169

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DEVELOPMENT DIVISION

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A test for evaluation of explosives performance in the aquarium technique is being extended, by replacement of water as the fluid in order to operate in the temperature range between -65 F and 165 F.

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SILICONE FLUIDS FOR AQUARIUM TEST

ABSTRACT

A group of silicone fluids is presented from which a specific fluid (7 ctsk dimethylpolysiloxane tri-methyl end-blocked) was chosen for use in the aquarium test. Data is extracted from current publications to indicate trends in physical properties due to changing conditions.

DISCUSSION

A study was made to select a fluid for use in the aquarium test. The properties required are (1) optical transparency at temperatures from -65 F to 165 F, (2) shock impedance of the fluid should be greater or equal to that of distilled water, (3) the fluid should not exhibit elastic or phase transitions over the temperature and pressure ranges of interest, (4) it should be chemically inert, non-flammable, and non-toxic and have low solvency for ease of handling and compatibility with HE and anticipated samples, (5) it should have electrical and thermal characteristics similar to distilled water, (6) simple chemical composition to permit future theoretical calculations and predictions and (7) it should be inexpensive.

Silicone fluids were investigated for two major reasons: being inert and retaining physical properties over a wide temperature range.

Compatibility data and experience accumulated favors silicone fluids with HE. The specific fluids are the dimethylpolysiloxane type which are tri-methyl end-blocked.

Three variations are selected.

- (1) dimethyl (ref. 1, 2, 3, and 4)

- (2) methyl-phenyl (ref. 1, 2, 3, and 4)

Table I. SILICON FLUIDS SURVEY FOR AQUARIUM UTILIZATION

	GENERAL ELECTRIC					DOW CORNING								UNION CARBIDE
	SF96	SF97 ^a	SF85 ^a SF81	SF1153	SF50	DC200		331		510				L-45
Viscosity, cstk, 25 C	5.0	10.0	50.0	100.0	70.0	1.0	1.5	2.0	10.5	50.0	100.0	500.0	1000.0	7.0
R Groups	Me	Me	Me	HePh	HeClPh	Me	Me	Me	Me	MePh	HePh	HePh	MePh	Me
Flash Pt. (D92) F	275.0	325.0	600.0	540.0	550.0	100.0	145.0	175.0	420.0 ^b	525.0	600.0	600.0	600.0	275.0
Pour Pt. (D97) F	-120.0	-100.0	-120.0	-100.0	-100.0	-123.0	-105.0	-119.0	-130.0	-100.0	-100.0	-100.0	-100.0	-160.0
Specific Gravity, 25 C	0.916	0.940	0.972	0.980	1.050	0.818	0.853	0.873	0.940	1.000	1.000	1.000	1.000	0.940
Thermal Expansion cc/cc/ C	0.00105	0.00108	0.00095	0.00094	0.00975	0.00134	0.00134	0.00117	0.00095	0.00096	0.00096	0.00096	0.00096	0.00111
Refractive Index, @ 25 C	1.397	1.399	1.403	1.422	1.428	1.382	1.387	1.390	1.400	1.425	1.425	1.425	1.425	1.398
Thermal Conductivity cal/sec/cm ² C	0.00027	0.00031	0.00037	0.00034	0.00036	0.00024	0.00025	0.00026	0.00034	0.00035	0.00036	0.00037	0.00037	0.00031
Specific Heat (25 C) cal/g/ C	0.360	0.360	0.360	0.390	0.340	0.492 ^c	0.492 ^c	0.450 ^c	0.430 ^c	0.372 ^c	0.372 ^c	0.372 ^c	0.372 ^c	0.340
Dielectric Strength (D877) v/mil	350.0	350.0	350.0	325.0	290.0	325.0 ^d	350.0 ^d	350.0 ^d	350.0 ^d	350.0 ^d	350.0 ^d	350.0 ^d	350.0 ^d	325.0 ^e
Dielectric Constant (D924) 25 C	2.60	2.60	2.74	2.75	2.90	2.29	2.36	2.44	2.70	2.77	2.78	2.80	2.81	2.65 ^h
Dissipation Factor (D924) 25 C	0.00010	0.00010	0.00010	0.00010	0.00013	0.00002 ^e	0.00002 ^e	0.00002 ^e	0.00015 ^e	0.00030 ^e	0.00030 ^e	0.00030 ^e	0.00030 ^e	0.00020 ^h
Volume Resistivity (D257) ohm/cm	10 ¹⁵	10 ¹⁴	10 ¹⁴	10 ¹⁴	8 x 10 ¹²	10 ¹⁶ ^f	5 x 10 ¹⁵ ^f	10 ¹⁵ ^f	10 ¹⁴ ^f	10 ¹⁴ ^f	10 ¹⁴ ^f	10 ¹⁴ ^f	10 ¹⁴ ^f	10 ¹⁴ ^f

