SANTOTHERM

HEAT TRANSFER FLUID BY Monsanto.

DESIGN MANUAL 1970 EDITION

CONTENTS

WHY USE SANTOTHERM?

More than 2,500 customers have specified Santotherm for new installations and conversion of existing systems in Europe and the U.S.A. The main reasons they chose Santotherm were:

Safety

Santotherm systems operate at or near atmospheric pressure in the liquid phase. Working at atmospheric pressure means safer systems.

In applications where the risk of fire has to be minimised the Santotherm FR fluids are chosen because they bring the added benefit of fire resistance (together with approval from Factory Mutual U.S.A., and certification as fire-resistant by Underwriters' Laboratory.

Lower Capital Costs

Without pressure you can usually save 25 to 50 % of your capital because you don't need heavy piping, relief valves or other devices associated with pressurised systems.

Lower Operating Costs

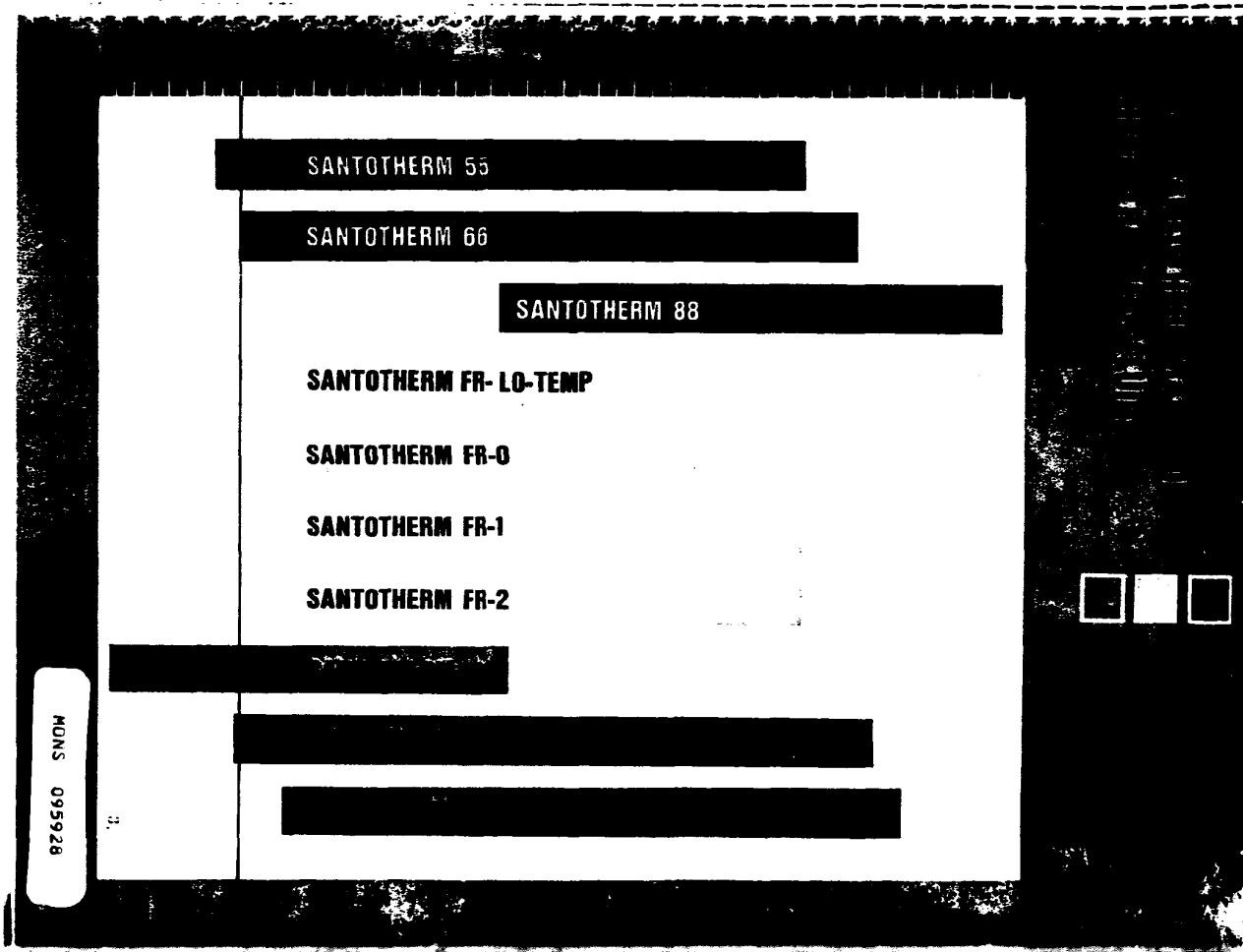
Very little fluid make-up is normally required. Temperature and heat losses expected with vapour systems are very much reduced. Routine maintenance is minimised and expensive operating personnel needed for pressurised systems are often unnecessary.

THE SANTOTHERM RANGE ...

... offers you a series of heat transfer fluids covering the operating range - 73°C (-100 °F) to 427°C (800°F). And for the future as your process temperature demands change you can choose a new Santotherm fluid to match your new needs. Many of the Santotherm fluids are interchangeable in your liquid heating system.

The Santotherm range includes ten fluids falling into three groups.

Santotherm 55 Santotherm 66 Santotherm 88	High Performance Fluids
Santotherm FR-LO-TEMP Santotherm FR-0 Santotherm FR-1 Santotherm FR-2	Fire Resistant Fluids
Santotherm 77 Santotherm 130 Santotherm 190	Special Purpose Fluids


SANTOTHERM 55
SANTOTHERM 66
SANTOTHERM 88
SANTOTHERM FR- LO-TEMP
SANTOTHERM FR-0
SANTOTHERM FR-1
SANTOTHERM FR-2

SANTOTHERM - APPLICATIONS UNLIMITED

CHEMICAL PROCESSING

... especially where flammable materials are handled. Santotherm has proved particularly successful for heating reactors, autoclaves, heat exchangers distillation columns, reboilers, mixers, dryers etc.

RESIN PROCESSING

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

PLASTICS AND RUBBER MOULDING; PAPER AND TEXTILES

... where uniform heating, rapid temperature flux and pint-point control is essential such as heating corrugating and drying rolls, crimping presses, calendars, platens and moulds.

FOOD PROCESSING

... for controlled, quality "cooking" of potato chips, pre-cooked/ frozen products, other foodstuffs.

PETROLEUM AND OFF-SHORE DRILLING

... offers control over a wide temperature range and the ability to accommodate sudden fluctuations in processing loads automated with complete safety.

SHIPS AND BARGES

... eliminates expensive boiler operators with a system that can heat fuel, cargo and living quarters.

SPACE HEATING

... ideal for hospitals hotels, apartment houses and office buildings where the goal is safety, low maintenance and reduced operating costs.

Section 1

HIGH PERFORMANCE FLUIDS

Santotherm 55

Santotherm 66

Santotherm 88

HIGH PERFORMANCE FLUID – SANTOTHERM 55

MAXIMUM BULK OPERATING TEMPERATURE	315°C	600°F
RECOMMENDED MAXIMUM FILM TEMPERATURE	335°C	635°F

Santotherm 55 is a synthetic heat transfer fluid developed for use in non-pressurized, indirect heating systems. Added to the extensive Monsanto line of heat transfer fluids to meet exacting needs, Santotherm 55 demonstrates thermal stability superior to that of petroleum oils.

Non-pressurized liquid systems using Santotherm 55 - type fluids are finding increasing use in applications which traditionally used steam as the heating medium. Savings in capital and maintenance costs are often gained.

HIGH PERFORMANCE FLUID - SANTOTHERM 55

TYPICAL PHYSICAL, CHEMICAL AND THERMAL PROPERTIES

Composition	Synthetic hydrocarbon
Appearance	Clear, brown liquid
Odour	slight
Coefficient of Expansion ^{o}C ^{o}F	 0.00085 0.00047
Density at 25 ^{o}C (77^{o}F) kg/m^3 lb/ft^3	 885 55.2
Boiling Range ^{o}C ^{o}F	335 - 390 635 - 734
Pour Point ^{o}C ^{o}F	- 29 - 20
Flash Point, Pensky-Marten (ASTM-D93 - 46) ^{o}C ^{o}F	180 355
Fire Point (Pensky-Marten) ^{o}C ^{o}F	210 410
Autoignition Temperature ^{o}C ^{o}F	 354 670
Viscosity at 0^{o}C cS	 300

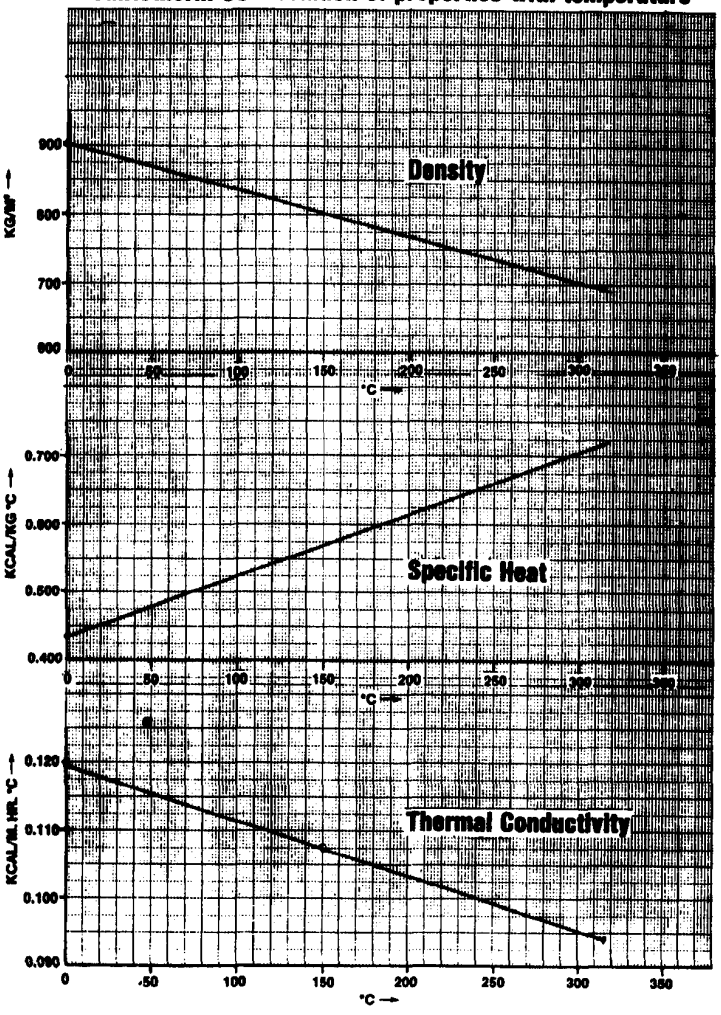
MONS 095933

HIGH PERFORMANCE FLUID - SANTOTHERM 55

VARIATIONS OF PROPERTIES WITH TEMPERATURE

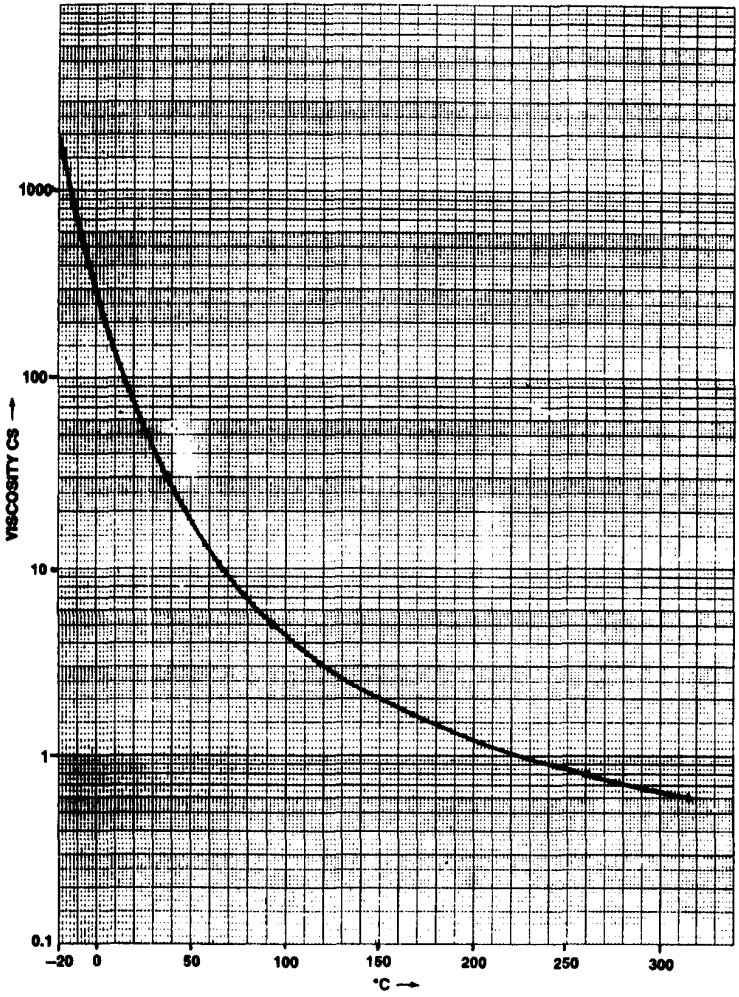
Temperature		Density		Specific Heat		Thermal Conductivity		Viscosity			Vapour Pressure	
°F	°C	lb/ft³	Kg/m³	BTU/lb. °F	Kcal/Kg. °C	BTU/ft. hr. °F	Kcal/m. hr. °C	lb/hr. ft	cP	cS	mmHg absolute	Kg/cm²
0	-18	57.1	915	0.420	0.420	0.0813	0.1210	3561	1472	1610	-	-
100	38	54.8	878	0.472	0.472	0.0784	0.1167	61.5	25.4	0.1	0.5	0.001
200	93	52.4	840	0.522	0.522	0.0753	0.1121	10.3	4.20	5.0	3.0	0.004
300	149	50.1	803	0.572	0.572	0.0724	0.1077	4.09	1.69	2.10	10	0.014
400	204	47.8	766	0.620	0.620	0.0692	0.1030	2.18	0.904	1.18	40	0.054
500	260	45.5	729	0.670	0.670	0.0661	0.0984	1.42	0.583	0.80	100	0.136
600	316	43.1	691	0.718	0.718	0.0630	0.0938	1.01	0.415	0.60	250	0.330

Santotherm 55 Variation of properties with temperature



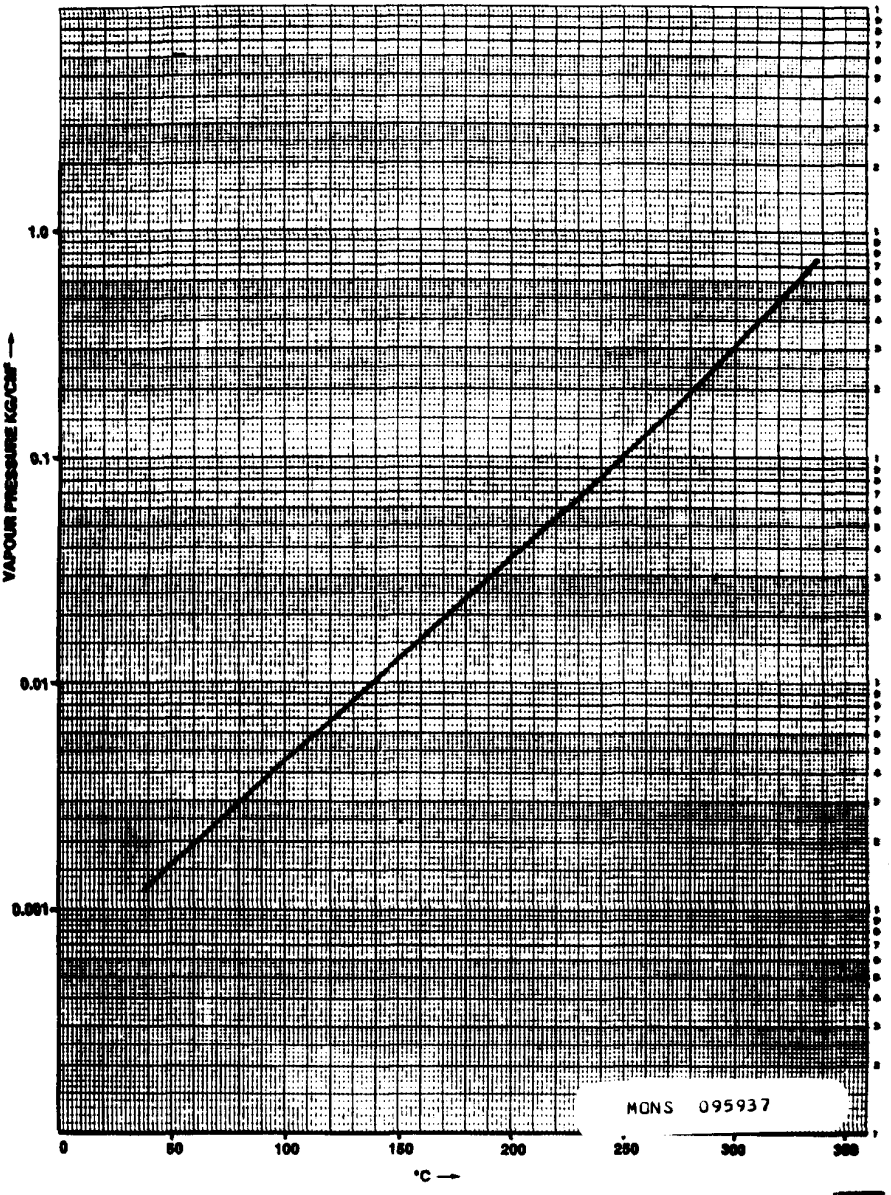
MONS 095935

Santotherm 55 Kinematic Viscosity



MONS 095936

Santotherm 55 Vapour Pressure



HIGH PERFORMANCE FLUID – SANTOTHERM 55

System Design Hints (see also Page .59..)

Santotherm 55 contains no additives.

Its compatibility with materials of construction is similar to petroleum oil – use of copper should be kept to a minimum.

To reduce fluid oxidation the expansion tank temperature should be kept below 38 °C (100 °F); otherwise an inert gas blanket should be used.

Fluid Maintenance (see Page .20...)

Safe Handling of Santotherm 55 (see Page .21...)

HIGH PERFORMANCE FLUID – SANTOTHERM 66

MAXIMUM BULK OPERATING TEMPERATURE	343°C	650°F
RECOMMENDED MAXIMUM FILM TEMPERATURE	371°C	700°F

Santotherm 66 was developed for use in non-pressurized systems. As a result, the capital costs of a Santotherm 66 system are generally lower than a diphenyl/diphenyl oxide system.

Santotherm 66 can also be used as top-up in liquid phase diphenyl/diphenyl oxide systems. Addition of 15 % of Santotherm 66 will depress the solidification point of the eutectic to around -9°C (15°F).

