

RISK ENGINEERING GUIDELINE

HEAT TRANSFER OIL SYSTEMS

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Preventive measures minimize the risk of fire during the operation of heat transfer oil systems.



General.

Heat transfer oil systems, also referred to as thermal oil systems are employed in almost all industrial production sectors for indirect heating of production facilities and processes. As opposed to hot water or steam, heat transfer oils, due to their specific properties, provide process heat across a very wide temperature range at slight excess pressure.

1 Risk situation and examples of losses.

1.1 Risk situation

From a risk engineering point of view and contrary to water, heat transfer oils have the disadvantage of being organic combustible liquids. The majority of industrial applications involve the use of heat transfer oils at temperatures far above their flash point; therefore the ignition behaviour of the heat transfer medium in operating condition equals that of a flammable liquid.



1.2 Examples of losses

Fire in an electroplating plant

Due to frequent shutdown and startup of the system an improperly tightened flange started to leak. The heat transfer oil leaked into the insulating material (mineral wool) surrounding the flange. Due to the insulation the leak remained undetected. Over a period of a few weeks the continually leaking heat transfer oil began to heat up due to oxidization (exothermic reaction), reaching a temperature exceeding its ignition point. This resulted in a major fire when the insulation layer was removed for a system modification and the hot oil suddenly ignited.

Fire in a chipboard factory

After a weekend shutdown time-pressure resulted in operations running the preheating step of the production facility at maximum furnace temperature instead of the prescribed lowest burner setting. This resulted in the process equipment reaching operating temperature quickly and production could commence. However the elevated temperatures resulted in the localized coking within the heat transfer oil system's furnace as the allowable film temperature of the oil was exceeded. This in turn lead to hotspots in the furnace system due to poor heat transfer across the coking which in turn resulted in tube rupture, spraying flammable heat transfer oil into the furnace chamber.

Fire in a textile finishing factory

During a heater overhaul the new inner lining was not welded with a continuous seam but only spot-welded. During commissioning of the unit the improperly welded seams cracked. The lines carrying the heat transfer oil were torn open spraying oil into the furnace. This resulted not only in the heater being completely burnt out but the extreme heat generated also lead to the failure of the structural steel supporting the surrounding building.

Fire in a foundry

A circulation pump was replaced as part of an annual maintenance procedure. Contrary to start-up instructions the mechanical seal was not filled with heat transfer oil but left dry. Shortly after start-up the mechanical seal on the pump failed. Due to non-existent leak monitoring the leak was not detected and an exposed hot surface ignited the pool of heat transfer oil.

These examples show typical causes of losses when using organic heat transfer media in industrial sites. A local release of heat transfer oil, ignited either by self- ignition or an ignition source, results in a fire. This may cause considerable loss because the burning liquid spreads quickly.

2 Process fundamentals.

Heat transfer oil systems, in relation to this Risk Engineering Guideline, include systems holding a liquid organic heat transfer fluid in a closed circuit and featuring quick-control and on/off heating. The atmospheric boiling point of the heat transfer fluid can be exceeded in this process.

Heat transfer oil systems can be classified by the type of heat source for the system. This results in the following groups; fired heater or furnace (as shown in figure 1), electric heater or an exhaust gas heat exchanger (waste heat boiler).





Additionally heating with solid fuels such as wood, coke and secondary raw materials (recycling waste) can occur however this is not dealt with in this document. These types of heating require special protection measures and this type of heating can usually not be switched off at short notice.

In view of the varied requirements and broad range of applications, there are a number of different process layouts, but all of these rely on the same basic principle (see simplified diagram in figure 1).

Process description

The heat transfer medium (oil) heated in the heater is directed to the heat consumer, releases heat and is fed back to the heater to be reheated. In most cases, the heat transfer medium circuit is maintained by a circulating pump (forced circulation).

A vented compensation tank which is also referred to as an expansion tank is provided at the highest point of the system. In most systems, the expansion tank vent line is connected to

an additional collecting tank (overflow tank) by an overflow line from where the vent leads out into the open.

Heat transfer fluids

The organic heat transfer fluids considered in this Risk Engineering Guideline can be sub-divided into two groups:

- mineral oil-based heat transfer oils,
- synthetic heat transfer oils.

In addition to the organic heat transfer fluids, silicone-based heat transfer oils ("silicone oils") are increasingly used because of their high thermal stability. These heat transfer fluids are not dealt with in this Risk Engineering Guideline because the special usage conditions require specialised safety concepts.

3 Hazard sources.

In view of the experience gained in loss events, the following frequent reasons for accidental release of heat transfer oils and the resulting fires can be identified:

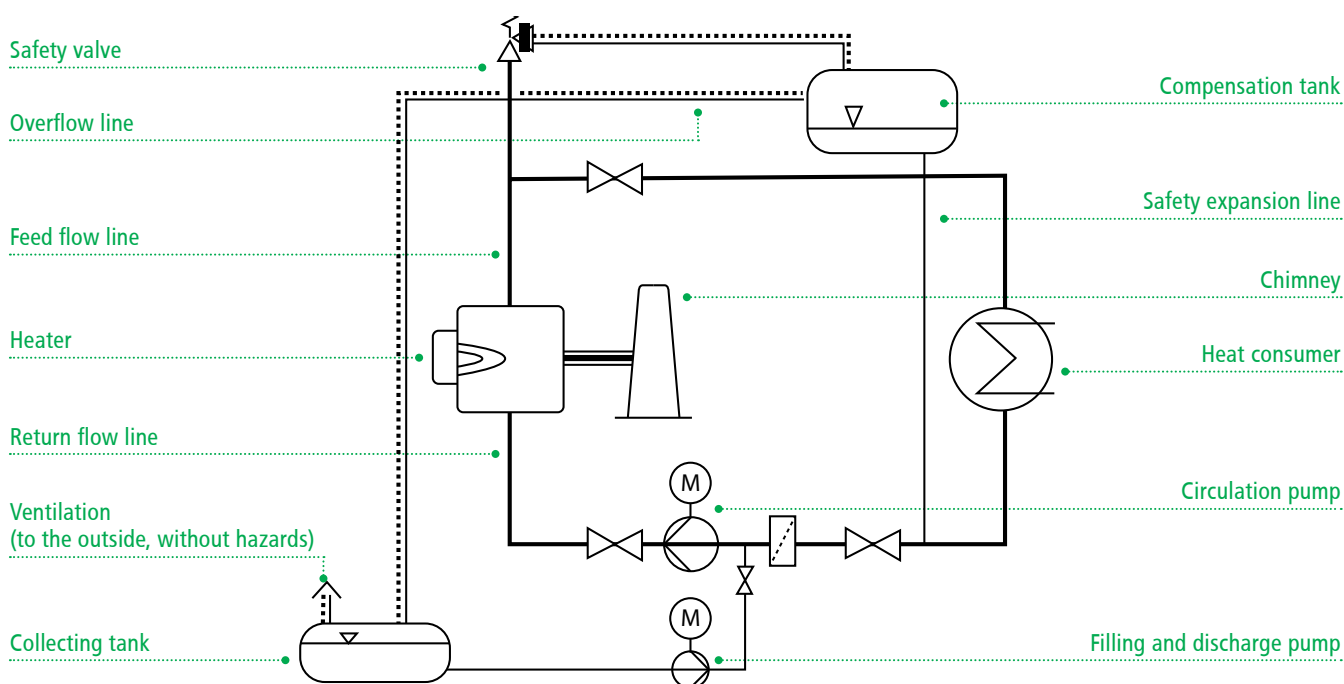


Fig. 1: Flow diagram of a typical heat transfer oil system (simplified)

■ Seal leaks

All non-welded joints of piping and system components as well as dynamic packing such as shaft passages of pumps, valves and heated rollers are typical leak points of heat transfer fluid. Static seals such as flange seals may fail due to ageing or following the expansion and contraction of piping occurring during heat up and cool down of the system.

