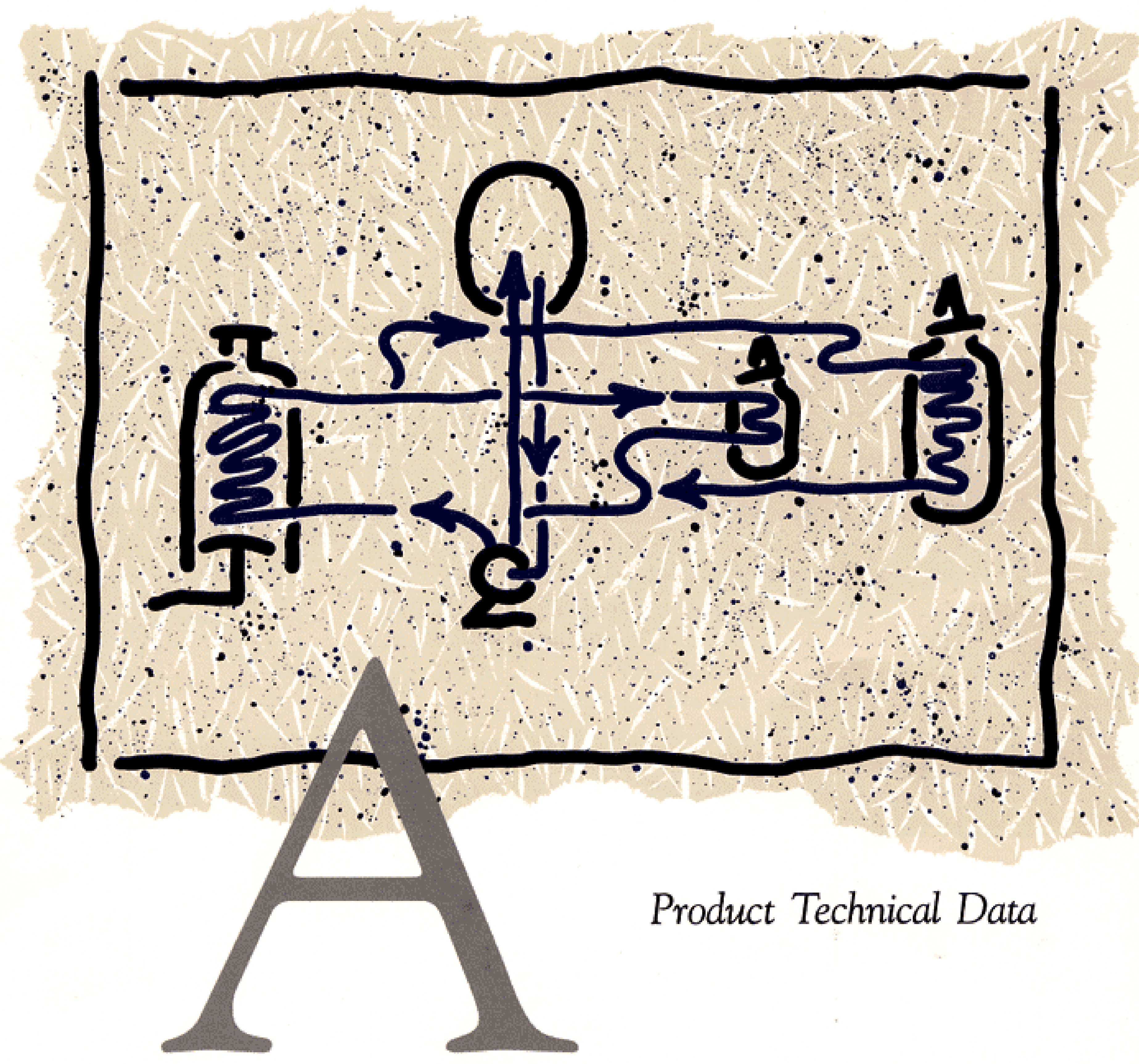
DOWTHERM A
Heat Transfer Fluid



Product Technical Data

Contents

Dowtherm A Heat Transfer Fluids

Versatile, Stable, and Preferred—Dowtherm A Heat Transfer Fluid

DOWTHERM* A heat transfer fluid is a eutectic mixture of two very stable organic compounds, biphenyl ($C_{12}H_{10}$) and diphenyl oxide ($C_{12}H_{10}O$). These compounds have practically the same vapor pressures, so the mixture can be handled as if it were a single compound. DOWTHERM A fluid may be used in systems employing either liquid phase or vapor phase heating. Its normal application range is 60° to 750°F (15° to 400°C), and its pressure range is from atmospheric to 152.5 psig.

Unsurpassed Thermal Stability and Efficiency with Technical Backup and Support to Match

DOWTHERM A fluid, which has been employed in industrial heat transfer systems for over 55 years, is the preferred product for a wide range of indirect heat transfer applications. It is stable, does not decompose readily at high temperatures, and can be used effectively in either liquid or vapor phase systems.

The low viscosity throughout the entire operating range results in efficient heat transfer; start-up and pumping problems are minimized. The fluid is noncorrosive to common metals and alloys.

Of equal importance, but often overlooked, is the support provided by the fluid manufacturer. Dow's assistance to industry is unequalled. This includes technical backup in the design phase, during operation and after shutdown, as needed. Moreover, free analytical testing is provided to monitor fluid condition.

When it is time to changeout your DOWTHERM A heat transfer fluid, Dow's Fluid Credit Program allows you to return the old fluid and receive typically 80 percent credit or more toward the purchase of your new fluid charge.

Finally, the capability of the manufacturer to supply quality product in a timely fashion must be considered. Dow's large manufacturing capacity and strategically placed warehouses make DOWTHERM A fluid available when and where you need it.

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Fluid Selection Criteria

Four important properties that help determine the viability of a heat transfer fluid in a particular application are stability, vapor pressure, freeze point, and viscosity. These are discussed below.

1. Stability

DOWTHERM A fluid possesses unsurpassed thermal stability at temperatures of 750°F. The maximum recommended film temperature is 800°F. However, DOWTHERM A fluid has been used successfully in applications up to 810°F bulk fluid temperature.

2. Vapor Pressure

DOWTHERM A fluid may be used in vapor phase heat transfer applications from 495°F to 750°F. It may be used in the liquid phase from 60°F to 750°F. Its vapor pressure is 3.96 psia at 400°F and 152.5 psia at the maximum recommended use temperature.

3. Freeze Point

DOWTHERM A fluid has a freezing point of 53.6°F (12°C) and can be used without steam tracing in installations protected from the weather.

4. Viscosity

The viscosity of DOWTHERM A fluid is low and changes only slightly between the melting point of the product and its top operating temperature. As a result, start-up problems are minimized.

Thermal Stability

The thermal stability of a heat transfer fluid is dependent not only on its chemical structure but also on the design and operating temperature profile of the system in which it is used. Maximum life for a fluid can be obtained by following sound engineering practices in the design of the heat transfer system. Three key areas of focus are: operating and designing the heater and/or energy recovery unit, preventing chemical contamination, and eliminating contact of the fluid with air.

For a more detailed overview of thermal stability, ask for our guide to understanding and interpreting thermal stability data for heat transfer fluids.

Heater Design and Operation

Poor design and/or misoperation of the fired heater can cause overheating resulting in excessive thermal degradation of the fluid. Some problem areas to be avoided include:

1. Flame impingement.

2. Operating the heater above its rated capacity.

3. Modifying the fuel-to-air mixing procedure to reduce the flame height and pattern. This can yield higher flame and gas temperatures together with higher heat flux in the shorter flame area.

4. Low velocity/high heat flux areas resulting in excessive heat transfer fluid film temperatures.

The manufacturer of the fired heater should be the primary contact in supplying you with the proper equipment for your heat transfer system needs.

Chemical Contamination

A primary concern regarding chemical contaminants in a heat transfer fluid system is their relatively poor thermal stability at elevated temperatures. The thermal degradation of chemical contaminants may be very rapid which may lead to fouling of heat transfer surfaces and corrosion of system components. The severity and nature of the corrosion will depend upon the amount and type of contaminant introduced into the system.

Air Oxidation

Organic heat transfer fluids operated at elevated temperatures are susceptible to air oxidation. The degree of oxidation and the rate of reaction is dependent upon the chemical structure of the heat transfer fluid as well as the temperature and the degree of mixing. Undesirable by-products of this reaction may include carboxylic acids which would likely result in system operating problems. Preventive measures should be taken to ensure that air is eliminated from the system prior to bringing the heat transfer fluid up to operating temperatures. A positive pressure inert gas blanket should be maintained at all times on the expansion tank during system operation.

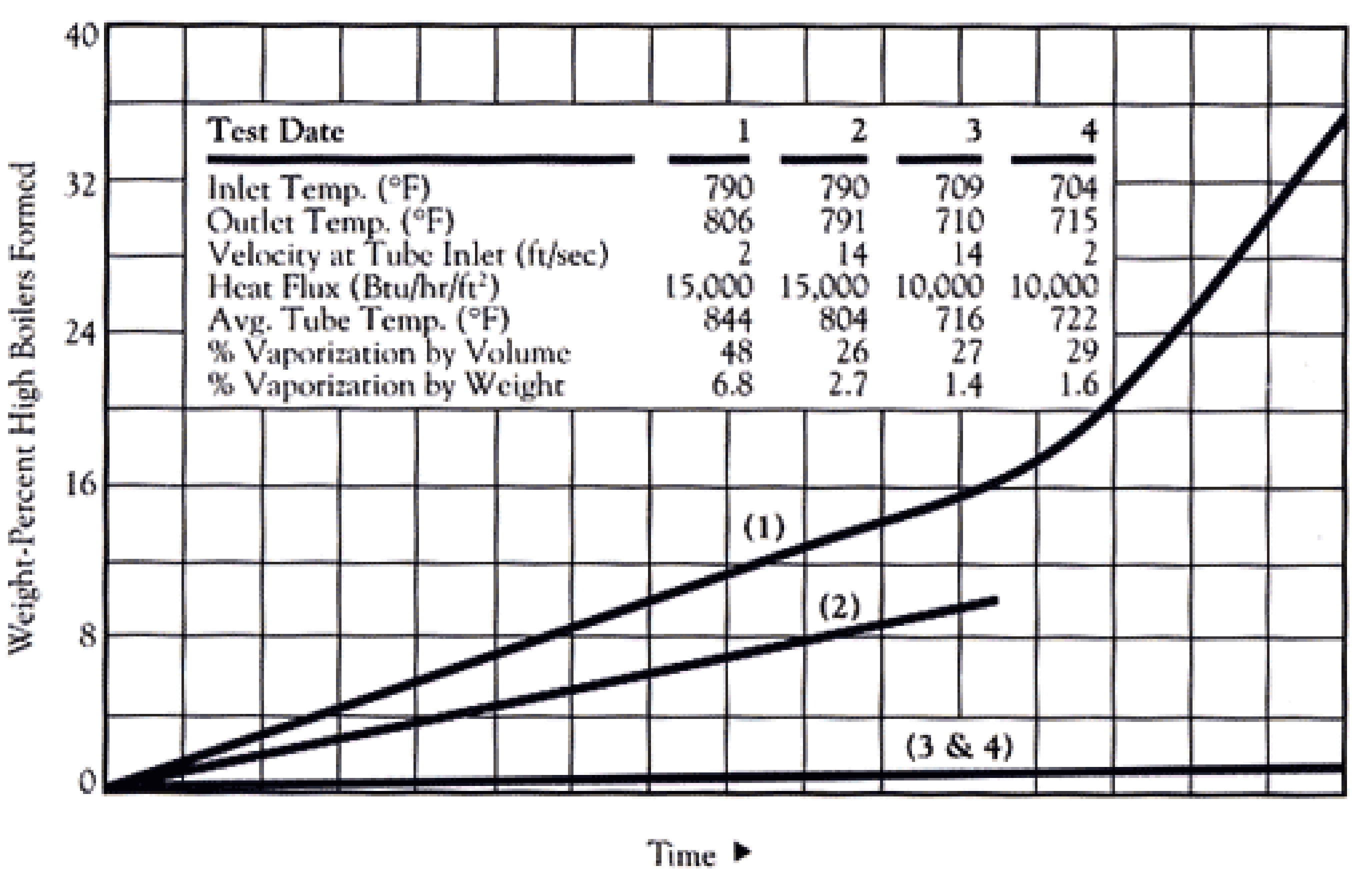
The rate of decomposition of DOWTHERM A fluid is also highly dependent upon conditions in the vaporizer or fired heater. The data in Figure 1 show the impact of high heat flux and low fluid velocity on the formation of degradation products in a diphenyl oxide/biphenyl eutectic mixture. Curve 1 shows the results obtained at an accelerated temperature, a high heat flux, and a low tube velocity. These conditions tend to cause high film temperatures. Curve 2 was obtained utilizing the same operating temperature and heat flux but a high tube velocity. The latter condition reduced the excessive film temperatures. Curves 3 and 4 illustrate the long fluid life that can be expected when units are operated under moderate conditions with the proper relationship between heat flux and tube temperature.

Units can be designed to operate at higher temperatures than those presently recommended in cases where the greater replacement costs of DOWTHERM A fluid—resulting from its increased decomposition rate—can be economically justified. In such units, adequate provision must be made for good circulation, lower heat fluxes, and frequent or continuous purification.

When units are operated at high temperatures, liquid velocities in heaters should be a minimum of 6 feet per second; a range of 6-10 feet per second should cover most cases. The actual velocity selected will depend on an economic balance between the cost of circulation and heat transfer surface as well as the replacement cost for new fluid. Operating limitations are usually placed on heat flux by the equipment manufacturer. This heat flux is determined for a maximum film temperature by the operating conditions of the particular unit. Removal of decomposed heat transfer medium can be accomplished by continuous or semi-continuous reclamation of medium. This is accomplished by passing a small side stream from the heater or vaporizer through a flash still.

Flash distillation serves to reduce high-boiling fractions to a minimum and to keep fluid quality and subsequent film coefficients at a maximum.

Figure 1 — Impact of Heat Flux and Fluid Velocity on the Thermal Stability of a Diphenyl Oxide/Biphenyl Eutectic Mixture



Test Date	1	2	3	4
Inlet Temp. (°F)	790	790	709	704
Outlet Temp. (°F)	806	791	710	715
Velocity at Tube Inlet (ft/sec)	2	14	14	2
Heat Flux (Btu/hr/ft^2)	15,000	15,000	10,000	10,000
Avg. Tube Temp. (°F)	844	804	716	722
% Vaporization by Volume	48	26	27	29
% Vaporization by Weight	6.8	2.7	1.4	1.6

Radiation Stability

DOWTHERM A fluid is stable up to dosages of 10^{10} rads. At higher dosages, a polymerization similar to thermal degradation begins to occur.

