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EFFECT OF COAL BENEFICIATION PROCESS ON RHEOLOGY/ATOMIZATION OF COAL WATER SLURRIES.

Quarterly Progress Report
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OVERALL OBJECTIVE:

The overall objective of this project is to perform experiments to understand the effect of coal beneficiation processes and high shear rheological properties on the atomization of coal-water slurries (CWS). In the atomization studies, the mean drop size of the CWS sprays will be determined at various air-to CWS. A correlation between the high shear rheological properties, particle size distributions and the atomization will be made in order to determine the influence of these parameters on the atomization of CWS.

PROJECT STATUS:

Rheological properties of the samples received as described in the previous quarter were determined. Rheological evaluations made include:

(A) Flow characteristics under low shear rates

(B) Flow Characteristics under high shear rates

(C) Viscoelastic behavior under low frequency of oscillation

In order to gain further understanding of the effect of stabilizers on the rheological properties of the slurries and beneficiation effect on atomization, rheological properties of simulated fluids were also carried out.

RESULTS

Conventional rheological evaluation of Coal-Water Slurries by steady shear flow measurements and specifications of plastic viscosity and yield stress, have provided a strong technical base for preparing and controlling the stability of CWS [1,2,3]. These specifications fail to provide complete insight into the CWS properties that control the flow properties and those necessary for their subsequent atomization [4,5]. This is because steady flow measurements reveal only the viscous, energy dissipative effects in the CWS flow for very long shearing time and with constantly increasing deformation.

Shear deformation of CWS suspensions produces a very significant elastic energy storage in addition to the viscous energy dissipation. Consequently, both the viscous and elastic properties of the CWS must be evaluated in order to gain a complete understanding of their interactive behavior.

Viscoelastic Behavior

Viscoelastic properties can be exhibited in systems which have internal structure. These properties could affect the stability and fuel breakup of ligaments upon exiting a nozzle or orifice [6]. The linear viscoelasticity can be measured by subjecting the sample through a small amplitude oscillatory test. For a system where the strain varies sinusoidally with time, t, The strain amplitude can be given by:

$$\gamma(t) = \gamma_{max} \mathrm{Sin}\,\omega t \qquad (1)$$

where γ_{max} is the maximum strain amplitude and ω is the angular frequency of oscillation [7]. The corresponding stress is given by

$$\tau(t) = \tau_{max} \mathrm{Sin}(\omega t + \delta) \qquad (2)$$

where δ is the phase shift between stress and strain.

The above equation, (2), can be re-written as:

$$\tau(t) = \gamma_{max}(G'\sin\omega t + G'' \cos \omega t) \qquad (3)$$

The storage modulus, G' and the loss modulus, G" are defined in terms of the phase angles as:

$$G' = (\tau_{max} \operatorname{Cos}\delta)/\tau_{max} \qquad (4)$$

$$G'' = (\tau_{max} \operatorname{Sin}\delta)/\tau_{max} \qquad (5)$$

The storage modulus G' represents the "stored' or elastic component of the stress and is in phase with the strain. The loss modulus, G", represents the viscous component and it is the out of phase component.

For a fluid that is purely viscous, G' is zero and the phase is 90° and for a purely elastic material where energy is stored but not dissipated, G"is zero and the phase is 0° [8].

The use of complex numbers greatly facilitates the manipulation of the viscoelastic function. The advantage is that no reference need be made as to the mechanism of damping, or to a particular experimental method.

Thus, equations (1) and (2) can be re-written as

$$\gamma^* = \gamma_{max}e^{i\omega t} \qquad (6)$$

$$\tau^* = \tau_{max}e^{i(\omega t + c)} \qquad (7)$$

The viscoelastic properties were measured using Haake RV20-CV20 and a Q45 sensor system. This system is integrated with an IBM/PS2 which allows for data acquisition and evaluation.

Figure 1 compares the storage modulus of the four samples: Uncleaned coal slurry, Heavy media Cleaned slurry, Floatation cleaned slurry and 0.1% Xantham gum solution. The plot shows that the uncleaned coal slurry has a much more elastic component than the rest of the samples examined. The cleaned samples however, have a lesser elastic component than xantham gum solution. This indicates that the cleaning process minimizes the elastic component of the slurries. The plot also shows that the xantham gum is fully cross-linked since $G'(\omega) \neq 0$ as $\omega \rightarrow 0$. However, at low frequencies(ω), $G(\omega) \rightarrow 0$ rapidly for the uncleaned slurry compared to the two cleaned slurries. Both low and high shear measurements (Figures 2-7) indicate that the uncleaned slurry show a larger deviation from Newtonian behavior than the cleaned samples.Figure 2 shows that the complex viscosity for the uncleaned slurry is higher than the two cleaned slurry samples. Further measurements are being made to ascertain these differences.

