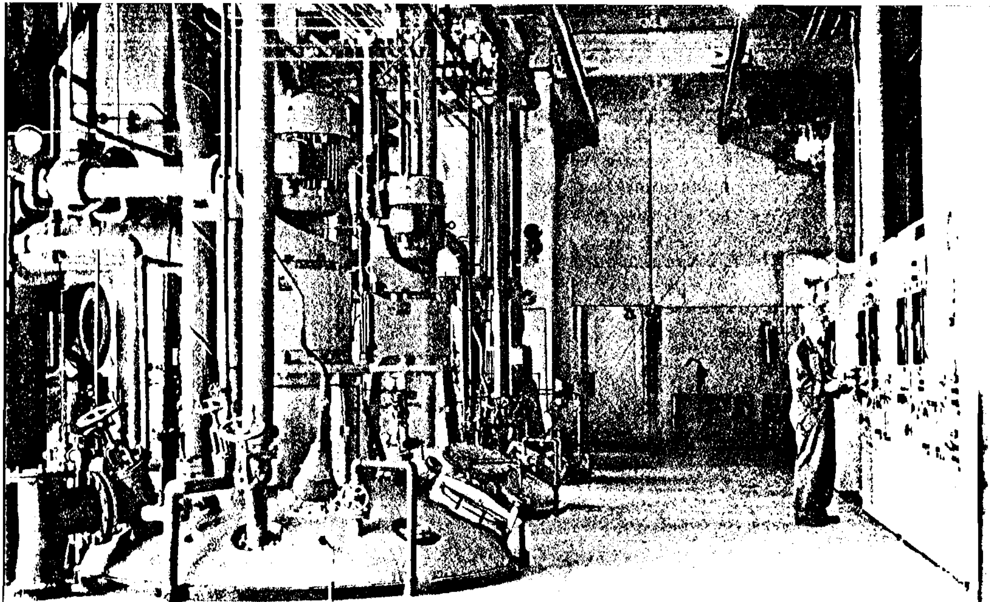

therminol FR FLUID HEAT SYSTEMS...

Delivering High-Temperature Process Heat as a Liquid

As recently as 1941, process engineers were limited to two methods of delivering process heat: DIRECT FIRING or PRESSURIZED VAPOR. Each method had definite drawbacks. Direct firing was often unsatisfactory because the heating was uneven, the temperatures difficult to control, and the processing of combustible materials extremely hazardous. Pressured-vapor, such as steam, required costly, high pressure piping, valves, and processing equipment—plus constant chemical "conditioning" of boiler water. Heat energy and temperature loss were common with pressured-vapor systems because of "blowdowns," condensation, and the inevitable pressure loss with long runs of piping.

Today, non-pressurized, high-temperature, fire-resistant heat transfer systems based on Monsanto's THERMINOL FR Heat Transfer liquids overcome practically all the deficiencies and drawbacks of direct firing and pressurized-vapor heating. THERMINOL FR—a series of high-boiling, heat-stable organic liquids, delivers processing heat to single or multi-users as a liquid without pressurizing. THERMINOL fluids are safe and fire resistant. Heating is uniform; and temperature control is accurate within a range of plus-or-minus 2°F.

Heat transfer systems now in use for several years have proved THERMINOL fluid heat successful in a wide variety of process heating operations . . . from food cooking to chemical processing, from distillations to drying ovens and in petroleum refining.

Design engineers and manufacturers have developed a variety of THERMINOL FR Fluid Systems ranging from small electrically heated units to giant gas or oil fired units—all capable of delivering heat AS A LIQUID.

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This manual explains and illustrates the fundamentals of THERMINOL fluid heat transfer systems design. It lists materials of construction and components for use with THERMINOL, and explains how each is "designed in" to make the most efficient system for safe, economical and reliable operation. It shows how these systems can be adapted to a wide variety of heating and cooling processes. This engineering heat transfer data has been compiled to aid the Process Engineer in designing a safe, minimum maintenance system for delivering heat to the points of use in practically any commercial or industrial process.

therminol FR HEAT TRANSFER LIQUIDS...

Monsanto THERMINOL FR heat transfer liquids are chlorinated biphenyls, manufactured under exacting process control to produce fluids consistent in all properties important to heat transfer. THERMINOL FR products are unique in that they are actually produced to rigid specifications for thermal stability, specific heat, thermal conductivity, vapor pressure, and viscosity.

There are three THERMINOL FR products, with a range of low temperature fluidity and boiling points that allows the user to select the best balance of fluid properties for a *specific* use:

THERMINOL FR 1

with lowest temperature fluidity — excellent for processes requiring both heating and cooling

THERMINOL FR 2

with optimum balance of properties for use in most common industrial heating applications

THERMINOL FR 3

with highest boiling point for special processing equipment applications

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PROPERTIES IMPORTANT TO HEAT TRANSFER DESIGN

THERMINOL FR-1

Temperature °F.	°C.	Enthalpy BTU/Lb.	Specific Heat BTU/Lb.—°F.	Thermal Conduct. BTU/Ft.², Hr., °F./Ft.	Density Lb./Gal.	Viscosity Lb./Hr.—Ft.	Vapor Pres. mm. Hg. Absolute
50	10.0	4.656	0.272	0.06098	11.683	745.36	
100	37.8	18.68	0.282	0.06060	11.458	56.144	
150	66	32.95	0.291	0.06021	11.216	15.972	
200	93	48.07	0.3047	0.05976	10.991	8.2431	
250	121	63.50	0.3151	0.05927	10.760	5.5270	
300	149	79.46	0.3255	0.05875	10.528	3.4158	
350	177	95.94	0.3359	0.05819	10.296	2.4753	10
400	204	112.96	0.3464	0.05760	10.065	1.8898	27
450	232	130.48	0.3568	0.05697	9.833	1.5028	65
500	260	148.52	0.3672	0.05630	9.601	1.2351	143
550	288	167.08	0.3776	0.05560	9.370	1.0428	291
600	316	186.16	0.3880	0.05487	9.138	0.90031	550
650	343	205.79	0.3985	0.05409	8.906	0.79186	18.8 psia
700	371	225.92	0.4089	0.05329	8.675	0.70731	31.9 psia

THERMINOL FR-2

Temperature °F.	°C.	Enthalpy BTU/Lb.	Specific Heat BTU/Lb.—°F.	Thermal Conduct. BTU/Ft.², Hr., °F./Ft.	Density Lb./Gal.	Viscosity Lb./Hr.—Ft.	Vapor Pres. mm. Hg. Absolute
50	10.0	4.59	0.257	0.05881	12.225	7090.6	
100	37.8	17.61	0.265	0.05852	12.000	151.01	
150	66	31.09	0.274	0.05801	11.750	27.83	
200	93	45.11	0.2840	0.05788	11.525	11.971	
250	121	59.43	0.2922	0.05748	11.293	6.949	
300	149	74.14	0.3003	0.05703	11.062	4.531	
350	177	89.26	0.3084	0.05655	10.830	3.201	6
400	204	104.81	0.3166	0.05603	10.598	2.399	15
450	232	120.74	0.3247	0.05548	10.367	1.881	37
500	260	137.08	0.3328	0.05488	10.135	1.529	84
550	288	153.85	0.3410	0.05424	9.903	1.2795	173
600	316	170.99	0.3491	0.05357	9.672	1.0971	340
650	343	188.58	0.3573	0.05286	9.440	0.9596	615
700	371	203.45	0.3654	0.05211	9.208	0.8535	20.3 psia

THERMINOL FR-3

Temperature °F.	°C.	Enthalpy BTU/Lb.	Specific Heat BTU/Lb.—°F.	Thermal Conduct. BTU/Ft.², Hr., °F./Ft.	Density Lb./Gal.	Viscosity Lb./Hr.—Ft.	Vapor Pres. mm. Hg. Absolute
50	10.0	4.28	0.239	0.05700	13.002	—	
100	37.8	16.37	0.245	0.05680	12.760	1628.6	
150	66	29.06	0.256	0.05634	12.534	101.64	
200	93	41.95	0.2629	0.05620	12.292	24.262	
250	121	55.36	0.2714	0.05598	12.061	12.091	
300	149	69.20	0.2799	0.05558	11.829	7.116	
350	177	83.46	0.2884	0.05513	11.597	4.669	3
400	204	98.15	0.2969	0.05466	11.366	3.306	9
450	232	113.26	0.3054	0.05415	11.134	2.476	24
500	260	128.77	0.3138	0.05360	10.902	1.937	55
550	288	144.73	0.3223	0.05302	10.671	1.5699	114
600	316	161.11	0.3308	0.05241	10.439	1.3095	223
650	343	177.92	0.3393	0.05176	10.207	1.1188	413
700	371	192.24	0.3478	0.05107	9.976	0.97531	735

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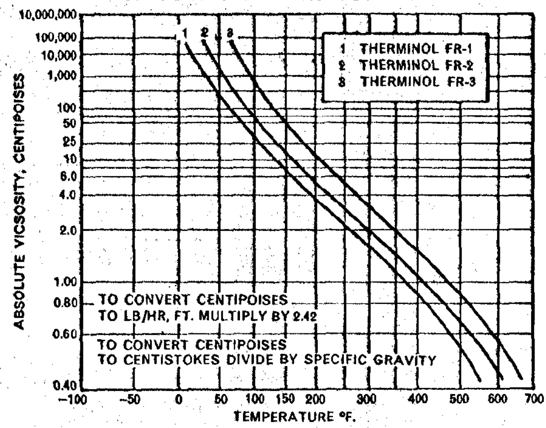
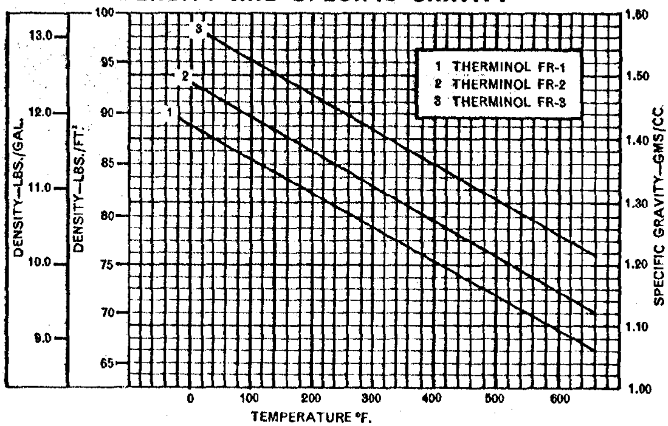
VISCOSITY-TEMPERATURE CHART



DENSITY AND SPECIFIC GRAVITY



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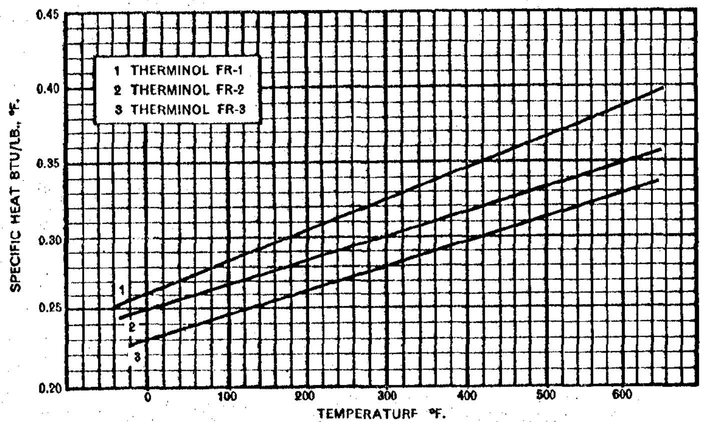
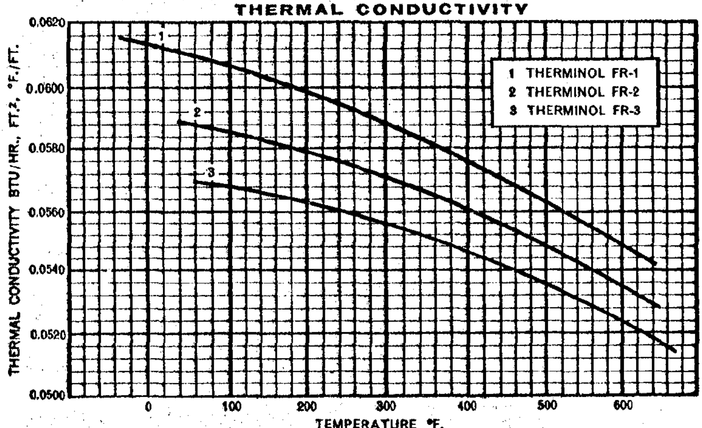
SPECIFIC HEAT



THERMAL CONDUCTIVITY



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SPECIFIC HEAT OF THERMINOL® FR

Its Relationship to Density

Specific heat—the quantity of heat required to raise the temperature of a material one degree, compared to the heat required to raise a like mass of water one degree—compares the material with water, pound for pound.

