Commission of the European Communities

DIRECTORATE-GENERAL
FOR SOCIAL AFFAIRS

Steel Industry Safety and Health Commission

OXYGEN

- Flexible pipes

LUXEMBOURG – 1974

V/1211/73 – E

1. Introduction

The aim of the present report is to illustrate the most suitable processes from the safety point of view with regard to the characteristics of the design and use of flexible pipes for gaseous oxygen for the steel industry. These processes are divided into two groups in accordance with the nature of the material in which the flow of oxygen is to circulate:

- flexible metallic pipes
- flexible pipes in organic materials

2. Flexible metallic pipes

2.1 Description and materials

The different types of flexible metallic pipes used for oxygen are formed from two parts:

- an inner skirt, i.e. the internal metallic piping
- the resistant sheathing to ensure the mechanical behaviour vis-a-vis the internal pressure and to afford protection against external influences (mechanical, thermal or other stresses).

The resistant sheathing is formed from one or a number of metallic braidings or plastic material.

In order to improve the degree of protection, additional braiding, asbestos or even laced metal can be added depending upon the external influences.

The inner skirts can be classified on the basis of their manufacturing methods in the following manner:

- from a drawn and subsequently corrugated tube
- from a welded and subsequently corrugated tube
- from spiral wound sheeting, with the edges welded

- from spiral wound sheeting, with the edges set together without any additional sealing strip being interposed
- from spiral wound sheeting, with the edges set together with additional sealing strip interposed.

At its ends, the flexible pipe is connected to collars. The sealing of the inner skirt vis-a-vis the exterior must be assured at this point and both the inner skirt and the sheathing must be firmly attached to these collars.

Stainless steels, special bronzes (phosphor, nickel, beryllium and aluminium) are suitable for all such inner skirts.

Because of subsequent corrosion, carbon steel cannot be used for the manufacture of inner skirts from wound and set sheeting.

It can be used, however, for the manufacture of inner skirts from a drawn or welded tube and also when the edges of the wound sheeting have been welded.

The sealing strip for the set edges can be in chlorate or nitrate elastomer, or in pure asbestos (free of cotton).

The resistant sheathing can be formed from a metallic or a plastic braiding.

The plastic braiding is not suitable for flexible pipes with a set inner skirt.

Moreover, it is only suitable for cases where there is no risk of deterioration (mechanical, thermal or any other) as a result of the external conditions.

The metallic braiding must be formed from carbon steel with an effective protecting cladding (zinc, cadmium nickel plating etc.), or in stainless steel.

Lastly, for both technical and practical reasons, the end collars should be of the same material as the inner skirt.

The proper choice from the wide range of flexible metallic pipes will depend upon a number of factors.

One of these factors is the inflammation temperature in oxygen of the metal comprising the inner skirt.

Carbon steel, stainless steels and special bronzes have inflammation temperatures in oxygen equal to or great than $900^{o}C$. These are therefore ideal components.

Nevertheless, when the flexible pipe is spiral wound with the interposition of an elastomer sealing strip, a much lower inflammation temperature than that quoted above has to be allowed for.

Preservation of the sealing properties through time and metal fatigue resistance of the inner skirt are further factors that have to be taken into account.

On these levels, the order of decreasing preference is as follows:

- flexible pipes manufactured from a drawn tube
- flexible pipes manufactured from a welded tube
- spiral welded flexible pipes
- spiral wound flexible pipes, set, with sealing strip
- spiral wound flexible pipes, set, without sealing strip.

The environmental conditions in which the flexible pipe will be used influence the choice of the outer sheathing.

If an additional protecting layer is required for a flexible metallic pipe, it is recommended that access be left to inspect the condition of the outer resistant braiding.

It should also be noted that all additional air-tight protecting layers (that is to say, in the form of a tube) or in non-fluorous material should be avoided.

2.2 Precautions to be taken during construction

To facilitate manufacture of the inner skirts, it is generally necessary to lubricate the tube or the sheeting in order to carry out the shaping. When, after this shaping has been effected, the spiral windings have to be welded together, the manufacturer carries out a very thorough degreasing first of all, in order to ensure the high quality of the welding and also to ensure that there are no deposits of grease on the inner skirt. But in other methods for the manufacture of inner skirts, the manufacturer does not carry out this degreasing for manufacturing reasons. But, for flexible pipes that are to be used with oxygen, this degreasing operation is indispensable and must be carried out subsequently.

