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MANUAL

HEAT TRANSFER FLUID (HTF) SYSTEMS

DEP 20.05.50.10-Gen.

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DESIGN AND ENGINEERING PRACTICE

PREFACE

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1. INTRODUCTION

1.1 SCOPE

This DEP specifies requirements and gives recommendations for the design of heat transfer fluid (HTF) systems operating at bulk temperature levels up to 400 °C. It includes the application of the organic (both mineral and synthetic) and silicone-based types of HTFs but excludes water/steam and molten, inorganic salts. The scope of this DEP is restricted to liquid phase operation only.

This DEP refers to HTFs as defined in (1.3.2) and explicitly excludes 'Hot Oils'. HTFs have the ability of long term operation at far higher operating temperatures than hot oils, at relatively low pressure and with low degradation and fouling.

This DEP is a revision of the DEP of the same number dated September 1992.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

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

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

1.3 DEFINITIONS

1.3.1 General definitions

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

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

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

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

1.3.2 Specific definitions

The temperature and pressure terms used in this DEP are defined in DEP 01.00.01.30-Gen. Further terms are defined below.

Expansion vessel	A vessel to accommodate expanded volume and surge of the HTF.
Heat transfer fluid (HTF)	A fluid capable of transporting heat energy within a specified temperature range. Specific hydrocarbon-based fluids are available on the open market for use in heat transfer applications. Generally, this includes synthetic aromatic, silicone-based and a limited selection of mineral oils.
Heater	The heat energy producer in the system, either a furnace or a waste heat recovery unit (WHRU).
Hot oil	A mineral oil product stream used for heat transfer purposes but not commercially available as branded HTF.
HTF system	All heaters, piping, pumps, vessels, heat exchangers and auxiliaries that constitute the closed circuit containing the HTF.
Maximum allowable bulk temperature	The maximum bulk temperature of the HTF allowed anywhere in the circuit, as specified by the manufacturer.
Maximum film temperature	The maximum temperature to which the HTF may be subjected in the system. This highest temperature is on the tube inner wall of the heater skin and is determined by the heat flux and heat transfer coefficient.
Maximum operating temperature	The maximum HTF bulk temperature at which the system is designed to operate and measured at the outlet of the heat source.
Minimum allowable bulk temperature	The minimum bulk temperature of the HTF allowed anywhere in the circuit, as specified by the HTF manufacturer.
Minimum operating temperature	The lowest HTF bulk temperature at which the system is designed to start up. It should always be higher than the pumpability limit (fluid maximum viscosity of 150 cm^2/s).
Return temperature	The temperature at which the HTF returns to the heat source.
Storage tank	A tank for storage of HTF, also capable of retaining the full HTF inventory in case of a hot fluid emergency evacuation of the circuit.
Supply temperature	The temperature at which the HTF is made available to the battery limit of the users.
Trim cooler	A cooler in the heating circuit, used to trim the temperature of the HTF.

1.4 CROSS REFERENCES

Where cross references to other parts of this DEP are made, the referenced section number is shown in brackets. Other documents referenced in this DEP are listed in (3).

2. GENERAL REQUIREMENTS FOR HEAT TRANSFER SYSTEMS

2.1 GENERAL

The Principal shall specify the HTF to be used.

Figures 1A and 1B show possible simplified schemes of HTF systems, one with a furnace and the other with a WHRU. They identify the main system components and basic controls.

NOTE: The final lay out and control scheme depends on the type of heat recovery, operational requirements and conditions and HTF characteristics in relation to operating temperatures.

2.2 HEATER

The heat source/energy producer may be a heater (furnace), a waste heat recovery unit (WHRU) linked to a gas turbine or other hot flue-gas producer, or a heat exchanger. The heater design shall ensure that the HTF will not be subjected to temperatures above the maximum allowable film and bulk temperature specified by the Principal. For systems with heaters arranged in parallel, sampling facilities shall be provided to allow evaluation of HTF degradation in the parallel loops.