^a Low moisture^b closed cup^c 40 C^d D824^e D877^f D1169^g D149-59^h 23 C

Physical properties were tabulated for screening in Table I. The data on the fourteen fluids illustrate trends due to change in viscosity (or molecular weight) and chemical structure (methyl or methyl phenyl). Dispersion fluids or fluids with additives were avoided because the additives for better low temperature properties, electrical properties, and antioxidant are not necessary. Only the lower viscosity fluids were considered within the fourteen fluids due to their low pour points. Among these a high specific gravity was desirable. The Union Carbide fluid was selected for further investigation for these reasons and the extensive detailed data available.

Union Carbide L-45 dimethylpolysiloxane tri methyl end-blocked was selected with a 7 centistokes (25 C) viscosity. Table II compares some of the properties of the fluid with water.

Table II

	<u>Water (5)</u>	<u>L-45 (4)</u>
Thermal Conductivity (cal/sec/cm ² -C)	0.001348	0.000306
Specific Heat (cal/gr/ C @ 25 C)	0.998280	0.340000
Dielectric Constant (@ 25 C)	1.013	2.650
Volume Resistivity (ohm/cm)	0.5 x 10 ⁶	10 ¹⁴
Thermal Expansion (cc/cc/ C)	0.0002	0.0011
Refractive Index (@ 25 C)	1.332	1.398
Sound Velocity (m/sec @ 25 C)	1498.0	1018.0
Surface Tension (dynes/cm @ 25 C)	71.97	19.50

The toxicological properties are good(4). "Testing in animals indicates that L-45 silicone fluids are of a very low order of toxicity by all routes of administration. Maximum possible doses by mouth produce no deaths in experimental animals. None of these materials produce eye or skin irritation, and are not absorbed in harmful amounts through the intact skin of animals. Breathing of saturated vapors for an eight-hour exposure killed none of the experimental animals." There is no precautionary labeling used on the containers.

The fluid is insoluble (less than 10%) in acetone, ethanol, ethylene glycol, water, glycerol, and isopropanol. The L-45 fluid is soluble (at least 30%) in benzene, chloroform, ethyl acetate, ethyl ether, hexane, methyl ethyl ketone, toluene, xylene and several fluorocarbons. It should be noted that unsealed, the fluid will be cloudy at low temperatures because of moisture and condensation. Reasonable care will prevent the cloudiness down to -60 C. Fluid that has been contaminated with water can easily be stripped by the addition of a drying agent (anhydrous calcium @ 0.1 to 0.5% concentration) followed by filtering with Fullers Earth or attapulugus clay. Storage containers should have a dry nitrogen atmosphere. A less desirable moisture removal technique is to heat and evacuate.

