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Group 2

RECOMMENDATION ON EQUIPMENT FOR HANDLING OF ANHYDROUS HYDROGEN FLUORIDE (AHF) AND HYDROFLUORIC ACID SOLUTIONS (HF)

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PREFACE

Anhydrous hydrogen fluoride/ hydrofluoric acid (AHF/HF) is essential in the chemical industry and there is a need for HF to be produced, transported, stored and used.

The AHF/HF industry has a very good safety record; nevertheless, the European AHF/HF producers, acting within Eurofluor (previously CTEF) have drawn up this document to promote continuous improvement in the standards of safety associated with AHF/HF handling.

This Recommendation is based on the various measures taken by member companies of Eurofluor.

Each company, based on its individual decision-making process, may decide to apply the present recommendation partly or in full.

It is in no way intended to be a substitute for various national or international regulations, which must be respected in an integral manner.

It results from the understanding and many years of experience of AHF/HF producers in their respective countries at the date of issue of this particular document.

Established in good faith, this recommendation should not be used as a standard or a comprehensive specification, but rather as a guide, which should, in each particular case, be adapted and utilised in consultation with an AHF/HF manufacturer, supplier or user, or other expert in the field.

It has been assumed in the preparation of this publication that the user will ensure that the contents are relevant to the application selected and are correctly applied by appropriately qualified and experienced people for whose guidance it has been prepared.

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The contents of this recommendation are based on the most authoritative information available at the time of writing and on good engineering practice, but it is essential to take account of appropriate subsequent technical developments or legislative changes. It is the intent of Eurofluor that this guideline be periodically reviewed and updated to reflect developments in industry practices and evolution of technology. Users of this guideline are urged to use the most recent edition of it, and to consult with an AHF/HF manufacturer before implementing it in detail.

AHF is an acronym for anhydrous hydrogen fluoride.

HF is an acronym for hydrofluoric acid solutions of any concentration below 100%.

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1. OBJECTIVE

This recommendation aims to introduce equipment inside a plant which handles anhydrous HF (AHF) and/or HF solutions at temperatures from -10 °C to +50 °C. It addresses mainly mechanical aspects. For more information on choice of material according to operating conditions (especially temperatures and HF concentrations) and corrosion rates, refer to our "Recommendation on materials of construction for Anhydrous Hydrogen Fluoride and Hydrofluoric Acid solutions" available from the publication webpage of www.eurofluor.org.

Various considerations and basic principles of design and construction are outlined and should be observed when designing this type of system.

Experience has shown that each installation requires individual consideration. Accordingly, this document must only be taken as a guide. It is not a comprehensive code and it should in no way interfere with competent engineering judgement and/or local legislation. It is recommended however that any proposed deviation be first discussed with an experienced expert (producer / user).

All recommendations for AHF within this document are also suitable for HF solutions above 85% concentration.

All materials of construction, which are mentioned in this document should be double-checked and there should be a search for more information on materials, in our "Recommendation on materials of construction for Anhydrous Hydrogen Fluoride and Hydrofluoric Acid solutions" available from the publication webpage of www.eurofluor.org.

2. AHF / HF SAFETY

AHF / HF is a highly toxic and corrosive substance which can provoke acute and chronic poisoning.

ANYONE WHO KNOWS OR EVEN SUSPECTS THAT HE HAS COME IN CONTACT WITH AHF / HF SHOULD IMMEDIATELY SEEK FIRST AID, AND BE REFERRED TO A DOCTOR EVEN THOUGH THE INJURY SEEMS SLIGHT.

More information, see First Aid and Medical Treatment documents on the publication webpage of Eurofluor website (www.eurofluor.org).

2.1 Special safety facilities

The following facilities should be strategically positioned readily accessible and easily identifiable in all areas where hydrofluoric acid or solutions of hydrofluoric acid are to be found.

2.1.1 Safety showers

Each shower should be capable of delivering approximately 100 litres of warm clean water per minute for 15 minutes. Deluge initiation should be simple and rapid. The water supply pipe work should be protected from frost (e.g. by insulation and/or trace heating). The temperature of the stored water must not exceed 20 °C in order to avoid any risk of legionella. The water should be verified regularly, e.g. during the periodic safety check.

2.1.2 Eye wash fountains

Like safety showers above, but each with a rated capacity of 10 to 15 litres per minute for at least 10 minutes.

2.1.3 Eye wash bottles

As an alternative to eye wash fountains sealed bottles containing a saline solution can be contained in suitable cabinets. Each cabinet should contain about one litre of solution and be regularly checked to ensure their contents are up to standard.

2.1.4 Calcium gluconate gel

Quantities of calcium gluconate gel should be located on the plant in the emergency cabinet and must be available for everybody.

Care must be taken that the gel is not expired for application and must be stored according to the supplier requirements.

3. PUMPS FOR ANHYDROUS HF (AHF)

3.1 Objective

This is a recommendation for canned and magnetic pumps used to handle liquid AHF. Canned pumps are preferred because of their secondary containment. Double diaphragm pumps are also used.

3.2 Field of application

For continuous or semi continuous processes pumps are a means of transferring AHF from low pressure to high-pressure systems.

The fact that the pump is the point where large amounts of energy are added to the system should be seen together with the physical, chemical and toxic properties of AHF.

3.2.1 Safety principles

The basic design and safety principles below apply to all handling of liquid AHF.

3.2.1.1 Air / inert gas quality

Air or inert gas, which is used as purge gas should be absolutely oil free and dried to a dew point of -40 °C or better (at atmospheric pressure). Non-lubricated air compressors are preferred.

3.2.1.2 Chemical reactions

Any material has to be proved to be no reactive at the expected temperature conditions (for more information on materials, see our “Recommendation on materials of construction for Anhydrous Hydrogen Fluoride and Hydrofluoric Acid solutions” available from Eurofluor publication webpage www.eurofluor.org).

3.2.1.3 Liquid velocity

The velocity must be limited. For example, with AHF, liquid velocity in carbon steel pipe work should be limited to a maximum of 1.5 m/s at room temperature (below 30°C) to maintain the layer formed that prevents corrosion. For clarifications, refer to our “Recommendation on materials of construction for Anhydrous Hydrogen Fluoride and Hydrofluoric Acid solutions” available from the publication webpage of www.eurofluor.org.

3.2.1.4 Installation and precommissioning

Before putting the equipment into service make a thorough and complete check of:

- the mechanical parts
- the safety systems
- the pipe work, including checks on proper steel quality, cleanliness, gaskets and bolts

- the dryness of the complete installation by purging at all dead ends and checking the purge gas for moisture. For proper procedures refer to section 5.11.2 Drying.
- gas tightness by testing with dry air or nitrogen
- that pipe-ends or terminal valves are fitted with blank flanges
- then introduction of a small amount of AHF
- and verify the integrity again.

Note: do not use water for the leak testing.

3.3 Design principles for canned pumps

Pump casing and motor casing are combined in one enclosure.

Pump impeller and motor rotor are one rotating assembly inside a common enclosure. This eliminates the need for a shaft seal, and consequently eliminates seal leaks to the outside.

A side stream of the pumped process liquid is taken at the discharge, and is used internally for the lubrication and cooling of the motor and pump bearings, and for the cooling of the motor windings (enclosed by the cans).

Within a specified operating range (flow rate Q-min to Q-max) the pump design provides for hydraulic balancing of all rotating parts (axially and radially). Therefore, devices have to be incorporated to ensure pump operation to be at all times in between Q-min and Q-max. This may be obtained by installing a Q-max limiting orifice at the pump discharge, and a minimum flow line with a Q-min orifice, returning to the suction side. A maximum intensity switch can also be considered depending on the specific situation.

The lubrication flow should be maintained above according pump spec value or damage to the bearings will inevitably occur.

3.3.1 Design pressure, temperature

The static design pressure should at least be equal to the highest pressure expected during abnormal operation as can be deducted from the safety study (PHA, Process Hazard Analysis) including effect of overheating. The stator housing and the connections box should be capable of withstanding the full design pressure with the can in a failed condition.

3.3.2 Materials of construction

Material used in any part of the pump should be resistant to AHF at the expected temperature conditions.

3.3.2.1 Casing, can and rotating parts

Ductile materials should be used, e.g. stainless steel. Brittle materials, e.g. normal cast iron, should not be used. Parts of the pump which in event of malfunction may come into contact with one another should wherever possible be made of dissimilar materials to minimize friction heat.

3.3.2.2 Bearings

If brittle materials are used, construction of the bearing should be in such a way, that only compressive forces can occur and the material should be supported by its housing over its entire length.

3.3.2.3 Motor

For the electrical part of the motor silicone rubber should not be used. Resin for impregnation of copper windings should not be readily reactive with AHF.