Corrosivity

DOWTHERM A heat transfer fluid, in both the liquid and vapor form, is noncorrosive toward common metals and alloys. Even at the high temperatures involved, equipment usually exhibits excellent service life. Original equipment in many systems is still being used after 30 years of continuous service.

Steel is used predominantly, although low alloy steels, stainless steels, Monel alloy, etc., are also used in miscellaneous pieces of equipment and instruments.

Most corrosion problems are caused by chemicals introduced into the system during *cleaning* or from process *leaks*. The severity and nature of the attack will depend upon the amounts and type of contamination involved.

When special materials of construction are used, extra precaution should be taken to avoid contaminating materials containing the following:

Construction Material	*Contaminant*
Austenitic Stainless Steel	*Chloride*
Nickel	*Sulfur*
Copper Alloys	*Ammonia*

Flammability

DOWTHERM A heat transfer fluid is a combustible material but has a relatively high flash point of 236°F (SETA), a fire point of 245°F (C.O.C.), and an autoignition temperature of 1139°F (615°C) (ASTM, E659-78). The lower flammable limit is 0.6% (volume) at 175°C while the upper limit is 6.8% at 190°C.

A leak from a vapor system into the combustion chamber of a furnace will result only in burning of the vapors; the percentage of carbon dioxide usually present will not permit the formation of an explosive mixture. A leak from a liquid system into a furnace compartment results in the burning of the liquid and the production of a large amount of black smoke due to incomplete combustion.

Vapor leaks to the atmosphere are also sometimes encountered. Such leaks, however small, should not be tolerated because of the cost of replacing lost medium. Experience has shown that leaking vapors have usually cooled well below the fire point and fire has rarely resulted. Due to the strong odor of the medium, such leaks rarely go undetected without corrective action.

Leaks from pipelines into insulation are likewise potentially hazardous as they can lead to fires in the insulation. It has been found, for example, that leakage of organic materials into some types of insulation at elevated temperatures may result in spontaneous ignition.

Vapors of DOWTHERM A fluid do not pose a serious flammability hazard at room temperature, because the saturation concentration is so far below the lower flammability limit. Flammable mists are, however, possible under extremely unusual circumstances where the time of exposure to an ignition source, the temperature of the source and the atmosphere, the volume of mixture, the fuel-air ratio, and the mist particle size all fall within a somewhat narrow range.

If used and maintained properly, installations employing DOWTHERM A fluid should present no unusual flammability hazards.

Liquid and Vapor Phase Technology

In choosing between liquid phase and vapor phase heating with DOWTHERM A heat transfer fluid, it is necessary to consider the overall process, the heat tolerance of the product, the equipment, and the overall economics. In many cases, the overall costs for the two types of systems will not differ significantly, and the choice must be based on other considerations.

With vapor phase systems, heat is transferred at the saturation temperature of the vapor. As a result, such units can provide uniform, precisely controlled temperatures. The heating of synthetic fiber spinnerettes represents just one of the many applications that take advantage of these vapor properties.

In liquid phase systems, the temperature of the heating medium decreases as it gives up its sensible heat. Thus, the temperature of the medium at the inlet will be higher than its temperature at the outlet. This nonuniformity of temperature can be harmful to heat-sensitive products, even when it is reduced by increasing the circulation rate of the medium. However, for heat-insensitive products, such changes in temperature are of little consequence.

In systems with multiple heat users, a combination of both vapor and liquid phase may be superior to either by itself. Economics is the deciding factor when considering line sizing, distances, pressure drop, type of equipment, method of temperature control, and temperature requirements.

Forced circulation units may be used with both liquid phase and vapor phase systems. Such units require a pump; hence, both initial and operating costs may, in some cases, be higher than equivalent costs for gravity systems with natural circulation vaporizers. However, costs should be investigated for each system since this may not always hold true. In a liquid phase system the pump for the forced circulation heater must be sized large enough for the entire system. If a forced circulation vaporizer is used, a pump may or may not be required to return the condensate, depending on the liquid head available.

Many systems use DOWTHERM A fluid for cooling, either by circulating it or by allowing it to boil and extracting the latent heat at a constant temperature. In addition, many use DOWTHERM A fluid for heating and cooling the same piece of equipment. Where unusually accurate and uniform cooling is required, baffles may be placed in the jacket to direct the liquid flow, or cooling may be accurately controlled by boiling DOWTHERM A at the controlled pressure.

Advantages of Liquid Phase Heating with DOWTHERM A Fluid

1. Unlike vapor phase systems, those employing liquid DOWTHERM A fluid require no condensate return equipment. This factor becomes more important when there are multiple users operating at widely differing temperatures.

2. Where alternate heating and cooling are necessary, liquid phase heating allows the use of simpler, more easily operated systems.

3. There is no temperature gradient due to pressure drop in the supply piping.

4. Liquid systems give a positive flow through the user with a minimum of venting.

5. Liquid phase heating eliminates the problem of condensate removal in such units as platen presses and horizontal sinuous coils.

Figure 3 shows a liquid phase heating system employing DOWTHERM A fluid.

Advantages of Vapor Phase Heating with DOWTHERM A Fluid

1. Vapor phase systems provide much more heat per pound of heat transfer medium passed through the user. With DOWTHERM A fluid at 500°F, for example, 12,690 Btu/hr. will be obtained by condensing 100 lbs/hr. To match this heat output using liquid medium, 2,372 lbs/hr. would be required with a 10°F temperature drop or 481 lbs/hr. with a 50°F temperature.

2. Vapor systems, with their condensing vapor, provide a more uniform heat source and precision temperature control of the user. An equivalent liquid system would have to be operated at extreme flow rates in order to maintain the same close temperature uniformity. This is illustrated in Figure 2.

3. Vapor phase heating has an advantage where it is difficult to control liquid flow pattern and velocity; e.g., in kettle jackets.

4. No pumps are needed when a gravity return condensate system is used with a natural circulation vaporizer.

5. A vapor system requires less working inventory of DOWTHERM A fluid since the line to the user, and the user, are filled with vapor rather than liquid.

6. With heat-sensitive products, where the maximum temperature of the heat transfer medium must be limited, heating may be accomplished more economically with condensing vapor than with liquid at high mass flow rates.

Figure 4 shows a vapor phase heating system employing DOWTHERM A fluid.

Figure 2 — Comparison of Liquid vs. Vapor Mass Flow Rates for DOWTHERM A Fluid at Various Liquid Δt

Basis: 600°F Inlet Temperature with 5°F Subcooling for Condensate of DOWTHERM A Fluid

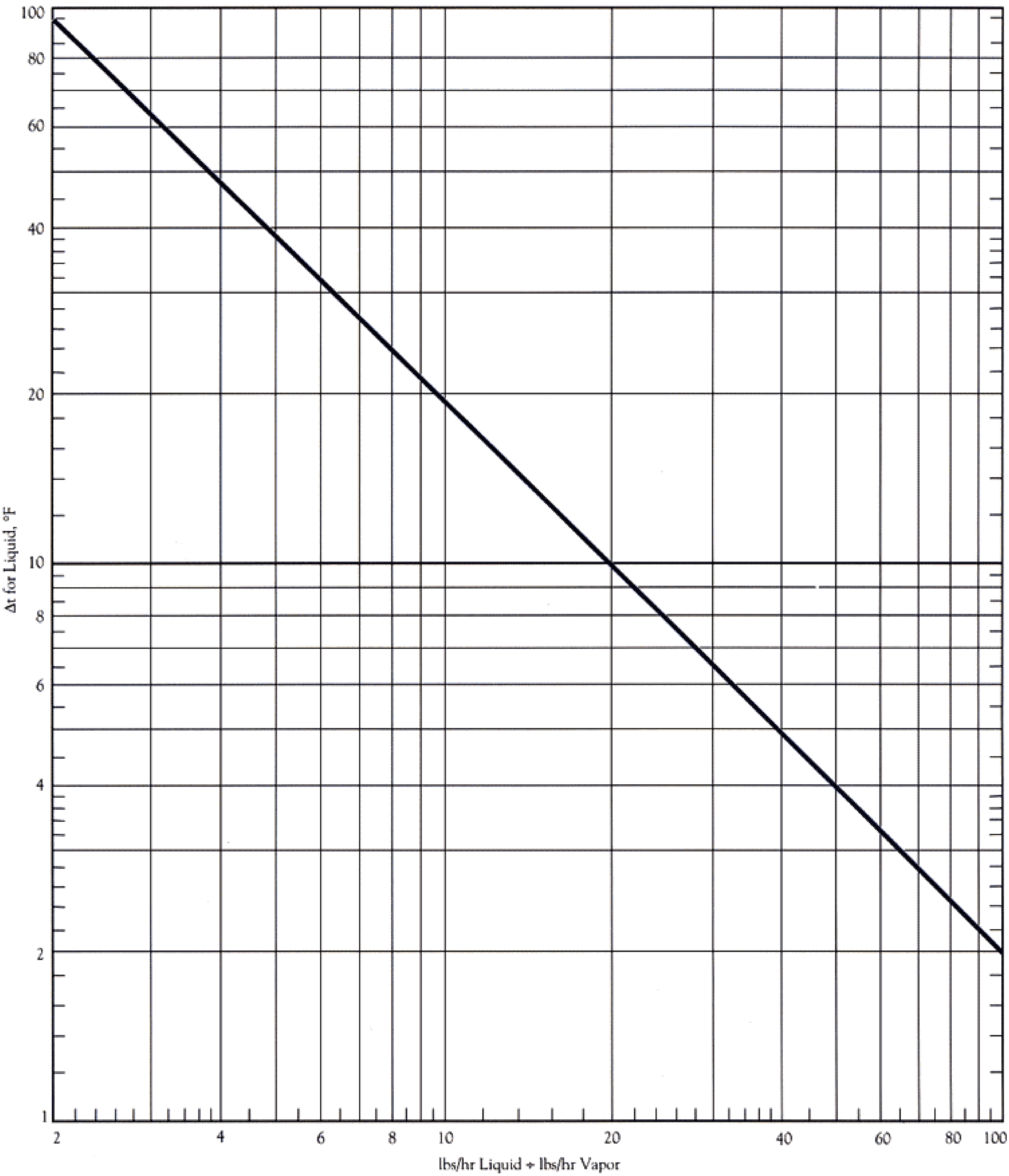
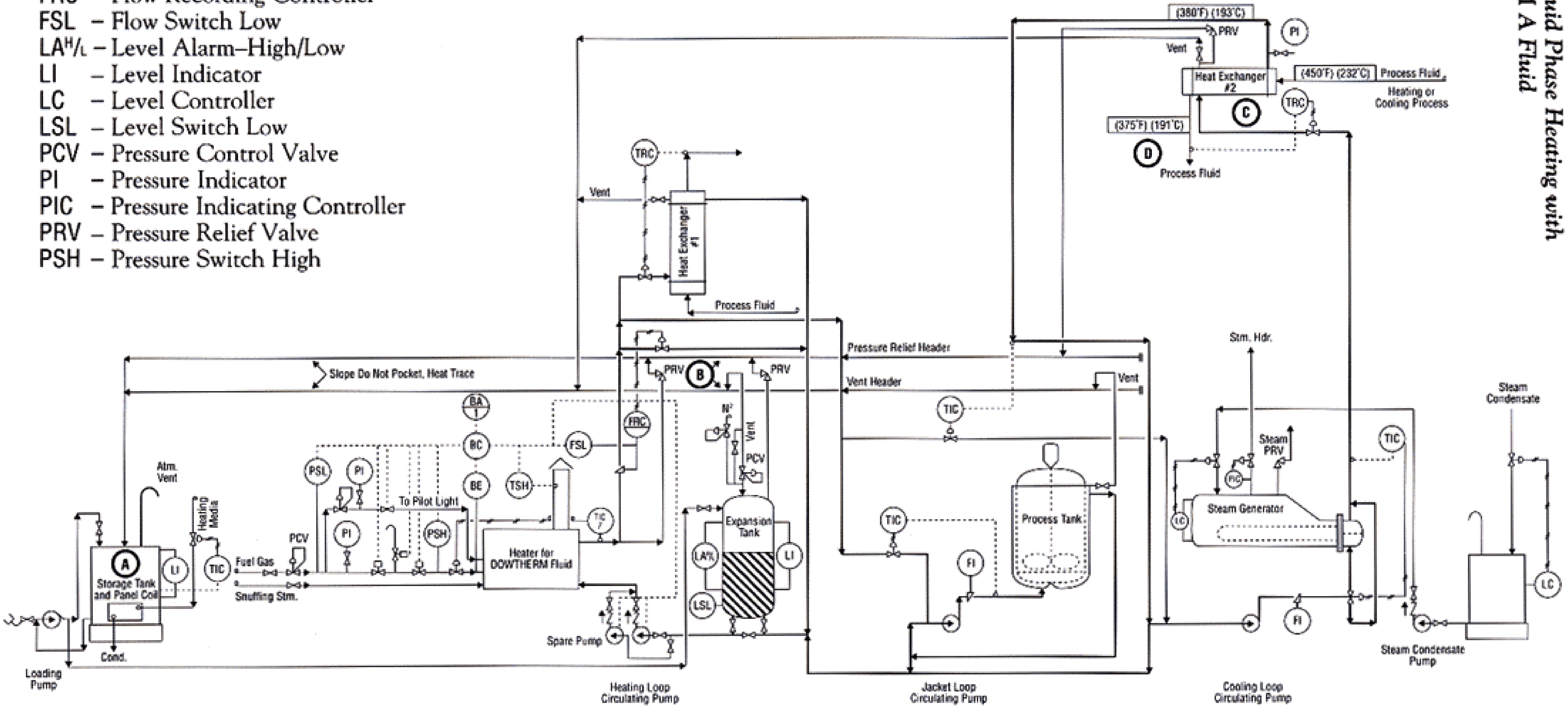


Figure 3 – Liquid Phase Heating with DOWTHERM A Fluid

Instrument Legend

BA – Burner Alarm
BC – Burner Control
BE – Burner Element (Fire-Eye)
FI – Flow Indicator (Orifice)
FRC – Flow Recording Controller
FSL – Flow Switch Low
$LA^{H}/_{L}$ – Level Alarm–High/Low
LI – Level Indicator
LC – Level Controller
LSL – Level Switch Low
PCV – Pressure Control Valve
PI – Pressure Indicator
PIC – Pressure Indicating Controller
PRV – Pressure Relief Valve
PSH – Pressure Switch High
PSL – Pressure Switch Low
TIC – Temperature Indicating Controller
TRC – Temperature Recorder Controller
TSH – Temperature Switch High

——— Principal Circuits with DOWTHERM Fluid
- - - - Electrical Lines
-//-//- Instrument Air Lines



Ⓐ – External heating required if fluid pumpability is limiting in cold weather.

