Thermera

heat transfer fluid

A natural solution for heat transfer in HVAC systems

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Product file

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Thermera, a new heat transfer fluid with extremely low environmental impact, was developed and tested in co-operation with end users and raw material manufacturers.

The main raw materials of Thermera are betaine, a by-product of the sugar manufacturing process, and water.

Betaine is a natural product, which makes Thermera a product with an extremely low impact on the environment.

As Thermera is non-toxic and environmentally acceptable, it is suitable for a wide range of applications.

Thermera is designed for use in closed circuits operating within the fluid temperature range of –45 °C - +110 °C.

Thermera fluid is excellent for the needs of HVAC systems in buildings and industry. This product is always delivered as a ready-to-use solution.

New uses can be found, particularly in areas in which health factors, in addition to environmental aspects, are important.

In the proper areas of application Thermera's thermal performance is at least equal to that of conventional heat transfer fluids.

Compared with conventional fluids, Thermera offers the additional advantages of excellent cold-flow and anti-corrosive features.

What is Thermera®?

History of product development
The development work of the new heat transfer fluid was market-oriented. New systems are vulnerable to propylene glycol's poor flow and heat transfer features under cold circumstances.
In many cases ethylene glycol cannot be used, because of its toxicity, and salt solutions often cause difficult corrosion problems.

We aimed at developing a heat transfer fluid with a wide operating temperature range, good corrosion properties, less toxicity than ethylene glycol, and better heat transfer characteristics than propylene glycol.

The research and development work resulted in Thermera. Thermera was tested at laboratories and application sites during the period 1995-2000, and the product was launched on the Finnish market in autumn 2000. The other nordic countries and Germany and the Benelux saw Thermera launch in 2002.

Thermera®
Thermera is a new environmentally acceptable heat transfer fluid, which is excellent for building HVAC systems, food and refrigeration technologies, and for industrial heat transfer needs.

Thermera is a mixture of ion-exchanged water and betaine, completed with non-toxic additives.

Betaine, or trimethylglycine, is a natural product, which is a by-product of the sugar manufacturing process. The natural raw material makes the end product environmentally very acceptable.

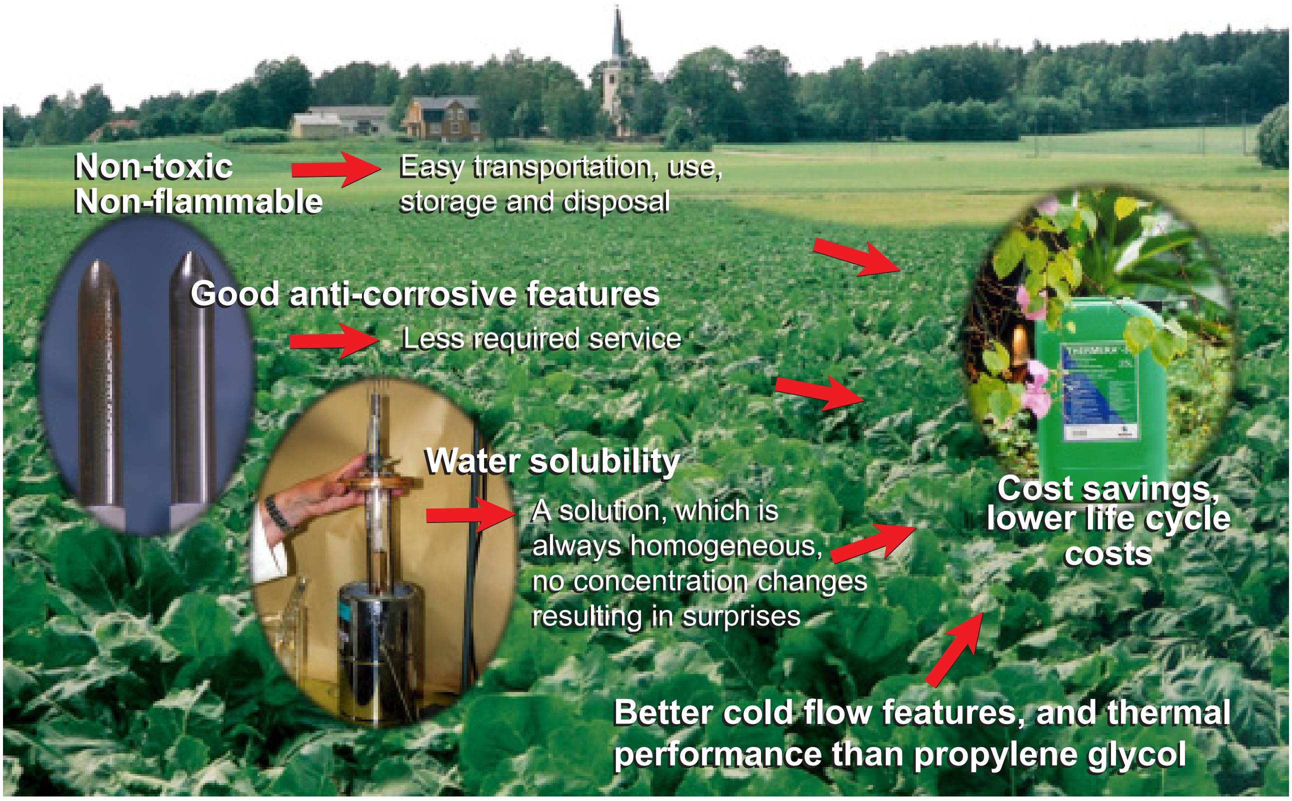
Betaine is used in several products of the food, pharmaceutical and cosmetics industries. As a chemical, it has been known for decades.

Thermera's thermal performance has been proved to be of the same class as that of the conventional heat transfer fluids. Thermera offers the advantages of non-toxicity, water solubility, and excellent cold-flow and anti-corrosive features.

Thermera and environmental features
Thermera has top-quality environmental features, which provide it with a wide operating range. The first areas in which Thermera's technical suitability has been proved are various HVAC building systems, and food and refrigeration technologies. Other suitable objects of use are being developed.

Thermera and the operating range
See item 4. Uses of Thermera.

Thermera’s advantages in use



Environment, health and safety (EHS)

The ecology of Thermera

Betaine
Betaine is one of the main raw materials of Thermera, in addition to water. Betaine, or trimethylglycine, is an amino acid, and it occurs in all living organisms. It is also used as an additive in foodstuffs, medicines, cosmetics, and animal feeds. Betaine as a chemical is well known and there is a lot of literature on this subject. Betaine used in Thermera is acquired from sugar beet.

Biodegradation of betaine
In general a substance is defined as easily biodegradable, if the mineralization degree after 28 days exceeds 60%. In the case of betaine, this value exceeds 88%, so it can be called highly biodegradable.

Stability of betaine
Betaine is very stable, both in view of temperature and microbiology. Betaine endures a continuous temperature of more than 110 °C. Betaine prevents the growth of micro-organisms, when the betaine content of a fluid is over 20 w-%.

Solubility of betaine
Betaine is completely water-soluble. This means a completely homogeneous aqueous solution under all circumstances. For comparison, glycols just mix with water (water and glycol may later separate in a solution).