To provide sufficient operational flexibility and, in the case of organic fluids, allow for the slowest possible degree of fluid ageing, the location of maximum HTF film temperature and peak heat flux should not coincide.

If parallel bundles are used for heating (either heat exchangers, heaters in parallel or individual coil passes with no valves installed per pass), the manifold shall be designed so that the ratio of lowest-to-highest flow is maximum 1.05.

2.3 EXPANSION VESSEL

2.3.1 Purpose

The expansion vessel allows for thermal expansion of the HTF and for venting low boiling components generated in the HTF during its ageing process, and is used to minimise the consequences of upsets in the HTF system operation. The designer shall take into account the following:

- the need to accommodate the thermal expansion of the HTF heated from minimum to maximum operating temperature;
- the need to maintain the required Net Positive Suction Head (NPSH) for the HTF circulating pumps under all operational scenarios;
- the need to reduce the risk of HTF loss into the flare system. In the event of a a tube rupture inside heat transfer equipment operating at process pressures above that of the HTF circuit, sudden displacement of fluid from the system into the vessel can result in HTF loss into the flare system. IPF classification shall be performed in accordance with DEP 32.80.10.10-Gen. to indicate whether measures need to be taken;
- possible presence of water in the circuit during start-up;
- the need for sufficient HTF inventory to allow filling of equipment and during re-commissioning after shutdown for maintenance.

2.3.2 Location and configuration

The expansion vessel shall be connected to the system return line on the pump suction side. The vessel should be elevated so that the normal operating level of the HTF in the vessel is higher than the highest possible HTF level in the system. (This will facilitate proper venting and provide sufficient NPSH for the pump.) If this requirement would be difficult to meet, a lower elevation may be selected but then provisions shall be made to prevent vapour being locked in the higher parts of the circuit and to evacuate such a vapour lock if it occurs.

A distinction is made between systems with and without an automatic HTF make-up and draw-off facility. HTF make-up and draw-off should normally be initiated by an operator; automatic HTF make-up and draw-off shall be incorporated in the design only if there is a clear justification.

The vessel and its piping should be designed for the full flow of the HTF through the vessel. The “single-leg” design (“cold fluid” expansion vessel) may be chosen only with the approval of the Principal.

The expansion vessel shall be equipped with a dry nitrogen blanket to serve as a barrier between the hot fluid (usually operating at a temperature above its flash point) and the atmosphere, contact which would otherwise speed up degradation of the HTF and allow moisture to enter the system (which might create corrosive acid compounds and a safety hazard).

For operation at high temperatures, particularly approaching or exceeding the boiling point of the HTF, a positive pressure of at least 1 bar to 2 bar above the vapour pressure of the HTF (at this temperature) should be maintained.

The nitrogen supply shall be equipped with a split-range controller and a non-return valve, which will regulate the nitrogen supply and its relief to flare.

A dead pressure zone is required between nitrogen supply pressure and relief to flare set pressure. In this dead zone, the pressure is not controlled and is allowed to float freely while the nitrogen supply and relief-to-flare valves are both closed. This dead zone will reduce nitrogen consumption.

At a certain controller output, the relief-to-flare valve should be prevented from starting to open while the nitrogen supply valve is not yet fully closed. (This could easily be the case due to small valve misalignments.)

The non-return valve shall prevent HTF and nitrogen back-flow into the nitrogen system in the event of pressure increase in the vessel.

Low boiling degradation products shall be vented periodically. If regular venting of vapours is unavoidable, the vent line should be routed through a condenser to the collecting drum and flare, for further incineration or safe disposal.

The vessel shall be equipped with a safety relief arrangement capable of protecting the system against over-pressure caused by fluid degradation, contamination, maloperation, overheating or tube failure in equipment.

To allow for the pressure rise during steaming-out or purging the heater coils, relief valve(s) shall be sized to accommodate a flow of steam or purge nitrogen equivalent to a vapour velocity of 15 m/s in the heater coils. If necessary, the purge flow may be limited by installing a restriction orifice in the common supply line.