From the different types of inner skirts, those comprising set windings are the most difficult to degrease, as the grease particles tend to lodge in the setting zones. For this reason, certain companies stipulate that the degreasing is carried out by immersion in a solvent with ultrasonic agitation.

The fixing of a flexible pipe on a collar can be effected in several ways. It is current practice in a number of companies to rely on the manufacturer in this connection who is to supply both the flexible pipe and the collars. Certain companies tend to be more demanding and stipulate themselves the nature of the fixing (electric welding, tin or copper brazing, or even sticking) taking into account both the nature of the material of the collar piece and the experience and the manufacturing methods of the manufacturer. Experience with the material differs widely, but the study group considers that with the present level of adhesion techniques using epoxy or polyamide resins, these latter are not suitable. In the opinion of one expert, copper brazing and induction heating would be the best solution, but would require a considerable amount of equipment to effect it.

With regard to tin brazing, the results can be disappointing as a result of the fissuring corrosion phenomena arising in the presence of oxygen.

2.3 Inspection before use

It is essential that every flexible pipe that is to be used with oxygen is subjected to inspection before use.

The study group is of the opinion that these tests should be carried out in the following chronological order:

On all flexible pipes

- resistance test: a hydraulic test at a pressure twice that of normal use;
- degreasing test: this test is carried out with the aid of a solvent (see in this connection the section entitled "The degreasing of conduits and other equipment" published in a separate document) introduced at the bottom of an inclined flexible pipe following a constant or a progressive angle of slope and by testing the grease content of the solvent as it leaves the top of the pipe. These inspections enable the moment to be identified at which the degreasing process is completed;
- air-tightness test: carried out with pressurized nitrogen (a neutral and clean gas) in a water tank at a pressure lower than that of normal service (in accordance with A.P.I. standard: 5.6 bars), with results confirmed by the absence of bubbles.

On a sample

- bursting resistance test: hydraulic test carried out at a pressure three times higher than that of normal service.

Immediately after the air-tightness test, the ends of the flexible pipe will be hermetically sealed by permanently effective means, sealed by the user in such a way that only persons responsible for their installation can dismantle them.

2.4 Precautions relating to the use of flexible metallic pipes

- When ordering flexible metallic pipes for oxygen purposes, companies should request the manufacturer to supply a certificate of conformity.

- It is strongly recommended that the assembly, maintenance and inspection of flexible pipes - at least those of large dimensions - should be carried out in conjunction with the manufacturers or their representatives.

- The flexible pipes must be installed by competent fitters and in accordance with the instructions issued by the manufacturer.

- Before the installation work is commenced, the complete cleanliness of the flexible pipe and the installation should be checked.

- During the installation, the initial cleanliness of the flexible pipe must be maintained. (See in this respect paragraph 2.3 concerning the protection of the ends of the flexible pipe).

- In the event of the violent breakage of a flexible pipe, a surging is produced by the massive outflow of oxygen. To avoid this surging, which is always very dangerous because it is uncontrolled, it is recommended that the flexible pipe is held in position by means of a safety cable attached to the flexible pipe at regular intervals. Additionally, this safety ensures the equipotentiality of the two ends of the flexible pipe.

- The outer braiding of the protecting layer of a flexible pipe in service must be inspected at regular intervals.

- All necessary precautions must be taken to prevent any deterioration during the assembly, storage and use of flexible pipes.

- The necessity of providing an earth connection for the flexible pipe will be taken into account for each separate case in conjunction with the electrical services.

- All precautions must be taken to ensure that a flexible pipe that has been used for a fluid other than oxygen is not used for this latter.

- It is the responsibility of the company, rather than the manufacturer, to indelibly mark the appropriate flexible pipes "oxygen".

3. Flexible pipes in organic materials

3.1 Description and materials

There are two such categories of flexible pipes currently on the market:

- flexible pipes consisting of alternating layers of chlorate or nitrate elastomers and cotton or metallic braiding, adhering or otherwise to the elastomer.

