TECHNICAL SPECIFICATION

GASEOUS OXYGEN SYSTEMS

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DESIGN AND ENGINEERING PRACTICE

USED BY

COMPANIES OF THE ROYAL DUTCH/SHELL GROUP

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1. INTRODUCTION

1.1 SCOPE

This DEP gives minimum requirements for the design, construction, testing, operation and maintenance of gaseous oxygen systems. This DEP replaces an earlier DEP of the same number and title, dated June 1983.

In the context of this specification, oxygen systems comprise vessels and heat exchangers, compressors, pipe, fittings, valves and instruments that come into contact with, and are used for the transport and utilisation of, gaseous oxygen (90% vol. oxygen and higher).

The Principal shall specify whether a system handling gas mixtures containing less than 90% vol. oxygen is to be considered an oxygen system.

For gas mixtures containing more than 21% vol. oxygen, and for air at pressures above 50 bar (ga), avoidance of oil and cleanliness inspection according to (6) is necessary.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by SIPM, the distribution of this document is confined to companies forming part of or managed by the Royal Dutch/Shell Group, and to Contractors nominated by them (i.e. the distribution code is "C", as defined in DEP 00.00.05.05-Gen.).

This DEP is intended for use in oil refineries, gas handling installations, chemical plants, supply/marketing installations and, where applicable, in exploration and production facilities.

If national and/or local regulations exist in which some of the requirements may be more stringent than in this DEP, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable as regards safety, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this document which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned with the object of obtaining agreement to follow this document as closely as possible.

1.3 DEFINITIONS

For the purpose of this DEP, the following definitions shall hold:

1.3.1 General definitions

The **Contractor** is the party which carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project or operation of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier** is the party which manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party which initiates the project and ultimately pays for its design and construction. The Principal will generally specify the technical requirements. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal.

The word **Shall** indicates a requirement.

The word **Should** indicates a recommendation.

1.3.2 Specific definitions

Dry means gaseous oxygen in which the dew point at the maximum operating pressure is less than 10 °C below the minimum operating temperature.

Fire safe valves are valves constructed according to the fire safe requirements of BS 6755 Part 2, API 6FA or API 607.

Flammable fluids are fluids having a flash point below 37.8 °C and a maximum vapour pressure of 276 kPa (abs) at 37.8 °C.

NOTE: This refers to flammability in **air**.

Monel means grade UNS N04400 ("Monel 400"). Acceptable alternative materials are given in (3.1). Where specific grades are required, they are specified.

Oxygen means any gas mixture containing 90% volume or more oxygen.

Stainless steel means austenitic stainless steel, e.g. alloys in the AISI '300' series.

1.4 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section number is shown in brackets. Other documents referenced by this DEP are listed in (9).

Further information regarding oxygen systems and related subjects may, if required, be found in the publications listed in (10).

2. GENERAL SAFETY PRINCIPLES

Once ignited, many materials (including most metals) will burn violently in an oxygen atmosphere. Because of the risks associated with the ignition of oxygen handling systems, the goal of high system integrity cannot be jeopardised. In some cases, hazard analyses may be necessary.

Ignition may occur upon supply of energy in any form, but the likelihood of ignition will vary for each particular case. Valves, fittings, heat exchangers and compressors are, for instance, locations with higher ignition risks than long straight lines and the shells of vessels.

It is important for heat energy to be able to dissipate before the ignition temperature is reached, and therefore the use of materials with a high thermal conductivity is preferred.

Ignition of materials in oxygen can be minimised by adhering to a number of basic rules:

1. Use materials which have a sufficiently high ignition temperature and possibly also a low heat of combustion and high thermal conductivity and which have proved to be suitable for oxygen service, see (3).
2. Remove all contaminants which may react easily, such as oil, grease and organic materials, see (6) and (7).
3. Avoid all sources of energy which could initiate a fire, e.g. high velocities, turbulence, uncontrolled elevation of temperature by adiabatic compression or gas vibration, see (4).
4. Avoid presence of dust or particulate matter which, due to friction and/or impact, may react with the oxygen and/or eventually may ignite the material of construction.
5. Safeguard personnel and equipment against flames by applying fire shields where necessary and/or remote operation of valves and machinery.
6. Use experienced personnel in precommissioning, operation and maintenance of oxygen systems.

These aspects have been elaborated in the following sections.

3. MATERIALS

3.1 METALLIC MATERIALS

Dry gaseous oxygen is normally handled in carbon steel or austenitic stainless steel, subject to the velocity limitations given in (4). Higher velocities, higher pressures and higher temperatures generally require the use of nickel-base (or copper-base) alloys. Specific metallic materials for oxygen system components shall be selected in accordance with the guidelines given in (4.2 to 4.7). In Appendix 1, properties and behaviour of materials are described.

Throughout this document Monel is specified when service conditions lie outside the critical conditions for stainless steel and carbon steel described in (4.2 to 4.7). Nickel 200, Inconel alloys and Hastelloy alloys are acceptable alternatives. Copper and copper-base alloys may also be used in place of monel, except that aluminium bearing copper alloys are only permitted with a maximum aluminium content of 2.5%.

Carbon steel shall only be used in 'dry' oxygen systems, it shall not be specified for services where internal rusting can occur, such as wet oxygen service or vent lines. In these cases, selection of stainless steel or an alloy from one of the higher alloy classes, consistent with oxygen temperature and pressure level, is required.

For oxygen piping systems operating at temperatures below -20 °C, the materials shall be selected to avoid the risk of brittle fracture. Carbon steel systems in oxygen service that may operate below this temperature shall be constructed from fully deoxidised, fine grained steel, e.g. ASTM A333 grade 6.

3.2 NON-METALLIC MATERIALS

The selection of all non-metallic components shall be in accordance with the limitations of the list produced by the Bundesanstalt fur Materialforschung und Prufung (BAM).

Organic materials have lower ignition temperatures than metallic materials. Once ignited, they may promote ignition in adjacent metal components. The volume of organic materials should be minimised and they should be surrounded by metal to maximise heat dissipation.

Fluorinated or chlorofluorinated resins and elastomers shall be used. They can be reinforced with oxides, glass ceramic, metals and alloys to improve their mechanical properties; however, such reinforcement shall not adversely affect the resistance to ignition.

Other non-metallic materials such as asbestos compounds may also be used. Their ignition temperature in oxygen, however, varies with the method of manufacture and any additives used. They should therefore be used only if previous tests have proved them safe to use.

4. COMPONENT DESIGN

4.1 GENERAL

The design recommendations given below relate to the general safety principles outlined in (2).

4.2 VELOCITY AND SIZING

Oxygen systems shall be designed so that the velocity does not exceed the limits shown in the oxygen service chart of Figure 1. For carbon steel piping, curve A shall be used. For stainless steel piping, curve B shall be used. The use of the curves shown in the service chart is applicable to all components, at all locations within a piping system and is subject to the following conditions: The curves are applicable to a maximum temperature of 100 °C for carbon steel and 150 °C for stainless steel piping. Monel shall be used for conditions which lie above the velocity curve in Figure 1.

4.3 PIPING AND FITTINGS

4.3.1 Materials

Materials for piping shall be selected in accordance with the velocity limits described in (4.2) and Figure 1. Fittings where direct impingement of entrained particles may occur, such as short radius elbows and tees, shall be made from monel. In areas where carbon steel or stainless steel construction is permitted, fittings with the same composition may be used if the velocity limit is reduced by half. Piping downstream of control valves shall be made from monel for a distance of 10 times the pipe diameter.

For pipe sizes below DN 50, carbon steel shall not be used; stainless steel shall be used, subject to the velocity limitations given in (4.2).

The minimum permissible thickness for carbon and stainless steel piping is 6 mm.

4.3.2 Design

Oxygen piping systems shall be kept as simple as possible, with the smallest possible number of valves, fittings, branches and nozzles. Consideration should be given to the combination of several instrument connections in one fitting or nozzle.

Oxygen piping shall be located as far as possible from other piping. Pipes containing flammable fluid or steam shall not be laid within 1m distance of oxygen piping. The free space may be utilised for lines carrying water, nitrogen or other non-flammable fluids at ambient temperature. At points where the above requirements cannot be fulfilled, the oxygen system shall be fire protected.

Oxygen pipelines shall be located on the outermost position of pipe bridges.

Running of oxygen pipelines through tunnels or (covered or uncovered) trenches should be avoided. If unavoidable, flanged connections or valves shall not be used and the tunnel or trench shall not contain lines carrying flammable fluids. Oxygen piping shall not support other pipes.

Underground oxygen piping may be applied outside process and other hazardous areas. They shall be clearly identified and kept separate from electricity cables and other piping.

The underground piping should have external corrosion protection.

Expansion bellows shall not be used.

Slip-on flanges, lap flanges, socket weld valves and fittings, or threaded connections shall not be used.

In carbon steel and stainless steel piping systems, branches shall be made with equal tees, reducing tees or swept outlets. In monel piping systems, branches should also be made with equal tees, reducing tees or swept outlets, but branch outlets (weldolets) and branch fittings (nipples) may be used.

Changes in diameter shall be minimised.

Dead ends in piping shall be avoided, see Figure 3.

The oxygen flow in piping shall be in one direction only. If flow in two directions cannot be avoided, Principal's agreement shall be obtained.

