EURO CHLOR

REPRESENTING THE CHLOR-ALKALI INDUSTRY

TRANSPORT OF CHLORINE

BY LONG DISTANCE PIPELINE

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Euro Chlor

Euro Chlor is the European federation which represents the producers of chlorine and its primary derivatives.

Euro Chlor is working to:

- improve awareness and understanding of the contribution that chlorine chemistry has made to the thousands of products, which have improved our health, nutrition, standard of living and quality of life;
- maintain open and timely dialogue with regulators, politicians, scientists, the media and other interested stakeholders in the debate on chlorine;
- ensure our industry contributes actively to any public, regulatory or scientific debate and provides balanced and objective science-based information to help answer questions about chlorine and its derivatives;
- promote the best safety, health and environmental practices in the manufacture, handling and use of chlor-alkali products in order to assist our members in achieving continuous improvements (*Responsible Care).*

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Prior to 1990, Euro Chlor's technical activities took place under the name BITC (Bureau International Technique du Chlore). References to BITC documents may be assumed to be to Euro Chlor documents.

RESPONSIBLE CARE IN ACTION

Chlorine is essential in the chemical industry and consequently there is a need for chlorine to be produced, stored, transported and used. The chlorine industry, conscious of the hazardous nature of its operations, has co-operated over many years to ensure that its activities cause the minimum harm to the well-being of its employees, local communities and the wider environment. This document is one in a series which the European producers, acting through Euro Chlor, have drawn up to promote continuous improvement in the general standards of health, safety and the environment associated with chlorine manufacture in the spirit of *Responsible Care*.

The recommendations, techniques and standards presented in these documents are based on the experiences and best practices adopted by member companies of Euro Chlor at their date of issue. They should be taken into account in the operation of existing processes and in the design of new installations. They are in no way intended as a substitute for the relevant national or international regulations which should be fully complied with.

It has been assumed in the preparation of these publications that the users will ensure that the contents are relevant to the application selected and are correctly applied by appropriately qualified and experienced people for whose guidance they have been prepared. The contents are based on the most authoritative information available at the time of writing and on good engineering, medical or technical practice but it is essential to take account of appropriate subsequent developments or legislation. As a result, the text may be modified in the future to incorporate evolution of these and other factors.

This edition of the document has been drawn up by the Transport Working Group to whom all suggestions concerning possible revision should be addressed through the offices of Euro Chlor.

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1 DEFINITIONS

This code concerns the transfer of dry chlorine by long distance pipelines. These are defined as pipelines longer than 1000 metres and passing, in general, outside the limits of the factory premises of a chlorine producer and/or a chlorine consumer.

2 GENERAL STATEMENTS

Chlorine can be transported safely by a long pipeline, either in the gas or liquid phase, provided the appropriate design conditions are satisfied. All precautions should be taken such that, in a pipeline designed to carry liquid chlorine, vaporisation cannot occur, and in a pipeline designed for the transport of chlorine gas nothing should lead to the formation of liquid. In each case, specific precautions are required. These are covered by two separate sections within this code.

2.1 Liquid phase

The design and operation of liquid phase pipelines is subject to the following limitations and conditions:

- The maximum transfer pressure which is technically achievable.
- The temperature and pressure of the chlorine at the inlet and exit of the pipeline in order to ensure continuity of phase.
- A maximum linear velocity.
- Total pressure drop.
- Quantity of chlorine contained in the pipeline may conflict with individual and societal risk contours.

These limitations determine the length and throughput of a particular pipeline system, because it is preferable to avoid the location of pumping stations outside the confines of a chlorine-producing or consuming factory. In Europe, there are many years experience of liquid phase pipelines up to a length of about 8 km with inlet pressures up to about 30 bar absolute.

2.2 Gaseous Phase

The design and operation of gas phase pipeline systems are subject to the following limitations and conditions:

- The maximum inlet pressure technically achievable.
- The risk of liquefaction associated with either the operating pressure or a fall in temperature.
- The maximum temperature of the trace heating system in all circumstances, particularly in the event of zero flow.

- The total pressure drop.
- The quantity of chlorine contained in the system.

In Europe, there are many years experience with gas phase pipelines up to a length of 4 km and with inlet pressures up to 5 bar absolute.

2.3 Choice of Phase

The choice of phase is determined by the requirements of the user plants and by safety considerations.

3 LIQUID PHASE PIPELINES

3.1 Basic Design and Installation

The pipeline should be protected from all risks of external fire or explosion, either where such risk exists at the time of installation of the pipeline or is brought about by subsequent installations. All other external risks to the pipeline should also be avoided, for example due to the proximity of another pipeline or of high-tension electric cables. If the pipeline is an above-ground installation and capable of inspection, it should be protected from any risk of mechanical damage such as falling objects, traffic etc. Where the pipeline passes through a pipetrench, it should be provided with sufficient support above the ground, together with drain provisions to remove rain - and drainwater or other corrosive liquids from the trench. The trench should also permit access for inspection of the pipeline.

The use of buried pipelines can be the most reliable depending upon local circumstances, and in many cases this will be the preferred solution. Where this is the case, the route of the pipeline should be well indicated at the surface, and it should be protected against any unauthorised excavation, by some form of below ground indicator (for example concrete slabs marked "buried pipeline").

