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DEFENCE RESEARCH ESTABLISHMENT SUFFIELD
RALSTON, ALBERTA

SUFFIELD REPORT NO. 389

CHARACTERIZATION OF K125/DIETHYL MALONATE SOLUTIONS USED AS SIMULANTS FOR THICKENED GD

by

S.J. Armour

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ABSTRACT

Thickened agents, especially thickened VX, thickened GD and thickened Lewisite, constitute an appreciable percentage of the USSR chemical arsenal. This report describes the characterization of solutions of diethyl malonate thickened with the acryloid polymer K125-EA, which are used to simulate thickened GD in dissemination trials. The properties measured are required to correlate with and predict dissemination characteristics such as drop size.

Density and surface tension were measured as a function of concentration at 25°C. Viscosity and first normal stress difference in steady shear and storage and loss moduli in dynamic mode were measured

as a function of concentration and temperature. Three equations, the power-law, the Carreau and the Allen-Uhlherr have been used to describe the viscosity-shear rate data.

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INTRODUCTION

1. The fact that thickened chemical agents constitute an appreciable percentage of the USSR chemical arsenal was supported by the display of munitions containing thickened VX, thickened GD and thickened Lewisite at Shikhany. The proposed US binary VX and GD munitions will also be thickened. Therefore, a knowledge of the characteristics of thickened agents is essential in order to develop adequate protective equipment and defensive postures. To facilitate these studies, especially large scale dissemination trials, several thickened simulants have been developed.

2. The present report describes the characterization of a simulant for thickened GD, namely diethyl malonate (DEM), which is thickened with the acryloid polymer K125-EA (1,2). Solutions of K125/DEM are used extensively for dissemination studies at the Defence Research Suffield and at U.S. laboratories (3-6), and have recently been used as the simulant in the development of the binary GD munition for the Multiple Launch Rocket System (7).

3. The physical properties of a solution are the principal characterization parameters used to describe the solution. For non-Newtonian solutions these include density, surface tension and the functional dependence of either viscosity and elasticity (first normal stress difference) on shear rate or storage and loss moduli on frequency. Since thickened agents and simulants are non-Newtonian solutions, a knowledge of these paramters is essential to describe the solution. Consequently, the present study of K125/DEM solutions was started in 1984 to provide the characterization parameters for the solutions used in DRES dissemination experiments (1). The parameters are also used as input and correlation parameters in models used to predict dissemination properties of solutions such as drop size and vapour evolution.

4. Several previous investigations of DEM solutions exist in the literature. Matta and Tytus (8) and Tytus (9) reported viscosity and first normal stress difference data for K125/DEM, high molecular weight polymethyl methacrylate (PMMA)/DEM and Elvacite 2041/DEM solutions. Matta and Harris (10) also reported die swell measurements for these solutions. Warren *et al*., (11) reported several rheological parameters for K125/DEM solutions. Armour and Gauthier-Mayer (12) provided viscosity, first normal stress difference, and storage and loss modulus data for a 40 g/L K125/DEM solution in a survey of simulant systems.

These previous studies of K125/DEM solutions, with the exception of reference 12, used either earlier or unspecified formulations of K125. The earlier formulations varied considerably in molecular weight and molecular weight distribution from the TTCP agreed upon formulation of K125-EA (lot number 3-6326). Consequently, data provided by these earlier studies, reference 12 excluded, is not relevant to K125/DEM solutions prepared with K125-EA (lot number 3-6326) and cannot be used to describe these solutions or predict their properties.

EXPERIMENTAL

Materials

5. The solvent, diethyl malonate (DEM), was obtained as USP grade (D9775-4) from the Aldrich Chemical Company. The physical properties of DEM are given in Table I.

6. The polymer, K125-EA (lot 3-6326) was supplied by Rohm and Haas. It consists of 82 mole percent methyl methacrylate, 12 mole percent ethyl acrylate and 6 mole percent butyl acrylate and has a weight average molecular weight of 2.05 x 10^6 (determined by gel permeation chromatography), a number average molecular weight of 6 x 10^5 and a polydispersity of 3.41 (13).

7. The solutions were prepared by pouring the solvent into a linear polyethylene bottle, adding the polymer, shaking vigorously to disperse the polymer and then rolling on a roller mixer for at least 24 hours at room temperature. Solution preparation took place entirely at room temperature; heat was not applied to hasten dissolution of the polymer. In all cases the resultant solutions were clear, homogenous and colourless.

Procedures

8. The densities of the K125/DEM solutions were measured at 25°C using an Anton Paar Model DMA 45 Digital Density Meter (14). The surface tension was measured at 25.0°C using the bubble rise technique (15).

9. As noted previously, to characterize a non-Newtonian solution, it is necessary to describe the functional dependence of viscosity and first normal stress difference (FNSD) on shear rate or that of storage and loss moduli on frequency. To adequantely describe this functional dependency, measurements must be made over as wide a shear rate or frequency range as practical. The temperature dependence of the viscosity and the FNSD must also be defined since experiments, especially those done in the field, can rarely be performed at the normal reference temperature of 25°C. To accomplish these objectives and also to provide a check on the data, especially the FNSD data, several different instruments are normally used.

10. A series of Brookfield SyncroLectric viscometers (LVT, RVT, HAT and HBT) (16) were used in the concentric cylinder configuration, to measure the viscosity of K125/DEM solutions as a function of temperature from 15.0 to 45.0°C.

11. Since the traditional method of characterizing solutions used in field trials is Ostwald viscosity, glass capillary viscometers of the Cannon-Fenske type (16) were used for this measurement.

12. A Rheometrics Fluids Rheometer (RFR)(17), a rotary rheometer, was used to measure viscosity and FNSD in steady shear and storage and loss moduli in dynamic mode for the K125/DEM solutions. The instrument

was used in cone and plate configuration with 5 cm diameter plates and a 2.29 degree cone. Measurements were made at 15.0 ± 0.1, 20.0 ± 0.1, 25.0 ± 0.1 and 35.0 ± 0.1°C.

13. For each solution, steady shear measurements were made in the clockwise and counterclockwise directions on at least 3 separate samples and the results averaged. Dynamic measurements were also made on these samples and the results averaged.

14. A Weissenberg R-17 Rheogoniometer (WR-17) (18) was also used to measure viscosity and FNSD in steady shear. it was used in the cone and plate configuration with 5 cm diameter plates and either 1 or 2 degree cones. Measurements were made at 25 ± 1°C.

RESULTS AND DISCUSSION

15. The densities and surface tensions of 7 solutions of K125/DEM are given in Table II. In all cases the densities were within one percent of the solvent density and the suface tensions were within 2.2 percent of the solvent surface tension. Consequently, surface tension cannot be considered as an important parameter in explaining the observed differences in physical behaviour, such as drop size on breakup, between the solvent and the polymer/solvent solutions.

16. The Ostwald viscosities, η_{C-F}, of the K125/DEM solutions as determined by glass capillary viscometers at 25.0°C are also given in Table II. For concentrations greater than 30 g/L, the viscosity increases very rapidly with concentration. Over the concentration range 10 g/L ≤ C ≤ 75 g/L, the viscosity obeys the following relationship:

$$\eta_{C-F} = -253.1 + 56.0\ C - 4.25\ C^2 + 0.153\ C^3 - 2.57 \times 10^{-3}\ C^4 + 1.89 \times 10^{-5}\ C^5 \quad [1]$$

17. Viscosity-shear rate curves were measured at 15.0°C, 20.0°C, 25.0°C, 35.0°C and 45.0°C using Brookfield SyncroLectric Viscometers. This data is listed in Tables III-IX for the 10.0 g/L, 19.8 g/L, 30.0 g/L, 39.9 g/L, 50.1 g/L, 59.6 g/L and 75.1 g/L K125/DEM solutions, respectively. A set of viscosity-shear rate curves for the 50.1 g/L solution is shown in Figure 1. These curves were of similar shape, which implied that temperature variations influenced viscosity only by altering the zero shear viscosity, η_0, and the shear rate, $\dot{\gamma}_0$, at which the viscosity began to decrease (19). Consequently the data could be reduced to a single master curve. The method of superposition employed was that described by Mendelson (20). The shear stress (τ_{12})-shear rate ($\dot{\gamma}$) curves were plotted at each temperature with the 25°C curve chosen as the reference curve. The values of the horizontal shift factors, a_T at each temperature were obtained by choosing two shear rates, $\dot{\gamma}_A$ and $\dot{\gamma}_B$, on the reference temperature curve and shifting the corresponding points (constant shear stress) to the other curves to coincide with these shear rates. The values of a_T were calculated using equation 2:

$$a_T = \dot{\gamma}(ref)/\dot{\gamma}(T) \quad (\tau_{12}) = \text{constant} \qquad [2]$$

The a_T values, obtained at the two shear rates ($\dot{\gamma}_A$ and $\dot{\gamma}_B$), were averaged to minimize errors. The resultant master curve for the 50.1 g/L K125/DEM solution is shown in Figure 2.

18. The values of the a_T factors are listed in Table X. The temperature dependence of the a_T factors could be expressed by an Arrhenius type equation of the form:

$$a_T = \beta \exp (E_a/RT) \qquad [3]$$

where T = temperature (°K) and E_a = shift factor activation energy (Kcal/mole) (see Figure 3). Values of β and E_a are listed in Table X.

19. Thus, a general technique exists for predicting viscosity flow curve data at various temperatures. Equation 2 can be considered in terms of shear rate at any temperature, T, so that

$$\dot{\gamma}(T) = \dot{\gamma}(ref)/a_T \qquad [4]$$

where the corresponding shear stress is the same at the two shear rates. Consequently, given a set of shear stress-shear rate data at the reference temperature and a knowledge of a_T as a function of temperature, sets of τ_{12}-$\dot{\gamma}$-η data may be obtained at any desired temperature. This is particularly useful for field trial work, where experiments are carried out at a variety of temperatures.

20. The viscosity and FNSD in steady shear was measured at 25.0°C for the 19.8 g/L, 30.0 g/L, 39.9 g/L, 50.1 g/L, 59.6 g/L and 75.1 g/L solutions of K125/DEM using the Rheometrics Fluids Rheometer (RFR) and the Weissenberg R17 Rheogoniometer (WR17). The RFR data is listed in Tables XI - XVI and the WR17 data in Tables XVII - XXI. Since the majority of the aerodynamic breakup trials were conducted at either 15°C or 20°C and since measurements of FNSD were required for analysis of trial data, additional measurements of viscosity and first normal stress difference were made at 15.0, 20.0 and 35.0°C for selected K125/DEM solutions using the RFR. This data is listed in Tables XI-XVI where applicable.

21. Figures 4-9 illustrate plots of viscosity and FNSD as a function of shear rate. The agreement between the data obtained with the RFR and that obtained with the WR-17 was good.

22. Several equations are widely used to describe viscosity-shear rate behaviour (19). The equations, which vary considerably in complexity, describe either a part of or the complete viscosity-shear rate curve. The most widely used equations are the power law equation and the Carreau equation. The recently introduced Allen-Uhlherr equation (21) is also gaining wide acceptance. All three of these equations were fitted to the viscosity-shear rate data obtained for the K125/DEM solutions and the goodness of fit assessed.

23. The "power law" equation, which is the simplest of the 3 equations, describes only the tilted straight line portion of the curve by a power law of the following form:

$$\eta = m\dot{\gamma}^{n-1} \qquad [5]$$

where η = viscosity (poise)

$\dot{\gamma}$ = shear rate (1/sec)

m and n = constants characteristic of the particular polymer solution

The values of the power law parameters obtained from a least squares fit of the data are listed in Table XXI.

24. This equation, together with a knowledege of the zero shear rate viscosity, η_0, and the shear rate, $\dot{\gamma}_0$, at which the viscosity begins to decrease from η_0, can be used to adequately describe most non-Newtonian viscosity curves. Inspection of Figures 4-9 indicated that, in some cases, measurements could not be made at low enough shear rates for the viscosity to reach a constant value, thus giving a definitive value of η_0. In these cases, values of η_0 were obtained by using the

extrapolation method of Vinogradov and Malkin (22) in which log $1/\eta$ vs shear stress (τ_{12}) was extrapolated to $\tau_{12} = 0$. The shear rate, $\dot{\gamma}_0$, was arbitrarily chosen as the rate at which the viscosity dropped to 90% of its value at η_0. The values obtained for η_0 and $\dot{\gamma}_0$ are listed in Table XXII.

25. The four parameter Carreau equation, which has the form

$$\frac{\eta - \eta_\infty}{\eta_0 - \eta_\infty} = [1 + (\lambda \dot{\gamma})^2]^{(n-1)/2} \qquad [6]$$

where η_0 = zero shear rate viscosity (poise)
η_∞ = infinite shear rate viscosity (poise)
λ = time constant (sec)
n = dimensionless power law index

describes the complete viscosity-shear rate curve. Since data is not normally available in the infinite shear rate viscosity region, η_∞ is usually set equal to the solvent viscosity giving a three parameter equation. The data were fitted to the 3 parameter Carreau equation using a non linear least squares regression routine. The values of the 3 parameters are listed in Table XXIII The values of η_0, obtained by fitting the Carreau equation, were slightly lower than those obtained from extrapolation (see Table XXII) while the values of n were usually slightly higher than those obtained from the power law equation.

26. The four parameter Allen-Uhlherr equation, which has the form

$$\frac{\eta - \eta_\infty}{\eta_0 - \eta_\infty} = (1 + \lambda \dot{\gamma})^{n-1} \qquad [7]$$

also describes the complete viscosity-shear rate curve. This equation is reported to provide a better fit to viscosity-shear rate data, especially in the region of onset of shear thinning behavior ($\lambda\dot{\gamma}=1$), than the Carreau equation. Allen and Uhlherr, in their original paper (21), did not use nonlinear regression to fit their equation but relied on the values of η_0, determined experimentally or by extrapolation, and n determined from the power law slope. The fluid character time, λ, was then obtained from the intersection of the zero shear and power law asymptotes. Table XXIV gives values of the paramter λ determined by intersection.

27. The Allen-Uhlherr equation was also considered as a 3 parameter equation by setting η_∞ equal to the solvent viscosity. The data was then fitted to the equation using a non linear least squares regression routine to give values of the parameters η_0, λ and n (see Table XXV). The values of η_0 obtained from fitting the equation were virtually identical to those obtained by extrapolation while the values of n were slightly lower than those obtained from the power law equation. The values of λ obtained by fitting were approximately half of those obtained from the intersection method.

28. A detailed error analysis was made for both the Carreau and Allen-Uhlherr equations (see Tables XXVI-XXVIII). The sum of the squares of the differences of the calculated and measured viscosity, the average percentage error, the maximum percentage error and the shear rate at which the maximum percentage error occurred, were determined. Both the Carreau equation and the Allen-Uhlherr equation (used as 3 parameter equations) gave good fits to the data over the

entire range of measurements. The average percentage error with the Allen-Uhlherr equation was less than one percentage while the error with the Carreau equation ranged from 0.07 to 3 percent. With the exception of the 19.8 g/L K125/DEM solutions, the Allen-Uhlherr equation provided the best fit to the data. For both equations, the maximum deviation between observed and calculated viscosities occurred at the highest shear rates. When the Allen-Uhlherr parameters were obtained by extrapolation, the average percentage error ranged from 1.7 to 5.7 percent.

29. When the zero shear viscosity, η_0, and the Ostwald viscosity, η_{C-F}, as measured by glass capillary viscometers, were compared the following relationship was observed:

$$\eta_{C-F} = 0.912\ \eta_0^{\ 0.978} \qquad [8]$$

30. A power law relationship was also observed between N_1 and the shear stress, τ_{12}

$$N_1 = \alpha \tau_{12}^{\ \beta} \qquad [9]$$

Values of the power law parameters α and β are listed in Table XXIX.

31. Measurements were also made in the dynamic mode at 20.0°C and 25.0°C using the Rheometrics Fluids Rheometer. The loss modulus, G'', and the storage modulus, G', are listed as functions of frequency, ω for the 19.8 g/L, 30.0 g/L, 39.9 g/L and 50.1 g/L, 59.6 g/L and 75.1 g/L K125/DEM solutions in Table XXX-XXXV, respectively. The dynamic viscosity, η', was calculated from equation 10:

$$\eta' = G''/\omega \qquad [10]$$

Figure 12 illustrates plots of η' as functions of ω and Figure 13 plots G' as functions of ω.

32. As in the case of the viscosity-shear rate data obtained in steady state experiments, the dynamic viscosity-frequency data can be described in terms of η_0, a characteristic frequency, ω_0, at which η' has decreased to 90% of its values at η_0 and a power law slope observed at high frequencies. The values of ω_0 and the power law parameters for the equation 11 are listed in Table XXXVI:

$$\eta' (\omega) = a\omega^{b-1} \qquad [11]$$

33. A comparison between $\eta(\dot{\gamma})$ and $\eta'(\omega)$ indicated that both reached a limiting value of η_0 as $\dot{\gamma}$ and ω approached zero and that both began to decline at comparable values of $\dot{\gamma}$ and ω. However, η' fell off more rapidly with ω, than η with $\dot{\gamma}$, as shown by the lower value of the power law slope, b. This decrease in $\eta'(\omega)$ was more pronounced for higher concentrations.

34. The Cox-Merz rule (23) was developed to obtain an improved relationship at high frequencies and shear rates. This rule predicts that the complex viscosity, η^*, should be comparable with viscosity, η, at equal values of ω and $\dot{\gamma}$.

$$\eta^*(\omega) = [(\eta'(\omega))^2+(G'(\omega)/\omega)^2]^{1/2} = \eta(\dot{\gamma}) \qquad [12]$$

Figure 13 illustrates a plot of $|\eta^*/\eta_0|$, η'/η_0 and η/η_0 as functions of reduced frequency β' and shear rate β, for the representative solution of 50.1 g/L K125/DEM.

$$\beta' = (\eta_0 - \eta_s)M\omega/cRT \qquad [13]$$

$$\beta = (\eta_0 - \eta_s)M\dot{\gamma}/cRT \qquad [14]$$

where η_0 = zero shear viscosity (poise)

η_s = solvent viscosity (poise)

M = molecular weight in g/mole of the polymer ($M = 2.06 \times 10^6$ g/mole for K125)

R = universal gas constant 8.314×10^7 erg/deg mole

c = concentration of the polymer solution in g/cm^3.

As expected $\eta^*(\omega)$ followed $\eta(\dot{\gamma})$ more closely than $\eta'(\omega)$ but still fell off more rapidly with ω than η did with $\dot{\gamma}$.

35. The data listed in Tables XXI and XXXI and presented in Figures 4-9 and 12 clearly showed that dynamic data could be used to obtain a value of η_0 and a reasonable approximation to $\dot{\gamma}_0$. The decrease of $\eta'(\omega)$ or $\eta^*(\omega)$ with ω was more pronounced than that of $\eta(\dot{\gamma})$ with $\dot{\gamma}$. This was consistent with previous polymethyl methacrylate (PMMA) solution observations (24).