Non-toxicity of Thermera
Betaine, the main raw material, is an absolutely non-toxic natural product, which is verified as a material suitable for several drugs by the United States FDA (Food and Drug Administration). Such small amounts of additives have been used in Thermera as to keep the end product non-toxic. (Cf. VTT Technical Research Centre of Finland's statement).

Combustibility of Thermera
Thermera is not a combustible fluid. See also the safety data sheet.

Destructibility of Thermera
Thermera can be disposed from the HVAC systems directly to the sewer system. However, the correct procedure shall always be checked with the local sewage treatment plant. Betaine does not cause any risk to a biological purification plant.

Storage and transportation of Thermera
Because of Thermera's non-toxicity, no official licences are needed for the storage and transportation of Thermera (Cf. Safety data sheet). Thermera should be stored protected from direct sunlight. Thermera should always be stored in a sealed container, to avoid evaporation of water from the product. Betaine which has possibly crystallized on the container edge (white deposit or powder) can be easily dissolved back to the solution by shaking the container.

Physical properties of Thermera

Operating temperature ranges

Thermera products can be used within a very extensive operating temperature range.

Freezing point is used as a basis for product classification.

Standard products

The standard Thermera products are:

Thermera -15
Thermera -35

Some other possible customized products:

Thermera -10
Thermera -20
Thermera -25
Thermera -30
Thermera -40

The figure in the product name indicates the freezing point of the product in question, i.e. **the recommended lowest continuous operating temperature of the fluid**.

In addition to the above standard products, Thermera can be delivered, in order to optimise large systems, with any frost resistance specified by the user, down to -50°C.

The continuous maximum operating temperature for all Thermera products is +110°C. In temperatures exceeding this point, betaine begins to degrade slowly, and in temperatures exceeding 150°C the degradation is quick. The degradation products of betaine are not corrosive or otherwise harmful to people or the environment.

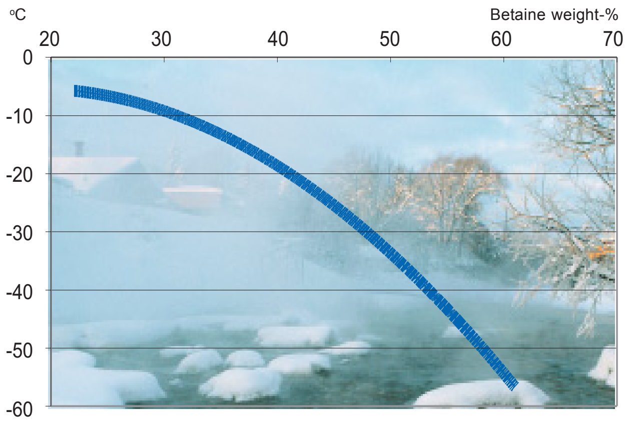
Freezing point

The method used for determination:
ASTM D 2386-97

Freezing point is the temperature below which solid crystals may build up in a solution. To determine the freezing point, a solution is cooled down while stirring, until crystals appear. After the first crystals have built up, the solution is left to warm up slowly while stirring. The temperature in which all the crystals have disappeared is the freezing point of the solution.

It is most common that the freezing point value is given for heat transfer fluids according to this method.

Freezing point



At the freezing point, and at least 4 degrees centigrade below this point, the product is still completely reliable. This means that Thermera -20, for instance, can be used in a continuous temperature of -20°C, and for short periods of time it endures even about -24°C.

Congealing point (or solidifying point)

The method used for determination:
ASTM D 1177-65

Congealing point is another term frequently used for cold endurance.

Congealing point is determined in the same way as freezing point, but cooling is continued as long as the sample has undergone so-called thickening, i.e. the viscosity has increased so much that the solution cannot be pumped any longer.

So congealing point is the temperature in which the product does not work any longer.

For low-concentration solutions, Thermera products' congealing point is about 4 degrees lower than the freezing point, and for high-concentration solutions it is about 10 degrees lower.

Frost resistance measurements of Thermera products

In addition to the manufacturer's own laboratories, the VTT Technical Research Centre of Finland has also measured the Thermera products. VTT is an impartial research organisation of 3,000 employees, which produces a wide range of technology and research services for both Finnish and international customers, companies and the public sector.

Property tables

Density kg/m^3

	Thermera -10	Thermera -15	Thermera -20	Thermera -25	Thermera -30	Thermera -35	Thermera -40
-30			1,091.3	1,100.8	1,105.5	1,113.1	1,118.2
-15	1,060.6	1,078.3	1,087.2	1,096.5	1,101.2	1,108.0	1,112.6
0	1,056.9	1,073.8	1,082.3	1,090.9	1,095.2	1,101.7	1,106.1
15	1,052.7	1,068.5	1,076.4	1,084.7	1,088.8	1,095.2	1,099.5
20	1,050.9	1,066.5	1,074.3	1,082.4	1,086.5	1,092.9	1,097.1
50	1,036.7	1,052.4	1,060.3	1,068.2	1,072.2	1,078.2	1,082.2

Kinematic viscosity mm^2/s

	Thermera -10	Thermera -15	Thermera -20	Thermera -25	Thermera -30	Thermera -35	Thermera -40
-40							256.0
-35							162.2
-30					57.8	87.1	106.6
-25					40.9	60.0	72.8
-15			13.9	19.7	22.6	31.8	37.9
0	3.9	6.2	7.3	9.8	11.0	14.7	17.2
20	2.2	3.2	3.7	4.8	5.4	6.8	7.8
40	1.4	2.0	2.3	2.8	3.1	3.8	4.3

Specific heat kJ/kgK

	Thermera -10	Thermera -15	Thermera -20	Thermera -25	Thermera -30	Thermera -35	Thermera -40
-30							2.69
-20					2.91	2.80	2.73
-10			3.06	2.99	2.95	2.84	2.77
0	3.26	3.13	3.07	3.01	2.98	2.88	2.81
10	3.28	3.15	3.09	3.04	3.02	2.92	2.85
20	3.29	3.17	3.11	3.07	3.05	2.95	2.88
30	3.31	3.20	3.14	3.11	3.09	2.98	2.91
40	3.33	3.22	3.16	3.13	3.12	3.01	2.94
50	3.34	3.23	3.18	3.16	3.15	3.05	2.98
60	3.35	3.24	3.19	3.18	3.17	3.07	3.00
70	3.36	3.25	3.20	3.19	3.19	3.09	3.03
80	3.38	3.27	3.21	3.21	3.21	3.11	3.05

Thermal conductivity W/m, °C

	Thermera -10	Thermera -15	Thermera -20	Thermera -25	Thermera -30	Thermera -35	Thermera -40
-10	0.439	0.404	0.387	0.369	0.361	0.352	0.339
0	0.443	0.408	0.390	0.373	0.364	0.355	0.342
10	0.451	0.416	0.398	0.380	0.371	0.362	0.349
40	0.460	0.423	0.405	0.386	0.377	0.368	0.354
50	0.464	0.427	0.409	0.390	0.381	0.372	0.358
80	0.477	0.439	0.420	0.401	0.391	0.382	0.368