To assist removal of the degreasing agent after cleaning, low points in equipment and piping, except underground piping, shall have drain connections without a valve but closed with a blind flange. Underground piping shall not be provided with drains for this purpose.

Above-ground oxygen systems shall be earthed.

Nitrogen systems used for automatic purging shall be equipped with a filter and two pressure indicators. They shall be designed to prevent the possibility of oxygen flowing back into the nitrogen system.

Connections for purging and venting shall be situated such that purging and venting of the system can only be done in the normal direction of the oxygen flow.

Where an oxygen line enters the plot of a process unit or a hazardous area, a block valve shall be installed. This valve, however, may only be used in cases of emergency and shall be operated from behind a fire shield, or remotely from a suitable location(s).

4.3.3 Insulating flanges

Insulating flanges of cathodically protected lines shall only be fitted in a vertical line section in order to avoid the deposition of particulate matter bridging the insulation, see Figure 4. The design and materials selection shall be subject to approval by the Principal.

Insulating flanges shall be protected against internal sparking caused by elevated electrical potential differences across the insulation, stray currents, induction or otherwise. Polarisation cells of sufficient rating shall always be installed across insulating joints or flanges.

4.3.4 Vent lines

Vent lines shall be made of stainless steel. They shall be sized for a maximum velocity of 50 m/s. Consequently the pipe diameter may have to be increased immediately downstream of the vent valve. Vent lines should be vertical and straight; however, if bends cannot be avoided, to avoid high turbulence they should not be installed within a distance of 20 pipe diameters downstream of the vent valve. To prevent ingress of rain or other foreign matter, a construction as shown in Figure 5 shall be applied. The vent valve shall be sized such that the maximum allowable velocity in the line to be depressurised shall not be exceeded (4.1). Sometimes, a control valve may be required.

4.3.5 Identification

Oxygen piping shall be clearly identified by colour coding.

4.4 VALVES AND INSTRUMENTS

Only valves and instruments especially made for oxygen service and that have proved to be reliable in oxygen service shall be used. For selection of materials of construction and type, reference is made to (3). Hand-operated valves (except those of the bellows-sealed type in sizes up to DN 50) shall have an extended spindle and be fitted with a fire shield designed to protect personnel in the event that the valve ignites.

If lubrication is required, a fluorocarbon lubricant suitable for oxygen service shall be used, the selection of which is subject to the approval of the Principal.

4.4.1 Control Valves

All process control valves are considered to be in throttling service. Throttling valves may generate sonic gas velocities and are therefore considered critical. Only globe valves or needle valves (including angle and Y types) shall be used for throttling. The body and internals shall be constructed of monel or K-monel.

Downstream of throttling valves a pipe section made of material suitable for high velocities (4.3.1) shall be installed.

4.4.2 Block valves

Block valves shall not be used for regulating flow. They shall only be operated in the fully open or fully closed position. They shall not be operated in the case of pressure differential. They shall only be opened in the case of equal pressures on both sides of the valve or be closed if there is no oxygen flow. Block valves larger than DN 50, having a pressure differential of 18 bar or more across the valve in the closed position, shall be installed with an accompanying bypass as shown in Figure 6 to permit pressure equalisation. Only ball valves or gate valves shall be used as block valves.

Exceptions to the above include nitrogen purge valves which must be opened only with a positive nitrogen pressure relative to the oxygen system, and where a block valve is to be operated (closed) in the case of extreme emergency. Examples are: a block valve at the entrance of a process plot and a block valve upstream of a filter and/or measuring station (4.6). The block valve shall in such cases be operable from behind a fire shield, or remotely from (a) suitable location(s).

Valves with non-rising stem (i.e. ball valves) are preferred. Block valves with bodies of carbon steel shall only be used up to 10 bar (ga).

Ball valves shall be of fire-safe design and have seals and seats of PTFE. The maximum temperature permitted is 120 °C, see Appendix 1. The volume of PTFE shall be as small as possible. Ball valves with all-metal seats may be used above 120 °C, provided the stem seal and trim seals are suitable, see Appendix 1. Any sealant connections shall be left undrilled or be permanently plugged.

Automatic (solenoid-operated) shut-off valves shall be single-seated globe valves with trim especially ground for tight shut-off. If agreed by the Principal, PTFE seat rings may be used when the temperature in the system is below 120 °C (see Appendix 1).

4.4.4 Relief Valves

Relief valves shall be designed to ensure maximum leak-tightness in the closed position. The internal elements shall be made from monel or K-monel. The valve body shall be made from monel for system pressures exceeding 10 bar (ga) and from stainless steel for lower pressures.

4.4.5 Check Valves

Check valves should be of the plate-disc type (compressor valve type) without helical springs. Valve plates and spring plates shall be of stainless steel, or of Inconel X-750 for pressures above 70 bar ga.

4.4.6 Instruments

All instrument parts in contact with oxygen shall be stainless steel or monel, and have smooth surfaces. Filling fluids for capsules and diaphragm seals shall be selected such that they do not present a hazard if the diaphragm should fail. The liquid shall be a fluorocarbon and the selected type shall be subject to the approval of the Principal. The special liquid shall be indicated on the outside of the item, e.g. by etching.

4.4.7 Identification

All valves and instruments shall bear the warning:

'OXYGEN! KEEP FREE FROM OIL AND GREASE!'

4.5 FILTERS

Filters should be used to remove possible dust or particulate matter from gaseous-oxygen systems, see (2, item 4). Filters should be placed upstream pieces of equipment which have internal moving parts (such as a compressor), or equipment which can create high velocity and thus accelerate particular matter (such as a control station or throttling valve).

Filters shall be of the candle type. The elements shall be made of copper or nickel alloy.

Pore size and velocity requirements are as follows:

- for filters upstream of control and measuring stations: max. pore/mesh size 50 µm, max. entry velocity 0.2 m/s based on filtering area
- for filters in oxygen feed to low-temperature reaction systems with flammable matter (such as ethylene oxide plants): max. pore size 10 µm, max. entry velocity 0.05 m/s based on filtering area
- for filters in suction lines to compressors, see (4.6).

The filter elements shall be easily removable for inspection and cleaning. The design of the filters shall be such that the trapped particles cannot enter the downstream piping when the elements are removed.

An external indication shall be provided to indicate the direction of flow.

A filter should be equipped with a blanked-off drain connection, a purge (and pressurising) connection downstream of the block valve and a vent connection downstream of the filter elements.

To avoid dead ends and possible accumulation of dust or foreign matter, spare filters should not be installed.

Nitrogen connections, to be used for purging and pressurising sections of the oxygen system located downstream of an oxygen filter, shall be equipped with filters that meet the pore size requirements of the upstream oxygen filter.

4.6 COMPRESSORS

Where oxygen has to be compressed, there are potential hazards relating to ignition that shall be recognised and controlled. Operating personnel shall be safeguarded from injury, and the risk of compressor breakdown by fire or explosion shall be minimised by adhering to correct design and operating procedures.

The design, installation requirements, operation, maintenance, control and instrumentation of oxygen compressors shall be in accordance with IGC document 10/81/E and IGC document 27/82/E.

4.7 OXYGEN MEASURING STATION

When oxygen is supplied (e.g. by a third party), it is often delivered by pipeline. At the point of entry to the plant, a measuring station is usually installed. The design and safety philosophy is described below.

Apart from its normal function for accounting purposes, the oxygen measuring station has two additional functions:

- separation of the responsibilities of supplier and customer, and
- safeguarding the supplier's system against damage caused by an emergency situation at the customer's end and vice versa.

An oxygen measuring station will normally contain the following main elements (starting from supplier's end): main block valve A, filter, flow measuring element, oxygen purity analyser, excess flow valve B with by-pass valve C, and block valve D (Figure 7).

The filter serves to avoid ingress of dust and other foreign matter from the oxygen supply line into consumer's distribution network and hence to minimise the risk of fire for the equipment downstream of the above filter (especially the valves). For safety reasons it is recommended to use a single filter only and to avoid the installation of spare filters. Relief valves shall not be installed in the measuring station. Carbon steel shall not be used for the parts of the measuring station from the filter onwards. The drain(s) at the lowest point(s) serve(s) to remove remnants of degreasing agents.

Main block valve A and excess flow valve B should be controlled such that on failure of one of the power media, the positions (status) of the valves remain unchanged. The valves shall only change position when a command for change is received. The power media for control of these two valves shall be uninterruptible maintained supply.

Control valve C is controlled such that this valve will close when one of the power media fails.

Block valve D has an extended spindle and is operated from behind a fire shield.

Normal manual closing of valve A (via remote station) shall only be performed when the oxygen supply line and measuring station have been taken out of operation. Under certain emergency conditions, valve A shall be closed. These are:

- manual emergency closure from the panel (manned supervising panel) or locally (at measuring station);
- at high flow (say 120 percent of contract), while the flow remains high after t_1 seconds (where t_1 is closing time of valve B, say 10 seconds);

  NOTE: At high flow, excess flow valve B will start to close immediately.

- at low pressure upstream of orifice, when pressure remains low after t1 seconds;

  NOTE: At low pressure (e.g. contract minimum minus 2 bar) excess flow valve B will start to close immediately.

