MECHANICS

PIPING

TRAINING MANUAL
COURSE EXP-PR-SM040
Revision 0.1

MECHANICS

PIPING

CONTENTS

1. OBJECTIVES

Safe and precise intervention during maintenance or when repairing damaged pipes.

This course mainly discusses the pipelines and the maintenance of the tubes and pipes.

An operator’s course on piping is available on the intranet.

2. INTRODUCTION PIPING

An assembly of pipes used for the circulation of fluids. In industry, piping is a pipeline system which conveys fluids or gasses from one place to another.

Figure 1: Pipe assembly

2.1. ROLE

A pipeline provides the flow of fluids (liquids, gas) of solids (in pulverulent form) from one machine to another; from a machine to a reservoir during manufacturing operations, alterations or the storage of a product.

2.2. FUNCTION

- Internal and external leak tightness
- Oxidation resistance and corrosive agent resistance
- Carry the fluids with a minimum loss of pressure and heat

2.3. GENERAL CONSTITUTION OF THE PIPING

The piping consists of various components such as:

- The actual pipes
- The fittings: tees, elbows, reducers, etc.…
- The range of connections: flanges, threaded fittings, weld fittings, etc.…
- The range of sealings: gaskets, etc.…

Figure 2: Pipes, fittings and gaskets

The fluid circulation devices:

- The pumps
- The compressors
- The ejectors.

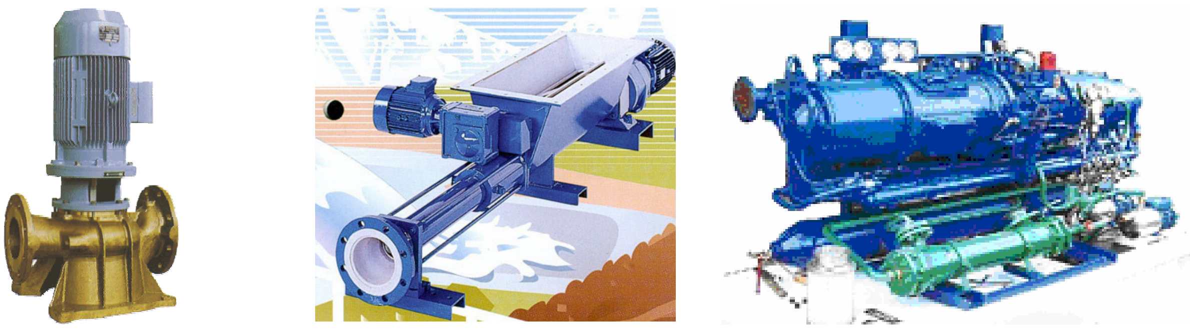


Figure 3: Pumps and compressor

The controlling devices placed in the piping system:

- Valves
- Slave valves
- Check valves
- Etc.…

Figure 4: Valve and check valve

The devices for **safety** and **protection**:

- Safety valves
- Rupture discs
- Flame arrestor
- Filters
- Etc.…

Figure 5: Safety valve, rupture disc, filter

The devices for **measuring, checking** and **controlling**:

- Pressure gauges
- Flowmeters
- Thermometers
- PH meters
- Meters

Figure 6: Pressure gauges, flowmeter, and thermometer

3. TUBE DESIGN

3.1. GENERALITIES

The tubes must be resistant to well determined burst stress, crushing stress and tensile stress. Moreover, they must also be buckling resistant.

In industries like the ones which use a steam process or chemical products, oil refinery or power production, there are many pipelines and tube assemblies which connect the components and transport liquids and gas from one place to another.

Without this complex network of metal (steel and copper) and plastic, the industry would not be able to operate.

Figure 7: Pipe network

Since a small leak or a clogging in a pipe can affect the activity of an entire system, the maintenance work on this network is an essential part of industrial production.

3.2. CODES, STANDARDS, SPECIFICATIONS

Main specialized organizations

In France:

- AFNOR : **A**ssociation **F**rançaise de **NOR**malisation
  - NF A49 : tubes and tubing products in steel
  - NF A29 : industrial piping-flanges and collars in unalloyed, alloy and stainless steel
  - NF 87 : oil industry (refinery, production, storage)
  - **NF EN 1057 (copper tubes)**
  - **NFA 51-121 (round copper tubes)**
  - **NF EN 1254 (copper fittings)**
- SNCTTI : **S**yndicat **N**ational de **C**haudronnerie, de **T**ôlerie et de **T**uyauterie **I**ndustrielle

International:

- ISO : **I**nternational **O**rganization for **S**tandardization
- CECT : **C**omité **E**uropéen de **C**haudronnerie et de **T**ôlerie

In the United States:

- ANSI : **A**merican **N**ational **S**tandards **I**nstitute
- ASME : **A**merican **S**ociety of **M**echanical **E**ngineers
- ASTM: **A**merican **S**ociety for **T**esting **M**aterials
- API: **A**merican **P**etroleum **I**nstitute

3.3. TUBE MANUFACTURING

3.3.1. Welded tubes

They are obtained with heat or cold. Depending on the envelope's manufacturing process, the weld can be longitudinal (butt seam/welded tube) or helical (spiral-wound tube).

- Hot-rolled without welding
- Drawn without hot or cold weld
- Lap welded
- Butt-welded
- Spiral butt seam (spiral-wound tube)

3.3.2. Centrifuged tubes

Obtained by pouring metal into a rotating cylindrical mould, these tubes are reserved for special steels. (Cast iron)

3.3.3. Seamless tubes

These are used most in the oil and petrochemical industry. They are obtained by heating a steel ball to about 1250°C then, after a piercing performed by a metal pear, the obtained tube is laminated and calibrated.

- Steel
- Copper
- Plastic

4. PIPE DIMENSIONING

These main criteria should be taken into consideration when determining the sizes of the pipes:

- the volume
- the flow rate
- the pressure and temperature.

A tube is defined by its diameter, the envelope thickness and the steel quality of which it is made.

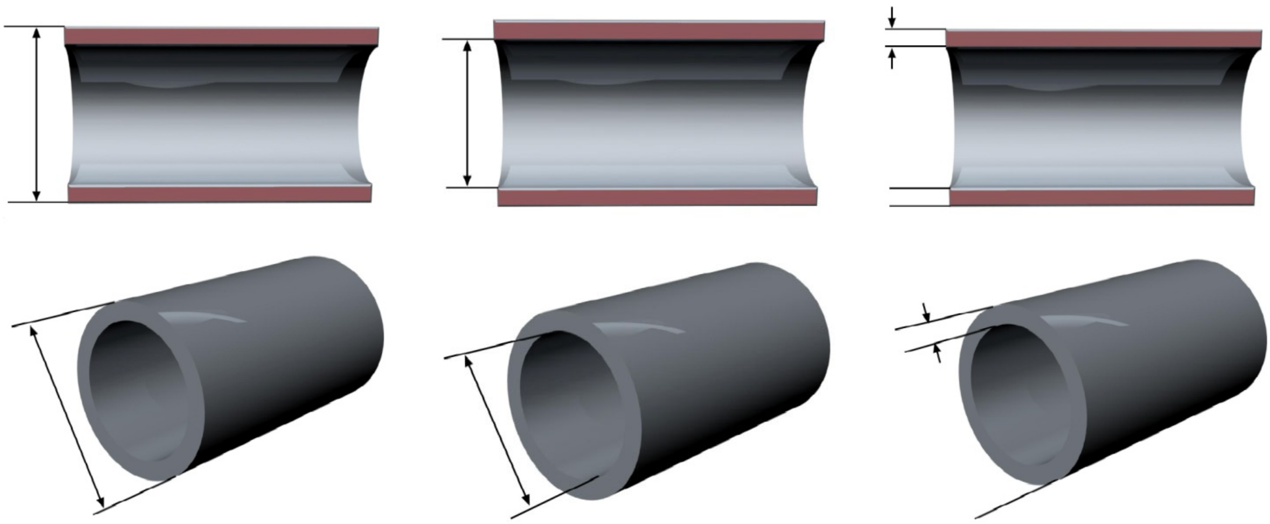


Figure 8: Tube dimensions

The pipe dimensions are standardized in inches but also in the metric system. On site the dimensions are usually marked in inches.

The dimensions range from ½'' to 60'' (even more for the pipelines)

5. COPPER PIPING

Copper tubes are best adapted for cold/hot water and gas pipes.

It is a metal with numerous qualities: it has a good resistance to both heat and pressure and it is easy to work with.

It can be found in the form of a rigid extended tube (hardened copper).

Figure 9: Copper tubes

It can also be found in coils, more malleable (annealed copper)

Figure 10: Copper coil

5.1. ANNEALING A TUBE

Sometimes it is necessary to anneal a rigid tube to make it more malleable to thus allow making an elbow or a flare on a pipe. Copper which is annealed like this will regain its original hardness after some time.

To make the tubes malleable again they must be heated until their colour starts to change to « dark red ». The annealing procedure is the result of a compromise between the temperature and the duration.

The lower the annealing temperature, the longer this temperature must be maintained.

Once annealed, the slightest shock can deform the tube.

Use a blowtorch to heat the tube to redness on the part which is to be annealed.

This work can be performed with an (oxyacetylene) torch but it is crucial to master the heating process if you do not wish the copper tube to melt.

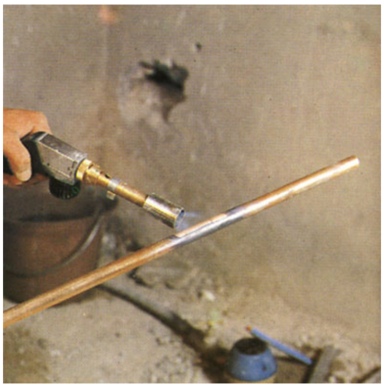


Figure 11: Heating a tube

Quickly dip the part which has been heated to redness in a container filled with cold water (here a bucket): after these two actions the copper is annealed.

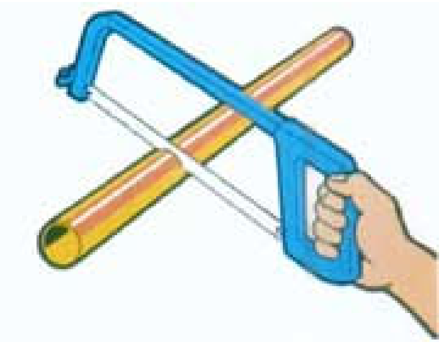
Figure 12: Cooling the copper

Then clean the tube with emery cloth.

Figure 13: Cleaning the tube (1)

Figure 14: Cleaning the tube (2)

5.2. CUTTING A PIPE



The copper can be cut with a hacksaw, but special care must be taken not to deform the tube since this will make it impossible to join the fittings.

Figure 15: Cutting with a saw

The use of a tubing cutter is preferred.

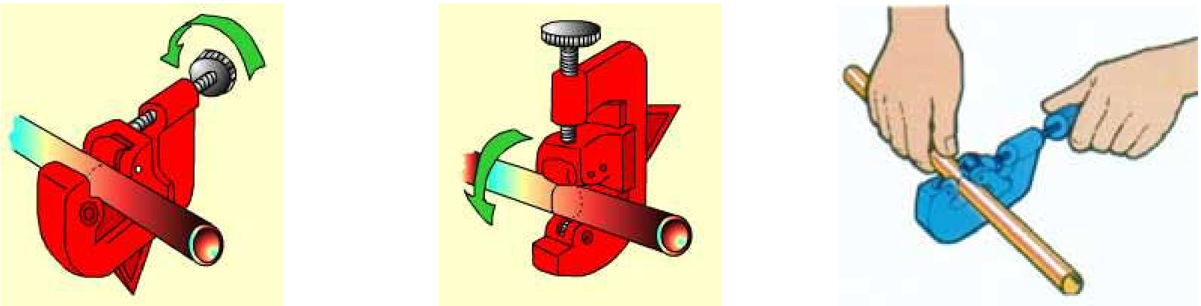


Figure 16: Using a tubing cutter

To cut the tubes, the tubing cutter allows clean work, without the risk of deforming the metal. Insert the tube into the jaw and tighten the blade thoroughly using the wheel.

Turn the tool around the tube while tightening the blade after each turn.

After cutting, ream the inside of the tube with the triangular blade on the tool or by using a round file for the inside and a flat or half-round file for the outside.

