	Leak detection system record	Every month

7.2 CONTINUING SURVEILLANCE AND DAMAGE PREVENTION

There should be an on-going pipeline surveillance program. Information should be recorded and evaluated to determine the condition of the pipeline and to schedule needed repairs. Operators of gas pipelines must be aware of, and comply with, the rules for pipeline integrity.

For buried pipelines outside the physical confines of the producer's / consumer's facility, a damage prevention program should be maintained. Public education may be required regarding the same.

7.3 PATROL

The pipeline, pipeline right-of-way and underground trenches should be surveyed visually 24x7. The survey should be by pedestrian patrol, vehicular patrol, aircraft patrol or any appropriate method as best suited by the routing of the line. The inspector should look for leaks, vegetation kills, or impending excavation or construction or water accumulation in trenches that could damage the pipeline.

7.4 MONTHLY INSPECTION

The pipeline should be inspected for insulation, electric heat tracing, painting, cathodic protection, instrument calibration, leaks, damage, or serious external corrosion each month. On underground pipelines, the cathodic protection (voltage, protection rectifier, reverse current switches, and interference bonds) should be inspected and preventive maintenance performed every two months.

7.5 BI-MONTHLY INSPECTION

Underground pipeline shall be inspected for visibility of marker board, content on the board etc. once in two months.

7.6 VALVE INSPECTION

Valves necessary for the safe operation of the system should be inspected and partially operated at intervals not exceeding 6 months.

7.7 ANNUAL INSPECTION

An inspection should be conducted every calendar year that includes the following:

- Ultrasonic testing of wall thickness at pre-specified points. These points should be defined and maintained throughout the lifetime of the pipeline.
- Safety valve calibration
- Verification of calibration and operability of inspection equipment.

7.8 CONTINUOUS OVERLINE CATHODIC PROTECTION SURVEY

For underground lines with cathodic protection applied, a continuous over line cathodic protection survey should be conducted once every five years to determine the level of uniformity of cathodic protection.

8. MATERIALS OF CONSTRUCTION

All the materials used have to be compatible with Chlorine in the design conditions. The materials and equipment should be obtained from approved suppliers with a documented quality assurance procedure. Refer Attached Annexure II – Piping Specification.

8.1 PIPING

The carbon steel chosen for the construction of the pipe work should be of a certified quality, fine grain steel and readily wieldable. Seamless pipe is preferred.

The metal used in branches and other pieces welded to the pipe should be of a quality compatible with the base metal chosen for the pipe itself. It is advisable to choose a quality of carbon steel which avoids the need for stress relief after welding.

8.2 FLANGES, NUTS AND BOLTS

The metal used for flanges, nuts and bolts should possess the same characteristics as that of the piping.

8.3 GASKETS

The gasket used should be made of material compatible with Chlorine. No grease which is not compatible with Chlorine shall be used.

The mounting of the gaskets should be performed by well-trained people; only new gaskets should be used.

The stress relaxation resistance of some gaskets decreases with increasing thickness. It is therefore recommended that gaskets be fitted inside the bolt circle and should have thickness compatible with the flange rating. Under no circumstances should gasket contact surfaces be machined in a manner that leaves tool marks extending radially across the seating surface.

Where spirally wound gaskets using metal windings and a Chlorine compatible filler material are used, care should be taken to ensure that the flange faces are machined to

the joint manufacturer's recommended standard and that the mating flanges are similar, i.e. of the same material and surface finish.

Jointing compounds are not recommended and paste should not be used with spiral wound, or PTFE gaskets under any circumstances. However, when paste is used for flanged joints which have to be broken and remade frequently for process or maintenance reasons, care should be taken to ensure that the paste is:

- Compatible with Chlorine
- Compatible with the gasket material
- Used sparingly and is not forced into the bore of the pipe.
- Spread evenly over the joint surface.

