# THE FLOW CHARACTERISTICS OF COMMERCIAL POWDERED CATALYSTS

by

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# THE FLOW CHARACTERISTICS OF COMMERCIAL POWDERED CATALYSTS

## OBJECTIVE

The basic aim of this investigation was to study the frictional pressure drop in a flow system containing a powdered solid of the 'fluid catalyst' type, and to correlate it with other variables insofar as possible. The other variables considered were the velocity and density of the flowing material, the size of the flow tube, and the nature of the solid involved.

A more specific consideration was the possibility of amending the standard fluid flow formulas and methods of calculation so as to include the 'fluid' solid system. This would be desirable since the fluid flow formulas are already universally known and used.

Finally, it was hoped that these experiments would provide some data and general information on the behavior of solids in the fluidized state for the benefit of future investigators in the field. At present this type of data is not generally available.

## INTRODUCTION

The term 'fluid catalyst' is used in reference to a catalytic material which while in the form of a fine aereated powder is circulated through the process equipment in the manner of a true fluid. It differs from a gaseous suspension in that the density of the flowing material is much nearer to that of the packed solid than to that of the entrained gas.

The first use of the fluid catalyst technique on a commercial scale was in the field of petroleum refining, and there it has become of major importance. This type of operation is certain to find more widespread use in chemical industries in the future both in catalysis and as a means of treating solid materials. It is therefore desirable that information on the behavior of 'fluid' type solids be available as a basis for design calculations. Unfortunately no data have been published which would yield such information. The work that has been done in the course of building the petroleum catalytic units now operating has been entirely commercial and the results are not generally available.

# APPARATUS

The equipment used in this work consisted basically of two parts; a standpipe which served as a reservoir and provided a pressure head for the catalyst, and a glass tube through which the catalyst flow could be metered while the resulting pressure drop was measured.

The standpipe was formed from a section of standard 3 inch pipe mounted vertically with a conical sheet metal hopper at the top. At the lower end of the pipe, fittings reduced it to a 1/2 inch pipe from which a connection was made to the flow tube with a short length of rubber tubing. A side connection, also at the lower end of the 3 inch pipe, joined a 1/8 inch compressed air line. The hopper was 2 feet in diameter and 2 feet high, while the standpipe itself was 5 feet longer.

The flow tube consisted of a length of glass tubing with a pressure tap near each end. These pressure taps were side outlets of smaller diameter tubing which preserved the inside contours of the main tube as far as possible. A water manometer was used to measure the pressure differences. The catalyst was prevented from entering the manometer circuit by filter plugs of glass wool in the taps. Flow tubes having the following dimensions were used.

| Tube No | Inside Diameter | Length between Taps | Overall Length |
|---|---|---|---|
| 1 | 0.490 in | 46 in | 50 3/8 in |
| 2 | 0.369 in | 24 in | 30 1/4 in |
| 3 | 0.292 in | 24 3/8 in | 32 in |

The entire apparatus was placed vertically in the laboratory with the hopper extending above the next floor level. The standpipe was suspended from this (upper) floor while the flow tube was independently mounted in a wooden framework resting on the next floor below. Use of rubber tubing to connect the standpipe and flow tube permitted the regulation of the flow by means of a screw clamp.

The arrangement described here was the final result of many additions and modifications to the original apparatus. The major change involved the use of a vertical flow tube rather than a horizontal one. The latter was discarded due to the tendency of the catalyst to 'freeze' in the tube rather than flow at low velocities. Once the flow had thus stopped it was impossible to make it start again without first emptying the flow tube. A second difficulty was the stratification of the low density catalyst (that having a large air content) in the glass tube with resulting erratic behavior, particularly in manometer readings. On the other hand the use of a vertical tube made it necessary to correct the pressure drop as read on the manometer for the difference in static head between the two pressure taps.

The method of introducing the compressed air into the standpipe was the subject of some experimentation. It was found that an ordinary pipe connection to a side outlet tee was better than having the air pipe brought inside the 3 inch pipe as the latter method tended to obstruct the flow of catalyst and did not improve flow control.

Since measurement of the density of the <u>flowing</u> catalyst was very important several methods for doing this were considered. However, the only practical method found was the one used. In it the ends of the flow tube were closed simultaneously by pinching the rubber tubing connections at both ends. Then the trapped catalyst was collected and weighed.

Other changes in the apparatus were not of major importance but in most cases were the means of providing for more efficient and faster operation of the equipment. The apparatus is shown diagrammatically in Figure 1.

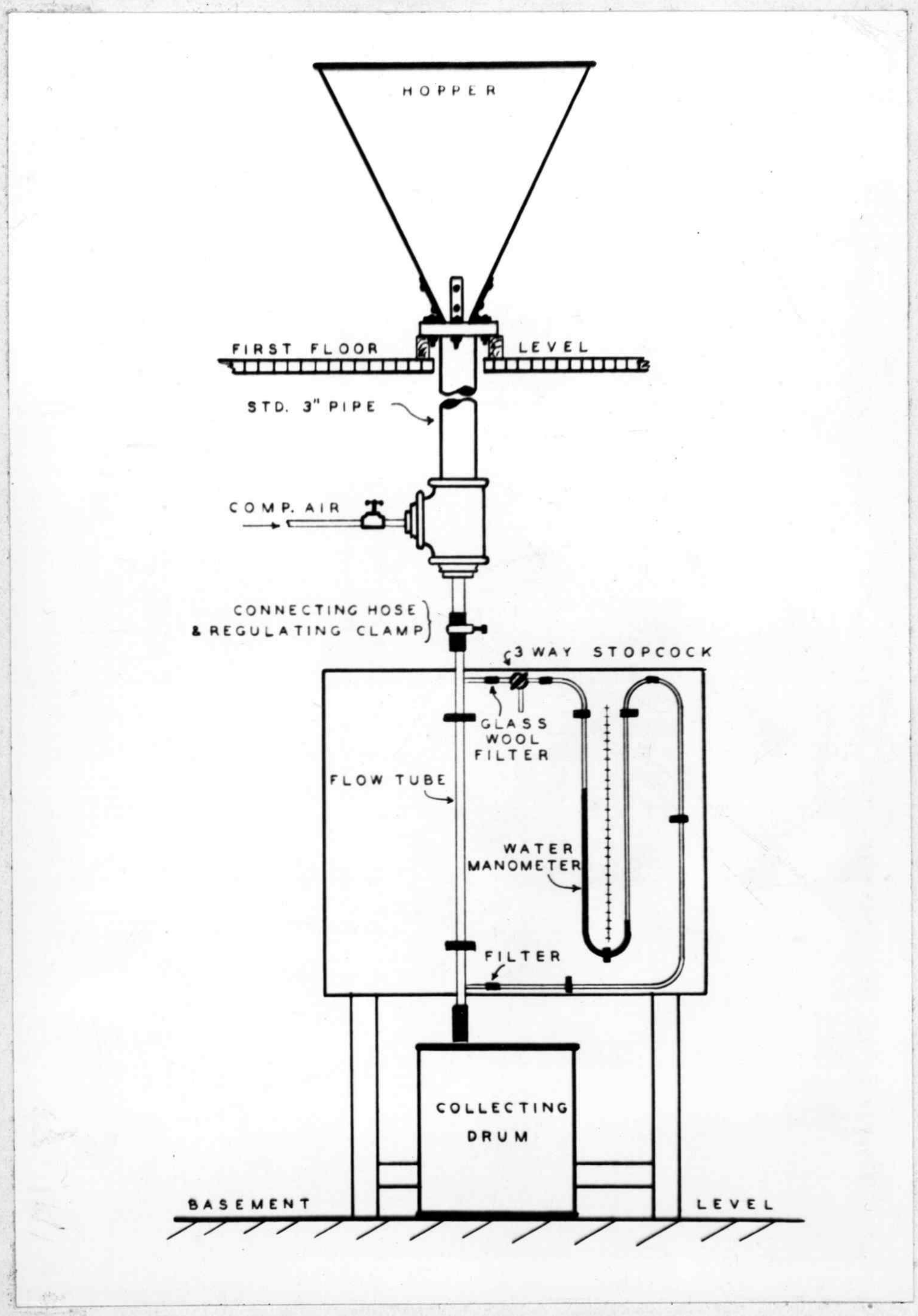


Figure 1

Diagram of Apparatus

## MATERIALS

Two fluid catalysts were used in these experiments. One is a refined form of a naturally occurring material and is sold for uses in commercial petroleum catalysis under the trade name Filtrol. The other, designated as Catalyst 3A by the manufacturing company, is a synthetic substance also used in petroleum refining. Both catalysts are hydrated aluminum silicates which have been ground to approximately the same degree of fineness (about 90 per cent through 100 mesh and 25 per cent smaller than 20 micron).

## TECHNIQUE

Measurements of catalyst flow were made with the hopper initially full of catalyst. During any individual run the change in the level of catalyst was negligible, and while the level was not the same for all runs no error was introduced thereby since only the pressure difference across the flow tube was considered.

To begin a run, the clamp at the adit of the flow tube was opened. Usually it was also necessary to open the valve on the air line to start the catalyst flowing. After the flow began the rate of flow was adjusted by the pinch clamp on the connecting tubing and the catalyst density regulated by the amount of air introduced. The degree of regulation provided by these controls was not high enough to permit the establishment of flow conditions at a definite preconceived point, but it did provide means for securing a range of flow variation over which the data could be obtained.