Comparison of properties with conventional heat transfer fluids

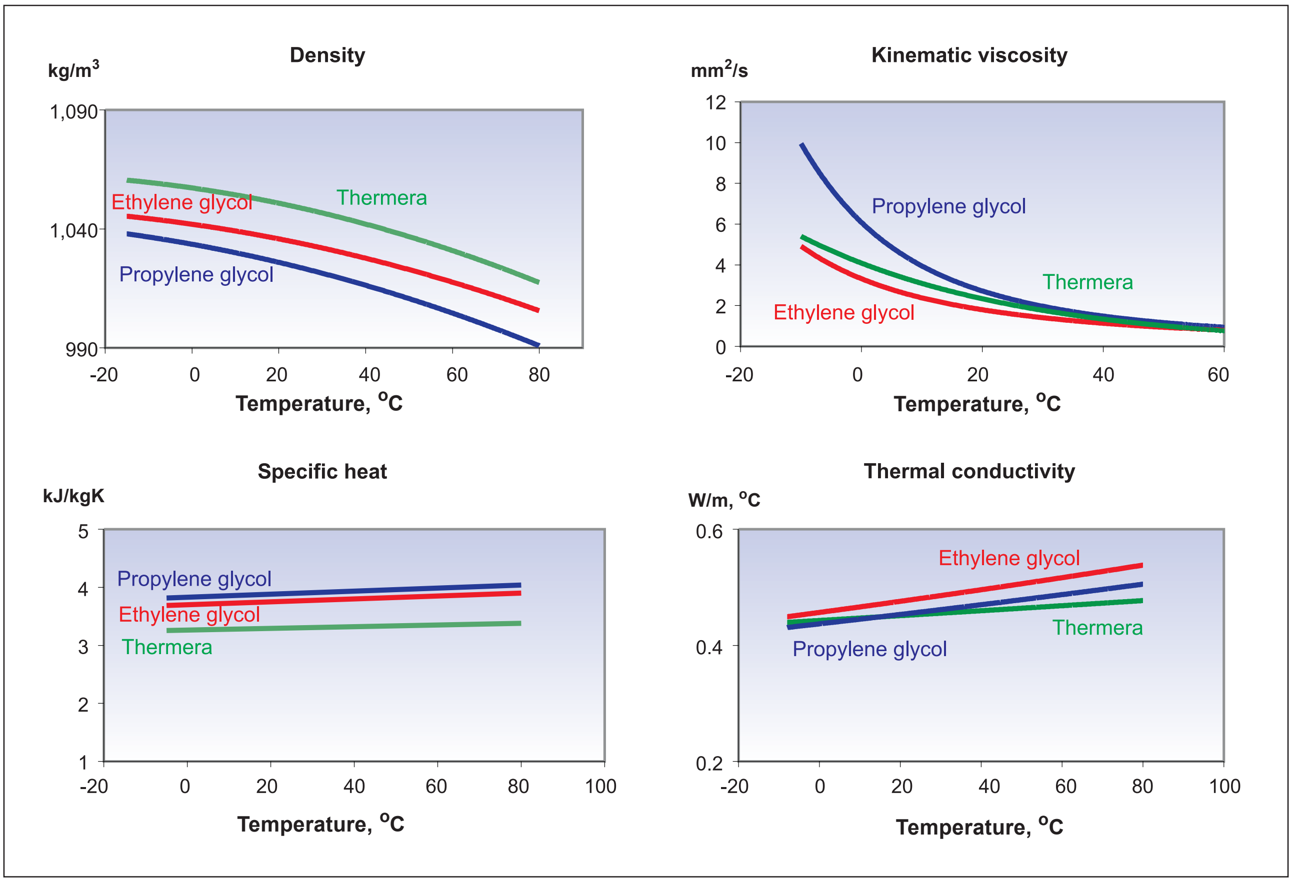
Density

Kinematic viscosity

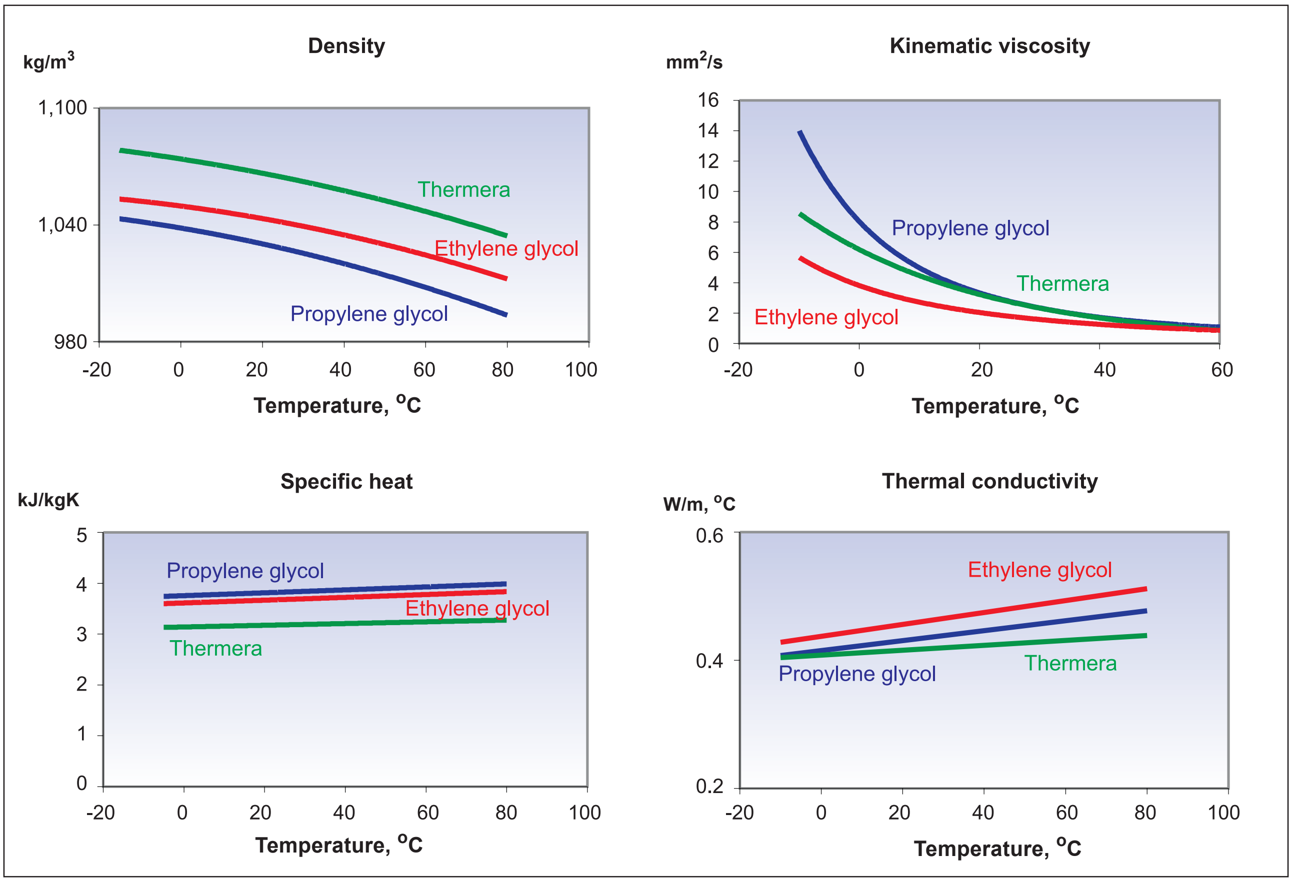
Specific heat

Thermal conductivity