■ Cracks in the oil-filled heater piping system

Overheating in the heater may cause stress corrosion cracking; in waste heat boilers, abrasive components may cause erosion of the piping walls and subsequent failure. When the heat transfer oil enters the furnace, it ignites immediately and burns generating much heat and soot.

■ Thermal overload of heat transfer oil

Thermal overload decomposes the heat transfer oil so that flammable low-boiling fractions and tar-like high-boiling fractions are increasingly formed. The increased portion of low-boiling fractions reduces the flash point and increases the viscosity of the oil. Tar-like fractions ("coking") deteriorate the heat transfer in the heater and therefore cause overload of the piping material. These substances may deposit in the circulating pumps and cause failure of seals.

■ Insufficient qualification of operating personnel

Defective heat transfer oil systems are frequently attributable to improper handling. Rushed start-ups may cause overheating of the heat exchanger material and the heat transfer medium.

4 Protective measures.

With decades of experience in the operation of heat transfer oil systems and modern safety standards, the safe operation of state of the art systems can be achieved.

Therefore the generally recognized technical rules should be used as a minimum standard for the design, construction and operation of such systems. Also the safety features of existing systems must be regularly reviewed using the state of the art standards.

Two essential, worldwide recognized regulations specifically applying to heat transfer oil systems with organic heat transfer media are:

- DIN 4754-1: Heat transfer installations working with organic heat transfer
- NFPA87: Standard for Fluid Heaters

Both standards, fully applied and not only parts of it can be used for the design, construction and operation of thermal oil systems. Standards or safety measures of the same or superior safety level can be used after approval of the authority having jurisdiction.

The protection measures can be sub-divided into technical protection measures (system and process safety) and general fire protection measures (structural, organisational, fixed protection systems and firefighting measures).

4.1 System and process safety

DIN 4754-1 and NFPA 87 list the minimum requirements for state of the art system and process safety. This includes requirements for

- design,
- material selection,
- construction,
- layout,
- inspections and
- system operation.

Beyond these general requirements, the necessary measures according to the process specific state of the art technologies must be taken into account, in particular considering the items below:

4.1.1 Heat transfer oil

It is vital that only the approved or specified heat transfer oils for the system in question are used. The safety margin between the maximum operating temperature and the specified maximum allowable feed flow temperature should be as large as possible. The maximum operating temperature should at least be 30K below the allowable maximum feed flow temperature.

The heat transfer medium should never be operated above its ignition temperature as in this case any leaking heat transfer oil would ignite immediately.

Heat transfer oils are usually water-polluting substances, as per the local environmental protection laws and directives. Therefore suitable protective measures must be taken. The requirements for the paving and/or sealing of floor

By definition, the data sheet figures of the maximum permitted feed flow temperature and film temperature for heat transfer oils, reflect the conditions in which the heat transfer oil will maintain stable working condition for one year.

It is advisable to select the heat transfer oil in consideration for the actually desired period of use, i.e. rather 5 or 10 years. Accordingly, the desired thermal stability of the heat transfer oil in the intended mode of operation should be guaranteed by the producer.

A representative heat transfer oil sample should be examined by a qualified laboratory at least once a year. This could be done by the oil producer.

surfaces, the determination of retention volumes and required organisational or technical protective measures must be chosen depending on the water hazard class (which can be taken from the safety data sheet supplied by the producer). The precise Standards are governed by the respective local ordinances for systems handling water-hazardous substances. This normally requires that,

- the floor must be an impermeable surface (with proof if required),
- retention capacity must be provided for the volume of water-hazardous substances that may be filled until suitable safety precautions become effective,
- automatic fault alarms in connection with a permanently manned station (e.g. control room) monitor possible leakage leading to contamination of the water systems.

Depending on the site conditions (e.g. location in a water reserve) and the water hazard class, further requirements may exist. Note that the retention volume for contaminated fire water must also be considered.

Providing all potential leaks with a metal drip tray or a collecting vessel is useful for collecting drip quantities and for early detection of leaks. Liquid level sensors provided in the drip trays and collecting vessels enable permanent monitoring (limit level sensor, see figure for an example). As an alternative, operator checks rounds can be carried out as part of routine plant inspections.

Any collected or pooling leakage of heat transfer oil must be removed without delay (Caution: oil-soaked rags may spontaneously ignite and must be disposed of accordingly!). Identified leaks must be repaired as soon as possible.

4.1.2 Electric equipment

As a basic rule, electric equipment must be installed, maintained and inspected according to the applicable local standards, e.g. the harmonized standards under the directives of the European Union or NFPA 79. National Electrical Code and NFPA79, Electrical Standard for Industrial Machinery, in the USA.

In operating premises where heaters, collecting tanks, pumps etc. with heat transfer oil are set up and in areas where non-welded piping joints (e.g. flanges, shaft passages of heated rollers) are located, it must be determined, if the areas around the equipment must be classified as hazardous location. In that case, electrical equipment and wiring must be appropriate for a hazardous (classified) location or zone according to the national standards.

The electric equipment must be designed, installed and located such that they do not become a source for ignition for the oil and that they are protected against external effects. Cables should not be laid on floor level where there is a risk to get in contact with puddles of spilled or leaked hot oil. Laying cables directly above system

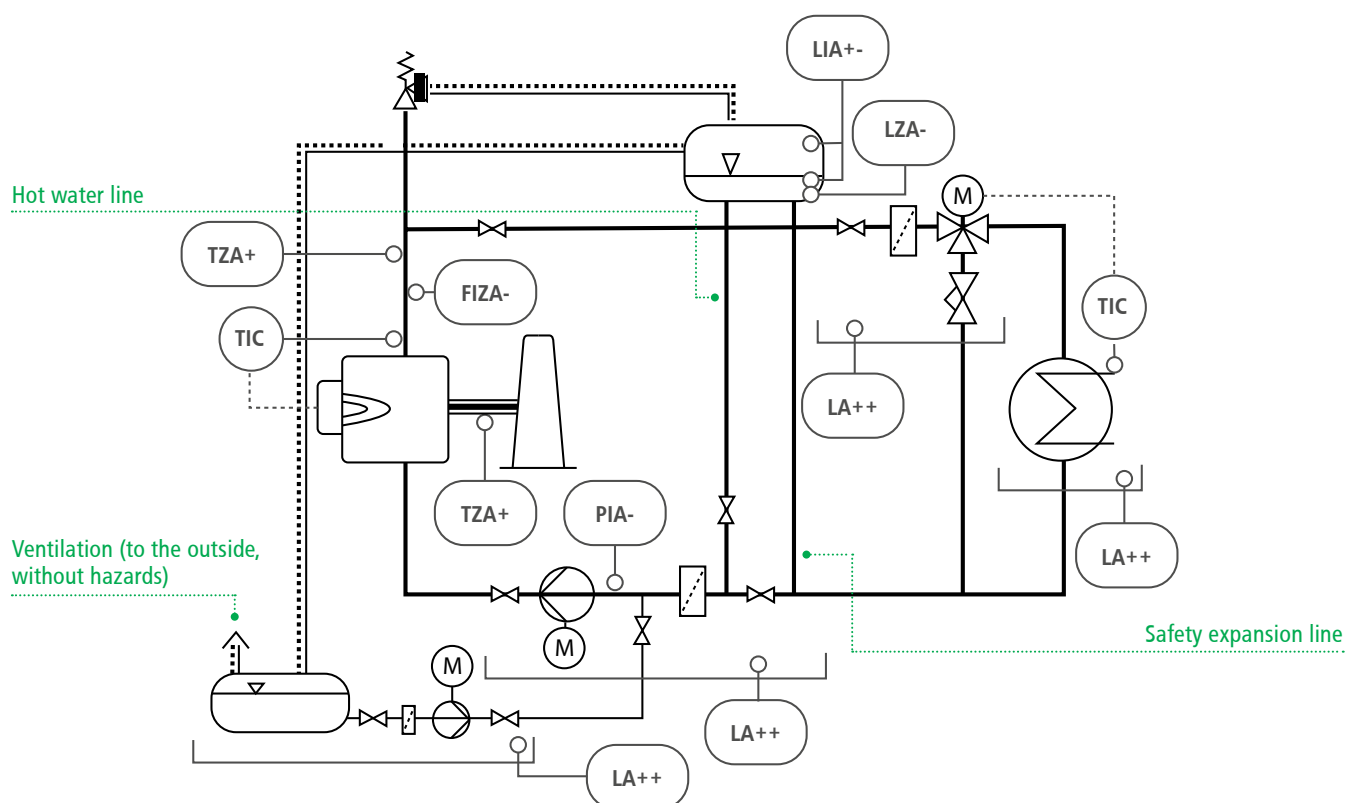


Fig. 2: Flow diagram of a typical heat transfer oil system (simplified)