When a satisfactory flow had been established, the catalyst flowing during a measured time interval (usually 5-10 sec) was collected and weighed. At this time the manometer reading was noted. Immediately afterward the flow was arrested by simultaneously clamping shut the tubing connections on both ends of the flow tube. The material caught in the tube was removed and weighed. These four measurements provided the data for each run. The use of two catalysts and three flow tubes permitted observation of the effect of these factors on the flow.

## RESULTS

For purposes of correlation the data obtained from the experimental runs had to be converted into the variables being considered. The density was calculated first, and from it and the rate of flow the linear velocity could be computed. The values for the frictional pressure drop were obtained by correcting the manometer readings. This correction amounted to the static pressure exerted by a height of catalyst equal to the distance between pressure taps. In most cases this increment was so large that it changed the direction of the pressure difference (since it was subtracted). These conversions are illustrated by sample calculations in the Appendix.

The pressure correction mentioned here was established by the application of the Bernoulli theorem to the fluid catalyst system. To do this it was necessary to make some assumption as to the nature of the system. While it contains some gas it could not be expected to behave as a perfect gas since the solid material constitutes a large portion of the flowing catalyst. Neither is the material incompressible, but since this state probably is closer to the true one than is that of a perfect gas, non-compressibility was assumed. This introduced errors into any energy balance made on the system due to the simplification of all terms involving volume changes (including enthalpy changes since $H = \Delta[E + Pv]$), but these errors will be relatively small if the assumption of non-compressibility is approximately correct.[1]

The data were first tested to see if they could be correlated by means of the Fanning equation, using the Reynold's number relationship to obtain the friction factor.[2] The Fanning equation for the steady isothermal flow of liquids in circular pipes is

$$\Delta P = 2fLV^2/gD$$

where $\Delta P$ is the pressure loss, L the duct length, D the pipe diameter, V the velocity, g the acceleration of gravity, and f the dimensionless friction factor (the other quantities being expressed in consistent units). This friction factor has been empirically determined as a function of Reynold's number for true fluid systems. Reynold's number is the dimensionless group $DV\rho/\mu$, where $\rho$ is the density and $\mu$ the viscosity of the fluid.

Since these expressions contain the viscosity of the fluid and this quantity could not be measured for the catalyst, it was necessary to use an 'apparent viscosity' in checking the data. In practice the calculation was

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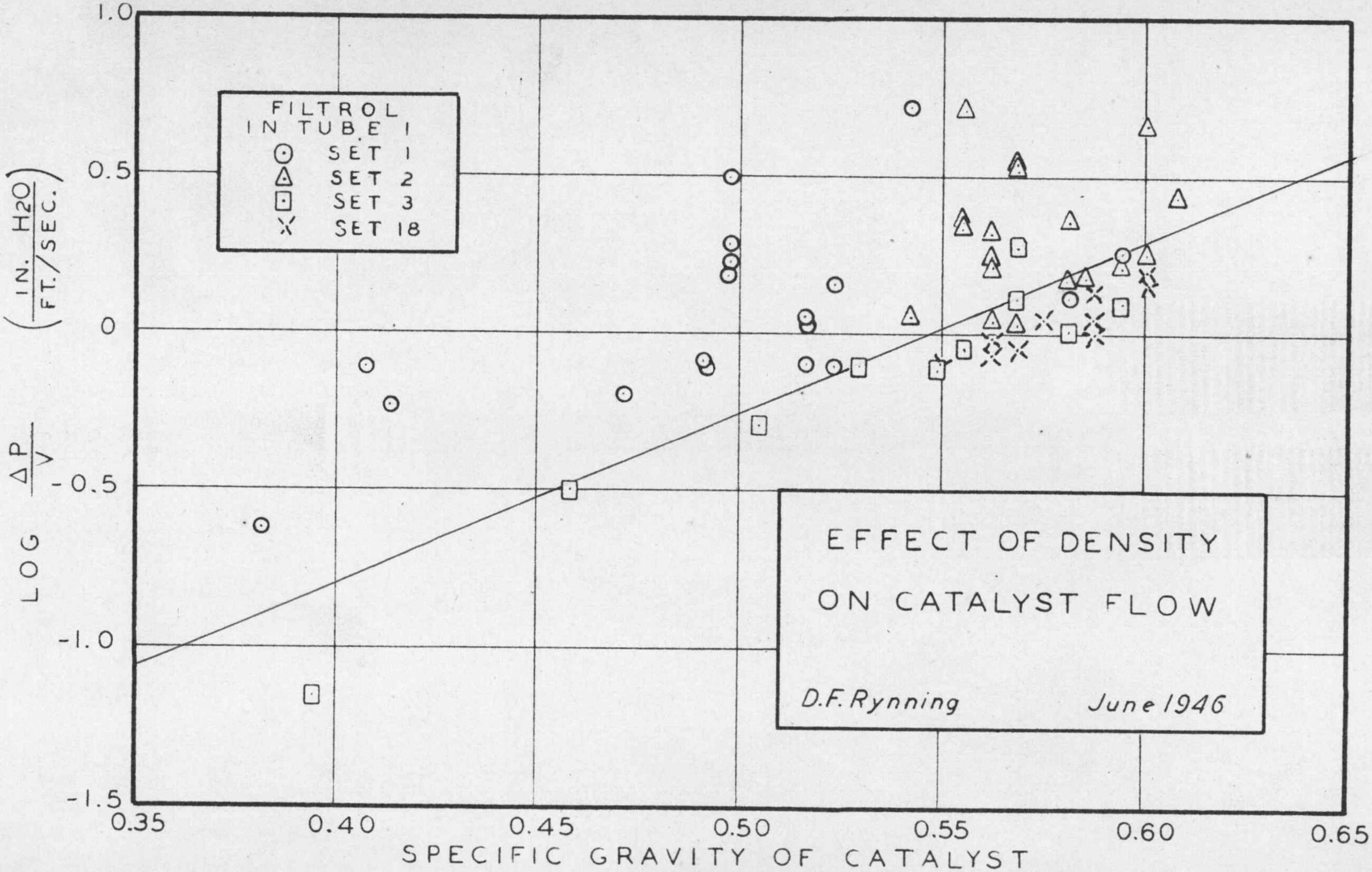
[1]The lower case letter v is used here to represent volume while a capital V is used to indicate velocity in the remainder of the report.

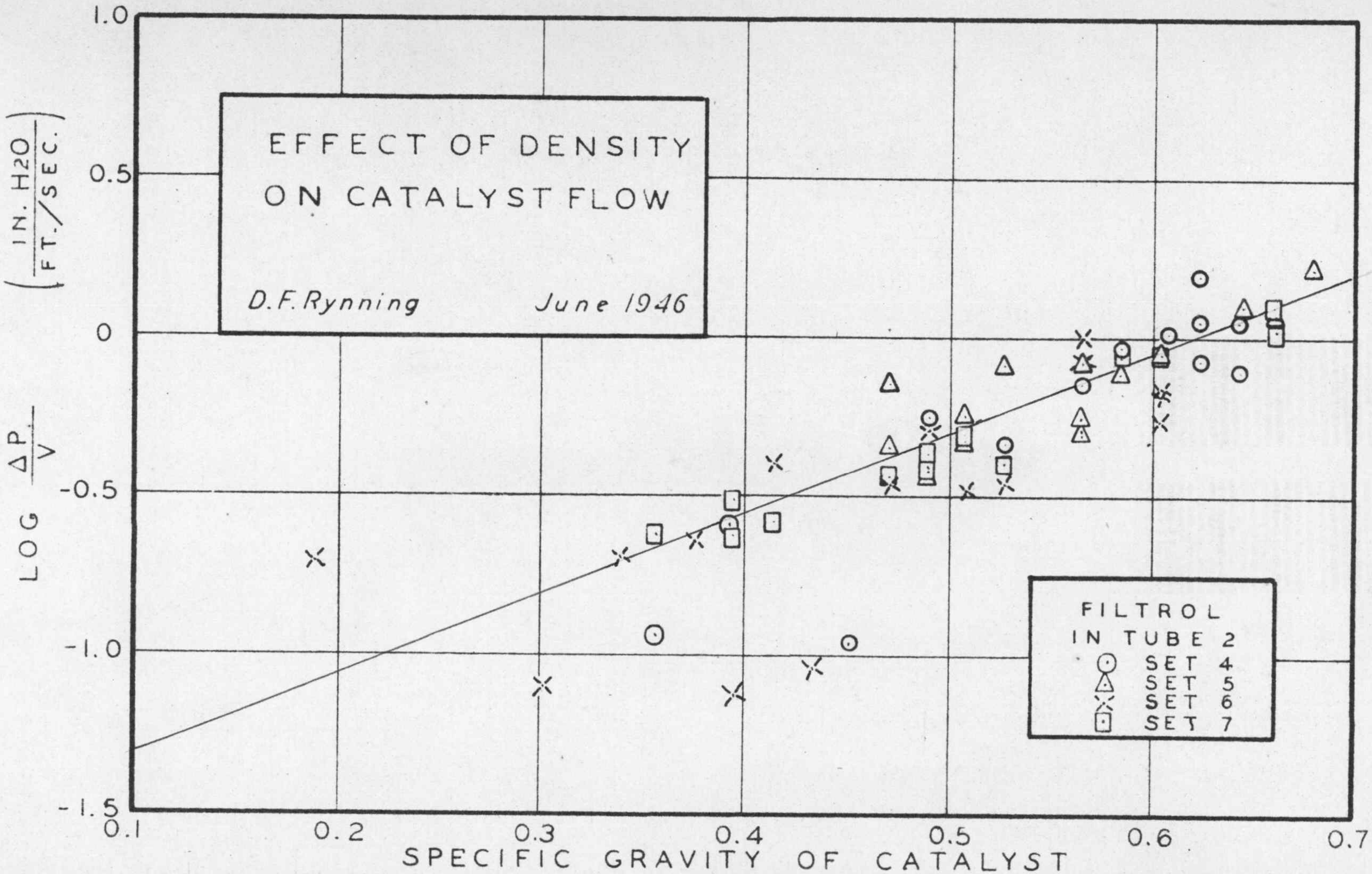
[2]Detailed discussions of fluid flow calculations may be found in Perry, J. H. Chemical Engineers' Handbook. 2nd ed. New York, McGraw-Hill Book Co., 1941 or any chemical engineering text.