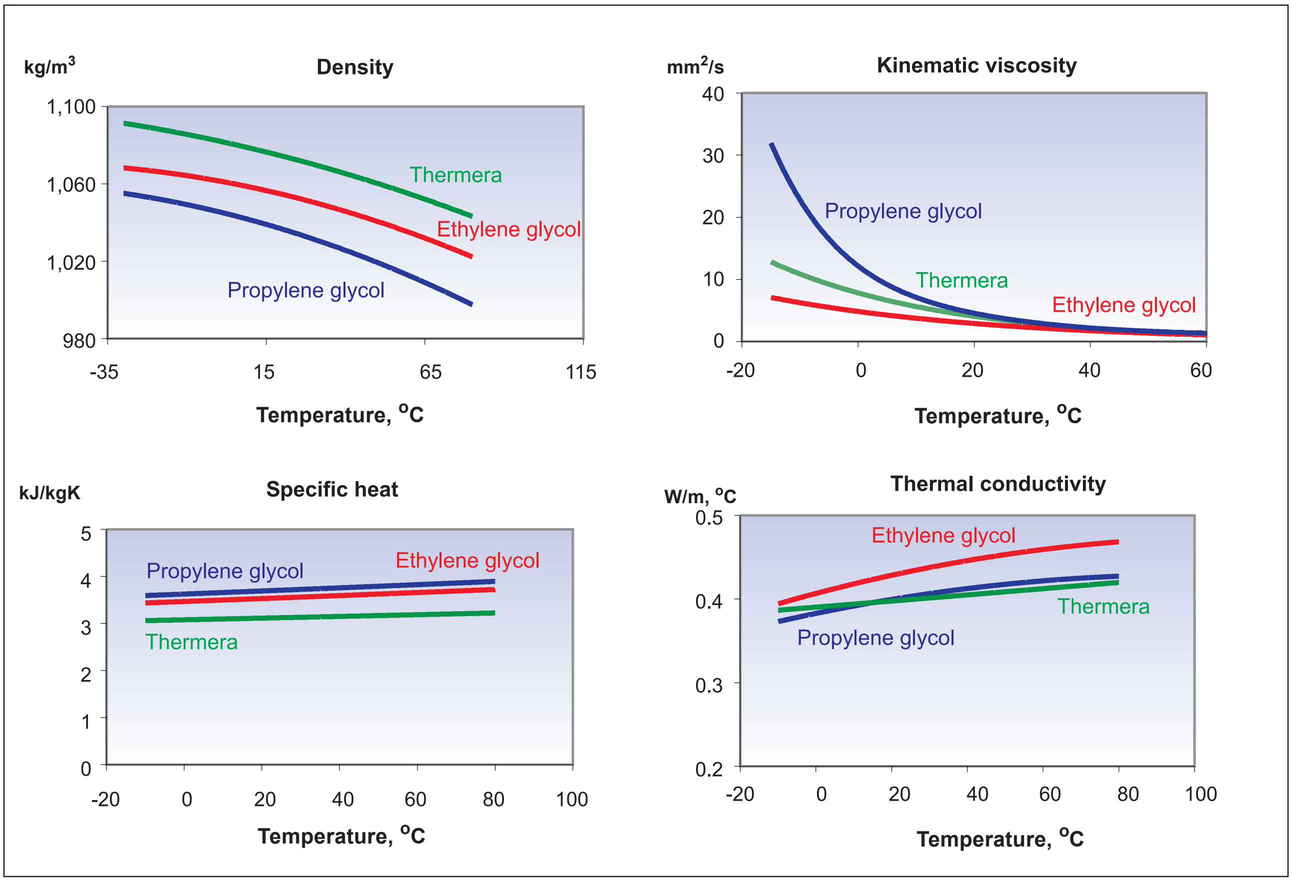
Comparisons between fluids with the same freezing point (- 10°C)



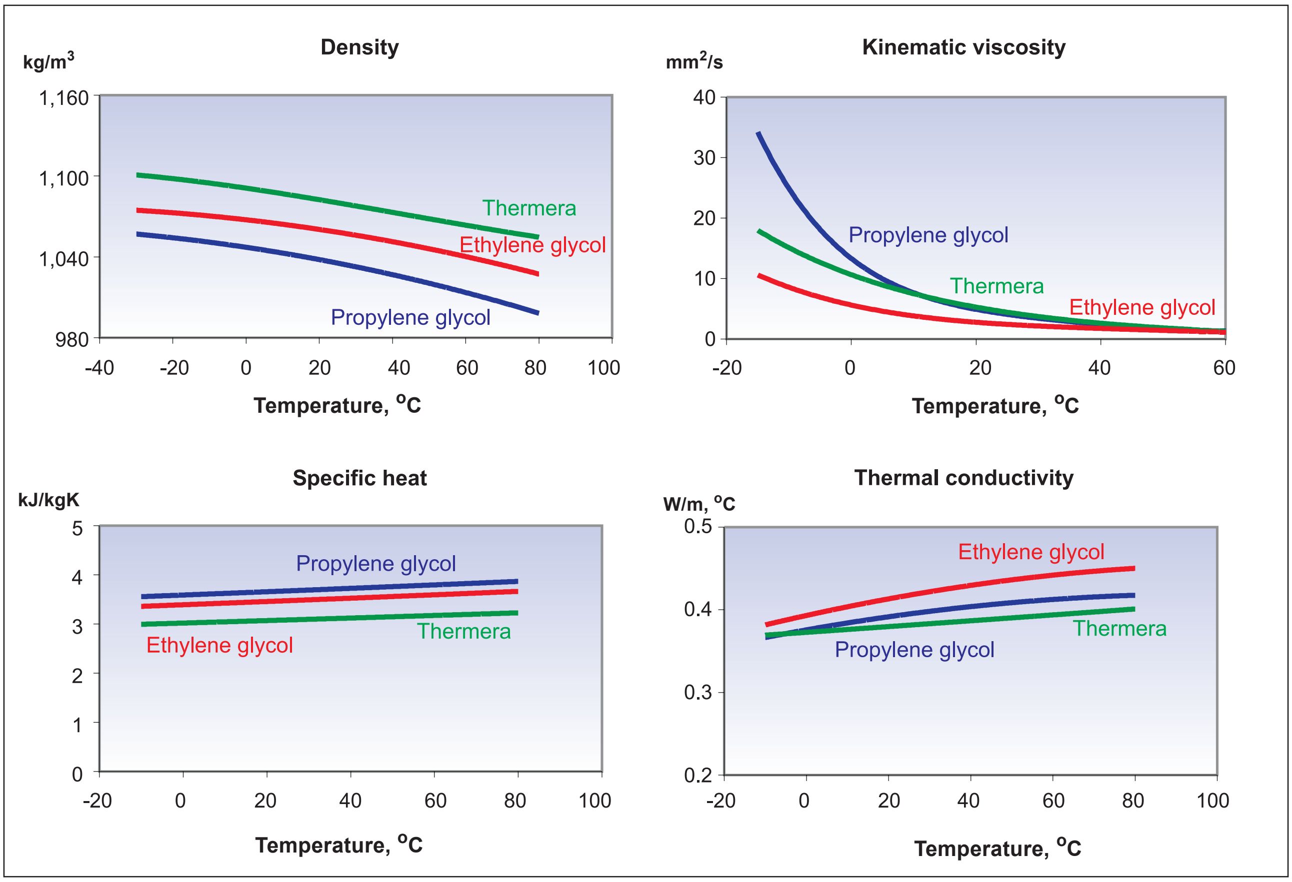
Comparisons between fluids with the same freezing point (- 15°C)



