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SURFACE TENSION, VISCOSITY, AND DENSITY MEASUREMENTS OF TWO FLUOROCARBON SOLVENTS, FC-43 AND FC-78

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Cleveland, Ohio

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ABSTRACT

The surface tension, viscosity, and density of two fluorocarbon solvents FC-43 and FC-78 were measured as functions of temperature. A Du Noüy tensiometer, a falling ball viscometer, and a specific gravity chainomatic balance were used in the measurements. Liquid temperatures were varied from 5° to 30° C. Property values at 20° C were 16.7 dynes per centimeter, 6.49 centipoise and 1.9053 grams per cubic centimeter, for FC-43 and 13.2 dynes per centimeter, 0.62 centipoise, and 1.7290 grams per cubic centimeter, for FC-78.

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SUMMARY

The surface tension, viscosity, and density of two fluorocarbon solvents FC-43 and FC-78 were measured as functions of temperature. A Du Noüy tensiometer, a falling ball viscometer, and a specific gravity chainomatic balance were used in the measurements. Liquid temperatures were varied from 5° to 30° C. Property values at 20° C were 16.7 dynes per centimeter, 6.49 centipoise and 1.9053 grams per cubic centimeter, for FC-43 and 13.2 dynes per centimeter, 0.62 centipoise, and 1.7290 grams per cubic centimeter, for FC-78.

INTRODUCTION

Scale model propellant tanks are being used in drop-tower studies to make parametric analyses of the low gravity behavior of propellant liquids in space vehicle tanks. Two parameters frequently considered are the Bond number B_o and the Weber number We. Both of these numbers are dimensionless. The first is the ratio of acceleration to surface tension forces. The second is the ratio of inertial to surface tension forces. To obtain Bond numbers and Weber numbers for the scale models that are comparable to those for real propellant tanks requires a variety of tank sizes and liquids. Desirable liquid properties are low kinematic surface tension and a range of viscosities. Two useful liquids are the fluorocarbon solvents FC-43 and FC-78. This report presents the results of experimental measurements of density, surface tension, and viscosity for these liquids as functions of temperature. Temperatures ranged from 5° to 30° C.

SYMBOLS

a	acceleration, cm/sec^2
B_o	Bond number, $B_o = \rho a L^2/\sigma$
C	mean circumference of ring, cm
F	correction factor
g	acceleration due to gravity, 981 cm/sec^2
k	constant
L	characteristic length, cm
m	mass, g
R	radius of ring, cm
r	radius of ring wire, cm
T	time, sec
v	velocity, cm/sec
We	Weber number, $We = \rho v^2 L/\sigma$
σ	surface tension, dynes/cm
σ'	apparent surface tension, dynes/cm
η	dynamic viscosity, cP
ρ	density, g/cm^3

Subscripts:

b	ball
D	lower phase (in this case the test liquid)
d	upper phase (in this case air)
l	liquid
w	water

LIQUID PROPERTY MEASUREMENTS AND RESULTS

Because the properties to be measured are affected by contaminants, it was essential that both liquids be of high purity and remain uncontaminated during storage and handling. Therefore, the liquids were stored and all measurements made in a class

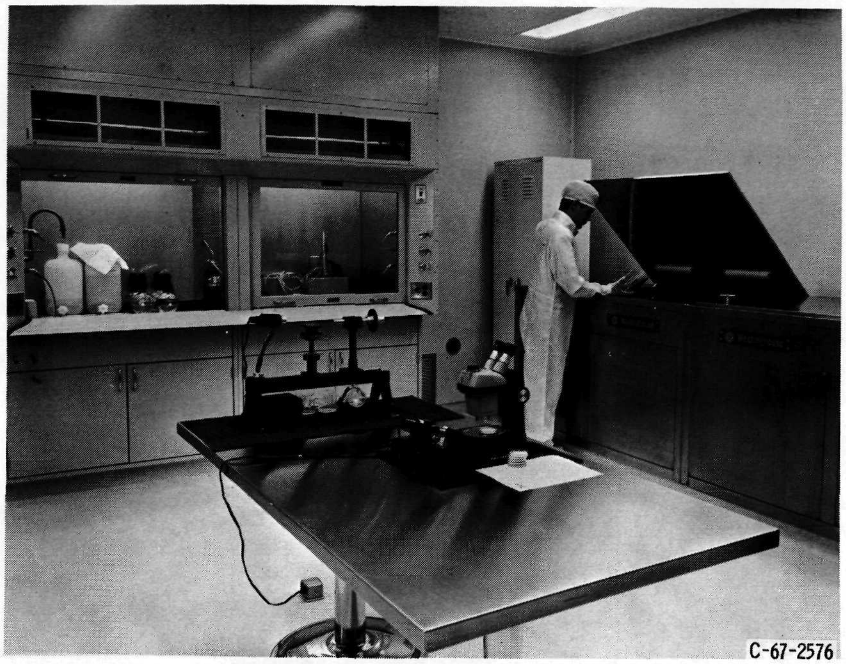

Figure 1. - Class 10 000 clean room.