components from which thermal oil may escape due to leaks from joints or dynamic packing should also be avoided. Otherwise, the cabling must be protected by measures ensuring a fire resistance of at least 60 minutes.

All system components, i.e. piping, valves, vessels, pumps etc. must be electrically coupled in order to avoid static charges. The heat transfer oil system should be earthed according to electrical engineering best practices.

4.1.3 Control system measures

The components and systems used for process control must reliably maintain the operating conditions as well as having the ability to safely handle process upset and system malfunctions. The minimum requirements on control system protection measures as described in DIN 4754-1 or NFPA 87 have to be applied. At least the following control loops (shown in figure 2) are required :

- Temperature monitoring of the heater feed line with a type approval-tested safety temperature limiter (TZA+) to avoid exceeding the permitted heat transfer medium temperature.
- Low level protection using a type-tested level limiter (LZA-) on the expansion vessel to prevent the system from running dry and assuring there is enough suction pressure for the circulation pump.
- Minimum flow rate safeguarding (FIZA-) by means of a type -tested instrument. This protects the system against running dry by shutting down the heater and the circulation pump.
- Pressure monitoring (PIA-) of suction pressure of the circulation pump in order to protect the pump against cavitation.
- Monitoring of circulation pump for
 - leaks (e.g. level switch in the leakage collecting tank),
 - exceeding the bearing temperature (temperature sensor),
 - vibration (vibration sensor).
- Flue gas temperature limiter (TZA+) which protects fired heaters and the heat transfer oil against overheating.
- Continuous level measuring (LIA+-) in the compensation tanks if the volume of heat transfer oil exceeds 1,000 l
- Leakage monitoring units (LA++) at critical points (e.g. level monitor in collecting trays).
- Safety monitoring when shutting down the heater and/or the circulation pump, must prevent automatic system re-start by a reliable controlled lock and an alarm must be triggered at the system itself and at a permanently manned station.

- Emergency stop button. When the emergency stop operating device is triggered (usually a pushbutton), the heat transfer oil system must be stopped without this process involving additional risks. A check must be made e.g. if electric equipment should remain in operation for safety reasons and if such equipment should consequently be fitted with explosion protection (e.g. emergency lighting).
- Emergency stop command in systems with secondary circuits requires an examination to be made to determine if these secondary circuits can continue operating safely after shutting down the primary circuit or if they must be included in the emergency shut-down (interlinking of processes).

4.1.4 System components

Pumps

Selected pumps must be specifically compatible (designed and approved) for heat transfer oil applications. Common water or hot water pumps are not suitable.

To avoid leaks, the use of hermetically sealed pumps (e.g. split-cage motor or magnetic drive pumps) is preferred over using shaft-sealed pumps. The hermetically sealed pumps should be fitted with two safety shells with split space monitoring. When operating the heat transfer oil above the atmospheric boiling point, hermetically sealed pumps must be used exclusively.

When operating the heat transfer oil below the atmospheric boiling point, pumps with a double mechanical face seal and atmospheric quenching tank can also be used (API 682 or ISO/DIS 21049 plan 52, atmospheric), depending on the overall risk situation (e.g. no ambient fire loads, no ignition sources) or sealing systems offering the same level of safety.

The shaft exit area of pumps sealed by mechanical face seals (including those in secondary circuits) must be provided with a splash guard in order to avoid spray from escaping pressurized heat transfer oil. When the media-side or the atmosphere-side mechanical face seal fails, this splash guard directs the escaping oil into the pump drip tray. In choosing the pump location, attention must be paid to the absence of possible ignition sources around the pump (e.g. hot surfaces) and to avoid pool-fires spreading beneath any other system components such as pipework and tanks in case of a pump fire (e.g. due to dry running).

Heaters

Besides the requirements made in regulations on fired pressure equipment, the heaters as well as the combustion and fuel handling systems must meet the common safety requirements for industrial thermo processing equipment according the local standards (e.g. in Europe EN 746-1, EN 746-2 and electric equipment according IEC 60204; in the USA NFPA 87, whereas the electric equipment must meet or NFPA 79).

The safety-related protection system must comply with NFPA 87, chapter 8 (for systems designed according NFPA 87) or DIN 4754 part 1 to 3 (for heat transfer oil systems designed according DIN 4754 part 1). Both standards allow a fail-safe programmable logic controller (PLC) for the safety functions. The determined safety integrity level (SIL) must be verifiably documented in every case.

If it is possible that the heat retention in the heat transfer oil system can lead to oil degradation or damage to the heater if heat users are switched off or the emergency stop is triggered, an emergency cooling system is required. This cooling system must run on back-up power in case of main electricity supply failure to the system. (Safety requirements for backup power to be observed.)

Electric heaters must meet the safety-related standards for electro heat installations, as well as the electric inspections. At least IEC 60519 part1 and 2, IEC 60398 and IEC 60204 are applicable. For heat transfer oil systems built according NFPA 87 the standard gives detailed requirements."

In addition, the following additional supervision features must be provided (all-pole disconnection by means of positively driven safety relay in each case):

- Safety temperature limiter for monitoring the maximum permitted temperature.
- Electronic dry running protection for monitoring the temperature rise rate (e.g. when heater bars are exposed).
- Residual-current circuit breaker cutting the energy supply in case of an earth fault, e.g. due to an electric arc between the heater bar and the protective tube.

In gas-fired systems (e.g. natural gas, LPG), the owner of the premises is responsible for the gas supply network between the point of delivery and the last shut-off device downstream of the gas consumer. It must be reassured that the installation and regular inspection is according to the national safety regulations for natural gas (e.g. NFPA 54 in the USA).

Particular requirements going beyond the scope of this Risk Engineering Guideline apply to heaters fired by solids (wood pellets, chippings, secondary raw materials). This is essentially due to that fact that combustion cannot be switched off immediately in case of emergency, as with all other types of firing and the electric heater.

Heat consumers

A variety of possible heat users in a multitude of technical applications require constant or tightly controlled temperature provided by oil heat transfer systems, e.g.:

- baking ovens,
- drying ovens,
- air heaters,
- steam generators

- agitator vessels,
- baths,
- rollers.

In view of the large number of applications, this Risk Engineering Guideline can only give some general design hints; the measures protecting against leaks and ignition of heat transfer oil must be defined per application.

