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VISCOSITY OF FUSED MIXTURES OF SODIUM FLUORIDE, BERYLLIUM FLUORIDE, AND URANIUM FLUORIDE

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AEC Research and Development REPORT

Mound Laboratory
Miamisburg, Ohio **Operated By**
Monsanto Chemical Company
Research and Engineering Division

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I. ABSTRACT

The viscosity of mixtures in the ternary system, sodium fluoride - beryllium fluoride - uranium fluoride, was investigated over the temperature range from 900°C to 450°C, or to the liquidus point on compositions having a liquidus below 850°C and high vapor pressure. The results are given in tabular and graphic form.

II. SUMMARY

Mound Laboratory was requested to measure the viscosity of fused mixtures of sodium fluoride, beryllium fluoride, and uranium fluoride. A Margules concentric-cylinder, high temperature viscometer was constructed. Viscosities of the ternary fused salts were measured under an inert atmosphere at temperatures from 900° to 450°C, or to the liquidus point. Areas of high beryllium fluoride composition were not measured because of the high viscosity, high vapor pressure, or both. The results are given in tabular and graphic form.

III. EXPERIMENTAL METHOD

APPARATUS

Of the instruments available for measuring viscosities, three types were considered applicable to this problem. These were a modified Brookfield Viscosimeter, a modified Ostwald capillary-type viscometer, and a concentric-cylinder viscometer which was modified from a type developed to measure viscosities of steel mill slags.

A Brookfield Viscosimeter was obtained, but was broken during assembly. Before it was repaired, the concentric-cylinder method had proven to be satisfactory, so the Brookfield instrument was not used.

A capillary-type viscometer was constructed and its performance was checked. In this instrument, the molten salt was forced through a capillary tube into a wider tube in which pairs of electrical contacts were located a known distance apart. The time required for a known volume of liquid to flow through the capillary could be recorded by means of these contacts.

This system proved to be unworkable for two reasons. Considerable error was introduced by adherence of liquids from previous runs to the walls of the tube and capillary, and the capillaries had a persistent tendency to become clogged by the corrosive action of the liquids being tested. Since only relative viscosities can be obtained with this viscometer at any given temperature, the instrument must be calibrated over the desired temperature range with liquids of known viscosities.

The most satisfactory apparatus found, and the one used for all the viscosity measurements reported in this paper, was the concentric cylinder viscometer. This method consists of measuring the torque developed on a fiber by a cylinder suspended from the calibrated fiber in a rotating liquid. The concentric cylinder method of measuring viscosities was devised theoretically by M. Margules[6]. He developed a simple equation, but made no actual measurements. Other workers however, have used Margules' original viscometer design to measure viscosities of molten slags[2,5]. Searles[9] modified Margules' design, and his modification has been used to measure the viscosity of molten glasses, light metal alloys, and slags. These instruments yield rough absolute viscosities, and precise relative viscosities. The chief advantage of the original Margules design over the Searles modification lies in its elimination of friction effects.

An instrument based on Margules' method was designed and constructed. Figure 1 shows this apparatus in cross section.

This apparatus consisted of an inner cylinder, (J), 1-inch in diameter and 2-inches long called a bob, which was made of Inconel. The bob was suspended from a 1/4-inch diameter nickel shaft, (I). The shaft contained a chromel-alumel thermocouple (K) which extended into the bob. This thermocouple provided a method of measuring the temperature of the melt. The shaft and the bob were supported by a torsion-calibrated, 0.010-inch, uniform-diameter molybdenum wire (A). The torsion fibers had constants of about 2000 dyne-centimeter/radian. The wire was held at each end by a pin vise (B), and the entire assembly was suspended from a calibrated micromanipulator anchored securely above the apparatus. The upper pin vise was mounted in a steel block, trapezoidal in cross section, which in turn fitted into

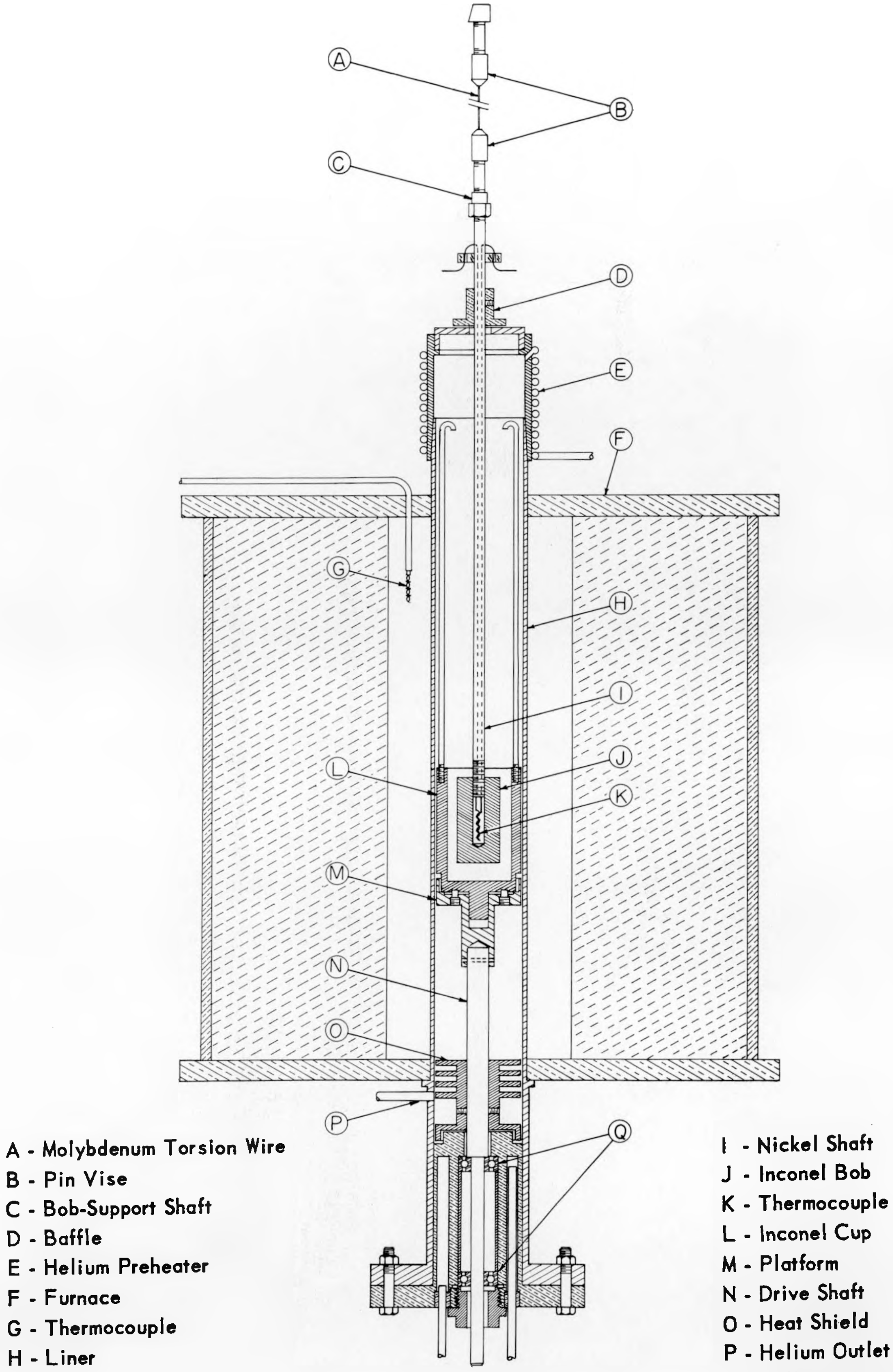

Figure 1. Viscosity Apparatus

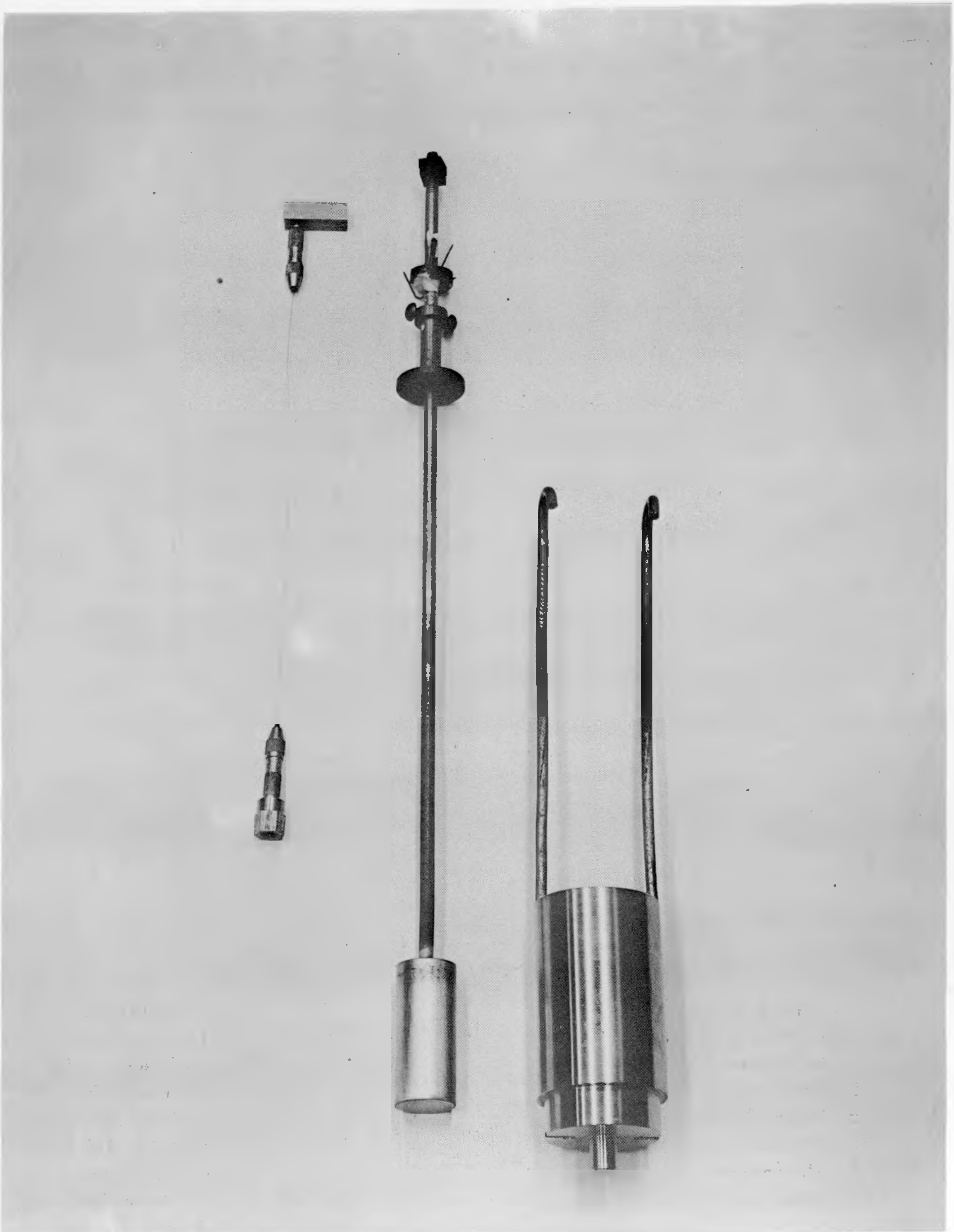

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Figure 2. Torsion Wire, Shaft, Bob, and Cup

a machined clamp on the micromanipulator. With this feature, the wire and bob assembly could be removed from the clamp, if necessary, and could be relocated precisely.

Coaxial with the bob was a hollow outer cylinder 2-inches in diameter and 3-1/2-inches long (L), called the cup, which was also made of Inconel. This cup contained the liquid under consideration during the viscosity determination. The portion of the cup containing liquid was cylindrical, 1-1/2 inches in diameter by 3-1/8 inches deep. Two nickel hooks mounted in the rim of the cup aided in placing the cup in the apparatus and in removing it. Figure 2 shows the bob, cup, and wire assembly. The inside bottom surface of the cup was flat and perpendicular to the cylindrical side. The cup was supported by a nickel platform (Figure 1,M) which in turn was pinned to the end of a stainless steel drive shaft (N). The shaft was supported by two ball bearings (Q) which permitted the shaft, platform, and cup to be rotated in either direction about the cylindrical axis. The bearings were kept cool by water circulation in the bearing mount and by a stainless steel heat shield (O) mounted on the shaft above the bearing mount. Positive drive contact between the platform and the cup was obtained by two nickel pins that projected from the platform into suitable milled slots in the bottom of the cup.

The drive shaft assembly, cup, bob, and bob-support shaft were enclosed in a large 2.3 KW resistance furnace (F). This furnace was heavily lagged at both ends and contained an Inconel inner liner (H) coaxial with the cup and bob. Clearance between the cup and the liner was 1/16-inch. Thermal control of the furnace was maintained by a chromel-alumel thermocouple (G) in conjunction with a Foxboro potentiometer controller and auxiliary relays.

During the viscosity measurements, a small mirror was mounted on the bob-support shaft at (C) to provide an optical lever to measure the angular displacement of the bob.

Because of the high-temperature corrosion effect of air on the apparatus, it was found desirable to maintain an inert atmosphere inside the furnace liner. To do this, commercial-grade helium was passed through a liquid-nitrogen trap to remove water vapor and then introduced at the top of the inner liner at a rate of 10 cubic feet per hour. To reduce temperature gradients inside the furnace, the helium was passed through a preheater (E) at the top of the furnace. Because of the toxicity of the salts used and, in particular, because of the extreme toxicity of the beryllium fluoride fumes evolved at high temperatures, helium was drawn from the base of the liner at (P) at a rate of 4 cubic feet per hour by an exhaust pump and was vented through a hood. The remaining six cubic feet per hour of helium was allowed to flow out of the top of the furnace around a baffle system (D). This flow effectively prevented back diffusion of air along this path. As an extra precaution, the entire apparatus shown in Figure 3 was surrounded by a large fume hood. The atmosphere in the fume hood was monitored to prevent possible beryllium exposure. The furnace controls for both the density and viscosity apparatus are shown in this photograph.

The cups and bobs that were used for the first few experiments were made of nickel. However, this material was not satisfactory because of excessive corrosion by the

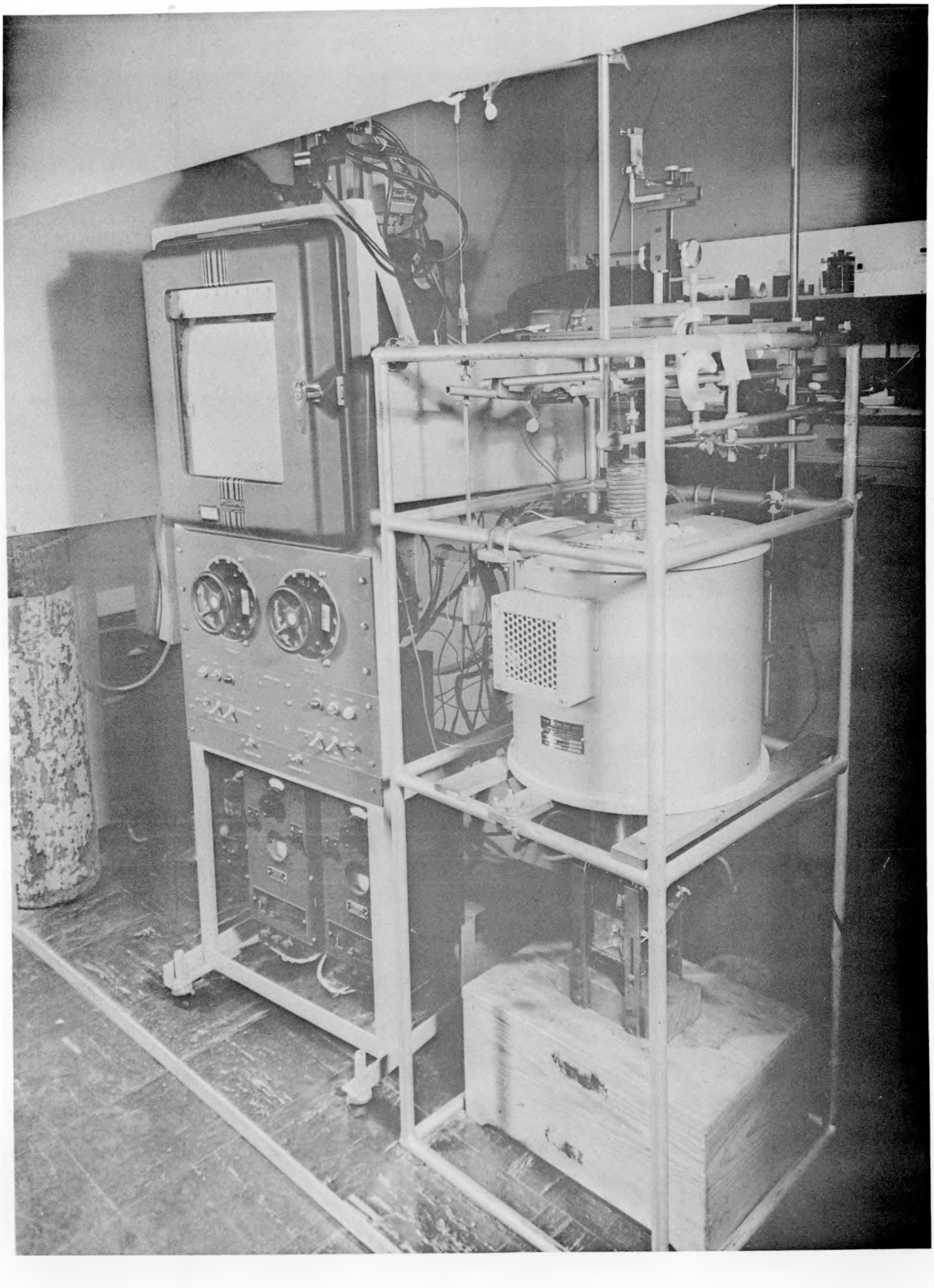

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Figure 3. Temperature Controller-Recorder and Viscometer

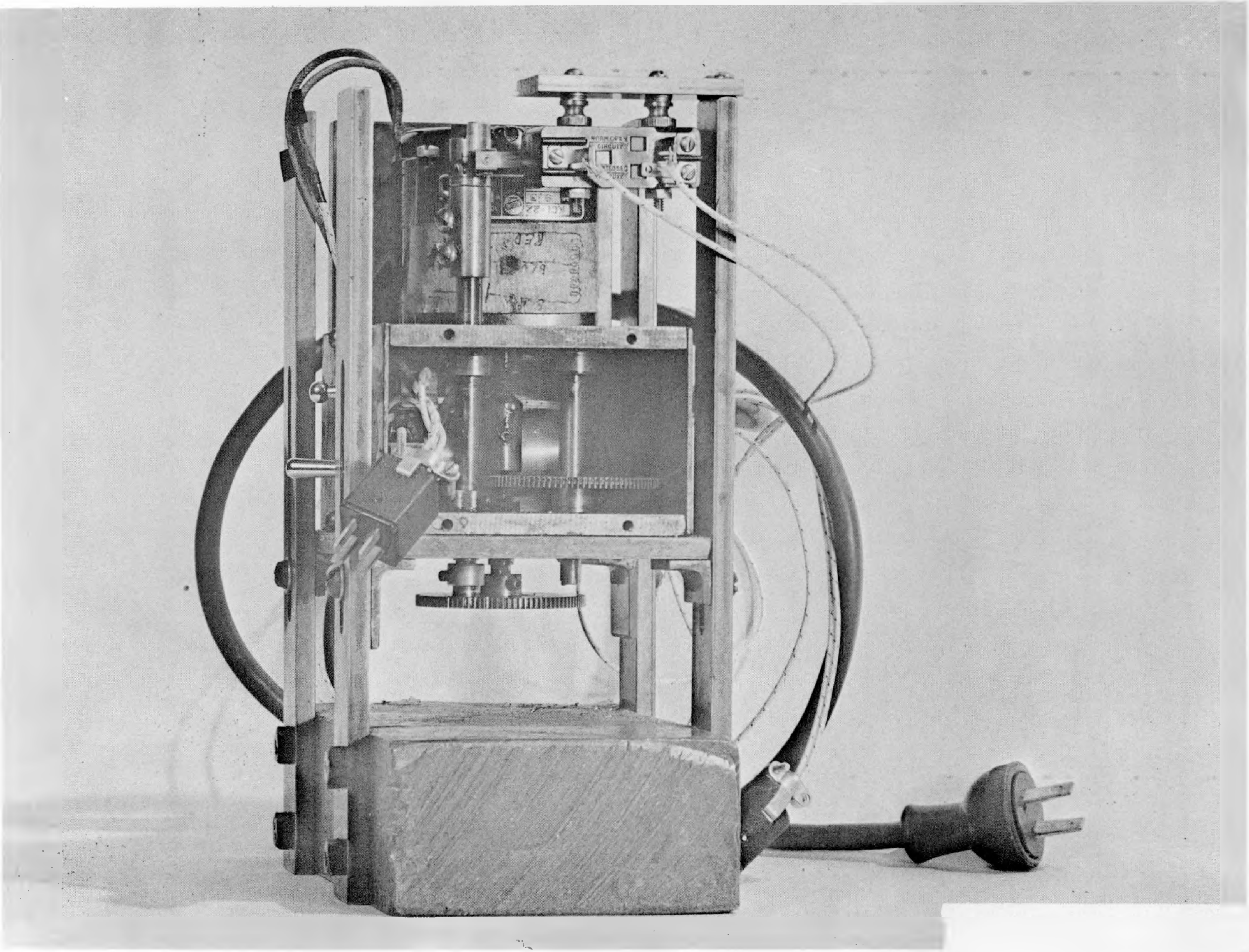

Figure 4. Motor Assembly

fused salts and because of a tendency of the metal to sag after exposure to prolonged high temperatures. Graphite has excellent corrosion resistance and dimensional stability but was also unsatisfactory because it was not wet by the liquid salts. Bobs and cups made of Inconel showed the greatest corrosion resistance and thermal stability of the materials tried; hence, Inconel parts were used for all the viscosity determinations.

Stainless steel was used originally for the furnace liner and cup-support platform but was unsatisfactory because of the corrosive action of fluoride vapors. Eventually these parts were replaced with ones made of Inconel and nickel, respectively.

The original torsion fibers were quartz, similar to those used on quartz-fiber microbalances. Although these fibers generally give more accurate data than metal fibers, because of less deformation under strain, it was found that they are too fragile to withstand constant use on this type of equipment. Tungsten fibers were found to be too stiff for the viscosity range to be covered. Molybdenum fibers of 0.005 and 0.010-inch diameter specially selected for uniformity were finally chosen. Later it was necessary to restrict the use to 0.010-inch fibers since the period of oscillation of the 0.005 inch fiber allowed the suspension to resonate with the rotational period of the cup, thus causing extreme difficulty in reading the oscillating optical lever.

The cup was rotated by a small, reversible, constant-speed motor and gear-box assembly which was coupled directly to the cup drive shaft beneath the furnace. Figure 4 shows the motor assembly. The period of rotation of the cup was selected by the ratio of two matched gears, shown exposed in Figure 4, which were mounted directly on the motor shaft and cup drive shaft coupling. Matched gear pairs are available that provide speed ratios of 1:0.250, 1:0.428, 1:0.667, 1:0.844, 1:1, 1:1.185, 1:1.500, 1:2.33, and 1:4.000, to the constant-speed motor shaft which had a period of 6.250 seconds.

There is also a back-gearing arrangement on this mechanism that provides speed reductions of one-tenth of the values given above.

The period of rotation was determined by means of a revolution counter which was actuated by the microswitch mounted as shown in Figure 4 and a precision timer, synchronized with the counter.

THEORY AND CALCULATIONS

The Margules equation for the rotational viscometer may be developed in the following manner.

For a new torsion liquid, the shearing stress, F, per unit area is directly proportional to shearing rate. The proportional coefficient, η, is the viscosity.

$$F = \eta \frac{dv}{dr}$$

$$dv = -\, r d\omega$$

$$F = -\, \eta r \frac{d\omega}{dr}$$

η = coefficient of viscosity

v = tangential velocity

r = radius

ω = angular velocity

The torque, L, per unit area is

$$L/2\pi rh = -Fr$$

$$= \eta r^2 \frac{d\omega}{dr}$$

h = height of liquid

L = torque

Solving for $d\omega$ and intergrating

$$\int_{0}^{\Omega} d\omega = \frac{L}{2\pi\eta h}\int_{r_1}^{r_2}\frac{dr}{r^3}$$

Solving for η

$$\eta = -\frac{L}{4\pi h\Omega}\left[\frac{1}{r_2^2} - \frac{1}{r_1^2}\right]$$

Since

$$\Omega = \frac{2\pi}{T}$$

And $L = K\theta$ Where

T = period of rotation

K = torsion constant

θ = angular displacement

Then

$$\eta = \frac{KT\theta}{8\pi^2 h}\left[\frac{1}{r_1^2} - \frac{1}{r_2^2}\right]$$

$$= \frac{KT\theta}{8\pi^2 h}\left[\frac{r_2^2 - r_1^2}{r_2^2 r_1^2}\right]$$

$$= \frac{KT\theta}{8\pi^2 h\left[\frac{r_1^2 r_2^2}{r_2^2 - r_1^2}\right]} \qquad \text{let } c = 8\pi^2\left[\frac{r_1^2\ r_2^2}{r_2^2 - r_1^2}\right]$$

$$= \frac{KT\theta}{ch}$$

Since this equation was developed without consideration of the effect of the bottom of the bob, some correction must be made for this additional area. This "end effect" results in an apparent increased depth of immersion, so an empirical amount was added to the height.

$$\eta = \frac{KT\theta}{c\ (h+\epsilon)}$$

Where ϵ = end-effect correction

Since the viscosities were to be measured at elevated temperatures, the radii of the bob and cup would be affected, thus:

$R_1 = \alpha_t r_1$ $\qquad$ $\alpha_t = (1 + A_t\, t)$ where

$R_2 = \alpha_t r_2$ $\qquad$ A_t = linear coefficient of expansion at temp. t

$$c_t = \frac{8\pi^2 R_1^2\, R_2^2}{R_2^2 - R_1^2} = \frac{8\pi^2 r_1^2 r_2^2}{r_2^2 - r_1^2}\,\alpha_t^2$$

R_1 and R_2 = radii of bob and cup at temp. t.

This gives us the variables that must be measured to determine viscosity, namely; K, r_1, r_2, α, h, θ, T, t, and ϵ.

The torsion constant K, was determined by measuring the change in period of oscillation of a pendulum suspended from the fiber as the moment of the pendulum was shifted. The pendulum consisted of four arms mounted horizontally at 90° to each other (Figure 5). Each arm had at its end a large disc-shaped piece of brass of known mass and dimension. There was a second position for the brass disc on each arm at a known distance from the center of the pendulum. A period was taken with all the brass weights extended on the cross arms, a second period with two weights extended and two weights in the intermediate position as shown in Figure 5, and a third period taken with all weights in the intermediate position.