Santotherm 66 is being used in Europe and the U.S.A. for the following applications:

Resin manufacture
Sodium processing
Phthalic anhydride distillation
Deodourising of fatty acids
Polyamide extruders
Polyethylene manufacture
Waste heat recovery
Polyester manufacture
Insecticide manufacture

HIGH PERFORMANCE FLUID - SANTOTHERM 66

TYPICAL PHYSICAL, CHEMICAL AND THERMAL PROPERTIES

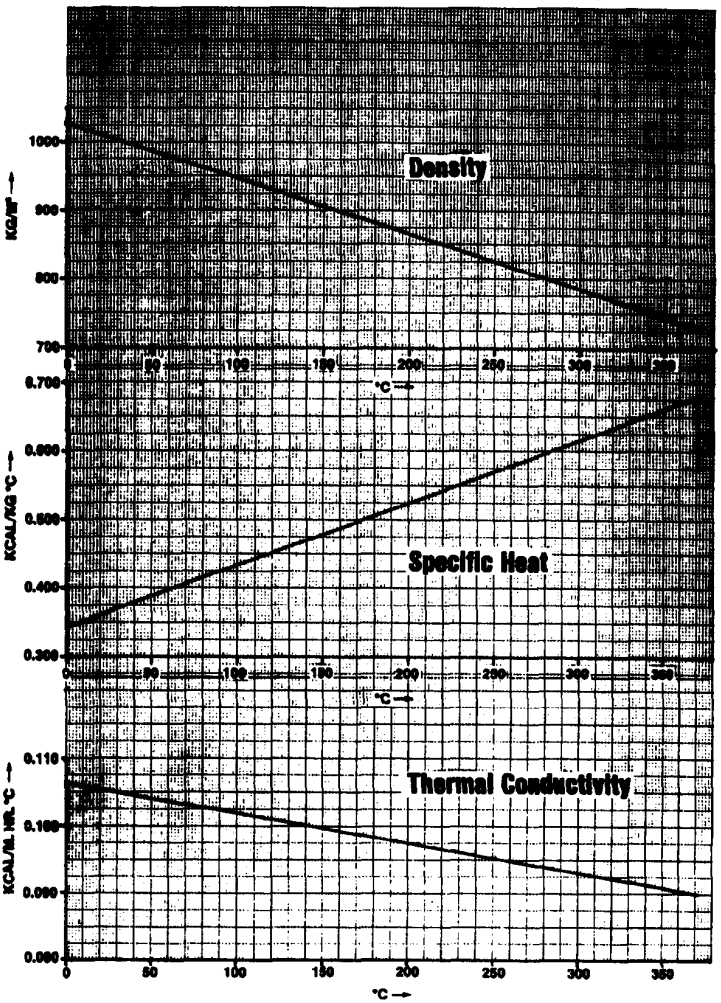
Composition	Synthetic hydrocarbon
Appearance	Oily liquid practically colourless
Odour	faint characteristic
Coefficient of Expansion °C °F	 0.00070 0.00039
Density at 25 °C (77°F) kg/m^3 lb/ft^3	 1005 62.7
Boiling Range °C °F	340 - 396 644 - 745
Pour Point °C °F	- 25 to - 28 -15 to -18
Flash Point, Pensky-Marten (ASTM-D93 - 46) °C °F	 179 - 180 354 - 356
Fire Point (Pensky-Marten) °C °F	190 - 200 374 - 392
Autoignition Temperature °C °F	 374 705
Viscosity at 0°C cS	 800

HIGH PERFORMANCE FLUID - SANTOTHERM 66

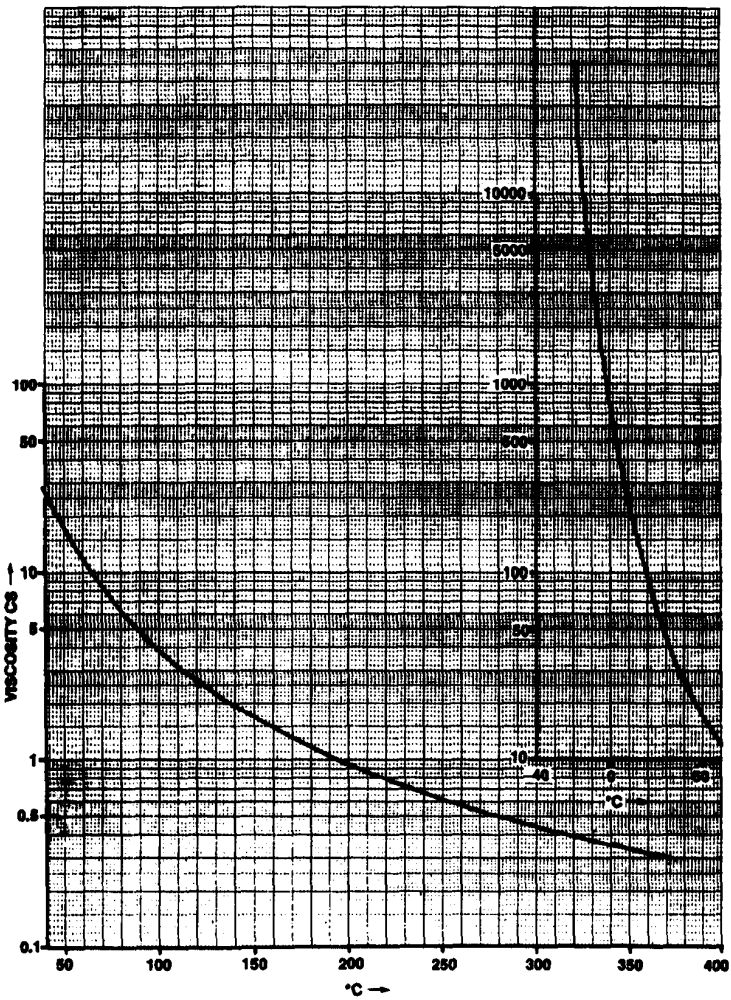
VARIATION OF PROPERTIES WITH TEMPERATURE

Temperature		Density		Specific Heat		Thermal Conductivity		Viscosity			Vapour Pressure	
°F	°C	lb/ft^3	Kg/m^3	BTU/lb. °F	Kcal/Kg. °C	BTU/ft. hr. °F	Kcal/m. hr. °C	lb/hr. ft	cP	cS	mmHg absolute	Kg/cm^2
0		64.9	1040	0.320	0.320	0.0720	0.1072	150000	62000	50000		
50	10	63.6	1020	0.350	0.350	0.0711	0.1058	617	255	250		
100	38	62.4	1000	0.380	0.380	0.0703	0.1046	67.8	28.0	28.0		
150	66	60.9	975	0.405	0.405	0.0695	0.1034	23.6	9.75	10.0		
200	93	59.3	950	0.430	0.430	0.0687	0.1022	10.1	4.18	4.40	0.1	
250	121	58.1	930	0.455	0.455	0.0678	0.1008	5.86	2.42	2.60		
300	149	56.8	910	0.480	0.480	0.0670	0.0997	3.75	1.55	1.70	2.0	0.003
350	177	55.3	885	0.505	0.505	0.0662	0.0985	2.57	1.06	1.20		
400	204	53.7	860	0.530	0.530	0.0653	0.0972	1.86	0.77	0.90	20.0	0.027
450	232	52.5	840	0.555	0.555	0.0645	0.0959	1.40	0.58	0.69	50.0	0.068
500	260	50.5	810	0.580	0.580	0.0637	0.0948	1.09	0.45	0.55	100.0	0.136
550	288	49.5	793	0.605	0.605	0.0628	0.0935	0.87	0.36	0.46	200.0	0.272
600	316	48.1	770	0.630	0.630	0.0620	0.0923	0.82	0.34	0.44	350.0	0.476
650	343	46.8	750	0.655	0.655	0.0613	0.0912	0.65	0.27	0.36	760.0	1.034
700	371	45.6	730	0.680	0.680	0.0605	0.0900	0.48	0.20	0.28	1000	1.360

Santotherm 66 Variation of properties with temperature

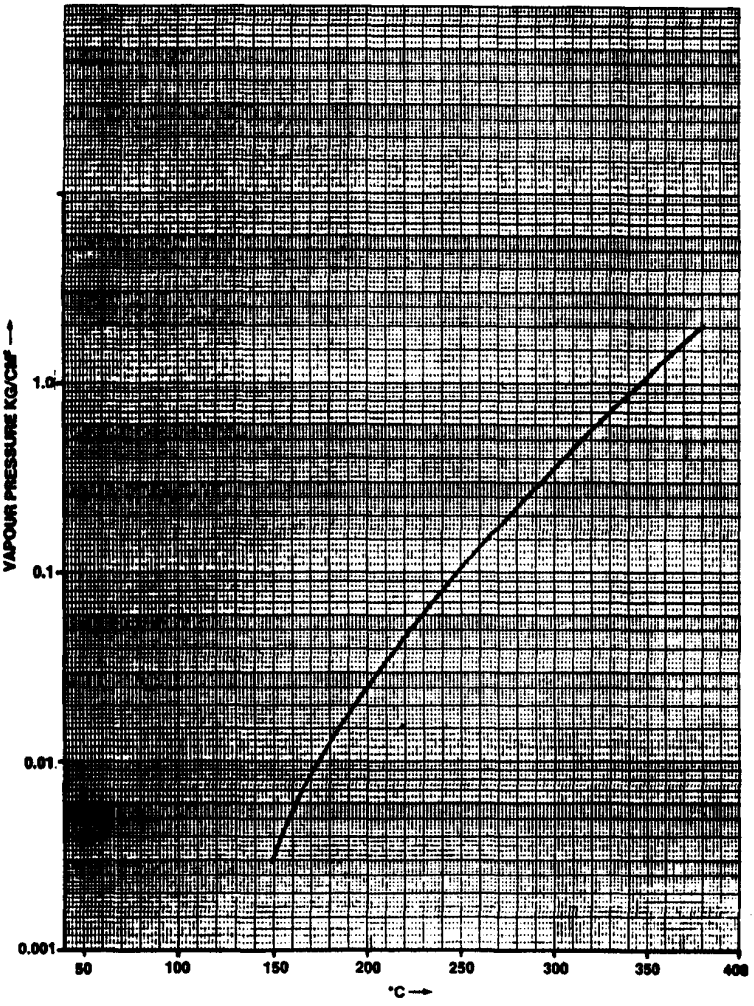


Santotherm 66 Kinematic Viscosity



MONS 095943

Santotherm 66 Vapour Pressure



MONS 095944

HIGH PERFORMANCE FLUID – SANTOTHERM 66

System Design Hints (see also Page 59)

To minimise fluid oxidation Santotherm 66 systems should be blanketed with nitrogen unless the fluid in the expansion tank can be kept below 38°C (100°F).

Copper and its alloys should be used sparingly as materials of construction.

Fluid Maintenance (see Page 20)

Safe Handling of Santotherm 66 (see Page 21)

HIGH PERFORMANCE FLUID – SANTOTHERM 88

MAXIMUM BULK TEMPERATURE	425°C	795°F
RECOMMENDED MAXIMUM FILM TEMPERATURE	435°C	815°F

Santotherm 88 is a fluid for high temperature operation in the liquid phase.

Santotherm 88 is a solid material which melts at 145°C (293°F) to become a thermally stable fluid for use in high temperature chemical processing plant.

Santotherm 88 is the latest addition to the Santotherm range and should be considered for applications at present using molten salt.

HIGH PERFORMANCE FLUID - SANTOTHERM 66

TYPICAL, PHYSICAL CHEMICAL AND THERMAL PROPERTIES

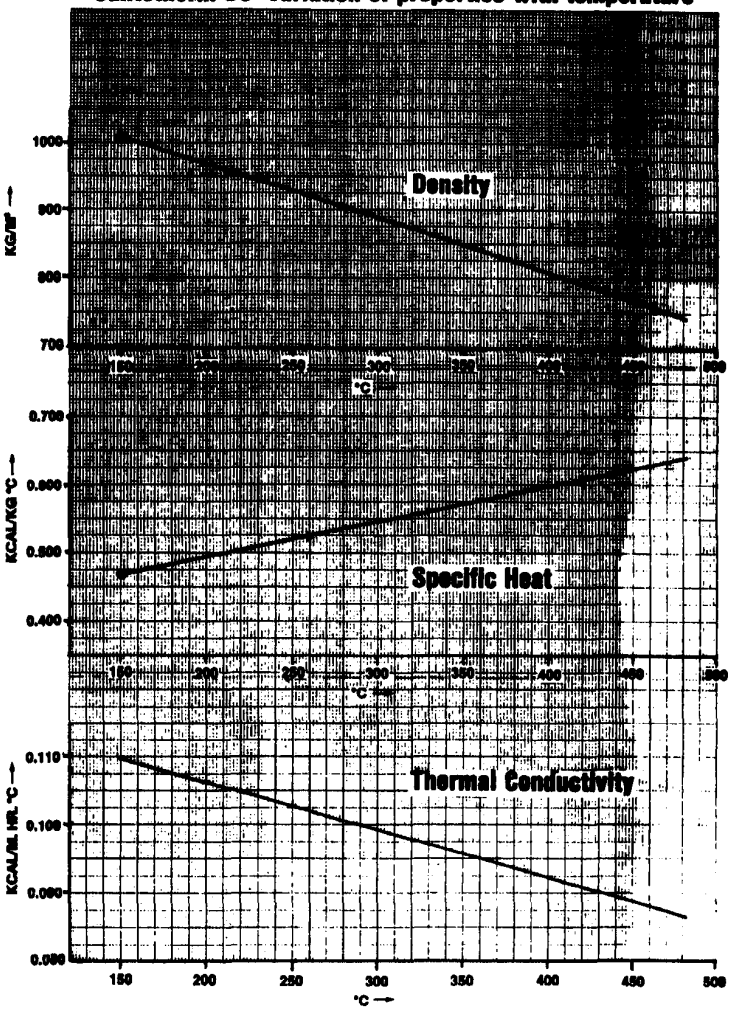
Composition	synthetic hydrocarbon
Appearance	Wax-like flakes at ambient temperature Light amber liquid above melting point.
Odour	faint, pleasant
Coefficient of Expansion ^{o}C ^{o}F	0.00085 0.00047
Density at 25°C (77°F) kg/m^3 lb/ft^3	1133 (solid) 1020 at melt. point 70.7 63.7 (149°C)
Boiling Range ^{o}C ^{o}F	364 - 418 687 - 784
Melting Point begins to soften at ..... completely liquid at	60°C (140°F) 145°C (293°F0
Viscosity at 149 °C 300 °F cS	1.6
Flash Point, Pensky-Marten (ASTM-D93 - 46) ^{o}C ^{o}F	191 375
Fire Point (Pensky-Marten) ^{o}C ^{o}F	238 460
Autoignition Temperature ^{o}C ^{o}F	above 538 above 1000
Latent Heat of Fusion kcal/kg BTU/lb	21.7 - 22.2 39.1 - 40.0

— HIGH PERFORMANCE FLUID - SANTOTHERM 66

VARIATION OF PROPERTIES WITH TEMPERATURE

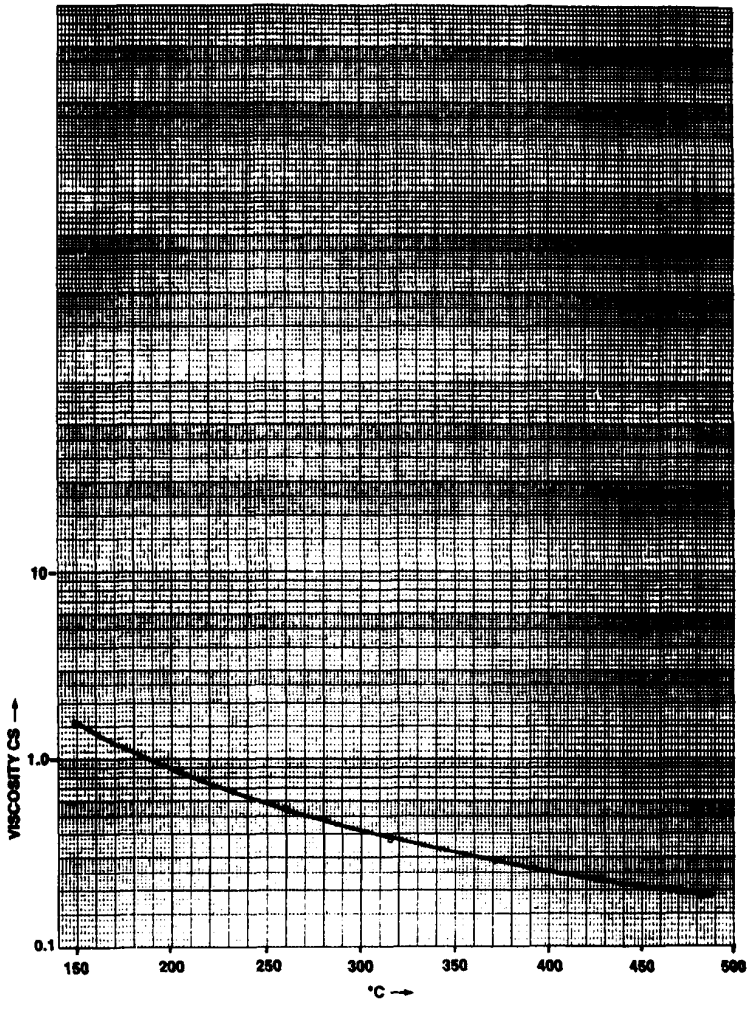
Tempe-rature		Density		Specific Heat		Thermal Conductivity		Viscosity			Vapour Pressure	
°F	°C.	lb/ft³	Kg/m³	BTU/lb. °F	Kcal/Kg. °C	BTU/ft. hr. °F	Kcal/m. hr. °C	lb/hr. ft	cP	cS	mmHg absolute	Kg/cm²
300	149	63.0	1010	0.467	0.467	0.0738	0.1077	3.84	1.585	1.57	1.2	0.00163
400	204	59.9	960	0.497	0.497	0.0712	0.1060	2.20	0.835	0.87	11	0.0150
500	260	57.4	920	0.525	0.525	0.0686	0.1021	1.24	0.506	0.55	65	0.0885
600	316	54.9	880	0.554	0.554	0.0660	0.0982	0.813	0.335	0.38	260	0.354
700	371	51.8	830	0.584	0.584	0.0634	0.0943	0.584	0.241	0.29	800	1.087
800	427	49.3	790	0.613	0.613	0.0608	0.0905	0.440	0.1815	0.23	1500	2.04
900	482	46.2	740	0.642	0.642	0.0581	0.0865	0.341	0.1405	0.19	3000	4.08