- The oil-carrying lines inside equipment must be easily accessible for cleaning.
- Drain and vent connections must be provided. Connections with seals on the thread are not allowed.
- The usually separable piping joints between the heat transfer oil circuit and the heat consumer should be realized in consideration of the tension and piping movements caused by thermal expansion and temperature changes.
- Possibly occurring vibrations due to e.g. rotating or moving parts of the heat consumer (rollers, presses) must be considered in the design of the separable piping joints.
- When transferring heat transfer oil to rotating or moving system components (e.g. presses or rollers), rotary unions suitable for the application and supported by a sufficient amount of experience shall be used. The fixed part of the rotary union must be secured by a rotary safeguard.
- If heat transfer oil is used for heating enclosed spaces such as halls, heating must be realized through a separate hot water circuit. Heat transfer to the water can then be accomplished in the heater room, using an oil/water heat exchanger and the transport of thermal energy into the rooms by a water circuit that is uncritical from a safety engineering point of view.



Fig. 3: Example of a flange splash guard

Pressure vessels and pipework

Pipework and its components shall be designed as metal lines according to national pressure vessel regulations for the maximum permitted temperature and pressure levels, but at least for a permitted pressure of 16 bar.

Regardless of the design according to the pressure vessel regulations, the compensating tank must be designed to withstand a pressure of 10 bar min. and all other tanks for 2 bar min.

The pipework must be arranged so that it is protected against accidental damage; sufficient piping supports must be provided and pipework expansion must be considered carefully because of the high thermal expansion upon heating-up of the system.

Pipework carrying heat transfer oil should always be laid so it is visible and accessible whereas laying in ducts and pits as well as underground should be avoided.

Heat transfer oil systems must be „reliably leak-free“. For this reason, piping joints should always be realized as welded joints, as a basic rule, and the number of separable piping joints shall be reduced to the absolutely required minimum. When separable piping joints cannot be avoided, they must be provided with a splash guard and should be located above a collecting tray if possible.

Threaded joints should not be used for separable piping joints, except for the exceptions mentioned in DIN 4754-1 or NFPA 87. When separable piping joints cannot be avoided, flange joints should be selected.

In general, separable piping joints should not be located in areas subject to bending loads due to thermal piping expansion ("Bending leg") because these points involve the danger of the joint breaking open in temperature changes.

Notably graphite gaskets with metal insert and inner eyelet and, for points subject to heavy temperature variations, spiral wound gaskets with graphite insert have proved suitable for systems operating below the atmospheric boiling point of the heat transfer oil.

The minimum requirements for flange joints shall be at least PN 16 and the flange bolts must be tightened evenly around the circumference up to the torque specified by the manufacturer of the gaskets.

Systems in which the heat transfer medium is used above its atmospheric boiling point must attempt to use welded joints exclusively if possible. If flange joints are unavoidable, weld gaskets should be used.

Moving piping parts (e.g. expansion bellows, rotary unions) should be used only if they are absolutely necessary for design reasons. These must be installed at suitable locations so they are easily visible and provided with a

splash guard to avoid spray fire due to escaping heat transfer oil under pressure.

In all cases the absence of possible ignition sources in the surroundings of separable piping joints must be ensured.

Valves

Valves must be durably technically tight and if possible, valves without spindle or shaft penetrations should be selected (see the figure for the example of a non-return valve).

In case of shut-off and control valves, the unavoidable spindle shaft must be sealed by a suitable sealing system, e.g. metal bellows with safety gland (see the figure for the example of a shut-off valve).

The maximum number of actuations specified by the manufacturer up to which the initial technical tightness is still guaranteed must be observed here. A maintenance schedule should be set up and followed to assure that the metal bellows subject to pressure and temperature load and possibly also to the accumulation of deposits are replaced in good time before they fail; the safety glands must be serviced at regular intervals as specified by the manufacturer.

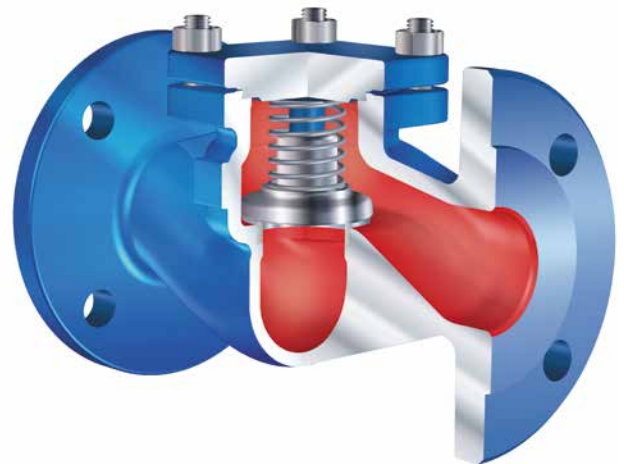


Fig. 4: Non-return valve without shaft penetration

The static valve seals (housing seals) should be chambered seals so they cannot be pushed out.

The connections of valves with pipework should be butt welding ends and maintenance and replacement of shutting-off and sealing components should be possible without having to remove the valve from the pipework.

Installing shut-off valves with the spindle pointing vertically upward has proved its worth. In this configuration, the danger of deposits near the spindle penetration (bellows) is the smallest. If required, the valve may also be installed with a horizontal spindle, but here the higher spindle friction with larger nominal diameters should be noted.

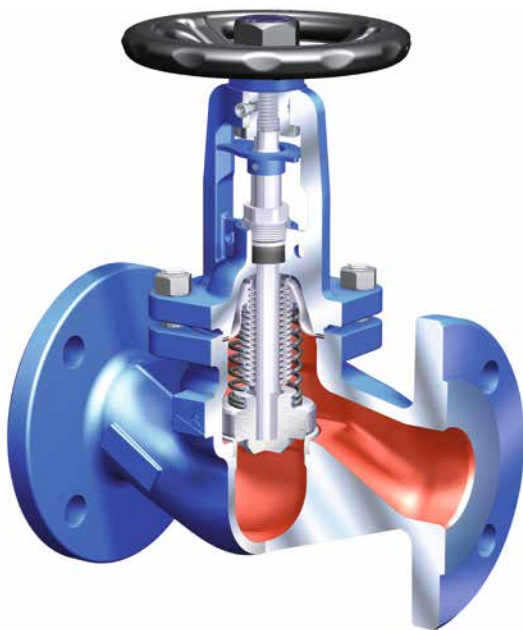


Fig. 5: Shut-off valve with metal bellows and safety gland

Valves with a spindle penetration such as shut-off and control valves should never be installed with the spindle pointing vertically downward. Deposits in the bellows may make the spindle seal fail (observe the installation instructions of the valve manufacturer).

To protect the circulation pumps against solids such as high-boiling fractions (tar-like to coke-like particles), metal particles (e.g. scale, rust, welding beads) and other dirt charge in the heat transfer oil used, suitable dirt collectors must be provided upstream of the pumps. If metal solids cannot be excluded, a magnetic separator must be integrated in the dirt collector.

Insulation

Self-ignition of escaped heat transfer oil into the piping insulation counts among the most frequent causes of fires on heat transfer oil systems.

Thermal insulation cannot be avoided on heat transfer oil systems as the surface temperature of piping and components may not exceed 85 °C to protect combustible building materials of adjoining components. Additionally the economic loss associated with the heat losses of uninsulated pipes would be large. Piping insulations must use non-combustible insulating material (temperature resistance of ≥ 1.000 °C), usually mineral and glass wool is used for this purpose.

