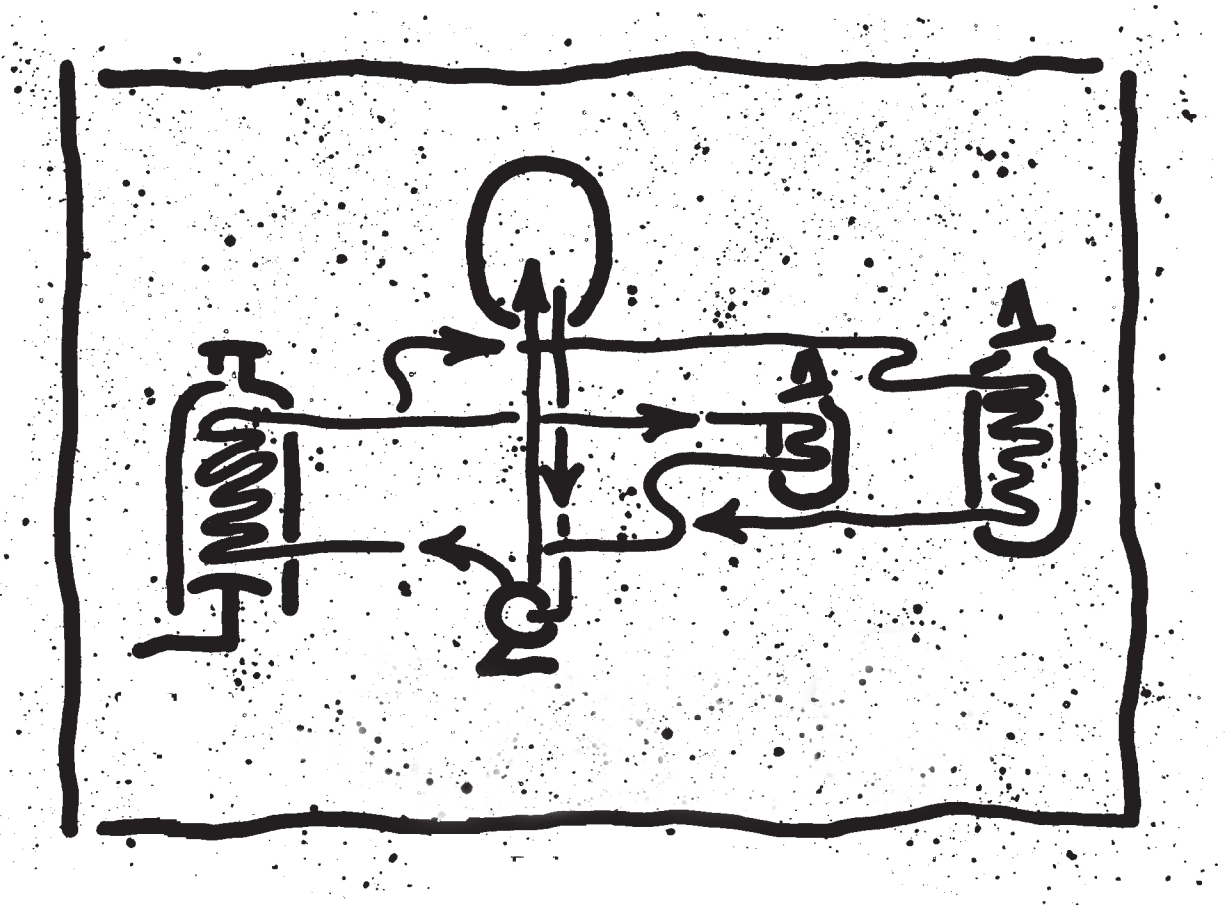




# DOWTHERM and SYLTHERM Heat Transfer Fluids in Sub-Zero Systems



*Application Guide*

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# CONTENTS

## Introduction

DOWTHERM J Heat Transfer Fluid .....	1
SYLTHERM XLT Heat Transfer Fluid .....	1
SYLTHERM HF Heat Transfer Fluid .....	1