When comparing specific heat values of THERMINOL FR liquids with corresponding values of other heat transfer fluids, it is important to note that the density of THERMINOL is much higher than the density of other fluids commonly used in heat transfer. In consequence, the heat capacity of THERMINOL fluids is greater than immediately apparent from the specific heat values.

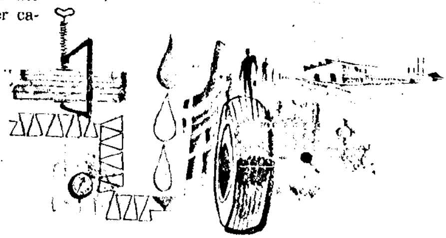
12.03 lbs./gal. vs. 8.82 vs 7.9 gal

In transferring heat, a *volume* of fluid is circulated to give up or absorb heat and the heat capacity of that *volume* of fluid is the factor that determines the heat transfer capacity of the system.

When a comparison is made on a volume basis (as illustrated below), THERMINOL liquids are comparable to other organic liquids and superior to some:

SPECIFIC HEATS OF VARIOUS FLUIDS at ROOM TEMPERATURE

	Pounds/ Gal.	Specific Heat (BTU/lb./ °F.)	Heat Capacity (BTU/gal./ °F.)
THERMINOL FR 2	12.03	0.276	3.32
Organic Fluid "A"	8.82	0.378	3.33
Petroleum Oil	7.9	0.378	2.98



THE FLUIDS

Key Benefits

benefits (6)

THERMINOL FR liquids are unique. They permit installation of a non-pressurized system operating with a liquid which has no fire point, and will not support combustion. THERMINOL FR liquids are so fire-resistant they have been *listed with Underwriters' Laboratories!*

Because of this extreme fire resistance and its recognition by insurance companies, important savings can be made in designing a process heating system around THERMINOL FR fluids. The savings include not only (1) the lower capital cost of non-pressurized equipment, (2) its simplified installation and (3) lower maintenance; but also elimination of some of the costly safety devices required in equipment circulating a flammable fluid at or above its fire point. These economies show up both in the type of components needed and in the layout of the system. (4)

Still another unique property of THERMINOL fluids is their unusual chemical inertness. They are among the most oxidation-resistant compounds known. This inertness prevents the formation of oxidation sludges if the hot fluid comes in contact with air. This extends the useful service life of the heat transfer fluid; occasionally allows economies in design. However, THERMINOL FR fluids are not intended for use in open vessels but in properly vented, closed systems. (5)

Chemically, THERMINOL FR fluids are resistant to strong acids, mild alkalies, and dilute solutions of strong alkalies.

THERMAL STABILITY

THERMINOL FR fluids are thermally stable. They are manufactured to meet strict thermal stability specifications. Each production run is tested in Monsanto's laboratories with special equipment developed by Monsanto to assure that these fluids meet the high standards of thermal stability. Any material which does not meet these standards is rejected.

It is characteristic of almost all organic materials to undergo chemical change when exposed to high temperatures for long periods of time. The *type* of chemical change depends upon the molecular structure of the fluid; the *degree* of change depends on the temperature, and the length of time of exposure.

THERMINOL FR fluids resist chemical change up to temperatures of 600°F. and show no measurable change after years of exposure to such temperatures. Exposure to temperatures above 600°F.—even localized overheating will only cause some formation of "high boilers". molecules of THERMINOL FR will join together to form larger molecules quite similar to the original material, but higher in viscosity and in boiling point. These high boilers are soluble in the fluid up to reasonable concentrations; so overheating only increases the fluids' room temperature viscosity slightly. When a concentration of approximately 5-10 percent "high boilers" has been formed, however, the viscosity begins to rise quite sharply.

Temp.
time

With this change, small but measurable amounts of dry hydrogen chloride gas are evolved. This should be removed from the system by appropriate venting. When THERMINOL FR fluids operate at high bulk temperatures, or, where some local overheating may occur, the system should be designed to prevent moisture from condensing in the vapor spaces where this hydrogen chloride gas is being vented.

When the hydrogen chloride is dry, it has little or no effect on metals in the system. However, if the hydrogen chloride dissolves in moisture, an acid corrosive to certain metals is formed. A properly designed heater and distribution system operated at or below 600°F., will allow use of the same fluid for many years.

While THERMINOL FR fluids normally are operated to a maximum temperature of 600°F. —systems specially designed for operation at higher temperatures have proved successful. At higher temperatures—"high boiler" formation with attendant viscosity increase is, of course, accelerated and a shorter service life must be expected. However, *side stream distillation* can be employed to constantly remove higher boiling materials while the system is in operation. Periodic make-up is added to replace the quantity of the high boiler material removed.

Solutions to "high boiler"

An alternate procedure for higher temperature operation, which is sometimes more suitable for smaller installations, is periodic replacement of the THERMINOL charge, *reclaiming the used fluid by straight take-over distillation.* (Monsanto should be contacted for details regarding this procedure.) On systems containing only 50-100 gallons of THERMINOL, it is usually most economical to periodically discard the entire charge and replace it with new fluid.

THERMINOL SYSTEM DESIGN

When designing a THERMINOL FR system it is important to remember this fact: THE FLUID CAN BE NO BETTER THAN THE SYSTEM! THERMINOL FR liquids are ideally suited for high temperature precision heating and temperature control applications, but only if the heater and distribution *system* are properly designed, constructed and operated. While there is nothing profoundly different or complicated about a THERMINOL system, certain design parameters must be rigidly observed if the system is to operate trouble-free, efficiently, and with realization of the full benefits of heat delivered by a liquid.

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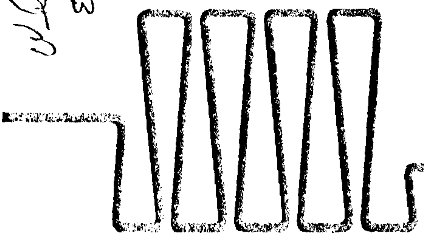
What Type is Eclipse?



THE HEATER

The heater is the most critical component in a THERMINOL system. Accordingly, the heater should be selected with great care!

Two basic heater designs for THERMINOL fluids are available: the liquid tube and fire tube types. In liquid tube heaters, the THERMINOL is pumped through the tubes at a definite flow rate as it is heated; in fire tube types, THERMINOL flows through the "shell" of the heater surrounding the fire tubes.

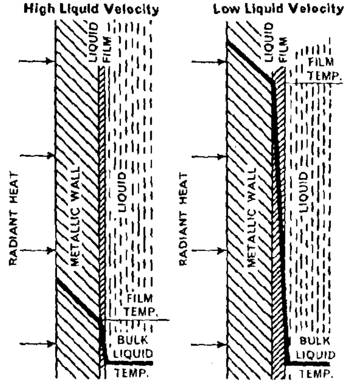
When operating temperatures of 500°F. (or higher) are required, a liquid tube type heater is to be preferred . . . *unless* a specific design is devised to force a steady flow over the heat donor surfaces.

Since THERMINOL fluids transfer heat in liquid form, they do not form vapor to accelerate convection circulation. To avoid hot spots in a THERMINOL heater, the fluid should be pumped over the heating surfaces so that no area of stagnant fluid occurs.

Fluid velocities over the heat donor surfaces should be relatively high; generally 4 to 10 feet per second. This helps avoid both excessive fluid film temperatures and also reduces the quantity of fluid in the high temperature film that is in direct contact with the heat donor surface.

The illustration shows the effect of fluid velocity on film temperature and indicates the importance of this design requirement.

EFFECT OF LIQUID VELOCITY ON FILM TEMPERATURE DURING HEATING



Importance of Fluid Velocity and Film Temperature through Heater

A bulk fluid temperature of 600°F. and a *maximum* film temperature of 640°F. assures long service life of THERMINOL FR fluids. Note the significance of "*maximum*" film temperature: heating is not uniform in fired

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heaters, and *maximum conditions*—not average—must be used to determine the recommended 640°F. ceiling.

Example:

The film coefficient for THERMINOL in a given heater is 250 BTU/hr. sq. ft., °F., and the fluid temperature is 570°F.

The average radiant absorption rate is 9,000 BTU/sq. ft., hr. The maximum radiant absorption rate is 17,000 BTU/sq. ft., hr.

The average film temperature is then

$$570^\circ + \frac{9{,}000}{250} = 606^\circ\text{F.},$$

but the maxmium film temperature is

$$570^\circ + \frac{17{,}000}{250} = 638^\circ\text{F.}$$

Past experience shows that when purchasing a heater, the buyer should insist that design and capacity provide optimum film temperature for the fluid.

The method of Lobo and Evans[1] is useful in calculating film temperatures in radiant heaters.

When electric heaters are used—heat flux is more even. However, it is important to remember that *all* of the heat from the electric element passes into the fluid. The watt-density on the surface of the heater tube and the fluid velocity past the tube should be in proper balance to avoid excessive THERMINOL film temperatures. Watt-densities in the range of 8 to 10 watts per square inch with a minimum velocity of 4 feet per second are suggested. However, watt-densities in the 18 to 22 watt per square inch range have proved satisfactory in properly designed installations.

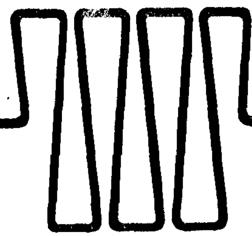
Heaters for THERMINOL should meet local code requirements. However, the fire resistance of THERMINOL FR fluids will often permit important economies in the design and placement of fired heater equipment. With gas-fired heaters, the THERMINOL unit need not be placed outside of the building or isolated in a fireproof structure unless the use process requires such precaution. Steam or inert gas smothering devices can generally be eliminated and a vapor tight firebox to retain smothering gases is not necessary.

The fuel for THERMINOL heaters is purely optional. Gas- or oil-fired heaters, and electric resistance heating are all used with success. Coal-fired heaters are generally not recommended because of their slow response to change of load at the heat source.

The over-all thermal efficiency of a fired heater will generally be comparable to steam boilers of similar size. Efficiencies of 75 to 80 percent can be expected when convection sections are added. Efficiencies of 60 to 70 percent are achieved with only a radiant section.

[1] Lobo, W. E., and J. E. Evans, Trans. AIChE, 35, 743 (1939)

Several types of heaters which have operated successfully in THERMINOL systems are illustrated on the following page.



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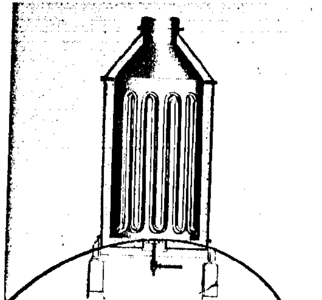
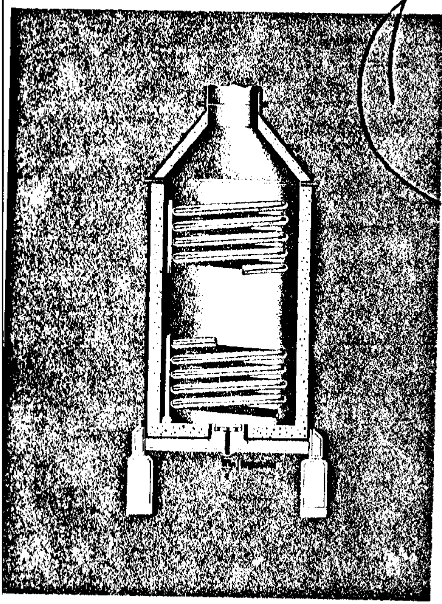
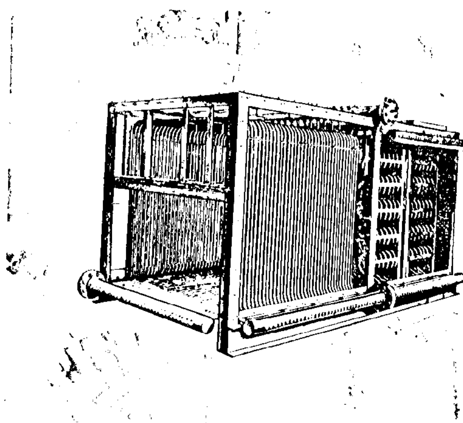


THE HEATERS

System Components:
(1) Heaters
(2) Pumps
(3) Piping
(4) Valves
(5) Rotary joints
(6) Expansion TANK

An expansion of diagram w. pieces.





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PUMPS FOR THE thermINOL FLUID HEAT SYSTEM...

In selecting pumps for a THERMINOL system, it is important that the pump capacity and pressure head be sufficient to circulate the fluid at the rate demanded by the particular installation. For large flow rates, the fluid circulating pump should generally be the centrifugal type and any one of a number of brands of standard high temperature centrifugal pumps designed for hot liquid service is suitable. Dean Brothers, Worthington, Ingersoll-Rand and Chempump for example, are all used satisfactorily. For most THERMINOL systems, cast steel pumps are best. Pump manufacturers usually specify that above 450°F. fluid temperatures, a water jacketed, deep stuffing box or mechanical seal and water-cooled bearings be used. Mechanical seals are used widely today.