- at high differential pressure over valve A;

  NOTE: This arrangement keeps valve A closed in the case of a high differential pressure, in order to avoid high velocities through valve and filter during re-opening. This is in particular valid in supply systems with a large difference between the pressure at normal flow and pressure at no-flow (long transport line). In order to be able to open valve A, the downstream system up to the excess flow valve B shall be pressurised with nitrogen to approx. supply line pressure. For the less complicated systems (e.g. short supply lines) it may be considered to replace the high differential trip by a standing instruction for the operating personnel (pressure equalisation). However, Principal's agreement shall be obtained in writing for this application.

Excess flow valve B will close under the following conditions:

- high flow (say 120 percent of contract maximum);
- low pressure upstream of orifice (say contract minimum pressure minus 2 bar);
- manual emergency closure from the panel (manned supervising panel) or locally (at

measuring station).

Valve B, when closed, cannot be (re)opened when:

- the differential pressure across the valve (in the direction of flow) exceeds a certain value (say 2 bar)
- the control valve C in the by-pass is open.

By-pass control valve C shall be sized such that when fully open under critical differential pressure conditions, the actual velocity will not be higher than maximum allowable (see Figure 1) in the main line(s) downstream of valve B. Normally, it is adequate if the maximum trim size for valve C is one quarter of that of valve B.

Block valve D, operated via an extended spindle from behind a fire shield, shall not be closed unless the oxygen flow is zero. The valve serves to attain a positive shut-off after the measuring station has tripped or has been taken out of operation.

Rupture and/or fire in the oxygen line will initiate the following actions:

- If rupture is in section (a), downstream of valve B, the high flow closes valve B and the flow will be reduced to zero after which valve D is shut manually.
- If rupture is in section (b), downstream of flow measurement orifice but upstream of valve B, the high flow closes valve B and because the flow remains high, valve A will be closed after t_1 seconds.
- If rupture is in section (c), downstream of valve A but upstream of orifice, the low pressure closes valve B and because the pressure remains low, valve A will be closed after t_1 seconds.
- If rupture is in section (d), upstream of valve A, the same action as above for section (c) will occur.

Amended per Circular 36/99

Figure 8 is an example of a typical logic diagram for the system shown in figure 7. This logic diagram may be simplified, but this requires approval by the Principal.

Personnel, buildings and other assets, shall be protected against possible blow-outs by means of concrete walls. It is recommended to protect also the individual pieces of equipment, e.g. filters, against each other by the installation of suitable fire shields. The walls on each side of the station can also act as fire shields for the operation of valves. Proper natural ventilation is recommended between the walls to avoid possible high oxygen concentrations.

In addition to the installation of the fire shields/walls mentioned above, the following minimum distances shall be adhered to:

- 25 m to public roads/railways, warehouses for flammable products, public parking places, vessels containing flammable products, loading/ unloading stations, oil catchers
- 15 m to plant buildings, unrestricted plant roads/railways, above ground pipelines containing inflammable products
- 10 m to private parking places, buried vessels and piping containing flammable products.

A blow-out in an oxygen system has the same appearance as a local explosion. The severity of the blow-out is related to the pressure level in the system. Care should be taken to avoid impingement of the `oxygen flame' and scattered burning metal particles on other equipment.

5. ORDERING, MARKING, PACKAGING

Orders for materials for oxygen service shall not be combined with those for other materials. The materials shall be delivered free from rust, scale, oil and grease, see (6). Small items of equipment shall be packed in plastic bags so that foreign material cannot enter during transport. If these items contain orifices, these should be sealed by metal, plastic or rubber plugs. Sealing with adhesive tape shall be avoided.

The openings of prefabricated pipework and components shall be sealed by means of blind flanges, metal or plastic covers. Small orifices shall be sealed by plugs.

The manufacturer shall clearly label all materials and equipment in bold lettering:

"SUITABLE FOR OXYGEN SERVICE"

6. CLEANING

6.1 GENERAL REQUIREMENTS

The importance of meticulous degreasing and careful cleaning cannot be over-emphasized, since remnants of organic matter and minute solid particles in the presence of high pressure and/or high velocity oxygen can cause burning with the possibility of violent reaction. Great attention shall, therefore, be paid to the cleanliness of oxygen systems.

Removal of contaminants such as greases, oil, thread lubricants, dirt, water, filings, weld spatter, paints, and other foreign matter is essential. This can be accomplished by precleaning all parts and maintaining this condition during construction; by completely cleaning the system after construction; or, as is normally the case for a large plant facility, by a combination of the two. The cleaning procedures and programme shall be established early in a project to ensure that the methods and sequence proposed are compatible with the plant design and construction programme. Any cleaning procedure shall be such that the final surface cleanliness, prior to system commissioning, will meet the inspection criteria given in (6.5).

6.2 PRECLEANING

All materials including vessels, pipe(work), valves, (instrument) fittings, pumps, compressors, filters, etc. shall be precleaned prior to final assembly/site erection. In the majority of cases, this cleaning requirement will be part of a purchase order or shop fabrication contract. Tender documents shall specify the internal surface cleanliness requirements given in (6.4) and require proposed cleaning procedures to be included in tender submissions.

For guidance, a list is given below of the typical methods used to preclean the internal surfaces of various items which go to make up an oxygen system:

Carbon steel vessels	:	[solvent or high pressure water (with or without detergent) or steam degreasing] + abrasive blast cleaning to surface finish ISO 8501-1, grade SA 2 1/2.
Stainless steel vessels	:	[solvent or high pressure water (with or without detergent)or steam degreasing] + [selective acidpickling/passivation]
Pipe(work)	:	[alkaline degreasing] + [acid pickling or abrasive blastcleaning to surface finish ISO 8501-1, grade SA 2 1/2]
Valves, compressors, pumps, filters	:	[solvent or high pressure water (with or without detergent)or steam degreasing] + [acid pickling or abrasive blast cleaning] for body/casing;[solvent (vapour) or high pressure water (with or without detergent) or steam degreasing] for internals.
Instruments/Instrument fittings	:	solvent (vapour) or high pressure water (with or without detergent) or steam degreasing.

Following precleaning, action shall be taken to preserve the internal cleanliness of the system components at least until they are installed in the plant on-site. This should take the form of:

1) Hermetically sealed wrapping, containing dessicant bag, for small items.
2) Firmly secured, end-caps, plugs or gasketed blank flanges, as appropriate, to seal all openings on non-hermetically packaged items.
3) Dessicant (bags), but not vapour phase inhibitors, attached to the inside of (temporary) end-caps and blank flanges.
4) Phosphate conversion coating for acid cleaned, carbon steel items.

All precleaned parts or final assemblies shall be labelled/marked in accordance with the requirements of (5).

6.3 POST ERECTION (IN-SITU) CLEANING

Large diameter items, e.g. vessels, compressors, filters, and instrument fittings should be isolated from pipework and cleaned separately, if required, using methods listed in (6.2).

Temporary spooling (in place of valves and the items mentioned above) or separating different sections shall be used to facilitate the in-situ cleaning of pipework. If the precleaned condition has been maintained during construction and erection, and there has been minimal site welding, in-situ cleaning can be limited to blowing the pipework out with high (near sonic) velocity, oil-free air, supplemented where necessary (and possible) with brush pigs.

If the precleaned condition has not been maintained during construction and erection, pipework should be cleaned by acid, detergent or solvent cleaning. Particular care shall be taken to ensure complete removal of any cleaning fluids. To reduce the drying time, low point drains should be provided. If a water-based cleaning fluid is used, the dew point of the residual air following rinsing and drying should be at least 10 °C below the minimum system service temperature. For solvent cleaning, because of the health and explosion hazards, inhibited 1,1,1-trichloroethane is the preferred solvent (see NOTE below). The removal of an organic solvent following cleaning may be considered complete when its concentration in the residual gas (air or nitrogen) is below the value specified by the Principal (for trichloroethane, this value is 20 mg/kg).

Any in-situ cleaning required should be carried out after any hydrotesting and by specialist contractors.

A system that is complete and has received final cleaning, but is not to be put into immediate service, shall be preserved by pressurising with clean, dry, oil-free nitrogen.

NOTE: There may be circumstances where the process may be adversely affected by solvent residue (e.g. poisoning of catalyst in ethylene oxide reactors). Under these circumstances, the Principal should be contacted for alternative solvents and/or cleaning procedures.

6.4 TRANSPORT LINES

Long carbon steel transport lines may not be so easily cleaned as small parts. In particular, the filling of long lines with solvent may present the danger of its incomplete removal. The hydrostatic pressure test also presents a problem because it will cause subsequent rusting. Preference is therefore given to testing, treatment and inspection of the pipes before they are joined together with close control of working conditions.

In cases where hydrostatic testing can be waived and is replaced by a pneumatic test (with prior 100% non-destructive inspection of welds), step (a) of the following procedure shall be carried out using oil-free, filtered air or nitrogen instead of water.

a) Clean line with cleaning pig (scraping and wire brushing type) driven with clean oil-free filtered fresh water. Repeat until water remains clean. (Perform hydrotest with the water contained in the line).

b) Empty line by means of pigs (ensure that "swabbing pigs" are non-linting), driven with oil-free filtered nitrogen.

c) Dry by flushing with oil-free filtered nitrogen.

d) Close off line and conserve by maintaining nitrogen pressure at 0.5 bar (ga).