## Physical and Thermal Properties

Comparing Heat Transfer at the Air Exchanger .....	2
Key Physical Properties Compared .....	2
Comparing Thermal Properties .....	2
Comparing Heat Transfer at the Evaporator .....	3
Choosing the Best Fluid for Your System .....	3
Calculating Overall Heat Transfer .....	3
Mostinski Equation for Vaporizing Film Coefficient .....	3

## Regulatory Status .....

## Health and Safety Status .....

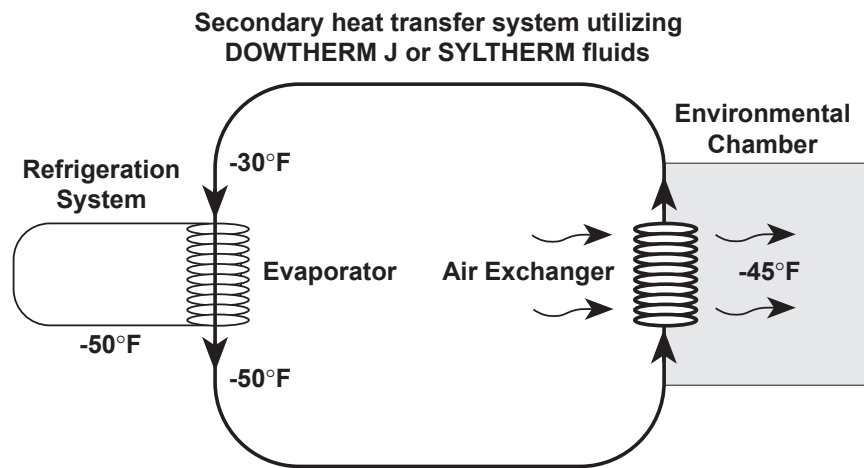
## System Engineering and Design

Water Removal .....	4
Metal Construction .....	5
Elastomers .....	5
Plastics .....	5
Flanges and Gaskets .....	5
General Operational Notes .....	5

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Figure 1 – Simplified Diagram of a Sub-Zero System

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*DOWTHERM J, SYLTHERM XLT, and SYLTHERM HF fluids function efficiently at the low temperatures required of a secondary heat transfer fluid in sub-zero systems. They also feature favorable environmental profiles, compatibility with commonly used materials of construction, and comprehensive technical support from Dow.*

## **DOWTHERM AND SYLTHERM HEAT TRANSFER FLUIDS IN SUB-ZERO SYSTEMS**

Most sub-zero heat transfer systems<sup>1</sup> such as environmental test chambers, commercial food freezers, systems for low-temperature reactions, and liquid gas vaporizers require the use of secondary heat transfer fluids which can function efficiently at temperatures as low as -160°F. Since most heat transfer fluids freeze or become excessively viscous at temperatures below 0°F, very few fluids transfer heat effectively at these sub-zero temperatures.

Today, many designers and users of sub-zero systems are specifying DOWTHERM\* J, SYLTHERM XLT<sup>†</sup>, and SYLTHERM<sup>†</sup> HF heat transfer fluids from Dow. These fluids provide many favorable characteristics as well as efficient heat transfer at low temperatures.

DOWTHERM J, SYLTHERM XLT, and SYLTHERM HF heat transfer fluids are noncorrosive toward metals and alloys commonly used in heat transfer systems. These fluids are also backed by full Dow technical support during system design, operation, and after shutdown.

This guide provides data and other information specific to the performance of DOWTHERM J, SYLTHERM XLT, and SYLTHERM HF heat transfer fluids in sub-zero applications. For more information on these fluids, or help in determining which fluid would be best for your application, contact your local Dow representative or call 1-800-447-4369. Outside the North America, call 1-517-832-1556.

## **DOWTHERM J Fluid for Superior Heat Transfer and Pumpability**

DOWTHERM J heat transfer fluid is a mixture of isomers of an alkylated aromatic hydrocarbon fluid specially engineered for demanding low-temperature applications. It has long been used in the chemical process industry for cooling to -110°F as well as heating to temperatures as high as 600°F.