The moment of the pendulum I, is

$$I_1 = 4\left[\frac{m}{12}(3r^2 + h^2) + md_1^2\right] + I_o$$

where

m = mass of the brass disc

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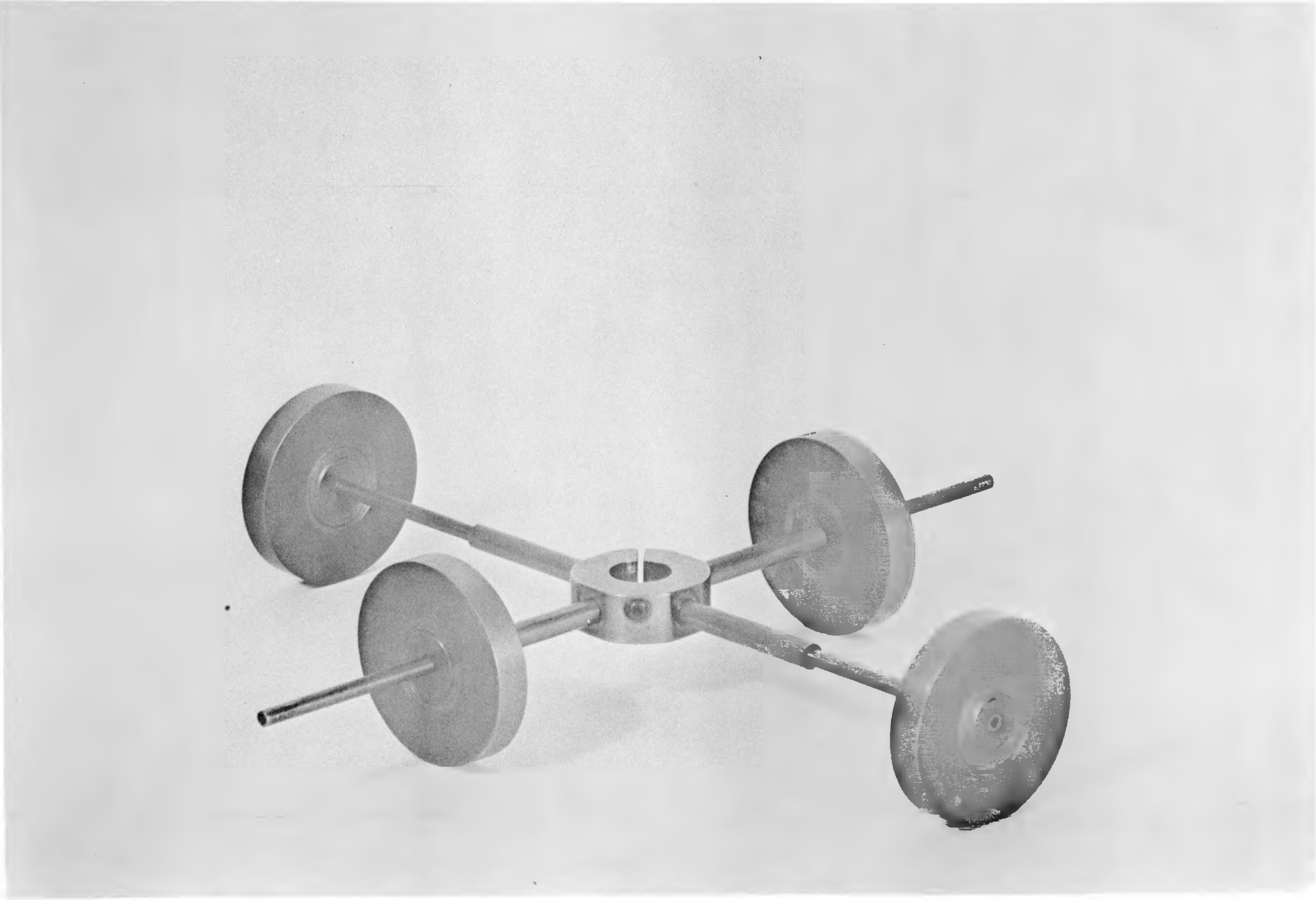

Figure 5. Pendulum

$$I_2 = 2\left[\frac{m}{12}(3r^2 + h^2) + md_1^2\right] + 2\left[\frac{m}{12}(3r^2 + h^2) + md_2^2\right] + I_o$$

$$I_3 = 4\left[\frac{m}{12}(3r^2 + h^2) + md_2^2\right] + I_o$$

r = radius of disc

h = thickness of disc

d = radius of gyration of disc

I_o = moment of fiber plus clamp and arms

The period T, of a pendulum is

$$T_n = 2\pi \sqrt{I_n/K}$$

Then

$$K = \frac{4\pi^2 \Delta(I)}{\Delta(T^2)} = \frac{4\pi^2 (I_1 - I_2)}{T_1^2 - T_2^2}$$

where K is elastic constant and T is the period of oscillation.

The radii of the bob and cup, r_1 and r_2, were measured directly with micrometer calipers and a telescoping gauge.

The coefficient of linear expansion α, for nickel and for Inconel were obtained from the International Critical Tables[4], Mellor[7], Harrison[3], and Wise and Schaefer[11]. A table of α and α^2 values over the range of operating temperatures was prepared from these data for convenience. The depth of immersion, h, of the bob in the liquid was calculated from the mass of mixture introduced and previous measurements of the density as a function of temperature.

$$V_t = m/\rho_t$$

V = volume
m^t = mass of salt
ρ_t = density

A fixed height of the bob over the cup bottom was maintained to simplify calculations. If this height is fixed at h_o, the volume V_1, of liquid below the bob is

$$\pi\ (\alpha\ r_2)^2\ h_o = V_1$$

Then the residual volume V_2 is distributed between the bob and cup walls.

$$V_2 = \pi\ [(\alpha\ r_2)^2 - (\alpha\ r_1)^2]\ h = V - V_1$$

$$h = \frac{1}{\pi\ (r_2^{\ 2} - r_1^{\ 2})}\ [V/\alpha^2 - \pi r_2^{\ 2}\ h_o]$$

The angular displacement θ, was measured by use of an optical lever. A small mirror was mounted on the fiber-retaining clamp, well above the furnace, and the displacement of a reflected image of a stationary light source was read on a scale approximately 3 meters from the mirror. The deflection was read in both directions, after centering the image to eliminate necessity of determining an exact zero point. Then $\theta = \frac{D}{4d}$, where D is the deflection in cm and d is the distance from the mirror to the scale in cm. Since the maximum displacement angle on the scale was less than 8^o, no correction was made for the lack of curvature of the scale.

The period of rotation, T, was measured directly with the aid of a revolution counter on the drive shaft, and a precision timer electrically connected to the counter.

The temperature, t, was measured with the chromel-alumel thermocouple in the bob in conjunction with an ice-bath cold junction and a Rubicon research potentiometer. Chromel and alumel connection clips were made for the respective lead wires to prevent secondary thermal effects.

The end-effect correction, ϵ, turned out to be a function of the geometry of the system and also of the viscosity of the liquid. The end effect was calculated by using liquids of known viscosity calibrated by the U. S. Bureau of Standards.

$$\epsilon = \frac{KT\theta}{\eta C_t} - h$$

The effectiveness of this expression was tested by using varying volumes of liquid, holding all other variables constant. An empirical end-effect correction curve was prepared over the spread of viscosity expected in the ternary fused salts. In order to apply the end effect correction, it was necessary to obtain a tentative viscosity and thereby determine an approximate end-effect correction. On most runs, it was found that a second-order end-effect correction is not necessary.

An empirical height correction had to be introduced to correct for the unequal thermal expansion of parts of the viscometer furnace. Since our calculations for height of immersion assumed a constant separation between bob and cup, this correction factor merely consisted of an additional height to be added on the vertical position of the micromanipulator supporting the bob. This additional height was measured at various temperatures over the range studied by noting the change of height an electrical contact indicated between the bob and cup as the furnace was heated.

PROCEDURE

The first step in measuring viscosity was the alignment of the furnace and the cup. The drive shaft and its supporting bearings were checked for concentricity to less than 1/1000 of an inch. The shaft was assembled in the furnace and a bubble level placed in the cup which was then set onto the shaft. The liner was then adjusted until the bubble level on the floor of the cup showed no deviation from level as the cup was slowly rotated. In general this adjustment does not change appreciably from run to run, and therefore the alignment must be checked only occasionally.

The bob and cup must be clean and the outer surfaces of the bob and the inner surface of the cup, particularly the bob, should be polished. This was found to be necessary so that no turbulence would develop in the liquid during the run. It was found that after most runs the salt residues and scale could be removed and the equipment reused, if the surfaces were redressed with a fine emery cloth after the fused salts were removed. Since the cup and bob were made of Inconel, it was not economically desirable to use a new cup and bob for each run. Occasionally because of corrosive action of the molten salt, pits developed in the bob or cup and it was necessary to remachine and polish the surface.

The bob and the cup must be located concentrically and their cylindrical surfaces must be parallel. If either of the cylindrical surfaces becomes tapered or out of round, it must be remachined and repolished. To assure that the bob's side surface was parallel with the cylindrical axis of the cup, the bob was suspended from the fiber and squared so that its surface was perpendicular at several points on its periphery to a level surface plate. Occasionally it was necessary to bend the bob shaft slightly to bring the bob into verticality. To align the suspension, a small ring which was machined to a slip fit with the cup was inserted in the cup, and the cup placed in the furnace. The inside diameter of the ring was a slip fit with the bob, so that when the bob was aligned precisely, it could be raised and lowered into the ring without binding or hanging-up on the side of the ring. The purpose of the three dimensional micromanipulator clamp, mentioned above, was to provide this delicate adjustment of bob assembly. By use of the two right-angle horizontal scales, the bob was located within 1/10 of a millimeter. The two positions were recorded for subsequent use. The vertical scale on the micromanipulator was used to determine the height of the bob from the bottom (h_o). To do this, the alignment ring was removed, and the bob was lowered until electrical contact with the cup was indicated by a servo mechanism. The vertical reading on the manipulator was recorded, and the cup and bob removed from the furnace.

The radii of the cup and bob were measured, and the cup was filled with an amount of salt mixture calculated to have a volume of 50 ml at 600°C.

Two of the salts were specially purified before use. The uranium tetrafluoride received HF and H_2 treatment at 500°C, and the sodium fluoride was dried at 185°C for over 24 hours. The beryllium fluoride was used as received. The salts were stored in a stainless steel dry box until use. The salts were pulverized, weighed, and mixed in the dry box. This weighed mixture was melted in the same dry box in a nickel crucible by radio-frequency induction heating. While molten, the fused salt mixture was poured into the cup which had been previously weighed. This procedure increased the homogeneity of the mixture. After cooling, the cup was weighed to determine the exact mass of salt transferred. The unmelted pulverized salt mixture was too bulky to be used directly as the cup was not large enough to accommodate a full load of the unfused mixture.

The charged cup and the bob were then reassembled in the furnace. The bob was suspended high enough to clear the unmelted charge. The baffles and helium preheater were placed at the upper end of the furnace and the air in the liner was displaced by helium while the furnace was being heated. Helium flow through the apparatus was maintained throughout the entire run. When the temperature was high enough to melt the salt mixture, the bob was lowered into the melt and adjusted approximately to the correct height. The separation of the bob and floor of the cup was arbitrarily set at 1.756 cm. Because of unequal thermal expansion of the furnace, cup, shaft and other parts, the empirical height correction, which was determined as a function of temperature, was added.

The melt temperature was measured by means of the Chromel-Alumel thermocouple within the bob. Connections for this thermocouple emerge from the shaft outside the furnace. Since the bob must be allowed to swing freely during the actual viscosity measurement, it was necessary to disconnect the thermocouple leads from the bob assembly during such measurement. Small chromel and alumel clips were provided for these connections.

The angular displacement of the bob, θ, was measured by means of an optical lever. The light reflection was centered on the scale of adjustments to the lamp and mirror with the rotating mechanism stopped. The rotating mechanism was started and displacements to the left, and on reversal of the drive motor, to the right, were read. The distance between the two extremes was considered the displacement. The distance, scale to mirror, was 337 cm, so that the angle of displacement, θ, was D/4 x 337, or $\frac{D}{1348}$. The size of the deflection was regulated by changing the speed of rotation so that the measured displacement was never less than 8 cm, nor more than 100 cm.

Runs were usually started by heating the melt to 900°C and taking measurements at intervals of decreasing temperature of 50 to 75°C until the liquidus of the mixture was reached. Higher temperatures were not attempted because the extreme thermal agitation of the melt made accurate measurements difficult, if not impossible, and because of the loss of beryllium fluoride from the melt by volatilization. By starting runs at the higher temperature, homogeneous melts were insured, and any entrapped air bubbles were released.

ERRORS

1. Dimensions of the cylinders were measured to the nearest 0.0001 inch and six measurements were averaged to the nearest 0.0001 inch. The linear coefficient of expansion was expressed to five significant figures with an implied sixth.

2. Torsion constant, K, was the most precisely determined value. Results were reproducible to less than 0.01%. Unless the fibers were abused, the torsion constants remained constant over long periods. Care was taken so that the calibrating pendulum was the same weight as the suspended bob. Heat shielding was provided so that the fiber, although

located over the furnace during a run, was not heated much above room temperature.

3. A series of measurements was made to determine the effect of non-concentricity. It was found that an error of 1 cm (5/13 of the liquid thickness) in centering the bob caused a change of deflection of only 15%. Apparently the rotating liquid has a self-centering effect on the bob, although readings were somewhat more unstable than when the bob was centered. Occasionally it was found that the bob was not perpendicular to the support shaft, or that the cup had sagged or tilted because of the heat relief of internal strains or that the cup drive shaft had been bent in some manner so that the system was no longer concentric. Lack of coaxial alignment was the largest contributor to instability. Although these factors, when present, made the reading of deflections very difficult, the average of a number of these unstable readings on several samples, gave values very close to those obtained during stable runs on identical samples.

Other causes of instability were thermal air currents from the furnace, and the normal air flow of the room ventilation system. A system of baffles was evolved that decreased the effect of these factors to less than 0.5 cm scale reading.

Readings of deflection were normally made in the range of from 8 cm to 100 cm, and successive readings at a given temperature corresponded within 0.2 cm. The scale was shifted after each reading to prevent psychological weighting of readings.

5. Temperature measurement of the melt was quite critical. An arbitrary requirement was imposed that the bob temperature, as recorded on the Speedomax recorder and measured on the potentiometer, had to be constant over a five-minute period before viscosity measurements were attempted. An inconsistency in the

temperature was more easily detected by changes in the deflection than by changes in the thermocouple potential, since the viscosity of the mixtures changes about 1% per ^{o}K at the higher temperature range. Hence, a constantly increasing or decreasing deflection, indicated that the system was not at thermal equilibrium.

The cup and the bob were located in the central five inches of the 13-inch furnace. By use of 1-3/4-inch thick fire brick lagging at each end of the furnace, and a closed one-inch air gap between the furnace and the Inconel liner, a reasonably uniform temperature at this central volume was assured. The vigorous stirring caused by the stationary bob in the rotating liquid aided in the maintenance of uniform melt temperatures.

6. The depth of immersion of the bob was a function of the density of the solution, the dimensions of the bob and cup, and the empirical height correction. The height could be set by the micromanipulator to 0.1 mm over a height of 4.5 cm. The density had been previously measured to within 1% error.

The empirical height constant changed approximately 0.1 mm every 20^{o} in the temperature range studied and reached 4.0 cm at 900^{o}C.

The data for each individual run were plotted as viscosity vs 1/T (°K) on two-cycle semilog paper. The curves were essentially linear as would be predicted from Reynold's[8] postulated relationship

$$\eta = \eta_o e^{B/T}$$

where,

η = viscosity at temp. T

η_o = viscosity at temp. T_o

B = energy constant

T = °K

This relationship had also been derived from thermodynamic considerations by Andraede[1], but later inclusion of change of potential energy with temperature and change of volume modified this to

$$\eta V^{1/3} = A e^{c/VT}$$

where,

c = constant resembling Van der Waal's "a"

A = constant

V = molecular volume

Andraede states that if the liquid does not change coordination with temperature, the simpler expression is usually sufficient.

Experimental results are given from which interpolated values at 600° and 800°C were obtained. At constant uranium fluoride concentrations, the graphs are plotted on the same sheet with a displacement of the temperature axis to prevent overlap.

Most of the data are given in the form of constant uranium fluoride composition. A few runs which did not fall into these isouranium compositions are tabulated. One such set is the "join" between Na_2BeF_4 and

Na_2UF_4.

The interpolated values at 800°, and at 600°C where possible, obtained for each run were used for comparison and further compilation. Compositions were planned to fall along constant mole fractions of one component so that one variable could be fixed.

The compositions used for cross plotting are shown on Figure 16. Measurements were limited to this area because of experimental difficulties with mixtures having a melting point greater than 850°C, or high vapor pressures and viscosities of the mixtures rich in beryllium fluoride. Also, engineering considerations of the molten fluoride reactor indicated maximum interest in the low uranium fluoride concentrations of low dynamic viscosity.

Straight lines were drawn between related interpolated points on these cross plots. No general statement can be made regarding the cross plots except that if smooth curves were to be expected, the experimental error is greater than calculated.

Cross plots are shown for 60, 47, 35, 15, 12, 10, 8, 6, 4, 3, 2, 1 and zero mole per cent uranium fluoride; and 76, 70, 66, 67, 64, 58, 52 and 46 mole per cent sodium fluoride. Interpolated cross plots are shown for 40, 30, 20, 10 and zero mole per cent beryllium fluoride. Cross plots were also made holding a constant ratio between two components and plotting viscosity vs the third component. Comparison of the family of curves formed with changes of ratio of the two components showed that uranium fluoride concentration seemed to be the dominating concentration factor in viscosity between zero and 50 mole per cent beryllium fluoride.

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Table 1

Viscosity ([redacted] poise), Density (g/ml), and Kinematic Viscosity (Stokes) of Mixtures Containing a Constant Mole Per Cent NaF

Composition Mole Per Cent			600°C			700°C			800°C		
NaF	BeF_2	UF_4	η	ρ	η/ρ	η	ρ	η/ρ	η	ρ	η/ρ
76	22	2					2.197		0.0270	2.152	0.0125
76	20	4				0.0547	2.381	0.0230	0.0361	2.328	0.0155
76	18	6				0.0573	2.605	0.0220	0.0331	2.543	0.0130
76	16	8				0.0658	2.751	0.0239	0.0386	2.687	0.0144
76	14	10		3.031			2.957		0.0294	2.879	0.0102
76	12	12	0.1168	3.171	0.0368	0.0700	3.078	0.0227	0.0445	3.017	0.0148
76	9	15	0.1682	3.416	0.0492	0.0935	3.354	0.0279	0.0598	3.291	0.0182
76	6	18				0.0932	3.548	0.0262	0.0596	3.494	0.0171
76	0	24		4.063		0.1225	3.980	0.0308	0.0724	3.895	0.0816
70	15	15	0.1409	3.379	0.0417	0.0768	3.297	0.0233	0.0470	3.215	0.0146
70	18	12	0.0943	3.162	0.0298	0.0532	3.074	0.0173	0.0370	3.013	0.0123
70	20	10	0.1258	3.024	0.0416	0.0744	2.946	0.0253	0.0483	2.874	0.0168
70	22	8	0.0941	2.834	0.0334	0.0482	2.766	0.0174	0.0274	2.695	0.0102
70	24	6	0.1069	2.633	0.0406	0.0634	2.569	0.0247	0.0412	2.505	0.0163
70	26	4	0.1012	2.476	0.0409	0.0562	2.409	0.0233	0.0383	2.350	0.0163
70	28	2	0.0615	2.249	0.0273	0.0340	2.178	0.0156	0.0230	2.144	0.0107
69.83	30.16	0	0.0503			0.0365			0.0281		
66.67	20.09	13.24	0.1243	3.130	0.0397	0.0701	3.029	0.0231	0.0458	2.980	0.0154
66.67	22.31	11.02	0.1132	3.030	0.0374	0.0642	2.928	0.0219	0.0399	2.880	0.0139
66.67	25.07	8.26	0.1248	2.810	0.0444	0.0618	2.718	0.0227	0.0356	2.660	0.0134
66.67	28.61	4.72	0.1268	2.470	0.0513	0.0710	2.432	0.0292	0.0438	2.360	0.0186
66.67	30.79	2.54	0.1010	2.310	0.0437	0.0571	2.263	0.0252	0.0359	2.220	0.0162
66.67	33.33	0	0.0904	2.110	0.0424	0.0591	2.060	0.0287	0.0418	2.010	0.0208
64	24	12	0.0958	3.122	0.0307	0.0533	3.046	0.0175	0.0289	2.983	0.00969
64	26	10	0.0965	3.002	0.0322	0.0528	2.925	0.0181	0.0316	2.852	0.0111
64	28	8	0.0830	2.819	0.0294	0.0461	2.751	0.0168	0.0300	2.683	0.0112
64	30	6	0.0840	2.604	0.0323	0.0496	2.538	0.0195	0.0328	2.481	0.0132
64	32	4	0.0917	2.467	0.0372	0.0549	2.403	0.0228	0.0365	2.345	0.0156
64	34	2	0.0738	2.254	0.0327	0.0452	2.183	0.0207	0.0314	2.144	0.0146
58	0	42				0.1313	4.946	0.0265	0.0864	4.822	0.0179
58	7	35				0.1102	4.539	0.0243	0.0726	4.418	0.0164
58	30	12	0.1241	3.117	0.0398	0.0624	3.046	0.0205	0.0349	2.986	0.0117
58	32	10	0.0928	0.2954	0.0314	0.0472	2.880	0.0164	0.0291	2.804	0.0104

Table 1 (Continued)

Composition Mole Per Cent			600°C			700°C			800°C		
NaF	BeF_2	UF_4	η	ρ	η/ρ	η	ρ	η/ρ	η	ρ	η/ρ
58	34	8	0.0948	2.779	0.0341	0.0492	2.709	0.0182	0.0303	2.650	0.0114
58	36	6	0.0942	2.601	0.0362	0.0507	2.498	0.0202	0.0310	2.477	0.0129
58	38	4	0.0891	2.443	0.0365	0.0492	2.377	0.0207	0.0308	2.313	0.0133
58	39	3	0.1042	2.399	0.0434	0.0642	2.336	0.0275	0.0410	2.277	0.0184
58	40	2	0.0986	2.227	0.0443	0.0553	2.166	0.0255	0.0361	2.118	0.0170
58	41	1	0.0944	2.121	0.0445	0.0520	2.077	0.0250	0.0371	2.025	0.0183
52	36	12	0.1156	3.104	0.0372	0.0538	3.032	0.0177	0.0289	2.073	0.00972
52	38	10	0.0954	2.926	0.0326	0.0470	2.859	0.0164	0.0276	2.794	0.00988
52	40	8	0.1138	2.767	0.0411	0.0578	2.701	0.0214	0.0331	2.639	0.0125
52	42	6	0.1204	2.573	0.0468	0.0603	2.504	0.0241	0.0343	2.445	0.0140
52	44	4	0.1158	2.397	0.0483	0.0600	2.338	0.0257	0.0348	2.279	0.0153
52	45	3	0.1010	2.295	0.0440	0.0538	2.241	0.0240	0.0306	2.182	0.0140
52	46	2	0.1293	2.211	0.0585	0.0710	2.154	0.0330	0.0439	2.104	0.0209
52	47	1	0.1050	2.137	0.0440	0.0622	2.085	0.0298	0.0448	2.032	0.0220
46	0	54				0.1248	5.379	0.0232	0.1784	5.231	0.0150
46	7	47				0.1124	5.075	0.0221	0.0664	4.933	0.0135
46	19	35				0.1279	4.491	0.0285	0.0661	4.380	0.0151
46	42	12	0.1653	3.094	0.0534	0.0730	3.021	0.0242	0.0361	2.878	0.0125
46	44	10	0.2730	2.927	0.0933	0.1249	2.861	0.0437	0.0652	2.797	0.0233
46	46	8	0.1757	2.749	0.0639	0.0818	2.689	0.0304	0.0431	2.632	0.0164
46	48	6	0.1862	2.579	0.0722	0.0862	2.487	0.0347	0.0451	2.441	0.0185
46	50	4	0.1816	2.381	0.0763	0.0870	2.322	0.0375	0.0474	2.275	0.0208
46	51	3	0.2557	2.281	0.1121	0.1330	2.116	0.0629	0.0741	2.171	0.0341
46	52	2	0.1610	2.181	0.0738	0.0800	2.131	0.0375	0.0462	2.082	0.0222
46	53	1	0.1816	2.115	0.0894	0.0933	2.067	0.0451	0.0523	2.020	0.0259

Table 2
Viscosity ([illegible] poise), Density (g/ml), and Kinematic Viscosity (Stokes) of Mixtures Containing a Constant Mole Per Cent BeF_2

Composition Mole Per Cent			600°C			700°C			800°C		
NaF	BeF_2	UF_4	η	ρ	η/ρ	η	ρ	η/ρ	η	ρ	η/ρ
76	0	24		4.063		0.1225	3.980	0.0308	0.0724	3.895	0.0186
58	0	42				0.1310	4.945	0.0265	0.0864	4.822	0.0179
46	0	54				0.1660	5.378	0.0309	0.1098	5.232	0.0210
40	0	60				0.1662	5.569	0.0298	0.1059	5.465	0.0194
30	0	70							0.1099	5.902	0.0186
76	10	14					3.263		0.0541	3.202	0.01690
70	10	20					3.641		0.0575	3.571	0.01610
66	10	24					3.898		0.0594	3.846	0.01547
58	10	32					4.363		0.0656	4.253	0.01542
55	10	35				0.1132	4.498	0.02517	0.0709	4.380	0.01619
46	10	44				0.1159	4.922	0.02355	0.0661	4.810	0.01374
43	10	47					5.082		0.0796	4.942	0.01611
30	10	60							0.1008	5.469	0.0184
76	20	4				0.0547	2.381	0.0230	0.0361	2.328	0.0155
74	20	6							0.0287	2.530	0.01134
									0.0356		0.01407
72	20	8	0.0887						0.0322	2.693	0.01196
70	20	10	0.1258	3.024	0.0416	0.0744	2.946	0.0253	0.0483	2.874	0.0168
68	20	12	0.0950	3.143	0.03026				0.0341	2.996	0.01138
58	20	22	0.1350	3.700	0.03649				0.0477	3.541	0.01347
46	20	34							0.0634	4.309	0.01471
45	20	35							0.0669	4.380	0.01527
33	20	47							0.1180	4.960	0.02379
20	20	60							0.243	5.401	0.0450
70	30	0	0.0498	2.113	0.0236	0.0392	2.063	0.0190	0.0281	2.012	0.0140
68	30	2	0.0631	2.249	0.02806				0.0254	2.144	0.01185
66	30	4	0.0878	2.470	0.0355	0.0527	2.414	0.0218	0.0357	2.347	0.0152
64	30	6	0.0840	2.604	0.0323	0.0496	2.538	0.0195	0.0328	2.481	0.0132

Table 2 (Continued)

Composition Mole Per Cent			600°C			700°C			800°C		
NaF	BeF_2	UF_4	η	ρ	η/ρ	η	ρ	η/ρ	η	ρ	η/ρ
62	30	8	0.0864	2.803	0.03375				0.0300	2.670	0.01124
60	30	10	0.0941	2.969	0.03169				0.0291	2.821	0.01032
58	30	12	0.1241	3.117	0.0398	0.0624	3.046	0.0205	0.0349	2.986	0.0117
55	30	15	0.1895						0.0502		
35	30	35							0.0792	4.381	0.01808
30	30	40							0.0901	4.610	0.01954
60	40	0		2.113			2.058		0.0379	2.007	0.01888
58	40	2	0.0986	2.227	0.0443	0.0553	2.166	0.0255	0.0361	2.118	0.0170
56	40	4	0.0891	2.427	0.03832				0.0322	2.294	0.01517
54	40	6	0.0810	2.583	0.03136				0.0313	2.456	0.01274
52	40	8	0.1138	2.767	0.0411	0.0578	2.701	0.0214	0.0331	2.639	0.0125
50	40	10	0.1348	2.926	0.04606				0.0355	2.796	0.01269
48	40	12	0.1476	3.096	0.04767				0.0338	2.997	0.01128
46	40	14	0.166	3.208	0.05174				0.0382	3.099	0.01233
45	40	15	0.231						0.0527		
25	40	35							0.1220		

Table 3

Viscosity ([redacted] poise), Density (g/ml), and Kinematic Viscosity (Stokes) of Mixtures Containing a Constant Mole Per Cent UF_4