Figure 17: Reaming the tube/reaming tool

5.3. BENDING THE TUBES

The tubes can only be slightly bent. The bending spring is cheaper than the bending pliers.

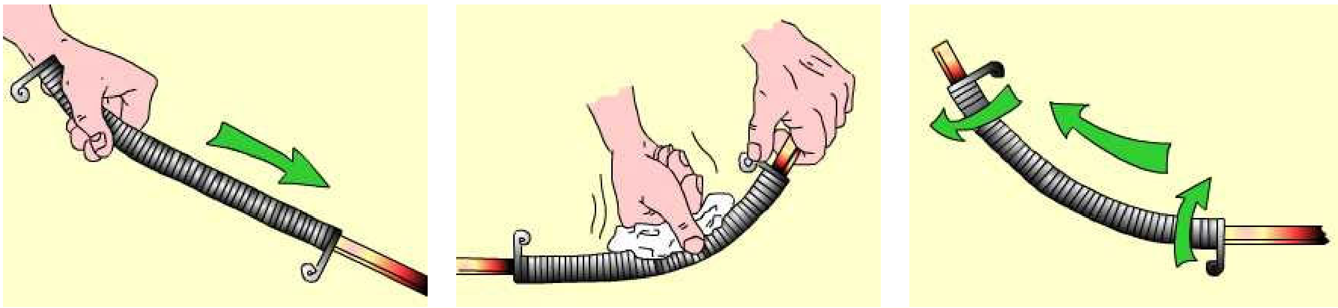


Figure 18: Bending of a tube with a bending string

The bending spring is the least expensive material for bending tubes. Slip the spring onto the part which is to be bent. Twist the spring by hand. Then remove the spring by using the two loops on its ends.

Bending pliers scan also be used.

Figure 19 : Bending pliers

Figure 20: Using the bending pliers

For small works weld elbow fittings are the easiest to use.

5.4. FLARE

The flare allows assembly of the tubes onto threaded fittings. Less resistant than a welded joint, it is detachable.

5.4.1. Making a flare

This concerns a rigid tube, so it is essential to anneal the copper. The tools are a cast and two dies.

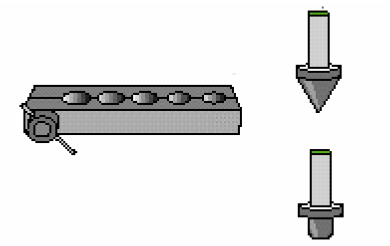
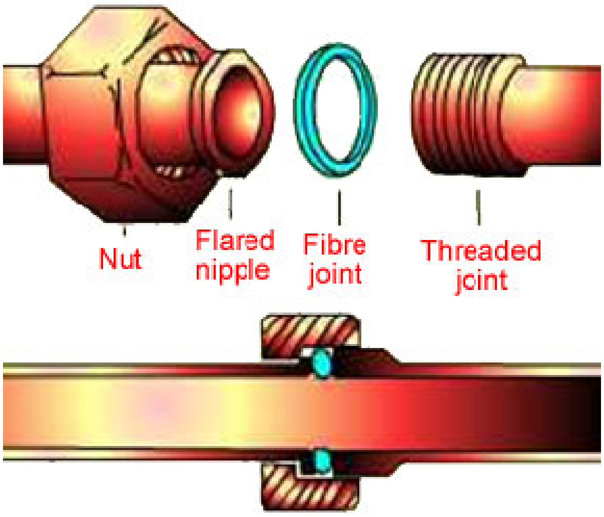


Figure 21: Cast and dies



The principle consists of flattening the end of the tube. The created flare (or lip) will jam the nut onto the threaded fitting.

Figure 22: Detail of flare sealing

The tools needed to make a flare are not very hard to use.

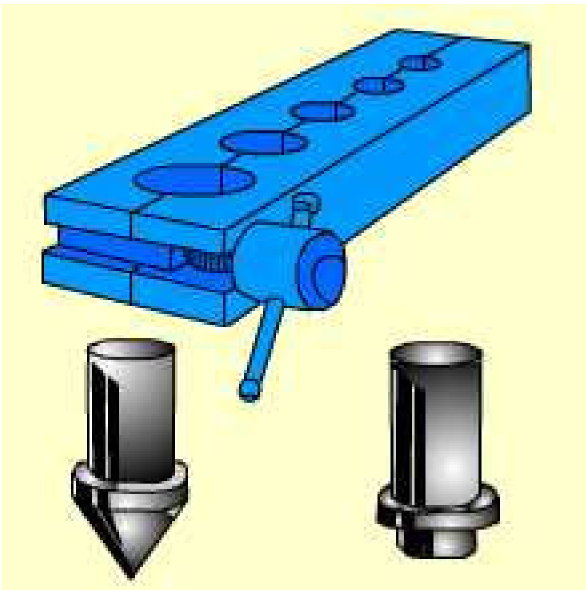


Figure 23: Flare tools

Anneal the end of the pipe and then quickly cool in water.

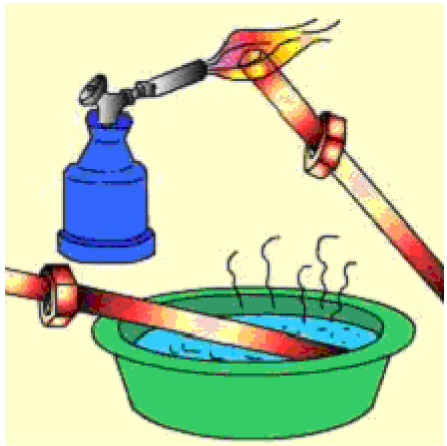
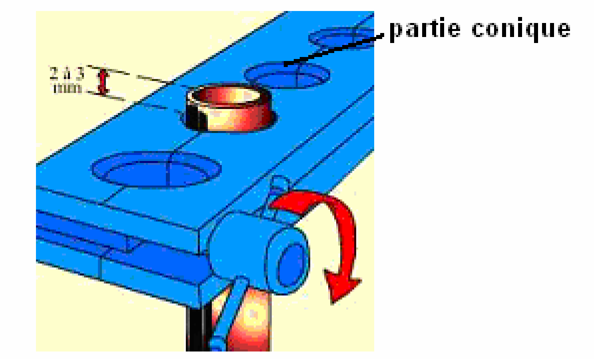


Figure 24: Preparing the tube

Do not forget to slip on the nut if the tube has already been welded



Insert the tube into the cast (and the cast in the vice), in the hole which matches its diameter, on the side where the entrance to the holes is conical.

Figure 25: Preparing the flare

Apply the cone-point die to the end of the tube and hit it with a hammer to expand the tube.

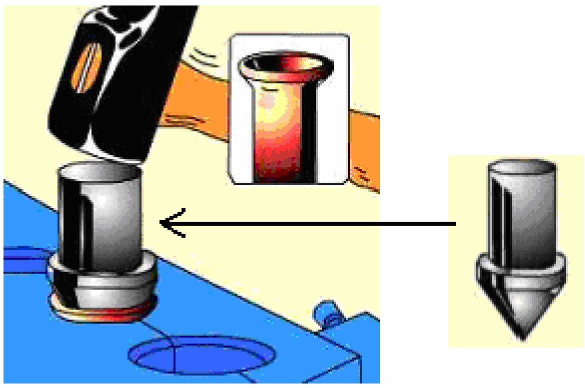
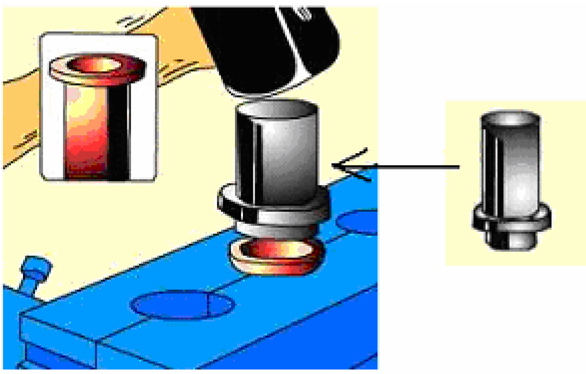


Figure 26: Flare 1st stage



Turn the cast over, side with flat holes, reinsert the tube and use the flat die to create the flare.

Figure 27: Flare 2nd stage

5.5. FITTINGS

A large number of brass fittings are used to connect the tubes to each other, to the valves and fittings or to parts of the installation. For example a hexagon flare nut (1), a plug (2), a cap (3).

Figure 28: Various threaded fittings

With heat (welding, soldering or brazing) or mechanically (threaded) the fittings allow connection of the different assembly units (valve, hose, pipes…)

5.5.1. Threaded fittings

5.5.1.1. Olive compression fittings

This concerns a ring with cone shaped edges (olive) which is slid onto the tube and crushed when the nut is tightened, thus holding the position and ensuring the assembly's sealing.

These olive compression fittings simplify the installation, but they cannot withstand several disassemblies.

When the nut is tightened, the crushing of the olive holds the fitting in place and ensures the sealing.

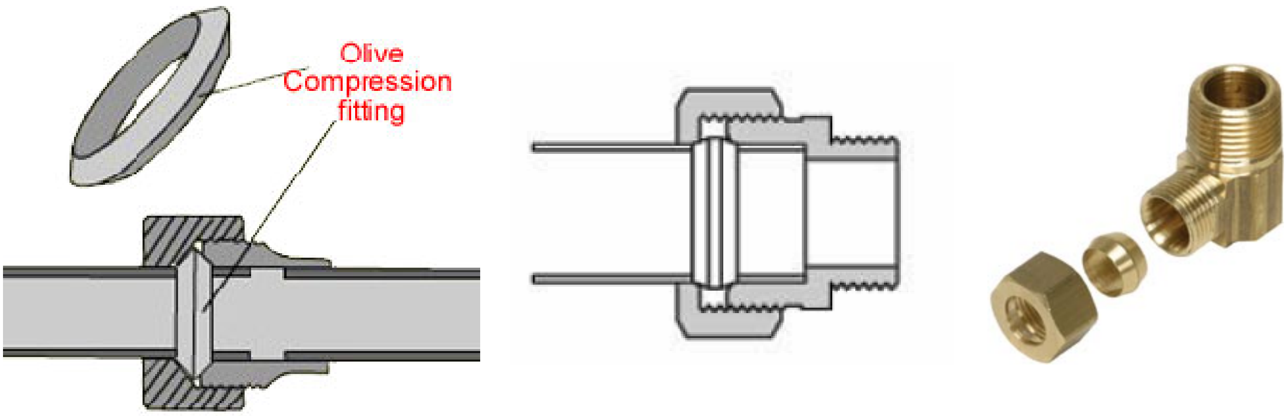


Figure 29: Olive compression fitting

Slip the nut onto the tube and then do the same with the compression olive. Fit the end of the tube and then the compression olive. Fit the end of the tube into the fitting and firmly tighten the nut.

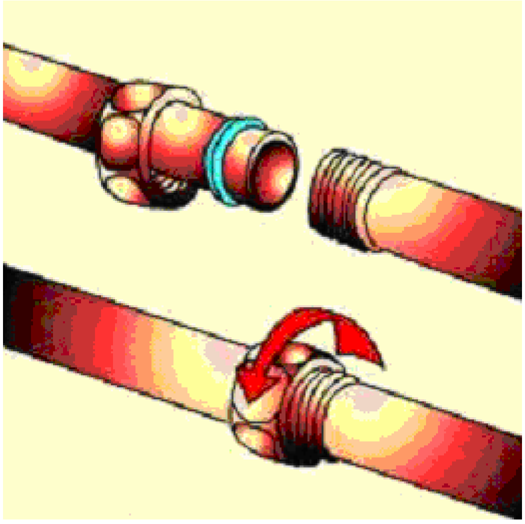


Figure 30: Installing the olive compression fitting

This type of fitting also exists in the form of a double fitting for threadless pipes. Then it consists of two compression olives (2), a threaded fitting (nipple) (3) and of two compression nuts (1).

When the nuts are tightened the tooth side of the olives is crushed against the tooth part of the nuts, thus creating the joint and containing the fitting on the tube.