Santotherm 88 Variation of properties with temperature



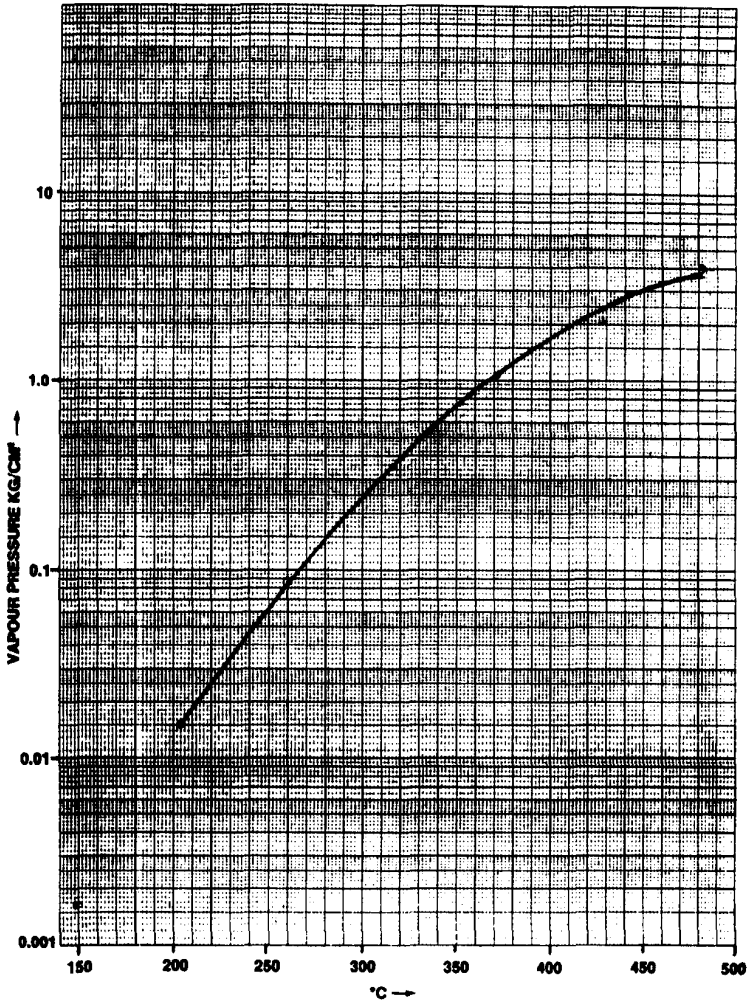
MONS 095949

Santotherm 88 Kinematic Viscosity



MONS 095950

Santotherm 88 Vapour Pressure



MONS 095951

HIGH PERFORMANCE FLUID - SANTOTHERM 88

SOLUBILITY IN MISCELLANEOUS SOLVENTS

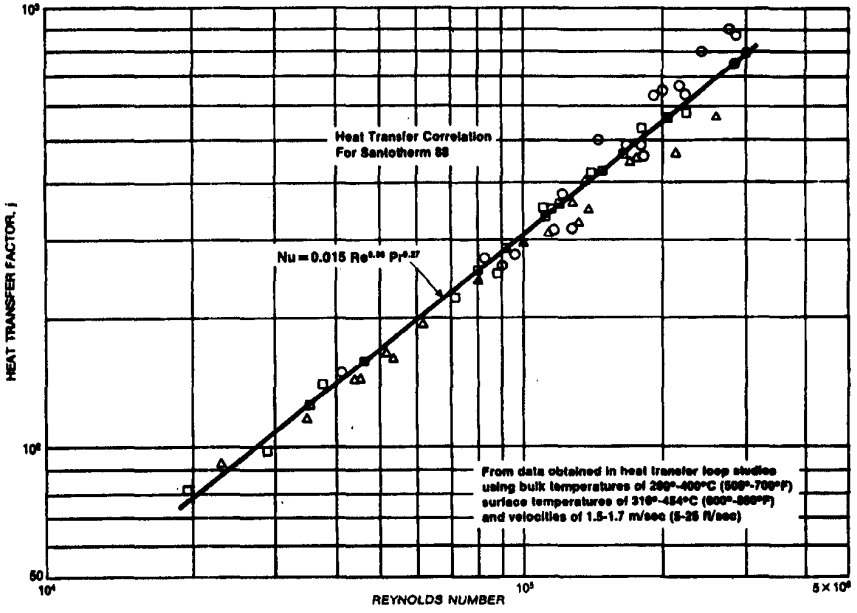
Solvent	Grms. Santotherm 88 per 100 ml. of solvent	
	25° C.	75° C.
3A Alcohol	0.008	0.6
Turpentine	1.2	9.0
Fuel Oil, API 36°, 38 S.U.S. at 100° F	1.66	8.4
Benzene	6.0	42.0
Trichlorobenzene	9.0	45.0
Stoddard's Solvent	0.7	8.0
Nitromethane	0.2	7.5
Nitroethane	2.0	15.0
1-Nitropropane	2.0	20.0
2-Nitropropane	2.0	20.0

HIGH PERFORMANCE FLUID

SANTOTHERM 88

Heat Transfer Correlation

This equation and j-factor plot is adequate to approximately plus/minus 7%



MONS 095953

HIGH PERFORMANCE FLUID - SANTOTHERM 88

System Design Hints (see also Page 59)

A combination drop and pump tank is used to conveniently drain high melting point Santotherm 88 from the system. On shut-down the fluid is drained into the tank which is large enough to contain all the Santotherm 88 fluid in the system. The tank is fitted with heating coils to melt the fluid for start-up.

A submerged pump is used to circulate the molten Santotherm 88 to the user equipment.

Tracing of the external system can be accomplished if necessary with an auxiliary Santotherm system or with high pressure steam. The combination tank can be easily blanketed, filled and vented as required.

Draining the secondary system depends on the fluid used to melt the Santotherm 88 in the drop tank.

Copper and its alloys should not be used as materials of construction.

Fluid maintenance (see Page 20)

Safe Handling (see Page 21)

HIGH PERFORMANCE FLUIDS – SANTOTHERM 55, 66, 88

Fluid Maintenance

Samples of fluid should be taken and tested every 3 months during the first year of operation. Afterwards, 6-monthly sampling is generally sufficient. Analytical procedures are available from Monsanto who will also comment on the results and advise in any corrective action required .

HIGH PERFORMANCE FLUIDS – SANTOTHERM 55, 66, 88

Safe Handling

Both animal toxicity studies and manufacturing and handling experience indicate that no special precautions are required in the handling of these products at ambient temperatures.

Vapours on the other hand whilst not dangerously toxic can rise to discomfort and systems should be made as leak tight as possible.

Repairs to leaks of hot fluid should be carried out under well ventilated conditions.

Section 2

FIRE RESISTANT FLUIDS

Santotherm FR-LO-TEMP

Santotherm FR-O

Santotherm FR-1

Santotherm FR-2

FIRE RESISTANT FLUIDS – SANTOTHERM FR SERIES

Flammability in Heat Transfer Systems

Santotherm FR fluids are fire-resistant. To the design engineer, the factor of "safety" must be weighed as heavily as reliability and efficiency. The "flammability" of industrial fluids for applications such as heat transfer can be defined as the ease of ignition combined with the ability to propagate flame. Many apparent anomalies occur in judging fire resistance unless these two aspects are considered together. Nearly all organic liquids pyrolize or oxidize if exposed long enough to a suffiently high temperature. The tendency is inherent in the type of chemical bonds. Volatile oxidation products can be formed which are flammable. The judgement of a fluid being "fire-resistant" - unless based on a number of applicable and accepted fire resistance tests - can be unfounded and dangerous. Not one test (other than the actual use and proof of safety in a service failure) can indicate the degree of fire resistance of a fluid nor the degree of fire resistance required for a given application.

The fire resistance of Santotherm FR fluids has been evaluated using the following tests

High pressure spray-test
Low pressure spray-test
Hot manifold test
Wick test

Results obtained in these and other tests have enabled Santotherm FR fluids to be listed as fire-resistant by Underwriters Laboratory Inc. USA. and approved by Factory Mutual.

Santotherm FR fluids are recommended for use whenever the risk of fire has to be minimised.

FIRE RESISTANT FLUID – SANTOTHERM FR-LO-TEMP

MAXIMUM BULK TEMPERATURE	205°C	400°F
RECOMMENDED MAXIMUM FILM TEMPERATURE	316°C	600°F

Santotherm FR-LO-TEMP can be used in a wide range of applications such as space heating and cooling, gas processing and distribution and industrial heating/cooling under conditions of low ambient temperature. A recent application is marine heating in Arctic conditions.

FIRE RESISTANT FLUID - SANTOTHERM FR-LO-TEMP

TYPICAL PHYSICAL, CHEMICAL AND THERMAL PROPERTIES

Composition	Chlorinated hydrocarbons
Appearance	Pale, yellowish liquid
Odour	characteristic
Coefficient of Expansion ^{o}C ^{o}F	 0.000513 0.000285
Density at 25 ^{o}C (77 ^{o}F) kg/m^3 lb/ft^3	 1440 89,9
Boiling Range ^{o}C ^{o}F	 222 - 331 432 - 627
Pour Point ^{o}C ^{o}F	 -51 -60
Flash Point, Pensky-Marten (ASTM-D93 - 46) ^{o}C ^{o}F	 138 280
Fire Point (Pensky-Marten) ^{o}C ^{o}F	 None to boiling
Autoignition Temperature ^{o}C ^{o}F	 over 593 over 1,100
Viscosity at 0 ^{o}C cS	 16

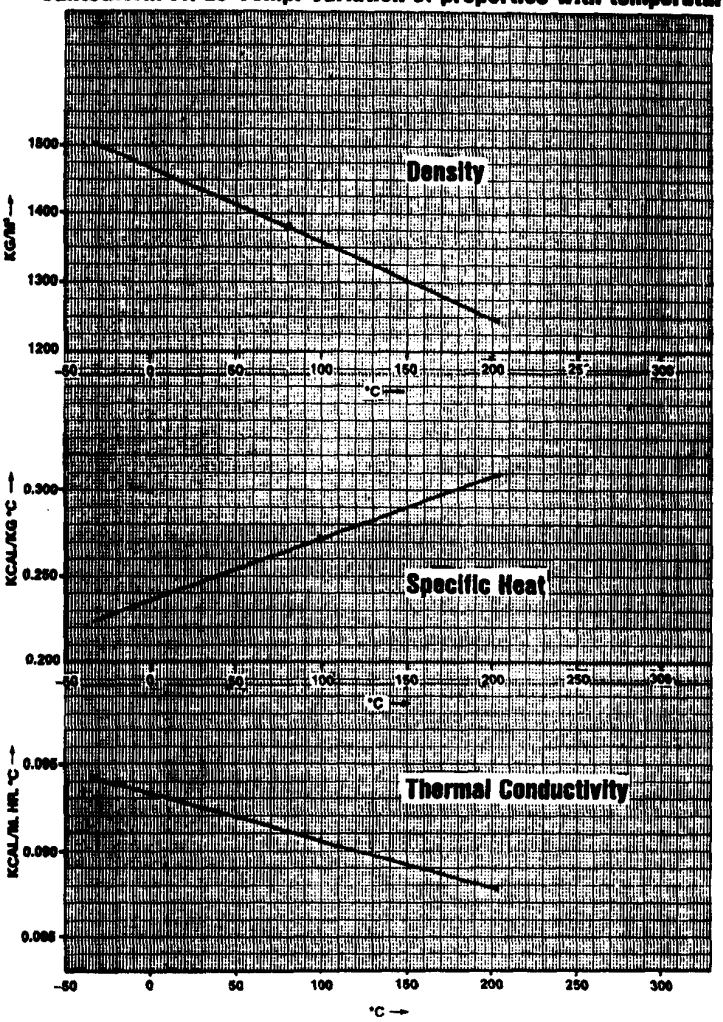
MONS 095961

FIRE RESISTANT FLUID - SANTOTHERM FR-LO-TEMP

VARIATION OF PROPERTIES WITH TEMPERATURE.

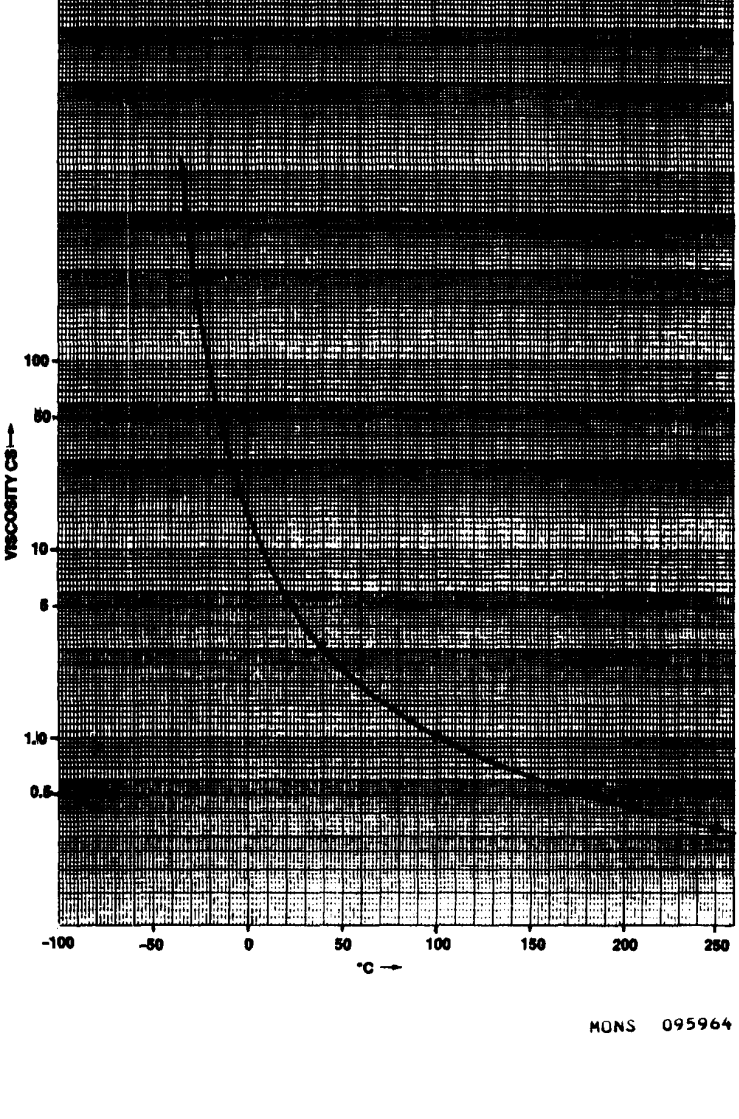
Temperature		Density		Specific Heat		Thermal Conductivity		Viscosity			Vapour Pressure	
°F	°C	lb/ft^3	Kg/m^3	BTU/lb. °F	Kcal/Kg. °C	BTU/ft.hr. °F	Kcal/m.hr. °C	lb/hr.ft	cP	cS	mmHg absolute	$Kg\ cm^2$
-30	-34	93.9	1505.1	0.224	0.224	0.0633	0.0942	2400	991	658	-	
-20	-29	93.5	1498.5	0.226	0.226	0.0632	0.0940	958	396	264	-	
0	-18	92.8	1487.0	0.230	0.230	0.0630	0.0937	234	96.6	65	-	
40	4	91.2	1463.0	0.238	0.238	0.0626	0.0931	43.1	17.8	12.2	1.1	0.0015
100	38	89.0	1426.0	0.250	0.250	0.0620	0.0922	11.7	4.83	3.39	2.7	0.0037
200	93	85.3	1366.5	0.270	0.270	0.0610	0.0907	3.80	1.57	1.15	12.6	0.0171
300	149	81.5	1306.0	0.290	0.290	0.0600	0.0892	2.06	0.85	0.65	69	0.094
400	204	77.8	1246.0	0.310	0.310	0.0590	0.0878	1.38	0.57	0.46	300	0.408

Santotherm FR-Lo-Temp. Variation of properties with temperature



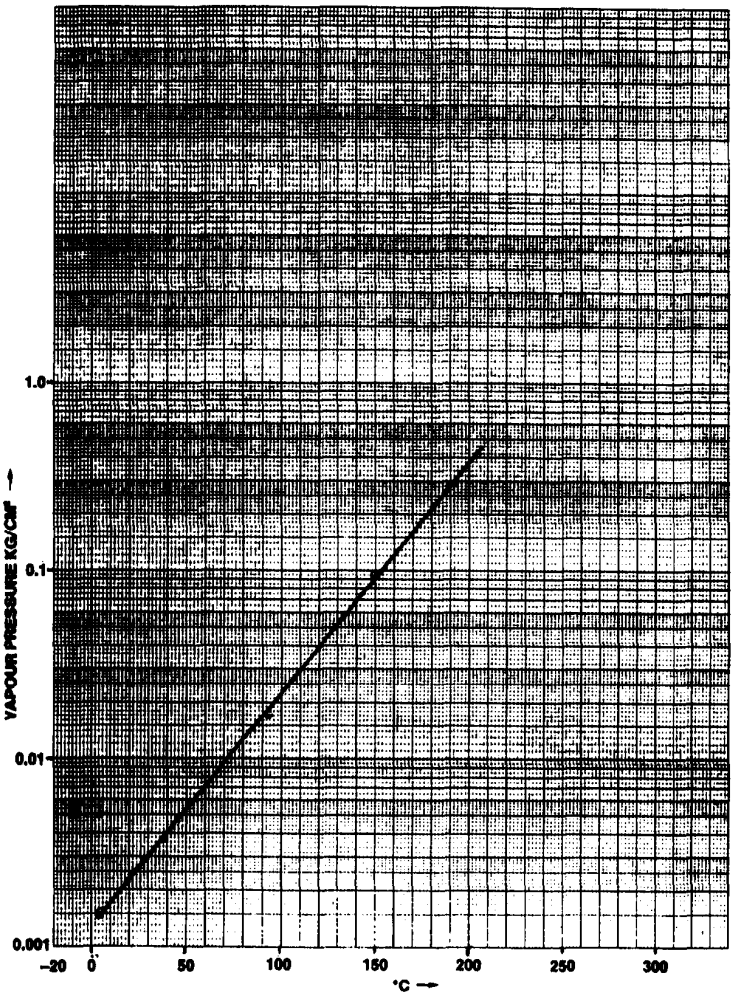
MONS 095963

Santotherm FR-Lo-Temp. Kinematic Viscosity



MONS 095964

Santotherm FR-Lo-Temp. Vapour Pressure



FIRE RESISTANT FLUID – SANTOTHERM FR-LO-TEMP

System Design Hints (see page ..39..)

Fluid Maintenance (see page ..40..)

Safe Handling (see page ..41..)

FIRE RESISTANT FLUID – SANTOTHERM FR-0

MAXIMUM BULK TEMPERATURE	260°C	500°F
RECOMMENDED MAXIMUM FILM TEMPERATURE	316°C	600°F

Santotherm FR-0 was developed specifically to eliminate freeze-up during cold weather shut down for in-transit heating of sulphur, pitch, asphalt, naphthalene, heavy fuel oil and high melting point resin materials. Santotherm FR-0 eliminates the need for high temperature reheating in order to pump out the material at its destination.

