



# **CLEANING OF EQUIPMENT FOR OXYGEN SERVICE**

## **GUIDELINE**

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# CLEANING OF EQUIPMENT FOR OXYGEN SERVICE - GUIDELINE

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## 1 Introduction

Oxygen is not flammable in itself but supports combustion. Oxygen can react with most materials. The higher the oxygen content and/or pressure in a system:

- the more vigorous the combustion up to explosive levels
- the lower the ignition temperature, up to ignition of materials, that normally do not burn in atmospheric air
- the higher the flame temperature and combustion velocity.

Care must be taken in the selection of equipment and materials, which need to be oxygen compatible and free from contaminants. The main contaminants to be avoided and/or eliminated are hydrocarbon oils and greases, which are easily combustible and particulate matter, which can easily ignite or cause ignition.

Recognition of oxygen's reactivity led to stringent requirements regarding cleanliness of equipment in oxygen service.

The first edition of this document issued 1986 recommended procedures and agents to clean and maintain the cleanliness of surfaces in contact with oxygen, inspection methods and acceptance criteria as well as practical examples.

Cleaning with solvents (as a main procedure at that time in the oxygen industry) was recommended in most examples.

The increasingly stringent environment regulations of the last years, regulations including the phasing out of most chlorofluorocarbons (CFC), restrictions in the use and the banning of some volatile organic compounds (VOC) led to the necessity to develop alternatives.

This document has been updated to take into account the evolution of the regulations on environment.

## 2 Scope and purpose

This document deals with the cleaning of equipment or parts to be used in contact with gaseous or liquid oxygen and nitrous oxide or oxidizing gases/mixtures with an oxygen index > 25% (see prEN 720-2 or ISO 10156).

Particularly, this document describes cleaning methods, lists cleaning agents, presents inspection methods and ways for conservation of cleanliness.

## 3 International Agreements/Regulations

This section gives an overview of the evolution and current status of the agreements/regulations phasing out or restricting the use of certain substances for environmental reasons.

### 3.1.1 Ozone Depleting Substances

Recognition of the contribution of CFCs to the depletion of the ozone layer has prompted a phasing out of these chemicals.

Since the end of the 70's some countries tried to reduce the emission of CFC by issuing laws, and after 1980 it was tried by conferences to come to international agreements.

The Vienna Agreement from 1985 was the result of a conference, but no specific measures were agreed then in the 1987 Montreal Protocol the involved countries agreed on concrete targets in the reduction of some substances. At the meetings in London 1990 and Copenhagen 1992 the phase-out dates were advanced and new substances added.

A summary of the European Union legislation on CFCs is as follows

The phase-out schedule, use, trade, and emission control and reporting provisions for ozone depleting substances is given in EU Regulation No. 2000/2037 replacing EC No 3093/94 on substances that deplete the ozone layer. Use of CFC and HCFC solvents is prohibited in non-contained solvent uses including open-top systems without refrigerated zone. More detailed information can be found in EIGA document 106/03 Environmental Issues Guide and EIGA Environmental Newsletters Nos.5 and 11

### **3.1.2 Volatile Organic Compounds**

VOCs are a major source of 'photochemical smog' and ground level ozone that have harmful effects on human health and the environment.

The main EU legislation covering the use of these substances is EU Directive 1999/13 on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain processes and industrial installations. One of the processes mentioned is surface cleaning.

Installations using solvents above the thresholds specified in the Directive must

- Comply with emissions limit values or solvent reduction plan
- Have a solvent management plan
- Have a permit for their activities

More stringent control measures are required for the most hazardous solvents (with Risk Phrases R45, 46, 49, 60, 61, i.e. carcinogenic, mutagenic, toxic to reproduction).

The Solvent Management Plan should assist the operator:

- to minimize emissions into the environment
- to verify the limit values of emissions
- to identify solvents which should, be substituted.

Information on the effects of CFC and VOC on the environment and reasons for their banning are given in Appendix A and in document 106/03 Environmental Issues Guide

## **4 Cleaning methods**

### **4.1 Procedure and Agent Qualification**

#### **4.1.1 General**

This section provides information to be considered when selecting a cleaning procedure/agent for an oxygen system.

Selection of the appropriate method of cleaning shall be determined by the final level of cleanliness required as set out in section 6.

There are a number of factors to be considered in choosing the most appropriate cleaning process.

- Technical aspects (process suitability/cleaning effect)
- Environmental and safety aspects
- Economical aspects (costs involved)

The selection criteria can be described as defining the characteristics required in the current situation. Each solution represents a compromise with advantages and disadvantages.

Before a decision is made about which cleaning method has to be used, the need for cleaning must be considered and established. It might be possible to reduce cleaning operations by making changes in the production process.

#### **4.1.2 Selection Criteria**

The procedure/cleaning agent should ideally meet the following criteria:

Technical:

- good degreasing properties
- easily removable
- non corrosive
- compatible with commonly used metallic and non-metallic materials
- cleaning agent and its residue to be compatible with oxygen
- non flammable or low flammability

Environmental / Safety :

- non toxic
- non ozone depleting
- environmentally safe
- disposable

Economical:

- inexpensive and readily available on the market
- alternative suppliers

The American Society for Testing Materials (ASTM) has published for this purpose a guideline G 127, "Standard Guide for the Selection of Cleaning Agents for Oxygen Systems"

#### **4.1.3 Additional Technical Criteria**

Other technical aspects to be considered are:

Size of parts:

- small parts (e.g. up to 500 mm)
- big parts as compressor casings, heat exchangers, vaporisers

Form of parts:

- simple
- complicated/dead ends, crevices
- elongated (pipes)

Surface to be cleaned:

- inner
- outer
- roughness

Location where cleaning is carried out:

- in the workshop
- on the installation site

Period when cleaning is carried out:

- during manufacture,
- commissioning,
- maintenance

State of the equipment to be cleaned:

- assembled
- disassembled

Cleaning frequency:

- continuously
- frequently
- occasionally

#### 4.1.1.1 Methods to Compare the Efficiency of Cleaning Agents

It is necessary to have standard methods in order to compare the ability of cleaning procedures/agents to remove oil and grease contaminants from metals.

In principle this can be carried out by contaminating test coupons, cleaning them and evaluating the cleaning effect by an adequate inspection method.

ASTM has also developed two standards which may be used for these purposes:

- ASTM G 121 "Standard practice for preparation of contaminated test coupons for the evaluation of cleaning agents".
- ASTM G 122 "Standard test method for evaluating the effectiveness of cleaning agents".

#### 4.1.4 Health, Safety and Environmental Aspects

The ideal agent is non-toxic or at least has a low toxicity. The main factors to take into consideration are:

- Inhalation effects
- Skin effects
- Eye effects

Follow SDS precautions and use proper PPE when necessary (toxic or hazardous cleaning agents). Dispose of properly.

There are four main issues concerning the environment:

- Emission to water
- Waste disposal
- Emission to air
- Energy.

Energy and emission to water are the main questions for consideration for aqueous cleaning, whilst emission to the atmosphere is of greater relevance for solvent cleaning.

For environmental aspects see also EIGA documents 107/03 "Guidelines on Environmental Management Systems", 106/03 'Environmental Issues Guide', and 88/02 Good Environmental Management Practices

#### 4.1.1.2 Emission to Water

Whichever process is used, contamination of water arises from improper waste disposal, inadequate effluent water treatment or in the case of solvents, accidental spillage caused by improper handling or storage.

#### 4.1.1.3 Waste Disposal

Degreasing with solvents gives rise to a residue containing oils, fats and greases. The solvent content can easily be reduced by distillation either in house or by a licensed recycler, thus recovering useful quantities of solvent. The residue emerges as a highly concentrated final waste.

This should be disposed of by a licensed contractor and procedures should meet local regulations. Support and guidance are also available from the solvent suppliers.

Cleaning in an aqueous system generates two types of effluent:

- The spent cleaning bath contains chemical products necessary for the cleaning process and is also contaminated with oils and greases. This residue must be treated in a waste water treatment plant which also generates a sludge requiring further processing before disposal.
- The rinsing effluent is less contaminated, although still containing dissolved salts. Some effluent may be recycled to an earlier cleaning stage. Any final effluent will require treatment before discharge.

The regulations for the treatment of spent aqueous cleaning effluent vary considerably from one locality to another.

#### **4.1.1.4 Emission to Air**

The limit values of emissions to air due to organic solvents are given in national regulations. There is also the before mentioned EU Directive on the limitation of the emissions due to cleaning processes (section 3.1.2)

#### **4.1.1.5 Energy**

Because of the wide variety of articles and circumstances in which they need to be cleaned, the energy requirements of cleaning processes vary considerably.

The total energy demand for cleaning includes:

- The energy needed for the production of chemicals
- The energy required for the cleaning process, including recycling and waste treatment.

When a drying stage is required aqueous cleaning processes can be more energy intensive than those using solvents.

#### **4.1.5 Costs**

All companies need to operate in the most cost efficient manner. However, in choosing a suitable process, costs are only the prime concern after the demands of technical performance, quality of cleaning, quality and reliability of the cleaned components, operator safety, and environmental requirements have been met.

Cost analysis should take into consideration all costs connected to the cleaning process including personnel, health survey, materials, machines and waste disposal.

### **4.2 Typical Methods**

Typical methods for cleaning of components, vessels and pipe work systems used in oxygen service are summarised in the following section and include:

- Mechanical cleaning
- Chemical cleaning
- Detergent cleaning
- Hot water (steam) cleaning
- Emulsion cleaning
- Solvent cleaning

Appendix B gives examples of cleaning equipment working with aqueous agents and solvents. In Appendix C- I are given examples of different cleaning procedures.

#### **4.2.1 Mechanical Cleaning**

This cleaning method is not used for accurately dimensioned components as the method can cause uneven material loss. It is usually a preparatory stage in the cleaning procedure, but some processes such as blast cleaning can be used as a cleaning process provided oils and greases if present are removed in the process. Critical contaminations which cannot be eliminated by blasting (e.g. markings carried out with some marking pens) shall be noted and removed by another process.

Selection of the mechanical cleaning method will depend upon several factors, which shall be considered:

- The extent of contamination.
- The ability of the method to remove the contaminants.

- Unit or component to be cleaned, its shape and the ability to remove all cleaning debris and cleaning materials.
- The effect of the cleaning materials/procedure relative to the construction materials.
- The surface finish required in/on the unit or component.

As, a final stage in the mechanical cleaning method it is essential that all cleaning materials and debris are removed by brushing, vacuuming or high velocity blow out using dry oil-free compressed air or nitrogen or a combination of these.

Mechanical cleaning is not suitable for non-metallic materials.

Mechanical cleaning can take the form of chipping, scraping, flailing, grinding, wire brushing or blast cleaning.

- Mechanical tube cleaners may be used. These are flexible shaft driven rotating wheel assemblies that carry out a chipping action on mill scale, etc.
- Wire brushes manufactured from non-ferrous wire are recommended. Carbon steel wire brushes shall not be used on aluminium or stainless steel surfaces. Any wire brushes previously used on carbon steel shall not be used on aluminium or stainless steel surfaces. Wire brushing can be utilised with alkaline solutions to enhance that cleaning method.
- Blast cleaning using abrasive materials such as grit, shot, copper slag, aluminium oxide, glass bead, sand etc. The blast cleaning method can be carried out using dry oil-free compressed air, nitrogen or high-pressure water as the carrying media.

This method should not be used on aluminium alloys due to uneven metal loss and embedding of grit that can occur.

It is recommended that blast-cleaning materials be used on a once through basis unless the material has been processed to remove any contaminants.

#### Notes

- a) Specifications for materials are given in Section 5, Cleaning Materials.
- b) Surface finish after mechanical cleaning is recommended to be as a minimum Standard N9, Rugotest No. 3 ISO 2632.  
Alternatives Sa 2 1/2 ISO 8501-1 or Swedish Standard SIS 055900.

#### 4.2.1.1 Health and Safety Precautions - Mechanical Cleaning

Mechanical cleaning creates the formation of dust and other particles resulting from the breakdown of the materials used and also by the removal of surface material from the parts being cleaned. The particulate matter formed if breathed can be hazardous to health (e.g. quartz dust) and can also cause serious damage in contact with the eyes.

Special precautions should be taken for blasting operations:

- 1) Suitable full protective clothing, including breathing provision, head cover, gloves, apron, face shield and/or goggles must be worn by the operator and measures to extract excessive dust from the cleaning area must be employed when necessary.
- 2) Hoses, nozzles, valves and accessories used shall be of a quality and condition suitable for the operation being undertaken.
- 3) National regulations and manufacturers recommendations for ventilation and safe use of blast cleaning cubicles or rooms and blast cleaning equipment shall be observed.
- 4) It is recommended to include a second operator as a "Designated attendant", out of the affected area, but attending the process in order to help in case of emergency.

#### 4.2.2 Chemical Cleaning

Chemical cleaning is a process involving acid or solutions and is used to remove the following alkaline type of contaminants:

- heavy or tenacious surface adherents
- rust, scale and oxide films
- brazing fluxes
- small amounts of paint, grease, oil film and drawing compounds.

The type of chemical cleaning material selected will depend, in most cases, on the equipment to be cleaned, the contaminants to be removed and the materials of construction. The manufacturer's specification for application of the cleaning agent and necessary safety precautions shall be strictly observed.

Selection of the chemical cleaning method will depend upon several factors, which shall be considered:

- Unit or component to be cleaned, its shape, size and ability to remove all residual cleaning materials.
- Unit or component material and the possible effect of the cleaning material on the materials of manufacture.
- Extent of material loss which can be permitted by exposure to acids.
- Contaminants to be removed.
- The surface finish required in/on the unit or component.

Acid cleaning is not generally used for the removal of oils and grease and these contaminants, if present, should be removed by a solvent or by an alkaline solution prior to acid pickling.

Chemical cleaning relates to the cleaning of components by the following alternatives:

- Immersion in a tank containing the cleaning material. Addition of some kind of mechanical energy is normally required.
- Spraying the equipment with the cleaning liquid.
- Complete filling of the component with the cleaning material. This may be applied to large pieces of equipment.
- Forced circulation of the cleaning material inside the component, in items such as tubular pieces of equipment.

The cleaning materials are used as aqueous solutions of either acids or alkaline products. The solutions prepared will be in concentrations appropriate to the materials used in the construction of components and the surface condition required. Multiple cleaning operations are sometimes necessary to treat some metal surfaces, e.g. passivation to retard corrosion.

After the completion of the chemical cleaning operation, by either acid or alkaline solution, all residual cleaning fluid must be completely drained from the component by flushing with clean oil-free water and purged.