Ⓑ – Thermal tracing system on vent and safety valve lines if ambient temperature = <80°F (27°C).

Ⓒ – Heat exchanger #2 is cooled with DOWTHERM A fluid to avoid any possibility of contaminating the process fluid with water in the event of a tube leak.

Ⓓ – Process fluid freezes at 350°F (177°C).

Figure 4 – Vapor Phase Heating with DOWTHERM A Fluid

Instrument Legend

BA – Burner Alarm
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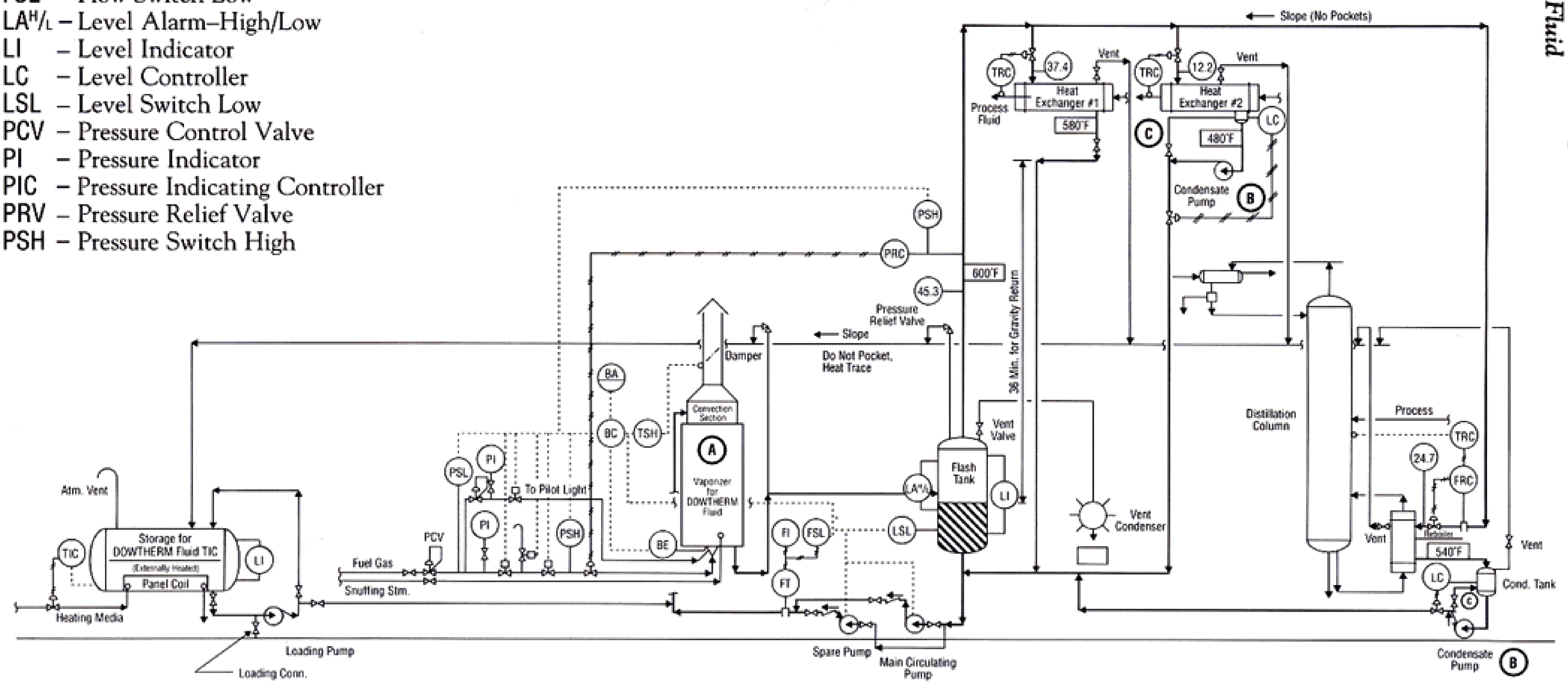


Thermal Tracing System required if ambient temperature = <60°F.

Ⓐ – Vaporizers for DOWTHERM A fluid utilize both natural and forced circulation.

Ⓑ – A pump is required where there is insufficient elevation between vaporizer and heat user to return condensate by gravity.

Ⓒ – Hand-throttled bypass required to prevent pump heat-up.

Health and Environmental Considerations

Results of animal studies along with manufacturing and use experience indicate that DOWTHERM A heat transfer fluid does not present an appreciable hazard to health when used in accordance with good manufacturing practices, and no special precautions are necessary. The medium likewise presents no serious pollution hazard; however, provisions must be made to prevent significant discharge into public waters.

Health Considerations

Inhalation. Animal studies indicate that DOWTHERM A fluid has a low order of inhalation toxicity. Limited studies in rats, rabbits, and guinea pigs did not show significant effects from exposures of 7-10 ppm, 7 hours a day, 5 days a week for 6 months. These were the highest vapor concentrations that could be maintained without condensation and fogging.

DOWTHERM A fluid has a striking odor that becomes quite disagreeable, even irritating to the eyes and nose, at concentrations far below 7 ppm. This odor serves as a warning to prevent excessive exposure to vapors and fumes. The OSHA standard for this mixture is 1 ppm. The ACGIV TLV is 1 ppm TWA, 2 ppm STEL for the diphenyl oxide component and 0.2 ppm TWA for the biphenyl component.

Whenever accidental or unusual conditions result in higher concentrations of vapors or fumes, workers should wear respiratory protection suitable for organic mists and vapors. Where there is a possibility of oxygen deficiency, workers should use an air-supplied mask or positive pressure, self-contained breathing apparatus. In regular operations, concentrations of vapors in the atmosphere should be kept at levels that are not disagreeable. If ill effects occur from accidental exposure to heavy concentrations in the air, remove the victim to fresh air and get immediate medical attention.

Ingestion. Oral administration of DOWTHERM A heat transfer fluid to laboratory rats has revealed a low order of systemic toxicity. The single-dose oral LD50 in female rats is 2487 mg/kg. Limited studies did not reveal significant toxicity in rats that received daily oral doses, 5 days a week for 1 to 6 months, of 100 mg/kg DOWTHERM A fluid. Liver and kidney effects were observed at higher doses.

Ingestion of small amounts of DOWTHERM A heat transfer fluid incidental to handling should not cause injury. It should, however, be recognized that ill effects will result if substantial amounts are swallowed. Induce vomiting if large amounts of DOWTHERM A fluid are ingested. Consult with medical personnel immediately.

Eye Contact. Contact with DOWTHERM A in both the liquid and vapor form may be painful, but otherwise is only slightly irritating to the eyes and will not cause corneal injury. Whenever there is the potential for gross eye contamination, face shields or chemical workers' goggles should be worn to avoid discomfort that might result from direct contact. Safety glasses are recommended for everyday use. If the eyes are accidentally contaminated with fluid, they should be thoroughly washed with flowing water for 5 minutes and medical attention obtained if there is any evidence of irritation.

If the fluid is contaminated with material being processed or with other materials, additional treatment may be required.

Skin Contact. Single exposures to DOWTHERM A in liquid form are not irritating to the skin. However, prolonged or repeated skin contact may cause irritation and should therefore be avoided. Fluid that has been used at high temperatures for extended periods of time can cause skin irritation or dermatitis.

The product is not likely to be absorbed in toxic amounts.

Contaminated skin should be immediately and thoroughly washed with soap and water. Contaminated clothing and shoes should be removed at once and the clothing decontaminated before reuse.

Environmental Considerations

Stability. DOWTHERM A fluid has a 5-day BOD of 1.70 parts/part, 62% of its theoretical oxygen demand. Its COD is 2.53 parts/part. This indicates that it is readily biodegradable and non-persistent in the environment. There is no evidence that harmful products are formed as a result of biodegradation. Once its bacteria are acclimated, a waste treatment system should achieve a high degree of removal of fluid before the wastewater effluent reaches the receiving body of water.

Movement. The water solubility of this material is very low—only 14 ppm at ambient temperatures—and if amounts exceeding this limit are mixed with water, the medium will settle to the bottom. Of course, turbulence and the presence of other materials may affect the physical condition of the solution. It is also possible that an emulsion may form under certain conditions.

Data indicate that a large percentage of the medium present in water will be stripped out during aeration in the primary stage of a waste treatment facility.

Bioconcentration. Dow studies have shown that both components of DOWTHERM A fluid—biphenyl and diphenyl oxide—bioconcentrate in trout, but that when these trout are exposed to fresh water, the compounds disappear from their tissues in a relatively short time.

Should this material be discharged into a body of water, it may bioconcentrate in fish, but at a significantly lower level than compounds such as polychlorinated biphenyl. Furthermore, because of the rapidity with which the material is cleared from the tissues and biodegrades, it is unlikely to pose a serious problem.

Customer Service for Users of DOWTHERM A Heat Transfer Fluid

Analysis

Dow offers an analytical service for DOWTHERM A heat transfer fluid. It is recommended that users send a one-pint representative sample at least annually to:

The Dow Chemical Company
Larkin Lab
1691 North Swede Road
Midland, Michigan 48674

Thermal Fluids Testing Lab

This analysis gives a profile of fluid changes to help ensure against trouble from product contamination or thermal decomposition.

When a sample is taken from a hot system it should be cooled to below 100°F before it is put into the shipping container. Cooling the sample below 100°F will prevent the possibility of thermal burns to personnel; also, the fluid is then below its flash point. In addition, any low boilers will not flash and be lost from the sample. Cooling can be done by either a batch or continuous process. The batch method consists of isolating the hot sample of fluid from the system in a properly designed sample collector and then cooling it to below 100°F. After it is cooled, it can be withdrawn from the sampling collector into a container for shipment.

The continuous method consists of controlling the fluid at a very low rate through a steel or stainless steel cooling coil so as to maintain it at 100°F or lower as it comes out of the end of the cooler into the sample collector. Before a sample is taken, the sampler should be thoroughly flushed. This initial fluid should be returned to the system or disposed of in a safe manner.

It is important that samples sent for analysis be representative of the charge in the unit. Therefore, they should not be drawn from condensate lines or sight glass connections. Ordinarily, samples should be taken from the (1) lower section of a natural circulation vaporizer, (2) circulating line of a forced circulation (pumped) vaporizer, or (3) main circulating line of a liquid system. Occasionally, additional samples may have to be taken from other parts of the system where specific problems exist. A detailed method for analyzing the fluid to determine its quality is available upon request.

Used heat transfer medium which has been stored in drums or tanks should be sampled in such a fashion as to ensure a representative sample.

Fluid Credit Program for DOWTHERM Fluids

If analysis of a particular fluid sample reveals significant thermal degradation of the medium, the customer will be advised to return the fluid in his system to Dow under the Fluid Credit Program. This program permits customers to minimize their heat transfer fluid investment and handling downtime, while assuring that replacement fluid is of the highest quality.

Under the Fluid Credit Program, Dow credits the customer at the full purchase price for all usable material recovered, less a small processing charge based on the total quantity returned. The customer uses this credit to offset the cost of the new Dow fluid purchased to recharge the heat transfer system. The program is not a reprocessing service; Dow Chemical U.S.A. supplies only new, unreprocessed fluids to customers for both original system fills and system recharges. When participating in the Fluid Credit Program, the customer should order sufficient new material to recharge the system before sending the old fluid to Dow.

If the fluid sample analysis reveals that the fluid is contaminated by organic materials of low thermal stability (which cannot be removed by distillation), it generally will not qualify for the Fluid Credit Program. In this case, Dow will advise the customer that the fluid should not be returned to Dow. No material should be sent to Dow until the fluid analysis has been completed and the customer has been informed of the results.

Before returning material for credit, contact the nearest sales office listed on the back of this bulletin. For further information, please contact your nearest Dow Thermal Fluids field representative or call 1-800-447-4369, and ask for DOWTHERM A.

Table 1 — Physical Properties of DOWTHERM A Fluid

(Laboratory values not to be confused with, or substitutes for, specifications). None of below are specifications.