3.3.3 Details of construction

3.3.3.1 Clearance between casing and impeller

Parts of the pump which in the event of malfunction may run in contact with one another should be designed in such a way that liquid AHF cannot be trapped. Liquid AHF between casing and front or back of the impeller should be free to escape in event of temperature rise as a result of loss of axial control.

3.3.3.2 Parts inside of the pump

The supplier should be able to demonstrate that all internal components are adequately secured, to prevent them coming loose during operation of the pump.

3.3.3.3 Can / evacuation

To avoid dimensional changes with changes in operating temperature it is recommended that the can is designed to withstand full vacuum. An equivalent solution may be acceptable depending on clearing procedure.

3.3.3.4 Screwed / flanged connections

Flanged connections should be used. Screwed connections are not accepted.

3.3.3.5 Maximum flow device

In case of maloperation such as starting against an empty delivery line with valves fully open, a maximum flow device, e.g. an orifice, may be used to provide security against running a pump into a state of cavitations.

3.3.3.6 Minimum flow device - dry running

In case of mal-operation such as starting with a closed suction valve or discharge valve and/or excessive temperature, a dry running protection should be used (e.g. low consumed power, level switch which detects loss of suction).

3.3.4 Lubricant / cooling stream

Maintaining the flow of lubricant is essential to ensure acceptable service life of pump bearings and axial balance on the rotor. Manufacturers of any AHF pump should be asked to state the lubricant flow under all operating conditions so that a proper control system can be devised during system design. This should ensure the pump cannot be run with dry bearings. See section 3.6 Instrumentation.

Note that AHF should be maintained under pressure - temperature conditions avoiding vaporisation.

3.3.4.1 Forced circulation

The stream of lubricant has to flow in such a way that cooling of the pump and lubrication of bearings are provided by forced circulation.

3.3.4.2 Internal/external lubricant flow

In some pumps the lubricant flows is totally inside the casing. Since there is no access for direct measurement or control of this flow the pumps may be equipped with a temperature alarm. For pumps with external lubricant flow, flow measurement and/or control should be installed. An axial position monitoring should be considered, see section 3.6 Instrumentation.

3.3.4.3 Strainer in lubricant flow

In case of an external lubricant flow is required a strainer may be necessary to remove coarse particles. Strainers which are too fine have led to loss of lubricant flow. With the lubricant flow totally inside the pump internal strainers should be avoided.

3.3.5 Axial thrust balancing

The pump manufacturer should present the best possible means for balancing the axial thrust. As already stated maintaining the flow of lubricant ensures axial balance of the rotor during operation of pump, see next section.

3.3.6 Self-draining and venting

Pumps should be able to be drained and vented without any opening and dismantling.

3.3.7 Barrel

The pump can be protected by a barrel that will limit the consequences of a leak. The pressure inside the barrel should be monitored on a regular basis to detect any leak.

3.4 Design principles for membrane pumps

3.4.1 Double diaphragm pump description

Double diaphragm pump can be used for transferring AHF (particle free) from low pressure to high pressure systems, up to five m^3/h flow. To prevent external leakage, a double membrane conception is applied: a piston pushes a primary membrane that is in contact with a confined barrier fluid, compatible with AHF – this fluid transmits that pressure to AHF through a secondary process membrane. Possible leakage of process membrane is detected by AHF presence in the barrier fluid.

Flowrate is maintained by adjusting piston stroke and/or piston speed.

Simplex (one head) or multiple heads (duplex, triplex) can be used

3.4.2 Double diaphragm pump design principles

To limit premature process membrane failure due to fatigue, designed flowrate should be double of the required flowrate. It allows to keep a low piston stroke.

Design of the suction line is critical to limit the risks of cavitation and membrane degradation:

- Available NPSH (Net Positive Suction Head) must be significantly higher than required NPSH
- Line diameter must be adapted to handle instantaneous maximum flowrate (typically three times the design flowrate for simple head)
- Limit any flow restrictions

3.4.3 Pump materials and installation

Material of process membrane has to be chosen so to provide:

- Chemical resistance to AHF – Typical materials are PTFE or PFA with very low permeation to AHF upon time, but poor mechanical properties
- Mechanical resistance – Typical plastic materials have poor chemical resistance to AHF
- Combined materials (sandwich membrane) can offer the best compromise

Membrane handling (poor manufacturing process, degradation during storage or during installation) is critical to avoid premature weak points, where fatigue would occur more easily

Check valves ensure that the whole chamber volume is used for the whole compression and that no internal recycle occurs, leading to cavitation:

- Material of ball and seat are compatible with AHF
- Avoid initial default of the seat with good machining of the surface
- No water / moisture in the pump before operation

3.4.4 Pump safety principles

Potential failure of the process membrane can be detected by:

- Continuous resistivity measurement of the intermediate fluid
- Pressure measurement in between the two layers of the sandwich membrane
- Continuous pH measurement of the intermediate fluid

If any failure, pump has to be stopped and isolated.

Intermediate fluid must be compatible with AHF to avoid any chemical reaction in case of membrane leakage

Design of the discharge pipe must be compatible with the maximum pressure that can be delivered by the pump

3.5 System design

3.5.1 General

It is important that the system is designed to meet the requirements of the pump. Entrained gases or liberated dissolved gases should be removed upstream of the pump and the required NPSH for the pump should be provided according to the temperature and pressure of the fluid. (Side channels pumps could also be used).

CAVITATION MUST BE AVOIDED BECAUSE OF THE RISK OF EXCESS TEMPERATURE.

If for some reason the pump operates against a closed delivery line, a minimum flow must be maintained via a bypass, cooled if necessary to avoid the risk of excess temperature.

The pump should be installed preferably in a bund and be accessible from at least two opposite directions. The pump should not be used as a fixed point in the layout of piping, which should be arranged so that mechanical stresses are not transmitted to the pump. However, the use of bellows is not recommended.

3.5.2 Pipe work construction details

- Flanges, bolts & gaskets
- Valves
- Protection against thermal expansion
- Thermal insulation

Follow Section 5 Plant piping systems for AHF.

3.5.3 Suction filter

A suction filter is generally not recommended. When it is essential to provide such a filter care should be taken to avoid trapped liquid and plugging. In addition in order to prevent cavitations due to the build-up of pressure drop across a filter it is necessary to provide a low flow device or a differential pressure alarm, see 3.6 Instrumentation.

3.5.4 Bypass line, bypass cooler

As stated in 3.5 System design, suitable bypass may be necessary to maintain a minimum flow across the pump according to the pump type. Bypass flow-control will allow a pump to run during a shutdown on a consumer plant. Cooling of the bypass flow can be either by flashing to the storage tank or by use of a cooler.

3.5.5 Purging / venting lines

For degassing, venting and purging operations lines should be provided for any part of the piping system which can be isolated by valves and for the pump itself.

3.6 Instrumentation

3.6.1 General

Specification and maintenance of instrumentation must meet the special needs for liquid AHF. All instrument components should be free of water, oil, aluminium, silicone oil & silicone rubber, etc. For transmitter filling only perfluorinated fluids should be used. Sintered polymers as cartridges in filters should not be used.

The following instrumentation is recommended:

3.6.2 Pressure, differential pressure

Minimum: Local pressure indicators immediately before and after pump or pressure difference between suction and discharge.

Optional: Pressure monitoring in control room.

3.6.3 Temperature of AHF

Optional: Local temperature indication in suction line.

3.6.4 Temperature of lubricant flow

Minimum: For pumps with internal flow a temperature indicator, with alarm in control room, from the expected hot spot within lubricant circuit.

Shutdown of the pump by high temperature of lubricant.

3.6.5 Main stream flow

Optional: Flow indication and/or recording may serve for better overall understanding of the system and be a basis for controlling a bypass and to avoid dry running.

3.6.6 Bypass control

Minimum: Bypass control will enable a minimum flow to be maintained, see 3.5 System design.

3.6.7 External lubricant control / monitoring (when adopted)

Minimum: Minimum flow switch in external lubricant stream, to stop the pump, with alarm in control room.

Optional: Flow measurement and/or control of external lubricant stream. High flow alarm if rotor balance problems will result when the flow is too high.

3.6.8 Electrical

Minimum: A low power trip should be installed to avoid dry run.

Optional: Amperage indicator.

Monitoring in the control room should be installed.

Overheating protection e.g. high temperature switch should be installed.

3.6.9 Axial position monitoring

Optional: For internal lubricant circuit without double casing, axial position monitoring with alarms in the control room.

Switches on both extreme positions to stop the pump should be installed. A recorder in control room should be installed.

Care must be taken in case of ingress of AHF into the stator windings to avoid further contact in the electric parts.

3.6.10 Vibration monitoring

Optional: Vibration monitoring is recommended for pumps. For existing pumps without vibration monitoring frequent preventive inspection is recommended until vibration monitoring is installed.