#### **4.2.2.1 Alkaline Cleaning**

This cleaning method is normally carried out as a chemical cleaning process to remove oils and greases, with a caustic solution at elevated temperature, in the range of 38°C to 82°C (100°F to 180°F), dependent upon solution concentration.

Caustic solutions are made up from powders, crystals or concentrated solutions. All are water soluble.

Other chemicals with functions like water softening, corrosion inhibition and wetting are often added.

The manufacturers specification for application of the cleaning agent shall be strictly observed.

After cleaning, all components shall be thoroughly rinsed using oil-free water, preferably hot to aid drying, unless otherwise specified by the supplier of the chemical materials. This is particularly important for copper, copper alloys and stainless steel in order to avoid the risk of stress corrosion

#### 4.2.2.2 Acid Cleaning

This is normally carried out with an aqueous solution of acids at ambient temperature. Phosphoric acid cleaning solution can be used for metals, for the removal of oxides, light rust, light soils, fluxes and certain protective coatings.

Hydrochloric acid solutions can be used for carbon and low alloy steels only. This solution will remove rust, scale, oxide coatings and will strip chromium, zinc and cadmium plating. It shall not be used on stainless steel and brass, which may as a result suffer stress corrosion.

Hydrochloric and nitric acid solutions require the use of inhibitors as the solubility of metal oxides in the solutions results in corrosive attack on the base metal.

Following pickling of ferrous surfaces using the above methods, passivation by use of phosphoric acid, sodium nitrite or phosphate treatment is necessary to prevent flash rusting.

Chromic and nitric acid solutions can be used for cleaning aluminium, copper and their respective alloys. These solutions in themselves are not adequate cleaning agents, but are regarded as de-oxidisers for brightening metals dulled by alkaline solution cleaning. Nitric acid solution in combination with copper and copper alloys produces toxic fumes, and therefore good ventilation is essential.

The manufacturer's recommendation regarding solution concentration, time and temperature shall be followed implicitly. Acid solutions should not be used unless their application and performance are known and have been discussed with the material supplier.

After cleaning, all components shall be thoroughly rinsed, using flowing oil-free water, preferably hot to aid drying, unless otherwise specified by the supplier of the chemical materials. Special care should be given to carbon and low alloy steel components.

#### 4.2.2.3 Notes on Alkaline and Acid Cleaning

- a) Advice on aqueous acid and alkaline solutions will be found by reference to Section 5 (Cleaning Materials).
- b) Completion of the flushing operation can be assessed by monitoring the outlet water pH value or conductivity relative to the clean inlet water.
- c) Pumps, hoses, bulk tanks, piping and valves used for acid cleaning shall be acid resistant and compatible with the solution being used.
- d) Contaminated cleaning agents and residues must be stored and disposed of according to manufacturer's recommendations. Local and national regulations shall be observed.

#### 4.2.2.4 Health and Safety Precautions - Acid and Alkaline Cleaning

- 1) Eye and skin contact with acid and alkaline chemicals should be avoided as burns or serious skin disorders can result. The breathing of fumes caused by the reaction of the chemicals with the metals being cleaned should also be minimised. Chemical cleaning agents shall only be used when their application, performance and health implications are fully understood and the manufacturers recommendations are complied with.
- 2) Suitable protective clothing, gloves, apron or sometimes overall suits, face shield and goggles must be worn by the operator whilst carrying out chemical cleaning operations.
- 3) Chemicals shall only be carried using suitable closed containers.
- 4) When acid cleaning in enclosed vessels special precautions need to be taken due to the formation of inflammable hydrogen gas or toxic fumes resulting from contact of some acids with the metal surfaces.
- 5) Acids shall always be slowly added to water when preparing aqueous solutions. Never use the reverse sequence.
- 6) Acids and alkalis must never be disposed of directly into the drainage system. For further advice on environmental considerations and disposal methods refer to IGC Technical Note 107/03.

### 4.2.3 Solvent Cleaning

This cleaning or degreasing method has to a great extent been replaced by other methods because of safety and environmental reasons. In situations where other cleaning methods cannot be applied, solvent cleaning may be considered. If this is the case a specific risk assessment should be carried out considering the hazardous properties of the solvent, the nature of the application and the experience of the personnel in order to define appropriate control measures including waste disposal.

Before starting a cleaning operation a reference sample of fresh clean solvent shall be retained. This sample will be used as a base reference. At intervals throughout the procedure, samples of used solvent shall be taken. These can be compared with the reference sample to determine the level of contamination and the cleaning procedure continued until the acceptance standard of cleanliness is reached.

Methods of determining contamination can be by comparison of colour to reference sample, fluorescence under ultra violet light, by analysis, or by evaporation. (See Section 6 Inspection). Long path length Nessler Tubes or glass bottles are recommended to be used for containing check samples.

Nessler tubes provide an effective and more sensitive means of discerning colour and clarity differences in clear solutions such as water or solvents. It is an effective and practical means for establishing when it is time to change-out a solvent or aqueous rinse solution to prevent recontamination of parts being cleaned.

The advantage of Nessler tubes versus small vials or bottles is that it allows one to look through a long pathlength of liquid, typically 8 to 12 inches. This enables the viewer to be able to better detect colour or clarity changes in the "used" solution versus virgin solution with only a minimal volume of solvent required.. This is far more sensitive and accurate than using small vials which offer short pathlength, typically less than 4 inches. The process simply involves comparing a reference Nessler tube filled to the mark (typically 50ml) with virgin solvent to an identical tube filled with the same volume of "used" solvent. The tubes are generally held in a rack, side by side, and light passes through the bottom of the tube through the test solutions. One looks at the solvent in each tube through the top of the tube, hence, the long pathlength. The user is required to establish what difference in colour or clarity between the two solutions mandates a change in working solution, i.e. solvent. The most conservative approach is any difference requires a working solution change.

A 50 millilitre Nessler tube is essentially a glass tube approximately 19mm ( $\frac{3}{4}$  inch) OD by 305mm (12 inch) in length. The tubes should be "Tall-Form" tubes. A 50 millilitre Nessler tube is sufficient, however 100ml tubes are also available. Such tubes are available from a variety of scientific equipment supply firms which can be easily found via a web search on "Nessler Tubes".

Due to the potential hazard caused by solvents in contact with oxygen, after the completion of any method of solvent cleaning, all residual cleaning fluid must be totally removed from the components. An assessment of the component or system to be cleaned shall be made to ensure there are no pipe or other dead ends or pockets present from which it will be difficult to completely drain or blow out the solvent. If not, then this method shall not be used, or alternatively the system can be modified to accommodate this method. The component shall be thoroughly drained, purged, and dried with warm, dry, oil-free air or nitrogen. Small components may be air dried only, if appropriate. A method of, checking that residual solvents have been eliminated is by using a commercially available vapour detector/analyser on completion of the purge and drying process following cleaning.

The unit used comprises an aspiration pump to measure the sample volume using disposable, calibrated, colorimetric detector tubes. This test can be supplemented by carrying out a sniff test when it is considered to be completely purged of solvent vapours.

Solvent cleaning methods used are described in the following sub-sections. However, components of a simple shape and with all surfaces accessible may be cleaned by wiping with a solvent using a lint-free clean cloth and followed by drying.

#### 4.2.3.1 Immersion in Solvent Method

Cleaning of individual components can be effected by immersing the component in a tank of solvent, at ambient temperature, and applying a means of agitation.

Disassembled parts can be cleaned by this method. The process can be improved by the use of an ultrasonic generator. Some methods utilising solvents are described in Appendix B Section 4.

#### 4.2.3.2 Forced Circulation Method

Cleaning by forced circulation of a flow of the solvent liquid through the component can be carried out. This is done with the solvent at ambient temperature.

The duration of cleaning by circulation shall be continued, using clean solvent, until the used solvent emerges from the component as clean as the solvent pumped in.

This method is a highly specialised cleaning procedure and is applied principally to assemblies, which cannot be disassembled, large size components and prefabricated circuits, pipeworks, etc. The use of this method is, however, limited by the ability of the solvent to reach contaminants present in a complex system and its subsequent complete removal.

#### 4.2.3.3 Vapour Phase Method

Solvent vapour phase cleaning of components consists of the removal of contaminants by the action of continued condensation of solvent vapour on the component surfaces.

The procedure requires that the equipment or component is colder than the solvent boiling point.

A significant advantage of solvent vapour phase cleaning is that revaporised solvent is always clean and contaminants remain in the evaporator liquid section, which will require periodic cleaning out.

A description of the method for one type of equipment is given in Appendix B.

#### 4.2.3.4 Notes on Solvent Cleaning

- a) Advice on suitable solvents will be found by reference to Section 5 (Cleaning Materials).
- b) Some plastic materials, including polyvinyl chloride (PVC) and poly-methylmetacrylate (PMMA) should not be used as containers as the plastics can be extracted by the solvent and be deposited on the component being cleaned. Similarly, rubber and neoprene are also affected. Therefore, products manufactured from these materials shall not be cleaned with chlorinated solvents.

Polytetrafluoroethylene (PTFE) is satisfactory for use with chlorinated solvents and is the most frequently used material. Generally, non-metallic materials require confirmation of acceptability before use.

#### 4.2.3.5 Health and Safety Precautions - Solvent Cleaning

Solvents are generally toxic and may act on the human body through inhalation, penetration of the skin and ingestion (see exposure limits for some solvents in Table 1). Some, such as dichloromethane, trichloroethylene and tetrachloroethylene are classified as suspected to be carcinogenic.

Solvent cleaning agents shall only be used when their application, performance and health implications are fully understood and the manufacturer's recommendations are complied with.

- 1) Vapours from some solvents are a powerful anaesthetic. Inhaled in small quantities it will cause drowsiness. In large quantities the vapour can cause unconsciousness and fatality. National regulations provide measures to control use of these products. Emission to the atmosphere has to be considered and kept to a minimum level and of course in accordance with legislation.

Care must be taken that adequate ventilation is provided in areas utilised for solvent cleaning to prevent people breathing excessive amounts of solvent vapour or the products of decomposition. In solvent cleaning operations outdoors, it may be possible to locate the working area to keep people up wind of solvent handling.

Receptacles for the solvent shall not be left in working areas without lids or caps fitted, and shall be suitably labelled.

To avoid exposure above permitted levels solvents shall not be removed from components by blowing dry in confined spaces.

- 2) Some solvents may decompose to form very toxic gases, e.g. phosgene in the presence of heat sources ( $> 200^{\circ}\text{C}$ ) or ultra violet rays.

Some mixtures are readily ignited with increased pressure and/or oxygen content.

Most solvent vapours are capable of creating an explosive mixture at certain concentrations with air or oxygen.

It is important to ensure that parts to be welded or heated shall be totally free of solvent.

Smoking and the performance of any operations involving the use of flame, arcing or other source of heat higher than  $200^{\circ}\text{C}$  shall be prohibited on premises where vapours of halogenated solvents are present. Exposure of the solvent to daylight over a prolonged period may also cause decomposition of the material.

Do not heat solvents above the allowable temperature. This temperature shall be checked with the solvent supplier or with other relevant information like the Material Safety Data Sheets.

Do not use chlorinated solvents for cleaning closed tanks or other elements where it is not possible to ensure total removal of the solvent.

- 3) Characteristics of solvents, toxicity, occupational exposure limits etc. will be found by reference to Section 3 (Cleaning Materials) and Table 1.
- 4) Due to the harmful effects skin contact must be avoided by using nitrile gloves, apron and safety glasses with side shields or facemask. Note that polyvinyl chloride (PVC) gloves are only suitable for short periods of use.
- 5) Solvents shall only be carried using suitable closed containers.
- 6) Manufacturers of solvent cleaning plants and associated equipment, including ultrasonic methods, issue recommendations on safe operation procedures. Operators shall comply with the manufacturer's advice. Enclosed systems shall always be equipped with pressure relief devices and a pressure gauge. Heating of solvents shall always be by indirect methods.
- 7) Aluminium and its alloys without the protective oxide film react vigorously with certain solvents to produce acid vapour, which is both toxic and corrosive. This particularly occurs on particles of aluminium such as swarf or grains from machining or cutting processes. When using solvents to clean aluminium; the following should be observed:
  - Use only clean solvent that contains the correct level of inhibitors for aluminium or light alloys.
  - Components should be placed gently into the degreasing tank to avoid rupturing the protective oxide film.
  - Newly machined aluminium and aluminium alloy components should be retained in the normal atmosphere in order to create an oxide film prior to being degreased.
  - Ensure that the material being cleaned is free from particles such as swarf or dust.
  - Solvents shall not be kept in contact with aluminium for extended periods. After cleaning remove solvents as quickly as possible.

#### 4.2.4 Detergent Cleaning

This method relates to the cleaning of plant components, vessels, piping systems etc., either externally or internally.

Detergent cleaning is done in water solutions containing chemicals with different functions like dirt solvency, dispersion, water softening, corrosion inhibition and wetting. It is normally performed in an alkaline environment, the higher pH value, and the better the degreasing efficiency.

Detergents are supplied in solid or concentrated liquid form. They are prepared for use by mixing with hot water to form aqueous solutions. Prepared solutions can be pumped, recirculated or jetted onto or through the component. They are well suited as cleaning agents in ultrasonic baths.

The degreasing strength of detergents is as good as that of the solvents.

Aqueous systems have few problems with worker safety compared to most other solvents. They are not flammable or explosive and toxicity is low for most formulations.

The omission to water is the main environmental question to consider in aqueous cleaning. Dependent on local regulations, type of contaminants and detergent, concentrations, pH etc., the waste from water based detergent cleaning might be disposed of into the sewer for which a permit or consent may be required.

#### 4.2.4.1 Notes on Detergent Cleaning

- a) Before use, ensure that detergent chemicals used are suitable as some non-metallic materials are not compatible with the detergent chemicals or may absorb the fluid.
- b) Advice should be sought and followed from the detergent manufacturer regarding solution concentration, the materials it is suitable for, and safety precautions required
- c) For details with narrow cavities, the cleaning stage should be of the immersion type, where all parts of the contaminated details come in contact with the cleaning agent. Spray cleaning machines like a normal dishwasher is therefore an unsuitable alternative.
- d) Aqueous cleaners have higher surface tension compared to organic solvents and therefore difficulty in penetrating into threads and narrow cavities. To get a good contact between cleaner and contaminated details, some kind of mechanical energy should therefore be added. This mechanical energy might be provided by air agitation, jet flushing or ultrasonics. Rotation may be necessary to ensure elimination of air pockets.
- e) Increased temperature improves the cleaning. The cleaning bath should therefore be equipped with a heating device and temperature control.
- f) An aqueous cleaning system requires a subsequent rinsing step. It is important that all cleaning products, grease as well as cleaner residues, are removed. The rinsing step must be performed immediately after the cleaning stage, before the cleaned details have dried. The higher rinsing temperature, the better. The final rinsing must be done with clean water.
- g) When water based cleaners with water rinsing are used, there is a risk for corrosion. Freezing of remaining water may also be a problem in certain installations.