reversed and the values of the apparent viscosity necessary to correlate the data were computed. Then an attempt was made to connect these values with the data in some predictable manner. The efforts in this direction were not successful. This apparent viscosity did not appear to be a function of any of the known variables or any simple combination thereof. Therefore the Fanning equation-Reynold's number approach could not be used to correlate the data. There is a possibility that experimentally measured values for the viscosity, if they could be obtained, would render the use of this calculation more successful.

Further efforts to systematize the data were directed toward finding some relationship among the known variables. For a given catalyst in a specific size of tube there were three; density, velocity, and pressure drop. These variables and various combinations of them were compared graphically and it was found that a general relationship existed between the density and the quantity $\Delta P/V$. As shown in Figures 2 to 7 inclusive, the log $\Delta P/V$ is a function (possibly linear) of the specific gravity of flowing catalyst. The width of the band over which the data points spread is due at least partially to the lack of precision in the data. However, it is quite probable that there are unrecognized factors affecting the relationship.

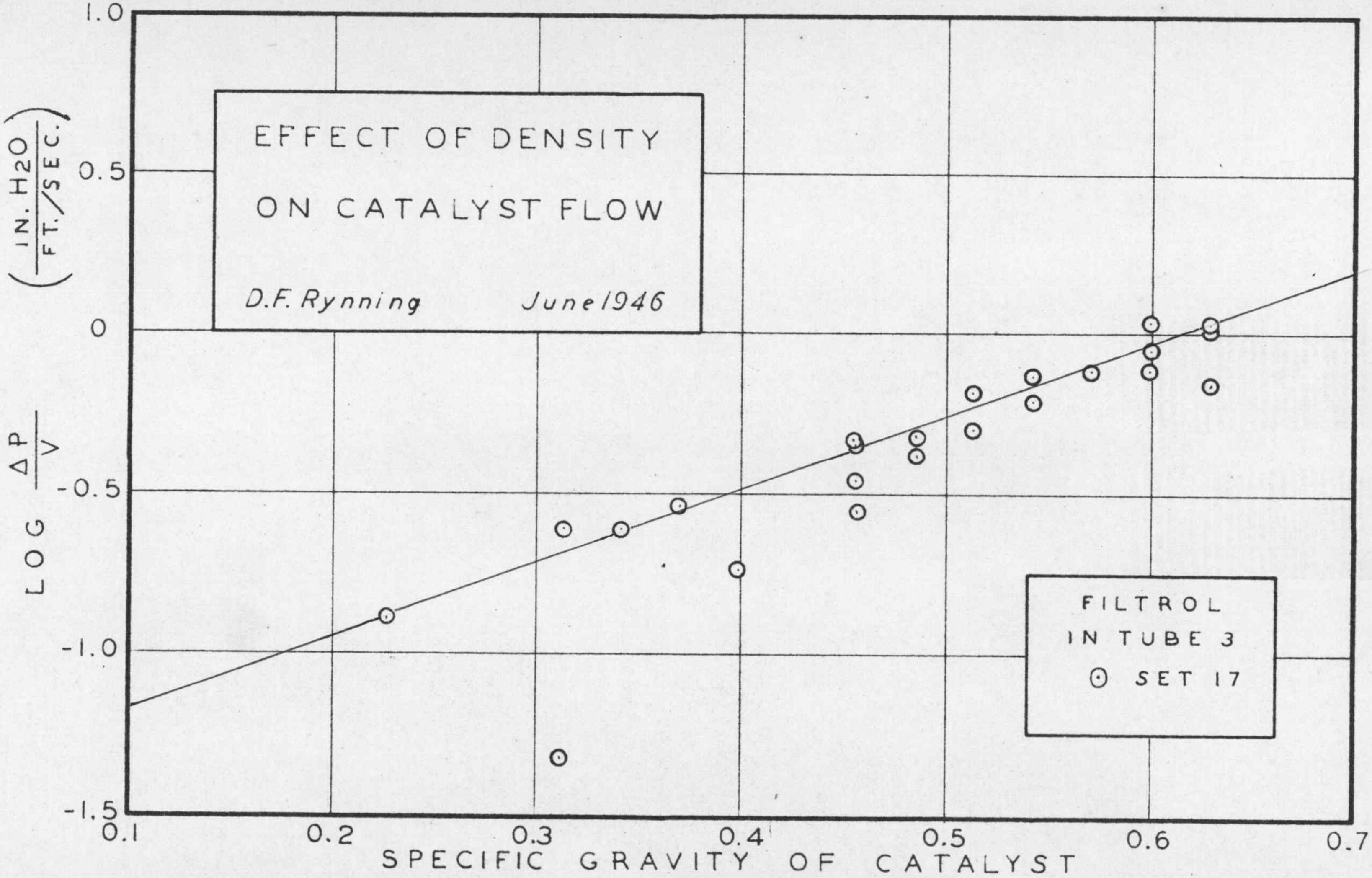
As a matter of convenience the different curves may be


FILTROL
IN TUBE 1
SET 1
SET 2
SET 3
SET 18
EFFECT OF DENSITY
ON CATALYST FLOW
D.F. Rynning
June 1946
LOG $\frac{\Delta P}{V}$ $\left(\frac{\text{IN. } H_2O}{\text{FT./SEC.}}\right)$
1.0
0.5
0
-0.5
-1.0
-1.5
0.35
0.40
0.45
0.50
0.55
0.60
0.65
SPECIFIC GRAVITY OF CATALYST
FIGURE 2



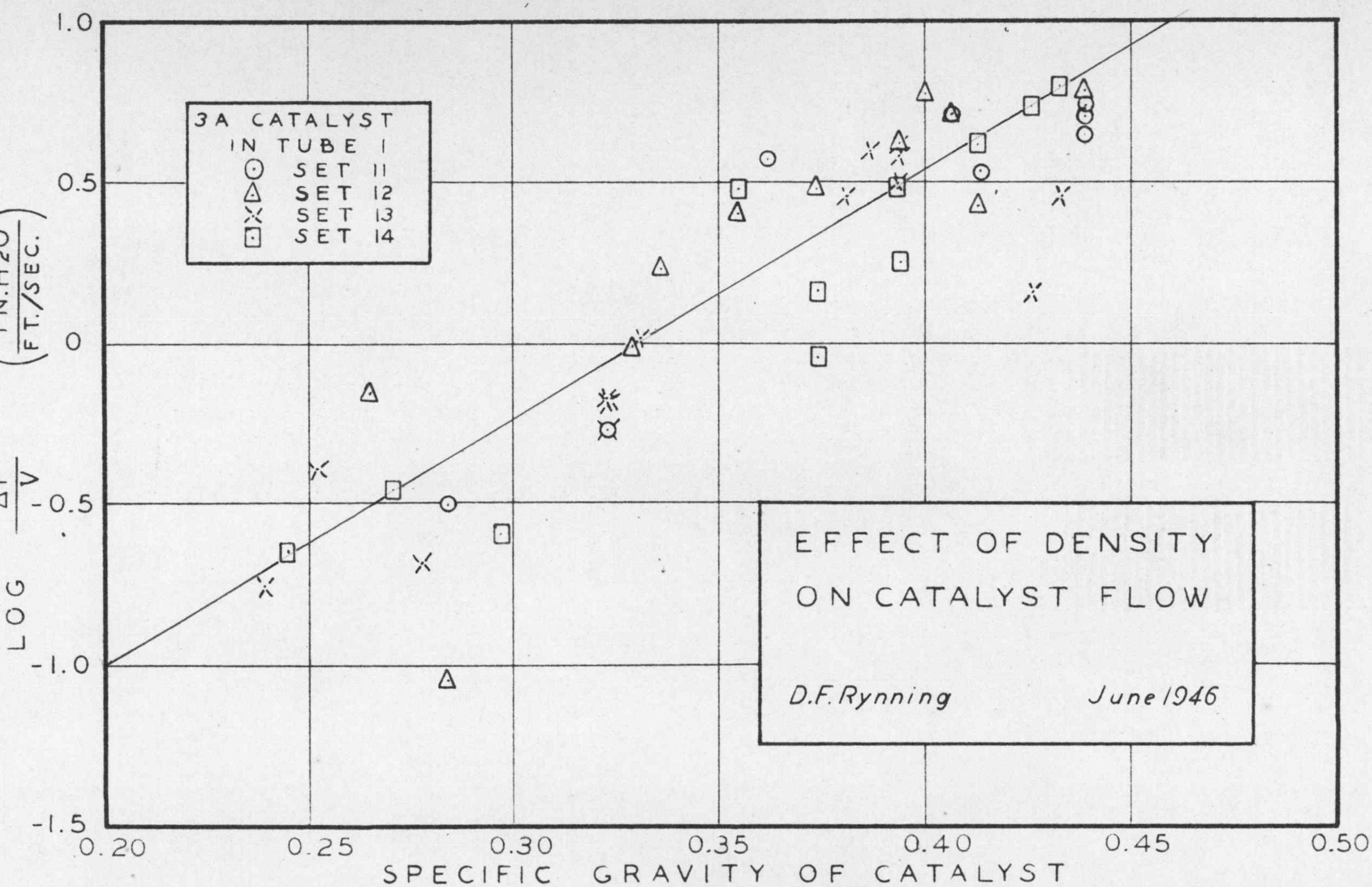
EFFECT OF DENSITY
ON CATALYST FLOW
D.F. Rynning
June 1946
FILTROL
IN TUBE 2
SET 4
SET 5
SET 6
SET 7
LOG $\frac{\Delta P}{V}$ $\left(\frac{\text{IN. } H_2O}{\text{FT./SEC.}}\right)$
SPECIFIC GRAVITY OF CATALYST
1.0
0.5
0
-0.5
-1.0
-1.5
0.1
0.2
0.3
0.4
0.5
0.6
0.7