It is suggested that with a stuffing box, eight rings of packing be provided. Durametallic No. D-110, Garlock No. 736 and equivalent packings are satisfactory for the pump, and an open, non-overloading impeller is desirable to handle the cool, relatively viscous liquid at start up.

When a new system is first put into operation, a slight leakage may be noticed at the pump packing. It is not advisable to tighten the pump gland, however, until the system has heated up close to the temperature of operation.

Canned pumps such as Chempump Series T require no seal and have proved very serviceable in THERMINOL systems. Small gear pumps are also used successfully in THERMINOL FR service because the fluids have good high temperature lubricating properties. However, gear pumps characteristically decrease in pumping capacity after extended use. When gear pumps are used, care should be taken in selecting the capacity so there is a margin that will assure adequate flow through the heater. Regardless of the type of pump selected, the flow rate should be checked regularly against its performance when new.

To avoid shaft trouble and leakage at the seals, it is important to provide adequate expansion joints and to support the piping in a way that avoids stresses on the body of the pump. Direct-connection pumps driven by 1,750 rpm. motors are most commonly used. Each pump should be fitted with a control to switch off the burner in case of pump failure.

If expansion loops are used in the pump suction piping, they should be horizontal or vertically downward. They should not be vertically upward, for in such a position they form a trap which can collect air and non-condensibles, and seriously hamper the pump's performance.

PIPING...

The most important factors in the piping layout for a THERMINOL FR system are: (A) Proper sizing for the required flow rate and (B) minimizing pressure drop. Because the system will undergo temperature changes,

0407118

adequate expansion joints and loops to relieve expansion and contraction stress are essential.

Generally, Schedule 40 seamless steel pipe is used with THERMINOL FR systems. It is characteristic of most organic fluids (including THERMINOL) to have a tendency to leak through joints and fittings at high temperatures unless these fittings are very tight. Therefore, flanged joints should be used sparingly to minimize potential leak points.

Threaded connections are used with THERMINOL FR up to a one-inch maximum size. Care is required in cutting the threads to assure a proper fit; a clean, new die is recommended. Careful attention to threading procedure should provide a good threaded connection. It is not wise to rely upon the use of pipe dope to eliminate leakage. However, pipe dope should be used. Q-seal (Quigley Company, Inc.); Plastiseal (Johns Manville); and Crane's No. 425 are all used successfully in THERMINOL FR systems.

In larger size pipes, welded connections should be used wherever practical. Careful layout and use of curved sections of pipe can minimize the welded or flanged connections required. When a flanged connection is made, 150 pound raised face flanges are recommended. The flange should be backwelded to the pipe and proper gasketing used. Spiral wound (Spiratalic or Flexitallic) asbestos and stainless steel gaskets are good. Small lip spiral wound gaskets are preferred over the wide lip type, because they allow better compression with the 150 pound flange. Garlock short fiber, pre-cut and cured asbestos gaskets have also proved satisfactory.

It is recommended that high temperature bolts, such as Crane Triplex steel bolts, which do not stretch, be used.

All high points in the piping system should be provided with vent valve connections.

VALVES...

One hundred and fifty pound cast steel valves with deep stuffing boxes are satisfactory for THERMINOL systems. Cast steel ball valves designed for high temperature (such as offered by Hills McCanna) have also proved very effective, particularly where quick open-and-close action is desired.

ROTARY JOINTS...

It is wise to take particular care in the installation and maintenance of rotary joints in order to assure long service life and minimum leakage. Install such joints with proper flexible connections to assure alignment at all times. Rotary joints should not be operated in a new system until the system has been thoroughly cleaned of abrasive particles which could score the sealing faces and cause leakage. Rotary joints such as those manufactured by the Johnson Corp. and Perfecting Service Co. are satisfactory with THERMINOL FR.

THE EXPANSION TANK...

Proper design of the expansion tank for the THERMINOL system is quite simple, but is also very important to proper system operation.

Characteristic of most organic liquids, THERMINOL expands in volume about 4 percent for every 100°F. temperature rise. In heating THERMINOL from room temperature (70°F). to 600°F., the fluid in the system expands about 20 percent. Therefore, the expansion tank should be large enough to accommodate about 20 percent of the total volume of the entire system, including the fluid content of the heater, piping and all heat users. The tank should be sized so it is about one quarter full when the system is cooled to 70°F. and three quarters full when the system is at a maximum operating temperature. The expansion tank should be fitted with a sight glass at the "full" range and with a float operated, low-level switch to shut off the burner in case of accidental fluid loss in the system.

Place the expansion tank in the circuit on the pump's suction side—above the highest point in the system.

The expansion tank also serves as the major venting point of most THERMINOL systems. The temperature of the fluid in the expansion tank is much lower than the bulk fluid temperature in the system. Connect the expansion tank to the system with a small diameter line to avoid thermal recirculation. However, make this line large enough to readily pass the flow caused by expansion and contraction in the system and to permit recirculation of fluid for moisture removal as explained below.

Because THERMINOL FR fluids are fire resistant, the vent need not be isolated from potential sources of ignition. However, the vent should be out of doors, particularly away from working areas, to eliminate prolonged or repeated contact with the vapors.

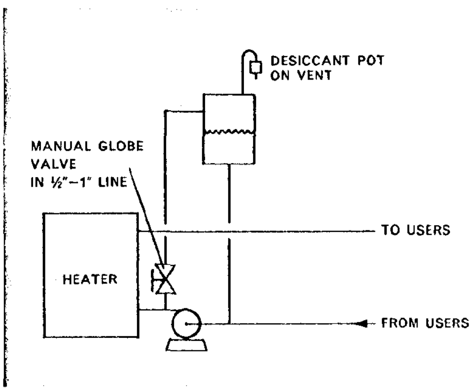
Care should be taken to prevent the entry of atmospheric moisture into the system as the expansion tank 'breaths' air. The vent can be equipped with an air dryer, such as a calcium chloride pot or other desiccant.

An alternate procedure would be to blanket the expansion tank with nitrogen. However, if this is done, the THERMINOL system should be *dried thoroughly* before the system is sealed with nitrogen.

In systems using THERMINOL above 600°F. (or in systems where accidental high film temperatures may occur in the heater) some provision must be made for venting any hydrogen chloride gas formed in the system and to assure that the system remains dry. Gas or water vapor will not escape readily through the "cold seal" connecting the expansion tank to the THERMINOL system. It is advisable to provide a pipe to feed a small side stream of hot THERMINOL through the expansion tank as illustrated at right to allow hydrogen chloride and water vapor to flash from the fluid. A small stream of hot THERMINOL from near the pump discharge should be piped directly into the vented expansion tank, so it enters the tank above the highest liquid level. A globe valve should be installed in the line to permit throttling the flow to the desired rate.

Experience shows this simple procedure to be extremely effective and completely satisfactory for removing hydrogen chloride and moisture from the THERMINOL system. Analysis of samples drawn from systems operating with such a device show that the THERMINOL fluid maintains minimum acidity and holds moisture at the low levels equivalent to newly manufactured fluid, even *after prolonged periods of operation.*

Provision should be made to prevent moisture from condensing in the vapor space above the liquid level in the expansion tank and in the vent. It is advisable to trace and insulate the expansion tank and the vent so that any moisture accidentally entering the system will remain as a vapor and will not condense. This will prevent corrosion of steel and eliminate the need for higher cost alloys. The use of non-metallic vent pipe is also recommended. Polyester piping (available from *Fibercast), resin lined steel piping or other* non-metallics resistant to THERMINOL vapors and to hydrogen chloride are commercially available and have been used with great success.



NOTES...
The expansion tank and vent should be traced and insulated. If steam is not available at the site, hot THERMINOL fluid can be passed through steel tracing tube.

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TESTING FOR LEAKAGE...

When a new system has been installed, it is important to test for leaks. Probably the most widely used technique is to check for leaks with ammonia gas. In this method, the system must be relatively dry and sealed. All vent valves should be closed and a temporary pipe cap or slip blank installed at the expansion tank vent and at other points where there is no valve.

Ammonia gas is fed into the sealed system followed by air under pressures up to ten pounds per square inch. Any leakage areas can be readily detected by the escape of ammonia. Tiny amounts of ammonia vapors can be made visible as white smoke by directing a small stream of hydrogen chloride gas over each joint or fitting, and around each welded connection. Any leakage points can be marked, tightened, and then the system purged free of ammonia with plenty of air.

A satisfactory alternate procedure is Halogen Testing: in this procedure, introduce one pound of Freon F-12 or Freon F-22 for each fifty cubic feet of volume of the system. Carefully introduce air not exceeding 10 psig of pressure. At this air pressure, the concentration of Freon will be sufficient to give a sensitive test.

Attach a halide torch to an acetylene tank and light it. Using the ¼ inch flame as a probe, explore for leaks by passing the end of the flame along seams and joints. If a leak is present, the escaping Freon will be drawn into the acetylene flame turning it green. A large leak will produce a violet color.

Leak testing with water is not recommended. Though effective, it creates a problem of introducing a large amount of water into the THERMINOL system which will be hard to remove.

CLEANING THE SYSTEM...

After testing for leaks and making any required adjustments, the system must be thoroughly cleaned.

A new system will contain dirt, weld and mill scale and other foreign particles. Unless removed, these particles will be carried in suspension by the circulating THERMINOL. They may "lodge" in valves, controls, mechancial seals, rotary joints and other mechanical equipment, causing faulty operation or component failure.

When purchasing the heating equipment, the supplier should be requested to clean the equipment as thoroughly as possible using brushes, wiping rags and suitable solvents, such as tri- or perchlorethylene.

When completed, fill the system with the operating charge of THERMINOL. Bring the system up slowly to approximately 200°F. At this temperature, the viscosity of THERMINOL will be very low. The turbulence from this low viscosity, plus the excellent solvent action of THERMINOL fluid, will further clean the system. Circulate the warm THERMINOL through the system *without operating rotary joints* (if they are installed in the system).

FILTERING...

Install a strainer, made of ordinary fine mesh screen backed up with ¼″ screen, in the pump suction of the new system. As foreign material collects, this screen should be periodically removed and cleaned. When, after several days during which the strainer collects no material, remove it permanently from the line. The system should be heated and cooled for a minimum of two cycles with the suction screen in place, since the resultant expansion and contraction will loosen mill

0407121

scale. The screen may be placed in the main stream line, gasketed between two flanges.

It is advisable, when operating where solids and contaminants might enter the system, to permanently install a high temperature filter on a by-pass line that can be isolated with valves for periodic cleaning.

CONTROLS...

Controls for heating systems using THERMINOL should be installed both on the heater itself and on the heat-using units. A wide variety of thermal-operating controls are available, and any reliable standard equipment is satisfactory.

Install heater controls to regulate the firing mechanism in direct proportion to the required output. These controls should increase or decrease the heat in-put to maintain the THERMINOL at the operating temperature required by the heat-demand of the user. Small units may be operated satisfactorily by relatively simple "on-off" or "high-low" controllers; larger units will operate more uniformly if equipped with modulating temperature controls.

Install *user* controls to regulate the flow of the heat transfer fluid in proportion to the heat-consumption of the heat-using equipment. In a multiple-user system, separate controls should be installed on each consuming unit, to assure the proper heat-delivery.

Safety Controls. In addition to activating controls, the heater must also be fitted with the proper safety controls to meet the local code requirements. Safety controls should include:

a. **High temperature cutoff at the heater outlet** . . . to shut off the burner in the event of an excessive temperature rise.

b. **High tube wall temperature cutoff.** A thermocouple sensing element should be installed in contact with the radiant heated surface at the highest temperature point in the heater and protected as much as possible from direct or reflected radiation. Such a controller is usually of the on-off type with the switch wired into the flame safety circuit so that the burner is shut down when the switch opens. Aside from protecting the tube bundle, this safety control protects the THERMINOL fluid from overheating.

c. **Low flow cutoff.** This control will shut down the burner should flow rate drop below design rates, or if a loss of flow occurs due to pump mal-function or failure.

Equip burners with regular automatic ignition controls and flame failure controls. In wide range firing operations, an over-fire draft control will increase the economy of the operation. Electric power failure and instrument air failure safety controls are also desirable. In general, the practice of "fail-safe" instrumentation and control is essential: use good quality indicating and recording gauges, with scales calibrated for the particular limits of operation for best reading accuracy.

0407122

OPERATION AND MAINTENANCE OF THE THERMINOL SYSTEM...

The following recommendations are intended only as guides. These suggestions are supplemental to the equipment manufacturer's recommendations as they relate to the particular heater or the user equipment in the installation. The following comments on start-up, shut-down, power failure precautions, and periodic fluid check-ups apply generally to all sizes and types of equipment.

NEW SYSTEM START-UP...