The system then needs to be carefully dried out. A purge of dry oil free air or nitrogen (min -40°C dew point) might be used. A final rinsing with alcohol (e.g. isopropyl alcohol) after water rinsing for improved water removal- might be used if the flammability risks can be controlled.

Care should be taken when drying out the system, not to rely purely on exit gas dew point readings. Prior to commencing drying, drain points should be checked to ensure that all freestanding liquid has been removed. Blowing through with dry oil free air or nitrogen at ambient temperature normally takes a very long time to achieve the necessary dryness.

- h) It is important that water-containing detergent is not directed to an oil/water separating system, as it will prevent such a system operating correctly.

#### 4.2.4.2 Health and Safety Precautions - Detergent Cleaning

- 1) Operators carrying out detergent cleaning shall wear goggles or facemask and gloves.
- 2) Skin contact with detergent chemicals should be avoided as serious skin disorder can result.
- 3) Materials used for pumps, hoses, valves and accessories shall be compatible with the selected detergent to be used.
- 4) The manufacturer's product information and material safety data sheets must be carefully studied.

#### 4.2.5 High Pressure Hot Water (Steam) Cleaning

This method can be carried out using commercially available specialised equipment (one type described in Appendix B section 3.1) for complete external and internal cleaning of major plant parts and pipes with internal diameters down to approximately 10 mm. It removes oil and grease as well as welding and brazing residues and other contaminants. The addition of detergents can improve the performance of this cleaning method. (One typical application is described in Appendix D)

The cleaning medium is heated potable water or water/steam which is jet sprayed onto the work pieces at a pressure of up to 180 bar. If a large flushing effect is required water only is used. The high temperature and the high pressure ensure that all contaminants are removed from the surface and washed away.

This method is not recommended for use on electrical equipment due to possible ingress of moisture.

Due to the jet being at high temperature and pressure care must be taken to ensure suitability of equipment for cleaning by this method.

Cleaning with high-pressure water demands an ample water supply, and good wastewater facilities. Wastewater must be directed to the foul sewer and not discharged directly to surface water.

##### 4.2.5.1 Health and Safety Precautions - High Pressure Hot Water Cleaning

- 1) Protective clothing, gloves, apron, eye and face protection are recommended to be worn by the operator whilst carrying out high pressure cleaning.
- 2) Follow the equipment supplier's instructions for the use and handling of the cleaning lances. Both hands shall always be on the handles and grips of the spray lance.
- 3) It is strictly prohibited that high pressure cleaning is used for personal cleaning.

#### 4.2.6 Emulsion Cleaning

Emulsion cleaning is a process for removing heavy contaminants like oil and grease from the surface of parts. Oxides cannot be removed.

Emulsions are used for the same type of parts as water based detergent cleaners. The applied methods and used equipment is also similar to detergent cleaning.

In an emulsion, a solvent is emulsified in water by surface-active agents. The cleaning is effected mainly by the solvent in the droplets whereupon the cleaner together with the cleaning products are removed by water rinsing. The cleaning efficiency can be increased by adding alkaline agents and surfactants (tensides). The cleaning action of the emulsion then combines the advantages of both detergent and solvent cleaning.

In other emulsion systems, water free solvents with added emulsifiers are used. The cleaning has then to be considered as solvent cleaning. The emulsifying of the solvent and cleaning products takes place first when water is added in the subsequent rinsing stage.

The concentration of dissolved contaminants in the cleaner can normally become considerably higher for emulsions compared to aqueous systems before the cleaning effect diminishes. The penetration into narrow hollows is better than for pure aqueous systems.

The cleaning is normally performed at ambient temperature.

The impact on the working environment from emulsion cleaners originates from vaporised solvent. This impact is however smaller compared to pure solvent systems because of the low solvent concentration and low solvent vapour pressure.

#### 4.2.6.1 Notes on Emulsion Cleaning

- a) Before use ensure that emulsion chemicals used are compatible with all metallic and organic materials.
- b) The cleaning must be followed by careful rinsing to prevent contamination from redepositing on the surface. The surface must not be allowed to dry between the cleaning and rinsing phase.

The rinsing is especially important when high boiling petroleum derived solvents are used in the emulsion. A thin film of high boiling hydrocarbons may otherwise remain on the details after cleaning, which might be a safety risk in oxygen service.

- c) As with pure water based cleaning, the cleaned parts need to be dried after rinsing. A purge of dry oil free air or nitrogen (min -40°C dew point) might be used. After water rinsing, a final rinse with alcohol (e.g. isopropyl alcohol) may be used to improve water removal if flammability risks can be controlled.
- d) The circulation and cleaning of spent cleaning liquid is relatively complicated in emulsion systems. Emulsified oil can be removed by ultra filtration, chemical decomposition, micro filtration, adsorption or biological treatment, but a lot of the chemicals in the cleaning liquid are normally lost in these operations.

The used contaminated cleaner must be disposed of as a waste in line with local or National Regulations.

See also Notes on Solvent Cleaning (section 4.2.3.4) and Notes on Detergent Cleaning (section 4.2.4.1).

#### 4.2.6.2 Health and Safety Precautions - Emulsion Cleaning

When using emulsions, the risks with the applied solvents and other chemical components must be carefully considered.

- 1) Advice shall be sought and followed from the emulsion manufacturer regarding contents of chemicals, solution concentration, the materials suitable for and the safety precautions required.
- 2) Materials used for pumps, hoses, valves and accessories shall be compatible with the selected emulsion to be used.
- 3) Emulsions are considered non-flammable in bulk form but can be flammable in an aspirated or mist conditions. Proper equipment design is essential to minimise risk from flammable mists. Some formulations can auto-oxidise into an undesirable condition.
- 4) The equipment including venting system must be explosion proof because of exposure to vaporised solvent.
- 5) Inhalation is the primary safety concern, but the degreasing of the skin must also be considered.

Operators carrying out emulsion cleaning shall wear face mask with appropriate filter or goggles depending on the composition of the emulsion and on the operation conditions.

Skin contact with emulsion chemicals should be avoided as serious skin disorder can result.

See also Safety Precautions for Solvent Cleaning (paragraph 4.2.3.5) and Safety Precautions for Detergent Cleaning (paragraph 4.2.4.2).

#### 4.2.7 Rinsing

The purpose of rinsing is to remove remaining cleaning agents and emulsified contaminants. This operation is performed after acid, alkaline, detergent and emulsion cleaning.

After the cleaning stage, the parts are immediately transferred to rinsing, which must be done before the parts have dried.

The rinsing operation can take place in one or several stages by immersion, spraying or a combination of these methods.

In immersion baths, some type of agitation is necessary. This might be accomplished by using an impeller, water jets, air injection or movement of the parts. Ultrasonic energy can also be used to improve the rinsing efficiency.

Spray rinsing can be used for details with smooth surfaces without cavities where all parts can be hit by the rinsing liquid.

High rinsing temperature improves the rinsing efficiency. Hot rinsing water will also heat up the cleaned parts, which saves time in the subsequent drying stage.

Cleaning agents with high alkalinity are more difficult to rinse away than other cleaners. Raised temperature may then be required.

The final rinsing must be done with clean water.

The removal of liquid from the details after rinsing can be enhanced by blowing off with nitrogen or oil-free pressurised air.

It is extremely important to perform the rinsing operation very carefully to ensure that all cleaning products, cleaner residue as well as contaminants, are completely removed. The supplier of the cleaner should be consulted when the rinsing conditions are decided.

#### **4.2.8 Drying**

Drying is applied to prevent corrosion and to speed up the total cleaning process in processes where water rinsing is used. This drying operation is often the most time consuming stage in the overall cleaning process. It may be performed in separate drying equipment or as an integrated stage in an automated cleaning apparatus.

Drying is accomplished either with hot gas (convection) or radiation.

In hot gas drying, the necessary energy for water vaporisation is transported to the goods by the hot gas itself.

In drying by radiation, the walls of the drying chamber are heated up, emitting heat radiation, which in turn heats up the goods enough for water vaporisation.

The gas temperature is often in the range of 70-150°C for hot gas drying. In drying, using radiation, the parts are heated to a temperature of 150-200°C. This temperature has to be considered when drying polymeric materials.

Porous parts and parts with small or narrow cavities are difficult to dry.

The drying process can be hastened by immersing the wet parts into a solvent miscible with water (e.g. alcohol), which lowers the surface tension and causes the water droplets to flow out into a thin film.

The humidified gas must be continuously vented from the drying chamber, as evaporation will cease when the gas is saturated with water vapour.

#### **4.2.9 Removal of Cleaning Agent**

Purging can be considered complete when the cleaning agent cannot be detected by appropriate methods in the gas venting from the vessel, piping or component being purged.

If the odour of cleaning agent is detected in the vicinity of the effluent purge gas, the equipment requires additional purging.

If the used cleaning agent is odourless, a leak detector specific for the cleaning agent has to be used.

In the specific case of aqueous cleaning agent, the sole hazard is the deposit of the cleaning agent, which could be flammable.

This situation cannot be possible if the choice of detergent insures that even the traces of solid residues of dry detergent are not flammable.

## **5 Cleaning materials**

This section gives guidance on materials, which are suitable for use as cleaning agents, limits of application and precautions to be taken in using the materials. Most cleaning materials are not completely compatible with oxygen. The cleaning agent must be completely removed from the system, via complete evaporation (for solvents) or thorough rinsing (for detergents) and drying. Special care shall be given to the properties of the cleaning agent regarding flammability, toxicity, corrosion effect, and environmental impact.

Tables 1 to 3 provide recommended materials. Materials used for precleaning processes and final cleaning are included. Alternatives may only be used with reservation when the recommended materials are not obtainable and with particular precautions.

Precautions must be taken when using cleaning materials according to the Material Safety Data Sheets (MSDS), the manufacturers recommendations, different local or national regulations and the rules of the supplier. Other general safety precautions to be taken are detailed in Section 4. Parts of equipment that are not compatible with the cleaning agent shall be removed or isolated.

### **5.1 Mechanical Cleaning Materials**

The following materials are recommended for use for mechanical cleaning.

#### **5.1.1 Blast Cleaning**

Materials used for blast cleaning operations and their carrier shall be free from oil and grease.

Blast cleaning of rough castings, forgings, plates, vessels, piping, cylinders etc. can be carried out using the following materials:

- Copper slag particles
- Aluminium oxide
- Glass beads in high pressure water or dry air
- Sand

Metallic shot (powder or grains of cast iron, iron, steel etc.) may be used. However, it is not recommended as in certain conditions it is capable of burning or initiating ignitions in oxygen. It shall therefore only be used if complete removal can be assured.

#### **5.1.2 Wire Brushes**

Wire brushes manufactured from stainless steel, copper, brass or bronze wire are recommended. Brushes shall be clean and in a good condition.

### **5.2 Chemical Materials**

Chemical cleaning materials are included in the following paragraphs under the types of chemicals:

- Alkaline Solutions
- Acid Solutions
- Solvents
- Detergents
- Emulsions

Tables 1 to 4 provide examples of application of the chemicals included. The safety precautions are detailed together in paragraphs 4.2.2.4, 4.2.3.5, 4.2.4.2 and 4.2.6.2.

### 5.2.1 Alkaline Chemicals

Aqueous solutions of the following alkaline chemicals, often as mixtures, may be used as cleaning materials.

Sodium hydroxide: NaOH (caustic soda).

Sodium carbonate: Na<sub>2</sub>CO<sub>3</sub> or sodium bicarbonate, NaHCO<sub>3</sub> (buffer solution)

Sodium phosphate: Na<sub>3</sub>PO<sub>4</sub> (water softener, emulsifier and buffer).

Sodium silicates: NaSiO<sub>4</sub> (emulsifiers and buffers).

Refer to Table 2 for details of recommended alkaline materials for the metal involved and reason for cleaning. Other treatments required in addition to water rinse and drying are shown.

### 5.2.2 Acid Chemicals

Aqueous solutions of acids are used as chemical cleaning materials for the following applications:

- chemical pickling
- temporary corrosion protection (passivation)

The acid chemicals used depend on the nature of the contaminant to be removed, the metal to be cleaned, and the application. Refer to Table 3 for details of recommended acid solutions for the material involved and the type of cleaning required. Other treatments required in addition to water rinsing and drying are shown.

Acid cleaning of steel components is normally preceded by degreasing using solvent or alkaline treatments to remove oil or grease contaminants.

Chemical pickling using aqueous solutions of acids is applied to vessels or pipe fabrications made of carbon or low alloy steels and removes rust, scale and certain protective coatings. The operation shall be completed by rinsing with a neutralising product or with running clean oil free water until the rinsing water outlet pH is neutral.

The following acid solutions are used for this application.

Nitric acid, HNO<sub>3</sub>

Hydrochloric acid, HCl

Sulphuric acid, H<sub>2</sub>SO<sub>4</sub>

Chromic acid, H<sub>2</sub>CrO<sub>4</sub>

Hydrofluoric acid, HF (stainless steel only)

Phosphoric acid, H<sub>3</sub>PO<sub>4</sub>

Chemical passivation is a treatment used to provide temporary corrosion protection of carbon and low alloy steel surfaces, which have been pickled. Phosphoric acid (H<sub>3</sub>PO<sub>4</sub>) or sodium nitrite solutions are used for this treatment. After treatment, the equipment shall be completely washed, drained and dried. Surfaces treated in this way have a uniform grey colour, occasionally with some highlights of a reddish brown colour due to deposits of salts of the passivation products. Any blackish deposits left on the surface which are slightly sticky to touch, are an indication that draining after passivation has been incomplete. Whitish surfaces with a tendency to be flaky indicate incomplete drying.

Acid solutions that attack the base metal or react with contained moisture may require the addition of inhibitors.

There are commercially available products and solutions designed either for descaling or for anti-corrosive protection, or to fulfil both of these functions simultaneously. The exact compositions of these products are not always provided. They should not, therefore, be used unless compatibility tests have demonstrated the safety of the

### 5.2.3 Solvents

Some chlorinated solvents are still acceptable and established alternatives include hydro chlorofluorocarbons (HCFCs), aliphatic hydrocarbons and some specialised constant boiling blends.