Dividing a pipeline for liquid chlorine into smaller segments, by automatic valves, in order to improve safety is not recommended. Such valves represent a weak point in the construction of the pipeline to which must be added the risk arising from the trapping of liquid chlorine between two closed valves and its possible thermal expansion thereafter. It is necessary, therefore, to avoid such isolation valves outside the confines of industrial premises if this is possible.

The need for rapidly closing isolation valves along the length of the pipeline is related to the length and to the quantity of chlorine held up in the pipeline. For safety considerations, this quantity should be related to the location of the pipeline.

3.2 Construction

3.2.1 Basis of Design

Design Pressure

The complete pipeline system should be designed for a maximum operating pressure equal to the vapour pressure of chlorine at the maximum operating temperature chosen, plus a safety margin above this determined by factors such as the magnitude of possible liquid hammer effects, pressure drop, the piping layout, the delivery pressure of the pumping system, the maximum pressure in the feed tank etc.

Design temperature

The design temperatures should be in all cases the most severe temperatures - lowest and highest- expected in service. The selected - minimum design temperature should be less than the minimum operating temperature, and less than the boiling point of chlorine at 1013 bar absolute, i.e. -34°C, in order to allow for conditions arising on venting down the pipeline or on purging by inert gas when evaporation can create temperatures below -40°C.

Liquid velocities

The velocity of chlorine in the pipeline should be limited to 2 metres per second, which is the maximum to avoid destruction of the protective film of ferric chloride by erosion. For very long pipelines, a lower velocity e.g. 1 metre per second may be chosen to reduce energy consumption in pumping. The prevention of flashing at any point is essential to avoid high two-phase velocities which can cause serious erosion.

Corrosion Allowance

A minimum corrosion allowance of 2 mm is recommended.

Radius of Curvature

Even where there is no intention to use a "pig", the radius of curvature should always be greater than 3 to 4 diameters.

Thermal Insulation

Thermal insulation is only employed for an above-ground pipeline in order to avoid external water condensation, frosting or possibly fire radiation. In the case of a buried pipeline, external thermal insulation must not be used, in order to avoid the risk of corrosion brought about by reduction of the cathodic protection.

Materials of construction

Piping

The steel chosen for the construction of the pipework should be of a certified quality, fine grain steel readily welded and with a satisfactory impact strength according to the standards being used, at -40°C after welding. The metalused in branches and other pieces welded to the pipe should be of a quality compatible with the base metal chosen for the pipe itself.

Flanges, Nuts and Bolts

The pipeline should be completely welded with only flanges at the beginning and the end. The materials of the flanges, nuts and bolts should possess the same characteristics as that of the piping. Weld neck flanges should be used for all flange connections. The flanges should be designed on the basis that the gasket cannot be expelled (e.g. male/female or tongue and groove type).

Gaskets

The gasket used should be of compressed asbestos fiber (CAF) or alternative material, see GEST 92/169 –Guidelines for the Safe Handling and Use of Chlorine, for further information.

Thermal Insulation

If the installation of thermal insulation is necessary the materials to be applied should meet the following criteria:

- Non-flammability
- Chemically inert to liquid or gaseous chlorine
- Totally sealed against the ingress of moisture
- Protected against mechanical shock.

The materials which correspond best to these criteria are, in general, expanded silica, diatomaceous earth, foam glass and vapour seal polyurethane (non-flammable or auto-extinguishing). Preventing the ingress of atmospheric moisture necessitates the choice of a closed pore structure material, or provision of a high quality external gas-tight wrapping.

❖ Supports

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

Above-ground Pipelines
The supports should be fixed on foundations, which provide adequate rigidity taking account of hydraulic hammer effects. The y should be insulated from the pipe with a mechanically robust material, which also provides adequate thermal insulation to avoid frosting on the support. The supports should permit the thermal expansion of

the pipeline due to any likely variations in temperature, and should also deal with any possible movement of the earth. The support system should be designed to avoid any ingress of moisture under the thermal insulation.

3.2.2 Stress Relief

It is advisable to choose a quality of steel which avoids the need for stress relief after welding.

3.3 Inspection and Testing

3.3.1 Inspection of Piping Materials

Piping materials should be tested to ensure conformity with the quality requirements of national or international codes such as, for example:

- Iso 404 1992 (General code)
- DIN - 17173 (seamless)
- DIN - 17174 (welded)

These tests are particularly important where they relate to the impact strength of the metal before and after welding. The material of the flanges and blanks, nuts and bolts, welds should also be subjected to inspection according to standards consistent with those indicated above.

3.3.2 Inspection procedures During Construction

In order to guarantee a fault-free construction, the inspection procedures should follow the required codes rigorously, and as a minimum should encompass the following points:

- 100% radiography of the welds
- Tests of tensile, bending and impact strength, of reference and welded test pieces.
- Thickness control.
- Certification of welders and of their methods of welding.
- Crack testing by dye penetrant and halogen leak testing before laying of the pipeline.
- Hydraulic pressure test at least at 1.5 times the maximum operating pressure after the laying of the pipeline.
- A leak test after the pipeline has been laid.

The quality of construction is considered to be the most important safety consideration.