High Shear Rheology

In a capillary flow, CWS rheology can be adequately described by a power law model:

$$\tau = K \gamma^n \qquad (8)$$

where τ = shear stress

γ = shear rate

K = consistency index

n = power law index

n = 1 for Newtonian

n > 1 dilatant fluids

n < 1 for pseudoplastic fluids

HVA-6 Capillary Viscometer was used to determine the high shear rheological properties. The HVA 6 automated high shear capillary viscometer permits measurements from medium up to high shear rates ($D=10^2$ to 10^6 S^{-1}). A capillary of diameter 0.8mm and length 100 mm was used in these measurements. The sample to be measured is forced through a capillary at definite pre-adjusted pressure and pressed into a burette where volume measurement takes place. Figure 3 shows a high shear flow behavior of: 63% CWS uncleaned, floatation, and heavy media cleaned slurries. Each of these slurries contain xantham gum as a stabilizer. Rheological analysis shows that the heavy media and the floatation cleaned slurries show a lesser deviation from Newtonian behavior (n=1.052 and 1.089 respectively) than the uncleaned slurries (n=1.12).

A low shear flow behavior of the coal slurries using Haake RV20 and an MV3 sensor is as shown in Figures 4-6. Also the effect of 0.1 % Xantham Gum solution on the flow behavior of Glycerol is shown in Figures 6-7. Rheological evaluations of the low shear flow behavior (Figures 4-5) show that the cleaned coal samples show a lesser deviation from Newtonian behavior (n=1.08 and 1.165) than the uncleaned samples (n=1.46). Also, rheological analysis shows that the addition of the xantham gum solution to the glycerol changes the flow behavior from Newtonian to dilatant (n=0.99 and 1.18 respectively).

The flow behaviors observed in Figures 7 and 8 thus indicate that the addition of the stabilizer has a significant effect on the flow behavior. Experiments are currently being performed to determine the optimum amount of the stabilizer to be added to the slurries.

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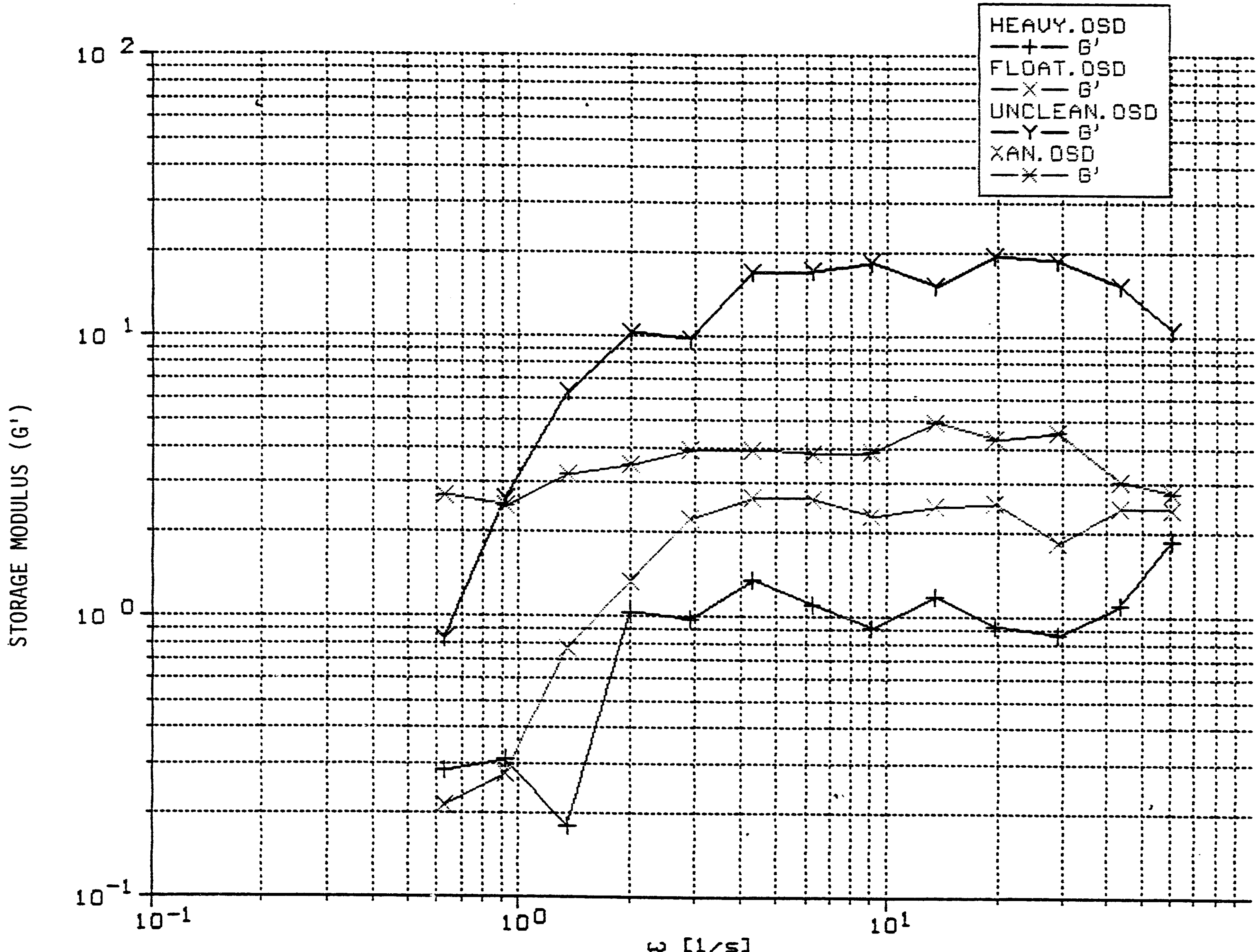