FIGURE 3



EFFECT OF DENSITY
ON CATALYST FLOW
D.F. Rynning June 1946
FILTROL
IN TUBE 3
⊙ SET 17
LOG $\frac{\Delta P}{V}$ $\left(\frac{\text{IN. } H_2O}{\text{FT./SEC.}}\right)$
1.0
0.5
0
-0.5
-1.0
-1.5
0.1
0.2
0.3
0.4
0.5
0.6
0.7
SPECIFIC GRAVITY OF CATALYST


FIGURE 4



3A CATALYST
IN TUBE 1
SET 11
SET 12
SET 13
SET 14
EFFECT OF DENSITY
ON CATALYST FLOW
D.F. Rynning
June 1946
LOG $\frac{\Delta P}{V}$ $\left(\frac{\text{IN. H2O}}{\text{FT./SEC.}}\right)$
SPECIFIC GRAVITY OF CATALYST
1.0
0.5
0
-0.5
-1.0
-1.5
0.20
0.25
0.30
0.35
0.40
0.45
0.50


FIGURE 5

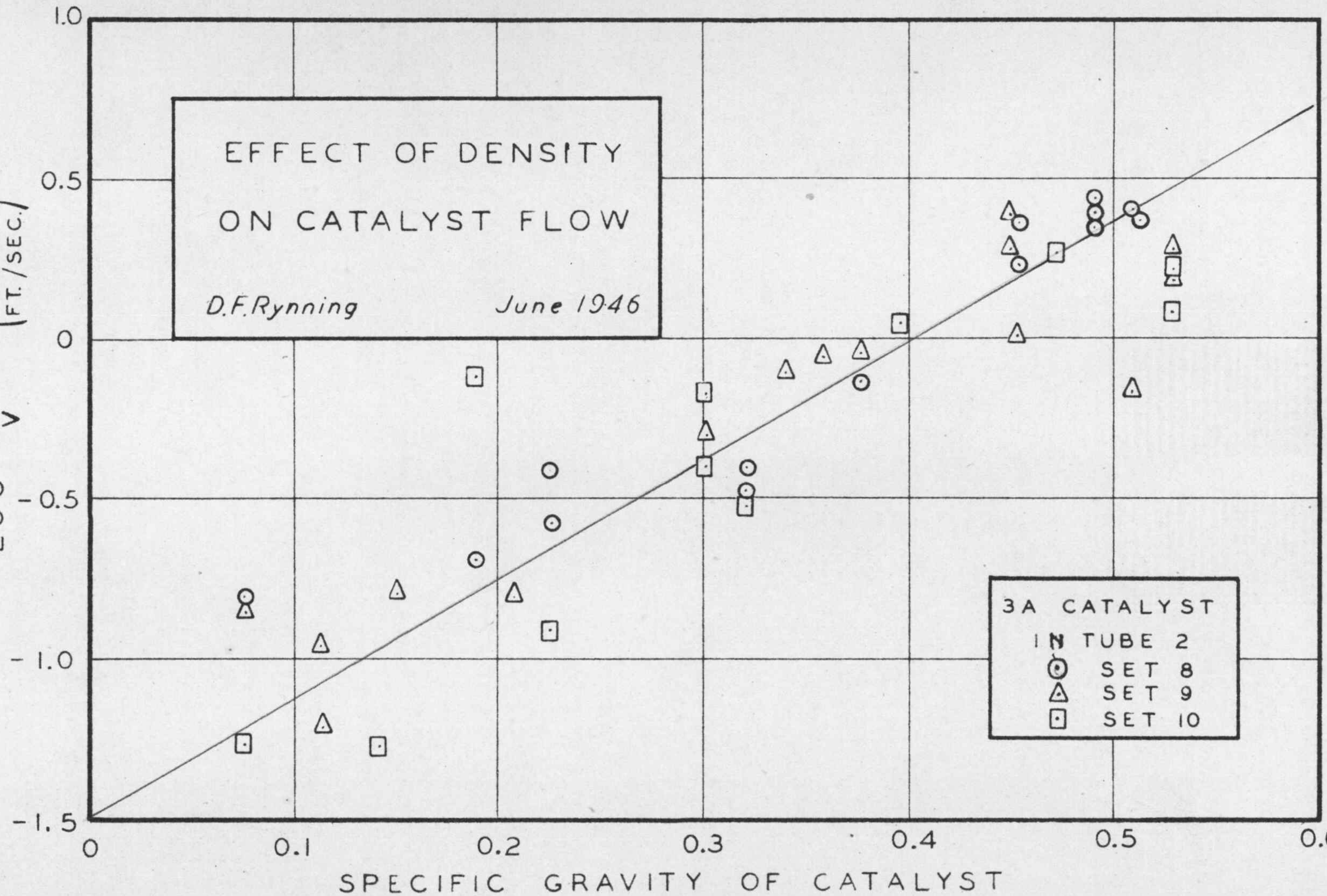
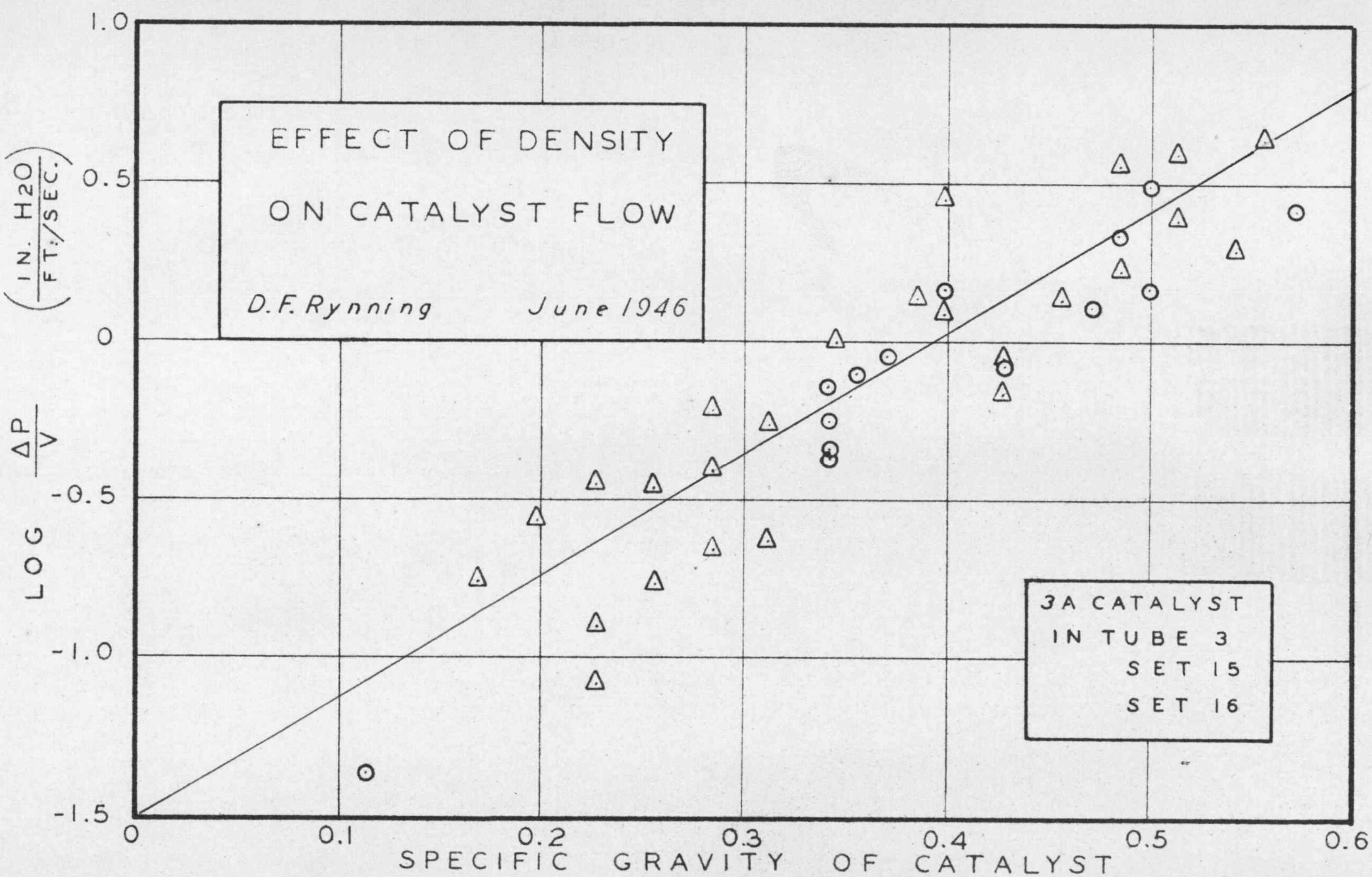