3.4 Accessories

3.4.1 Flanges, Branches and Ancillary Equipment

The number of flanges and branches should be limited to the minimum strictly necessary. Their location in parts of the main which are below ground should be avoided. If this cannot be avoided they should be placed in an inspection chamber, and should be accessible to personnel wearing protective clothing. Large diameter branches should be fitted with guide bars if the pipeline is to be treated by "pigging".*

3.4.2 Valves and Isolation

The material of the valves should be compatible with that of the pipe. They should conform to recommendations of Euro Chlor. Refer to the following codes for further information:

- GEST 83/140 - Specification for Vertical Globe Valves for Use with Liquid Chlorine
- GEST 90/150 – Specification for Flanged Steel Globe Valves – Packed Gland – for Use on Liquid Chlorine
- GEST 93/180 – Specification for Flanged Steel Ball Valves for Use on Liquid Chlorine.

Plug or ball valves should not be used in long pipelines. Satisfactory valve operation should be guaranteed at the minimum operating temperature envisaged, and in all circumstances at the boiling point of liquid chlorine at atmospheric pressure: -34°C.
If the pipeline is to be cleaned with a "pig", the valves should be of the full opening type in order to permit ease of passage.

Isolation valves, if any are used to separate the pipe in different sections, should be remotely operated rapid closure type. At the same time, all necessary precautions must be taken to avoid liquid hammer in the event of too rapid closing of the valve, for example by controlling the rate of closure or by the installation of a buffer vessel with a guaranteed gas cushion. At the design stage, it is recommended that a full theoretical analysis be carried out to determine the maximum pressures and support reaction forces which can arise from rapid valve closure.
All such valves should be carefully chosen and should be located and protected so as to prevent unauthorised access by third parties.

3.4.3 End Connections

Remotely operable isolation valves should be provided at the ends of the pipeline. In the case of upset at any point in the system (for example following an abnormal drop in pressure) they should close automatically, but not so quickly as to induce serious hydraulic shock effects.

3.4.4 Vessels and Accessories

Feed Tank

* Small diameter branches should be of sufficient wall thickness to avoid any possibility of deformation (see GEST 79/81 –Dry Liquid Chlroine Piping Systems Located inside Producers or Consumers' Plants.

The pipeline should never be connected directly to a liquefaction system or to a mobile container. Any pipeline should always be fed from a fixed storage system (see Euro Chlor GEST 72/10 concerning pressure storage of liquid chlorine).

Means for Emptying

Emptying:

- Liquid phase. In order to empty a liquid phase pipeline, vessels large enough to receive the entire contents of the pipeline should be provided at the producer's side but preferably at both ends of the pipeline. It is desirable in the event of failure of the transfer method to be able to empty the pipeline by gravity. It is also possible to empty the pipeline by gas pressure or by the use of a "pig". It is also desirable that the pipeline can be rapidly depressurised.

- Gas phase. It should be possible to vent chlorine down and receive it within a suitable installation (compression and liquefaction of plant of adequate capacity, a permanently guaranteed consumer plant, or absorption by a reagent or neutralising medium). It should be noted that this venting down will take place at low temperature. All equipment associated with the operation, therefore, should be suitable for the actual temperatures which will arise.

Purging:

Inert dry gas (dew point less than -40°C) of adequate quantity and pressure should be permanently available. Purge gas should be passed through a suitable absorption installation to remove chlorine, before being vented to atmosphere.

Remark: purging with inert gas should not be done as long as the pipeline contains liquid and gaseous chlorine. Purging at atmospheric pressure (inert + chlorine at 1.013 bar abs), while still liquid chlorine is present, results in much lower temperatures (-50°C or -60°C) than assumed as the design base (see 3.2.1.2.). This is because of the partial chlorine pressure which is lower than 1.013 bar in this situation.

3.4.5 Transfer Equipment

Choice of method for pressurising the chlorine to feed the pipeline is a function of the characteristics of the piping system (throughput, operating pressure, maximum pressure).

two methods are recommended:

- Transfer from a vessel padded by chlorine gas pressure, or by a dry inert gas, taking into account the maximum pressure appropriate for all accessories on the container.
- Transfer by pumping from a vessel. Equipment should be installed on the discharge of the pump to prevent reverse flow, e.g. by a pressure difference measurement activating an automatic valve in the pump discharge pipeline. Reserve flow could cause vaporisation in the pipeline or overfilling of the feed tank.

3.4.6 Protection against Thermal Expansion

Liquid chlorine

Where two isolation means are provided along the length of the pipeline, provision must be made to allow for thermal expansion of any liquid chlorine trapped between the two points of isolation. Such provision should preferably be provided at the extremities of the pipeline and situated inside the confines of an industrial location. This can be achieved by either of the following methods:

- Closed expanse tanks, in which it is necessary to verify the permanent presence of a gaseous phase. This gas phase can be obtained either by vaporised chlorine, or by the use of an inert gas. One simple method of verification, for example, is to measure change of temperature of a heated thermocouple.
- By bursting discs or relief valves which discharge to a vessel or collection system. These relief devices should be capable of isolation for maintenance.