Because of its low viscosity at extremely low temperatures, DOWTHERM J fluid provides the best heat transfer of the three fluids described in this guide. It is usually the fluid of choice to retrofit systems which were initially designed to use chlorinated solvents. In addition, its excellent fluid characteristics usually result in lower operational and engineering costs.<sup>2</sup>

## **SYLTHERM XLT Fluid for Excellent Low Temperature Performance, Plus Very Low Odor**

SYLTHERM XLT heat transfer fluid is a silicone polymer based on dimethyl polysiloxane. In addition to offering outstanding low temperature heat transfer and pumpability, SYLTHERM XLT is essentially odorless and is low in acute oral toxicity. It is often used in sub-zero applications in areas where fluid leaks could lead to odor concerns or personal exposure. SYLTHERM XLT can be used over a -160°F to 500°F temperature range.<sup>3</sup>

## **SYLTHERM HF Fluid for the Additional Advantages of a High Flash Point**

Like SYLTHERM XLT heat transfer fluid, SYLTHERM HF fluid offers excellent low temperature performance, low odor, and low acute oral toxicity. In addition, the 145°F flash point of SYLTHERM HF provides a margin of safety and can reduce system and engineering costs. What's more, the waste product of SYLTHERM HF can be managed as a non-hazardous waste based on ignitability characteristics. The temperature use range for SYLTHERM HF is -100°F to 500°F.<sup>4</sup>

<sup>1</sup>Sub-zero heat transfer systems (also called cryogenic systems) are generally defined as those operating below 0°F.

<sup>2</sup>A complete review of DOWTHERM J technical properties can be found in brochure No. 176-1240 available from Dow.

<sup>3</sup>Detailed technical information on SYLTHERM XLT is found in brochure No. 176-01434 available from Dow.

<sup>4</sup>Detailed technical information on SYLTHERM HF is found in brochure No. 176-01460 available from Dow.

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†Trademark of Dow Corning Corporation

## PHYSICAL AND THERMAL PROPERTIES

Table 1 compares the key physical properties of DOWTHERM J, SYLTHERM XLT, and SYLTHERM HF fluids. Note that these fluids all share the characteristics of low freezing points and high boiling points. As a result, the vapor pressures of these fluids are low and evaporation is slow.

A comparison of fluid viscosity points out the advantage enjoyed by DOWTHERM J fluid. It is difficult to obtain adequate heat transfer where fluid viscosity is greater than 10 cps.

Note also the differences in flash points for the fluids. The National Fire Prevention Association designates fluids with flash points of 100-139°F as Class II Combustible Liquids. Fluids with flash points of 140-200°F are considered Class IIIA Combustible Liquids by NFPA.

Table 2 shows how the physical properties of DOWTHERM J and the SYLTHERM fluids affect their heat transfer ability and pumpability at a temperature of -50°F. When only considering thermal properties, DOWTHERM J is preferred over SYLTHERM XLT, which in turn would be favored over SYLTHERM HF.

## Comparing Heat Transfer at the Air Exchanger

Simply comparing heat transfer coefficients of fluids does not give the complete picture of their relative performance. By calculating overall heat transfer at the air exchanger and at the evaporator for each of these fluids, we arrive at a more meaningful comparison.

Because the heat transfer coefficient for the air side and the fouling factors play significant roles in overall heat transfer, the differences in heat transfer coefficients for SYLTHERM XLT, SYLTHERM HF, and DOWTHERM J fluids are reduced

**Table 1 – Key Physical Properties Compared**

	DOWTHERM J	SYLTHERM XLT	SYLTHERM HF
Freeze Point (°F)	-120	-168	-115
Boiling Point (°F)	358	345	410
Flash Point (°F)	136	116	145
Viscosity (cps at -70°F)	4.6	7.6	10.0
(cps at -100°F)	8.0	12.6	16.7
Vapor Pressure (psia at 70°F)	0.015	0.02	.01

**Table 2 – Comparing Thermal Properties at -50°F**

	DOWTHERM J	SYLTHERM XLT	SYLTHERM HF
Thermal Conductivity (Btu/hr ft <sup>2</sup> °F/ft)	.0822	.0717	.0712
Density (lb/ft <sup>3</sup> )	56.87	56.28	58.56
Specific Heat (Btu/lb°F)	.394	.354	.364
Viscosity (cP)	3.3	5.6	7.3
Heat Transfer Coefficient (Btu/hr ft <sup>2</sup> °F) (7 ft/sec, 1" pipe)	195	134	123
Pressure Drop (psi/100 ft)	11.15	12.27	13.44
Pump Horsepower (100 ft of pipe & 70% pump efficiency)	.159	.175	.191

when comparing overall heat transfer.