Composition Mole Per Cent			600°C			700°C			800°C		
NaF	BeF_2	UF_4	η	ρ	η/ρ	η	ρ	η/ρ	η	ρ	η/ρ
40	0	60				0.1662	5.569	0.0298	0.1054	5.465	0.0194
30	10	60							0.1008	5.469	0.0184
20	20	60							0.2430	5.401	0.0450
46	7	47				0.1124	5.079	0.0221	0.0664	4.933	0.0135
37	16	47					5.089		0.1121	4.961	0.0226
26.5	26.5	47					5.087		0.1297	4.959	0.0262
58	7	35				0.1102	4.539	0.0243	0.0726	4.418	0.0164
46	19	35				0.1279	4.491	0.0285	0.0661	4.380	0.0151
32.5	32.5	35				0.1937	4.499	0.0431	0.0704	4.381	0.0161
20	45	35					4.493		0.1780	4.419	0.0403
76	9	15	0.1682	3.416	0.0492	0.0935	3.354	0.0279	0.0598	3.291	0.0182
70	15	15	0.1409	3.379	0.0417	0.0768	3.297	0.0233	0.0470	3.215	0.0146
42.5	42.5	15	0.2430	3.311	0.0734	0.1062	3.244	0.0327	0.0532	3.154	0.0169
72	12	12	0.1168	3.171	0.0368	0.0700	3.078	0.0227	0.0445	3.017	0.0148
70	18	12	0.0943	3.162	0.0298	0.0532	3.074	0.0173	0.0370	3.013	0.0123
54	24	12	0.0958	3.122	0.0307	0.0533	3.046	0.0175	0.0289	2.983	0.00969
58	30	12	0.1241	3.117	0.0398	0.0624	3.046	0.0205	0.0349	2.986	0.0117
52	36	12	0.1156	3.104	0.0372	0.0538	3.032	0.0177	0.0289	2.973	0.00972
46	42	12	0.1653	3.094	0.0534	0.0730	3.021	0.0242	0.0361	2.876	0.0125
76	14	10		3.031			2.957		0.0294	2.897	0.0102
70	20	10	0.1258	3.024	0.0416	0.0744	2.946	0.0253	0.0483	2.874	0.0168
64	26	10	0.0965	3.002	0.0322	0.0528	2.925	0.0181	0.0316	2.852	0.0111
58	32	10	0.0928	2.954	0.0314	0.0472	2.880	0.0164	0.0291	2.804	0.0104
52	38	10	0.0954	2.926	0.0326	0.0470	2.859	0.0164	0.0276	2.794	0.00988
46	44	10	0.2730	2.927	0.0933	0.1249	2.861	0.0437	0.0652	2.797	0.0233
76	16	8				0.0658	2.751	0.0239	0.0386	2.687	0.0144
70	22	8	0.0946	2.834	0.0334	0.0482	2.766	0.0174	0.0274	2.695	0.0102
64	28	8	0.0830	2.819	0.0294	0.0461	2.751	0.0168	0.0300	2.683	0.0112

Table 3 (Continued)

Composition Mole Per Cent			600°C			700°C			800°C		
NaF	BeF_2	UF_4	η	ρ	η/ρ	η	ρ	η/ρ	η	ρ	η/ρ
58	34	8	0.0948	2.779	0.0341	0.0492	2.709	0.0182	0.0303	2.650	0.0114
52	40	8	0.1138	2.767	0.0411	0.0578	2.701	0.0214	0.0331	2.639	0.0125
46	46	8	0.1757	2.749	0.0639	0.0818	2.689	0.0304	0.0431	2.632	0.0164
76	18	6				0.0573	2.605	0.0220	0.0331	2.543	0.0130
70	24	6	0.1069	2.633	0.0406	0.0634	2.569	0.0247	0.0409	2.505	0.0163
64	30	6	0.0840	2.604	0.0323	0.0496	2.538	0.0195	0.0328	2.481	0.0132
58	36	6	0.0942	2.601	0.0362	0.0507	2.498	0.0203	0.0320	2.477	0.0129
52	42	6	0.1204	2.573	0.0468	0.0603	2.504	0.0241	0.0343	2.445	0.0140
46	48	6	0.1862	2.579	0.0722	0.0862	2.487	0.0347	0.0451	2.441	0.0185
76	20	4				0.0547	2.381	0.0230	0.0361	2.328	0.0155
74	22	4							0.0349	2.340	0.0149
72	24	4	0.0982	2.468	0.0398	0.0576	2.410	0.0239	0.0370	2.343	0.0158
70	26	4	0.1012	2.476	0.0409	0.0562	2.409	0.0233	0.0383	2.350	0.0163
68	28	4	0.0897	2.473	0.0363	0.0520	2.416	0.0215	0.0343	2.348	0.0146
66	30	4	0.0878	2.470	0.0355	0.0527	2.414	0.0218	0.0357	2.347	0.0152
64	32	4	0.0917	2.467	0.0372	0.0549	2.403	0.0228	0.0365	2.345	0.0156
58	38	4	0.0891	2.443	0.0365	0.0492	2.377	0.0207	0.0308	2.313	0.0133
52	44	4	0.1158	2.397	0.0483	0.0600	2.338	0.0257	0.0348	2.279	0.0153
46	50	4	0.1816	2.381	0.0763	0.0870	2.322	0.0375	0.0474	2.275	0.0208
58	39	3	0.1042	2.399	0.0434	0.0642	2.336	0.0275	0.0420	2.277	0.0184
52	45	3	0.1010	2.295	0.0440	0.0538	2.241	0.0240	0.0306	2.182	0.0140
46	51	3	0.2557	2.281	0.1121	0.1330	2.116	0.0629	0.0741	2.171	0.0341
76	22	2					2.109		0.0270	2.152	0.0125
70	28	2	0.0615	2.249	0.0273	0.0340	2.178	0.0156	0.0230	2.144	0.0107
64	34	2	0.0738	2.254	0.0327	0.0452	2.183	0.0207	0.0314	2.144	0.0146
58	40	2	0.0986	2.227	0.0443	0.0553	2.166	0.0255	0.0361	2.118	0.0170
52	46	2	0.1293	2.211	0.0585	0.0710	2.154	0.0330	0.0439	2.104	0.0209
46	52	2	0.1610	2.181	0.0738	0.0800	2.131	0.0375	0.0462	2.082	0.0222
58	41	1	0.0944	2.121	0.0445	0.0520	2.077	0.0250	0.0371	2.025	0.0183
56	43	1	0.0942	2.131	0.0442	0.0548	2.073	0.0264	0.0358	2.023	0.0177

Table 3 (Continued)

Composition Mole Per Cent			600°C			700°C			800°C		
NaF	BeF_2	UF_4	η	ρ	η/ρ	η	ρ	η/ρ	η	ρ	η/ρ
52	47	1	0.1050	2.137	0.0440	0.0622	2.085	0.0298	0.0448	2.032	0.0220
46	53	1	0.1861	2.115	0.0894	0.0933	2.067	0.0451	0.0523	2.020	0.0259
81.7	18.3	0							0.0360	2.026	0.0178
72.96	27.04	0				0.0406			0.0289	2.031	0.0142
69.83	30.16	0	0.0503			0.0365			0.0281	2.030	0.0138
66.67	33.33	0	0.0920	2.170	0.0436	0.0591	2.060	0.0287	0.0410	2.010	0.0204
55.59	44.41	0	0.0992	2.102	0.0472	0.0568			0.0360	2.021	0.0178
47.8	52.2	0	0.1719	2.071	0.0830	0.0880			0.0502	1.986	0.0253
42.7	57.3	0				0.1297			0.0549	1.989	0.0256
35.89	64.11	0				0.2590			0.1104	1.990	0.0555
21.93	78.07	0							0.5520	1.988	0.2777

Table 4

Viscosity ([redacted] poise), Density (g/ml), and Kinematic Viscosity (Stokes) of Mixtures Containing a Constant Ratio of NaF to BeF_2

Ratio	Composition Mole Per Cent			600°C			800°C		
$NaF:BeF_2$	NaF	BeF_2	UF_4	η	ρ	η/ρ	η	ρ	η/ρ
3:1	75	25	0				0.0304		
"	73.5	24.5	2				0.0261		
"	72.0	24	4	0.0982			0.0370		
"	70.5	23.5	6	0.1065			0.0408		
"				0.0642			0.0220		
"	70	23.33	6.67	0.1020			0.0377		
"				0.0700			0.0224		
"	69	23	8	0.0918			0.0279		
"	67.5	22.5	10	0.1129			0.0405		
"	66.67	22.22	11.11	0.1148			0.0426		
"	66.0	22.0	12	0.0958			0.0316		
"	63.75	20	20	0.1250			0.0448		
"	58	19.23	22.67				0.0486		
"	48.75	16.25	35				0.0672		
"	46	15.33	38.67				0.0660		
"	39.75	13.25	47				0.0956		
"	30	10	60				0.1008		
2:1	66.67	33.33	0	0.0920			0.0410		
"	65.34	32.66	2	0.0688			0.0296		
"	64.00	32.00	4	0.0917			0.0365		
"	62.67	31.33	6	0.0820			0.0322		
"	61.34	30.66	8	0.0878			0.0301		
"	60	30	10	0.0940			0.0292		
"	58.67	29.33	12	0.1197			0.0337		
"	56.67	28.33	15	0.1832			0.0498		
"	43.34	21.66	35				0.0669		
"	40	20	40				0.0839		
"	35.34	17.66	47				0.1152		
"	26.67	13.33	60				0.1021		

Table 4 (Continued)

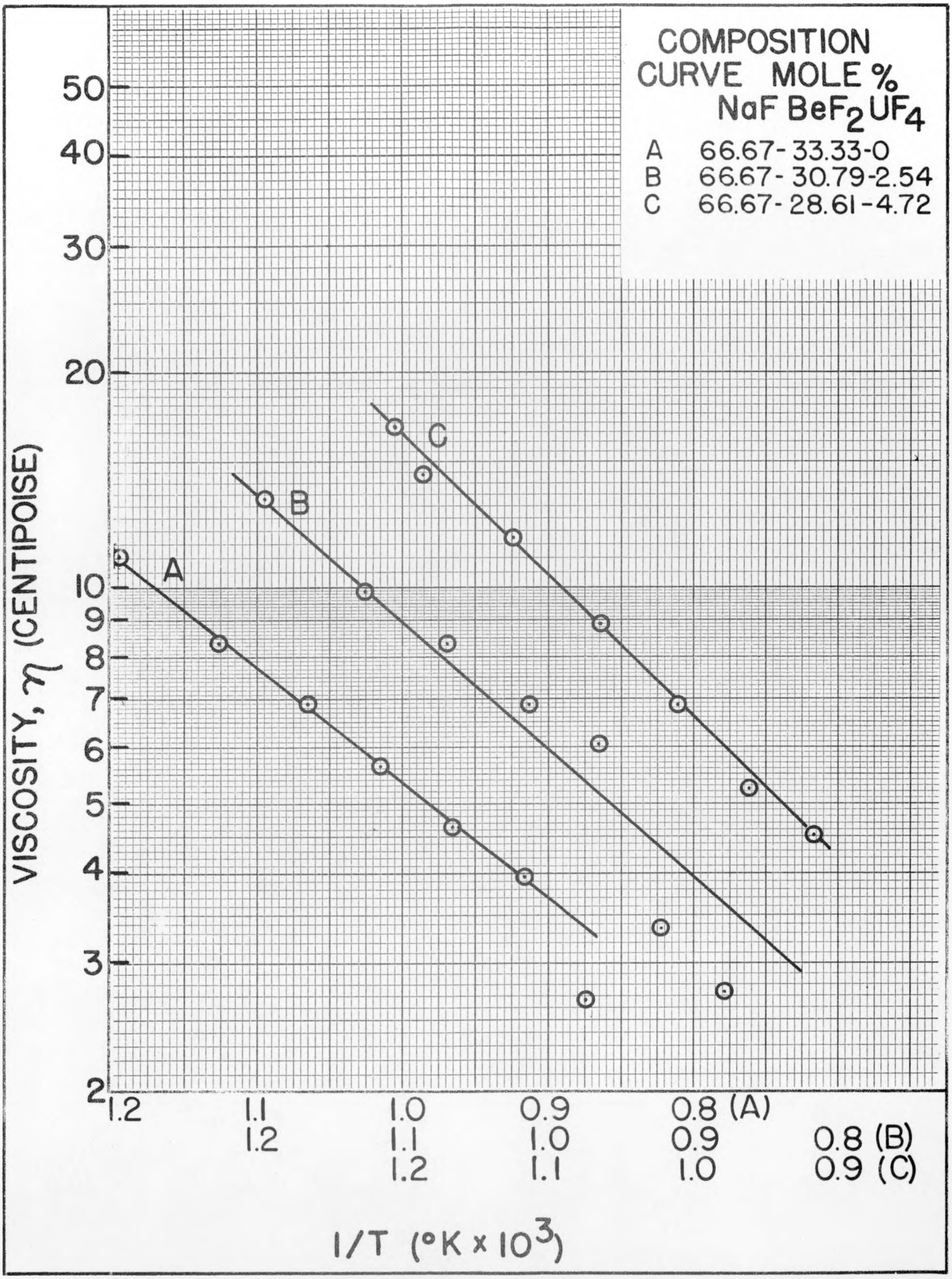
Ratio	Composition Mole Per Cent			600°C			800°C		
NaF:BeF$_2$	NaF	BeF$_2$	UF$_4$	η	ρ	η/ρ	η	ρ	η/ρ
3:2	60	40	0	0.0959			0.0381		
"	58.8	39.2	2	0.0911			0.0356		
"	57.6	38.4	4	0.0891			0.0310		
"	56.4	37.6	6	0.0913			0.0318		
"	55.2	36.8	8	0.1058			0.0315		
"	54.0	36.0	10	0.0947			0.0226		
"	52.8	35.2	12	0.1161			0.0292		
"	51.0	34.0	15	0.2062			0.0511		
"	39	26	35				0.0638		
"	45	30	25				0.0681		
"	31.8	21.2	47				0.1208		
"	30	20	50				0.1390		
"	24.0	16.0	60				0.1110		
1:1	50	50	0	0.1458	2.070	0.07043	0.0458	1.969	0.02326
"	49	49	2	0.1400	2.196	0.06375	0.0450	2.092	0.02151
"	48	48	4	0.1598	2.384	0.06703	0.0431	2.277	0.01881
"	47	47	6	0.1610	2.578	0.06245	0.0432	2.442	0.01769
"	46	46	8	0.1757	2.749	0.06391	0.0431	2.632	0.01638
"	42.5	42.5	15	0.2430	3.311	0.07339	0.0532	3.184	0.01671
"	40	40	20	0.1454	3.631	0.04004	0.0312	3.490	0.00894
"	32.5	32.5	35				0.0704	4.318	0.01630
"	26.5	26.5	47				0.1297	4.959	0.02616
"	20	20	60				0.243	5.401	0.04499

Table 5
Viscosity ([redacted] poise), Density (g/ml), and Kinematic Viscosity (Stokes) of Mixtures Containing a Constant Ratio of BeF_2 to UF_4

Ratio	Composition Mole Per Cent			600°C			700°C			800°C		
BeF_2:UF_4	NaF	BeF_2	UF_4	η	ρ	η/ρ	η	ρ	η/ρ	η	ρ	η/ρ
9:2	76	19.63	4.37							0.0352		
"	75.56	20	4.44							0.0391		
"	70	24.55	5.45	0.1048						0.0391		
"	67	27	6	0.0937						0.0363		
"	63.33	30	6.67	0.0828						0.0317		
"	58	34.36	7.64	0.0928						0.0303		
"	51.11	40	8.89	0.1210						0.0339		
"	45	45	10	0.181						0.0472		
"				0.214						0.0522		
13:8	76	14.86	9.14							0.0326		
"	70	18.57	11.43	0.0986						0.0406		
"	67.69	20	12.31							0.0348		
"	58	26	16							0.0393		
"	51.54	30	18.46							0.0545		
"	46	33.43	20.58							0.0458		
"	39	39	24							0.0386		
19:30	76	9.30	14.70							0.0581		
"	58	16.28	25.72							0.0540		
"	48.42	20	31.58							0.0598		
"	46	20.94	33.06							0.0630		
"	28.5	28.5	45							0.1161		
1:3	76	6	18				0.0931	3.548	0.0262	0.0597	3.444	0.0171
"	60	10	30							0.0639		
"	58	10.5	25.2							0.0647		
"	53.33	11.67	35							0.0699		
"	46	13.5	40.5							0.0661		
"	37.33	15.67	47							0.111		
"	20	20	16							0.2430	5.401	0.0450

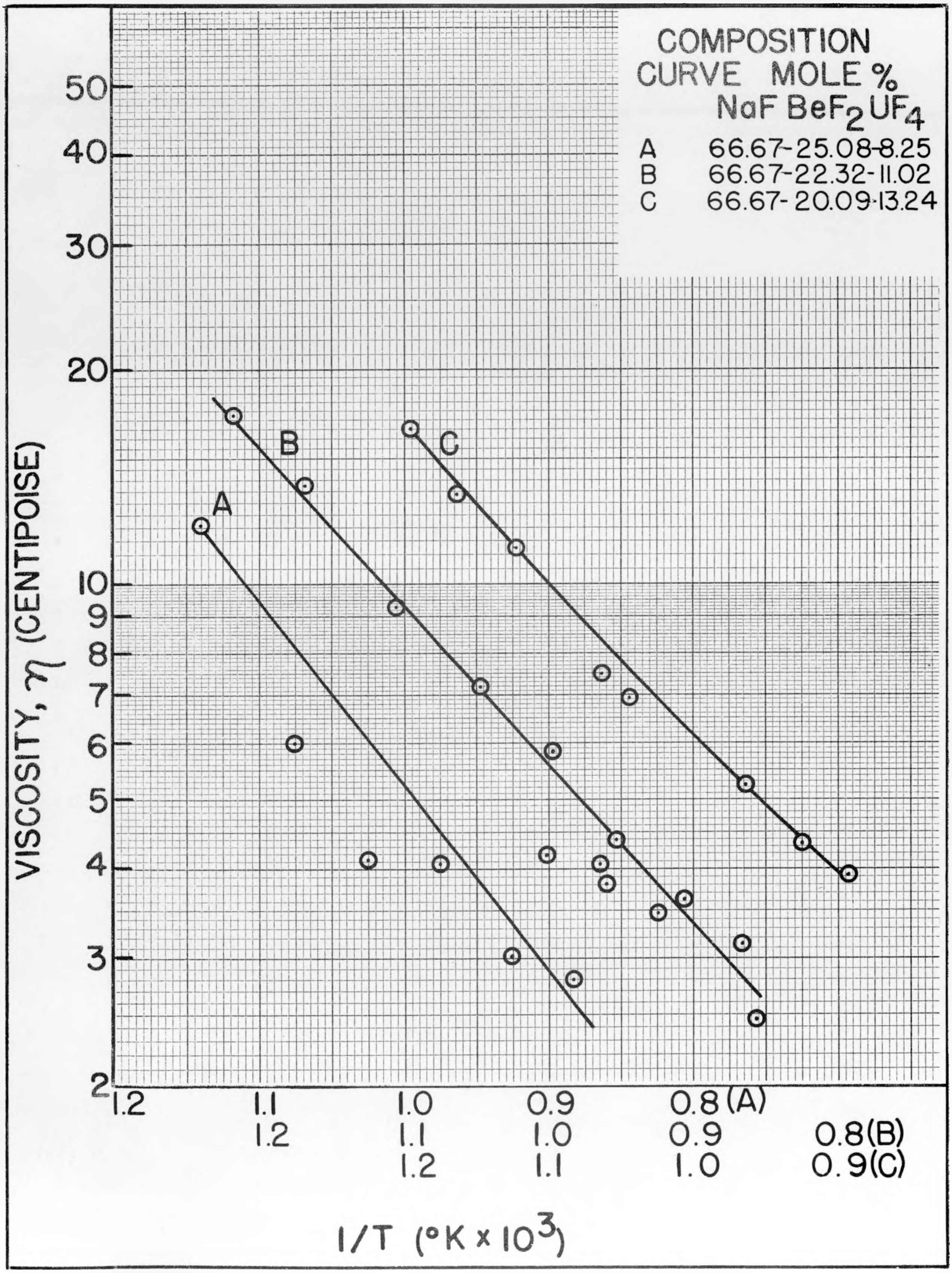
Table 6
Viscosity ([illegible]poise), Density (g/ml), and Kinematic Viscosity (Stokes) of Mixtures Containing a Constant Ratio of NaF to UF_4

Ratio	Composition Mole Per Cent			700°C			800°C		
$NaF:UF_4$	NaF	BeF_2	UF_4	η	ρ	η/ρ	η	ρ	η/ρ
3:1	75	0	25	0.1003			0.0572		
"	67.5	10	22.50				0.0590		
"	60	20	20				0.0446		
"	52.5	30	17.5				0.0533		
"	45	40	15				0.0527		
"	42.9	42.8	14.3				0.0516		
2:1	66.67	0	33.33	0.1150			0.0693		
"	60	10	30				0.0640		
"	53.33	20	26.67				0.0530		
"	46.67	30	23.33				0.0608		
"	40	40	20				0.0312		
5:3	62.5	0	37.5	0.1240			0.0762		
"	58	7	35	0.1102			0.0726	4.418	0.0164
"	56.25	10	33.75				0.0672		
"	50	20	30				0.0574		
"	43.75	30	26.25				0.0650		
"	38.3	38.3	23.40				0.0372		
7:6	53.84	0	46.16	0.1299			0.0827		
"	49	10	41				0.0698		
"	46	15	39				0.0660		
"	43.07	20	36.93				0.0727		
"	35	30	35				0.0791		
"	37.58	32.21	30.2				0.0534		



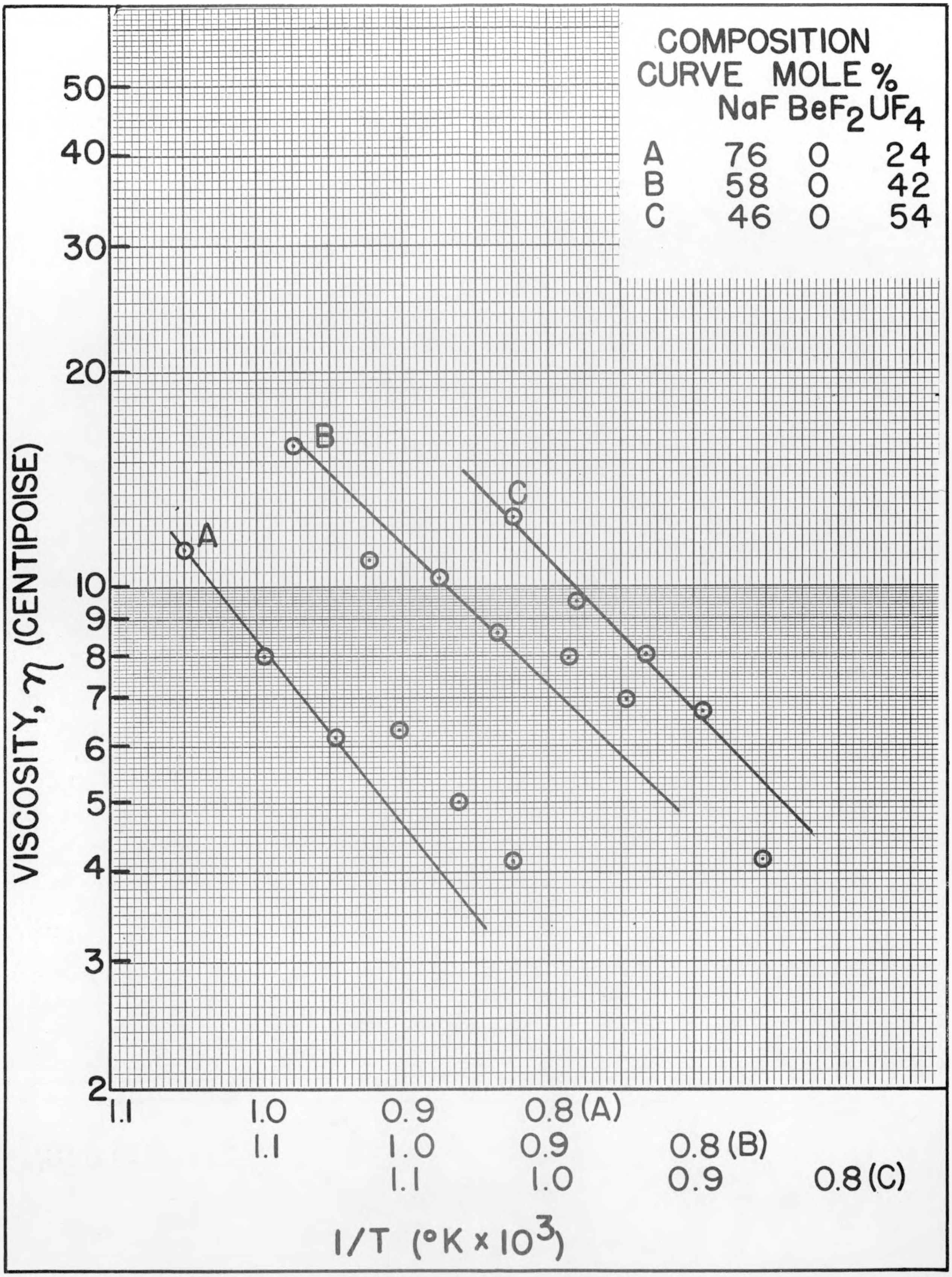
VISCOSITY as a FUNCTION of ABSOLUTE TEMPERATURE FOR MIXTURES of NaF, BeF_2 and UF_4

FIGURE 6A



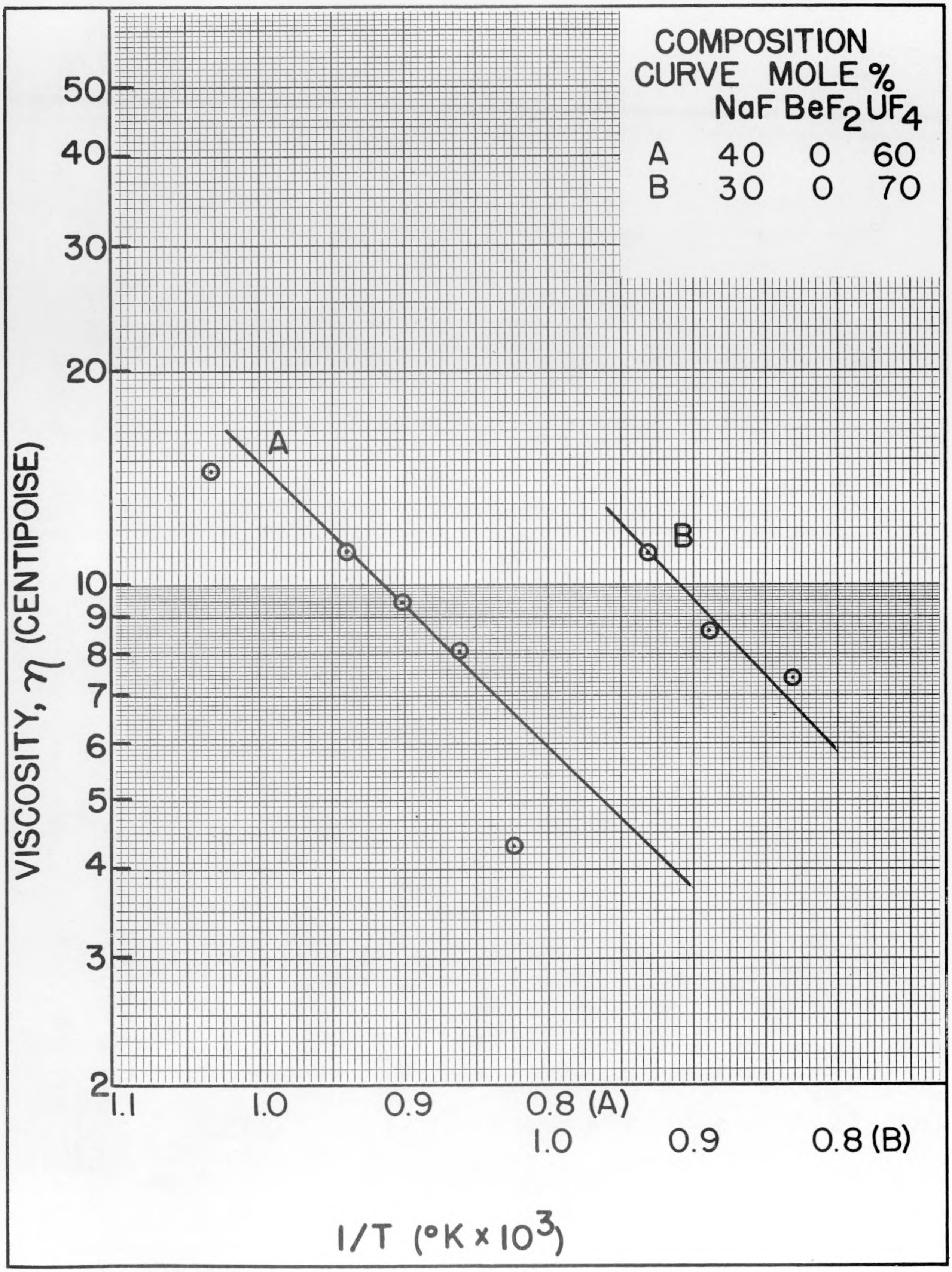
VISCOSITY as a FUNCTION of ABSOLUTE TEMPERATURE FOR MIXTURES of NaF, BeF_2 and UF_4