36. When $N_1/\dot{\gamma}^2$ and $2G'/\omega^2$ were plotted as functions of $\dot{\gamma}$ and ω, the $2G'/\omega^2$ curve fell off more rapidly with ω than the $N_1/\dot{\gamma}^2$ curve with $\dot{\gamma}$. Figure 14 illustrates these curves for a representative solution of 50.1 g/L K125/DEM. This was again consistent with previous PMMA solution observations (24).

CONCLUSIONS

37. A detailed physical characterization has been provided for a series of solutions of the thickened GD simulant, K125/diethyl malonate. This data can be used to correlate with and predict the dissemination characteristics of this simulant.

38. The viscosity and first normal stress difference was measured as a function of shear rate in steady shear for a series of K125/DEM solutions using two different rheological instruments, a Rheometrics Fluids Rheometer and a Weissenberg R-17 Rheogoniometer.

39. The storage and loss moduli were also measured as a function of frequency in dynamic mode for the same solutions using a Rheometrics Fluids Rheometer.

40. Comparison between viscosity as a function of shear rate and complex viscosity as a function of frequency show that while both measurements go to η_0 as $\dot{\gamma}$ and ω approach zero and give similar values for $\dot{\gamma}_0$ and ω_0, the complex viscosity decreases more rapidly as a function of frequency than the viscosity as a function of shear rate. A similar comparison between $N_1/\dot{\gamma}^2$ as a function of shear rate and $2G'/\omega^2$ as a function of frequency shows that $2G'/\omega^2$ falls off more rapidly with frequency than $N_1/\dot{\gamma}^2$ with shear rate. These observations imply that for K125/DEM solutions dynamic data, which is often easier to measure, should not be substituted for steady shear data in calculations and correlations.

41. Three equations, the power law, the Carreau and the Allen-Uhlherr were used to describe the viscosity-shear rate data obtained

for the K125/DEM solutions. Both the Carreau and Allen-Uhlherr equations provided good fits to the complete viscosity-shear rate curve with the Allen-Uhlherr equation giving the better fit.

REFERENCES

1. S.J. Armour, "Aerodynamic Breakup of K125/DEM Solutions", Suffield Report (in draft).

2. International Task Force - 8, "Simulants and Training Agents", Report of Second Meeting, February 1988. UNCLASSIFIED.

3. J.E. Matta, R.P. Tytus and J.L. Harris, "Aerodynamic Atomization of Polymeric Solutions", Chem. Eng. Commun. 19: 191-204 (1983).

4. J.E. Matta and R.P. Tytus, "Viscoelastic Breakup in a High Velocity Airstream", J. Appl. Polymer Sci. 27: 397-405 (1982).

5. J.E. Matta, "Non Linear Viscoelastic Breakup in a High Velocity Airstream", ARCSL-TR-80067 (1981). UNCLASSIFIED.

6. C.F. Bauer, J.E. Matta and W.M. Sayler, "Viscoelastic Breakup Using a Small Scale Dissemination Device", CRDC-TR-84079 (1984). UNCLASSIFIED.

7. MLRS Binary Chemical Warhead Dissemination Tests at Dugway Proving Ground, LTV Missiles and Electronics Group Report Number 4-39100/7R-003 (1987). UNCLASSIFIED.

8. R.P. Tytus and J.E. Matta, "Low Shear Rate Normal Stress Predictions for Thickened Diethylmalonate", ARCSL-TR-82033, (1983). UNCLASSIFIED.

9. R.P. Tytus, "Rheological Measurements of Thickened Liquid Simulants", ARCSL-TR-81023 (1981). UNCLASSIFIED.

10. J.E. Matta and J.L. Harris, "A Technique to Estimate the Elastic Shear Compliance from Swell Measurements", J. Non Newtonian Fluid Mech., 12: 225-232 (1983).

11. B.C.H. Warren, J.A. Miles and M.G. Dalzell, "An Investigation of the Physical Properties of Thickened Simulants", Part I - Preliminary Studies (U), CDE Technical Paper No. 261, (1979). UNCLASSIFIED.

12. S.J. Armour and M.D. Gauthier-Mayer, "Survey of Possible Simulant Systems (U)", Suffield Report No. 387, (1986). UNCLASSIFIED.

13. B.V. Gerber, TTCP-E3 correspondence DRD ARCLB-P 22 February 1980. UNCLASSIFIED,

14. O. Kratky, H. Leopold and H. Stabinger, "DMA 45 Calculating Digital Density Meter-Instruction Manual", Anton Paar K.G., Graz, Austria.

15. M.D. Gauthier-Mayer, J.M.G. Ogston and S.J. Armour, "Surface Tension Measurements Using the Maximum Bubble Pressure Technique", Suffield Research Note 895 (1988). UNCLASSIFIED.

16. S.J. Armour, M.D. Gauthier-Mayer and P. Wu, "DRES Physical Chemistry Laboratory Manual, Volume I, Viscosity Measurement", in preparation. UNCLASSIFIED.

17. M.D. Gauthier-Mayer, "DRES Physical Chemistry Laboratory Procedures Manual, Volume II, Rheometrics Fluids Rheometer", Suffield Special Publication No. 105 (1987). UNCLASSIFIED.

18. S.J. Armour, "DRES Physical Chemistry Laboratory Procedures Manual, Volume III, Weissenberg R-17 Rheogoniometer", in preparation. UNCLASSIFIED.

19. R.B. Bird, R.C. Armstrong and O. Hassager, "Dynamics of Polymer Liquids", John Wiley, (1977).

20. R.A. Mendelson, "Prediction of Melt Viscosity Flow Curves at Various Temperatures for Some Olefin Polymers and Copolymers", Polymer Eng. Sci., 8: 235-240 (1968).

21. E. Allen and P.H.T. Uhlherr, "Elastic Parameters for Polymer Solutions from Simple Steady Shear", IUPAC Polymer '85 Sym. Melbourne (1985), 358-362.

22. G.V. Vinogradov and A.Y. Malkin, "Temperature Independent Viscosity Characteristics of Polymer Systems", J. Polymer Sci., A2: 2357-2372 (1964).

23. W.P. Cox and E.H. Merz, "Correlation of Dynamic and Steady Flow Viscosities", J. Polymer Sci., 38: 619-622 (1958).

24. K. Osaki, M. Tamura, T. Kotaka and M. Karata, "Normal Stress and Dynamic Moduli in Polyer Solutions", J. Phys. Chem., 69: 3642-3645 (1965).

TABLE I

PHYSICAL PROPERTIES OF DIETHYL MALONATE (DEM)

formula	$C_7H_{12}O_4$
molecular weight (g/mole)	160.17
melting point (°C)	-50.0*
boiling point (°C)	198-199*
density (g/cm³) @ 25°C	1.049
viscosity (cp) @ 25°C	1.94
surface tension (dynes/cm) @ 25°C	30.67
vapour pressure (mmHg) @ 25°C	0.376
solubility parameter (hildebrand)	9.9#

* Merck Index, 9th Edition, Merck & Co. Inc., Rahway, Rahway, New Jersey, (1976)

\# Polymer Handook ed. Brandrup and Immergut, Wiley-Interscience, New York (1975)

TABLE II

DENSITY, SURFACE TENSION AND OSTWALD VISCOSITY FOR K125/DEM SOLUTIONS**

concentration (g/L)	density (g/cm^3)	surface tension* (dynes/cm)	viscosity (η_{C-F}) (cpoise)
10.0	1.0507	31.13	11.9
19.8	1.0516	30.94	38.7
30.0	1.0532	31.29	116.5
39.9	1.0548	31.30	327.7
50.1	1.0564	31.01	906.4
59.6	1.0567		2167.3
75.1	1.0585		8192.8

* data from reference 13

** all measurements made at 25.0°C

TABLE III

SHEAR RATE, SHEAR STRESS AND VISCOSITY DATA FOR A 10.0 g/L SOLUTION OF K125/DEM AS A FUNCTION OF TEMPERATURE BROOKFIELD VISCOMETER DATA

	$\dot{\gamma}$ (sec^{-1})	τ_{12} (dynes/cm^2)	η (poise)
	27.7	4.44	0.160
T=15.0°C	39.1	5.73	0.146
	55.4	8.54	0.154
	78.3	11.2	0.143
	27.8	4.08	0.147
T=20.0°C	39.1	5.15	0.132
	55.6	7.73	0.139
	78.2	10.2	0.130
	27.7	3.62	0.131
T=25.0°C	39.1	4.72	0.121
	55.5	6.95	0.125
	78.2	9.29	9.119
	27.5	2.98	0.108
T=35.0°C	39.2	4.11	0.105
	55.1	5.94	0.108
	78.4	7.93	0.101
T=45.0°C	39.2	3.48	0.089
	78.3	6.77	0.086

TABLE IV

SHEAR RATE, SHEAR STRESS AND VISCOSITY DATA FOR A 19.8 g/L SOLUTION OF K125/DEM AS A FUNCTION OF TEMPERATURE BROOKFIELD VISCOMETER DATA

	$\dot{\gamma}$ (sec^{-1})	τ_{12} ($dynes/cm^2$)	η (poise)
T=15.0°C	7.83	3.85	0.492
	11.1	5.50	0.497
	15.7	7.66	0.489
	27.7	13.5	0.488
	39.1	18.8	0.481
	55.3	26.2	0.473
	78.3	36.4	0.465
	92.2	41.7	0.452
	130.5	57.8	0.443
T=20.0°C	11.1	5.03	0.455
	15.6	6.96	0.446
	27.6	12.3	0.443
	39.0	17.1	0.438
	55.3	23.7	0.428
	78.0	33.1	0.424
	130.0	52.1	0.401
T=25.0°C	11.1	4.59	0.415
	15.7	6.38	0.407
	27.6	11.2	0.404
	39.2	15.6	0.397
	55.3	21.7	0.392
	78.4	30.1	0.384
	130.6	47.8	0.366
T=35.0°C	11.0	3.84	0.347
	15.7	5.36	0.342
	27.6	9.38	0.340
	39.2	13.2	0.336
	55.2	18.4	0.334
	78.3	25.4	0.324
	130.6	40.4	0.310

TABLE IV (Cont'd)

	$\dot{\gamma}$ (sec^{-1})	τ_{12} (dynes/cm^2)	η (poise)
	15.7	4.56	0.292
	27.6	7.92	0.287
T=45.0°C	39.1	11.2	0.286
	55.2	15.6	0.282
	78.3	21.6	0.275

TABLE V

SHEAR RATE, SHEAR STRESS AND VISCOSITY DATA FOR A 30.0 g/L SOLUTION OF K125/DEM AS A FUNCTION OF TEMPERATURE BROOKFIELD VISCOMETER DATA

	$\dot{\gamma}$ (sec^{-1})	τ_{12} ($dynes/cm^2$)	η (poise)
	2.78	4.76	1.71
	3.93	6.15	1.56
	5.56	9.25	1.66
	7.86	12.0	1.53
	11.1	17.7	1.59
T=15.0°C	15.7	23.3	1.48
	27.8	41.9	1.51
	46.4	65.8	1.42
	65.5	85.8	1.31
	92.7	120.4	1.30
	131.1	153.9	1.17
	3.93	5.40	1.38
	5.57	8.17	1.47
	7.86	10.7	1.36
	11.1	15.8	1.42
T=20.0°C	15.7	20.9	1.33
	27.8	37.3	1.34
	46.4	59.3	1.28
	65.5	78.2	1.19
	92.8	107.6	1.16
	131.0	139.9	1.07
	3.93	4.91	1.25
	5.57	7.48	1.34
	7.85	9.68	1.23
	11.1	14.4	1.29
T=25.0°C	15.7	19.0	1.21
	27.9	33.8	1.21
	46.4	53.1	1.14
	65.5	71.1	1.09
	92.8	97.4	1.05
	130.9	128.6	0.983

TABLE V (Cont'd)

	$\dot{\gamma}$ (sec^{-1})	τ_{12} (dynes/cm^2)	η (poise)
	3.92	4.06	1.03
	5.56	6.10	1.10
	7.85	7.98	1.02
	11.1	11.7	1.05
T=35.0°C	15.7	15.7	1.00
	27.8	27.7	0.995
	39.2	37.5	0.956
	65.4	59.5	0.910
	92.7	81.3	0.877
	130.8	109.4	0.836
	5.54	4.87	0.880
	7.84	6.59	0.840
	11.1	9.61	0.867
	15.7	13.1	0.837
T=45.0°C	27.7	22.9	0.828
	39.2	31.6	0.805
	65.4	50.8	0.777
	92.4	70.2	0.760
	130.7	94.1	0.720

TABLE VI

SHEAR RATE, SHEAR STRESS AND VISCOSITY DATA FOR A 39.9 g/L SOLUTION OF K125/DEM AS A FUNCTION OF TEMPERATURE BROOKFIELD VISCOMETER DATA

	$\dot{\gamma}$ (sec^{-1})	τ_{12} (dynes/cm^2)	η (poise)
	0.789	3.73	4.73
	1.40	6.69	4.78
	1.97	9.06	4.59
	2.80	13.0	4.66
	3.95	17.6	4.46
	5.60	25.0	4.46
	7.89	33.9	4.30
T=15.0°C	13.2	52.3	3.98
	18.6	73.2	3.92
	26.3	98.0	3.73
	46.6	159.6	3.42
	65.8	207.3	3.15
	93.2	275.3	2.95
	131.5	347.7	2.64
	1.40	6.03	4.31
	1.98	8.16	4.13
	2.80	11.8	4.21
	3.95	15.7	3.97
	5.59	22.3	4.00
	7.90	30.2	3.82
T=20.0°C	13.2	46.9	3.56
	18.6	65.2	3.50
	26.3	88.1	3.35
	46.6	145.3	3.12
	65.8	188.1	2.86
	93.2	251.5	2.70
	131.7	319.0	2.42

TABLE VI (Cont'd)

	$\dot{\gamma}$ (sec^{-1})	τ_{12} (dynes/cm^2)	η (poise)
	1.39	5.11	3.66
	1.97	7.09	3.59
	2.79	10.1	3.62
	3.95	14.0	3.54
	5.58	19.5	3.50
	7.89	27.0	3.42
	11.2	37.8	3.39
T=25.0°C	13.2	41.5	3.15
	18.6	57.7	3.10
	26.3	78.8	2.99
	46.5	131.5	2.83
	65.8	169.9	2.58
	93.0	229.2	2.47
	131.6	290.6	2.21
	1.97	5.72	2.90
	2.79	7.97	2.86
	3.94	11.2	2.84
	5.58	15.8	2.83
	7.88	21.8	2.76
T=35.0°C	11.2	30.6	2.74
	18.6	47.8	2.57
	26.3	64.1	2.44
	46.5	108.8	2.34
	65.7	143.2	2.18
	93.0	193.1	2.08
	131.4	244.3	1.86

TABLE VI (Cont'd)

	$\dot{\gamma}$ (sec^{-1})	τ_{12} (dynes/cm^2)	η (poise)
	1.97	4.91	2.49
	2.78	6.61	2.37
	3.94	9.52	2.42
	5.57	13.1	2.35
	7.88	18.1	2.30
T=45.0°C	11.1	25.2	2.27
	15.8	34.8	2.21
	26.3	53.3	2.03
	46.4	91.8	1.98
	65.7	121.6	1.85
	92.8	164.5	1.77
	131.4	211.6	1.61

TABLE VII

SHEAR RATE, SHEAR STRESS AND VISCOSITY DATA FOR A 50.1 g/L SOLUTION OF K125/DEM AS A FUNCTION OF TEMPERATURE
BROOKFIELD VISCOMETER DATA

	$\dot{\gamma}$ (sec^{-1})	τ_{12} ($dynes/cm^2$)	η (poise)
	0.396	6.01	15.2
	0.563	7.88	14.0
	0.791	11.9	15.0
	1.41	19.2	13.6
	1.98	27.8	14.1
	2.81	36.9	13.1
	3.30	43.0	13.0
	4.69	56.4	12.0
T=15.0°C	6.59	80.4	12.2
	9.38	105.0	11.2
	13.2	145.0	11.0
	18.8	184.7	9.84
	26.4	245.0	9.29
	46.9	365.1	7.78
	65.9	465.2	7.06
	93.8	585.1	6.24
	0.396	4.90	12.4
	0.562	6.96	12.4
	0.792	9.58	12.1
	1.41	16.4	11.7
	1.98	22.3	11.3
	2.81	31.6	11.2
	4.68	49.0	10.5
	6.60	66.4	10.1
T=20.0°C	9.37	91.7	9.79
	13.2	121.5	9.20
	18.7	163.7	8.74
	26.4	210.3	7.96
	46.8	327.9	7.00
	66.0	406.7	6.16
	93.7	527.9	5.64
	132.0	645.1	4.89

TABLE VII (Cont'd)

	$\dot{\gamma}$ (sec^{-1})	τ_{12} (dynes/cm^2)	η (poise)
	0.396	4.51	11.4
	0.562	6.14	10.9
	0.792	8.61	10.9
	1.40	14.6	10.4
	1.98	20.1	10.1
	2.81	27.9	9.94
	6.60	57.6	8.72
T=25.0°C	9.36	79.5	8.49
	13.2	106.0	8.03
	18.7	143.9	7.69
	26.4	186.5	7.06
	46.8	293.8	6.28
	66.0	367.3	5.56
	93.6	476.5	5.09
	132.0	582.5	4.41
	0.561	4.68	8.34
	0.793	7.14	9.00
	1.40	10.9	7.81
	1.98	16.3	8.24
	2.80	21.2	7.57
	3.97	30.5	7.70
	5.61	40.4	7.21
	6.61	46.6	7.05
T=35.0°C	9.35	62.5	6.69
	13.2	87.2	6.60
	18.7	115.2	6.16
	26.4	155.7	5.89
	46.7	240.5	5.15
	66.1	313.4	4.74
	93.4	398.4	4.26
	132.2	502.0	3.80

TABLE VII (Cont'd)

	$\dot{\gamma}$ (sec^{-1})	τ_{12} (dynes/cm^2)	η (poise)
	0.791	5.56	7.03
	1.40	8.98	6.40
	1.98	12.8	6.46
	2.81	17.1	6.11
	3.96	24.5	6.19
	5.61	32.7	5.82
	9.36	49.6	5.30
T=45.0°C	13.2	69.9	5.30
	18.7	94.1	5.03
	26.4	129.0	4.89
	46.8	199.6	4.27
	65.9	266.0	4.04
	93.6	337.4	3.61
	131.8	433.8	3.29

TABLE VIII

SHEAR RATE, SHEAR STRESS AND VISCOSITY DATA FOR A 59.6 g/L SOLUTION OF K125/DEM AS A FUNCTION OF TEMPERATURE
BROOKFIELD VISCOMETER DATA

