MONSANTO

ENGINEERING
HEAT TRANSFER
DATA for use with

aroclor® 1248

a fire-resistant,
heat-transfer agent
that operates up to [illegible]
in the liquid phase

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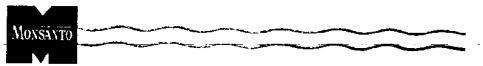
TOWOLDMON0037845
WATER_PCB-00022314

1248



*Trade name reg. U. S. Pat. Off.

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. . . . . .has been used successfully since 1941 as a liquid phase heat transfer medium at atmospheric pressure and temperatures up to 600°F.

The compound, essentially tetrachlorobiphenyl, is a fire-resistant and non-corrosive liquid, which does not crystallize at low temperatures. Handled properly, in well-designed forced circulation heat exchangers which avoid localized over heating damage, the fluid gives satisfactory continuous service for many years without replacement.

Most significant, Aroclor 1248 is practically non-flammable. In one installation of record, a ruptured pipe that spewed the hot fluid into gas flames failed to cause the fluid to ignite.

For general heat transfer, Aroclor 1248 has several other important qualities: it is highly mobile and can be readily pumped at temperatures as low as 50°F. If cooling is necessary, the heat transfer fluid can be put through a water cooler to be used as a coolant . . . using this single fluid for both heating and cooling.

Aroclor 1248 transfers heat (up to 600°F.) as a *liquid*. This liquid phase heat transfer makes it unnecessary to use the expensive pressurized equipment required by a heat transfer medium that operates as a vapor. Aroclor 1248 operates safely and efficiently with gas-fired, oil-fired, or electrical heat sources. It is used successfully in the following types of applications . . . .

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- Chemical Processing Equipment, particularly for reacting flammable materials
- Cooking of Alkyd resins, varnishes, waxes
- Plastics molding, extruding, calendering
- Rubber processing
- Heating asphalt
- Food Processing, including potato chip and doughnut frying in vegetable oils
- Processing titanium, magnesium, other non-ferrous metals
- Fabrication of magnesium and aluminum honey-comb structures for aircraft
- Indirect heating in dyestuff manufacture
- Heating of corrugating rolls
- Indirect heating of distillation equipment
- Saponification of fats
- Calcining Ovens
- Impregnation and lamination of fibrous materials

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physical properties

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		Temperature	
Appearance	**Practically colorless mobile liquid.**		
		°Centigrade	**°Fahrenheit**
Absolute density, g./ml.	1.44	30	86
	1.41	60	140
	1.37	100	212
	1.27	200	392
	1.17	300	572
Absolute viscosity, centipoises	112.0	30	86
	17.5	60	140
	4.2	100	212
	0.99	200	392
	0.47	300	572
Thermal Conductivity, Btu./hr.sq. ft./°F./ft.	0.0571	30	86
	0.0564	60	140
	0.0555	100	212
	0.0534*	200	392
	0.0512*	300	572
	* Extropolated Data.		
Spec. Volume, ml./g.	0.696	30	86
	0.709	60	140
	0.728	100	212
	0.787	200	392
	0.860	300	572

Table 1

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(Table 1, cont.)

		°Centigrade	°Fahrenheit
Spec. Heat, cal./g./°C.	0.283	50	122
	0.297	100	212
	0.326	200	392
	0.355	300	572
Vapor Pressure, mm. Hg.	0.00037	37.8	100
	0.16	100	212
	2.9	150	302
	18.0	200	392
	350.0	300	572
Distillation Range, ASTM D-20		345-385	652-725
Flash Pt., Cleveland Open Cup, ASTM D 92-45		193-196	379-384
Fire Pt., Cleveland Open Cup, ASTM, D 92-45	None	—	—
Pour Pt., ASTM, D-97		—7	19.4
Average Coefficient of Expansion cc./cc./°F.	0.00037	—17.8 to 37.8	0 to 100
	0.00038	37.8 to 93.3	100 to 200
	0.00041	93.3 to 149	200 to 300
	0.00044	149 to 204	300 to 400
	0.00047	204 to 260	400 to 500
	0.00052	260 to 316	500 to 600

PHYSICAL CHARACTERISTICS of AROCLOR 1248

A complete knowledge of the physical characteristics of heat transfer media is highly essential to their satisfactory application in a heat exchanger. These physical constants have a major bearing on the equipment design, its maintenance, and its operation.

The following figures and charts give basic physical data on Aroclor 1248.

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DENSITY OF AROCLOR 1248

(Top axis, lbs./cu. ft.; bottom axis, gm./ml.)

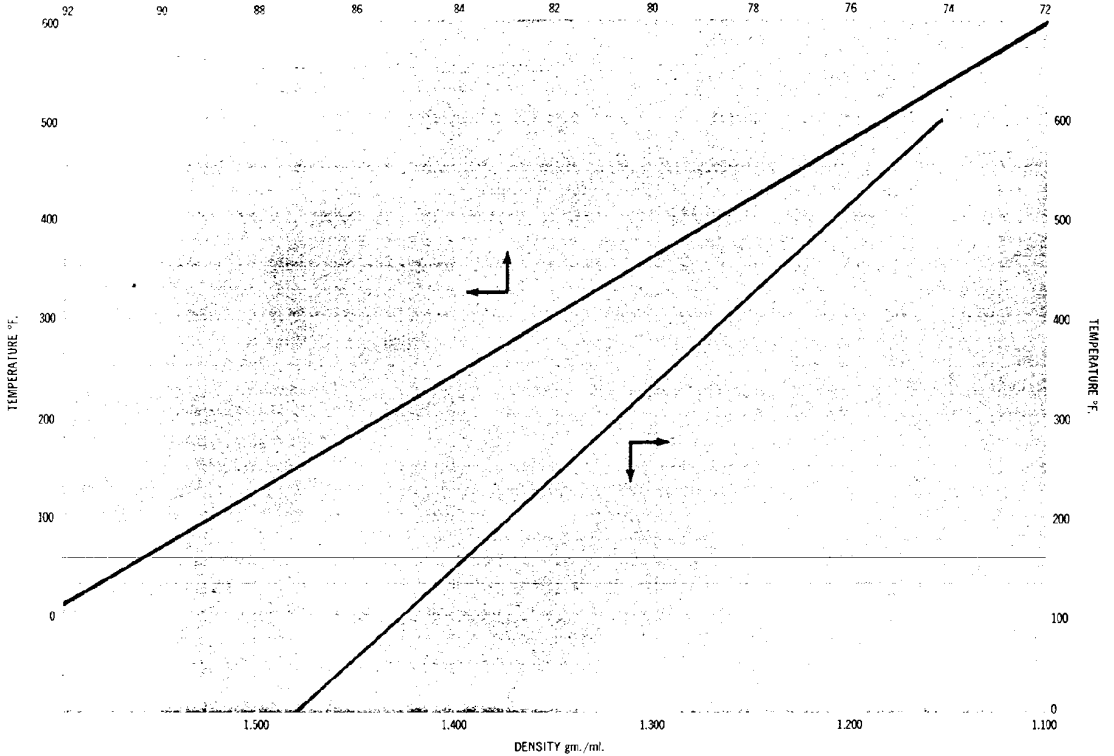

Figure 1

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VISCOSITY OF AROCLOR 1248

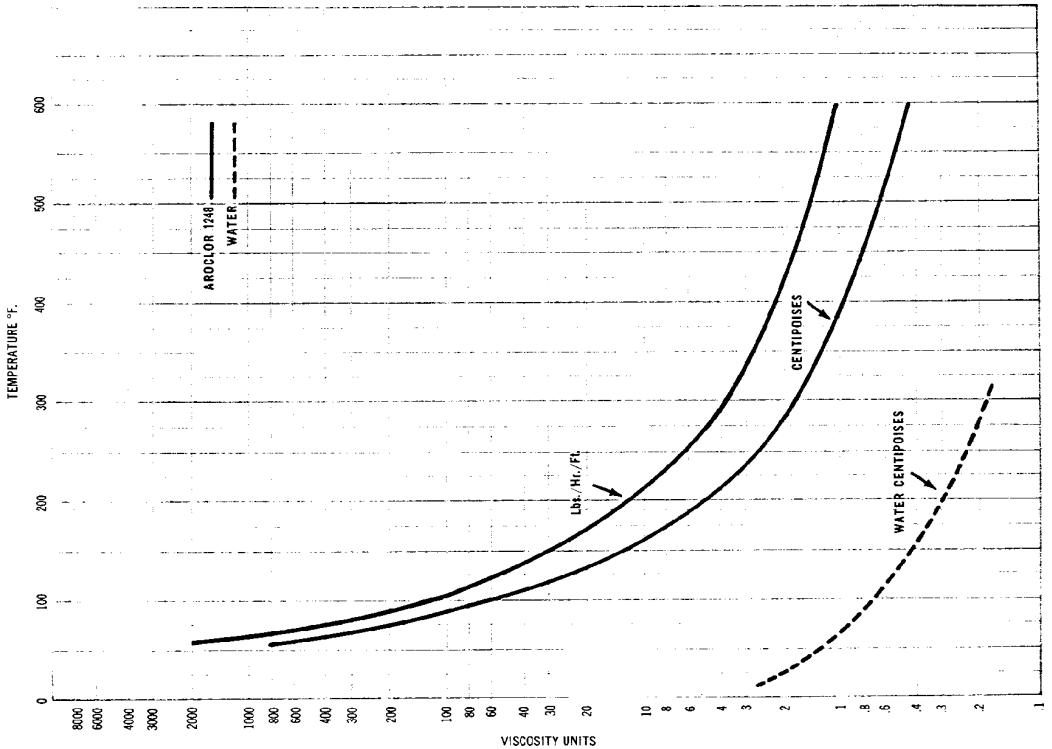

Figure 2

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VISCOSITY OF AROCLOR 1248

(Saybolt Universal Seconds)