Leaking heat transfer oil penetrates the normally employed fiber-type or open-cell insulating materials, the oil oxidize

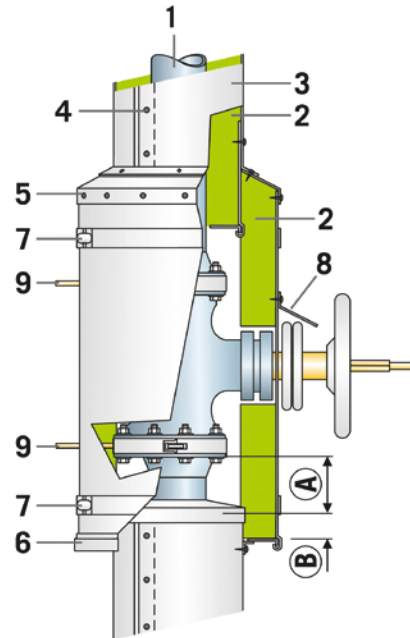


Fig. 6: Insulation of a valve, flanges with a splash guard

1. Piping - 2. Insulation material: wire mesh mat - 3. Sheet metal jacket - 4. Self-tapping screw or rivet - 5. Face disc - 6. Face disc - 7. Straps - 8. Rain deflector - 9. Leakage location nipple - $B \geq 50$ mm - $A = \text{Screw length} + 30$ mm

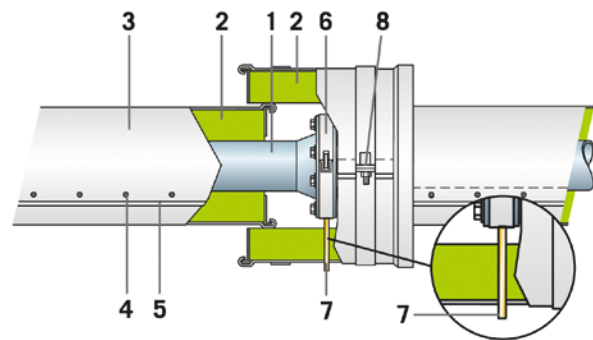


Fig. 7: Insulation of a flange joint, flange with splash guard and leak location nipple

1. Piping - 2. Insulation material: ProRox wire mesh mat - 3. Sheet metal - 4. Self-tapping screw or rivet - 5. Groove - 6. Flange straps - 7. Leak location nipple - 8. Tensioning straps

more than usual due to the considerable surface increase. The high operating temperatures inside the insulation support this exothermal process. The hot oil could ignite spontaneously upon contact with oxygen, e.g. when opening the insulation during maintenance.

The use of closed-cell insulating materials such as cellular glass is recommended instead of fiber-type or open-cell insulating materials such as mineral wool, but is rather costly. For this reason, this type of material is mostly not used for sealed vessels and welded joints. Closed-cell insulating material is, however, to be preferred on safety-relevant components such as pumps, valves and flanges.

Suitable action for leakage detection on the insulation should be taken at leakage prone spots (e.g. flange joints).

This can be achieved e.g. by installing a splash guard (strap) with leak location nipple. Escaping oil must be collected in a collecting tank with leakage monitoring.

The insulation of valves must also allow for leak detection/identification additionally oil leaks at the spindle penetration should be prevented from soaking the insulating material.

Fixtures enabling easy dismantling and fitting of the insulation should be provided for regular checks of separable piping joints, valves, measuring instruments and other potential heat transfer oil leakage points. This can be achieved very economically e.g. by specially conditioned and highly heat-resistant insulating mats with easily opening and closing Velcro and buckle locks.

Insulations must be protected against mechanical impact and weather influence by a sheet metal layer of sufficient thickness (except for the heat-resistant insulating mats described above). Temporary jackets, e.g. using PE or aluminum foils are not allowed from a fire protection point of view. End and collar washers at the transition points from the insulated to the uninsulated sections must always be arranged so that any possible heat transfer oil leak is drained to the outside and cannot penetrate the insulating material.

Quick-acting shut-off devices

To avoid large quantities of heat transfer oil leaking out in case of damage, large systems should be sub-divided into sections of around 5,000 l by means of automatic quick-acting shut-off valves. When closing one of the valves (limit switch actuated in open valve position), the heater and the circulation pump must be shut down.

Quick-acting shut-off devices must also be provided on both sides of a fire or complex separating wall when fire spread by the overheated and evaporating liquid must be feared (see also "Structural fire protection").

Before shutting off system sections by quick-acting shut-off devices, a check must be carried out whether heat transfer (e.g. by solar radiation or heat-emitting process plants) into the shut-off piping components is possible. In this case, an excess pressure safeguard must be provided for the system sections concerned (usually a safety valve).

Discharge of low-boiling fractions

Low-boiling fractions are formed as decomposition products of the heat transfer oil at high temperatures and must be discharged from the system. An excessive portion of low-boiling fractions (guideline value: > 3%) may cause component damage and an explosion or fire when released into the atmosphere. Discharge of the low-boiling fractions can be by boiling off at pre-set intervals or automatically by a low-boiling fractions separation process step. This improves the availability of the overall system as the operation standstills required for boiling off are not necessary.

It is important to observe that the low-boiling fractions are flammable liquids of undefined composition (properties are similar to those of gasoline). The filling point for condensed low-boiling fractions must be treated like an explosion-hazardous area (preparation of explosion protection document, suppression of potential ignition sources, marking).

Sample cooler

The heat transfer oil sample should always be taken at the same point in the circuit and under the same conditions in order to be representative. It is important not to modify the sample properties by the way the sample is taken. The best sampling option is to provide a permanently installed closed "cooling trap" in the system, enabling safe and representative sampling.

4.1.5 Organisational measures

Organisational measures cannot substitute design and control engineering safety devices, but are absolutely necessary in order to maintain the safety of a heat transfer oil system permanently, e.g. by correct operation and suitable maintenance.

Responsible person

The operating company shall nominate a responsible person and a deputy for the heat transfer oil systems used who, after suitable instruction by the installation company, must ensure that the heat transfer oil system is kept ready for operation. Regular training courses held by the producers/ suppliers of the heat transfer oil system and of the heat transfer liquid are useful for the responsible persons and their deputies and, if applicable, also for other persons working on the system.

Maintenance

To enable safe operations over an extended period of time, regular maintenance services for all system components are required.

When an oxidised heat transfer oil leak is suspected to have occurred in the insulation, e.g. because of noticeable heat dissipation or even discolouration of the jacket, this insulation area must be flushed with a sufficient amount of inert gas (e.g. nitrogen) through suitable openings before removing the jacket.

The jacket and the soaked insulating material must be removed while wearing suitable protective equipment and under the supervision of a qualified fire safety officer, with a sufficient amount of firefighting agent (usually foam) available. In case of a major hazard, it is recommended to call emergency services.

- As a basic rule, the manufacturer's information regarding the scope and intervals of inspections must be observed. Repair work on heat transfer systems may only be carried out by specifically trained personnel with the necessary specialist knowledge, approvals and certificates (e.g. welder's certificate). Repairs may be carried out only after issuing the necessary work permits by the responsible person or its deputy.
- Before carrying out necessary hot works (welding, torch-cutting, grinding, brazing, etc.), the heat transfer medium must be completely drained from the system section in question and collected in suitable containers. Hot work may be carried out on system components only when ignitable vapour/air mixtures have been reliably removed by flushing with inert gas and when this flushing process is maintained during the work.
- When removing leaks (piping repair, replacement of gaskets), all damage insulation must be removed as well.

Insulating material soaked with heat transfer oil is subject to self-ignition and must be replaced without exception during a maintenance process!

- The low-boiling fractions resulting from thermal decomposition of the heat transfer oil must be removed from the system by boiling-out at regular intervals unless an automatic discharge of low-boiling fractions is provided. At any rate, the produced gasoline-like condensate must be disposed of safely and properly (see also in 4.1.4 "System components").
- Regular sampling of the heat transfer oil must be carried out as per the rules and regulations in force (see also chapter 5.3 "Recurring inspections"). Monitoring the quality and composition of the heat transfer oil during maintenance delivers important information about the system condition and is safety critical.

From a risk point of view, it is recommended that a note about the daily, monthly and annual inspections be entered in the inspection book (see also chapter 5.2 "Inspections during commissioning").

Start-up processes

Start-up processes after a system standstill require particular attention because, as experience indicates, most mistakes are made at this stage, causing faults and possibly a fire either immediately or after a short time.