FIGURE 6B



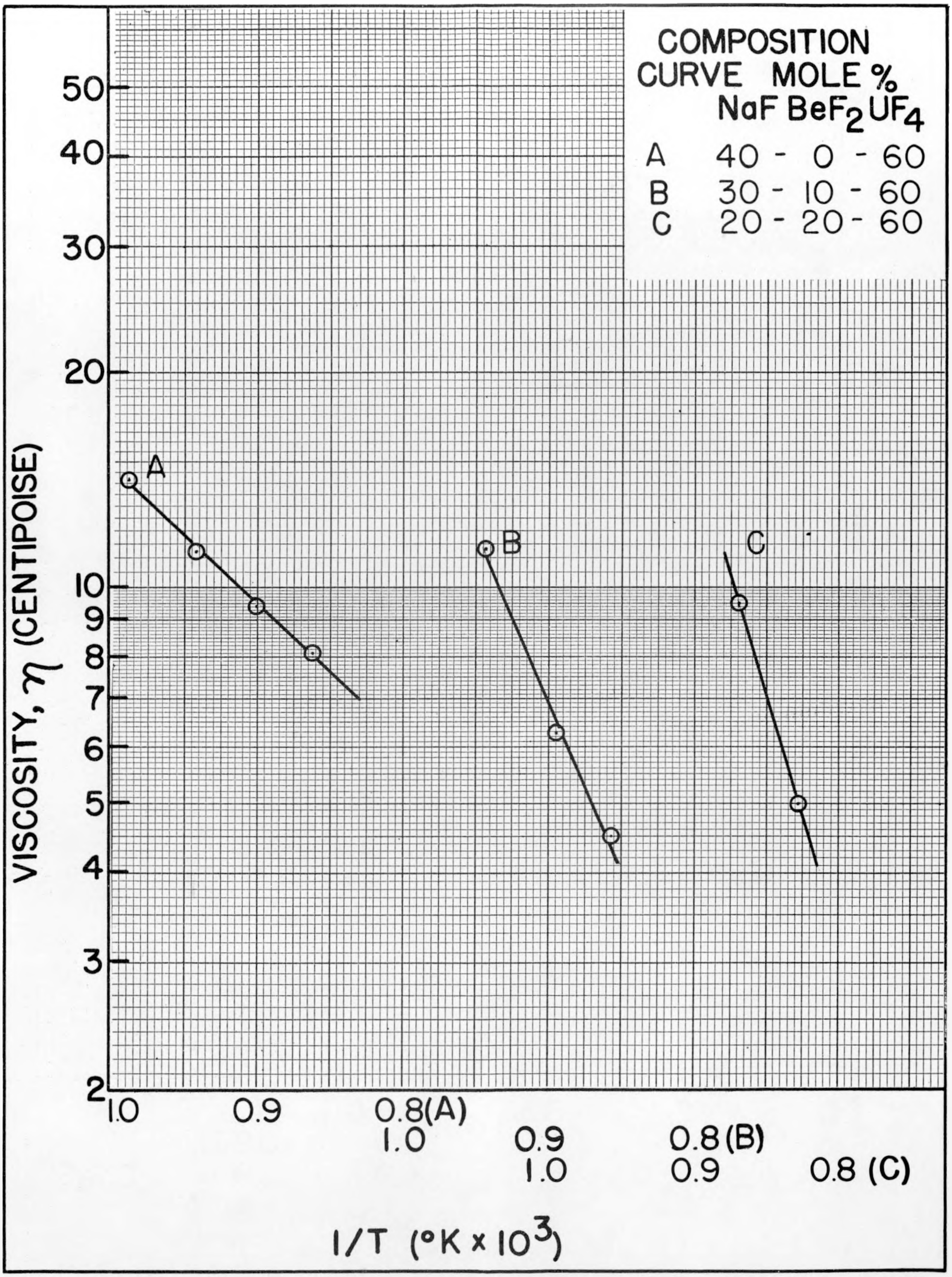
VISCOSITY as a FUNCTION of ABSOLUTE TEMPERATURE FOR MIXTURES of NaF, BeF_2 and UF_4

FIGURE 7A



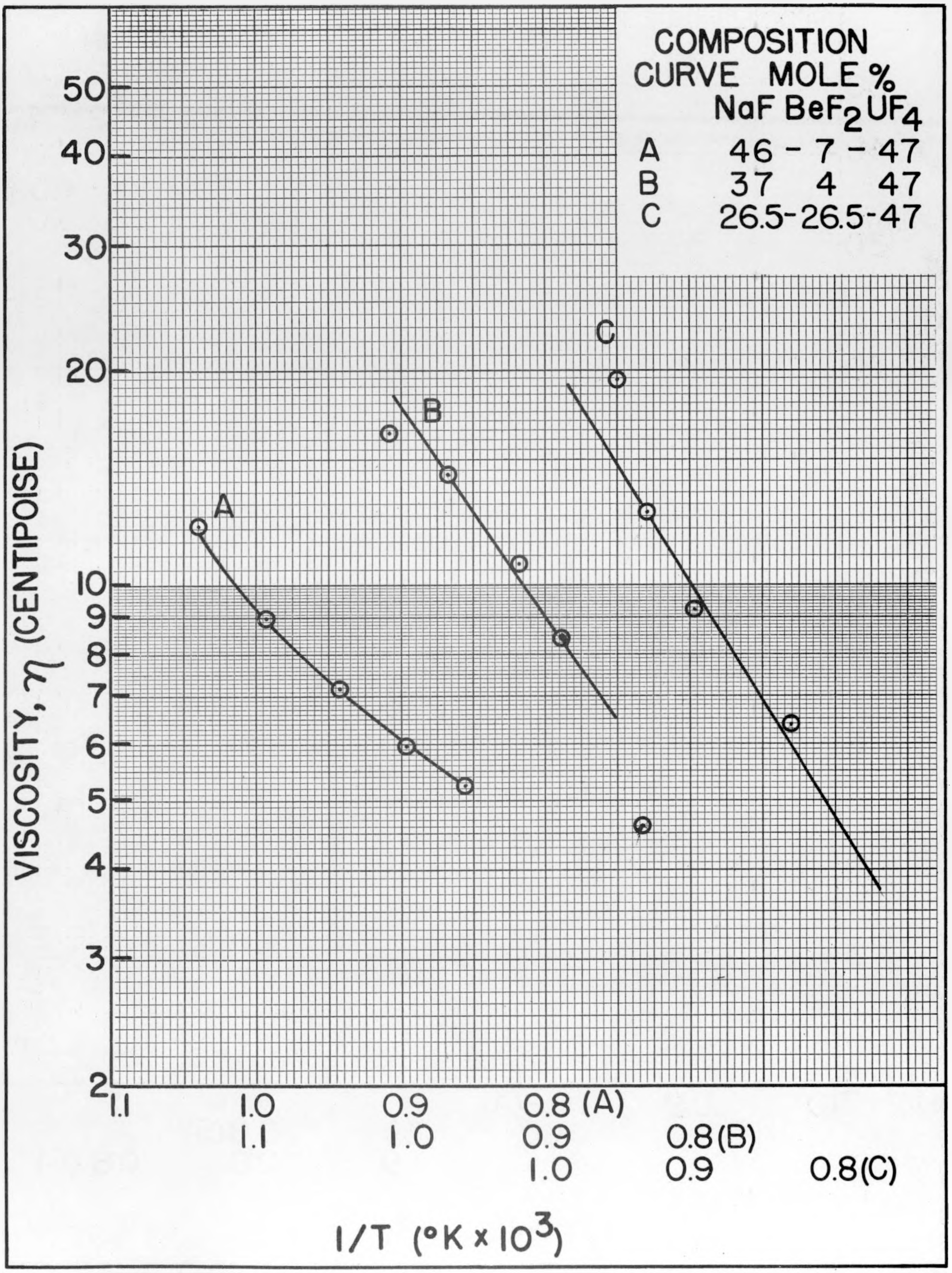
VISCOSITY as a FUNCTION of ABSOLUTE TEMPERATURE FOR MIXTURES of NaF, BeF_2 and UF_4

FIGURE 7B



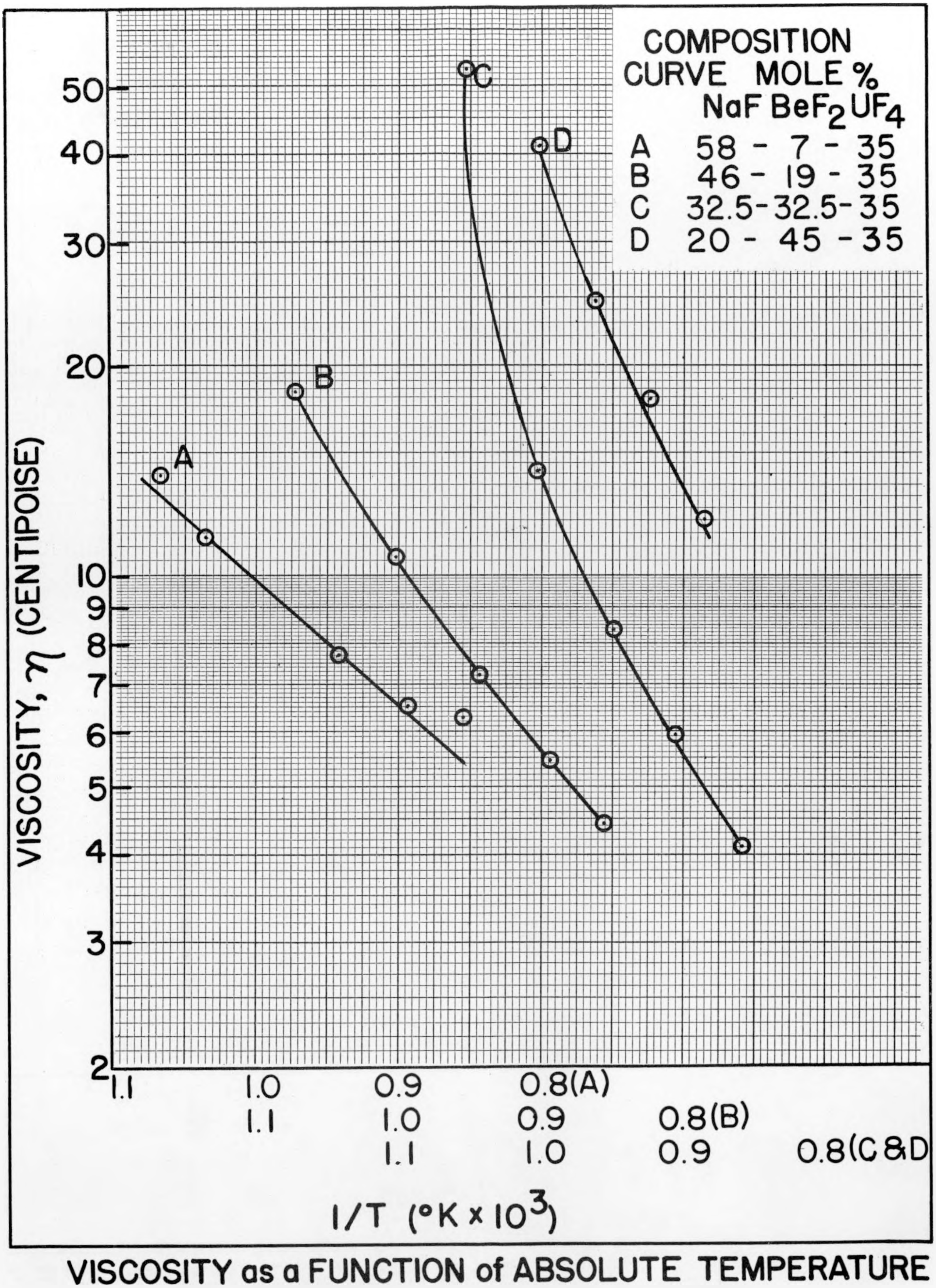
VISCOSITY as a FUNCTION of ABSOLUTE TEMPERATURE FOR MIXTURES of NaF, BeF_2 and UF_4

FIGURE 8A



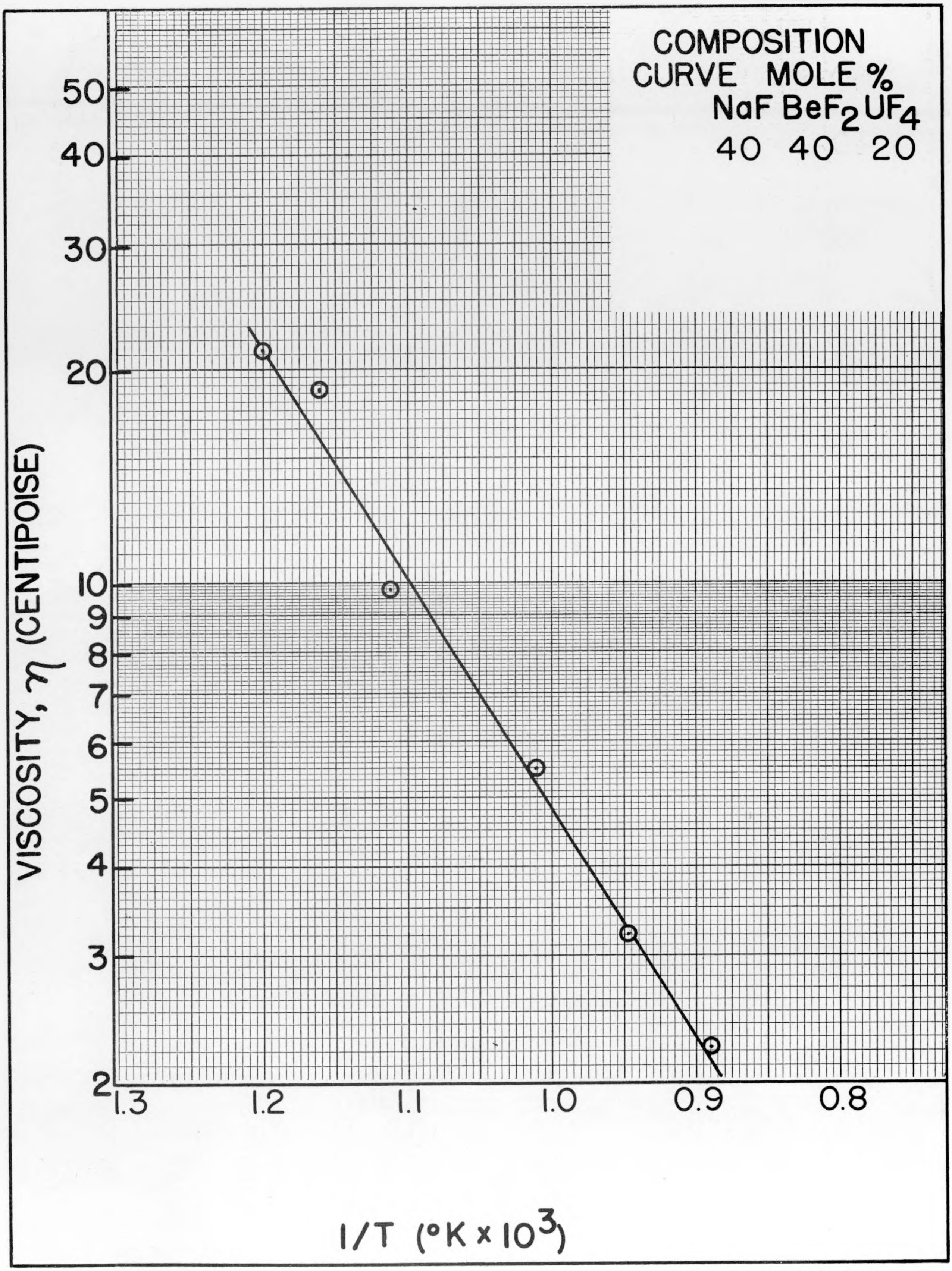
VISCOSITY as a FUNCTION of ABSOLUTE TEMPERATURE FOR MIXTURES of NaF, BeF_2 and UF_4

FIGURE 8B



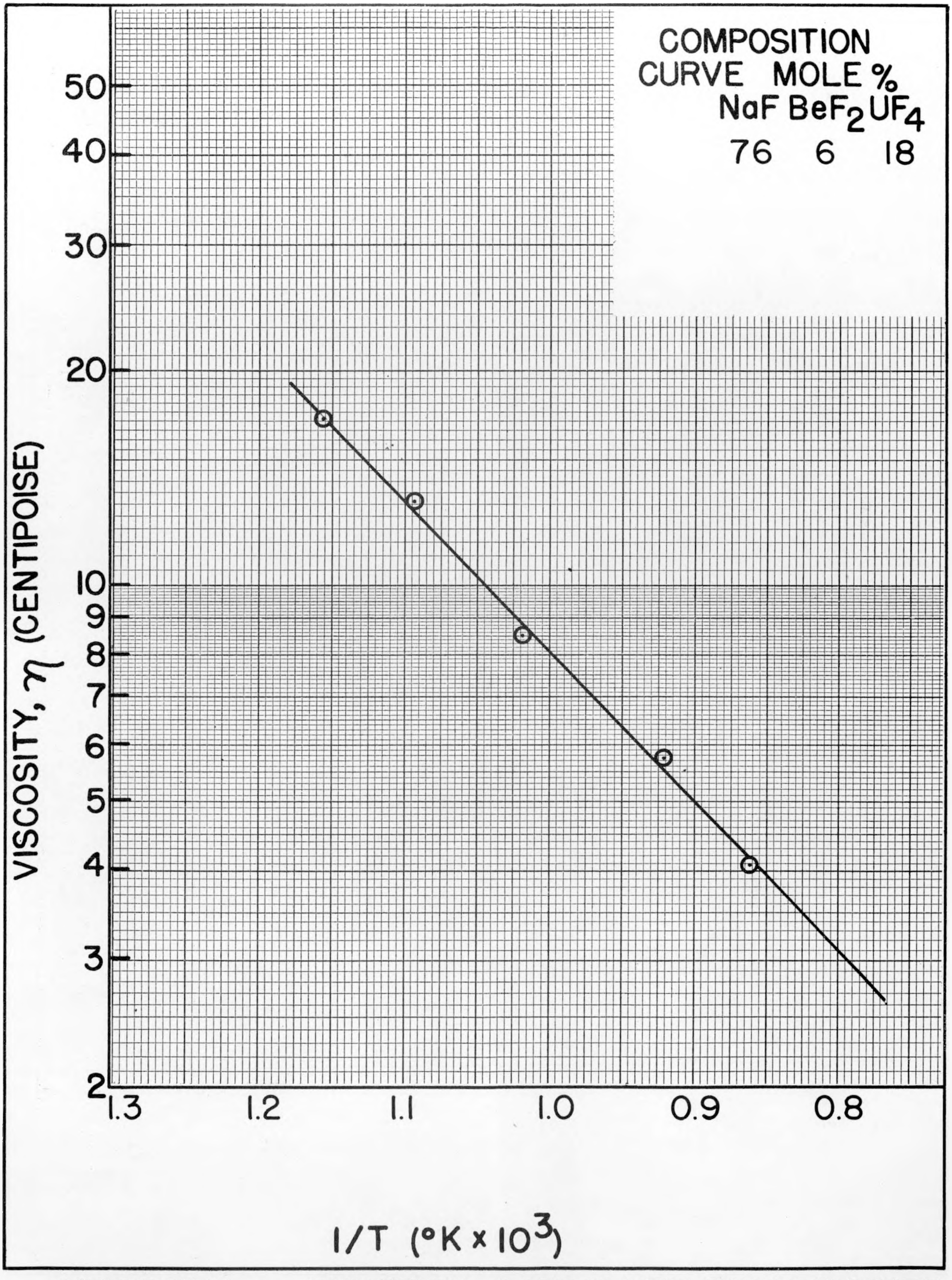
VISCOSITY as a FUNCTION of ABSOLUTE TEMPERATURE FOR MIXTURES of NaF, BeF$_2$ and UF$_4$

FIGURE 8C



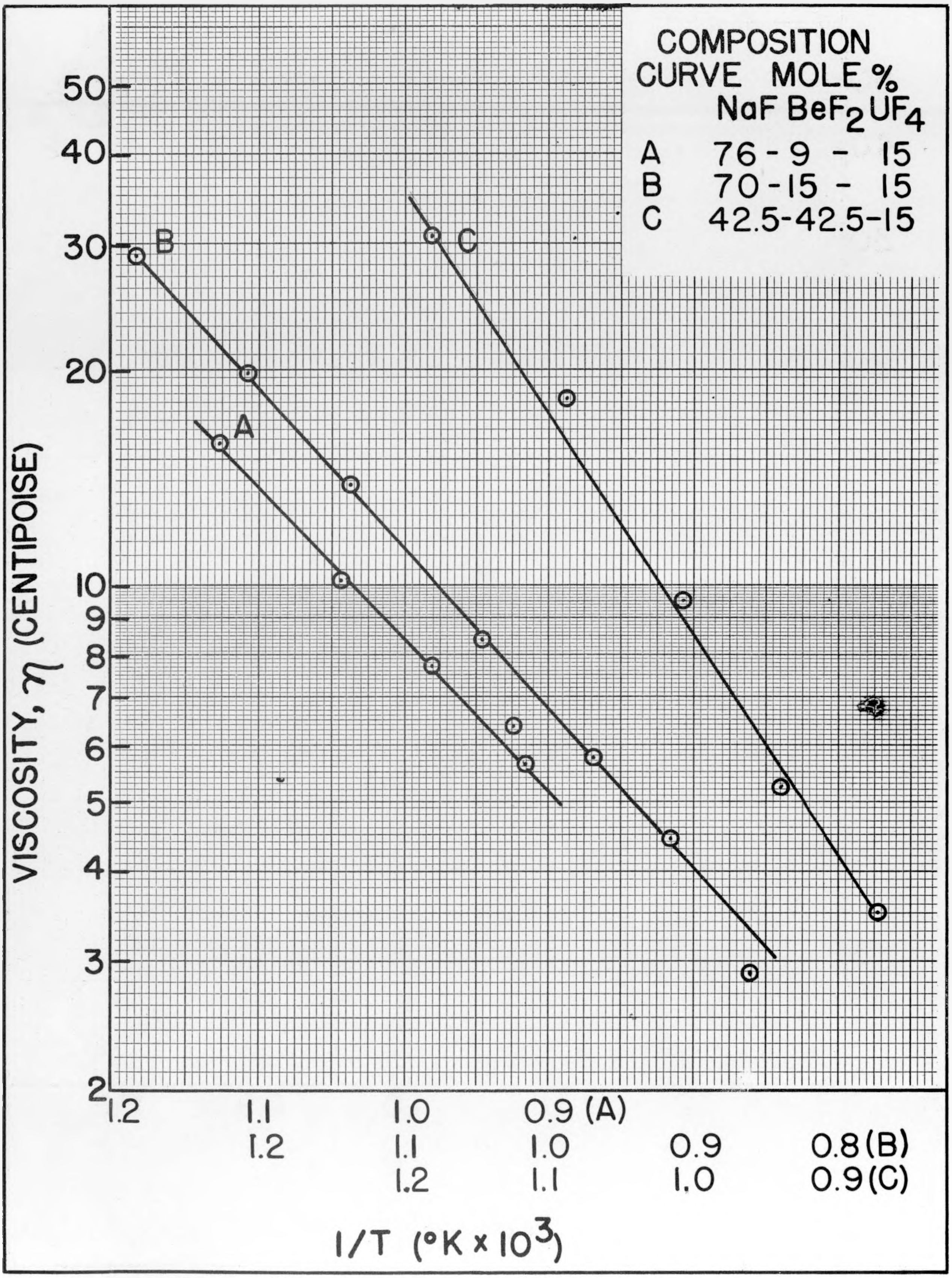
VISCOSITY as a FUNCTION of ABSOLUTE TEMPERATURE FOR MIXTURES of NaF, BeF_2 and UF_4

