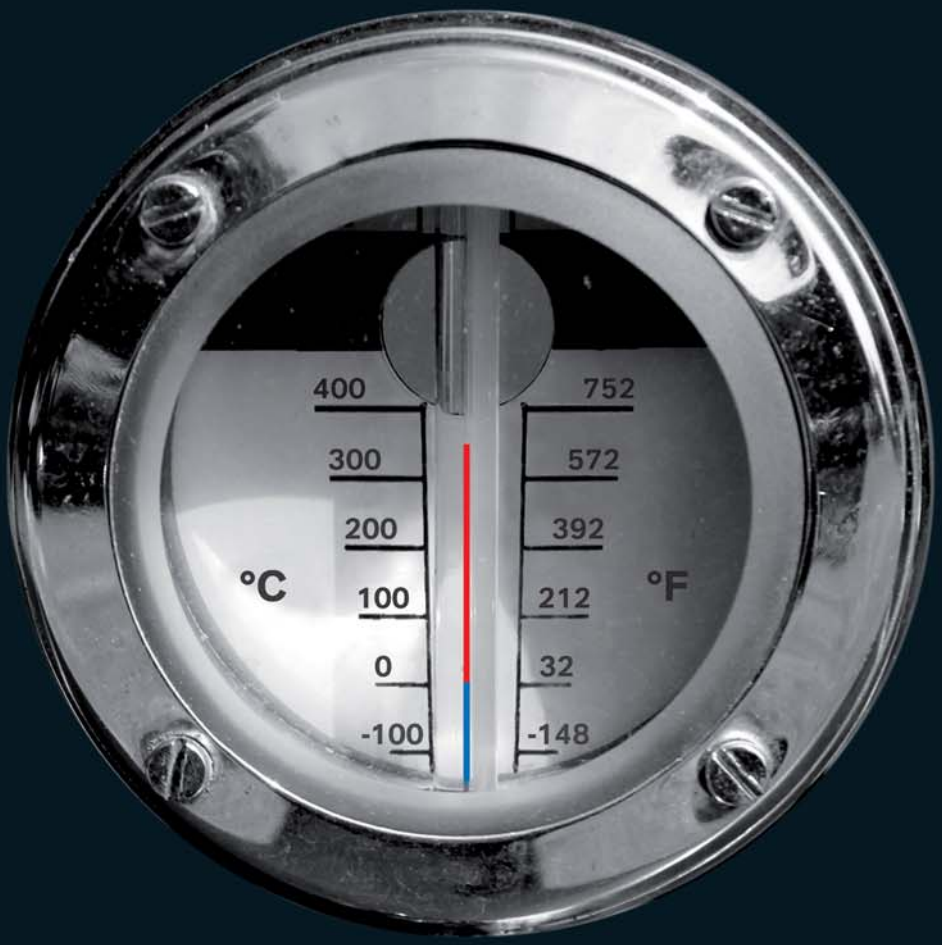
QUALITY HEATS.



Heat Transfer Fluids

Diphyl® Diphyl® DT Diphyl® KT Diphyl® THT

QUALITY WORKS.

LANXESS

LANXESS Distribution GmbH

WELCOME
TO LANXESS DISTRIBUTION

LANXESS is a leading specialty chemical company, currently represented with more then 50 production sites worldwide. The core business of LANXESS is the development, manufacture and marketing of plastics, rubber, intermediates and specialty chemicals.

As a 100% subsidiary, LANXESS Distribution GmbH is focused on the marketing and distribution of premium chemical products, providing expert solutions and specialist advice to our customers.

Combined with our technical expertise, international network, flexible lot sizes and outstanding service, this has made us a reliable, long-term partner for industry worldwide.

We offer products for the chemical industry, personal care, animal nutrition and selected plant protection products.



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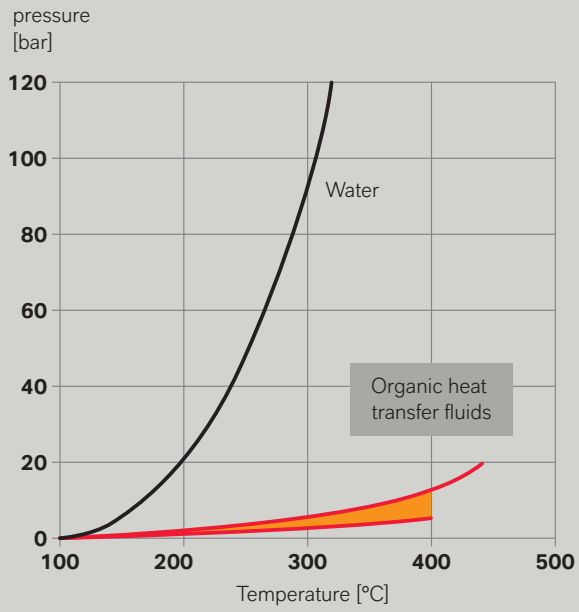
1. GENERAL INFORMATION

1.1. Applications

In many branches of industry, particularly in the manufacture of chemical and petrochemical base materials, large quantities of heat often have to be transported at high temperatures. Heating, for instance, can be most simply accomplished directly with a flame. However, this method is often impractical due to the risk of localised overheating, imprecise control of the temperature of the material being heated, and the ignition of flammable substances.

These disadvantages are generally avoided by way of indirect heating with fluids, so-called Heat Transfer Fluids (HTF). HTF can be used for heating and for temperature control, as well as for cooling, e.g. in the case of strongly exothermic processes. In addition, they offer the possibility of economically channelling generated waste heat back to suitable processes linked to the circuit, or for preheating reactants.

Vapour pressure curves of water and organic heat transfer fluids



In comparison with direct heating via the burning of fossil fuels, such as gas, oil and coal, or via electricity, indirect heating using organic HTF offers the following advantages:

- several processes can be heated using a single heat source
- local overheating of the product due to high surface temperatures is ruled out
- reduced fire risk when heating flammable media
- the heat transfer medium can be adapted to the process temperature with a very high degree of accuracy
- flexible adaptation with regard to changes in load due to temperature
- the heat transfer conditions can be optimised via design measures

Compared to heating with high-pressure steam – a method often used in the chemical industry – heating with organic HTF at comparatively high temperatures is advantageous in that the media can be used without pressure, or at only slight excess pressure (see diagram).

The plant itself can thus be designed more simply and at a lower cost, and the entire process can be carried out more economically. As a result, Diphyl® HTF are used in any situation where high demands are placed on precise temperature control, such as in the manufacture and processing of synthetic fibres, plastics, rubber and chemicals. The wood, metal, textile, oil and gas industries and organic ranking cycle modules (biomass) are further applications. Nowadays, large volumes of HTF are also used in concentrated solar power plants (CSP see picture) where solar energy is concentrated by parabolic reflectors and used to heat up fluids to very high temperatures.