Changing the heat transfer oil

When replacing the heat transfer oil by another product, the usability for the existing system must be verified:

- Only products approved by the installation company of the heat transfer oil system are allowed (see system type plate according to DIN 4754-1). Otherwise, the suitability of the desired substitute product shall be verified by the system installation company (e.g. max. allowed film/feed flow temperature, suitability of gasket material) and confirmed in writing.
- After draining the old heat transfer oil, the system must be flushed completely according to instructions by the producer of the new heat transfer oil unless the producer confirms in writing that flushing is not necessary because the products are compatible.
- Any necessary flushing or cleaning of the heat transfer oil system must use the flushing liquid approved by the producer of the heat transfer oil, solvents such as toluene may never be used.

4.2 Structural fire protection

Heaters of heat transfer oil systems shall be located so that the employees and the environment will not be exposed to any hazards including fire, deflagration or hot heat transfer medium.

It makes sense to integrate the pumps, feed flow and return flow manifolds forming part of the heat transfer oil system in the heater room so that the protective measures for the heater apply to these system components as well.

In heater room or outdoor locations

If requested by the local standards, heaters must be set up in so-called boiler rooms or outdoors.

In case of outdoor location, a minimum distance of 20 m from buildings having walls without a fire rating must be respected. This safety distance may be reduced by structural measures (building a fire wall or a separating wall with a fire rating).

In work room locations

Directly fired heaters and electrically heated units with a certain maximum heat transfer oil volume may be set up in work rooms, following the approval of authorities having jurisdiction and by the occupational health and safety authorities. As minimum requirement a fire zone of at least 1 m has to be free of combustible materials around the systems.

Beyond the combustible materials free zone required in DIN 4754-1, and NFPA 87, great care must be taken to ensure that a fire on the heat transfer oil system cannot spread to equipment that is important for production operations and to load-carrying and reinforcing components of systems and buildings.

To achieve this, a distance of at least 20 m must be maintained or a separation with a fire rating must be provided. Possible leaking burning oil must be taken into account and draining, e.g. by means of a flooring slope, should never be directed towards equipment that is important for production operations, towards media supply systems and rescue routes.

Raised edges may serve this purpose because they form a sufficient collecting space for the leaking oil. The occupational safety regulations (e.g. avoiding of trip hazards in escape routes) must be observed when arranging raised edges.

Pipework and valves

The pipework carrying heat transfer oil frequently leads from the heater room or the place where the heat transfer oil system is set up through other building sections. In this process, penetrations through fire walls or complex separating walls according to building laws or insurance regulations may occur. The rating of the pipework penetrations must not be less than the required fire resistance of the wall.

Fire spread by the heat transfer oil from the separate fire-rated boiler room to other operational areas must be prevented by an automatic shut-off valve. This should be located outside of the heater room at a distance of at least 500 mm from the fire-rated wall. Fire spread due to heat conduction through the piping between the wall and the valve must be prevented by an insulating material collar made of mineral fibres of building materials class A-1 acc. to EN 13501 with a melting point of $\geq 1000^\circ\text{C}$.

In case of fire walls and complex separation walls, such isolation units must be provided on both sides in order to prevent burning liquid from escaping into the area adjacent to the fire. The shut-off units must be provided with limit switches which shut down the heater and the circulation pump of the heat transfer oil system upon actuation of the valve (limit switch actuated when valve is in open position).

Electric lines

When installing electric lines, the local building regulations and the applicable technical standards must be observed. Moreover, only absolutely necessary electric lines should be laid through rooms or areas where heat transfer oil systems are set up because these lines represent an

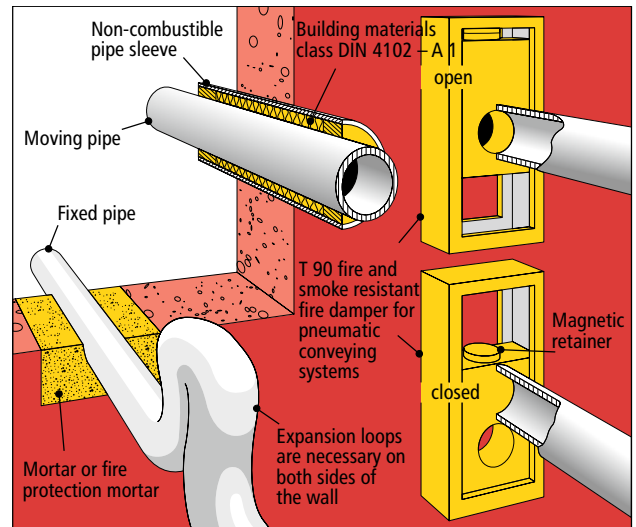


Fig. 8: Wall penetration for non-combustible pipework (detail)

additional fire load in case of fire, adding the hazard of generating corrosive smoke to the fire risk.

4.3 Organisational fire protection

Fire protection documentation

Complete fire protection documentation (e.g. fire safety policy, fire safety plans and emergency response plan) must be available and updated in operations using heat transfer oil systems, regardless of legal or authority requirements.

The fire safety plan is a set of site plans and floor drawings, which show the physical fire safety arrangements, such as locations of fire safety equipment, fire rated walls, fire brigade access routes and special hazards. So the fire safety plan should include the location of the heat transfer oil system, the pipelines and any other possible accumulated hazards. All areas where firefighting with water is not permitted must be clearly highlighted.

In an emergency response plan the detailed flow charts and check lists indicating the responsible persons and contacts for cases of extraordinary events must be available. Special events may include e.g.:

- fire / large-scale fire,
- escape of large oil quantities (environmental accidents),
- accidents with serious injuries (e.g. scalding),
- power failure, water pipe burst, gas leak,
- investigations by the Police / public prosecutor,
- bomb threats / finds of munitions.

In the emergency response plan, the necessary water protection measures in case of large oil leakages or polluted fire water, following a large scale fire, need to be taken into account.

Safety signs

Besides the warning signs placed according the job hazard analysis, permanent and well-visible signs e.g. as below must be provided near the heat transfer oil system:

Caution! Do not use water to extinguish heat transfer oil!

**Instruction of operating personnel**

The operations manager shall instruct the operating personnel regarding fire protection before starting work for the first time and then at adequate intervals, but at least once a year.

4.4 Firefighting

The fire brigade in charge should be involved as early as possible the planning stage of a heat transfer oil system in order to coordinate the preventative fire protection measures as well as quick and effective firefighting options. It must be prepared to extinguish major quantities of burning liquid because burning heat transfer oil cannot be extinguished solely with water.

The fire brigade must be allowed to develop fire pre-plan before the thermal oil system is put into operation so it has local knowledge that should be updated by regular follow-up surveys. In case of large-scale systems, emergency exercises should also be carried out with the fire brigade for training firefighting and personal rescue operations in realistic scenarios.

4.5 Fixed fire protection

Hazard alarm systems

Heat transfer oil system rooms, pumping and distribution stations must be monitored by automatic fire alarm systems designed and installed according to the standards determined by the authorities having jurisdiction.

Heat transfer oil usually burns with dense black smoke. If there are no other deception variables in the surroundings which can cause false alarms smoke detectors should be preferred over other detectors types (e.g. flame or thermal detectors) because smoke detectors react early to smouldering fires (e.g. in the insulation) or even sprayed and unignited heat transfer oil.

After a fire has been detected, the heat transfer oil system shall be brought to a safe condition as quickly as possible.

Extinguishing systems

Fires involving heat transfer oil systems are extremely intense when major heat transfer oil quantities escape. This is due to the system- and material-specific characteristics. Experience indicates that such fires cannot be fought manually and result in extensive destruction of the system components in its vicinity. Use of a fixed automatic fire protection system is therefore necessary as a function of the assessment of the overall risk situation (importance of system for the production process, interruption periods, etc.).