Figure 1. Storage Modulus as a Function of Frequency.

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Sensor system : Q45	System : CV20	

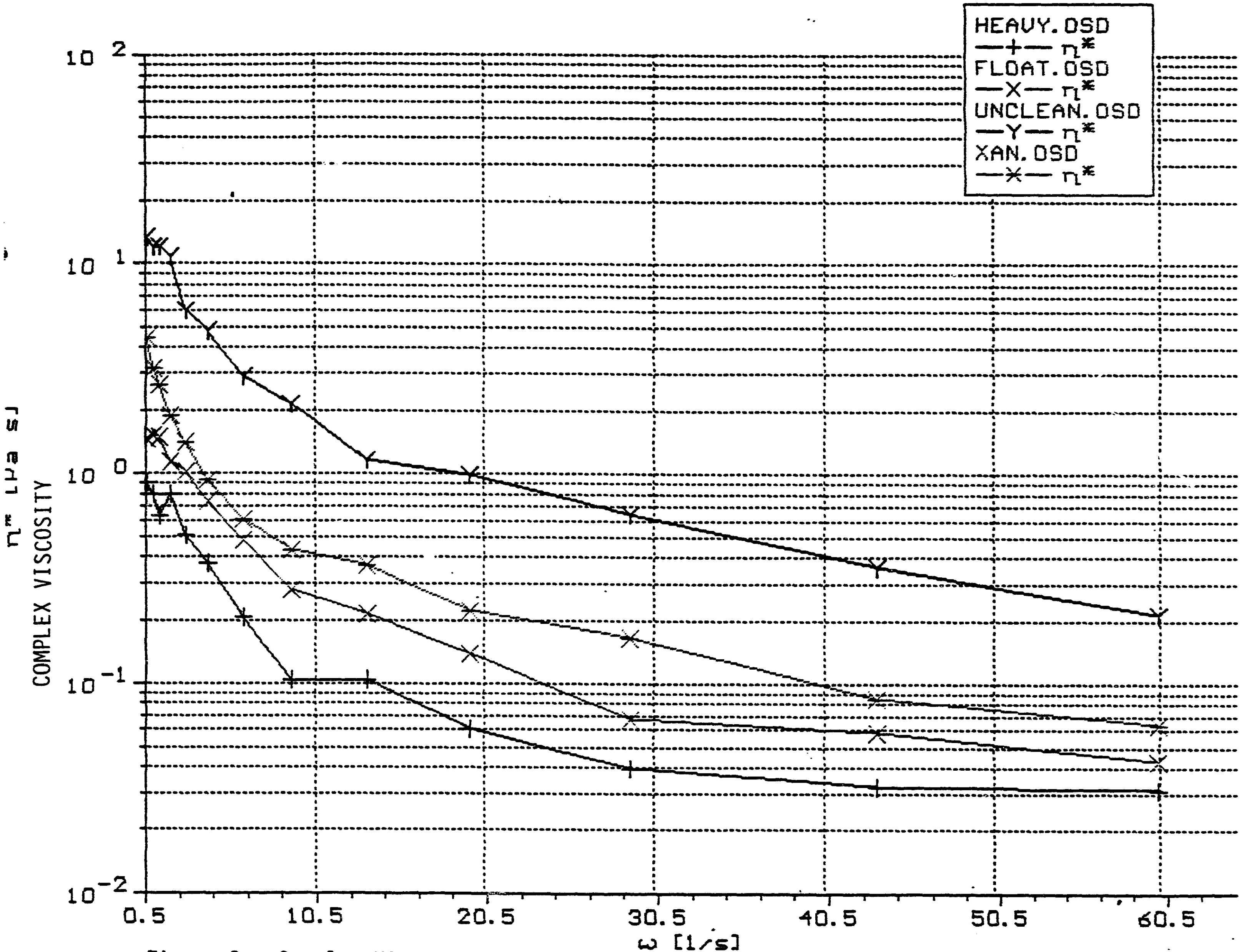

Figure 2. Complex Viscosity as a Function of Frequency.