Steel Pipe

The thermal expansion and contraction of the pipe should be carefully studied and all precautions should be taken to avoid any unacceptable consequences. The calculation of the thermal expansion of the pipeline should be taken between the maximum and minimum temperatures capable of being achieved<>. The minimum temperature to take into account should be at least -34°C (the boiling point of chlorine at atmospheric pressure). For thermal expansion, bends with a large radius should be used. Expansion bellows must not be used because they are considered as weak points in the construction. For a buried pipeline account must be taken of the longitudinal stresses which will result from the maximum variation in temperature.

3.4.7 Protection against corrosion

All pipelines, whether they are overhead or buried, should be provided with an effective protection against external corrosion.
Buried pipelines should be protected cathodically, and receive an adequate external coating (polyethylene according to DIN 30670, bituminous material, …). For these pipelines the following, protection procedures should be carried out:

A dielectric test of the state of the external surface coating before laying the pipeline.

An inspection by the use of an impressed electrical signal of this surface coating in The year following the laying of the pipeline.
Periodic inspection to ensure the satisfactory functioning of the cathodic protection.

3.4.8 Equipment for Measurement and Monitoring the Condition of the pipeline

All pipelines should include as a minimum the following equipment:

- Measurement and recording of the pressure and temperature at the inlet and outlet.
- Maximum and minimum pressure alarms at the inlet and exit and, if appropriate, means of relaying their signals to both ends of the pipeline.

It is desirable to have available a measurement of throughput. Measurement of the weight of the feed or discharge tanks used to be the most reliable method available (this is however a batchwise operation). Reliable flow measurements are available nowadays to measure accurately on a continuous basis.

Personnel at both ends of the pipeline should be provided with methods for monitoring the functioning and status of the safety measures indicated above, i.e.:

- Remotely operated isolation valves at the two ends.
- Remotely operated isolation valves along the length of the pipeline if any.
- Bursting discs and relief valves.
- Connections to the venting system or drain tank.

If the pipe is completely or partly double walled for a specific reason, a leak detector (e.g. pressure alarm or chlorine detector) should be installed on the purge gas (preferably dry air for personnel safety).

It is necessary to provide permanent connections by dedicated telephone and telefax and/or computer connection between the two ends of the pipeline.

3.4.9 Maloperation Measurement/Procedures

All precautions should be taken to avoid maloperation by means such as locks, logic systems, interlocks etc. The transfer of chlorine into the pipeline should be stopped automatically in the event of overpressure or abnormal drop in pressure within the system.

Means should be provided at one end of the pipeline at least, to drop the pressure within the pipeline rapidly and to vent it down.

It is also appropriate to provide a back-up system for the energy supply to the safety equipment e.g. caustic circulation pumps in the chlorine absorption system.

3.5 Operation

3.5.1 Cleaning and Drying before Putting into Service

Before putting into service the pipeline, vessels and all equipment should be degreased, cleaned and dried. If an hydraulic pressure test is imposed, it is necessary to replace the gaskets after the test, as otherwise the system is difficult to dry out. A further dry air test should then be carried out with the new joints in place, the quality of which should be carefully checked. All these operations should be carried out before the installation of valves and other accessories.

Drying should be carried out with the aid of a dry inert gas to obtain a dew point of less than -40°C at 1.013 bar absolute at the exit of the pipeline. Drying by the use of methanol or hydrocarbons, which could cause a risk of explosion in the presence of chlorine, should be done only in well documented circumstances where perfect draining of the pipe can be ensured and additional purging with nitrogen, not forgetting the branches. If possible, vacuum drying may be used.

For greasing internal equipment which can possibly come into contact with the chlorine, only greases compatible with chorine can be used (chlorofluorinated grease).

3.5.2 Leak Testing

In addition to the test procedures laid down in paragraphs 3.3.2. and 3.5.1. before putting the pipeline into service, all valves and other accessories should be tested in order to guarantee their perfect leak tightness under all conditions of service. The following test methods may be used:

- Halogen test at 2 bars air pressure in a calm and non-ventilated atmosphere.
- Tests with a mixture of chlorine and dry air at a pressure of 2 bars, the jointing systems being checked with the aid of ammonia.
- An air pressure test above the maximum operating pressure but below the design pressure, and the detection of leaks by the use of water containing a frothing aid.

3.5.3 Commissioning and Testing out of Service

A certain number of precautions should be taken before putting the pipeline into service:

- A check on the quality of chlorine introduced (see 3.5.4.).
- Purging of the pipeline with chlorine gas to eliminate all inerts before putting it under pressure.
- A further check on the leak-tightness and good operation of all the accessories.
- The introduction of liquid chlorine while the main remains under pressure of chlorine gas.
- Progressive putting into operation up to the desired throughput.
- A final check on the system.

For a shutdown, not followed by emptying, one end of the pipeline should be left open to a vessel in order to avoid trapping liquid within the pipeline. If the shutdown is to be followed by emptying, it is possible, in order to reduce the time of this operation, to remove the liquid chlorine with the aid of dry compressed air. The pipeline should then be vented down and purged towards an appropriate installation (liquefaction, absorption, etc). This operation should be continued until the residual chlorine content within the system permits opening or dismantling without risk of corrosion or gassing of personnel. To carry out this operation in a risk-free manner,

means that the quality of chlorine introduced into the system should be checked periodically and should meet the specifications given in 3.5.4.