FIGURE 8D

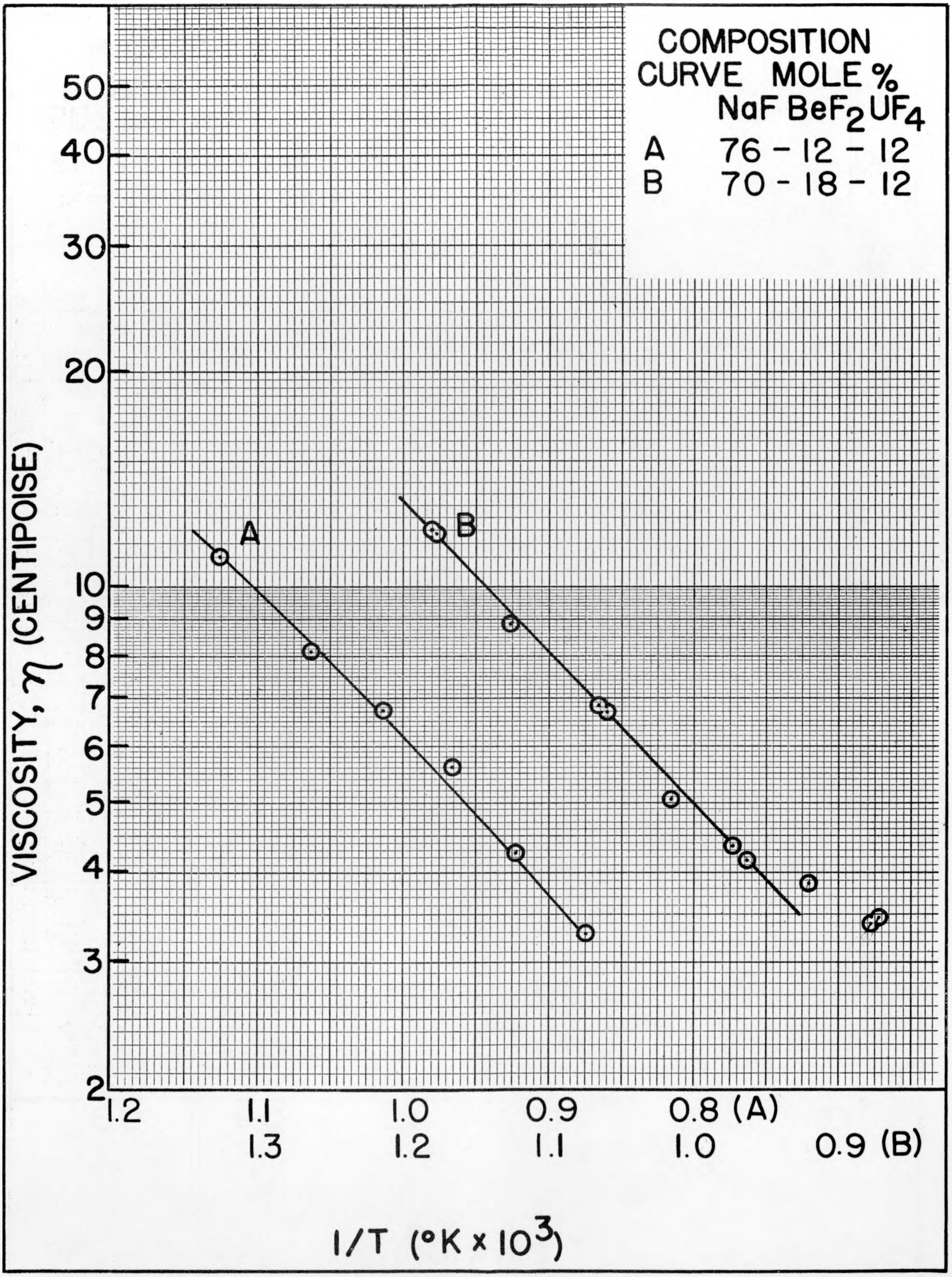


VISCOSITY as a FUNCTION of ABSOLUTE TEMPERATURE FOR MIXTURES of NaF, BeF_2 and UF_4

FIGURE 8 E

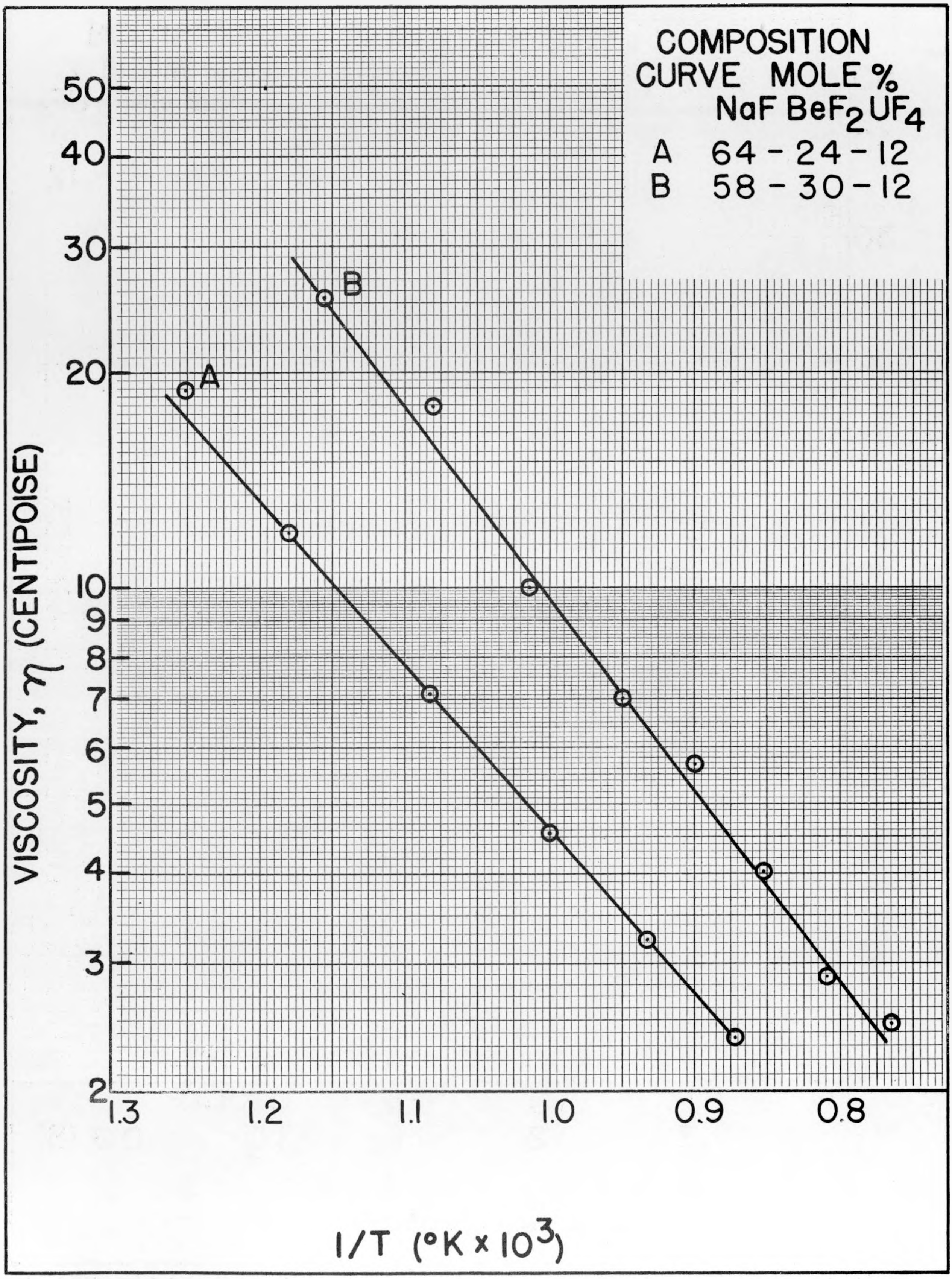


VISCOSITY as a FUNCTION of ABSOLUTE TEMPERATURE FOR MIXTURES of NaF, BeF$_2$ and UF$_4$
FIGURE 8F



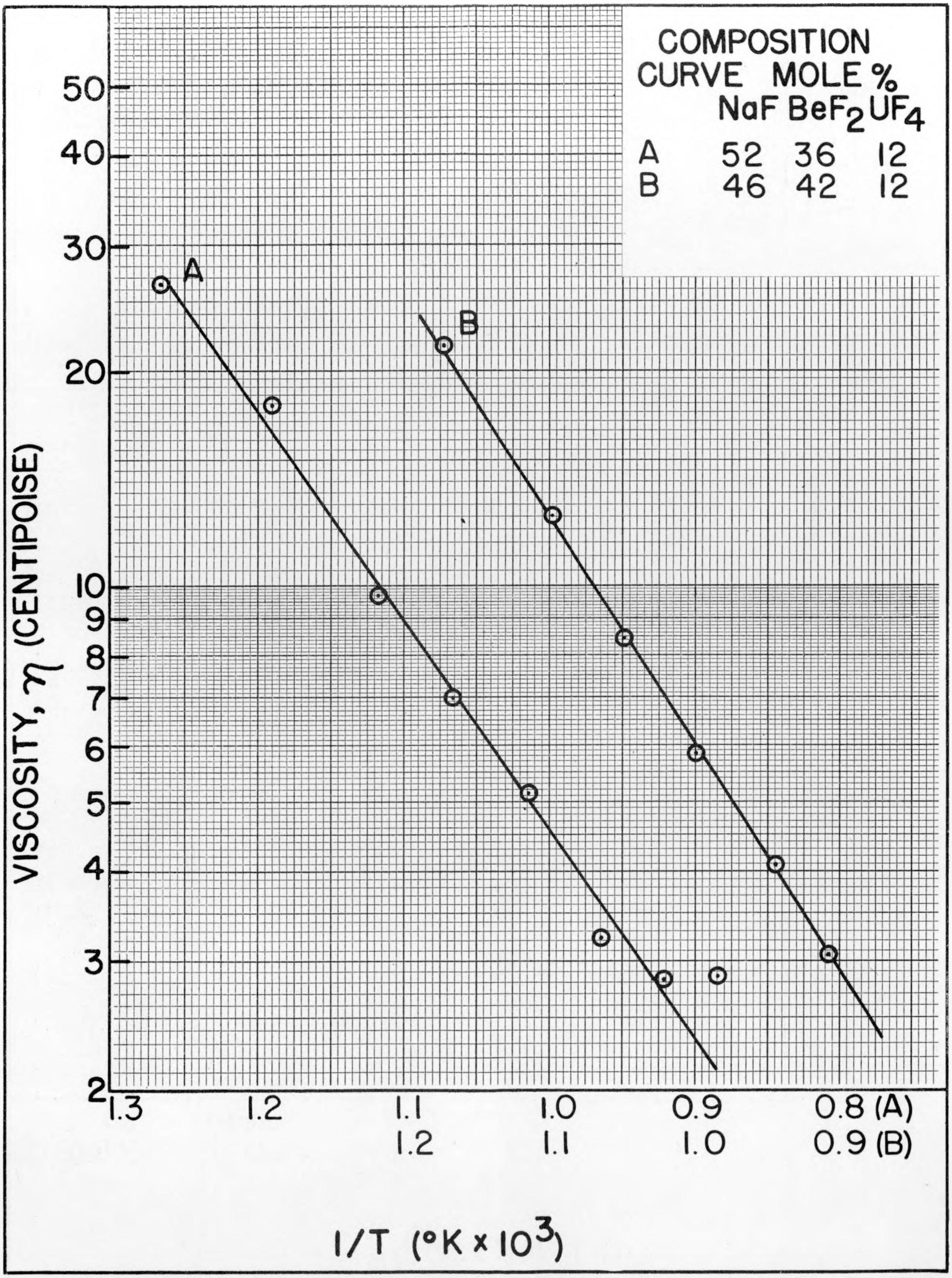
VISCOSITY as a FUNCTION of ABSOLUTE TEMPERATURE FOR MIXTURES of NaF, BeF_2 and UF_4

FIGURE 8G1



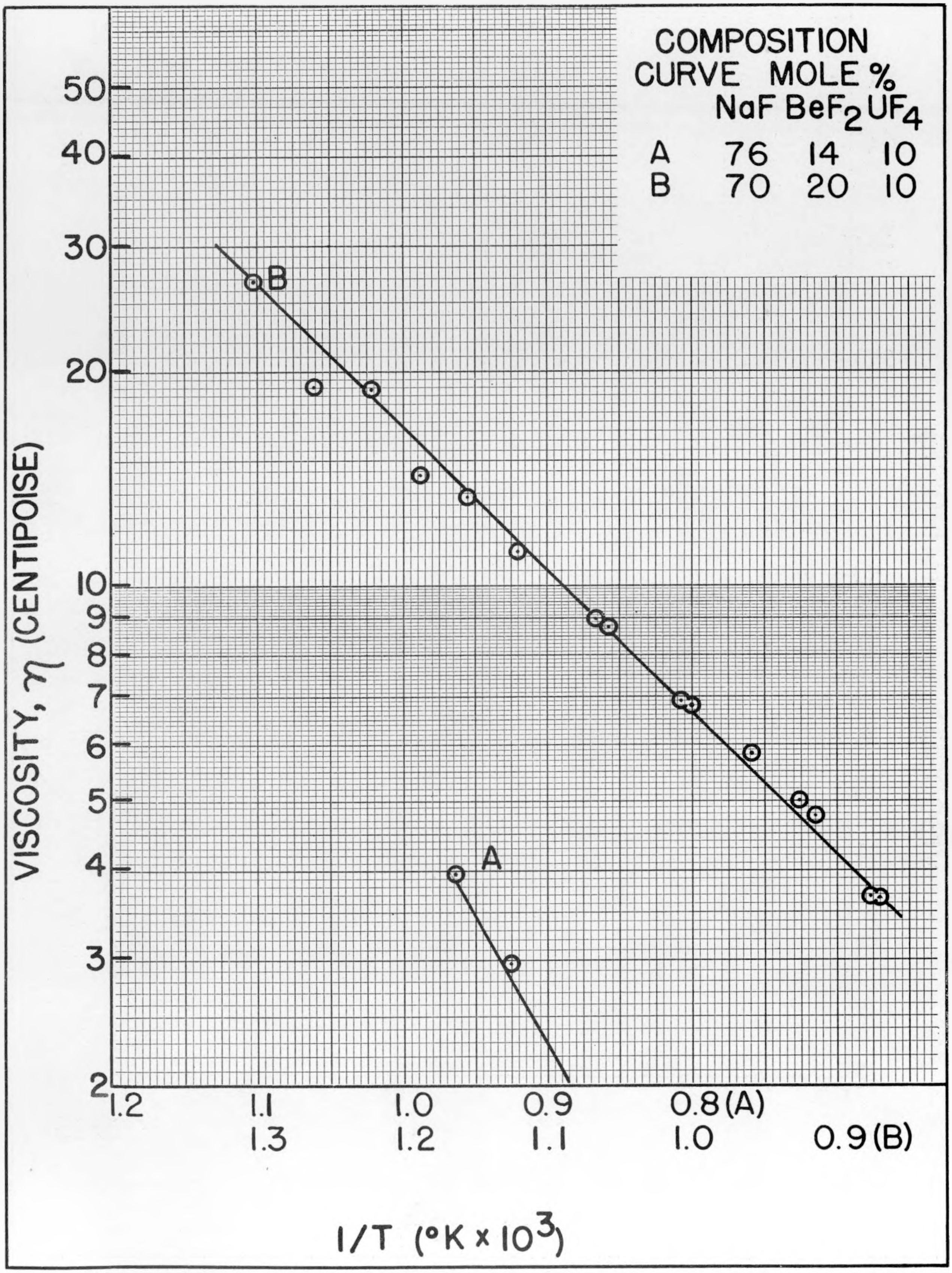
VISCOSITY as a FUNCTION of ABSOLUTE TEMPERATURE FOR MIXTURES of NaF, BeF_2 and UF_4

FIGURE 8G2



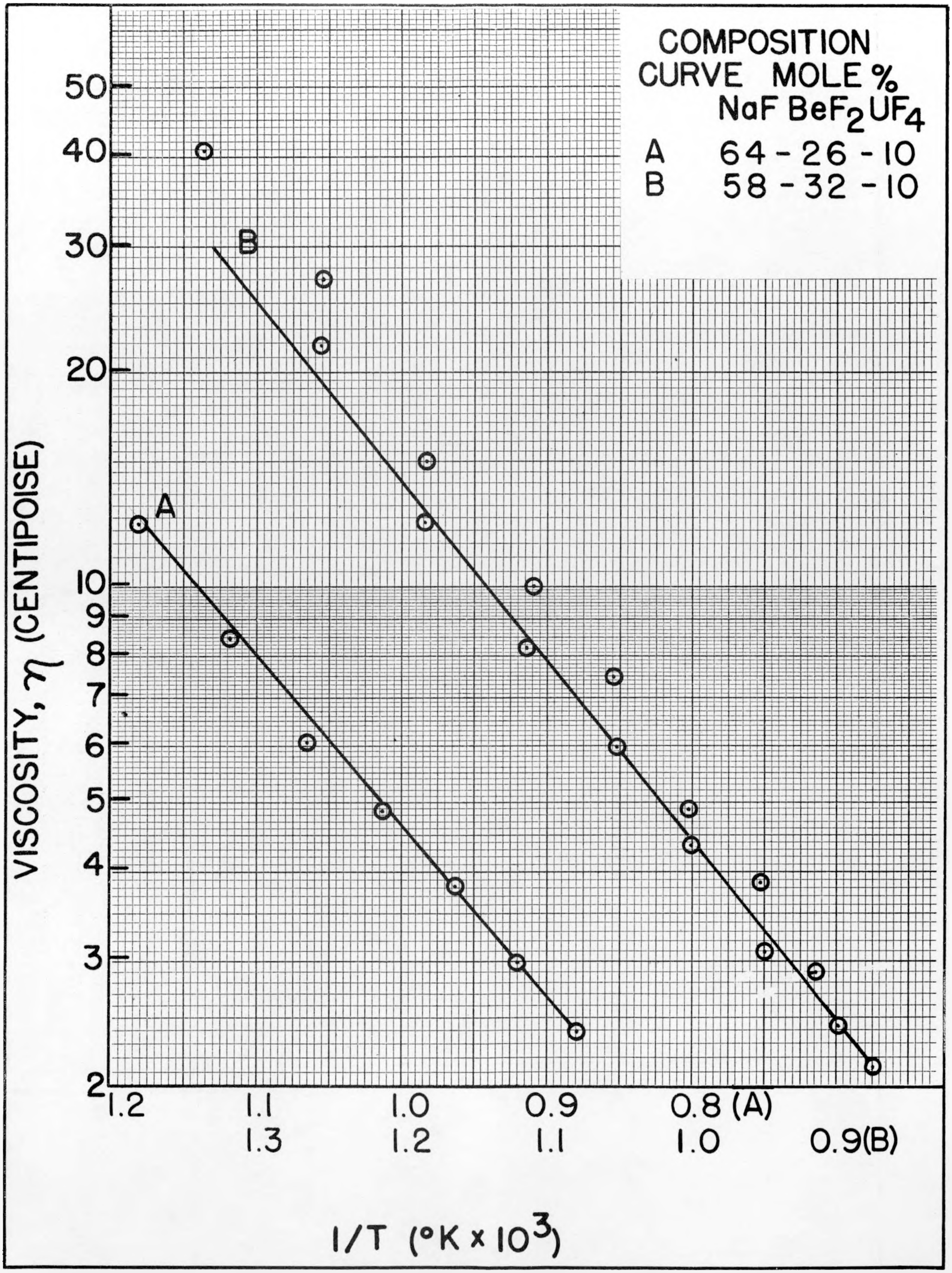
VISCOSITY as a FUNCTION of ABSOLUTE TEMPERATURE FOR MIXTURES of NaF, BeF_2 and UF_4

FIGURE 8G3



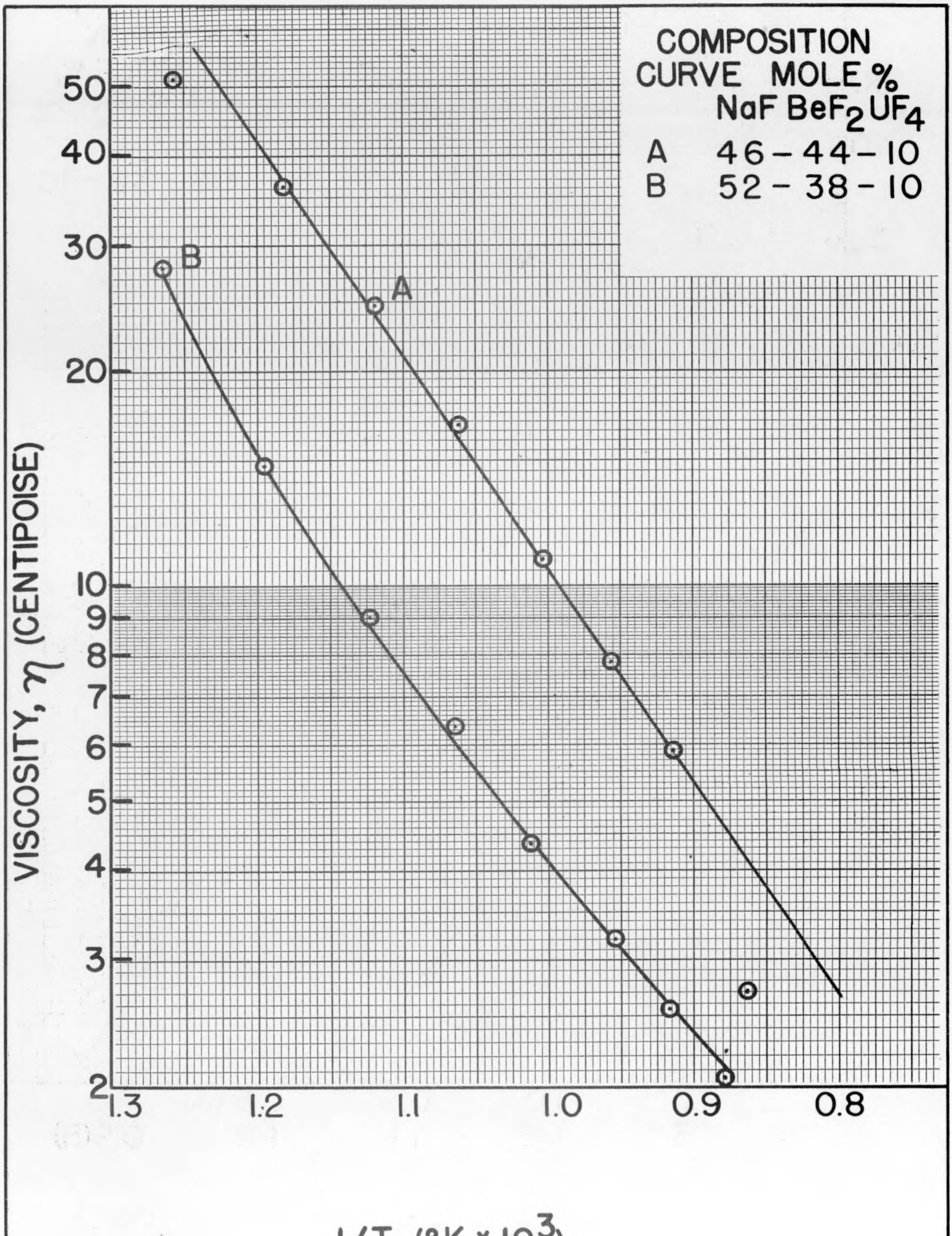
VISCOSITY as a FUNCTION of ABSOLUTE TEMPERATURE FOR MIXTURES of NaF, BeF_2 and UF_4

FIGURE 8H1



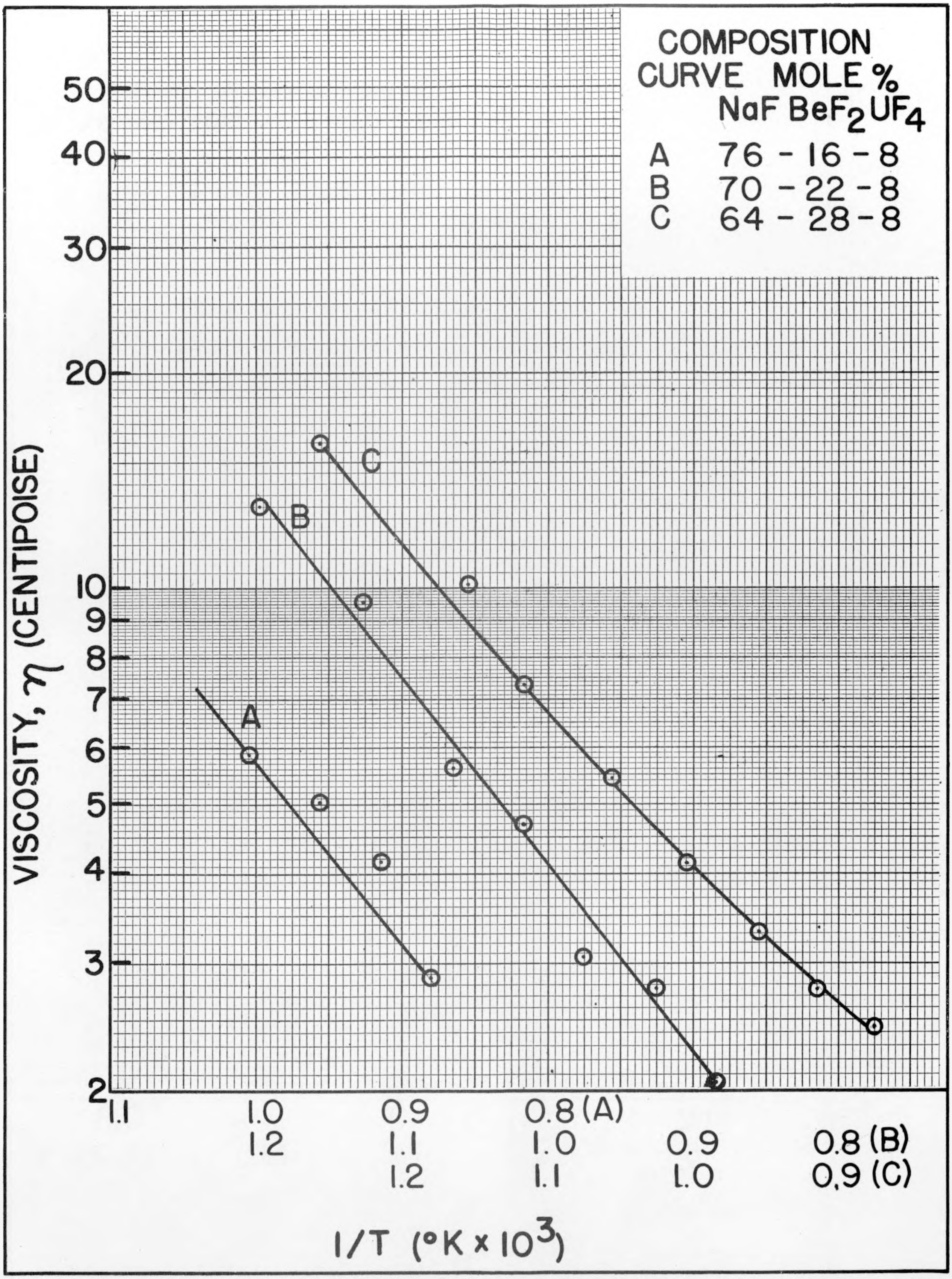
VISCOSITY as a FUNCTION of ABSOLUTE TEMPERATURE FOR MIXTURES of NaF, BeF_2 and UF_4

FIGURE 8H2



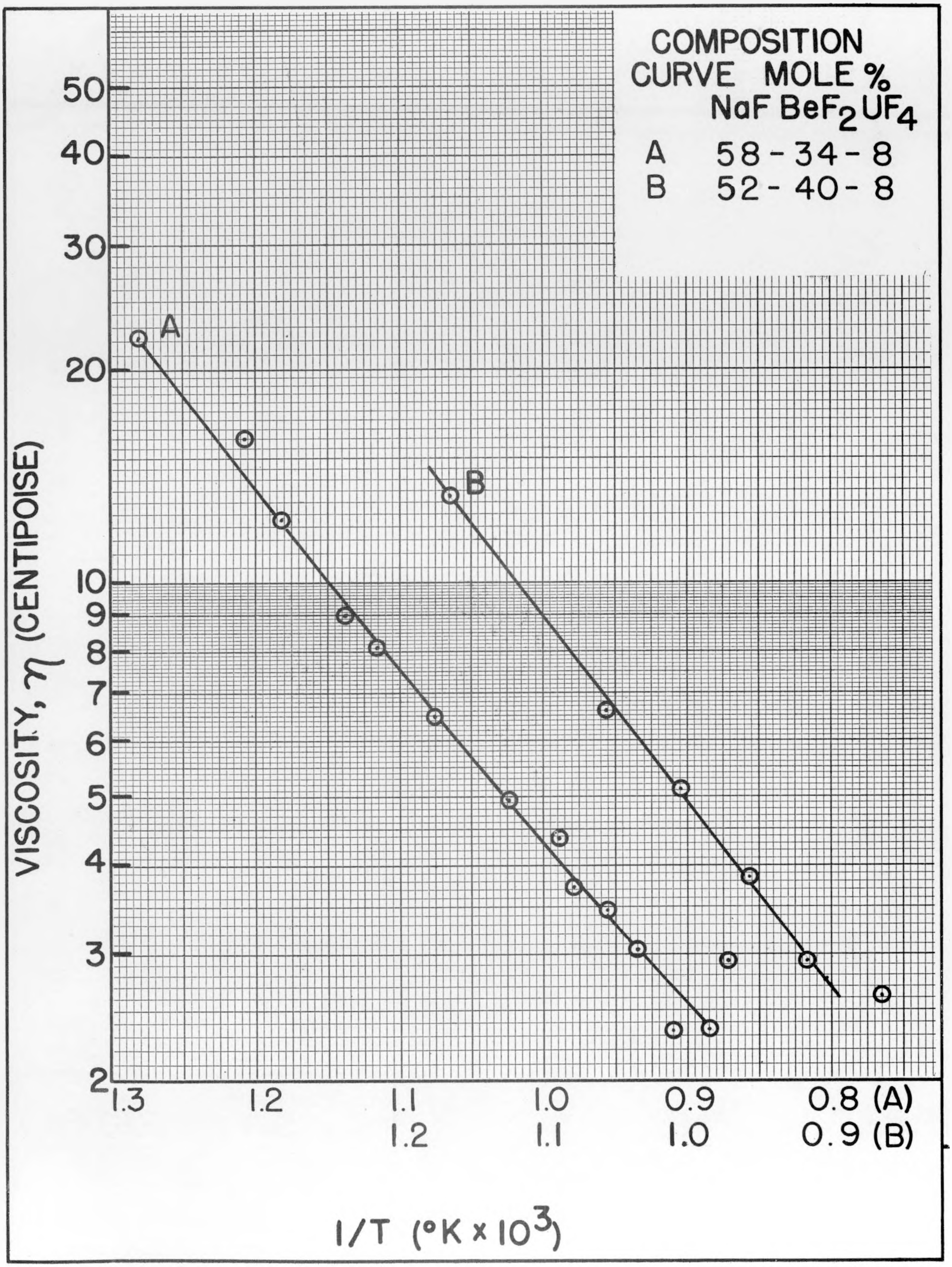
VISCOSITY as a FUNCTION of ABSOLUTE TEMPERATURE FOR MIXTURES of NaF, BeF_2 and UF_4