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Figure 3. High Shear Flow Behavior of CWS.

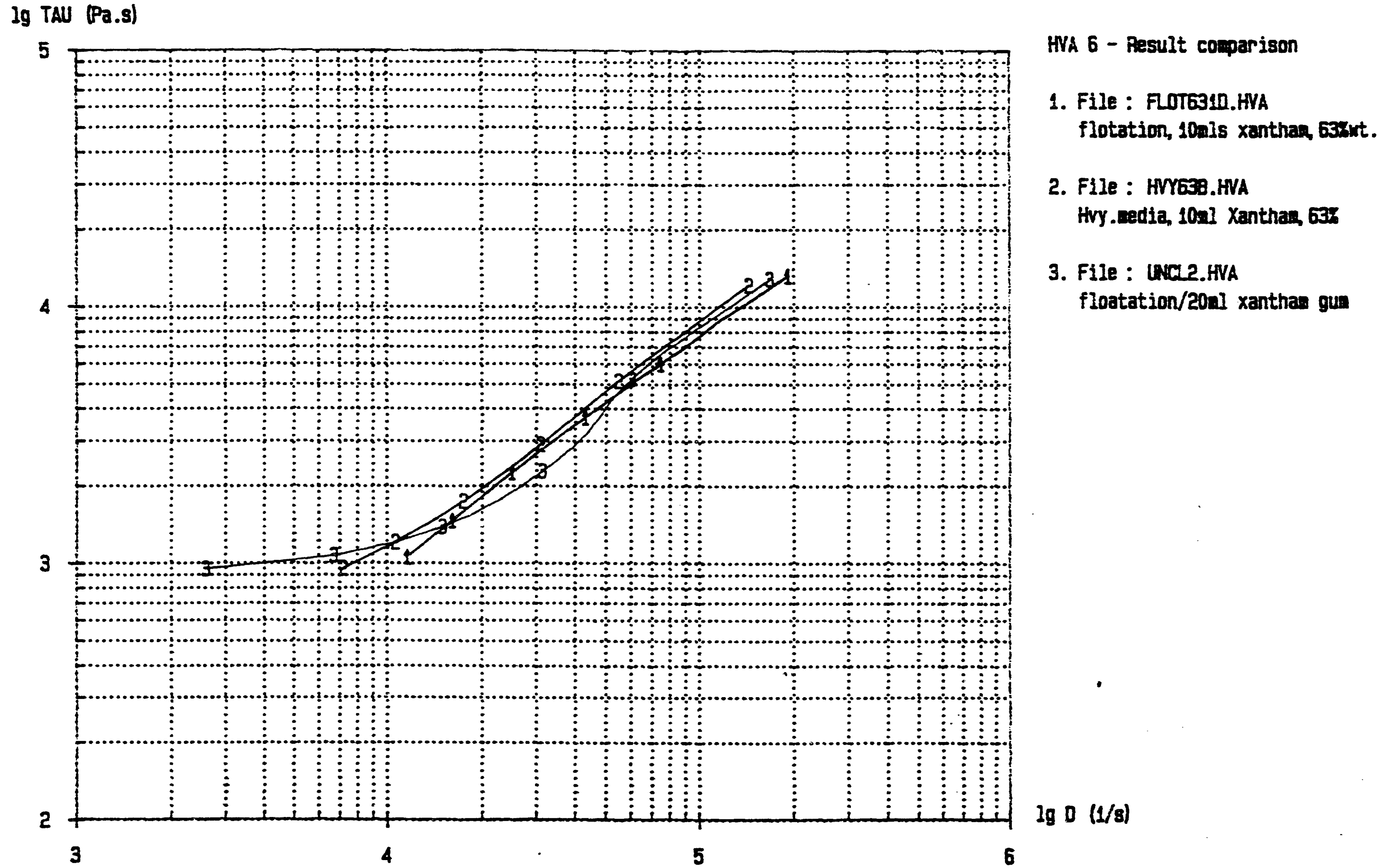


Figure 4. Low Shear Flow Behavior of Floatation Cleaned CWS.