Vibration monitoring with appropriate electronic filtering of signals has been used to assess the mechanical performance of pumps.

This enables malfunction to be detected at an early stage.

3.6.11 Remote shutdown

All pumps should be capable of being shut down remotely. It is also advisable to shut off the pump discharge line by a remotely operated valve.

3.6.12 AHF gas monitoring

Consider provision of AHF detecting device near the pump with alarm in control room and remote shut off valves to isolate the pump in case of leak.

3.7 Operation

3.7.1 Inspection

Make sure that the pump and all the system including valves, dead ends and instruments are dry, free from solid matter (grit blasting, residues from welding, etc.) and tested for tightness.

3.7.2 Commissioning

Strictly follow the pump manufacturer's guidelines, including the checking of the direction of the rotation. AHF pumps operating below ambient temperature and on standby duty may be kept filled and cold by using a small bleed stream. However, it should be noted that this may cause build-up of deposits inside the pump depending on the quality of AHF. If a pump which has not been filled with liquid and has to be taken into service this may be done as follows:

- Feed liquid AHF through the pump for sufficient time to cool the whole pump and motor down to the temperature of the AHF storage
- Start the pump and adjust flow outlet valve

- Check rotor direction of rotation (if possible)

The pump should never operate without flow. If it occurs, heat which develops in the pump and is normally transported away with the cooling / lubricating flow would cause a rapid and dangerous temperature increase.

Successful start-up is shown by the correct increase of pressure across the pump (and by sufficient coolant / lubricating flow).

3.7.3 Shutdown

Depending on what is to be done with the pump it may be kept on standby with or without a bleed stream. For taking a pump out of service it should be vented and purged until it is totally free of AHF. Heating with steam will help in that respect. All open ends should be blanked immediately. Care should be taken to prevent ingress of moisture.

3.8 Maintenance (repair and preventive maintenance)

Preventative maintenance should include vibration monitoring and check for AHF leakage at the terminal box.

For any maintenance (on-site or off-site), suitable PPE (Personal Protective Equipment) must be worn at all stages of the complete repair as prescribed by operations.

Pumps should be totally decontaminated e.g. by using ammonia solutions, sodium carbonate or caustic solutions, before any repair work is undertaken.

3.8.1 Repair workshop

Repair work on canned pumps should be done by skilled and experienced personnel in a properly equipped workshop because AHF could still be trapped in pockets inside the pump. People shall wear appropriate PPE.

3.8.2 Dismantling and inspection - decontamination

Before dismantling, see 3.7 Operation. Partial dismantling may be necessary to ensure thorough decontamination.

3.8.3 Inspection of electrical parts

Rotor and stator should be checked by electrical maintenance personnel.

Resistance: check the resistance between windings and the resistance between windings and casing.

3.8.4 Re-use of parts

O-rings and gaskets shall not be re-used.

3.8.5 Cleaning and drying

Clean re-used parts with water, blow water away with clean dry gas and place parts in a drying oven. New parts should be thoroughly degreased and dried as above.

3.8.6 Assembly

Strictly follow manufacturer's instructions and the clearances specified.

3.8.7 Dynamic balancing

Consider balancing each rotating part and the whole assembly dynamically.

3.8.8 Drying of pump assembly

After the pump has been assembled drying should be repeated following a written procedure according to section 5.11.2 Drying.

3.8.9 Leak testing

The assembled pump should be leak tested according to 5.8.2.3 Leak testing.

3.8.10 Pump storage in warehouse

Following drying, see 3.9 Supply requirements / documentation, all nozzles should be blanked (don't forget gaskets). For long-term storage a slight overpressure of dry nitrogen or air should be kept inside the pump or equivalent measures to avoid moisture ingress.

3.8.11 Log filing

All repairs details and measurements should be kept in a technical file which shall be unique for each pump.

3.9 Supply requirements / documentation

3.9.1 Quality assurance

The manufacturer should be able to demonstrate to the purchaser that he has an acceptable procedure for quality assurance (see ISO norm for example, certificates, CE-marking).

3.9.2 Receiving inspection

User should validate upon receiving that materials meet requirements.

3.9.3 Operating instructions

The manufacturer of a pump should supply detailed operating instructions.

3.9.4 Drawings

Sectional drawings with part numbers, nomenclature and material specification for each component of the pump must be supplied.

3.9.5 Clearances / tolerances

Data sheets showing each part of the pump complete with clearances / tolerances should be supplied in the maintenance book / manual.

3.9.6 Performance data

Performance data should be provided based on a test run carried out in accordance with the following procedure.

3.9.7 Test run procedure

Water is an ideal substance for test running before shipping as it is very similar to liquid AHF in density, viscosity and specific heat. It is recommended that test runs are carried out using this substance.

The following data should be provided:

- Differential head versus flow rate over the whole range Q-max - Q-min.
- Electrical power consumption over the whole range.
- Required NPSH as a function of flow rate.
- Axial force as a function of flow rate.*
- Axial force as a function of displacement of the rotor.*
- Quantity of the lubricant flow as a function of flow rate.*
- Temperature rise of the lubricant flow as a function of flow rate.*
- Lubricant flow supply pressure as a function of flow rate.*

* As far as this applies to the detailed design of the pump.

3.9.8 Cleaning and drying

After the test run the pump should be dismantled, and inspected then cleaned and dried according to section 5.11.2 Drying.

3.9.9 Manufacturer's recommendations

The manufacturer should supply details of any specific design / maintenance / monitoring requirements for the pump.

3.9.10 Shipping protection

For shipping the pump should be kept under an atmosphere of dry nitrogen, with the cable gland sealed.

3.9.11 Shipping packaging

If necessary, the pump should be fitted with an anti-rotation pin and be protected. Proper packaging should be supplied to avoid mechanical damage during transport (special care for bearings).

3.10 Specific technical details for magnetic drive pump

Magnetic pumps should be avoided for AHF-service because of absence of a secondary containment. Canned pumps are preferred.

In addition to the information of canned pumps the following apply for magnetic drive pumps.

3.10.1 Design principle

The pump impeller drive shaft is entrained by the coupling of magnets located on this shaft and on an outside motor's drive shaft. The pump impeller drive shaft is located inside a can, and the power is transmitted through this can. As for canned pump a part of the energy is converted into Eddy currents which heat the can itself, cooling system evacuates this heat.

3.10.2 Design pressure

Special care must be taken to prevent and to confine any leak in case of can failure, as the motor drive shaft housing may not be able to resist AHF or pressure.

3.10.3 Materials of construction

Can will be less affected by Eddy currents if it is built with Hastelloy (compared to stainless steel).

3.10.4 Motor

Electric motor is actually separated from the pump itself and cannot be in contact with AHF (specific recommendations for canned pump do not apply).

3.10.5 Clearance between casing and impeller

This clearance will affect the efficiency of the magnetic coupling. However, a minimum clearance shall be provided in order to allow a good cooling circulation.

3.10.6 Additional instrumentation

High temperature of the containment and minimum flow can be:

Minimum: indicator and alarm.

Optional: shut down of pump.

3.10.7 Electrical

As overall efficiency could be low, power consumption indicator is recommended instead of amperage indication.

3.10.8 Assembly / dismantling

Care must be taken when assembling and dismantling since magnets can cause mechanical shocks to fingers and bearings and also can attract magnetic particles. Pumps must be repaired in clean and non-magnetic area.

4. PUMPS FOR 70% AND LOWER HF SOLUTIONS

4.1 Objective

The objective is to recommend proper pump selection for service in HF solutions of less than 70 %.

4.2 Field of application

Pump is made of plastic material of construction, or internally lined (e.g. PTFE) steel construction for proper corrosion protection.

Remark: Due to the limitation of the magnetic coupling with respect to torque transmission, large pump sizes are not available in this duty.

4.3 Design principles

4.3.1 Leak free enclosure

The leak-free design is based on absence of pump shaft seal. The pump shaft and the motor shaft are not mechanically but magnetically coupled by means of two magnets, usually of concentric cylindrical shape. The inner magnet is fixed to pump shaft and is separated by a static can from the outer magnet which is fixed to motor shaft. The pump casing, including the closed can, is therefore a hermetically closed leak-free enclosure.

For small flows, as an alternative diaphragm pump can be used with compatible materials, inside a box equipped with leak detection vented to a scrubber. For detailed requirements, contact Eurofluor.

4.3.2 Pump bearings

The internal pump shaft bearings are immersed in the pumped process liquid and are of same type as used in canned pumps (e.g. silicon carbide). A side stream is taken via a filter from the pumped process liquid and acts as lubricant and coolant for the pump bearings and also coupling can.

4.3.3 Hydraulic balance of rotor

It is imperative that residual axial and residual radial load on pump rotor, and hence on internal pump bearings, is kept minimal to avoid premature bearing wear. Therefore, the hydraulic forces on the rotor have to be in balance. This imposes restrictions on the operating range of the pump.