	$\dot{\gamma}$ (sec^{-1})	τ_{12} ($dynes/cm^2$)	η (poise)
T=15.0°C	0.281	8.42	29.9
	0.396	11.6	29.4
	0.563	16.6	29.5
	0.791	22.6	28.5
	1.41	39.7	28.2
	2.34	61.6	26.3
	3.30	82.4	25.0
	4.69	114.0	24.3
	6.59	151.6	23.0
	9.38	201.1	21.4
	13.2	253.2	19.2
	18.8	335.2	17.9
	26.4	411.0	15.6
	46.9	598.4	12.8
	0.282	7.20	25.5
	0.565	14.4	25.5
	1.41	34.6	24.5
T=20.0°C	2.35	52.4	22.3
	3.33	72.5	21.8
	4.70	99.0	21.1
	6.66	134.6	20.2
	9.41	176.2	18.7
	13.3	231.5	17.4
	18.8	297.4	15.8
	26.6	378.3	14.2
	47.0	551.6	11.7
	94.1	842.2	8.95

TABLE VIII (Cont'd)

SHEAR RATE, SHEAR STRESS AND VISCOSITY DATA FOR A 59.6 g/L SOLUTION OF K125/DEM AS A FUNCTION OF TEMPERATURE
BROOKFIELD VISCOMETER DATA

	$\dot{\gamma}$ (sec^{-1})	τ_{12} (dynes/cm^2)	η (poise)
	0.282	6.19	21.9
	0.398	8.80	22.1
	0.564	12.3	21.8
	0.796	17.4	21.8
	1.41	29.9	21.2
T=25.0°C	2.35	45.6	19.4
	3.31	64.1	19.3
	4.70	86.7	18.4
	6.63	116.7	17.6
	9.40	157.8	16.8
	13.3	203.9	15.4
	18.8	269.9	14.4
	26.5	336.7	12.7
	47.0	504.5	10.7
	66.3	616.0	9.29
	94.0	782.0	8.32
	132.6	936.2	7.06
	0.281	4.79	17.1
	0.395	7.12	18.0
	0.562	9.44	16.8
	0.791	14.0	17.7
	1.40	23.0	16.4
T=35.0°C	1.98	33.4	16.9
	3.30	49.9	15.2
	4.68	66.9	14.3
	6.59	95.0	14.4
	9.36	124.8	13.3
	13.9	169.6	12.9
	18.7	220.8	11.8
	26.4	288.0	10.9
	46.8	422.5	9.03
	65.9	550.2	8.34
	93.6	659.4	7.05

TABLE VIII (Cont'd)

Shear Rate, Shear Stress and Viscosity Data for a 59.6 g/L Solution of K125/DEM as a Function of Temperature Brookfield Viscometer Data

	$\dot{\gamma}$ (sec^{-1})	τ_{12} (dynes/cm^2)	η (poise)
	0.396	5.47	13.8
	0.563	7.26	12.9
	0.792	10.7	13.5
	1.41	17.7	12.6
	1.98	26.0	13.1
T=45.0°C	2.81	34.3	12.2
	4.69	53.1	11.3
	6.60	75.0	11.4
	9.37	101.3	10.8
	13.2	138.2	10.5
	18.7	180.7	9.64
	26.4	239.1	9.06
	46.9	359.9	7.68
	66.0	454.0	6.88
	93.7	569.4	6.08
	132.0	702.3	5.32

TABLE IX

SHEAR RATE, SHEAR STRESS AND VISCOSITY FOR A 75.1 g/L SOLUTION OF K125/DEM AS A FUNCTION OF TEMPERATURE BROOKFIELD VISCOMETER DATA

	$\dot{\gamma}$ (sec^{-1})	τ_{12} ($dynes/cm^2$)	η (poise)
T=15.0°C	0.285	31.9	111.9
	0.474	50.4	106.2
	0.666	70.1	105.3
	0.949	94.7	99.7
	1.33	129.4	97.2
	2.37	203.6	85.8
	3.33	264.3	79.4
	4.75	340.7	71.8
	6.66	421.0	63.2
	9.49	530.9	55.9
	19.0	813.7	42.9
T=20.0°C	0.285	27.8	97.6
	0.670	59.2	88.4
	0.949	82.1	86.5
	1.34	110.9	82.7
	2.37	178.3	75.3
	3.35	230.7	68.9
	4.75	302.9	63.8
	6.70	377.6	56.4
	9.49	486.8	51.3
	13.4	594.2	44.3
	19.0	752.7	39.6
	26.8	896.3	33.5
T=25.0°C	0.284	23.8	83.7
	0.400	32.4	80.8
	0.947	71.2	75.2
	1.33	94.6	71.2
	2.37	156.5	66.0
	3.34	201.4	60.3
	4.73	270.0	57.1
	6.67	337.2	50.5
	9.47	438.1	46.3
	13.4	535.1	40.1
	18.9	682.1	36.0
	26.7	820.3	30.7

TABLE IX (Cont'd)

SHEAR RATE, SHEAR STRESS AND VISCOSITY FOR A 75.1 g/L SOLUTION OF K125/DEM AS A FUNCTION OF TEMPERATURE BROOKFIELD VISCOMETER DATA

	$\dot{\gamma}$ (sec^{-1})	τ_{12} ($dynes/cm^2$)	η (poise)
T=35.0°C	0.281	18.0	63.8
	0.397	22.3	56.1
	0.563	34.7	61.7
	0.938	51.1	54.5
	1.32	71.9	54.3
	2.35	119.4	50.8
	3.31	157.0	47.4
	4.69	207.1	44.2
	6.62	269.7	40.7
	9.38	347.2	37.0
	13.2	441.2	33.3
	26.5	686.7	25.9
T=45.0°C	0.285	14.0	49.1
	0.397	17.0	42.7
	0.570	26.9	47.3
	1.32	57.7	43.6
	2.37	91.7	38.7
	3.31	126.0	38.1
	4.75	165.8	34.9
	6.62	220.6	33.3
	9.50	285.6	30.1
	13.2	366.2	27.7
	19.0	461.2	24.3
	26.5	578.2	21.8
	47.5	827.6	17.4
	95.0	1215.1	12.8

TABLE X

SHIFT FACTORS FOR K125/DEM SOLUTIONS

CONCENTRATION (g/L)	a_T temperature (°C)					β	E_a (Kcal/mole)
	15	20	25	35	45		
10.0	1.444	1.197	1.000	0.886	0.800	3.29×10^{-3}	3.46
19.8	1.209	1.100	1.000	0.848	0.712	4.53×10^{-3}	3.22
30.0	1.256	1.110	1.000	0.816	0.681	1.93×10^{-3}	3.73
39.9	1.265	1.137	1.000	0.802	0.667	1.30×10^{-3}	3.97
50.1	1.407	1.155	1.000	0.790	0.631	3.37×10^{-3}	4.78
59.6	1.407	1.233	1.000	0.800	0.621	2.08×10^{-4}	5.05
75.1	1.403	1.177	1.000	0.792	0.546	8.84×10^{-5}	5.54

TABLE XI

SHEAR RATE AND VISCOSITY DATA FOR A 19.8 g/L SOLUTION OF K125/DEM RHEOMETRICS FLUIDS RHEOMETER DATA

T = 20.0°C

shear rate (sec^{-1})	viscosity (poise)	standard deviation
50.1	0.444	0.028
63.1	0.440	0.023
79.4	0.435	0.017
100.0	0.429	0.013
125.9	0.422	0.008
158.5	0.413	0.006
199.6	0.402	0.004
250.7	0.390	0.003
316.3	0.378	0.003

T = 25.0°C

shear rate (sec^{-1})	viscosity (poise)	standard deviation
50.0	0.395	0.019
63.0	0.392	0.017
79.3	0.388	0.014
99.8	0.385	0.012
125.6	0.378	0.007
158.1	0.371	0.007
199.1	0.363	0.006
250.6	0.353	0.006
315.5	0.343	0.006

TABLE XII

SHEAR RATE, VISCOSITY AND FIRST NORMAL STRESS DIFFERENCE DATA FOR A 30.0 g/L SOLUTION OF K125/DEM RHEOMETRICS FLUID RHEOMETER DATA

T = 20.0°C

shear rate (sec^{-1})	viscosity (poise)	standard deviation	first normal stress difference ($dynes/cm^2$)	standard deviation
10.0	1.46	0.14		
12.6	1.45	0.12		
15.8	1.44	0.10		
19.9	1.42	0.08		
25.1	1.40	0.07		
31.6	1.37	0.05		
39.7	1.35	0.04		
50.0	1.32	0.03		
63.0	1.28	0.03		
79.3	1.24	0.02		
99.8	1.20	0.02		
125.6	1.15	0.02	121	18.0
158.2	1.10	0.01	163	17.5
199.1	1.05	0.01	213	16.2
250.7	0.992	0.01	258	14.0
315.6	0.941	0.01	299	21.9

TABLE XII cont'd

T = 25.0°C

shear rate (sec^{-1})	viscosity (poise)	standard deviation	first normal stress difference ($dynes/cm^2$)	standard deviation
10.0	1.24	0.11		
12.6	1.23	0.09		
15.9	1.23	0.07		
20.0	1.23	0.07		
25.1	1.22	0.05		
31.6	1.20	0.04		
39.8	1.19	0.03		
50.1	1.17	0.02		
63.1	1.14	0.02		
79.4	1.11	0.02		
100.0	1.07	0.01		
125.9	1.04	0.01	107	7.4
158.5	0.992	0.01	143	7.8
199.6	0.943	0.01	188	8.9
251.2	0.891	0.02	231	11.9

TABLE XIII

SHEAR RATE, VISCOSITY AND FIRST NORMAL STRESS DIFFERENCE DATA FOR A 39.9 g/L SOLUTION OF K125/DEM RHEOMETRICS FLUID RHEOMETER DATA

T = 15.0°C

shear rate (sec^{-1})	viscosity (poise)	standard deviation	first normal stress difference ($dynes/cm^2$)	standard deviation
2.50	4.75	0.30		
3.15	4.73	0.24		
3.96	4.69	0.20		
4.99	4.65	0.19		
6.28	4.60	0.16		
7.91	4.54	0.11		
9.95	4.46	0.08		
12.5	4.37	0.05		
15.8	4.26	0.04		
19.9	4.14	0.04		
25.0	4.01	0.04		
31.5	3.87	0.02	130	6.4
39.6	3.70	0.02	179	6.3
49.9	3.52	0.02	242	7.3
62.8	3.34	0.02	327	9.1
79.1	3.16	0.01	439	11.2
99.6	2.97	0.01	594	23.7
125.3	2.77	0.04	806	63.5
157.8	2.59	0.02	1051	61.9
198.6	2.41	0.02	1339	52.0
250.1	2.24	0.02	1701	42.9

TABLE XIII cont'd

T = 20.0°C

shear rate (sec^{-1})	viscosity (poise)	standard deviation	first normal stress difference ($dynes/cm^2$)	standard deviation
5.00	4.13	0.26		
6.30	4.08	0.22		
7.93	4.04	0.18		
10.0	3.97	0.14		
12.6	3.89	0.10		
15.8	3.81	0.08		
19.9	3.70	0.07		
25.1	3.58	0.05		
31.6	3.45	0.04		
39.7	3.32	0.04	125	17.5
50.0	3.17	0.03	176	18.2
63.0	3.01	0.02	242	19.5
79.3	2.85	0.02	328	22.1
99.8	2.69	0.02	441	27.0
125.6	2.52	0.02	587	39.8
158.2	2.35	0.02	782	72.4
199.1	2.19	0.02	1024	74.0
250.7	2.03	0.01	1310	82.0
315.6	1.88	0.01	1680	93.0

TABLE XIII cont'd

T = 25.0°C

shear rate (sec^{-1})	viscosity (poise)	standard deviation	first normal stress difference ($dynes/cm^2$)	standard deviation
2.50	3.85	0.68		
3.15	3.80	0.57		
3.96	3.70	0.46		
5.00	3.67	0.38		
6.28	3.67	0.33		
7.91	3.61	0.29		
9.95	3.57	0.24		
12.5	3.50	0.18		
15.8	3.44	0.14		
19.7	3.36	0.12		
25.0	3.27	0.10		
31.5	3.17	0.08		
39.6	3.06	0.07		
49.9	2.93	0.06	137	12.4
62.8	2.79	0.05	191	10.2
79.1	2.66	0.04	267	8.6
99.6	2.51	0.04	365	9.3
125.3	2.36	0.04	491	16.0
157.8	2.21	0.03	643	24.0
198.6	2.06	0.03	844	32.1
250.1	1.91	0.03	1087	46.5

TABLE XIII cont'd

T = 35.0°C

shear rate (sec^{-1})	viscosity (poise)	standard deviation	first normal stress difference ($dynes/cm^2$)	standard deviation
3.96	3.07	0.40		
4.99	3.09	0.33		
6.28	3.08	0.28		
7.91	3.06	0.25		
9.95	3.03	0.22		
12.5	2.99	0.18		
15.8	2.93	0.15		
19.9	2.88	0.12		
25.0	2.81	0.11		
31.5	2.73	0.10		
39.6	2.64	0.09		
49.9	2.54	0.08	105	10.5
62.8	2.43	0.08	147	13.4
79.1	2.32	0.07	202	16.4
99.6	2.20	0.06	272	20.3
125.3	2.08	0.05	355	35.8
157.8	1.95	0.05	481	30.0
198.6	1.83	0.04	626	39.5
250.1	1.70	0.04	806	52.6

TABLE XIV

SHEAR RATE, VISCOSITY AND FIRST NORMAL STRESS DIFFERENCE
DATA FOR A 50.1 g/L SOLUTION OF K125/DEM
RHEOMETRICS FLUID RHEOMETER DATA

T = 15.0°C

shear rate (sec^{-1})	viscosity (poise)	standard deviation	first normal stress difference ($dynes/cm^2$)	standard deviation
2.50	13.1	0.49		
3.15	12.9	0.42		
3.96	12.6	0.29		
4.99	12.3	0.27		
6.28	12.0	0.29		
7.91	11.6	0.26		
9.95	11.2	0.22		
12.5	10.7	0.17	135	7.8
15.8	10.2	0.12	188	8.5
19.9	9.67	0.11	254	8.2
25.0	9.15	0.14	366	55.3
31.5	8.58	0.12	453	15.3
39.6	8.02	0.12	596	22.6
49.9	7.47	0.11	786	37.5
62.8	6.93	0.11	1047	71.2
79.1	6.41	0.10	1416	103
99.6	5.89	0.07	1807	50.6
125.3	5.40	0.06	2301	41.7
157.8	4.93	0.07	2879	77.0
198.6	4.49	0.06	3669	91.5
250.1	4.08	0.05	4664	111

TABLE XIV cont'd

T = 20.0°C

shear rate (sec^{-1})	viscosity (poise)	standard deviation	first normal stress difference ($dynes/cm^2$)	standard deviation
5.00	10.8	0.20		
6.30	10.5	0.17		
7.93	10.2	0.13		
9.98	9.89	0.09		
12.6	9.51	0.08	103	18.2
15.8	9.10	0.06	145	19.0
19.9	8.67	0.05	200	17.9
25.1	8.21	0.04	272	16.6
31.6	7.73	0.04	364	15.8
39.7	7.27	0.03	483	13.6
50.0	6.78	0.03	636	10.8
63.0	6.29	0.03	831	10.5
79.3	5.82	0.03	1088	37.5
99.8	5.36	0.03	1462	76.7
125.6	4.93	0.02	1870	64.1
158.2	4.51	0.02	2364	74.1
199.1	4.12	0.01	2994	66.2
250.7	3.75	0.01	3815	93.0
315.6	3.40	0.01	4789	117.9

TABLE XIV cont'd

T = 25.0°C

shear rate (sec^{-1})	viscosity (poise)	standard deviation	first normal stress difference ($dynes/cm^2$)	standard deviation
2.50	10.4	0.49		
3.15	10.3	0.42		
3.96	10.1	0.38		
5.00	9.91	0.25		
6.28	9.69	0.23		
7.91	9.44	0.20		
9.95	9.13	0.17		
12.5	8.82	0.14		
15.8	8.47	0.13	116	10.8
19.9	8.09	0.12	163	11.9
25.0	7.69	0.09	223	13.3
31.5	7.29	0.08	304	15.0
39.6	6.85	0.07	406	15.7
49.9	6.41	0.07	538	18.4
62.8	5.97	0.06	709	22.6
79.1	5.54	0.06	928	35.2
99.6	5.11	0.05	1217	51.5
125.3	4.69	0.05	1571	89.7
157.8	4.30	0.04	1979	102
198.6	3.92	0.03	2486	98.4
250.1	3.57	0.03	3135	104

TABLE XIV cont'd

T = 35.0°C

shear rate (sec^{-1})	viscosity (poise)	standard deviation	first normal stress difference ($dynes/cm^2$)	standard deviation
2.50	8.68	0.63		
3.15	8.56	0.57		
3.96	8.45	0.49		
4.99	8.30	0.42		
6.28	8.16	0.34		
7.91	7.97	0.32		
9.95	7.76	0.30		
12.5	7.51	0.27		
15.8	7.24	0.24		
19.9	6.95	0.22	113	13.0
25.0	6.63	0.20	156	10.4
31.5	6.31	0.18	203	30.7
39.6	5.97	0.17	277	28.0
49.9	5.61	0.15	374	24.1
62.8	5.25	0.14	495	20.0
79.1	4.89	0.13	654	18.7
99.6	4.53	0.11	850	22.1
125.8	4.18	0.09	1099	33.1
157.8	3.84	0.08	1407	47.4
198.6	3.52	0.06	1795	52.1
250.1	3.21	0.05	2240	29.6

TABLE XV

SHEAR RATE, VISCOSITY AND FIRST NORMAL STRESS DIFFERENCE
DATA FOR A 59.6 G/L SOLUTION OF K125/DEM
RHEOMETRICS FLUID RHEOMETER DATA

T = 20.0°C

shear rate (sec^{-1})	viscosity (poise)	standard deviation	first normal stress difference ($dynes/cm^2$)	standard deviation
0.500	28.4	1.51		
0.630	28.3	1.27		
0.793	27.9	1.11		
1.00	27.5	1.09		
1.26	27.0	1.07		
1.58	26.6	1.01		
1.99	26.0	0.93		
2.51	25.3	0.88		
3.16	24.6	0.78		
3.97	23.9	0.69		
5.00	23.0	0.62		
6.30	22.0	0.57	106	11.7
7.93	21.0	0.55	147	23.5
9.98	19.9	0.50	204	32.8
12.6	18.7	0.43	277	39.0
15.8	17.6	0.40	374	43.2
19.9	16.5	0.35	498	51.2
25.1	15.3	0.31	646	59.6
31.6	14.1	0.27	847	68.1
39.7	13.0	0.24	1099	84.1
50.0	11.9	0.21	1422	101
63.0	10.9	0.19	1856	130
79.3	9.88	0.17	2371	171
99.8	8.94	0.14	2950	151
125.6	8.05	0.12	3599	125
158.2	7.25	0.11	4529	217
199.1	6.52	0.10	5685	219