Water with film-forming additives, foam or inert gas are possible fire extinguishing agents. Water without filming or foaming additives is not suitable for fighting a liquid fire because escaping heat transfer oil will float on top of the fire water and spread in the room. Planning and installation of the extinguishing systems must follow the standards determined by the authorities having jurisdiction.

Fire extinguishers

Operating areas from where heat transfer oil can escape constitute areas of increased fire hazard. Compared with areas of normal fire hazard, a higher quantity of suitable fire extinguishers should be provided for initial firefighting, with foam being the primary extinguishing agent. Depending on the heat transfer oil quantity that may possibly escape, large foam-type extinguishers (e.g. 50 litres of foam) may need to be provided in order to enable successful firefighting.

4.6 Explosion protection

In their risk assessment the manufacturer of a heat transfer oil system must consider the hazard caused by the formation of explosive atmospheres. In case explosive atmospheres cannot be completely excluded, necessary explosion protection measures must be listed in the instruction manual.

The party operating the system, on the other hand, has to consider possible explosion hazards within the framework of his hazard assessment according to the local safety regulations and to exclude such hazards by taking suitable measures.

In systems operated at a temperature above the atmospheric initial boiling point and with a flash point of < 220 °C, heat transfer oil escaping from leaky spots must be expected to partly evaporate. When a large quantity leaks out, the room will heat up and reaching the lower explosive limit can no longer be excluded. For this reason, all leaks in such systems should be avoided by design measures if possible, e.g.:

- piping components completely welded,
- use of weld gaskets when flange joints cannot be avoided,
- use of hermetically sealed pumps (e.g. split cage pumps with a second safety shell),
- Inert gas blanket in compensation and collecting tanks.

Potential leak points of evaporated heat transfer oil or low-boiling components must be treated as an explosion protection zone, depending on the frequency of an explosive atmosphere to be expected (preparation of explosion protection document, keeping potential ignition sourced out, marking). This includes above all the

- ventilation line of the expansion and collecting tank,
- safety valves and
- low-boiling fractions drain.

The vent lines and the discharge lines of safety valves should therefore be realized as completely welded lines and laid to a safe point outdoors. The low-boiling fractions drain must be treated as an explosion protection zone, which is adequate to the risk.

Exit openings of heat transfer oil system vents and of safety valves must be free of potential ignition sources and must also be protected against overvoltage from lightning and against the effects of lightning strike at a greater distance.

In addition, the ingress of water, foreign substances and small animals (e.g. birds, insects) must be prevented by suitable measures.

No intake openings of room ventilation systems or of technical systems (e.g. heater feed air) may be located near outlet openings.

5. Inspections.

Heat transfer oil systems are subject to the local safety regulations because, from a legal point of view, they are working equipment. They shall be rated as systems requiring surveillance if they contain at least one pressure device requiring surveillance in the sense of the local safety regulations. The scope of inspections for the system must be defined accordingly in order to prevent hazards to employees and third parties.

The inspections to be carried out can be sub-divided into three groups:

- inspections prior to commissioning,
- inspections during commissioning,
- recurring inspections.

5.1 Inspections prior to commissioning

After the installation of the system or after a major modification, the heat transfer oil system must be checked to confirm that it is in a good working condition. The aspects to be checked include

- completeness (order inspection),
- tightness,
- pressure resistance,

- function and
- cleanliness (i.e. weld slag, spatter, mill scale, water).

5.2 Inspections during commissioning

In the first commissioning phase, the water still present in the system (at least the water portion dissolved in the heat transfer oil) and other gaseous constituents must be removed by boiling-out. Depending on system design, this is achieved either by an installed gas separator or by heating up the expansion vessel and using a boil out line. Boiling-out must be continued at least until no more pressure variations occur in the system when including the entire system volume into the heating-up process.

Following a thorough system check for

- tightness,
- pipe expansion and deformation,
- unpermitted stress and

checking of all temperature and pressure gauges, the set operating temperature can be approached in step by step increments. In this process, sufficient heat dissipation on the consumer side must always be ensured and the system must permanently be monitored for tightness, leaks and deformations.

After reaching the set temperature, the thorough visual inspection of the system must be repeated. At this time, the alignment of the pump shaft and the motor shaft of baseplate-design pumps (process design) must be checked and corrected if necessary because an offset may in the long term destroy the bearings and seals.

Now the function of all safety devices must be checked by varying the switching points and the switching point default values must be set.

The system documentation is an important part of the system and contains, for safe operation, instruction of employees working on the system and for proving inspections. The documentation should be complete by the time of system commissioning and at hand-over to the operating company at the latest. In addition, an inspection book must be kept for each heat transfer oil system.

5.3 Recurring inspections

The period of recurring inspections of systems and system parts shall be determined by the operating party using the installer's manual and according the local occupational health and safety regulations. It is advisable to consult the heat transfer oil system manufacturer in this process.

In case of systems and system parts requiring surveillance and to be inspected by an approved surveillance agency at regular intervals, the maximum periods specified in the operational safety regulations must not be exceeded.

All system parts (including valves, pumps, trace heating, electric equipment and special equipment) are subject to obligatory regular inspections; the type and scope of inspections can be taken from the legal and authority regulations, from technical rules and the operating instructions of the manufacturers.

The entire system must be visually inspected by an instructed employee at regular intervals, but at least once a month. During system operation, hints pointing to defects should always be observed, e.g.

- liquid pools or traces,
- accumulated incrustations,
- deformations,
- discolourations,
- unusual noises and smells,
- unusual smoke colours and
- smoke or steam escaping from component joints or vents.

Safe once, safe forever?

"Safety does not last forever!" The system operating company is obliged to keep the system in safe condition for employees and third parties "during the entire service life" according to state of the art technology. This includes the obligation to observe the improvements in technical best practices regularly and, should there be any new findings, e.g. following accidents, to implement the consequences resulting from that experience in its system within a reasonable period of time.

The continued usability of the heat transfer oil must be checked as needed, but at least once a year (DIN 4754-1).

Cases of need e.g. include:

- when start-up operation is finished,
- three months after putting the system into operation
- for the first time,
- three months after changing the heat transfer medium,
- after the heat transfer medium was overheated,
- when the mode of operation is changed.

A complete fluid test must be carried out by a qualified laboratory for examining the heat transfer oil. The test should have as a result:

- flash point,
- viscosity,
- total acid number,
- moisture,
- insoluble solids,
- low and high boiling components .

In this process, the boiling curve (portion of high- and low boiling fractions) should also be determined. It is recommendable to let the test be done by the manufacturer of the heat transfer oil.

6. Further reading.

6.1 Legal and authority safety regulations

The applicable legal and authority safety regulations shall be taken into account for the country where the heat transfer system is erected. At minimum must be considered the national

- pressure vessel codes,
- electrical safety codes,
- building regulations,
- fire safety standards,
- explosion prevention codes,
- occupational health and safety regulations,
- environmental protection codes.

Technical rules

- NFPA 54, National Fuel Gas Code, 2015 edition.
- NFPA 70, National Electrical Code.
- NFPA 85, Boiler and Combustion Systems Hazards Code, 2011 edition.
- NFPA 86, Standard for Ovens and Furnaces, 2015 edition.
- NFPA 87, Standard for Fluid Heaters, 2018 edition.

European and international Standards

- API Standard 682 – 4th Edition Pumps – Shaft Sealing Systems for Centrifugal and Rotary Pumps.
- EN 746-1:2010-02; Industrial thermo processing equipment – Part 1: Common safety requirements for industrial thermo processing equipment.
- EN 746-2:2011; Industrial thermo processing equipment – Part 2: Safety requirements for combustions and fuel handling systems.
- EN 1127-1:2011; Explosive atmospheres, Explosion prevention and protection. Basic concepts and methodology.
- EN 13501-1:2007+A1:2009; Fire classification of construction products and building elements – Part 1: Classification using data from reaction to fire tests.
- IEC 60204-1: – 2016; Safety of machinery – Electrical equipment of machines – Part 1: General requirements.
- IEC 60519 – 1:2015; Safety in electro heating and electromagnetic processing installations – Part 1: General requirements.
- EN 60519-2:2006; Safety in electro heating installations – Part 2: Particular requirements made on resistance heating equipment.
- EN 60398:2015; Electro heating installations and electromagnetic treatment – general test procedures.
- ISO/DIS 21049:2010; Pumps – Shaft sealing systems for centrifugal and rotary pumps.
- DIN 4754-1 Heat transfer installations working with organic heat transfer.