FIRE RESISTANT FLUID - SANTOTHERM FR-0

TYPICAL PHYSICAL, CHEMICAL AND THERMAL PROPERTIES

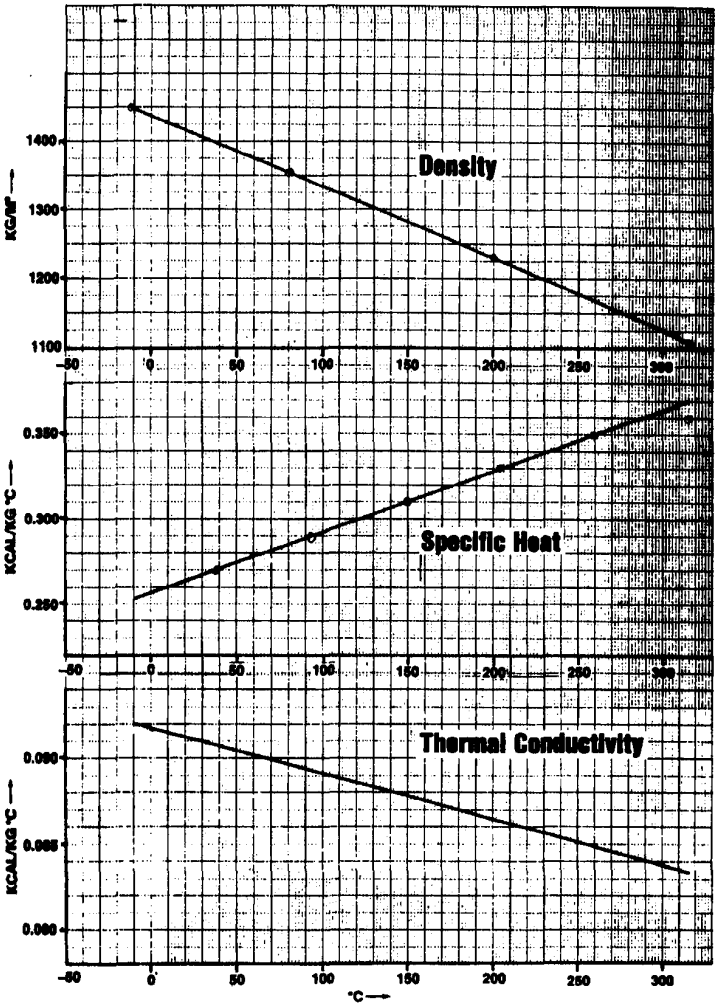
Composition	Chlorinated, hydro-carbons
Appearance	Pale, yellowish liquid
Odour	Characteristic
Coefficient of Expansion ^{o}C ^{o}F	0.000415 0.00023
Density at 25 ^{o}C (77 ^{o}F) kg/m^3 lb/ft^3	1410 88.0
Boiling Range ^{o}C ^{o}F	271 - 324 520 - 615
Pour Point ^{o}C ^{o}F	- 26 - 15
Flash Point, Pensky-Marten (ASTM-D93 - 46) ^{o}C ^{o}F	151 305
Fire Point (Pensky-Marten) ^{o}C ^{o}F	None to boiling
Autoignition Temperature ^{o}C ^{o}F	Over 649 Over 1,200
Viscosity at 0 ^{o}C cS	130

FIRE RESISTANT FLUID - SANTOTHERM FR-O

VARIATION OF PROPERTIES WITH TEMPERATURE

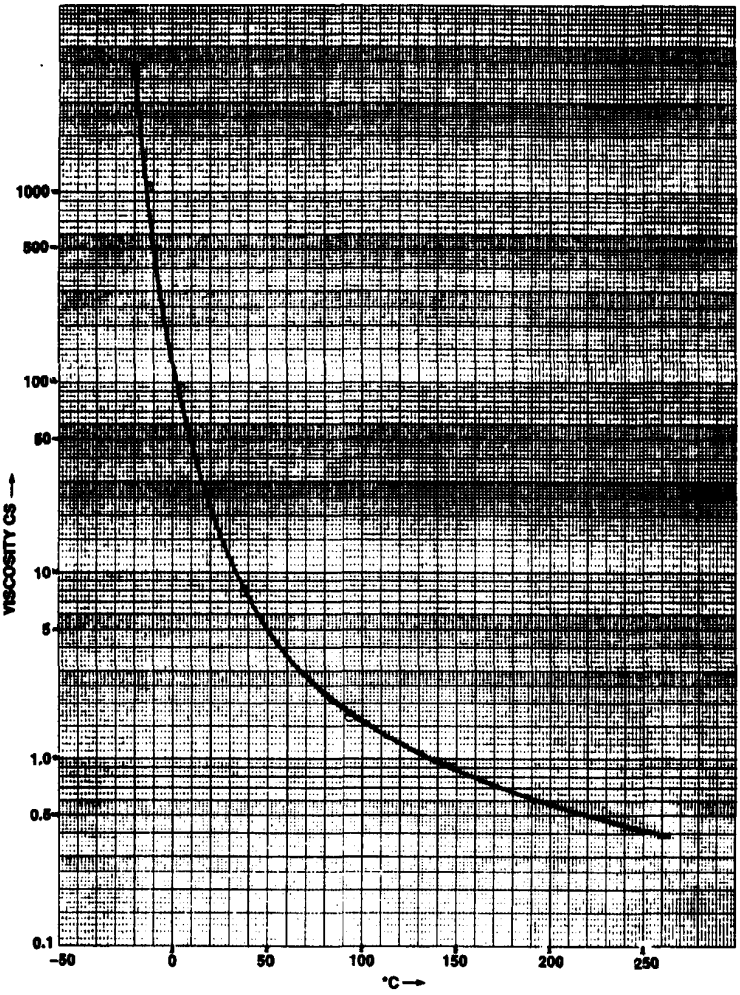
Temperature		Density		Specific Heat		Thermal Conductivity		Viscosity			Vapour Pressure	
°F	°C	lb/ft^3	Kg/m^3	BTU/lb. °F	Kcal/Kg. °C	BTU/ft. hr. °F	Kcal/m. hr. °C	lb/hr. ft	cP	cS	mmHg absolute	$Kg\ cm^2$
- 5	-21	-	-	-	-	-	-	-	-	4545	-	-
410	-12	90.5	1449.6	-	-	-	-	3533	1460	1007	-	-
40	4	89.2	1428.0	-	-	-	-	320	132.2	92.55	-	-
100	38	87.5	1401.7	0.27	0.27	0.061	0.091	27.6	11.4	8.10	-	-
200	93	83.7	1340.6	0.29	0.29	0.060	0.089	5.6	2.3	1.70	1.35	0.0018
300	149	80.0	1280.7	0.31	0.31	0.059	0.088	2.9	1.2	0.95	13.00	0.0177
400	204	76.8	1230.4	0.33	0.33	0.058	0.086	-	-	-	76.00	0.1034
500	260	73.0	1169.3	0.35	0.35	0.057	0.085	-	-	-	315	0.4284
600	316	69.3	1110.6	0.36	0.36	0.056	0.083	-	-	-	915	1.2444

Santotherm FR-O Variation of properties with temperature



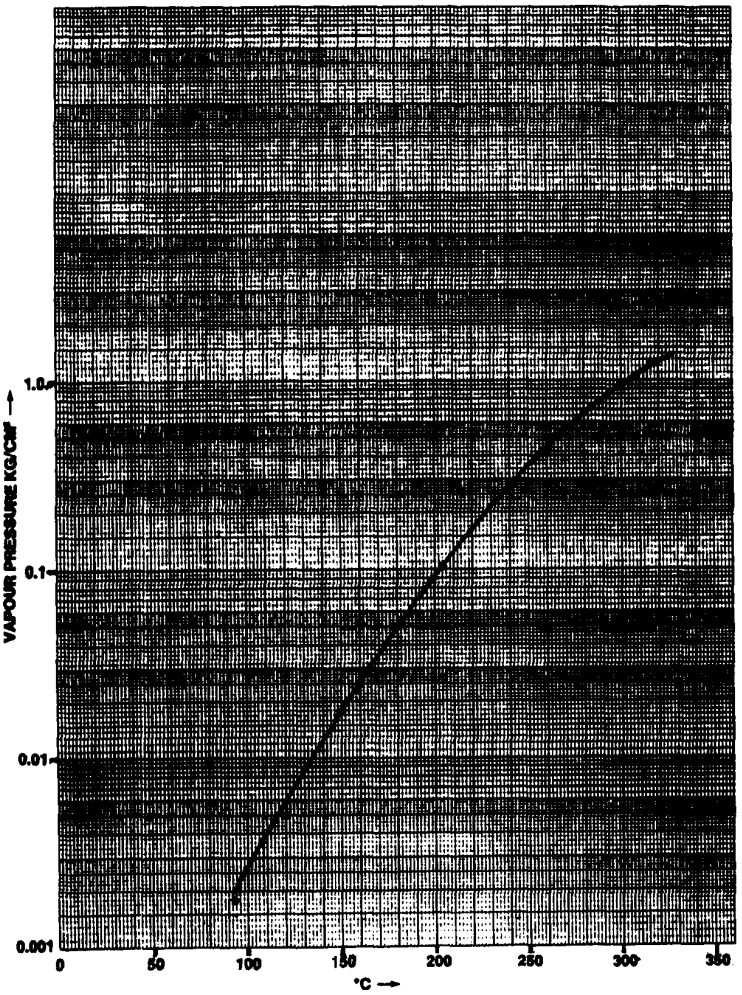
MONS 095970

Santotherm FR-0 Kinematic Viscosity



MONS 095971

Santotherm FR-0 Vapour Pressure



MONS 095972

FIRE RESISTANT FLUID – SANTOTHERM FR-O

System Design Hints (see Page ...39..)

Fluid Maintenance (see Page ..40.)

Safe Handling (see Page ..41.)

FIRE RESISTANT FLUID – SANTOTHERM FR-1

MAXIMUM BULK TEMPERATURE	315°C 600°F
RECOMMENDED MAXIMUM FILM TEMPERATURE	340°C 644°F

Santotherm FR-1 is a general purpose fire-resistant fluid. It is being used in Europe and the U.S.A. for the following applications :

Copper concentration	Solvent recovery
Mould heating	Wax coating
Resin reactors	Space heating
Bitumen coating	Asphalt heating
Plywood presses	Drying ovens
Calendering rolls	Maleic anhydrid production
Rotational moulding	Oil additive production
Thin film processors	Rubber chemicals production
Glycol dehydration	

FIRE RESISTANT FLUID - SANTOTHERM FR-1

TYPICAL PHYSICAL, CHEMICAL AND THERMAL PROPERTIES

Composition	Chlorinated, aromatic hydrocarbons
Appearance	liquids
Odour	characteristic
Coefficient of Expansion ^{o}C ^{o}F	 0.00056 0.00031
nsity at 25 ^{o}C ($77^{o}F$) kg/m^3 lb/ft^3	 1385 85.5
Boiling Range ^{o}C ^{o}F	 327 - 360 620 - 680
Pour Point ^{o}C ^{o}F	 -19 2.2
Flash Point, Pensky-Marten (ASTM-D93 - 46) ^{o}C ^{o}F	 177 350
Fire Point (Pensky-Marten) ^{o}C ^{o}F	 None to boiling
Autoignition Te mperature ^{o}C ^{o}F	 652 1,206
Viscosity at $0^{o}C$ cS	 2,500

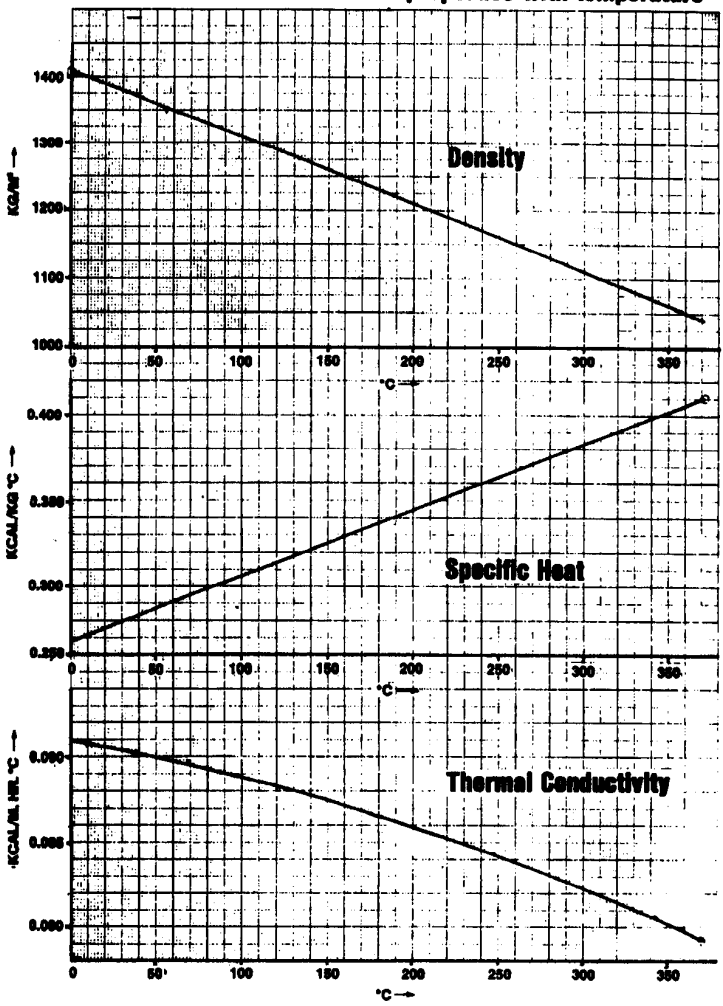
MONS 095975

FIRE RESISTANT FLUID - SANTOTHERM FR-1

VARIATION OF PROPERTIES WITH TEMPERATURE

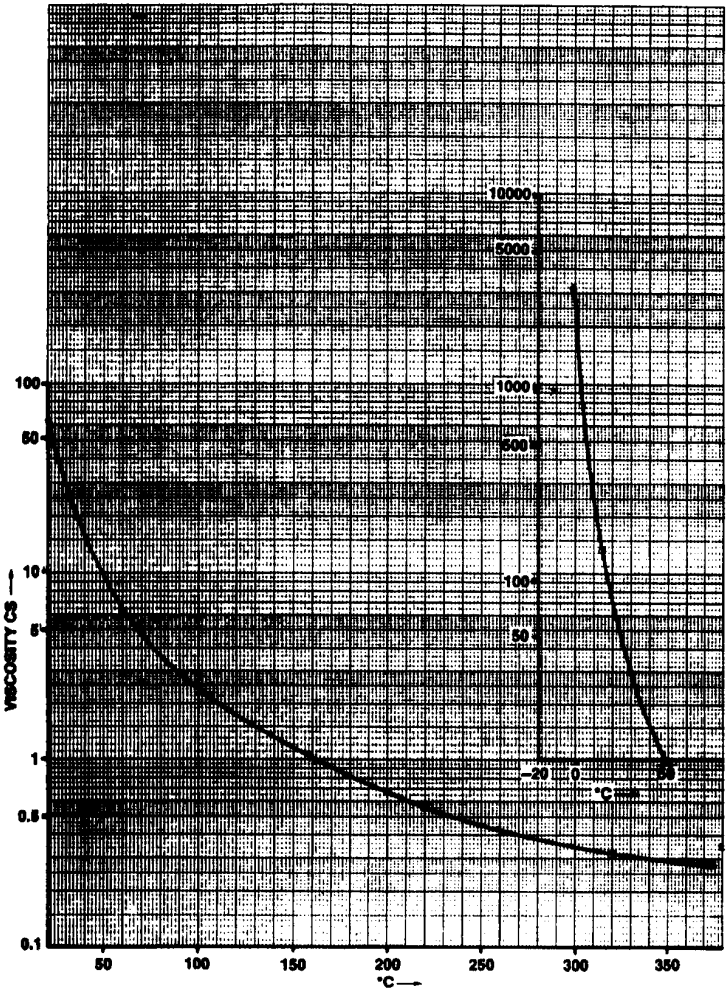
Temperature		Density		Specific Heat		Thermal Conductivity		Viscosity			Vapour Pressure	
°F	°C	lb/ft^3	Kg/m^3	BTU/lb. °F	Kcal/Kg. °C	BTU/ft. hr. °F	Kcal/m. hr. °C	lb/hr. ft	cP	cS	mmHg absolute	Kg/cm^2
50	10	87.4	1399.6	0.272	0.272	0.06098	0.0907	745.36	308	220	-	-
100	38	85.7	1372.7	0.282	0.282	0.06060	0.0902	56.144	23.2	16.9	-	-
150	66	83.9	1343.7	0.291	0.291	0.06021	0.0896	15.972	6.6	4.9	-	-
200	93	82.2	1316.7	0.3047	0.3047	0.05976	0.0889	8.2431	3.4	2.6	-	-
250	121	80.5	1289.1	0.3151	0.3151	0.05927	0.0882	5.5270	2.3	1.8	-	-
300	149	78.7	1261.3	0.3255	0.3255	0.05875	0.0874	3.4158	1.4	1.1	-	-
350	177	77.0	1233.5	0.3359	0.3359	0.05819	0.0866	2.4753	1.0	0.8	10	0.0136
400	204	75.3	1205.8	0.3464	0.3464	0.05760	0.0857	1.8698	0.8	0.7	27	0.0367
450	232	73.5	1178.0	0.3568	0.3568	0.05697	0.0848	1.5028	0.6	0.5	65	0.0884
500	260	71.8	1150.2	0.3672	0.3672	0.05630	0.0838	1.2351	0.5	0.4	143	0.1945
550	288	70.1	1122.5	0.3776	0.3776	0.05560	0.0827	1.0428	0.4	0.4	291	0.3958
600	316	68.3	1094.7	0.3880	0.3880	0.05487	0.0817	0.90031	0.4	0.3	550	0.7480
650	343	66.6	1066.9	0.3985	0.3985	0.05409	0.0805	0.79186	0.3	0.3	18.8psia	1.3218
700	371	64.9	1039.3	0.4089	0.4089	0.05329	0.0793	0.70731	0.3	0.3	31.9psia	2.2429

Santotherm FR-1 Variation of properties with temperature



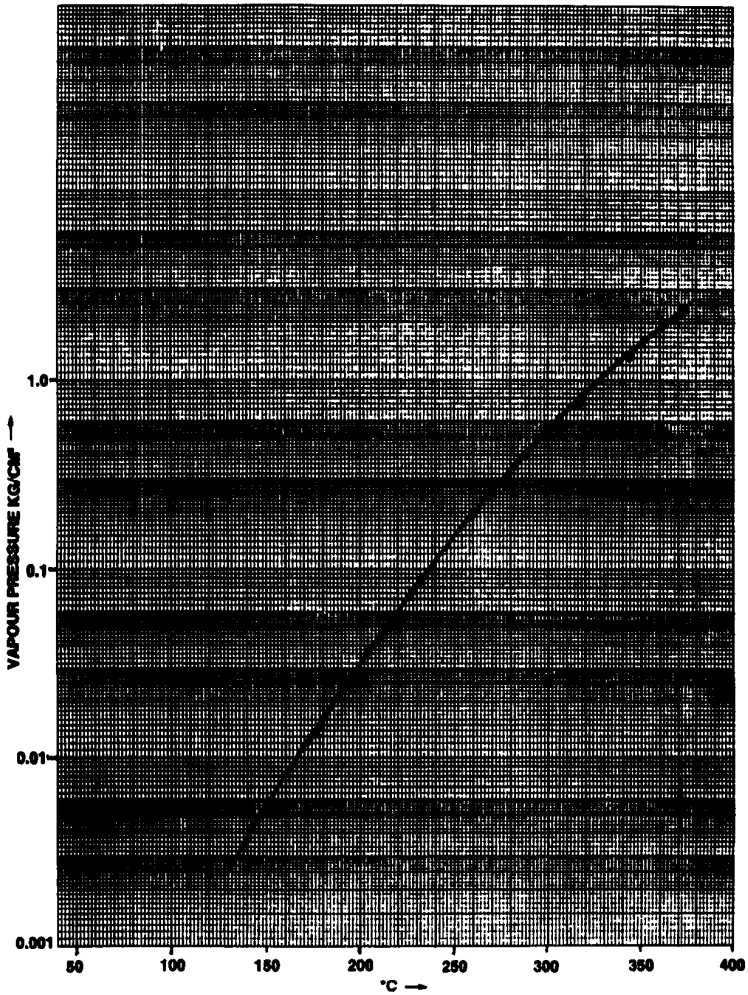
MONS 095977

Santotherm FR-1 Kinematic Viscosity



MONS 095978

Santotherm FR-1 Vapour Pressure



MONS 095979

FIRE RESISTANT FLUID – SANTOTHERM FR-1

Systems Design Hints (see Page ..39..)