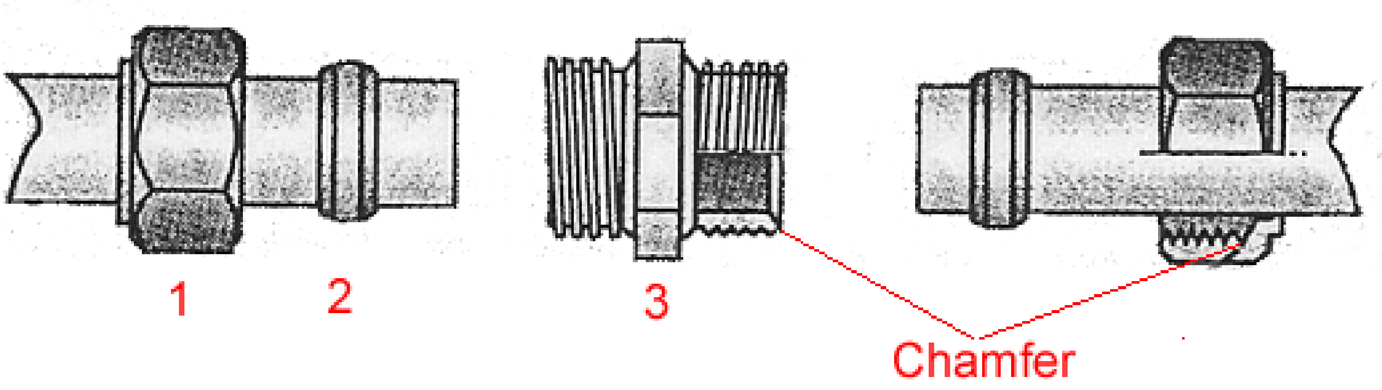


Figure 31: Double compression fitting

These fittings cannot withstand several disassemblies. The olive and teeth of the threaded fitting are too damaged after several placements and removals.

5.5.1.2. Grip fitting

The principle is that of a collar with a gasket and a ring. When the nut is tightened the gasket is crushed thus procuring the sealing while the tube is contained by the ring. For a beginner this principle is the easiest and has the advantage of being indefinitely detachable.

When the nut is tightened, the metal washer opens and contains the tube in the fitting. The gasket procures the sealing.

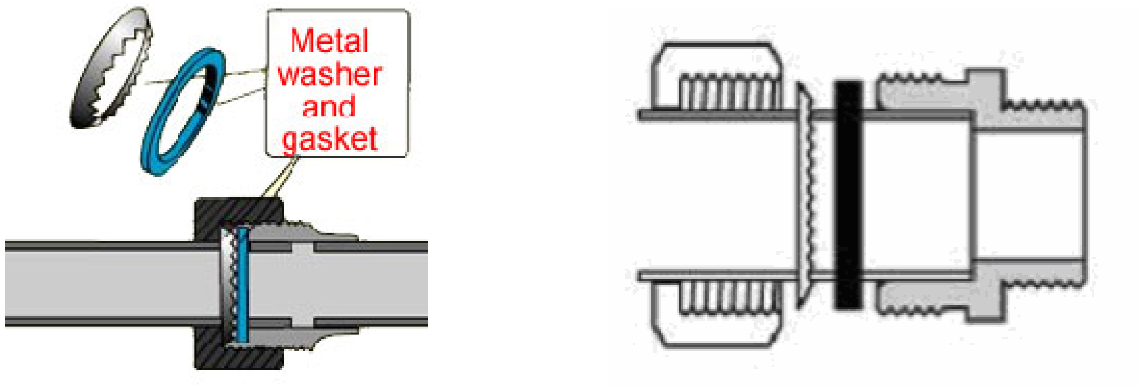


Figure 32: Grip fitting

Slip the nut, the washer (tooth side towards the fitting) and then the gasket onto the tube. Join the tube and tighten the nut firmly.

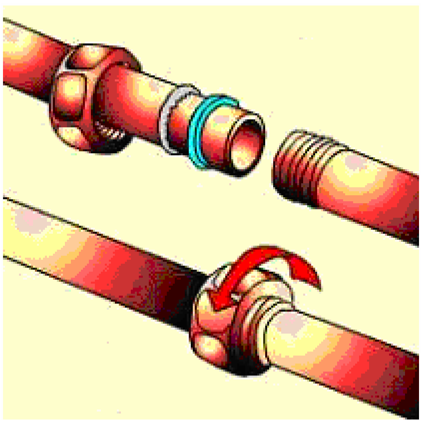


Figure 33: Placing the Grip fitting

This fitting can also consist of two clamp nuts (1), two rubber gaskets (3), two lockwashers (2) and a threaded fitting (4) (for threadless pipes)

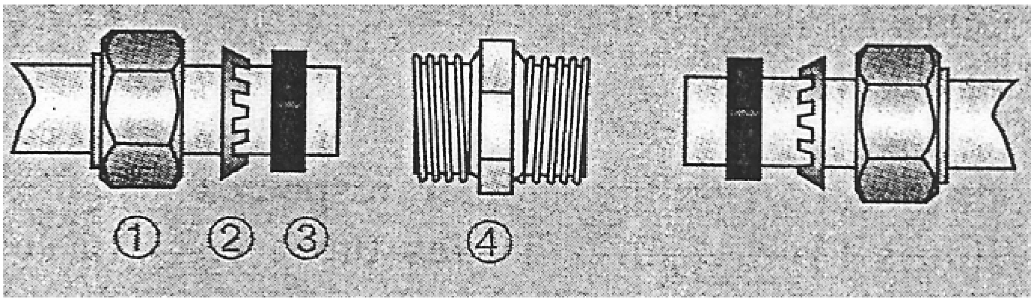


Figure 34: Double Grip fitting

When tightening the crushing of the rubber gasket procures the sealing, while the 2 lockwashers contain the fitting on the tube. The rings must bite into the copper, so it must be tightened firmly.

Change the ring and the gasket with each disassembly.

5.5.1.3. Flare fitting

It consists of a female nut and a male union fitting. To install this type of fitting it is necessary to create a flare first (expansion of the tube to create a flare). This fitting requires the installation of a fibre or rubber gasket for the sealing.

Figure 35: Union fitting and flare

This fitting requires the installation of a fibre or rubber gasket for the sealing.

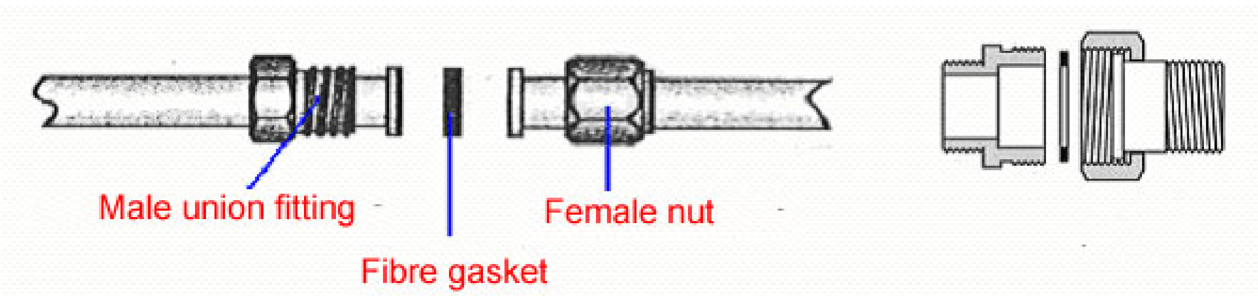


Figure 36: Connection with union and two flares

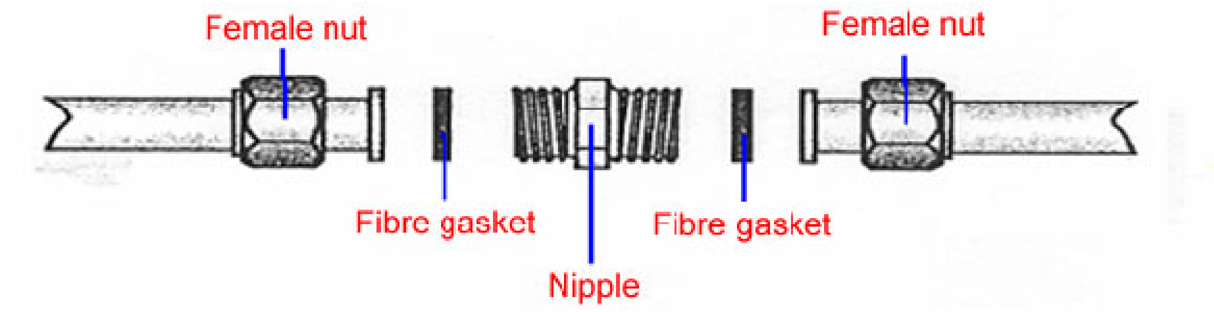


Figure 37: Nipple and two flares

The internal diameters of the nuts and male unions exist in various Ø so they can correspond with the tube that is to be equipped.

All these fittings are forbidden for gas.

5.5.2. Sealing the threaded fittings

For brass, bronze parts the threading must be grooved with a saw blade (imperative to prevent the oakum from sliding).

Figure 38: Grooves on the threading

To prevent the oakum from sliding on the threading when tightening the fitting it is recommended to "scratch" at regular intervals using a pair of tongue and groove pliers or a hacksaw blade.

Work clockwise (anticlockwise for left coupling thread) using strands of oakum to cover the threading completely. Finish with a layer of thread sealant.

Figure 39: Oakum

The thread sealant improves the sealing. By lack of thread sealant, oil (even used) can be used as a replacement: furthermore the oil will make it easier to disassemble the fitting, even after a long period without disassembly.

Figure 40: Applying oakum

By lack of oakum, teflon tape may be used as replacement. The work procedure is the same as when working with oakum.

Sometimes the oakum turns immediately when you start screwing; stop everything and make the joint again. The oakum must not turn. This is why it is imperative to start placing the oakum on the first thread.

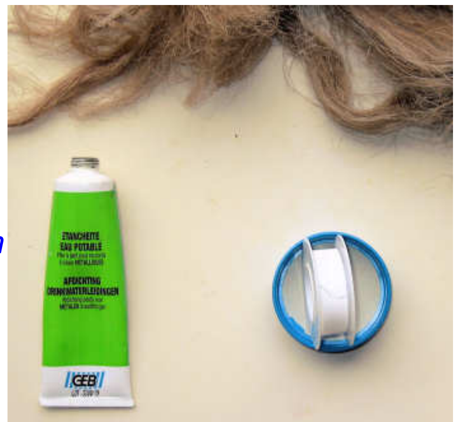


Figure 41: Thread sealant, teflon tape and oakum

This also counts for steel tubes except for the grooving of the threading when they are made of steel.

5.5.2.1. Progressive ring fittings (Ermeto)

The Ermeto fitting is very popular thanks to its easy assembly which only needs two flat wrenches.

Designed exclusively for metric tubes, these fittings can be used at high pressure and they are small.

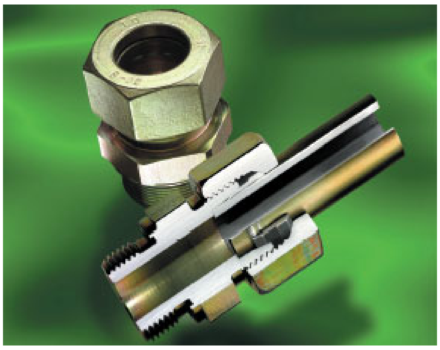


Figure 42: Ermeto fitting + detail

With the assembly of the Ermeto fitting three essential functions are carried out:

- **Penetration of the ring into the tube**: The penetration of the ring into the tube procures the sealing and containment of the tube.
- **Containment of the tube**: The back of the ring is designed to contain the tube firmly. This pressure suppresses vibrations where the ring penetrates, thus efficiently preventing fractures at this level.
- **Spring effect**: Due to the specific design of the ring, the material of which it is made and the heat treatments which it has received the ring bends elastically, like a spring, inside the fitting. This spring effect compensates for the stress due to the penetration of the ring and procures a long-lasting sealing without having to tighten the fitting nuts.

