UNCLASSIFIED

OAK RIDGE NATIONAL LABORATORY

Operated By

UNION CARBIDE NUCLEAR COMPANY

UCCPOST OFFICE BOX X
OAK RIDGE, TENNESSEE

EXTERNAL TRANSMITTAL AUTHORIZED

ORNL
CENTRAL FILES NUMBERCF-57-4-97

DATE: April 10, 1957

COPY NO. 34

SUBJECT: THORIUM OXIDE SLURRY FALLING BALL VISCOMETER -
FINAL CO-OP REPORT, WINTER, 1957

TO: D. E. Ferguson

FROM: P. E. Novak

DISTRIBUTION

1. D. E. Ferguson
2. J. C. Bresee
3. F. R. Bruce
4. F. L. Culler
5. N. A. Krohn
6. J. T. Long
- 7-21. J. P. McBride
22. P. E. Novak
23. E. O. Nurmi
24. Dept. of Industrial Relations
Northwestern Technological Institute
Evanston, Illinois
25. Laboratory Records (RC)
- 26-27. Laboratory Records
- 28-42. TISE, AEC

NOTICE

This document contains information of a preliminary nature and was prepared primarily for internal use at the Oak Ridge National Laboratory. It is subject to revision or correction and therefore does not represent a final report.

UNCLASSIFIED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

- A. Makes any warranty or representation, express or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or
- B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission to the extent that such employee or contractor prepares, handles or distributes, or provides access to, any information pursuant to his employment or contract with the Commission.

SUMMARY

A falling ball viscometer under development at ORNL, employing a flow system and an electromagnetically operated dash-pot pump, was evaluated for possible use with aqueous ThO_2 slurry systems under reactor irradiation. Interchangeable check valve inserts were designed and fabricated to investigate several pump designs. Magnetic flux concentrations which originally prevented circulation of the ferritic stainless steel viscometer ball through the electromagnetic pump were eliminated by substitution of iron-magnetic stainless steel inserts.

Viscosity was correlated through a logarithmic plot of the dimensionless Reynolds number vs Froude number with the ratio of ball diameter to tube diameter as a parameter. The relation is linear in the laminar flow region.

Viscometer development was assigned as a co-op student project.

INTRODUCTION

Several of the present and proposed aqueous homogeneous reactor designs utilize ThO_2 slurries as blanket material. It is necessary in designing these systems to know that the slurry properties are not impaired by radiation to the extent that ordinary engineering equipment becomes infeasible or uneconomical. It is, therefore, desirable to carry out small scale slurry experiments in-pile for the purpose of measuring slurry properties while under reactor irradiation. Studies have been made on both settled and agitated slurries in in-pile bombs to determine the effect of irradiation on slurries at these conditions.¹ It would also be highly desirable to study slurries in a small in-pile dynamic system to obtain data on the effect of irradiation on viscosity, particle degradation, and other kinetic and radiolytic aspects of the system. Presented here is a summary of the initial phase of the laboratory evaluation of a small scale falling ball viscometer under development at ORNL² to circulate aqueous ThO_2 slurry and fit in a

mock MTR type fuel element. This device would operate principally as an in-pile slurry viscometer and its contents could be removed and evaluated in post-irradiation studies.

A brief evaluation of a three-month co-op period assignment to the Chemical Development Section of the Chemical Technology Division is also presented from the point of view of a Northwestern University senior in his sixth co-op period in the Division.

APPARATUS

The falling ball viscometer consisted of a stainless steel loop containing an electromagnetically operated dash-pot pump capable of circulating ThO_2 slurry and a small (approximately 0.050 in. dia.) magnetic stainless steel ball. Viscosity measurements were made by momentarily stopping the pump and allowing the ball to drop in free fall through the slurry. The time of drop between two fixed sensing coils was electronically detected and recorded.

The viscometer, shown in Fig. 1 attached to the sensing equipment, was approximately 40 in. high and had a maximum width of 2-5/8 in. The dimensions of this model allow it to be inserted into a mock MTR type fuel element. The magnetic pump located in the lower part of the loop pumps downward and thus slurry circulated from the pressurizer to the top of the pump, through the pump, and returned to the pressurizer.

The diameter of the up tube was such that a sufficient liquid velocity was easily maintained to circulate the small steel ball required for the viscosity measurement. Check valve clearances allowed the ball to pass freely through the pump. The magnetic pump power supply (Fig. 2) was the same type unit used to stir the dash-pot irradiation bombs.¹

Photo-40208
UNCLASSIFIED

Fig. 1 Falling Ball Viscometer Attached to
Drop Time Recording Instrument

Photo-16508
UNCLASSIFIED

Fig. 2 Power Supply and Instruments for Operating
Falling Ball Viscometer

EXPERIMENTAL

Equipment Evaluation

The original viscometer design (Fig. 3) required that the top end piece of the plunger be machined into the plunger body of 410 stainless steel. This provided a sharp zone of magnetic flux concentration which consistently attracted and held the ferritic stainless steel viscometer ball, thus making the viscometer inoperable.

The holdup of the steel ball on the plunger was determined as follows: Several of the viscometer balls (approximately 0.050 in. dia.) were irradiated for one week in the X-10 graphite pile. After a reasonable decay period these balls read approximately 5 mr/hr on contact. One of these balls was operated in the viscometer. When the ball ceased to circulate, the apparatus was probed with a geiger counter. The ball was consistently located on the top of the plunger and would not dislodge during operation of the pump.

To eliminate the magnetic flux concentration on the integrally machined plunger end piece, a separate 347 stainless steel end piece insert was fabricated to screw into the plunger body. The insert was held in place with a special locking ring.