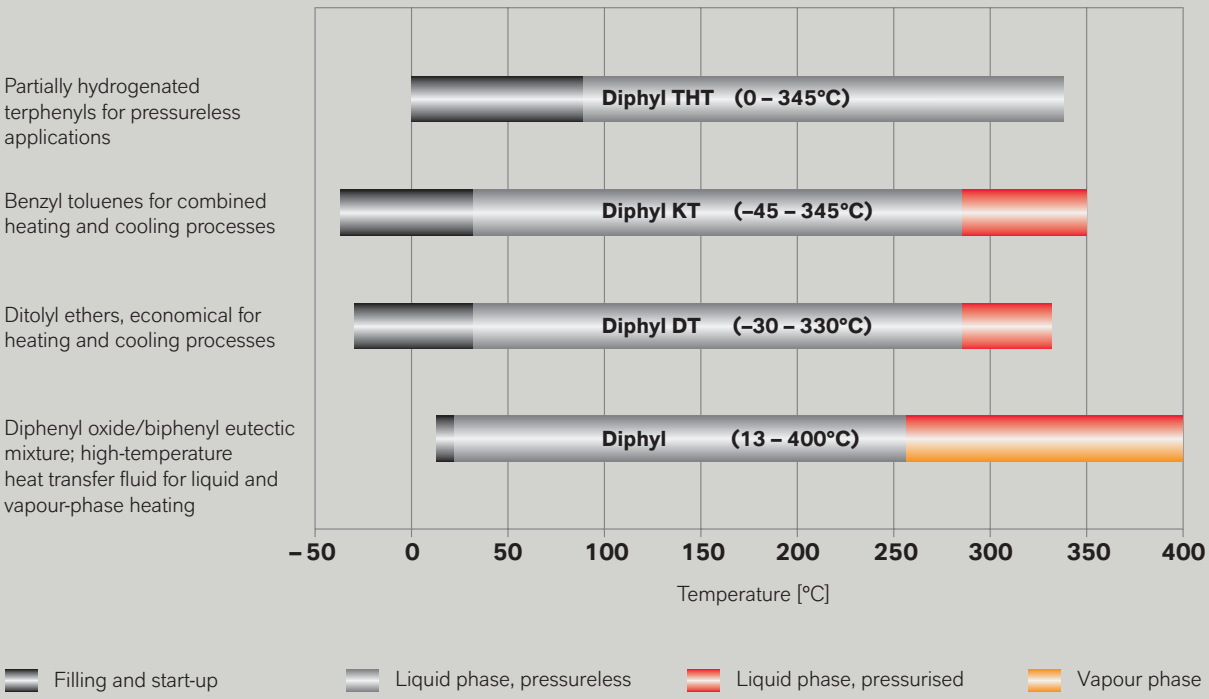
Diphyl application: concentrated solar power plant (CSP) – Parabolic trough system

1.2. Requirements

The respective operating conditions always play a role in the selection of an optimum HTF. Organic heat transfer fluids should generally fulfil the following demands:

- excellent thermal stability in the operating temperature range
- high boiling point and thus low vapour pressure in the upper temperature range
- low sensitivity to oxidation
- high specific heat and favourable heat transfer properties
- good flow at start-up temperature
- non-toxic, low environmental burden
- low safety risks when using the HTF (compatible with product)
- optimum material compatibility; no corrosive effect on materials used in plant construction

Diphyl® Heat Transfer Fluids from LANXESS and their application ranges



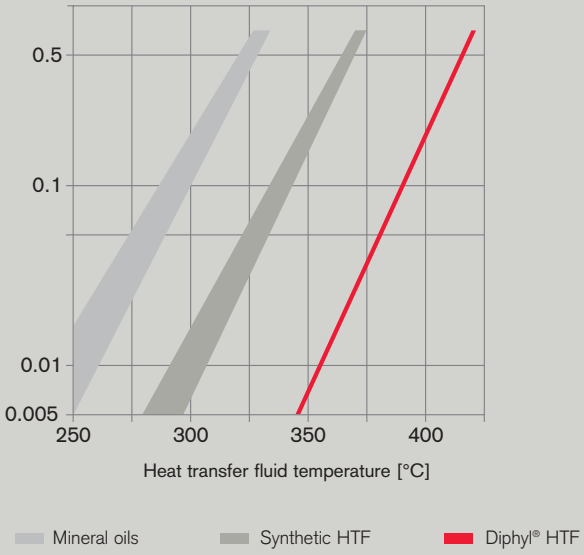
1.3. Heat Transfer Fluids

The LANXESS portfolio of HTF is based on synthetic products which are designed for use in the high temperature range. Four products which are based on very stable aromatic molecules allow for a wide range of application, from liquid at temperatures from -45 to 350°C to pressurized liquid/vapour up to 400°C. The unique products can be used in an almost unlimited number of applications in the wood, metal, oil refinery, chemical, polymer and many other industries.

Diphyl®	HTF for very high temperatures, pressure(less) application in liquid/vapour phase
Diphyl® DT	HTF for low to medium temperatures, pressure(less) application in liquid phase
Diphyl® KT	HTF for low to high temperatures, pressure(less) application in liquid phase
Diphyl® THT	HTF for high temperatures, application in liquid phase

1.4. Selection Criteria for HTF

An essential factor in the selection of a heat transfer medium is its thermal stability at the working temperature required for the process. The thermal stability determines the service life of the HTF and also influences the design of the heater and the heat users. Diphyl® provides the highest level of thermal stability of any of the HTFs currently on the market, having a maximum operating temperature of 400 °C. Diphyl® has the particular advantage that it can also be used in the vapour phase. This means that simple systems can be used to heat large and also complex plants, while maintaining an equal temperature at all points where heat transfer occurs.



Decomposition of organic HTF (static, in antoclave)

1.5. Thermal Stability

The thermal stability is an expression of the durability of an organic HTF when exposed to high temperatures. The determination of the thermal stability of fresh HTF is described in DIN 51528.

Every organic HTF undergoes thermal decomposition to a small degree above a certain temperature, i.e. is partially transformed into low-boiling, high-boiling and non-evaporable components. The decomposition rate increases exponentially in the upper temperature range. In this range, a temperature increase of 10K can be expected to double the rate of decomposition. The decomposition of a HTF is influenced by its chemical structure, purity and temperature, and also by plant specific conditions, such as the temperature profile and contamination. In practice, thermal decomposition becomes noticeable starting at roughly 50 K below the permissible feed temperature.

Aromatics such as the Diphyl® products have shown superior thermal stability compared to mineral HTF (see figure). The low-boiling components dissolved in the HTF reduce the flash point and increase the vapour pressure, which can lead to evaporation in the event of local pressure drops. Resultant products which have a higher boiling point or are non-evaporable can lead to an increase in the viscosity of the HTF and thus to deteriorating heat transfer and a growing pressure loss. As a result, the boundary layer temperature may increase due to a drop in the flow velocity.

The thermal stability of a HTF under thermal stress and isolated from atmospheric oxygen determines the upper operating temperature limit. According to DIN 4754-1, the upper operating temperature limit should be selected in such a way that the HTF remains in usable state for at least one year. A decomposition rate of a few percent of the HTF filling per year is considered acceptable for reasons of economy.

The thermal stability of Diphyl® is so outstanding that it can be used up to 400°C. Under these operating conditions, the physical property data change only slightly, even after several thousand hours of operation.

Bearing in mind that the thermal stress on the HTF should be kept to a minimum, long inlet pipes should be avoided and, where large systems are divided into primary and secondary circuits, the process requiring the highest temperature should be supplied from the primary circuit, since the temperature in this circuit is bound to be higher if coupling is achieved via heat exchangers, for example.

1.6. Chemical Stability

Above 100°C, organic HTF react exothermically with atmospheric oxygen to form decomposition products containing oxygen (including organic acids) and high-molecular condensation products.

These reaction products are thermally less stable than the non-oxidised and can lead to acceleration of the decomposition rate, as well as to an increase in viscosity. A rule of thumb states that the ageing process accelerates exponentially at temperatures above 60°C and doubles for every 10 K increase in temperature. Certain materials (non-ferrous metals and their alloys) and contaminants (rust, water) act as catalysts and speed up the ageing process even further. Oxygen and other gases are dissolved to a greater degree by cold HTF than by warm ones.

When filling or refilling the system, care should therefore be taken to prevent oxygen from entering the system with the cold fluid. An easy way of preventing the infiltration of oxygen is to use a nitrogen blanket.

1.7. Customer Support and Analytical Testing

According to DIN 4754-1, German Pressure Vessels Regulation (Druckbehälterverordnung) VDI 3033 and the accident prevention regulations (UVV BGV D3) the suitability of the organic HTF for continued use must be tested as required, or at least once a year. In general, situations requiring testing include:

- irregularities in the plant which might indicate deterioration of the HTF
- in plants with a content > 5,000 litres
- 3 months after conclusion of start-up operation or
- 3 months after converting to a different HTF

Used HTF are tested in order to obtain analytical data which permit a decision to be made concerning the further use of the medium. If necessary, recommendations are given for improving the physical property data, such as degassing or filtering of the heat transfer fluid, or reprocessing.



The HTF can be further used if the property values that are heat-relevant for heat transfer are within the permissible ranges and no corrosion of the structural materials is to be expected.

Within the framework of a Diphyl® analysis programme, LANXESS offers to test Diphyl® HTF for its customers at a reasonable price. A roughly one-litre sample of the HTF needs to be tapped from the main circuit, using a sample cooler if the plant is hot, or at temperatures below 100°C.