TABLE XV cont'd

T = 25.0°C

shear rate (sec^{-1})	viscosity (poise)	standard deviation	first normal stress difference ($dynes/cm^2$)	standard deviation
1.00	23.9	1.26		
1.26	23.7	1.23		
1.59	23.4	1.03		
2.00	23.1	0.76		
2.51	22.6	0.64		
3.16	22.0	0.64		
3.98	21.4	0.52		
5.01	20.7	0.44		
6.31	19.8	0.38		
7.94	19.0	0.36		
10.00	18.1	0.30	146	34.3
12.6	17.1	0.26	208	35.8
15.9	16.1	0.23	287	39.3
20.0	15.0	0.21	389	41.4
25.1	14.0	0.18	517	43.3
31.6	13.0	0.17	684	45.6
39.8	12.0	0.15	891	48.5
50.1	11.0	0.13	1152	58.3
63.1	10.1	0.12	1486	82.7
79.5	9.15	0.10	1934	120
100.0	8.31	0.08	2471	146
125.9	7.51	0.07	3021	81.8
158.9	6.76	0.06	3719	101
199.6	6.09	0.05	4667	93.6

TABLE XVI

SHEAR RATE, VISCOSITY AND FIRST NORMAL STRESS DIFFERENCE DATA FOR A 75.1 G/L SOLUTION OF K125/DEM RHEOMETRICS FLUID RHEOMETER DATA

T = 20.0°C

shear rate (sec^{-1})	viscosity (poise)	standard deviation	first normal stress difference ($dynes/cm^2$)	standard deviation
0.500	101.7	2.61		
0.630	100.7	3.28		
0.793	98.0	3.06		
1.00	95.4	2.16		
1.26	91.9	2.08		
1.58	88.1	1.76		
1.99	84.1	1.68	116	63.7
2.51	79.9	1.60	163	71.7
3.16	75.3	1.43	223	81.7
3.97	70.8	1.16	304	84.5
5.00	66.2	1.02	402	87.0
6.30	61.5	0.92	533	96.1
7.93	56.8	0.76	693	109
9.98	52.3	0.69	901	116
12.6	47.8	0.61	1153	128
15.8	43.5	0.53	1461	140
19.9	39.5	0.55	1845	168
25.0	35.6	0.47	2336	198
31.6	32.1	0.37	2984	241
39.7	28.8	0.34	3714	375
50.0	25.7	0.26	4529	378
63.0	22.8	0.16	5408	246
79.3	20.3	0.12	6539	235
99.8	18.0	0.09	8109	241

TABLE XVI cont'd

T = 25.0°C

shear rate (sec^{-1})	viscosity (poise)	standard deviation	first normal stress difference ($dynes/cm^2$)	standard deviation
1.00	84.8	2.44		
1.26	82.4	2.16		
1.59	79.5	1.97		
2.00	76.3	1.75	105	4.31
2.52	72.8	1.49	141	8.66
3.16	69.0	1.46	194	8.75
3.98	65.0	1.33	262	14.2
5.01	61.1	1.17	355	16.6
6.31	56.9	1.06	466	19.3
7.94	52.8	0.92	604	26.4
10.0	48.8	0.81	779	22.2
12.6	44.8	0.69	1002	28.2
15.9	40.9	0.57	1272	29.7
20.0	37.1	0.41	1600	28.6
25.1	33.6	0.33	2004	31.3
31.6	30.3	0.29	2480	44.5
39.8	27.1	0.24	3027	80.0
50.1	24.2	0.22	3723	75.8
63.1	21.6	0.23	4495	58.6
79.5	19.2	0.20	5501	87.5
100.0	17.0	0.18	6755	107

TABLE XVII

SHEAR RATE, VISCOSITY AND FIRST NORMAL STRESS DIFFERENCE DATA FOR A 30.0 g/L SOLUTION OF K125/DEM WEISSENBERG RHEOGONIOMETER DATA

T = 25.0°C

shear rate (1/sec)	viscosity (poise)	standard deviation	first normal stress difference ($dynes/cm^2$)	standard deviation
434.0	0.720	0.02	540	23
344.7	0.760	0.03	438	28
273.8	0.802	0.02	354	17
217.5	0.836	0.03	271	22
172.8	0.879	0.03	204	24
137.2	0.917	0.03	160	25
109.0	0.952	0.02	119	16
86.6	0.994	0.03	87.1	5.7
68.8	1.01	0.03		
54.6	1.04	0.03		
43.4	1.06	0.04		
34.5	1.09	0.04		
27.4	1.10	0.04		
21.8	1.11	0.04		
17.3	1.11	0.05		
13.7	1.13	0.05		
10.9	1.15	0.04		
8.66	1.15	0.07		
6.88	1.17	0.01		

TABLE XVIII

SHEAR RATE, VISCOSITY AND FIRST NORMAL STRESS DIFFERENCE DATA
FOR A 39.9 g/L SOLUTION OF K125/DEM
WEISSENBERG RHEOGONIOMETER DATA

T = 25.0°C

shear rate (1/sec)	viscosity (poise)	standard deviation	first normal stress difference (dynes/cm²)	standard deviation
273.8	1.67	0.01	1291	67
217.5	1.79	0.01	955	63
172.8	1.93	0.01	725	31
137.2	2.06	0.01	549	39
109.0	2.20	0.02	422	40
86.6	2.34	0.02	311	48
68.8	2.46	0.04	233	39
54.6	2.58	0.01	167	37
43.4	2.68	0.03	124	22
34.5	2.80	0.00	92.6	26
27.4	2.92	0.02		
21.8	2.97	0.03		
17.3	3.10	0.00		
13.7	3.15	0.03		
10.9	3.20	0.01		
8.66	3.26	0.03		
6.88	3.31	0.00		
5.46	3.20	0.04		
4.34	3.38	0.02		
3.45	3.39	0.08		
2.74	3.39	0.03		

TABLE XIX

SHEAR RATE, VISCOSITY AND FIRST NORMAL STRESS DIFFERENCE DATA
FOR A 50.1 g/L SOLUTION OF K125/DEM
WEISSENBERG RHEOGONIOMETER DATA

T = 25.0°C

shear rate (1/sec)	viscosity (poise)	standard deviation	first normal stress difference (dynes/cm²)	standard deviation
217.5	3.43	0.06	2864	
172.8	3.80	0.10	2217	39
137.2	4.14	0.13	1708	45
109.0	4.51	0.14	1329	35
86.6	4.86	0.13	997	31
68.8	5.24	0.14	771	15
54.6	5.65	0.18	605	7.3
43.4	6.05	0.16	462	16
34.5	6.42	0.20	352	4.7
27.4	6.80	0.21	269	6.1
21.8	7.14	0.27	200	10
17.3	7.53	0.26	148	6.9
13.7	7.87	0.28	113	5.4
10.9	8.22	0.35		
8.66	8.60	0.25		
6.88	8.55	0.01		
5.46	8.72	0.14		
4.34	8.88	0.09		
3.45	9.05	0.17		
2.74	9.26	0.04		

TABLE XX

SHEAR RATE, VISCOSITY AND FIRST NORMAL STRESS DIFFERENCE
DATA FOR A 59.6 g/L SOLUTION OF K125/DEM
WEISSENBERG RHEOGONIOMETER DATA

T = 25.0°C

shear rate (1/sec)	viscosity (poise)	standard deviation	first normal stress difference (dynes/cm²)	standard deviation
217.5	5.75	0.05	5300	75
172.8	6.38	0.11	4250	60
137.2	7.04	0.10	3420	58
109.0	7.75	0.13	2627	53
86.6	8.38	0.17	2019	48
68.8	8.70	0.21	1551	45
54.6	9.33	0.18	1190	41
43.4	10.8	0.13	914	38
34.5	11.8	0.17	703	30
27.4	12.7	0.14	540	25
21.8	13.8	0.20	415	15
17.3	14.5	0.14	319	8.9
13.7	15.7	0.13	244	10
10.9	16.4	0.16	188	7.8
8.66	17.0	0.20	144	5.4
6.88	17.8	0.10	111	6.0
5.46	18.1	0.13		
4.34	19.0	0.09		
3.45	19.2	0.08		
2.74	20.0	0.13		
2.18	20.3	0.07		
1.73	20.5	0.05		

TABLE XXI

SHEAR RATE, VISCOSITY AND FIRST NORMAL STRESS DIFFERENCE
DATA FOR A 75.1 g/L SOLUTION OF K125/DEM
WEISSENBERG RHEOGONIOMETER DATA

T = 25.0°C

shear rate (1/sec)	viscosity (poise)	standard deviation	first normal stress difference (dynes/cm²)	standard deviation
217.5	11.4	0.13	15534	105
172.8	13.2	0.18	12201	89
137.2	14.7	0.20	9623	85
109.0	16.8	0.09	7769	73
86.6	18.2	0.16	6115	70
68.8	20.1	0.13	4985	68
54.6	22.2	0.17	4185	60
43.4	25.1	0.07	3284	58
34.5	27.4	0.08	2715	43
27.4	30.3	0.13	2220	45
21.8	33.2	0.17	1780	34
17.3	36.7	0.20	1450	29
13.7	40.5	0.09	1120	23
10.9	44.0	0.16	870	20
8.66	47.5	0.18	679	12
6.88	52.5	0.11	525	18
5.46	55.1	0.21	401	25
4.34	58.5	0.24	304	15
3.45	62.1	0.22	225	9.6
2.74	65.0	0.18	180	11
2.18	67.8	0.25	137	6.8
1.73	71.5	0.23	108	5.3

TABLE XXII

PARAMETERS FOR THE POWER LAW EQUATION FOR K125/DEM SOLUTIONS*

concentration (g/L)	temperature (°C)	$\eta=m\dot{\gamma}^{n-1}$ m	n	η_0 (poise)	$\dot{\gamma}_0(.90)$ (1/sec)
19.8	20.0	0.735	0.912	0.461	150
19.8	25.0	0.685	0.880	0.408	175
30.0	20.0	3.27	0.785	1.50	43.0
30.0	25.0	2.97	0.783	1.25	70.0
39.9	15.0	11.8	0.699	4.87	13.0
39.9	20.0	11.3	0.689	4.31	14.0
39.9	25.0	10.3	0.695	3.89	15.0
39.9	35.0	8.86	0.701	3.16	25.0
50.1	15.0	35.8	0.607	14.1	3.70
50.1	20.0	32.0	0.612	12.0	5.00
50.1	25.0	29.6	0.618	11.0	5.60
50.1	35.0	25.4	0.625	9.09	7.00
59.6	20.0	65.1	0.568	29.5	1.50
59.6	25.0	59.3	0.572	24.7	2.50
75.1	20.0	171.2	0.513	110.1	0.750
75.1	25.0	150.1	0.532	97.0	0.880

* from RFR data

TABLE XXIII

PARAMETERS FOR THE CARREAU VISCOSITY EQUATION*

concentration (g/L)	temperature (°C)	η_0 (poise)	$\tau \times 10^{-2}$ (sec)	n
19.8	20.0	0.450	0.880	0.840
19.8	25.0	0.399	0.811	0.850
30.0	20.0	1.46	2.52	0.796
30.0	25.0	1.24	1.58	0.770
39.9	15.0	4.70	5.99	0.738
39.9	20.0	4.10	4.91	0.727
39.9	25.0	3.73	5.40	0.758
39.9	35.0	3.08	3.92	0.750
50.1	15.0	13.0	11.5	0.672
50.1	20.0	10.9	8.07	0.655
50.1	25.0	10.3	9.42	0.684
50.1	35.0	8.55	8.40	0.696
59.6	20.0	27.6	25.9	0.664
59.6	25.0	23.6	18.7	0.651
75.1	20.0	101.5	57.2	0.602
75.1	25.0	85.8	40.4	0.588

* from RFR data

TABLE XXIV

PARAMETERS FOR THE ALLEN-UHLHERR VISCOSITY EQUATION OBTAINED FROM EXTRAPOLATION*

concentration (g/L)	temperature (°C)	η_0 (poise)	$\tau \times 10^{-2}$ (sec)	n
19.8	20.0	0.461	0.500	0.912
19.8	25.0	0.408	1.33	0.880
30.0	20.0	1.50	2.67	0.785
30.0	25.0	1.25	1.85	0.783
39.9	15.0	4.87	5.29	0.699
39.9	20.0	4.31	4.51	0.689
39.9	25.0	3.89	4.11	0.695
39.9	35.0	3.16	3.18	0.701
50.1	15.0	14.1	9.34	0.607
50.1	20.0	12.0	7.98	0.612
50.1	25.0	11.0	7.49	0.618
50.1	35.0	9.09	6.46	0.625
59.6	20.0	29.5	16.0	0.568
59.6	25.0	24.7	12.9	0.572
75.1	20.0	110.1	40.4	0.513
75.1	25.0	97.0	39.3	0.532

* from RFR data

TABLE XXV

PARAMETERS FOR THE ALLEN-UHLHERR VISCOSITY EQUATION OBTAINED BY LEAST SQUARES REGRESSION*

concentration (g/L)	temperature (°C)	η_0 (poise)	$\tau \times 10^{-2}$ (sec)	n
19.8	20.0	0.464	0.280	0.677
19.8	25.0	0.410	0.238	0.683
30.0	20.0	1.51	1.01	0.670
30.0	25.0			
39.9	15.0	4.88	2.67	0.617
39.9	20.0	4.32	2.55	0.623
39.9	25.0	3.86	2.28	0.635
39.9	35.0	3.19	1.45	0.589
50.1	15.0	14.0	7.15	0.585
50.1	20.0	12.0	5.63	0.574
50.1	25.0	10.9	5.23	0.581
50.1	35.0	9.02	4.41	0.583
59.6	20.0	29.1	14.0	0.565
59.6	25.0	25.0	10.4	0.546
75.1	20.0	111.0	37.3	0.510
75.1	25.0	96.0	28.9	0.498

* from RFR data

TABLE XXVI

ERROR ANALYSIS FOR CARREAU VISCOSITY EQUATON

conc. (g/L)	temp. (^{o}C)	$\sum(\eta_{exp} - \eta_{calc})^2$	avg. % error	max. % error	$\dot{\gamma}$ (max.% error)
19.8	20.0	2.36×10^{-6}	0.102	-0.210	79.4
19.8	25.0	1.98×10^{-6}	0.097	0.207	99.8
30.0	20.0	1.18×10^{-3}	0.601	-1.47	315.6
30.0	25.0	3.19×10^{-4}	0.362	0.817	125.9
39.9	15.0	3.90×10^{-2}	1.08	-3.04	250.1
39.9	20.0	2.38×10^{-2}	1.06	-3.12	315.6
39.9	25.0	5.33×10^{-2}	1.38	-3.89	250.1
39.9	35.0	7.22×10^{-3}	0.685	-2.26	250.1
50.1	15.0	4.27×10^{-1}	1.65	-6.10	250.1
50.1	20.0	1.78×10^{-1}	1.35	-4.56	315.6
50.1	25.0	3.31×10^{-1}	1.70	-5.99	250.1
50.1	35.0	2.17×10^{-1}	1.57	-5.58	250.1
59.6	20.0	6.89	2.99	-12.8	199.1
59.6	25.0	2.48	2.22	- 9.21	199.6
75.1	20.0	45.7	2.87	-12.7	99.8
75.1	25.0	20.6	2.35	- 9.56	100.0

TABLE XXVII

ERROR ANALYSIS FOR ALLEN-UHLHERR VISCOSITY EQUATION (PARAMETERS OBTAINED BY EXTRAPOLATION)

conc. (g/L)	temp. (°C)	$\sum(\eta_{exp} - \eta_{calc})^2$	avg. % error	max. % error	γ (max.% error)
19.8	20.0	6.25×10^{-3}	5.72	-12.2	316.3
19.8	25.0	1.57×10^{-3}	3.46	4.24	99.8
30.0	20.0	4.44×10^{-2}	3.98	5.45	99.8
30.0	25.0	6.49×10^{-2}	5.60	7.42	125.9
39.9	15.0	5.86×10^{-1}	4.21	6.33	31.5
39.9	20.0	3.72×10^{-1}	4.21	5.81	63.0
39.9	25.0	2.44×10^{-1}	3.33	5.95	79.1
39.9	35.0	3.01×10^{-1}	4.73	6.47	79.1
50.1	15.0	1.44	2.97	4.64	79.1
50.1	20.0	1.38	3.36	4.82	39.7
50.1	25.0	1.30	3.32	5.27	49.9
50.1	35.0	1.05	3.56	5.71	62.8
59.6	20.0	2.78	1.74	4.22	39.7
59.6	25.0	8.79	3.62	5.29	31.6
75.1	20.0	63.2	2.74	4.54	15.8
75.1	25.0	93.7	3.84	6.00	15.9

TABLE XXVIII

ERROR ANALYSIS FOR ALLEN-UHLHERR VISCOSITY EQUATION (PARAMETERS OBTAINED BY LEAST SQUARES REGRESSION)

conc. (g/L)	temp. (°C)	$\sum(\eta_{exp} - \eta_{calc})^2$	avg. % error	max. % error	$\dot{\gamma}$ (max.% error)
19.8	20.0	3.60×10^{-6}	0.120	0.265	125.9
19.8	25.0	4.81×10^{-6}	0.151	0.463	99.8
30.0	20.0	1.33×10^{-4}	0.173	-0.591	31.6
30.0	25.0				
39.9	15.0	4.53×10^{-4}	0.102	-0.297	125.3
39.9	20.0	3.81×10^{-4}	0.117	-0.290	31.6
39.9	25.0	1.10×10^{-2}	0.461	1.83	2.50
39.9	35.0	3.06×10^{-3}	0.314	-1.42	3.96
50.1	15.0	1.36×10^{-2}	0.298	-1.26	250.1
50.1	20.0	1.37×10^{-2}	0.313	-1.21	315.6
50.1	25.0	1.27×10^{-2}	0.326	-1.16	250.1
50.1	35.0	6.55×10^{-3}	0.272	-1.05	250.1
59.6	20.0	4.53×10^{-1}	0.793	-3.67	199.1
59.6	25.0	8.58×10^{-2}	0.401	-1.68	199.6
75.1	20.0	2.94	0.727	-3.37	99.8
75.1	25.0	1.24	0.596	-2.56	100.0

TABLE XXIX

PARAMETERS FOR THE EQUATION $N_1 = \alpha\tau_{12}^{\beta}$ K125/DEM SOLUTIONS*

concentration (g/L)	temperature (°C)	$N_1=\alpha\tau_{12}^{\beta}$ $\alpha \times 10^{-2}$	β
30.0	20.0	11.2	1.41
30.0	25.0	10.9	1.42
39.9	15.0	3.61	1.71
39.9	20.0	2.76	1.73
39.9	25.0	2.25	1.75
39.9	35.0	3.17	1.68
50.1	15.0	2.51	1.75
50.1	20.0	2.48	1.74
50.1	25.0	2.43	1.73
50.1	35.0	2.49	1.71
59.6	20.0	1.69	1.78
59.6	25.0	1.12	1.83
75.1	20.0	1.30	1.78
75.1	25.0	1.85	1.72