EFFECT OF DENSITY
ON CATALYST FLOW
D.F. Rynning
June 1946
3A CATALYST
IN TUBE 2
SET 8
SET 9
SET 10
LOG $\frac{\Delta P}{V}$ $\left(\frac{\text{IN. } H_2O}{\text{FT./SEC.}}\right)$
1.0
0.5
0
-0.5
-1.0
-1.5
0
0.1
0.2
0.3
0.4
0.5
0.6
SPECIFIC GRAVITY OF CATALYST

FIGURE 6


EFFECT OF DENSITY
ON CATALYST FLOW
D.F. Rynning June 1946
3A CATALYST
IN TUBE 3
SET 15
SET 16
1.0
0.5
0
-0.5
-1.0
-1.5
LOG $\frac{\Delta P}{V}$ $\left(\frac{\text{IN. H2O}}{\text{FT./SEC.}}\right)$
0
0.1
0.2
0.3
0.4
0.5
0.6
SPECIFIC GRAVITY OF CATALYST
FIGURE 7

compared on the basis of straight lines drawn so as to approximately average the position of the data points (after making allowance for the probable relative value of the various sets of data). This does not assume that the functions are necessarily linear but it does provide a method for describing the general position of each data pattern. For the six graphs given, the descriptions of the lines are as follows:

| Catalyst | Tube No. | Line slope | Intercept at 0 density |
|---|---|---|---|
| Filtrol | 1 | 5.45 | -4.64 |
| Filtrol | 2 | 2.55 | -2.96 |
| Filtrol | 3 | 2.28 | -2.79 |
| 3A | 1 | 7.70 | -4.21 |
| 3A | 2 | 3.72 | -2.88 |
| 3A | 3 | 3.82 | -2.90 |

(These intercepts are corrected to unit tube length)

It should be noted that since the data points spread over more or less broad bands the lines chosen to represent them here are not unique. Hence the above table could be subjected to a certain amount of modification.

It is apparent that both the type of material flowing and the size of the tube have a pronounced effect on flow behavior. Tube size is a simpler variable than the characteristics of the material. From the preceeding table it is seen that the results obtained with the largest tube

(No. 1) differ from those resulting from the use of the smaller tubes. In the case of the Filtrol catalyst there also seems to be some difference between results of the two smaller tubes. Tube size influences flow in two ways; through the difference in friction resulting from the difference in the wall surface-volume ratio, and by causing changes in the degree of turbulence of the fluid. These might be described as the 'external' and 'internal' frictions of the fluid, respectively.

In a true liquid system the turbulence increases with an increase in tube diameter at constant velocity (the Reynold's number will become larger). The pressure drop will be less because the friction factor has been decreased. Apparently the same effect is found in the case of the fluid solid. However the effect becomes less at higher values of catalyst density. The behavior of the system in this respect at density values higher than those actually encountered in the experiments could not be predicted with certainty since it would be necessary to extrapolate the data.

The fact that the data measured in tubes 2 and 3 were very similar when the material was 3A catalyst but not in quite such close agreement when Filtrol was used requires some explanation. Assuming that the discrepancies were not due entirely to experimental errors it is logical to connect them to the nature of the catalysts themselves. In this connection it is interesting to note that the pressure drops may not be the same though two materials having the same density and the same velocity flow in tubes of the same size. The cause of the difference, due to the physical characteristics of the solid materials, is related to the concept of apparent viscosity. It is therefore possible that the flow of the Filtrol was more turbulent than that of the 3A under the same conditions. If such was the case and there was turbulent flow in tube 2 with the Filtrol but streamline flow in this tube with the 3A and also streamline flow in tube 2 with both materials, the results obtained might be explained on this basis. In other words the equation of flow might be considered as being less complex in the region of streamline flow. This is only a hypothesis since the experimental data do not suffice to prove it. Apparent viscosity (the name is convenient although it is not a true viscosity) is important in the flow of fluid solids as a measure of the characteristics of the solid itself. The size and shape of the individual particles, and the nature of their surface probably would all contribute to this factor. While the two catalysts tested had approximately the same particle size and chemical composition, the difference in the results obtained indicated the presence of a variation in some characteristic such as particle structure or cohesiveness. In this connection it may be mentioned that there was an observable difference in the general appearance and feel of the two materials. The 3A catalyst seemed to be somewhat less granular and more 'fibrous' than the Filtrol. Studies are being carried out in the same laboratory by other investigators on these characteristics of various types of solids.

The degree of dryness of the materials is thought to exert an influence on their flow. In future studies of this nature it may be desirable to carry out the experiments with solids of a constant moisture content.

Evaluation of the effect of the physical characteristics of the material on the flow of fluid solids is fundamentally important. For this purpose measurements must be made on materials differing widely in many physical properties. Only when this has been done can calculations for solid flow systems be made applicable to widely different systems.

## CONCLUSIONS

The results of this investigation may be summarized in a few general conclusions.

One: The absence of any other data and the limitations on the number of systems that could be studied here prevented the formulation of any general quantitative expressions for fluid solid flow.

Two: The behavior was found to be similar though not identical with that of true fluid systems. The 'apparent viscosity' factor necessary to convert the data to the usual fluid flow calculations could not be predicted from the variables studied here.

Three: The relationship between the density of the flowing catalyst and the quantity, $\Delta P/V$, was noted as well as the fact that tube diameter and the nature of the solid itself affected this relationship. The exact function involved could not be determined but it appeared that the log $\Delta P/V$ might be approximately linear with respect to the density. The size of the tube and the catalyst characteristics both influence the slope as well as the position of these lines.

# APPENDIX

SAMPLE CALCULATIONS

Run No. 25 Set 2 Filtrol in Tube No. 1

Data

| | |
|---|---|
| Manometer reading (between two taps) | 38 cm $H_2O$ |
| Rate of mass flow of catalyst | 97.0 g/sec |
| Weight of catalyst trapped in tube | 86 g |
| Volume of tube No. 1 | 154.9 cc |
| Over-all length of tube No. 1 | 50.375 in |
| Length between taps of tube No. 1 | 46 in |