The sample container must be sealed immediately and remain sealed until testing. It should also be labelled.

Please send samples to:
Currenta GmbH & Co. OHG
Analytik/Chromatografie
Building Q18
51368 Leverkusen, Germany
Fax +49 (0) 214-30-61120
eMail: auftagseingang.analytik@currenta.de

The results are given in an analysis certificate containing the tested data and limit values relevant for judging the further usage of the used Diphyl®, plus a statement regarding the suitability of the medium for further use.

1.8. Health and Safety

To date, no harmful effects resulting from the use of Diphyl® as a HTF have been detected in the human organism. Food and drink must be protected against contamination with Diphyl®. Splashes of hot Diphyl® (>60°C) on the skin should be immediately and thoroughly cooled with cold water, in order to minimise the damage caused by scalding. Diphyl® vapour smells extremely unpleasant even in very low concentrations, so that it is unlikely that anyone would inhale it in excessive quantities. A protective mask with a filter (type A) should be worn when entering a room filled with Diphyl® vapour.

These are the minimum requirements to be observed by anyone working with organic liquids in the chemical industry. More detailed guidelines and information are included in the corresponding safety data sheets.

These data sheets include detailed information on:

- the chemical properties of the Diphyl® HTF, toxicological and ecological aspects
- physical and safety-related properties, e.g. flash point and autoignition temperature
- transport
- technical and personal protective measures
- storage and handling
- procedures in the case of accidents

Further information concerning CPP, GHS and REACH is given in our safety data sheet.

1.9. LANXESS Know-How

At LANXESS and its predessesor Bayer, organic HTF have been employed in heat transfer systems in numerous plants involving various processes and technologies for decades. For this reason, Lanxess not only has a range of outstanding HTF under the brandname Diphyl®, but has also acquired extensive know-how in heat transfer technology. Thanks to years of practical experience with Diphyl® heat transfer installations and the technical cooperation between production plant engineers and plant designers, LANXESS possesses comprehensive knowledge on the technical design of such installations, in addition to basic product knowledge.

We are pleased to make this knowledge and experience available to our customers, without obligation, whenever they are searching for technical problem solutions for heat transfer systems. This experience gives us the chance to offer diversified pre and after sales service. LANXESS can give support in the planning and operation status of the plant.

2. Design of DIPHYL® PLANTS

2.1. Heat Transfer Plant

The following goals, which are closely linked to the requirements of the process, must be pursued when designing a heat transfer plant:

- heater, expansion and receiver vessels are usually to be set up away from the production plant in compliance with the relevant regulations, standards and guidelines, particularly UVV/BGV D3, DIN 4754, VDI 3033, VAwS (regulation on plants used for the storage, filling and transport of substances classified as hazardous to water) and possibly the Pressure Vessels Regulation (Druckbehälterverordnung)
- keep the quantity of HTF low by using short connecting pipes and the quantity of heat transfer fluid
- heat exchangers are to be favourably designed as regards heat transfer and the quantity of HTF
- the quantity which escapes in the event of a leak should be minimised by dividing large systems into sub-systems which can be shut off from a safe location, or are connected to the primary circuit via secondary circuits using heat exchangers

In systems with central heaters, it must be ensured that

- the permissible operating pressures are maintained
- the permissible pressures are not exceeded by connecting several pumps in series
- the nitrogen blanket and inherent vapour pressures are taken into account
- the static liquid pressure is considered

In order to reduce the quantity escaping from the heating system in the event of a fault, the installation of a rapid evacuation system, possibly also for sub-systems, is recommended. An evacuation period of 10 to 20 minutes should be targeted, depending on the quantity of HTF in the plant. In each case, the evacuation period should be coordinated with the local fire brigade. The feedback effect on the production process must be taken into consideration when designing the rapid evacuation system.

The evacuation controls must be operable from a safe location and protected against operating errors and power failures. They should be installed in such a way that hot and pressurised parts of the evacuation lines are short. Evacuation can be carried out, for example, using:

- gravity
- inert gas/inherent vapour pressure

The evacuation lines for the liquid must be installed at the lowest points of the heat transfer (sub-)system. When sizing the pipe system, it must be kept in mind that flash evaporation and thus also vapour hammers can occur in the case of HTF operating above their boiling point. The pipes must be heated if there is the possibility of the HTF reaching its solidification point. The HTF should be cooled below the boiling point before entering the receiver vessel. When operating with the HTF above the boiling point, a drop in pressure in the receiver vessel and condensation of the flash vapour are also possible, in which case, however, large volume flows occur. A low-boiling component in the HTF vapour must be taken into consideration when designing the condensers required in this situation.

A post-condenser is suitable for preventing vapour escape. The vent pipes of the receiver vessel and condensers should be equipped with a flame arrester if the danger of explosion cannot be ruled out. Shorter testing intervals and, if necessary, trace heating of the piping and fittings must be provided in view of the danger of clogging due to HTF or components thereof having a high solidification temperature. The supply of coolant to the heat transfer fluid cooler must also continue to operate if power systems fail.

Expansion vessels should be separately partitioned off and drained because they belong to the cold HTF section. Decentralised heat transfer systems are advantageous for small and medium capacities. They allow individual temperature levels and a temperature control which is independent of the connection or disconnection of sub-systems.

2.2. Materials

Diphyl® HTF have no corrosive effect on the structural materials normally used (construction steel). However, in connection with water, products of decomposition can lead to corrosion phenomena. Non-ferrous heavy metals, their alloys and

impurities, such as rust or water, can catalytically accelerate the ageing rate of the HTF. DIN 4754 and UVV/BGV D3 must be observed as a minimum during selection.

2.3. Pumps

It is advantageous to install the pumps only slightly above the base level of the plant. This results in favourable pressure conditions and a low plant filling height.

It is important to observe the required minimum volumetric flow for safe operation of the plant (adherence to the maximum allowed film temperature). DIN 4754-1 describes the basic requirements in this context.

The lower operating temperature is both the ambient temperature prevailing during filling or start-up of the plant, and also the lowest working temperature of the HTF. The HTF must be pumpable at these temperatures and measuring instruments or lines to safety systems must not freeze. The pumpability limit depends on the type of pump used. The viscosity of the HTF at the lower operating temperature is decisive in this context.



Pumps must offer a particularly high degree of operating reliability. Perfectly tight shaft seals are important for this reason. Pumps with a canned motor or a magnetic drive offer advantages as regards safety in comparison with other types, because only static seals are used on the HTF side.

2.4. Piping Systems

Even though piping that transports heat transfer media is not subject to the Pressure Vessels Regulation, it must fulfil the following requirements:

- short paths must be designed, particularly for large nominal diameters
- the thermal expansion must be considered
- the approved pipe forces for pumps, rotary transmission leadthroughs and equipment flanges must be observed
- pipe supports must be dimensioned according to expansion conditions and sufficiently insulated
- saddles and traps should be avoided where possible
- pipes carrying heat transfer medium in the vapour phase must be checked for unimpeded condensate drainage
- drains and vents of the entire system must be realised with a minimum of pipes and fittings and, if necessary, designed for rapid evacuation. Trace heating may also be required.

Welded joints are preferable to flanged joints in piping systems for HTF. The nominal diameters must be designed for minimum quantities and short dwell times of the HTF. In addition, leaks must be easy to detect and repair, due to the tendency of the HTF to creep.

Spiral-wound gaskets with graphite inserts or toothed gaskets with graphite coating are suitable as seals. When using metal-plated seals, it is recommended that the flanges be designed for PN 25 as a minimum; DIN 4754-1 must be observed as regards the screw connections.

2.5. Thermal Insulation

The thermal insulation, which is required due to the heat loss from pipes and other equipment, should be characterised by:

- easy access for inspection purposes
- reuse of insulation after disassembly or inspection
- good accessibility to individual equipment items

Closed-cell insulating materials prevent heat transfer fluid fires in the insulation.

Protection against contact via thermal insulation is generally required at temperatures above 60°C due to the danger of injury.