An alternate method of cleaning transport lines is the use of "sand jetting" using grit and compressed nitrogen. This should be considered if the method is available at the site in question.

6.5 INSPECTION FOR CLEANLINESS

It is necessary to verify that no rust, dust, dirt or any other particulate matter is present in the system.

The maximum allowable concentration of oil on the metal surface is 1 g/m^2. Oil is then not visible (see Appendix 2).

6.5.1 Direct inspection

All surfaces shall be subjected to direct visual inspection where possible, by both bright white light and ultra-violet light methods as described in ASTM G93. The inspected surface shall be dry and free from:

- Cleaning agents;
- Adhered scale, weld spatter, loose particles or fibres;
- Organic substances such as grease, oil, paint, sealants.

When direct inspection by ultraviolet light is not possible, surfaces shall be wiped with a clean white lint-free cloth which may be dipped in trichloroethane (6.3). The cloth is then inspected to ensure the absence of any oil, residue, discolouration, fibres, etc.

6.5.2 Indirect inspection

Parts which are inaccessible to visual inspection, either directly or with a boroscope or similar instrument, shall have trichloroethane circulated through them. A representative sample of the effluent solvent shall be taken and inspected as follows:

- The sample shall be inspected under bright white light and compared with a sample of new, unused solvent. No difference shall be detectable and there shall be no residue.
- The sample shall also be inspected under ultra-violet light (wavelength 0.32-0.38 µm) and again compared with unused solvent. Contamination of 0.1 g oil/litre or more will cause fluorescence of the solvent.
- In doubtful cases, an analysis of the solvent used may be required. After evaporation at 100 °C, the sample shall not contain more than 20 mg/kg residue.

7. CONSTRUCTION

7.1 CLEANLINESS PRECAUTIONS

Equipment used for the erection of an oxygen system should not be assigned to other work during the entire job. Transfer of personnel from other work should also be avoided to reduce the risk of oil contamination of the system.

Special care shall be taken that clothes and shoes of personnel working on the oxygen system bear no oil or grease and that all tools are completely free from oil, grease or other organic matter. Clean gloves shall be used.

All materials and equipment used for the oxygen system shall be stored and labelled in such a way that a positive separation from other construction materials and equipment is achieved. Cleaning, packing and jointing materials shall be kept in closed/sealed containers until they are used.

Before installation commences, each part shall be carefully checked for cleanliness and, if required, be cleaned in accordance with (6).

During field jointing of pipe, seals and covers shall be kept in place until immediately before jointing in order to avoid ingress of foreign matter. Any oily matter that has contaminated the pipe shall be removed and the cleanliness shall be checked (wipe test) before each joint is made.

7.2 WELDING

All welding shall be performed by qualified welders using qualified welding procedures. Qualification tests for welders and welding procedures shall comply with ASME IX.

Only full penetration welds shall be made; the root pass shall be done by the TIG welding process. Socket welds and fillet welds are not permitted. Gas welding is not permitted.

Selection of welding consumables and application of welding procedures shall be in accordance with DEP 30.10.60.18-Gen.

7.3 INSPECTION AND TESTS

All butt welds shall be 100% radiographed. Interpretation of radiographs shall be in accordance with BS 5500, ASME VIII part UW, or ANSI B31.3.

To ensure that the piping is smooth and without obstructions, a gauge having a diameter of 2 mm less than the inside diameter of the pipe (taking into account the permitted tolerances) shall be passed through each section after welding.

Pressure testing shall be performed in accordance with the requirements of DEP 31.38.01.31-Gen. with oil-free potable water or boiler feed water. No detergents shall be added. Special care shall be taken that the system is dried after testing to prevent subsequent rusting of carbon steel.

It should be borne in mind that drying and cleaning carbon steel piping after pressure testing with water may be difficult. If allowed by the Principal, a pressure test with oil-free air or nitrogen may be substituted.

8. OPERATION AND MAINTENANCE

8.1 GENERAL

Operation and maintenance personnel shall be properly trained and instructed of the risks caused by an excess or deficiency of oxygen. They shall wear suitable clean clothing, free from oil and easily combustible contaminants. Smoking shall be forbidden where there is any possible risk of oxygen enrichment. People who have been exposed to enriched atmospheres shall not be allowed to approach fires, burning cigarettes, etc., until after thorough ventilation of their clothing.

8.2 OPERATION

The oxygen system shall be operated in such a way that the design and safety considerations are obeyed. For carbon steel and stainless steel systems, the velocities shall remain within the limits shown in Figure 1.

Block valves which are not equipped with a pressure-equalising bypass shall be in open position during pressurising and depressurising operations.

Pressurising, depressurising, venting and purging the system shall be done only in the normal direction of flow. This also precludes back blowing of installed filters. In the case of purging, the operator shall ensure that the nitrogen is free from contaminants and that the nitrogen pressure is and will remain higher than the oxygen pressure before hooking up the nitrogen system.

After cleaning, filters shall be pressurised, preferably with nitrogen, using the connection at the inlet.

For the operation of compressors, see the Codes of Practice referred to in (3.5) and (9).

8.3 MAINTENANCE

Before any inspection, maintenance or repair work on oxygen systems may commence, all oxygen shall be removed by venting and subsequent purging with oil-free nitrogen.

If internal inspection of equipment or piping parts is necessary these shall be separated from the oxygen system by complete removal or by placing clean spades (having visible handles) at all connections. Before entering by personnel, all nitrogen shall be replaced by air and an adequate ventilation shall be maintained.

Repair work shall be carried out in accordance with (4) and (6), with particular reference to the safety precautions mentioned in (6.1). It is desirable to have a clean working area available.

9. REFERENCES

In this DEP reference is made to the following publications:

NOTE: Unless specifically designated by date, the latest edition of each publication shall be used, together with any amendments/supplements/revisions thereto.

Amended per Circular 36/99

SHELL STANDARDS

Index to DEPs and standard specifications	DEP 00.00.05.05-Gen.
Welding of metals	DEP 30.10.60.18-Gen.
Shop and field fabrication of steel piping	DEP 31.38.01.31-Gen.

AMERICAN STANDARDS

Specification for fire test for valves	API 6FA
Fire test for soft-seated quarter turn valves	API 607

Issued by:
American Petroleum Institute
1220 L Street, N.W.
WASHINGTON DC

ASME Boiler and Pressure Vessel Code Section VIII - Unfired pressure vessels	ASME VIII
Section IX - Welding and brazing qualifications	ASME IX

Issued by:
American Society of Mechanical Engineers,
345 East 47th Street,
New York, NY 10017,
USA

Chemical Plant and Petroleum Refinery Piping	ANSI B31.3

Issued by:
American National Standards Institute
1430 Broadway,
New York, NY 10018,
USA

Standard specification for seamless and welded steel pipe for low temperature service	ASTM A333
Cleaning methods for material and equipment used in oxygen-enriched environments	ASTM G93

Issued by:
American Society for Testing and Materials
1916 Race St., Philadelphia
Pa. 19103,
USA

BRITISH STANDARDS

Unfired fusion welded pressure vessels	BS 5500
Testing of valves:	BS 6755 Part 2

specification for fire type - testing requirements

Issued by:
British Standards Institution
2 Park Street
London W1A 2BS,
England

INTERNATIONAL STANDARDS

Visual assessment of surface cleanliness Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings	ISO 8501-1

Issued by
International Organization for Standardization
1, Rue de Varembe
CH-1211 Geneva 20
Switzerland

Copies of ISO standards are also obtainable through the National Standards Organizations.

MISCELLANEOUS STANDARDS

Liste der nichtmetallischen Materialien.

Issued by:
Bundesanstalt fur Materialforschung und -prufung (BAM)
6900 Heidelberg 1
Postfach 103140
Germany

Reciprocating compressors for oxygen service (code of practice)	IGC document 10/81/E
Turbo compressors for oxygen service (code of practice)	IGC document 27/82/E

Issued by:
Industrial Gases Committee,
32, Boulevard de la Chapelle,
75880 Paris Cedex 18,
France

10. BIBLIOGRAPHY

The following publications provide, if required, further information regarding oxygen systems and related subjects:

Standard guide for designing systems for oxygen service — ASTM G 88

Issued by:
American Society for Testing and Materials
1916 Race St., Philadelphia
Pa. 19103, USA

Code of practice for cleaning and preparation of metal surfaces — BS CP3012

Specification for phosphate treatment of iron and steel — BS 3189

Code of practice for procedures for ensuring the cleanliness of industrial process measurement and control equipment in oxygen service — BS 6869

Issued by:
British Standards Institution
2 Park Street
London W1A 2BS, England

Industrial practices for gaseous oxygen transmission and distribution piping systems — CGA G4.4

Issued by:
Compressed Gas Association
1235 Jefferson Davis Highway,
Arlington VA 22202
USA

Prevention of accidents arising from enrichment or deficiency of oxygen in the atmosphere — IGC document 8/76/E

The transportation and distribution of oxygen by pipeline — IGC document 13/82/E

Issued by:
Industrial Gases Committee,
32, Boulevard de la Chapelle,
75880 Paris Cedex 18, France

NASA design guide for high pressure oxygen systems — NASA Publication 1113.