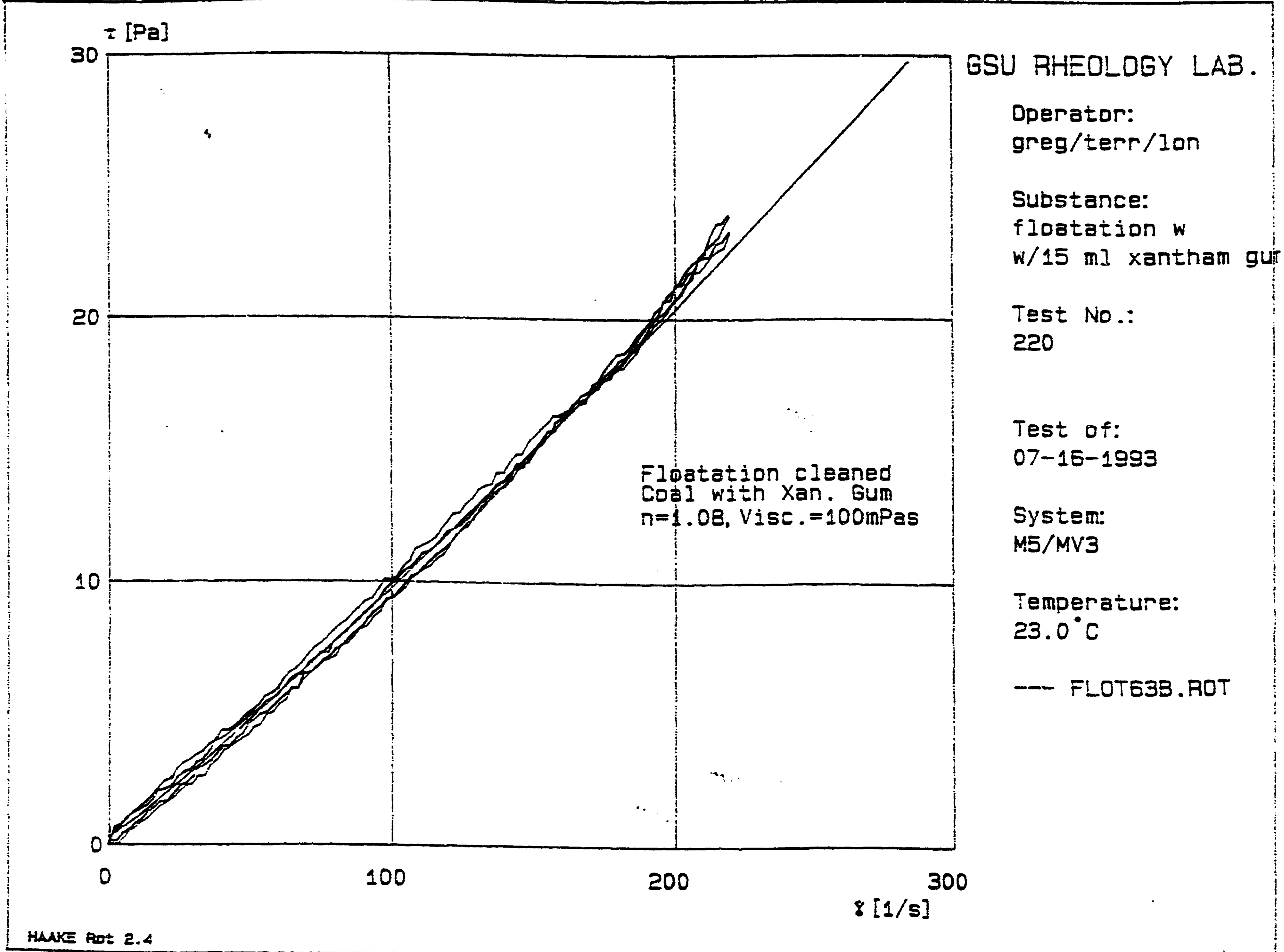


Figure 5. Low Shear Flow Behavior of Heavy Media CWS.