* from RFR data

TABLE XXX

FREQUENCY, LOSS MODULUS AND STORAGE MODULUS FOR A 19.8 g/L SOLUTION OF K125/DEM RHEOMETRICS FLUIDS RHEOMETER DATA

T = 20.0°C

frequency (1/sec)	loss modulus (dynes/cm²)	standard deviation	storage modulus (dynes/cm²)	standard deviation
10.0	4.25	0.04	0.423	0.02
12.6	5.34	0.05	0.607	0.03
15.9	6.72	0.09	0.890	0.05
20.0	8.43	0.11	1.30	0.06
25.1	10.6	0.13	1.89	0.09
31.6	13.2	0.17	2.75	0.11
39.8	16.3	0.19	4.00	0.15
50.1	20.1	0.20	5.83	0.22
63.1	24.6	0.19	8.52	0.29
79.4	29.8	0.16	12.4	0.43
100.0	35.6	0.10	18.2	0.65

T = 25.0°C

frequency (1/sec)	loss modulus (dynes/cm²)	standard deviation	storage modulus (dynes/cm²)	standard deviation
10.0	3.60	0.09	0.499	0.03
12.6	4.57	0.12	0.680	0.03
15.9	5.81	0.14	0.949	0.04
20.0	7.34	0.15	1.32	0.05
25.1	9.24	0.18	1.85	0.07
31.6	11.6	0.20	2.63	0.08
39.8	14.4	0.24	3.76	0.10
50.1	17.9	0.29	5.41	0.12
63.1	21.9	0.36	7.87	0.16
79.4	26.5	0.41	11.4	0.24
100.0	31.6	0.49	16.8	0.36

TABLE XXXI

FREQUENCY, LOSS MODULUS AND STORAGE MODULUS FOR A 30.0 g/L SOLUTION OF K125/DEM RHEOMETRICS FLUIDS RHEOMETER DATA

T = 20.0°C

frequency (1/sec)	loss modulus (dynes/cm²)	standard deviation	storage modulus (dynes/cm²)	standard deviation
5.00	7.13	0.04	0.639	0.04
6.30	8.88	0.10	0.909	0.12
7.93	11.1	0.04	1.33	0.06
10.0	13.9	0.05	1.38	0.07
12.6	17.2	0.09	2.65	0.09
15.8	21.2	0.13	3.73	0.11
19.9	26.1	0.13	5.20	0.13
25.1	32.0	0.17	7.18	0.16
31.6	39.0	0.22	9.87	0.20
39.7	47.2	0.25	13.4	0.27
50.0	56.9	0.22	18.2	0.33
63.0	68.2	0.36	24.5	0.42
79.3	81.3	0.43	33.0	0.53
99.8	96.6	0.51	44.6	0.70
125.6	113.5	0.62	59.9	0.87
158.2	133.1	0.65	81.6	1.04
199.1	154.1	0.84	113.0	1.00

T = 25.0°C

frequency (1/sec)	loss modulus (dynes/cm²)	standard deviation	storage modulus (dynes/cm²)	standard deviation
10.0	12.1	0.21	1.84	0.23
12.6	15.1	0.19	2.46	0.27
15.9	18.7	0.19	3.36	0.31
20.0	23.1	0.21	4.58	0.34
25.1	28.4	0.21	6.26	0.41
31.6	34.7	0.22	8.53	0.48
39.8	42.2	0.25	11.6	0.60
50.1	51.2	0.31	15.7	0.75
63.1	61.5	0.40	21.3	0.87
79.4	73.6	0.45	28.8	1.10
100.0	87.5	0.53	39.1	1.42
125.9	103.3	0.52	53.3	1.57
158.5	121.6	0.66	73.8	1.56
199.6	140.7	0.60	103.7	1.37

TABLE XXXII

FREQUENCY, LOSS MODULUS AND STORAGE MODULUS FOR A 39.9 g/L SOLUTION OF K125/DEM RHEOMETRICS FLUIDS RHEOMETER DATA

T = 15.0°C

frequency (1/sec)	loss modulus (dynes/cm²)	standard deviation	storage modulus (dynes/cm²)	standard deviation
2.50	11.3	0.17	1.61	0.07
3.15	14.2	0.16	2.12	0.07
3.96	17.5	0.16	2.98	0.08
4.99	21.7	0.34	4.07	0.09
6.28	26.8	0.04	5.38	0.25
7.91	32.7	0.24	7.39	0.00
9.95	39.8	0.29	9.93	0.00
12.5	48.1	0.34	13.2	0.01
15.8	57.8	0.28	17.5	0.04
19.9	69.0	0.42	22.8	0.06
25.0	82.0	0.49	29.6	0.13
31.5	96.7	0.50	37.9	0.18
39.6	113.5	0.64	48.2	0.31
49.9	132.9	0.71	60.6	0.51
62.8	154.1	0.78	75.8	0.53
79.1	178.3	0.99	94.2	0.71
99.6	206.1	1.06	116.8	0.92
125.3	237.6	1.27	144.8	1.13
157.8	275.4	1.41	180.5	1.27
198.6	319.8	1.48	228.5	1.41

TABLE XXXII cont'd

T = 20.0°C

frequency (1/sec)	loss modulus (dynes/cm²)	standard deviation	storage modulus (dynes/cm²)	standard deviation
5.00	19.3	0.34	3.36	0.39
6.30	23.6	1.14	4.29	0.51
7.93	29.2	0.60	6.13	0.40
10.0	35.7	0.73	8.29	0.41
12.6	43.2	0.76	11.1	0.51
15.8	52.2	0.84	14.8	0.60
19.9	62.6	0.93	19.6	0.78
25.1	74.5	0.96	25.7	1.03
31.6	88.4	0.99	33.3	1.35
39.7	104.3	0.80	42.7	1.94
50.0	122.4	0.92	54.2	2.53
63.0	142.7	0.79	68.2	2.79
79.3	166.0	0.84	85.7	3.83
99.8	192.7	0.85	107.4	4.80
125.6	222.8	0.77	133.8	5.98
158.2	258.6	0.68	167.6	6.69
199.1	301.3	0.98	210.9	2.50

TABLE XXXII cont'd

T = 25.0°C

frequency (1/sec)	loss modulus (dynes/cm²)	standard deviation	storage modulus (dynes/cm²)	standard deviation
2.50	9.44	0.17	1.13	0.10
3.15	11.7	0.18	1.59	0.15
3.96	14.6	0.25	2.13	0.19
4.99	18.2	0.27	2.88	0.26
6.28	22.4	0.23	3.87	0.32
7.91	27.5	0.34	5.29	0.41
9.95	33.5	0.43	7.12	0.52
10.0	33.0	0.41	7.00	0.26
12.5	40.8	0.52	9.54	0.69
12.6	40.1	0.43	9.39	0.31
15.8	49.3	0.65	12.7	0.92
15.9	48.5	0.51	12.6	0.40
19.9	59.2	0.81	16.8	1.25
20.0	58.3	0.64	16.7	0.53
25.0	70.7	1.04	22.0	1.62
25.1	69.7	0.75	21.9	0.71
31.5	83.9	1.30	28.5	2.12
31.6	82.9	0.88	28.5	0.94
39.6	99.1	1.56	36.6	2.81
39.8	98.0	1.06	36.7	1.23
49.9	116.8	1.95	46.7	3.64
50.1	115.5	1.34	46.8	1.58
62.8	136.2	2.44	59.1	4.61
63.1	135.1	1.51	59.5	1.98
79.1	158.5	2.71	74.4	5.79
79.4	157.4	1.77	75.1	2.52
99.6	184.2	2.91	93.7	7.13
100.0	182.9	2.11	94.4	3.24
125.3	214.1	2.89	118.8	7.50
125.9	212.2	2.33	118.8	3.84
157.8	249.4	3.09	152.4	6.96
158.5	247.5	2.80	151.0	4.09
198.6	291.4	2.86	199.2	4.93
199.6	289.4	2.96	195.5	3.76

TABLE XXXII cont'd

T = 35.0°C

frequency (1/sec)	loss modulus (dynes/cm²)	standard deviation	storage modulus (dynes/cm²)	standard deviation
2.50	7.73	0.26	0.908	0.16
3.15	9.65	0.58	1.25	0.08
3.96	12.1	0.54	1.65	0.10
4.99	15.2	0.74	2.21	0.09
6.28	18.8	0.57	3.02	0.20
7.91	23.1	0.95	4.10	0.23
9.95	28.5	1.04	5.59	0.35
12.5	34.8	1.22	7.56	0.41
15.8	42.4	1.43	10.3	0.53
19.9	51.2	1.75	13.7	0.67
25.0	61.6	1.94	18.2	0.83
31.5	73.7	2.19	23.9	1.05
39.6	87.5	2.46	31.2	1.34
49.9	103.9	2.83	40.3	1.55
62.8	122.1	3.04	51.7	1.85
79.1	143.0	3.32	65.9	2.24
99.6	166.9	3.82	84.0	2.50
125.3	194.4	4.31	106.8	2.90
157.8	227.2	5.02	136.5	3.11
198.6	265.6	6.01	177.5	3.39

TABLE XXXIII

FREQUENCY, LOSS MODULUS AND STORAGE MODULUS FOR A 50.1 g/L SOLUTION OF K125/DEM RHEOMETRICS FLUIDS RHEOMETER DATA

T = 15.0°C

frequency (1/sec)	loss modulus (dynes/cm²)	standard deviation	storage modulus (dynes/cm²)	standard deviation
2.50	29.5	0.94	6.05	0.23
3.15	36.4	1.39	8.20	0.24
3.96	44.0	1.30	11.1	0.46
4.99	53.3	1.47	14.6	0.74
6.28	64.0	2.14	19.4	0.05
7.91	76.1	1.89	25.4	0.76
9.95	90.1	2.11	32.9	0.91
12.5	105.9	2.26	42.2	0.95
15.8	123.9	2.47	53.5	1.06
19.9	143.7	2.62	67.1	1.26
25.0	166.0	2.97	83.3	1.44
31.5	190.5	3.32	102.2	1.70
39.6	217.6	3.82	124.3	1.84
49.9	248.1	4.10	150.0	2.26
62.8	280.4	4.81	179.6	2.69
79.1	317.0	5.16	213.5	3.04
99.6	358.0	5.80	253.1	3.61
125.3	404.6	6.22	299.1	4.03
157.8	460.1	7.00	354.2	4.53
198.6	527.3	8.98	424.9	5.87

TABLE XXXIII cont'd

T = 20.0°C

frequency (1/sec)	loss modulus (dynes/cm²)	standard deviation	storage modulus (dynes/cm²)	standard deviation
5.00	48.9	0.57	12.2	0.31
6.30	58.5	0.62	16.3	0.29
7.93	70.2	0.71	21.5	0.49
10.0	83.5	0.81	28.2	0.65
12.6	98.4	0.94	36.4	0.80
15.8	115.4	1.09	46.4	1.04
19.9	134.6	1.26	58.7	1.35
25.1	155.9	1.42	73.4	1.72
31.6	179.7	1.61	90.8	2.12
39.7	206.0	1.78	111.3	2.66
50.0	235.2	1.96	135.1	3.23
63.0	267.3	2.13	162.7	3.87
79.3	303.1	2.41	194.8	4.65
99.8	343.8	2.63	232.6	5.61
125.6	388.8	2.65	275.7	6.42
158.2	442.8	2.97	328.8	6.84
199.1	507.3	2.87	396.6	6.12

TABLE XXXIII cont'd

T = 25.0°C

frequency (1/sec)	loss modulus (dynes/cm²)	standard deviation	storage modulus (dynes/cm²)	standard deviation
2.50	24.8	0.43	4.08	0.33
3.15	30.3	0.36	5.67	0.35
3.96	36.9	0.52	7.61	0.58
4.99	44.9	0.63	10.3	0.80
6.28	54.3	1.05	13.8	0.89
7.91	64.8	1.02	18.1	1.39
9.95	77.2	1.26	23.7	1.85
10.0	78.0	0.40	24.7	0.84
12.5	91.4	1.58	30.7	2.44
12.6	92.3	0.46	32.0	1.11
15.8	107.5	1.90	39.3	3.24
15.9	108.8	0.61	41.0	1.43
19.9	125.8	2.34	49.9	4.21
20.0	127.3	0.78	51.9	1.78
25.0	146.2	2.83	62.6	5.40
25.1	148.0	0.96	65.2	2.34
31.5	168.9	3.38	77.6	6.87
31.6	171.2	1.19	81.0	3.00
39.6	194.2	3.96	95.5	8.66
39.8	197.2	1.42	99.6	3.78
49.9	222.6	4.68	116.4	10.7
50.1	226.0	1.76	121.4	4.62
62.8	253.4	5.43	141.0	13.1
63.1	257.7	2.14	147.4	5.72
79.1	287.9	6.21	169.4	15.9
79.4	293.0	2.49	177.2	6.96
99.6	327.4	6.59	203.5	18.5
100.0	332.7	2.89	212.3	8.32
125.3	372.5	6.45	245.5	19.0
125.9	377.9	2.86	254.0	9.41
157.8	426.8	6.13	299.2	16.9
158.5	432.4	2.99	306.1	9.23
198.6	493.0	4.64	370.1	12.0
199.6	498.4	2.16	374.7	6.69

TABLE XXXIII cont'd

T = 35.0°C

frequency (1/sec)	loss modulus (dynes/cm²)	standard deviation	storage modulus (dynes/cm²)	standard deviation
2.50	21.1	0.86	3.25	0.23
3.15	26.1	1.16	4.40	0.25
3.96	31.9	1.22	6.15	0.49
4.99	39.2	1.65	8.38	0.53
6.28	46.8	1.72	11.1	0.95
7.91	57.0	2.06	15.0	0.88
9.95	68.4	2.31	19.9	1.12
12.5	81.6	2.64	26.1	1.43
15.8	96.9	3.01	33.9	1.68
19.9	114.2	3.46	43.5	2.05
25.0	133.8	3.89	55.5	2.43
31.5	155.7	4.38	69.7	2.82
39.6	180.4	4.8	86.4	3.45
49.9	208.4	5.59	107.4	3.89
62.8	238.6	6.08	131.3	4.60
79.1	272.8	6.79	159.6	5.30
99.6	311.3	7.35	192.8	6.43
125.3	354.9	8.13	232.8	6.76
157.8	407.0	9.12	281.5	7.50
198.6	469.1	10.3	344.6	8.27

TABLE XXXIV

FREQUENCY, LOSS MODULUS AND STORAGE MODULUS FOR A 59.6 G/L SOLUTION OF K125/DEM RHEOMETRICS FLUIDS RHEOMETER DATA

T = 20.0° C

frequency (1/sec)	loss modulus (dynes/cm²)	standard deviation	storage modulus (dynes/cm²)	standard deviation
0.500	13.6	0.17	1.51	0.07
0.630	16.9	0.23	2.14	0.07
0.793	20.9	0.26	2.99	0.11
1.00	25.9	0.35	4.18	0.07
1.26	31.6	0.41	5.73	0.27
1.58	38.7	0.56	7.96	0.12
1.99	46.7	0.76	10.9	0.20
2.51	56.8	0.87	14.4	0.42
3.16	68.3	1.15	19.5	0.37
3.97	81.4	1.25	25.4	0.49
5.00	96.7	1.46	33.1	0.75
6.30	113.5	1.99	42.7	1.33
7.93	133.2	2.05	54.3	1.48
9.98	155.2	2.38	68.7	1.91
12.6	179.0	2.72	85.5	2.43
15.8	205.6	3.10	105.5	3.10
19.9	234.8	3.59	129.1	3.85
25.1	266.5	4.02	156.3	4.77
31.6	301.1	4.39	187.8	5.77
39.7	338.4	5.03	223.3	6.97
50.0	379.3	5.65	263.7	8.26
63.0	423.2	6.12	308.9	9.87
79.3	471.8	6.63	360.1	11.5
99.8	526.4	7.31	418.3	13.5
125.6	586.4	7.30	482.4	14.6
158.2	658.3	7.66	559.0	15.2

TABLE XXXIV cont'd

T = 25.0° C

frequency (1/sec)	loss modulus (dynes/cm²)	standard deviation	storage modulus (dynes/cm²)	standard deviation
1.00	23.2	0.47	3.57	0.18
1.26	28.4	0.49	5.01	0.12
1.59	34.8	0.53	6.81	0.31
2.00	42.7	0.85	9.16	0.24
2.51	51.5	0.67	12.5	0.30
3.16	62.2	0.88	16.5	0.63
3.98	74.4	0.90	22.0	0.70
5.01	88.7	0.98	28.9	0.82
6.31	104.5	1.16	37.4	1.05
7.95	123.1	1.31	47.9	1.36
10.0	143.8	1.43	60.7	1.74
12.6	166.6	1.63	76.1	2.18
15.9	192.2	1.85	94.7	2.71
20.0	221.5	4.32	116.4	3.35
25.1	250.8	2.21	141.7	4.20
31.6	284.2	2.41	170.9	5.03
39.8	320.5	2.70	204.4	6.13
50.1	360.2	2.97	242.4	7.26
63.1	403.1	3.12	285.4	8.51
79.5	450.3	3.53	334.0	10.06
100.0	502.7	3.89	388.7	11.82
125.9	561.5	4.11	450.5	13.61
158.5	631.9	4.00	524.4	14.16

TABLE XXXV

FREQUENCY, LOSS MODULUS AND STORAGE MODULUS FOR A 75.1 G/L SOLUTION OF K125/DEM RHEOMETRICS FLUIDS RHEOMETER DATA

T = 20.0° C

frequency (1/sec)	loss modulus (dynes/cm²)	standard deviation	storage modulus (dynes/cm²)	standard deviation
0.500	46.1	0.31	9.77	0.22
0.630	55.9	0.36	13.2	0.34
0.793	67.4	0.44	17.7	0.43
1.00	81.1	0.54	23.4	0.55
1.26	96.7	1.29	30.9	0.59
1.58	113.6	0.74	39.8	0.77
1.99	134.0	1.16	51.0	0.84
2.51	156.8	1.17	65.0	1.62
3.16	182.0	1.15	82.0	2.10
3.97	210.3	1.52	101.9	2.85
5.00	241.4	1.79	125.7	3.68
6.30	274.3	1.76	153.8	3.93
7.93	311.4	2.06	186.4	5.46
9.98	351.1	2.48	224.4	6.70
12.6	392.3	2.93	266.5	8.09
15.8	436.7	3.23	314.6	9.58
19.9	483.8	3.55	368.8	11.3
25.1	533.4	3.74	428.8	13.3
31.6	585.7	4.05	495.2	15.6
39.7	640.4	4.54	567.8	18.0
50.0	699.1	5.18	647.3	20.8
63.0	760.9	5.05	733.0	23.3
79.3	828.0	5.22	826.2	26.4
99.8	902.8	5.26	928.3	29.5