10 000 clean room (fig. 1). Glassware was cleaned ultrasonically or, when possible, with a solution of chromic-sulfuric acid. All metals and plastics were cleaned ultrasonically.

Density

The density of FC-43 and FC-78 was measured using a specific gravity chain balance. This instrument uses the plummet displacement principle with a chain weight system. Liquid temperatures were varied from 5° to 30° C by using a constant temperature circulator. A glass container with double walls permitted even circulation of a constant t temperature liquid around the test liquid. Test liquid temperatures were controlled and measured to within $\pm 0.2^\circ$ C.

In most cases, several readings of specific gravity were taken for each temperature chosen within the above range. These were averaged and the density calculated from the relation (ref. 1)

$$\text{specific gravity} = \frac{\rho_l}{\rho_w(4^\circ\ \mathrm{C})}$$

The handbook value for the density of water at 4° C is 0.999973 gram per cubic centimeter (ref. 2); consequently, the correction is very small. Table I shows the density for both

TABLE I. - DENSITY

Liquid	Temperature, °C	Density, ρ, g/cm^3
[a]FC-43	8.9	1.9292
	12.7	1.9206
	16.5	1.9126
	19.9	1.9055
	22.6	1.8996
	25.3	1.8928
	27.5	1.8892
	29.6	1.8846
[a]FC-78	6.0	1.7673
	7.0	1.7644
	10.5	1.7549
	14.2	1.7444
	18.0	1.7337
	21.2	1.7245
	24.0	1.7164
	27.2	1.7070
	29.9	1.6998

[a]Fluorocarbon solvent manufactured by the 3M Co.

liquids and the corresponding temperature at which each measurement was made. Figures 2 and 3 are plots showing density as a function of temperature. The measurements are accurate to ±0.0002 gram per cubic centimeter.

Surface Tension

The surface tension of both FC-43 and FC-78 was measured using a Du Noüy ring tensiometer (refs. 3 and 4). This instrument is a torsion balance measuring the torque in a stretched wire required to break a wire ring from the liquid surface being tested. In this case, the ring wire was platinum-iridium. The contact angle between the ring and the test liquids was 0° as required.

This tensiometer is calibrated so that the surface tension σ is given by the relation (ref. 5)

$$\sigma = \sigma' \times F \tag{1}$$

where σ' is the instrument reading in dynes per centimeter or the "apparent surface tension" and F is a correction factor. The correction factor is given by the equation

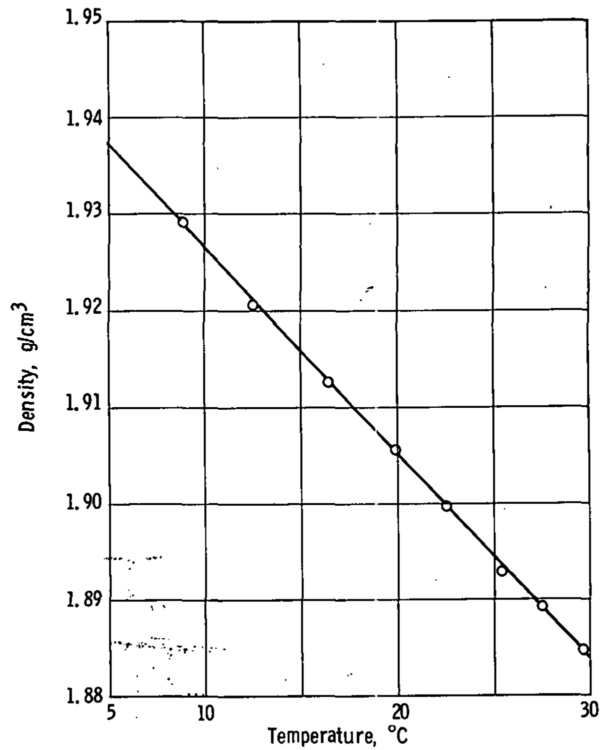

Figure 2. - Density of FC-43 as function of temperature.