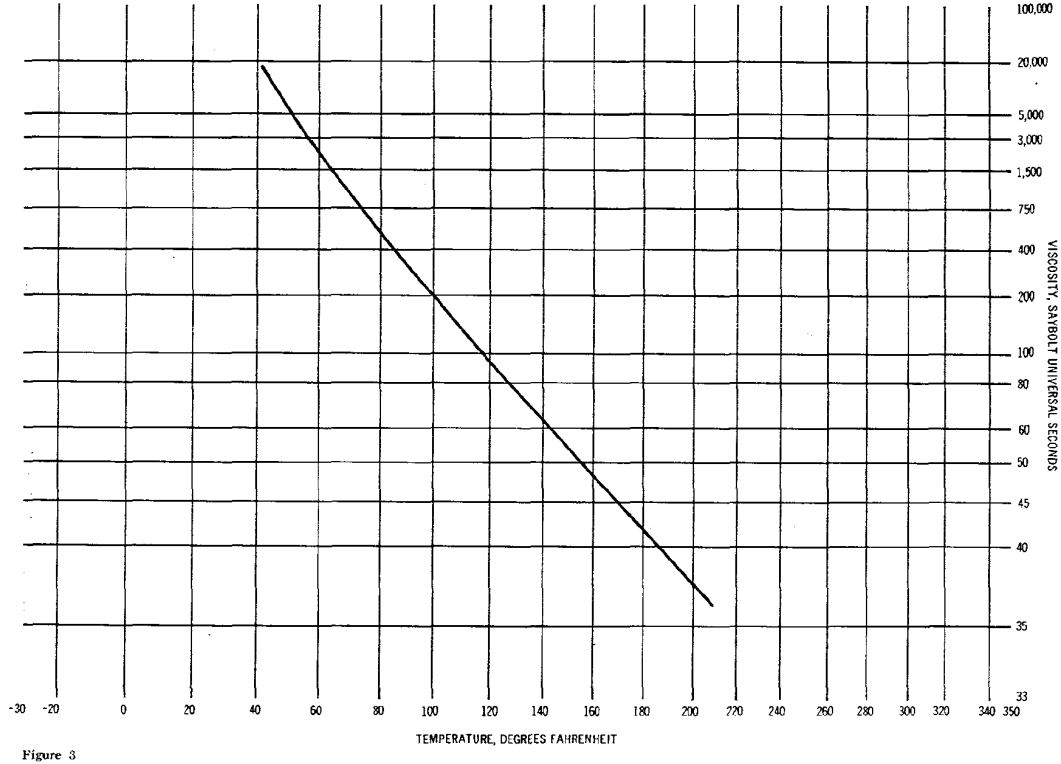

Figure 3

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HEAT CAPACITY

and Its Relationship to Density

Systematic errors exist in the various accepted procedures for making specific heat determinations. Consequently values may vary depending upon the procedure used. In practical operation, it frequently appears that the values for Aroclor 1248 shown in Figure 4 are somewhat low. Consequently, although these values have been accurately determined, they may be regarded as conservative.

When comparing the specific heat values of Aroclor 1248 with corresponding values for other heat transfer fluids, it is important to note that the density of Aroclor 1248 is much higher relatively than the density of other liquids used for heat transfer. Accordingly, when comparison of heat capacity is made on a **volume** basis (which is most pertinent in equipment design and efficient operation) the heat capacity of Aroclor 1248 shows itself to better advantage than by direct comparison of specific heat values.

Although specific heat values are important, they represent only one of several important constants that enter into the equations for calculating over-all heat transfer efficiency.

Through the use of these conservative heat capacity values, it is possible that equipment engineered from such data might be slightly "overdesigned." It may be one of the factors that accounts for the exceptionally good operating performance of a number of highly successful commercial applications.

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SPECIFIC HEAT OF AROCLOR 1248

(Btu. per lb. per degree F.)

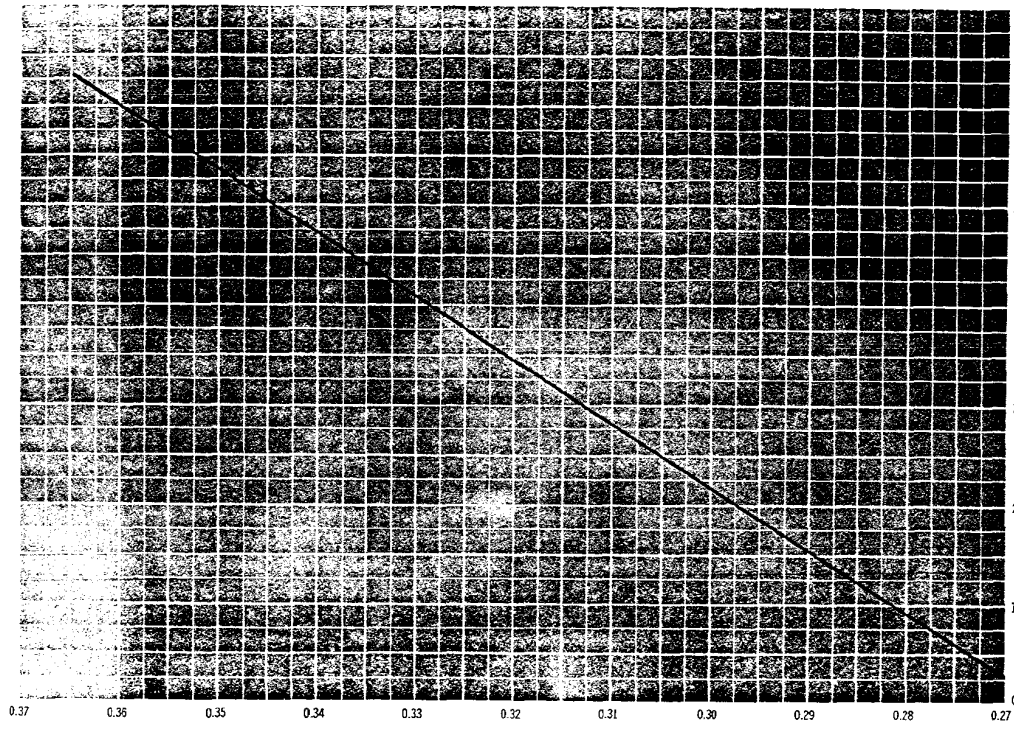

Figure 4

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HEAT CONTENT

of Aroclor 1248

Temperature °C.	Temperature °F.	Specific Heat Btu./lb./°F.	Heat Content Btu./lb.
0	32	.269	0.0
10	50	.272	4.85
38	100	.280	18.65
66	150	.288	32.85
93	200	.295	47.43
121	250	.303	62.38
149	300	.311	77.58
177	350	.319	93.48
204	400	.327	109.66
232	450	.335	126.21
260	500	.343	143.17
288	550	.351	160.52
316	600	.359	178.27

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THERMAL CONDUCTIVITY
and VISCOSITY

The thermal conductivity values of Aroclor 1248 are shown in Figure 5. The curve shows this value over Aroclor 1248's operating temperature range, from 50°F. to 600°F.

As freshly charged into a heat exchanger, Aroclor 1248 has an initial viscosity of 74 (S.U.S.) at 130°F. which corresponds to a viscosity of approximately 5000 (S.U.S.) at 50°F. – which temperature is assumed for practical purposes to be about the limit at which Aroclor 1248 can be conveniently pumped with a centrifugal pump.

The following table shows a comparison of the initial viscosity and the viscosity after a year's continuous service at 600°F. in a LaMont forced circulation heater:

TABLE III

	Original	After one Year of service at 600°F.
Appearance	Colorless Liquid	Dark Brown Liquid
Specific Gravity, 65° C.	1.410	1.418
Viscosity, S. U. S. at 130°F.	74.0	83.5

Although Aroclor 1248 tends to darken in use, this darkening is not harmful and does not indicate decomposition. In actual use at Monsanto, it has not been found necessary to replace the fluid after seven years of continuous use; additional fluid is only added as necessary to make up spills or leaks.

In Figure 6, the horizontal line indicating viscosity limit of pumpability at 50°F. shows that the rate of viscosity increase based on a year's continuous service should permit Aroclor 1248 to serve approximately four years before increased viscosity may interfere with its pumpability when cold. In practice, Aroclor 1248 has given satisfactory pumpability for much longer periods. A simple S.U.S. viscosity determination by the ASTM-D-88 method can be used for periodic checks on the fluid.