9. SUPPORTS

The supports of the pipeline should permit the thermal expansion/ contraction of the pipeline due to any likely variations in temperature, taking into account the maximum and minimum achievable temperatures. They should also deal with any possible earth movement. For above ground pipelines, it is preferable to use large radius expansion loops.

Expansion bellows should not be used because they may be weak points in the construction, unless a detailed study proves adequacy. For straight lines, where free expansion cannot take place, account must be taken of the longitudinal stresses which will result from the maximum variation in temperature. The support system should be designed to avoid any ingress of moisture under the thermal insulation, where fitted.

9.1.1 Buried Pipeline

If the terrain to be crossed is unstable or susceptible to movement, a pipeline should not be buried in the ground.

9.1.2 Pipelines Above-Ground or in Trenches

The supports should be fixed on foundations, which provide adequate rigidity. They should be insulated from the pipe with a mechanically robust material, which also provides adequate thermal insulation to avoid frosting on the support, leading to external corrosion.

10. EMERGENCY PLANNING

10.1 EMERGENCY CONTROL PLAN

Each pipeline operator will have written procedures to minimize the hazards resulting from a Chlorine pipeline emergency.

Pipeline operators must comply with requirements of The Chemical Accidents (Emergency, Planning, Preparedness and Response) Rules 1996 and participate in "Chlorine Emergency Response Network (Guide for Chlorine Consumers & Transporters)"

The emergency control plan must be able to reach all areas affected by any pipeline emergency. The pipeline operator should establish a continuing education program on emergency procedures to enable operators, customers, the public and appropriate organizations (police, fire) to recognize a pipeline emergency. It is also necessary to involve the State Disaster Response Force (SDRF) and integrate the emergency control plan into the SDRF module.

A Community Awareness and Emergency Response (CAER) system should be established at each plant location in cooperation with the Local Crises Group in that area for the purpose of alerting the public to a potential release of Chlorine. This system should provide for notification of all individuals within the predicted area of exposure to allow those persons to evacuate or to prepare to stay indoors until the danger has passed as per The Chemical Accidents (Emergency, Planning, Preparedness and Response) Rules 1996.

10.2 EMERGENCY PLAN IN CASE OF PIPELINE LEAK

Provision shall be kept to isolate the pipeline both at producer end and consumer end in case leak detected. It is also recommended to keep provision to isolate the pipeline by remote operated shut-off valves during emergency. The pipeline after isolation can be evacuated by opening shut off valve to Chlorine absorption unit. It is recommended to have Chlorine absorption unit at producer end as well as at consumer end. Capacity of Chlorine absorption unit can be decided based on capacity of Chlorine inventory to be evacuated and time required to evacuate the inventory is based on risk modelling studies like QRA study, etc. Isolation of pipeline and evacuation of pipeline shall be carried out from DCS or via dedicated SIL certified Emergency Shutdown System (ESD), manual operation is not recommended. In case of pipeline rupture or major leak, communication to be established with SDRF for emergency plan implementation.

10.3 SECURITY

Needs for security should be developed with local, state and central agencies.

10.4 PERSONNEL QUALIFICATION

Each pipeline operator should have a written qualification program for individuals who perform operational, inspection and maintenance tasks on pipelines. This includes record keeping and emergency response training. Operators should have qualification as required by local, state, and/or central regulations.

11. RECORDKEEPING

11.1 DESIGN AND INSTALLATION

Drawings, specifications, construction records, pressure test records, cathodic protection system details, maps, material verification, and modification records, etc. should be kept up-to-date by the producer / consumer for the life of the pipeline. These should be kept where operation and maintenance activities are being conducted.

11.2 PIPELINE OPERATION

A manual of written procedures for operation of the pipeline must be prepared, made available and kept updated by the producer / consumer. For the operating life of the pipeline, training programs for the pipeline facility operating personnel should be maintained and updated, as necessary. At least once each calendar year, the performance of operating personnel should be reviewed and it should be verified that operating supervisors maintain a thorough knowledge of their responsibilities. Record of operating history must be maintained. An emergency control plan with written procedures should be established as detailed in section 7.