Issued by:
National Aeronautics and Space Administration
Washington DC
USA

FIGURES

	Figure
Maximum velocity versus internal pressure for carbon steel and stainless steel piping systems	1
Bends, branches and reductions in carbon steel and stainless steel for oxygen service	2
Examples of a) unacceptable and b) acceptable end configurations	3
Examples of a) unacceptable and b) acceptable insulating flange installation	4
Vent connection (shown on carbon and stainless lines)	5
Block valve with by-pass (carbon steel or stainless steel line)	7
Typical flow scheme of oxygen measuring station	8
Typical functional logic diagram for oxygen measuring station	

FIGURE 1 MAXIMUM VELOCITY VERSUS INTERNAL PRESSURE FOR CARBON STEEL AND STAINLESS STEEL PIPING SYSTEMS

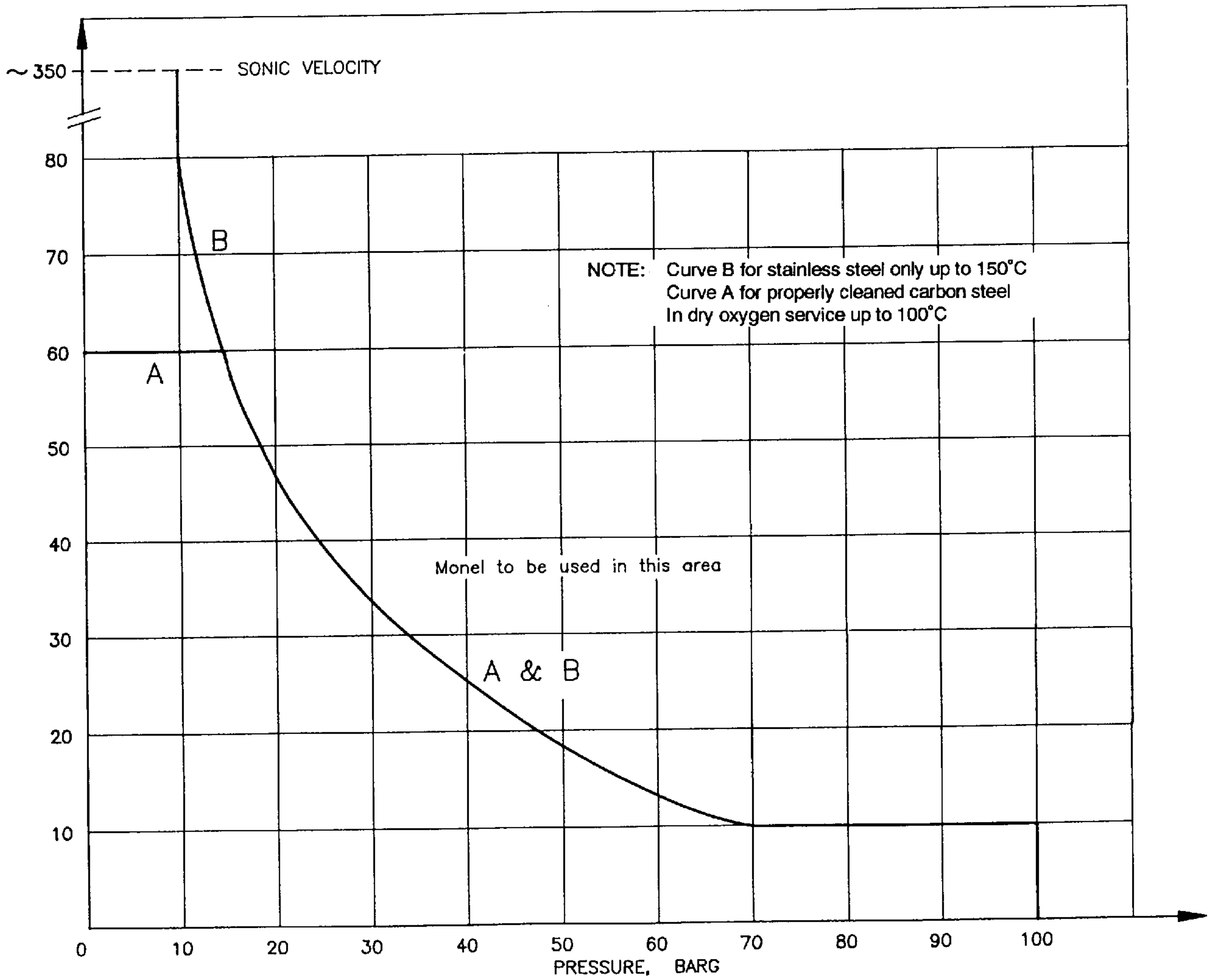
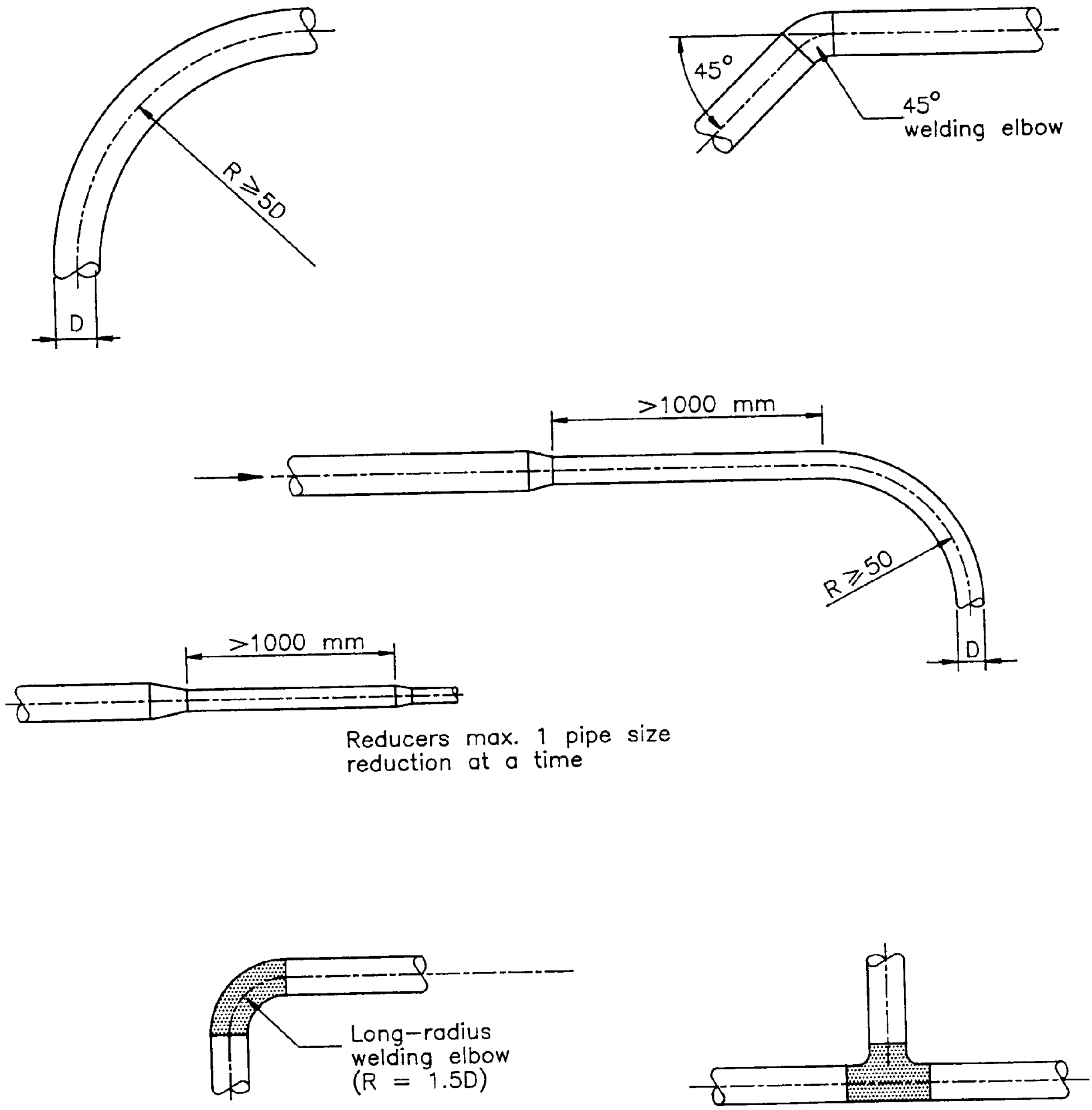


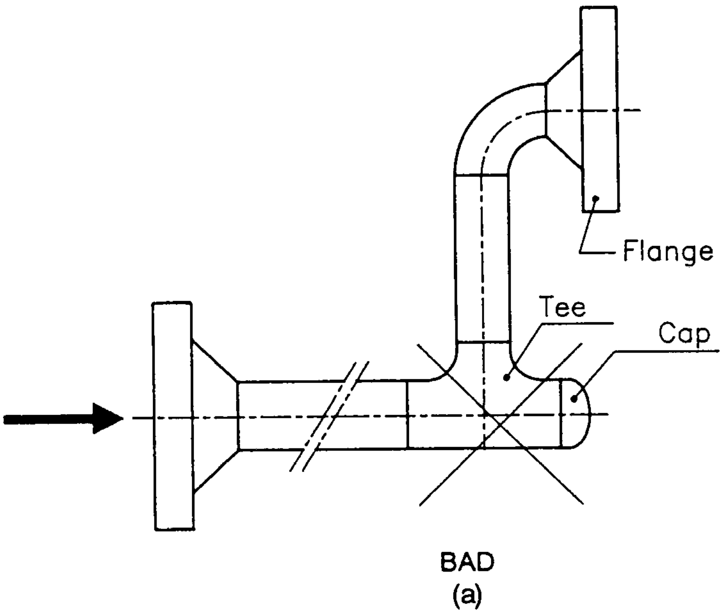
FIGURE 2 BENDS, BRANCHES AND REDUCTIONS IN CARBON STEEL AND STAINLESS STEEL FOR OXYGEN SERVICE