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THERMAL CONDUCTIVITY OF AROCLOR 1248

(Dotted extension indicates extrapolated data)

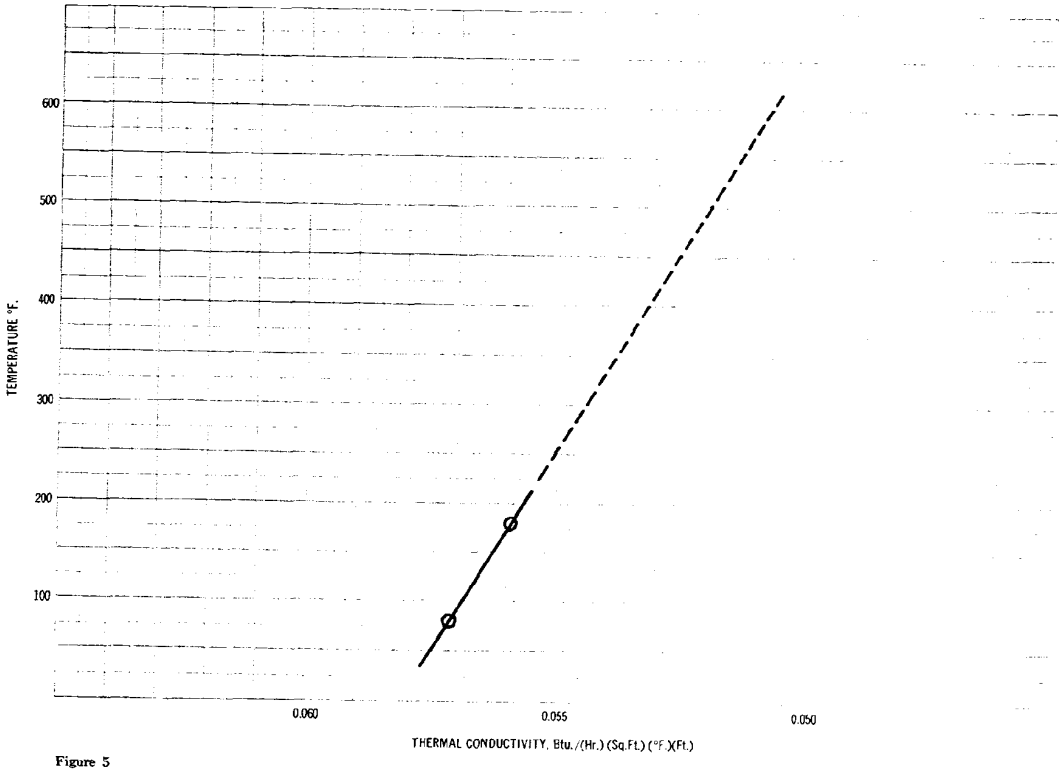

Figure 5

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EXPECTED MINIMUM SERVICE LIFE IN A FORCED CIRCULATION HEATER

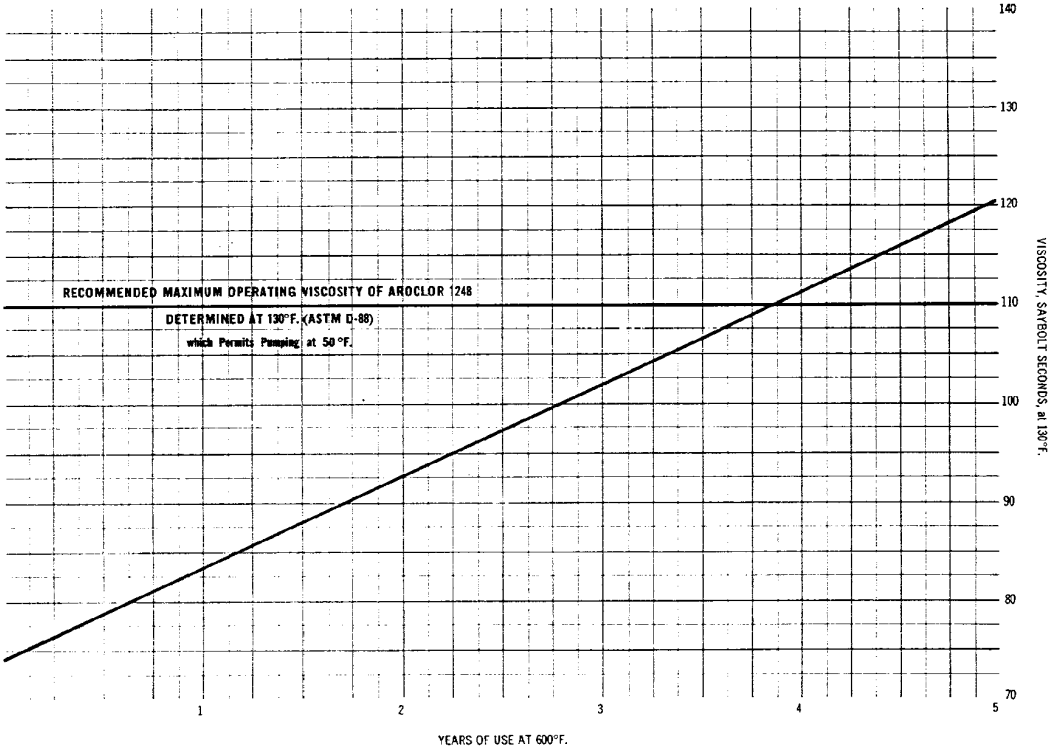

Figure 6

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STABILITY

Aroclor 1248 is an extremely stable chemical compound. Tests over long periods of time have shown that 600°F. is a safe maximum temperature for continuous operation in heaters that are properly designed and operated to eliminate intense, localized overheating. At this temperature the fluid is 52°F. below the initial temperature of its boiling range, and consequently remains a liquid.

Near its boiling point Aroclor 1248 tends to dehydrohalogenate to a very slight but measurable degree. If this occurs as a result of accidental overheating, the small amount of HCl gas evolved tends to pass through the vent tank without harm to the equipment provided that the system is dry.

Experimental observations using ideally-suited heat exchangers operating at a temperature of 650°F. with imposed nitrogen pressures of 30 and 70 psig. showed that application of pressure did not prevent this small amount of thermal decomposition, which also occurs when the material is heated above 600°F. at atmospheric pressure.

When heated continuously at 650°F. under nitrogen pressure a gradual increase in the viscosity of the fluid occurs indicating that its service life would be limited to about 6 months to one year.

Results of operating at 600°F., however, without imposed nitrogen pressure indicate Aroclor 1248 can be heated continuously at this temperature for about 4 years before any viscosity increase could be expected to interfere with its pumpability at 50°F. which is slightly below normal room temperatures.

Provision should be made to prevent water contamination of the system. If the system becomes contaminated with water, any HCl liberated by localized overheating may dissolve in the water film which will float on top of Aroclor 1248 in the expansion tank. The acidic solution thus formed can cause corrosion. It is recommended that moisture be eliminated from the expansion tank by installing a moisture trap or by sealing the tank and applying 15 to 30 psig. of nitrogen gas. With exception of the expansion tank, the system should be kept full of Aroclor 1248 at all times to prevent formation of air pockets where moisture may condense when the system cools off between periods of operation.

Many years of practical operating experience has shown that Aroclor 1248 is virtually non-corrosive to valves, piping, tanks, and jackets made of cast steel, steel, or stainless steel. In actual use, brass valves have been used satisfactorily.

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SAFETY of OPERATION

Aroclor 1248 can be considered a non-flammable liquid; no fire point is obtained by the Cleveland Open Cup method on heating to its boiling point (650°F.). The spontaneous ignition temperature[2] is 1,299°F.

In actual use, the following reported accident in a heating system demonstrates the fire resistance of Aroclor 1248 and the freedom it offers from the hazard of fire propagation. An operator's failure to start the circulation pump when the gas heater was on resulted in excessive coil temperatures. The line containing Aroclor 1248 sagged into the fire chamber. A weld ruptured and Aroclor 1248 poured into the red-hot fire chamber in contact with the flame. Dense smoke and fumes arose from the heater but there was no external fire. After the gas flame was cut off, the smoking stopped.

Insurance authorities allow the use of Aroclor 1248 heaters in many locations with a minimum of protection. No fire walls are required to isolate the heaters.

Aroclor 1248 has a low vapor pressure. In systems that employ a vented expansion tank, the loss due to evaporation is not measurable. If Aroclor 1248 in the expansion tank would reach a temperature of 266°F., the vapor pressure of the fluid would be only 1 mm. of Hg.

SAFETY OF HANDLING

Aroclor 1248 is an inert, unreactive liquid. If it is spilled on the skin, there are no noticeable ill effects. It is advisable, however, to wash the skin with soap and water after contact.

A skin burn resulting from accidental contact with hot Aroclor 1248 should be treated in the normal manner for hot oil burns. Any liquid adhering to the burned area need not be removed immediately unless treatment of the burn demands it. If the burn must be cleaned, soap and water or repeated washings with a vegetable oil (olive oil) may be used.

The vapors emitted by Aroclor 1248 heated to elevated temperatures are injurious on prolonged exposure and should not be breathed. It is indicated that 2.0 mg. of Aroclor 1248 per cubic meter of air is the maximum safe amount permissable in workrooms. In commercial heat transfer installations, it is presumed that Aroclor 1248 will be used in a closed system free from leaks. Accordingly, their should be little or no opportunity for workers to come in contact with Aroclor 1248 vapors.

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design features

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HEATER

The most significant factor to remember when selecting or designing a heat exchanger for Aroclor 1248 use is this:

Aroclor 1248 transfers heat **as a liquid,** at the maximum recommended temperature of 600°F. for continuous operation, which is approximately 50°F. below the boiling point. Consequently, Aroclor 1248 does not form vapor to accelerate convection circulation. Ordinary fire-tube or water-tube heaters which depend solely upon convection perform satisfactorily only at relatively low temperatures.