  It should be noted in this connection, that it is preferable to use flexible pipes where there is an adhesion between the elastomer and the braiding, as - in this case - the mass of the elastomer and the braiding is reduced and this, from the point of view of the oxygen, is of prime importance.

- flexible pipes with inner skirts in fluorous resins and metallic braiding or in non-adhesive polyamide.

  In flexible pipes of fluorous resins, the inner skirt assures only the air-tightness of the piping, while the polyamide or the metallic braiding provides the mechanical resistance and protection against external influences.

Flexible pipes entirely in polyamide have been used only since recently for gaseous oxygen under pressure.

All conditions being equal, flexible pipes in fluorous resins offers three advantages in comparison with flexible pipes in chlorate or nitrate elastomers and, to a large extent, also in comparison with flexible polyamide pipes:

- a considerably lower mass of organic material
- a higher inflammation temperature (at least twice)
- a much lower calorific value (seven times lower).

The inflammation temperature and the calorific value of polyamides are in the same range as those of chlorate and nitrate elastomers, but their

mechanical resistance is much higher with the result that the thickness of the pipe is lower, resulting in a much lower mass of organic material and, in the event of inflammation, a lower heat emission.

The above data enables the following decreasing order of preference to be established with regard to flexible pipes in organic materials and also with regard to their risk of inflammation:

- flexible pipes in fluorous resins
- flexible pipes in polyamides (*)
- flexible pipes in chlorate or nitrate elastomers, in which there is an adhesion between the braiding and the elastomer
- flexible pipes in chlorate or nitrate elastomers, in which there is no adhesion between the braiding and the elastomer

With regard to air-tightness, the flexible pipes in polyamide have an excellent performance. Flexible pipes in chlorate or nitrate elastomers and in fluorous resins are not so outstanding. But the difference is slight and this argument does not make up for the advantages offered by the fluorous resins, by virtue of their low mass, their high inflammation temperature and their low calorific value.

With regard to their thermal stresses, these are best resisted by the flexible pipes with a metallic braiding. For this reason, it is the flexible pipes in fluorous resins or elastomers (with this type of braiding) that are most suitable.

With regard to mechanical stresses, the advantage belongs again to the flexible pipes in chlorate or nitrate elastomers with or without adhesive metallic braiding.

In conclusion, it is the flexible pipes in fluorous resins that offer the most advantages and it is these that should be preferred.. However, they do not come in all dimensions and, moreover, have a low resistance to mechanical

---

(*) Reference is also made to the fact that there are flexible pipes in polyvinyl chloride, reinforced or otherwise, the appearance of which is similar to the flexible pipes in polyamide.

stresses. When such stresses are foreseeable, or when flexible pipes in fluorous resins are not available, preference should be given to flexible pipes in chlorate or nitrate elastomers with metallic braiding and in which there is an adhesion between the inner skirt and the metallic braiding.

3.2 Precautions to be taken during manufacture

To facilitate the extrusion of fluorous resins, light petroleum is added to the PTFE powder. Other processes for the manufacture of the extrusion paste make use of light oils.

If the use of light petroleum does not entail any risks for the manufacture of flexible pipes in fluorous resins for oxygen, and if the light petroleum becomes volatile during the heating, this is not the case for the oil, as a certain quantity remains in the resin lowering the inflammation temperature and this by a not inconsiderable level.

The result is therefore that light petroleum should be exclusively preferred for the manufacture of flexible pipes in fluorous resins for oxygen.

Flexible pipes in plastic materials must be internally cleaned by a suitable method and will subsequently be the subject of a contradictory examination between the manufacturer and the user.

The fixing of a flexible pipe onto the collar pieces is a delicate operation requiring great care, special tools and competent staff. The study group recommends that this fixing be carried out solely at the premises of the supplier and not on site in the steel industry where where suitable conditions cannot be obtained, taking into account the requirements of the oxygen. In the same spirit, the use of recoverable collars is not recommended.

The requirements given above relating to the fixing of the flexible pipes onto the collar pieces do not apply in the case of pressures of less than 8 bars. The manual welding and oxy-acetylene torches should not therefore be fitted with flexible pipes in accordance with these conditions.

During the fixing by press of the flexible pipe onto the collar piece, a lubricator is used to prevent any deterioration of the inner skirt. For flexible pipes for oxygen, it is recommended that one of the following lubricators be used: water, graphite, talc or molybdenum bisulphide.