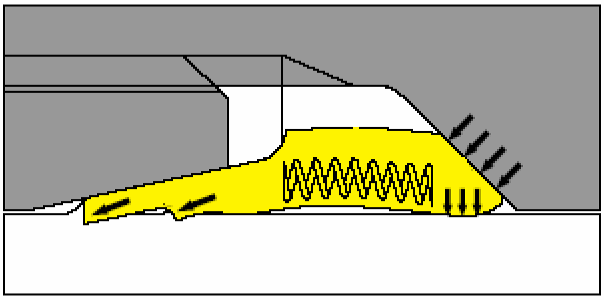


Figure 43: Sealing detail

Naturally, there are many assembly possibilities for threaded fittings as well as for the Grip, union and olive fittings.

Each fitting exists in almost all diameters, different forms (elbow, tee, Y, pitcher tee, coupling…) with a multitude of possibilities (equal, reduced, male/male, female/female, male/female, 45°, 90°.

5.5.2.2. Spherical seat union

The sealing of the assembly is achieved by linear contact between the cone of the nipple and the sphered surface of the bushing.

The tightening of the nut locally crushes the metal thus procuring a tight sealing.

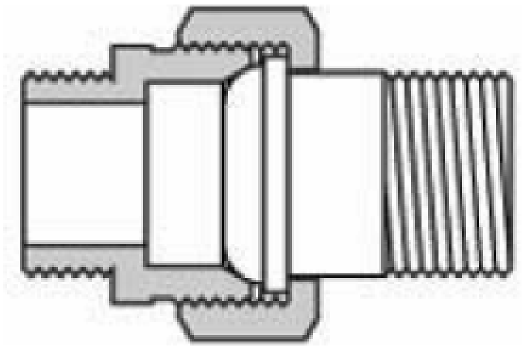


Figure 44: Spherical seat union

This type of fitting also exists in a version which can be welded.

Figure 45: Weld fitting (male and female)

5.5.3. Weld fittings

There are several kinds of copper weld fittings. The ones used most in industry will be discussed in the following paragraph.

In fact, with copper piping, the term “welding” is not used; we speak of soldering or brazing. Welding is a broad term to define the assembly of two parts.

Soldering and brazing consist of a lapped joint assembly of two pieces of metal (the same or different metals) by capillarity, using a welding rod.

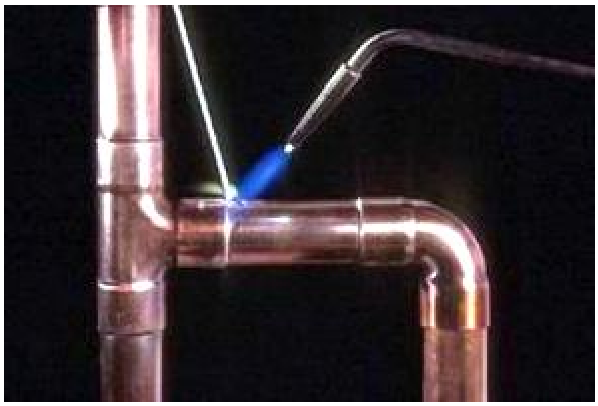


Figure 46: Soldering or brazing

Its melting point stays smaller than that of the metals which are to be assembled. So, properly speaking, we cannot speak of a fusion of the metals: Only the rod melts and infiltrates between the two pieces; into the joint, by capillarity.

Soldering and brazing have several advantages: easy to perform, good mechanical resistance, guaranteed sealing.

On the other hand, it does demand that the parts be carefully prepared. (Careful, if the copper tubes thus assembled are meant for gas piping; Gaz de France imposes standards: the welding rod must contain a minimum of 40 % silver.)

But the metal must always be prepared before starting the work so the soldering or brazing will be better received. This ensures a successful soldering or brazing.

The difference between soldering and brazing:

- ***Soldering**: operation which consists of assembling metal parts by melting metal filler, with a melting point **smaller than 450°Celsius**, in the space between the parts.*

Figure 47: Soldering

- ***Brazing**: operation in which the metal filler melts at a temperature **higher than 450°Celsius.** The procedure is the same; the only change lies in the nature of the metal filler and the flux.*

Figure 48: Brazing

So there is a difference between "soldering" used most for electronics and electricity and "brazing" which is used for piping.

Two things should be noted when speaking of soldering or brazing:

- *Capillary effect / capillarity:* This is a phenomenon where a liquid spreads between the cracks of two parts in contact and which slowly progresses whatever the position of the parts. By heating the parts which are to be assembled to the melting point of the rod a phenomenon of attraction will attract the weld; this phenomenon is called capillarity, this attraction will be all the stronger if the parts have been linked well, thus facilitating the capillarity by preventing a too large clearance between the parts.

- *Wetting:* When the bond between the soldering or brazing and the workpiece is free of apparent defects and the flow of the soldering or brazing appears even we speak of wetting.

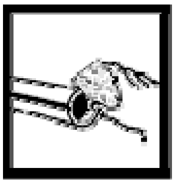
5.5.3.1. Preparing the parts

- Degrease if necessary with a solvent impregnated cloth.
- Tube cut straight and square, burrs meticulously removed.
- Clean with a wire brush, steel wool or emery cloth.
- Fit the parts in their final position; eventually make a mark.
- Apply, before (if possible) or during the welding, weld flux to the parts. This weld flux or flux is a substance which promotes the capillarity by procuring a chemical cleaning of the surfaces.
- It is usually found in the form of paste, powder, liquid or it can coat the soldering or brazing rod.

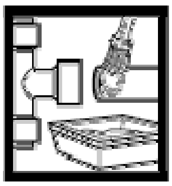
To prepare the pipes a good cleaning is performed with emery cloth.

Figure 49: Cleaning the tube

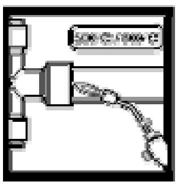
5.5.3.2. Stages of soldering or brazing



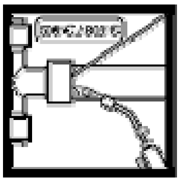
Cut the tube with a tubing cutter, ream it and clean it with the emery cloth



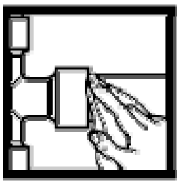
Apply the flux (except if the welding rod is already coated with flux)



Heat the assembly which is to be welded with a blowtorch



Apply the metal filler, melt a drop of solder and divide it evenly over the joint which is to be assembled



Let it cool down and wipe. The traces can be removed with a stroke of the wire brush followed by wiping with a cloth.

This is what a finished solder or braze should look like:

- The metal filler is spread evenly around the tube.
- If this is not the case it means that it has not been done right: Maybe the tubes did not reach a sufficient temperature; maybe the metal was not sufficiently prepared?
- In this case it is necessary to restart all the preliminary preparations: cleaning with abrasive, application of flux paste.

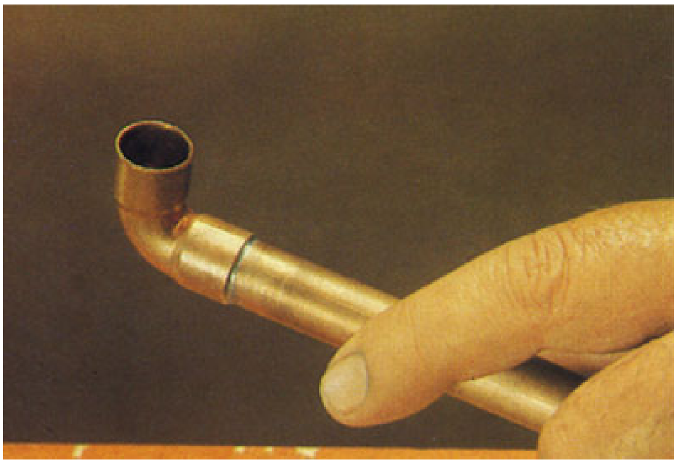


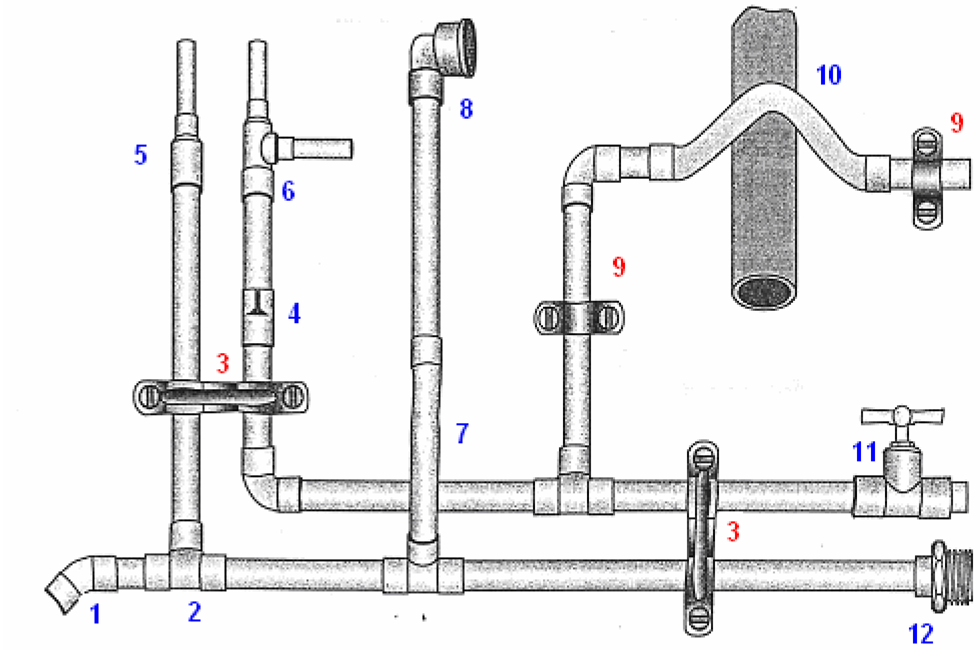
Figure 50: Finished solder or braze

The damages which the structure of the metal can withstand depend on the temperature, but also on the time during which this temperature is maintained.

Consequently, brazing operations, especially those made with filler alloys whose melting point is in the range of 700°C, must be realized as quickly as possible and without hesitation.

Weld fittings are practically identical to threaded fittings. They are found in the same dimensions and forms.

Furthermore, couplings exist which allow connecting two tubes without a fitting or avoiding a pipe by passing above it.



1 : 45° elbow	*7 : Crossover pipe*
2 : 90° equal tee	*8 : Wall crossing*
3 : (double) pipe clamp	*9 : (single) pipe clamp*
4 : Equal coupling	*10 : Crossover pipe*
5 : Reducer	*11 : Valve*
6 : 90° reducing tee	

Figure 51: Weld fittings

Each fitting exists in almost all diameters, different forms (elbow, tee, Y, pitcher tee, coupling…)

There is a multitude of possibilities (equal, reduced, male/male, female/female, male/female, 45°, 90°, etc.…)

Figure 52: Fittings

6. STEEL PIPING

The steel pipes are much larger than those made of copper but steel pipes can also be found in small sizes.

Most of the fittings used for copper pipes can be used for steel pipes (in this case the fittings are made of steel), this up to a certain diameter, then it necessary to use flanged fittings.

Steel is an iron-based alloy with a small added percentage of carbon (content from 0.008 to around 2.14%).

Steel is divided into three categories:

- The non-alloy steels
- The alloy steels
- The stainless steels

The choice of steel for the piping will depend on the nature, temperature and pressure of the transported fluid.

This choice is usually made by the engineering and design department.

To connect steel pipes the same process is used as for copper pipes.

Steel tubes, like copper tubes, can be soldered or brazed, bent, cut and extended according to ones wishes.

6.1. BENDING

The difference between the two materials (copper and steel) lies in how the tube is annealed. An annealed copper tube will stay softer than the steel tube.

There are several ways to bend a steel tube:

- Hot bending: Heating the tube on the place which is to be bent making it possible to shape it into the desired form.

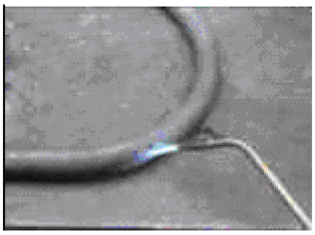


Figure 53: Hot bending

- Cold bending: bending with a specific device (hydraulic bender or a manual one for small diameters)

Figure 54: Cold bending

6.2. FITTINGS

6.2.1. Threaded fittings

Threaded steel fittings are mainly found in the following forms:

- **Coupling**: connects two tubes of the same diameter for an installation without frequent (but possible) disassembly.