"Cold" HTF pipes without flow should not be insulated in order to avoid corrosion, but should be given a long-lasting coat of paint.

2.6. Plant Start-up

Before starting up a Diphyl® HTF, check that

- electrical installations have either a manufacturer's type test certificate or have been tested and certified by an expert
- all required acceptance tests have been carried out according to the Pressure Vessels Regulation or DIN 4754-1
- welded seams have been checked

Flanges should not be fitted with thermal insulation during assembly of the piping and equipment, in order to be able to detect leaks during the leakage test and the first heating cycle. The flanges should also be completely free from water.

Following assembly, the presence and correct installation of all specified pumps, dirt traps, fittings, measurement and control devices must be verified.

Heat transfer plants must be subjected to specific tests according to UVV 64 and the Pressure Vessels Regulation (pressure test, leakage test) during the first run and then at regular intervals and after any modifications or repair work.

The plant is filled at ambient temperature, at which time it must be ensured that gas pockets can escape.

Special care must be exercised when filling outdoor plants at low outside temperatures. In order to prevent solidification, the Diphyl® must be preheated or the plant heated up using hot air. It is advantageous first to fill only the heater and to further heat the Diphyl® using a short-circuit line in the heater. One segment of the plant after the other is then filled with hot Diphyl® from the heater, while preheated Diphyl® is fed into the heater.

The plant must be heated up slowly the first time or after an extended downtime. Vent pipes may not be shut off.

It is expedient to maintain the temperature at 120 to 130°C for several hours, in order to evaporate any remaining water. All flanges must be checked for leaks as heating continues (e.g. in steps of 10°C) and retightened after about every 100°C and when the final temperature has been reached.

The exhaust gases of flame-heated plants must be checked as regards temperature, CO_2, CO and NO_X values, and soot levels. The burner setting should be checked as needed.

Welding work may only be carried out in compliance with specific safety measures (DIN 4754-1, UVV/BGV D3).

2.7. Fire and Explosion Protection

Like all commercial organic HTF, Diphyl® has a flash point. The flash point is the lowest temperature, determined under fixed experimental conditions, at which Diphyl® vapours form in such quantities that a vapour/air mixture with a concentration within the explosion limits accumulates and can be ignited by an outside ignition source. However, with an ignition temperature of over 600°C, Diphyl® offers a high degree of safety as regards selfignition.

As the application range of virtually all HTF is above their flash point, more stringent demands must be placed on the leakproof condition of the plant and the installation sites for the heater and other equipment.

The electrical equipment is not required to be of explosion-protected design (except for specific components as per UVV 64, 11) if the plant can be designated as technically leak-proof.

Electrical lines are to be laid so that they are protected against damage from possible leakage of hot heat transfer fluid. Electric trace heating systems must be protected so that the HTF cannot be ignited in the event of leakage.

In contrast to many high-boiling HTF, smouldering Diphyl® fires in insulation have not been observed to date.

However, if the Diphyl® HTF should catch fire, a strong jet of water should definitely not be used to extinguish it. Spraying with a fine water spray is permissible in the case of large fires. Recommended extinguishing substances: CO_2 foam, extinguishing powder.



3. DIPHYL®

3.1. General Properties

Diphyl® is a high temperature HTF for the application in liquid and vapour phase. It conists of an eutectic mixture of diphenyl oxide and biphenyl. The fluid solidifies at approx. 12.3°C without a reduction in volume when Diphyl® changes from the fluid to the solid state. This means tha there is no risk of plant or pipelines being damaged if Diphyl® solidifies.

Diphyl® has a high boiling point of 257°C at an atmospheric pressure, thus permitting the pressureless operation in standard heat transfer systems at temperatures up to 250°C. At a maximum application temperature of 400°C, the pressure amounts to only 10.7 bar. This means that simple plant designs can be used, even in high temperature regions. The plant should be designed so that the temperature at the heating surface is limited to 410°C.

The water content of Diphyl® is in equilibrium with the atmospheric humidity and amounts to a maximum of 0.02% by weight on delivery.

Diphyl® is not hygroscopic and is virtually immiscible with water. Even at 30°C and 100% relative humidity, a maximum of only 0.07% by weight water dissolves in Diphyl®. As with all combustible fluids, there is also the possibility of Diphyl® forming an explosive mixture with air. However the explosive range between 1.0 and 3.5% by volume for Diphyl® vapour is very small.

Diphyl® will not ignite spontaneously before reaching an autoignition temperature above 615°C. Diphyl® thus belongs to Temperature Class T1. The typical, inherent odour of Diphyl® enables leaks to be identified quickly. The level of production-related impurities, such as chlorine and sulphur compounds, is so low in Diphyl® that corrosive damage caused by the heat transfer fluid coming into contact with the materials of the plant can be ruled out.

3.2. Characteristic Data

Parameter	Unit	Diphyl®
Appearance		clear, colourless to yellowish liquid
Odour		geranium like
Diphenyloxide/biphenyl content	weight-%	min. 99.9
Solidification point	°C	12.3
Boiling temperature	°C	257
Flash point	°C	115
Autoignition temperature	°C	615
Maximum film temperature	°C	420
Density (20°C)	kg/m³	1061
Kinematic viscosity (20°C)	mm²/s	4.05
Surface tension(20°C)	mN/m	40
Thermal conductivity (20°C)	W/m.K	0.144
Mean specific heat (20°C)	kJ/kg.K	1.56
Net caloric value HU	MJ/kg	36.2
Coeff. of therm. expansion (20-300°C)	K^{-1}	$10.6 \cdot 10^{-4}$

Physical Properties

Temp.	Vapour pressure	Dynamic Viscosity		Density		Specific heat		Thermal conductivity		Evap. enthalpy	Surface tension
		Liquid	Vapour	Liquid	Vapour	Liquid	Vapour	Liquid	Vapour		
°C	mbar	mPa·s	mPa·s	kg/m³	kg/m³	kJ/kg·K	kJ/kg·K	W/m·K	W/m·K	kJ/kg	mN/m
20		4.26		1061		1.557		0.144		365	
40		2.63		1047		1.611		0.141		361	
60	0.45	1.78		1031	0.005	1.665		0.137		356	
80	1.61	1.29		1015	0.013	1.718		0.133		351	
100	4.91	0.99	0.0071	998	0.035	1.772	1.306	0.130	0.013	346	32.6
120	13.1	0.79	0.0075	981	0.081	1.826	1.374	0.126	0.014	340	30.1
140	30.9	0.65	0.0079	963	0.172	1.879	1.440	0.122	0.015	333	27.7
160	66.5	0.55	0.0083	945	0.339	1.933	1.503	0.119	0.016	326	25.3
180	131.4	0.47	0.0087	925	0.626	1.987	1.564	0.116	0.018	319	23.1
200	241.6	0.41	0.0091	905	1.092	2.041	1.623	0.112	0.019	311	20.8
220	417.8	0.37	0.0094	885	1.815	2.094	1.680	0.109	0.020	303	18.7
240	685.3	0.33	0.0098	863	2.888	2.148	1.734	0.106	0.021	294	16.7
260	1074	0.30	0.0102	842	4.427	2.202	1.786	0.103	0.023	285	14.7
280	1620	0.28	0.0106	819	6.564	2.255	1.835	0.100	0.024	276	12.8
300	2364	0.26	0.0110	796	9.449	2.309	1.883	0.097	0.026	266	11.0
320	3354	0.24	0.0113	772	13.249	2.363	1.927	0.094	0.027	255	9.2
340	4648	0.22	0.0117	748	18.144	2.416	1.970	0.091	0.028	244	7.5
360	6318	0.21	0.0121	723	24.328	2.470	2.010	0.088	0.030	233	5.9
380	8454	0.20	0.0125	697	32.001	2.524	2.048	0.085	0.031	221	4.4
400	11177	0.19	0.0128	670	41.371	2.577	2.084	0.082	0.033	209	3.0

Characteristic Data Diagramms

The fluidic and thermodynamic relationships are defined by complex mathematical equations. The tables and diagrams in a separate USB stick are showing the characteristic data of the Diphyl® HTF for the entire temperature range, to serve the purpose of reliable and economical project planning. In addition the stick offers extensive calculation examples and further numerical data for intermediate values. For further informations see our technical data sheet or our Diphyl® homepage.