Fluid Maintenance (see Page .40...)

Safe Handling (see Page .41...)

FIRE RESISTANT FLUID – SANTOTHERM FR-2

MAXIMUM BULK TEMPERATURE	315°C	600°F
RECOMMENDED MAXIMUM FILM TEMPERATURE	340°C	644°F

This fluid is suitable for continuous processing operation without shut downs. It has the benefit of a lower vapour pressure at the maximum operating temperature.

FIRE RESISTANT FLUID - SANTOTHERM FR-2

TYPICAL PHYSICAL, CHEMICAL AND THERMAL PROPERTIES

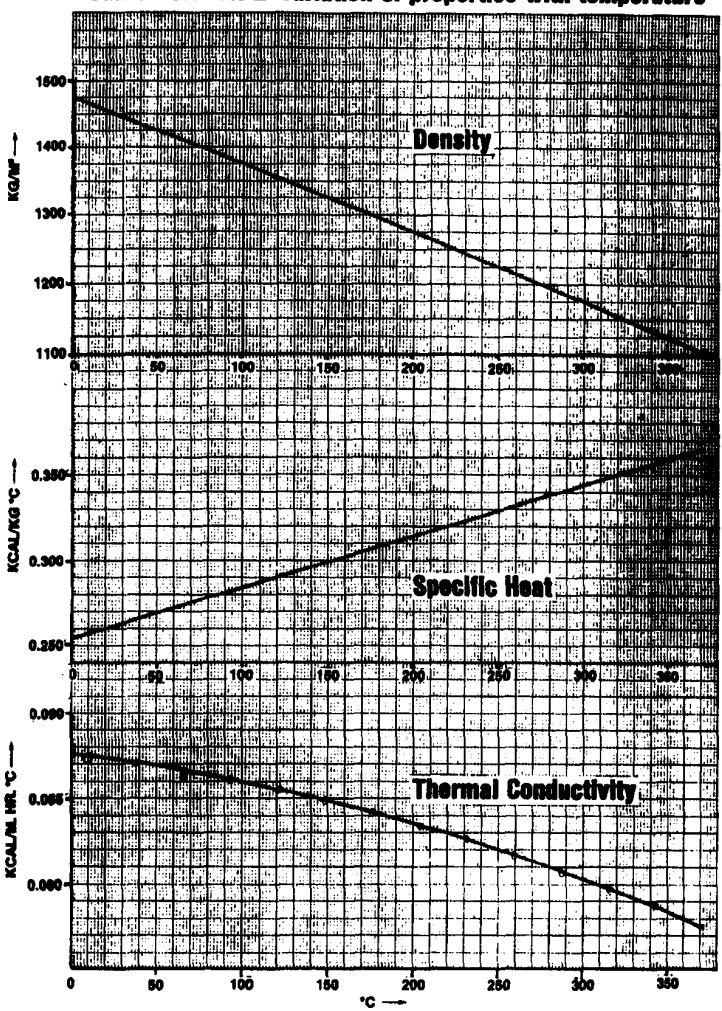
Composition		Chlorinated aromatic hydrocarbons
Appearance		Pale yellow liquid
Odour		Characteristic
Coefficient of Expansion	per °C per °F	0.00052 0.00029
Density at 25°C (77°C)	kg/m3 lb/ft3	1,450 90.5
Distillation Range	°C °F	343-375 650-707
Pour Point	°C °F	-7 19.4
Viscosity at O°C	cS	10,000
Flash Point, Pensky-Marten Closed cup ASTM-D93 - 46	°C °F	196 385
Fire Point, Pensky-Marten Closed cup ASTM-D93 - 46	°C °F	None to boiling
Auto-ignition Temperature	°C °F	672 1243

FIRE RESISTANT FLUID - SANTOTHERM FR-2

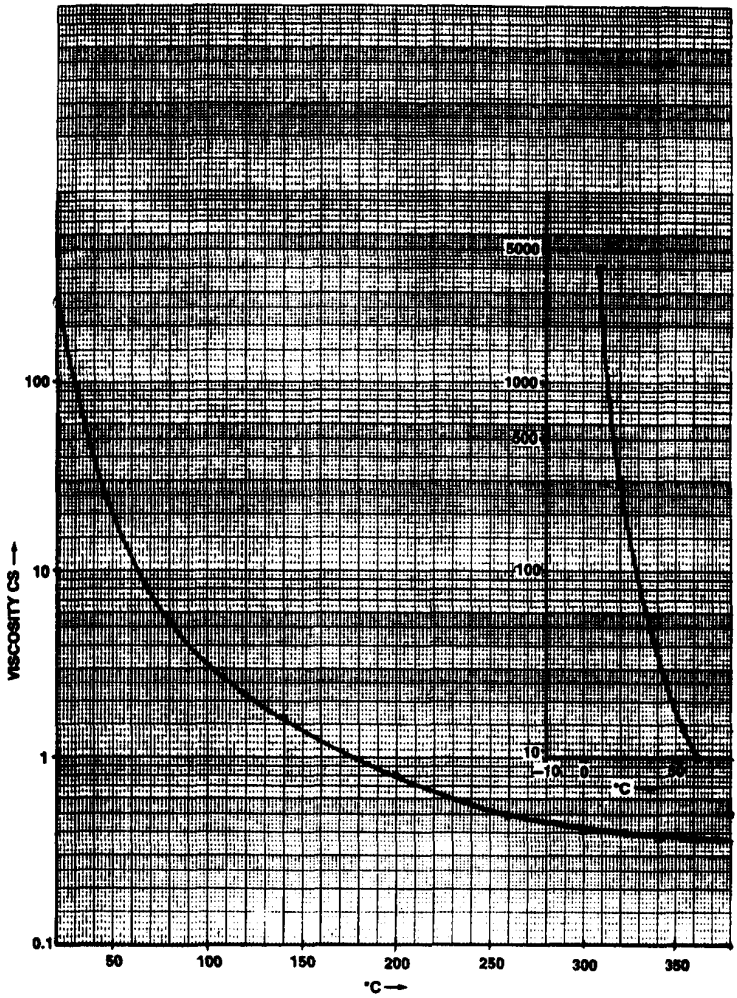
VARIATION OF PROPERTIES WITH TEMPERATURE

Temperature		Density		Specific Heat		Thermal Conductivity		Viscosity			Vapour Pressure	
°F	°C	lb/ft^3	Kg/m^3	BTU/lb. °F	Kcal/Kg. °C	BTU/ft. hr. °F	Kcal/m. hr. °C	lb/hr. ft	cP	cS	mmHg absolute	Kg/cm^2
50	10	91.4	1464.6	0.257	0.257	0.05881	0.0875	7090.6	2928	1999	-	-
100	38	89.8	1437.6	0.265	0.265	0.05852	0.0871	151.01	62.4	43.4	-	-
150	66	87.8	1407.7	0.274	0.274	0.05801	0.0863	27.83	11.5	8.2	-	-
200	93	86.2	1380.7	0.2840	0.2840	0.05788	0.0861	11.971	4.9	3.6	-	-
250	121	84.5	1352.9	0.2922	0.2922	0.05748	0.0855	6.949	2.9	2.1	-	-
300	149	82.7	1325.2	0.3003	0.3003	0.05703	0.0849	4.531	1.9	1.4	-	-
350	177	81.0	1297.4	0.3084	0.3084	0.05655	0.0842	3.201	1.3	1.0	6	0.0082
400	204	79.3	1269.6	0.3166	0.3166	0.05603	0.0834	2.399	1.0	0.8	15	0.0204
450	232	77.5	1242.0	0.3247	0.3247	0.05548	0.0826	1.881	0.8	0.6	37	0.0503
500	260	75.8	1214.2	0.3328	0.3328	0.05488	0.0817	1.529	0.6	0.5	84	0.1142
550	288	74.1	1186.4	0.3410	0.3410	0.05424	0.0807	1.2795	0.5	0.4	173	0.2353
600	316	72.3	1158.7	0.3491	0.3491	0.05357	0.0797	1.0971	0.5	0.4	340	0.4624
650	343	70.6	1130.9	0.3573	0.3573	0.05286	0.0787	0.9596	0.4	0.4	615	0.8364
700	371	68.9	1103.1	0.3654	0.3654	0.05211	0.0775	0.8535	0.4	0.4	20.3 psia	1.4273

Santotherm FR-2 Variation of properties with temperature

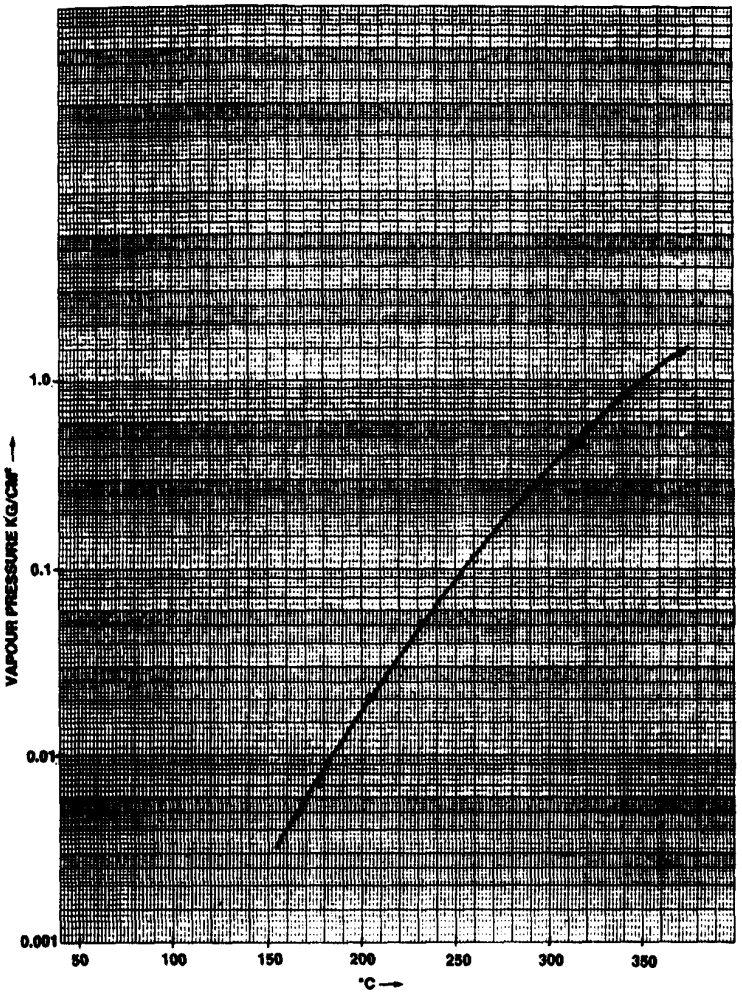


Santotherm FR-2 Kinematic Viscosity



MONS 095985

Santotherm FR-2 Vapour Pressure



MONS 095986

FIRE RESISTANT FLUID – SANTOTHERM FR - SERIES

System Design Hints

A good system design allows for the rapid removal of low boiling materials and moisture from the system.

Moisture is automatically removed if the expansion tank and vent pipe are kept at over 100°C and we suggest that the expansion tank is kept at 105/110°C. This is most easily done by taking a bore line from the heater outlet direct to the expansion tank.

In the case of systems operating intermittently this small bore line will in some cases be insufficient to bring the expansion tank up to temperature rapidly and we recommend circulating the bulk of the fluid through the expansion tank at start-up.

Santotherm FR fluids are oxidation-resistant and an inert gas blanket is not required - in fact it would interfere with the continuous venting of the system described above.

The vent pipe from the expansion tank should be of generous diameter and be taken outside the building; it should preferably be lined with a corrosion-resistant material e.g. teflon as the combination of moisture and the low boiling degradation products of Santotherm FR fluids are corrosive at ambient temperatures.

Lagging of the vent pipe is recommended as is the fitting of a device to prevent direct ingress of water.

A vapour separator should not be necessary as the procedures outlined above allows for venting of the system.

FIRE RESISTANT FLUID - SANTOTHERM FR - SERIES

Fluid Maintenance

The fluid should be analysed within 24 hours of start up and every 3 months for the first year of operation.

Afterwards, sampling once every 6 months is generally sufficient. Analytical procedures are available from Monsanto who will also comment and advise in any corrective action required.

FIRE RESISTANT FLUIDS - SANTOTHERM FR-SERIES

Safe Handling

On the basis of animal toxicity studies, Santotherm FR fluids may be considered only slightly toxic from the standpoint of accidental massive skin exposure or accidental ingestion. Similarly, single exposures to high concentration of vapours (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 vapour concentrations precludes voluntary exposure. Repeated or prolonged skin exposure should be avoided since Santotherm FR fluids act 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 exposure to paint thinners. More important, Santotherm FR fluids may be absorbed if 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 their low vapour pressure, there is no significant vapour inhalation hazard when Santotherm FR fluids are at room temperature For example there is no vapour exposure problem while transferring the fluid from its shipping container to the heat transfer system. On the other hand, the vapours emitted by Santotherm FR fluids heated to elevated temperatures are injurious on prolonged exposure. It is indicated that the "threshold limit value" or atmospheric vapour concentration which cannot be safely exceeded (on a daily basis) is 0.5 - 1.0 milligrams of Santotherm FR vapour 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 vapours.

It should also be noted that Santotherm FR fluids contain chemical compounds of extreme stability which will persist in the environment if allowed to escape. Pollution of the environment must be prevented by good system design and construction so that leakages and spillages are minimised and any that occur are contained and collected. Salvaged Santotherm FR fluids should be returned to Monsanto for redamation or disposal. Do not dispose of waste Santotherm FR into drains or sewers

Section 3

SPECIAL PURPOSE FLUIDS

Santotherm 77

Santotherm 130

Santotherm 190

SPECIAL PURPOSE FLUID - SANTOTHERM 77

MAXIMUM BULK TEMPERATURE	370°C	700°F
RECOMMENDED MAXIMUM FILM TEMPERATURE	410°C	770°F

Santotherm 77 has been used for several years in commercial scale and pilot plant systems in a diversity of applications: e.g. paint and resin manufacture, high-temperature plastic extrusion, lamination of plastics, chemical processing, laboratory baths and thermostatic devices.

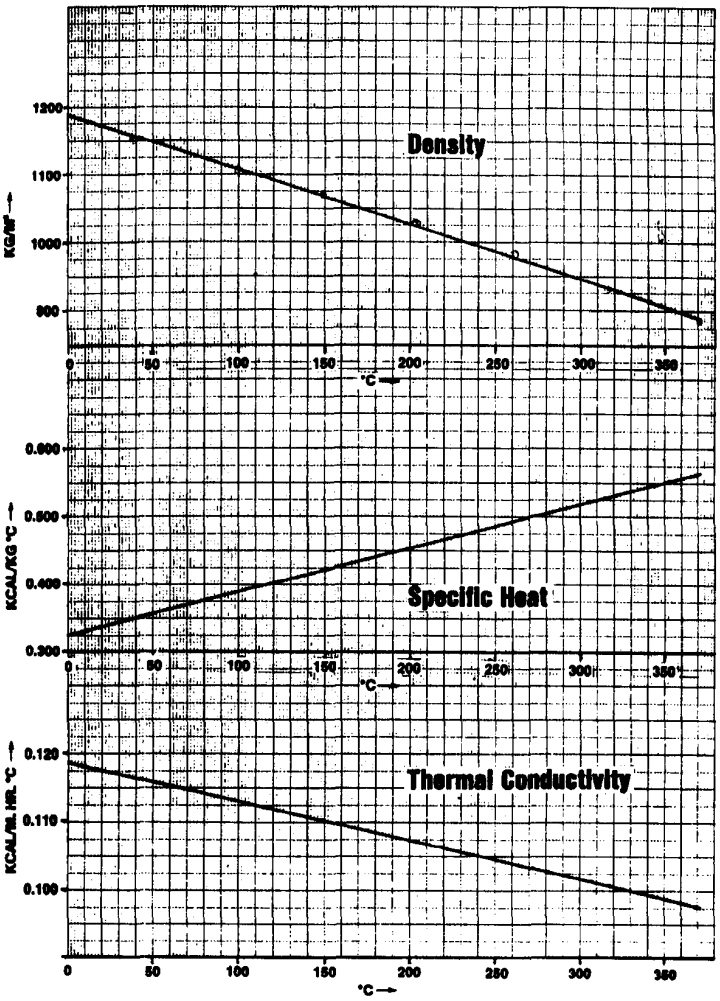
SPECIAL PURPOSE FLUID - SANTOTHERM 77

TYPICAL PHYSICAL, CHEMICAL AND THERMAL PROPERTIES

Composition	Aromatic Ether
Appearance	Oily liquid
Odour	faintly phenolic
Coefficient of Expansion °C °F	 0.00061 0.00034
Density at 25 °C (77°F) kg/m^3 lb/ft^3	 1165 72.7
Boiling Range °C °F	 Approx. 443 Approx. 830
Pour Point °C °F	 7 45
Flash Point, Pensky-Marten (ASTM-D93 - 46) °C °F	 238 460
Fire Point (Pensky-Marten) °C °F	 282 540
Autoignition Temperature °C °F	 318 605
Viscosity at 0°C cS	 -