11.3 PIPELINE MAINTENANCE

A manual of written procedures for operation of the pipeline must be prepared, made available and kept up-to-date. For the life of the pipeline, maintain records of inspections, tests, investigation, repairs and modifications of the pipeline. These records should also include information on line patrols, leak surveys, actual leaks and instances of maintenance line breaks.

11.4 RECORD RETENTION PERIOD

All records pertaining to pipeline operation and maintenance should be kept for minimum 10 years.

12. ACCIDENT REPORTING AND ANALYSIS

- Accidents of Gas Pipeline facilities have to be reported as per Codes of Practices for Emergency Response and Disaster Management Plan
- All accidents have to be reported to respective State Director of Factories, local authorities and State Pollution Control Boards.
- A Root Cause Analysis is to be done for all accidents and learning from incidents shared with all operating and maintenance personnel

13. ANNEXURES

- Annexure I Chlorine vapour pressure curve
- Annexure II Piping Specification
- Annexure III Typical aboveground pipeline section
- Annexure IV Typical underground pipeline section

14. APPLICABLE RULES

Transportation of Chlorine is governed by following rules:

- The Chemical Accidents (Emergency, Planning, Preparedness and Response) Rules, 1996
- Manufacture, Storage and Import of Hazardous Chemicals Rules, 1989
- Factories Act, 1984
- The Public Liability Insurance Act, 1991
- The Environment (Protection) Act, 1986
- Static and Mobile Pressure Vessel (SMPV) Rules, 1981

15. BIS STANDARDS

- IS 646 – Liquid Chlorine purity
- IS 2379-1963 – Colour code for identification for pipelines
- IS 4263-1967 – Code of Safety for Chlorine
- IS 8867 – Hydraulic Stretch Test – test pressure
- IS 5844 – Hydrostatic stretch test – Procedure (welded cylinder)

16. REFERENCES

A. The Chlorine Institute Documents

Pamphlet	Title
1	Chlorine Basic Edition 7 Pamphlet 1; The Chlorine Institute: Arlington, VA, 2008
6	Piping System for Dry Chlorine, Edition 16 Pamphlet 6; The Chlorine Institute: Arlington, VA, 2013
60	Chlorine Pipelines; The Chlorine Institute: Arlington, VA, 2013
64	Emergency Response Plans for Chlor-Alkali, Sodium Hypochlorite and Hydrogen Chloride Facilities, Edition 6 Rev. 1 Pamphlet 64; The Chlorine Institute: Arlington, VA, 2008
95	Gaskets for Chlorine Service, Edition 4 Pamphlet 95; The Chlorine Institute: Arlington, VA, 2008
100	Dry Chlorine Behaviors of Moisture in Chlorine and Analytical Issues, Edition 4 Pamphlet 100; The Chlorine Institute: Arlington, VA, 2011
164	Reactivity and Compatibility of Chlorine and Sodium Hydroxide with Various Materials, Edition 2 Pamphlet 164; The Chlorine Institute: Arlington, VA, 2007

B. Euro Chlor Documents

Standard	Title
GEST 10/362	Corrosion Behavior of Carbon Steel in Wet and Dry Chlorine, 2nd Edition, 2013
GEST 73/25	Transport of Chlorine by Pipeline Outside site boundaries, 11th Edition, 2014
GEST 79/82	Materials of Construction for Use in Contact with Chlorine, 11th Edition, 2013
GEST 80/84	Commissioning and Decommissioning of Installations for Dry Chlorine Gas and Liquid, 6th Edition, 2013
GEST 87/133	Overpressure Relief of Chlorine Installations, 5th Edition, 2012
GEST 92/176	Chlorine Emergency Equipment, 2nd Edition, 2004
GEST 93/179	Emergency Intervention in case of Chlorine Leak, 8th Edition, 2003
GEST 94/216	Experience of Gaskets in Liquid Chlorine and Dry or Wet Chlorine Gas Service, 4th Edition, 2013