When temperatures of 500-600°F. are required, a forced circulation type heater is recommended. A satisfactory type of heater design would consist of a specified number of tubes in parallel, properly orificed to provide a high velocity fluid flow of 8 to 10 feet per second. These should be spaced to permit uniform heat absorption throughout their entire length. A typical construction is shown in Figure 7.

In its fabrication, the heater should be ASME Code all-welded construction, conforming to state and local ordinances. Tube joints, which in an ordinary steam heater would be the expanded type, must be seal-welded to prevent leakage. All connections larger than ¾" should be flanged connections, since ordinary threaded pipe connection is not suited for Aroclor 1248 service. Spiral-wound stainless steel and asbestos combination is recommended for sealing joints and plugs.

Drain valves should be installed at all low points on the heater and the valves must conform with ASME requirements for "blow down" valves.

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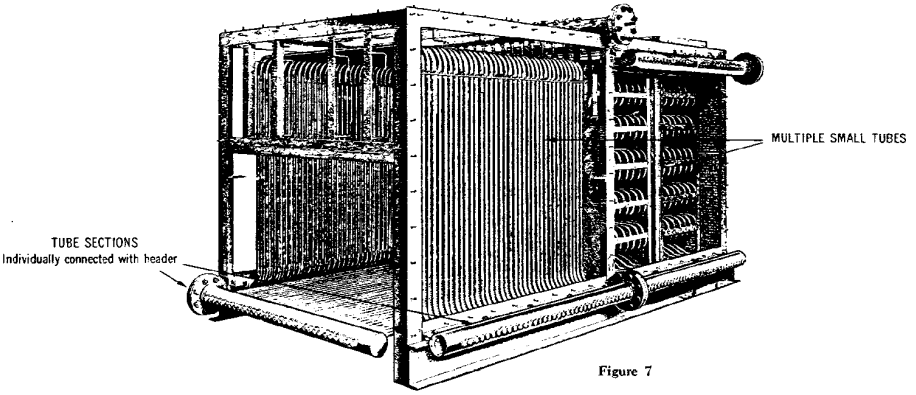

Figure 7

Since a heater operating on Aroclor 1248 is completely filled with liquid, costly liquid-level controls and condensate return pipes, fittings, traps, etc. are completely eliminated.

Heaters can be provided with any desired kind of firing. Portable and small size stationary are frequently electrically heated; larger units may be gas- or oil-fired. In installations where an open flame presents a fire hazard, to meet insurance requirements the heater may be installed in a separate building with piping carrying the hot Aroclor 1248 to the point of use. Properly constructed transmission pipes may extend for hundreds of feet.

HEATER EFFICIENCY

Forced circulation heaters with integral economizers will show an efficiency of from 75 to 80%. Heaters of the straight connector type show efficiencies of 65 to 75%, depending upon the discharge temperatures.

HEATER CAPACITIES

Heaters using Aroclor 1248 (gas- or oil-fired) are available in output capacities ranging from approximately 250,000 Btu. per hour to large units rated over 10 million Btu. per hour. A heat flux density (or heat energy input) of approximately 5,000 Btu. per hour per square foot of tube surface is regarded as satisfactory.

For lower output rate, electrically-heated units are favored, employing watt densities of 12 to 16 watts per square inch.

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THE USERS

The "users" or recipients of the heat at the point of processing can be any type of heating pan, platen, jacketed kettle, or coils of steel or stainless steel construction. Ordinary low pressure construction is satisfactory, since the pressure imposed on the Aroclor 1248 seldom exceeds 50 psig. In the user, however, it is important that all-welded construction be used. Threaded connections may allow leakage of the hot fluid. As in the heater, all connections ¾" and over should be flanged and all joints sealed with spiral wound stainless steel and asbestos gasket material. Alloy bolts should be used to secure flanges. A typical system with several users is shown in Figure 8.

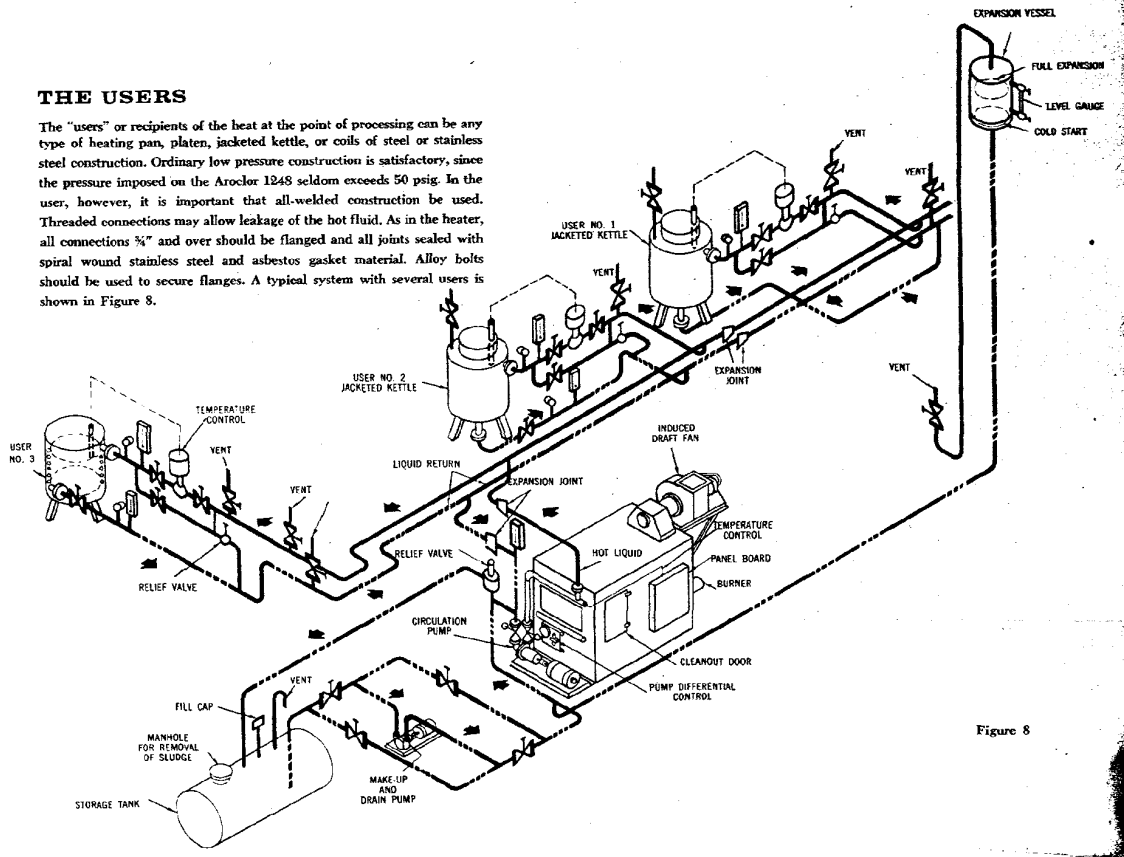

Figure 8

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THE PUMP

For most systems, cast-steel centrifugal pumps with water-cooled stuffing box and bearings are to be preferred. However, high temperature centrifugal pumps with mechanical seals are now available which give excellent performance. In some installations, immersion pumps have been used. Whatever type is selected, the pump capacity and pressure head must be sufficient to circulate the volume of fluid at the rate the particular installation demands.

To avoid shaft trouble and leakage at the seals, it is important to provide adequate expansion joints and to support the piping in a manner to avoid 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 positive differential control to switch off the burner in case of pump failure.

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

PIPING LAYOUT

The most important factors in the piping layout for Aroclor 1248 systems are (a) proper sizing for the required flow rate and (b) minimizing pressure drop. Because the system will undergo temperature changes, adequate expansion joints and loops to relieve expansion and contraction stress are essential.

All pipe lines and connections should be of extra heavy or Schedule 80 welded construction meeting A.S.M.E. requirements. Flanged joints should be used as sparingly as possible to minimize potential leak points.

All valves and controls should be cast steel construction with stainless steel seats. Pipe lines should be well insulated and those exposed to temperatures below 70°F. should be steam jacketed.

All high points in the piping system should be provided with vent valves; all low points should have drain connections. Piping should be well anchored at frequent intervals, particularly near expansion loops, to prevent vibrations.

Figure 9 shows a typical piping diagram that illustrates the important features of an Aroclor 1248 piping system. These may be varied to suit the installation.

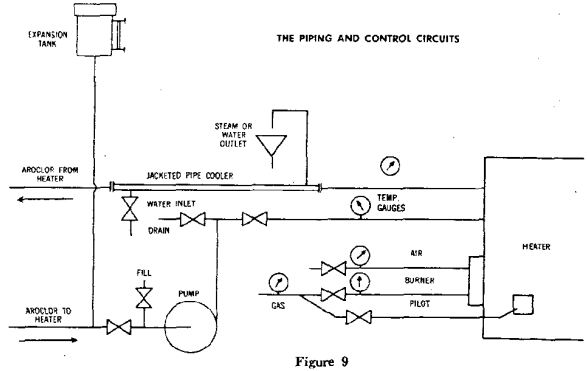

Figure 9

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THE EXPANSION TANK

The expansion tank should be large enough to accommodate about 20% of the total volume of the entire system, including the fluid content of the heater, piping, and all heat-users. Tank should be sized to be ¼-full when system is cooled to 70°F. and ¾-full when system is at maximum operating temperature. Expansion tank should be fitted with a sight glass at the "full" range and a float-operated low-level switch to shut off burner in case of accidental fluid loss in the system.