3.3. Applications

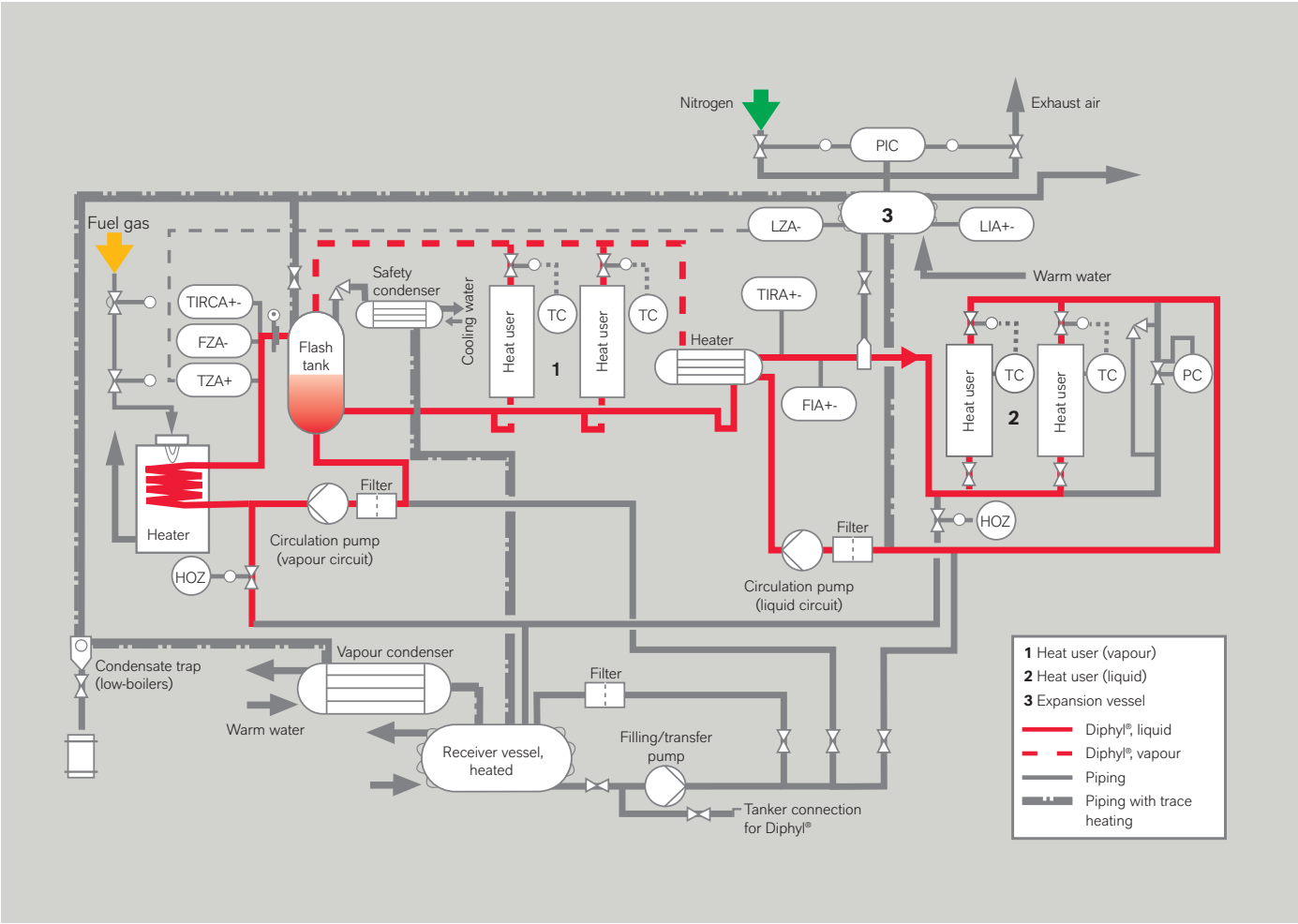
The selection of suitable heating and cooling methods can be of decisive importance for the improvement of known manufacturing processes and the development of new ones. Many processes require uniform heating to high temperatures, precise temperature control, or transfer of generated heat for the purpose of heat recovery. Diphyl® completely fulfils these requirements and can be used as follows under widely varying operating conditions ranging from 20 to 400°C:

- in the region of the boiling point in the vapour and liquid phase in pressure or vacuum systems
- below the boiling point in the liquid phase in pressureless systems
- above the boiling point in the liquid phase in pressurised systems

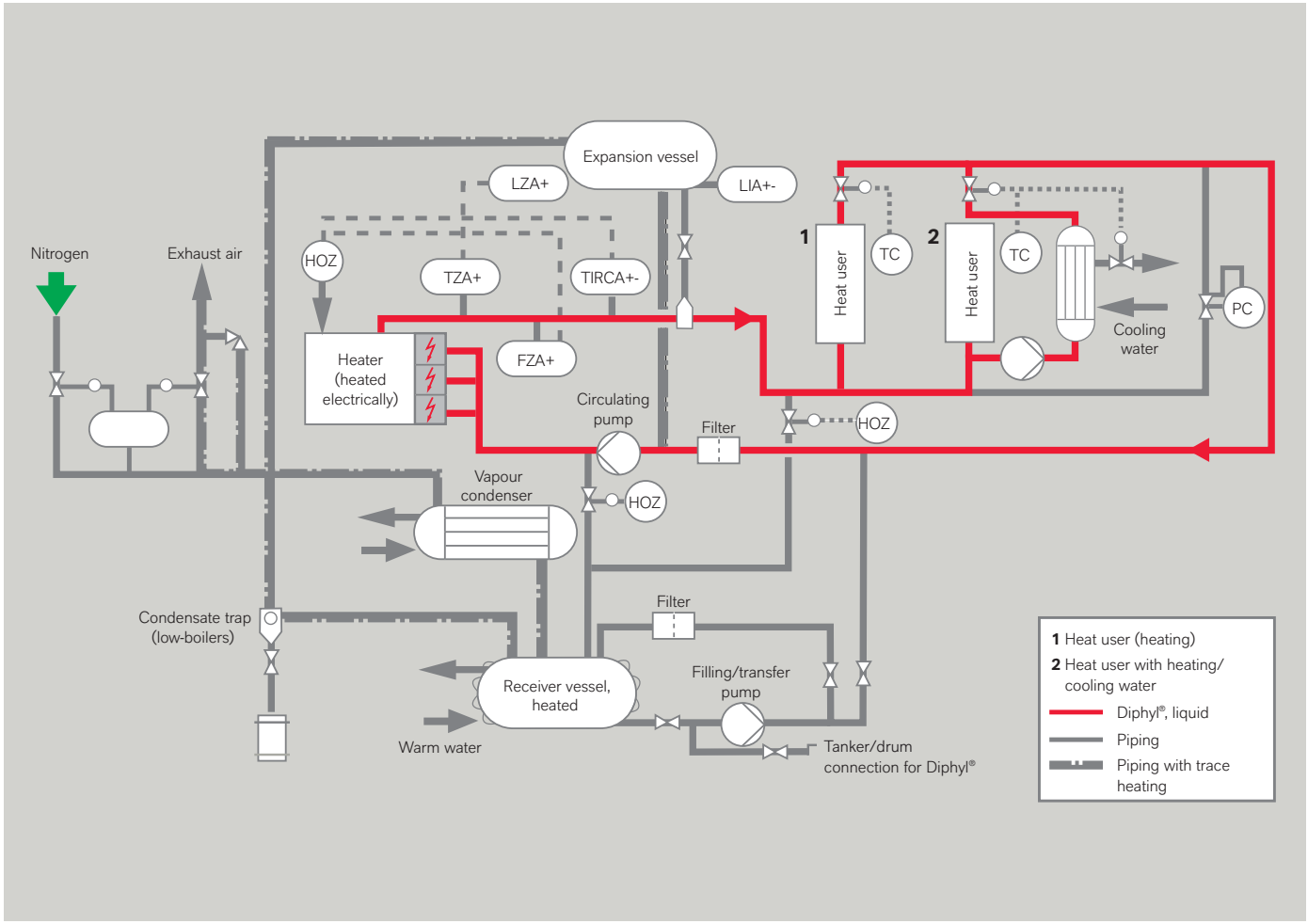
Use as Liquid & Vapour in Central Systems

The transfer of heat via central systems using liquid Diphyl® and Diphyl® vapour has proven effective in many large-scale plants. The plant can consist of a heater with flash tank, one section heated with Diphyl® vapour and one heated with liquid Diphyl® (see flow chart). A separate Diphyl® circuit with forced circulation is provided for the flow heater and flash tank.