Overall heat transfer can be calculated using the equation in Figure 2. The example calculation shows that although the individual heat transfer coefficient of SYL THERM XLT fluid (134 Btu/hr ft<sup>2</sup>°F) is only 69% of that for DOW THERM J (195 Btu/hr ft<sup>2</sup>°F), the calculated overall heat transfer at the air exchanger for SYL THERM XLT fluid (57) is actually 83% of that for DOW THERM J fluid. Similarly, the overall heat transfer coefficients for SYL THERM XLT and SYL THERM HF fluids are virtually identical.

### Comparing Heat Transfer at the Evaporator

At the evaporator, the thermal fluid can impact overall heat transfer in much the same way. Heat transfer on the evaporator side can be determined using the Mostinski equation for vaporizing film coefficient for R-22 at -50°F (Figure 3).

In this case the heat transfer coefficient of the refrigerant plays a more significant role in determining the overall heat transfer. The overall coefficient when using SYL THERM XLT is only 13% lower than when DOW THERM J fluid is used. Since both the refrigerant and the secondary heat transfer fluid contribute significantly to heat transfer, it is important to evaluate their impact on the specific design parameters for individual sub-zero systems.

In addition, the operation of the compressor in the refrigeration loop must be tailored to match the heat transfer properties of the secondary fluid. Proper design of compressor and evaporator will allow the use of SYL THERM XLT and SYL THERM HF as well as DOW THERM J fluids.

### Choosing the Best Fluid for Your System

While DOW THERM J, SYL THERM XLT, and SYL THERM HF fluids are all suitable for use in sub-zero applications, each product has unique advantages which can favor its use. Table 2 shows that DOW THERM J is more efficient for both heat transfer and pressure drop. Consequently, it is often selected to retrofit systems that previously used other secondary heat transfer fluids.

SYL THERM XLT fluid offers very low odor and acute oral toxicity as well as a lower freeze point. SYL THERM XLT fluid also has

excellent thermal properties that satisfy the requirements of many sub-zero systems.

SYL THERM HF fluid provides the added benefit of a higher flash point while retaining most of the desirable low temperature heat transfer properties of SYL THERM XLT. Depending on your needs, any of these three fluids may be candidates for use in your sub-zero system.

If you'd like help in determining which fluid will best meet your needs, please contact your local Dow representative or call us at 1-800-447-4369. Outside North America, call 1-517-832-1556.

Figure 2 – Calculating Overall Heat Transfer (Q/A=UΔT)

$$1/U = 1/h_f + 1/h_a + r_w + r_{fi} + r_{fo}$$

U = overall heat transfer coefficient

$h_f$  = heat transfer coefficient of fluid corrected for surface area ( $r_i/r_o$ ) = .525/.657 = .8 $h_f$

$h_a$  = heat transfer coefficient of air ≈ 20 with 10X finned surface area ≈ 200

$r_w$  = resistance through the wall =  $t/k$  = .012383/223 = .0001 (1 inch copper Schedule 40)

$r_{fi}$  = .0015 = inside fouling factor

$r_{fo}$  = .0015 = outside fouling factor

**Example:** For SYL THERM XLT fluid at -50°F,  $U_{XLT}$  = 57 as calculated below. For DOW THERM J fluid at -50°F,  $U_j$  = 69. For SYL THERM HF at -50°F,  $U_{HF}$  = 55.

$$1/U = 1/134(.8) + 1/200 + .0001 + .003 = .0093 + .005 + .0001 + .003 = .0174$$

$$U = 1/.0174 = 57$$

Figure 3 – Mostinski Equation for Vaporizing Film Coefficient (R-22 at -50°F)

$$h_{R-22} = .00658(722 \text{ psia})^{.69} (2000)^{.7}$$

$$[1.8 (11.7/722)^{.17} + 4(11.7/722)^{1.2}] = 116 \text{ Btu/hr} \cdot \text{ft}^2 \cdot \text{°F}$$

**Example:** For SYL THERM XLT,  $U_{XLT}$  = 48 as calculated below. For DOW THERM J,  $U_j$  = 55. For SYL THERM HF,  $U_{HF}$  = 46

$$1/U = 1/134(.8) + 1/116 + .0001 + .003 = .02105$$

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## REGULATORY STATUS

The choice of fluids to be used in sub-zero systems is often strongly influenced by the degree of regulation of those fluids and subsequent reporting requirements. DOWTHERM J, SYLTHERM XLT, and SYLTHERM HF fluids have been specifically chosen by Dow to minimize these concerns by users.