Property	English Units	Metric Units
Atmospheric Boiling Point	494.8°F	257.1°C
Freezing Point	53.6°F	12.0°C
Flash Point, SETA	236°F	113°C
Fire Point, C.O.C.†	245°F	118°C
Auto Ignition Temp.††	1110°F	599°C
Density at 75°F	66.0 lb/ft^3	1.056 g/cc @ 25°C
	8.80 lb/gal. @ 25°C	
Volume Contraction upon Freezing	6.63%	
Volume Expansion upon Melting	7.10%	
Heat of Fusion	42.2 Btu/lb	23.4 cal/g
Specific Resistivity	1.2×10^{12} ohm cm @ 32°F	
	6.4×10^{11} ohm cm @ 68°F	
	3.9×10^{11} ohm cm @ 104°F	
Dielectric Constant at 75°F		
frequency 10^3	3.26	
frequency 10^4	3.27	
frequency 10^5	3.27	
Dissipation Factor at 75°F		
frequency 10^3	0.0012	
frequency 10^4	0.0001	
frequency 10^5	0.0001	
Dielectric Strength at 75°F	530 volts/mil	
Surface Tension in Air	40.1 Dynes/cm 68°F	
	37.6 Dynes/cm 104°F	
	35.7 Dynes/cm 140°F	
Critical Temperature	927°F	497°C
Critical Pressure	30.93 atm	31.96 kg/cm^2
Critical Volume	0.0508 ft^3/lb	3.17 cm^3/g
Heat of Combustion	15,500 Btu/lb	8,600 cal/g
Molecular Weight (Avg.)	166.0	

†Cleveland Open Cup

††ASTM E659-78

Table 2 — Saturation Properties of DOWTHERM A Fluid (English Units)

TEMP.	VAPOR PRESSURE		ENTHALPY			SPECIFIC HEAT	DENSITY		SPECIFIC GRAVITY
	Absolute	Gauge	Liquid	Latent	Vapor	Liquid	Liquid	Vapor	Liquid
°F	lb/in²	Vacuum in Hg	Btu/lb			Btu/(lb •°F)	lb/ft³		t/25°C
53.6	0.000	29.92	0.0	175.2	175.2	0.371	66.54	0.0000	1.069
60	0.000	29.92	2.4	174.4	176.8	0.374	66.37	0.0000	1.066
70	0.000	29.92	6.1	173.2	179.3	0.377	66.10	0.0000	1.062
80	0.001	29.92	9.9	172.2	181.9	0.381	65.82	0.0000	1.057
90	0.001	29.92	13.8	170.7	184.5	0.385	65.55	0.0000	1.053
100	0.001	29.92	17.6	169.6	187.2	0.388	65.27	0.0000	1.049
110	0.002	29.92	21.5	168.4	189.9	0.392	65.00	0.0001	1.044
120	0.003	29.92	25.5	167.2	192.7	0.396	64.72	0.0001	1.040
130	0.005	29.92	29.5	166.0	195.5	0.400	64.44	0.0001	1.035
140	0.007	29.91	33.5	164.9	198.4	0.403	64.16	0.0002	1.031
150	0.010	29.91	37.5	163.8	201.3	0.407	63.88	0.0003	1.026
160	0.014	29.90	41.6	162.7	204.3	0.411	63.60	0.0004	1.022
170	0.020	29.89	45.7	161.6	207.3	0.414	63.32	0.0005	1.017
180	0.027	29.87	49.9	160.4	210.3	0.418	63.03	0.0007	1.013
190	0.037	29.85	54.1	159.4	213.5	0.422	62.75	0.0009	1.008
200	0.051	29.83	58.3	158.3	216.6	0.426	62.46	0.0012	1.003
210	0.068	29.79	62.6	157.2	219.8	0.429	62.17	0.0016	0.999
220	0.091	29.74	66.9	156.2	223.1	0.433	61.88	0.0021	0.994
230	0.120	29.69	71.3	155.1	226.4	0.437	61.59	0.0027	0.990
240	0.16	29.60	75.7	154.0	229.7	0.440	61.30	0.0034	0.985
250	0.20	29.52	80.1	153.0	233.1	0.444	61.00	0.0044	0.980
260	0.26	29.40	84.5	152.0	236.5	0.448	60.71	0.0055	0.975
270	0.33	29.26	89.0	151.0	240.0	0.451	60.41	0.0069	0.971
280	0.41	29.09	93.6	149.9	243.5	0.455	60.11	0.0086	0.966
290	0.51	28.89	98.1	148.9	247.0	0.459	59.81	0.0106	0.961
300	0.63	28.65	102.7	147.9	250.6	0.463	59.50	0.0129	0.956
310	0.78	28.34	107.4	146.8	254.2	0.466	59.20	0.0157	0.951
320	0.96	27.97	112.1	145.8	257.9	0.470	58.89	0.0191	0.946
330	1.17	27.55	116.8	144.8	261.6	0.474	58.59	0.0229	0.941
340	1.41	27.06	121.5	143.8	265.3	0.477	58.28	0.0274	0.936
350	1.70	26.47	126.3	142.8	269.1	0.481	57.96	0.0326	0.931
360	2.03	25.80	131.2	141.7	272.9	0.485	57.65	0.0385	0.926
370	2.42	25.00	136.0	140.8	276.8	0.488	57.33	0.0454	0.921
380	2.86	24.11	140.9	139.8	280.7	0.492	57.02	0.0532	0.916
390	3.37	23.07	145.9	138.7	284.6	0.496	56.70	0.0620	0.911
400	3.96	21.87	150.9	137.6	288.5	0.500	56.37	0.0720	0.906
410	4.62	20.52	155.9	136.6	292.5	0.503	56.05	0.0833	0.901
420	5.37	19.00	160.9	135.6	296.5	0.507	55.72	0.0959	0.895
430	6.22	17.27	166.0	134.5	300.5	0.511	55.39	0.1100	0.890
440	7.18	15.31	171.1	133.5	304.6	0.514	55.06	0.1258	0.885
450	8.25	13.13	176.3	132.4	308.4	0.518	54.72	0.1432	0.879
460	9.44	10.71	181.5	131.3	312.8	0.522	54.38	0.1626	0.874
470	10.77	8.00	186.7	130.3	317.0	0.526	54.04	0.1840	0.868
480	12.24	5.01	192.0	129.1	321.1	0.529	53.70	0.2076	0.863
490	13.86	1.71	197.3	128.0	325.3	0.533	53.35	0.2335	0.857
494.8	14.70	psig 0.00	199.9	127.4	327.3	0.535	53.18	0.2470	0.854
500	15.65	0.95	202.7	126.9	329.5	0.537	53.00	0.2618	0.851
510	17.62	2.92	208.1	125.7	333.8	0.541	52.65	0.2929	0.846
520	19.78	5.08	213.5	124.5	338.0	0.545	52.29	0.3267	0.840
530	22.14	7.14	219.0	123.3	342.3	0.549	51.93	0.3636	0.834
540	24.71	10.01	224.5	122.1	346.6	0.554	51.56	0.4037	0.828
550	27.51	12.81	230.1	120.8	350.9	0.558	51.20	0.4472	0.823
560	30.55	15.85	235.7	119.5	355.3	0.562	50.82	0.4943	0.816
570	33.83	19.13	241.4	118.2	359.6	0.567	50.45	0.5452	0.811
580	37.38	22.68	247.1	116.9	364.0	0.571	50.06	0.6003	0.804
590	41.21	26.51	252.8	115.5	368.3	0.575	49.68	0.6597	0.798
600	45.34	30.64	258.6	114.1	372.7	0.579	49.29	0.7237	0.792
610	49.76	35.06	264.4	112.7	377.1	0.582	48.89	0.7926	0.785
620	54.51	39.81	270.2	111.3	381.5	0.586	48.49	0.8667	0.779
630	59.59	44.89	276.1	109.8	385.9	0.589	48.08	0.9464	0.772
640	65.03	50.33	282.0	108.3	390.4	0.593	47.67	1.032	0.766
650	70.82	56.12	288.0	106.8	394.8	0.596	47.25	1.124	0.759
660	77.00	62.30	294.0	105.2	399.2	0.599	46.82	1.223	0.752
670	83.57	68.87	300.0	103.6	403.7	0.602	46.38	1.328	0.745
680	90.56	75.86	306.1	102.0	408.1	0.605	45.94	1.442	0.738
690	97.97	83.27	312.2	100.3	412.5	0.608	45.49	1.564	0.731
700	105.8	91.10	318.3	98.6	416.9	0.611	45.03	1.695	0.723
710	114.2	99.50	324.5	96.8	421.3	0.615	44.56	1.836	0.716
720	123.0	108.30	330.7	95.0	425.8	0.619	44.08	1.988	0.708
730	132.3	117.60	337.0	93.1	430.2	0.623	43.59	2.151	0.700
740	142.1	127.40	343.4	91.2	434.6	0.628	43.09	2.327	0.692
750	152.5	137.80	349.7	89.2	438.9	0.633	42.57	2.517	0.684
760	163.4	148.70	356.2	87.1	443.3	0.640	42.04	2.723	0.675
770	174.9	160.20	362.7	84.9	447.6	0.647	41.49	2.946	0.667
780	187.1	172.40	369.3	82.6	451.8	0.655	40.93	3.190	0.658
790	199.8	185.10	375.9	80.1	456.0	0.664	40.34	3.456	0.648
800	213.3	198.60	382.7	77.6	460.2	0.675	39.74	3.749	0.638

Table 3 — Saturation Properties of DOWTHERM A Fluid (Metric Units)

TEMP.	VAPOR PRESSURE		ENTHALPY			SPECIFIC HEAT	DENSITY		SPECIFIC GRAVITY
	Absolute	Gauge	Liquid	Latent	Vapor	Liquid	Liquid	Vapor	Liquid
°C	kg/cm²		kcal/kg			cal/g •°C	g/cm³	kg/m³	t/25°C
12.0	0.0000		0.0	97.3	97.3	0.371	1.066	0.000	1.069
15.0	0.0000		1.1	96.9	98.0	0.373	1.064	0.000	1.067
20.0	0.0000		3.0	96.3	99.3	0.376	1.060	0.000	1.063
25.0	0.0000		4.9	95.7	100.6	0.380	1.056	0.000	1.059
30.0	0.0000		6.8	95.1	101.9	0.383	1.052	0.000	1.055
35.0	0.0000		8.7	94.5	103.2	0.387	1.048	0.000	1.051
40.0	0.0001		10.6	93.9	104.6	0.390	1.044	0.000	1.047
45.0	0.0002		12.6	93.3	105.9	0.393	1.040	0.002	1.043
50.0	0.0002		14.6	92.7	107.3	0.397	1.036	0.002	1.039
55.0	0.0003		16.6	92.1	108.7	0.400	1.032	0.002	1.035
60.0	0.0005		18.6	91.6	110.2	0.404	1.028	0.003	1.031
65.0	0.0007		20.6	91.0	111.6	0.407	1.024	0.005	1.027
70.0	0.0009		22.6	90.5	113.1	0.410	1.020	0.006	1.023
75.0	0.0013		24.7	89.9	114.6	0.414	1.016	0.008	1.018
80.0	0.0017		26.8	89.3	116.1	0.417	1.012	0.010	1.014
85.0	0.0023		28.9	88.8	117.7	0.420	1.007	0.013	1.010
90.0	0.0030		31.0	88.3	119.3	0.424	1.003	0.016	1.006
95.0	0.0039		33.1	87.7	120.8	0.427	0.999	0.021	1.002
100.0	0.0051		35.2	87.2	122.4	0.430	0.995	0.027	0.998
105.0	0.0066		37.4	86.7	124.1	0.433	0.991	0.035	0.994
110.0	0.0084		39.6	86.1	125.7	0.437	0.987	0.043	0.989
115.0	0.0107		41.8	85.6	127.4	0.440	0.982	0.053	0.985
120.0	0.0134		44.0	85.1	129.1	0.443	0.978	0.067	0.981
125.0	0.0168		46.2	84.6	130.8	0.447	0.974	0.083	0.977
130.0	0.0208		48.4	84.1	132.5	0.450	0.970	0.102	0.972
135.0	0.0257		50.7	83.6	134.3	0.453	0.965	0.124	0.968
140.0	0.0315		53.0	83.0	136.0	0.456	0.961	0.151	0.964
145.0	0.0384		55.2	82.5	137.8	0.460	0.957	0.181	0.959
150.0	0.0466		57.6	82.0	139.6	0.463	0.952	0.216	0.955
155.0	0.0562		59.9	81.5	141.4	0.466	0.948	0.257	0.950
160.0	0.0674		62.3	81.0	143.2	0.470	0.943	0.306	0.946
165.0	0.0805		64.6	80.5	145.1	0.473	0.939	0.361	0.942
170.0	0.0956		67.0	80.0	146.9	0.476	0.934	0.425	0.937
175.0	0.1131		69.3	79.5	148.8	0.479	0.930	0.497	0.933
180.0	0.1331		71.8	78.9	150.7	0.483	0.925	0.579	0.928
185.0	0.1560		74.2	78.4	152.6	0.486	0.921	0.672	0.924
190.0	0.1820		76.6	78.0	154.6	0.489	0.916	0.777	0.919
195.0	0.2120		79.1	77.5	156.5	0.493	0.912	0.895	0.914
200.0	0.2540		81.6	76.9	158.5	0.496	0.907	1.025	0.910
205.0	0.2830		84.1	76.4	160.4	0.499	0.902	1.172	0.905
210.0	0.3250		86.6	75.9	162.4	0.503	0.898	1.334	0.900
215.0	0.3730		89.1	75.4	164.4	0.506	0.893	1.516	0.896
220.0	0.4250		91.6	74.9	166.5	0.510	0.888	1.717	0.891
225.0	0.4840		94.2	74.3	168.5	0.513	0.884	1.939	0.886
230.0	0.5490		96.8	73.8	170.5	0.517	0.879	2.183	0.881
235.0	0.6210		99.4	73.2	172.6	0.520	0.874	2.450	0.876
240.0	0.7000		102.0	72.7	174.7	0.523	0.869	2.742	0.871
245.0	0.7870		104.6	72.2	176.7	0.527	0.864	3.061	0.866
250.0	0.8830		107.2	71.6	178.8	0.530	0.859	3.409	0.861
255.0	0.9870		109.9	71.0	180.9	0.534	0.854	3.786	0.856
257.1	1.0330	0.000	111.1	70.8	181.8	0.535	0.852	3.957	0.854
260.0	1.1000	0.068	112.6	70.5	183.0	0.538	0.849	4.194	0.851
265.0	1.2250	0.192	115.3	69.9	185.1	0.541	0.844	4.643	0.846
270.0	1.3590	0.326	118.0	69.3	187.2	0.545	0.839	5.126	0.841
275.0	1.5050	0.472	120.7	68.7	189.4	0.548	0.834	5.648	0.836
280.0	1.6630	0.630	123.5	68.1	191.5	0.552	0.828	6.210	0.831
285.0	1.8330	0.800	126.2	67.4	193.7	0.556	0.823	6.816	0.825
290.0	2.0170	0.984	129.0	66.8	195.8	0.559	0.818	7.466	0.820
295.0	2.2140	1.181	131.8	66.1	198.0	0.583	0.812	8.163	0.815
300.0	2.4260	1.393	134.7	65.5	200.2	0.567	0.807	8.911	0.809
305.0	2.6520	1.619	137.5	64.8	202.4	0.571	0.801	9.712	0.804
310.0	2.8950	1.862	140.4	64.1	204.5	0.574	0.796	10.570	0.798
315.0	3.1540	2.121	143.3	63.4	206.7	0.578	0.790	11.490	0.792
320.0	3.4310	2.398	146.2	62.7	208.9	0.582	0.784	12.480	0.787
325.0	3.7250	2.692	149.1	62.0	211.1	0.585	0.779	13.530	0.781
330.0	4.0390	3.006	152.0	61.3	213.3	0.589	0.773	14.650	0.775
335.0	4.3710	3.338	155.0	60.6	215.5	0.592	0.592	15.850	0.769
340.0	4.7240	3.691	157.9	59.8	217.8	0.594	0.761	17.120	0.763
345.0	5.0980	4.065	160.9	59.0	220.0	0.597	0.755	18.480	0.757
350.0	5.4930	4.460	163.9	58.2	222.2	0.600	0.749	19.930	0.751
355.0	5.9120	4.879	166.9	57.4	224.4	0.602	0.742	21.460	0.744
360.0	6.3530	5.320	170.0	56.6	226.6	0.605	0.736	23.100	0.738
365.0	6.8190	5.786	173.0	55.8	228.8	0.608	0.729	24.860	0.731
370.0	7.3100	6.277	176.1	54.9	231.0	0.611	0.723	26.730	0.725
375.0	7.8270	6.794	179.2	54.1	233.2	0.614	0.716	28.740	0.718
380.0	8.3710	7.338	182.3	53.2	235.4	0.617	0.709	30.870	0.711
385.0	8.9430	7.910	185.4	52.2	237.6	0.621	0.702	33.150	0.704
390.0	9.5430	8.510	188.5	51.3	239.8	0.625	0.695	35.890	0.697
395.0	10.1700	9.141	191.6	50.3	241.9	0.630	0.688	38.190	0.690
400.0	10.8400	9.802	194.9	49.3	244.2	0.635	0.680	40.980	0.682
405.0	11.5300	10.496	198.2	48.3	246.4	0.641	0.673	43.980	0.674
410.0	12.2600	11.222	201.4	47.2	248.6	0.647	0.665	47.200	0.667
415.0	13.0200	11.983	204.7	46.0	250.7	0.655	0.657	50.710	0.658
420.0	13.8100	12.780	208.0	44.8	252.8	0.663	0.648	54.510	0.650
425.0	14.6500	13.613	211.4	43.5	254.9	0.671	0.639	58.650	0.641