Apparent specific gravity

$$\frac{86}{154.9} = 0.555$$

Velocity

$$\frac{(97.0)(50.375)}{(86)\ (12)} = 4.73 \text{ ft/sec}$$

Corrected $\Delta P$

$$(0.555)(46)(2.54) - 38 = 26.8 \text{ cm } H_2O$$

$\Delta P/V$

$$\frac{26.8}{(2.54)(4.73)} = 2.23 \ \frac{\text{in } H_2O}{\text{ft/sec}}$$

# EXPERIMENTAL DATA ON FLOW OF FLUID CATALYST

| Run No | Manometer cm $H_2O$ | Flow Rate g/sec | Quan in Tube grams | Apparent Sp Gr | Velocity V ft/sec | $\Delta P$ due to flow cm $H_2O$ | $\Delta P/V$ $\frac{\text{in } H_2O}{\text{ft/sec}}$ |
|---|---|---|---|---|---|---|---|
| | | Set No. 1 | Filtrol in Tube No. 1 | | | | |
| 1 | 32 | 121.2 | 77 | 0.497 | 6.60 | Horizontal | 1.918 |
| 2 | 17 | 60.8 | 22 | 142 | 11.60 | flow tube, | 0.583 |
| 3 | 27 | 62.8 | 77 | 497 | 3.42 | $\Delta P$ same as | 3.150 |
| 4 | 30 | 113 | 77 | 497 | 6.16 | manometer | 1.942 |
| 5 | 56.2 | 105.8 | 84 | 542 | 5.28 | 7.1 | 5.287 |
| 6 | 39 | 146.4 | 80 | 516 | 7.68 | 21.3 | 1.091 |
| 7 | 48.8 | 119.3 | 81 | 523 | 6.18 | 12.3 | 0.783 |
| 8 | 44.8 | 114.5 | 92 | 594 | 5.22 | 24.6 | 1.853 |
| 9 | 42.8 | 118 | 80 | 516 | 6.19 | 17.5 | 1.112 |
| 10 | 39.8 | 86.5 | 64 | 413 | 5.67 | 8.5 | 0.589 |
| 11 | 36.8 | 101.2 | 77 | 497 | 5.51 | 21.3 | 1.519 |
| 12 | 39.8 | 114 | 81 | 523 | 5.90 | 21.3 | 1.419 |
| 13 | 29 | 139 | 63 | 407 | 9.26 | 18.6 | 0.790 |
| 14 | 37 | 174 | 59 | 381 | 12.38 | 7.5 | 0.238 |
| 15 | 42 | 138.7 | 73 | 471 | 7.97 | 13.0 | 0.641 |
| 16 | 37 | 170.7 | 76 | 491 | 9.42 | 20.4 | 0.851 |
| 17 | 45 | 139 | 80 | 516 | 7.29 | 15.3 | 0.825 |
| 18 | 39 | 163.7 | 76 | 491 | 9.04 | 18.4 | 0.801 |
| | | Set No. 2 | Filtrol in Tube No. 1 | | | | |
| 19 | 49 | 102.4 | 93 | 0.600 | 4.62 | 21.1 | 1.797 |
| 20 | 51 | 116.8 | 88 | 568 | 5.57 | 15.4 | 1.088 |
| 21 | 49 | 107.6 | 92 | 594 | 4.91 | 20.4 | 1.635 |
| 22 | 49 | 106.8 | 90 | 581 | 4.98 | 18.9 | 1.493 |
| 23 | 41 | 36.6 | 86 | 555 | 1.78 | 23.8 | 5.243 |
| 24 | 41 | 85.2 | 86 | 555 | 4.15 | 23.8 | 2.252 |
| 25 | 38 | 97 | 86 | 555 | 4.73 | 26.8 | 2.238 |
| 26 | 43 | 89.8 | 94 | 607 | 4.01 | 27.9 | 2.739 |
| 27 | 34 | 76.8 | 88 | 568 | 3.66 | 32.4 | 3.481 |
| 28 | 32 | 70.8 | 93 | 600 | 3.19 | 38.1 | 4.693 |
| 29 | 30 | 88.2 | 88 | 568 | 4.20 | 36.4 | 3.406 |
| 30 | 45 | 99.6 | 87 | 562 | 4.80 | 20.7 | 1.695 |
| 31 | 46 | 90.6 | 87 | 562 | 4.37 | 19.7 | 1.773 |
| 32 | 47 | 117.6 | 90 | 581 | 5.48 | 20.9 | 1.500 |
| 33 | 51 | 108 | 87 | 562 | 5.21 | 14.7 | 1.110 |

| Run No | Manometer cm $H_2O$ | Flow Rate g/sec | Quan in Tube grams | Apparent Sp Gr | Velocity V ft/sec | $\Delta P$ due to flow cm $H_2O$ | $\Delta P/V$ $\frac{\text{in } H_2O}{\text{ft/sec}}$ |
|---|---|---|---|---|---|---|---|
| 34 | 40 | 99.8 | 87 | 0.562 | 4.81 | 25.7 | 2.100 |
| 35 | 40 | 101.6 | 90 | 581 | 4.73 | 27.9 | 2.317 |
| 36 | 46.6 | 114.2 | 84 | 542 | 5.70 | 16.7 | 1.152 |
| 37 | 48 | 105.2 | 89 | 575 | 4.96 | 19.2 | 1.523 |
| | | Set No. 3 | | Filtrol in Tube No. 1 | | | |
| 38 | 54 | 88.6 | 93 | 0.600 | 3.99 | 16.1 | 1.585 |
| 39 | 53 | 104.6 | 90 | 581 | 4.87 | 14.9 | 1.202 |
| 40 | 54 | 97.2 | 89 | 575 | 4.58 | 13.2 | 1.133 |
| 41 | 52 | 130.2 | 87 | 562 | 6.28 | 13.7 | 0.858 |
| 42 | 51 | 124.2 | 87 | 562 | 5.99 | 14.7 | 0.965 |
| 43 | 51 | 128.6 | 85 | 549 | 6.35 | 13.1 | 0.812 |
| 44 | 52 | 132.6 | 88 | 568 | 6.32 | 14.4 | 0.896 |
| 45 | 52 | 136.8 | 91 | 587 | 6.31 | 16.6 | 1.035 |
| 46 | 49 | 122.2 | 91 | 587 | 5.63 | 19.6 | 1.368 |
| 47 | 52 | 122.4 | 91 | 587 | 5.64 | 16.6 | 1.157 |
| 48 | 51 | 112.8 | 93 | 600 | 5.09 | 19.1 | 1.476 |
| 49 | 50.4 | 101 | 90 | 581 | 4.71 | 17.5 | 1.462 |
| 50 | 51 | 108.6 | 90 | 581 | 5.06 | 16.9 | 1.313 |
| 51 | 48 | 144 | 90 | 581 | 6.71 | 19.9 | 1.166 |
| 52 | 48 | 108.6 | 91 | 587 | 5.01 | 20.6 | 1.618 |
| 53 | 38 | 112.5 | 68 | 439 | 6.94 | 13.3 | 0.753 |
| 54 | 50 | 105.6 | 90 | 581 | 4.92 | 17.9 | 1.430 |
| 55 | 50 | 131 | 88 | 568 | 6.24 | 16.4 | 1.033 |
| 56 | 51 | 122.6 | 88 | 568 | 5.84 | 15.4 | 1.036 |
| 57 | 44 | 81.8 | 90 | 581 | 3.81 | 23.9 | 2.466 |
| 58 | 36 | 91 | 58 | 374 | 6.58 | 7.7 | 0.460 |
| 59 | 52 | 119.2 | 91 | 587 | 5.49 | 16.6 | 1.188 |
| 60 | 52 | 109.8 | 92 | 594 | 5.01 | 17.4 | 1.367 |
| | | Set No. 4 | | Filtrol in Tube No. 2 | | | |
| 61 | 25.8 | 74.6 | 33 | 0.623 | 5.69 | 12.2 | 0.842 |
| 62 | 26.8 | 67 | 34 | 642 | 4.96 | 12.3 | 0.974 |
| 63 | 17.8 | 67 | 14 | 264 | 12.06 | -1.7 | |
| 64 | 23.8 | 79.2 | 28 | 528 | 7.13 | 8.4 | 0.467 |
| 65 | 20.8 | 86.2 | 26 | 491 | 8.35 | 9.1 | 0.428 |
| 66 | 22.8 | 50.9 | 26 | 491 | 4.93 | 7.1 | 0.566 |
| 67 | 24.8 | 59.2 | 33 | 623 | 4.52 | 13.2 | 1.149 |
| 68 | 22.8 | 46.4 | 16 | 302 | 7.31 | -4.4 | |

| Run No | Manometer cm $H_2O$ | Flow Rate g/sec | Quan in Tube grams | Apparent Sp Gr | Velocity V ft/sec | $\Delta P$ due to flow cm $H_2O$ | $\Delta P/V$ $\frac{\text{in } H_2O}{\text{ft/sec}}$ |
|---|---|---|---|---|---|---|---|
| 69 | 26.8 | 50.8 | 30 | 0.566 | 4.26 | 7.7 | 0.710 |
| 70 | 25.8 | 62 | 34 | 642 | 4.59 | 13.3 | 1.139 |
| 71 | 26.8 | 48.6 | 32 | 604 | 3.82 | 10.0 | 1.028 |
| 72 | 18.8 | 67.8 | 21 | 396 | 8.13 | 5.3 | 0.256 |
| 73 | 18.8 | 75.6 | 19 | 358 | 10.03 | 3.0 | 0.117 |
| 74 | 24.8 | 59.5 | 21 | 396 | 7.14 | -0.7 | |
| 75 | 25.8 | 62.4 | 24 | 453 | 6.55 | 1.8 | 0.108 |
| 76 | 24.8 | 43.8 | 33 | 623 | 3.34 | 13.2 | 1.553 |
| 77 | 23.8 | 61.2 | 15 | 283 | 10.28 | -6.5 | |
| 78 | 24.8 | 57 | 31 | 585 | 4.63 | 10.9 | 0.925 |
| | | Set No. 5 | | Filtrol in Tube No. 2 | | | |
| 79 | 26 | 81.2 | 30 | 0.566 | 6.82 | 8.5 | 0.490 |
| 80 | 27 | 55 | 32 | 604 | 4.33 | 9.8 | 0.890 |
| 81 | 22 | 83.6 | 26 | 491 | 8.10 | 7.9 | 0.383 |
| 82 | 23 | 68.7 | 12 | 226 | 14.43 | -9.8 | |
| 83 | 27 | 49.6 | 33 | 623 | 3.78 | 11.0 | 1.142 |
| 84 | 27 | 59.8 | 35 | 660 | 4.30 | 13.2 | 1.206 |
| 85 | 25 | 53 | 27 | 509 | 4.94 | 6.0 | 0.477 |
| 86 | 29 | 41.6 | 36 | 679 | 2.91 | 12.4 | 1.675 |
| 87 | 27 | 69 | 30 | 566 | 5.79 | 7.5 | 0.509 |
| 88 | 24 | 87.6 | 30 | 566 | 7.36 | 10.5 | 0.561 |
| 89 | 22 | 57.4 | 25 | 472 | 5.78 | 6.8 | 0.462 |
| 90 | 27 | 50.2 | 34 | 642 | 3.72 | 12.1 | 1.279 |
| 91 | 27 | 55.4 | 31 | 585 | 4.50 | 8.7 | 0.760 |
| 92 | 18 | 59 | 25 | 472 | 5.94 | 10.8 | 0.714 |
| 93 | 24 | 37.7 | 20 | 377 | 4.75 | -1.0 | |
| 94 | 20 | 80.2 | 27 | 509 | 7.48 | 11.0 | 0.578 |
| 95 | 21 | 59.6 | 28 | 528 | 5.36 | 11.2 | 0.821 |
| 96 | 24 | 58 | 30 | 566 | 4.87 | 10.5 | 0.848 |
| | | Set No. 6 | | Filtrol in Tube No. 2 | | | |
| 97 | 33 | 38 | 27 | 0.509 | 3.54 | -2.0 | |
| 98 | 27 | 35.6 | 30 | 566 | 2.99 | 7.5 | 0.987 |
| 99 | 29 | 72.2 | 32 | 604 | 5.68 | 7.8 | 0.539 |
| 100 | 26 | 63.2 | 27 | 509 | 5.90 | 5.0 | 0.333 |
| 101 | 23 | 65.8 | 25 | 472 | 6.64 | 5.8 | 0.344 |
| 102 | 25 | 58.6 | 23 | 434 | 6.42 | 1.5 | 0.091 |
| 103 | 23 | 67.6 | 30 | 566 | 5.68 | 11.5 | 0.797 |