The safety relief line shall be routed to flare.

If the ambient temperature can fall below the fluid’s or its degradation products’ freezing points, or if accumulated high boilers can plug the lines, nitrogen, vent-back-pressure and safety relief lines and valves shall be heat traced in order to prevent plugging.

If the ambient temperature can fall below the HTF’s pumpability limit, heating the expansion vessel should be considered. In order to eliminate the risk of HTF contamination in the event of coil rupture, either electrical heating or external heat tracing should be applied. Heating with steam or hot water should be avoided in order to minimise HTF contamination.

NOTE: The possibility to evacuate the total HTF inventory would eliminate the need for a special heating device for the vessel.

The expansion vessel shall be insulated.

2.3.3 Sizing

The size of the expansion vessel depends upon the expansion coefficient, maximum temperature and quantity of the fluid in the circuit. The preliminary sizing shall be based upon the estimated quantity of fluid and shall be adjusted when the final design stage is completed. It is the responsibility of the Contractor to review and, if necessary, revise the vessel dimensions during the detailed design phase, when the relevant equipment sizes, line sizes, plot plans and piping layouts are known.

The expansion vessel has the combined function of an expansion vessel and a knock-out vessel. It shall have sufficient capacity to cater for various operating upsets in the system. The vessel dimensions shall be calculated and the maximum level set according to DEP 31.22.05.11-Gen.

The vessel can be divided into three sections, as follows:

1) Up to low level

   The expansion vessel shall be located high enough to ensure adequate NPSH for the HTF circulation pump at minimum level. It shall be checked whether the NPSH requirements are met at relevant working temperatures. The minimum level should be at 25% of the vessel volume.

2) Low up to high level

   The volume between high and low level shall be equal to the expansion volume of the total fluid inventory from minimum possible operating temperature to maximum possible operating temperature in the system. An additional 20% shall be added to cater for various operating upsets in the systems such as vaporisation of residual water in the system and a tube burst.

   Although the design pressure on the HTF side may be higher than that on the process side, the working pressures may be the reverse, which means that process fluid could enter the HTF in the event of a tube or vessel rupture.

3 Above high level

   The remaining 25% of the vessel volume shall be filled with nitrogen and kept for uncontrolled fluid volume increase.

2.4 STORAGE TANK

The HTF storage tank shall have sufficient capacity to hold the full inventory of the system, plus an additional 10% volume to accommodate make-up of losses caused by venting and mechanical leaks.

The minimum fluid level in the tank shall be set to ensure sufficient NPSH for the make-up pump. If the ambient temperature can fall below the HTF minimum pumpability temperature, the tank should be heated, preferably electrically, and the suction line to the pump should be heat-traced and insulated. The storage tank shall be equipped with a dry nitrogen blanket to serve as a barrier between the fluid and the atmosphere to limit degradation and moisture ingress

Sudden drainage of the hot HTF to the storage tank (in case of emergency evacuation of a part of or the whole fluid inventory) could result in excessive vapour release inside the tank. That shall be avoided either by installing a drop volume cooler (expensive option) or by feeding the hot HTF to the tank through a perforated pipe submerged in the cold fluid. The latter option shall be designed so that there is thorough mixing of the hot fluid, giving rise to rapid cooling and elimination of, or sufficient reduction in, vapour production. For the latter option, this amount of cold HTF shall be added to the minimum tank capacity as defined above.

2.5 PIPING

Piping shall be carbon steel unless specified otherwise. To minimise the possibility of leakage, the connections shall be welded as far as possible.

All low points of piping shall be equipped with drains for removal of residual water prior to commissioning the system. An underground equipment draining system should be installed to collect HTF and return it to storage when equipment is drained for maintenance.

Provisions shall be made for blowing out the system with hot air or (preferably) nitrogen to ensure the system is dry prior to start-up.

In systems with heat users operating at pressures above that of HTF system, the piping design shall account for all hazards caused by a tube rupture inside this equipment.