For all maintenance operations it is recommended that the pipeline should be isolated from the two stock tanks at its extremities, by the installation of a blank flange, or the removal of a spool piece provided for this purpose.

3.5.4 Quality of the Chlorine Introduced

The chlorine should be dry, clean and with a NCl3 content in accordance with GEST 76/55. It must contain no organic material which is capable of reacting with chlorine.

3.5.5 Precautions against the Ingress of Moisture or Other Reactive Materials

All necessary precautions must be taken to avoid the entry of moisture or reactive materials into the pipeline. In addition if an inert gas is used for transfer or purging of the chlorine, this gas should have a dew point of less than -40°C at atmospheric pressure. The pressure of this gas should be least at 1.5 to 2 barg greater than that which can occur in the pipeline, and all precautions must be taken to ensure that this difference is permanently maintained, and that the gas cannot be polluted by any other fluid.

Periodical Inspection and Testing
Supervision
The following measures are recommended:
Above Ground Installation

- A visual inspection at least once per week of the pipeline and its surroundings should be carried out. Particular attention should be paid to the following aspects.

Areas of frosting or deterioration of the thermal insulation.
Circumstances arising in the vicinity of the pipeline which could present any risk to it e.g. crane activity.

Buried Pipelines

- A visual inspection of the route, from the air and/or on foot, with a frequency which is at least once per week.
- A check that the confines of the pipeline are as specified.
- A check on the cathodic protection. (At least once per year).
- A check that the warning devices (flow - and pressure measurement) and communication systems are functioning correctly.

Inspection and Test
Periodic inspection and testing of the system is required, the interval between which should never exceed 4-5 years. It should take into account the following aspects:

- ❖ Thickness testing of the pipe walls in specific areas as specified at the time of construction (ultrasonic).
- ❖ A check on all equipment. As a general rule, all accessories should be replaced in a systematic manner before there is any risk of them becoming defective.
- ❖ Inspection of the supports for above ground pipeline systems.

Re-Testing

- ❖ A hydraulic re-test of the pipeline is formally not considered advisable, because of the subsequent risk of internal corrosion to the piping system which could occur in a potentially uncontrolled manner.

3.5.6 Emergency Procedures and Training

The following precautions should be taken:

An emergency plan, and precise instructions and communications systems in case of emergency, should be permanently available and brought to the knowledge of all personnel involved including external emergency services.

All personnel, including those of the public authorities who could be asked to assist in the event of an emergency, should be specifically instructed in the means of dealing with leakages of chlorine, and periodic exercises should be organised.

Self-contained breathing sets and protective clothing suitable for dealing with a liquid chlorine leak should b e available in lockers located near to the ends of the pipeline and accessible at all times in case of emergency.

A means of indicating the wind direction should be installed in order to tell the operators of the direction of dispersion of gas that might occur in the event of an accident.

During the periodic check of the pipeline, as indicated above in 3.5.6, the personnel carrying out the inspection should be provided with a checklist covering the principal points to be covered. These checklists and, if necessary, additional remarks are collected in a logbook.

Bearing in mind the specific hazards associated with fire, a study should be carried out of the means of dealing with a fire in the vicinity of the pipeline. Common routing of the pipeline with electric cables or flammable fluids should be avoided.

4 GAS PHASE PIPELINES

4.1 Basic Design and Installation

the pipeline should be protected from all risks of external fire or explosion, whether such risk exists at the time of installation of the ppeline or that it is brought about by subsequent installations. At the same time, all danger of external corrosion should be avoided, for example due to the proximity of another pipeline or of high tension electrical cables. An entirely above ground pipeline is recommended for a gas phase system. In this case, the pipeline should be protected from any risk of mechanical

damage such as falling objects, traffic etc. In circumstances where the pipeline is laid in a pipe trench, it should be provided with sufficient supporting above the ground, together with drain provisions to remove rain - and drainwater or corrosive liquids from the trench. A buried pipeline should not be considered except where operating conditions do not necessitate either trace heating or thermal insulation to avoid risk of liquefaction, that is only in circumstances where the pipeline is to operate at a sufficiently low pressure.

The need for rapidly closing isolation valves along the length of the pipeline is related to its length and to the quantity of chlorine held up in the pipeline. For safety considerations, the quantity should be related to the location of the pipeline. Such valves represent a weak point in the construction of the pipeline. It is necessary, therefore, to avoid such isolation valves outside the confines of industrial premises if this is possible.

4.2 Construction

4.2.1 Basis of Design

4.2.1.1 Design Pressure

The complete pipeline system should be designed for a minimum pressure of 1.5 times the maximum operating pressure.

4.2.1.2 Design Temperature

The complete system should be designed for the maximum temperature capable of being attained at zero throughput and for the lowest temperature that can occur.

4.2.1.3 Corrosion Allowance

A minimum corrosion allowance of 1 mm should be used.

4.2.1.4 Radius of Curvature

Even where there is no intention to use a "pig", the radius of curvature of bends should always be greater than 3 - 4 diameters.

4.2.1.5 Thermal Insulation

Thermal insulation is required when the pipeline is trace heated. In other circumstances, it should be provided if it is the only means of avoiding all risk of liquefaction. Other means include low operating pressures, adequate chlorine delivery temperatures, permanent gas circulation. It should be noted that in the event of a prolonged shut down, the thermal insulation becomes ineffective. All efforts must be made before restart to confirm the absence of any liquid phase chlorine.