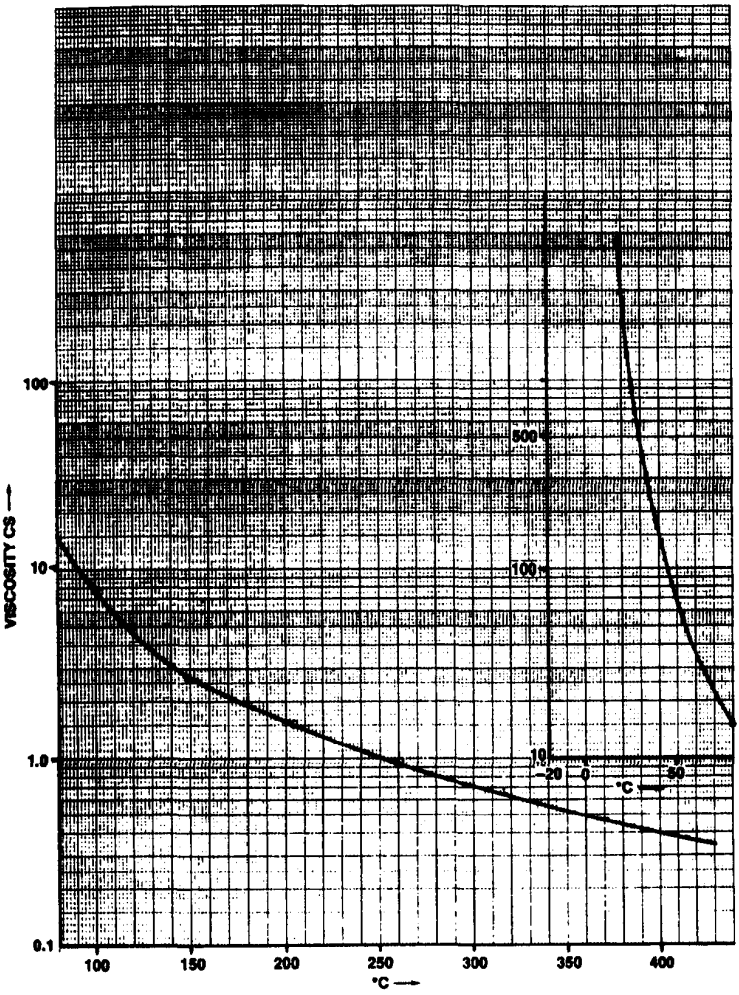
MONS 095994

Santotherm 77 Variation of properties with temperature



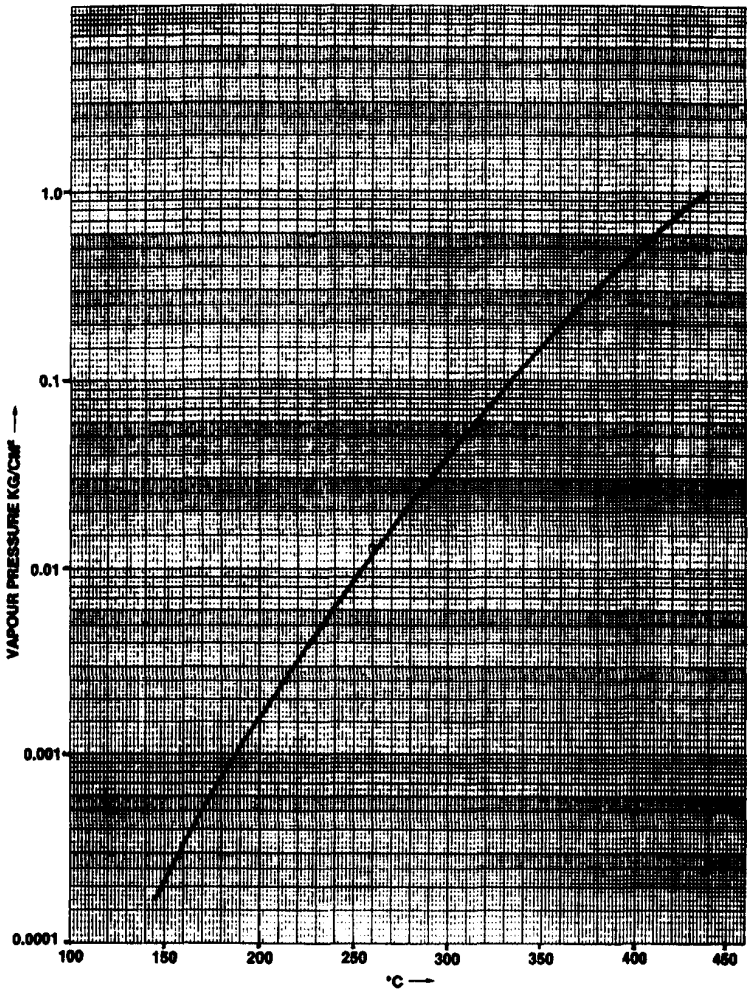
MONS 095995

Santotherm 77 Kinematic Viscosity



MONS 095996

Santotherm 77 Vapour Pressure



MONS 095997

SPECIAL PURPOSE FLUID - SANTOTHERM 77

VARIATION OF PROPERTIES WITH TEMPERATURE

Temperature		Density		Specific Heat		Thermal Conductivity		Viscosity			Vapour Pressure	
°F	°C	lb/ft³	Kg/m³	BTU/lb. °F	Kcal/Kg. °C	BTU/ft. hr. °F	Kcal/m. hr. °C	lb/hr. ft	cP	cS	mmHg absolute	Kg/cm²
100	38	70.3	1152	0.350	0.350	0.0781	0.1163	445	184	181	-	-
210	100	69.0	1106	0.375	0.375	0.0760	0.1132	20.8	8.59	7.78	-	-
300	149	66.6	1070	0.420	0.420	0.0739	0.1100	6.89	2.84	2.65	0.27	0.0003
400	204	64.2	1029	0.455	0.455	0.0719	0.1070	3.72	1.54	1.50	1.03	0.0014
500	260	61.2	981	0.495	0.495	0.0698	0.1040	2.27	0.94	0.96	9.2	0.0125
600	316	58.0	931	0.530	0.530	-	-	1.47	0.61	0.66	44	0.06
700	371	55.2	885	0.560	0.560	-	-	0.99	0.41	0.46	168	0.229
800	427	-	-	0.600	0.600	-	-				530	0.722

SPECIAL PURPOSE FLUID - SANTOTHERM 77

System Design Hints

Aluminium should not be used as a material of construction inside the system. Copper too is best kept to a minimum especially when operating over 370°C (700°F).

Fluid Maintenance (see Page ..57..)

Safe of Handling (see Page ..58..)

SPECIAL PURPOSE FLUID - SANTOTHERM 130

MAXIMUM BULK TEMPERATURE	150°C	302°F
RECOMMENDED MAXIMUM FILM TEMPERATURE	170°C	338°F

Santotherm 130 was special developed for use at very low temperatures.

SPECIAL PURPOSE FLUID - SANTOTHERM 130

TYPICAL PHYSICAL, CHEMICAL AND THERMAL PROPERTIES

Composition	Organic Silicate
Appearance	Oily liquid
Odour	characteristic
Coefficient of Expansion ^{o}C ^{o}F	 0.0011 0.00063
Density at 25 ^{o}C ($77^{o}F$) kg/m^3 lb/ft^3	 870 54.3
Boiling Range ^{o}C ^{o}F	 216 - 349 420 - 660
Pour Point ^{o}C ^{o}F	 less than -73 less than -100
Flash Point, Pensky-Marten (ASTM-D93 - 46) ^{o}C ^{o}F	 77 170
Fire Point (Pensky-Marten) ^{o}C ^{o}F	 82 180
Autoignition Temperature ^{o}C ^{o}F	 - -
Viscosity at $0^{o}C$ cS	

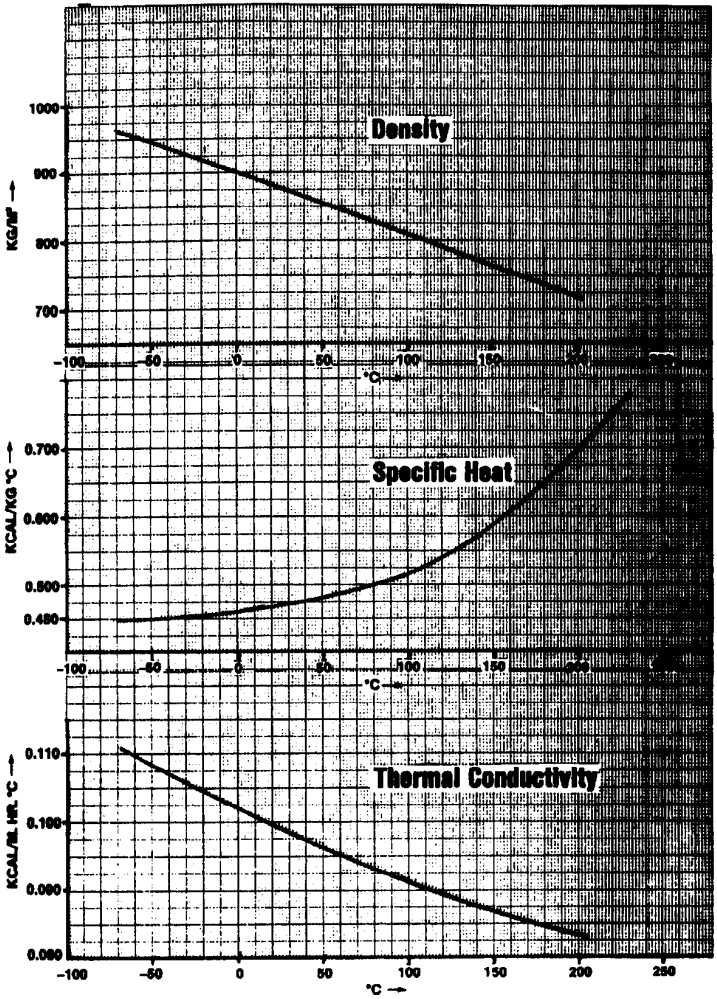
MONS 096001

SPECIAL PURPOSE FLUID - SANTOTHERM 130

VARIATION OF PROPERTIES WITH TEMPERATURE

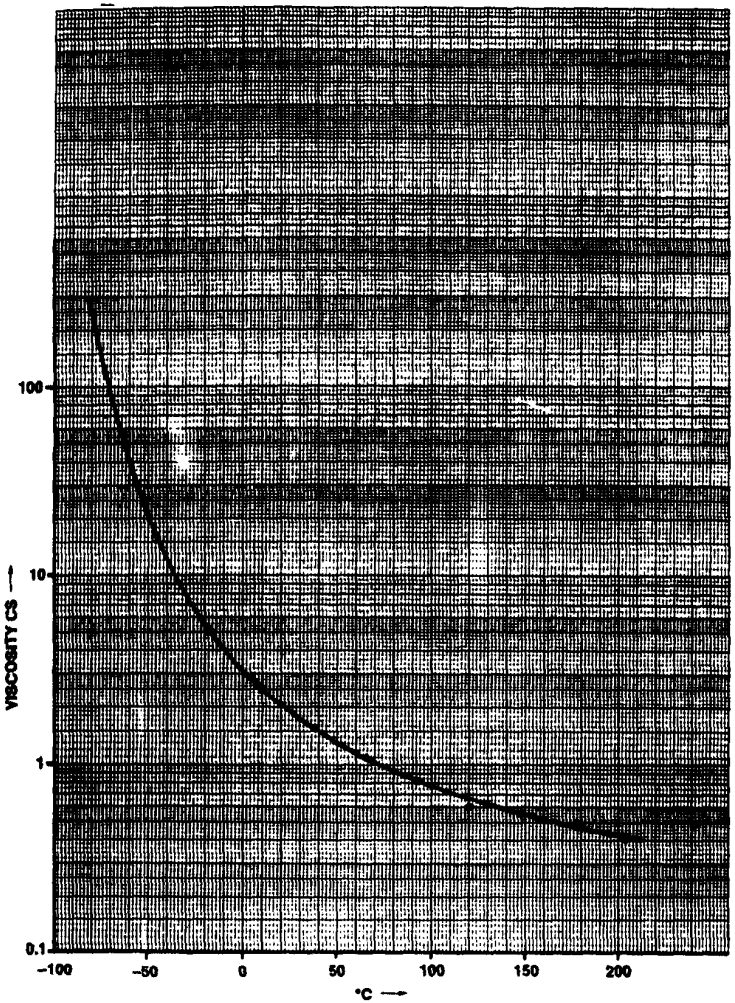
Temperature		Density		Specific Heat		Thermal Conductivity		Viscosity			Vapour Pressure	
°F	°C	lb/ft³	Kg/m³	BTU/lb. °F	Kcal/Kg. °C	BTU/ft. hr. °F	Kcal/m. hr. °C	lb/hr. ft	cP	cS	mmHg absolute	Kg/cm²
-100	-73	60.4	967.6	0.450	0.450	0.0747	0.1112	280.9	116	120	-	-
- 50	-46	58.8	941.9	0.455	0.455	0.0724	0.1077	36	15	16	-	-
0	-18	57.2	916.3	0.460	0.460	0.0701	0.1042	11.10	4.6	5.01	-	-
50	10	55.7	891.5	0.465	0.465	0.0680	0.1011	5.30	2.2	2.50	-	-
100	38	54.1	866.7	0.470	0.470	0.0659	0.0981	3.24	1.3	1.55	0.6	0.0008
150	66	52.5	841.0	0.490	0.490	0.0640	0.0952	2.18	0.9	1.10	3	0.0041
200	93	50.9	816.0	0.520	0.520	0.0621	0.0924	1.62	0.7	0.82	12	0.0163
250	121	49.4	790.6	0.535	0.535	0.0604	0.0899	1.21	0.5	0.61	33	0.0449
300	149	47.8	765.8	0.610	0.610	0.0587	0.0873	0.99	0.4	0.54	100	0.1360
350	177	46.2	739.3	0.625	0.625	0.0572	0.0851	0.97	0.4	0.50	250	0.3400
400	204	44.5	716.0	0.730	0.730	0.0557	0.0829	0.70	0.3	0.40	550	0.7480

Santotherm 130 Variation of properties with temperature



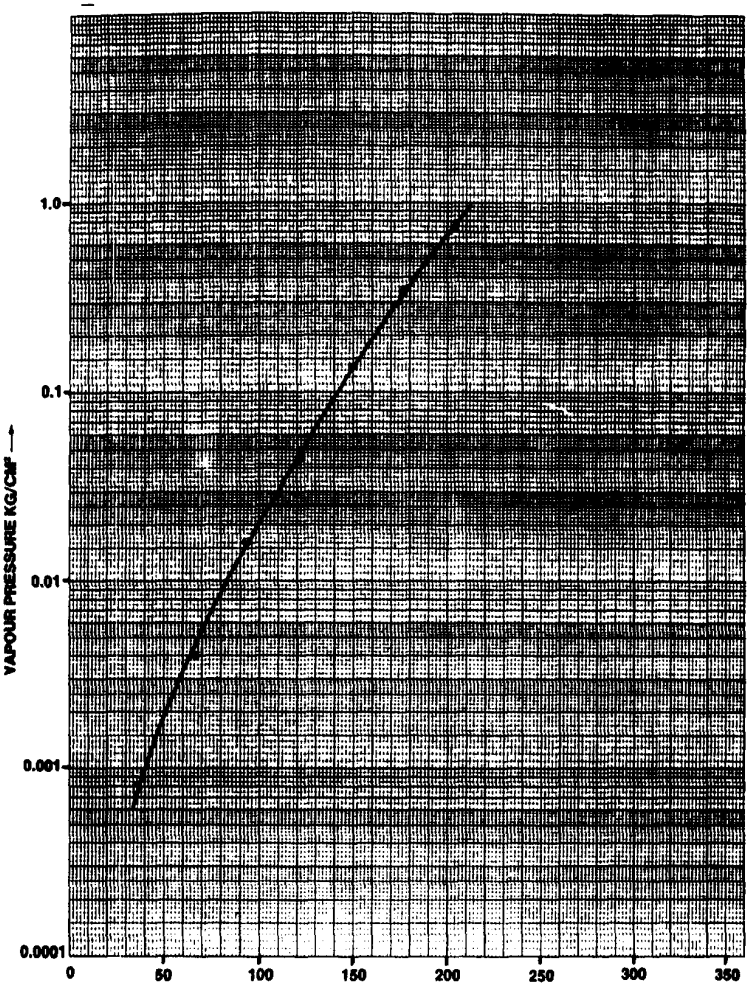
MONS 096003

Santotherm 130 Kinematic Viscosity



MONS 096004

Santotherm 130 Vapour Pressure



MONS 096005

SPECIAL PURPOSE FLUID – SANTOTHERM 130

System Design Hints

Santotherm 130 is suspectible to oxidation and moisture. It is suggested that the system be filled under vacuum though a paper or earth filter so as to remove any traces of moisture arising out of drum handling.

An inert gas blanket will have to be used on the expansion tank. Chlorinated solvents should not be used for plant cleaning. Aluminium should not be used as a material of construction.

Fluid Maintenance (see Page ...57.)

Safe Handling (see Page ...58.)

SPECIAL PURPOSE FLUID – SANTOTHERM 190

MAXIMUM BULK TEMPERATURE	355°C	670°F
RECOMMENDED MAXIMUM FILM TEMPERATURE	385°C	725°F

Santotherm 190 was the first high temperature heat transfer fluid manufactured by Monsanto.

Since its introduction it has proved itself in numerous chemical processes, which require high temperatures and accurate heat control.

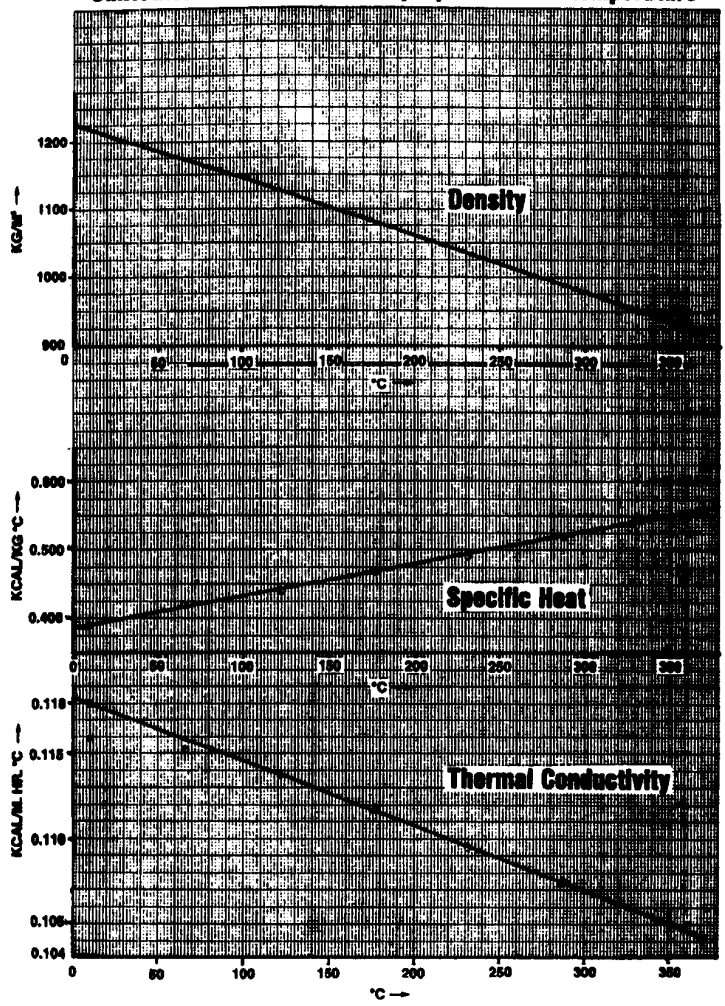
SPECIAL PURPOSE FLUID - SANTOTHERM 190

TYPICAL PHYSICAL, CHEMICAL AND THERMAL PROPERTIES

Composition	Organic Silicate
Appearance	Oily liquid
Odour	characteristic
Coefficient of Expansion ^{o}C ^{o}F	0.00068 0.00038
nsity at 25 ^{o}C (77^{o}F) kg/m^3 lb/ft^3	1.190 74.2
Boiling Range ^{o}C ^{o}F	427 800
Pour Point ^{o}C ^{o}F	-29 -20
Flash Point, Pensky-Marten (ASTM-D93 - 46) ^{o}C ^{o}F	238 460
Fire Point (Pensky-Marten) ^{o}C ^{o}F	285 545
Autoignition Te mperature ^{o}C ^{o}F	593 1,100
Viscosity at 0^{o}C cS	