Piping shall be sized for a total flow of 110% of the maximum flow.

The spill-over lines and control valves shall be sized for the flow of the largest consumer to allow for a sudden block-off of the heat user. Manual bypass lines shall be sized for 100% flow.

The following shall apply except for double-pipe heat exchangers:

> If the process pressure exceeds the HTF system pressure, the preferred arrangement is to ensure a free flow (no valves) from the consumer (heat exchanger) to the expansion vessel. The following alternatives may be applied:
>
> 1. The HTF system shall be designed for the higher pressure; or
> 2. Safety relief valves shall be installed at the outlets of the the affected heat exchangers, with relief to flare via a liquid separator.

HTF velocities shall be based on optimising the system with respect to Capex (line size and pump size) and Opex (pumping power). However the circulation pump suction line shall be based on a maximum velocity of 3 m/s. For high velocities care shall be taken to avoid erosion problems.

Piping shall be in accordance with DEP 31.38.01.11-Gen and DEP 31.38.01.12-Gen. (piping class 31160).

Pipe supports shall be in accordance with DEP 31.38.01.29-Gen.

2.6 HEAT EXCHANGERS (CONSUMERS)

If designed and operated properly, HTF systems can be considered to be non-fouling, so U-tube type heat exchangers may be applied if the HTF flows inside the tubes. This is cheaper than floating head type heat exchangers and significantly reduces the risk of leakage and, consequently, contamination of the HTF or process fluid.

To ensure proper design of the heat exchangers, the requisition sheet shall clearly mention the type of HTF to be used, or its trade name. For the design specification of HTF systems a fouling resistance of 0.00017 m^2/kW shall be used. This is lower than the values listed in DEP 20.21.00.31-Gen due to the low fouling potential.

If leakage of the HTF into the process side (liquid or gas) could lead to hazardous situations, the equipment design pressure shall be at least twice the highest working pressure of the HTF system. Flanged connections shall be avoided where possible.

All heat exchangers should be equipped with drains and vents to allow the HTF to be drained into a collection system from where it can be pumped back to the storage tank (e.g.

to allow maintenance of the system). To speed up the evacuation, a nitrogen purge point may be considered.

2.7 PUMPS

Two 100% capacity pumps shall be provided unless there is a clear justification for three 50% capacity pumps. If continuous filtration is applied via a bypass over the pump, the capacity of the pumps shall include this additional flow.

In the event of low HTF pressure, the spare pump shall take over automatically. This shall be indicated in the control room by an audible and visual alarm.

If the HTF reaches its auto-ignition temperature, the heat source shall be tripped out.

Pump seals shall be selected based on the hazard classification in DEP 31.29.00.33-Gen. Dual seals shall be applied in hazardous service as defined in DEP 31.29.02.30-Gen.

2.8 INSTRUMENTATION AND CONTROL

Instrumentation shall be selected and designed according to DEP 32.31.00.32-Gen. and DEP 32.36.01.17-Gen.

The system shall be designed to allow stable operation at continuous turn-down of heat demand from design heat duty to zero. As heat demand from, and HTF flow to, the heat consumers decreases, HTF flow to the HTF heater shall be maintained at or above a certain minimum level to avoid high film temperatures, depending on the heater design. This is achieved by a flow controller in the HTF feed line to the heater which opens the spill-over bypass. An example is given in Figure 1A where the flow controller is overriding the PDC signal to the spill-over bypass. If the flow through the spill-over bypass is not sufficient, the signal can also override the return temperature controller and open the full-flow bypass.

A fired heater will turn down to its minimum firing condition and the design operating heater outlet HTF temperature shall be maintained by dissipating the heat absorbed via a trim cooler either parallel to the consumers or in the return line to the heater. In Figure 1A the furnace outlet temperature controller, together with the flow controller, can decrease the set point of the return temperature controller. The return temperature controller will increase the flow through the cooler by opening the full flow bypass. As a result the PDC controller will decrease the flow in the spill-over bypass.