For a new installation, or an existing system that has been drained and is idle:

1. Check the safety and control devices. Check the safety and control devices for proper installation, proper range settings for the operation, and actual operation (by manually activating the instrument).

For protection of the over-all system and for predictable long fluid life, it is vital that all instruments and controls perform properly.

2. Check for leaks (see section on leak testing, page 14.)

3. Pull Vacuum on System.

a. The vacuum should be pulled from a point of high elevation in the system; usually at a point just below the expansion tank. Prior to drawing a vacuum, *close* all valves to the expansion tank; close all valves and vent connections to the atmosphere; close all valves to non-pressure equipment in the system (such vessels may collapse under vacuum) and *open* all valves in the interconnecting piping of the system.

b. Turn on vacuum equipment and evacuate the entire system (including the "users") to 26-27 inches of mercury vacuum (if possible), or until the absolute pressure of the system has reached the limit of the available vacuum equipment.

c. Shut off vacuum equipment.

4. Charge the System with THERMINOL.

a. Fill the expansion tank with THERMINOL, and introduce the fluid slowly into the system through the expansion tank valve until the tank is almost empty. Close the valve and again fill the tank. Open the valve allowing the fluid to enter the system and repeat until it no longer flows by gravity.

b. Open all valves then start the main circulating pump in accordance with the manufacturer's recommendations. Observe the liquid level in the expansion tank repeating "a" above until the system has been filled. The thermal expansion of THERMINOL must be allowed for in determining the cold charge level. (A 20% expansion can be expected when heated to 600°F.—as a guide, the expansion tank should be 70-75% full at the hot operating condition.)

c. Circulate the THERMINOL fluid through the system for about 3 to 4 hours to eliminate air pockets and to assure complete fill of the system.

BEFORE FIRING HEATER, BE SURE THAT THERMINOL IS CIRCULATING FREELY.

5. Fire Heater.

a. On new installation start-up, or after prolonged shut-down, bring the system up to temperature slowly—about 100°F. per hour. This will prevent thermal shock to heater tubes, tube/header joints, refractory materials, etc., and allow operators to check the functioning of instruments and controls and become familiar with the equipment's operation. The slow heat-up will also allow any moisture trapped in the system to escape as a vapor.

b. Bring system to operating temperature and put "users" on the line.

DAILY START-UP... when equipment has been shut down overnight or for weekends, follow this procedure:

1. Start the circulating pump and check the expansion tank level to see that the

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THERMINOL is at the proper cold-start level (¼-full).

2. Start burner at the "low" flame setting and continue full circulation until the THERMINOL bulk temperature reaches 180°F.
3. Turn heater up to full heat.

SHUT-DOWN . . . should be performed as follows to avoid overheating:

1. Shut off burner completely with circulating pump still operating. Continue to run the pump at full capacity for at least 30 minutes to dissipate residual heat in the combustion chamber of the burner.
2. Shut off circulating pump after ½ hour, and switch off all heater electrical controls.

COLD WEATHER PRECAUTIONS . . .

When the THERMINOL system is exposed to low ambient temperatures, it is often most practical to leave the system "idling." Turn the burner to "low" position, and allow the fluid to circulate continuously at about 200°F. The unit will then be "at ready" for immediate high-temperature operation, and the viscosity of the fluid will remain low and workable.

IN CASE OF POWER FAILURE . . .

The burner circuit should be shut down by the heater controls. When the power comes on, run the circulating pump for a few moments to eliminate any vapor pockets that might have been formed by the fluid remaining static in the hot combustion chamber. If there is no knocking in the piping system, full-fire may be resumed immediately if the fluid temperature is above 180°F.

PERIODIC CHECK-UPS . . .

The regular maintenance inspection schedule should include the manufacturer's recommendations, as well as inspection of the THERMINOL. Following is a listing of inspection check-points:

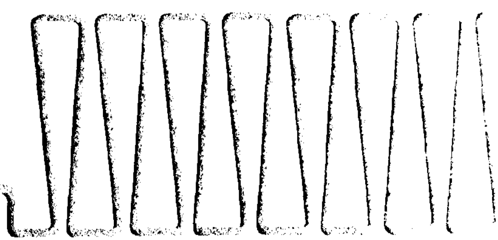
1. Lubrication of moving parts.
2. Operating fidelity and accuracy of readings of safety controls and temperature limit controls.
3. Inspection of heater tubes, burner, refractory linings.
4. Periodic inspection of heater surfaces.
5. Inspection of water cooling at the circulating pump.
6. Repacking of stuffing boxes (according to manufacturer's specifications).
7. Semi-annual or annual sampling and analysis of THERMINOL.

Under normal operating conditions, it should not be necessary to check on the condition of the fluid more than once or twice annually. The analysis for fluid condition is a simple test of fluid viscosity. The exact viscosity limits will be affected by the specific mode of operation and can vary somewhat from system to system. Monsanto should be contacted to determine specific values for the intended operation. Most users do their own testing; some have the viscosity determination made by an outside laboratory. A simple test kit for in-plant testing of THERMINOL is available at a low cost.

Customers can have their fluid tested by Monsanto free of charge. For sampling container and application data form, write to:

MONSANTO COMPANY
FUNCTIONAL FLUIDS MARKETING
ORGANIC CHEMICALS DIVISION
ST. LOUIS, MISSOURI 63166

Analysis results will be returned to the customer with complete recommendations for improving or continuing the performance of THERMINOL heat transfer liquid.



0407124

TYPICAL THERMINOL® FR SYSTEMS

THE HEATING PLANT

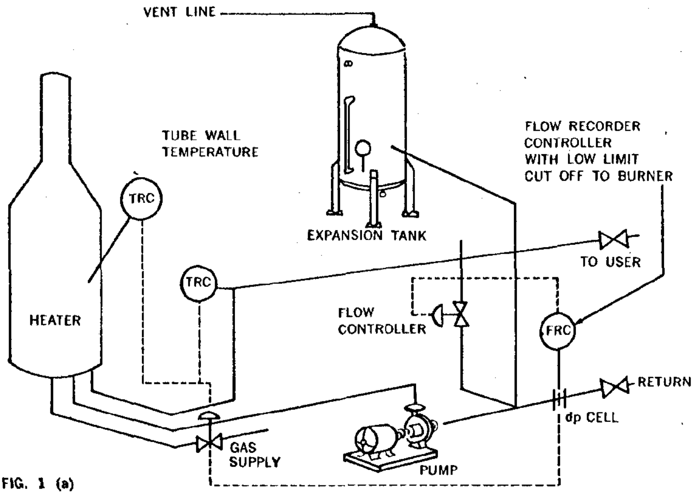


FIG. 1 (a)

Figure 1 above illustrates a typical basic heating "plant" for a THERMINOL FR system. Note the use of instruments to control THERMINOL temperature leaving the heater and by-pass flow control to assure adequate flow through the heater regardless of "user" demands.

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HEATING A SINGLE USER:

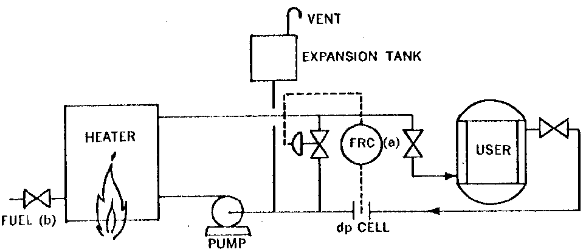


FIG. 2 FRC=FLOW RECORDER CONTROLLER WITH LOW LIMIT CUTOFF TO BURNER

Note that the user temperature can be controlled by either (a) rate of flow of THERMINOL to the user, or (b) temperature of THERMINOL, varied by fuel input to the heater.

HEATING MULTIPLE USERS:

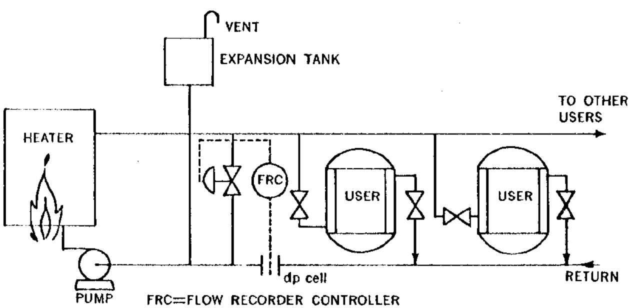
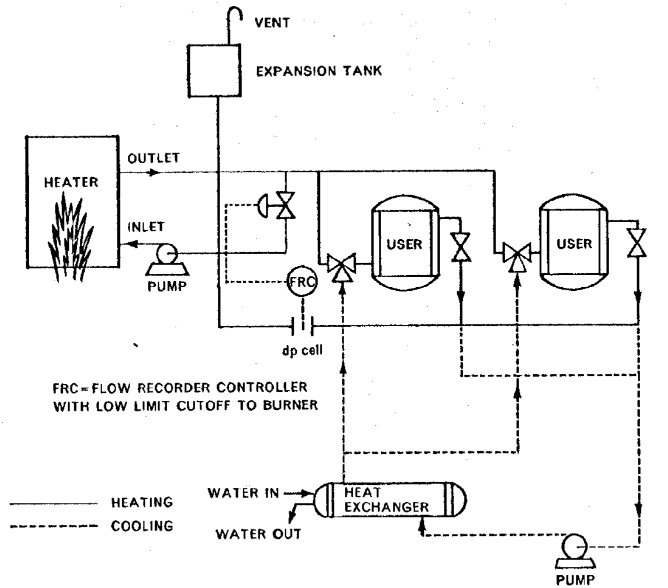


FIG. 3 FRC=FLOW RECORDER CONTROLLER WITH LOW LIMIT CUTOFF TO BURNER

Note that each user can be controlled at a different temperature by control of the flow of THERMINOL and therefore the rate of flow of heat offered.

0407126

HEATING OR COOLING SEVERAL USERS SIMULTANEOUSLY



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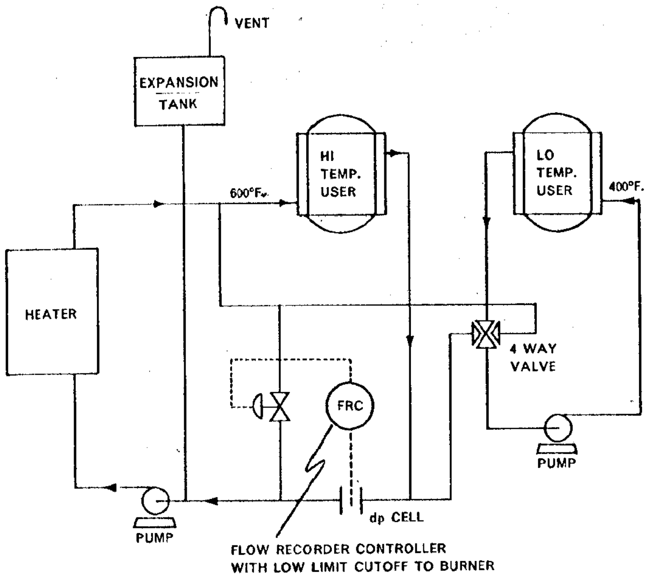
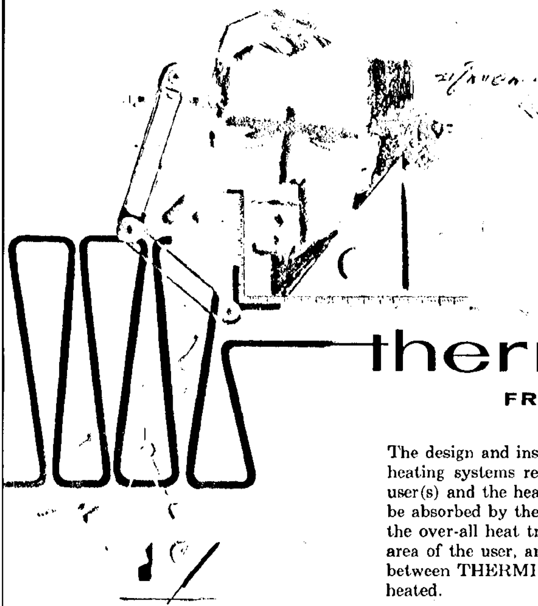
TEMPERATURE CONTROL BY BLENDING



Single heater system provides varying THERMINOL temperatures to users ...finds application for processing heat-sensitive materials.

0407128



therminol®

FR ENGINEERING DATA

The design and installation of THERMINOL indirect heating systems requires a heat balance between the user(s) and the heater. The amount of heat which will be absorbed by the user in a given time depends upon the over-all heat transfer coefficient, the heat transfer area of the user, and the mean temperature difference between THERMINOL and the process or area being heated.

In processing most organic chemicals, oils, food cooking —the rate of heat transfer is usually dictated by the process and not by the heating medium. However, in designing a system—it is important to know the heat transfer coefficient of THERMINOL. This is affected by a number of variables, probably the most important of which is flow rate.