The expansion tank should be mounted on a platform high enough to support the liquid reservoir at least six feet higher than the highest point in the piping system.

THE FEED and DRAIN PUMP

To eliminate manual filling and draining of the heating system, it is recommended that a small 2-to-5 gpm. positive displacement pump be installed at some convenient point to pump the Aroclor 1248 into or out of the system.

CONTROLS

Controls for heating systems using Aroclor 1248 should be installed both on the heater itself and on the heat-using units. A wide variety of thermo-operating controls are available and any reliable standard equipment is satisfactory.

Heater controls should be installed 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 Aroclor 1248 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 may operate more uniformly if equipped with modulating temperature controls.

User Controls should be installed to regulate the flow of the heat transfer fluid in direct 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 A.S.M.E. requirements. Safety controls should include:

1. A high temperature limit control operating at the heater outlet to shut off the burner in the event of an excessive temperature rise.
2. A suitable low-limit temperature control to hold the burner at low fire until the Aroclor 1248 in the system reaches a temperature level of 180°F.

The low limit temperature control is essential because the viscosity of Aroclor 1248 is rather high at normal room temperature. To avoid localized overheating upon start-up, it is not advisable to apply full heat from the burner until all the fluid in the system has attained a viscosity that allows good flow and unimpeded circulation. Cold start-ups require slow up-heats.

Burners should be equipped with automatic ignition controls and flame failure controls. In wide-range firing operations, an over-fire draft control will increase the economy of operation. Induced draft fans are another factor which should be considered as a means of avoiding the expense of high chimneys.

Where they are needed throughout the system, good quality recording or indicating gauges should be installed.

COOLING EQUIPMENT

Where fast reduction of temperature is required suitable, air- or water-cooling installations may be used. If the cooler is to be a water-type unit, it is suggested that stainless steel tubing be used for the coils to avoid corrosion on the water side. If a cooler is installed in the system, low temperature limit controls should also be installed to avoid excessive cooling that might raise the viscosity to the point of impeding the circulation in the system.

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FILTERING EQUIPMENT

When heating systems operated on Aroclor 1248 are run continuously near the maximum temperature of recommended operation (600°F.), it is advisable to provide a filtering device that can be attached to the drain line of the storage tank. In this way discrete particles of dirt that may get into the system can be filtered out periodically. This is an advisable maintenance step since it will eliminate the danger of dirt clogging the valve seats or lodging in parts of the control mechanisms.

A small portable filter such as those manufactured by Honan-Crane Corporation (Lebanon, Ind.) or Sparkler Manufacturing Company (Mundelein, Ill.) is quite satisfactory.

CONNECTIONS and GASKETS

In a system operated on Aroclor 1248, welded connections are preferable; threaded screw connections should be avoided wherever possible. This precaution will minimize leaks with consequent make-up. All connections 1" and over should be of the flanged type fastened with alloy bolts to prevent frozen connections. Steel connectors should be used for all instruments and controls. For gasketing, spiral wound gaskets of corrugated stainless steel and asbestos combination should be used on all flanged connections.

TESTING and CLEANING THE SYSTEM

When a new system has been installed, it is essential to test the entire system hydrostatically for leaks, and to wash out all the lines to remove dirt, oil films, or pipe scale. Both the cleaning and the testing can be done with a single operation, such as the following:

Fill the entire system with a water solution containing 5 pounds of soda ash and 5 pounds of caustic soda for every 1000 pounds (120 gal.) of water used. Thoroughly vent the system at all of the highest points in the piping system to assure complete filling . . . then start the circulating pump. With the pump running, the entire system is next inspected for leaks.

Next, turn on the burner at low-fire rate and raise the temperature of the wash solution to 180°F. This hot wash solution should be circulated continuously through the entire system (heater and all users) for at least 24 hours. At regular intervals a portion of the solution should be drained and replaced by fresh water. This partial draining should be continued at regular intervals until the drainage from the system is clear.

At the end of the 24 hour period, the temperature of the circulating wash solution should be brought up to 240°F. and the fire turned off. The whole system should then be drained and all vents in the piping opened. Residual heat will dry the pipes and the heater through the vents, which should remain open until inspection shows that the system is entirely dry. When all traces of water have dried out, the drains and vents are closed.

Aroclor 1248 is then charged into the cleaned, dry system. The circulating pump is started and firing begun at low heat until the Aroclor 1248 has reached a temperature of 250°F. Periodically during this initial up-heating, the lines should be vented every 10-15 minutes for at least two hours to allow any residual moisture or air to escape. After it is certain that all moisture has been eliminated from the system, the entire system should be inspected for leaks with the pump circulating the hot fluid. As a final inspection, the expansion tank should be checked to make sure that the tank is ¼ full. After this, the burner can be set to full-fire and the system brought up to operating temperature.

When the temperature of operation has been reached all controls should be checked and adjusted so that the burner is regulated for full modulation. When the system is brought to full operating temperature, all pipe lines should be given a final inspection for expansion and bracing.

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GENERAL RECOMMENDATIONS for Operation and Maintenance

The following recommendations are primarily guides for the manner of using Aroclor 1248 in an operating system. They are supplemental to the equipment manufacturer's own recommendations for operation and maintenance that relate to the heaters or the heat-using installations themselves. The recommendations for start-up, shut-down, precautions in event of power failure, and periodic check-ups on the fluid and equipment apply as generally accepted practice on all types and sizes of systems. By following these recommendations, the trouble-free service life of the heat transfer fluid will be increased.

START-UP

When systems have been shut down for week-ends or over-night and the fluid is cooled to room temperature, follow this start-up procedure:

1. Start the circulating pump and check the expansion tank to make certain the Aroclor 1248 is at the proper cold-start level [Tank should be ¾-full.];
2. Start burner at minimum flame setting and continue full circulation until Aroclor 1248 is heated to 180°F. when measured on the **return** side of the heater.
3. Turn heater up to full heat.

SHUT-DOWN

The following procedure will eliminate overheating of the fluid when shutting down:

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

PRECAUTIONS IN COLD WEATHER

When heat exchanger is exposed to ambient temperatures below 50°F., it is recommended that unit not be shut down. It is recommended that the burner be turned low and the fluid circulated continuously at about 200°F. The unit will then be "at ready" for immediate high temperature operation.

PRECAUTIONS IN CASE OF POWER FAILURE

In case of power failure, the burner circuit is interrupted by the heater controls. When power comes on, the circulating pump should first be run for a few minutes to eliminate any vapor pockets that might have been formed by the fluid's being held static in the hot combustion chamber. If there is no knocking in the piping system, full-fire may be resumed immediately.

PERIODIC CHECK-UPS

The regular maintenance inspection schedule should include the equipment manufacturer's recommendations and also inspection of the heat transfer fluid. The following is a listing of 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 cleaning of heater surfaces.
5. Inspection of water cooling at the circulating pump.
6. Regular repacking of stuffing boxes according to the manufacturer's recommendations.
7. Semi-annual or annual sampling and analysis of Aroclor 1248.

Under normal operating conditions not affected by frequent power failures or accidental overheating, when Aroclor 1248 is operated at 600°F. it should not be necessary to check on the condition of the fluid more often than once or twice a year.

The analysis for fluid condition is a simple determination of viscosity. The information given in Figure 6 serves as a guide to estimate the condition of the fluid, according to viscosity values. Most users do their own testing; some have the viscosity determination made by an outside laboratory.

Customers can have their fluid tested by Monsanto free of charge. A one-quart sample is required, and sample should be carefully packed to avoid breakage in shipment. Samples should be shipped to:

Monsanto Chemical Company
Organic Chemical Division — Industrial Fluid Sales
St. Louis, Missouri

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engineering data

Designing or purchasing equipment for a heating system to be operated with Aroclor as a medium to deliver heat into a process requires consideration of heat transfer characteristics of both the user and the heater. The actual heat which can be absorbed by a user, for example, depends upon the over-all heat transfer coefficient, heat transfer area, and a mean temperature difference between Aroclor and the material being heated. Both overall heat transfer coefficient and mean temperature difference are, in turn, affected by the flow rate of the Aroclor. This inter-relation of flow rate, heat, and temperature is usually solved by a trial and error procedure as covered in standard reference texts. The approach of Granet[3] may be used to minimize or eliminate trial and error.

The following tables and graphs of physical properties and engineering data are provided as an aid in layout and design calculations for systems to be operated with Aroclor 1248 as a heat transfer fluid in the liquid phase.

Table IV lists properties useful in heat balance calculations by which the flow rate is related to the heat transferred and the temperature change of the Aroclor. This relation is also shown graphically in Figure 10.

The over-all heat transfer coefficient for the heater or user may be estimated by the methods outlined in the texts of McAdams[4] or Kern[5]. This is usually done by combining the individual film coefficient of the Aroclor with other coefficients and conductivities to yield the over-all coefficient. Table V contains physical properties of Aroclor as a function of temperature which are needed for calculating the Aroclor film coefficient. Tables VI gives typical film coefficients for Aroclor flowing through a 0.81 inch i.d. tube. These are listed as a function of temperature and flow rate in a tubular heat exchanger. Other tube sizes would, of course, require a correction for the diameter in the Reynolds and Nusselt group of the equation (from McAdams) given at the top of Table VI. Correlations for estimating film coefficients for various material that might be processed by indirect heating may be found in the texts 4 and 5 cited and elsewhere in the literature.