4.4 Safety

4.4.1 Dry run protection

It is imperative that under all circumstances lubrication and cooling of internal bearings and of coupling are guaranteed. Therefore, a dry run protection has to be installed on the suction side of the pump, which trips the pump automatically in case of lack of suction or cavitations.

Remark: In case a suction strainer is used, the dry run protection has to be installed downstream the strainer.

4.4.2 Temperature protection

Temperature switches can be installed to monitor temperature of coupling can and/or bearings.

4.4.3 Rotor displacement protection

Internal friction switches (based on temperature rise) can be installed to monitor axial and/or radial displacement of rotor, e.g. in case of excessive bearing wear.

4.5 System design

In general, pump should be installed and operated in accordance with manufacturer's specifications. In addition to safety requirements under 4.4 Safety, the following is required.

4.5.1 Maximum and minimum flow requirements

For proper operation of pump with respect to internal cooling and hydraulic balance, an operating range with a minimum and a maximum flow has to be imposed. This can be obtained by installing a Q-max orifice at the pump discharge to exclude flow rates above maximum allowed flow rate, and by installing a Q-min orifice in a minimum flow line which tees off upstream the discharge valve and returns to suction side to guarantee at all times, including blocked-in discharge, that a given minimum flow is circulating.

Based on circumstances the minimum flow might require cooling to prevent overheating and hence cavitations of the system. It should be noted however that, as opposed to canned pumps used in AHF service, where heat of motor cooling is absorbed in pumped process liquid, the amount of heat to be removed in magnetic coupled pumps is much less as motor is of standard design with air cooling.

4.5.2 Piping and instrumentation

Pumps should have flanged connections. Local pressure indicator should be installed at pump discharge depending on the pressure resistance of the pipe.

4.5.3 Pump casing

The minimum design pressure rating of the pump should be PN 16 (or more if required by higher operating pressure). Metallic components should be made of ductile materials, i.e. standard cast iron is excluded. Pump casing should preferably have drain point.

4.6 Maintenance

Proper precautions have to be taken to avoid presence of HF when taking out and disassembling the pump. When inspecting the internals of the pump, special attention has to be given to the following:

- Can should not show any trace of friction or other damage. Damaged cans have to be replaced.
- Bearing clearance (axial and radial) should not exceed manufacturer’s tolerances. Bearings have to be replaced when tolerances are exceeded.
- Condition of liner or of plastic casing has to be carefully checked for damage or deformation.
- Gaskets and O-rings should be replaced and not re-used.
- After re-assembling, the pump should be pneumatically leak tested in accordance with pump operating pressure to ensure perfect tightness of the pump.
- When re-installing the pump, it has to be checked that Q-max and Q-min orifices are in place, and filters, if applicable, are cleaned. In order to avoid confusion between the orifice plates, they have to be clearly marked.

5. PLANT PIPING SYSTEMS FOR AHF

5.1 Introduction

This chapter aims at defining the criteria which should be complied with in piping systems, which handle ANHYDROUS HF (AHF) inside a plant which produces or consumes AHF. For HF solutions, see our "Recommendation on materials of construction for Anhydrous Hydrogen Fluoride and Hydrofluoric Acid solutions" available from Eurofluor publication webpage www.eurofluor.org.

5.2 Scope and definitions

5.2.1 General

This guide covers plant piping systems and local on-site inter-plant pipe work. It excludes cross country "pipelines", instrument piping downstream of a process isolation valve and loading / unloading installations.

The term piping systems is used to cover all elements, which form part of the construction of a line between two pieces of equipment, and is an assembly of fabricated pipe, fittings, valves and supports, etc.

5.2.2 Conditions of operation

Piping systems that handle liquid AHF should be capable of resisting all static or dynamic forces for the temperature ranges stated below and under test conditions described in section 5.8 Pressure testing.

If one is seeking to handle liquid or gas at a temperature below -10 °C, one should seek a quality of steel which gives the same quality of impact resistance at the temperatures required as that quoted in section 5.4.2 Mechanical properties. Take into account that corrosion rate will increase significantly above 50°C. For corrosion rate and choice of material, refer to our "Recommendation on materials of construction for Anhydrous Hydrogen Fluoride and Hydrofluoric Acid solutions" available from the publication webpage of www.eurofluor.org.

5.3 Design

If no other requirements exist, the ANSI B31.3 piping code may be used.

5.3.1 Standards and specifications

Before design work is commenced, it is recommended that pipeline specification sheets are produced. These should clearly state the standards to be used for pipe, fittings, flanges, valves, bolts, gaskets, etc. All piping materials should comply with national and regional standards and specifications.

5.3.2 Design temperature

The design temperature for the piping system should be the most severe temperature (highest and lowest) expected in service.

In all cases the metal temperature should be taken as the fluid temperature and should include an adequate margin to cover uncertainties in temperature predictions. Be careful with low temperature (below -10°C).

5.3.3 Design pressure

The design pressure of the piping system should be at least able to meet the most severe condition of internal or external pressure to which the system can be subjected during service.

The most severe condition is that which results in the greatest required component thickness and the highest component rating.

In selecting the design pressure, account should be taken of the vapour pressure of AHF at the chosen maximum design temperature and to any pressure surge conditions which may arise as a result of abnormal circumstances, e.g. pump start-up, etc.

In the absence of specific design pressure conditions, bearing in mind the potential risk involved with AHF, it is recommended that as a general rule the maximum allowable operating pressure should be set with a margin of 20% below the design pressure of the weakest component in the piping system. The use of components with a design pressure below 25 barg can only be accepted where the service conditions are fully known and documented. This must in no way downgrade the safety of the system and must be carried out in conjunction with an experienced AHF expert (producer / user).

In the case of external pressure, consideration should be given to the situation where a vacuum may be applied in order to dry out the system, see 5.11.2 Drying.

5.3.4 Flanges

As a general rule in Europe where use of PN standards in the norm, the minimum acceptable flange rating should be PN 25 or higher as necessary to take account of design conditions. ANSI standards can also be used usually with a minimum flange rating of class 150. Though in systems where the circumstances are fully documented and their use does not downgrade safety, PN 16 flanges are acceptable.

In all cases the flange rating should be suitable for the design conditions of the system. If, however, specific design conditions are not known, bearing in mind the potential risks involved with AHF, as a general rule the maximum allowable operating pressure should be set with a margin of 20 % below the design pressure.

For gaskets, see section 6.

For all pipe sizes, it is recommended that weld neck flanges be used.

5.3.5 Piping sizing, and material thickness allowance

5.3.5.1 Corrosion, erosion allowance

An allowance should be made for the potential risk of internal or external corrosion or erosion in AHF pipe work.

In the case of carbon steel pipe, a minimum of 1.5 mm should be added to the calculated thickness required for the pressure design condition.

5.3.5.2 Velocities

To minimise erosion within the piping system, design velocities should be:

- A maximum of 1.5 m/s for liquids at room temperature.
- A maximum of 10 m/s for gases without liquid entrainment. Take care with entrainment of liquid AHF droplets in vapour that greatly accelerate the corrosion of carbon steel and other metals.

5.3.5.3 Pipe

The minimum pipe size in the process plant area should be l"NS (25 mm) and for long inter-plant lines you have to consider to protect or reinforce the pipeline. In all cases it is recommended to limit the upper size of liquid AHF lines to 6" NS (150 mm).

5.3.5.4 Branches

The minimum branch size for AHF lines should be 1" NS (25 mm) up to the primary isolation valve.

Small branches should be reinforced using proprietary fittings such as butt welding tees, weld lets, etc. and their stand-out restricted to a minimum. (i.e. 1" and 1½") set on construction is not recommended because of vulnerability to mechanical damage.

For all branches 2" NS and over, the need for pressure reinforcement should be checked using a recognised code. Where this has not been carried out weld tees or weld lets or similar forms or reinforcement should be used.

5.3.5.5 Pipe wall thickness for liquid AHF lines

Various standards are available which provide guidance to the designer for calculating the mechanical strength and wall thickness of pipe. However, where calculations have not been carried out the following minimum wall thickness is provided for guidance. These thicknesses take into account mechanical robustness and commercial availability.

1"	NS 4,5 mm
1 ½"	NS 5,0 mm

2"	NS 5,54 mm
3"	NS 5,4 mm
4"	NS 6,0 mm
6"	NS 7,1 mm

5.3.6 Applied loads and stresses

The following factors should be taken into account when considering the loads and stresses applied to piping systems:

- Internal and external pressure
- Thermal expansion and contraction
- Weight of pipe and associated equipment
- Weight of operating medium (density of liquid AHF is approx. 1 000 kg/m^3)
- Weight of insulation
- Reaction from lines discharging to lower pressure systems
- Forces arising from two phase flow
- The effect of "water hammer"
- Wind loads
- Seismic effects
- Snow and ice (particularly where there is the possibility of ice forming on non-lagged lines).