The circulating pump forces the liquid Diphyl® through the heater. After leaving the heater, the liquid flows into the flash tank, where the vapour is separated from the liquid Diphyl®. The Diphyl® vapour flows out of the flash tank to the heat users directly heated with Diphyl® vapour. The vapour is condensed there and then flows via the flash tank back into the circuit.



Flow chart of a Diphyl® heat transfer system with forced circulation for heating in the vapour and liquid phases.



Flow chart of a Diphyl® heat transfer system with forced circulation for heating and cooling in the liquid phase.

Parallel to the direct consumers, the Diphyl® vapour also flows to a heat exchanger and heats a secondary, circulated liquid Diphyl® circuit which heats additional heat consumers at a somewhat lower temperature level. If heat is to be withdrawn from the system, a cooling circuit can also be connected. The heat is transferred to a water-cooled heat exchanger.

Use in the Liquid Phase

Diphyl® can be used as a directly heated, pressureless bath up to 250°C. For uniform temperature distribution, e.g. in a mixing tank, the space between the double shell is filled with Diphyl®. By measuring the temperature of the Diphyl®, heating can be controlled such that the inner tank wall temperature never exceeds the maximum permissible product temperature.

In order to avoid a pressure increase in the double shell due to expansion of the Diphyl® during heating, the double shell must be vented. The temperature of the Diphyl® charge can be increased to just under the boiling point, i.e. up to about 250°C. The loss of Diphyl® at these temperatures is avoided by cooling the vent pipe.

If there is a need to withdraw heat from the product rapidly after heating, this can be done using water-cooled cooling coils which run through the double shell. The entire inner wall can be uniformly cooled to room temperature thanks to the low viscosity of Diphyl®. The solidification point of Diphyl® must be considered when selecting the temperature of the cooling medium.

The principle of heating or cooling via natural circulation can be applied if direct heating of a double shell filled with Diphyl® is impossible or undesirable. Diphyl® is particularly suited to this simple method because its low viscosity and the large change in density as a function of temperature favour the use of natural circulation. The advantages are higher circulation speeds, improved heat transfer, shorter heating times and smaller heating surfaces.

It is also possible to reach temperatures above 257°C with liquid Diphyl® in this manner. Boiling of the Diphyl® at temperatures up to 400°C can be suppressed by applying a gas blanket via the system pressure. Heating wall temperatures significantly above 400°C should be avoided.

In large-scale plants where heater installation and heat users are physically separated, the Diphyl® system is usually operated with forced circulation using a pump (see flow chart). Higher flow velocities on the heat exchange surfaces improve the heat transfer and lead to lower film temperatures. The expansion vessel

required must be installed above the highest point of the plant, so that all heat users can be vented during filling.

Diphyl® heaters should be purchased from companies which have sufficient experience in this field and can provide the necessary information for the expedient set-up of the overall plant.

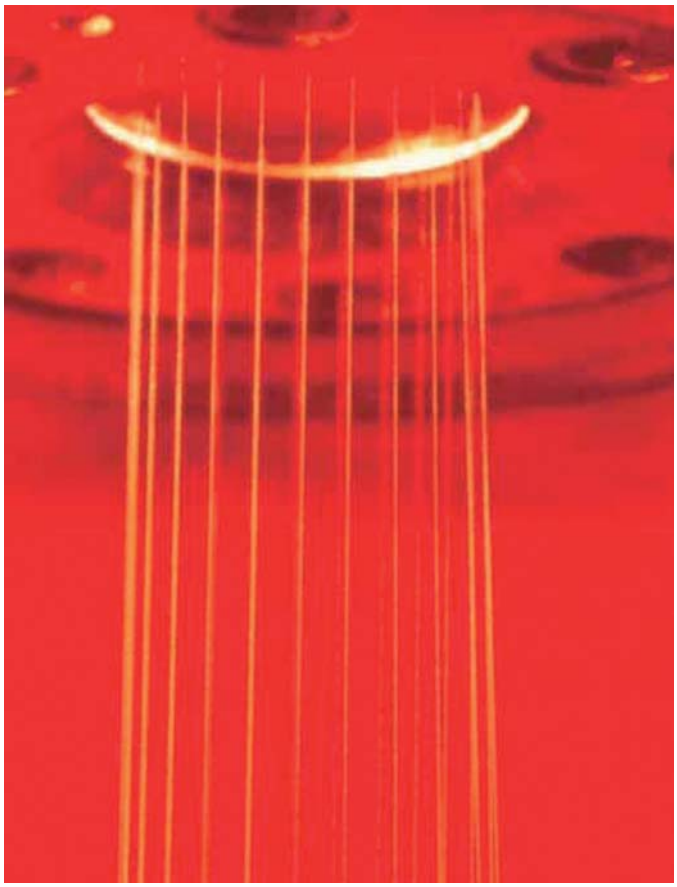
Use in the Vapour Phase

Diphyl® has a defined boiling point and can therefore be used in the vapour phase (see flow chart). Due to the fact that there is virtually no difference between the feed and return temperatures, a uniform temperature distribution prevails which would only be achievable in a liquid heating system with uneconomically large volumetric flows. Exploitation of the condensation enthalpy allows the quantity of HTF in a system to be reduced, while maintaining the same heating capacity. The heat transfer on complex heat exchange surfaces is decisively improved in comparison with liquid heating.

Heat transfer using Diphyl® vapour thus allows:

- large heating surfaces to be heated to the same temperature by condensing the vapour
- large quantities of heat to be transferred to small heating surfaces
- cooling of an exothermic reaction by evaporation with the advantages described above

If the vapour is to be transported over lengthy distances, the piping must be designed to ensure the lowest possible pressure loss. Appropriate piping dimensions are necessary for the larger quantities of vapour required. It must be ensured that vapour feed, condensate drain and vent pipes are properly connected. The accumulation of non-condensable components can be detected via temperature measurement.



Heat transfer using Diphyl® vapour at vapour temperatures below 257°C is only possible if at least a partial vacuum corresponding to the desired vapour temperature prevails in the entire system. Air inevitably penetrates the system after prolonged operation, causing the partial vacuum to drop and the temperature of the Diphyl® vapour to rise. Thus, an air trap must be integrated in the circuit. In an installation including a double shell filled with Diphyl® which can be directly heated, the product can be heated up to 285°C using Diphyl® vapour. The shell is filled at room temperature up to one-quarter to one-third of its height, in order to ensure the reliable presence of liquid Diphyl® for evaporation on the flue gas-heated surface during operation. If operations require a Diphyl® temperature above 285°C, the formation of a partial vacuum in the double shell during cooling must be avoided, e.g. by applying a blanket of N_2. The vapour is usually generated in a heater installed separately from the heat user and equipped with a safety valve and bypass lines.

4. DIPHYL® DT

4.1. General Properties

Diphyl® DT is a mixture of isomeric ditolyl ethers (dimethyl diphenyloxides). It boils in the temperature range between 284 and 294°C at 1.013 bar. Under pressure it can be operated in the liquid phase up to a temperature 330°C.

Special mention should be made of the low viscosity of Diphyl® DT even at low temperatures. With a pour point of -54°C, Diphyl® DT can be operated even at temperatures as low as -30°C.

It has a water content of maximum 0.02% by weight on delivery, is not hygroscopic and is virtually immiscible with water. Even at 30°C and 100% relative humidity, a maximum of only 0.07% by weight water dissolves in Diphyl® DT.