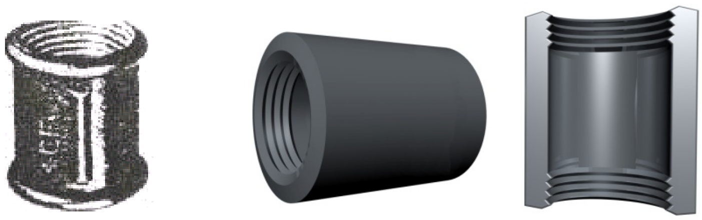


Figure 55: Examples of couplings

- **Reducer**: connects two tubes with different diameters for an installation without frequent (but possible) disassembly.

Figure 56: Reducer

- **Nipple**: connects two tubes of the same diameter (also exists as a reducer) but the tube is threaded. Also used for non-frequent disassembly.

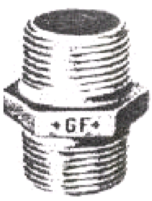


Figure 57: Nipple

- **Elbow**: connects two tubes of the same diameter (also exists as a reducer) to form an angle (90° or 45°). Used for possible (non-frequent) disassembly.

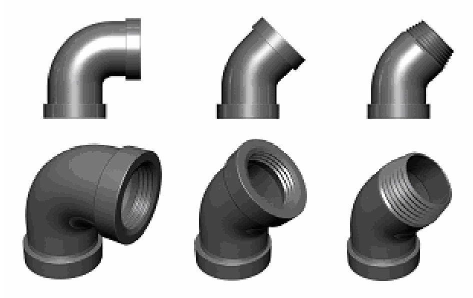
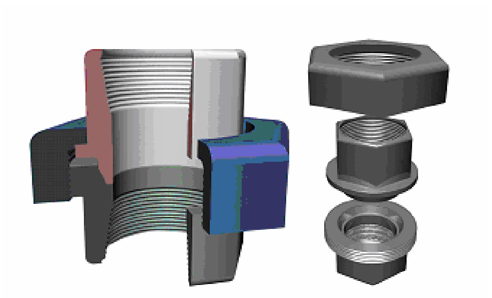


Figure 58: Elbows



- **Union fitting**: connects two tubes of the same diameter. Used for regular disassembly.

Figure 59: Union fitting

- **Tee and cross**: the tee connects three tubes of the same diameter where one tube will be perpendicular to the other two. Used for non-frequent disassembly. The cross connects four tubes of the same diameter.

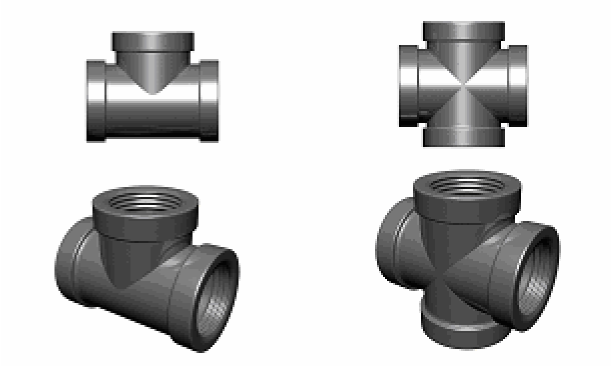


Figure 60: Tee and cross

- **Cap**: used to isolate a portion of the piping.

Figure 61: Caps

To use these threaded fittings the tubes must be threaded. For this a threading tool exists, called a die stock (or pipe threader) and the dies for the threads go up to 60 mm. After that it will be necessary to use weld fittings or flanges.

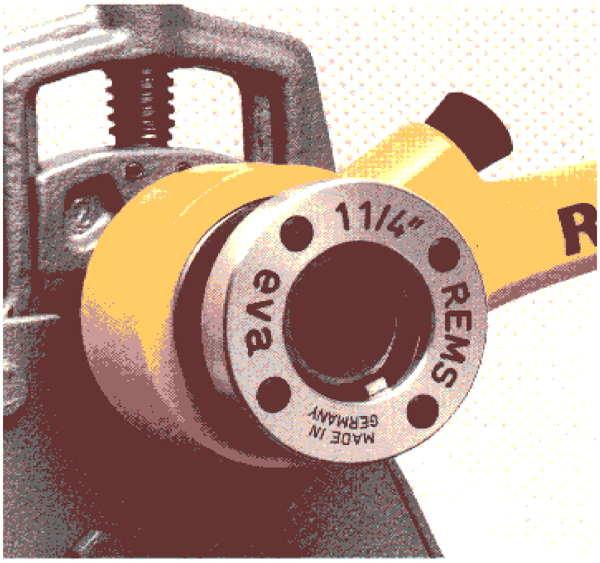


Figure 62: Die and die stock

6.2.2. Weld fittings

Weld fittings for pipes are more or less identical to those for copper pipes, except for one or two exceptions.

Figure 63: Steel weld fittings

6.2.3. Flanges

Due to their nature and design steel pipes are larger than copper pipes, so when their diameter surpasses that of the largest fittings they are fit with flanges.

Figure 64: Flanged fittings

The steel tubes with a small diameter can also be fit with flanges depending on the nature and pressure of the transported fluid.

Figure 65: Flange dimensions

6.2.3.1. Flange disassembly

The flanges can only actually be maintained once they have been disassembled.

The disassembly will be all the easier if the bolts have been slightly greased during assembly. If this is not so, depending on the exposure of the flange which is to be disassembled, and on the state of the bolts (oxidation, etc.…) the disassembly may prove to be very difficult.

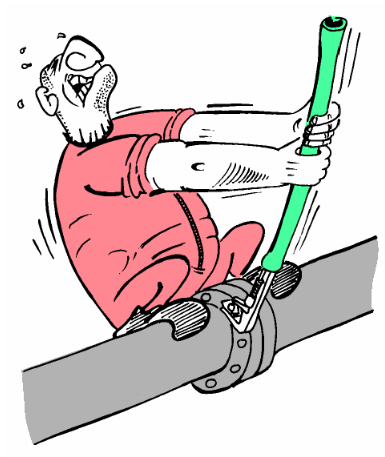


Figure 66: Difficult disassembly

There is no miraculous method for disassembling oxidised or damaged bolts. Heating the bolts with a blowtorch may be enough but depending on the nature of the transported fluid or on the disassembly area (explosive atmosphere), this may be impossible.

For oxidised nuts and bolts, penetrating oil may be suitable (several brands exist). It can be found in the form of a spray or oil can. In both cases it should be applied on the oxidised parts and left to react several minutes (it is often preferable to start the operation over several times). For heavy seizing patience is of the essence.

Figure 67: Penetrating oils

Then comes the radical solution; cutting the bolt. There are various ways to do this:

- Grinder or flame cutting (beware of an explosive atmosphere)
- Cutting with a hacksaw (very lengthy depending on the number of bolts)
- Cutting with a chisel (idem)

In all the cases, care must be taken not to damage the flanges.

The last solution consists of (trying to) break the bolts by using enough force during the disassembly (use long wrenches or extend them with metal tubes) or use a nut splitter.

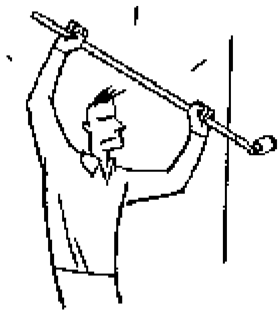


Figure 68: Wrench with extension

Figure 69: Manual and hydraulic nut splitters

The flange may have been disassembled for several reasons:

- Damaged gasket
- Damaged Flange seatings
- Damaged pipe

6.2.3.2. Gaskets

In all the cases, an attempt will be made to change the gasket. This prevents a possible leak when the pipe is put into service.

Before the installation is reassembled, the state of the flanges must be checked, meaning the place where the gasket is installed. It is possible that fluid entered during the leak and that this has damaged the gasket seating; also make sure there are no more traces of the old gasket.

Figure 70: Leak on a water pipe flange

It is imperative that the flange seatings be clean and unmarked; if they are not then leaking is inevitable.

Leaking fittings are usually easy to see.

Figure 71: Leaking water pipe flanges

In the case of a leak, before beginning disassembly, certain measures must be taken.

- Isolate the circuit (after consent)
- Tag the valve(s)

Figure 72: Tagged valve

Then, begin the disassembly and remove the old gasket.

Figure 73: Damaged gasket

The two flanges may stay stuck even though there are no more bolts to keep them in place. This is due to the fact that the gasket is subject to temperature variations and with time it sticks firmly to the surface of the flange.

If this happens you can use a flange spreader (easy to use), a copper wedge or a wooden wedge to separate the flanges.

Figure 74: Copper wedge

The flange spreader can damage the edges of the flanges, be very careful when using it.

Figure 75: Flange spreader

Also be very careful when separating the flange with the copper (or wooden) wedge. If the pipe was under pressure, the flange may abruptly separate and the pipe can suddenly break away.

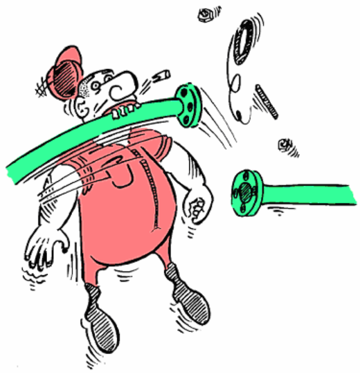


Figure 76: Pressure pipe

6.2.3.3. Flange reassembly

Once this has been done, after checking the flanges, changing the gaskets, the pipe must be reassembled after the flanges have been cleaned with a scraper or a wire brush.

Figure 77: Cleaning the gasket seating

It is easier to apply the gasket once both parts of the flange are exposed. Therefore place two screws underneath. They form a seating to receive the new gasket. To facilitate the placing of the screws and nuts, it is possible to use a conical stem or, if that doesn't work, a rather large screwdriver.

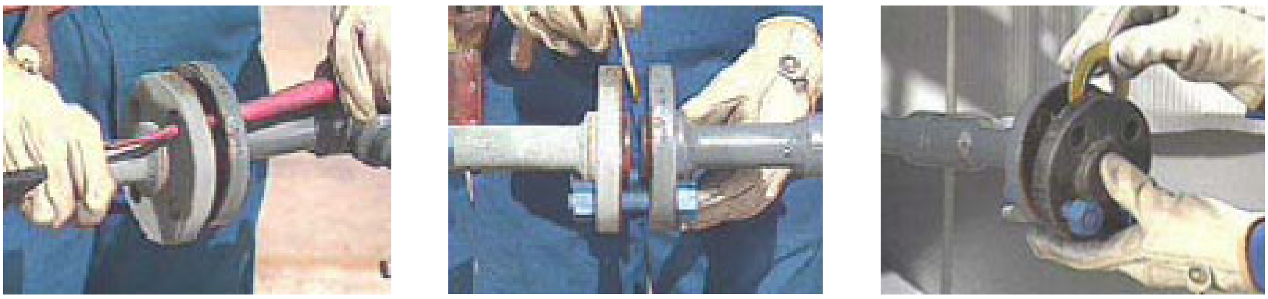


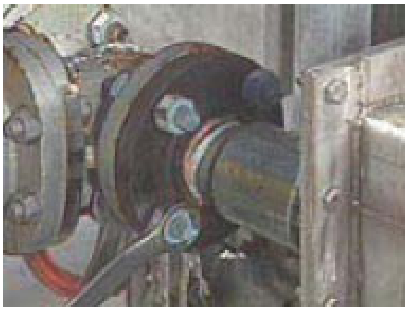
Figure 78: Installation of the bottom screws and the gasket

The screws should be greased to limit corrosion and to allow an easier disassembly during the next intervention.

Figure 79: Lubrication of the screws

The screws must correspond with the Ø of the holes in the flange (certainly not smaller) and be long enough for the end of the bolt to surpass the nut once it is screwed.

Also make sure the material of which the screws are made is compatible with the flanges.



Many small leaks can be repaired without disassembly, by simply tightening the bolts to compress the gasket a bit more; be careful all the same since the pressure in the pipe make cause the gasket to yield which could be very dangerous.

Figure 80: Correction of a small leak

6.2.4. Temporary repair of pipes

Due to factors such as time, corrosion, poor assembly (friction) the pipes may puncture and start to leak out.
.