FIGURE 8H3



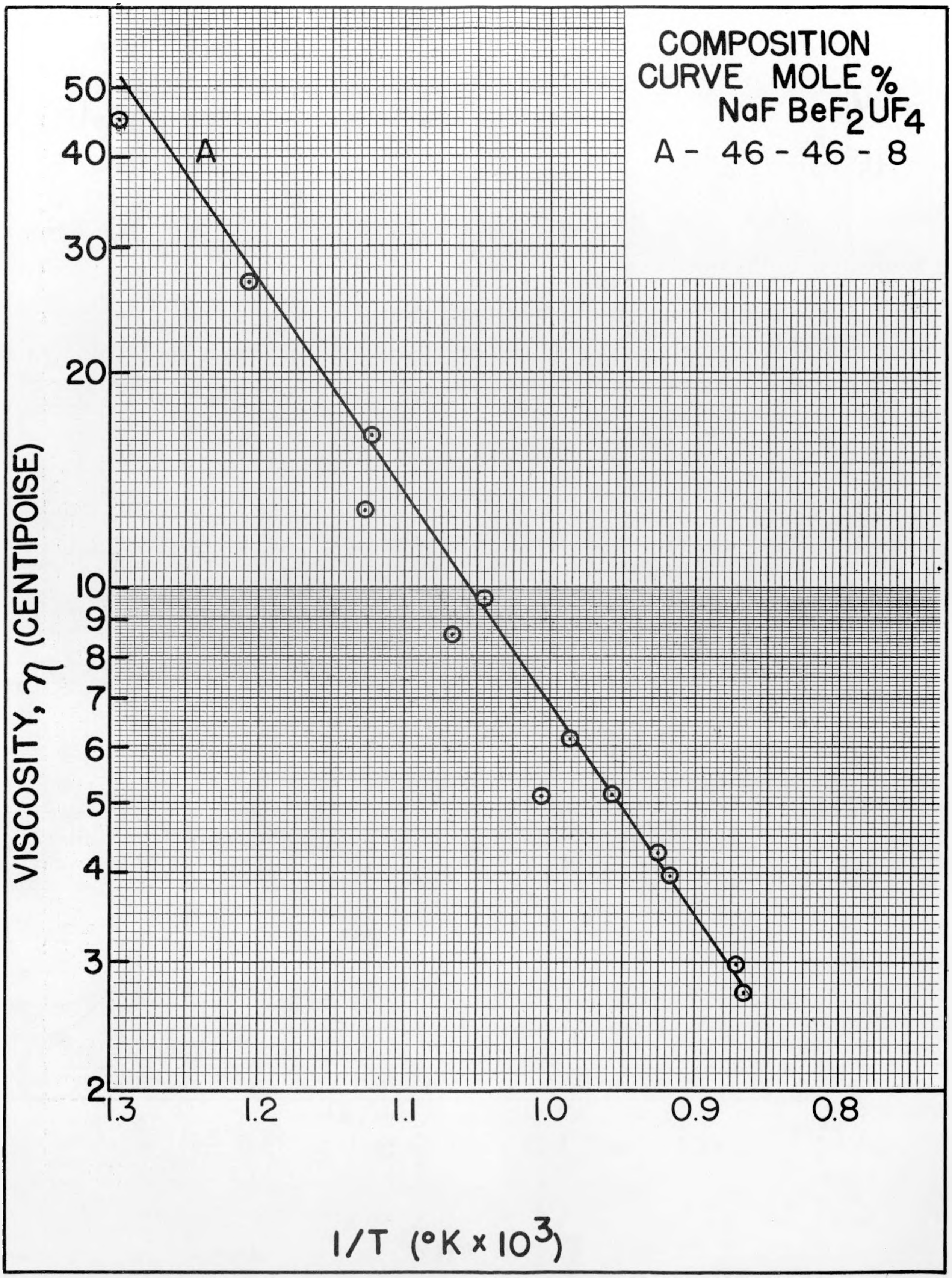
VISCOSITY as a FUNCTION of ABSOLUTE TEMPERATURE FOR MIXTURES of NaF, BeF_2 and UF_4

FIGURE 8J1



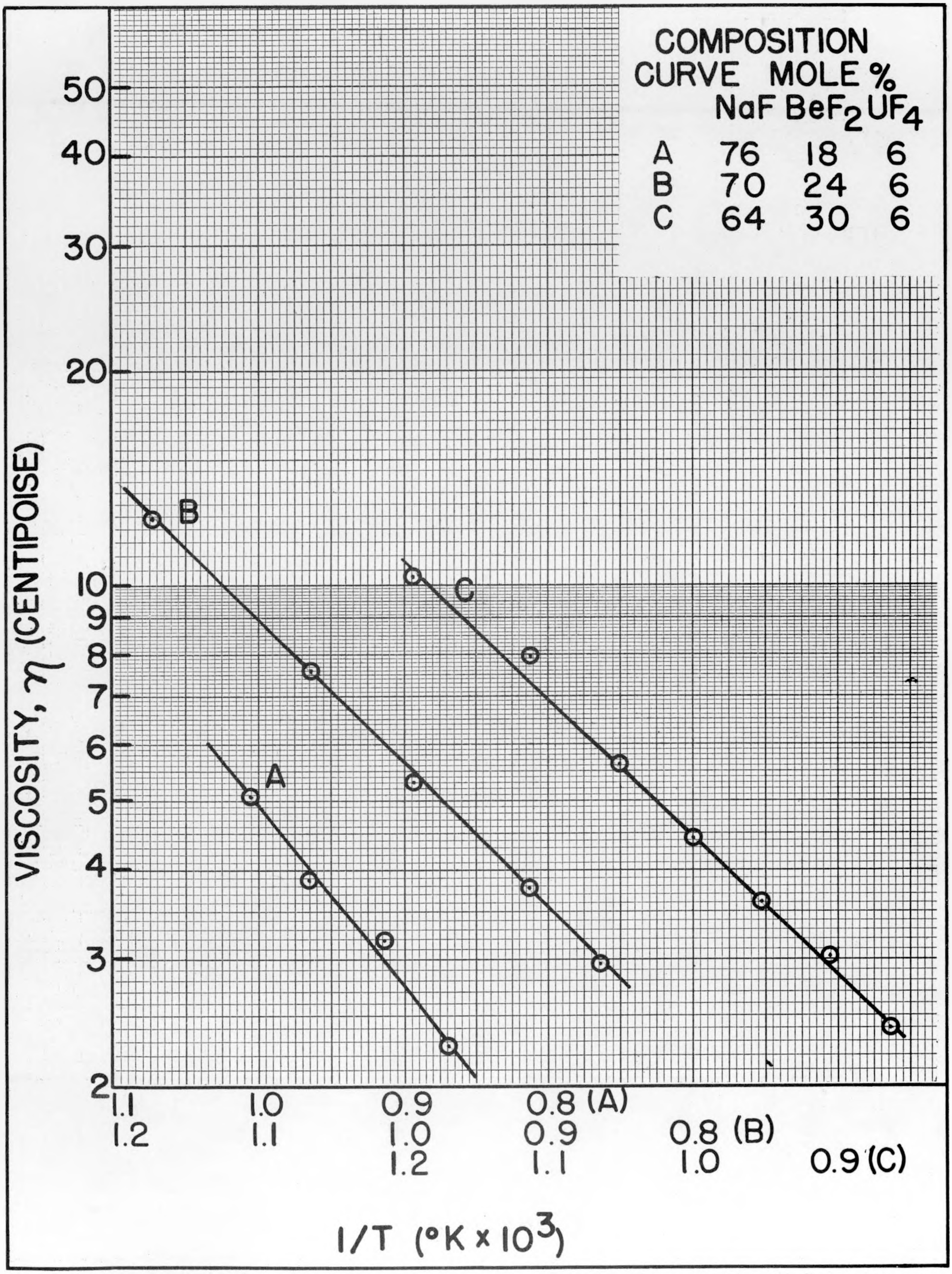
VISCOSITY as a FUNCTION of ABSOLUTE TEMPERATURE FOR MIXTURES of NaF, BeF_2 and UF_4

FIGURE 8J2



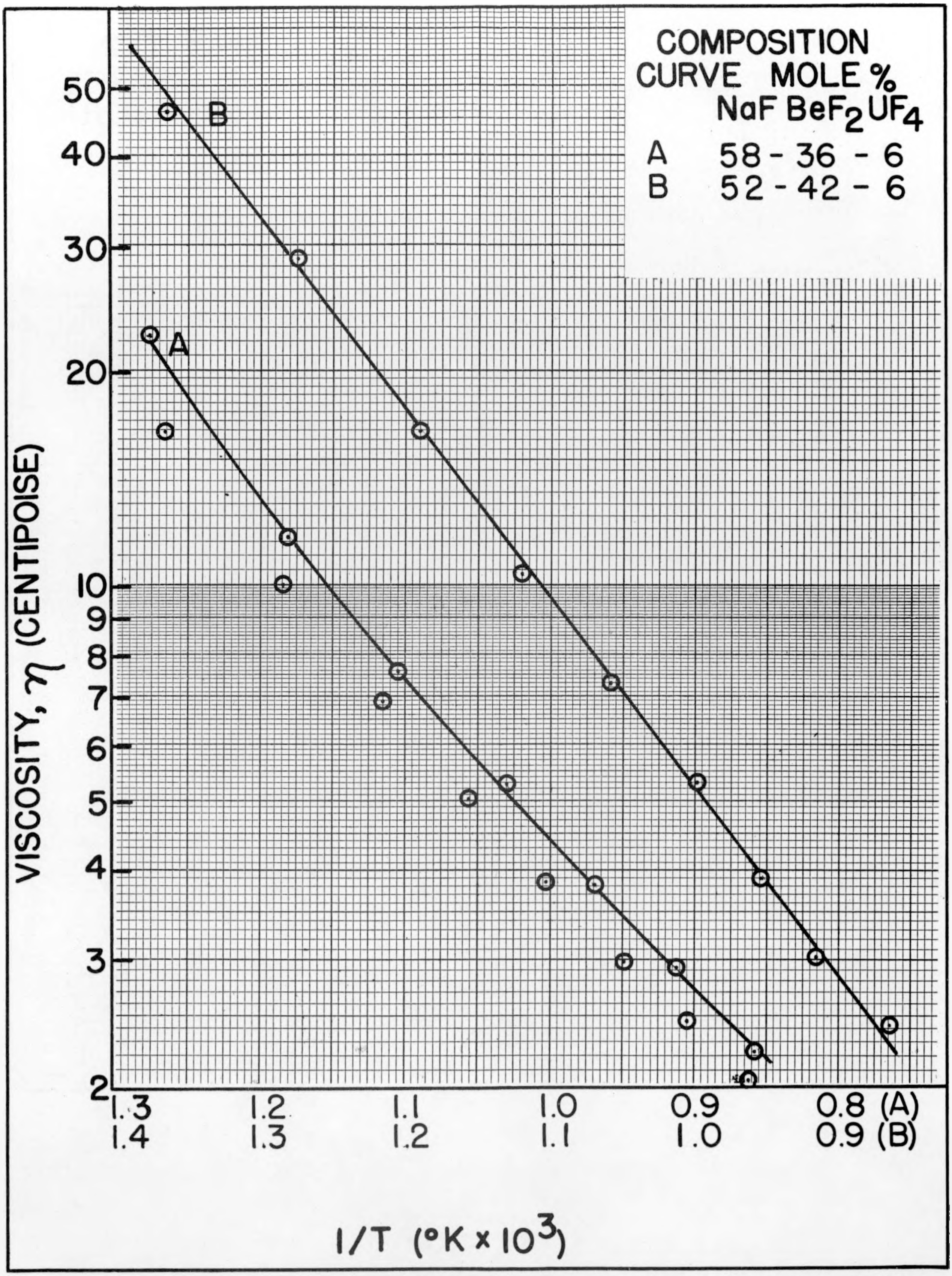
VISCOSITY as a FUNCTION of ABSOLUTE TEMPERATURE FOR MIXTURES of NaF, BeF_2 and UF_4

FIGURE 8J3



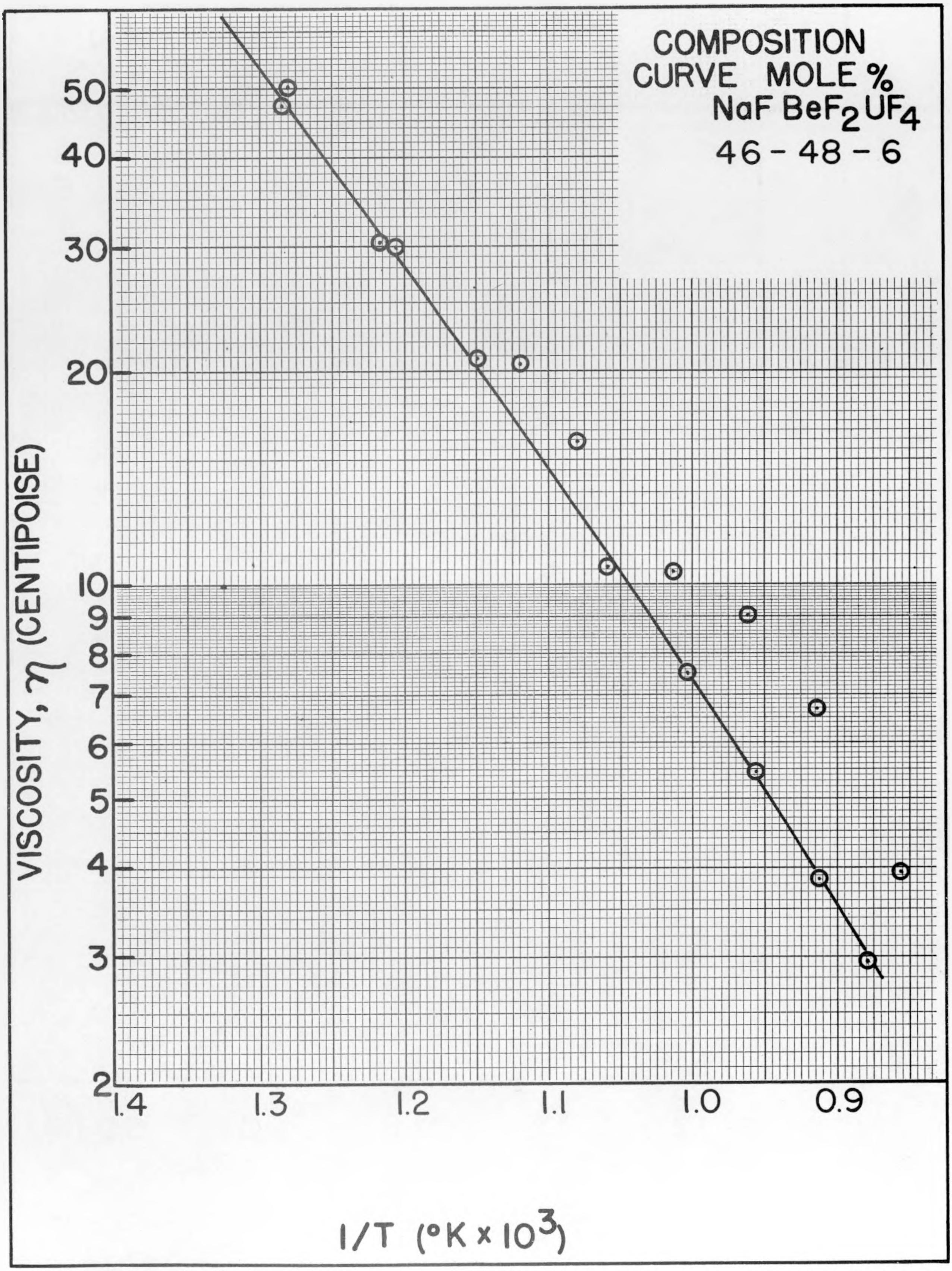
VISCOSITY as a FUNCTION of ABSOLUTE TEMPERATURE FOR MIXTURES of NaF, BeF_2 and UF_4

FIGURE 8K1



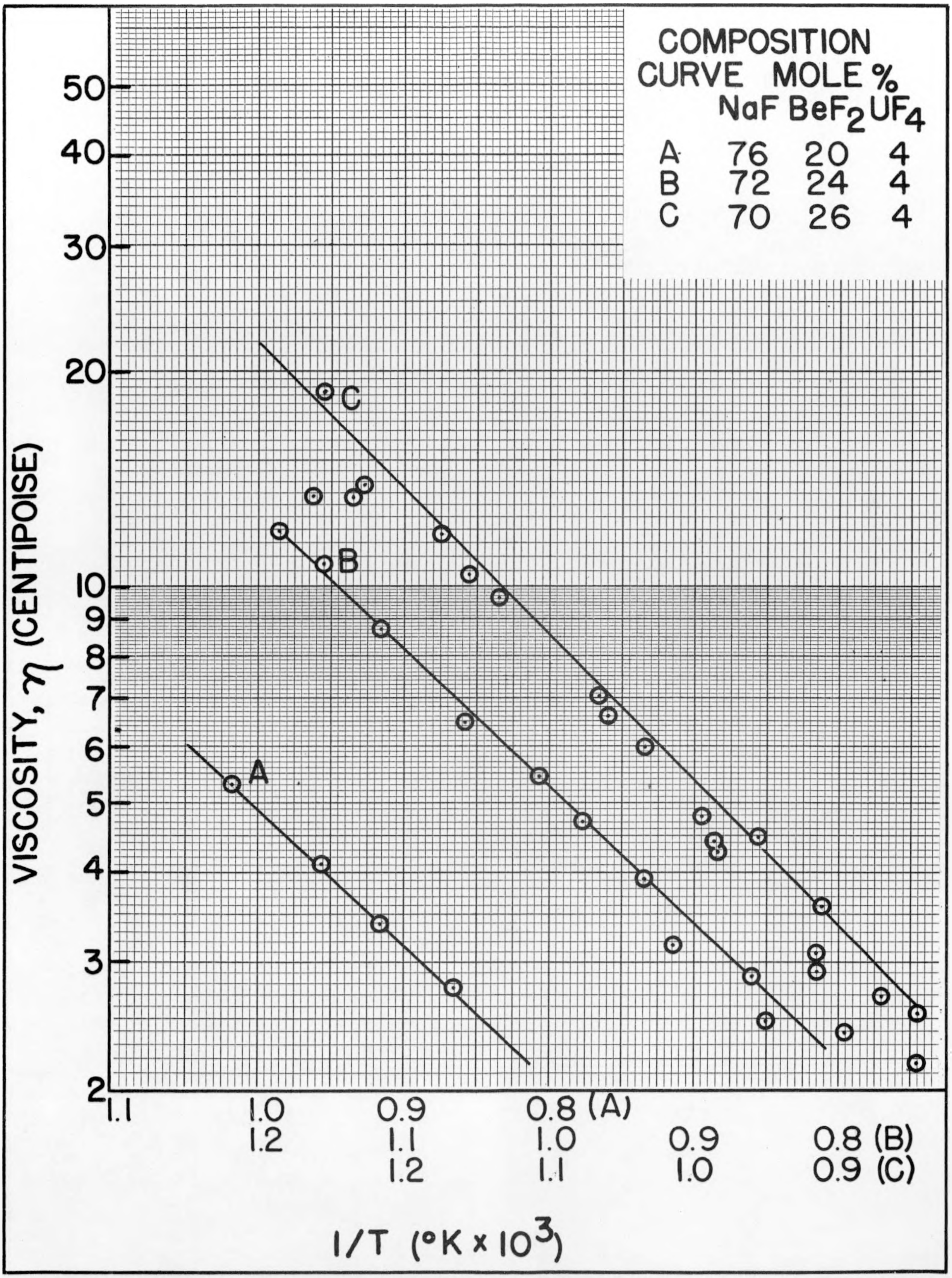
VISCOSITY as a FUNCTION of ABSOLUTE TEMPERATURE FOR MIXTURES of NaF, BeF_2 and UF_4

FIGURE 8K2



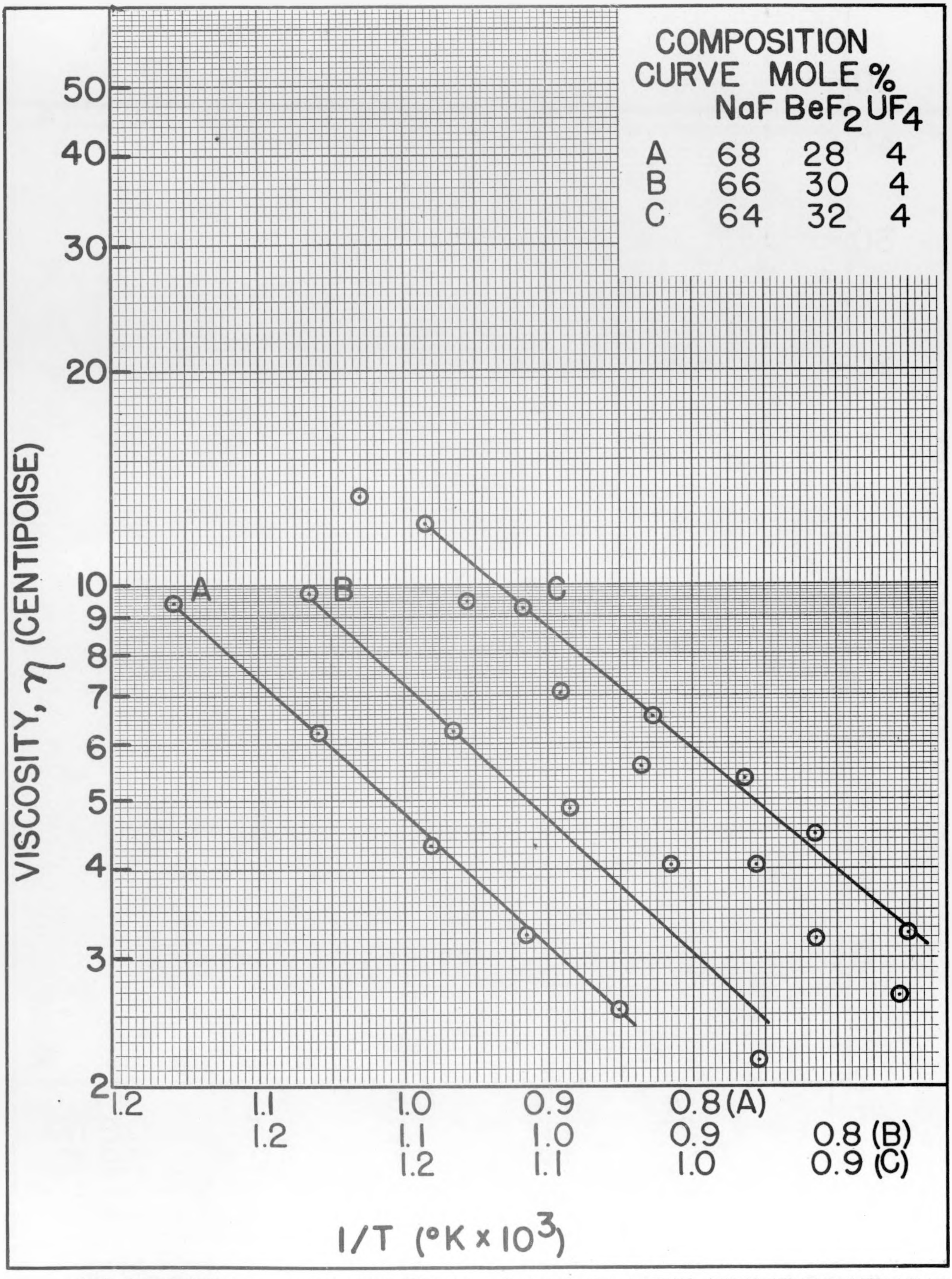
VISCOSITY as a FUNCTION of ABSOLUTE TEMPERATURE FOR MIXTURES of NaF, BeF_2 and UF_4

FIGURE 8K3



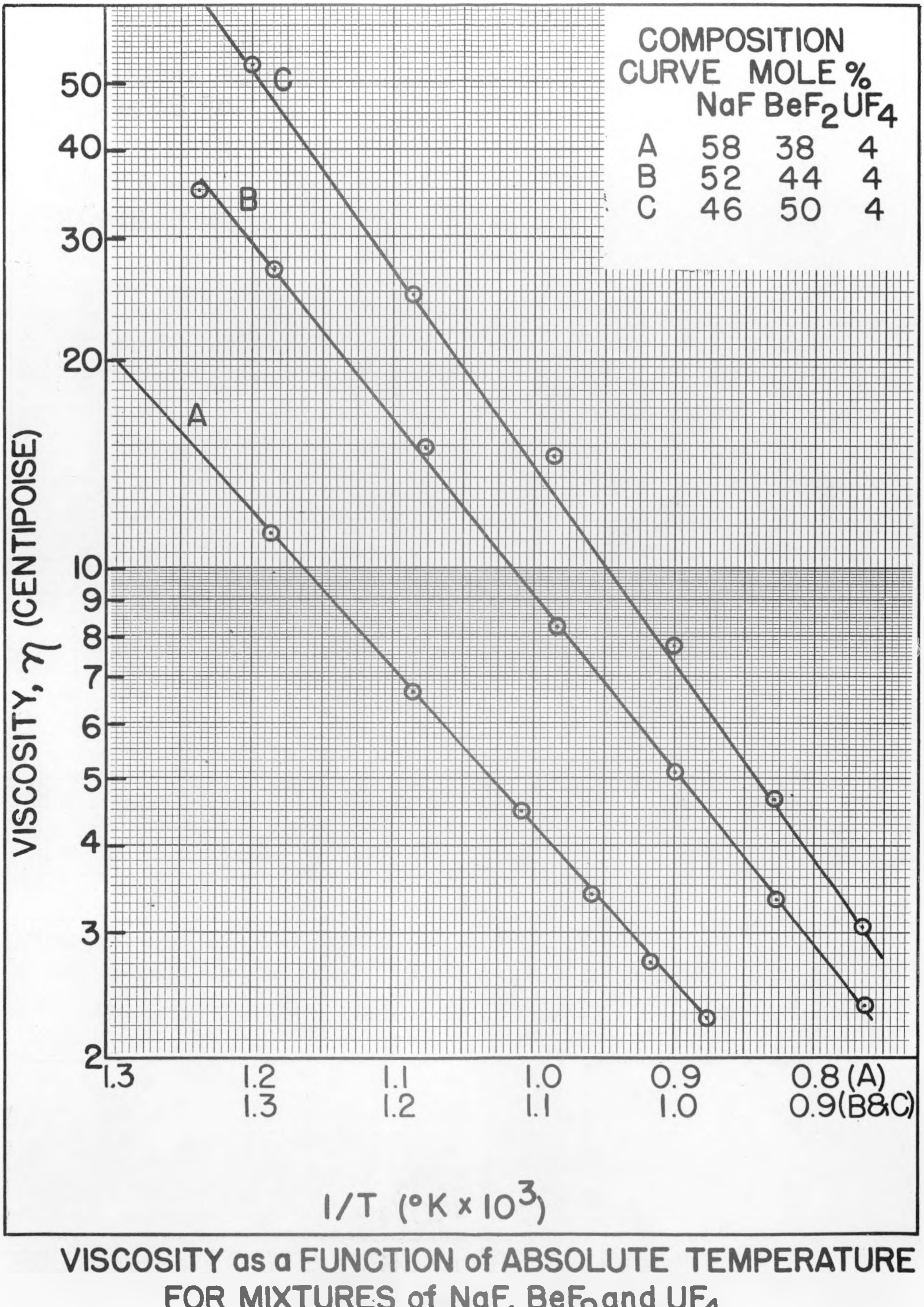
VISCOSITY as a FUNCTION of ABSOLUTE TEMPERATURE FOR MIXTURES of NaF, BeF_2 and UF_4

FIGURE 8L1



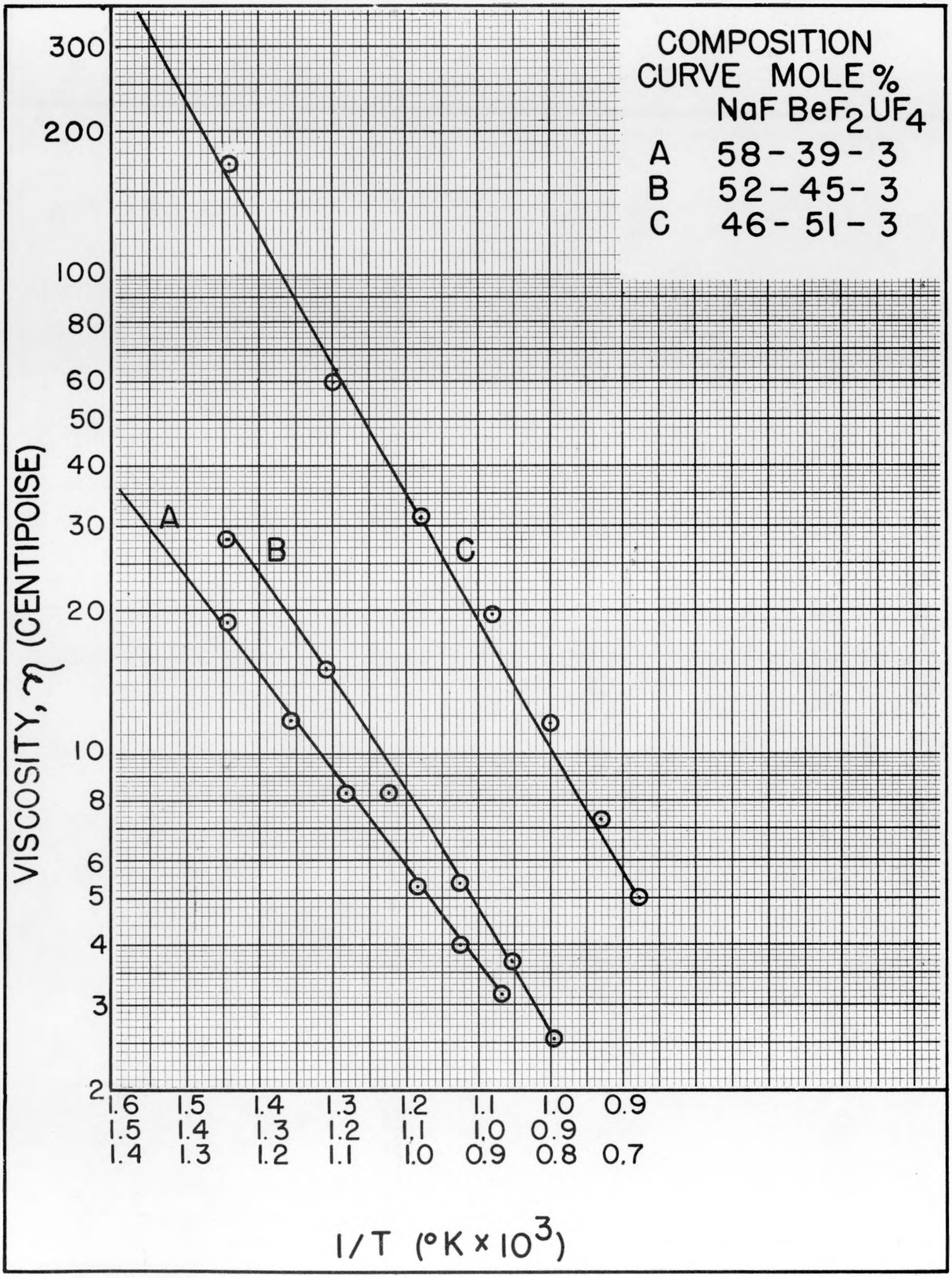
VISCOSITY as a FUNCTION of ABSOLUTE TEMPERATURE FOR MIXTURES of NaF, BeF_2 and UF_4