The use of HCFCs should only be regarded as transition alternatives due to the possibility of their phasing out in the future, see section 3.

Chlorinated solvents offer an advantage in that they tend to be usable in conventional degreasing equipment. A selection of solvents for cleaning oxygen service equipment is listed in Table 1.

Pertinent data that is available on these products is also included.

Although the solvents listed are low in their ozone depleting potential, they are volatile organic compounds and will, in some cases, also have a global warming potential. This should be taken into account when considering any investment in cleaning equipment.

In addition to the cleaning ability of the solvent, material compatibility, toxicity and environmental issues in the application, and waste disposal aspects must all be considered when choosing the most suitable solvent for a given cleaning application. On completion of cleaning it is essential that all traces of solvent remaining are removed, leaving minimal to nil non-volatile residue (NVR) See 6.4 for acceptance criteria). If necessary, this should be confirmed with appropriate detection equipment (e.g. halogen leak detector or detector tube for chlorinated solvents). When the favoured method of cleaning is to use a solvent, its choice will represent a compromise combination of relevant properties. Solvents used shall be of a stabilised grade of proven suitability.

It is important to ensure that the solvent is compatible with the materials used in the construction of parts being cleaned. Unstabilized solvents can cause metal corrosion. The presence of moisture accelerates the corrosive effects of trichlorethylene and it is therefore essential that care is taken to maintain the quality of the solvents in use.

Solvent degreasing must be carried out in a well-ventilated area and appropriate personal protective clothing should be used. The occupational exposure limits/threshold limit values shall be considered.

Any changes of cleaning agent must be accompanied by a rigorous assessment of the risks to health of those involved in the changed process. Any necessary controls must be established and information provided to those involved with the changed solvent. This is required by legislation in most countries.

**Flammability is an important safety issue with hydrocarbons, and chlorinated solvents as they are also flammable in O<sub>2</sub>.**

Alcohol, oil spirits, some solvents and dry residues of aqueous detergents are flammable with oxygen.

These characteristics of flammability are well known and the use of flammable products for oxygen cleaning are strongly limited. However if this type of product is used, the procedure for rinsing, purging and checking has to be carefully qualified.

It shall be ensured that after the complete procedure no residuals of flammable vapour or liquid remain in the equipment especially in complicated configurations, dead ends etc.

The qualified procedure is specific for a given equipment.

When non-flammable solvents are chosen, hydrocarbon-free grades should be used.

The recycling of solvents and their ultimate safe disposal must conform to national legislative requirements. Accurate records should be maintained with a view to establishing a mass balance. Where disposal of spent solvent is required, it will normally be necessary to employ an approved professional waste disposal agent.

National legislation will normally stipulate the storage and transport requirements. All solvent, recovered solvent and waste must be clearly labelled. Solvent must never be discharged directly into drains, sewers or natural watercourses. Checks should be carried out on the purity of solvent that is reused or has been recovered.

#### **5.2.4 Water Based Detergents**

Detergent cleaning is done in water solutions containing chemicals with different functions. It is normally performed in an alkaline environment, the higher pH value, the better the degreasing efficiency

Common components in alkaline detergents and their main functions are shown in table 4.

The most important detergent components are the surfactants. They decrease the surface tension of the water solution, penetrate the organic contaminants and make them disperse as small droplets into the water solution.

Proprietary synthetic detergents are available for use to clean different polymers, metals and alloys. It is most important the manufacturer's recommendations are complied with and also the effect on any non-metallic materials which are present.

It is important to ensure that the used detergents have a high rinsability. Ideal is a detergent that rinses freely and completely leaving minimal residues.

#### **5.2.5 Emulsion Cleaners**

Emulsion cleaner systems have three main components - water, an organic solvent and surfactants.

They are used in two ways:

- The solvent emulsified in water is applied in a manner similar to standard aqueous cleaners. The solvent is the main dirt dissolver and the surfactants work principally as emulsifiers.
- Water-free solvents with added emulsifiers are applied in concentrated form and then rinsed with water. The emulsifying of the solvent and cleaning products takes place first when water is added in the subsequent rinsing stage.

For safety and environmental reasons, solvents with high flash point and low vapour pressure are normally chosen. Examples of solvents are different high) oiling hydrocarbons, citrus based terpenes. (e.g. d-limonene) and pine based terpenes. Other examples are esters (e.g. lactate esters) and glycol ethers.

Proprietary emulsion cleaners are available to clean different polymers, metals and alloys. It is most important the manufacturers recommendations are complied with and also the effect on any non-metallic materials which are present.

### **5.3 Cleaning Cloths**

Cloths used for wiping components or small areas of equipment surfaces shall be clean, lint-free and free from traces of oil or grease. Cotton, linen or paper re commonly used materials.

Cleaning cloths should not have fluorescent dyes or brighteners or other additives in them which could transfer to the part surface giving indication that the surface is fluorescing. Cloth used should be a non-fluorescent or weakly fluorescent lint free cloth.

### **5.4 Desiccating Materials**

Desiccating materials are sometimes placed in equipment after cleaning to prevent any corrosion, or other deterioration due to humidity of air that may be present during the period of shipment or storage.

The following may be used:

- alumina
- silica gels
- molecular sieve
- regenerated clays

Certain colour additives may be included in the products to give an indication of the moisture content.

### **5.5 Drying/Purging Gas**

The gas used shall be dry air or nitrogen and free from oil, grease and particulate matter. Air is considered suitable when its content of oil, grease and particulate matter is less than 1 mg/m<sup>3</sup> and dry if its dew point value is equal or lower than -40°C at 1.013 bar. For continuous purging of equipment, using air, filtered atmospheric air compressed by a non-oil lubricated compressor is recommended.

Table 1: Industrial solvents<sup>1</sup>

Solvent (trivial / common name)	Chemical formula	Occupat. Exposure Limit <sup>2</sup> ppm	Solvent power Kauri- butanol Index <sup>3</sup>	Flammab. limits in %	Boiling point (°C) (Re. evap. time) <sup>5</sup>	ODP <sup>6</sup> HGWP <sup>7</sup> POCP <sup>8</sup>
<b>CHLORINATED SOLVENTS</b>						
Dichloromethane (Methylene Chloride)	CH <sub>2</sub> Cl <sub>2</sub>	100	136	11.7-68	39.8 (1.5)	ODP zero HGWP nil POCP 0.9
Trichloroethylene	C <sub>2</sub> HCl <sub>3</sub>	100	130	7.5-95	86.9 (2.7)	ODP zero HGWP nil POCP 7
Tetrachloroethylene (Perchloroethylene)	C <sub>2</sub> Cl <sub>4</sub>	50	90	10-65	120.9 (7.1)	ODP zero HGWP nil POCP 0.5
<b>HYDROCHLOROFLUOROCARBONS (HCFCs)</b>				<b>Also used in blends with other solvents</b>		
2,2-Dichloro 1,1,1 trifluoroethane (HCFC 123)	C <sub>2</sub> HCl <sub>2</sub> F <sub>3</sub>			none	2	ODP 0.02 HGWP 0.02
1,1-Dichloro -1- fluoro-ethane (HCFC 141b)	C <sub>2</sub> H <sub>3</sub> Cl <sub>2</sub> F		61	5.6-17.7 <sup>4</sup>	32 <sup>9</sup>	ODP 0.11 HGWP 0.1
3,3-Dichloro-1,1,1,2,2 pentafluoropropane (HCFC 225 ca)	C <sub>3</sub> HCl <sub>2</sub> F <sub>5</sub>		34		51.1	ODP 0.025
1,3-Dichloro-1,1,2,2,3 pentafluoropropane (HCFC 225 cb)	C <sub>3</sub> HCl <sub>2</sub> F <sub>5</sub>		30		56.1	ODP 0.033
<b>MISCELLANEOUS SOLVENTS</b>						
1- Bromopropane	C <sub>3</sub> H <sub>7</sub> Br	100		4.6- 8.5	69.5 (4.5)	ODP 0.012 HGWP nil
Acetone	C <sub>3</sub> H <sub>6</sub> O	750		3.0-11 <sup>4</sup>	56.5	
Isopropanol	C <sub>3</sub> H <sub>8</sub> O	400		2.5-12 <sup>4</sup>	82.5	
Methylethyle ketone	C <sub>4</sub> H <sub>8</sub> O	200		1.8-11.5 <sup>4</sup>	79.6	
Natural oils <sup>10</sup>						

## Notes on Table I

- Potential users should determine whether the solvent has been declared acceptable by national authorities. Solvents shall only be used in stabilised form.
- Occupational exposure limits are those cited in the UK by the Health & Safety Executive in the 1994 edition of their annual publication. The figures refer to a time weighted average for an 8-hour day. The terminology used varies in different countries, e.g. threshold limit values (TLV) in Belgium, France, Italy, USA, MAK/TRK in Germany and MAC in the Netherlands. The values used should always be those cited in the National regulations relating to the country in which operations are being conducted.
- The Kauri-butanol index (KB) is a measure of the relative solvent power of the chemical. It corresponds to the volume of solvent which when added to a solution of kauri gum in butanol causes commencement of cloudiness in the solution. The better the product as a solvent, the higher the KB value.
- The figures quoted are the lower and upper flammability limits expressed as a percentage by volume of the vapour in air.
- The relative time of evaporation is the ratio between the evaporation time of the liquid concerned and that of diethylether at a temperature of 20±2° C and a relative humidity of 55±5%.
- Ozone depleting potential (ODP) is expressed relative to CFC- 11 (Fluorotrichloro-methane)= 1.
- Halocarbon global warming potential (HGWP ) is expressed relative to CFC -11 =1.
- Photochemical ozone creation potential (POCP) is a relative measure of the ability of volatile organic compounds to enter into reactions that lead to poor air quality due to the formation of low altitude ozone. The base is taken as ethylene = 100.
- Not suitable for cold cleaning.
- e.g.: proprietary orange oils/mineral spirits. They are typically of high boiling point (200°C) and low volatility.

**Table 2: Alkaline chemical cleaning materials  
(Also applicable to Alkaline Detergents)**

METAL	USED FOR	CLEANING CHEMICALS	OTHER TREATMENT
Carbon, Low Alloys Steels and 9% Nickel	Removal of heavy soil, grease and oil	Mixtures of Sodium hydroxide, carbonates, phosphates and silicates and synthetic wetting agents	Solutions should not be allowed to dry on the component, they must be thoroughly rinsed away before passivation
Austenitic Stainless Steel	Removal of heavy soil, grease, light oils and cutting fluids	Mixtures of Sodium hydroxide, carbonates, phosphates and silicates and synthetic wetting agents	(See Note 3)
Copper and Alloys	Removal of greases, lubricating oils, drawing compounds, oxides, metallic particles or other contaminants	Mixtures of Sodium hydroxide, polyphosphates, silicates, carbonates, wetting agents	Usually bright dipped in dichromate chromic acid solution (See Note 3)
	Removal of brazing fluxes	Hot water	
Aluminium and Alloys	Removal of greases, oils and oxides	Etching: Mixed solution of sodium hydroxide and sodium phosphate  Non Etching: Mixed solution of sodium carbonate, sodium silicate, sodium pyrophosphate and sodium metasilicate	Dilute nitric acid dip to remove deposits remaining after alkali dipping.

**Note:**

- 1) The manufacturers specification for application of the cleaning agent shall be strictly observed.
- 2) After cleaning using alkaline chemicals, all components shall be thoroughly rinsed, using flowing oil-free water, preferably hot to aid drying, unless otherwise specified by the supplier of the cleaning materials.
- 3) There is a risk of stress corrosion attack unless the components have all chemical cleaning materials removed.

**Table 3: Acid chemical cleaning materials**

METAL	USED FOR	CLEANING CHEMICALS	OTHER TREATMENT
Carbon and low alloy steels	Removal of scale and oxide films (pickling)	Inhibited hydrochloric acid or sulphuric acid and wetting agents	Dilute alkali dip to neutralise acid followed by passivation treatment using sodium nitrite or phosphoric acid
	Removal of light rust	Citric acid or sulphuric and phosphoric acids	Light scrubbing action helpful
Cast Iron	Removal of oxides	Chromic acid and sulphuric acid	
Austenitic Stainless Steel	Removal of oxides, tarnish and scale and metallic deposits / contaminants	Chromic acid and sulphuric acid and hydrofluoric acid, or nitric and hydrofluoric and phosphoric acids	Nitric acid solution used to brighten
Copper and Alloys	Removal of scale and oxide (pickling)	Hydrochloric or sulphuric acid	Sulphuric and nitric and hydrochloric acids are used to brighten
Aluminium and Alloys	Removal of oxides (Etching Cleaning)	Chromic / sulphuric acid, Nitric / Hydrofluoric acid, Phosphoric / chromic acid	Nitric / phosphoric acid for chemical brightening.

Note:

- 1) The manufacturers specification for application of the cleaning agent shall be strictly observed or the properties of the metals can be impaired (e.g. hydrogen embrittlement).  
Time/temperature/concentrations are very important.
- 2) After cleaning using acid, all components, except carbon and low alloy steels, (see 3.2.2) shall be thoroughly rinsed, using flowing oil-free water, preferably hot to aid drying, to avoid corrosion risk, unless otherwise specified by the supplier of the cleaning materials. Some components require treatment using neutralising solutions after certain cleaning procedures

**Table 4: Common components in alkaline detergents and their main function**

<b>Main function</b>	<b>Examples of common components</b>
Dirt Dissolvers PH Raising Agents	Sodium Hydroxide Potassium Hydroxide Sodium Carbonate Sodium Silicate
Dispersers	Surfactants (Tensides) Sodium Silicate Polyphosphates
Softeners	Polyphosphates Borates Glyconates
Corrosion inhibitors	Sodium Silicate Borates Amines
Wetting Agents	Polyphosphates Glyconates Surfactants (Tensides)

## 6 Inspection methods and acceptance criteria

### 6.1 Introduction

It is essential that equipment supplied for use in oxygen service complies with the users specified cleanliness requirements. Agreement on the manufacturer's detailed quality control procedures and standards is required between the manufacturer and the user.

Inspection by the user at the manufacturer's location is desirable. Initial and periodical auditing of the cleaning method and cleanliness control provisions. If the manufacturers' workshops or site installations, cleaning and quality control provisions and its use, is necessary.

### 6.2 Inspection Methods

Various methods exist for determining the cleanliness of the cleaned parts. It is necessary that the method selected complements the cleaning method used and shows whether the acceptance criteria are achieved.

This section covers the most practical and effective methods available. Qualified inspectors with the necessary training and relevant industrial experience are needed for this activity.