For sizing pipe lines and pumping requirements, Figure 11 shows pressure drop vs. flow rate and pipe size for Aroclor 1248 at temperatures over 300°F. Above this temperature Aroclor 1248 flows freely like water.

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THERMODYNAMIC PROPERTIES OF AROCLOR No. 1248
TABLE IV

Temperature °F	Temperature °C.	Enthalpy Btu./lbs.	C_p (Spec. Heat) Btu./lbs. °F.	Density Lbs./cu. ft.	Lbs./gal.	Specific Gravity	Absolute Viscosity in Centipoises
32	0	0.000	0.2695	91.6	12.22	1.47	
40	4	2.162	0.2711	91.3	12.19	1.46	
50	10	4.881	0.2727	90.9	12.13	1.455	
60	16	7.616	0.2743	90.6	12.08	1.45	850
70	21	10.367	0.2759	90.2	12.03	1.445	380
80	27	13.134	0.2775	89.8	12.00	1.40	200
90	32	15.917	0.2791	89.5	11.96	1.432	115
100	38	18.716	0.2807	89.1	11.91	1.425	66
110	43	21.531	0.2823	88.8	11.87	1.420	47
120	49	24.362	0.2839	88.4	11.82	1.414	32
130	54	27.209	0.2855	88.1	11.77	1.409	24
140	60	30.072	0.2871	87.8	11.73	1.404	18
150	66	32.951	0.2887	87.4	11.69	1.400	14
160	71	35.846	0.2903	87.0	11.64	1.393	11
170	77	38.757	0.2919	86.6	11.58	1.387	9.1
180	82	41.784	0.2935	86.2	11.53	1.381	7.5
190	88	44.727	0.2951	85.9	11.47	1.375	6.3
200	93	47.686	0.2967	85.6	11.42	1.370	5.2
210	99	50.661	0.2982	85.2	11.38	1.365	4.4
220	104	53.651	0.2998	84.8	11.34	1.359	3.9
230	110	56.657	0.3014	84.4	11.29	1.353	3.35
240	116	59.679	0.3030	84.1	11.24	1.348	3.00
250	121	62.717	0.3046	83.7	11.18	1.342	2.68
260	127	65.771	0.3062	83.4	11.14	1.336	2.38
270	132	68.841	0.3078	83.1	11.10	1.331	2.08
280	138	71.927	0.3094	82.9	11.06	1.326	1.96
290	143	74.029	0.3110	82.6	11.03	1.321	1.82
300	149	77.147	0.3126	82.3	10.98	1.316	1.68
310	154	80.281	0.3142	81.9	10.94	1.311	1.58
320	160	83.431	0.3158	81.6	10.90	1.305	1.46
330	166	86.597	0.3174	81.2	10.85	1.300	1.42
340	171	89.779	0.3190	80.9	10.81	1.296	1.30
350	177	92.977	0.3206	80.6	10.76	1.291	1.22
360	182	96.191	0.3222	80.2	10.71	1.286	1.15
370	188	99.421	0.3238	79.8	10.67	1.280	1.10
380	193	102.667	0.3254	79.4	10.62	1.274	1.05
390	199	105.929	0.3269	79.1	10.57	1.269	1.00
400	204	109.206	0.3285	78.8	10.53	1.264	0.96
410	210	112.499	0.3301	78.5	10.48	1.259	0.91
420	216	115.808	0.3317	78.2	10.43	1.253	0.87
430	221	119.133	0.3331	77.9	10.39	1.248	0.84
440	227	122.474	0.3349	77.6	10.34	1.243	0.80
450	232	125.831	0.3365	77.2	10.30	1.237	0.76
460	238	129.204	0.3381	76.8	10.25	1.231	0.73
470	243	132.593	0.3397	76.4	10.20	1.225	0.71
480	249	135.998	0.3413	76.1	10.16	1.220	.068
490	254	139.419	0.3429	75.7	10.11	1.214	0.65
500	260	142.856	0.3445	75.4	10.06	1.208	0.61
510	266	146.309	0.3461	75.0	10.02	1.202	0.60
520	271	149.778	0.3476	74.7	9.98	1.196	0.57
530	277	153.267	0.3492	74.4	9.94	1.191	0.55
540	282	156.762	0.3508	74.1	9.90	1.186	0.53
550	288	160.278	0.3524	73.7	9.85	1.180	0.51
560	293	163.810	0.3540	73.4	9.80	1.175	0.49
570	299	167.358	0.3556	73.0	9.76	1.170	0.47
580	304	170.922	0.3572	72.7	9.71	1.165	0.45
590	310	174.502	0.3588	72.4	9.67	1.160	0.43
600	316	178.098	0.3604	72.0	9.63	1.155	0.42
610	321	181.710	0.3620	71.7	9.58	1.150	0.40
620	327	185.338	0.3636	71.4	9.53	1.144	0.39
630	332	188.982	0.3652	71.0	9.48	1.138	0.37

Table 4

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FLOW RATES FOR AROCLOR #1248

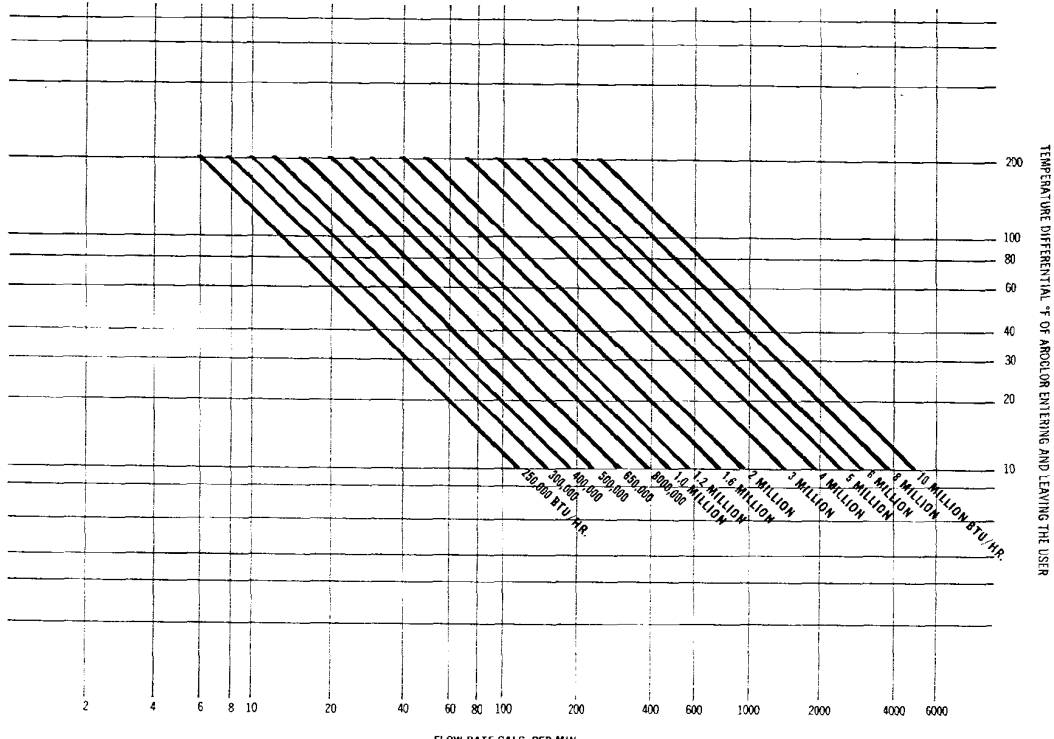

Figure 10

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WATER_PCB-00022340

THERMODYNAMIC PROPERTIES of AROCLOR 1248

PRANDTL

Temperature °F.	Temperature °C.	μ Absolute Viscosity Lbs. Hr. Ft.	k Thermal Conductivity Btu. Ft. Hr. °F.	$\frac{Cp\,\mu}{k}$	$\left[\frac{Cp\,\mu}{k}\right]^{0.4}$
32	0	.....	0.0577	.....	.....
40	4	.....	.0576	.....	.....
50	10	.....	0.575	.....	.....
60	16	2060	.0574	9844	39.5
70	21	960	.0573	4430	28.7
80	27	485	.0572	2353	22.3
90	32	278	.0570	1361	17.9
100	38	160	.0569	789	14.4
110	43	114	.0568	566	12.6
120	49	77.5	.0566	388	10.8
130	54	58.0	.0565	293	9.7
140	60	43.5	.0564	221	8.7
150	66	33.8	.0563	173	7.88
160	71	26.6	.0562	137	7.15
170	77	22.0	.0560	115	6.68
180	82	18.2	.0559	95	6.18
190	88	15.2	.0558	80	5.78
200	93	12.6	.0557	67	5.38
210	99	10.6	.0555	57	5.05
220	104	9.45	.0554	51.1	4.83
230	110	8.10	.0553	44.1	4.55
240	116	7.26	.0552	39.8	4.36
250	121	6.48	.0550	35.9	4.18
260	127	5.76	.0549	32.1	4.00
270	132	5.03	.0548	28.2	3.81
280	138	4.75	.0547	26.8	3.73
290	143	4.40	.0545	25.1	3.63
300	149	4.07	.0544	23.4	3.53
310	154	3.83	.0543	22.2	3.45
320	160	3.53	.0542	20.6	3.35
330	166	3.34	.0541	19.6	3.29
340	171	3.14	.0540	18.5	3.22
350	177	2.95	.0539	17.5	3.15
360	182	2.78	.0537	16.7	3.08
370	188	2.66	.0536	16.1	3.04
380	193	2.54	.0535	15.4	2.99
390	199	2.42	.0534	14.8	2.94
400	204	2.32	.0532	14.3	2.90
410	210	2.20	.0531	13.7	2.85
420	216	2.10	.0530	13.1	2.80
430	221	2.03	.0529	12.7	2.76
440	227	1.93	.0527	12.3	2.73
450	232	1.83	.0526	11.7	2.68
460	238	1.76	.0525	11.3	2.64
470	243	1.71	.0524	11.0	2.61
480	249	1.64	.0523	10.7	2.58
490	254	1.57	.0521	10.3	2.54
500	260	1.51	.0520	10.0	2.51
510	266	1.45	.0519	9.67	2.46
520	271	1.38	.0518	9.26	2.43
530	277	1.33	.0516	9.00	2.40
540	282	1.28	.0515	8.72	2.37
550	288	1.22	.0514	8.36	2.34
560	293	1.18	.0513	8.14	2.31
570	299	1.13	.0512	7.85	2.28
580	304	1.09	.0510	7.63	2.25
590	310	1.04	.0509	7.33	2.22
600	316	1.01	.0508	7.16	2.20