FIGURE 8L2



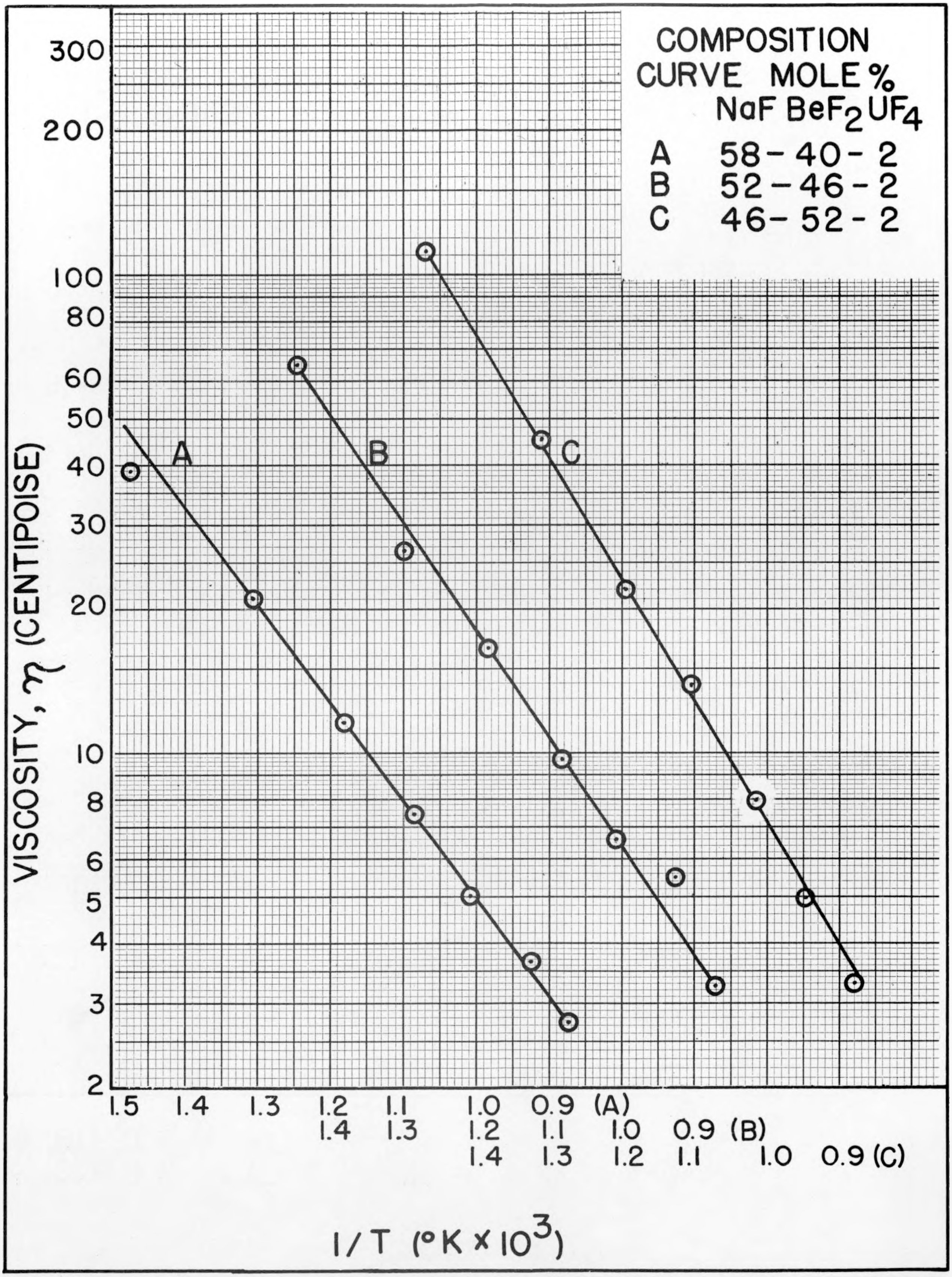
VISCOSITY as a FUNCTION of ABSOLUTE TEMPERATURE FOR MIXTURES of NaF, BeF_2 and UF_4

FIGURE 8L3



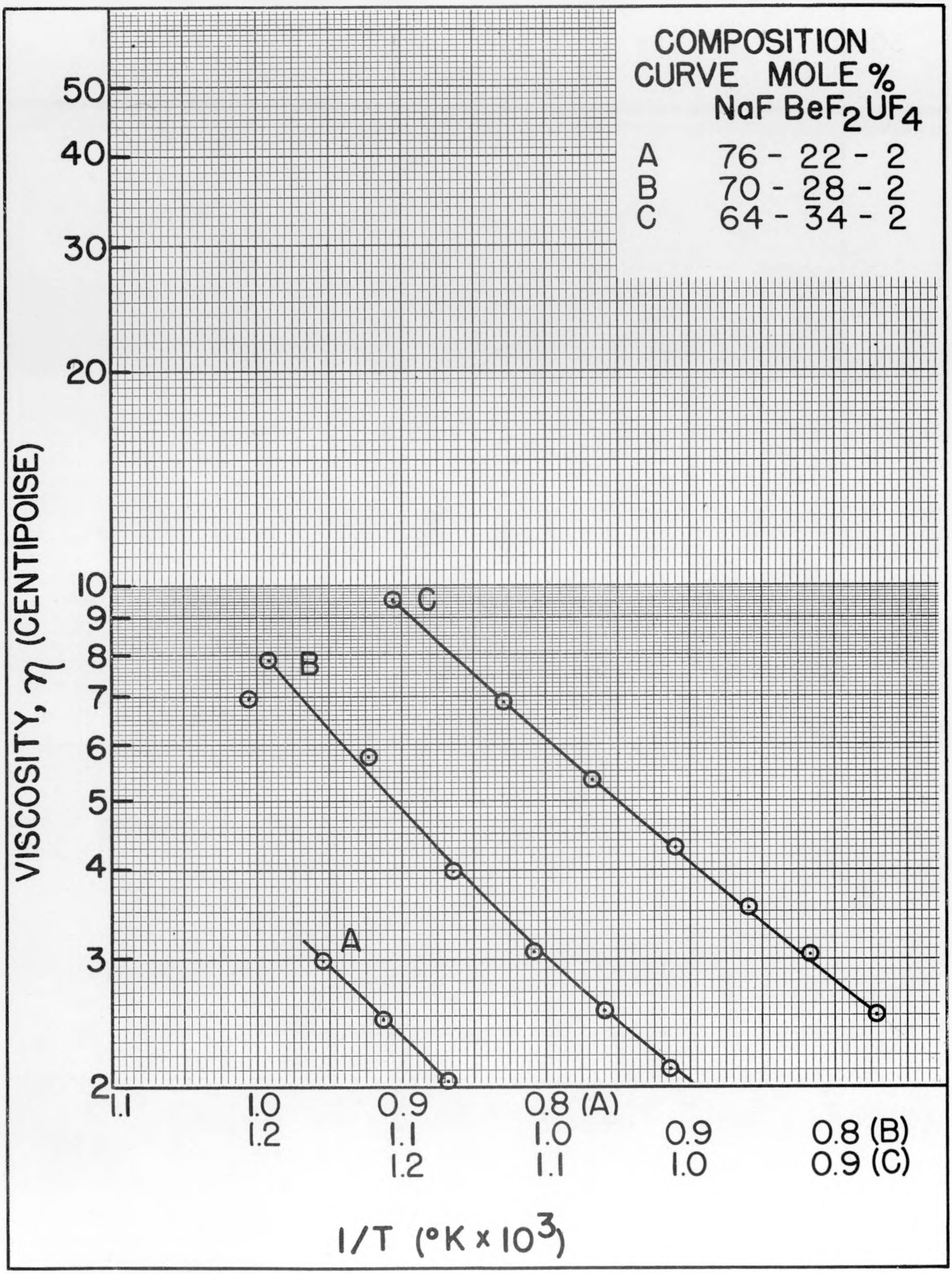
VISCOSITY as a FUNCTION of ABSOLUTE TEMPERATURE FOR MIXTURES of NaF, BeF_2 and UF_4

FIGURE 8M



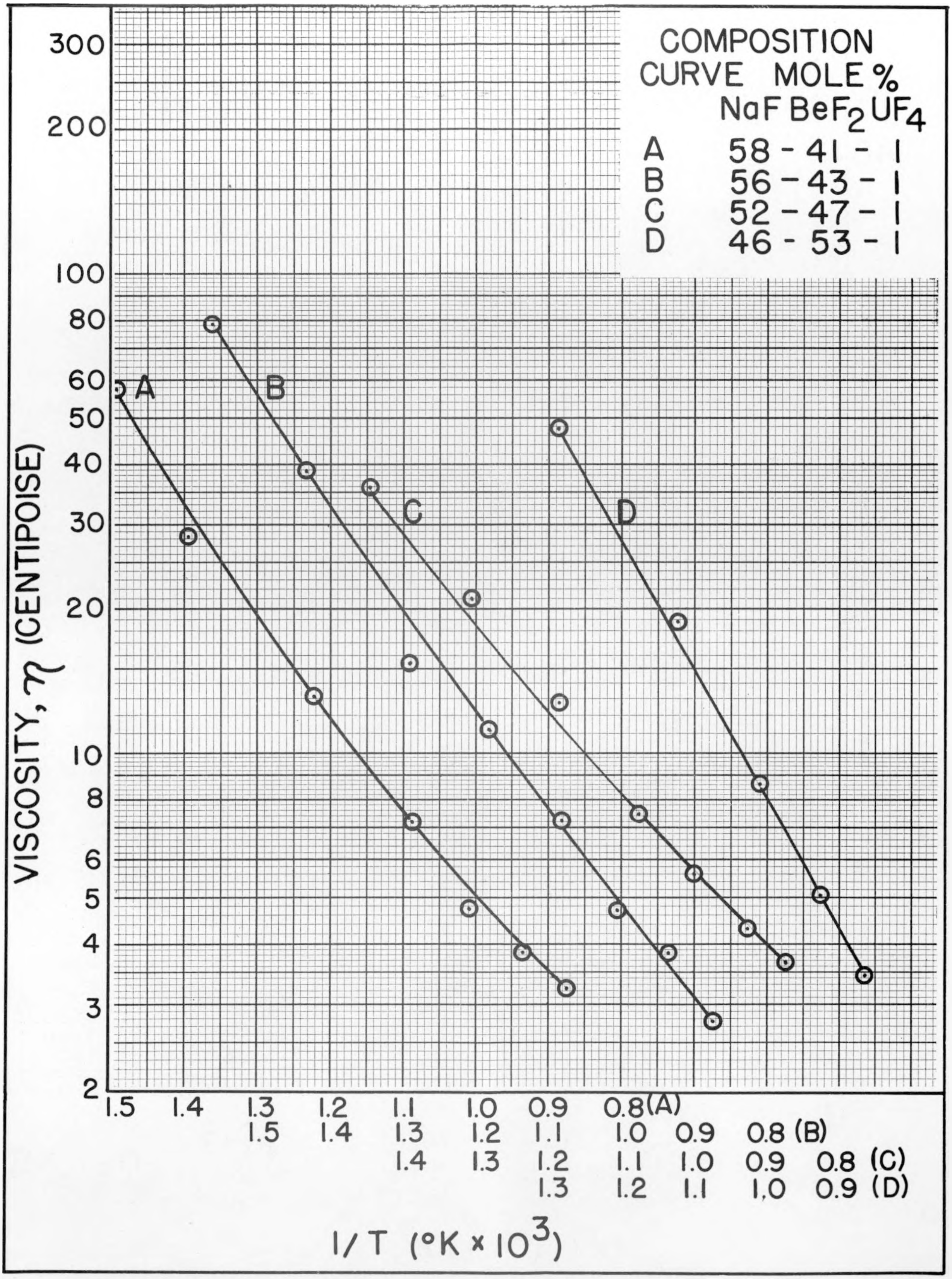
VISCOSITY as a FUNCTION of ABSOLUTE TEMPERATURE FOR MIXTURES of NaF, BeF_2 and UF_4

FIGURE 8N1



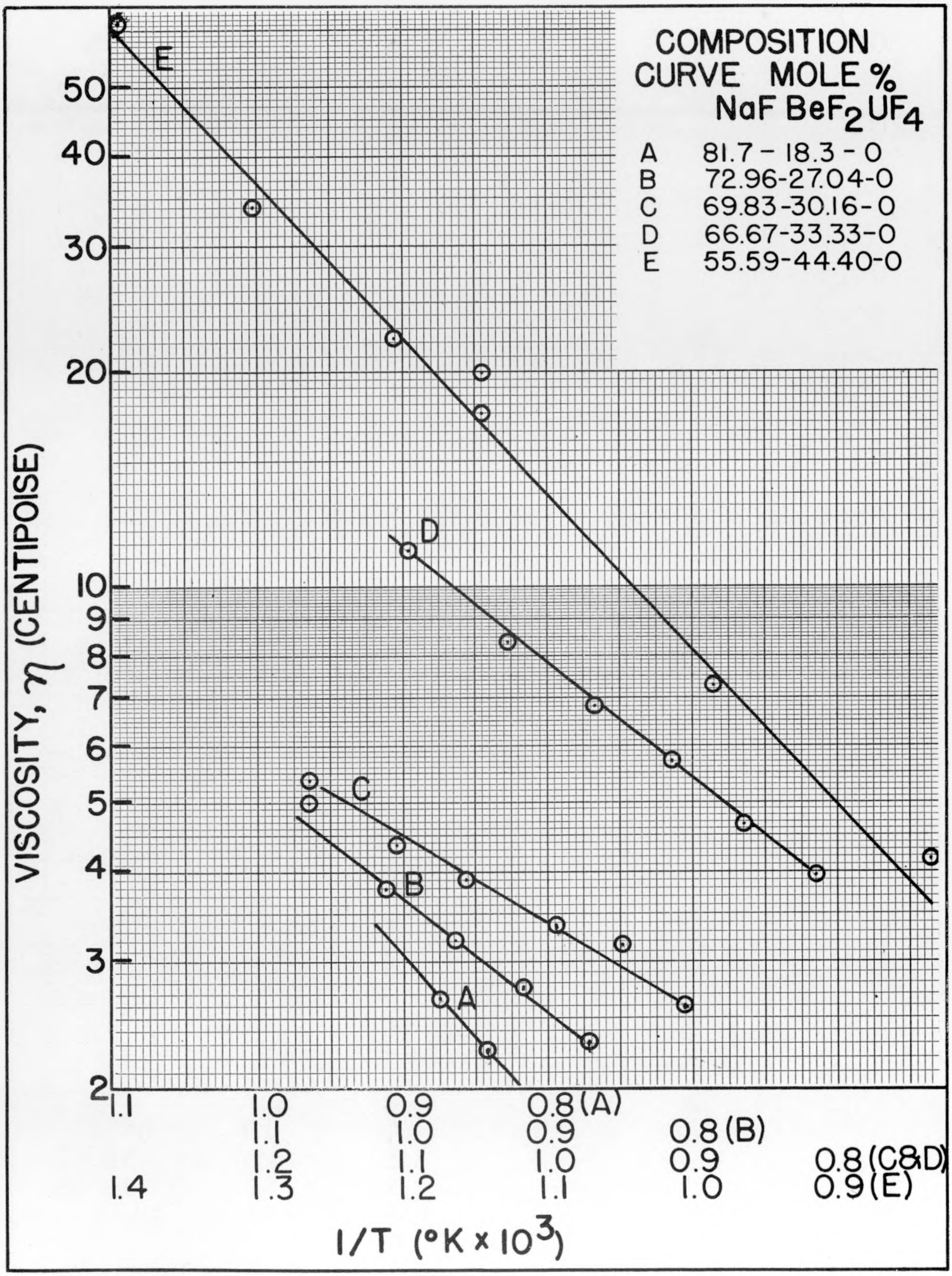
VISCOSITY as a FUNCTION of ABSOLUTE TEMPERATURE FOR MIXTURES of NaF, BeF_2 and UF_4

FIGURE 8N2



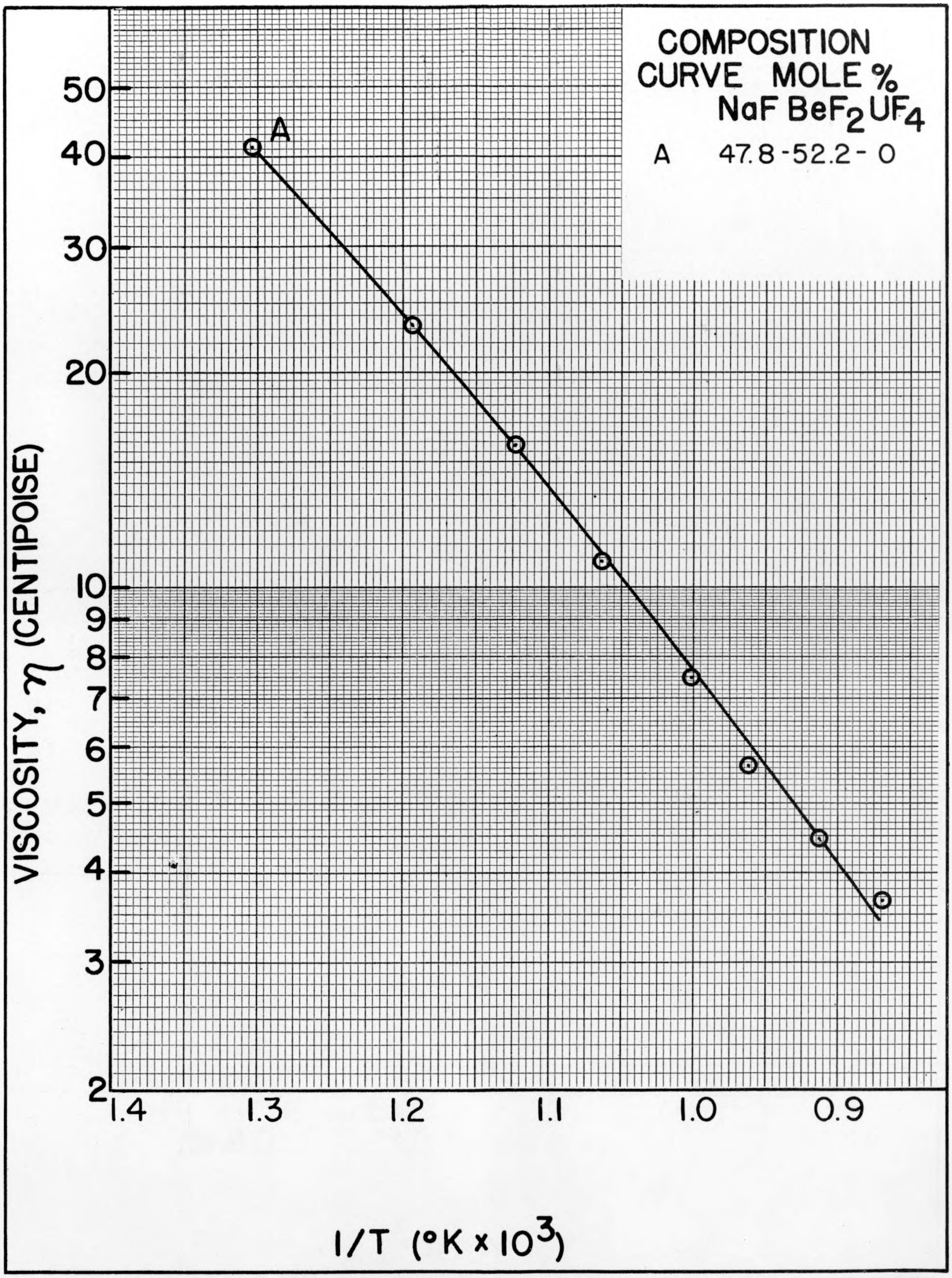
VISCOSITY as a FUNCTION of ABSOLUTE TEMPERATURE FOR MIXTURES of NaF, BeF_2 and UF_4

FIGURE 8P



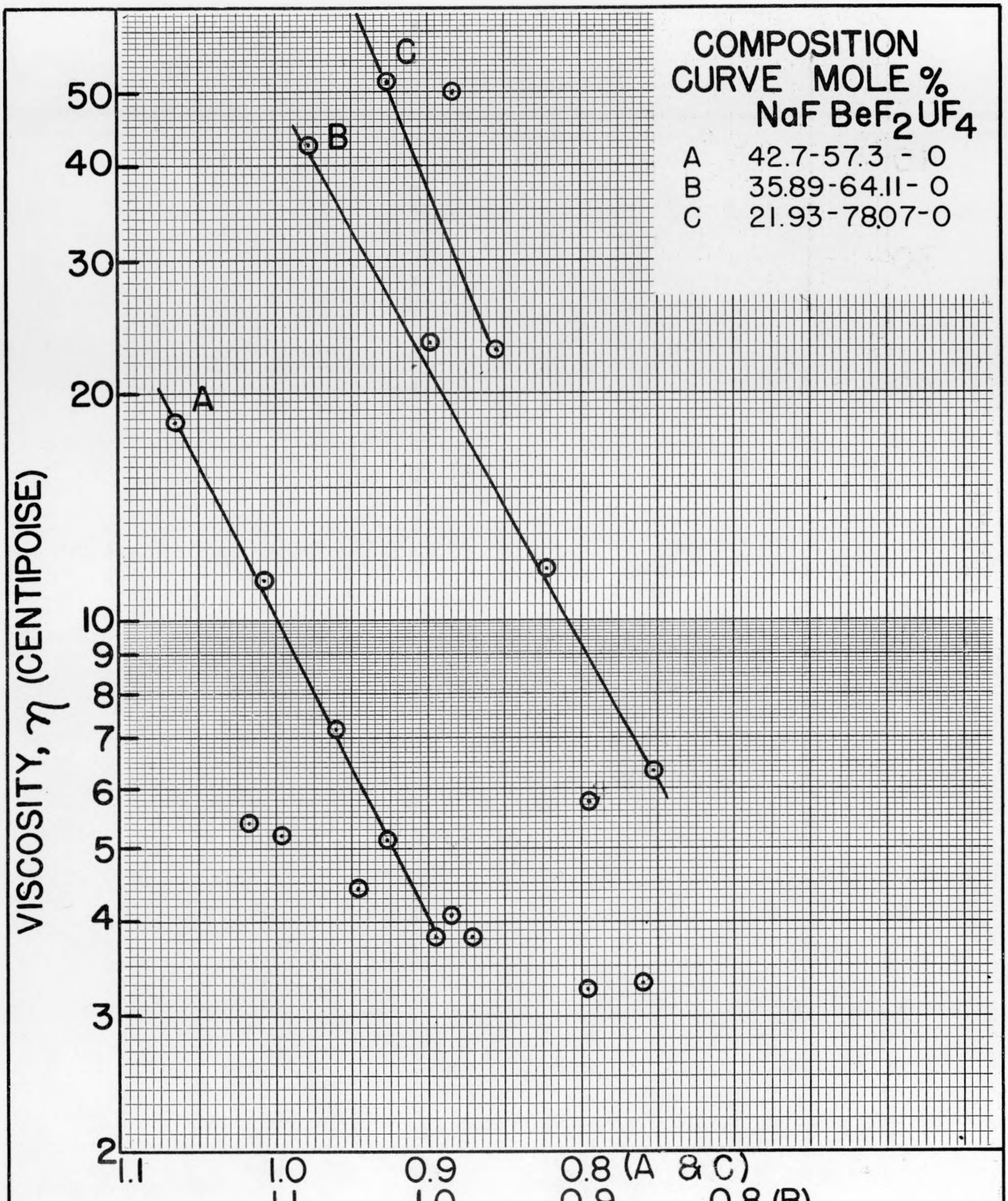
VISCOSITY as a FUNCTION of ABSOLUTE TEMPERATURE FOR MIXTURES of NaF, BeF_2 and UF_4

FIGURE 8Q1



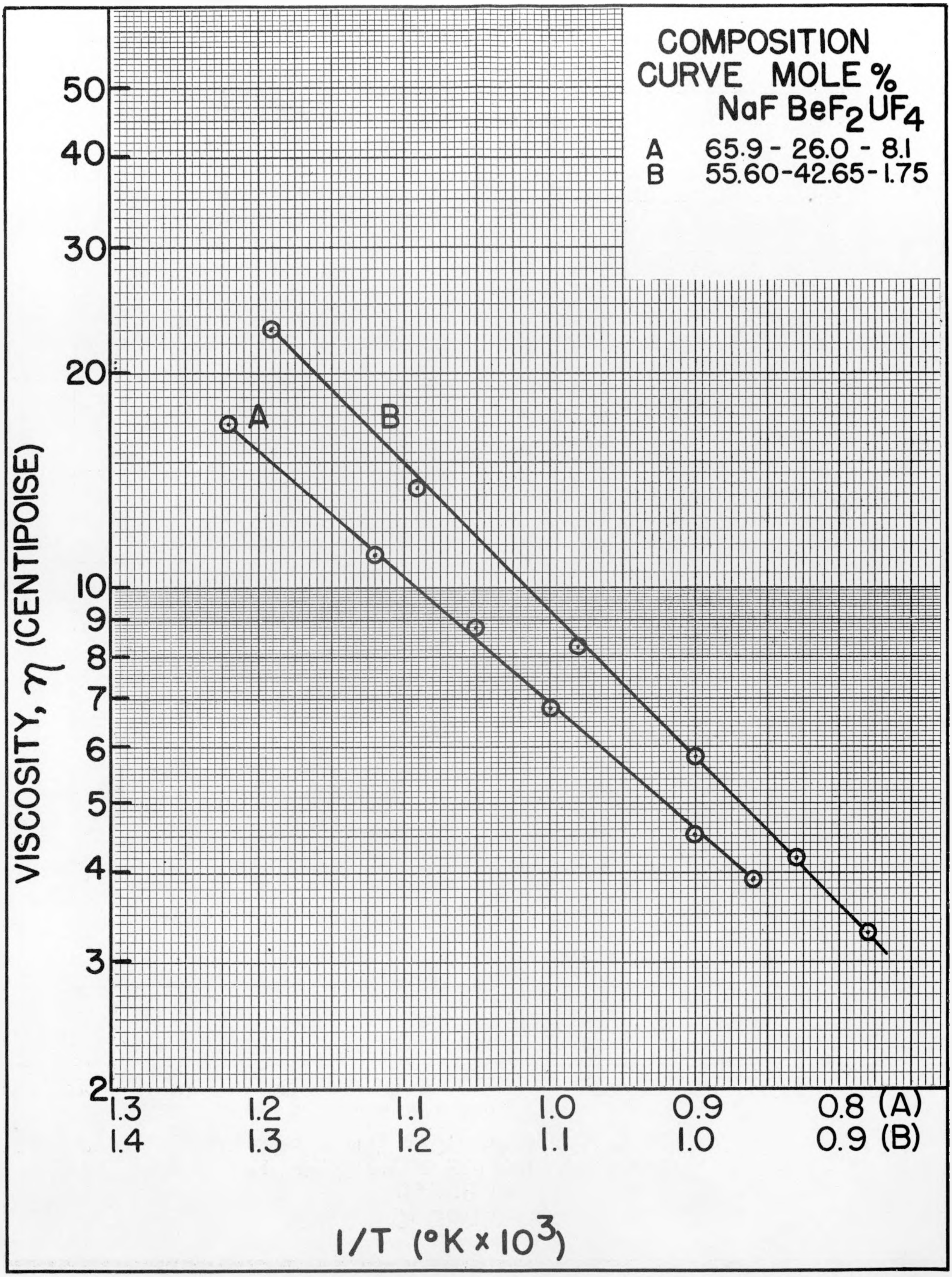
VISCOSITY as a FUNCTION of ABSOLUTE TEMPERATURE FOR MIXTURES of NaF, BeF$_2$ and UF$_4$