The basis for any calculation on expansion and contraction in the system should be the maximum and minimum temperatures arising from:

- Normal operation
- Start-up and shut-down, including abnormal conditions arising from maintenance and commissioning activities
- Predictable transient conditions, e.g. de-icing and cases where the piping system can operate alternatively above and below ambient.

5.3.7 Pipe work flexibility

Liquid AHF pipe work should be designed to accommodate all thermal movement by the use of bends, loops or offsets - it is strongly advised not to use bellows.

It is recommended that at the design stage a judgment is made of all liquid AHF lines, based on experience of similar systems, to decide if a formal flexibility analysis is required. If any doubt exists regarding the ability of the system to cater adequately for thermal expansion and contraction, a more formal examination, using one of the following methods, should be carried out paying particular attention to connections to sensitive equipment e.g. storage tanks on load cells, vaporisers and pumps:

- Experienced judgement by trained personnel
- An acceptable simplified method of calculation which has been demonstrated to be adequate for the type of configuration being considered

- A comprehensive analysis carried out in accordance with a national design code and possibly involving a proven computer programme.

5.3.8 Supporting

Pipe supports should be designed with ample strength to carry the loads caused by the factors listed in 0

Applied loads and stresses.

When supporting pipe work operating at sub-zero temperatures, the pipe should be insulated from its support by a load bearing material such as preformed Calcium silicate.

To protect against serious damage being done due to corrosion the preferred arrangement is a guide or sliding type of support resting on structural steelwork. Where sliding supports are not, however, a practicable solution, then consideration should be given to the use of hanger assemblies which are safeguarded by physical stops placed a short distance beneath the pipe to limit its movement should the hanger fail. For AHF systems which operate at ambient and above, local corrosion between pipe and support or steelwork can be a problem. Although the potential for corrosion cannot be totally eliminated in the design of such supports, attention to details such as protection of the pipe with a suitable tape wrap before attaching a clamp-on type support will improve the situation (clamp-on supports are recommended for all sub-zero duties). The importance of formalised routine inspection and maintenance is also stressed.

Liquid AHF pipe work should not be supported by or from other pipe work, see section 5.5 Pipe work layout and arrangement.

5.3.9 "Water Hammer"

When the velocity of a fluid in a line is changed, pressure waves are set up due to the change in momentum. When the amplitude of these pressure waves becomes critical this situation is generally known as a "Water Hammer". The usual sources for initiating this condition are: too rapid closure of a valve or tripping of a pump. Where it is anticipated, therefore, that "Water Hammer" is a potential problem, measures should be taken to extend the time it takes to stop flow in the line. This may be achieved for example, by controlling the rate of valve closure or by the installation of a buffer vessel.

5.3.10 Protection from excess pressure

Liquid AHF has a high coefficient of thermal expansion; consequently, any warming of liquid AHF, e.g. by the sun, if trapped between closed valves, will lead to a build-up of pressure which can rapidly become excessive. Pipe work should therefore be designed and isolation procedures devised which avoid the possibility of trapping AHF / HF between two points of isolation.

Inevitably there will be times when this is not possible and in such cases provision must be made to allow for thermal expansion of any trapped liquid.

To keep a piping system simple, it is preferable to avoid the need for relief system. However, relief is required unless the combination of the probability of a leak and its consequences are acceptable.

Factors affecting the probability include:

- Operating procedures – higher probability where valves are controlled by different operators;
- The pressure of the trapped liquid AHF will rise quite fast with temperature increase due to thermal expansion of the liquid AHF.

Factors affecting the consequences include:

- Location – system running close to highly populated areas or hazardous areas or equipment having a high risk factor;
- Volume of trapped liquid. This will be influenced by factors such as location etc.

When assessing the consequences of a leak it should be assumed that the entire inventory of the system between the closed valves will be discharged in the event of a failure.

For example:

Rupture discs, relief valves or a combination of these which discharge to a vessel or collection system.

An expansion chamber separated from the AHF flow by a bursting disc.

5.4 Materials

5.4.1 General

All materials and components used in liquid AHF piping systems should at least comply with national codes and standards.

All components used in piping systems should be fabricated in materials which are compatible with anhydrous liquid HF (AHF).

For more information on materials, see our “Recommendation on materials of construction for Anhydrous Hydrogen Fluoride and Hydrofluoric Acid solutions” available from Eurofluor publication webpage www.eurofluor.org.

5.4.2 Mechanical properties

The mechanical properties of materials used for construction should be satisfactory for use at a low temperature according to option A or B and for the stresses encountered in designing for the factors listed in section 0

Applied loads and stresses.

Moreover, certain national codes can require impact tests to be carried out to determine the impact strength of materials to be used in construction as well all other parts and fittings undergoing static or dynamic loads.

5.4.3 Pipe

Generally, carbon steel seamless pipe is recommended for AHF and is normally welded, fine grain steel. Where welded pipe is used it should be obtained from approved suppliers.

5.4.3.1 Flanges

The materials of the flanges should be suitable for the selected temperature conditions and be compatible with the associated pipe and fittings. Metal shall be checked for lamination and inclusions defects and suitable hardness.

5.4.3.2 Bolting

Bolts and nuts should conform to a recognised national standard and be suitable for the selected temperature. Very good experience is obtained with B7M (carbon steel with special heat treatment) or equivalent.

5.4.3.3 Gaskets

See Section 6 Gaskets.

5.4.3.4 Jointing compounds

Jointing compounds (paste-like) are not allowed.

5.4.3.5 Control and isolation valves

See section 7 Valves for AHF

5.4.3.6 Excess flow & check valves

Simple self-actuating excess flow or check valves can give some protection in certain circumstances against major incidents. Problems with sticking or blocking with solid fluoride compounds need to be carefully considered as is many situations it would be found difficult to check or test such valves. For these reasons power actuated valve either manually operated or automatically operated by flow rate or reverse pressure differential are generally preferred. In either application it is the responsibility of the operator to ensure that adequate testing and maintenance is carried out to ensure effective protection.

Excess flow valves can also lead to water hammer and should be used carefully.

5.4.3.7 Miscellaneous

All pipe fittings and attachments, including those not directly exposed to the service pressure, but which are welded to the pipe, e.g. supports, should have the same mechanical and low temperature properties as the pipe.

Socket and screw connections are not permitted

5.5 Pipe work layout and arrangement

5.5.1 General

The optimum route for AHF pipe work will generally be found by attempting to satisfy the following basic criteria:

- A route which provides the shortest and least complicated design, thereby minimising the fluid inventory in the line, while maintaining the ability to accommodate satisfactorily thermal movement.
- A route which provides the maximum of protection to the line from all risk of external damage (mechanical, corrosive, fire or explosion). Consider sacrificial construction steel in front a pipe bridge crossing a road.
- A route which avoids any risk of the normal line temperature being affected by an external source of high heat output, such as adjacent steam mains.
- A route which permits convenient access for routine inspection even though permanent facilities may not be necessary.

5.5.2 Piping joints

A piping system should be designed using an all welded construction with a minimum of flanged joints. Flanged joints will, however be required to allow disassembly of pipe work for cleaning, inspection and maintenance or for connections to inline equipment and vessels.

5.5.3 Pipe tracks

As a general rule pipe work should be run in groups to save space and cost.

This approach can often be advantageous for AHF pipe work as careful positioning in the track can provide a degree of protection from external damage. Consideration, however, should be given to its relative position within the tracks, see above in this section 5.5 Pipe work layout and arrangement.

5.5.4 Dead legs

All lines should, where possible, be self-draining, to facilitate site testing, to reduce the chances of accumulating dirt and scale and to reduce the chances of building up concentrations of impurities.

5.5.5 Valve arrangement

Careful consideration should be given to the relationship of equipment and associated valves to provide a logical arrangement of valves which will reduce the risk of operator error. It is recommended that all valves and pipelines should be clearly labelled.

5.5.6 Venting and purging

In order to facilitate venting and purging for maintenance, branches fitted with blanked off valves should be provided as near as possible to each end of an isolated section of pipeline. Temporary connections can then be made to an absorption system from one end of the line and to a source of dry air or nitrogen at the other. Permanently piped connections are not recommended unless stringent precautions are taken to prevent accidental transfer of AHF into the purge and vent systems and to prevent back diffusion of moisture into the AHF system. Such stringent back flow prevention precautions could be by a redundant system of protection.

Temporary rigid or flexible pipe work can be used provided the design employed is compatible with both the steady state and upset conditions envisaged (see also section 5.2.1 General).

Where entrainment of liquid AHF into a vent system is generally a problem, a knockout drum should be fitted.