Long–radius welding elbows and tees (shaded) shall be made from Monel unless velocities are limited (see 5.1)

D = nominal pipe size

FIGURE 3 EXAMPLES OF A) UNACCEPTABLE AND B) ACCEPTABLE END CONFIGURATIONS



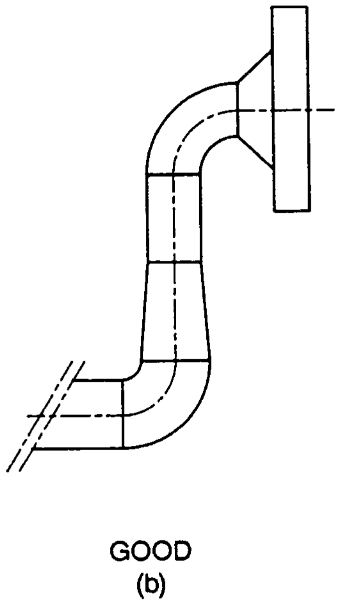


FIGURE 4 EXAMPLES OF A) UNACCEPTABLE AND B) ACCEPTABLE INSULATING FLANGE INSTALLATION

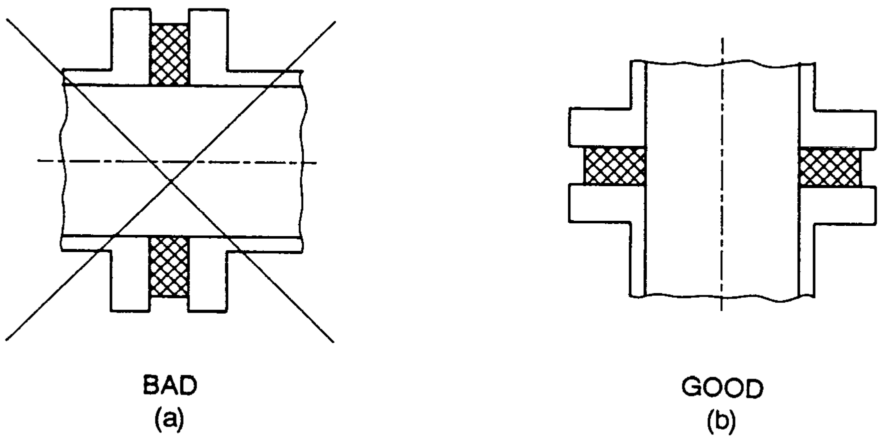
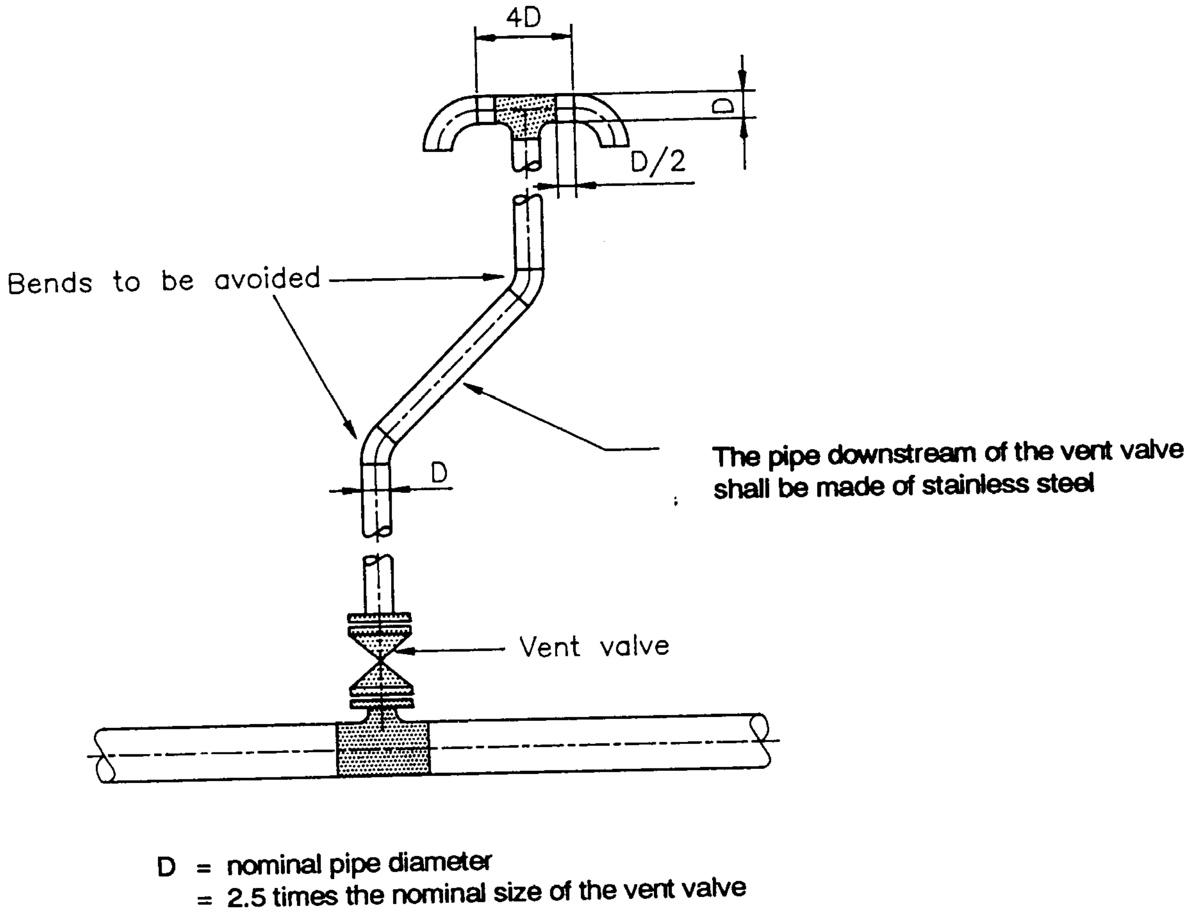
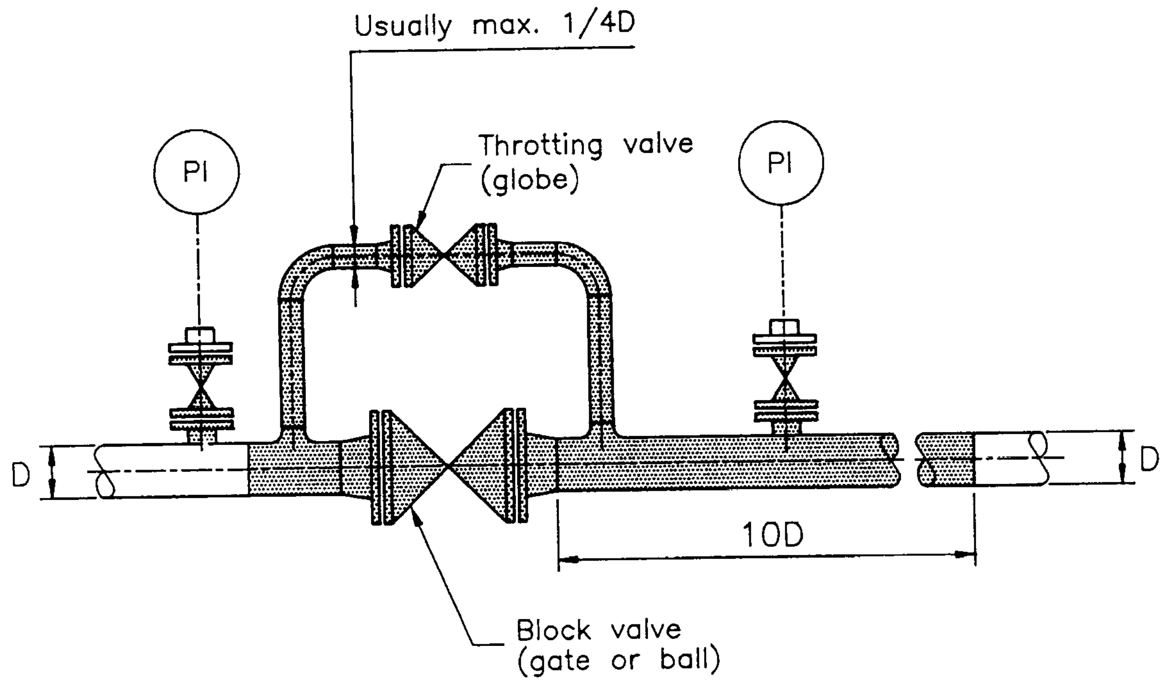


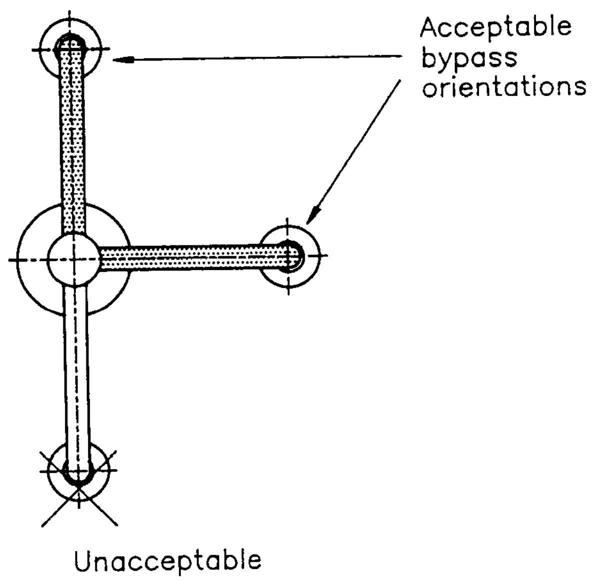
FIGURE 5 VENT CONNECTION (carbon steel or stainless steel line)



For carbon steel and stainless steel piping shaded parts to be made of Monel.