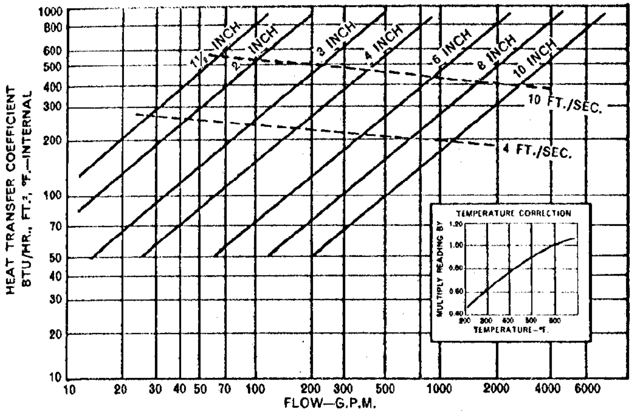
The following curves provide engineering data on THERMINOL heat transfer coefficients as a function of flow rate . . . and pressure drop as a function of flow rate . . . in various common sizes of pipes and tubes.

NOTE: The following charts depicting heat transfer coefficients and pressure drops for various sizes of pipes and tubes are available in full page reproduction for greater accuracy in interpretation. Write to:

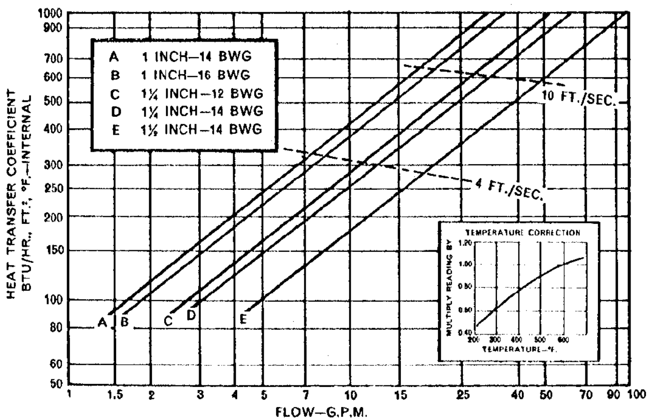
Monsanto Company
Organic Chemicals Div.
800 N. Lindbergh Blvd.
St. Louis, Mo. 63166

THERMINOL FR-1

HEAT TRANSFER COEFFICIENTS INSIDE SCHEDULE 40 PIPE



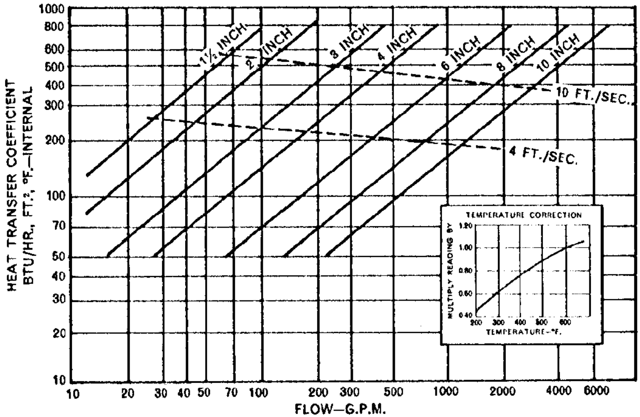
HEAT TRANSFER COEFFICIENTS INSIDE TUBES



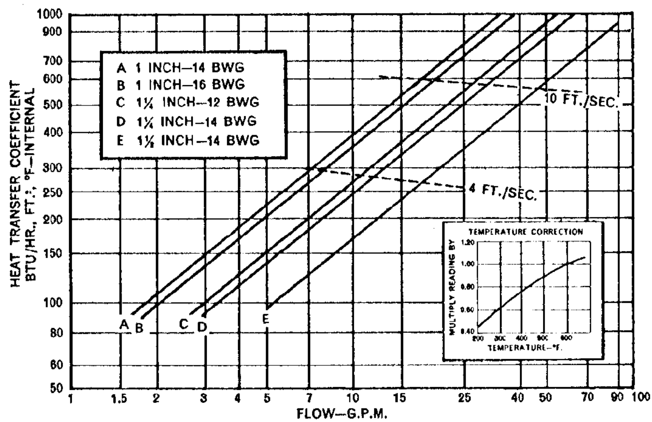
0407130

THERMINOL FR-2

HEAT TRANSFER COEFFICIENTS INSIDE SCHEDULE 40 PIPE



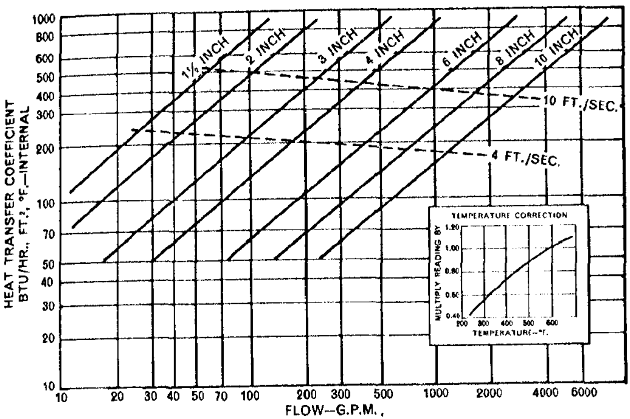
HEAT TRANSFER COEFFICIENTS INSIDE TUBES



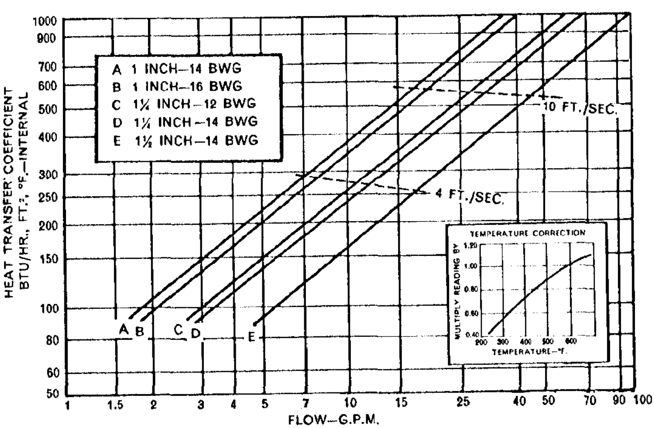
0407131

THERMINOL FR-3

HEAT TRANSFER COEFFICIENTS INSIDE SCHEDULE 40 PIPE



HEAT TRANSFER COEFFICIENTS INSIDE TUBES



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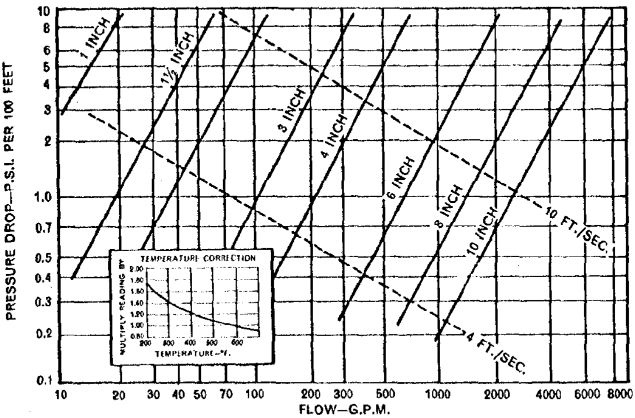
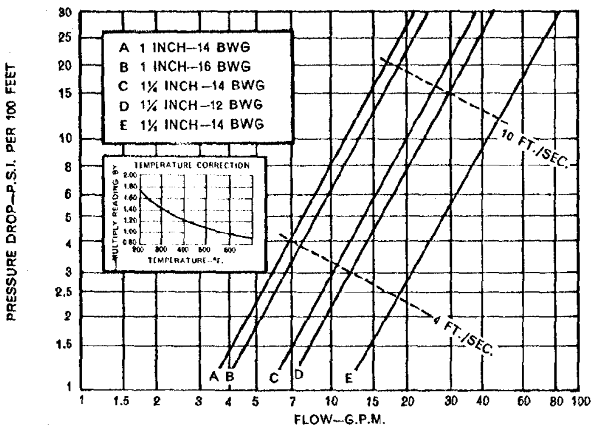
THERMINOL FR-1

PRESSURE DROP IN SCHEDULE 40 PIPE



PRESSURE DROP IN TUBES



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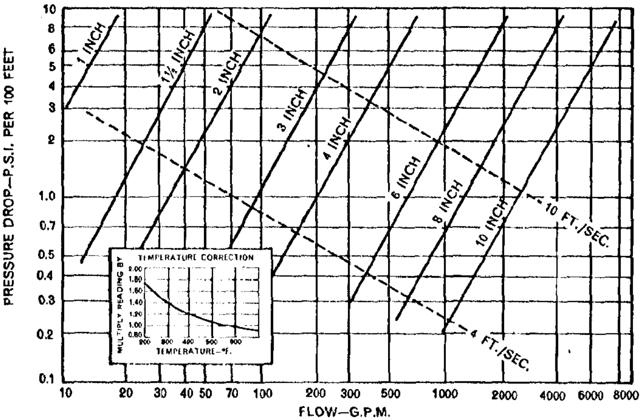
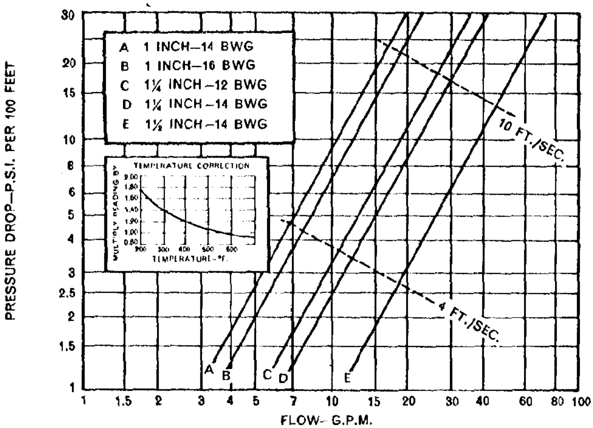
THERMINOL FR-2

PRESSURE DROP IN SCHEDULE 40 PIPE



PRESSURE DROP IN TUBES



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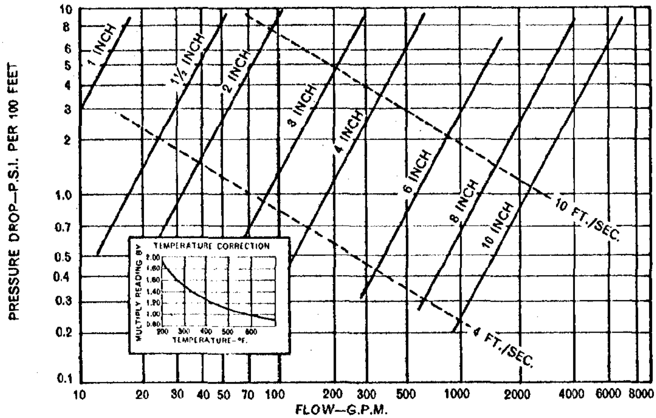
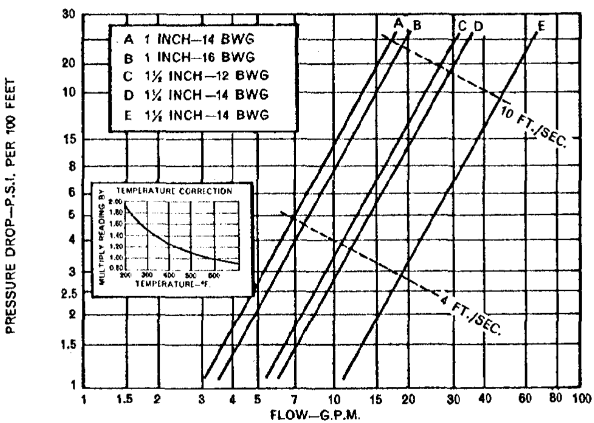
0407134

THERMINOL FR-3

PRESSURE DROP IN SCHEDULE 40 PIPE



PRESSURE DROP IN TUBES



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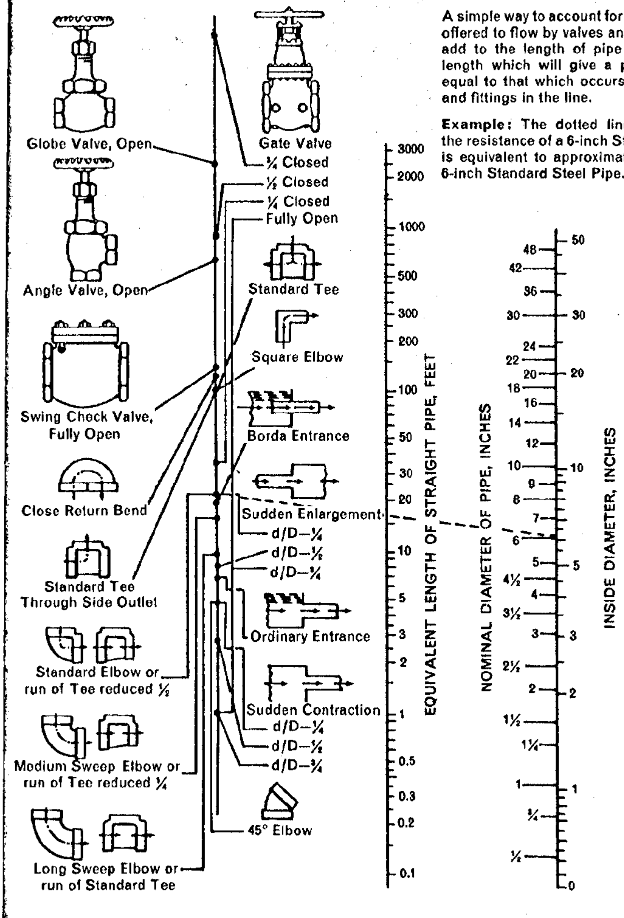
TOWOLDMON0030852
WATER_PCB-00015321

RESISTANCE OF VALVES AND FITTINGS TO FLOW OF FLUIDS

A simple way to account for the resistance offered to flow by valves and fittings is to add to the length of pipe in the line a length which will give a pressure drop equal to that which occurs in the valves and fittings in the line.