The technical standards listed above are considered industry best practise at the time of printed this Risk Engineering Guideline. The valid issues of each of the above documents must be used for design, installation and operation of heat transfer oil systems.

6.2 Other literature - Bibliography

- Dow Chemical Co. Engineering Manual for DOWTHERM Heat Transfer Fluids, Form No. 176-1334-591 AMA, 1991.
- DOW Chemical Co. Health, Environmental and Safety Considerations in High Temperature Heat-Transfer Fluid Systems. Form No. 176-1336-87, 1987.
- Green, R.L. and A. H. Larsen, et. Al. „Get Fluent About Heat-Transfer Fluids“. Chemical Engineering Vol.96, No.2 (February 1989)
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- Mobil Oil Company, Heating with Mobiltherm Heat-Transfer Oils. Mobil Technical Bulletin.
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- Andre Garcia McDonald, Hugh Magande; Introduction to the thermo fluid systems design. Chichester, West Sussex, United Kingdom: John Wiley & Sons Inc., 2013.

6.3 Terms

- **Qualified persons**
A qualified person in the sense of the present Risk Engineering Guideline is someone who, by possession of a recognized degree, certificate, or professional standing, or who by extensive knowledge, training and experience, has successfully demonstrated his ability to solve or resolve problems relating to the subject matter, the work, or the project (following the OSHA definition).
- **Operating company**
The "Operating company" in the sense of the present Risk Engineering Guideline is the "employer" in the sense of the local occupational health and safety regulations.
- **Approved supervision agency**
An approved supervision agency is any supervision agency nominated by the local Ministry for Labour and Social Affairs as inspection agency for a certain scope of tasks by the state authority in.
- **Authority having jurisdiction**
An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure.
- **Consumer circuit**
In most systems, the temperature at the heat consumer is not controlled at the heater, but by using constant flow rate control with a bypass line and a three-way valve (for an example see figure 2).
- **Feed low temperature**
The feed flow temperature in the sense of this Risk Engineering Guideline is the heat transfer medium temperature measured directly at the heater outlet.
- **Film temperature**
The film temperature in the sense of this Risk Engineering Guideline is the wall temperature of the system components on the heat transfer medium side. The spot with the highest film temperature is the spot of the highest thermal load of the heat transfer medium.
- **Fire-resistant**
In the sense of this Risk Engineering Guideline, components are fire-resistant if they meet at least fire resistance class EI90-A according to EN13501 or if at least fire resistance class EI90-A was proved for them by fire tests according to the conditions of EN13501 or if a test certificate has been issued and/or a "General construction supervision approval" has been granted.
- **Fire-retardant**
In the sense of this Risk Engineering Guideline, components are fire-retardant if they meet at least fire resistance class EI30 according to EN13501-1 or if at least fire resistance class EI30 was proved for them by fire tests according to the conditions of EN13501-1 or if a test certificate has been issued and/or a "General construction supervision approval" has been granted.
- **Flash point**
The lowest temperature of a liquid at which its vapours will form a combustible mixture with air.
- **Heaters**
Heaters in the sense of this Risk Engineering Guideline include system components heated by fire, waste gas, electric energy or steam in which organic heat transfer media are heated.
- **Hermetically sealed pump**
Pumps in which no shaft penetration from the liquid-filled inside to the outside is required for drive purposes are referred to as hermetically sealed pumps (or no-leak pumps). Typical designs include the magnetic drive pump and the canned pump.
- **High-boiling fractions**
Under a thermal load, large molecules form in organic heat transfer media due to polymerisation and/or condensation which are dissolved in the heat transfer oil to a certain degree, but which may also deposit in the system as tar-like or solid residues.
- **Low-boiling fractions**
The thermal load on the heat transfer oil breaks up bonds in the molecular structure, generating decomposition products.

- **Magnetic drive pump**

The magnetic drive pump is a pump without a shaft seal, transmitting its shaft torque by a permanent-magnet clutch drive (magnetic clutch), using magnetic induction.

- **Manufacturer (also referred to as "Installation company")**

The "Manufacturer" or "Installation company" of a heat transfer oil system in the sense of this Risk Engineering Guideline is the "Manufacturer" in the sense of the Machinery Directive. This may be the installation company of either a complete heat transfer oil system or e.g. the installation company of a production plant in which the purchased components of a heat transfer oil system are only a part of the overall system.

- **Maximum permitted operating temperature**

The maximum permitted operating temperature in the sense of this Risk Engineering Guideline is the highest heat transfer medium temperature fixed by the system installation company for the various components for safety reasons.

- **Minimum flow rate**

The minimum flow rate in the sense of this Risk Engineering Guideline is the flow rate in the forced-circulation heater (circulation by circulation pump) which must be provided as a minimum in order to avoid unpermitted overheating of the heat transfer medium.

- **Organic heat transfer media**

Organic heat transfer media ("Heat transfer oils", "Thermal oils") in the sense of this Risk Engineering Guideline include organic liquids transferring thermal energy.

- **Secondary circuit**

To enable regulating the temperature of several heat consumers by means of a heater, several separate hydraulic circuits (secondary circuits) are connected to the heater circuit (primary circuit).

- **Canned pump**

The canned pump is a unit without a shaft seal. The motor and the pump constitute a unit having the rotor and the impeller arranged on one common shaft. The drive motor stator is separated from the rotor space by a thin split cage.

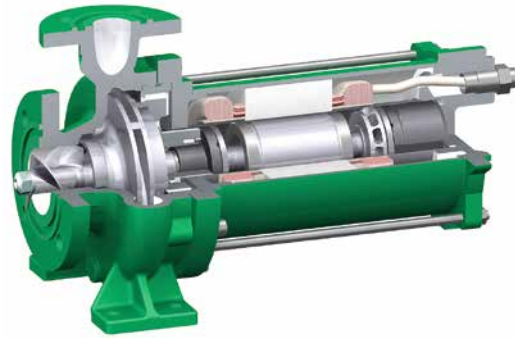


Fig. 9: Canned pump

- **State of the art**

The state of the art is the development status of advanced processes, facilities or operating modes which makes the practical suitability of a measure or procedure for protecting the health and safety of employees or other persons appear safe. When determining the state of the art, especially similar processes, facilities or operating modes that have successfully been used in practice shall be considered.

- **Technical rules (generally recognized...)**

"Generally recognized technical rules are those principles and solutions that have been tried and tested in practice and that have gained acceptance by the majority of practitioners of the trade." Therefore besides the theoretical component – i.e. suitable scientific findings – a practical component is also necessary: The process must have proved its worth in practice. There is no need to fix technical rules in writing.

- **Technically tight, permanently**

See EN 1127-1:2011 Explosive atmospheres, Explosion prevention and protection. Basic concepts and methodology.



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HDI Risk Consulting GmbH
HDI-Platz 1 – D-30659 Hannover
Phone: +49 511 645-3219
Fax: +49 511 645-4542
Internet: www.hdi.global

Imprint
Responsible for the content:
HDI Risk Consulting GmbH

Layout: Insignio Kommunikation GmbH
Fotos: ARI-Armaturen, Flangeguards, Fotolia,
HERMETIC-Pumpen GmbH, HTT energy
GmbH, ROCK-WOOL Technical Insulation
Process Manual , VdS