4.2.1.6 Trace Heating

The need for trace heating is determined by the operating pressures, the length of the pipeline and other ambient conditions required to avoid all risk of liquefaction of the chlorine. All precautions must be taken to ensure the permanent availability of the heating system and to avoid any localised over heating to prevent local corrosion or chlorine/iron fire. Such over heatign can be prevented on the basis of suitable calculation of the heating density, such that at no point can the metal temperature exceed 80°C.

4.2.2 Choice of Techniques and Materials of Construction

Piping
The steel chosen for the construciton of the pipework should be of certified quality and readily weldable.

Flanges, Nuts and Bolts

The metal used in flanges, nuts and bolts should be of the same quality as that of the pipe itself. Weld neck flanges should be used for all flange connections. The flanges should be designed on the basis that the gasket cannot be expelled (e.g. male/female - or tongue and groove type).

Gaskets

The gaskets used should preferably be of compressed asbesos fibers (CAF) or alternative material, see GEST 92/169.

Thermal insulation

The specification for the materials used in the thermal insulation should meet the following criteria:
Non flammability
Chemically inert to liquid of gaseous chlorine
Totally sealed against the ingress of moisture
Protected against mechanical damage.

The materials which correspond best to these criteria are in general expanded silica, diatomaceous earth, foam glass and polyurethane (non-flammable or auto-extinguishing). Preventing the ingress of atmospheric moisture necessitates choice of a closed pore structural material, or provision of a high quality external gas-type wrapping.

Remark: the bare pipeline (carbon steel) should be coated before the insulation is applied, to prevent corrosion by moist air.

Trace heating

Preferred trace system
Electrical trace heating by means of quality resistance (self limiting in temperature) elements attached to but insulated from the chlorine pipeline.

The resistance elements should preferably be armoured, externally protected against corrosion and the ingress of moisture.

The capacity should be calcuolated as a function of the thermal losses, and not as a funcitonof the heat input required for the revaporiation of the liquid chlorine.

spirally wound trace heating should be avoided except over short distances.

Resistance heating using the pipe itself must be avoided.

Electrical trace heating will normally be the most reliable method available outside the confines of an industrial installation.

Alternative trace system

Trace heating by the use of steam, using tubing attached to but insulated from the chlorine pipeline. Steam can be replaced by any other heating fluid.

If steam trace heating is applied all connections should be outside the insulation to prevent corrosion due to wet insulation resulting from leaks.

4.2.3 Supports

Buried Pipeline

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

Above-Ground Pipelines

The supports should be fixed on foundations which provide adequate rigidity. They should be insulated from the pipe by a mechanically robust material, which also provides adequate thermal insulation to avoid any frosting. The supports should permit the thermal expansion of the pipeline due to any likely variations in temperature, and also deal with any possible earth movement. The support system should be designed to avoid any ingress of moisture under the thermal insulation.

4.2.4 Stress Relief

It is advisable to choose a quality of steel which avoids the need for stress relief after welding.

4.3 Inspection and Testing

4.3.1 Inspection of Piping materials

Piping materials should be tested to ensure conformity with the quality requirements of national or international codes such as, for example:

- Iso 404-1992 (General Code)
- DIN - 17173 (seamless)
- DIN - 17174 (welded)

The material of the flanges and blanks, nuts and bolts, welds should be subjected to inspection according to standards consistent with those indicated above.

4.3.2 Inspection Procedures during Construction

Due to the different aspects of a long pipeline and in order to obtain a high quality construction, the inspection procedures should follow the required codes rigorously, and as a minimum should encompass the following points:

- 100% radiography of the welds
- Tests of tensile, bending, and impact strength of reference and welded test pieces.
- Thickness control
- Certification of welders and of their methods of welding.
- Crack testing by dye penetrant and halogen leak testing before the laying of the pipeline (for buried pipeline only).
- Hydraulic pressure test at at least 1.5 times the maximum operating pressure after the laying of the pipeline.
- Leak testing after the pipeline has been laid.
- A check on the trace heating system.

The quality of construction is considered to be the most important safety consideration.

4.4 Accessories

4.4.1 Flanges and Branches

The number of flanges and branches should be limited to the minimum strictly necessary. Their location in parts of the main which are below ground should be avoided. If this cannot be avoided, they should be placed in an inspection chamber, and should be accessible to personnel wearing protective clothing. Large diameter branches should be fitted with guide bars if the pipeline is to be treated by 'pigging'[*].

4.4.2 Valves and Isolation

The material of the valves should be compatible with that of the pipe.

[*] Small diameter branches should be of sufficient weall thickness to avoid any possibility of deformation (see GEST 79/81).

The Euro chlor specifications and recommendations for valves used on liquid chlorine are safe guidelines for the selection of valves to be applied in systems handling dry gaseous chlorine (see 3.4.2). Materials to be adjusted to gas service requirements.

If the pipeline is to be cleaned with a "pig", the valves should be of the full opening type in order to permit ease of passage.

Isolation valves if any are used to separate the pipe in different sections should be remotely operable rapid closure type.