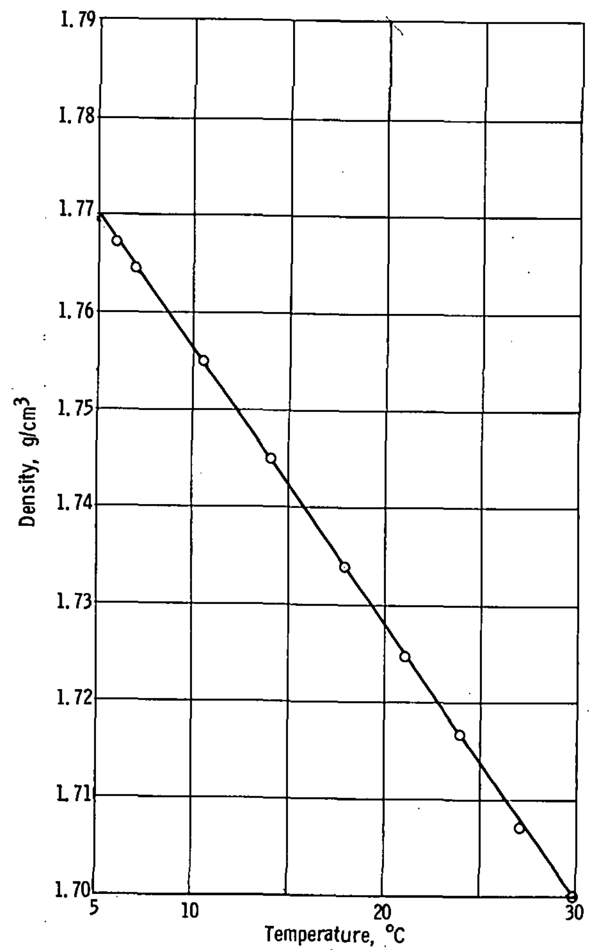

Figure 3. - Density of FC-78 as function of temperature.

$$(F - 0.7250)^2 = \left(\frac{0.00363}{\pi^2 R^2}\right)\left(\frac{\sigma'}{\rho_D - \rho_d}\right) + 0.04534 - 1.679\,\frac{r}{R} \tag{2}$$

The instrument is calibrated to read dynes per centimeter by placing precision weights on the ring and adjusting the reading σ' to that given by the equation

$$\sigma' = \frac{mg}{2C} \tag{3}$$

After calibration, several readings of σ' were taken for temperatures ranging from 5° to 30° C. Temperature control and cleaning procedures were those described earlier with the addition that the ring was flame cleaned over a Bunsen burner. Table II shows the surface tension σ calculated from the averaged readings and corrected by the factor F. (The surface tension σ differed from σ' by approximately 10 percent.) Figure 4 shows the surface tension plotted as a function of temperature for both liquids. The data have been approximated by a straight line in this figure. The measurements are accurate to ± 0.1 dynes per centimeter. With these surface tension values the contact angle on borosilicate glass and most acrylic plastics is nearly zero degrees.

TABLE II. - SURFACE TENSION

Liquid	Temperature, $^{\circ}$C	Surface tension, σ, dynes/cm
FC-43	7.9	17.6
	10.6	17.4
	14.7	17.1
	18.6	16.9
	22.1	16.5
	25.7	16.3
	28.0	16.0
FC-78	7.8	14.5
	9.8	14.3
	12.4	14.0
	15.2	13.6
	17.7	13.4
	19.9	13.2
	21.7	13.0
	25.2	12.6
	26.9	12.4
	28.6	12.3

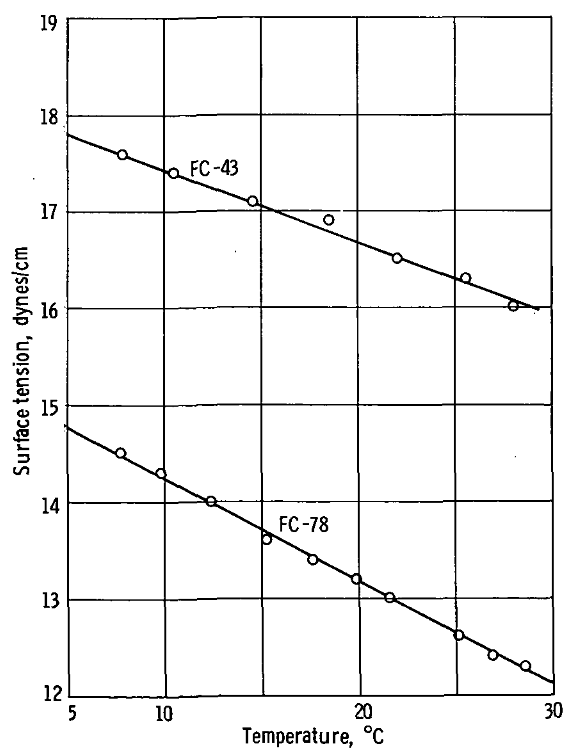

Figure 4. - Surface tension of FC-43 and FC-78 as function of temperature.