Table 5

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HEAT TRANSFER DATA for AROCLOR 1248

(FILM COEFFICIENT)

$$h = \left[\frac{12\,k}{0.81}\right] \times 0.023 \left[\frac{D\,G}{M}\right]^{0.8} \left[\frac{Cp\,\mu}{k}\right]^{0.4} \text{(Mc Adams)}$$

Based on flow through 0.81" I. D. tube (1" O. D. x 13 ga.) expressed in Btu./sq. ft. hr. °F.

FLOW ATE GPM

°F.	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0
150	.....	.....	.....	.....	.....	83.2	86.2	93.8	103	114	123	130
200	.....	44.9	63.4	78.7	94.0	109	124	138	151	164	179	191
250	33.5	58.5	80.9	102	122	141	159	177	195	212	229	245
300	40.5	70.1	97	122	146	169	191	212	233	254	274	294
350	45.3	79.0	109	137	164	190	215	239	252	286	309	331
400	49.0	85.5	118	149	178	206	232	259	284	309	334	358
450	53.3	93	128	162	193	224	253	282	309	336	363	388
500	56.3	98	136	171	204	236	267	297	327	356	383	411
550	60.5	105	145	183	219	253	286	319	350	381	411	441
600	64.2	112	155	195	233	269	305	339	373	405	437	469

Calculations for other pipe sizes can be made using the data found in Tables IV and V.

No film coefficients were calculated for flow rates where the Reynolds number was less than 2100.

Table 6

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FRICTION LOSSES IN SYSTEM PIPING
AROCLOR 1248, ABOVE 300°F.

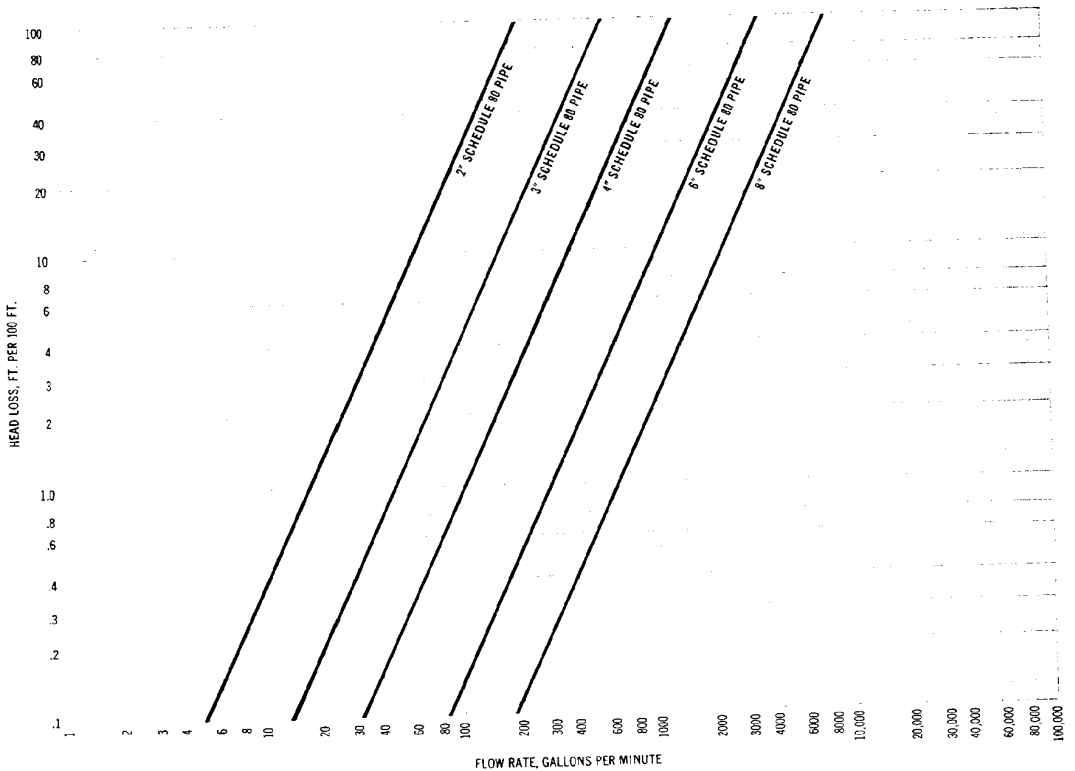

Figure 11

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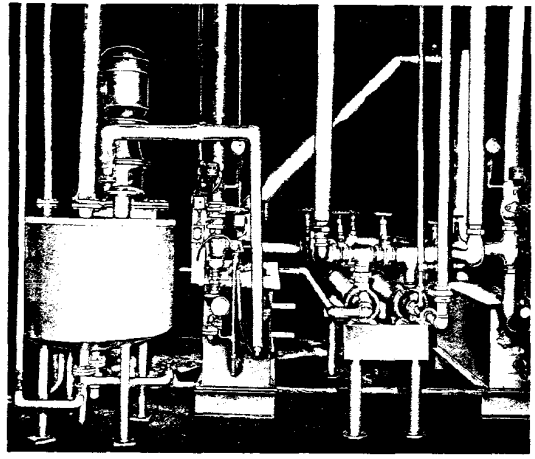
TYPICAL HEATERS USING AROCLOR 1248



A 200,000 Btu. (right) and a 300,000 Btu. heater, both gas-fired, have been in use at Monsanto for over 14 years for organic chemicals reactions. The heaters have operated near 600°F. with the same charge of Aroclor 1248 for periods of 7 years.

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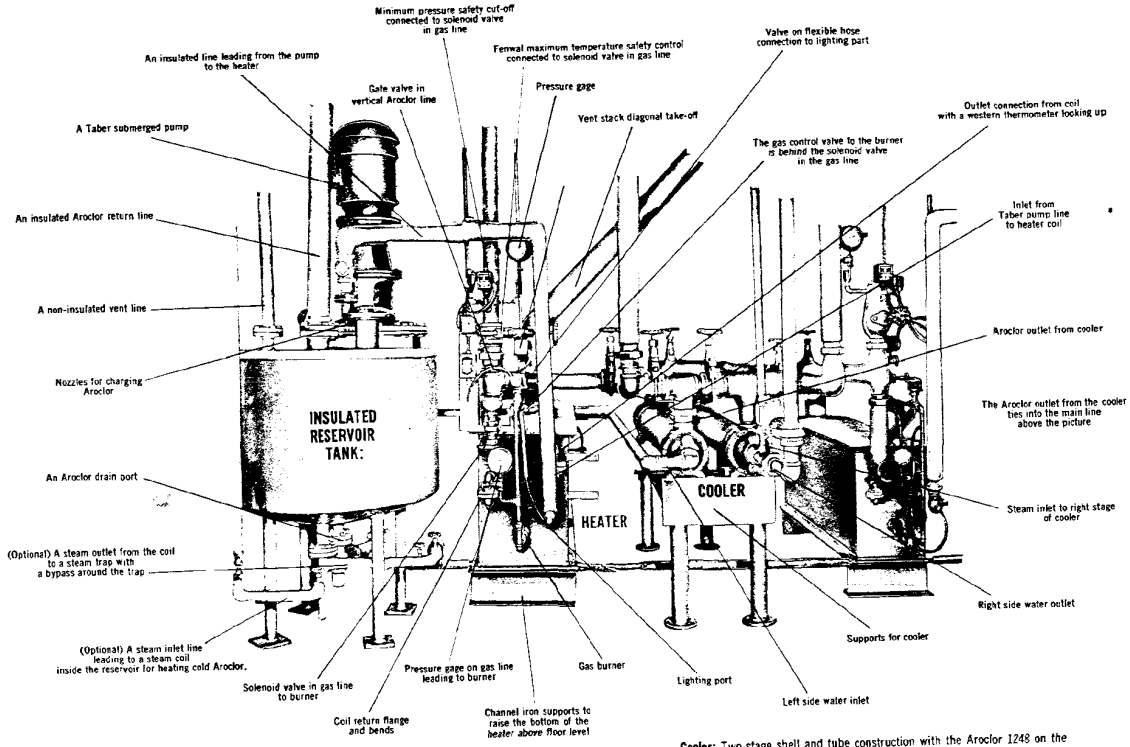

Aroclor Heater: The heater consists of fire brick lined walls and bottom inside a steel shell with steel baffles to force the hot combustion gases for three passes over the Aroclor coil. The top is a steel plate.

