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Cryogenic Gel Flow Viscometer

The problem:
To measure the viscous properties of gelled cryogenic propellants under conditions closely resembling flow in rocket engine systems.

The solution:
A coiled section of tubing immersed in the gel propellant.

How it's done:
The viscometer consists of ⅜-inch copper tubing (diameter about 1 cm) coiled to fit inside a glass gelling vessel. The coil diameter is about 100 mm and the total length of the tubing is 179.5 cm. The inlet to the coil is in the form of an inverted J with the entrance near the bottom of the glass gelling vessel. The position of the entrance permits the major portion of the gel to be used for the measurement; it also minimizes coring. Near the entrance to the coil is positioned a small tube which injects helium into the viscometer tubing. The helium is cooled by passing it through a coil of ⅛-inch tubing (diameter about 0.3 cm) which also is immersed in the gel. The injection of helium prevents the gel from filling the viscometer tube while the gel is being prepared in the gelling vessel; thus, there is no need for a valve in the flow system.

The inverted-J inlet section of tubing is followed by the coiled section containing the major portion of the total length of tubing, and this is followed by a straight outlet section which returns to the bottom of the coils and extends through the bottom of the glass gelling vessel by means of a ball-socket joint (glass to stainless steel).

Two parameters are measured during an experiment with a flow viscometer: the ΔP across the tubing and the flow rate. The parameters are plotted in the form of $D\Delta P/4L$ versus $8V/D$, where D is the diameter of the tubing, L is the effective length of the tubing, and V is the velocity at which the gel is transferred through the tubing. The velocity is calculated from the measured flow rate. The term $D\Delta P/4L$ is commonly known as the shear stress, and the term $8V/D$ is the shear rate. The ratio of shear stress divided by the shear rate is the viscosity of the fluid at that particular shear rate. The plot of the $D\Delta P/4L$ versus $8V/D$ produces a curve which is called the "characteristic flow curve" for the fluid being tested.

The method of data presentation, i.e., the characteristic flow curve, provides data necessary for the design of prototype hardware systems using the liquid or gel of interest. For example, in the region of laminar flow, if the flow rate and the diameter and length of the pipe are known, the pressure drop which will occur can be determined from the curve. Alternatively, by selection of a pressure drop value for a length of pipe and flow rate, the required diameter of pipe can be calculated. Further, because the curve provides the viscosity value of the liquid over a range of shear rates, the Reynolds number can be calculated for the liquid at various flow conditions. Experimentally, the turbulent mode of flow can be determined by increasing the flow rate until the data display a sharp departure from a smooth laminar-flow curve. If the flow measurements are repeated with another size of tubing and the flow rate

(continued overleaf)

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is again increased until the turbulent mode is reached, the point at which the transition from laminar to turbulent flow occurs can be calculated from the data for any size piping and flow rate. The turbulent flow properties as represented by branches from the laminar flow curve can be used for system design in the same manner as the data available in the laminar region of the curve.

The only value which is not directly obtainable is L, the effective length of the tubing, because flow in coils or bends encounters an additional resistance over flow in straight tubing. In the laminar region the effective length may be calculated from the expression, $L = D^2 \Delta P / 32 \eta V$, using a fluid of known viscosity. In the turbulent region, L is calculated from the conventional empirical relationships for turbulent fluid flow.

Reference:

Globus, R. H.; and Vander Wall, E. M.: System Analysis of Gelled Space-Storable Propellants. Proc. AIAA 6th Propulsion Joint Specialist Conference, June 15-19, 1970, San Diego, California.

Note:

No other documentation is available. Specific questions, however, may be directed to:

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No patent action is contemplated by NASA.

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