Provisions shall be taken for liquid expansion where there is the possibility of isolating AHF between 2 closed valves.

5.6 Fabrication and erection

All welders employed on the fabrication of AHF piping systems should be fully experienced and certified for making the type of welds specified.

All fabrication work (shop and site), should be carried out in accordance with an approved specification of code of practice for sub-zero duties when required. In particular, this specification should cover the following points:

- Qualification requirements for welding procedure approval
- Qualification and performance requirements for welder approval
- Welding procedures (including cleaning, preparation, alignment, inspection, etc.) for each material and type of weld to be specified, e.g. butt, fillet, flange and branch welds
- Procedures and requirements for pipe bending including thermal treatment (if required)
  Flattening of a bend, as measured by the difference between the maximum and minimum outside diameter at any cross section, shall not exceed 8% of the original outside diameter of the pipe for internal pressure and 3% for external pressure.

  Except where otherwise specified the wall thickness after bending shall be equal to or greater than 87.5% of the wall thickness before bending.

- Procedure and requirement for heat treatment, for example, where pipe has been cold formed.

5.7 Inspection

5.7.1 Visual examination

All welds should be visually examined on the outside surface and, where practicable, in the bore to ensure conformity with the requirements of the specification, see section 5.6 Fabrication and erection.

5.7.2 Non-destructive testing

100% of all shop made circumferential butt welds should be 100% examined by radiography and the results shall be controlled by the inspector.

All site made circumferential butt welds should be 100% examined by radiography.

All longitudinal butt welds should be 100% examined by radiography.

Where the nominal size of a set on branch is two thirds or more of the nominal size of the main pipe, the flank welds should be examined by radiography, ultrasonic, magnetic particle or dye penetrated examination.

Depending on national or local regulations filled welds may require magnetic particle or dye penetrated examination.

5.7.3 Auditing

Shop audits at a frequency of around every 3 years are helpful to maintain conformance.

5.8 Pressure testing

5.8.1 General

All pipe work should be site or shop pressure tested prior to initial operation, to confirm its mechanical suitability for service.

The test pressure to be applied should, in all cases, be at least 10% higher than the design pressure of the system and in the case of hydrostatic testing follow the standard construction code. This test pressure should be maintained for a period which depends on the length of pipe being tested, e.g. the time to determine any leakage and the difference between the test fluid and ambient temperatures. In no case should the test period be less than 30 minutes. Inspection for leakage, seepage, and distortion should not commence until 10 minutes after a stable pressure has been reached. A test certificate should be made available and retained to record testing which is carried out.

5.8.2 Choice between hydrostatic and pneumatic testing

5.8.2.1 Testing at site

The probability of failure under pneumatic test at a given temperature is no greater than under hydrostatic test at the temperature and pressure and it is known that failures on hydrostatic test are rare. Since, however, the consequences of failure on pneumatic test may be much more serious, hydrostatic testing is normally regarded as the preferred choice. On erected AHF pipe work, however, there is strong incentive to keep the system dry and pneumatic testing is thus often the preferred option.

Before selecting the type of pressure test to be applied to erected piping systems the following points should be considered:

- Is the stored energy of the test gas sufficient to do material damage to objects in the immediate vicinity and particularly plant already commissioned, in the event of failure?

It is recommended that the total stored energy at any one time should not exceed the value of 103 obtained by multiplying the test pressure in barg by the volume in cubic meters. Where this figure is exceeded, consideration should be given to testing the system in smaller sections or hydrostatic testing.

- Can the system be readily dried out if hydrostatic tested?
  When hydrostatically testing AHF lines it is recommended that valves and inline items are replaced by temporary spools and that all gaskets are changed following testing. In consequence a leak test would then be necessary to prove the integrity of the remade joints.
- A hydrostatic test requires the provision of vent points to eliminate any trapped air and drain points on all lutes and dead legs. These increase the amount of fabrication on the pipe work and the extra flanges constitute potential leak points.

The final choice of test will be made by balancing the disadvantages associated with hydrostatic testing vs. the hazards associated with pneumatic proof testing. These hazards can be minimised by hydraulic proof testing the component parts of a welded pipeline prior to erection. Such a test cannot however be regarded as a substitute for a proof test on the completed line.

5.8.2.2 Testing at fabrication shop

All pressure testing carried out in the fabrication shop should be hydrostatic.

5.8.2.3 Leak testing

Leak testing is only relevant to erected pipe work and it does not demonstrate the strength of the pipe system. The need for leak testing is normally only required when any part of the system has been dismantled following pressure testing or maintenance replacement.

Leak testing should be carried out at the maximum operating (which is below the design pressure) using dry oil free air or nitrogen.

5.9 External protection from corrosion

Some AHF piping systems operate at low temperatures. Carbon steel is the most commonly used material and with this range of temperatures there is a special need to consider the initial surface protection (e.g. paint) and/or the insulation and its maintenance.

The choice between paint, other surface protections, insulation or a combination of these will be governed by a compromise between the points listed below. however, the principle objective should be to ensure an effective level of corrosion protection for the pipe work.

- Initial cost.
- Inspection and maintenance frequencies required and their costs.
- Thermal considerations.

5.10 Insulation

The insulation is mainly aimed at eliminating condensation and preventing ice formation.

The qualities required from the insulation material are as follows:

- Non flammability.
- Chemical inertness to AHF.
- Vapour seal to external humidity.
- Load bearing ability when supports are directly against the insulation.

Greater safety is obtained from a global approach when AHF piping system is to be insulated. The supporting, see section 5.3.8 Supporting, external protection and insulation should, therefore, be designed as a whole.

Flange insulation should only be carried out after the piping system has passed a pressure / leak test.

5.11 Commissioning

5.11.1 Cleaning

All pipe work should be internally cleaned to remove grease, scale and rust.

If chemical cleaning is specified, the choice between chemical cleaning the pipe work on or off site (i.e. when erected) will largely be dependent on the method selected for pressure testing the pipe work. When a pipe is hydrostatically tested, this must be carried out before chemical cleaning.

Pipe work which is to be pneumatically leak or pressure tested at site, after erection, should preferably be chemically cleaned off-site after fabrication.

If pipe work is to be hydrostatically leak or pressure tested at site, after erection, it is often preferable to chemically clean on site following erection and testing. In this case adequate provision should be made at the design stage for the draining, venting and drying of the system.

It is important that the integrity of the piping system has been proved by pressure testing before any chemicals are introduced.

Although mixtures based on dilute inhibited hydrochloric acid can be used for cleaning, it is preferable to choose products based on phosphoric acid which enables scale to be removed without attacking the metal itself. The supplier will be required to certify that the proposed product contains no ingredient which might react with AHF.

When cleaning is completed all residual traces of product should be eliminated.

5.11.2 Drying

When piping erection is completed, tests and inspection finished, the system should be dried in liaison with fabricator. Dry oil free air or nitrogen should be used for this purpose. Dew point of out coming gas should be measured at intervals until a dew point, for example below -40 °C is obtained at atmospheric pressure.

Alternatively, the system may be dried by the application of full vacuum to the system for a minimum period of 12 hours. This approach ensures small cavities in valves and in-line fittings which normally retain moisture are effectively dried.

When drying is completed, the system should be slightly pressurised and sealed in order to minimize internal corrosion due to moisture ingress.

5.11.3 Initial operational checks

Immediately following introduction of AHF into the pipe work the system should be given a final visual check for leaks by suitably protected personnel.

5.11.4 Control procedures

It is recommended that formal procedures for controlling and recording that all necessary pressure testing, drying, leak testing and initial operational checks are adopted.

5.12 Maintenance

5.12.1 Inspection

Each AHF piping system should be assessed with regard to the likelihood of failure and the consequences.

A judgement then needs to be made as to the type, extent and frequency of inspection which is necessary during the life of the piping system.

As data is gathered the initial judgement can be reviewed.

A formal procedure should be operated to ensure that the required inspections are carried out, the detailed findings recorded and relevant corrective actions completed. It is recommended to perform an annual external visual inspection of the pipe work.

5.12.2 Modifications

A formal procedure for controlling modifications (e.g. changes to the original design) to AHF piping systems is recommended.

The aim of the procedure being to ensure that assessment of the modification proposed is carried out by suitably trained individuals and that modifications are only carried out after relevant authorisation has been given.

6. GASKETS

6.1 General

All gaskets must be changed after each flange opening and a new gasket should be used each time. Replacement of gaskets following the hydraulic test is necessary. For detailed information on gaskets, refer to our "Recommendation on materials of construction for Anhydrous Hydrogen Fluoride and Hydrofluoric Acid solutions" available from the publication webpage of www.eurofluor.org.

7. VALVES FOR AHF

The objective of this section is the establishment of the technical characteristics of valves used for AHF.