Figure 5 – Characteristics of Biphenyl-Diphenyl Oxide Mixtures

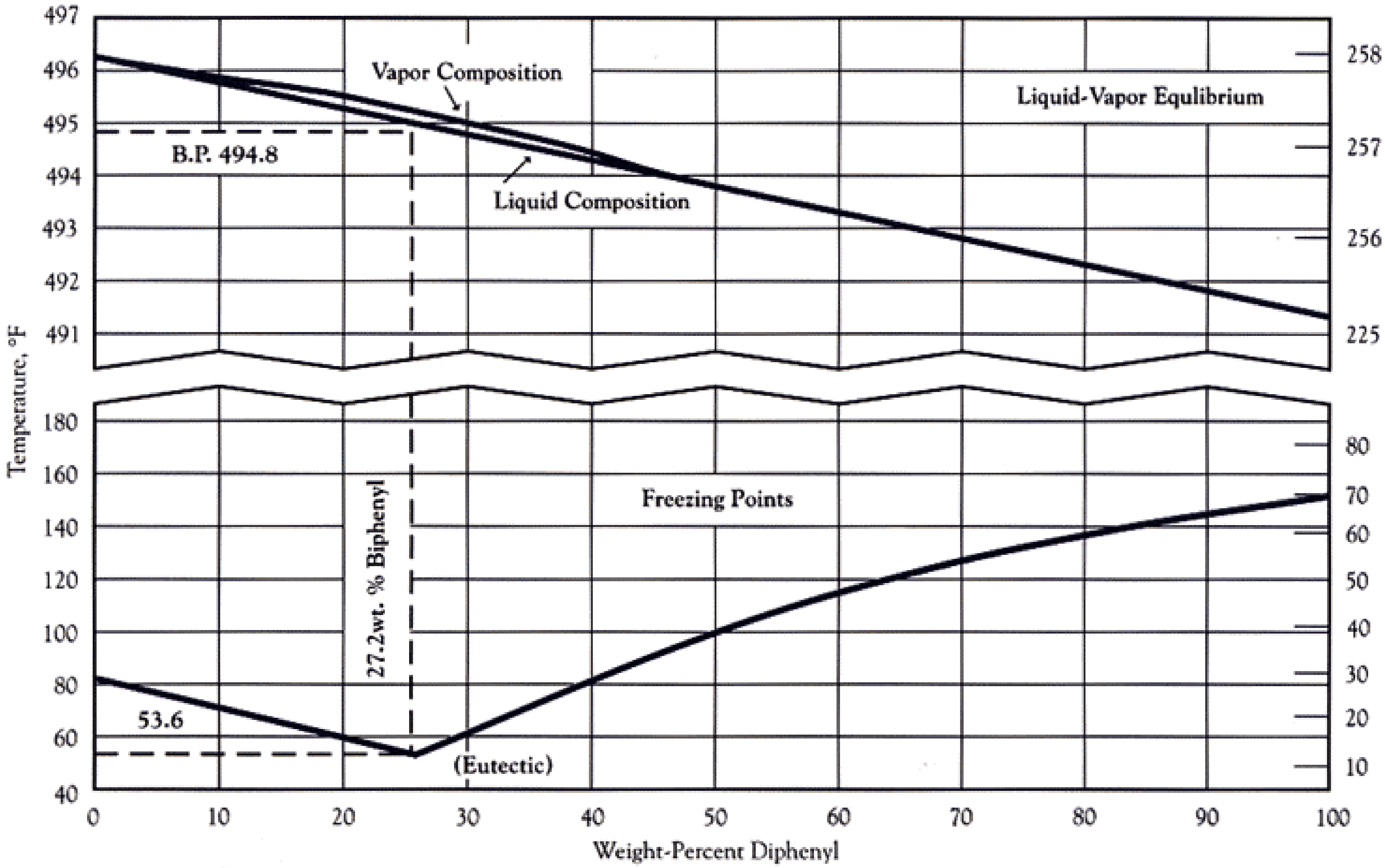


Figure 6-Expansion of DOWTHERM A Liquid

Basis: 100 Gallons at 60°F.