But at the same time, those lubricants acceptable for oxygen cannot be used as a result of the risk of confusion they present with hydraulic fluids.

When the flexible pipe comprises braiding in highly inflammable materials (cotton, cellulose acetate or the like), the ends or these braidings must be carefully trimmed right back to the level of the plastic material, as, if it overlaps this, it can inflame under some external influence and thereby constitute a risk of inflammation to the flexible pipe, and this even more so, in the event of there being a leak between the flexible pipe and the collar piece.

3.3 Inspection before use

Each flexible pipe in plastic material must be subjected to a resistance test, hydraulic test at a pressure equal to twice that of normal service.

The airtightness between the collar piece and the flexible pipe is to be tested in a water tank, with the flexible pipe being filled with nitrogen at normal operating pressure.

A bursting resistance test must be carried out on a certain percentage of the flexible pipes by means of a hydraulic test carried out at a pressure three times greater than that of normal service.

Immediately after the air-tightness test, the ends of the flexible pipe are to be hermetically sealed by permanently effective means, sealed by the user in such a way that only those persons responsible for their installation can dismantle them.

3.4 Precautions relating to the use

- When ordering flexible pipes in plastic materials for oxygen materials, companies should request the manufacturer to supply a certificate of conformity.

- The flexible pipes must be installed by competent fitters and in accordance with the instructions issued by the manufacturer.

- Before the installation work is commenced, the complete cleanliness of the flexible pipe and the installation should be checked.

- During the installation, the initial cleanliness of the flexible pipe must be maintained. (See in this respect para. 3.3 concerning the protection of the ends of the flexible pipe).

- In the event of the violent breakage of the flexible pipe, a surging is produced by the massive outflow of oxygen. To avoid this surging, which is always very dangerous because it is uncontrolled, it is recommended that the flexible pipe is held in position by means of a safety cable attached to the flexible pipe at regular intervals. Additionally, this safety ensures the equipotentiality of the two ends of the flexible pipe.

- The outer braiding of the protective layer of the flexible pipe in service must be inspected at regular intervals.

- All necessary precautions must be taken to prevent any deterioration during the assembly, storage and use of flexible pipes.

- The necessity of providing an earth connection for the flexible pipe will be taken into account for each separate case in conjunction with the electrical services.

- All precautions must be taken to ensure that a flexible pipe that has been used for a fluid other than oxygen is not used for this latter.

- It is the responsibility of the company rather than the manufacturer to indelibly mark the appropriate flexible pipes "oxygen".

Groupe de travail "Sécurité - Conduites à oxygène"

Arbeitsgruppe "Arbeitssicherheit - Sauerstoffleitungen"

Gruppo di lavoro "Condotte di ossigeno"

Werkgroep "Veiligheid - Zuurstofleidingen"

Working Group "Safety - Oxygen Pipes"

DEUTSCHLAND

R. Dreissig	Betriebschef August Thyssen-Hütte AG 4100 Duisburg-Hamborn
A. Erenz	Dr. Ing. - Leiter des Technischen Aufsichtsdienstes Hütten- und Walzwerksberufsgenossenschaft 4300 Essen
O. Göller	Dipl.-Ing. Berufsgenossenschaft der Chemischen Industrie 8500 Nürnberg

BELGIQUE .....

FRANCE

Ph. Arragon	Ingénieur-conseil S.A. Air Liquide 75007 Paris
H. Hermann	Ingénieur Energie SOLLAC - FENSCH 57240 Knutange

ITALIA

F. Fatica — Capo Reparto Teco
Soc. A.F.L. Falck-Unione
20099 Sesto San Giovanni

L. Ivaldi — Capo Fabbrica Ossigeno
ITALSIDER
16152 Genova-Cornigliano

LUXEMBOURG

H. Kirsch — Ingénieur - Service Electromécanique
ARBED
Differdange

NEDERLAND

H.J. Kool — Chef Centraal Onderhoud
Hoogovens IJmuiden BV
IJmuiden

L.J.W. Pichel — Bedrijfsleider Zuurstoffabrieken
Hoogovens IJmuiden BV
IJmuiden