The design, materials and method of operation of the valves must in a general way conform to this objective for all pressures and temperatures of service indicated below.

7.1 Shut off valves with internal sealing

7.1.1 Conditions of use

The conditions of use for the valve should be carefully defined, specially relating to the minimum and maximum temperatures and pressures of service, even in exceptional conditions and, at least, for a range of:

Pressure range

Maximum pressure: In order to take into account the potential risks associated with AHF, it is recommended that a margin of 20% is allowed compared to the nominal pressure for which the valve has been constructed.

7.1.2 Materials and construction

Materials of construction are thoroughly described in Eurofluor "Recommendation on materials of construction for Anhydrous Hydrogen Fluoride and Hydrofluoric Acid solutions" available from Eurofluor Publication webpage www.eurofluor.org.

7.1.3 Standardised inspection requirements

Valves which have not previously been given approval for use on AHF duty should be subjected to a range of testing and inspection as detailed below:

7.1.3.1 Drawings and definitions

For all valves, whether they are made from cast or forged steel and for each diameter covered by the specification, a large scale sectional drawing should be supplied together with the nomenclature for the complete list of components. The drawing should indicate clearly the principal dimensions, the machining tolerances and the surface specification, to enable the entire specification to be understood as well as indicating the thicknesses of the valve body and head. The detailing of the individual components should indicate in an explicit manner the exact characteristics of the material employed. For metallic components reference should be made to the various standards employed.

Analytical and mechanical test certificates should be supplied, including the impact strength of the materials being used. For non-metallic components such as joints or gland packing, a precise description should be supplied together with an indication of the origin of the material. The total weight of the valve should be indicated on the drawing.

7.1.4 Tests and tolerances

The tightness's indicated below will be required on all new or revised items of equipment.

7.1.4.1 Hydraulic testing

Hydraulic testing of the resistance of the valve body and bonnet before assembly of the internal components should be performed at ambient temperature and at pressure equal to 1.5 times the nominal pressure of the valve. For this test, the pressure should be maintained for at least two minutes and any material in the joint which would hide any defects must be avoided. No leakage or deformation can be tolerated.

7.1.4.2 Leak testing with gas

Tests will take place at ambient temperature using dry air or dry nitrogen.

The test pressure will be:

- Maximum test pressure: 6.0 bar absolute
- Minimum test pressure: 0.20 bar absolute

7.2 Plug valves

7.2.1 Design requirements

The valves shall be of plug type, not lubricated, 90° turn command, straight opening, reduced bore, steel flanges, tested and designed for a minimum working pressure of at least 16 barg and a suitable temperature range of the specific working conditions.

The body should be made in one piece.

The valve should be designed without internal dead zones in order to prevent any risk of solid deposit which could cause a difficult operation. Outside, any gap in which dirt and moisture can accumulate must be avoided by all possible means.

When the valve is closed, no AHF must be trapped in the plug. This can be obtained for example by using a drain hole in the plug to keep the liquid AHF in the system.

In this case, to prevent any mistake in assembly, the flow direction should be marked on the valve.

Tightness and lubrification should be obtained by using a PTFE sleeve inserted in the valve body. Particular attention should be provided to the fixation of this sleeve in order to prevent any deformation cold flow, movement, pulling off or rotation.

In addition to the normal sealing of the valve obtained by the PTFE sleeve tightness, a supplementary sealing device should be provided between the body and the cap of the valve. This device should provide the tightness of the valve under the nominal design pressures and at the design temperatures. This device should be designed to avoid accidental ejection of the plug.

A special external device, easy to handle, to ensure the pressure necessary to obtain the tightness between the plug and the PTFE casing should be provided. This device should be protected against AHF corrosion in case of leakage.

For manual valves, the rotation of the plug should be obtained by the use of a wrench. The wrench parallel to the flow direction should correspond to the open position of the valve.

The closed position should be obtained by turning the wrench in the clock wise direction.

A blocking device should prevent the wrench turning more than 90 degrees.

The stem must have a double-D or equivalent design, intended to force the rupture of the stem between the stem packing and the actuator in case of excessive torque, in order to avoid emission or leak of fluid to the atmosphere.

7.2.2 Materials and construction

Materials of construction are thoroughly described in Eurofluor "Recommendation on materials of construction for Anhydrous Hydrogen Fluoride and Hydrofluoric Acid solutions" available from Eurofluor Publication webpage www.eurofluor.org.

7.3 Globe valves

7.3.1 Design requirements

We strongly recommend the use of Euro Chlor certified valves, or at least valves with the same design.

The valve should be of a vertical spindle type, with flanges, in steel, and tested and designed for a minimum working pressure of at least 16 barg and a suitable temperature range of the specific working conditions.

The overall size of the valve and its flanges should under all circumstances correspond to the existing norms. The flanges should preferably be of tongue and groove type.

The valve spindle should operate vertically and without a turning movement (outside screw & yoke type), and should have a polished surface of such a quality that during its movement it does not lead to damage to the gland packing.

The valve must be fitted with a device to indicate opening or closing.

Closing of the valve manually should always be in a clockwise direction and this closure must always be obtainable without tools by hand.

The valve plug should be articulated and free to move on the spindle.

The attachment of the spindle should be such that whatever stresses are put on to the assembly (e.g. by the act of back seating), the plug and spindle should remain permanently connected.

The contact surface between the plug and the seat should be as small as possible. In particular, a horizontal region at the plane of the contact surface is not recommended.

It is desirable in order to facilitate the movement of the valve spindle, and to avoid any restriction due to the gland follower, that the bearing surfaces should be coated with a low friction material.

The gas seal around the valve spindle should be formed by a bellows seal:

The bellows should not come into contact with the flow. The bellows should in any case be backed up by a gland packing as a safety measure.

The gland packing should be sufficiently long such that the part of the valve spindle which is in contact with AHF never sees the outside atmosphere.

The joint between the valve head and the body should employ a trapped gasket.

All the wearing pieces or components which are subjected to permanent wear must be rapidly interchangeable with the aid of simple tools. Such maintenance operations should be capable of being carried out by the normal factory maintenance personnel.

Any gaps in which dirt and moisture can accumulate must be avoided by all possible means. Those gaps which are inevitable must be protected against moisture by waterproof sealing or filling compound with permanent elasticity.

8. RELIEF VALVES FOR LIQUID OR GASEOUS AHF

8.1 Objective

The objective of this section is to define the criteria for sizing, design, construction, installation, inspection and maintenance, as well as conditions of use, for relief valves intended to protect storage systems, vessels or pipe work containing either liquid AHF or AHF gas.

8.2 Reasons for use

Relief valves may be used to provide protection against over-pressure.

Relief valves are only recommended when an ultimate means of protection against over-pressure is desired and when the automatic closure of the protective device, once the over-pressure has been eliminated, is seen as an advantage.

If there is an explosion risk in an AHF mixture gas phase system, other means of protection should be used, as a relief valve is not suitable.

Relief valves which provide an effective means of dealing with excess pressure, with automatic opening and closure, can be used for the protection of:

- liquid AHF stock tanks,
- storage systems or large sections of pipe work in which there is a risk of isolating liquid AHF,
- any equipment where there is a risk that the pressure will exceed a permitted value due to abnormal application of heat,
- equipment where the excess pressure can be due to the pressure attained by the gas transfer system or purge gas system,
- pipe work or storage systems located downstream of a source of pressure,
- downstream liquid AHF pressure vessel when the design pressure can be exceeded by the discharge pressure of a liquid AHF pump.

As a general rule, however, one should make every effort to locate the protective device directly on the potential source of over-pressure for example:

- any process reactor using AHF where there is a risk of excess pressure should have its own pressure relieving device
- directly on the transfer gas or purge gas supply system,
- at the discharge or if appropriate at each stage of a positive displacement compressor.

The discharge from a relief valve must be directed into a system for containing or recovering AHF or for its absorption or neutralisation. This excludes the use of relief valves on mobile transport containers destined for use on land [1]

[1] For maritime transport the IMO regulations require a relief valve to be fitted.

8.3 Calculation of the relief rate

The calculation of the relieving rate should take into account the following considerations:

8.3.1 Stock tanks or storage systems

In principle all stock tanks or storage systems designed to contain liquid AHF should be installed in such a manner that the input of heat resulting from a fire or from any other external source of radiation is avoided. As a consequence, the possibility of fire is not a design basis for calculating the throughput of a relief valve. The design criteria normally considered when determining relieving rates are:

- thermal expansion of liquid AHF following over-filling or liquid trapped within a closed system
- over filling
- excess pressure of liquid in a pumped system
- over-pressure due to the gas transfer system
- over-pressure due to inert gas and increase in temperature
- increase of temperature in a low pressure or low temperature liquid
- back pressure from another source.