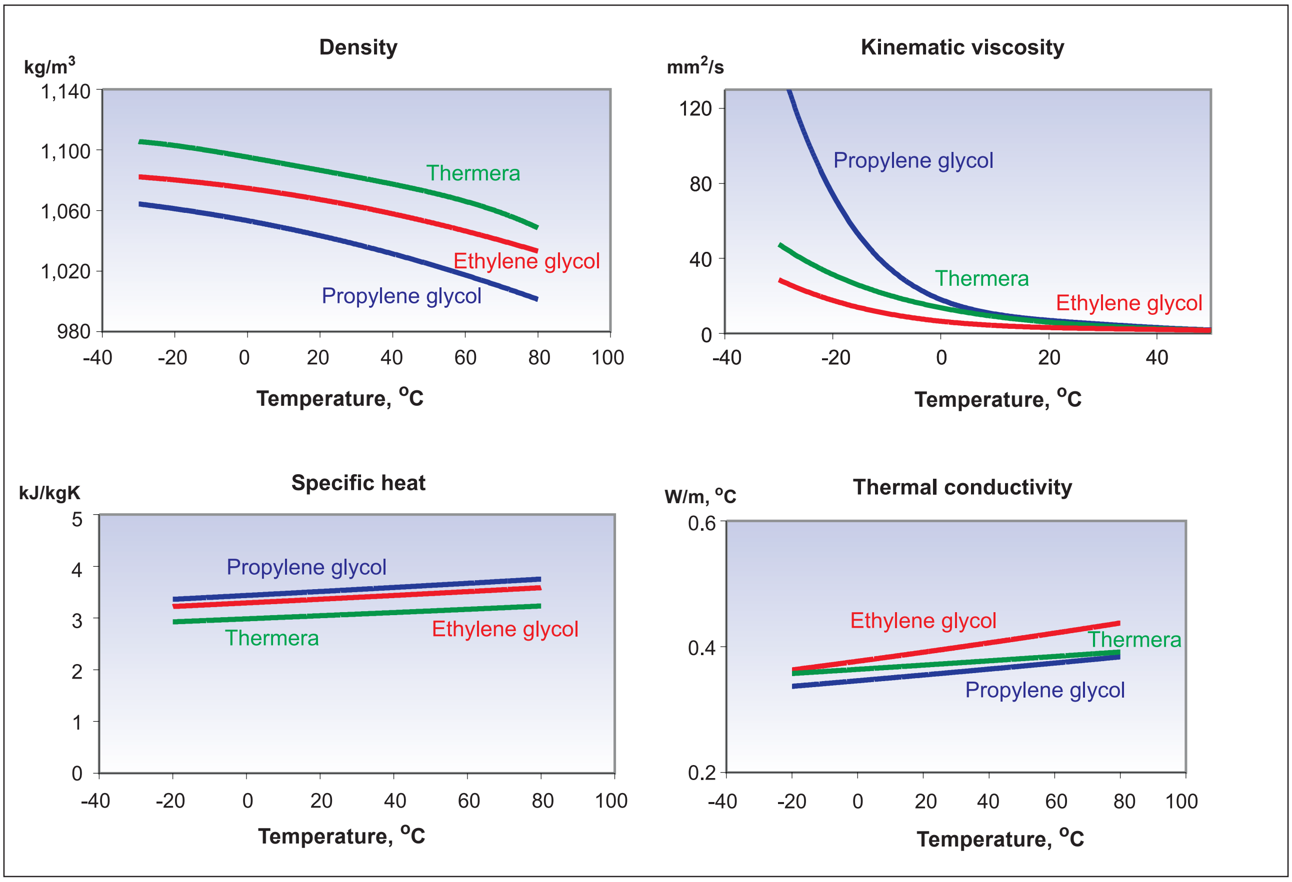
Comparisons between fluids with the same freezing point (- 20°C)



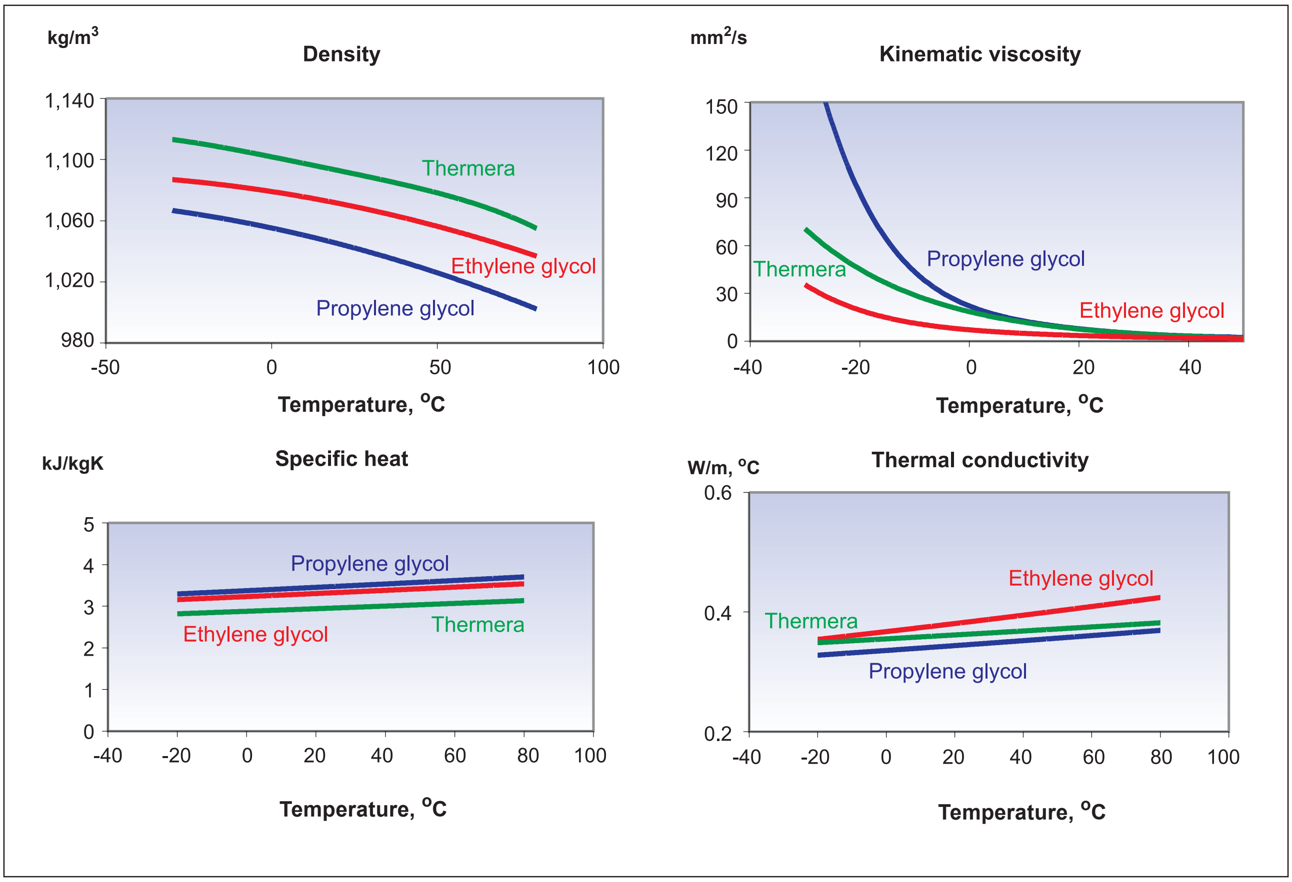
Comparisons between fluids with the same freezing point (- 25°C)