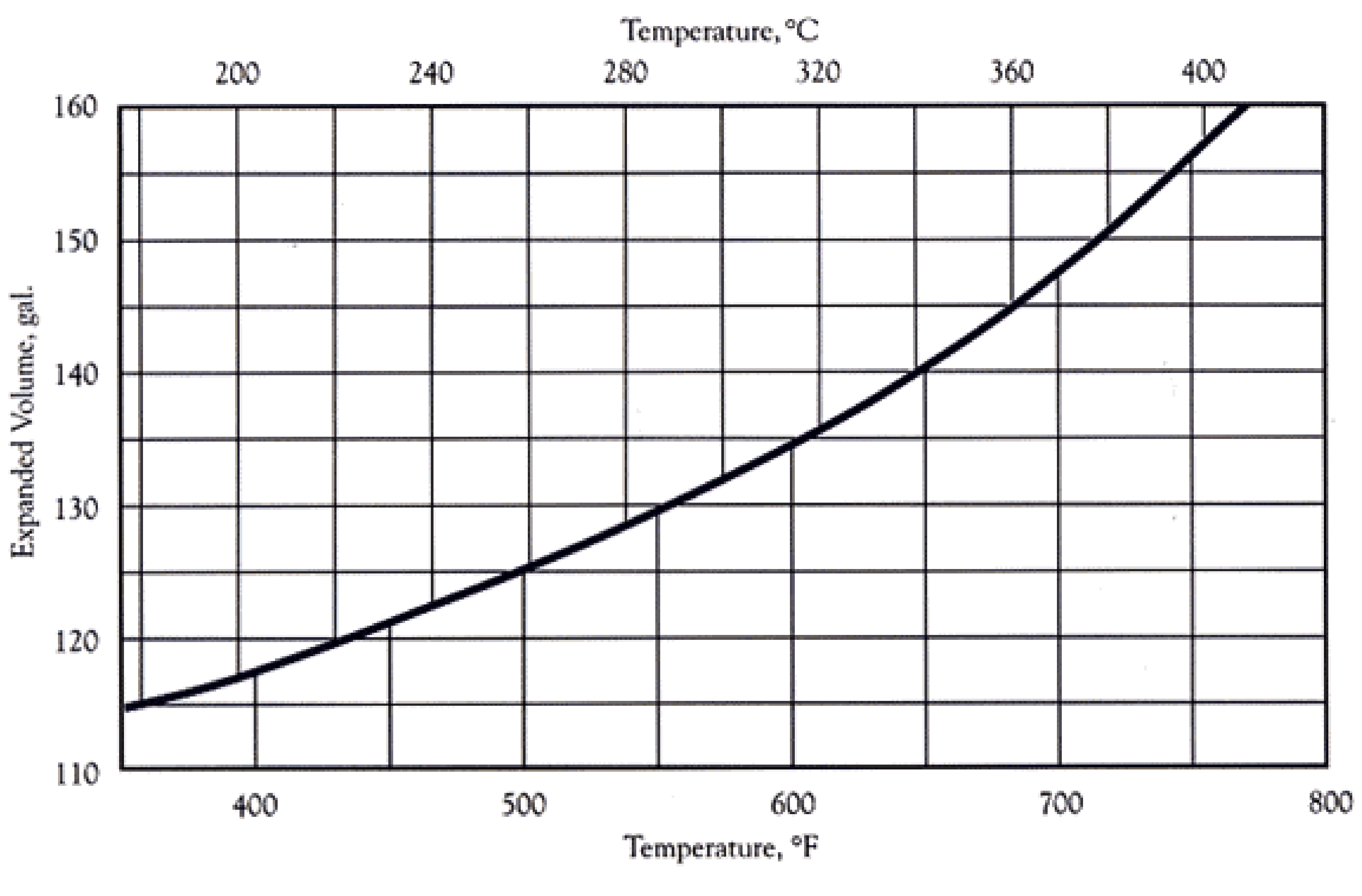


Figure 7 – Solubility of Water in DOWTHERM A Fluid at Atmospheric Pressure

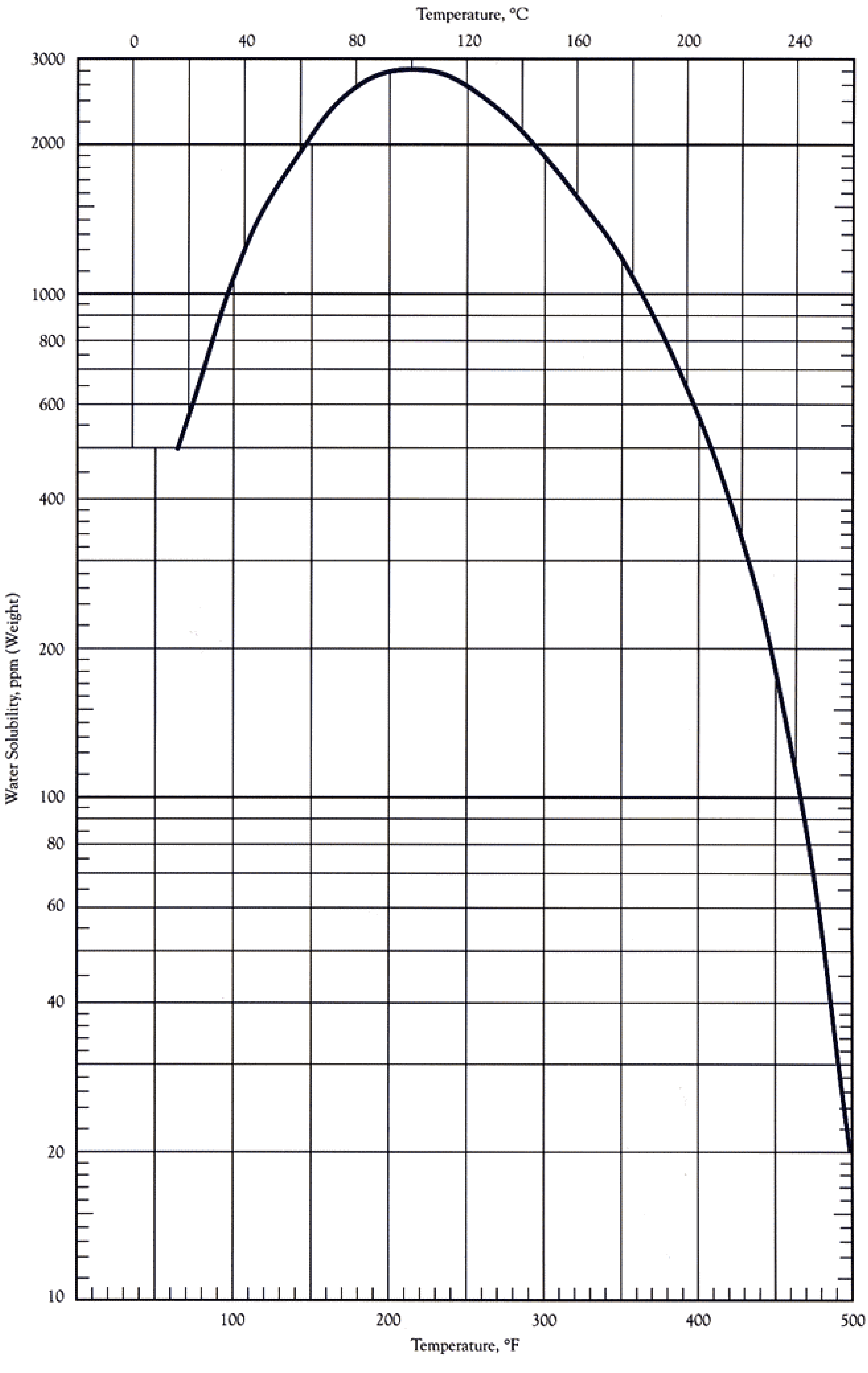


Figure 8 – Liquid Viscosity of DOWTHERM A Fluid

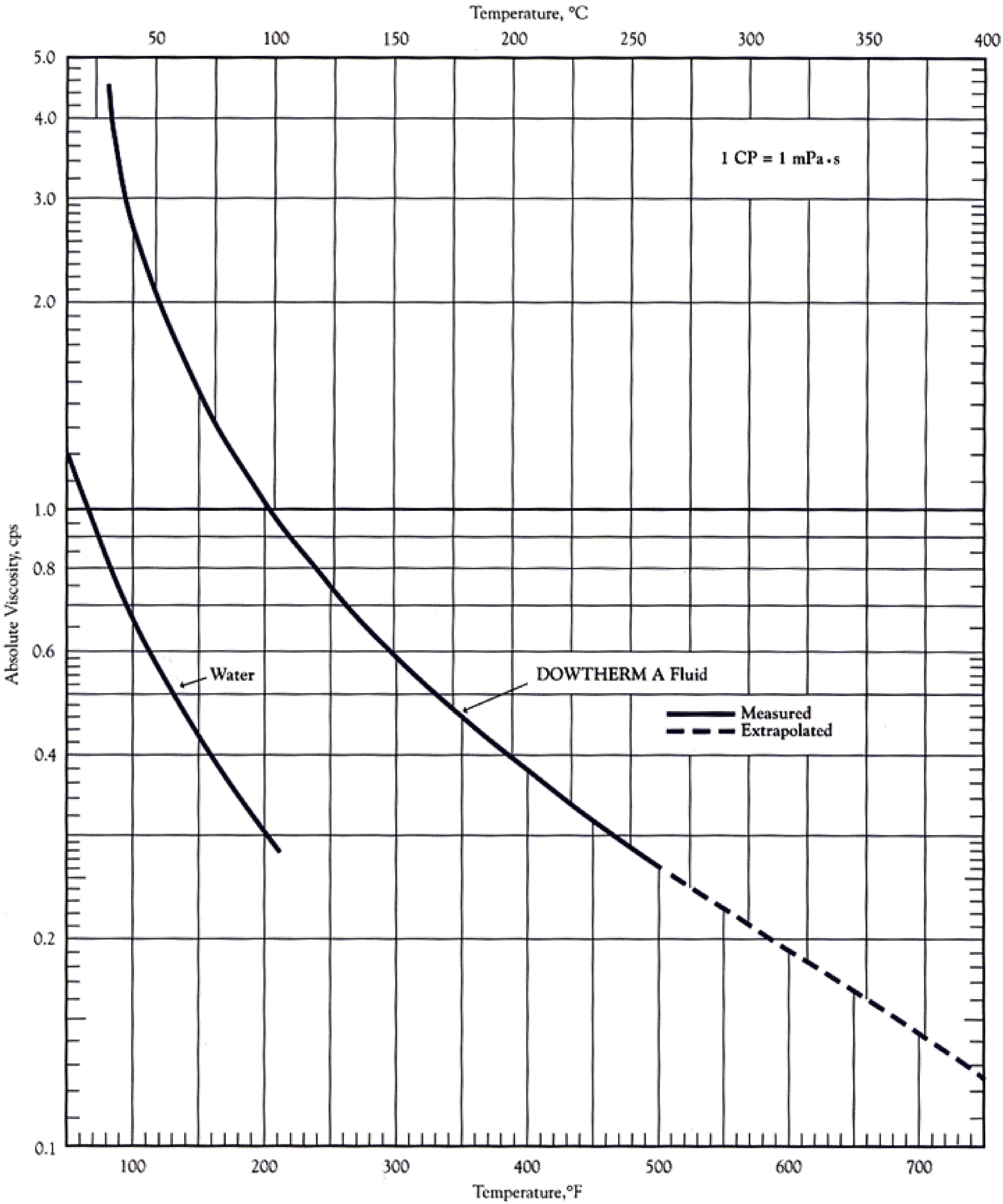


Figure 9 – Calculated Viscosity for Vapors of DOWTHERM A Fluid

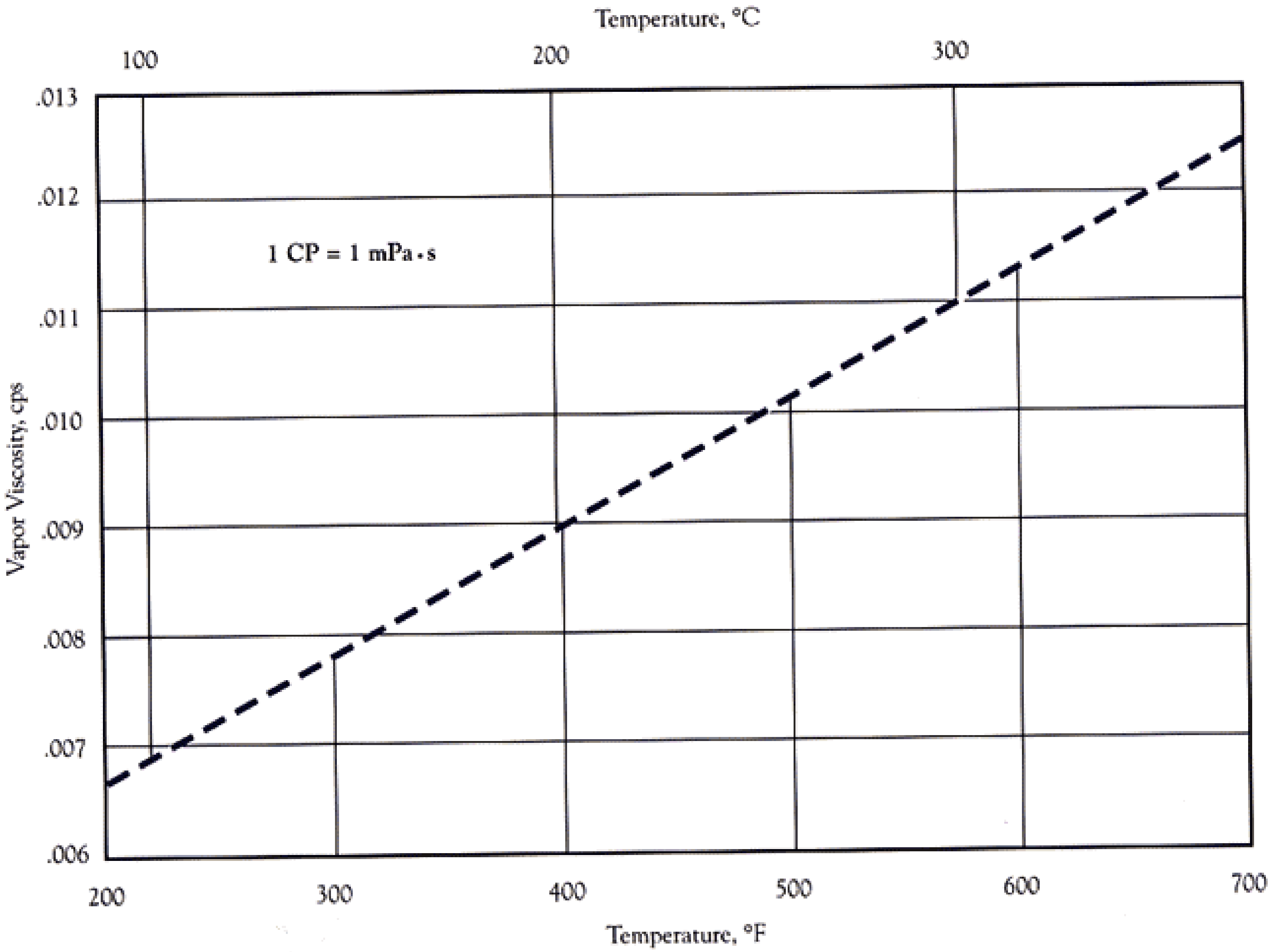


Figure 10 – Thermal Conductivity of DOWTHERM A Liquid

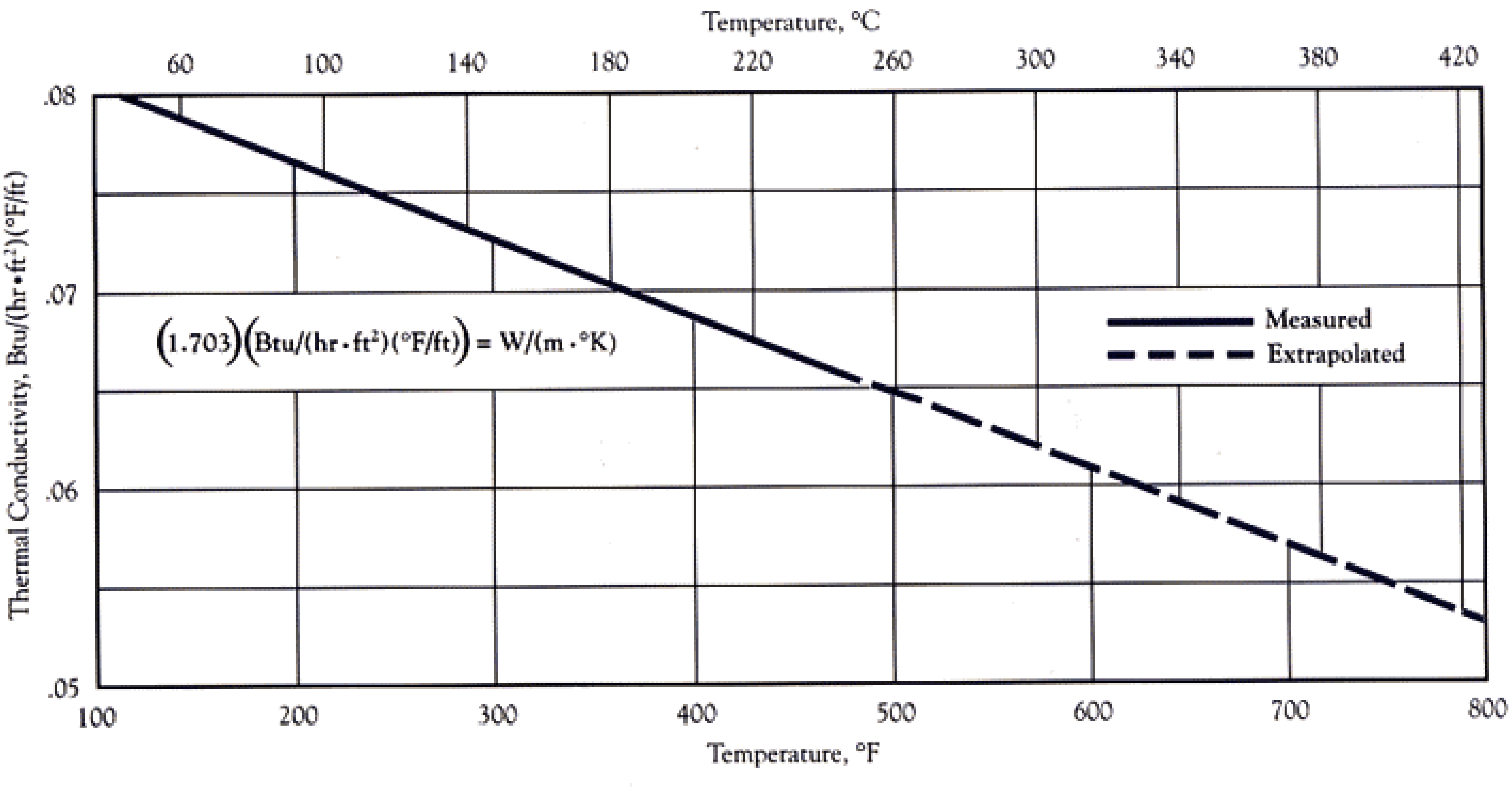


Figure 11 – Calculated Specific Heat for Vapors of DOWTHERM A Fluid

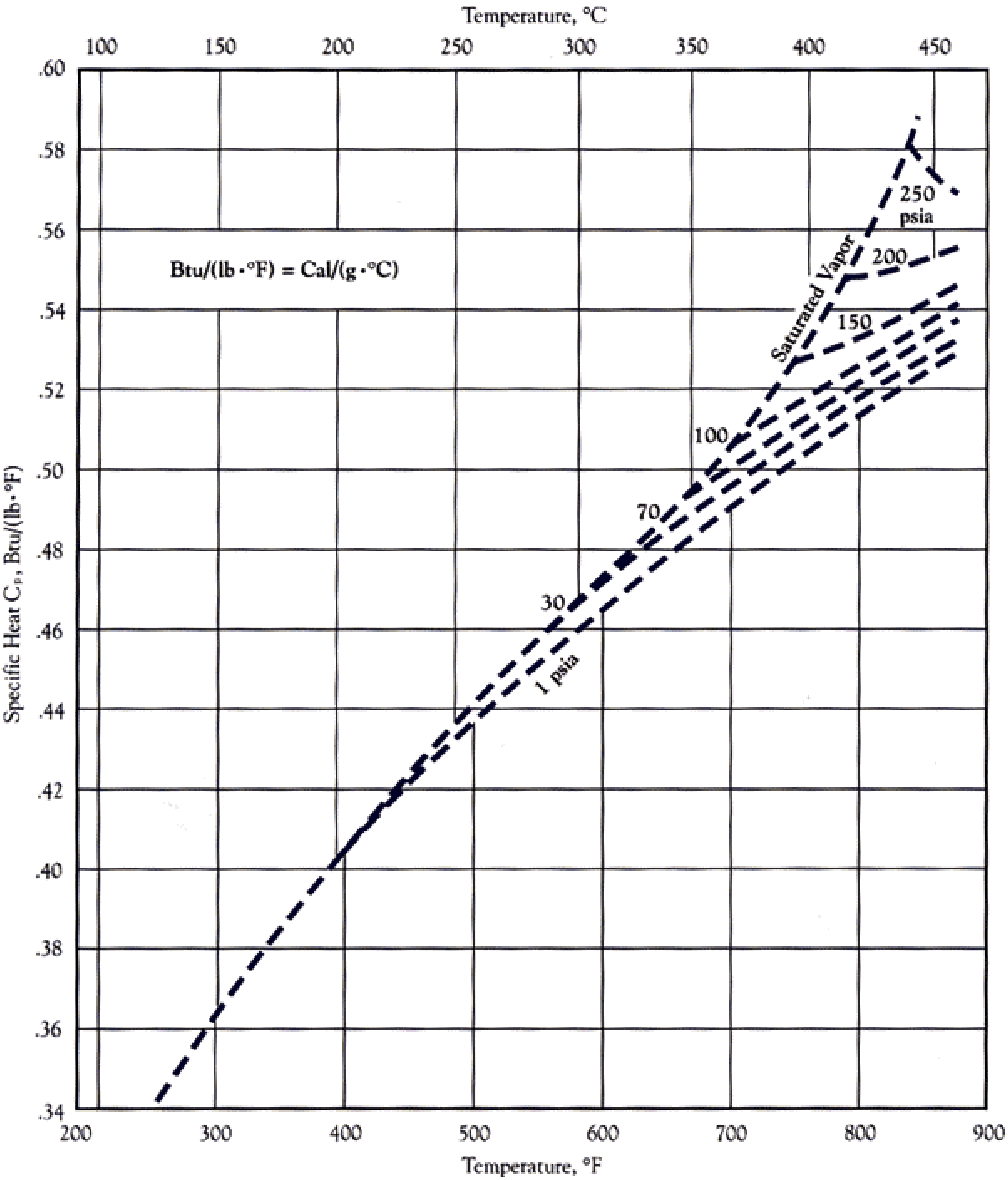


Figure 12 – Calculated Specific Heat Ratio for Vapors of DOWTHERM A Fluid

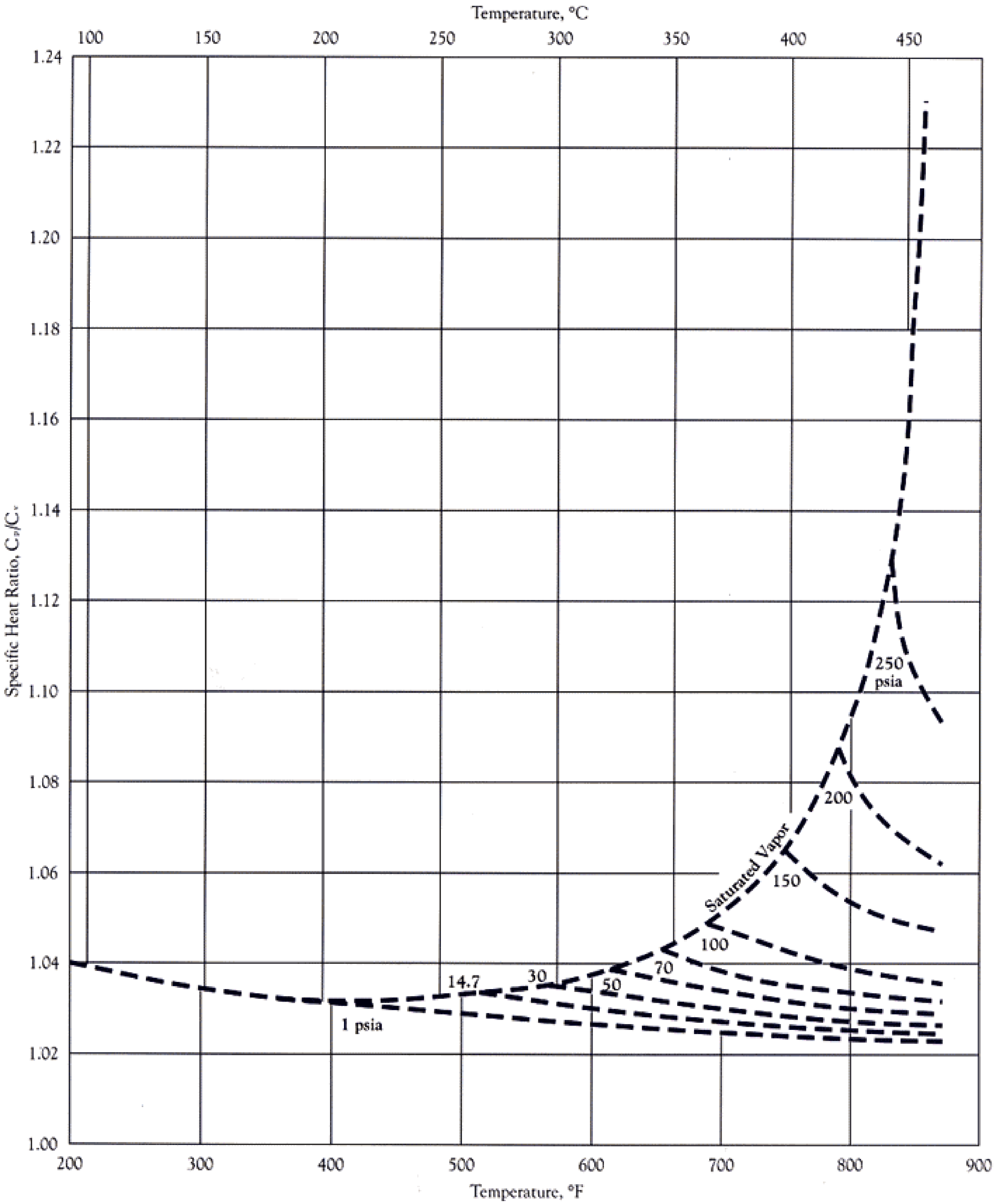
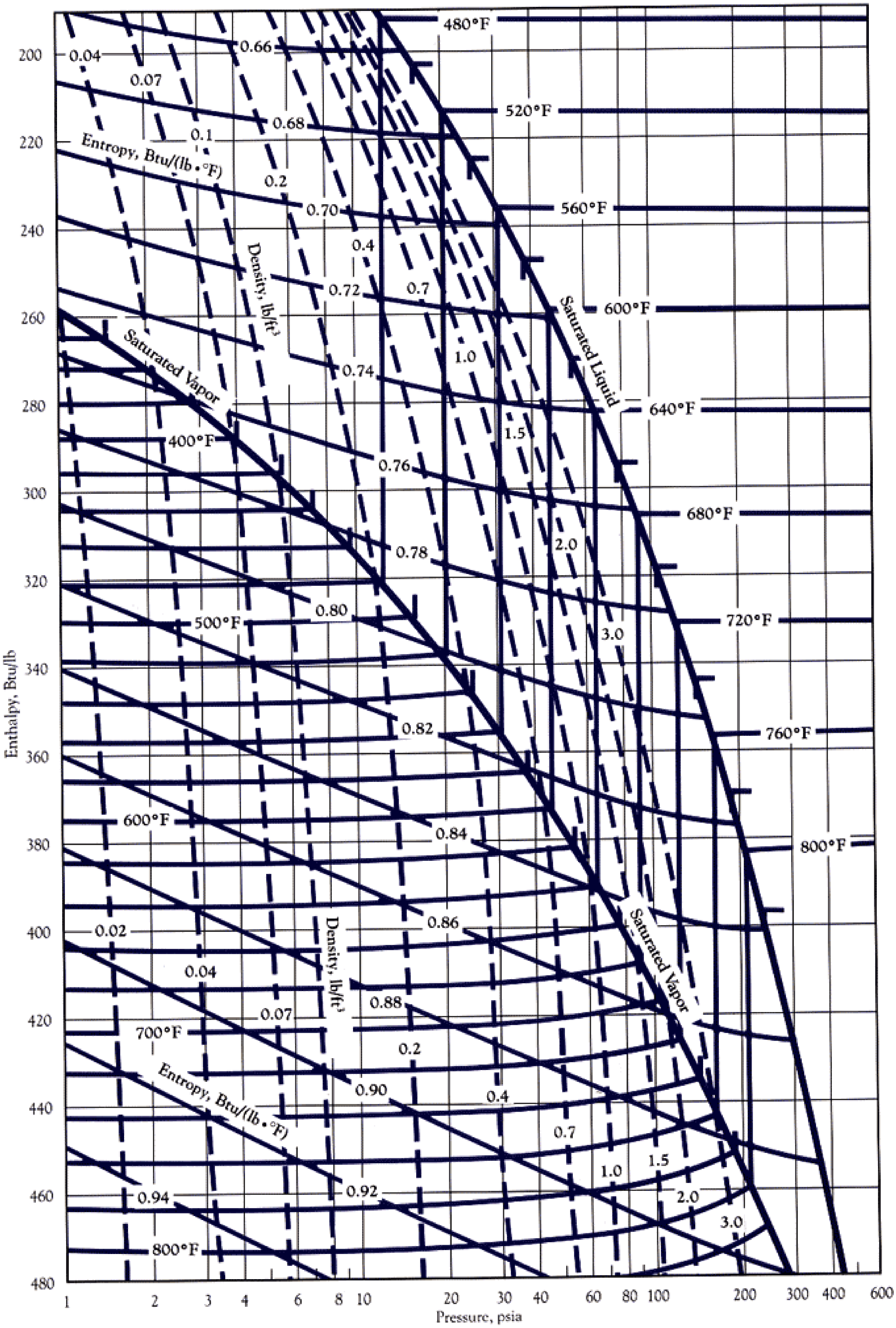


Figure 13 – Calculated Pressure vs. Enthalpy for DOWTHERM A Fluid