All such valves should be carefully chosen and should be so located and protected as to prevent unauthorised access by third parties.

4.4.3 End Connections

Remotely operable isolation valves should be provided at the two ends of the pipeline. In the case of upset at any point in the system (for example following an abnormal drop in pressure) they should close automatically.

4.4.4 Equipment for Emptying and Venting Down

The pipeline should be capable of being depressurised by venting chlorine to a suitable installation (compression and liquefaction of adequate capacity, a consuming installation guaranteed as permanently available, absorption by a reagent or neutralising medium). Inert dry gas (dew point less than or equal to -40°C at 1.013 bar absolute) of adequate quantity and pressure should be permanently available. The purge gas should be passed through an absorption installation to remove chlorine, before being vented to atmosphere.

4.4.5 Transfer Equipment

The choice of compressor for feeding the pipeline system is a function of the characteristics required (throughput, operating pressure, maximum pressure). A non return device should be installed on the down stream side of the compressor and particular attention must be paid to its reliability (the choice of an automatic valve is recommend).

4.4.6 Protection Against Over Pressure and Thermal Expansion

Over pressure of the chlorine gas phase

As a minimum relief valves at each end of the system should be provided. Their size should be related to the pressure in the pipeline, the mode of compression and the effect of trace heating if used. One should also attempt to avoid the location of relief valves outside the confines of an industrial installation. These relief valves should always be connected to an absorption system or a point of use in the liquefaction. They should be capable of being isolated from the pipeline for maintenance.

Thermal expansion of the steel

The problem of thermal expansion of the pipeline should be specifically studied, and all measures should be taken to ensure that no problems result due to thermal expansion. The design basis for thermal expansion should be between the maximum and minimum temperatures capable of being achieved. Expansion devices should be given specific detailed attention. For above ground pipelines, it is preferable to use large radius expansion loops. For buried pipelines where free expansion cannot take place, account must be taken of the longitudinal stresses which will result from the maximum variation in temperature.

Protection against corrosion

All pipelines, whether they are above or below ground, should be provided with an effective protection against external corrosion. buried pipelines should be protected cathodically, and receive an adequate external coating (polyethylene according to DIN 30670, bituminous material, ...).

In all circumstances, the following inspection procedures should be followed:

A dielectric test to determine the state of the external protective coating before laying the pipeline.

A check by means of an impressed electric signal of the state of this protective coating during the first year following the laying of the pipeline.
A routine check of the satisfactory functioning of the cathodic protection.

Equipment for Measurement and Monitoring the Condition of the Pipeline
General

All pipelines should include as a minimum the following equipment:

- Measurement and recording of the pressure and temperature at the ilet and outlet.
- Maximum and minimum pressure and temperature alarms at the inlet and exit, and if appropriate means for relaying their signal to both ends of the pipeline.
- It is desirable to have available a flow measurement to check the throughout.

The personnel at the two ends of the pipeline should be provided with appropriate methods for monitoring the functioning and status of the safety measures indicated above, i.e.:

- Remotely operated isolation valves at the two ends.
- Remotely operated isolation valves along the length of the pipeline when appropriate.

- Bursting discs and relief devices (which should be capable of isolation for maintenance).
- Connections to the venting system.

It is necessary to provide permanent connections by dedicated telephone and telefax and/or computer connection between the two ends of the pipeline.

4.4.6.1 Maloperation measures/procedures

All precautions should be taken to avoid maloperation by means such as locks, logic systems, interlocks etc. The transfer of chlorine into the pipeline should be stopped automatically in the event of abnormal pressures or temperatures within the system.

Means should be provided, at one end of the pipeline at least, to drop the pressure within the pipeline rapidly and to vent it down.

It is also appropriate to provide a back-up system for the energy supply to the safety equipment.

4.4.6.2 Specific Equipment

Pipeline Overheating

In order to ensure that the requirements laid down in 4.21.6. are met, the pipeline should be fitted with a means for measuring the temperature of the chlorine gas as well as the wall temperature of the pipe, and to deal with breakdown of the trace heating system. the thermostats used should be given detailed attention. The number required depends on the driving force and means of heating. As operating conditions approach the limits of operation for chlorine gas, the greater the need to provide monitoring systems. For electric trace heating systems, one thermostat per electrical circuit and per source is desirable.

Accidental Liquefaction

A check against accidental liquefaction should be provided in the low points of the system by installing liquid chlorine detectors (temperature measurements of the pipe wall for example).

4.5 Operation

4.5.1 Cleaning and Drying before Putting into Service

Before putting into service the pipeline, vessels and all equipment should be degreased, cleaned and dried. If a hydraulic pressure test is carried out, it is necessary to replace the gaskets after the test, as otherwise the system is difficult to dry out. A further dry air test should then be carried out with the new joint sin place, the quality of which should be carefully checked. All these operations should be carried out before the installation of valves and other accessories.

Drying should be carried out with the aid of a dry inert gas to obtain a dew point of less than -10°C at 1.013 bar absolute at the exit of the pipeline. Drying by the use of methanol or hydrocarbons which could cause a risk of explosion in the presence eof chlorine should be done only in well documented circumstances where perfect draining of the pipe can be ensured and additional purging with nitrogen, not forgetting the branches. If possible, vacuum drying may be used.