FIGURE 6 BLOCK VALVE WITH BY-PASS (carbon steel or stainless steel line)





By–pass piping (shaded in sketch) to be made of Monel.

By–pass to be made above or in same horizontal plane as main pipe, but never below.

By–pass on the valve body, as supplied by certain valve manufacturers, is acceptable.

FIGURE 7 TYPICAL FLOW SCHEME OF OXYGEN MEASURING STATION

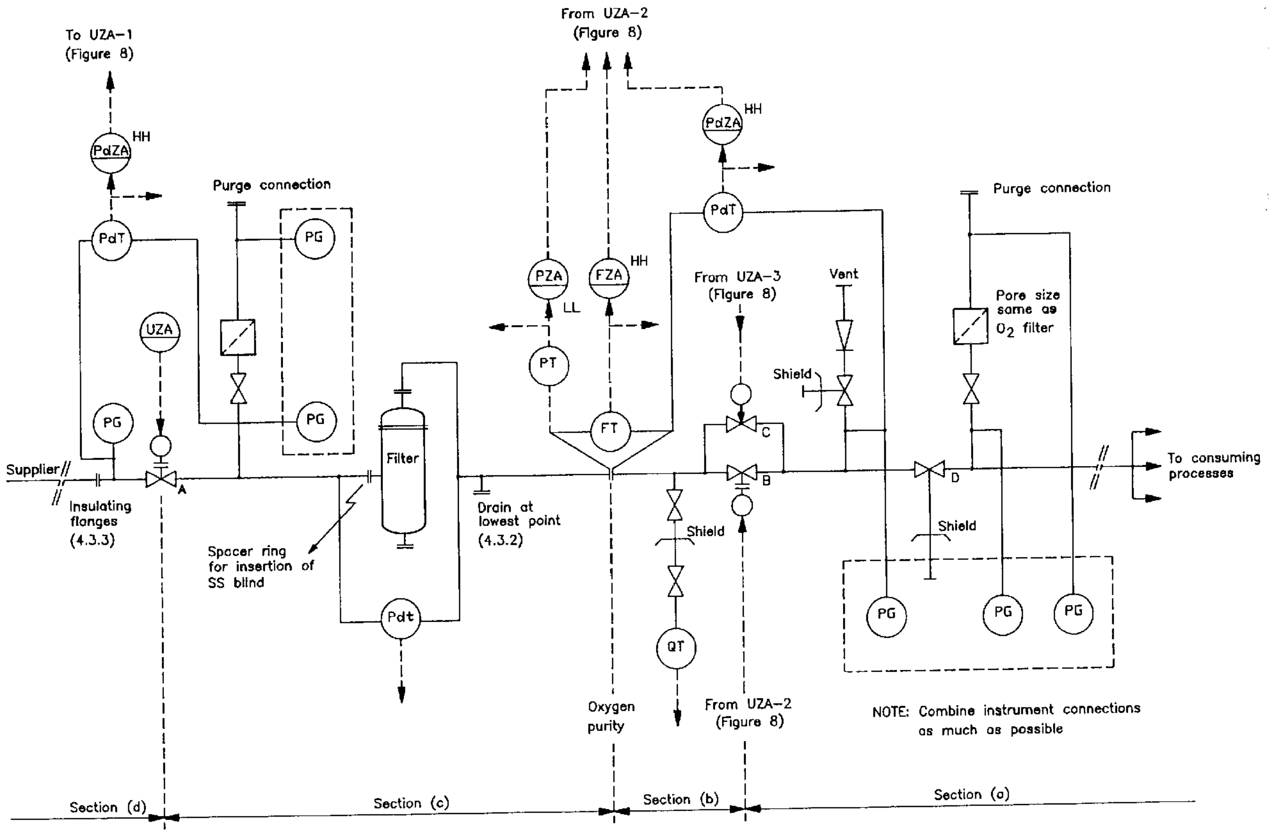
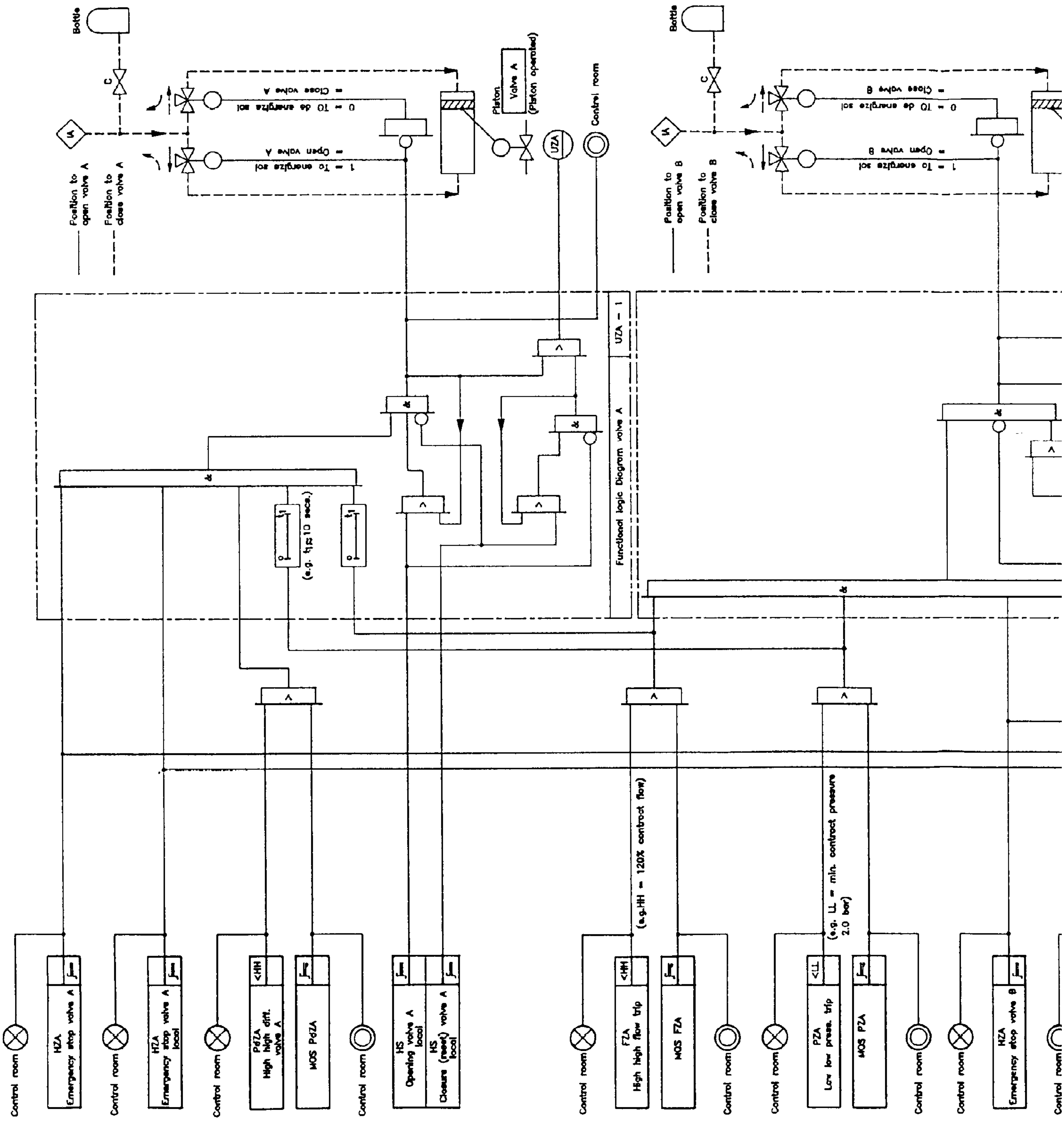
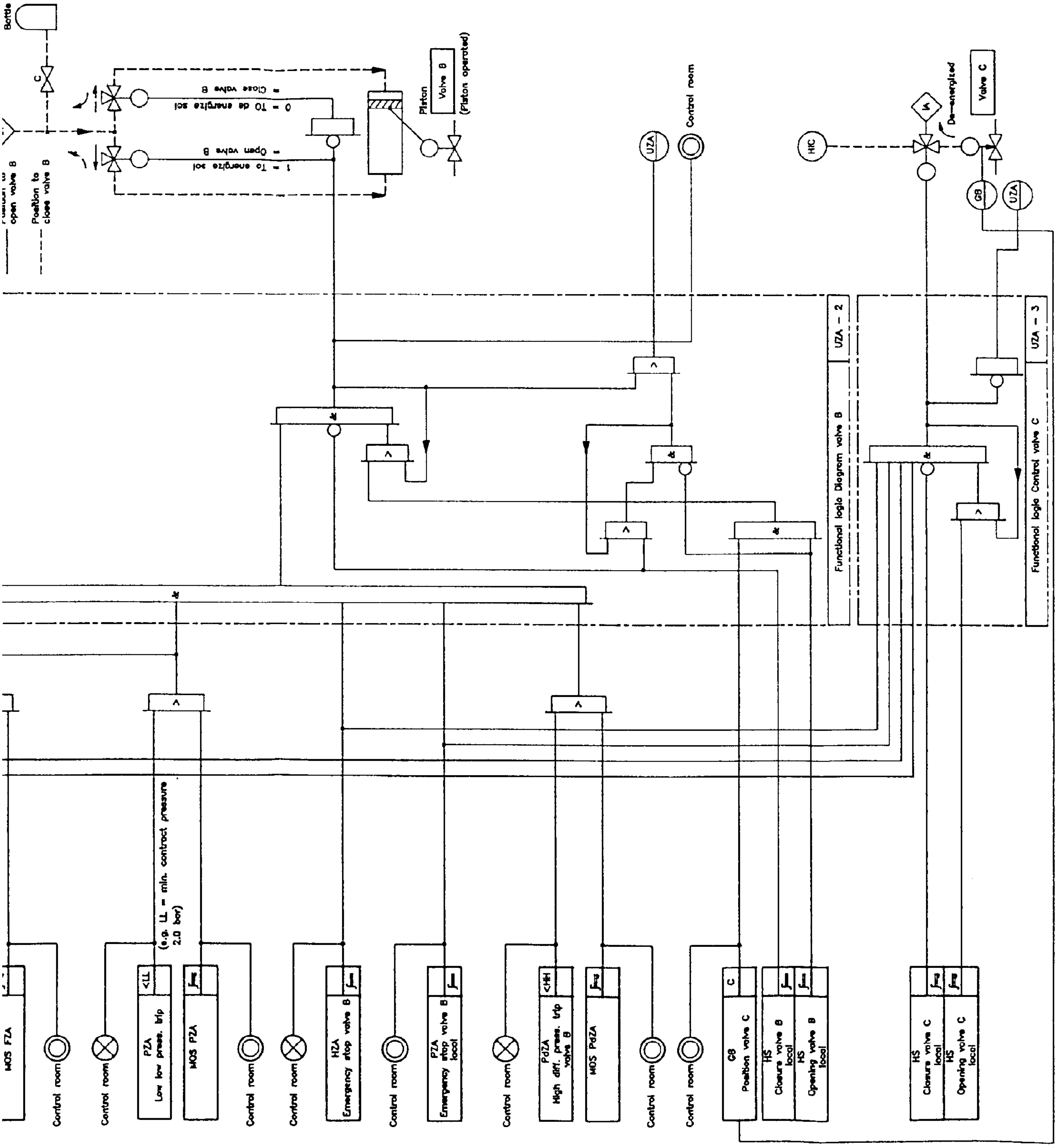