Nomenclature and Symbols

C_p	Specific Heat (Constant Pressure)	Btu/(lb · °F)
C_v	Specific Heat (Constant Volume)	Btu/(lb · °F)
d	Diameter	inch
D	Diameter	ft
G	Mass Velocity	lb/(hr · ft²)
G'	Mass Velocity	lb/(sec · ft²)
h	Average Film Coefficient	Btu/(hr · ft² · °F)
k	Thermal Conductivity	Btu/(hr · ft²)(°F/ft)
Q	Heat Flow	Btu/hr
v	Fluid Velocity	ft/sec
W'	Condensation per Tube	lb/hr
Δ (delta)	Difference	
Δ t	True or Effective Temperature Difference	°F
λ (lambda)	Latent Heat	Btu/lb
μ (mu)	Viscosity μ = (cps x 2.42)	lb/(hr · ft)
ρ (rho)	Density	lb/ft³

Subscripts:

f	film
i	inside
o	outside
w	wall

Figure 14—Liquid Film Coefficient for DOWTHERM A Fluid Inside Pipes and Tubes (Turbulent Flow Only)

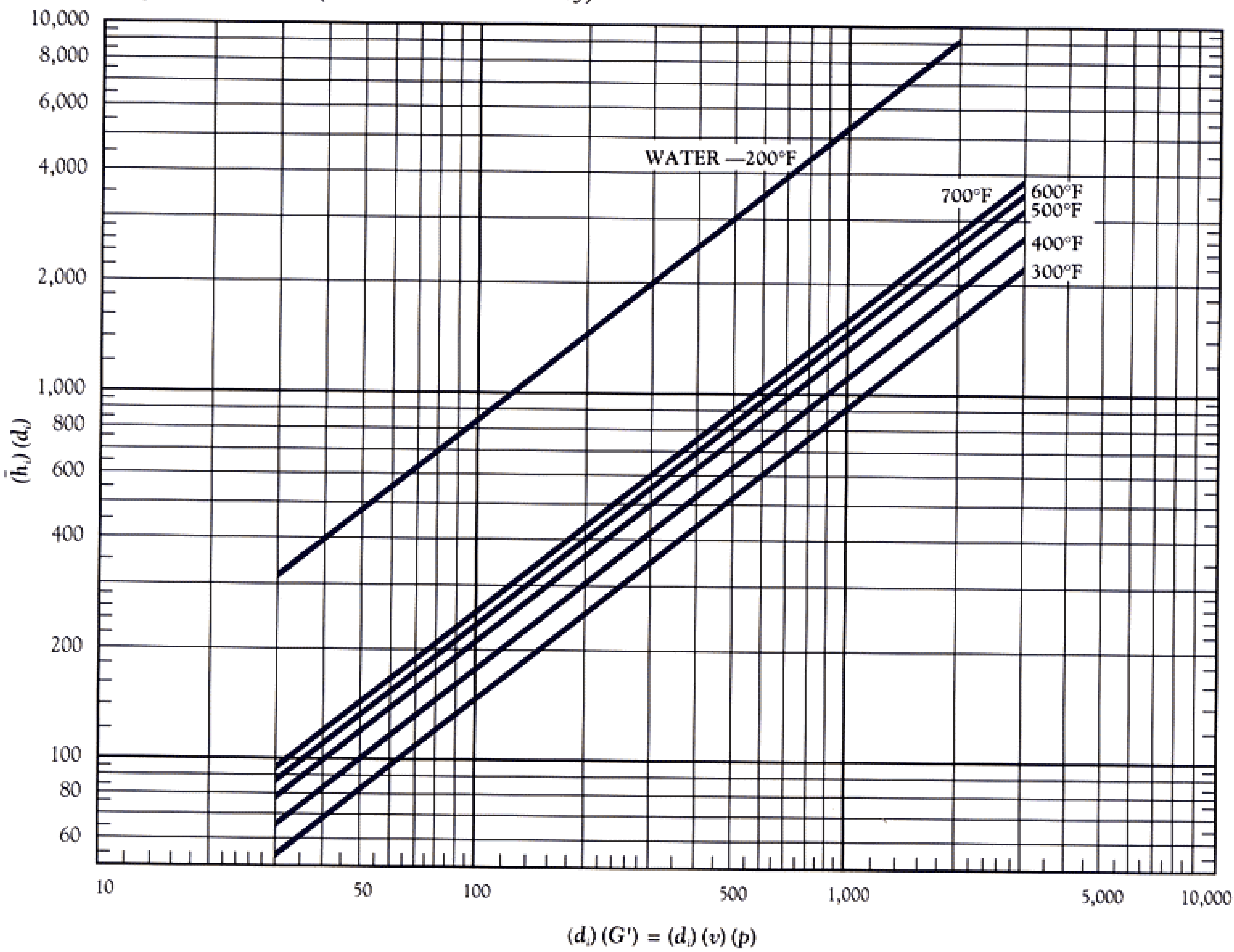
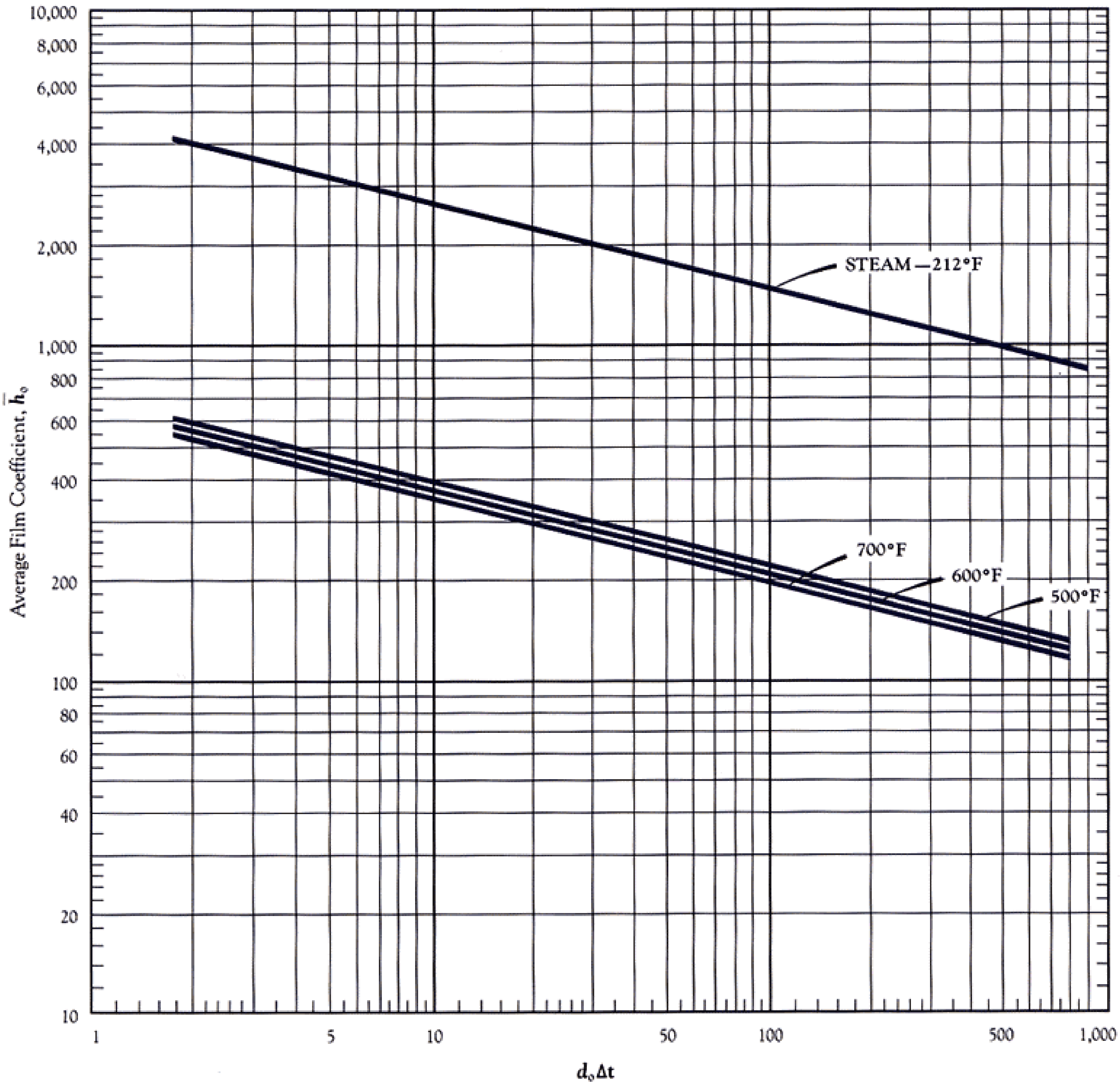