The autoignition temperature is 545°C, meaning Diphyl® DT is classified as temperature class T1. Unlike water, the conversion from a liquid to a solid state reduces the volume. Apparatus and pipelines are not damaged by solidification of the Diphyl® DT filling. The typical inherent odour of Diphyl® DT enables leaks to be identified quickly. The level of production-related impurities, such as chlorine and sulphur compounds, is so low that corrosive damage caused by the HTF is unlikely.

4.2. Characteristic Data

Parameter	Unit	Diphyl® DT
Appearance		clear, pale yellow liquid
Odour		inherent odour
Ditolyl ether content	weight-%	min. 97.5
Pour point	°C	-54
Boiling range	°C	284-294
Flash point	°C	135
Autoignition temperature	°C	545
Maximum film temperature	°C	340
Density (20°C)	kg/m³	1035
Kinematic viscosity (20°C)	mm²/s	6.3
Surface tension(20°C)	mN/m	37
Thermal conductivity (20°C)	W/m.K	0.134
Mean specific heat (20°C)	kJ/kg.K	1.58
Net caloric value HU	MJ/kg	37.6
Coeff. of therm. expansion (-20 to 300°C)	K^{-1}	$10.6 \cdot 10^{-4}$

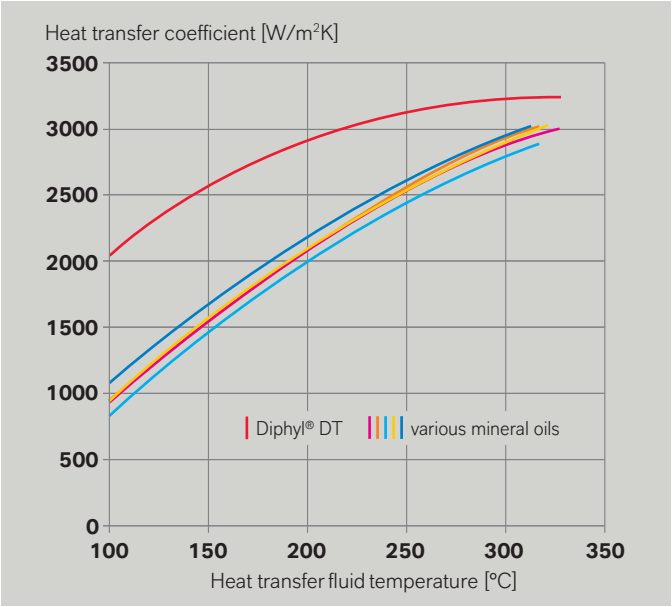
Physical Properties

Temperature	Vapour pressure	Dynamic viscosity	Density Liquid	Specific heat Liquid	Thermal conductivity	Surface tension
		Liquid			Liquid	
°C	mbar	mPa·s	kg/m³	kJ/kg·K	W/m·K	mN/m
-20		35.43	1056	1.475	0.140	
0		12.43	1044	1.530	0.137	38.7
20		5.88	1031	1.585	0.134	37.0
40		3.35	1017	1.640	0.131	35.3
60		2.17	1003	1.696	0.128	33.6
80		1.53	988	1.751	0.125	31.9
100		1.15	972	1.806	0.122	30.2
120		0.90	956	1.861	0.119	28.6
140	10.2	0.74	939	1.916	0.116	26.9
160	23.9	0.62	922	1.971	0.113	25.2
180	51.4	0.53	904	2.026	0.111	23.5
200	101.6	0.47	885	2.081	0.108	21.8
220	187.6	0.42	865	2.136	0.105	
240	326.3	0.38	845	2.192	0.102	
260	539.3	0.34	824	2.247	0.100	
280	853.0	0.32	803	2.302	0.097	
300	1299	0.29	781	2.357	0.094	
320	1914	0.27	758	2.412	0.092	
340	2742	0.26	735	2.467	0.089	

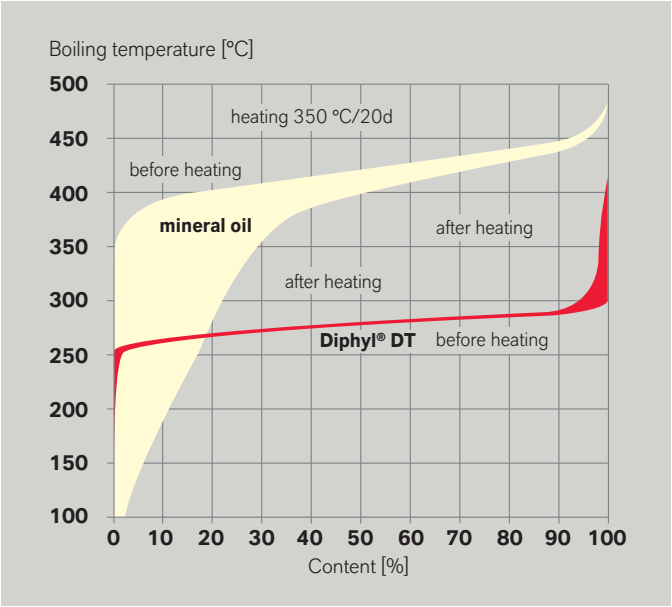
4.3. Diphyl® DT versus Mineral Oils

Whereas mineral oil-based HTF are isomeric mixtures of paraffin or naphthene-basic hydrocarbons, synthetic organic HTF like Diphyl® DT have well defined compositions and are much more stable due to the aromatic nature of the molecules. Diphyl® DT has appreciable advantages in application over mineral oil based types. Its high thermal stability increases life expectancy 2-3 times over that of mineral oil based HTF. Moreover, circuits filled with Diphyl® DT can be started up faster and more easily.

The heat transfer coefficients are also much better than those for mineral oils under identical conditions (see figure).



Heat transfer coefficient of Diphyl® DT compared with various mineral oils



Thermal stability acc. to DIN 51528, simulated distillation GC with Diphyl® DT and mineral oil

4.4. Applications

Many processes require uniform heating to high temperatures, precise temperature control, or removal and recovery of heat.

For the medium temperature range up to 330°C, Diphyl® DT is a cost-effective organic HTF of consistent composition. Its special properties are its low viscosity and low pour point. With this HTF – which should only be used in the liquid phase – all the advantages of the liquid phase process can be ex-ploited. For example, plants can be started up in winter time without any preheating and without a positive-displacement pump. No accompanying heating is needed. Another important feature is its low viscosity. This means greater safety against overloading in the heater, a smaller heating surface area of the consumer and/or faster heating.

Moreover, the low viscosity combined with the high thermal expansion coefficient offers the possibility of designing simple, cost effective plants with natural circulation of the HTF.

Diphyl® DT in Coating Resin Production

In the synthesis of various coating raw materials such as polyesters, polyamide and polypropylene, it is very important indeed to have accurate and reliable temperature control, for heating and cooling the individual stages of the process. Key properties of Diphyl® DT in the range from 30 – 300°C are its low vapour pressure, high auto-ignition temperature, good heat transfer properties and in particular accurate temperature control within narrow limits and high temperature stability.

Diphyl® DT in Phthalic Anhydride Production

In the production of phthalic anhydride, products are alternately precipitated and melted down in so-called switch condensers. Organic HTF have been used for many years for these cooling and heating processes.

Diphyl® DT in particular has proved itself for this application compared with mineral oils. Due to its low viscosity, higher thermal stability and consequently its low formation of solid substances, as well as its good heat transfer properties, Diphyl® DT is nowadays being used in a large number of phthalic anhydride production plants throughout the world.

Other Applications

Diphyl® DT can be used virtually anywhere where work is being carried out at high temperatures, typically between 200 and 300°C. Depending on the particular operating conditions, the HTF is used for heating or for dissipating the heat. Because of its outstanding versatility, a large number of applications have opened up for Diphyl® DT. The possibilities for using Diphyl® DT should be examined not only with reference to the examples shown here, but should be considered for any process which requires heating or cooling.

5. DIPHYL® KT

5.1. General Properties

Diphyl® KT is a blend of mono- and dibenzyltoluene isomers. It is used as organic HTF with low viscosity and excellent thermal stability for installations combining heating and cooling cycles in liquid phase. It can be applied pressureless from -45 to 290°C and under pressure uo to 350°C.