Parts that are inaccessible for inspection after assembly may require to be disassembled or inspected prior to assembly.

If an inspection reveals the presence of non-acceptable contamination, with oil or grease, residues of cleaning agent, or particles, the item of equipment must be partially or even completely recleaned. Persistent rejection requires a re-evaluation of the cleaning methods used and of the quality control provisions.

The usual inspection methods are:

- Direct Visual Inspection with White Light
- Direct Visual Inspection with Ultra Violet (U.V) Light
- Wipe Test
- Solvent Extraction
- Water Break Test
- Chromatographic and Spectrometric Methods and other Special Methods.

The method(s) selected depends on the required cleanliness.

#### 6.2.1 Direct Visual Inspection with White Light

This is the most simple inspection method used to detect the presence of contaminants on equipment with accessible surfaces. This method will detect without magnification small particulate matter, dust, oil, grease and moisture in amounts, which could be too high. It shall be used in conjunction with other methods.

It is important to have a sufficiently bright level of artificial or natural daylight.

Acceptance criteria:

Visual inspection of the surfaces under bright light shall show no evidence of:

- organic material such as oil, grease, paint, etc.
- cleaning agents including detergents
- rust and loose scale, weld spatters, particles dust, fibres or Other foreign matter
- flux residues from welding, brazing or soldering moisture

### 6.2.2 Direct Visual Inspection with UV. Light (Black Light)

An UV-light with a wavelength of about 0,37  $\mu\text{m}$  and a UV intensity of at least 1000uW/cm<sup>2</sup> is used in dark or near darkness at a distance of about 10 to 20 cm from the surface or piece being examined. Blacklight bulbs generally in the 50 to 150 watt range meet this criteria. Many common but not all hydrocarbons or organic oils fluoresce under UV-light. The method might indicate fluorescent areas to be further inspected by other tests such as wipe or solvent test.

The intensity of the fluorescent reflection from various oils is very different. For some vegetable and chemical oils it is zero. Therefore it is important not to rely solely on the result of this test in evaluating the cleanliness of equipment cleaned for oxygen service.

Note that excessive exposure to direct or reflected ultraviolet light can cause eye and skin damage and therefore care must be taken when it is being used and lamp manufacturers instructions shall be complied with.

Acceptance criteria:

This qualitative method can better be used, if the contaminating oil and its reflecting capacity are known. The method should be used in conjunction with a quantitative test. A low specified amount of small particles can be detected by the U.V -light-test.

### 6.2.3 Wipe Test

This test is useful when white light inspection and/or UV light inspection has been inconclusive or not possible.

The surface is rubbed lightly with white filter paper or with clean lint-free cotton or linen cloth. This paper or cloth is examined under white light and/or U.V light to find any contaminating traces. Several areas of the parts surfaces shall be tested. Since it is not acceptable to leave cloth or paper particles on the equipment, this method is not suitable for rough surfaces.

For example: A contamination of 1000 mg/m<sup>2</sup> Oil uniformly distributed would have a thickness of approx. 1  $\mu\text{m}$ .

Acceptance criteria:

A light oxide discolouration or dust is in some cases acceptable.

Any stain from the presence of oil or grease is unacceptable.

### 6.2.4 Solvent Extraction

Solvent extraction is one of the methods giving quantitative figures regarding the amount of soluble contaminants. The method is used especially for inaccessible surfaces or as verification of a cleaning process or of other qualitative methods.

For most small components it may be easier and more economical to disassemble for inspection or to inspect before assembly. It should be taken into account that this method of inspection is limited by the ability to reach and dissolve the contaminants if present. Local contamination in pockets of complex equipment may be detected using this method of inspection by getting successive slight but constant indications of contamination. Considerable experience is necessary to assess the results of this method.

The method is based on the comparison of used and unused solvent. The level of or freedom from contamination present during solvent cleaning can be closely followed by taking successive solvent samples during the entire cleaning process until inspection confirms that the acceptance standard is reached. Checking the amount of contaminants in a used sample is a good indication of the cleanliness level reached.

The amount of contaminants in a sample can be determined in three ways.

- weight of residue (laboratory test)
- volume of residue (laboratory test)
- light transmission (laboratory test for qualitative figures)

This method is accurate in determining low amounts of oil or grease residues with small tolerances.

#### 6.2.4.1 Weight of Residue

A known quantity ( $M_s$ ) of a representative sample of unfiltered used solvent is contained in a small weighed beaker and is evaporated to dryness being careful not to overheat the residue and the weight ( $m_2$ ) of the residue established. In the same manner the weight ( $m_1$ ) of residue from a similar quantity of clean unused solvent is determined.

The difference in weight between the two residues and the quantity of representative sample used is related to the total quantity ( $M_v$ ) of solvent used and can be taken to compute the amount of residual contaminant removed per square metre ( $m_c$ ) of surface area ( $A$ ) cleaned.

$$m_c = \frac{(m_2 - m_1)m_v / m_s}{A}$$

$m_1$  = weight of residue (clean solvent)

$m_2$  = weight of residue (used solvent)

$m_s$  = weight of representative sample (used solvent)

$m_v$  = total weight of solvent used

$A$  = surface area of component cleaned

$M_c$  = weight of contamination present per area cleaned.

#### 6.2.4.2 Volume of Residue

A measured quantity of a sample of the unfiltered used solvent can be placed in an Imhoff cone and evaporated to dryness. The volume of residue can be measured directly and used to compute the volume contaminant extracted per square metre of surface area cleaned. Greater sensitivity can be achieved by successive evaporation of quantities of the same extracted solvent batch in the same Imhoff cone.

#### 6.2.4.3 Light Transmission

A sample of the unfiltered used solvent is compared a reference sample of unused solvent by comparing light transmission through the two samples simultaneously. The difference in colour or light absorption of the solvents is a qualitative indication of the amount of contaminants dissolved. The quantity of any contaminant in a sample can be estimated by analysis techniques e.g. making use of UV or infrared light.

#### 6.2.5 Water Break Test

Drinking or distilled water is sprayed on a surface as horizontal as possible. If the amounts of oil or grease are very small an unbroken layer of water stays for some seconds. If higher amounts of oil or grease are on the surface the water quickly contracts and forms small beads or droplets between water free areas.

#### 6.2.6 Spectrometric, Chromatographic and other Special Methods

The measuring instruments used for these methods are very different. For their use special operating instructions are necessary. By some of them low amounts of oil or grease contamination can be detected and measured. In some cases the tolerances are low.

Another method is the Total Organic Carbon Analysis-TOC". The technique is based on oxidation of the samples in furnace in flowing oxygen. The TOC-concentration gives an accurate quantitative

value of the total surface carbon content and also semi quantitative information on the presence of hydrocarbons (the amount of carbon can be considered as being 0,8 - 0,9 of the total hydrocarbon weight).

### 6.3 Detection Limits

The results of measurements depend in a physical and optical way on the contaminating agent e.g. type of oil or grease. This is the reason for the wide range of the detection limits given in the table below. The quoted ranges are for information only.

Test method	Informative threshold of detection mg/m <sup>2</sup>
bright white light	500 - 1700
UV light	40 - 1500
wipe test	30 - 600
water break test	30 - 60
TOC, solvent extraction	< 10

A combination of test methods results in a lower threshold of detection.

### 6.4 Acceptance Criteria

This section gives quantitative values for two pressure ranges.

The pressure strongly influences the ability of the contaminant to ignite. Contaminants are foreign unwanted matter that can have a negative effect on system operation life or reliability. They are mainly:

- a) oils greases detergents
- b) other foreign matter (solid particles, dust layers, liquids) being either
  - organic substances e.g. wood, paper, cloth, plastics, rubber, adhesives, fibres, paints or anticorrosive, solvents or
  - inorganic substances for instance metal chips, scale, weld splatter, welding rod remnants, rust particles, sand, water drops, or any other particles.

Maximum allowable quantities of foreign matters

Pressure Range Bar gauge	Oil, Detergents, Grease, organic coatings mg/m <sup>2</sup>	Particles	Moisture
< 30	500 <sup>1</sup>	Single small chips or fibres can be tolerated <sup>2</sup>	No drops of water visible
>30	200 <sup>1</sup>	Single very small chips or fibres can be tolerated <sup>2</sup>	No drops of water visible

- 1) The values are given considering a uniform distribution of the contamination at a max temperature of 70 °C.

The quoted figures should be considered as guidance only. Lower figures could be requested depending on the specific application (type and state of fluid, temperature, pressure, flow, velocity, product purity), or effects like migration.

Clusters of fibres other particles and dust i.e. relative high local concentrations must not be visible.

#### 6.4.1 Odour Test

If requested (e.g. for medical gases) - an odour test shall be performed. The odour can be determined by one of the following procedures:

- During purging operations by sniffing a moderate flow of purge gas from the equipment being tested.
- From equipment in service containing gaseous oxygen by sniffing a moderate flow of oxygen from the equipment being tested.
- From equipment in service containing liquid oxygen by taking out a liquid sample for testing.

Odour in the liquid oxygen sample is checked by evaporating to dryness a quantity of liquid in a loosely covered beaker with a fresh filter paper in the bottom. The cover is removed at the point of complete evaporation and the beaker is odour tested several times until, it has warmed to above the freezing point of condensed water on the outside.

The result of the inspection shall confirm the absence of odour. In either of the above procedures do not place face directly in front of valve or beaker. Instead cup the band and bring some of the gas being vented towards the nose.

### 6.5 Inspection records

Records are made of inspections and acceptances for the cleaned equipment or assembly. The record will include:

- a) Identification of the item covered
- b) Cleanliness specifications
- c) Cleaning method employed
- d) Method of inspection
- e) Results of inspection
- f) Inspector's signature and date

## 7 Labelling for oxygen service

All equipment components and spare parts delivered single or bulk packed in accordance with this specification shall bear a label stating that the items have been

- CLEANED FOR OXYGEN SERVICE

Additional information may be included as follows:

- To be kept free from oil and grease particles and water.
- Showing date of inspection and stamps of supplier or workshop.
- Stating the designation of the equipment and its serial number (if applicable).
- Warning of asphyxiation hazard if applicable indicating medium and pressure.

The label must be visible and securely attached to the item by an appropriate means and not invalidate oxygen clean condition. Avoid the use of adhesive labels directly on metals as the adhesive may cause corrosion and/or contamination.

Any other information or notices required relative to shipping storage and cleanliness conservation to be included on labels is given in Section 6.

## 8 Conservation of cleanliness

The purpose of this section is to provide protection to conserve the cleanliness of equipment for oxygen use during shipping and storage until installation prior to commissioning.

Once a piece of equipment has been cleaned for oxygen service and certified as conforming to the cleanliness specifications (see Section 4) it shall be adequately protected to prevent contamination.

The protection provided will depend on a number of factors such as the size and type of equipment, method of shipping, duration, and conditions of storage.

The packaging material used shall be clean, strong, to be sealed, waterproofed and suitable for the purpose.

## **8.1 Protection Methods**

### **8.1.1 Small Equipment**

Accessories or parts such as valves, gaskets, etc. shall be packaged individually, after cleaning in a clean polyethylene tube or, bag and sealed. Any openings on the parts shall be closed with degreased plastic or metal plugs. The interior of the sealed bag may be evacuated of atmospheric air or filled with oil free nitrogen.

### **8.1.2 Large Equipment**

Openings on equipment shall preferably be sealed with degreased caps, plugs, or suitable blind flanges. The equipment may be purged of atmospheric air and filled with oil-free dry clean air or inert gas at a slightly positive pressure. A notice shall be attached stating that the equipment is under pressure and the pressurising medium used.

## **8.2 Pressure Testing**

When any test is carried out on equipment after completion of the cleaning operation it is essential to conserve the oxygen clean conditions. The test medium shall be compatible with the equipment materials and free from contaminants.

When a hydraulic test is carried out, oil free, clean water shall be used and after testing the equipment shall be dried, purged, and blown out. For pneumatic testing, oil- free, dry, clean air or nitrogen shall be used. The testing medium shall be removed before the equipment is put into service.

## **8.3 Notes**

The packing must be carried out in the area(s) temporarily or permanently allocated to equipment for oxygen service.

All equipment shall be labelled according to Section 7.

The internals of equipment that are liable to rust, that cannot be purged with a dry inert gas, shall be protected by the insertion of fibre, perforated or porous sachets containing silica gel, activated alumina or similar moisture absorbing agent. The sachets shall be secured inside the equipment, preferably to a removable part such as a cap or blank flange.

The equipment shall have a notice indicating that it contains moisture adsorbents, the number of sachets and their locations.

The adsorbents may contain a colour-indicator that will change colour if saturated with moisture.

Sachets shall, if possible, be connected in groups so that they can be removed together. Small loose sachets of desiccant shall not be used as they may inadvertently be left inside the equipment after installation. When removing the sachets, care shall be taken to ensure that they are intact and that all sachets are removed.

Cleaned components shall be stored until installation in a suitable dedicated area free from contamination.

The packing shall not be opened until the equipment is ready to be installed. Prior to installation, the cleanliness shall be checked again to ensure that the specified standard has been maintained, and that the equipment is suitable for oxygen service.

## **9 Design and manufacturing considerations for cleanliness**

The ability to clean, and the method(s) to be used shall be considered in the design and manufacture of equipment and components for oxygen service.

Where possible, components shall not have recesses that cannot be directly inspected for cleanliness.

Preferably, components shall be cleaned prior to assembly, and cleanliness maintained throughout assembly and testing.

Where this is not possible, trial assemblies shall be dismantled after cleaning and components examined for cleanliness.

Only approved lubricants shall be used in the assembly of components.

The root weld run on piping systems and small pressure vessels should utilise welding process 141 [Tungsten inert gas arc welding (TIG welding)] to ISO857/ISO4063, in order to ensure a smooth root weld profile on the surface exposed to oxygen.

### **9.1 Quality Assurance for Cleanliness when Buying Equipment or Components**

Any supplier or sub-contractor supplying or cleaning equipment or components for oxygen service shall be evaluated.

Quality records of acceptable suppliers and sub-contractors shall be maintained.

Evaluation and records shall include, where appropriate:

- Cleaning methods, equipment and fluids.
- Method(s) used to evaluate cleanliness.
- Training and experience of operatives.
- Methods used to ensure cleanliness during testing.

Records of inspections for cleanliness witnessed or subsequently carried out by the purchaser.

Methods used to maintain cleanliness up to and during storage.