Unlike some alternative fluids, DOWTHERM J, SYLTHERM XLT, and SYLTHERM HF are not classified as, or subject to the regulatory restrictions of,:

**CERCLA** – Comprehensive Environmental Response, Compensation, and Liability Act.

**Clean Air Act**, Section 112

**Clean Water Act Priority Pollutant**

**Safe Drinking Water Act**

**SARA 313** – Superfund Amendment Reauthorization Act

**Volatile Hazardous Air Pollutant**

**RCRA<sup>1</sup>** – Resource Conservation and Recovery Act

<sup>1</sup>RCRA governs the classification of waste products and their subsequent disposal. SYLTHERM HF fluid waste is considered nonhazardous. Although DOWTHERM J and SYLTHERM XLT fluids are not listed as potential hazardous wastes, they do have flash points below 140°F and thus their waste must be handled as characteristic hazardous waste. Note that used DOWTHERM J may be eligible for the Dow Fluid Credit Program. For a description of this program, see brochure No. 176-1240, available from Dow. Or call 1-800-447-4369

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## HEALTH AND SAFETY STATUS

A complete summary of the health and safety aspects of DOWTHERM J, SYLTHERM XLT, and SYLTHERM HF fluids can be found in their respective material safety data sheets. When appropriately designed in a closed system, there should be minimal exposure to any of these fluids.

Occasionally however, a leak from a valve or failed pump seal could result in an unwanted fluid release. The odor of DOWTHERM J fluid can be detected at levels of approximately 10 ppm and can be objectionable to workers in the area. SYLTHERM XLT or SYLTHERM HF fluid should be favored for applications in areas which are extremely sensitive to even small fluid leaks.

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## SYSTEM ENGINEERING AND DESIGN

Comprehensive information relating to system design and engineering requirements for DOWTHERM and SYLTHERM thermal fluids can be found in *Equipment for Systems using DOWTHERM Heat Transfer Fluids* (Form No. 176-1335) and *Engineering Manual* (Form No. 176-1334).

### Water Removal

Since sub-zero systems operate at temperatures below the freezing point of water, the presence of any moisture in the secondary heat transfer fluid can cause ice crystal formation in the fluid that could result in pumping problems or system plugging. Similarly, if ice forms on the evaporator surface it will act as a foulant, reducing heat transfer efficiency.

Water solubility at room temperature in DOWTHERM J fluid is less than 400 ppm and in SYLTHERM fluids is less than 200 ppm. Moisture exceeding these levels will freely separate and collect at low points in the system. Provisions should be made to drain any free water from the system.

DOWTHERM J and SYLTHERM fluids have typical moisture levels less than 150 ppm as supplied. However, it is recommended that moisture levels be reduced to less than 50 ppm to prevent operational problems.

Also avoid other sources of potential water contamination such as cleaning, flushing, or testing fluids, or exposure to moist air which will condense onto cold fluid. An inert gas pad should be free of moisture. Equipment and piping should be cleaned and dried prior to installation.

To pressure test a system for leaks, it is suggested that dry air or inert gas be used initially to evaluate for gross leaks. This procedure can be followed by hydraulic pressure testing with DOWTHERM J or the SYLTHERM fluid that is to be used in the system. This will detect any leaks prior to start-up. In spite of taking appropriate precautions, it is likely that moisture will need to be purged from the system upon start-up. Consider these alternatives:

(1) Heating – If the system can be heated to temperatures above 200°F, the vapor pressure of water increases to the point that it can be vented from the system.