Figure 81: Perforated tube

In this case a temporary repair may be considered, rather than stopping the installation. A flexible clamping ring (Serflex) and a piece of rubber placed on the hole will seal the leak long enough to find a better solution.

Clean the tube with emery cloth, use a flexible clamping ring (Serflex) with a small piece of rubber and tighten the assembly onto the micro leak.

Figure 82: Flexible clamping ring (Serflex)

Repair couplings also exist; designed for tube reparations but only at low pressure.

Figure 83: Repair coupling

7. PIPE PROTECTION

Corrosion protection is very important for many professional groups.

For insulated installations the corrosion protection is even more important since the corrosion may eventually form underneath the insulation and will only be noticed once the damage is done.

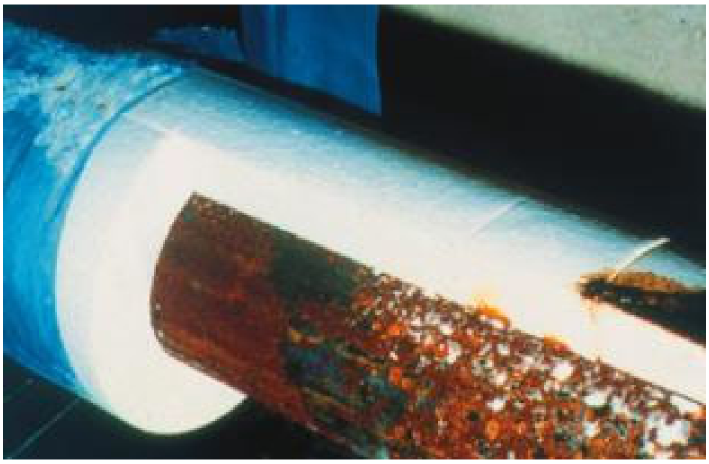


Figure 84: Hidden corrosion

The insulation and corrosion protection are two different domains which must nevertheless be compatible.

First of all, the corrosion protection materials and the insulating materials must be compatible in terms of components (for ex.: the glue).
Then the risk of corrosion can be significantly reduced thanks to the use of adequate insulation materials.

The technical insulation cannot replace the corrosion protection.

Due to operating temperature fluctuations some installations need, even for short periods of time, an efficient corrosion protection. This also counts for pipes in a wet and (or) saline environment.

7.1. CONTACT CORROSION

Contact corrosion occurs when pipes made of different materials are connected.

Depending on the connection of materials, a contact corrosion, caused by electrochemical processes, may appear around the points where the metal comes into contact and, in the worst case, corrosive damage may occur.

In the following chapters, we will discuss the basics concerning the contact corrosion mechanism.

7.1.1. Electrochemical series of the metals

The nature of a metal is especially defined by the ease with which it can be oxidised.

Metals which corrode easily are known as the common metals (- potential) and those which corrode with difficulty as the precious metals (+ potential).

The electrochemical potential series of the metals is given by their oxidation capacity.

7.1.2. Choice of materials in function of their potential

We speak of precious metals when they have a high potential; they have very little tendency to bond.

Metals with a low potential are called common metals; they have a high tendency to bond.

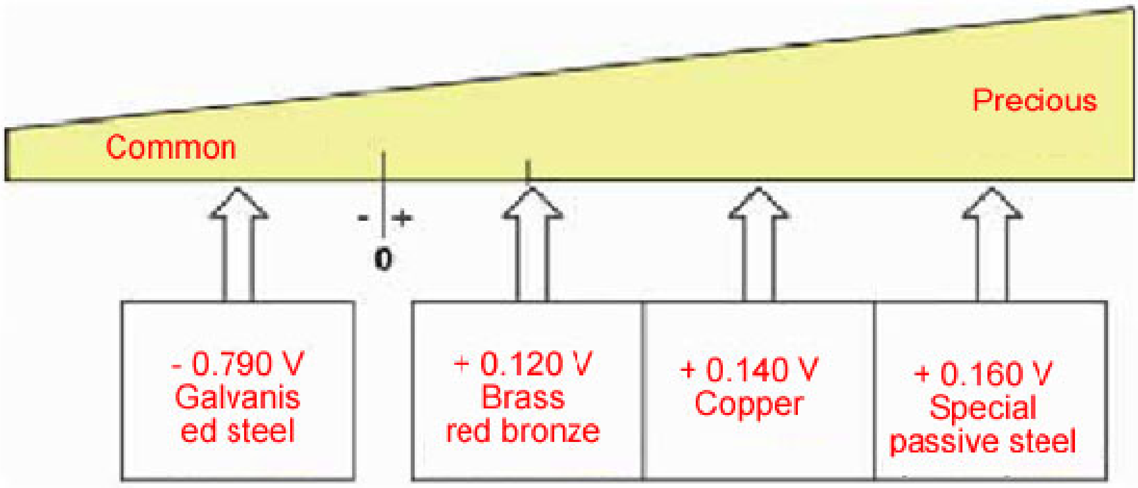


Figure 85: Various potentials

The various potentials in the figure are measured in potable water. The potential values may differ slightly depending on the composition of the potable water.

7.1.3. Contact corrosion mechanism

In a mixed installation, a galvanic unit, short-circuited with a potential difference will appear at the points where the different metals are in contact with each other and in the presence of a fluid acting as an electrolyte. A corrosion current flows (direct current).

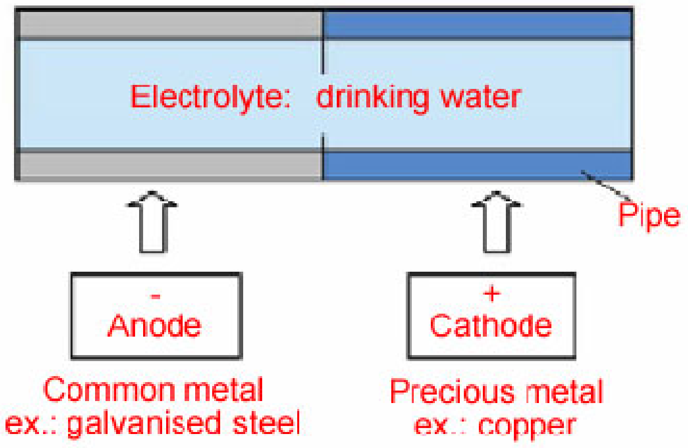


Figure 86: Galvanic unit

7.1.4. Potential difference and corrosion current

When connecting metal parts with different natures « precious/common » the importance of the potential difference and corrosion current depends on:

- The position of the two metals or alloys in the electrochemical potential series along with the eventual presence of passive layers or coating.
- The composition and the properties of the electrolyte (ex: water); in particular the conductivity, PH, oxygen content (oxygen saturation), salt content and temperature.
- The environment: humidity of the air, presence of associated aggressive and corrosive substances in the air.

7.1.5. Corrosion current density/surface rules

The smaller the surface of the anode (metal/common alloy) compared to the surface of the cathode (metal/precious alloy), the higher the importance of the corrosion current density to act on the anode and inversely.

A high corrosion current density causes the corrosion of the anode (metal/common alloy) to accelerate.

7.1.6. Risks and safety measures

Flow rule:

The flow rule must in all the cases be respected for connections with copper pipes: copper pipes must always be installed after < in the direction of the flow > the galvanised steel machine elements (this prevents corrosion caused by the arrival of copper ions).

Combining materials in the installations:

If pipe sections or machine elements made of different materials are connected, the contact corrosion at the connection points can be avoided by disconnecting or interrupting the potential difference.

Steam condensate:

To prevent the formation of steam condensate, and therefore also an eventual contact corrosion, the pipes and fittings subject to cold must be completely insulated with adequate substances.

Preventing contact corrosion of the screws:

The stainless steel pipe fittings must be especially taken into account. In this case the use of galvanised steel screws for the tube flanges and connections is not allowed since, if the formation of steam condensate occurs, the corrosion of the screws is inevitable.

Separating the potential difference:

The assembly of a fitting or valve in red copper interrupts the potential difference between the galvanised and stainless steel (i.e. it is diminished at the contact points).

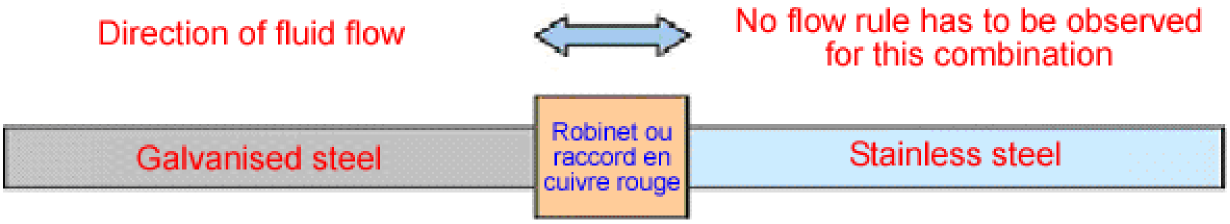


Figure 87: Contact corrosion

The potential difference between copper and stainless steel is very small. This is why the separation of the potential differences is not necessary (exception: copper surface which is very small compared to the steel; for example when only a single copper fitting is used).

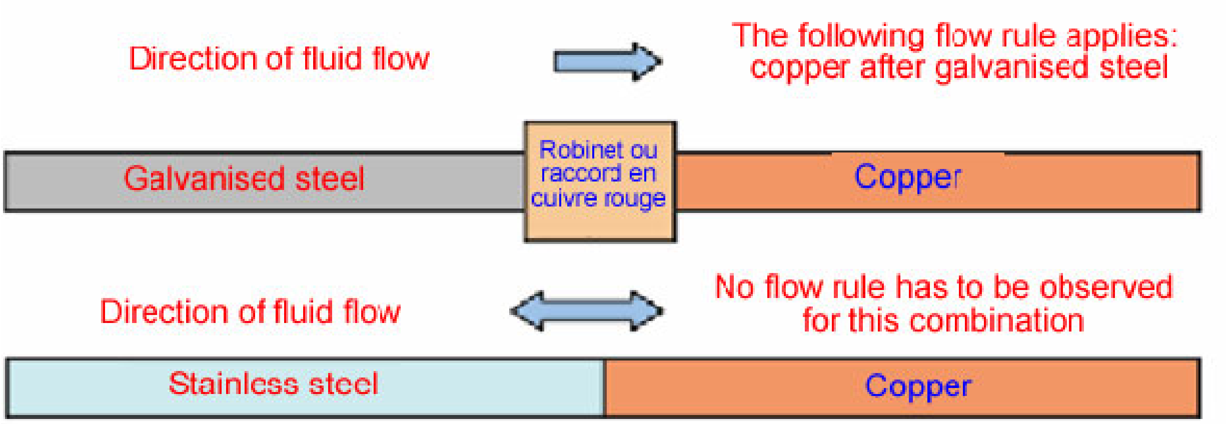


Figure 88: Surface rule

Interrupting the potential difference:

Metal pipes and tubes made of different materials are electrically insulated with insulating gaskets, insulating flanges, threaded fittings (union) or pipe sections in synthetic materials. Thus contact corrosion is avoided.