## Appendix A: Effect of CFC and VOC on the environment

### 1. Effect of CFC on the Environment / Reasons for their Banning

CFC due to their high vapour pressure vaporise very quickly and go directly into the atmosphere. Since 1974 scientists have established that CFC deplete the ozone layer in the stratosphere. Only the discovery of the "ozone hole" over the Antarctic in the mid 1980's and subsequent research brought this problem to the attention of the public and politicians. Today, it is accepted that ozone depletion represents a global environmental problem.

The ozone layer protects the biosphere against the strong U.V.-radiation of the sun. A reduction of the layer damages human beings, animals and plants (skin cancer and genetic damage). Chlorine, produced as a result of CFC decomposition is mainly responsible for ozone depletion.

The atoms of chlorine set free one of the three atoms of oxygen from the ozone molecule, which recombine to an oxygen molecule. Every chlorine atom reacts many times before entering into a stable combination.

Another negative effect of CFC is the warming up of the atmosphere. Two figures: The "ozone depletion potential" (ODP) and the "halocarbon global warming potential" (HGWP) give an indication of the magnitude of the negative effects of different hydrocarbons.

The ODP is defined as the ratio relative to the calculated depletion for CFC 11 taken as a reference.

In a parallel manner HGWP is a relative figure taking the warming effect of CFC 11 as a reference. 1GWHP depends also on the atmospheric lifetime.

### 2. Effects of VOC

An organic compound means any compound containing at least carbon and hydrogen or in which hydrogen is replaced or completed by halogens, oxygen, sulphur or nitrogen.

A VOC is an organic compound that is volatile under the particular conditions of use and which is used alone or in combination with other agents.

Main representatives of the VOC in connection with cleaning processes are tetrachloroethylene, tetrachloromethane, and trichloroethylene.

VOC evaporate and, as a result of photochemical reactions, cause atmospheric oxygen to be converted into tropospheric ozone under certain climatic conditions.

For VOC a factor POCP (Photochemical Ozone Creating Potential) relative to that of ethylene is defined.

Some VOC as 1, 1, 1- trichloroethane are also ozone depleting.

Some values for the ODP, HGWP and POCP are listed on page 30.

ODP values are taken from the EC-Directive, HGWP and the lifetimes from literature.

Substance	Formula	ODP	HGWP	POCP	Lifetime years
CFC11	$\text{CCl}_3\text{F}$	1.0	1.04		60
CFC 113	$\text{CCl}_2\text{-CClF}_2$	0.8	1.4		90
HCFC 141B	$\text{CH}_3\text{-CCl}_2\text{F}$	0.11	0.1		7.8
HFC 134a	$\text{CH}_2\text{F-CF}_3$	0	0.025-0.291		15.5
Trichloroethylene	$\text{C}_2\text{HCl}_3$	0	0	7	
Tetrachloroethylene	$\text{C}_2\text{Cl}_4$	0	0	0.5	
Dichloromethane	$\text{CH}_2\text{Cl}_2$	0	0	0.9	

## Appendix B: Cleaning equipment working with aqueous agents and solvents

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4	Cleaning Equipment for Organic Cleaners
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### 1 Considerations in the Equipment Selection Process

The selection of the cleaning process and equipment is based on:

- cleaning agent to be used
- surface properties of the parts to be cleaned
- shape and geometry of the material
- the types and amounts of contaminants

The degree of automation, the size and capacity of the equipment is determined from

- size of the material to be cleaned
- required cleaning rate

All equipment must, together with the used chemicals, fulfil as a minimum the legislation for health, safety and environment.

The choice of equipment has to be based on the efficiency of cleaning versus cost.

The efficiency is controlled by utilising typical samples, written procedures and requested criteria for cleanliness.

### 2 Health, Safety and Environmental Aspects

Aqueous cleaning agents may be highly alkaline and corrosive and special care has to be taken to avoid contact with eyes and skin, which might cause permanent damage. Inhalation is the primary health concern for cleaning equipment-using solvents, but the degreasing of the skin must also be considered.

The water jet from a high pressure-cleaning machine can cut like a knife and can also throw loose particles around. Protective gloves, goggles and clothes must be used.

The emission to water is the main environmental question for consideration in the use of machines for aqueous cleaning. The emission to the atmosphere is the main impact from solvents.

The disposal of waste must follow local regulations. The disposal methods used for water-based processes will depend on type of contaminants, concentrations, pH etc. The residue from a solvent-based process is obtained as a highly concentrated waste, which has to be disposed of according to regulations in force.

All electrical equipment including that of the venting system must have the correct flame/explosion proof ratings as defined by national regulations when flammable solvents are used.

For environmental aspects see also IGC document TN 107/03 "Guidelines for Environmental Management".

### **3 Washing Machines for Aqueous Agents**

#### **3.1 Mobile High Pressure Cleaning Equipment**



**Fig. 1. High pressure cleaning equipment**

Working principle:

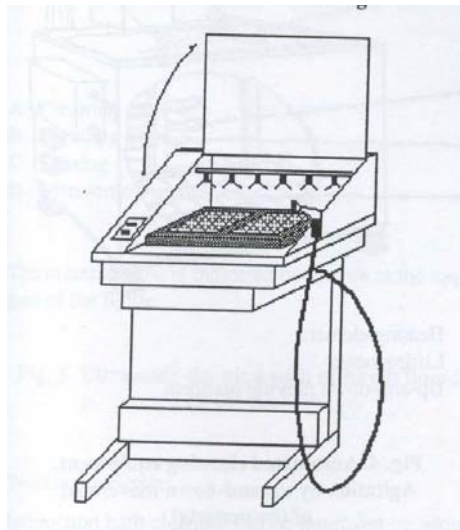
The main parts are a high-pressure water pump and a high-pressure hose with nozzles. The cleaning agent is applied at low pressure and the rinsing is then performed by high-pressure water with very high velocity. For more difficult contaminants, hot water is required. In some kind of equipment it is possible to inject the dissolved cleaner together with the high-pressure water.

Applications:

A high pressure cleaning apparatus is suitable for cleaning of big pieces of equipment with easily accessible surfaces like outer surfaces of pumps and compressors. Protect- water sensitive parts of the equipment from high-pressure liquid that may penetrate into internal parts.

This kind of equipment can also be used for internal cleaning of pipes. (See Appendix D "Detergent cleaning of pipes with high pressure cleaning -equipment").

### 3.2 Wash Cabins for Manual Cleaning



**Fig. 2. Wash cabin for manual cleaning**

Working principle:

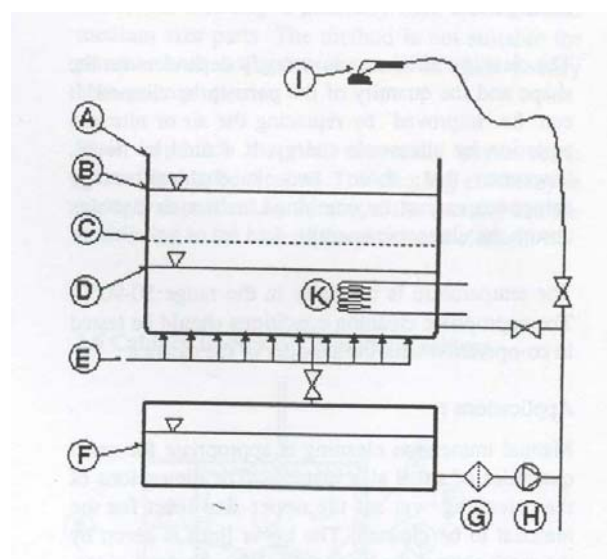
The equipment can be open or covered by a lid, with or without venting. The pieces to be cleaned are placed on a grid or a perforated plate. The cleaner can be applied manually by brushing and/or by spraying at low pressure. The cleaner is then recirculated via a particle filter. Some types of apparatus are equipped with automatic spraying with fixed nozzles or a rotating spraying arm. When the cleaner has become too contaminated for use, the tank is emptied and cleaned.

The cleaning agent is normally used at ambient temperature. After rinsing with clean water, drying is done by dripping off followed by blowing with oil-free, dry, clean air or nitrogen.

Applications:

This type of equipment is suited mainly for intermittent cleaning of small details for instance in correction with repair and maintenance work.

### 3.3 Manual Immersion Cleaning Equipment



**Fig. 3. Immersion cleaning equipment with means for brushing and spraying.**

- A) Cleaning vat
- B) Liquid level in "immersion mode"
- C) Perforated plate
- D) Liquid level in "spraying/brushing mode"
- E) Air inlet for agitation
- F) Cleaner reservoir
- G) Filter
- H) Pump
- I) Spraying/brushing device for manual cleaning
- K) Heating element

Working principle:

The parts to be cleaned are placed on the perforated plate in the vat. By pumping cleaning liquid from the cleaner tank, the level in the vat rises so that all parts are immersed in the liquid. The liquid might be heated and agitated e.g. by air or nitrogen injection.

After a while, the parts should be moved around in the vat for improved accessibility.

When the contaminants have been dissolved, the liquid level is lowered below the perforated plate. If necessary, remaining contaminants can be removed by brushing and spraying.

The rinsing is normally performed in a separate rinsing bath.

The cleaning efficiency is strongly dependent on the shape and the quantity of the parts to be cleaned. It can be improved by replacing the air or nitrogen agitation by ultrasonic energy. It should be noted, however, that these two mechanical energy categories cannot be combined, as the air bubbles absorb the ultrasonic energy.

The temperature is normally in the range 50-90°C. The appropriate cleaning conditions should be tested in co-operation with the supplier of the cleaner.

Applications:

Manual immersion cleaning is appropriate for small quantities of small size material. The dimensions of the cleaning vat set the upper size limit for the material to be cleaned. The lower limit is given by the mesh size of the basket. Details with dead space, narrow and deep cavities can successfully be cleaned in this type of equipment.

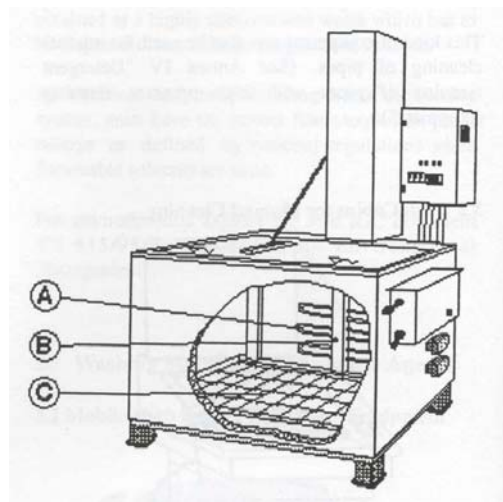
### 3.4 Automatic Immersion Cleaning Machines with Agitation

Working principle:

The material to be cleaned is immersed into a bath containing heated cleaning agent. Agitation can be accomplished by thermal agitation, impellers, liquid nozzles or air injection. The agitation can also be carried out by rotating, lifting and sinking the material in the bath.

In high capacity plants, the material is continuously transported e.g. in conveyors from the cleaning bath to one or several rinsing baths. A drying stage may also be integrated in the equipment. For small and medium capacities, all stages may be integrated in the same machine.

Fig 4 shows a machine in which the agitation is accomplished by up-and-down movements of the parts in the cleaning liquid.



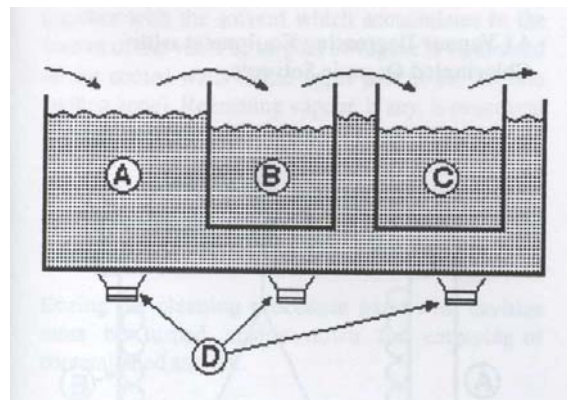
- A) Heating element
- B) Lifting beam
- C) Up-and-down moving platform

**Fig. 4. Automated cleaning equipment. Agitation by up-and-down movement of the material.**

#### Applications

Automatic immersion cleaning in integrated machines is appropriate for small and medium size material. Provided efficient agitation can be arranged, details with narrow and deep cavities can successfully be cleaned in this type of equipment.

#### 3.5 Immersion Cleaning Equipment with Ultrasonic Energy



- A) Cleaning stage 1
- B) Cleaning stage 2
- C) Rinsing
- D) Ultrasonic transmitters

The material flow is indicated by arrows in the upper part of the figure.

**Fig. 5. Ultrasonic cleaning with different liquids in one bath.**

#### Working principle:

Immersion bath cleaning can be improved by adding ultrasonic energy. The equipment can be manual as well as automatic.

An alternating current generates ultrasonic vibrations which give rise to cavitation bubbles in the liquid. When they implode, mechanical cleaning energy in the form of small jets is created.

Cleaning of small parts can be performed in mesh baskets or in containers with holes, which are immersed into the main ultrasonic bath. Some of the ultrasonic energy is then lost however. Containers and baskets should not be made from soft material as they absorb much of the ultrasonic energy. The cleaning time in ultrasonic baths is considerably shorter compared to ordinary immersion cleaning.

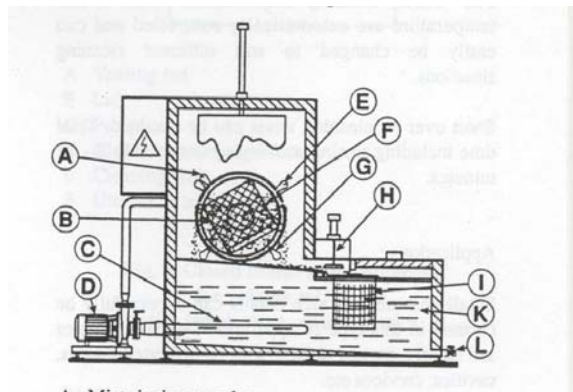
The liquid in the bath must be free from gas bubbles these absorb the ultrasonic energy. A pump design should be used which does not give rise to gas bubbles in the liquid. For the same reason, air agitation cannot be combined with ultrasonic energy. The rinsing and drying might be done in the same apparatus ( Fig 5 ), but is normally performed in separate stages.

Applications:

Ultrasonic cleaning is generally used for small and medium size parts. The method is not suitable for porous and soft parts because of their energy absorption properties.

It is important that the ultrasonic waves reach all surfaces to be cleaned. The cleaning efficiency is strongly dependent on the shape, the quantity and the positioning in the bath of the parts to be cleaned.