Cooler: Two-stage shell and tube construction with the Aroclor 1248 on the outside of the tubes. The two-stage cooler is piped so that one stage can be used on each Aroclor heater or both stages can be used on either Aroclor heater.

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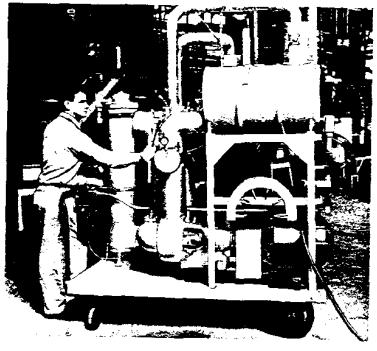
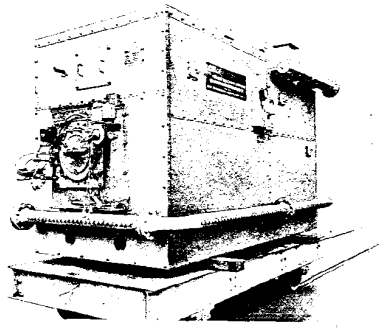
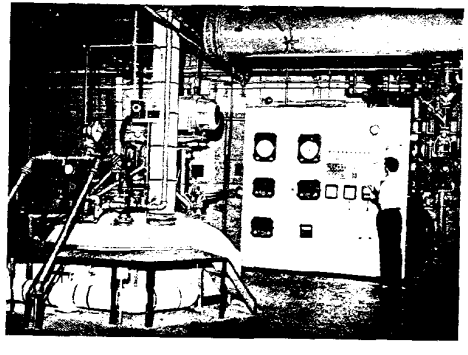
A 40,000 Btu. per hour electrically heated portable heat exchanger used to heat vessels of about 50 gallons working capacity. This unit was built for a variety of small scale chemical reactions. It was initially designed to vaporize approximately 200 lbs./hr. of an organic compound which has a heat of vaporization of 150 Btu. per pound; a 30% heat loss was allowed for. Experience with the heater indicates that a horizontal rather than the vertical mounting of the immersion heater (at operator's left) would have been more satisfactory.



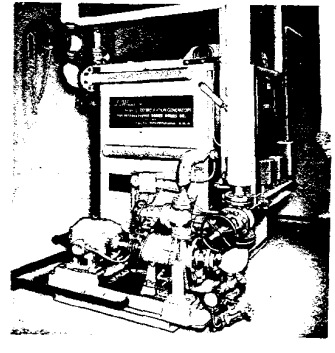


A 4,000,000 Btu./hr. forced circulation International LaMont heater.

Control panel for a 3,000,000 Btu./hr. International LaMont heater that operates the 3,500 gallon, glass-lined kettle shown on the left. This kettle is the largest of its kind in the United States.



Commercial heaters operating on Aroclor 1248 are available in any capacity desired. This is a 1,200,000 Btu./hr. installation.



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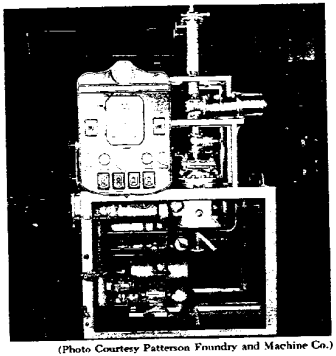
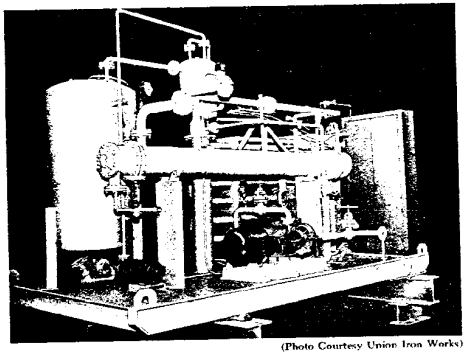


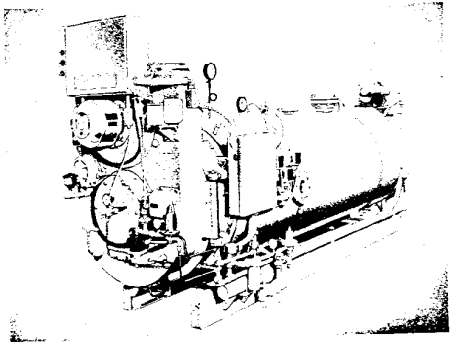
(Photo Courtesy Patterson Foundry and Machine Co.)



(Photo Courtesy Union Iron Works)

A pilot plant resin processing vessel operated on indirect heat transferred by Aroclor 1248. Vessel and heater are mounted together in one unit.

This 500,000 Btu./hr. forced circulation heater is electrically heated and designed for a liquid temperature of 500°F. The construction is similar to a double pipe heat exchanger with the electric heating elements in the inner pipe; the Aroclor 1248 circulates through the annular space between inner and outer pipe. The liquid Aroclor 1248 is delivered from the heater at a temperature of 500°F. and heats the contents of a jacketed kettle with a batch capacity of 1,000 gallons.



This design for a forced circulation heater was developed by Cleaver Brooks Company.

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[redacted]

DIE CUT
FILE TAB

aroclor

LIQUID HEAT TRANSFER FLUID

Temperatures up to 600°F.

Long-lasting, trouble-free service

Fire-resistant, non-corrosive

Operates in un-pressured, minimum cost equipment

Monsanto supplies Aroclor 1248, but not the heat exchangers. Monsanto will be happy to recommend sources of supply.

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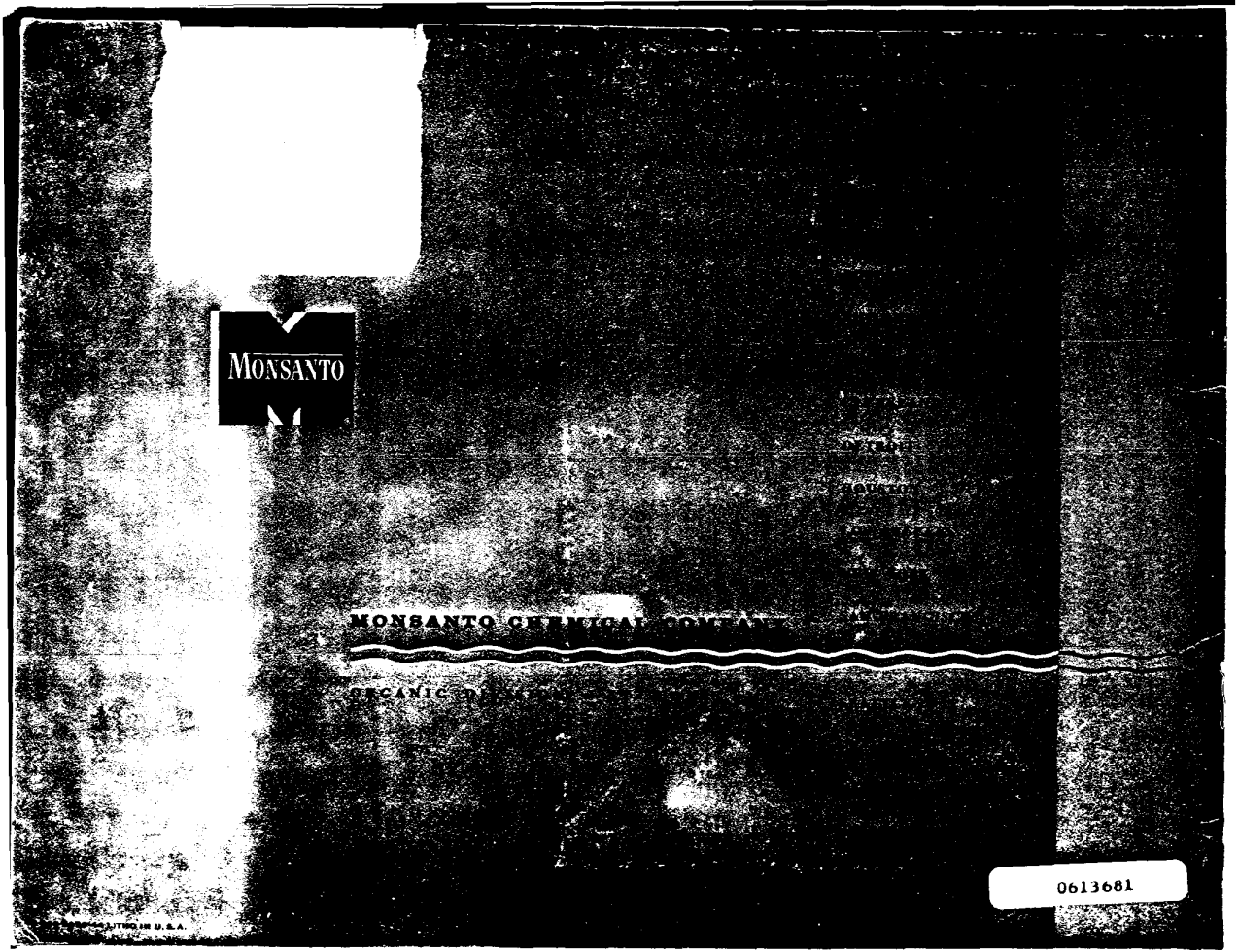

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