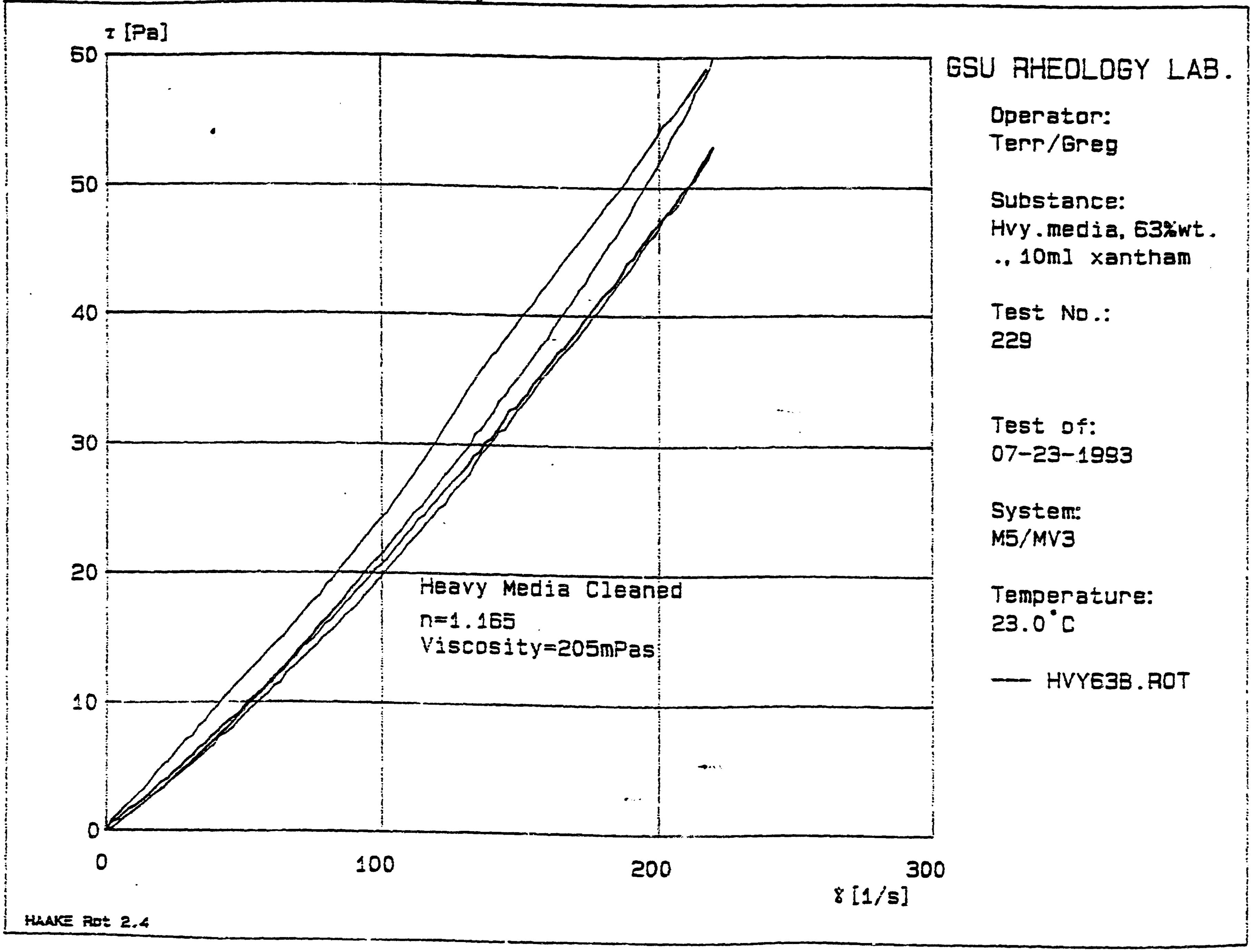


Figure 6. Low Shear Flow Behavior of Uncleaned CWS.