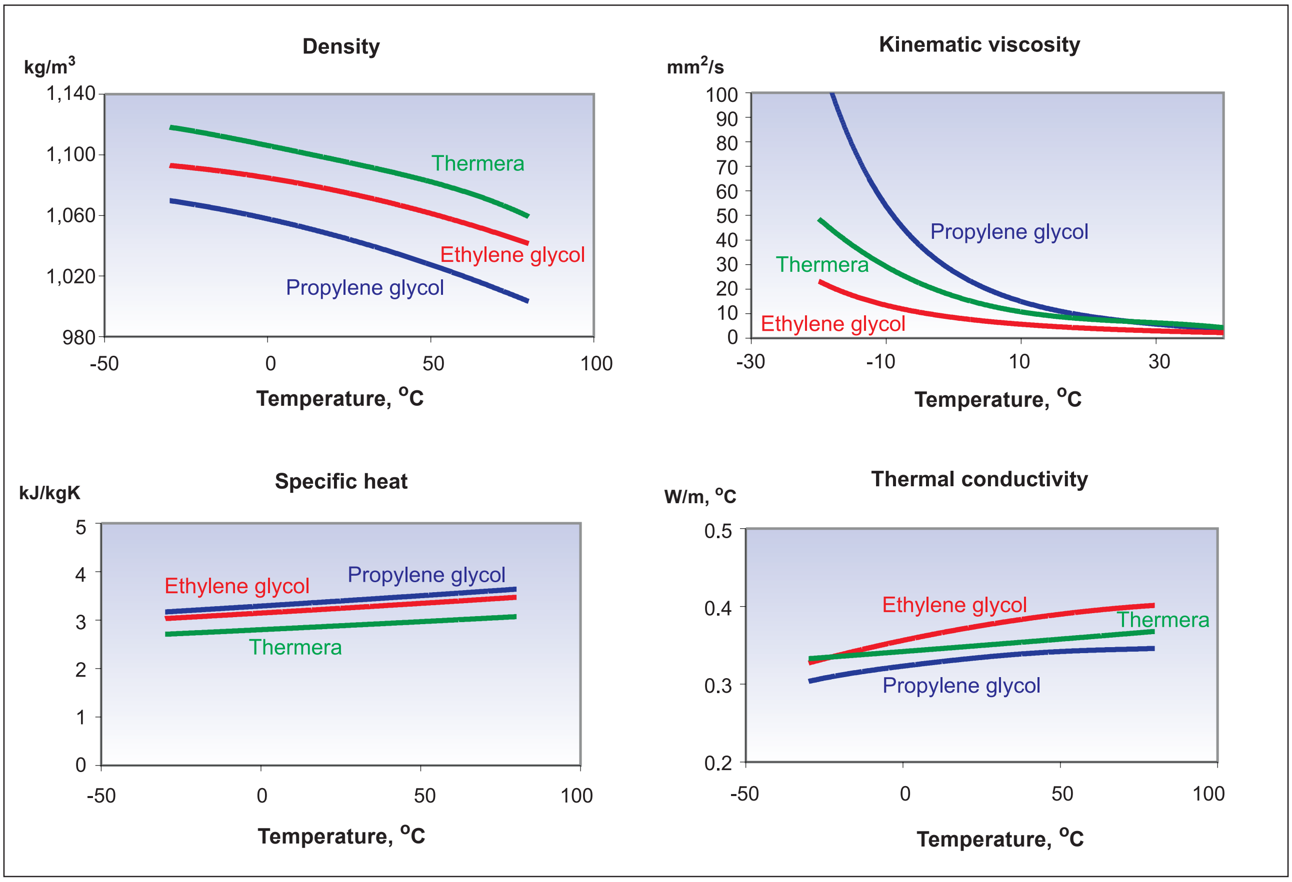
Comparisons between fluids with the same freezing point (- 30°C)

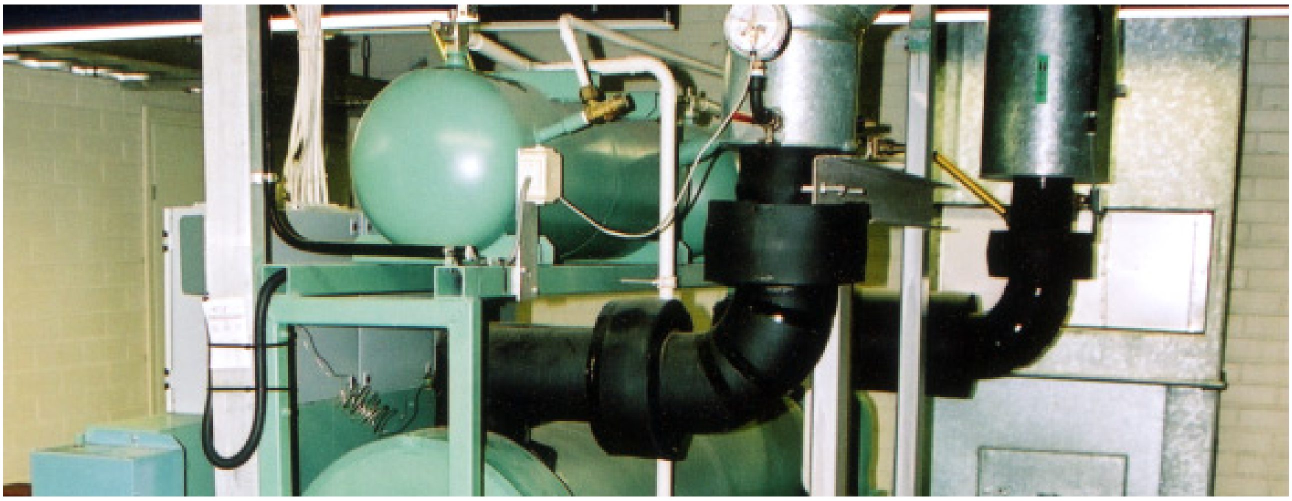


Comparisons between fluids with the same freezing point (- 35°C)



Comparisons between fluids with the same freezing point (- 40°C)





Use of Thermera

System
Thermera is a completely dissolved solution of water and betaine. It is intended mainly for closed systems and circuits. In an open system, part of Thermera's water content might evaporate and the concentration of the fluid change. In an open circuit, oxygen also dissolves in the solution, and corrosion prevention becomes more difficult, as with all heat transfer fluids. So technically Thermera can be used in open systems as well, but careful condition monitoring is essential.
General instruction for the choice of materials: system components are selected in the same way as in the use of glycols.