For greasing internal equipment which can possibly come into contact with chlorine, only greases compatible with chlorine can be used (chlorofluorinated grease).

4.5.2 Leak Testing

In addition to the test procedures laid down in paragraphs 4.3.2. and 4.5.1., before putting the pipeline into service, all valves and other accessories should be tested in order to guarantee their perfect leak tightness under all conditions of service. the following test methods may be used:

Halogen test at 2 bars air pressure in a calm and non-ventilated atmosphere.

Test with a mixture of chlorine and dry air at a pressure of 2 bars, the jointing system being checked with an aid of ammonia.

Air pressure test above the maximum operating pressure, and a detection of leaks by the use of water containing a frothing aid.

4.5.3 Commissioning and Taking Out of Service

A certain number of precautions should be taken before putting the pipeline into service:
A check on the quality of chlorine introduced (see 4.54.).
Purging of the pipeline with chlorine gas to eliminate all inerts before putting it under pressure.
A further check on the leak tightness and good operation of all the accessories.
Progressive putting into operation up to the desired throughput and pressure.
A final check on the system.

For a shutdown not followed by emptying, the temperature of the chlorine should be maintained (e.g. by reduction of the pressure). If the shutdown is to be followed by emptying, the pipeline should be vented down and purged towards an appropriate installation (liquefaction, absorption etc). This operation should be continued until the residual chlorine content within the system permits its opening up or dismantling without risk of corrosion or gassing of personnel. To carry out this operation in a risk free manner, the quality of chlorine introduced into the system should be checked periodically and should meet the specifications given in 4.5.4.

For all maintenance operations it is recommended that the pipeline should be isolated by the installation of blanks or the removal of a spool piece provided for this purpose.

4.5.4 Quality of the Chlroine Introduced

The chlorine should by dry, clean, contain only low levels of hydrogen and no organic materials which are likely to react with chlorine. The inert gas content should be compatible with the usage to which the chlorine is to be put.

4.5.5 Precautions against Ingress of Moisture or Other Reactive Materials

All necessary precautions must be taken to avoid the entry of moisture or reactive materials into the pipeline. In addition, if an inert gas is to be used for purging of the main, this gas should have a dew point of less than -40°C at 1.013 bar absolute. The pressure of this gas should be at least 1.5 to 2 bars greater than that which can occur in the pipeline, and all precautions must be taken to ensure that this difference is permanently maintained, and that the gas cannot be contaminated by any other fluid.

4.5.6 Precautions in the Event of Failure of the Trace Heating

In the event of failure of trace heating system, for which the operating personnel should be aware by means provided under 4.4.8.2, it is preferable to reduce the pressure in the pipeline and to vent it down until liquid chlorine cannot be formed. If accidental liquefaction does take place, it is essential to reduce the pressure in the pipeline and to allow it to vent down before being put back into service.

4.5.7 Periodical Inspection

supervision
The following measures are recommended:

<u>Above Ground Installation</u>

A visual inspection at least once per week of the pipeline and its surroundings should be carried out. Particular attention should be taken to the following aspects:
Points of deterioration of the thermal insulation where this is installed.
Circumstances arising in the vicinity of the pipeline which could present a risk to it e.g. crane activity.

<u>Buried Pipelines.</u>

A visual inspection of the route, from the air and/or on foot, with a frequency which is preferably every day and in no case should be less than once a week.
A check that the confines of the pipeline are as specified.
A check on the cathodic protection.
A check on the adequacy of all the warning devices (flow and pressure measurement) and communicaiton systems.
Inspection and Test
Periodic inspection and testing of the system is required at the interval between whicvh should never exceed 4-5 years. It should take into account the following aspects:

Thickness testing of the pipe walls in specific areas as specified at the time of construction (ultrasonic).

A check on all equipment. As general rule all accessories should be replaced in a systematic manner before there is any risk of them coming defective.
A check on the trace heating system.
Periodic inspection of the supports for above-ground pipeline systems.
Retesting
A hydraulic retest of the pipeline is formally not considered advisable, because of the subsequent risk of internal corrosion to the piping system which could occur in a potentially uncontrolled manner.

4.5.8 Emergency Procedures and Training

The following precautions should be taken:

An emergency plan, and precise instructions and communication systems in case of emergency, should be permanently available and brought to the knowledge of all personnel involve, including external emergency services.

All personnel, including those of the public authorities who could be asked to assist in the event of an emergency, should be specifically instructed in the means for dealing with leakages of chlorine, and periodic exercises should be organised.

Self-contained breathing sets and protective clothing suitable for dealing with a chlorine leak should be available in lockers located near to the ends of the main and accessible at all times in case of emergency.

A means of indicating the wind direction should be installed in order to tell the operators of the direction of dispersion of gas that might occur in the event of an accident.

During the periodic check of the pipeline, as indicated above in 4.5.7, the personnel carrying out the inspection should be provided with a checklist covering the principal pints to be covered. The checklists and, if necessary, additional remarks are collected in a logbook.

Bearing in mind the specific hazards associated with fire, a study should be carried out of the means of dealing with a fire in the vicinity of the pipeline. Common routing of the pipeline with electric cables or flammable fluids should be avoided.

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