TABLE XXXV cont'd

T = 25.0° C

frequency (1/sec)	loss modulus (dynes/cm²)	standard deviation	storage modulus (dynes/cm²)	standard deviation
1.00	76.8	0.92	20.9	0.55
1.26	91.9	1.17	27.7	0.70
1.59	109.1	0.96	36.3	0.98
2.00	128.9	1.02	46.9	1.73
2.51	151.3	1.76	59.9	1.95
3.16	176.3	1.87	75.4	2.10
3.98	204.3	2.15	94.7	2.88
5.01	235.0	2.25	117.3	3.63
6.31	268.5	4.44	144.8	4.39
7.95	305.2	2.99	175.6	5.69
10.0	344.6	3.27	211.8	6.95
12.6	386.6	3.56	253.0	8.32
15.9	431.8	3.87	300.3	9.93
20.0	479.4	4.14	353.3	11.8
25.1	529.6	4.48	412.0	13.8
31.6	582.5	4.76	477.3	16.1
39.8	638.6	5.12	549.4	18.6
50.1	697.9	5.49	627.9	21.5
63.1	761.2	5.85	713.5	24.3
79.5	829.2	6.22	806.2	27.5
100.0	903.8	6.67	906.9	31.1

TABLE XXXVI

PARAMETERS FOR THE EQUATION $\eta' = a\omega^{b-1}$ FOR K125/DEM SOLUTIONS*

concentration (g/L)	temperature (°C)	$\eta = a\omega^{b-1}$ a	b	ω_0 (1/sec)
19.8	20.0	0.897	0.800	28.0
19.8	25.0	0.809	0.796	38.0
30.0	20.0	4.59	0.664	14.0
30.0	25.0	2.93	0.735	27.0
39.9	15.0	10.3	0.651	4.50
39.9	20.0	9.08	0.663	4.70
39.9	25.0	8.32	0.672	7.90
39.9	35.0	7.15	0.684	10.4
50.1	15.0	27.0	0.563	1.50
50.1	20.0	25.0	0.570	2.20
50.1	25.0	22.1	0.588	2.50
50.1	35.0	19.1	0.606	3.70
59.6	20.0	51.3	0.507	0.750
59.6	25.0	48.3	0.510	1.40
75.1	20.0	136.8	0.415	0.310
75.1	25.0	131.7	0.424	0.500

* from RFR data

Figure 1:
Viscosity as a Function of Shear Rate and Temperature for a 50.1 g/L Solution of K125/DEM

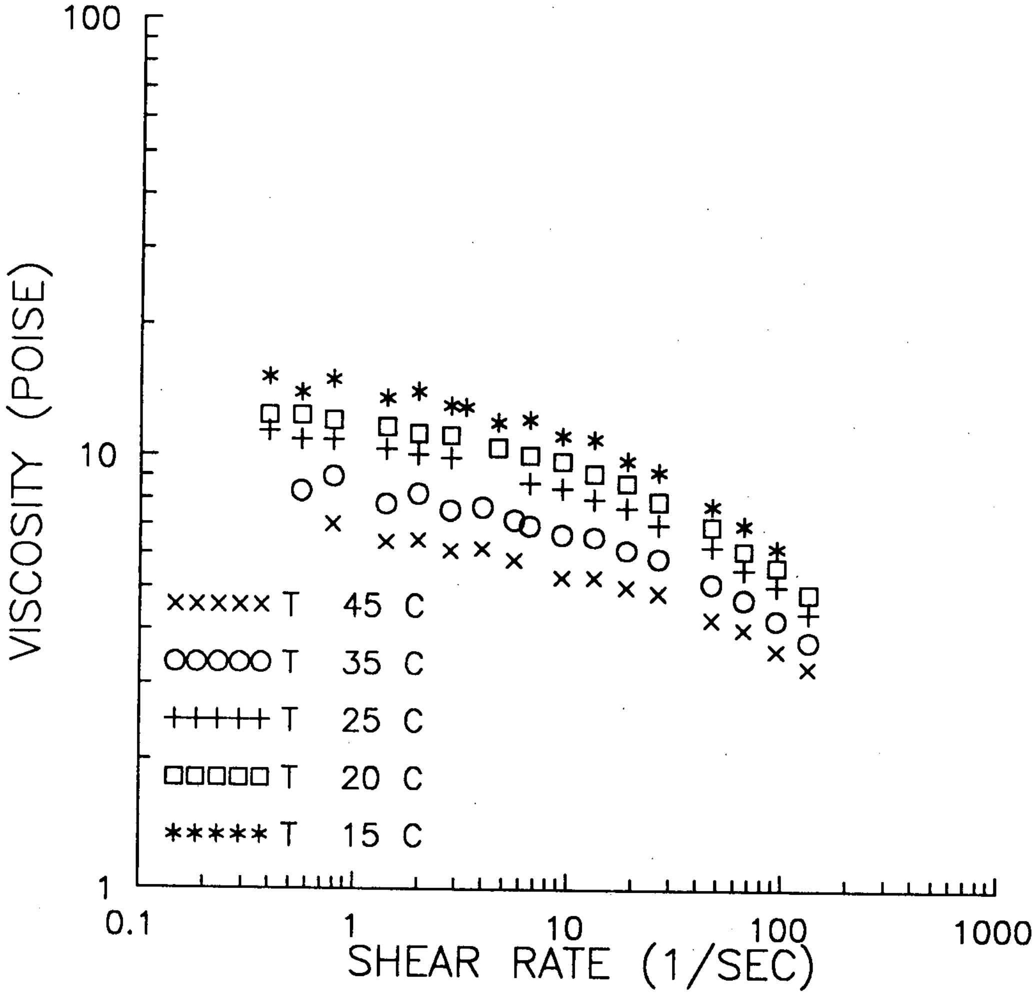


Figure 2:
Viscosity as a Function of Shear Rate for a 50.1 g/L Solution of K125/DEM. All Data Reduced to 25.0 C.

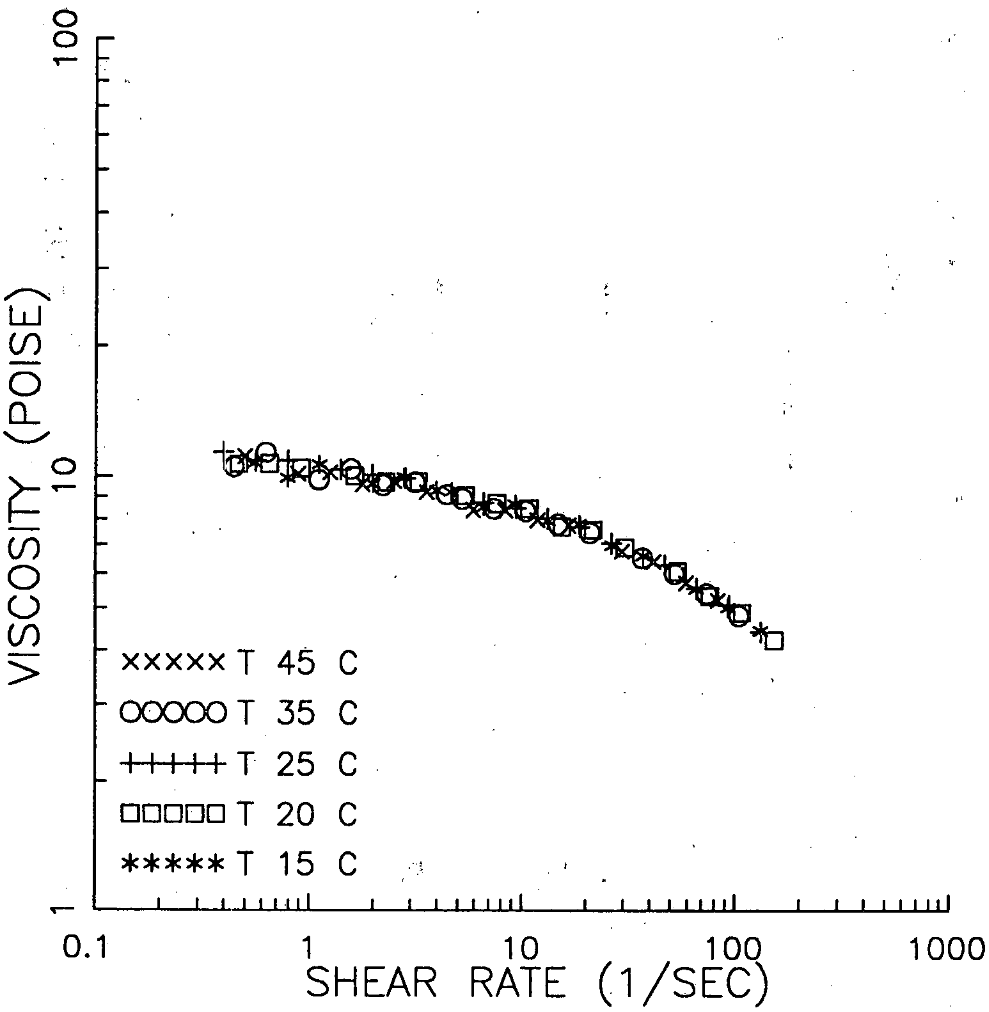


Figure 3: A_T as a Function of 1/T for a 50.1 g/L Solution of K125/DEM

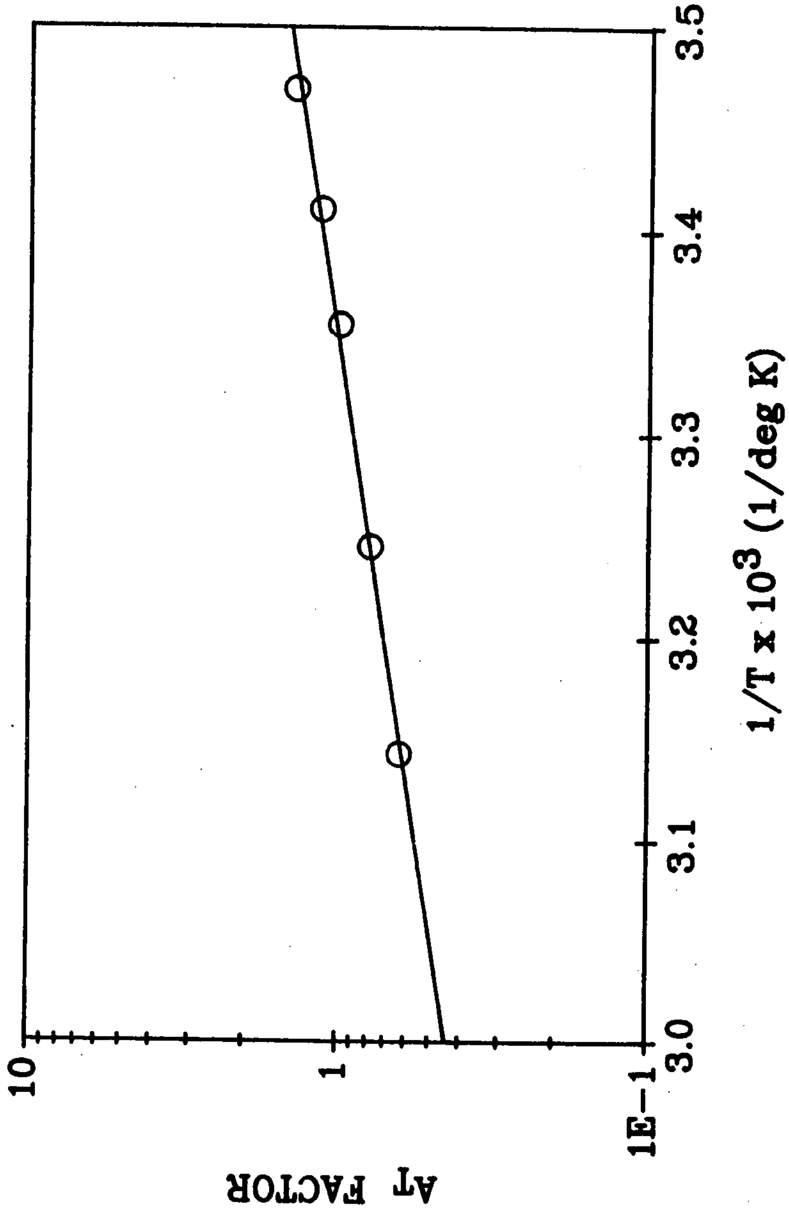


Figure 4:
Viscosity as a Function of Shear Rate for a 19.8 g/L Solution of K125/DEM at 25.0 C

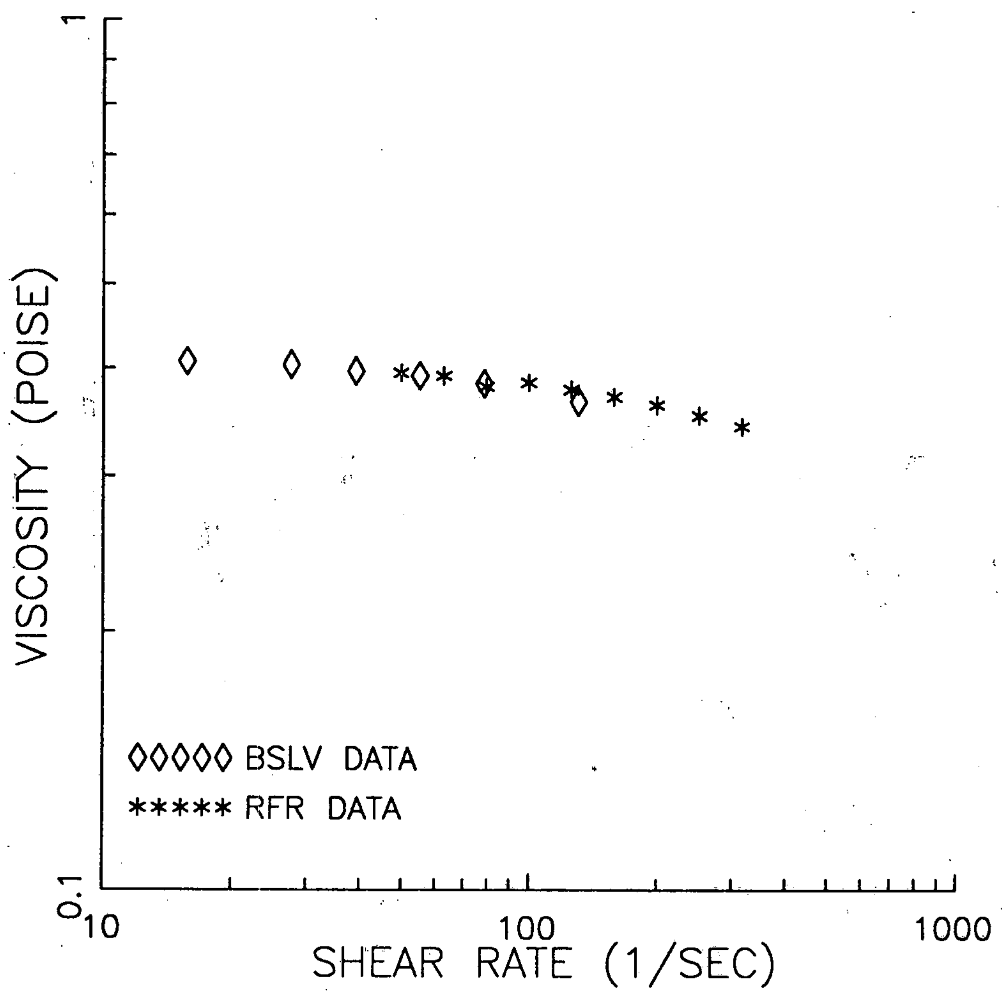


Figure 5:
Viscosity and First Normal Stress Difference as a Function of Shear Rate for a 30.0 g/L Solution of K125/DEM at 25.0 C.

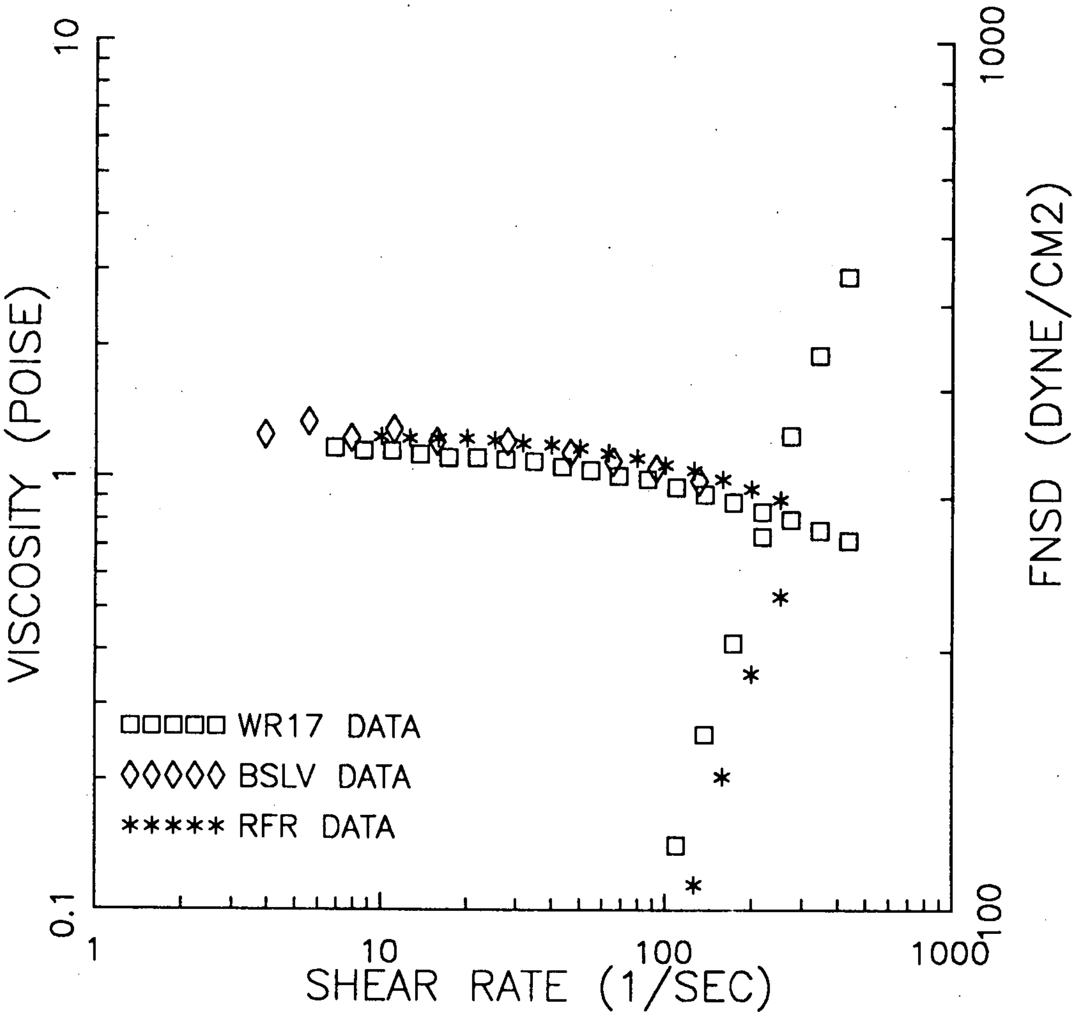


Figure 6:
Viscosity and First Normal Stress Difference as a Function of Shear Rate for a 39.9 g/L Solution of K125/DEM at 25.0 C.