General instruction for the dimensioning of the components and heat transfer: dimensioning is done specifically for each system using Thermera's physical properties (cf. also the appended CD-ROM). It is usually observed that in heat recovery, and heat pump applications, the replacement of ethylene glycol with a Thermera product with corresponding freezing point does not lower the efficiency of the system.

Temperature range
The highest operating temperature recommended for Thermera products is 110°C. This is the temperature above which betaine is no longer completely stable; a certain amount of degradation may occur. In practice the temperatures of building systems are below 50°C. If Thermera is used in higher temperatures, the seller's expert should be consulted.

The name of the Thermera product refers to the lowest operating temperature. Consequently the lowest operating temperature of Thermera -20 is -20°C. It is highly important to note that the lowest operating temperature refers to such **temperature of Thermera fluid** in which the fluid starts to crystallize and viscosity starts to increase to a great extent. So in normal operation the lowest operating temperature does not refer to the outdoor temperature.

If a Thermera fluid is kept for a long time in a temperature which is much lower than its lowest operating temperature (Thermera -10 is used in the temperature of -20°C, for instance), the fluid crystallises heavily. This can be seen as similar partial phase transition as in conventional glycols; Thermera fluid turns into snow-like mass. However, only minor thermal expansion will occur, so pipe burst protection reaches considerably beyond the lowest operating temperature. Extreme-temperature tests have shown that use of the Thermera product has caused no damage to pipes or heat exchangers.

Materials
Thermera is completely compatible with all the used pipe and equipment materials. We have test results and operating experiences of copper, carbon steel, brass, solder, cast iron, and stainless steel. All the used elastomers and sealants have also been

tested to be compatible with Thermera products. A universally applicable rule is that the system shall be implemented in the same way as in glycol use. So the sealants shall be chosen to be glycol-resistant. Consequently, Thermera products are directly compatible to replace glycols in existing systems.

Deaerators
Spindle-operated, automatic deaerators are not recommended. A moving spindle is a potential leakage point.

Filters
If the system includes filters, they should be cleanable.

Pumps
All the general pumps made for heat transfer fluids are suitable for Thermera, if they are equipped with so-called glycol-resistant seals.
(for example Grundfos R)

Valves
Ball valves are recommended.

Connections
Welded and flanged joints are recommended. Seals should be glycol-resistant.

Filling and changing a heat transfer fluid

Generally the equipment manufacturer's instructions are followed.

Cleanliness of the system shall be checked before the system is filled with the fluid. Effective flushing with water and careful draining are sufficient.

Thermera products are always ready-to-use, so no water or other materials are added when filling a system. It is recommendable to make a note of the product used in the system and reserve a full canister of corresponding Thermera product in the vicinity of the system. This guarantees that the system's fluid concentration and protection against freezing does not change with later fill-ups.

The system should be filled through the lowest filling valve, thus taking full advantage of the deaeration system.

The installation personnel should know the theoretical volume of the system. If the input amount of fluid is much smaller than the theoretical volume, this may be an indication of an air lock, for instance.

After the test run of the system, please check the volume of heat transfer fluid. If there has been air in the system, it may be necessary to add fluid. If the condition of the fluid is intended to be monitored during operation, the first sample should be taken in this phase, and later operation-time measurements should be compared to this sample.

When filling an old system with Thermera fluid, it should be carefully drained and flushed. The earlier used fluid, which may be toxic, shall also be disposed of in an environmentally acceptable and legal way.

Condition monitoring
Thermera has operated well up to expectations and maintained its condition at all sites. If you want to monitor the conservation of Thermera's condition, you can take a sample every second year, for example, and compare this sample with the first sample. Usually the freeze protection properties, pH and condition of the additives are measured.

The condition monitoring of the system also covers monitoring of possible leaks. If Thermera seeps through the system, there will be small white flakes at the leaking point, as water evaporates from the fluid, leaving harmless betaine crystals. This makes a leaking point easily detectable. The flakes are completely non-toxic and they can be wiped from all the surfaces with a wet towel.

If it will be necessary to fill the system, simply add the correct Thermera product. Filling shall be done from a container, which has been closed during storage.

Operating characteristics

Temperature stability.
Research results indicate that Thermera products are highly stable up to a temperature of 110 °C, and no degradation has been detected in the tests.

Microbiological stability.
The research results indicate that Thermera products are highly stable. No fungal, yeast or bacterial growth has been found.

The research and practical experiences have shown that betaine, the raw material of Thermera, prevents microbial growth in fluid concentrations of over 20 w-% of betaine.

Foaming.
Thermera does not foam in normal applications.

Operating life.
As Thermera has a good thermal and microbiological stability and it contains only a very small amount of inhibitors, its operating life is most often longer than that of the conventional heat transfer fluids. The exact operating life always depends on the specific system, and no exact life span can be given.

Disposal.
As Thermera is a completely non-toxic and environmentally acceptable natural product, it can be disposed of with normal sewage water. In case of major volumes, the local sewage treatment plant or the municipality should be consulted for detailed instructions.

Storage
Thermera should be stored in a closed and air-sealed container. This guarantees that no water will evaporate into the air and Thermera heat transfer fluid will remain in top condition. A container possibly located under the filling pump shall also be hermetically closed. A stored product shall be protected against direct sunlight.

Corrosion

Corrosion, or rusting, is a well-known chemical effect.

Corrosion refers to a phenomenon, in which a metal or an alloy is partly oxidized as a result of air or other gases and solutions.

Corrosion may be wet (effect of a solution) or dry (effect of dry gases). Dry corrosion is less frequent and it occurs in special circumstances, as a metal surface which is in contact with air is always in contact with moisture as well.

Corrosion is classified into two categories:
chemical corrosion and
electrochemical corrosion

In electrochemical corrosion, two metals form an electric couple. In this reaction, the metal which is more electronegative corrodes.

In chemical corrosion, a metal reacts with oxygen in the air or an acid solution.

This can be avoided by using corrosion inhibitors. An inhibitor forms a protective coating on the metal surface.