If a WHRU is used instead of a fired heater there could be no turn-down of heat input to HTF available. In such a case, the flow rate through the heating coil shall be controlled or maintained and excess absorbed heat shall be dissipated by coolers. The position and number of coolers shall be optimised for the system design (a single system cooler will normally be sufficient). An example is given in Figure 1B where the WHRU HTF outlet temperature is controlled via the flow through the WHRU which, in turn, is controlled via a bypass over the pump. In the event that the flow through the WHRU is at maximum (bypass fully closed) and the WHRU HTF outlet temperature exceeds the set point, the resulting signal from the temperature and flow controllers will decrease the set point of the return temperature controller. Similar to Figure 1A, this results in a lower WHRU inlet temperature.

Heater firing shall be tripped if HTF flow to the heater falls below the minimum allowed. The trip shall be provided with a timer (10 seconds) to override the trip signal during a short period of low flow. Such moments of low flow may take place when the spare circulation pump - triggered by the HTF low pressure reading (signal) - takes over automatically. The minimum circulation flow trip shall be set at approximately 70% of minimum flow as specified for the furnace.

2.9 MISCELLANEOUS

2.9.1 Trim cooler

In order to improve operation and increase the flexibility of the HTF system, a trim cooler should be installed which is capable of replacing the minimum heater duty. Typically, an air-cooled heat exchanger should be selected.

2.9.2 Insulation

Because of their low surface tension and low viscosity at operating temperatures, HTFs have a tendency to penetrate joints, gaskets and seals. This results in leaks that can lead to accumulation of fluid inside insulation. Insulation materials such as mineral wool or similar, when saturated with organic HTFs, can cause slow exothermic oxidation starting at temperatures above 250 °C. The large internal surface area, poor heat dissipation and the possible catalytic activity of the insulation material may cause significant temperature build-up within the insulation mass. Such slow reaction may progress undetected and may lead to unsafe situations such as sudden fires when cladding is damaged or opened for maintenance.

No insulation or non-absorbent insulation (e.g. foam glass) shall be used at potential fluid ‘creepage’ locations (instrument connections, valve stems, flanges and joints). For silicone-based fluid, closed cell styrofoam (or similar) may be used.

2.9.3 Strainers and filters

During commissioning, the suction line of the circulation pump shall be fitted with a temporary wire mesh strainer to prevent mill scale, weld spatter, sand and other debris from entering the pump (see Standard Drawing S 38.002). To avoid flow obstruction during operation, the fine mesh should be removed as soon as these solids have been removed from the system.

Fitting permanent filters shall be considered for continuously filtering the HTF. If permanent filters are installed, at least two shall be fitted in the bypass around the pump in parallel with the valve. Either a delta pressure indicator over the filters or a flow indicator in the bypass shall be fitted to allow monitoring of fouling.

3. REFERENCES

In this DEP, reference is made to the following publications:

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

SHELL STANDARDS

Index to DEP publications and standard specifications	DEP 00.00.05.05-Gen.
Definition and determination of temperature and pressure levels	DEP 01.00.01.30-Gen.
Fouling resistances for heat transfer equipment	DEP 20.21.00.31-Gen.
Gas/liquid separators	DEP 31.22.05.11-Gen.
Fired heaters, including waste heat boilers (amendments/supplements to API 560)	DEP 31.24.00.30-Gen
Shaft sealing systems for centrifugal and rotary pumps (amendments/supplements to API 682)	DEP 31.29.00.33-Gen
Centrifugal pumps (amendments/supplements to API Std 610)	DEP 31.29.02.30-Gen.
Piping - general requirements	DEP 31.38.01.11-Gen
SIOP piping classes	DEP 31.38.01.12-Gen.
Pipe supports	DEP 31.38.01.29-Gen.
Instruments for measurement and control	DEP 32.31.00.32-Gen.
Control valves - selection, sizing and specification	DEP 32.36.01.17-Gen
Classification and implementation of Instrumented Protective Functions	DEP 32.80.10.10-Gen.