(2) Bubbling dry gas in the expansion tank – Dry nitrogen or dry air, when bubbled through DOWTHERM J or SYLTHERM XLT fluids, will pick up moisture which will be carried out of the system as the gas is vented.

(3) Filters – When ice crystals form in the thermal fluids they can be physically filtered from the system. A 10 micron filter is appropriate.

(4) Molecular Sieve – A 3-4 Angstrom molecular sieve is capable of removing soluble moisture down to levels of 1 ppm. Installation of a side stream molecular sieve is an effective method to maintain moisture free operating conditions in sub-zero systems.

## Metal Construction

The usual construction metal for use with thermal fluids is carbon steel. However, at temperatures below -20°F carbon steel should not be used due to its loss of ductility. The designer should consider the use of 304 or 316 stainless steel because of the good low temperature ductility of these materials. Another alternative is to use

carbon steel that has been manufactured specifically to retain good ductility at low temperatures. For example:

Carbon Steel  
 -20 to 750°F  
 SA - 333 - GR1  
 -20 to -50°F  
 SA - 333 - GR7  
 -50 to -100°F  
 SA - 333 - GR3  
 -75 to -150°F  
 SA - 333 - GR6  
 to -50°F

The use of copper and aluminum is not recommended at high temperatures (above 350°F) because of potential loss of strength. However, for sub-zero systems these metals may offer advantages in certain non-structural applications that can utilize the improved thermal conductivity characteristics these metals offer such as in heat exchangers or evaporators.

## Elastomers

At high temperatures (>300°F) the use of elastomers for gaskets and seals is not recommended due to their loss of strength and lack of resistance to attack from the thermal fluid. For sub-zero applications, certain fluorinated elastomers are suitable for use with DOWTHERM J and SYLTHERM fluids subject to the temperature limitations suggested by the manufacturer:

VITON <sup>1</sup> GLT/GFLT	-55°F
Tetrafluoro ethylene (VITON/CHEMRAZ <sup>2</sup> FLOUREL <sup>3</sup> )	-20°F
Vinylidene fluoride/HFP	-40°F
Phosphonitrilic	-85°F
Fluorosilicone	-100°F

## Plastics

In general, most plastic products will deteriorate in contact with DOWTHERM J or SYLTHERM fluids and should be avoided as a

material of construction for sub-zero systems. In addition, many plastics become embrittled at very low temperatures which can lead to fracture failure. When use of plastic is necessary, a fluoroelastic such as Teflon<sup>1</sup> is satisfactory for use at temperatures as low as -150°F.

## Flanges and Gaskets

It is desirable to minimize the number of flanges in any thermal fluid system since they can be a source of leaks which may develop due to piping stresses and thermal cycling. The use of 150 lb. flanges as outlined in *Equipment for Systems using DOWTHERM Heat Transfer Fluids* (Form No. 176-1335) is suitable for sub-zero applications operating below 300°F. When 150 lb. flanges are specified, use FLEXITALLIC<sup>4</sup> CGI-LS gaskets for flange seals. Properly seal flanges to minimize fluid leaks.

## General Operational Notes

1) Because of the very low operating temperatures, special care should be taken to account for thermal contraction/expansion of piping and equipment. Unrelieved thermal stress will cause leaks to occur, particularly with pump seals.

2) Seal-less pumps should be considered for use in areas where fluid leaks are particularly undesirable. Remember, however, that canned pumps are more prone to failure from particulate contamination and they tend to be highly sensitive to cavitation from potential outgassing of adsorbed nitrogen from inert padding.

3) Joints should be welded whenever possible to minimize leaks. Avoid screwed fittings for 1 inch and larger lines.

<sup>1</sup>Trademark of E.I. du Pont, Inc.

<sup>2</sup>Trademark of Greene, Tweed, Inc.

<sup>3</sup>Trademark of 3M Co.

<sup>4</sup>Trademark of Flexitallic, Inc.



# DOWTHERM and SYLTHERM Heat Transfer Fluids in Sub-Zero Systems

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## *Application Guide*

**For further information, call toll-free 1-800-447-4369  
(Outside North America, call 1-517-832-1556).**

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**NOTE:** SYLTHERM heat transfer fluids are manufactured by Dow Corning Corporation and distributed by The Dow Chemical Company in the United States.