Example: The dotted line shows that the resistance of a 6-inch Standard Elbow is equivalent to approximately 16 feet of 6-inch Standard Steel Pipe.



0407136

PRESSURE DROP AND HEAT TRANSFER RATE FOR HEAT EXCHANGERS

Part I

PROCEDURE TO OBTAIN PRESSURE DROP SHELL SIDE OF TUBULAR EXCHANGERS WITH THERMINOL FR-2

1. Enter Chart No. 1 with GPM @ average flowing temperature—read average shell side velocity.
2. Multiply average shell side velocity with baffle correction (Bc—Chart No. 3) to obtain corrected velocity.
3. Enter Chart No. 3 with corrected velocity—read uncorrected pressure drop.
4. Correct pressure drop—3 above—for temperature, tube diameter and tube length.

Example:

THERMINOL FR-2 400°F. 400 GPM
20" Shell ¾" Tubes on 15/16"
Baffles 12" Pitch
Tubes 16' Long

1. **Chart No. 1**
   400 GPM—20" shell—2.7 ft/sec. average velocity.
2. **Chart No. 3**
   12" *Baffle Pitch*—0.6 correction
   2.7 ft/sec. x 0.6 = 1.62 ft/sec. corrected velocity
3. 1.62 ft/sec. in 20" Shell = 4.1 PSI uncorrected pressure drop.
4. Correct for temperature, tube size and length.
   Pressure Drop = 4.1 x 1.2 x 1.0 x 1.33 = 6.54 Ans.

Part II

PROCEDURE TO OBTAIN HEAT TRANSFER RATE SHELL SIDE OF TUBULAR EXCHANGERS WITH THERMINOL FR-2

1. Enter Chart No. 1 with GPM at average flowing temperature—read average shell side velocity.
2. Multiply average shell side velocity with baffle correction (Bc1, Chart No. 2) to obtain corrected velocity.
3. Enter Chart No. 2 with corrected velocity—read uncorrected h.
4. Correct h—(3 above)—for temperature and tube diameter.

Example:

THERMINOL FR-2 300° 350 GPM
20" Shell 1" on 1¼"
Baffles 10" Pitch

1. **Chart No. 1**
   350 GPM—20" Shell = 2.35 ft/sec. average velocity.
2. **Chart No. 2**
   10" *Baffle Pitch*—0.875 correction
   2.35 ft./sec. x 0.875 = 2.06 ft./sec. corrected *velocity*
3. 2.06 ft./sec. Chart No. 2 = 225 uncorrected h.
4. Correct h for temperature and tube diameter.
   225 x 0.61 x 0.88" = 121 Ans.

Part III

NOTES:

a. Tubes to be on triangular pitch ⅝" on ¹³⁄₁₆"; ¾" on ¹⁵⁄₁₆"; 1" on 1¼".
b. All baffles cut 1 row of tubes past horizontal centerline.
c. Charts have base condition—¾" on ¹⁵⁄₁₆"; Baffles at 8" pitch. THERMINOL FR-2 at 550°F.

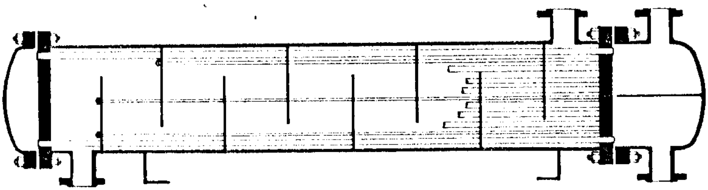
Data on shell side pressure drop and coefficients Courtesy of Struthers Wells Corporation.

0407137

UNIT SELECTION CHART

ARRANGEMENT

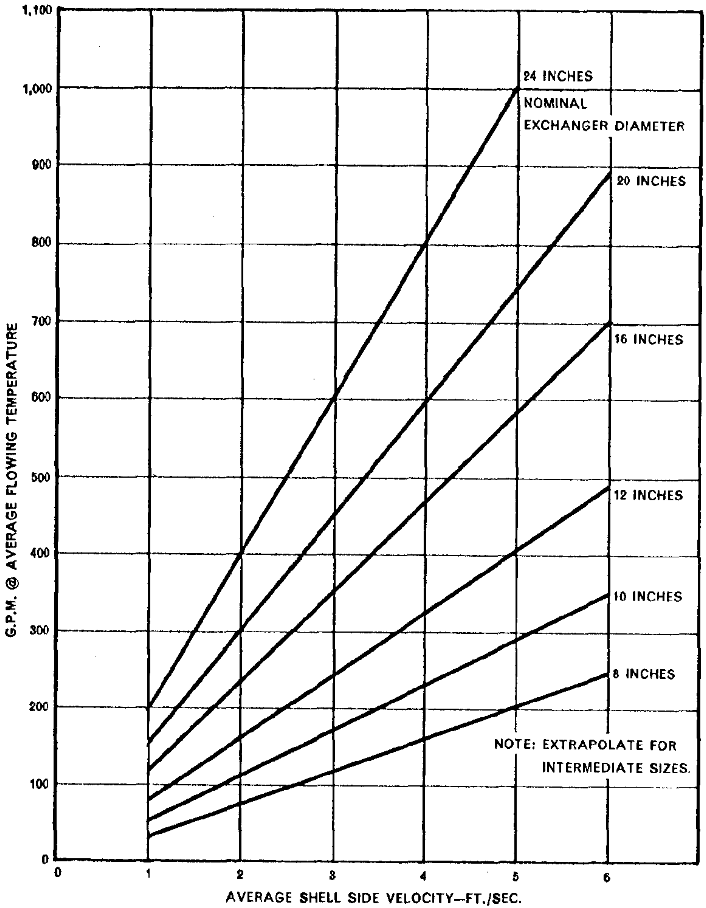
Nom. Shell Diameter Inches	Tube Length Feet	⅝" O.D. on No. of Tubes	13/16" Tri. Surface Sq. Ft.	¾" O.D. on No. of Tubes	15/16" Tri. Surface Sq. Ft.	1" O.D. on No. of Tubes	1¼" Tri. Surface Sq. Ft.
6	4	36	24	26	20	14	15
6	8	36	48	26	40	14	30
8	8	68	89	48	75	26	55
10	8	114	150	82	129	48	101
10	12	114	224	82	193	48	151
12	12	164	322	120	283	66	208
14	12	210	412	152	358	82	258
16	12	286	562	208	490	110	346
18	12	348	684	252	593	138	434
20	12	432	850	314	740	174	546
20	16	432	1132	314	985	174	730
24	16	652	1710	474	1485	268	1122



0407138

CHART No. 1

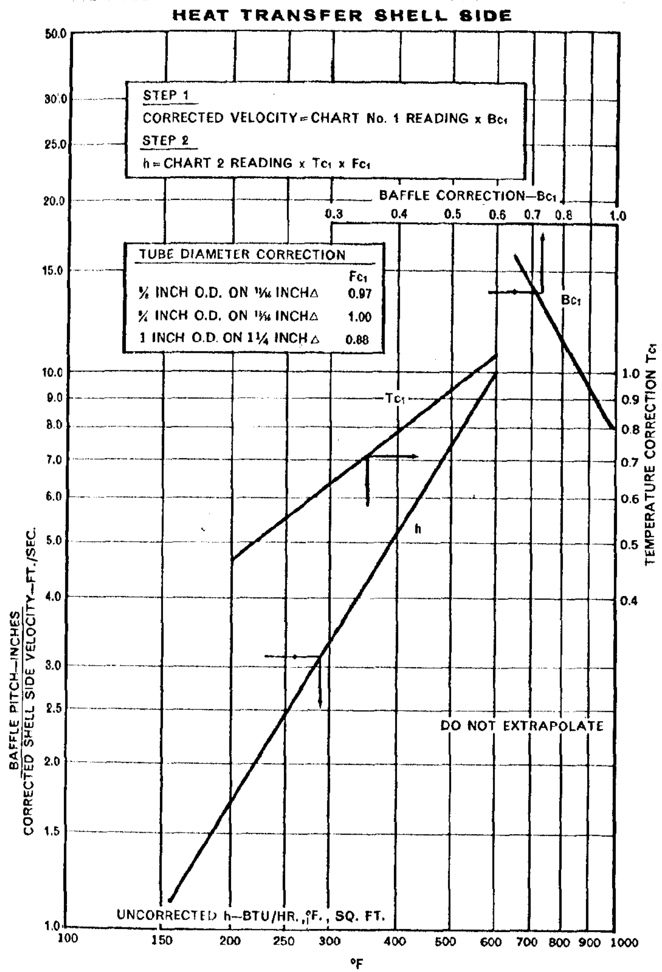
AVERAGE SHELL SIDE VELOCITY



0407139

CHART No. 2

HEAT TRANSFER SHELL SIDE



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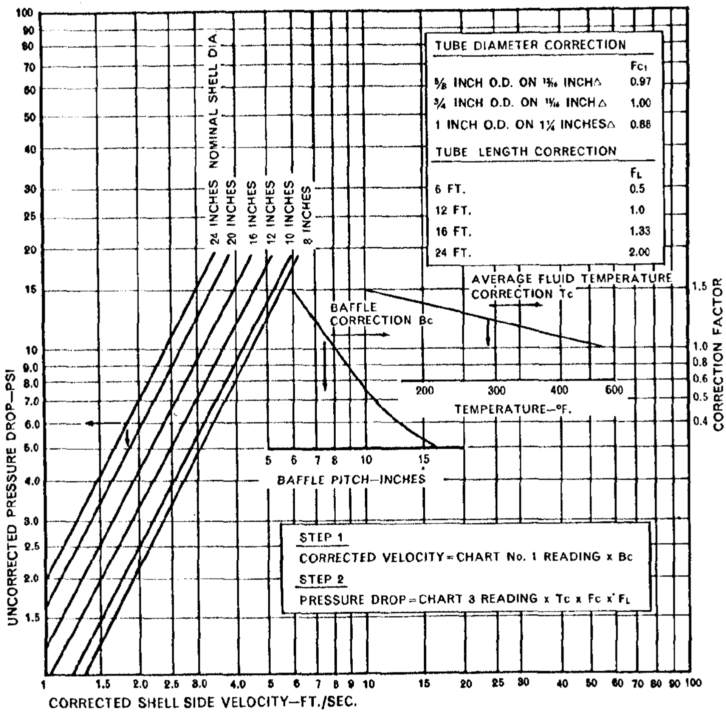
TOWOLDMON0030857
WATER_PCB-00015326