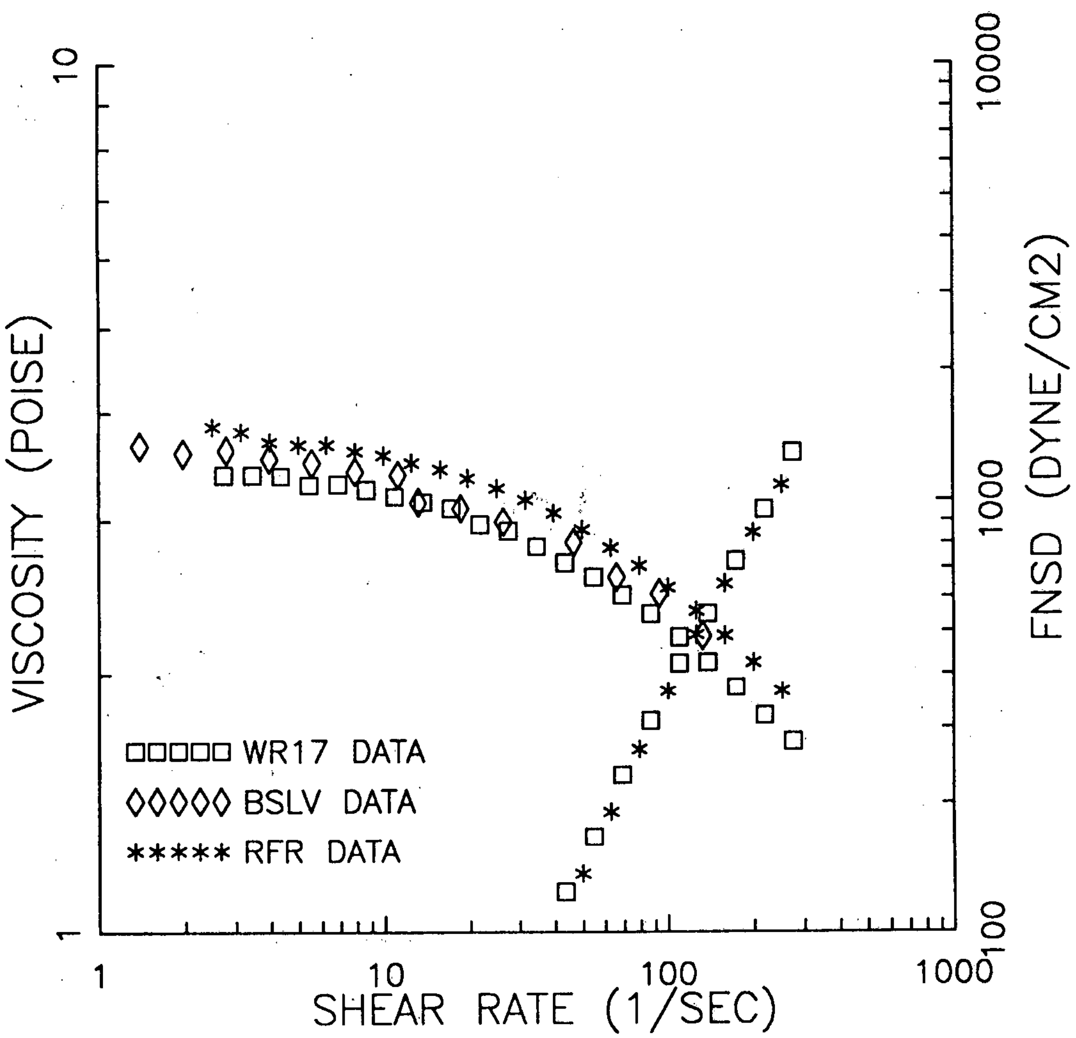


Figure 7:
Viscosity and First Normal Stress Difference as a Function of Shear Rate for a 50.1 g/L Solution of K125/DEM at 25.0 C.

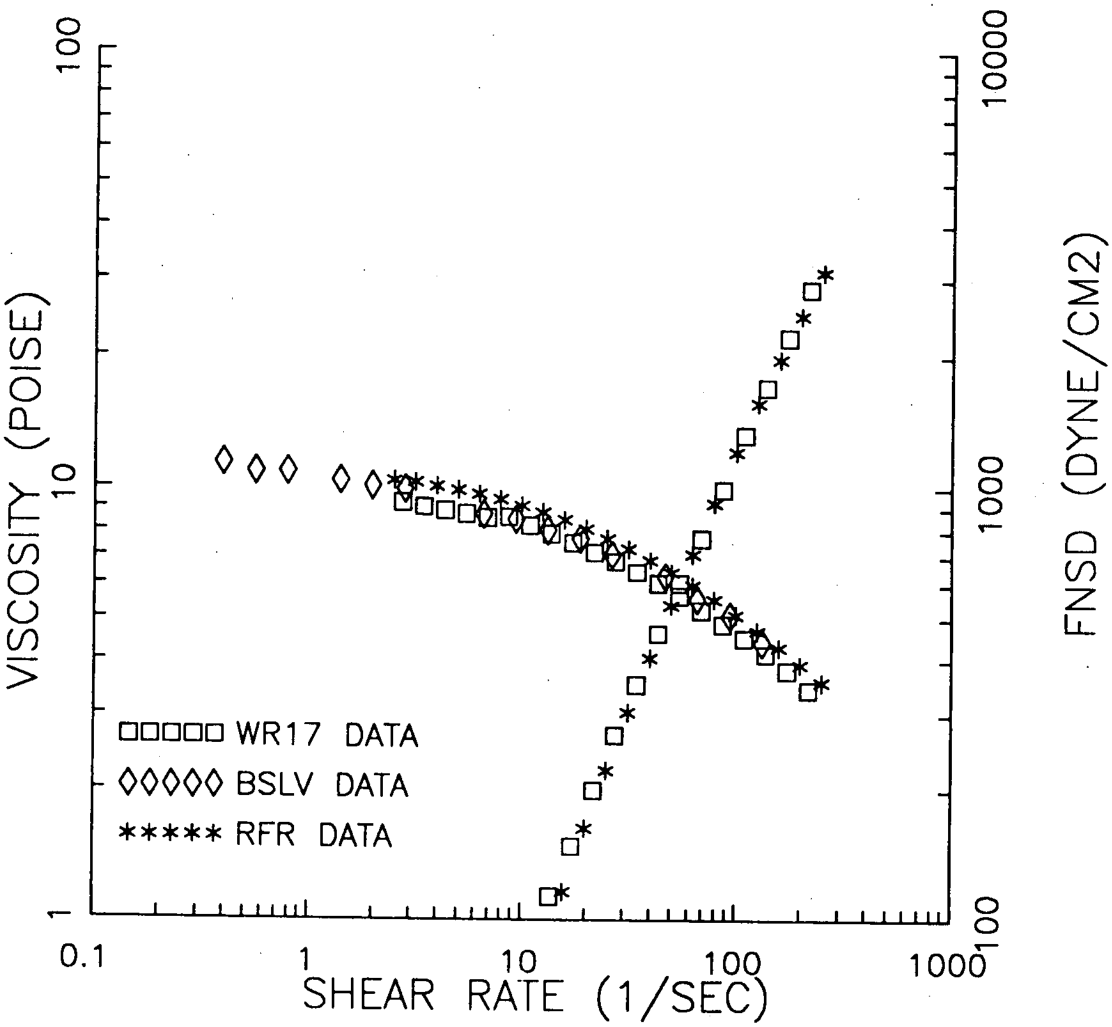


Figure 8:
Viscosity and First Normal Stress Difference as a Function of Shear Rate for a 59.6 g/L Solution of K125/DEM at 25.0 C.

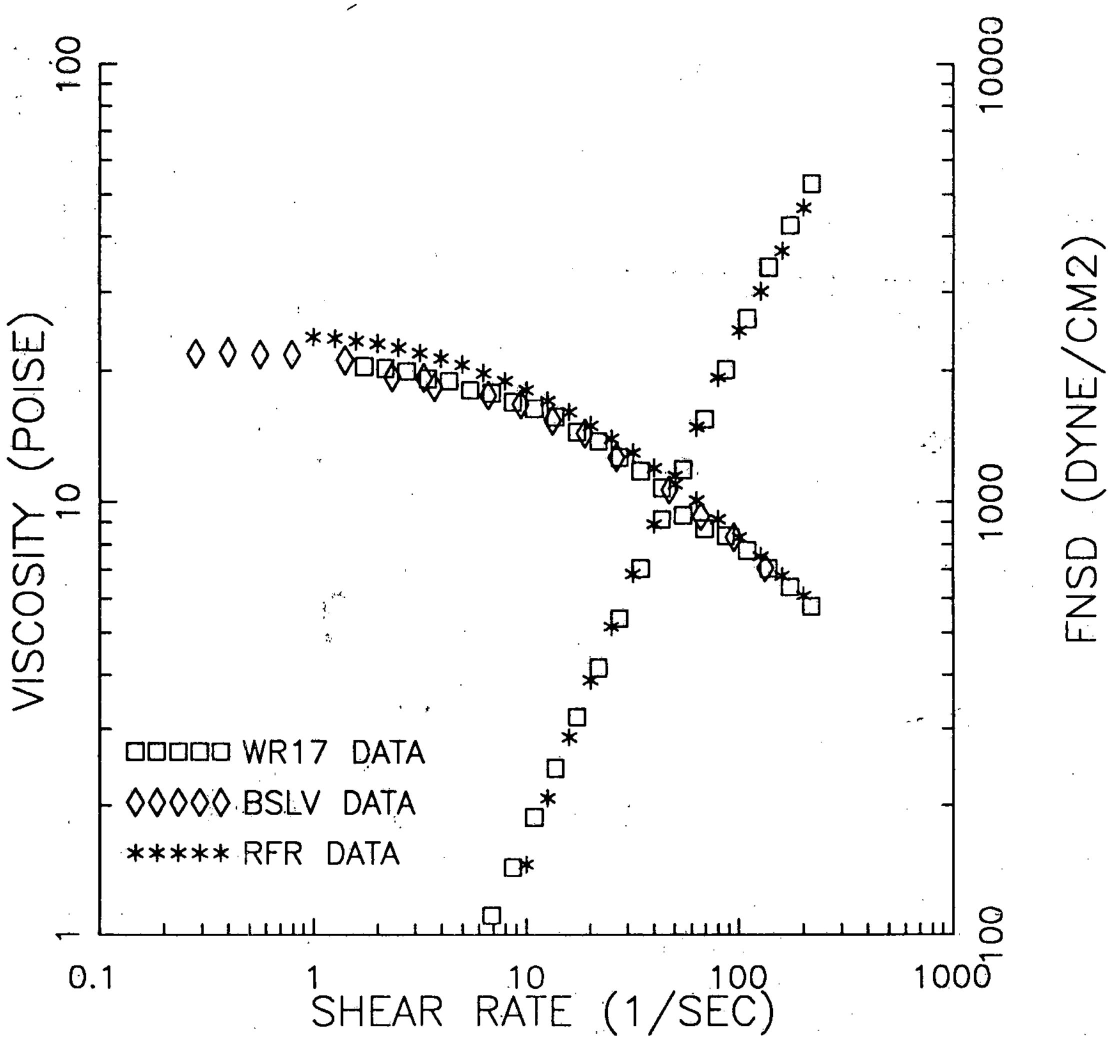


Figure 9:
Viscosity and First Normal Stress Difference as a Function of Shear Rate for a 75.1 g/L Solution of K125/DEM at 25.0 C.

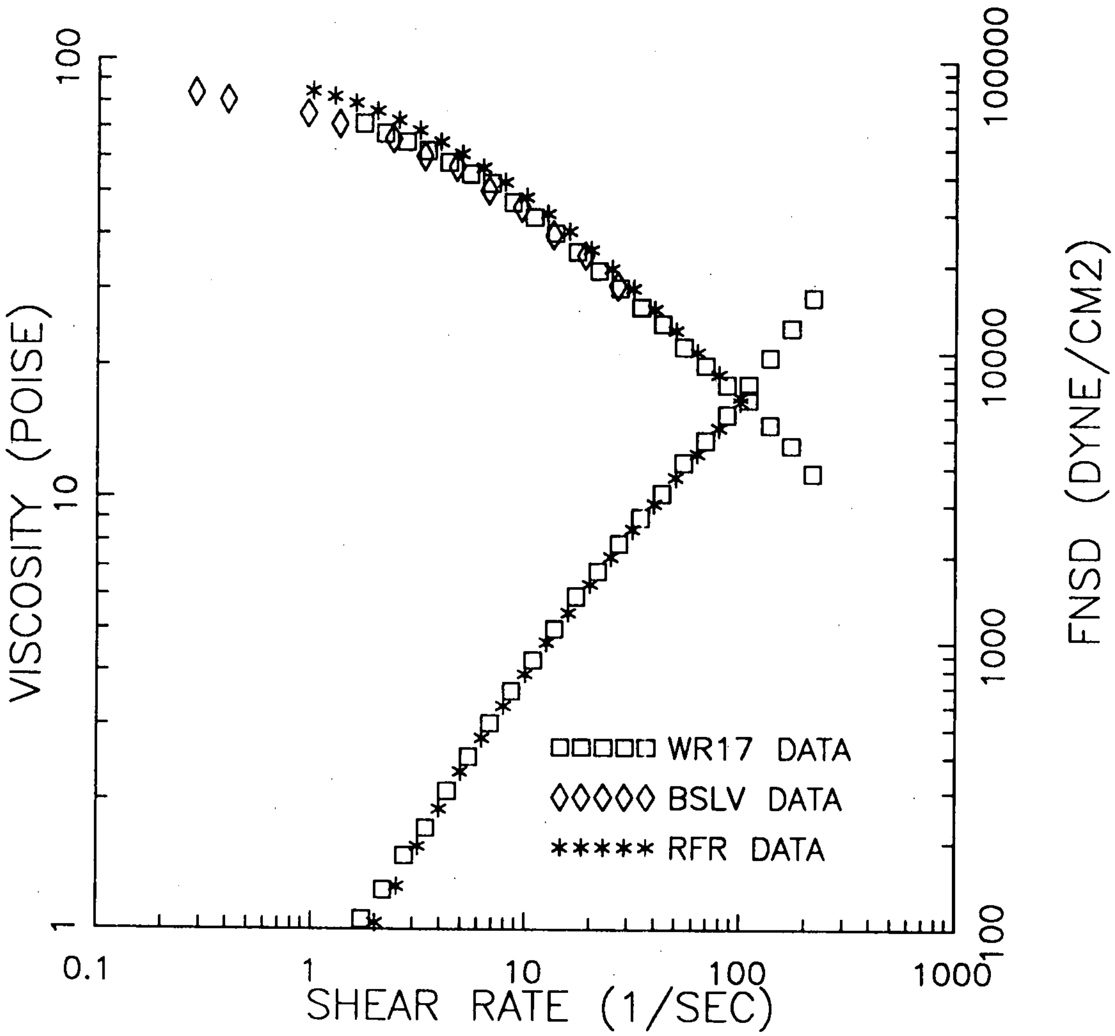


Figure 10:
The Carreau Viscosity Equation Fitted to Viscosity Shear Rate Data for a 50.1 g/L Solution of K125/DEM at 25.0 C.

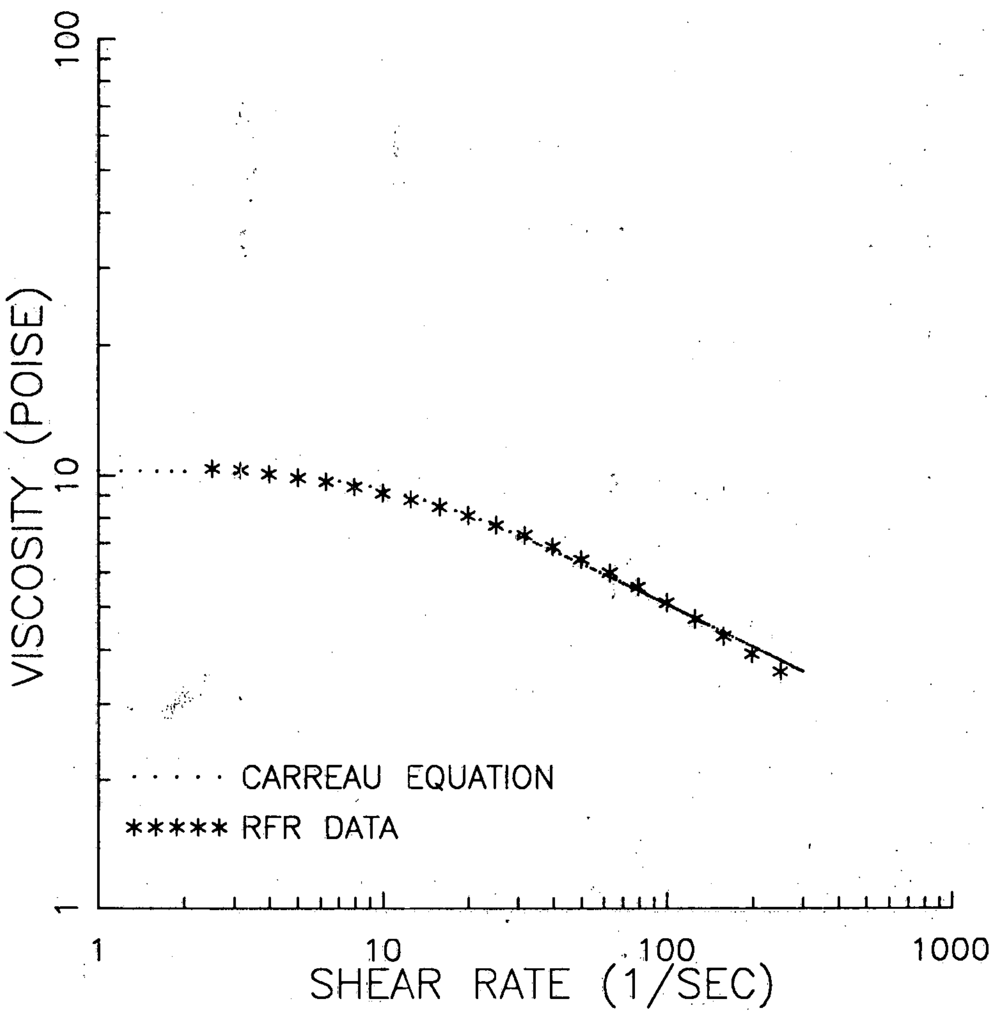


Figure 11:
The Allen–Uhlherr Viscosity Equation Fitted to Viscosity Shear Rate Data for a 50.1 g/L Solution of K125/DEM at 25.0 C.