| Run No | Manometer cm $H_2O$ | Flow Rate g/sec | Quan in Tube grams | Apparent Sp Gr | Velocity V ft/sec | ΔP due to flow cm $H_2O$ | ΔP/V $\frac{\text{in } H_2O}{\text{ft/sec}}$ |
|---|---|---|---|---|---|---|---|
| 104 | 25 | 85.2 | 32 | 0.604 | 6.71 | 11.8 | 0.692 |
| 105 | 15 | 107.6 | 16 | 302 | 16.95 | 3.4 | 0.078 |
| 106 | 25 | 87.6 | 32 | 604 | 6.90 | 11.8 | 0.673 |
| 107 | 22 | 13.4 | 20 | 377 | 1.689 | 1.0 | 0.233 |
| 108 | 25 | 90.2 | 28 | 528 | 8.12 | 7.2 | 0.349 |
| 109 | 23 | 53.6 | 26 | 491 | 5.19 | 6.9 | 0.522 |
| 110 | 23 | 54.6 | 22 | 415 | 6.25 | 2.3 | 0.144 |
| 111 | 7 | 52.2 | 10 | 189 | 13.16 | 4.5 | 0.134 |
| 112 | 12 | 120.2 | 18 | 340 | 16.83 | 8.7 | 0.203 |
| 113 | 21 | 134.8 | 21 | 396 | 16.18 | 3.1 | 0.075 |
| | | Set No. 7 | | Filtrol in Tube No. 2 | | | |
| 114 | 23 | 86 | 28 | 0.528 | 7.74 | 9.2 | 0.467 |
| 115 | 21 | 86.9 | 31 | 585 | 7.06 | 14.7 | 0.819 |
| 116 | 26 | 55 | 31 | 585 | 4.47 | 9.7 | 0.853 |
| 117 | 21 | 48.7 | 16 | 302 | 7.67 | -2.6 | |
| 118 | 26 | 63.5 | 35 | 660 | 4.57 | 14.2 | 1.222 |
| 119 | 26 | 72.9 | 35 | 660 | 5.25 | 14.2 | 1.064 |
| 120 | 15 | 123.7 | 21 | 396 | 14.85 | 9.1 | 0.241 |
| 121 | 25 | 51.4 | 26 | 491 | 4.98 | 4.9 | 0.387 |
| 122 | 15 | 82.8 | 19 | 358 | 10.99 | 6.8 | 0.243 |
| 123 | 21 | 84.8 | 32 | 604 | 6.68 | 15.8 | 0.931 |
| 124 | 24 | 59.3 | 27 | 509 | 5.53 | 7.0 | 0.497 |
| 125 | 16 | 86.1 | 21 | 396 | 10.34 | 8.1 | 0.308 |
| 126 | 19 | 82.6 | 22 | 415 | 9.46 | 6.3 | 0.262 |
| 127 | 20 | 92.9 | 25 | 472 | 9.36 | 8.8 | 0.369 |
| | | Set No. 8 | | 3-A Catalyst in Tube No. 2 | | | |
| 128 | 16 | 23.7 | 17 | 0.321 | 3.51 | 3.6 | 0.403 |
| 129 | 13 | 51.9 | 17 | 321 | 7.69 | 6.6 | 0.337 |
| 130 | 10 | 26.5 | 12 | 226 | 5.56 | 3.8 | 0.268 |
| 131 | 2 | 10.1 | 4 | 075 | 6.36 | 2.6 | 0.160 |
| 132 | 9 | 40.2 | 8 | 151 | 12.67 | 0.2 | 0.006 |
| 133 | 15 | 20.1 | 24 | 453 | 2.11 | 12.6 | 2.349 |
| 134 | 15 | 27.6 | 24 | 453 | 2.89 | 12.6 | 1.711 |
| 135 | 15 | 28.1 | 27 | 509 | 2.62 | 16.0 | 2.401 |
| 136 | 15 | 33.7 | 20 | 377 | 4.24 | 8.0 | 0.741 |
| 137 | 13 | 25.7 | 26 | 491 | 2.39 | 16.9 | 2.773 |
| 138 | 6 | 41.9 | 10 | 189 | 10.56 | 5.5 | 0.205 |
| 139 | 0.8 | 61.2 | 12 | 226 | 12.86 | 13.0 | 0.397 |

| Run No | Mano-meter cm $H_2O$ | Flow Rate g/sec | Quan in Tube grams | Appar-ent Sp Gr | Velocity V ft/sec | $\Delta P$ due to flow cm $H_2O$ | $\Delta P/V$ $\frac{\text{in } H_2O}{\text{ft/sec}}$ |
|---|---|---|---|---|---|---|---|
| 140 | 14 | 25.6 | 26 | 0.491 | 2.48 | 15.9 | 2.548 |
| 141 | 16 | 24.6 | 26 | 491 | 2.38 | 13.9 | 2.294 |
| 142 | 16 | 24.8 | 27 | 509 | 2.31 | 15.0 | 2.550 |
| | | Set No. 9 | | 3-A Catalyst in Tube No. 2 | | | |
| 143 | 11 | 36.2 | 16 | 0.302 | 5.70 | 7.4 | 0.510 |
| 144 | 13 | 33.9 | 18 | 340 | 4.74 | 7.7 | 0.638 |
| 145 | 13 | 34.0 | 20 | 377 | 4.28 | 10.0 | 0.928 |
| 146 | 5 | 28.6 | 6 | 113 | 12.02 | 1.9 | 0.062 |
| 147 | 13 | 21.9 | 24 | 453 | 2.30 | 14.6 | 2.497 |
| 148 | 15 | 26 | 24 | 453 | 2.73 | 12.6 | 1.816 |
| 149 | 16 | 44.9 | 28 | 528 | 4.04 | 16.2 | 1.577 |
| 150 | 15 | 44.8 | 24 | 453 | 4.70 | 12.6 | 1.054 |
| 151 | 12 | 31.9 | 19 | 358 | 4.23 | 9.8 | 0.911 |
| 152 | 10 | 28.6 | 11 | 208 | 6.55 | 2.7 | 0.162 |
| 153 | 5 | 15.8 | 6 | 113 | 6.63 | 1.9 | 0.112 |
| 154 | 6 | 24.5 | 8 | 151 | 7.72 | 3.2 | 0.163 |
| 155 | 0.8 | 15.9 | 4 | 075 | 10.02 | 3.7 | 0.145 |
| 156 | 16 | 30.3 | 27 | 509 | 2.82 | 5.0 | 0.695 |
| 157 | 15 | 38.5 | 28 | 528 | 3.46 | 17.2 | 1.953 |
| | | Set No. 10 | | 3-A Catalyst in Tube No. 2 | | | |
| 158 | 1.6 | 15.3 | 2 | 0.038 | 19.28 | 0.7 | 0.014 |
| 159 | 14 | 30 | 25 | 472 | 3.025 | 14.8 | 1.926 |
| 160 | 16 | 41.5 | 28 | 528 | 3.73 | 16.2 | 1.707 |
| 161 | 16 | 57.4 | 28 | 528 | 5.16 | 16.2 | 1.234 |
| 162 | 5 | 12.9 | 10 | 189 | 3.25 | 6.5 | 0.786 |
| 163 | 13 | 31.9 | 21 | 396 | 3.82 | 11.1 | 1.141 |
| 164 | 10 | 55.3 | 12 | 226 | 11.62 | 3.8 | 0.128 |
| 165 | 16 | 32.1 | 17 | 321 | 4.76 | 3.6 | 0.297 |
| 166 | 2.4 | 25.0 | 4 | 075 | 15.76 | 2.2 | 0.054 |
| 167 | 6.4 | 72.9 | 16 | 302 | 11.49 | 12.0 | 0.411 |
| 168 | 11 | 27.1 | 16 | 302 | 4.27 | 7.3 | 0.673 |
| 169 | 8 | 28.8 | 8 | 151 | 9.07 | 1.2 | 0.052 |
| 170 | 8 | 22.7 | 6 | 113 | 9.53 | -1.3 | |
| 171 | 8 | 23.5 | 7 | 132 | 8.46 | | |
| | | Set No. 11 | | 3-A Catalyst in Tube No. 1 | | | |
| 172 | 27 | 28.3 | 68 | 0.439 | 1.74 | 24.3 | 5.476 |
| 173 | 34 | 74.9 | 41 | 265 | 7.66 | -3.0 | |