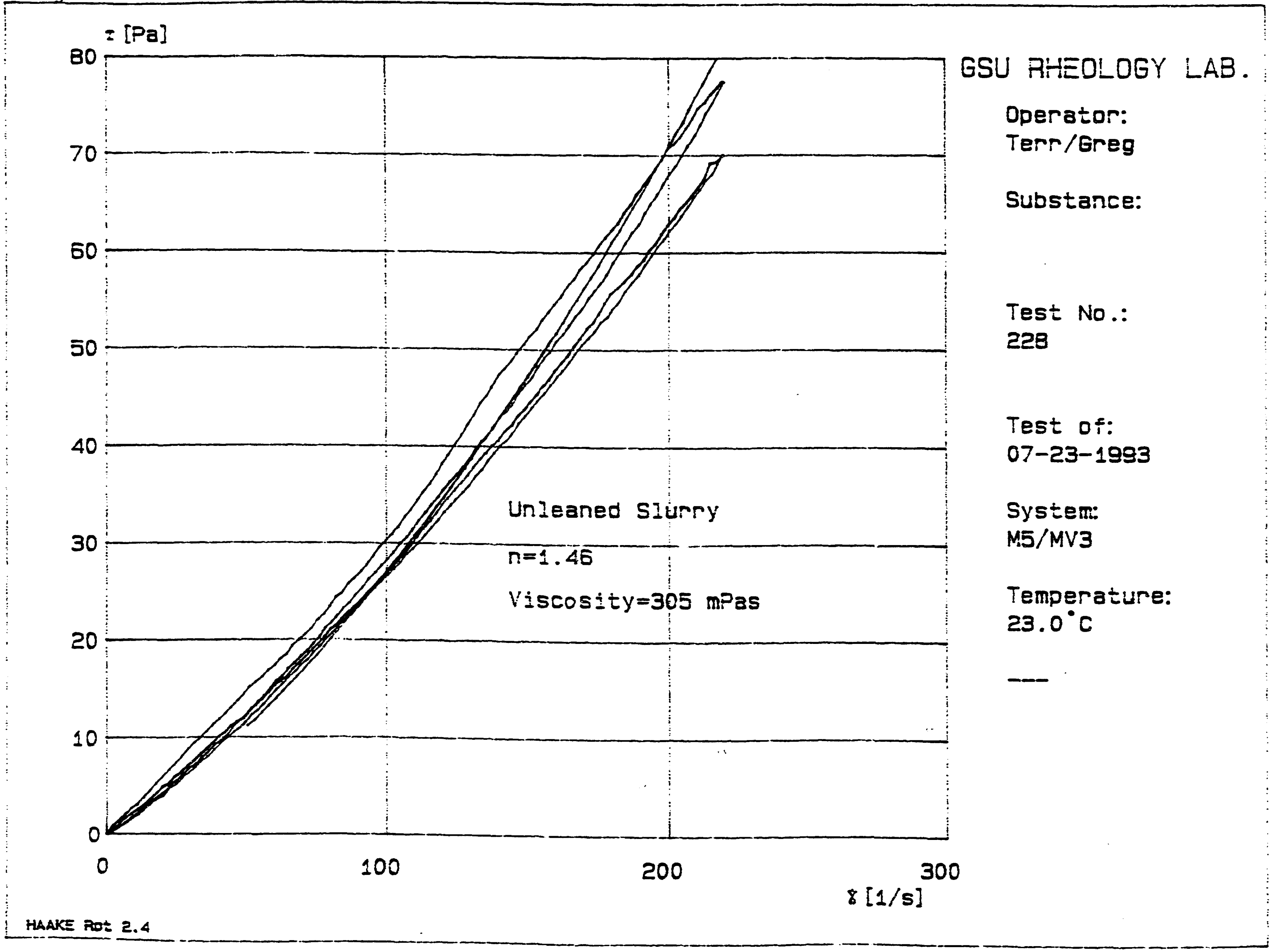


Figure 7. Flow Behavior of Glycerol.