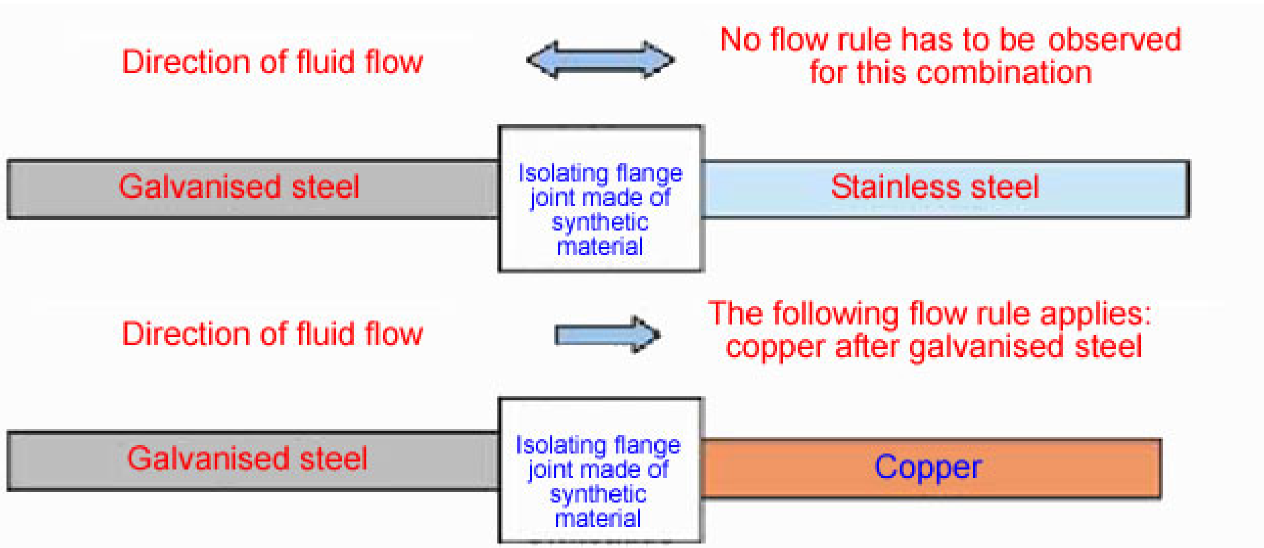


Figure 89: Interrupting the difference potentials

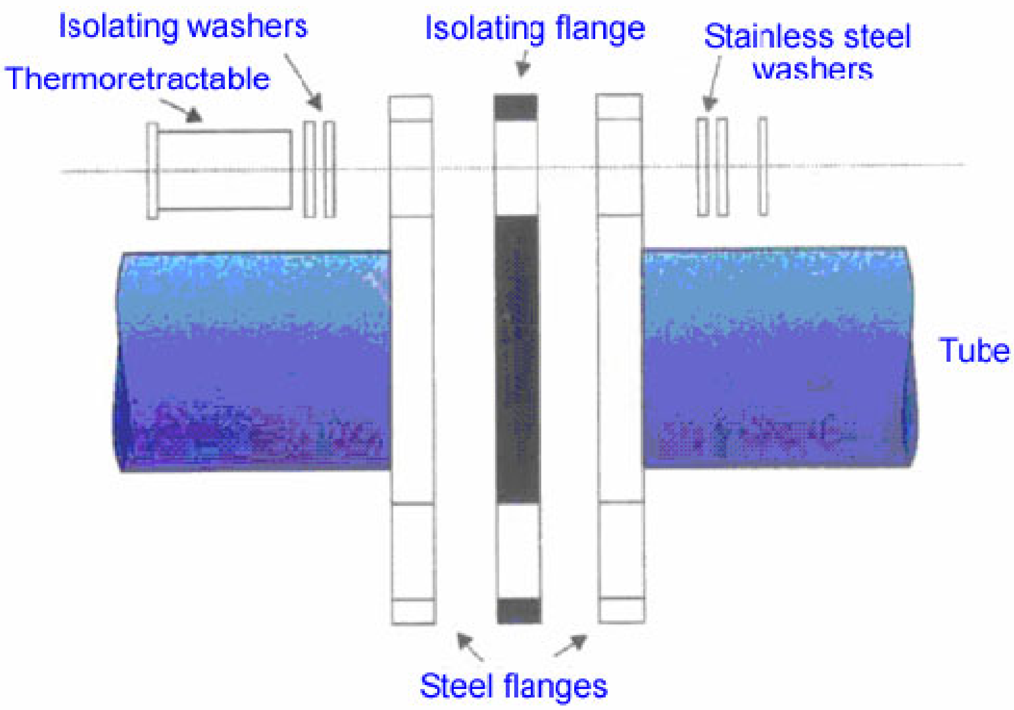


Figure 90: Insulating flange

7.2. CATHODIC PROTECTION

The cathodic protection protects a metal against corrosion.

The basic principle consists of bringing the potential of a metal to a so-called level of passivation.

To modify the potential of a metal which is to be protected cathodically, an anode is installed in the same electrolyte.

There are two types of anodes: the anodes with a higher negative electrochemical potential than the metal which is to be protected (sacrificial anode), and the anodes connected to a direct voltage generator which creates a potential difference between the two metals (method with impressed current).

Cathodic Protection is a technique used to control the corrosion of a metal surface by transforming this surface into the cathode of an electrochemical cell.

The cathodic protection is used to protect the metal the structures against corrosion; notably the steel, water lines, pipelines, reservoirs, steel pier piles, ships and oil platforms.

See the operator's course on cathodic protection.

7.3. VARIOUS TYPES OF PROTECTION

There are several possible corrosion protection methods.

7.3.1. Corrosion inhibitors

They constitute a means of fighting against the corrosion of metals and alloys.

The originality lies in the fact that the anticorrosion treatment does not take place on the metal itself (coating, choice of a corrosion-resistant material) but by means of the corrosive environment.

However, the idea is not to change the nature of this environment but to add a small amount of inhibitor (isolated molecule, mixture of molecules) to the corrosive environment.

7.3.2. Surface treatments

This comprises the chemical or electrochemical operations which change the properties of the surface of the materials in order to confer them with a better corrosion-resistance.

This operation is usually preliminary to the application of paint.

7.3.3. Organic coatings

The use of protective organic coatings is the most commonly used method to improve the durability of metal structures.

Paint layers comprise an insulating layer between the surface of the metal and the aggressive environment.

In practice, the layers have defects (holes, grooves) through which the aggressive species penetrate through to the metal where the corrosion starts.

The corrosion processes under the organic coatings are complex and depend on several parameters such as, for example, the properties of the paint and of the metal/paint interface in terms of adhesion.

Figure 91: Poor adherence of the paint

To counter the formation and progression of the rust, several processes are currently used.

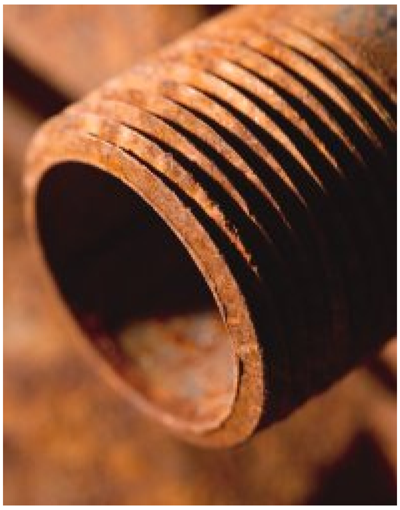


Figure 92: Rusty threaded tube

Whatever the quality of the paints used, the obtained results are usually not those which are expected since these paints only cover the parts which are easy to access and the pigments in the paint do not reach the bright metal due to the viscosity.

So the paints can only partially fulfill their task.

Applied to porous surfaces, a layer of paint imprisons enough air and moisture between itself and the bright metal for the rust to develop quickly.

The rust appears after blistering and cracking the paint film which covered it: “rust penetration” takes place.

Figure 93: Rust penetration

In order to avoid this risk at a maximum, an operation imposes itself: a meticulous preparation of the surface, operation which is usually performed by mechanical processes: sand blasting, shot blasting, tapping, scraping, wire brushing, etc.

Figure 94: Severe oxidation

8. PIPE MOUNTING

The various pipes tend to vibrate when in operation, either because they are more or less rigidly connected to parts which already vibrate themselves, or because the pressure pulsations in the flowing fluid are in resonance with their natural vibration frequency.

In all the cases, these vibrations expose the pipes to fatigue fractures in the vicinity of their extremities or to frictional wear.

To limit these incidents it is necessary to:

- Counter the vibrations
- Ensure an efficient mounting (maximum immobility) of the pipes by using clamps fixed to the partitions, the floor or to other tubing.

The mountings are generally defined at the initial installation of the pipes, but during various disassemblies and reassemblies, changing of the pipes, it is possible to see the poor condition (twisted, torn off …) or the disappearance of these mountings.

The pipes are often suspended and must pass through openings in the partitions and floors.

Without adequate support these pipes could reach the point of breaking or leaking.

Several other factors must also be taken into consideration when the pipes are installed.

These include possible damages such as:

- The dilatation and the contraction of the pipes (thermal shocks)
- The vibrations transmitted to the pipes
- The flow rate changes in the pipes

The supports are available in many different designs, but they are usually divided into two categories:

- The pipe supports which support the pipes from underneath
- The piping suspension loops (or U-bolts) used to mount the pipes on the ceiling.

Figure 95: Support from underneath

Figure 96: Fastening to the ceiling

The choice depends on the demands of a particular system.

There are several mounting methods:

- A clamp fixed to another pipe or to a partition

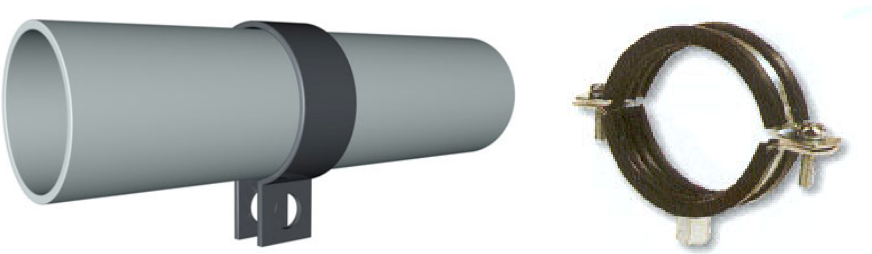


Figure 97: Clamps

- To a rail
- To a metal support
- To a partition
- To the floor
- Etc…

Figure 98: Possible Mountings

Connecting clamps to the ends of these mountings is sufficient to keep the pipes from vibrating.

Figure 99: Mounting the clamps

It is also possible to place a tightener between the clamp and the mounting.

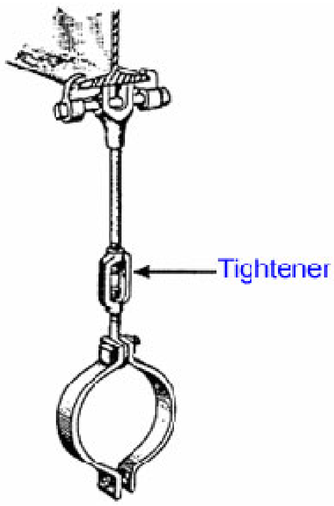
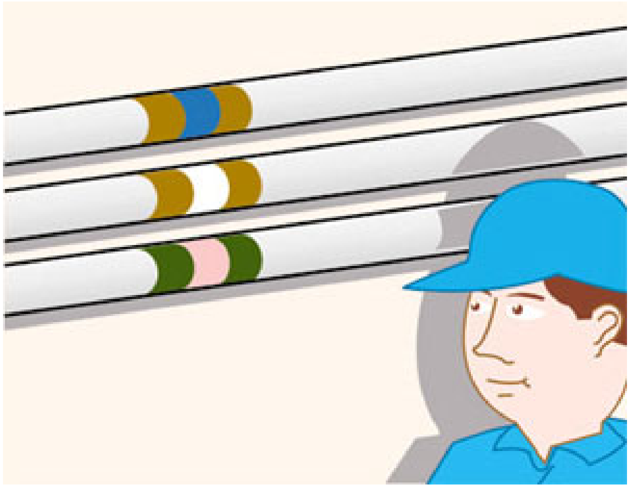


Figure 100: Detail of tightener

It is essential to respect the integrity of the mountings of all the pipes and, if it needs improvement, to improve it but carefully; i.e. while not creating harmful effects to another part of the circuit.

In all the cases, always place a piece of rubber or neoprene between the pipe and the clamp, so as to not wear the pipe with the clamp.

9. COLOUR CODING OF RIGID PIPES



Colour coding is used to alert on the hazard associated with the contents of a rigid pipe.

The goal of such a marking is to make the task easier for the technicians, to facilitate intervention by safety crews in case of damage and to thus prevent any confusion which could lead to incidents or to serious accidents.

Figure 101 : Example of colour codes

The identification of the fluids in the pipes is done with three series of colours:

- The **main identification (background) colour**: specifies the family of the fluid
- The **secondary identification colour**: allows identification of certain specific fluids
- The **status identification colour:** indicates the state of the fluid

9.1. MAIN IDENTIFICATION COLOUR

Each family of fluids has its own specific main identification colour. This colour can be placed:

- Along the **whole length** of the piping
- Or on **part** of the piping:
  - In the form of a ring
  - In the form of a band

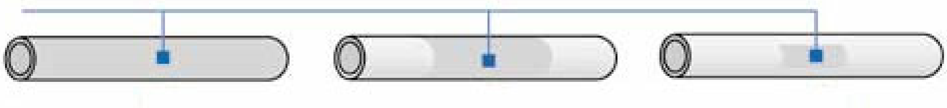


Figure 102: Main identification colour

9.2. SECONDARY IDENTIFICATION COLOUR

Some fluids have a specific colour called the secondary identification colour.