The colourless, clear liquid has the following characteristic properties:

- high thermal stability
- low viscosity
- good heat transfer coefficient
- low odour
- good biological degradability
- recyclability

5.2. Characteristic Data

Parameter	Unit	Diphyl® KT
Appearance		clear, colourless liquid
Odour		low odour
Mono-/dibenzyl toluene isomers	weight-%	min. 98
Pour point	°C	-65
Boiling range	°C	290
Flash point	°C	146
Autoignition temperature	°C	490
Maximum film temperature	°C	370
Density (20°C)	kg/m³	1008
Kinematic viscosity (20°C)	mm²/s	5.8
Surface tension(20°C)	mN/m	37.7
Thermal conductivity (20°C)	W/m.K	0.13
Mean specific heat (20°C)	kJ/kg.K	1.59
Coeff. of therm. expansion (-20-300°C)	K-1	$7.6 \cdot 10^{-4}$

Physical Properties

Temperature	Vapour pressure	Dynamic viscosity	Density Liquid	Specific heat Liquid	Thermal conductivity	Surface tension
		Liquid			Liquid	
°C	mbar	mPa·s	kg/m³	kJ/kg·K	W/m·K	mN/m
-50		177	1052	1.38	0.137	
-20		26.9	1034	1.47	0.134	
0		11.5	1021	1.53	0.131	39.4
20		5.96	1008	1.59	0.129	37.7
40		3.54	994	1.65	0.127	36.0
60	0.10	2.31	980	1.71	0.124	34.3
80	0.43	1.63	965	1.77	0.122	32.5
100	1.47	1.21	950	1.83	0.119	30.8
120	4.31	0.94	935	1.88	0.117	29.1
140	11.1	0.75	920	1.94	0.115	27.4
160	25.4	0.62	904	2.00	0.112	25.7
180	53.2	0.53	887	2.06	0.109	24.0
200	102.7	0.45	870	2.12	0.106	22.3
220	185.6	0.40	853	2.18	0.103	
240	316.4	0.35	836	2.24	0.100	
260	513.6	0.32	818	2.30	0.097	
280	799.6	0.29	799	2.36	0.094	
300	1201	0.26	780	2.42	0.091	
320	1751	0.24	761	2.47	0.088	
340	2489	0.22	742	2.53	0.085	
370	3895	0.20	712	2.62	0.080	

5.3. Applications

Diphyl® KT is applied for heating and cooling processes in the chemical and petrochemical industry as well as in rubber and polymer processing. It is especially of importance for plants which are filled and maintenanced at low temperatures.

6. DIPHYL® THT

6.1. General Properties

Diphyl® THT is a high-performance heat resistant synthetic HTF for use in the liquid phase in closed heat transfer systems.
It is a clear, colourless to pale yellow liquid. Diphyl® THT is odourless and, because of its polyphenyl structure (chemically: partly hydrogenated terphenyls), it has an extremely high thermal stability with a long operating life.

Because of its high boiling range, Diphyl® THT can be used in pressure-less systems over the entire operating range.

The high purity i.e. absence of e.g. chlorine and sulphur contaminants, ensures that there is no corrosion whatsoever of the metals normally employed for heat transfer equipment. The application range is between 0°C and 345°C. The film temperature should not significantly exceed the limit of 370° C, nor exceed it for very long.

6.2. Characteristic Data

Parameter	Unit	Diphyl® THT
Appearance		clear, pale yellow liquid
Odour		odourless
Terphenyls, partially hydogenerated	weight-%	min. 99.5
Pour point	°C	-33
Initial boiling point	°C	352
Flash point	°C	190
Autoignition temperature	°C	380
Maximum film temperature	°C	370
Density (20°C)	kg/m^3	1004
Kinematic viscosity (20°C)	mm^2/s	102
Surface tension(20°C)	mN/m	37.9
Thermal conductivity (20°C)	W/m.K	0.109
Mean specific heat (20°C)	kJ/kg.K	0.154
Coeff. of therm. expansion (20-300°C)	K^{-1}	$8.4 \cdot 10^{-4}$

Physical Properties

Temperature	Vapour pressure	Dynamic viscosity	Density Liquid	Specific heat Liquid	Thermal conductivity	Surface tension
		Liquid			Liquid	
°C	mbar	mPa·s	kg/m³	kJ/kg·K	W/m·K	mN/m
0		918.5	1017	1.48	0.110	39.6
20		102.4	1004	1.54	0.109	37.9
40		26.6	991	1.61	0.109	36.4
60		10.7	978	1.68	0.108	34.9
80		5.5	965	1.74	0.108	33.5
100		3.4	952	1.81	0.107	32.0
120		2.3	939	1.88	0.107	30.5
140		1.7	926	1.95	0.106	29.1
160	3.00	1.3	913	2.01	0.105	27.6
180	7.13	1.0	900	2.08	0.105	26.1
200	15.7	0.87	887	2.15	0.104	24.7
220	32.0	0.74	874	2.22	0.104	
240	61.3	0.65	861	2.29	0.103	
260	110.3	0.58	848	2.36	0.103	
280	190.3	0.52	835	2.43	0.102	
300	312.0	0.47	822	2.51	0.102	
320	491.1	0.44	809	2.58	0.101	
340	745.8	0.40	796	2.65	0.101	
370	1318	0.37	777	2.76	0.100	

6.3. Applications

Diphyl® THT is being used all over the world in numerous applications for the indirect heating of process plants in the chemical and petrochemical industry. Diphyl® THT is suitable above all as a heat transfer medium in reactors, polymerization processes, distillation columns and processing machines, e.g. for the production of synthetic resins, plastic raw materials, polyester film and fibers and for fatty acid processing, phthalic anhydride distillation, polyamide extrusion etc.

Besides this, Diphyl® THT is also used in waste heat recovery in the steel and petrochemical industries for optimum energy utilization.

A good example for the use of Diphyl® THT is the manufacture of PBT, PET, purified terephthalic acid (PTA) which are applied in many fiber spinning plants worldwide.

7. RELEVANT TECHNICAL STANDARDS AND REGULATIONS

UVV/BGV D3
Heat transfer installations using organic heat transfer fluids (with handling instructions).

DIN 4754-1
Heat transfer installations working with organic heat transfer fluids; safety requirements, testing.

Druckbehälterverordnung
Pressure Vessels Regulation (particularly Appendix II, No. 37, to § 12), EU-PED (pressure Equipment Directive).

TRB
Technical regulations concerning pressurised vessels subject to the Pressure Vessels Regulation, particularly TRB 801, No. 37.

VDI 3033
Regulations for heat transfer installations using organic heat transfer media – operation, maintenance, repair.

DIN 18230
Structural fire protection in industrial buildings. Part 1: Analytically required fire resistance time;

Part 2: Determination of combustion behavior of materials in storage arrangement – combustion factor m.

EX-RL
Selection of examples for plants as per DIN 4754.

DIN/ISO 6743, Part 12
Classification Family Q, heat transfer media.

DIN 51522
Heat transfer oils (type Q), specifications, test.

DIN 51528
Determination of thermostability of unused heat transfer fluids.

DIN 51529
Testing and evaluation of used heat transfer fluids.

VAWS
Plant regulation concerning the handling of substances classified as hazardous to water and specialty operations.

Special Construction Components:

DIN 3440
Thermostats, temperature limiters, cut-offs for heating systems.

VDE 0631
Temperature control systems and other similar equipment.

DIN 32728
Routine controls; low fluid cut off (control) for heat transfer installations with organic fluids (safety requirements and test).

DIN 32727
Flow switches for heat transfer installations; safety requirements and test.

VDE 0116 (DIN 57116)
Electrical equipment of furnaces.

Only for Systems in Explosion Hazard Areas:

Ex VO
Explosionsschutzverordnung

ElexV
Regulation on electrical equipment in explosion risk areas.

Further relevant specifications and standards are included in the above.

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Further information on all Diphyl® HTF from LANXESS for the planning and design of heat transfer plants can be found on the Diphyl® USB stick.

It can be obtained from:
LANXESS Distribution GmbH
Advanced Materials
D-51369 Leverkusen, Germany
Tel. +49 0221 888-55212
www.diphyl.com

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