FIGURE 8 TYPICAL FUNCTIONAL LOGIC DIAGRAM FOR OXYGEN MEASURING STATION




Bottle
Position to close valve B
1 = To energize sol = Open valve B
0 = TO de energize sol = Close valve B
Piston
Valve B
(Piston operated)
UZA
Control room
HIC
De-energized
Valve C
GB
UZA
UZA - 2
Functional logic Diagram valve B
UZA - 3
Functional logic Control valve C
(e.g. LL = min. contract pressure 2.0 bar)
MOS FZA
Control room
PZA Low low press. trip
MOS PZA
HZA Emergency stop valve B
PZA Emergency stop valve B local
PdZA High diff. press. trip valve B
MOS PdZA
GB Position valve C
HS Closure valve B local
HS Opening valve B local
HS Closure valve C local
HS Opening valve C local

APPENDICES

	Appendix
Properties and behaviour of materials in oxygen service	1
Effects of oily contamination	2

APPENDIX 1 PROPERTIES AND BEHAVIOUR OF MATERIALS IN OXYGEN SERVICE

CARBON STEEL

Carbon steel is extensively used for oxygen service. Its ignition temperature is rather high; the hot strength is reasonable, as are the specific heat and the heat conductivity. The heat of combustion is high, however. Hence, if heat is developed in the system the metal will absorb and also dissipate heat. If the ignition temperature is reached the metal will start burning, generating more than ample heat to maintain the temperature above ignition level. The metal will not only weaken by the temperature effect but also start thinning. Eventually blow-out will occur, after which the fire may extinguish but possibly continue.

Obviously carbon steel should not be used for services where chances for generation of heat are amply present (high velocities, turbulence, i.e. valves, in-line instruments, elbows, manifolding).

It is clear that an increased wall thickness to provide `draining' possibilities for heat and extra strength are favourable.

AUSTENITIC STAINLESS STEEL

Stainless steel is also extensively used, the main reason being its very high ignition temperature, which is above the melting point, and its very good hot strength. Specific heat and heat of combustion are about equal to those of carbon steel; the thermal conductivity is much lower than of carbon steel.

Hence, if heat is developed in the system the metal temperature will easily rise (particularly if the wall thickness is small, as is often customary for stainless steel) but the metal ignition temperature is not easily reached. Hot strength is such that major blow-out is unlikely to occur. However, if ignition occurs the metal will burn violently, causing a local blow-out. Burning will continue until so much (refractory) chromium oxide is formed that fresh metal cannot be reached. It is stressed that a wall at least as thick as for carbon steel is imperative.

NICKEL

Nickel (and also Monel and Inconel) are reported as being very difficult to ignite in oxygen. The heat conductivity of nickel is high, as are its ignition temperature (above melting point) and hot strength. The heat of combustion is low; the specific heat is reasonable. Hence, if heat is developed in the system the metal will not easily reach a temperature high enough for ignition. If it is ignited the ignition temperature is unlikely to be maintained, thus a blow-out is not probable.

COPPER

Copper is often used for oxygen systems because it has a high heat conductivity and a low heat of combustion. Its ignition temperature (although above the melting point) is low, it has poor hot strength and the specific heat is reasonable. Hence, in the case of development of heat in the system, copper will not easily reach its ignition temperature (the heat is conducted away) but once it burns the damage will be small, as the heat generated by combustion is not likely to be sufficient to maintain the temperature above ignition level. It should be borne in mind that at ignition temperature level the strength of copper is so low that blow-out may occur even if burning is superficial.

SILVER

Silver has properties comparable to those of copper. The low strength renders it suitable only for non-pressure-containing parts. Because the heat conductivity is very high and the coefficient of friction and heat of combustion are very low, it is the best material for labyrinths in high-speed machinery.

ALUMINIUM

Aluminium is extensively used for cryogenic equipment including oxygen-producing plant. It is sometimes used outside the cold box for short stretches of oxygen piping up to ambient temperature and about atmospheric pressure. The metal has a high heat conductivity and high specific heat. Its ignition temperature is low (although above the melting point), it has a high heat of combustion and poor hot strength. If heat is developed in the system, aluminium will not easily reach its ignition temperature, but once it burns the damage will be extensive and a blow-out will occur.

POLYTETRAFLUOROETHYLENE (PTFE)

PTFE, often considered non-combustible, is not completely safe in oxygen service, as combustible products will form above its decomposition temperature. Although the specific heat is high, the decomposition temperature is easily reached because the heat conductivity is very poor. If used in oxygen systems the amounts used should be kept small and well enveloped in metal. Seal rings and piston rings are good examples. In the case of piston rings in compressors, dissipation of heat is important and therefore the PTFE is filled with graphite to improve heat conductivity. This has proved to increase the reliability even though the ignition temperature is slightly lower. PTFE filled with graphite and glass fibres is suitable for slightly higher pressures.

NOTES:

1. The ignition temperature of most materials decreases with increasing oxygen pressure.
2. Metallic coatings and linings should not be considered unless a metallurgical bond provides good dissipation possibilities for heat.

APPENDIX 2 EFFECTS OF OILY CONTAMINATION

Regarding the concentration of oily contamination of metal surfaces, the following information may contribute to a better understanding of the problem.

- At a concentration of 1 g/m^2 oil is not visible and smears cannot be detected when the surface is rubbed with a finger and the area inspected under a bright white light.
- At 2.7 g/m^2 the surface has a slightly oily appearance but no smearing is discernible after testing as above.
- At 5.4 g/m^2 the oil will flow and a slight smear can be detected.
- At 10.8 g/m^2 smearing is considerable.
- At 27 g/m^2 the oil can be pushed with a finger.

NOTE: The most rigorous cleaning can reduce oily contamination to about 0.05 g/m^2.