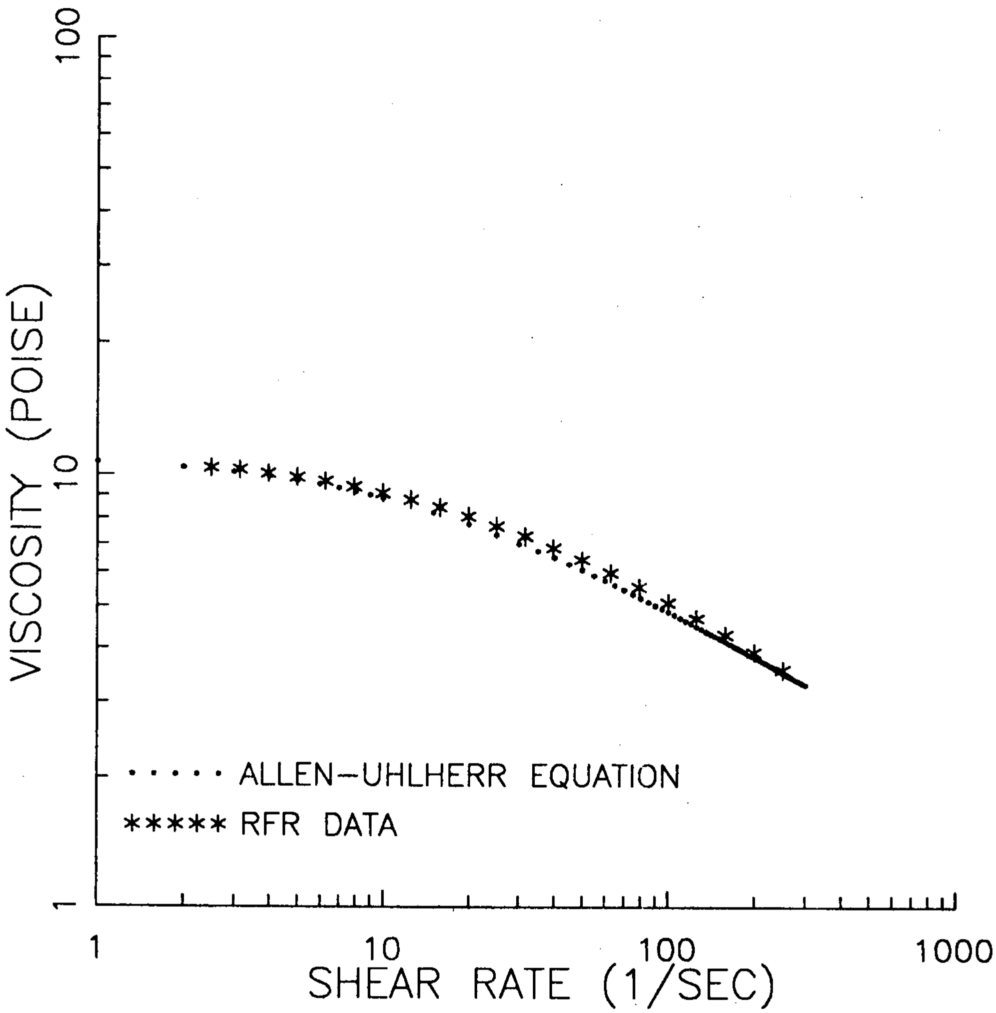


Figure 12:
Dynamic Viscosity as a Function of Frequency for K125/DEM Solutions at 25.0 C.

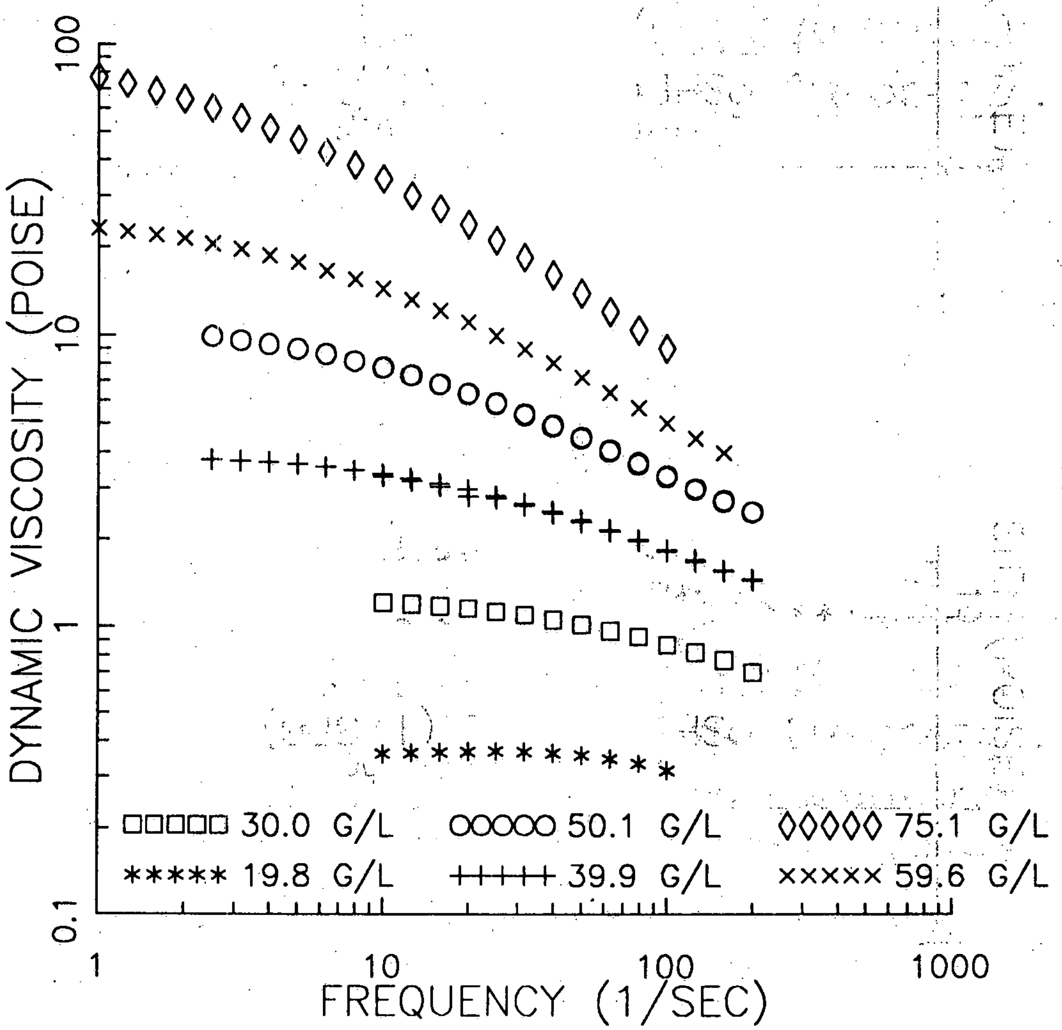


Figure 13:
Storage Modulus as a Function of Frequency for K125/DEM Solutions at 25.0 C.

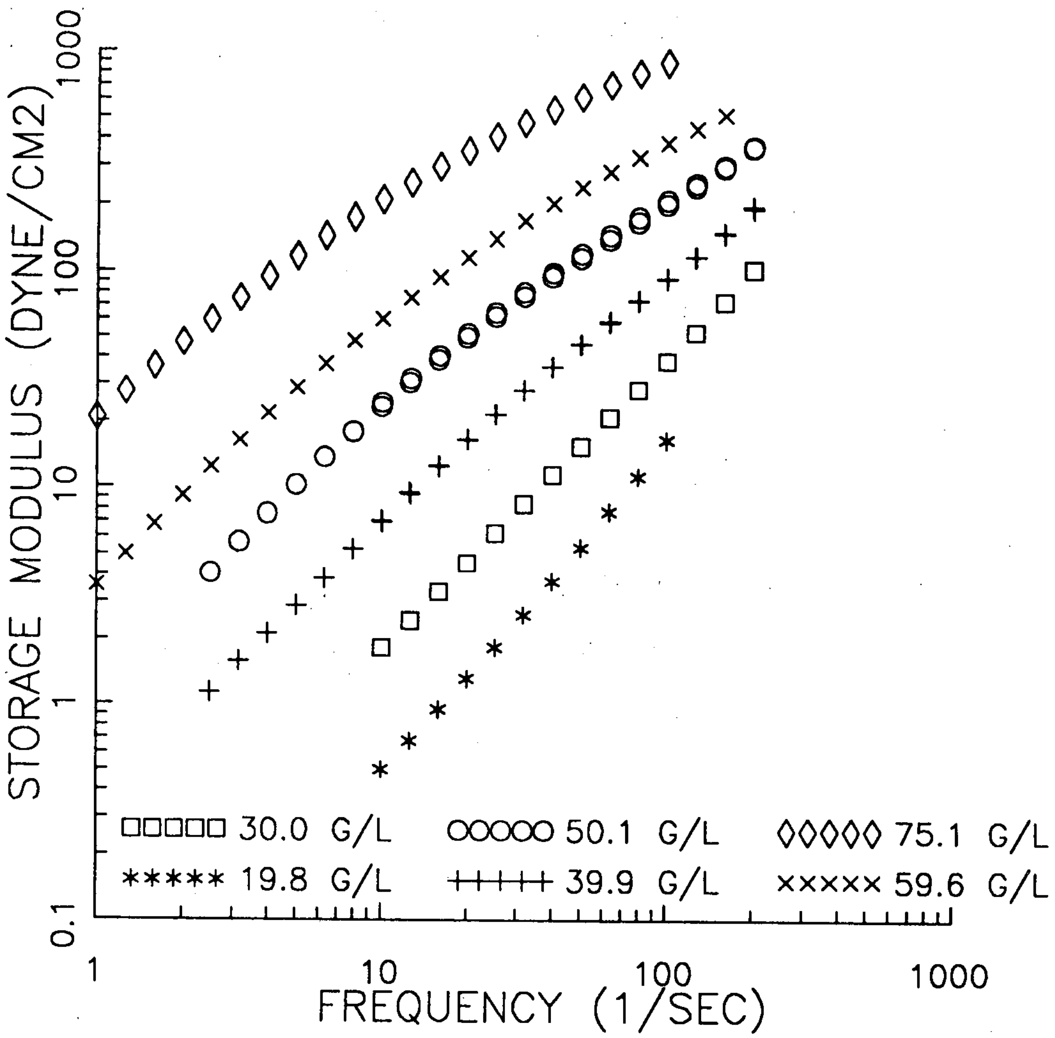


Figure 14: Reduced Viscosity, Dynamic Viscosity and Complex Viscosity as a Function of Reduced Shear Rate or Frequency

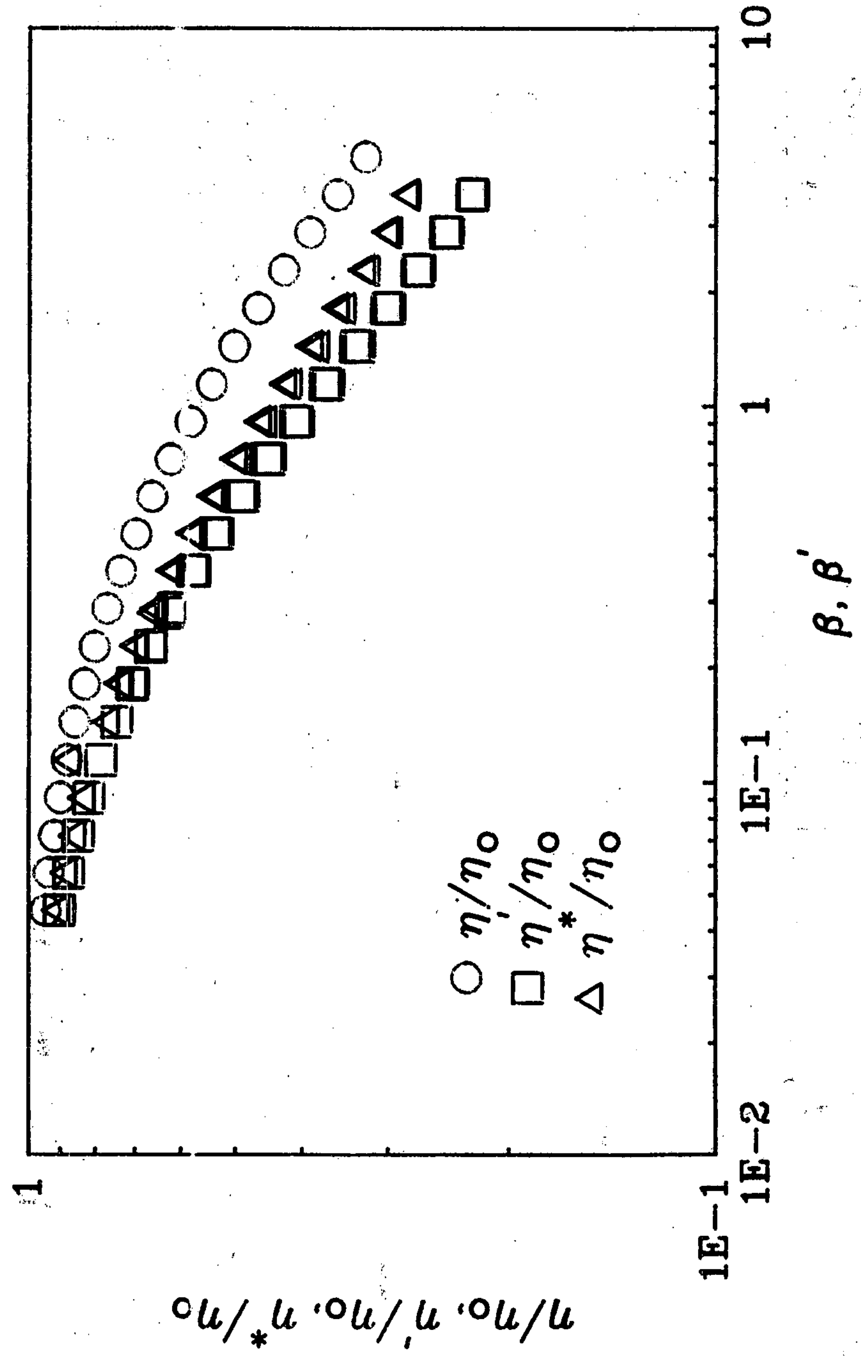
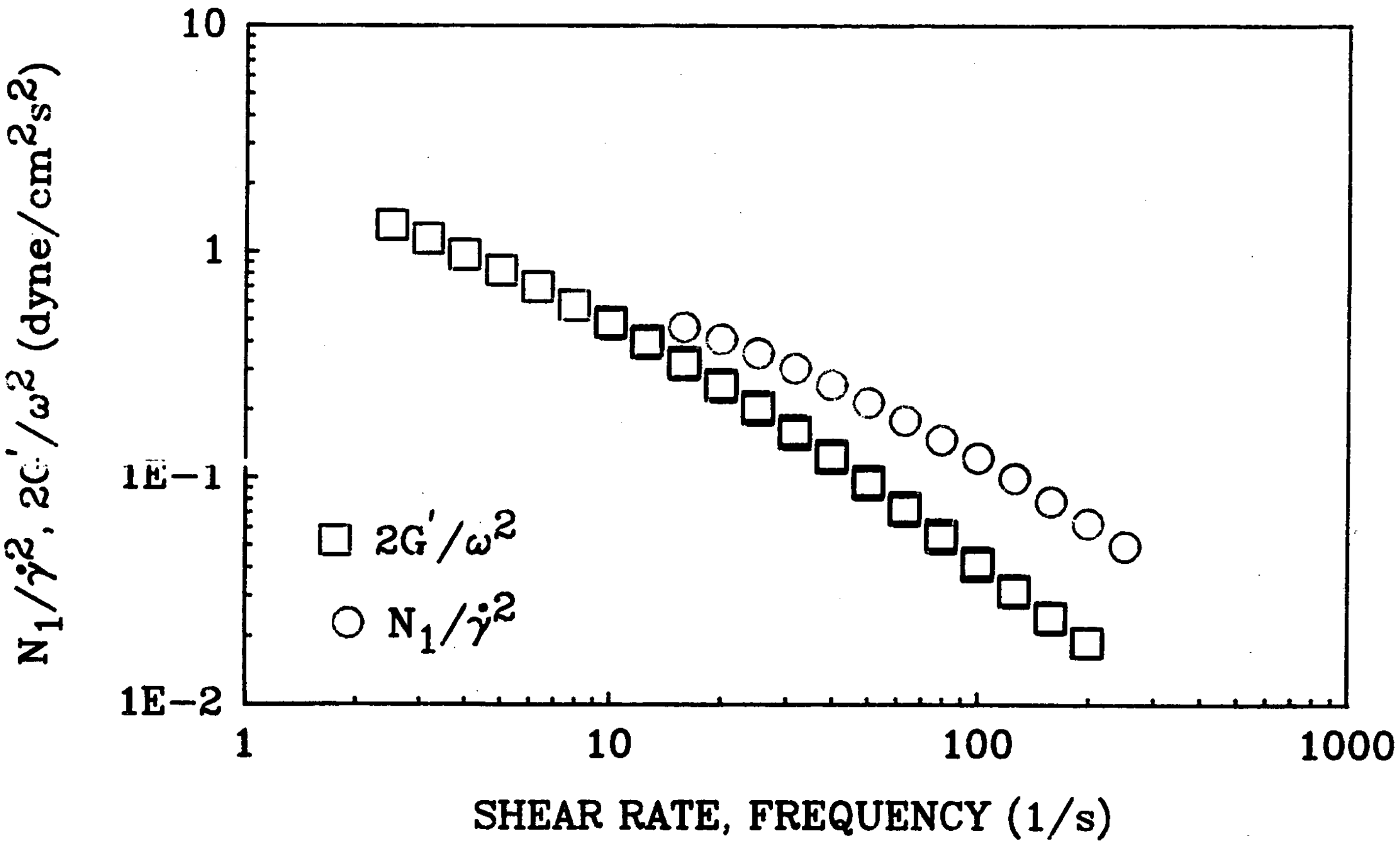


Figure 15: $(N_1/\dot{\gamma}^2)$ and $(2G'/\omega^2)$ as a Function of Shear Rate or Frequency for a 50.1 g/L Solution of K125/DEM



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Density and surface tension were measured as a function of concentration at 25°C. Viscosity and first normal stress difference in steady shear and storage and loss moduli in dynamic mode were measured as a function of concentration and temperature. Three equations, the power-law, the Carreau and the Allen-Uhlherr have been used to describe the viscosity-shear rate data.

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