Figure 3 also shows the location of parachute check valves in the top of the plunger and the bottom of the 410 stainless steel plunger. The parachute check valves were found to be unsatisfactory for water and silicone oil systems due to excessive hydraulic instability and jamming.

Greater versatility in check valve design was achieved by designing and fabricating various interchangeable check valve inserts that would also screw into place and lock with rings or pins. Figure 4 shows the disassembled magnetic pump with the plunger removed. Shown also are the three interchangeable check valves and the special locking ring.

7

D-25692
UNCLASSIFIED

Fig. 3 Falling Ball Viscometer Loop Assembly

Photo-40206
UNCLASSIFIED

Fig. 4 Disassembled Magnetic Pump and Plunger with Valve Inserts

Figure 5 shows the upper check valve assembly. The tubular plunger stop fits over the valve insert and also the end of the drop tube assembly. The locking pin holds the plunger stop in place and prevents the valve insert from unscrewing. One of the electronic sensing coils may be seen above the valve assembly.

Viscosity Measurements

Systems of water and of 50 centistoke silicone oil were evaluated to calibrate the viscometer. Low viscosity oil systems were obtained by insulating and heating the apparatus. Initial techniques magnetically arrested the viscometer ball in the pressurizer. The ball was released after the pump was turned off and the time of fall between two sensing coils, located 10 inches apart, was recorded on a Sanborn model 127 recorder.

The modified viscometer required a new viscosity determination technique resulting from the fact that the increased fluid circulation rates realized with the new check valves made the magnetic arrest of the ball difficult. The new technique consisted of interrupting the pump operation as the ball passed through the pressurizer. The ball then fell freely through the drop tube. At present the pump interruption is accomplished by trial and error timing. Future determinations may be made by locating a detection coil at the pressurizer inlet, the signal from this coil stopping the pump and allowing the ball to free fall through the detection zone.

VISCOSITY CORRELATIONS

Since laminar flow conditions are not present in all of the systems under investigation, Stoke's law does not apply simply to viscosity calculations. However, a promising relationship that may be applied to the systems under study involves a logarithmic plot of Reynolds number vs Froude number with the ratio of ball diameter to tube diameter as a

Photo-40207
UNCLASSIFIED

Fig. 5 Upper Check Valve Assembly with Valve Inserts

parameter.³ The above relation is linear for laminar flow (see Fig. 6). As turbulence is approached, the slope increases. An empirical curve of the type in Fig. 6 may be necessary for the final viscometer calibration.

The in-pile falling ball data will be useful to evaluate relative changes in slurry properties under irradiation, although the limitations of single shear rate viscosity determinations on non-Newtonian slurries are fully realized.

PROPOSED STUDIES

Since the modified viscometer has only recently been received, development will be required to make the present model applicable for in-pile use.

1. The water and silicone oil systems should be investigated through a continuous viscosity range from 0.16 centipose to 45 centipoises to insure that the curve type shown in Fig. 6 is a continuous function of viscosity.

2. It may be advantageous to investigate a few viscosities obtained with a glycerol-water mixture to determine any dependence of viscosity upon composition.

3. The optimum check valve must be selected for slurry operation. It may be possible that different valves will be required for different slurry materials.

4. The detection coil suggested for automatic viscosity measurement must be optimally located so that the slurry will reach quiescence before measurement and yet will not settle appreciably.

PERSONAL CO-OP EVALUATION

This quarter's cooperative work assignment to the Chemical Development Section of the Chemical Technology Division was interesting and

Fig. 6 Viscosity Correlation by Dimensionless Groups

informative. Evaluation and development of the falling ball viscometer was specifically assigned and freedom was allowed to follow the problem for the full period.

The opportunity was presented to inquire into all of the programs under study in the Chemical Development Section. This gave a broad opportunity to see the initial development of various new processes and continued research on present schemes.

Many new and interesting facilities were visited in the Oak Ridge vicinity on the regularly scheduled bi-weekly co-op tours sponsored by the Chemical Technology Division. Weekly written reports and bi-weekly co-op seminars were also provided to acquaint the student with the various research programs under study.

The effort put forth by the Division to provide a versatile, challenging, and interesting co-op program for the last three years is greatly appreciated and has contributed greatly to the growth of the students engaged in the program.

APPENDIX

Sample Viscosity Calculation

The following calculation was made to determine the linearity of the Reynolds number vs the Froude number relation in the laminar region. Thus the known viscosity is inserted in the equation to determine the point. The inverse procedure would be followed to determine viscosity from a known curve.

$$\text{Reynolds number} = \frac{d v (\rho - \rho^1)}{\mu}$$

$$\text{Froude number} = \frac{v^2}{dg}$$

diameter of ball = 0.119 cm

diameter of tube = 0.624 cm $d/D = 0.191$

drop time/25.4 cm = 2.39 sec at 40°C = 10.6 cm/sec

density of ball = 7.65 gm/cm³

density of oil = 0.95 gm/cm³

viscosity of oil = 36 centipoises

$$\text{Reynolds' number} = \frac{0.119(10.6)(7.65-0.95)}{0.36} = 23$$

$$\text{Froude number} = \frac{(10.6)^2}{(0.119)(980)} = 0.96$$

REFERENCES

1. N. A. Krohn, J. P. McBride, "Reactor Irradiation of Thorium and Uranium Oxide Slurries," ORNL-CF-57-1-119, January 29, 1957; paper delivered at first winter meeting of American Nuclear Society, Washington, D. C., December, 1956.
2. Homogeneous Reactor Project Quarterly Progress Report, ORNL-2148, p 124, July 31, 1956.
3. A. J. McNeil, Jr., "Wall Correction for the Falling Sphere Viscometer," M.S. Thesis, Georgia Institute of Technology, July, 1956.