8.3.2 AHF vaporisers

When a relief valve is associated with a AHF vaporiser, the design criteria should also take into account the possibility of over-pressure due to the total heat input from the heat transfer medium.

8.3.3 Pipeline systems

The design criteria for relief valves for pipeline systems may include the following:

- radiant heat (for liquid AHF pipe work)
- thermal expansion of liquid AHF between closed valves when an unacceptable over pressure can be anticipated
- over-pressure due to transfer or purge gas
- over-pressure due to liquid AHF pumping system
- over-pressure due to a AHF gas compressor

8.4 Design pressure

Once the maximum operating pressure has been designated, for each piece of equipment or storage system, the following pressure levels should be set in accordance with the design codes or national regulations:

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for Iso-container tank for the transport of HF, see Eurofluor "Recommendation on transport, distribution and handling of Anhydrous Hydrogen Fluoride and Hydrofluoric Acid solutions", available from Eurofluor publication webpage www.eurofluor.org.

- set pressure of the relief valve equal or less than the design pressure which shall be at least 10% greater than the maximum operating pressure.
- full opening pressure of the relief valve.
- bursting pressure of the bursting disc at the design temperature if installed.

Account should be taken of the back-pressure which can exist within the vent system, and of the pressure drop resulting from the venting of the relief valve at full opening in order that the pressure which results inside the system being protected should not exceed the over-pressure allowed by the above regulations.

As the operation of the relief valve is to be minimized as much as possible, a reasonable margin shall be taken between the maximum operating pressure and the set pressure of the relief valve.

8.5 Sizing of relief valves

Once the throughput to be vented and the pressure at full opening of the valves have been determined, the size of the valve and the diameter of the orifice should be calculated as formally specified in the various national design codes and regulations.

The parameters for sizing the valve must include the specific physical or thermodynamic properties of AHF especially:

- molecular weight which varies with temperature and concentration
- latent heat
- compressibility factor
- ratio of the specific heats
- and also the possible back pressure (see section 8.4 Design pressure)
- and the two phase flow gas-liquid ratio.

Take care of potential very high volume expansion of AHF which can generate very high pressure increase.

8.6 Type and construction

The relief valve used should be spring-loaded, specifically designed and constructed to resist all the static or dynamic forces to which it can be subjected and should be gas-tight in the closed position.

This gas-tight seal should be assured for the normal operating pressure of the container or system protected. In order to achieve this, it is recommended that the relief system should incorporate an upstream protective bursting disc equipped with a pressure indication and alarm in the control room. This should be designed to avoid interference with the valve by material from a failed disc.

Relief valves should be designed in such a manner that during operation no leakage towards the external environment can occur. All parts of the relief system under pressure, designed to protect storage systems or equipment containing liquid AHF, should be designed and constructed for a nominal pressure at least equal to that of the equipment it protects.

The valve body, internal equipment, and all components which are subject to static or dynamic stress, should be manufactured in materials which are compatible with AHF and which possess adequate mechanical characteristics to operate under the stresses to which they will be subjected.

8.7 Protection of the relief valve

As a general rule, all AHF relief valves must be protected against deterioration.

For this reason, it is normal to fit a disc upstream of the valve to keep it out of contact with AHF. The relief valve should also be protected against return of moisture from the vent system. This can be achieved either by controlled purging by an inert dry gas, or by the use of a protective diaphragm. The relief valve should be capable of being isolated for maintenance by a sufficiently safe system such as, for example, a locked open valve or an inter-locked double valve system. When the relief valve is intended to protect storage systems or equipment which can contain liquid AHF, the isolation valves should follow recommendations laid down in section **Error! Reference source not found. Error! Reference source not found.**. Wh en there is a risk of back flow of AHF at the outlet of the relief system, isolation for maintenance should be provided with a sufficiently safe system, such as, for example, a locked open valve. In case of double valve system or in case of valve in the relief exit, the valve should never be closed without having taken appropriate measures to ensure that the operating pressure of the system is never exceeded.

8.8 Attachment to the vent system

The pipe work attached to the relief valve on the venting side should never have a diameter less than that of the exit flange of the relief valve itself. Vents should be retained in a suitable installation, such as an empty vessel, compression and liquefaction of the gas, guaranteed consumption or absorption by a reagent or neutralising medium. When the relief device discharges into a gas collection header or an absorption system, it should be sufficiently gas-tight and have a pressure rating able to contain, without leakage, all the product discharged.

8.9 Design characteristics of the vent system

The vent system and the installation for the retention of AHF located downstream of the relief valve should not induce a significant pressure drop, even with two phase flow, which can in any way interfere with the operation of the relief device.

The pipe work should be adequately sized, such that AHF release at any point within the system cannot lead to discharge of AHF from any of the other systems attached to the network. The pipe work should be sized to take into account the number of relief valves which could operate simultaneously.

When the relief collection system is connected to several relief valves, which operate at different pressure, the pipe work should be studied with particular care such that the operation of one or more relief valves at high pressure does not lead to any detrimental effect on the operability of valves designed to operate at lower pressure (especially of the downstream protective membrane or diaphragm): in certain circumstances, it may be necessary to install buffer expanse systems or to use separate collection headers, each one dedicated to relief devices which operate at comparable pressures.

The materials of construction of the collection header should be appropriate to the quality, composition and temperature of the vents, even under abnormal circumstances.

T branches or other connections made to the collection header should preferably be from above.

All precautions should be taken to avoid accumulation of liquid AHF in low points within the collection headers (and drainage points should be provided to deal with these circumstances if necessary).

One should avoid the mixing or the possibility of mixing, in the collection headers, of gases of a composition such that chemical reaction can result.

All the elements of the collection header and supports should be designed to have sufficient mechanical strength to deal with the maximum stresses that the operation of the relief valves can induce. The design of the relief pipe work should provide suitable facilities for inspection and cleaning.

8.10 Buffer vessels

A buffer vessel should be provided on the downstream side of each relief valve or group of relief valves in case of:

- in situations where the operation of a relief valve can lead to a discharge of liquid AHF, in order to protect the gas collection header and absorption unit,
- in situations where it is necessary to limit the rate at which AHF is discharged towards the AHF containing system, the buffer vessel serving in this case to attenuate the throughput discharged to the containing system.

Buffer vessels which can be subjected to discharge of liquid AHF should be constructed in materials and be equipped with accessories which are suitable for AHF service. The presence of liquid AHF in the buffer vessel should be signalled by an alarm detector and provision should be made for the emptying of liquid AHF in complete safety from the buffer vessel after operation.

8.11 Expansion tanks

Closed expansion tanks should be provided on the downstream side of a pressure relief valve intended to protect a liquid AHF system from thermal expansion. These tanks should be fitted with a pressure alarm. There should be no other permanent connection except where it is necessary to provide a connection for possible emptying of the vessel.

8.12 Marking of relief valves

Each relief valve and mount should have solidly attached a corrosion resistant indicator plate which carries at least the following information:

- identification number
- pressure rating of the valve body
- design temperature
- “Hydrogen Fluoride”
- cold spring set pressure and opening pressure

- orifice diameter and coefficient of opening (α or CV)

8.13 Maintenance procedures

Preventive maintenance should be carried out with a frequency dictated as a function of the characteristics of service for the valve. During this maintenance, inspection to determine that the valve is operating properly should be carried out according to national codes and recommendations of the supplier. The user should maintain a register of all relief devices and inspection records.

As a general rule, all equipment should be replaced systematically before there is any risk of it becoming defective. After any occasion, when it is known that the valve has been exposed to AHF, the valve and its protective devices should be replaced or overhauled.

The vent piping and the scrubber should also be part of the maintenance procedure to check for deposits and obstruction in the vent piping and the scrubber.

8.14 Drawings and nomenclature

For all relief valves covered by this section, and for each diameter, a large scale sectional drawing should be supplied together with the nomenclature for the complete list of components. The drawing should indicate clearly the principle dimensions, machining tolerances and surface specification. The detailing of the individual components should indicate in an explicit manner the exact characteristics of the material employed. For metallic components reference should be made to the various standards employed. Failing this, analytical and mechanical test certificates should be supplied, including the impact resistance of the materials being used. For non-metallic components a precise description should be supplied, together with the origin of the material.

8.15 Certification

Valves should be designated as suitable for AHF and should be delivered with:

- a hydraulic test certificate
- set pressure certificate
- certification of materials of construction

8.16 Delivery

Valves should be delivered completely dry and clean. Components which should be greased must exclusively make use of grease which is compatible with AHF.

All traces of scale should be eliminated and untreated surfaces which will not come in contact with AHF should be treated with a coat of anti-rust paint. Machined or threaded sections should similarly be treated with an anti-corrosion protective coating.

Ports and flanges should be blanked off and protected by plastic plugs or metallic plates. These plugs or plates should be of a diameter such that the whole surface of the joints is protected.