CHART No. 3

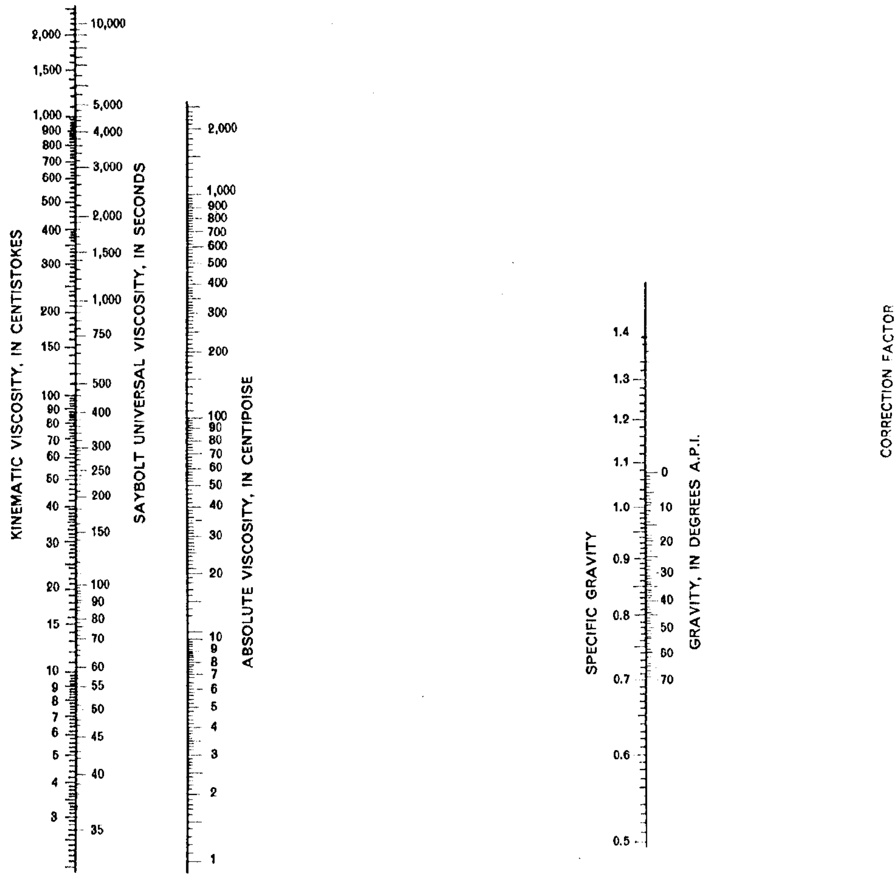
PRESSURE DROP SHELL SIDE



04C7141

VISCOSITY CONVERSION CHART

(Converting Kinematic and Saybolt Viscosity to Absolute Viscosity)



0407142

ENGINEERING CONVERSION FACTORS

MULTIPLY	BY	TO OBTAIN
ATMOSPHERES	14.70	lb./sq. in.
ATMOSPHERES	2116.8	lb./sq. ft.
ATMOSPHERES	760	mm. Hg.
ATMOSPHERES	29.92	in. Hg.
ATMOSPHERES	33.90	ft. of water
ATMOSPHERES	1.033×10^{4}	kg./sq. meter
British thermal units	778.2	ft. lb.
British thermal units	107.6	kg.-meters
British thermal units	1055	joules
British thermal units	0.2520	kg.-cal.
British thermal units	3.930×10^{-4}	hp. hr.
British thermal units	2.930×10^{-4}	kw. hr.
British thermal units	0.5556	P.C.U.*
Btu/cu. ft.	8.90	kg.-cal./cu. meter
Btu/hr.	3.927×10^{-4}	hp.
Btu/hr. sq. ft.	2.712	kg.-cal./hr. sq. meter
Btu/(hr. sq. ft. ° F.)	4.882	kg.-cal./(hr. sq. meter ° C.)
Btu/(hr. sq. ft. ° F.)	1.0	P.C.U.*/(hr. sq. ft. ° C.)
Btu/(hr. sq. ft. ° F.)	1.356×10^{-4}	gram-cal./sec. cm.^{2} ° C.
Btu/(hr. sq. ft. ° F.)	5.68×10^{-4}	watts/cm.^{2} ° C.
Btu/(hr. sq. ft. ° F.)	2.035×10^{-3}	watts/sq. in. ° F.
(Btu/hr. sq. ft.)/(° F./in.)	12.4	(kg.-cal./hr. sq. meter)/(° C./cm.)
(Btu/hr. sq. ft.)/(° F./in.)	3.445×10^{-4}	(gram-cal./sec. cm.^{2})/(° C./cm.)
(Btu/hr. sq. ft.)/(° F./ft.)	4.13×10^{-3}	(gram-cal./sec. cm.^{2})/(° C./cm.)
(Btu/hr. sq. ft.)/(° F./ft.)	0.0173	(watts/cm.^{2})/(° C./cm.)
(Btu/hr. sq. ft.)/(° F./ft.)	14.88	(gram-cal./hr. cm.^{2})/(° C./cm.)
Btu/min.	12.97	ft. lb./sec.
Btu/min.	0.02358	hp.
Btu/min.	0.01758	kw.
Btu/lb.	0.556	gram-cal./gram
Btu/lb. mol.	0.556	gram-cal./gram mol.
Btu/lb. ° F.	1.0	gram-cal./gram ° C.

*Pound-Centigrade Unit

0407143

MULTIPLY	BY	TO OBTAIN
Btu/sec.	778.2	ft. lb./sec.
Btu/sec.	1.4147	hp.
Btu/sec.	1.0549	kw.
Btu/sec.	107.6	kg.-meter/sec.
Btu/sq. ft.	0.2712	gram-cal./cm.^{2}
Btu/sq. ft.	2.712	kg.-cal./sq. meter
CALORIES	See gram-cal.	
CENTIMETERS	0.3937	in.
CENTIMETERS	0.0328	ft.
cm. Hg.	0.01316	atm.
cm. Hg.	0.1934	lb./sq. in.
cm. Hg.	27.85	lb./sq. ft.
cm. Hg.	136.0	kg./sq. meter
cm. Hg.	5.353	in. of water
cm. Hg.	0.4461	ft. of water
cm./° C.	0.2187	in./° F.
cm./sec.	1.969	ft./min.
cm./sec.	0.03281	ft./sec.
cm./sec.	0.036	km. /hr.
cm./sec.	0.60	meters/min.
cm./sec.	0.02237	mph
CENTIPOISES	0.01	poises
CENTIPOISES	2.42	lb./ft. hr.
CENTIPOISES	6.72×10^{-4}	lb./ft. sec.
CENTIPOISES	3.60	kg./meter hr.
cubic centimeters	0.06102	cu. in.
cubic centimeters	3.531×10^{-5}	cu. ft.
cubic centimeters	2.642×10^{-4}	gal.
cm.^{3}/sec.	2.119×10^{-3}	cu. ft./min.
cm.^{3}/sec.	0.0864	cu. meter/day
cm.^{3}/sec.	0.01585	gal./min.
cm.^{3}/sec.	3.6	liter/hr.
cm.^{3}/gram	0.01602	cu. ft./lb.
cm.^{3}/gram mol.	0.01602	cu. ft./lb. mol.
CUBIC FEET	0.02832	cu. meters
CUBIC FEET	7.481	gal.

MULTIPLY	BY	TO OBTAIN
CUBIC FEET	28.32	liters
CUBIC FEET	62.43	lb. of water
cu. ft. gas (60° F. at 1 atm)	2.636×10^{-3}	lb. mol.
cu. ft./lb.	62.43	$cm.^3$/gram
cu. ft./min.	472.0	$cm.^3$/sec.
cu. ft./min.	0.1247	gal./sec.
cu. ft./sec.	448.8	gal./min.
cu. ft./sec. sq. ft.	0.0305	liters/sec. $cm.^2$
CUBIC INCHES	16.39	$cm.^3$
CUBIC INCHES	5.787×10^{-4}	cu. ft.
CUBIC INCHES	0.01639	liters
CUBIC INCHES	4.329×10^{-3}	gal.
CUBIC METERS	35.31	cu. ft.
CUBIC METERS	264.2	gal.
cu. meters/day	11.57	$cm.^3$/sec.
degrees/sec.	2.778×10^{-3}	rev./sec.
degrees/sec.	0.1667	rpm
ERGS	1.0×10^{-7}	joules
FEET	30.48	cm.
FEET	0.3048	meters
ft. of water	0.0295	atm.
ft. of water	2.242	cm. Hg.
ft. of water	0.8826	in. Hg.
ft. of water	304.8	kg./sq. meter
ft. of water	62.43	lb./sq. ft.
ft. of water	0.4335	lb./sq. in.
ft./min.	0.508	cm./sec.
ft./min.	0.01667	ft./sec.
ft./min.	0.01829	km./hr.
ft./min.	0.01136	mph
ft./sec.	1.097	km./hr.
ft./sec.	18.29	meters/min.
ft./sec.	0.6818	mph
FOOT POUNDS	1.285×10^{-3}	Btu
FOOT POUNDS	3.239×10^{-4}	kg.-cal.
FOOT POUNDS	3.766×10^{-7}	kw. hr.
FOOT POUNDS	5.05×10^{-7}	hp. hr.

*Pound-Centigrade Unit

0407145

MULTIPLY	BY	TO OBTAIN
ft. lb./min.	3.03×10^{-5}	hp.
ft. lb./min.	2.26×10^{-5}	kw.
ft. lb./sec.	0.0771	Btu/min.
ft. lb./sec.	1.818×10^{-3}	hp.
ft. lb./sec.	0.01943	kg.-cal./min.
ft. lb./sec.	1.356×10^{-3}	kw.
GALLONS (imperial)	1.201	gal. (U.S.)
gal. (U.S.)	231	cu. in.
gal. (U.S.)	0.1337	cu. ft.
gal. (U.S.)	3785	$cm.^3$
gal. (U.S.)	3.785	liters
gal./hr.	3.71×10^{-5}	cu. ft./sec.
gal./min.	2.228×10^{-3}	cu. ft./sec.
gal./min.	0.227	cu. meters/hr.
gal./min.	0.06309	liters/sec.
gal./min. of water	500.8	lb./hr. of water
GRAMS	980.7	dynes
GRAMS	2.205×10^{-3}	lb.
gram mole gas	2.24×10^{4}	$cm.^3$ gas (0° C. and 760 mm.)
gram-cal.	3.968×10^{-3}	Btu
gram-cal./gram	1.8	Btu/lb.
gram-cal./gram mol.	1.8	Btu/lb. mol.
gram-cal./gram ° C.	1.0	Btu/lb. ° F.
gram-cal./$cm.^2$	3.687	Btu/sq. ft.
(gram-cal./$cm.^2$)/cm.	1.452	(Btu/sq. ft.)/in.
gram-cal./(sec. $cm.^2$ ° C.)	7.373×10^{3}	Btu/(hr. sq. ft. ° F.)
(gram-cal./sec. $cm.^2$)/(° C./cm.)	2.903×10^{3}	(Btu/hr. sq. ft.)/(° F./in.)
gram-cm.	9.294×10^{-8}	Btu
gram-cm.	980.6	ergs
gram-cm.	7.233×10^{-5}	ft. lb.
gram-cm.	2.342×10^{-8}	kg.-cal.
grams/cm.	5.60×10^{-3}	lb./in.
grams/$cm.^3$	1.0	specific gravity at 4° C.
grams/$cm.^3$	62.43	lb./cu. ft.
grams/$cm.^2$	0.07355	cm. Hg.
grams/$cm.^2$	10	kg./sq. meter
grams/$cm.^2$	0.394	in. of water
grams/$cm.^2$	0.03281	ft. of water

0407146

MULTIPLY	BY	TO OBTAIN
grams/cm.^{2}	9.678×10^{-4}	atm.
grams/cm.^{2}	0.01422	lb./sq. in.
grams/cm.^{2}	2.048	lb./sq. ft.
HORSEPOWER	42.41	Btu/min.
HORSEPOWER	3.3×10^4	ft. lb./min.
HORSEPOWER	550	ft. lb./sec.
HORSEPOWER	10.7	kg.-cal./min.
HORSEPOWER	0.7457	kw.
hp. (boiler)	3.3479×10^4	Btu/hr.
hp. (boiler)	9.804	kw.
hp. hr.	2.545×10^3	Btu
hp. hr.	1.98×10^6	ft. lb.
hp. hr.	2.684×10^6	joules
hp. hr.	641.2	kg.-cal.
hp. hr.	2.737×10^5	kg.-meters
hp. hr.	0.7457	kw. hr.
hp. hr.	1.414×10^3	P.C.U.*
INCHES	2.54	cm.
in. Hg.	0.03342	atm.
in. Hg.	1.133	ft. of water
in. Hg.	0.4912	lb./sq. in.
in. Hg.	70.73	lb./sq. ft.
in. Hg.	345.3	kg./sq. meter
in. of water	2.458×10^{-3}	atm.
in. of water	0.07355	in. Hg.
in. of water	0.1869	cm. Hg.
in. of water	25.40	kg./sq. meter
in. of water	0.03613	lb./sq. in.
in. of water	5.202	lb./sq. ft.
in./° F.	4.572	cm./° C.
KILOGRAMS	9.807×10^5	dynes
KILOGRAMS	70.93	poundals
KILOGRAMS	2.205	lb.
KILOGRAMS	1.102×10^{-3}	tons (short)
kg.-meters	9.302×10^{-3}	Btu
kg.-meters	7.233	ft. lb.
kg.-meters	2.344×10^{-3}	kg.-cal.
kg.-meters	2.724×10^{-6}	kw. hr.