STANDARD DRAWING

Y-type strainers, ANS classes 150 and 300	S 38.002

APPENDIX 1 FIGURES

FIGURE 1A OVERALL LAYOUT OF AN HTF SYSTEM WITH A FURNACE

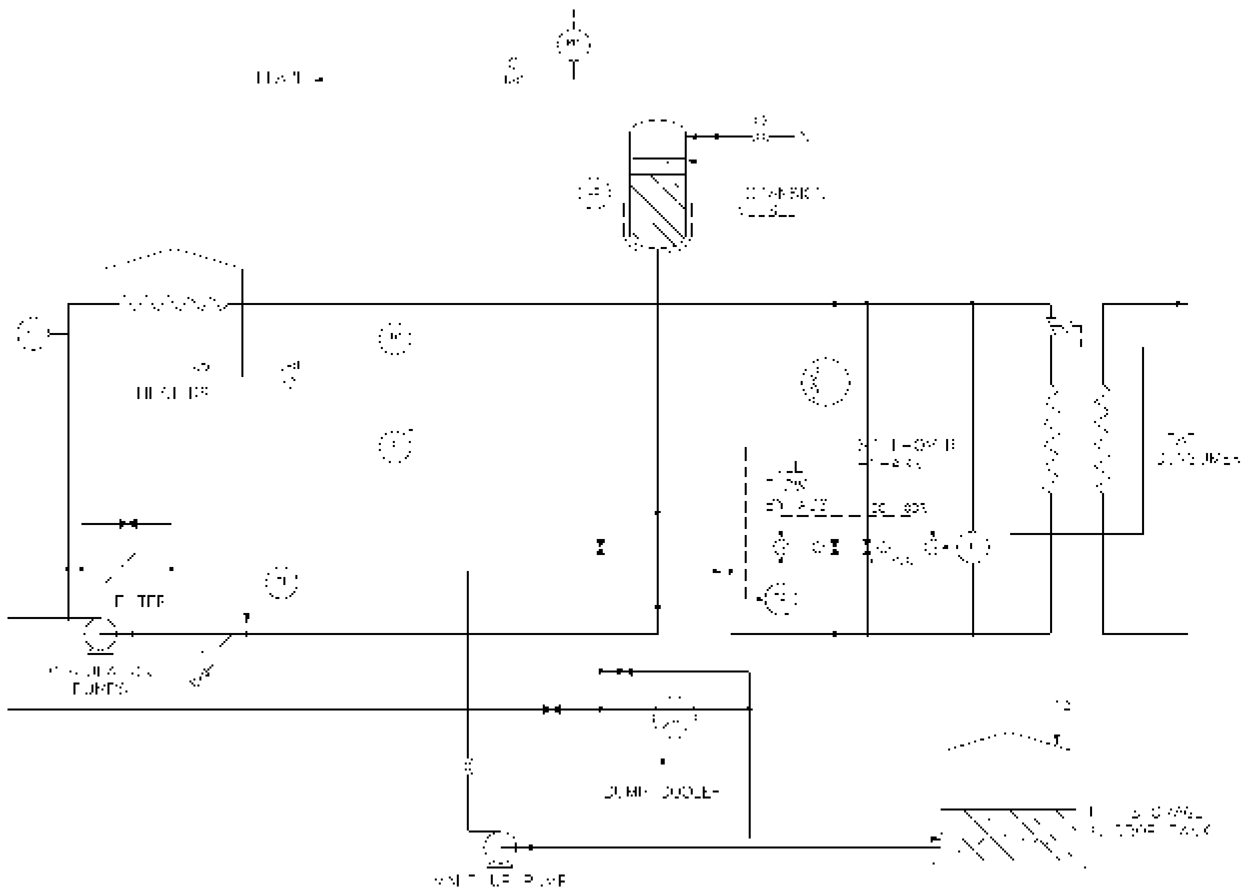

FIGURE 1B OVERALL LAYOUT OF AN HTF SYSTEM WITH A WHRU