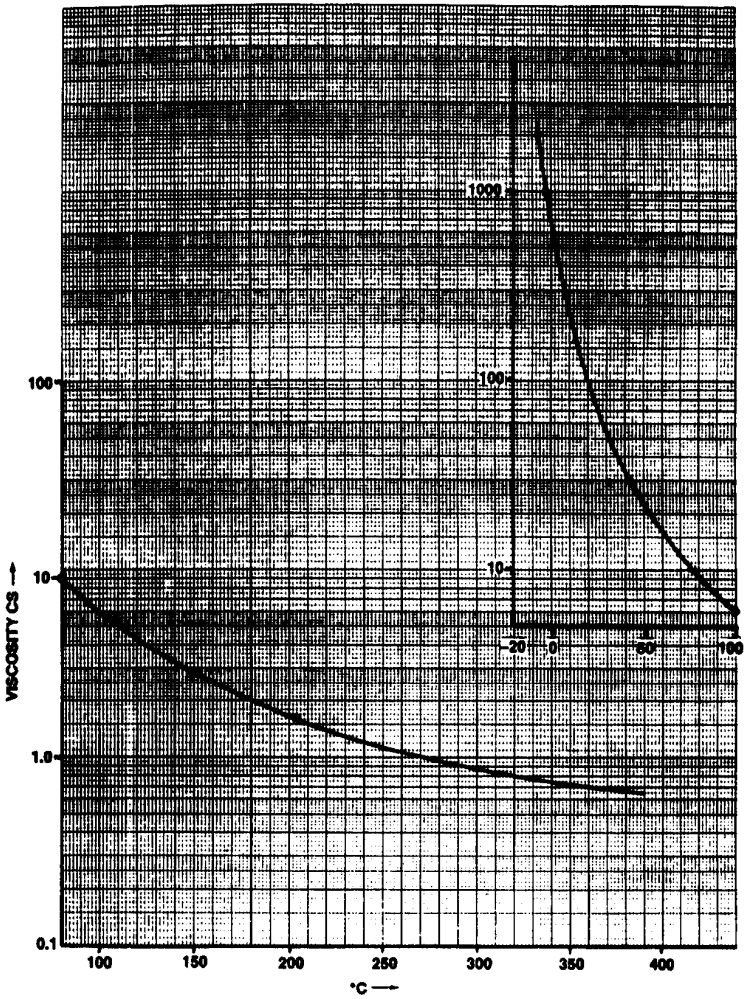
MONS 096008

Santotherm 180 Variation of properties with temperature



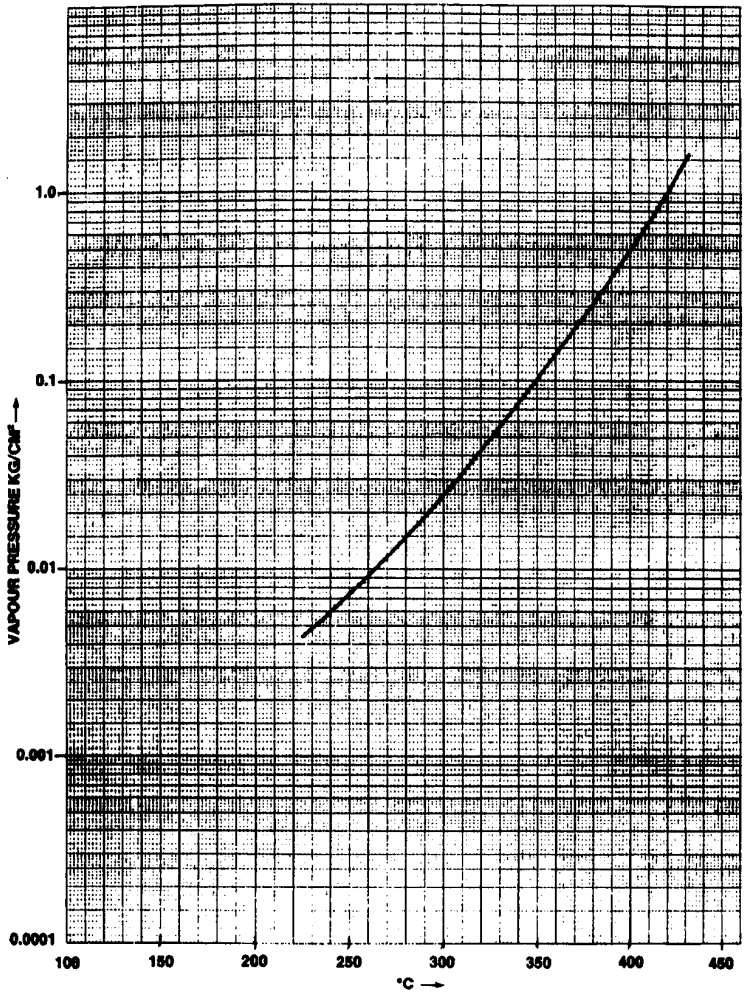
MONS 096009

Santotherm 190 Kinematic Viscosity



MONS 096010

Santotherm 190 Vapour Pressure



MONS 096011

SPECIAL PURPOSE FLUID - SANTOTHERM 190

VARIATION OF PROPERTIES WITH TEMPERATURE

Temperature		Density		Specific Heat		Thermal Conductivity		Viscosity			Vapour Pressure	
°F	°C	lb. ft³	Kg./m³	BTU/lb. °F	Kcal/Kg. °C	BTU/ft. hr. °F	Kcal/m. hr. °C	lb/hr. ft	cP	cS	mmHg absolute	Kg/cm²
50	10	76.4	1223.9	0.39	0.39	0.0793	0.1180	529.9	245	200	-	-
100	38	74.4	1191.9	0.41	0.41	0.0786	0.1170	104.1	43.0	36.1	-	-
150	66	73.0	1170.2	0.42	0.42	0.0775	0.1153	38.7	16.0	14.0	-	-
200	93	71.7	1148.6	0.43	0.43	0.0768	0.1143	18.87	7.8	6.8	-	-
250	121	70.2	1124.6	0.44	0.44	0.0764	0.1137	12.10	5.0	4.4	-	-
300	149	68.7	1100.6	0.46	0.46	0.0758	0.1127	7.19	3.0	2.7	-	-
350	177	67.3	1078.1	0.47	0.47	0.0750	0.1116	6.05	2.5	2.3	-	-
400	204	65.9	1055.7	0.48	0.48	0.0743	0.1105	4.11	1.7	1.6	-	-
450	232	64.5	1033.3	0.49	0.49	0.0736	0.1095	2.90	1.2	1.2	-	-
500	260	63.1	1010.9	0.51	0.51	0.0729	0.1085	2.66	1.1	1.1	6	0.0082
550	288	61.7	987.6	0.52	0.52	000722	0.1075	2.18	0.9	0.9	15	0.0204
600	316	60.2	964.4	0.54	0.54	0.0714	0.1063	1.93	0.8	0.8	30	0.0408
650	343	58.8	942.0	0.55	0.55	0.0707	0.1052	1.69	0.7	0.7	60	0.0816
700	371	57.4	919.6	0.56	0.56	0.0700	0.1042	1.45	0.6	0.7	150	0.2040

SPECIAL PURPOSE FLUID - SANTOTHERM 190

System Design Hints

Santotherm 190 will hydrolyse in the presence of water giving rise to products that resemble the effects of severe fluid degradation so moisture must be kept out of the system.

Canned (glandless) pumps are the only ones recommended for use with Santotherm 190.

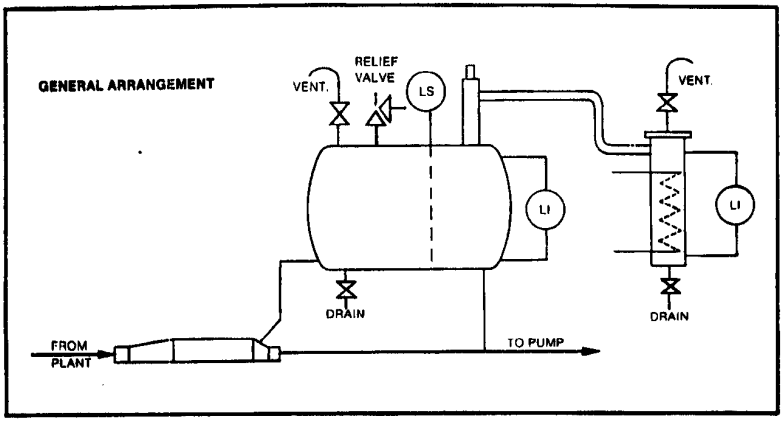
Aluminium should not be used as a material of construction inside the system and the use of copper should be kept to a minimum. The expansion tank should be sized to accomodate 70% of the entire system.

An efficient vapour separator is essential (as illustrated) on all Santotherm 190 systems to remove low boilers formed during the long service life of the fluid. The separator should be installed at the highest point of the ring main on the fluid return side.

To produce a lower pressure in the expansion tank to promote any "low boilers" vapour readily flashing off, the tank should be at least 6 feet (1.8 meters) above the level of the return main. It should be insulated to prevent moisture condensation. Part of the liquid from the vapour separator will by-pass the ring main and flow through the expansion tank, entraining vapours from the main. The condensing vessel should not be lagged, since this will produce a difference of operating temperature between the expansion tank and the condenser and the vapour pressures of the low-boilers will be different in each vessel. This will result in released vapours from the fluid in the expansion tank migrating to the condensation vessel where they will condense.

Rating of the separator should be based on a phenol formation rate of 1 part of phenol by volume per hour per 1000 parts by volume of Santotherm 190 in the system.

SANTOTHERM 190 SYSTEMS EXPANSION TANK, VAPOUR SEPARATOR AND CONDENSER



SPECIAL PURPOSE FLUIDS - SANTOTHERM 77, 130, 190

Fluid Maintenance (77 and 130)

Samples of fluid should be taken from the system 24 hours after start-up and every 3 months for the first year of operation. Afterwards, sampling at 6-monthly intervals is generally sufficient. Analytical procedures are available from Monsanto who will comment on results and advise on any corrective action required.

Fluid Maintenance (190)

The viscosity of the fluid stripped of low boilers is measured according to a procedure available from Monsanto. Should the stripped viscosity need reducing in order to improve heat transfer properties, Santotherm 1000 (a solid with a m. p. of 50°C) can be added to the system.

SPECIAL PURPOSE FLUIDS - SANTOTHERM 77, 130, 190, 1000

Safe Handling

Santotherm 77, 190 as liquids, are of low toxicity but through hydrolysis with water and as a result of thermal decomposition, phenol is produced and the handling precautions of used fluid should, therefore, be the same as those for phenol.

Should these Santotherm fluids come in contact with the skin, the affected parts should immediately be washed with water or soap and water. If reddening or soreness of the skin develops, a lanolin based cream should be applied. No ointments should be used on severe burns which must be covered with a dry dressing. Operators handling the liquid should wear anti-splash goggles or face visors; if the liquid accidentally enters the eye, it should be copiously washed with water for at least 15 minutes. In a factory with adequate ventilation the vapour should not present a problem and no immediate or chronic effects have been noted among the workers in the plants that manufacture these fluids.

Safe Handling of Santotherm 130

Santotherm 130 as a liquid is of low toxicity. There is a tendency for it to dry the skin on long contacts but otherwise no special handling precautions are necessary.

Safe Handling of Santotherm 1000

Care must be taken when adding solid Santotherm 1000 (m. p. 50°C) to hot Santotherm 190 (at 100-200°C) through the expansion tank. Operators should be provided with protective clothing and the addition process should be carried out under well ventilated conditions.

1. GENERAL DESIGN HINTS FOR SANTOTHERM SYSTEMS

TYPES OF HEATER

The heater is the most critical component in a Santotherm system. Accordingly, on the basis of the properties of the fluid selected for its operating range — the heater should be specified with great care.

The type and size of heater is governed by the heat demand of the user-system considered in balance with the maximum recommended bulk temperature of the Santotherm fluid selected, and the fluid film temperature at a practical flow velocity over the heat donor surfaces.

Two basic heater designs for Santotherm fluids are available : the liquid tube and fire tube type. In liquid tube heaters, the fluid is pumped through the tubes at a definite flow rate as it is heated; in fire tube types, the fluid flows through the « shell » of the heater that surrounds the fire tubes.

In systems where operating temperatures of 500 °F (260 °C) or higher are required, a liquid tube type heater is preferred... unless a specific design is devised to force a steady flow of the fluid over the heat donor surface.

The fuel for Santotherm heaters is purely optional. Gas, oil-fired heaters, and electrical heating elements are all used with success. Coal fired heaters are generally not recommended because of their slow response to changes of load.

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

CIRCULATION OF HEAT TRANSFER COEFFICIENTS & PRESSURE DROP DATA

Santotherm systems are outstanding for serving multiple-users at different temperature levels. When designing a Santotherm liquid heat transfer system, it is important to remember that the FLUID AND ITS SERVICE LIFE CAN BE NO BETTER THAN THE ENGINEERING OF THE SYSTEM.

Santotherm heat transfer fluids are ideally suited for systems requiring high temperature precision heating, precise temperature control, minimum capital expense, low maintenance, and a high degree of safety. The systems, however, must be properly designed and constructed. While there is nothing profoundly different or greatly complicated about Santotherm liquid heat transfer — certain design parameters must be rigidly observed if the system is to give trouble-free service, run efficiently, and to return the full benefits of heat delivered by unpressurized liquid.

A summary of these parameters is : the heater and the fluid flux, the moisture-tightness of the system, and the fail-safe control devices provided. When these factors of design are properly observed, normal maintenance and simple operating procedures will assure years of reliable, trouble-free operation.

FILM TEMPERATURES

Since heating is not uniform in fired heaters, the **maximum heat stress conditions** must be used to determine what will be the film temperatures encountered.

Example :

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

Thus, the **average** film temperature is :

$$570° + \frac{9{,}000}{250} = 606\ °F$$

but the **maximum** film temperature is :

$$570° + \frac{17{,}000}{250} = 638\ °F$$

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

For radiant heaters, the method of Lobo and Evans* is useful in calculating the film temperatures.

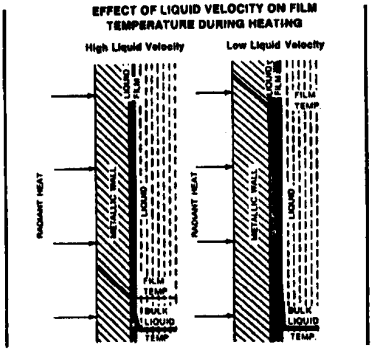
When electric heaters are used — the heat flux is more uniform. However, it is important to remember that **all** of the heat from the heating element passes into the fluid. Therefore, the watt-density on the surface of the heater tube and the fluid velocity

across the heat-donor surface should be in proper balance to avoid excessively high film temperature. Watt-densities in the range of 8 to 10 watts per square inch (1.25 to 1.5 watts per sq.cm.) with a minimum velocity of 4 feet per second (1-1/3 meter per second) are suggested. However, higher watt-densities in the range of 18 to 22 watts per square inch (3.0 to 3.5 watts per square centimetre) have proved satisfactory in properly-designed installations with fast flow.

** Lobo, W.E. and Evans, J.E., Trans. AICHE 35,743 (1939).*

FLUID VELOCITIES

Fluid velocities over the heat donor surfaces should be relatively high; generally 4 to 10 feet per second (1-1/3 to 3 meters per second). This helps avoid both excessive film temperatures and also reduces the quantity of fluid present in the film that is in direct contact with the high temperature heat-donor surface. The illustration shows the effect of fluid velocity on film temperature and indicates the importance of this design requirement.



ACCURATE DETERMINATION OF HEAT TRANSFER COEFFIDIENT

To determine overall heat transfer coefficients for the heating system, individual coefficients have to be calculated for heat donor side and the fluid service side at each user station. Film heat transfer coefficients for Santotherm liquids are best calculated with the Dittus-Boelter* equation, using the data from the fluids' physical property charts.

The Dittus-Boetler equation is :

$$\frac{hD}{k} = 0.023\left[\frac{(DG)}{(\mu)}\right]^{0.8}\left[\frac{(Cp.\,\mu)}{(k)}\right]^{x}$$

$x = 0.3$ when Santotherm is used for **providing** heat

$x = 0.4$ when Santotherm is used for **removing** heat

$\frac{DG}{\mu}$ = Reynolds Number (dimensionless)

$\frac{Cp.\,\mu}{k}$ = Prandtl Number (dimensionless)

$\frac{hD}{k}$ = Nusselt Number (dimensionless)

The units to be used to maintain the dimensionless qualities of the numbers.

h = Santotherm film heat transfer coefficient

D = Internal pipe diameter

k = Thermal conductivity of Santotherm at temperature « t »

G = Mass velocity of Santotherm

Cp = Specific heat of Santotherm at temperature « t »

μ = Absolute viscosity of Santotherm at temperature « t »

** The Dittus-Boelter equation is only applicable for truly turbulent flow conditions when the Reynolds Number exceeds 10,000. (Dittus-Boelter : University of California Publications in Engineering 1930.2, 13, pp. 443-461). Morris and Whitman (Morris and Whitman, Ind. Engineering. Chem. 1928, 20 234) have devised a modified calculation which is necessary for determining coefficients under laminar flow conditions.*

Pumps

Pumps must have sufficient capacity and pressure head to circulate the fluid at the rate required by the particular installation. For large flow rates, the pump should generally be the centrifugal type; any one of a number of the standard brands of high temperature pumps is suitable. For most systems, cast steel pumps are best. Pump manufacturers usually specify that above 450°F fluid temperatures (230°C), a water jacketed, deep stuffing box or mechanical seal and water-cooled bearings should be used. Mechanical seals are used widely today. On pumps with a stuffing box, at least five rings of packings should be provided, with graphite-impregnated metal foil around an asbestos core at each end and in the centre, and semi-plastic asbestos compound impregnated with graphite on either side. 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. The pump gland should not be tightened however, until the system has heated up to close to the temperature of operation. Canned (glandless) pumps require no seal and have proved very serviceable in Santotherm systems.

Regardless of the type of pump selected, the flow rate should be checked regularly against the pump's performance when new. To avoid shaft trouble and seal leakage, it is important to avoid pipe support stresses on the body of the pump. Each pump should be fitted with a control device to switch off the burner in case of pump failure.

If expansion loops are used in the pump section piping, they should be horizontal or vertically downward. Loops should not be vertically upwards, because this forms a trap which can collect air and vapour which seriously hamper the pump performance.

Filters

In a new system , install a wire mesh strainer in the pump section.

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

Materials of Construction

The majority of metals show good corrosion resistance to Santotherm fluids. Mild steel is generally used but see under each fluid for materials to be avoided.

The Expansion Tank and venting arrangements

The expansion tank should be installed at the highest point in the system on the suction side of the pumps and it should serve as the main venting point of the system.

The vent line from the tank should be led outside of the building so that any hot vapours do not enter the working area.

When using a nitrogen blanket moisture should be driven off from the fluid before the gas pressure is set.
The expansion tank should be sized so that it is 1/4 full when the system is at room temperature and 3/4 full when the system is at operating temperature. It should be fitted with a sight glass at the full range and with a float operated, minimum level switch to shut off the heater in the event of accidental fluid loss.

Pipework

The most important factors in the piping layout for Santotherm systems are : (A) Proper sizing for the required flow rate and (B) minimizing pressure drop. Because the system will undergo temperature changes, adequate loops to relieve expansion and contraction stress are essential. Hot forge seamless pipework should be used throughout the system. It is characteristic of most organic fluids (including Santotherm) to have a tendency to leak through joints and fittings at high temperatures unless these fittings are very tight. Therfore flanged joints should be used sparingly to minimize potential leak points. Threaded connections are used with Santotherm up to a 1-inch (cm) maximum size. A new die is recommended in cutting the threads to ensure a proper fit. Careful attention to threading procedure should provide a good connection; do not rely on the use of pipe dope to eliminate leakage. The connections must be steel and the thread cut taper to taper.