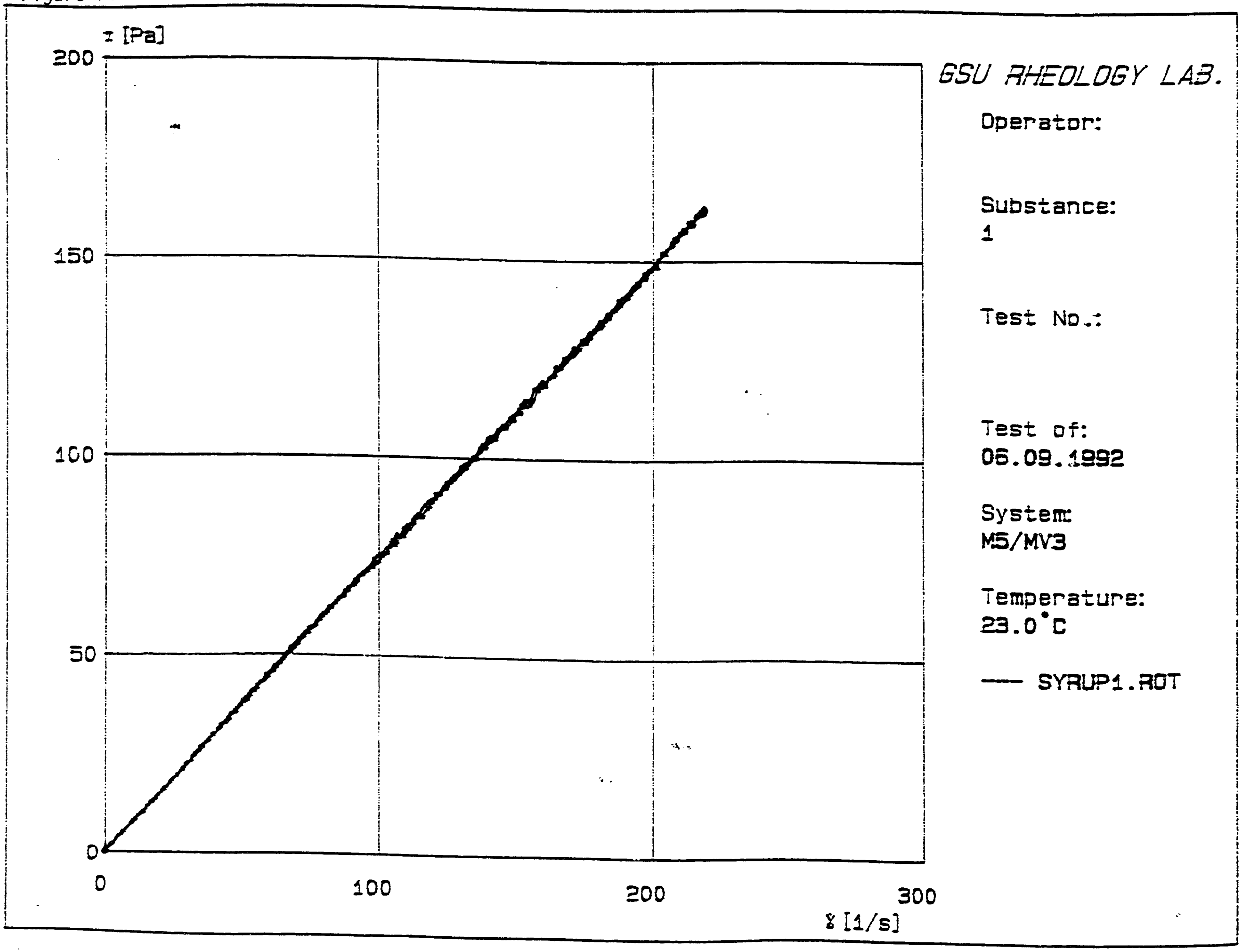
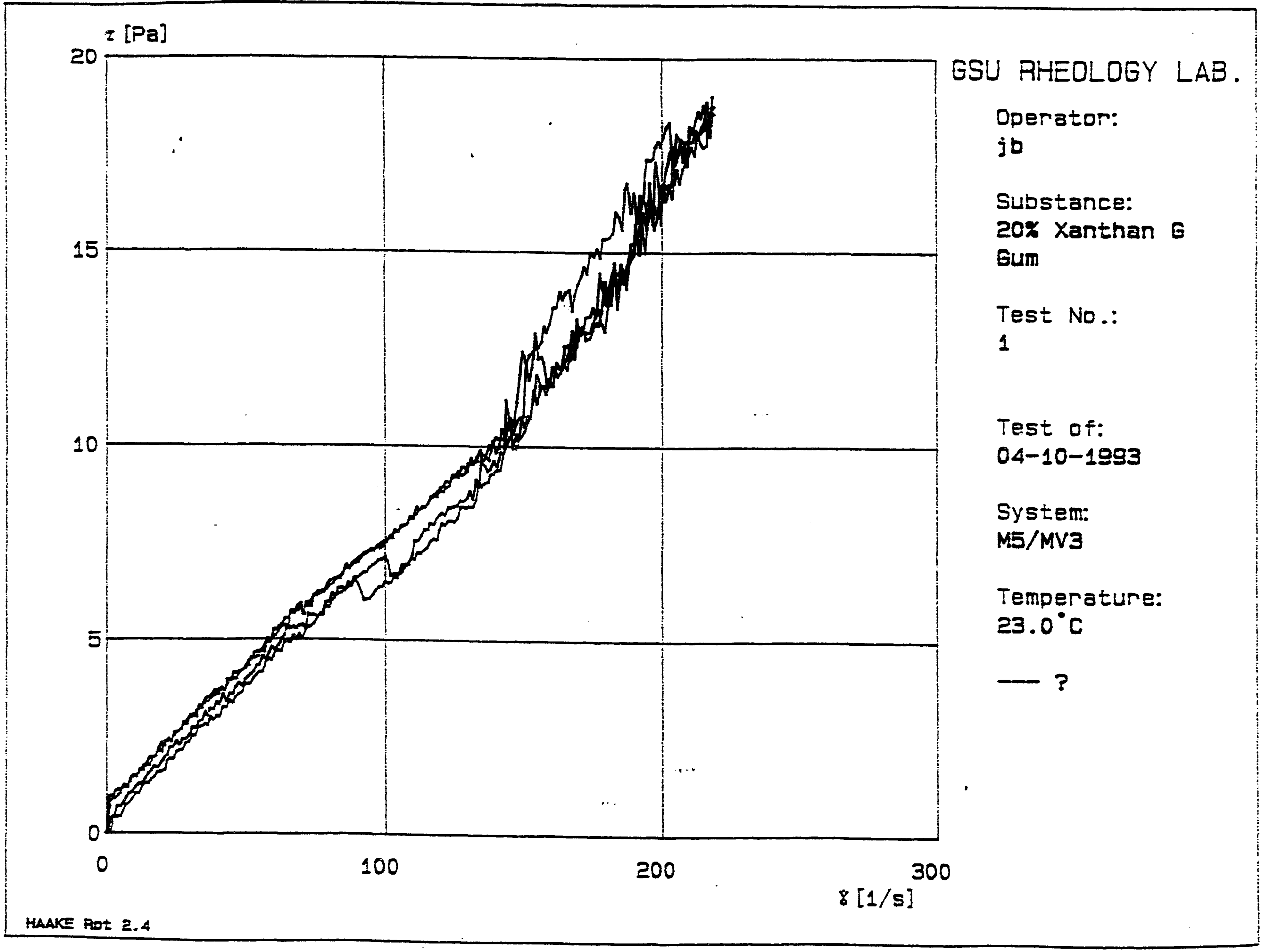


Figure 8. Flow Behavior of 80% Glycerol in 0.1% Xanthum Gum.



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