*Pound-Centigrade Unit

0407147

MULTIPLY	BY	TO OBTAIN
kg.-meters	5.165×10^{-3}	P.C.U.*
kg./cu. meter	1.0×10^{-3}	gram/cm.^{3}
kg./cu. meter	0.06243	lb./cu. ft.
kg./meter	0.6720	lb./ft.
kg./sq. meter	9.678×10^{-5}	atm.
kg./sq. meter	7.355×10^{-3}	cm. Hg.
kg./sq. meter	3.281×10^{-3}	ft. of water
kg./sq. meter	2.896×10^{-3}	in. Hg.
kg./sq. meter	0.2048	lb./sq. ft.
kg./sq. meter	1.422×10^{-3}	lb./sq. in.
KILOMETERS	3.281×10^{3}	ft.
KILOMETERS	0.6214	mi.
km./hr.	27.78	cm./sec.
km./hr.	54.68	ft./min.
km./hr.	0.9113	ft./sec.
km./hr.	16.67	meters/min.
KILOWATTS	56.92	Btu/min.
KILOWATTS	4.425×10^{4}	ft. lb./min.
KILOWATTS	737.6	ft. lb./sec.
KILOWATTS	1.341	hp.
KILOWATTS	14.34	kg.-cal./min.
KILOWATTS	1×10^{3}	watts
kw. hr.	3.413×10^{3}	Btu
kw. hr.	2.655×10^{6}	ft. lb.
kw. hr.	1.341	hp. hr.
kw. hr.	3.6×10^{6}	joules
kw. hr.	860.5	kg.-cal.
kw. hr.	1.895×10^{3}	P.C.U.*
LITERS	1×10^{3}	cm.^{3}
LITERS	0.0353	cu. ft.
LITERS	61.02	cu. in.
LITERS	0.2642	gal. (U.S.)
LITERS	1.057	qt. (liq.)
liters/gram mol.	16.02	cu. ft./lb. mol.
liters/hr.	0.2778	cm.^{3}/sec.
liters/kg.	0.01602	cu. ft./lb.
liters/min.	6.0×10^{4}	cm.^{3}/hr.
liters/min.	5.885×10^{-4}	cu. ft/sec.

*Pound-Centigrade Unit

0407148

ENGINEERING CONVERSION FACTORS

MULTIPLY	BY	TO OBTAIN
liters/min.	15.851	gal./hr.
liters/min.	4.403×10^{-3}	gal./sec.
liters/sec. $cm.^2$	32.8	cu. ft./sec. sq. ft.
METERS	3.281	ft.
METERS	39.37	in.
meters/° C.	1.824	ft./° F.
meters/min.	1.667	cm./sec.
meters/min.	0.05468	ft./sec.
meters/min.	0.06	km./hr.
meters/min.	0.03728	mph
meters/sec.	196.8	ft./min.
meters/sec.	3.6	km./hr.
meters/sec.	2.237	mph
OUNCES	28.35	grams
OUNCES	0.0625	lb.
OUNCES (fluid)	1.805	cu. in.
OUNCES (fluid)	0.02957	liters
oz./sq. in.	1.732	in. of water
POISES	1	gram/cm. sec.
POUNDS	4.448×10^5	dynes
POUNDS	453.6	grams
POUNDS	32.17	poundals
lb. mols gas	379.4	cu. ft. gas (60° F. at 1 atm.)
lb. of water	0.01602	cu. ft.
lb. of water	0.1198	gal.
lb. of water/hr.	2.669×10^{-4}	cu. ft./min.
lb. of water/hr.	1.997×10^{-3}	gal./min.
lb./cu. ft.	0.01602	$grams/cm.^3$
lb./cu. ft.	16.02	kg./cu. meter
lb./cu. in.	27.68	$grams/cm.^3$
lb./ft.	1.488	kg./meter
lb./ft. hr.	4.13×10^{-3}	grams/cm. sec.
lb./ft. hr.	0.413	centipoises
lb./gal.	0.1198	$grams/cm.^3$
lb./in.	178.6	grams/cm.
lb./sq. ft.	0.01602	ft. of water
lb./sq. ft.	4.882	kg./sq. meter

0407149

MULTIPLY	BY	TO OBTAIN
lb./sq. ft.	6.944×10^{-3}	lb./sq. in.
lb./sq. in.	0.06804	atm.
lb./sq. in.	2.307	ft. of water
lb./sq. in.	2.036	in. Hg.
lb./sq. in.	51.7	mm. Hg.
lb./sq. in.	703.1	kg./sq. meter
lb./sq. in.	144	lb./sq. ft.
REFRIGERATION—STD. TON	200	Btu/min.
SQUARE CENTIMETERS	1.076×10^{-3}	sq. ft.
SQUARE CENTIMETERS	0.1550	sq. in.
SQUARE FEET	929	sq. cm.
SQUARE FEET	144	sq. in.
SQUARE FEET	0.0929	sq. meters
SQUARE INCHES	6.452	$cm.^2$
SQUARE INCHES	6.944×10^{-3}	sq. ft.
SQUARE INCHES	6.452×10^{-4}	sq. meters
SQUARE KILOMETERS	1.076×10^{7}	sq. ft.
SQUARE KILOMETERS	0.3861	sq. mi.
SQUARE METERS	10.76	sq. ft.
temperature °C. 273	1.0	abs. temp. °K.
temperature °C. 17.8	1.8	temp. °F.
temperature °F. 460	1.0	abs. temp. °R.
temperature °F. −32	0.5555	temp. °C.
TONS (long)	1.016×10^{3}	kg.
TONS (long)	2.24×10^{3}	lb.
tons (metric)	1×10^{3}	kg.
tons (metric)	2.205×10^{3}	lb.
tons (short)	907.2	kg.
tons (short)	2×10^{3}	lb.
tons (short)/sq. ft.	9.765×10^{3}	kg./sq. meter
tons (short)/sq. ft.	13.89	lb./sq. in.
tons (short)/sq. in.	1.406×10^{6}	kg./sq. meter
tons (short)/sq. in.	2×10^{3}	lb./sq. in.
tons of refrigeration	See refrigeration	
WATTS	0.05692	Btu/min.
WATTS	1×10^{7}	ergs/sec.
WATTS	44.26	ft. lb./min.

0407150

MULTIPLY	BY	TO OBTAIN
WATTS	0.7376	ft. lb./sec.
WATTS	1.341×10^{-3}	hp.
WATTS	0.01434	kg.-cal./min.
WATTS	1.0×10^{-3}	kw.
WATT HOURS	3.413	Btu
WATT HOURS	2.655×10^{3}	ft. lb.
WATT HOURS	1.341×10^{-3}	hp. hr.
WATT HOURS	0.8605	kg.-cal.
WATT HOURS	367.1	kg.-meter
WEEK	168	hr.
WEEK	1.008×10^{4}	min.
WEEK	6.048×10^{5}	sec.
YEARS (common)	8.76×10^{3}	hr.

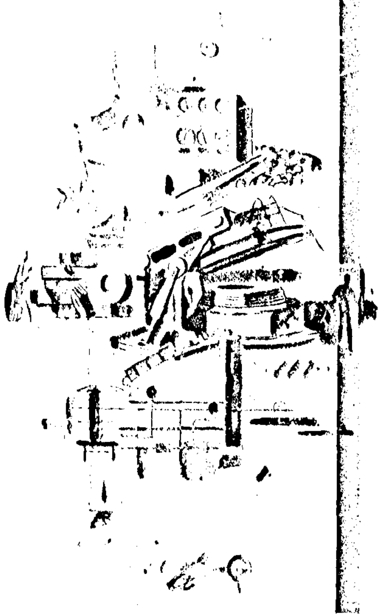
STEEL PIPE DIMENSIONS—CAPACITIES AND WEIGHTS*

Nominal pipe size, in.	Outside diam., in.	Schedule No.	Wall thick-ness, in.	Inside diam., in.	Cross-sectional area metal, sq. in.	Inside sectional area, sq. ft.	Circumference, ft., or surface sq. ft. per ft., of length		Capacity at 1 ft. per sec. velocity		Weight of pipe per ft. lb.
							Outside	Inside	U. S. gal. per min.	Lb. per hr. water	
¼	0.540	40	.088	.364	.125	.00072	.141	.0954	.323	161.5	.43
⅜	0.675	40	.091	.493	.167	.00133	.177	.1293	.596	298.0	.57
½	0.840	40	.109	.622	.250	.00211	.220	.1630	.945	472.5	.85
¾	1.050	40	.113	.824	.333	.00371	.275	.2158	1.665	832.5	1.13
1	1.315	40	.133	1.049	.494	.00600	.344	.2745	2.690	1,345.0	1.68
1¼	1.660	40	.140	1.380	.669	.01040	.435	.362	4.57	2,285.0	2.28
1½	1.990	40	.145	1.610	.799	.01414	.498	.422	6.34	3,170.0	2.72
2	2.375	40	.154	2.067	1.075	.02330	.622	.542	10.45	5,225.0	3.66
2½	2.875	40	.203	2.469	1.704	.03322	.753	.647	14.92	7,460.0	5.80
3	3.500	40	.216	3.068	2.228	.05130	.917	.804	23.00	11,500.0	7.58
3½	4.000	40	.226	3.548	2.680	.06870	1.047	.930	30.80	15,400.0	9.11
4	4.500	40	.237	4.026	3.173	.08840	1.178	1.055	39.6	19,800.0	10.8
5	5.563	40	.258	5.047	4.304	.1390	1.456	1.322	62.3	31,150.0	14.7
6	6.625	40	.280	6.065	5.584	.2006	1.734	1.590	90.0	45,000.0	19.0
8	8.625	40	.322	7.981	8.396	.3474	2.258	2.090	155.7	77,850.0	28.6
10	10.75	40	.365	10.020	11.90	.5475	2.814	2.620	246.0	123,000.0	40.5
12	12.75	40	.406	11.938	15.77	.7773	3.338	3.13	349.0	174,500.0	53.6

*Based on A. S. A. Standards B36.10.

TYPICAL APPLICATIONS FOR thermINOL LIQUID HEATING SYSTEMS...

Indirect liquid heating with THERMINOL FR systems is recommended wherever low-pressure, high-temperature processing—requiring safe, uniform delivery of heat—is needed. Here are a few typical applications.



CHEMICAL PROCESSING

. . . especially where flammable materials are handled.

VARNISHES AND RESINS PROCESSING

. . . where a single "circuit" with multiple users and varying temperatures is desirable.

PLASTICS AND RUBBER MOLDING

. . . where uniform heating, rapid temperature flux, and pin-point control is essential.

BITUMINOUS MATERIALS HEATING

. . . for maximum safety where explosive gases and volatile fumes occur.

FOOD PROCESSING

. . . for controlled, quality "cooking" of potato chips, pre-cooked soups, other foodstuffs.

MATERIALS CONVERSION

. . . to heat corrugating rolls, crimping presses, calenders.

METALS TREATING OVENS

. . . for heat-treating metals such as titanium and vanadium; for "seasoning" weldments, castings and forgings.

MALT COOKING AND LIQUID DISTILLATION

. . . for efficient indirect heating of distillation equipment.

0407152

ND

thermınol FR SAFETY OF HANDLING

On the basis of animal toxicity studies, THERMINOL FR may be considered only slightly toxic from the standpoint of accidental massive skin exposure or accidental ingestion. Similarly, single exposures to high concentrations of vapors (when heated sufficiently to volatilize) or high concentrations of decomposition products (if the fluid is accidentally discharged into the fire chamber) are not serious hazards because the irritating character of such concentrations preclude voluntary exposure.

Repeated or prolonged skin exposure should be avoided since THERMINOL FR acts as a solvent for fats and oils of the skin. Removal of these natural, protective barriers can lead to drying and chapping such as occurs with exposures to paint thinners. More important, THERMINOL FR may be absorbed if it is allowed to remain on the unbroken skin. For these reasons, we recommend that the skin be washed with soap and water if there is contact. A skin burn resulting from accidental contact with hot fluid should be treated in the normal manner for any thermal burn due to hot oils.

Because of its low vapor pressure, there is no significant vapor inhalation hazard when THERMINOL FR is at room temperature. For example, there is no vapor exposure problem while transferring the fluid from its shipping container to the heat transfer system. On the other hand, the vapors emitted by THERMINOL FR heated to elevated temperatures are injurious on prolonged exposure. It is indicated that the "threshold limit value" or atmospheric vapor concentration which cannot be safely exceeded (on a daily basis) is 0.5—1.0 milligrams of THERMINOL FR vapor per cubic meter of air in the workroom. In heat transfer installations, the fluid must be used in a closed system free from leaks with the expansion tank vented to the outdoors. Accordingly, there should be little or no opportunity for workers to come in contact with vapors.

0407154

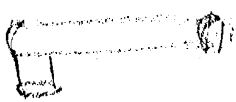
TOWOLDMON0030871
WATER_PCB-00015340

FR-0 = $6/gal.

$2-3/gal

Aluminum pricing sheet - filed.

reach (if find) engineer before his system is on the drawing board we can sell him 8 out of 10 times.



Monsanto

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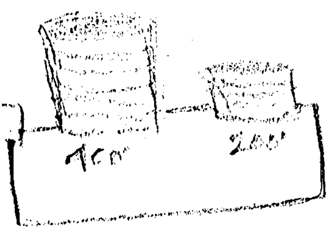

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