The following data from Union Carbide illustrates trends of the L-45 7 centistokes fluid with changing conditions. Fig. 1 is viscosity change with temperature. Fig. 2 compares viscosity with shear rate. These figures are determined in rotational viscosity with apparent viscosity a function of the torsional resistance of the turning cylinder while the shear rate is dv/dr or the change of velocity with respect to the cylinders radius. The kinematic viscosity by capillary-tube viscometers is expressed in centistokes (cstk). Figs. 3 and 4 are plots of two fluids from the previous figures but at elevated temperatures. Thus, at shear rates up to 1,000 reciprocal seconds it behaves as a Newtonian fluid. Above that it behaves as a pseudo-plastic fluid with apparent viscosity decreasing.

Fig. 5 indicates density change with temperature. The table below the figure gives the specific points for the five temperature readings. Figs. 6 and 7 indicate changes in thermal conductivity and specific heat respectively, varying with temperature.

Figs. 8 and 9 display the trends of 50 cstk L-45 fluid in compression. Data on 7 cstk fluid was not available, but it is estimated to be approximately 2% more compressive @ 10 kpsi. Fig. 10 is the thermal expansion property of a 10 cstk fluid, the 7 cstk fluid should lie very close as indicated by the trend due to the 100 and 1000 cstk plot. The volume at the various temperatures is obtained by multiplying the volume (ambient) by the ratio from the figure at the specific temperature chosen (i.e. - 25 to 150 C). The average volume thermal coefficient of expansion for 7 cstk fluid is 11.1×10^{-4} cc/cc/ C (0-100 C) and 10.8×10^{-4} (0-100 C)/ 11.4×10^{-4} (100-150 C) for 10 cstk.

Fig. 11 indicates change in surface tension with temperature for the 7 cstk fluid. The values drop 0.05 dynes/cm per 1 C temperature increase. Figs. 12 and 13 indicate trends in the dielectric constant with respect to viscosity, temperature, and frequency.

All the data presented is applicable to the pure dimethylpolysiloxane-trimethyl end-blocked fluid. Silicone fluids with other chemical structures, molecular weights, or additives such as antioxidants do not generally have these specific properties.

Fig. 1

Fig. 2. Viscosity vs Shear Rate

Fig. 3. Viscosity vs Shear Rate

Fig. 4. Viscosity vs Shear Rate

Fig. 5. "Union Carbide" L-45 Silicone Fluids: Density Versus Temperature

Fig. 6. Thermal Conductivity vs Temperature: "Union Carbide"
L-45 Silicone Fluid (7 CSTK.)

Fig. 7. Specific Heat vs Temperature: "Union Carbide" L-45
Silicone Fluid (7 CSTK.)

Fig. 8. Compressibility of Silicone Fluids Versus Petroleum Products

Fig. 9. Compressibility and Bulk Modulus* of L-45, 50 CSTK. and Higher

Fig. 10. Effect of Temperature on Volume of "Union Carbide" L-45 Silicone Fluid

Fig. 11. Surface Tension vs Temperature: "Union Carbide" L-45
Silicone Fluid (7 CSTK.)

Fig. 12

Fig. 13

CONCLUSIONS

Data extracted from current publications on silicone fluids indicate that Union Carbide L-45 (7 centistoke) fluid can be used for the "Aquarium Test" to study shock properties of HE at temperature extremes (-65 to 165 F). Variations of typical physical properties of the dimethylpolysiloxane tri-methyl end-blocked fluids are presented but should not be extrapolated to the high energies associated with the shock zones. Some properties are compared with water (the currently used ambient temperature aquarium fluid). The following characteristics are given: molecular structure, toxicity, solubility, contamination, kinematic viscosity/temperature, apparent viscosity/shear rate/temperature, density/temperature, thermal conductivity/temperature, specific heat/temperature, compressibility, bulk modulus, thermal expansion/temperature, surface tension/temperature, dielectric constant/temperature, frequency, flash point, pour point, specific gravity, refractive index, dielectric strength, dissipation factor, and volume resistivity.

The qualities above are suggested as a basis for the fluid selection rather than hydrodynamic data because the latter is not known to exist for these silicone fluids in situ. It is predicted that actual use of the L-45 fluid in the "Aquarium Test" will produce sufficient data to verify the fluid selection.

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