However, there will be problems if a lot of inhibitors are required. They decompose and lose their effect as a result of heat, flow and pressure. This is how corrosion starts to take affect, although the heat transfer fluid would not otherwise have lost its properties.

Another corrosion effect which is typical of heat transfer fluids is the impact of organic acids.

It is possible that acid is formed in heat transfer fluids following a chemical reaction, and this acid results in corrosion in the structural material.
This is particularly typical of glycols.

Thermera and corrosion

Consequently, corrosion refers to material wear and thinning as a result of an electrochemical effect.

This thinning rate is described with the term corrosion rate, and the unit used is micrometer per year, µm/a.

The corrosion rate can be measured by measuring the electric current of corrosion, or directly the thinning of the raw material. To improve reliability, both of these quantities are often measured, as was done with Thermera in the product development stage.

Additives

With Thermera, the need of additives is considerably smaller than with conventional products.
So there is no major concern about the durability or toxicity of additives as long as Thermera is used. Neither does betaine, the main raw material, form any corrosive disintegration products, unlike conventional products. Even a Thermera product without any additives has better anti-corrosive features than water. So betaine is a natural corrosion preventing agent.

Thermera is slightly scented with an odorant used in the food industry (< 1w-%).

Because of its good anti-corrosion features, only a minor amount of corrosion inhibitors have been added to Thermera (< 1w-%, active ingredients total less than 0,1 w-% in the end product).

The additives used do not have any effect on Thermera's toxicity. (Cf. VTT Technical Research Centre of Finland's statement).

As Thermera is always a ready-to-use product, each Thermera product has always the correct additives, despite varying betaine concentrations. For example: the corrosion protection of Thermera –10 corresponds thus completely with that of Thermera –40.

Thermera's corrosion rates for various materials:

In this test, a Thermera product with an average betaine concentration of 35 w-% of betaine was used. The testing method used was ASTM 1384, temperature 50 °C.

	Thermera®	Water	
Copper	0.3	1.6	µm/a
Carbon steel Fe37	0.3	68	µm/a
Brass	0.3	0.9	µm/a
Bronze	0.3	1.7	µm/a
Cast iron	22.0	95.0	µm/a
Aluminium	2.4	18.0	µm/a
Zinc	4.0	not tested	µm/a

The corrosion rates shown in the table guarantee that all the known service life requirements of the equipment manufacturers will be fulfilled. The corrosion protection provided by Thermera is at least as good as that of the conventional products, often much better.

Calculation

CALCULATION OF THERMERA'S PHYSICAL PROPERTIES AND FLOW CHARACTERISTICS

The forms on the disk are used to calculate the following properties for the various THERMERA products:

- Density, dynamic and kinematic viscosity, thermal conductivity and heat capacity, with fluid operating temperature given as basic data.
- Flow velocity and pressure drop in a specific pipe section, with flow rate and length and diameter of the pipe section given as basic data.
  The pipe is assumed to be smooth in the calculation of the pressure drop.
- Thermal power, with temperature difference given as basic data.
- In addition, the form gives the Reynolds number and flow type (turbulent or laminar).

The equations used:

Re > 2320 (turbulent flow)

$\Delta P_{turb} = (0.0028+0.25/Re^{0.32}) \cdot L \cdot v^2 \cdot \rho/d$

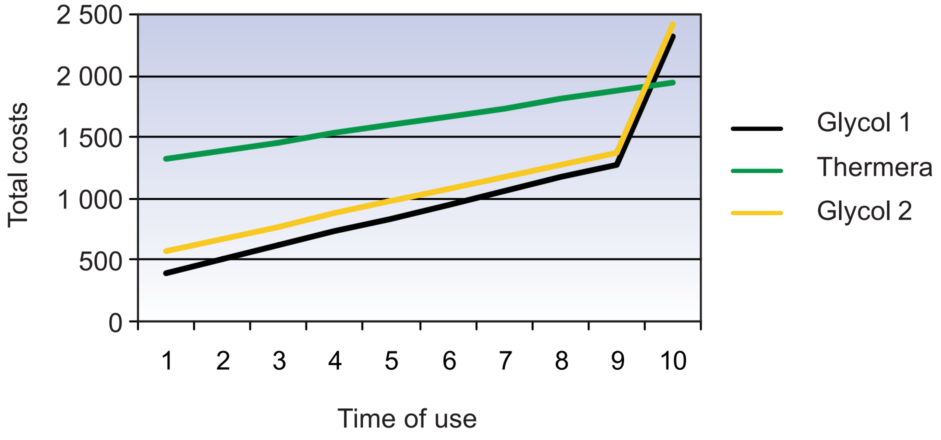
Re < 2320 (laminar flow)

$\Delta P_{lam} = 32 \cdot L \cdot v^2 \cdot \rho/(Re \cdot d)$

ΔP = Pressure drop in the pipe section, Pa
Re = Reynolds number = $d \cdot v/\nu$
L = Length of the pipe section, m
v = Flow velocity, m/s
ρ = Density, kg/m^3
d = Inside diameter of the pipe section, m
ν = Kinematic viscosity, mm^2/s

Life cycle cost

Life cycle costs in a new system



An indicative life cycle cost comparison between the various conventional glycol products and Thermera. The calculation is based on the prices of the products and the disposal costs in Finland. In the real-life example shown in the picture,a glycol product is about 24% more expensive. In small-scale systems, in which the disposal costs of the spent fluid will grow, the difference may be as high as 77%.

Uses of Thermera

The development of Thermera was initiated on the basis of the end users' need to replace conventional glycols with a more environmentally benign option with no compromises over the most important characteristics in view of the use.

So the general principle can be considered to be that Thermera can be used everywhere where ethylene and propylene glycols are used today. Thermera is excellent for buildings' HVAC systems: it can be used for cooling in air conditioning systems and for heat recovery in office buildings, shopping centres and industrial buildings. Thermera is also suitable for geothermal heat pumps. Heated pedestrian streets, which are becoming common in urban areas in the north, are another significant use for Thermera.

Thanks to Thermera's environmental acceptability and non-toxicity, it can be used in systems in which ethylene glycol is not acceptable. Thermera is an excellent heat transfer fluid for the food industry, for instance. Thermera is used as heat transfer fluid in the secondary circuit in refrigeration systems.

In several applications, Thermera competes successfully with salt solutions. However, extremely cold circumstances, i.e. continuous operation under –25 °C, are not the best operating areas for Thermera.

Sample applications of use - Thermera heat transfer fluid

This list introduces certain characteristic sample objects of various application areas, in which Thermera heat transfer fluid has been used.

Nokia office buildings at Pitäjänmäki in Helsinki
Thermera –15 in heat recovery systems.
Equipment supplier ABB.

Fortum at Myyrmäki in Vantaa
Thermera –35 in the anti-freezing system of a parking lot ramp, ABB Fläkt.

Fortum at Myyrmäki in Vantaa
Thermera –25 in air conditioning systems, ABB Fläkt.

One-family house in Halikko
Thermera –15 in a geothermal heating system, Suomen Lämpöpumpputekniikka.

Helsinki University of Technology, Valotalo, at Otaniemi in Espoo
Thermera –35 in a solar heating system.

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