### 3.6 Cabinet Jet/Spray Cleaning Machines



- A) Mist rinsing nozzles
- B) Rotating material to be cleaned
- C) Heating element
- D) Pumps (one for cleaning and one for rinsing)
- E) Tubes spraying with nozzles
- F) Cleaning chamber
- G) Jet flushing nozzles
- H) Valve
- I) Filter
- J) Cleaner/ Rinsing reservoirs (located behind each other)
- K) Drainage valve

**Fig. 6. Cabinet jet/spray cleaning machine.**

Working principle:

This new type of cabinet machine utilises a combination of immersion, flushing and spraying. Immersion is obtained by increasing the liquid level in the cleaning chamber. During this phase, a highly turbulent flow is created in the cleaning liquid by jet flushing nozzles. The details to be cleaned are placed in a basket or drum which can be rotated or rocked in the cleaning liquid simultaneously with flushing / spraying from the nozzles. The powerful agitation and mechanical impact gives a very good cleaning effect, which also may be utilised for decreasing the concentration of chemicals and the cleaning temperature.

The cleaning stage is followed by rinsing with water from a separate tank in the same unit. It can also be equipped with facilities for drying, oil separation and chemical dosage.

The whole cleaning sequence as well as the temperature are automatically controlled and can easily be changed to suit different cleaning situations.

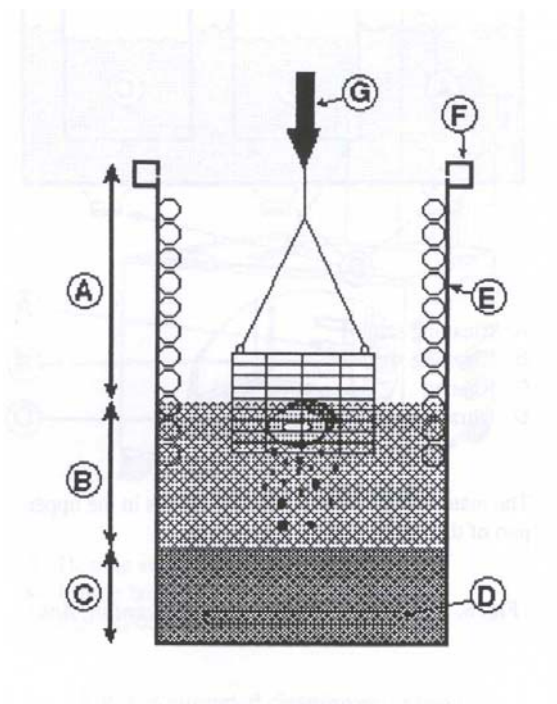
Short over all cleaning times can be obtained. Total time including rinsing and drying is typically 8 - 12 minutes.

Applications:

Small and medium size details can successfully be cleaned in this type of apparatus. Typical examples are closely packed details with complicated shapes, cavities, crevices etc.

#### 4 Cleaning Equipment for Organic Cleaners

##### 4.1 Vapour Degreasing Equipment with Chlorinated Organic Solvents



- A) Cooling zone
- B) Vapour zone
- C) Liquid solvent
- D) Heating element
- E) Cooling tubes
- F) Vapour evacuation
- G) Lifting device

**Fig. 7. Traditional vapour degreasing equipment (In some countries only closed installations are allowed)**

Working principle:

The chlorinated solvent is heated to its boiling point in the bottom of the vat with the vapour rising upwards. The parts to be cleaned are immersed in the vapour phase in the lower part of the vat (the vapour zone) where they are suspended during the cleaning process. The solvent condenses on the surface of the parts, dissolving oil and grease, which drain off together with the solvent, which accumulates in the bottom of the vat. The surplus of vapour is condensed on the cooled walls in the

upper part of the vat (the cooling zone). Remaining vapour, if any, is evacuated through slots just below the upper edge of the vat.

This self-distilling principle means that clean solvent condenses on the parts even if the solvent in the sump is heavily contaminated.

During the cleaning procedure parts with cavities must be turned upside down for emptying of contaminated solvent.

The cleaning stops when the temperature of the parts reaches the boiling point of the solvent. If this happens before the parts are adequately cleaned, the parts have to be cooled down with cold solvent before the degreasing process can proceed.

Vapour degreasing can be combined with ultra sonic immersion and spraying, usually in separate areas of the machine.

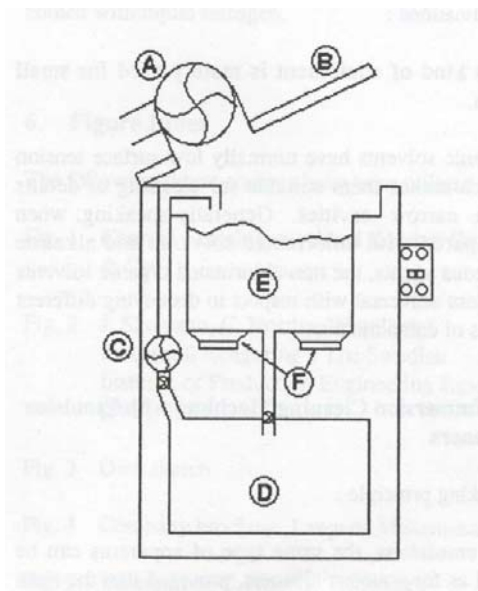
Regular checks of the solvent in the sump according to the solvent manufacturers recommendations is necessary to ensure that the condition of the solvent being used is always suitable for safe and efficient use.

Special precautions are necessary including the requirement of entry permits into a confined space, the use of suitable breathing apparatus and the wearing of protective clothing.

Applications:

Vapour degreasing can be applied to all kind of parts if the vapour can reach and condense on all surfaces. Problems may occur for small and thin details which are quickly heated up to the boiling temperature.

#### 4.2 Immersion Cleaning Machines with Non-Chlorinated Volatile Organic Solvents



- A) Venting fan
- B) Lid
- C) Pump
- D) Closed cleaner reservoir
- E) Cleaning bath
- F) Ultrasonic transmitters

**Fig. 8. Closed immersion equipment for volatile solvents with supplementary ultrasonic.**

### Working principle

Equipment using volatile organic solvents are totally closed apparatus keeping the operator separated from contact with the solvent. The parts to be cleaned are immersed into the solvent, which is agitated by stirring or by ultrasonic energy. Spraying is also used.

The parts are normally loaded into the empty vat, the lid of the cleaning machine closed, and the solvent pumped in from a separate closed solvent storage tank. After the cleaning cycle is completed, the solvent is pumped away from the vat. The solvent vapours are evacuated by the venting system before the lid or door is opened and the details are removed.

Examples of solvent used are alcohol and acetone.

### Applications:

This kind of equipment is mainly used for small parts.

Organic solvents have normally low surface tension, which makes them suitable for cleaning of details with narrow cavities. Generally speaking, when compared with chlorinated solvents and alkaline aqueous agents, the non-chlorinated organic solvents are less universal with respect to dissolving different types of contaminants.

## 4.3 Immersion Cleaning Machines with Emulsion Cleaners

### Working principle:

For emulsions, the same type of apparatus can be used as for aqueous cleaners, provided that the risk with the applied solvent is considered.

When water free solvents with added emulsifiers are used, the cleaning has to be considered as solvent cleaning. The equipment design and requirements are then the same as for pure solvents.

### Applications:

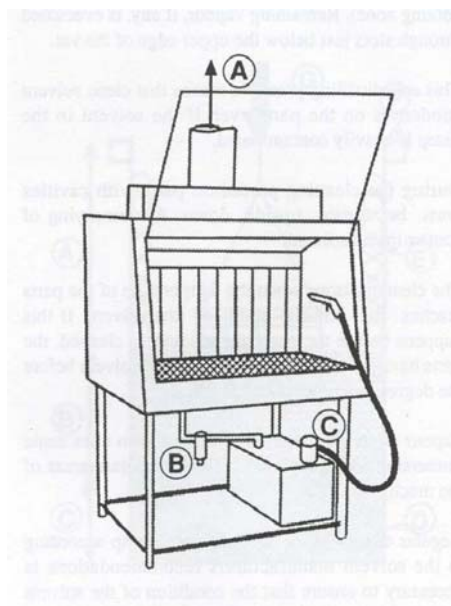
Emulsion cleaners can be used for the same type of parts as for aqueous systems. The penetration into narrow cavities is better than for pure aqueous systems.

It is important that the water rinsing that follows the cleaning stage removes all high boiling point residues that may remain on the parts.

## 4.4 Wash Cabins for Manual Cleaning with Low Volatile Solvents

### Working principle

The same type of wash cabins as for aqueous systems can be used with low volatile solvents, provided they are equipped with venting systems and the solvent properties are considered. Often these kind of cabins are designed for use with aqueous as well as low volatility solvents.



- A) Venting
- B) Filter
- C) Pump

**Fig. 9. Wash cabin for manual cleaning.**

#### Applications:

This type of equipment is suitable mainly for intermittent cleaning of small parts where all surfaces can be directly inspected. Examples are cleaning in connection with repair and maintenance work.

Components cleaned by this method must be carefully checked for a residue from the cleaning solvent.

### 5 Auxiliary Equipment

Beside the equipment necessary for the cleaning process, there are also different kinds of equipment, which decrease the amount of waste and may save a lot of money.

#### 5.1 Particle Removal from Process Liquids

The removal of particles from re-circulating process liquids is essential in order to minimise the wear on mechanical parts like pumps and valves and to avoid clogging the spray nozzles.

The particles can be removed as sediment from the tanks or by different types of filters e.g. wire screen filters in the piping system.

#### 5.2 Oil Separation

The lifetime and efficiency of cleaners and rinsing water depends on the maintenance of the original composition of these liquids. By recirculating purified process liquids, considerable savings can be obtained in chemicals, water and waste dumping costs.

The oil in the spent cleaner or rinsing water can exist Fig, free oil or as an emulsion.

Free oil can be separated by means of gravity, by filtration or by adsorption. Examples of equipment used are oil skimmer, lamella separator, coalescence filter, oil adsorbing bag filter, and propylene filter.

Emulsified oil can be removed by ultra filtration, chemical decomposition, micro filtration, adsorption or biological treatment. Evaporators and vapour compression apparatus are also used.

### 5.3 Vapour Emission Control

The control of vapour emission from solvent based cleaning equipment is essential from an environmental as well as safety viewpoint.

In carbon or molecular sieve adsorption equipment, the vapour in the vent air is trapped in adsorption beds. When the beds are saturated, they are regenerated by steam or hot gas.

Cryogenic condensation can also be applied, alone or in combination with carbon filter. The solvent is condensed from the vent air in a heat exchanger cooled with liquid nitrogen.

## 6 Figure Index

The following figure sources have been utilised

Fig. 1 Company catalogue. Alfred Kärcher GmbH & Co.

Fig. 2 J. Skogsmo, C. Norrby, "Handbok i Industriell Rengöring", The Swedish Institute of Production Engineering Research (IVF), 1994.

Fig. 3 Own sketch.

Fig. 4 Company brochure. Langeds Mekaniska AB.

Fig. 5 J. Skogsmo, C. Norrby, "Handbok i Industriell Rengöring", The Swedish Institute of Production Engineering Research (IVF), 1994. Company brochure. Viverk Försäljnings AB.

Fig. 7 J. Skogsmo, C. Norrby, "Handbok i Industriell Rengöring", The Swedish Institute of Production Engineering Research (IVF), 1994.

Fig. 8 J. Skogsmo, C. Norrby, "Handbok i Industriell Rengöring", The Swedish Institute of Production Engineering Research (IVF), 1994.

Fig. 9 J. Skogsmo, C. Norrby, "Handbok i Industriell Rengöring", The Swedish Institute of Production Engineering Research (IVF), 1994.

## Appendix C: Cleaning of carbon steel pipeline

### 1 General

This annex deals with the distribution network from the supply stations of oxygen plants to the distribution stations at customers works.

It does not deal with other parts of a complete network such as piping in the oxygen plant, distribution piping in the workshop, or at the points of use.

### 2 Specific Design Requirements

Pipeline shall be designed such that it can if necessary be cleaned by a 'pigging' operation.

Consideration must be given to minimum bend radii and changes involving reductions in pipe diameter.

Low level points where liquids or debris can accumulate should be avoided.

Where this is not possible low point drains should be provided to facilitate drainage and visual examination.

Drain points should be permanently blanked after pressure testing and/or cleaning has been completed.

### 3 Materials and Components

- 1 Pipe material - Carbon Steel
- 2 Pipe fittings - Carbon Steel
- 3 Proprietary – Pig launcher and catcher.

### 4 Alternative A

Involving use of components pre-cleaned to oxygen clean standard.

#### 4.1 Initial Cleaning Method

All pipe lengths and pipe fittings to be purchased with internal surfaces blast cleaned. (surface finish Sa 21h to ISO 9501-1).

#### 4.2 Initial Inspection

Inspection by direct visual method as per Para. 4.2.1 and 4.2.2 is normally sufficient. Pipe lengths and pipe fittings to be sealed with caps and waterproof masking tape immediately after cleaning. Desiccant bags should be placed inside each pipe and fitting as per Para. 6 on pages 27 & 28.

#### 4.3 Fabrication

Exercise care in order to maintain cleanliness throughout subsequent fabrication and testing.

Welds should be inspected as work progresses and any weld repairs executed. Pipe ends must be sealed at all times except when fabrication is actually taking place. A gas purge should be maintained during welding and between fabricating operations.

Nitrogen gas may be substituted for argon back purge between welding. Paper dams to limit use of argon back purge should not be used. Trenches must be adequately drained of water.

Attach pig launcher and catcher to ends of pipeline.

#### 4.4 Post Fabrication Cleaning

Gauging pig made from oxygen compatible materials should be blown through line using nitrogen gas or oil free air as the propellant.

Any debris removed from line should be examined to ensure that it is not contaminated by substances which are incompatible with oxygen.

#### 4.5 Pressure Testing

If permitted by responsible authority, this should be a pneumatic strength test.

Adequate safety precautions should be taken when carrying out this test.

This would normally include having completed 100% radiographic examinations of all circumferential welds.

If it is not permissible to carry out a pneumatic strength test, clean oil free water to which a deoxygenating agent and passivation agent has been added, should be used for a hydraulic strength test.

Repeat pigging operation to remove water.

Open drain points to remove any remaining water.

Purge pipeline with dry nitrogen or clean air (minimum dew point  $-40^{\circ}\text{C}$ ).

#### 4.6 Post Test and Cleanliness Inspection

Check dew point of purge gas.

Check internals of pipeline for oxygen cleanliness by visual examination of ends and through drain points.

Re-institute nitrogen purge and maintain until pipeline is ready for commissioning.