Below 450°F (230°C), P.T.F.E. tape can be used for sealing threaded connections. Above 450°F (230°C), powdered graphite mixed with S.A.E. 30 oil to a consistency of thick oil paint has been used successfully. The graphite mixture is not suitable for lower temperatures, since the higher temperature is needed for baking. In large size pipes, connections should be welded wherever practical. Careful layout and use of curved sections can minimize the number of welded or flanged connections required. When a flanged connection is made, ASA 150 or equivalent raised-face flanges are recommended. The flanges should be back welded to the pipe and proper gasketing used, such as spiral wound asbestos and stainless steel gasket. Small lip spiral wound gaskets are to be preferred over the wide lip type, because they allow better compression with the ASA 150 flange. Short cut, pre-cut and cured asbestos gaskets have also proved satisfactory. It is recommended that stretch-resisting high-temperature alloy stud bolts, be used. All high points in the pipework should be provided with vent valve connections.

Valves

Cast steel valves equivalent to ASA 150 with deep stuffing boxes are satisfactory for Santotherm systems. If it is possible, globe valves with an outside screw (as a protection against high temperatures) should be used throughout the system since they provide the only truly effective seal against Santotherm fluids. Gate valves do not always provide a tight shut-off. Gland rings should be of asbestos yarn reinforced with wire encasing an asbestos core impregnated with graphite; as many rings as possible should be used.

Controls

Controls for heating systems using Santotherm 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 Santotherm 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 system must also be fitted with the proper safety devices 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) Heater low flow cutoff ... to shut down the burner, should flow rate drop below design rates, or if a loss of flow occurs due to pump malfunction or failure.

Burners should be equipped with regular automatic ignition controls and flame failure controls. In wide-range firing, an over-fire draft control will save heat losses. Electric power failure and instrument air failure safety controls are also desirable. In general, a policy of "fail-safe" instrumentation and control in the designing is essential, using good quality indicating - and recording gauges, with accurate-reading scales calibrated for the particular limits of operation.

(C) Expansion tank low level switch ... to shut off the heater in the event of accidental fluid loss.

2. TYPICAL SYSTEM LAYOUTS

The transfer of process heat as a liquid offers these benefits to the installation :

- Precise heating levels
- Closer temperature control at each user station
- Minimum cost installations
- Greater operating safety
- Low maintenance costs

Santotherm systems are characterized by their extreme flexibility. A single heater can serve multiple « users » operating at the same or different temperature levels. The systems can be devised to deliver and to remove heat. Since the heat transfer is done with a liquid, there are no problems of condensation, pressure drop, and great heat surges.

The following diagrams illustrate the basic features of the heater off-take connections and the various arrangements of heat users that can be operated on Santotherm fluids.

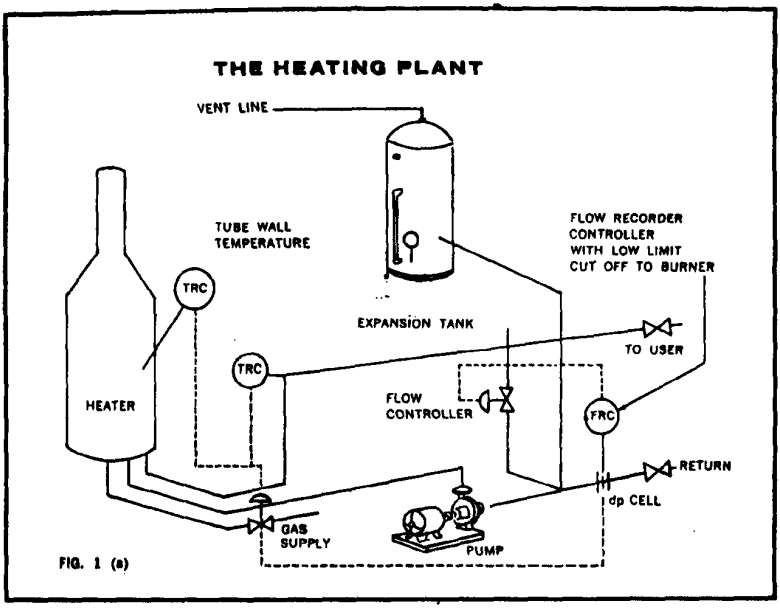


FIG. 1 (a)

This diagram illustrates a typical basic heating plant for a SANTOTHERM FR system. Note the use of instruments to control the fluid temperature leaving the heater and the by-pass flow control to assure adequate flow through the heater regardless of « user » demands.

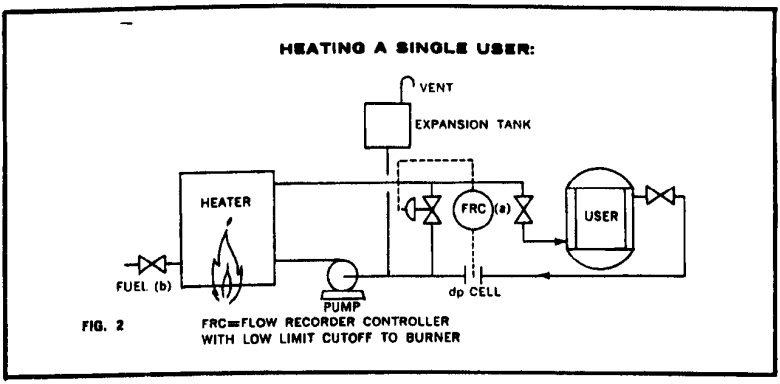


FIG. 2

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

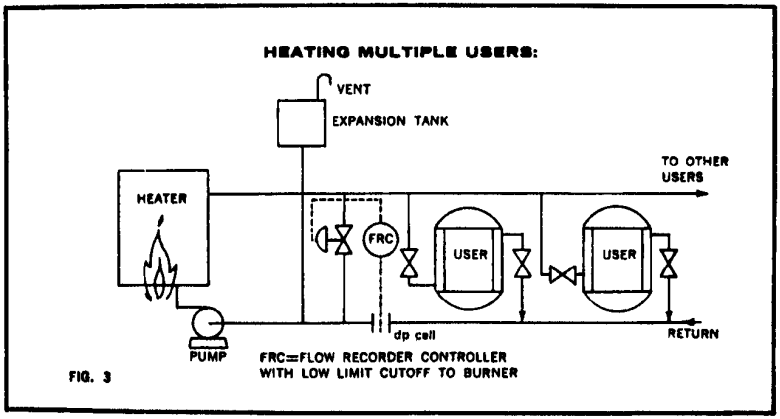
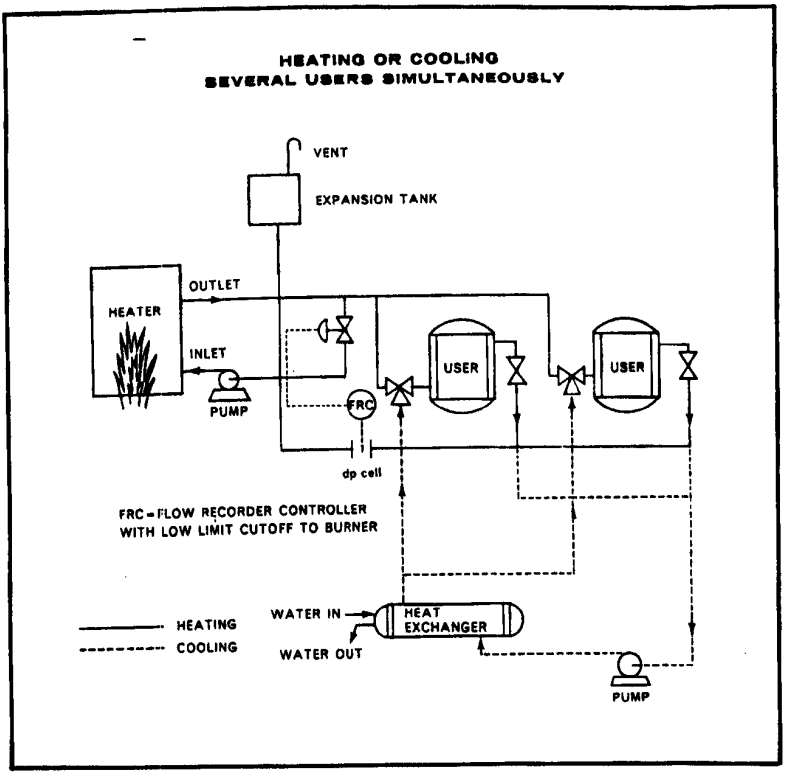


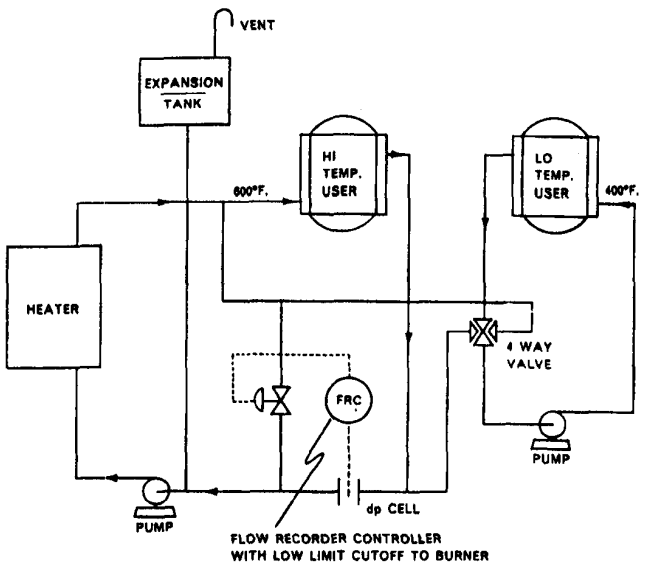
FIG. 3

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



Note that with this arrangement, a Santotherm system can be used to cool a batch process rapidly after reaction. The heat taken out can be used as a source of hot water taken off from the heat exchanger. The cooling process is achieved simply by by-passing the users and cutting in a cooling circuit in which the fluid passes through a heat exchanger.

TEMPERATURE CONTROL BY BLENDING



A single heater supplying hot fluid in this arrangement can provide widely differing temperature levels to multiple users. The high heat circuit is connected into the low heat circuit through a 4-way valve that blends the hot and cool fluid. This type of system finds application for processing heat-sensitive materials.

SUGGESTED START-UP PROCEDURE FOR NEW SYSTEMS

For a new system or one that returns to service after draining, the following check points are recommended as guides. They are supplemental to the heater manufacturers' and the heat-user processing equipment makers' recommendations apply generally to the care of the fluid in all sizes and types of systems:

(1.) Check Safety and Control Devices

... for proper installation and functioning, making sure that the range settings are proper for the operation. Manually activate the instruments and apply all tests necessary to assure proper functioning. For protection of the system and for the expected long service life of the fluid it is vitally important that all instruments and controls function properly.

(2.) Check for leakage

(3.) Remove moisture from the system, using dry compressed air.

(4.) Fill the System with Santotherm

A. Fill the expansion tank with Santotherm, 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, refilling as necessary until the system has been filled. Allow for the thermal expansion of Santotherm in determining the cold charge level. The expansion tank should be adjusted to 70-75 % full when the hot operating temperature is reached.

C. Circulate the Santotherm 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 SANTOTHERM IS CIRCULATING FREELY.

(5) Start the Heater

A. Bring the system up to temperature slowly - about 100°F per hour. This will prevent thermal shock to heater tubes, tube/heater joints, refractory materials, etc. ... and allow operators to check the functioning of instruments and controls. The slow heat-up will also allow any moisture trapped in the system to escape as a vapour.

B. Bring System to operating temperature and put the "users" on the line.

C. The fluid is generally analysed within 24 hours of plant start-up and every 3 months during the first year of operation. (See details under the fluid in question).

D. Check the filter. As foreign material collects, the filter should be periodically removed and cleaned. After several days of operation with no foreign material on the screen - it may be permanently removed. The system should be heated and cooled for at least two cycles with the screen in place since the resulting expansion and contraction will loosen mill scale.

SUGGESTED OPERATING INSTRUCTIONS FOR LIQUID PHASE HEATING SYSTEM USING SANTOTHERM FLUIDS

(1) CHECK SAFETY CONTROLS

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

(See Page 65)

(2) START-UP TEMPERATURE PRECAUTIONS

1. Temperature of fluid at start-up is important: Consult your plant or pump supplier for the minimum recommended start-up temperature. This should correspond with the maximum permitted fluid viscosity.

Failure to comply with their recommendations may lead to a burnt out motor on pumps.

2. If you have to start-up at low temperatures (below those specified), the fluid should be heated in a safe way, for example with electric tapes etc...

3. One way of avoiding start-up temperature problems is to keep the system idling at 105°C - especially in cold weather.

(3) PROCEDURE FOR START-UP (COLD FLUID)

1. When the start-up temperature is O.K., start the circulating pump and check the expansion tank level to see that the Santotherm is at the proper cold-start level (1/4 full).

2. Start burner at the "low" flame setting and continue full circulation until the Santotherm bulk temperature reaches 105°C.

3. Turn heater to full heat.

(4) PROCEDURE FOR START-UP (HOT FLUID)

Start-up after an automatic shut-down by the safety controls - (fluid should still be above 105°C)

1. Run the circulating pump for ten minutes or so to eliminate any vapour pockets formed when the fluid has remained static in the heater.

2. If there is no knocking in the system, the heater can be turned to full fire.

(5) PROCEDURE FOR SHUT-DOWN

1. Shut off burner completely with circulating pump still operating. Continue to run the pump at full capacity for at least one hour to dissipate residual heat in the combustion chamber of the burner.

2. Shut off circulating pump after one hour and switch off all heater electrical controls.

(6) PLANNED MAINTENANCE

Regular maintenance inspection schedules should include the manufacturers' recommendations for the heater and the components as well as inspection of the Santotherm fluid. The following is a list of inspection check points :

1. Lubrication of moving parts
2. Operating fidelity and the accuracy of the readings of safety controls and temperature limit controls.
3. Inspection of heater tubes, burner, refractory linings.
4. Periodic inspection of heater service.
5. Inspection of the water cooling at the circulating pump.
6. Re-packing of stuffing boxes (according to the manufacturers specification).
7. Inspection of the expansion tank venting system - vent pipe, dessicant pot.
8. Half-yearly or annual sampling and analysis of the Santotherm fluid.

The fluid is normally analysed with 24 hours of plant start-up and every three months during the first year of operation. Afterwards, six-monthly checks are usually sufficient. Monsanto provides analytical procedures for sample testing and will advise on corrective action required should results be outside acceptable values for used fluid.

(7) DISPOSAL OF USED FLUID

Used Santotherm fluids should never be poured down normal drainage systems. Contact Monsanto for advice on safe and efficient disposal.

5. UNITS CONVERSION CHART

	To Convert from	To	Multiply by
Length	cm ft	ft cm	3.28×10^{-2} 30.5
Area	cm^2 ft^2	ft^2 cm^2	1.08×10^{-3} 9.29×10^{2}
Volume	cm^3 ft^3 gallon (Imp) gallon (Imp) gallon (Imp)	ft^3 cm^3 ft^3 litre gallon (US)	3.53×10^{-5} 2.83×10^{4} 1.61×10^{-1} 4.55 1.20
Mass	kg lb	lb kg	2.20 4.54×10^{-1}
Density	gm/cm^3 lb/ft^3 kg/m^3	lb/ft^3 gm/cm^3 lb/ft^3	62.4 1.60×10^{-2} 6.24×10^{-2}
Pressure	gm/cm^2 lb/in^2	lb/in^2 atmosphere	1.42×10^{-3} 6.80×10^{-2}
Heat	K cal BTU	BTU K cal	3.97 2.52×10^{-1}
Heat Transfer per unit time	K cal/hr Kilowatt Kilowatt	Kilowatt K cal/hr BTU/hr	1.16×10^{-3} 8.60×10^{2} 3.41×10^{3}
Heat Transfer per unit time per unit area	$K\ cal/m^2\ hr$ $BTU/ft^2\ hr$ $BTU/ft^2\ hr$ $Watt/cm^2$	$BTU/ft^2\ hr$ $K\ cal/m^2\ hr$ $Watt/cm^2$ $BTU/ft^2\ hr$	3.69×10^{-1} 2.71 3.15×10^{-4} 3.17×10^{3}
Heat Transfer coefficient	$K\ cal/m^2\ hr\ ^oC$ $BTU/ft^2\ hr\ ^oF$ $cal/cm^2\ sec\ ^oC$	$BTU/ft^2\ hr\ ^oF$ $K\ cal/m^2\ hr\ ^oC$ $BTU/ft^2\ hr\ ^oF$	2.05×10^{-1} 4.88 7.37×10^{3}
Thermal Conductivity	$K\ cal\ m/hr\ m^2\ ^oC$	$BTU\ ft/hr/ft^2\ ^oF$	6.72×10^{-1}
Viscosity	Centipoise Centipoise	lb/ft hr kg/hr m	2.42 3.60
Kinematic viscosity	Centistoke Centistoke	ft^2/sec ft/hr	1.08×10^{-5} 3.88×10^{-2}

The information in this manual is to our best knowledge true and accurate but all instructions, recommendations or suggestions are made without guarantee. Since the conditions of use are beyond their control, Monsanto Company and its subsidiaries disclaim any liability for loss or damage suffered from use of these data or suggestions. Furthermore no liability is accepted if use of any product in accordance with these data or suggestions infringes any patent.

MONSANTO EUROPEAN OFFICES

HEAD OFFICE
Monsanto Europe S.A.
Place Madou 1
B - 1030 Brussels, Belgium
Telephone : (02)19.11.01
Telex : 22110/21966

AUSTRIA :
Monsanto (Österreich) GmbH.
Wien 1
Rudolfsplatz 12
Telephone : 63.81.70
Telex : 75801

BELGIUM / LUXEMBURG :
Monsanto Europe N.V.
Mechelsesteenweg 163
B - 2000 Antwerp, Belgium
Telephone : (03) 30.58.40
Telex : 31657

FRANCE :
Société Monsanto
9, rue d'Argenson
Paris 8ème
Telephone : 265.65.20
Telex : 65261

GERMANY :
Monsanto Deutschland GmbH.
Immermannstraße 3-5
4000 Düsseldorf
Telephone : (0211)36.75.1
Telex : 858-1307

ITALY :
Monsanto Italiana S.p.A.
Via F. Filzi 24
20124 Milano
Telephone : 66.62.84 - 66.63.73
Telex : 38209

NETHERLAND :
Monsanto N.V.
54, Jan van Nassaustraat
's Gravenhage
Telephone : (070)24.55.78
Telex : 32208

U. K. :
Monsanto Chemicals Limited
10-18, Victoria Street
London S.W.1
Telephone : ABBEY 5678
Telex : 916093

SPAIN :
Monsanto Iberica S.A.
Lepanto 350
Barcelona 13
Telephone : 255.10.00 - 255.64.00
Telex : 52050

SWEDEN :
Monsanto Scandinavia AB
Ulvsundavägen 108
Bromma - Stockholm
Telephone : 80.28.30
Telex : 17359

Monsanto

Sales Offices
in principal cities of Europe