FIGURE 8Q2



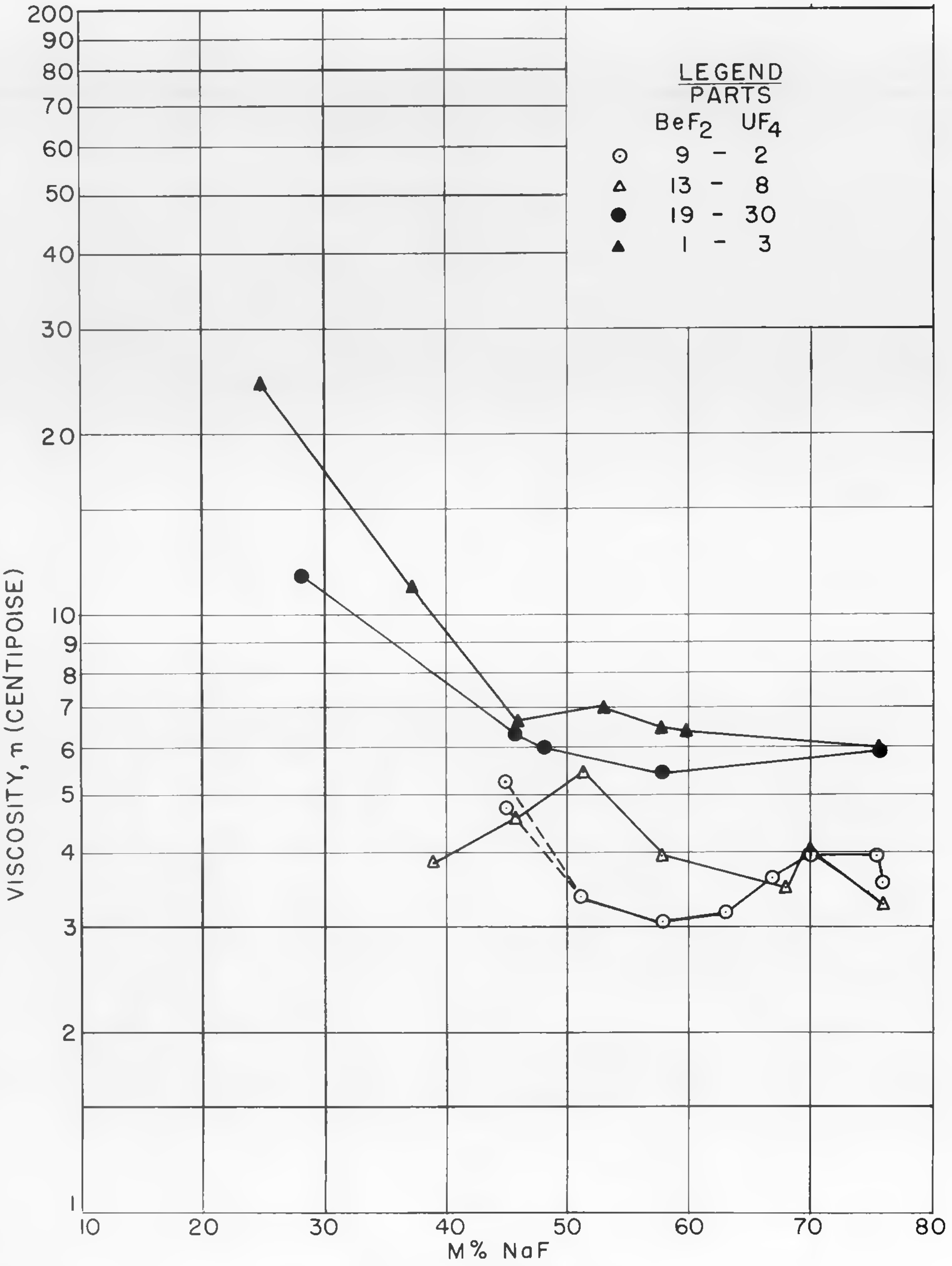
VISCOSITY as a FUNCTION of ABSOLUTE TEMPERATURE FOR MIXTURES of NaF, BeF_2 and UF_4

FIGURE 8Q3



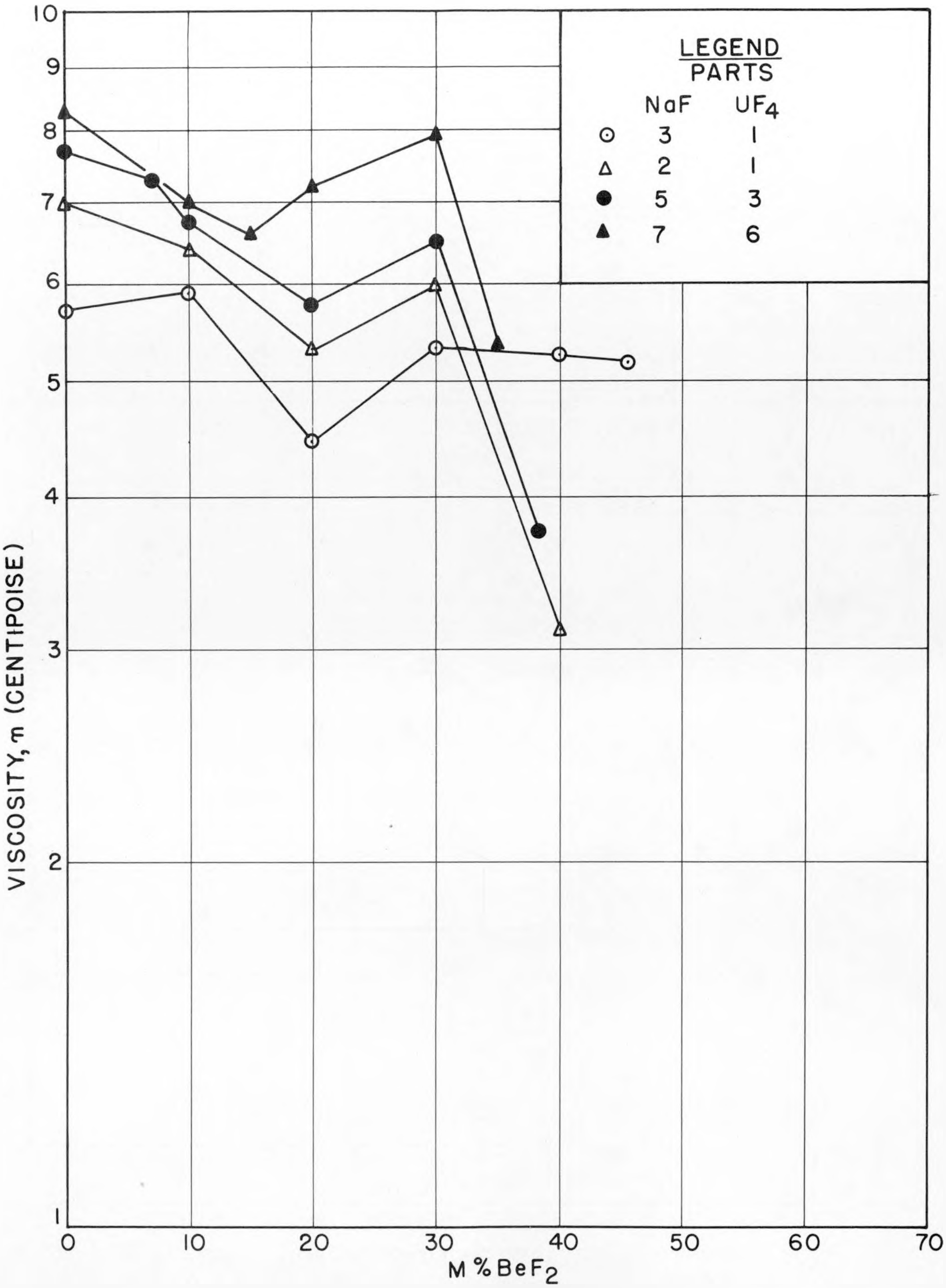
VISCOSITY as a FUNCTION of ABSOLUTE TEMPERATURE FOR MIXTURES of NaF, BeF_2 and UF_4

FIGURE 9

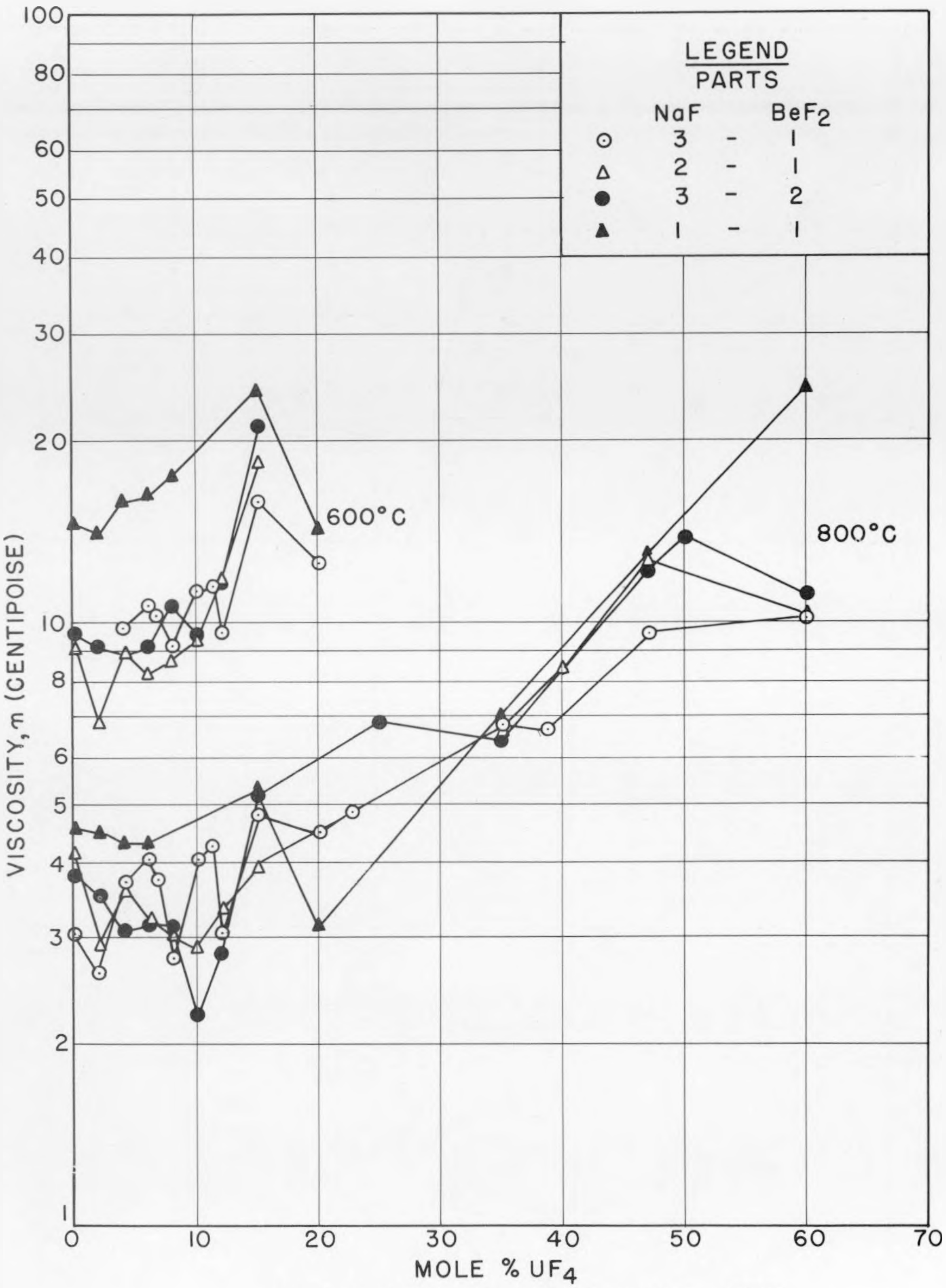


VISCOSITY VS MOLE % NaF FOR CONSTANT RATIOS OF BeF_2 TO UF_4 AT 800°C

FIGURE 10

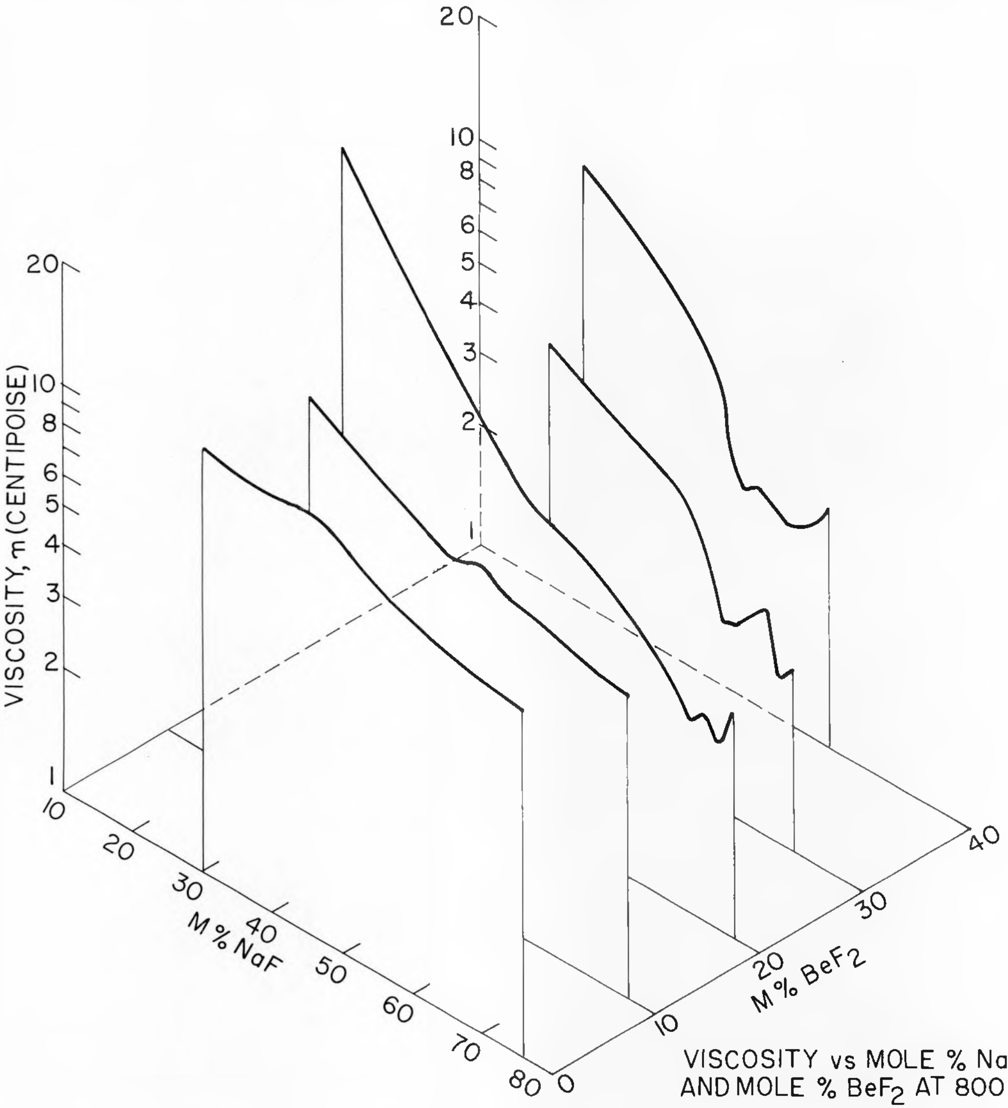


VISCOSITY VS MOLE % BeF_2 FOR CONSTANT RATIOS OF NaF TO UF_4 AT 800°C
FIGURE 11



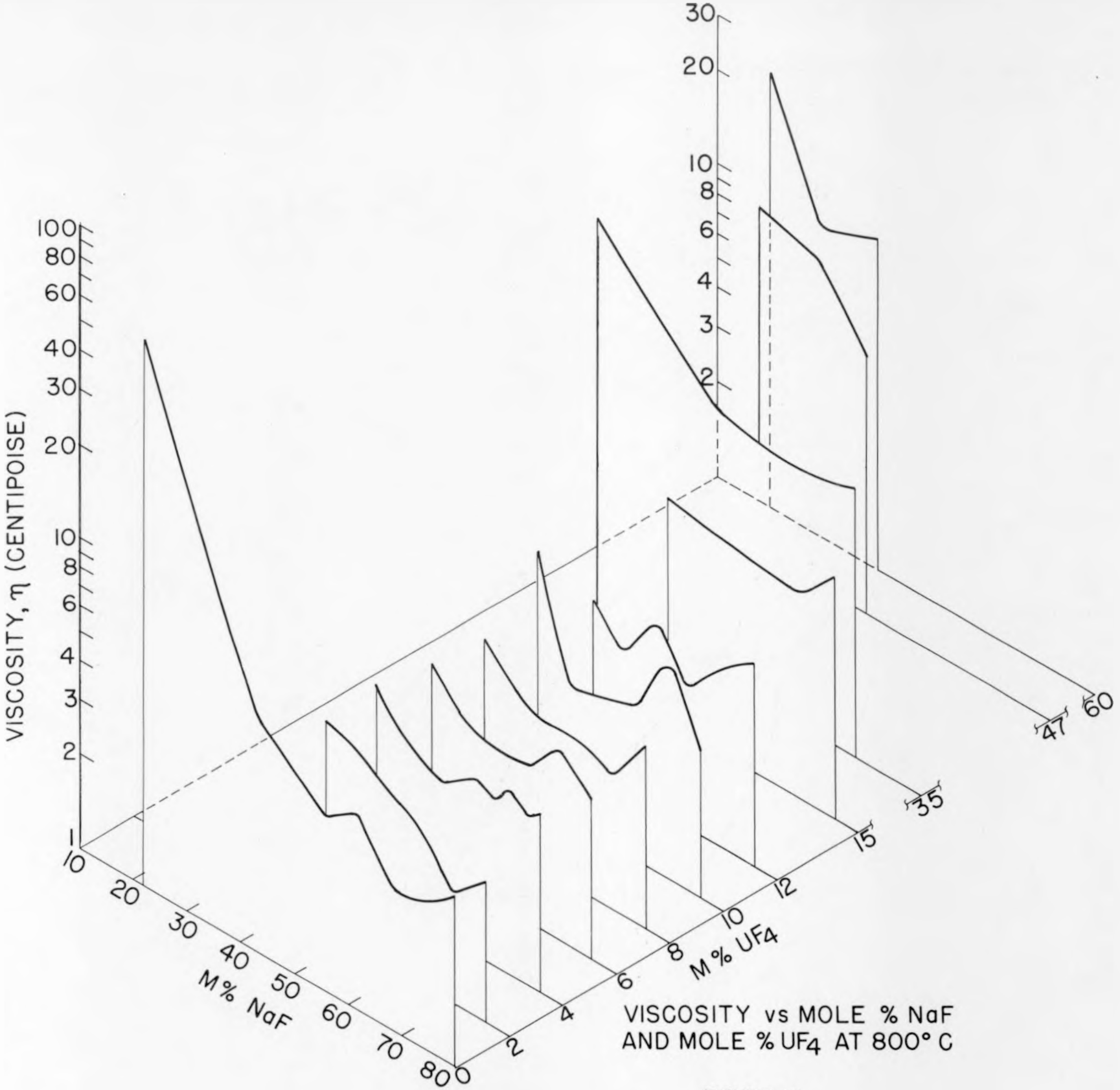
VISCOSITY VS MOLE % UF_4 FOR CONSTANT RATIOS OF NaF TO BeF_2 AT 600 °C & 800 °C

FIGURE 12



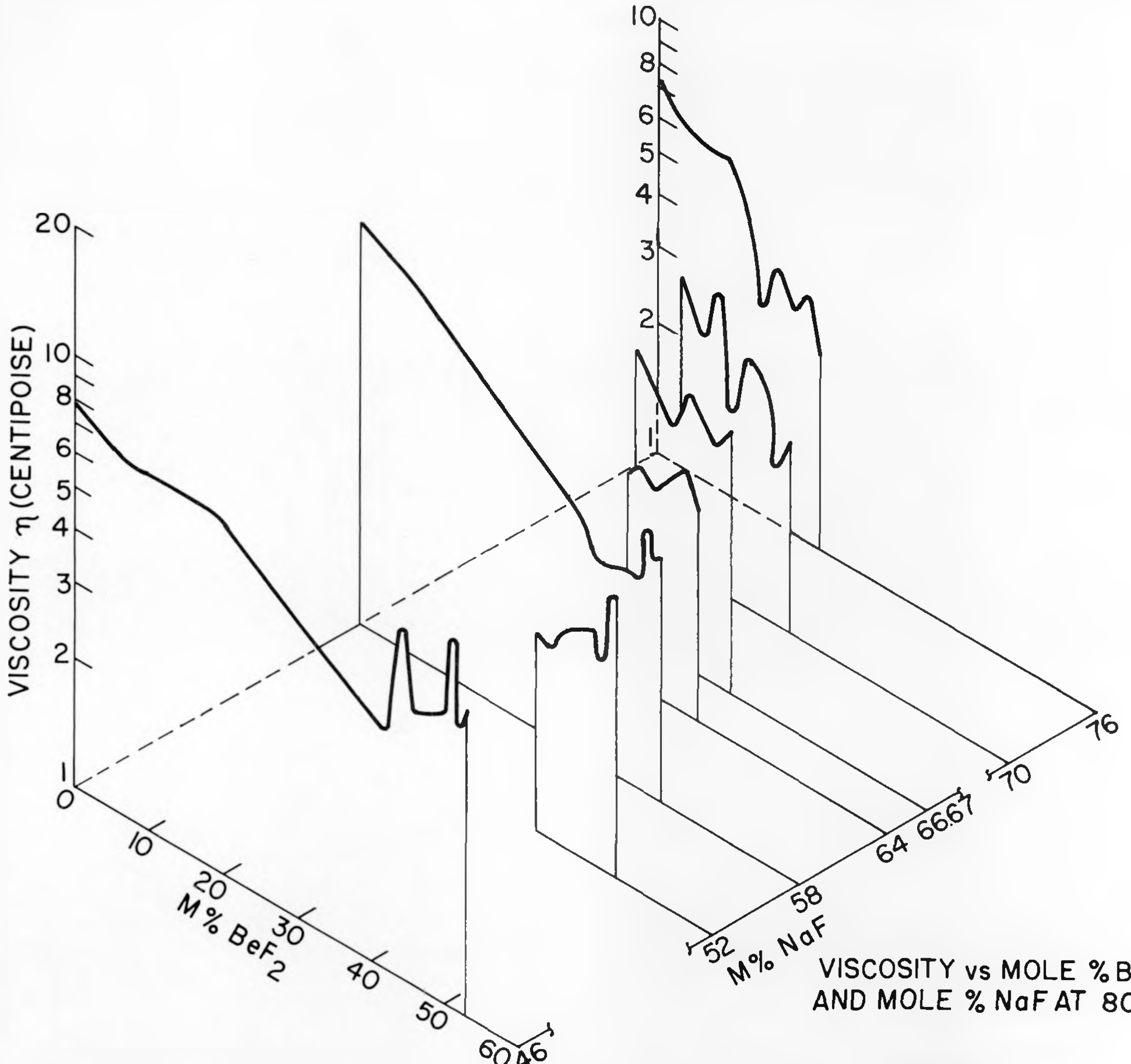
VISCOSITY vs MOLE % NaF AND MOLE % BeF_2 AT 800°C

FIGURE 13



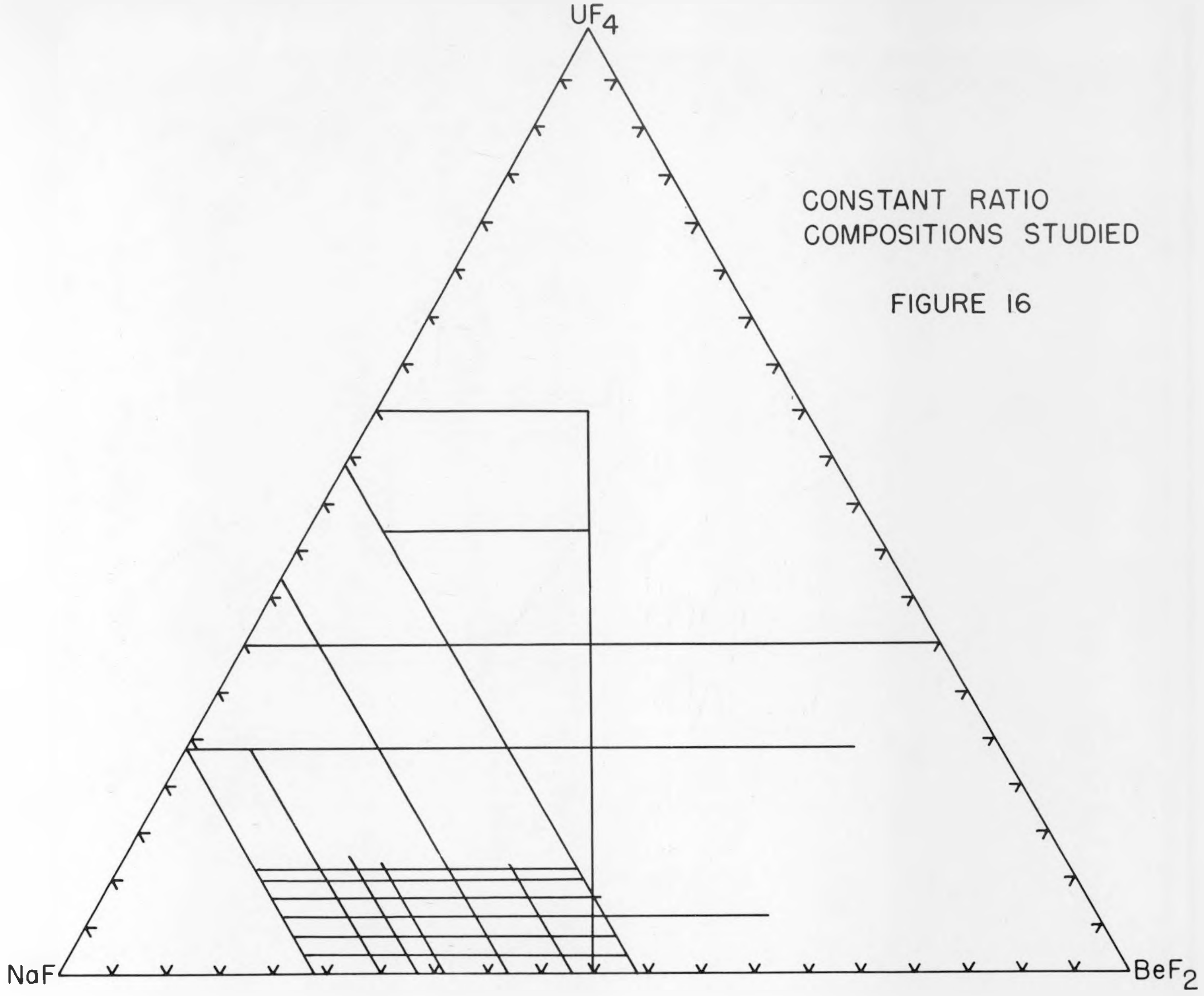
VISCOSITY vs MOLE % NaF AND MOLE % UF_4 AT 800° C

FIGURE 14



VISCOSITY vs MOLE % BeF_2 AND MOLE % NaF AT 800°C

FIGURE 15



CONSTANT RATIO COMPOSITIONS STUDIED

FIGURE 16