### 5 Remedial Action

Should visual examination show contamination, remedial action should be as per Para. 6.5 of this annex.

### 6 Alternative B

Involving use of components that have had components chemically cleaned to remove mill scale etc.

#### 6.1 Initial Cleaning Method

Chemical cleaning by alkaline and/or acid pickling following by rinsing with clean water and passivation. Additional mechanical cleaning may be required.

#### 6.2 Initial Inspection

Visual inspection to ensure that internals are free from mill scale, heavy rust, paint, varnish and hydrocarbons etc.

#### 6.3 Fabrication

After fabrication attach pig launcher and catcher to ends of pipeline. Complete post weld examination as required by Design Code.

#### 6.4 Pressure Testing

Carry out hydraulic strength test using clean oil free water to which a de-oxygenating agent and passivation agent has been added.

Pig line to remove water using a pig made from oxygen compatible material; with nitrogen gas or oil free air as the propellant.

Open drain points, drain remaining water then close.

Pneumatic test line if required by code.

#### 6.5 Post Test Cleaning

Pass through pipeline two pigs with an approved solvent (such as Methylene Chloride) trapped between them.

Pigs should be of the abradable type of a material that is both oxygen and solvent compatible.

Pigs to be propelled by nitrogen gas or oil free air.

Examine solvent for presence of contaminants per Para. 4.2.4 on pages 24 and 25.

If contamination is present, repeat test- with fresh solvent until cleanliness is judged to meet the acceptance criteria in accordance with Para. 4.2:4 and 4.4 on pages 24, 25 and 26.

Remove pig launcher and catcher.

Purge pipeline with dry nitrogen (minimum dew point -40 °C).

#### 6.6 Post Test and Cleanliness Inspection

As Alternative A, Paragraph 4.6.

### 7 Remedial Action

Should after repeated pigging with fresh solvent, the solvent is still found to be contaminated, possible remedial action is chemical cleaning in situ using alkaline and/or acid solutions followed by passivation and flushing with water and then post test cleaning as Alternative B, Paragraph 6.5 above.

Another possible remedial solution is shot blasting in situ using proprietary equipment.

### 8 Additional Information

Further information on the design, installation, fabrication and testing of a Carbon Steel Pipeline can be found in the IGC Document 13/82 entitled 'The Transport and Distribution of Oxygen by Pipeline'.

Information concerning solvents in the IGC Document 13/82 should however not be used as it is obsolete as a result of the Montreal Protocol.

## **Appendix D: Detergent cleaning of pipes with high pressure cleaning equipment**

### **1 Parts to be Cleaned**

Bent and straight pipes.

Welded, brazed and soldered manifolds.

Minimum internal pipe diameter:

- Around 13 mm (Depending on hose and nozzle diameter).

Maximum internal pipe diameter:

- Around 300 mm (Depending on nozzle design and pressure.)

Maximum bending angle:

- 90°

Minimum bending radius

- 100-150 mm (Depending on pipe diameter, hose flexibility etc.)

Material

- Stainless steel pipes/manifolds. Some with brass connections soldered to the pipes.

Maximum pipe length

- Up to 30 m. Depending on hose length, number of pipe bends, pipe diameter.

### **2 Processing of the Parts before Detergent Cleaning**

Stainless steel pipes exposed to different kind of treatment like bending, soldering and welding followed by pickling and pressure testing with potable water.

### **3 Cleaning Equipment**

A high pressure cleaning equipment with high pressure flexible hose and pipe cleaning nozzles. (See fig 1).

The backward directed jets from the nozzle pull the hose into and through the pipe while flushing the internal surface.

Hot potable water or apparatus equipped with water heating facilities may be required for heavy duty cleaning.

### **4 Cleaning**

The cleaning agent is applied at low pressure and ambient temperature via the hose and the nozzle. In this sequence, the hose must be transported through the pipe manually.

The cleaner foam must wet the whole internal surface.

The cleaner foam is left 5-10 minutes inside the pipe for dirt dissolving action. During this time period, the pipe should be rotated/turned around 2-3 times to ensure good cleaner accessibility.

### **5 Rinsing**

The internal surface of the pipe is rinsed by warm high pressure clean water from the pipe cleaning nozzle. The hose is slowly transported back and forth so that all internal surfaces are in contact with the high pressure jet. Rinsing is continued until the pH value of the used rinsing water is the same as that of the fresh incoming water. (pH value may be tested by litmus reactive paper).

The hose is normally self-transported forward through the pipe, but in case of numerous bends, pipe restrictions and other obstacles, the hose may need some manual help for transportation.

In some cases, the cleaning/rinsing procedure may be repeated from other pipe openings.

## **6 Drying**

Prior to commencing drying, all free standing water must be emptied from the pipe. Special care must be taken where dead ends and other pockets exist.

The drying is effected by blowing through hot nitrogen or clean oil free air. It is important to check that all parts are reached by the hot gas.

## **7 Cleaning Agent**

Water based alkaline detergent. A foaming agent is preferred due to its ability to stick to vertical surfaces. Several proprietary cleaners are available on the market.

Cleaning conditions like detergent concentration, rinsing water temperature etc. should be determined through tests and should comply with the detergent supplier's recommendations.

Typical conditions are

- Cleaner concentration 20-50 %
- pH, diluted solution 12
- Rinsing temperature 50 °C
- 

## **8 Safety**

Protective clothing, gloves, apron, eye and face protection are recommended to be worn by the operator whilst carrying out high pressure cleaning.

Skin contact with detergent chemicals should be avoided as serious skin disorder can result.

The manufacturer's product information and material safety data sheets must be carefully studied and followed.

## **9 Inspection Method - Direct visual inspection with White Light.**

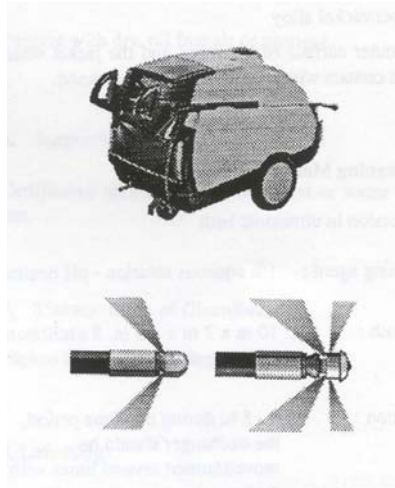
Wipe test all pipe openings. A cloth fastened to a lick may be used for wipe test of deeper internal surfaces.

## **10 Conservation of cleanliness**

All pipe ends are sealed with plastic plugs.

## **11 Labelling**

Cleaned for oxygen service  
Keep free from oil and grease  
Inspection date/stamp



**Fig 1. High pressure cleaning equipment and two types of pipe cleaning nozzles.**

## **Appendix E: Cleaning of a tubular heat exchanger in an ultrasonic bath using an aqueous cleaning agent**

### **1 Material / Size**

Approx. 900 x 4300 mm

Copper/nickel alloy

The outer surface of the pipes and the jacket which are in contact with oxygen have to be cleaned.

### **2 Cleaning Method**

Immersion in ultrasonic bath.

Cleaning agent : 1 % aqueous solution - pH neutral

US-bath: 10 m x 2 m x 1.5 m. 8 oscillators, stainless steel

Duration: 4 - 5 h; during this time period, the exchanger should be moved/turned several times with a crane.

Temperature: 50 - 60°C

### **3 Rinsing**

Immersion in a second stainless steel bath with deionised water, 1.5 h at 40 - 50°C. Exchanger moved/turned 2 times.

### **4 Drying**

In a tent with clean air 4 - 5 h at 30 - 40°C

### **5 Inspection Method**

Wipe test and visual inspection with UV light.

### **6 Conservation of Cleanliness**

Packed in a clean polyethylene bag (thickness > 0.15 mm) and sealed

### **7 Labelling**

The bag is provided in and outside with a label. "Cleaned for oxygen service. Keep free from oil and grease. Inspection date/stamp".

## **Appendix F: Cleaning of parts in an ultrasonic bath using an aqueous cleaning agent**

### **1. Size of Parts**

Generally up to 500 mm, depending on the capacity/dimensions of the bath.

### **2. Material of Parts**

Steel, copper alloys. Cleaning of outer/inner surfaces.

### **3. Cleaning Method**

Immersion in ultrasonic bath with/without precleaning.

#### **3.1 Cleaning Agent**

20 % agent in water concentrate pH = 10

#### **3.2 Precleaning**

In bath with or without ultrasonics.

Duration : 15 min.

Temperature : approx 60°C.

Solution circulated by pump or slight manual movement of the basket containing the parts.

#### **3.3 Cleaning**

In ultrasonic bath (same conditions as in precleaning bath).

If oil spots are visible on the solution surface, this solution has to be renewed as well as the solution in The precleaning bath. Used solution has to be disposed.

### **4. Rinsing**

Immersion in bath/spraying as an alternative; with at approx. 40 °C.

### **5. Drying**

Purging with dry, oil free air or nitrogen.

### **6. Inspection Method:**

Certificated spot checks by wipe test or water break test.

### **7. Conservation of cleanliness**

Packed in clean plastic bag and sealed.

### **8. Labelling**

With a label "Cleaned for oxygen service. Keep free from oil and grease. Inspection date/stamp";

## Appendix G: Cleaning of a vessel with aqueous agent and solvent

### 1. Material /Size

Stainless steel or aluminium alloy

Dimensions up to Ø 3000 x 4000 mm

### 2. Pre-cleaning

Prior to welding, vessel shell and ends are pre-cleaned separately with an aqueous agent (phosphate free with low alkaline content) at a temperature of approximately 50°C, then flushed with demineralised water for approximately 60 minutes.

### 3. Inspection before Welding

A wipe test is carried out after the drying operation. If there is any indication of grease or oil, the pre-cleaning operation is to be repeated.

### 4. Cleaning

After final welding a tube is installed in order to carry out a complete jet spray cleaning using solvent 141 b (see figure and chapter 3, table 1).

### 5. Inspection after Cleaning

Quantitative control by solvent extraction (weight of the residue after vaporisation)

### 6. Conservation of Cleanliness

At all stages of assembly, components are protected against contamination. After inspection the tank is sealed with degreased flanges and slightly pressurised with nitrogen.

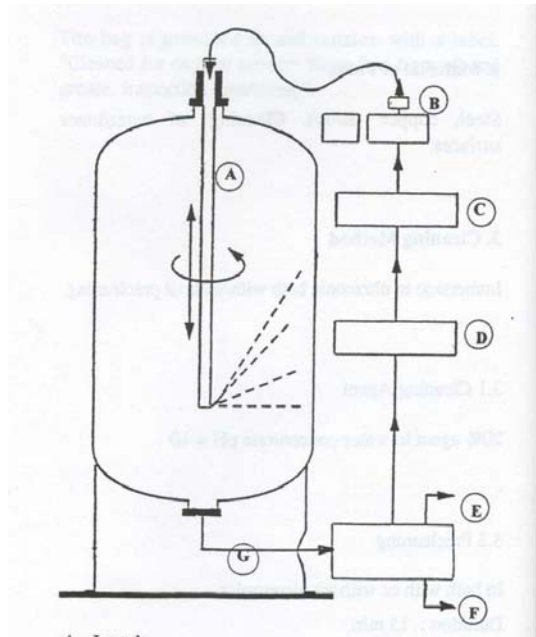
### 7. Labelling

"CLEANED FOR OXYGEN SERVICE

Pressurised with N2 .....bar

Keep free from oil and grease

Inspection date/stamp"



- A) Jet tube
- B) Injection
- C) Condensation
- D) Purification
- E) Control
- F) Disposal
- G) Solvent recycling

## Appendix H: Cleaning of a vessel with aqueous agent

### 1 Material/Size

Stainless steel; volume of the vessel from 1000 to 40000 litres.

### 2 Cleaning Method

#### 2.1 Mechanical Cleaning

Before final welding interior surfaces shall be mechanically cleaned (grinding, brushing, grit blasting).

#### 2.2 Dedusting

Internal surfaces shall be swept and vacuumed.

#### 2.3 Degreasing

After welding and hydrostatic testing, a jet spray cleaning operation is carried out using phosphate free detergent (50°C, duration 1 h) followed by flushing with clean water at 50-60°C.

### 3 Rinsing

Spraying with de-mineralised water.

### 4 Drying

Purging with dry, oil free, clean air or nitrogen.

### 5 Inspection

Direct visual inspection with White Light and Ultraviolet Light.

### 6 Conservation of Cleanliness

At all stages of assembly, components are protected against contamination. After inspection the vessel is sealed with degreased caps and slightly pressurised with nitrogen.

### 7 Labelling

"CLEANED FOR OXYGEN SERVICE"  
Pressurised with N2 ..... bar

Keep free from oil and grease

Inspection date/stamp"

## **Appendix I: Cleaning of a transportable vacuum insulated vessel**

### **1. Material / Size**

Inner vessel and outer jacket: Stainless steel.

Volume: Up to 500 litres.

### **2. Initial Cleaning Method**

Shell and vessel ends are purchased precleaned and packed to oxygen standard. Root weld should be by y TIG welding in order to ensure smooth root weld profile and avoid welding debris.

### **3. Cleaning Method**

Before final welding and isolation of the inner vessel the surfaces are manually cleaned with acetone using a dry cloth.

### **4. Pressure Test**

Carried out with nitrogen or oil free air. Testing is carried out in a special container or chamber capable of withstanding a potential explosion of the vessel.

### **5. Inspection Method**

Wipe test and UV light inspection of parts before final welding.

### **6. Conservation of Cleanliness**

At all stages parts are protected against contamination.  
Openings are closed with caps.

### **7. Labelling**

"CLEANED FOR OXYGEN SERVICE"  
To be kept free from oil and grease

Inspection date/stamp"

## **Appendix J: Remedial cleaning on a construction site**

Facilities and equipment readily available for recleaning on or near a construction site are frequently limited.

When deciding on the method that can be used to carry out remedial cleaning, consideration shall be given to the design, construction, size and materials of construction.

While reference should be made to the original cleaning method, it should be appreciated by all parties, that duplication of any given cleaning method at another location, is often difficult.

The original equipment manufacturer may be consulted on the proposed recleaning method.

Facilities that can usually be provided on site are:

- Portable high pressure steam cleaning
- Pickling baths
- Solvent or detergent baths.

Small localised cleaning can be carried out by wiping with Tint free cloth and a solvent.

Care shall be taken that no hazardous residuals remain.

Care must be taken that the values of oil, grease and other contaminants are below the given figures acc. to this document.

The cleaning procedure and the test-results should be recorded.