Viscosity

The dynamic viscosity η of FC-43 and FC-78 was determined as a function of temperature by means of a falling ball viscometer (ref. 6). The falling ball viscometer consists of a glass column surrounded by a temperature jacket and a set of glass and steel spheres of varying size and material. Viscosity is determined by filling the column with the test liquid and measuring the time required for a ball to fall through the liquid. The formula relating fall time to viscosity is

$$\eta = (\rho_b - \rho_l)Tk_b \tag{4}$$

The temperature of the liquid within the column was controlled as described previously. Liquid temperatures were varied from 5° to 30° C. At each temperature chosen within this range, two measurements of the fall time T were made. These were aver-

TABLE III. - VISCOSITY

Liquid	Temperature, °C	Dynamic viscosity, η, cP
FC-43	7.7	10.85
	9.3	10.13
	11.3	9.24
	13.0	8.61
	15.6	7.66
	18.7	6.83
	21.5	6.14
	24.6	5.55
	26.3	5.22
FC-78	8.3	0.98
	10.3	.94
	13.6	.91
	16.7	.86
	19.1	.82
	21.9	.79
	25.2	.75

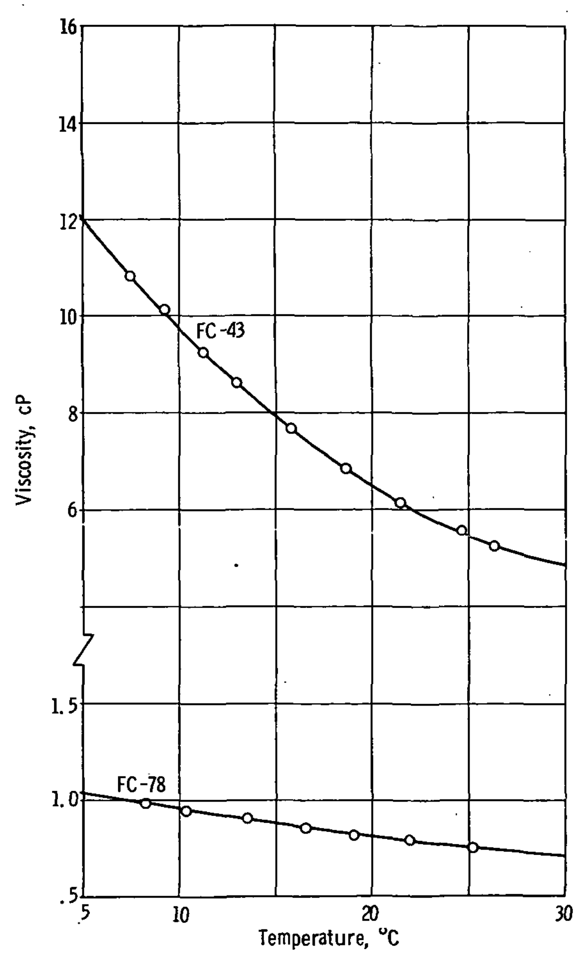

Figure 5. - Viscosity of FC-43 and FC-78 as function of temperature.

TABLE IV. - SUMMARY OF THE LIQUID

PROPERTIES OF FC-43 AND FC-78

Liquid	Temperature, ^{o}C	Density, ρ, g/cm^3	Surface tension, σ, dynes/cm	Dynamic viscosity, η, cP
FC-43	0	1.948	18.2	14.6
	5	1.937	17.8	12.0
	10	1.927	17.4	9.7
	15	1.916	17.1	7.9
	20	1.905	16.7	6.5
	25	1.895	16.3	5.4
	30	1.884	15.9	4.8
FC-78	0	1.782	15.3	1.12
	5	1.767	14.8	1.03
	10	1.756	14.3	.95
	15	1.742	13.7	.88
	20	1.728	13.2	.81
	25	1.714	12.6	.75
	30	1.699	12.1	.70

aged and substituted into equation (4). Liquid density was taken from figures 2 and 3. Table III shows the resulting data. Figure 5 is a plot of viscosity as a function of temperature. The measurements are accurate to ±0.05 centipoise.

SUMMARY OF RESULTS

A summary of the liquid properties for both FC-43 and FC-78 is presented in table IV. Values for the density, surface tension, and viscosity are given for 5^{o} increments between 0^{o} and 30^{o} C. These values were extrapolated from the experimental data.

Lewis Research Center,
National Aeronautics and Space Administration,
Cleveland, Ohio, May 28, 1969,
124-09-17-01-22.

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