OAK RIDGE NATIONAL LABORATORY
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POST OFFICE BOX P
OAK RIDGE, TENNESSEE

ORNL
CENTRAL FILES NUMBER

CF-52-10-134

COPY NO. 1-A

DATE: October 21, 1952

SUBJECT: **HYDRODYNAMIC STUDIES IN THREE GLASS MODELS**

TO: C. B. Graham

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Photostat Price \$ 3.30

Microfilm Price \$ 2.40

Available from the
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DATE: 2-3-56

For The Atomic Energy Commission

Chief, Dept.

Classification Changed to: Unclassified

Authorized by: R.R. Cochran 2/3/56

Changed by: H. Kinsler

Date 7-25-13

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October 21, 1952

As an initial attempt to select a second core for study on an intermediate (8') scale, studies of flow pattern, pressure drop, mixing, and gas holdup were conducted in small glass models of possible core configurations. These models, geometrically similar to a 15' reactor operating at a power density of 20-40 kw/l with a limiting inlet velocity of 20 ft./sec., were chosen to examine the characteristics of a well mixed type flow and the possibility of modifying rotational flow to reduce the pressure drop. Flow pattern and gas holdup determinations were on a purely qualitative basis, while measurements of mixing and overall pressure drop were of a semi-quantitative nature.

Visual observations and color motion pictures were utilized in an attempt to gain some qualitative idea of flow pattern and gas holdup. Methylene blue was used in the study of flow pattern and mixing. A Klett-Summerson photoelectric colorimeter was used to determine color concentrations in the mixing studies.

Fig. 1 is a sketch of Model I. It consisted of a 12" glass sphere with two 2.174" I.D. polar outlets and six 1.75" I.D. approximately radial inlets located at the equator. The inlets were offset approximately 2° from the radial and a slight amount of rotation was produced as a consequence of this. Flow within the sphere appeared to be quite turbulent and well mixed; no stagnation was observed with both outlets open. However, when either outlet was closed, a central stagnant region appeared in that hemisphere. Because of the rotation, a gas void aligned with the outlet pipes was formed. There appeared to be some slight amount of gas separation in the sphere itself; however, most of the gas seemed to be centrifuged out in the outlet pipes.

Pressure drop, corrected for the difference in inlet and outlet velocities, was of the order of 1.5 inlet velocity heads when all six inlets were being used, and approximately 2.5 inlet velocity heads when only three inlets were used.

Fig. 2 is a plot of the pressure drop data.

Mixing studies were conducted by injecting methylene blue into the inlet stream until a constant color density was attained at the outlet; at this point dye injection was stopped, and the outlet color density was measured at intervals to determine the concentration decay curves. The decay constants were determined graphically from semilog plots of these data and were found to approximate those calculated for a perfectly mixed system. Fig. 3 is a plot of these decay constants against flow rate for the tests run using all six inlets and both outlets. The straight line on the plot represents the theoretical values of these constants.

Fig. 4 is a sketch of Model II. It was a 12" diameter glass sphere with two 2.174" I.D. polar outlets, two 2.174" I.D. tangential inlets, and two 2.174" I.D. radial inlets. This model represents a hybrid of the rotational type core and the well mixed type as typified by Model I.

Flow in this model did not appear to be as turbulent or well mixed as in Model II, but the flow did have a much stronger rotational component. No stagnation was apparent with both outlets open; however, when one outlet was closed a central stagnant region appeared in that hemisphere.

Gas separation within the sphere itself appeared to be good; the gas void formed seemed to be fairly stable, and the bubbles which were not removed within the sphere itself apparently were centrifuged into the void in the outlet pipe.

Pressure drop for this model was on the order of 10 inlet velocity heads when all four inlets and both outlets were in use. These data are plotted in Fig. 5.

Mixing studies were run in the same manner as before and the decay constants thus arrived at were approximately 50% greater in magnitude than those which would be predicted for a perfectly mixed system. This would seem to indicate that the slug flow component of this system is of the same order of magnitude as the mixing of the system. Fig. 6 is a plot of the decay constants for this system.

Fig. 7 is a sketch of Model III. It had one 3.25" I.D. polar inlet and four 2.174" I.D. outlets parallel to the axis and located in the same hemisphere.

Flow within this model appeared to be turbulent and fairly well mixed. No stagnant regions were found when operating with all four outlets open.

Using the central pipe as the inlet, and the four smaller pipes as outlets, gas bubbles were trapped at the bottom of the central jet. When the inlets and outlet were reversed, an unstable vortex (not aligned with the outlet pipe) was formed. For these reasons, this particular configuration would probably not be feasible for a reactor utilizing a fuel which exhibits any appreciable gas generation.

Experimental data on pressure drop for this model exhibited so much scattering that the only conclusion which could be drawn from it was that the pressure drop was small.

Mixing studies were conducted in the same manner as before, and the decay constants thus determined indicate that there is some slug flow component present in this system. Fig. 8 is a plot of these decay constants against flow rate.

Conclusions:

1. A configuration similar to that of Model I could probably be used to produce an essentially isothermal reactor with a reasonably low pressure drop. However, the equilibrium gas concentration in the core would be higher than in the rotational type core and the structure would be more complicated than the straight through type of core. There is the added possibility of offsetting the inlets slightly to produce enough rotation so that extension of the outlet pipes might provide for external gas separation.
2. Model II shows promise of a possible modification of the rotational type of core to reduce pressure drop while retaining the feature of lower gas holdup in the core. As in Model I, there is the possibility of extension of the outlet pipes to provide for the necessary external gas separation. The structural complications in this model also exceed those in a straight through type of core.
3. Although Model III is the simplest of the three structurally, it is the least satisfactory from the gas holdup standpoint. Since gas tends to stagnate in this core, this configuration is probably not feasible where any appreciable amount of gas is generated.
4. The temperature distribution in any of the three models would probably be reasonable.
5. Flow pattern, mixing, and pressure drop for these models can probably be scaled up directly to the 15' size.

L. B. Lesem

FIG. 1 FIG-1 MODEL I

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Drawing #16671

PRESSURE DROP IN FEET OF WATER

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PRESSURE DROP
IN MODEL NO. I

FIGURE 2

INLET VELOCITY IN FT./SEC.

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Drawing #16672

CONCENTRATION DECAY CONSTANTS

MODEL NO. 1

DECAY CONSTANT IN SEC.⁻¹

8-620

FLOW IN G.P.M.

THEORETICAL CURVE

FIGURE 3

FIG. 4 MODEL II

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FIGURE 5

Drawing 11664

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11-6679 DEAY CONSTANT IN SEC.⁻¹CONCENTRATION DECAY CONSTANTS
MODEL NO. II

THEORETICAL CURVE

FIGURE 6

Drawing #16675

FIG. 7

MODEL III

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Drawing #16677

CONCENTRATION DECAY CONSTANTS
FOR MODEL No. III

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