Chart based on $\left(\frac{\mu}{\mu_w}\right)^{.14} = 1$

$$\frac{\bar{h}_i d_i}{k} = 31.06 \left(\frac{d_i G'}{\mu}\right)^{.8} \left(\frac{C_p \mu}{k}\right)^{1/3} \left(\frac{\mu}{\mu_w}\right)^{.14}$$

SIEDER AND TATE EQUATION Process Heat Transfer, D. Q. Kern (1950) p. 103

Figure 15 — Condensation Film Coefficients for DOWTHERM A Fluid Outside Horizontal Pipes or Tubes



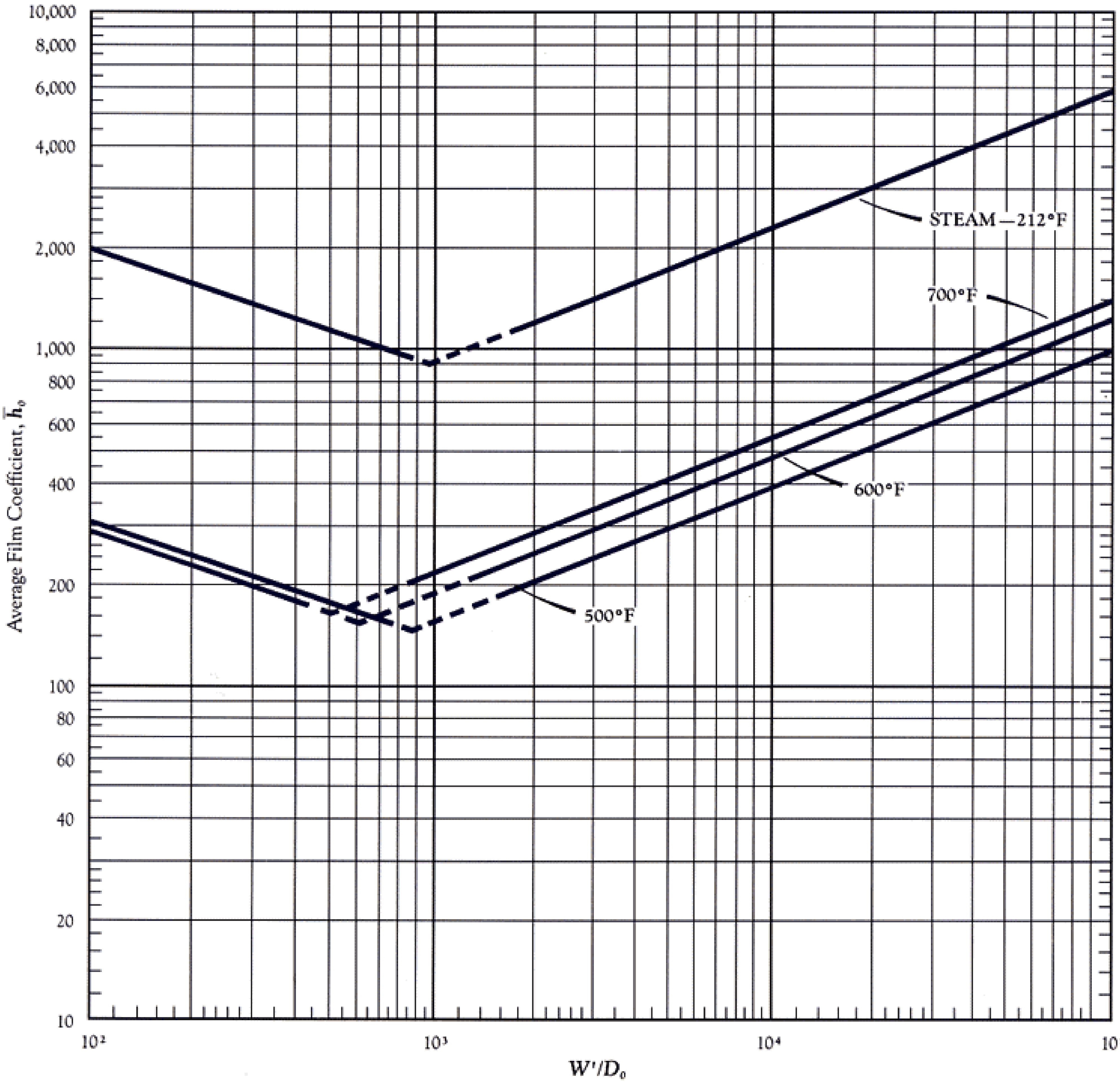
$$\bar{h}_o = 192.8 \left(\frac{k_f^3 \rho_f^2 \lambda}{\mu_f d_o \Delta t} \right)^{1/4}$$

Δt = Temperature Difference Between Vapor and Tube, °F

NUSSELT EQUATION

Process Heat Transfer, D. Q. Kern (1950) p. 263

Figure 16 — Condensation Film Coefficients for DOWTHERM A Fluid Outside Vertical Pipes or Tubes



$\bar{h}_o$ Values Are Approximate Between Tube Lengths of Six and Eight Feet

Process Heat Transfer, D. Q. Kern (1950) pp. 261-270

Figure 19—Pressure Drop vs. Flow Rate of DOWTHERM A Liquid in Tubes

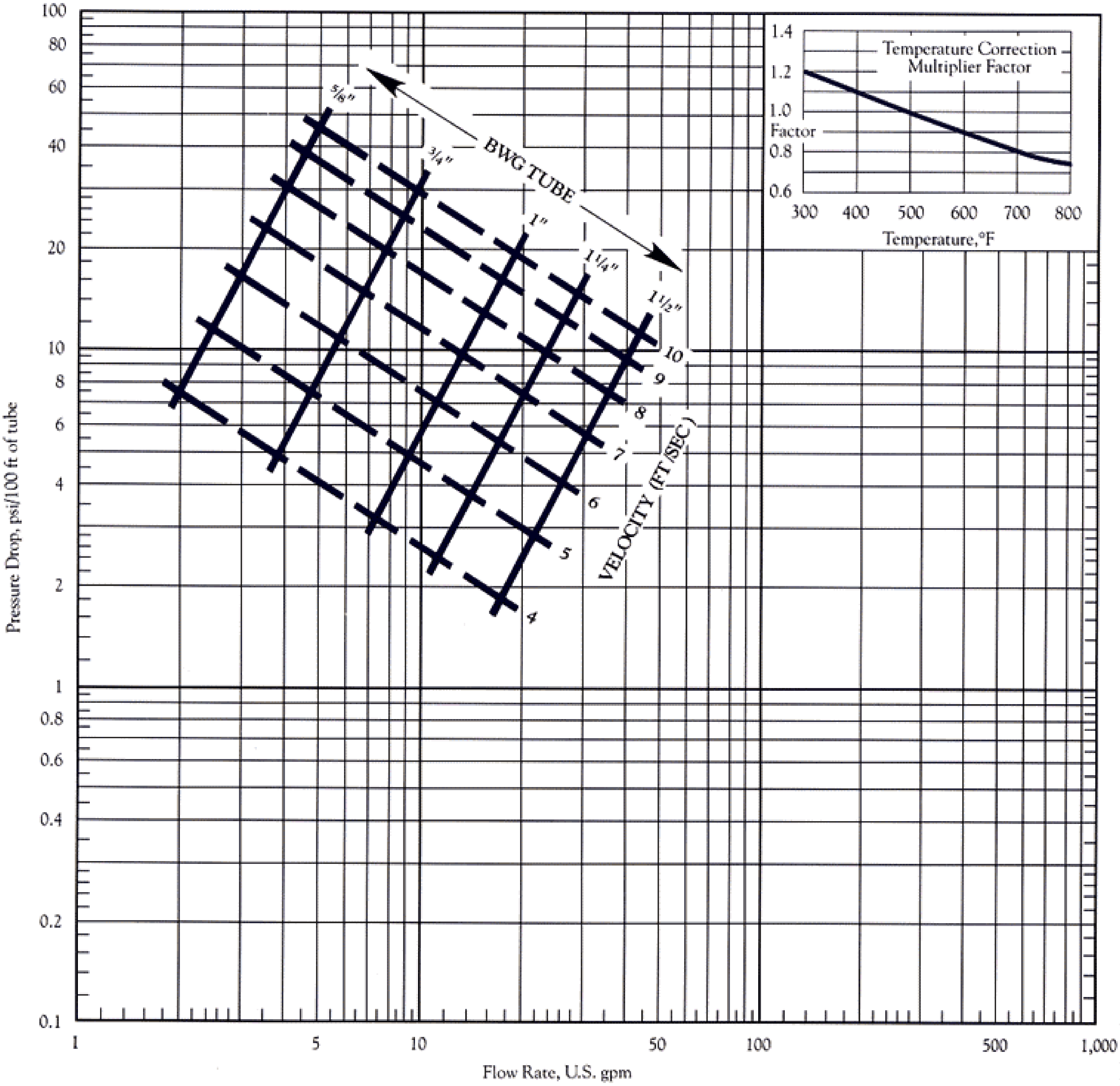
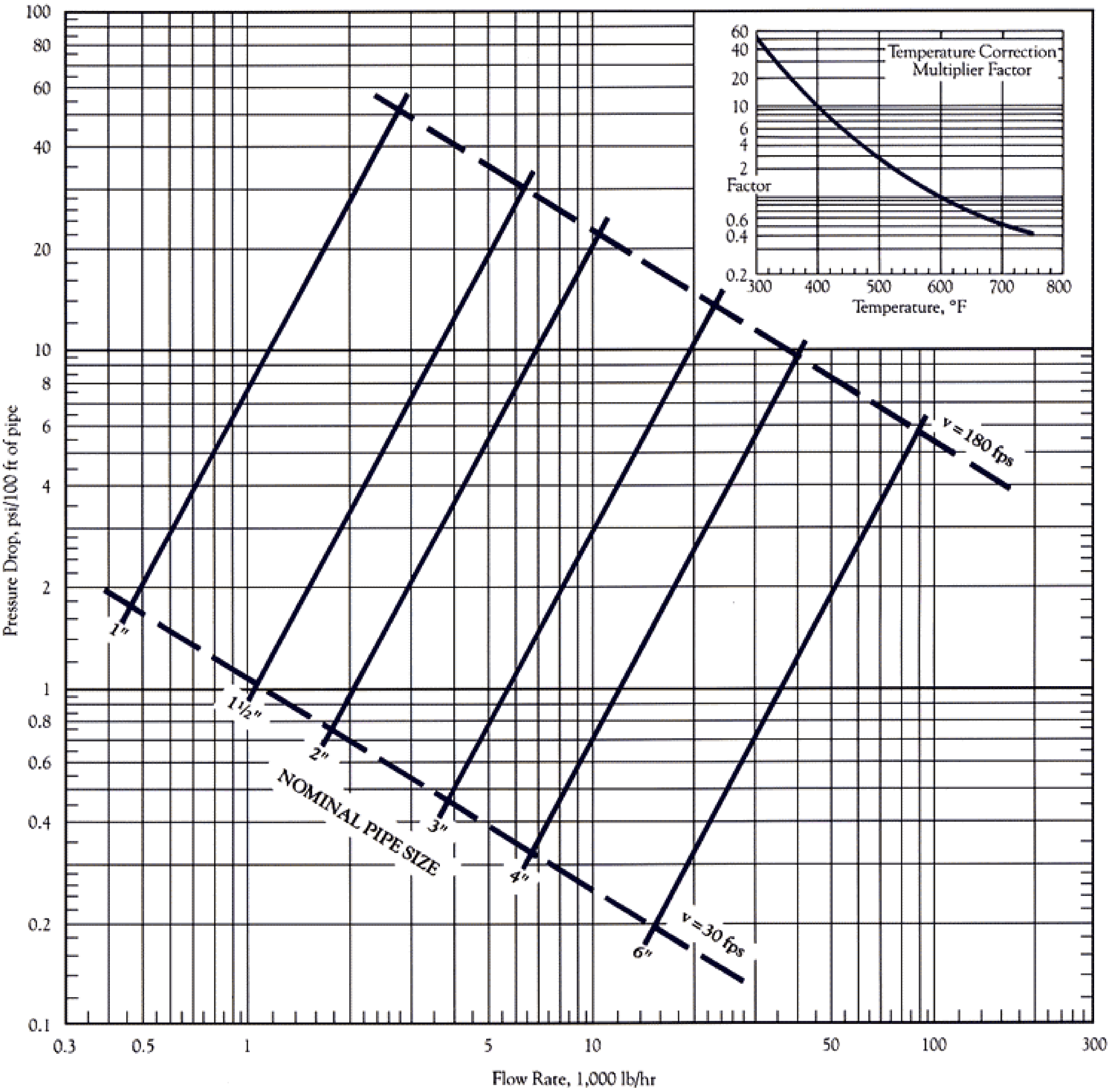


Figure 20—Pressure Drop vs. Flow Rate for Vapors of DOWTHERM A Fluid in Schedule 40 Nominal Pipe



DOWTHERM*A Heat Transfer Fluid

Product Technical Data

THE DOW CHEMICAL COMPANY MIDLAND, MICHIGAN 48674

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