This colour is placed on several places, along the whole length of the main identification colour, in the form of a ring or band.

To distinguish a mixture of fluids, several secondary identification colours can be used.

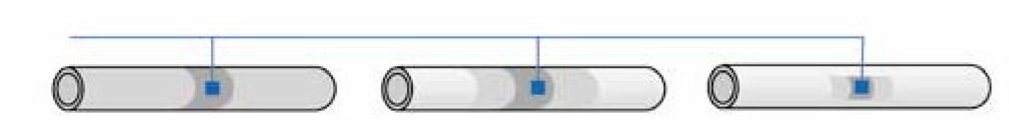
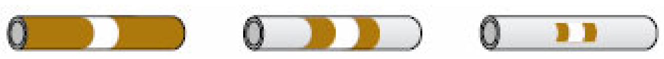


Figure 103: Secondary identification colour

Note: The secondary identification colours may be separated with a slight interval or black or white line, in order to procure a better contrast.

A table resumes the various colours found on the pipes and indicates the fluid hazards on account of the regulations for hazardous substances and mixtures (orders by the Minister of Labor, dated April 20th 1994, concerning the declaration, classification, packing and labeling of substances ; modified on February 21st 1990 concerning the labeling of mixtures)

	White and black	Breathable air for medical use
	Green-Yellow	Medical air
	Medium pink	Industrial, domestic or natural fuel gas
	Light brown	Acetylene
	Green-light yellow	Ammonia
	Medium yellow	Argon

	Black	Nitrogen
	Very clear grey / blue-green	Chlorine
	Orangey grey	Cyclopropane
	Dark grey	Carbon dioxide
	Medium violet	Ethylene
	Blue-bright violet	Nitrous oxide (dinitrogen oxide-laughing gas)
	Medium brown	Helium
	Red-bright orange	Hydrogen
	White	Oxygen
	White and black	Breathable mixture oxygen nitrogen
	Medium pink	Distilled purified or demineralised water
	Light grey	Potable water
	Black	Non-potable Seawater
	White	Very flammable liquids with flash point < 0 °C

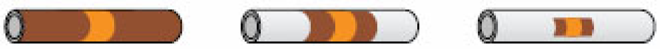
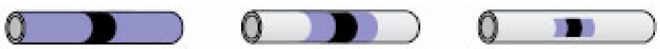
	Green-light yellow	Flammable liquids with flash point < 55 °C or with flash point ≥ 55 °C and with a temperature equal to or higher than their flash point
	Blue-bright violet	Flammable liquids with flash point ≥ 55 °C and with a temperature smaller than their flash point
	Medium yellow	Lubricants
	Bright orange	Liquids for hydraulic power transmission
	White	Acids
	Black	Bases
	Nil (only name in clear)	All fire suppression fluids

Table 1: Table with summarization of the secondary identification colours

The ISO/R508 recommendation indicates blue as secondary identification colour for soft water, potable or non-potable.

9.3. THE STATUS COLOUR

This colour specifies some of the fluid's properties: pressure, temperature or purity.

This indication can be useful for the pipes subject to rules and regulations concerning steam and gas pressure vessels.

In addition to its intrinsic danger, the state in which the fluid is transported in the rigid pipes engenders risks (burns, injuries caused by the expansion of pressurized products, etc.…) or increases, for some kinds of pressurized gas, the risk of asphyxia due to replacement of the oxygen.

This colour is placed, sometimes on several spots, in the form of a ring or a band.

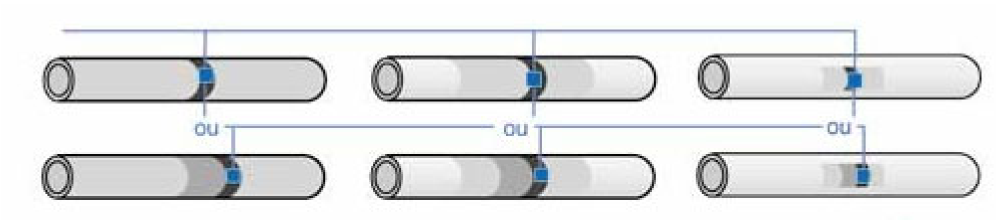


Figure 104: Status colour properties

In the case there should be both a secondary identification colour and a status colour; the two rings or bands are joined.

The table below gives various examples of main, secondary and status identification colours.

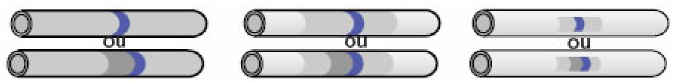
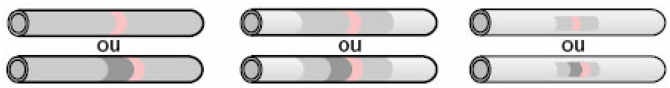
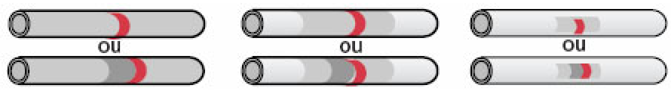
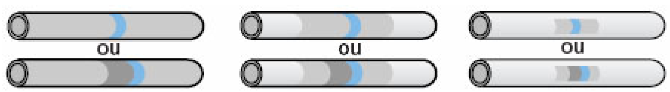
	Orangey grey	Hot or superheated
	Medium violet	Cold or cooled
	Medium pink	Liquefied gas
	Red-bright orange	Pressurized
	Light blue	Rarefaction gas under very low pressure
	Medium brown	Polluted or foul

Table 2: Examples of combinations

9.4. DIRECTION OF THE FLOW

Indicating the direction of the flow can prove very useful to quickly locate the block valves in case of an emergency.

If the main identification colour is continuous, a white or black arrow (so as to ensure a better contrast with the main identification colour) is placed in the direction of the flow.

For two-way flows, a double arrow is placed.

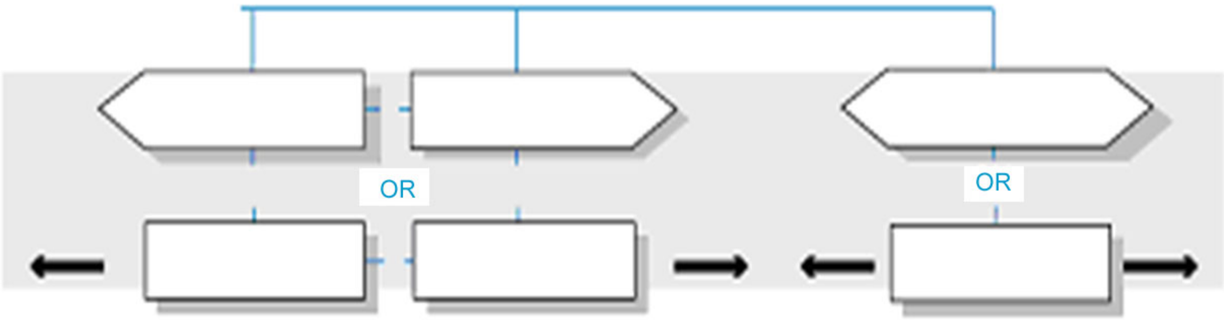


Figure 105: Direction of the flow

If the main identification colour is discontinuous, each ring or band with a main identification colour ends in the point of an arrow or an arrow is added (white or black).

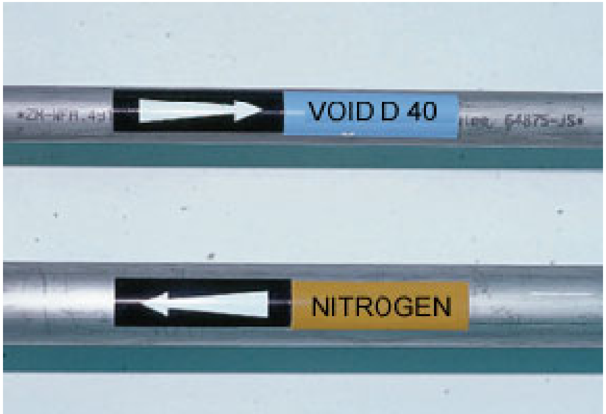


Figure 106: Direction of the flow and colour code

For two-way flows, each end is applied in the form of a point with two arrows joined to it.

9.5. ADDITIONAL INFORMATION

It is often recommended to attract the personnel's attention to the hazardous nature of certain fluids more explicitly.

Therefore labels, plates, writings or icons are attached to the piping close to the main identification colour.

The hazard warning sign is a yellow equilateral triangle showing a general hazard warning or, using an icon, the nature of the specific hazard.

	General warning
	Flammable or oxidizing materials
	Explosive materials
	Corrosive or irritating materials
	Toxic or noxious materials
	Materials at high temperatures
	Substances under pressure

Table 3: Warning signs

Some indications concerning the fluid (pressure, temperature, etc.…) can be found in a blue rectangle situated underneath the triangle.

Thus the fluid can, along with the colour code, be identified by its name written, in full or abbreviated, in clear (notably when the gas concerned is not defined with a secondary identification colour).

A numeric or alphanumeric code marker, such as the one defined by the regulations concerning the transport of hazardous materials, may eventually be used.

Colour coding only supplies partial information. The main idea is to inform about the absence of danger, the physico-chemical properties which could lead to a fire and/or explosion hazard, or about the toxicological properties related to the action of the fluid on living beings. Only the acute toxicity is considered, i.e. the one which could result from an accident such as the leaking or fracturing of a pipe

9.6. FLUID PROPERTIES

9.6.1. Physico-chemical properties

- **Extremely flammables (F+) :**

  Substances and liquid mixtures with an extremely low flash point and a low boiling point; and substances and gas mixtures which, at ambient temperature and pressure, are flammable in air.

- **Easily flammables (F) :**

  Substances and mixtures : which can heat up to the point of igniting in the air at ambient temperature without input, in liquid state, with a very low flash point, which produces extremely flammable gas in hazardous quantities when it comes into contact with water or moist air.

- **Flammables :**

  Substances and liquid mixtures, with a low flash point

- **Oxidizers (O) :**

  Substances and mixtures which have a highly exothermic reaction when they come into contact with other substances, notably the flammables.

9.6.2. Toxicological properties

- **Very toxics (T+) :**

  Substances or mixtures which lead to acute/chronic risks or death when inhaled, ingested or absorbed through skin absorbed in very small quantities.

- **Toxics (T) :**

  Substances or mixtures which lead to acute/chronic risks or death when inhaled, ingested or absorbed through skin in small quantities

- **Corrosives (C) :**

  Substances and mixtures which cause damage to living tissue on contact

- **Irritants (Xi) :**

  Non-corrosive substances and mixtures which cause an inflammatory response upon immediate, prolonged or repeated contact with the skin or mucous membranes

These hazardous properties can also be associated.

The colours used for the identification can fade over time and, since they are next to each other, they can end up being confused with each other, thus creating a hazard which joins the one which the substance itself may represent.

To make the recognition easier, any alterations in the colours, all marking defects, which could lead to confusion, should be corrected as soon as possible.

This standard identification method with colour codes does in no way substitute the regulation identification and service labels to which gas and steam pipes are subject (decree of January 18th 1943 modified with regulations for gas pressure vessels).

Whichever the identification method used a quick and easy identification of the contents of a pipe and its hazards can only be ensured if the internal operators have been trained to counter the specific risks of the company.

The training is still the most efficient means of prevention.

9.7. AFNOR STANDARDS

AFNOR Standards concerning colour codes:

- **NF X 08-003**: safety colours and labels.
- **NF X 08-100**: rigid pipes - identification of the fluids with colour codes.
- **NF X 08-101**: colour codes of the pipes. Table of base pigments which can be used to realize the colour codes on the pipes.
- **NF X 08-105**: chemical plants. Identification of the fluids transported in the pipes.
- **ISO/R 508**: colour codes for the identification of the pipes transporting gas or liquid fluids in the installations on land and aboard the ships.

10. FIGURES

11. TABLES