| Run No | Mano-meter cm $H_2O$ | Flow Rate g/sec | Quan in Tube grams | Appar-ent Sp Gr | Velocity V ft/sec | $\Delta P$ due to flow cm $H_2O$ | $\Delta P/V$ in $H_2O$ / ft/sec |
|---|---|---|---|---|---|---|---|
| 174 | 23.6 | 33.9 | 68 | 0.439 | 2.09 | 27.7 | 5.210 |
| 175 | 33 | 51.7 | 30 | 194 | 7.23 | -10.3 | |
| 176 | 29 | 32.5 | 18 | 116 | 7.58 | -15.4 | |
| 177 | 23 | 26.9 | 56 | 362 | 2.01 | 19.3 | 3.769 |
| 178 | 23 | 45.5 | 64 | 413 | 2.98 | 25.3 | 3.338 |
| 179 | 27 | 42.8 | 29 | 187 | 6.19 | -5.2 | |
| 180 | 30 | 67.5 | 50 | 323 | 5.66 | 7.7 | 0.534 |
| 181 | 27 | 67.3 | 31 | 200 | 9.11 | -3.6 | |
| 182 | 21 | 43.4 | 68 | 439 | 2.67 | 30.3 | 4.452 |
| 183 | 28 | 68.0 | 44 | 284 | 6.48 | 5.2 | 0.315 |
| 184 | 31 | 88.0 | 42 | 271 | 8.79 | 0.7 | 0.031 |
| 185 | 30 | 20.4 | 63 | 407 | 1.35 | 17.6 | 5.098 |
| 186 | 31 | 64.7 | 38 | 245 | 7.14 | -2.4 | |
| | | Set No. 12 | | 3-A Catalyst in Tube No. 1 | | | |
| 187 | 21 | 24.9 | 62 | 0.400 | 1.63 | 25.7 | 6.001 |
| 188 | 33 | 94.3 | 44 | 284 | 8.99 | 0.2 | 0.087 |
| 189 | 33 | 58.1 | 27 | 174 | 9.03 | -12.7 | |
| 190 | 27 | 71.3 | 30 | 194 | 9.97 | -4.3 | |
| 191 | 19.6 | 32.8 | 63 | 407 | 2.18 | 28.0 | 5.042 |
| 192 | 21.6 | 31.2 | 68 | 439 | 1.92 | 29.7 | 6.071 |
| 193 | 23 | 40.9 | 52 | 336 | 3.30 | 16.3 | 1.943 |
| 194 | 23 | 43.6 | 41 | 265 | 4.46 | 8.0 | 0.705 |
| 195 | 21 | 34.1 | 61 | 394 | 2.34 | 25.0 | 4.193 |
| 196 | 31 | 36.9 | 51 | 329 | 3.03 | 7.4 | 0.959 |
| 197 | 27 | 29.6 | 55 | 355 | 2.25 | 14.5 | 2.527 |
| 198 | 31.6 | 82.4 | 38 | 245 | 9.10 | -3.0 | |
| 199 | 28 | 45.6 | 64 | 413 | 2.99 | 20.3 | 2.672 |
| 200 | 23.8 | 36.6 | 58 | 374 | 2.64 | 19.9 | 2.957 |
| | | Set No. 13 | | 3-A Catalyst in Tube No. 1 | | | |
| 201 | 23 | 42.3 | 61 | 0.394 | 2.91 | 23.0 | 3.110 |
| 202 | 22 | 62.4 | 67 | 433 | 3.91 | 28.6 | 2.879 |
| 203 | 20 | 38.5 | 61 | 394 | 2.64 | 26.0 | 3.864 |
| 204 | 22 | 32.9 | 60 | 387 | 2.30 | 23.2 | 3.967 |
| 205 | 32 | 64.9 | 36 | 232 | 7.56 | -4.9 | |
| 206 | 25 | 61.8 | 51 | 329 | 5.08 | 13.4 | 1.037 |
| 207 | 22.6 | 104.7 | 37 | 239 | 11.88 | 5.3 | 0.175 |
| 208 | 23 | 106.8 | 50 | 323 | 8.967 | 14.7 | 0.645 |
| 209 | 31 | 81.1 | 66 | 426 | 5.15 | 18.8 | 1.434 |
| 210 | 20 | 46.9 | 59 | 381 | 3.33 | 24.5 | 2.890 |
| 211 | 27 | 96.6 | 50 | 323 | 8.11 | 10.7 | 0.519 |

| Run No | Mano-meter cm $H_2O$ | Flow Rate g/sec | Quan in Tube grams | Appar-ent Sp Gr | Velocity V ft/sec | $\Delta P$ due to flow cm $H_2O$ | $\Delta P/V$ $\frac{\text{in } H_2O}{\text{ft/sec}}$ |
|---|---|---|---|---|---|---|---|
| 212 | 20 | 37.7 | 61 | 0.394 | 2.59 | 26.0 | 3.946 |
| 213 | 27 | 74.9 | 50 | 323 | 6.28 | 10.7 | 0.669 |
| 214 | 14.4 | 132.9 | 39 | 252 | 14.31 | 15.0 | 0.412 |
| 215 | 25.6 | 134.0 | 43 | 278 | 13.08 | 6.9 | 0.207 |
| | | Set No. 14 | 3-A Catalyst in Tube No. 1 | | | | |
| 216 | 22.4 | 32.9 | 55 | 0.355 | 2.51 | 19.1 | 2.994 |
| 217 | 23.4 | 35.8 | 64 | 413 | 2.34 | 24.9 | 4.175 |
| 218 | 27.4 | 59.7 | 61 | 394 | 4.10 | 18.6 | 1.782 |
| 219 | 27.4 | 60.3 | 58 | 374 | 4.36 | 16.3 | 1.470 |
| 220 | 24 | 59.5 | 29 | 187 | 8.61 | -2.2 | |
| 221 | 12 | 26.1 | 16 | 103 | 6.84 | | |
| 222 | 13.4 | 34.6 | 12 | 077 | 12.10 | -4.4 | |
| 223 | 24.8 | 39.6 | 61 | 394 | 2.72 | 21.2 | 3.062 |
| 224 | 22.4 | 31.3 | 66 | 426 | 1.99 | 27.4 | 5.418 |
| 225 | 33.4 | 89.0 | 40 | 258 | 9.34 | -3.3 | |
| 226 | 31.4 | 102.9 | 46 | 297 | 9.39 | 3.3 | 0.138 |
| 227 | 22.4 | 96.3 | 38 | 245 | 10.64 | 6.2 | 0.229 |
| 228 | 25.4 | 24.8 | 67 | 433 | 1.55 | 25.2 | 6.384 |
| 229 | 31.4 | 73.7 | 58 | 374 | 5.33 | 12.3 | 0.907 |
| 230 | 21.4 | 115.2 | 42 | 271 | 11.51 | 10.3 | 0.352 |
| | | Set No. 15 | 3-A Catalyst in Tube No. 3 | | | | |
| 231 | 4.8 | 28.7 | 17 | 0.486 | 4.51 | 25.3 | 2.205 |
| 232 | 6.2 | 11.9 | 4 | 114 | 7.98 | 0.9 | 0.044 |
| 233 | 10.4 | 44.6 | 12 | 343 | 9.91 | 10.8 | 0.428 |
| 234 | 7.6 | 23.8 | 14 | 400 | 4.54 | 17.2 | 1.487 |
| 235 | 9.2 | 28.7 | 12 | 343 | 6.38 | 12.0 | 0.739 |
| 236 | 9.2 | 27.5 | 20 | 571 | 3.67 | 26.2 | 2.808 |
| 237 | 12.4 | 34.8 | 6.5 | 186 | 14.28 | -0.9 | |
| 238 | 14.8 | 31.8 | 15 | 429 | 5.66 | 11.6 | 0.806 |
| 239 | 10.4 | 16.9 | 17.5 | 500 | 2.58 | 20.6 | 3.132 |
| 240 | 10.6 | 40.3 | 12 | 343 | 8.97 | 10.6 | 0.465 |
| 241 | 11.0 | 32.5 | 12 | 343 | 7.22 | 10.2 | 0.555 |
| 242 | 9.2 | 26.7 | 3 | 086 | 23.77 | -3.9 | |
| 243 | 11.0 | 40.8 | 4 | 114 | 27.24 | -4.0 | |
| 244 | 10.2 | 27.1 | 12.5 | 357 | 5.79 | 11.9 | 0.809 |
| 245 | 10.2 | 26.5 | 13 | 371 | 5.43 | 12.8 | 0.927 |
| 246 | 10.4 | 35.3 | 17.5 | 500 | 5.38 | 20.6 | 1.506 |
| 247 | 8.2 | 38.9 | 16.5 | 471 | 6.28 | 21.0 | 1.315 |
| 248 | 13.6 | 27.3 | 6 | 171 | 12.16 | -3.0 | |

| Run No | Manometer cm $H_2O$ | Flow Rate g/sec | Quan in Tube grams | Apparent Sp Gr | Velocity V ft/sec | $\Delta P$ due to flow cm $H_2O$ | $\Delta P/V$ $\frac{\text{in } H_2O}{\text{ft/sec}}$ |
|---|---|---|---|---|---|---|---|
| | | Set No. 16 | 3-A Catalyst in Tube No. 3 | | | | |
| 249 | 12.6 | 13.6 | 17 | 0.486 | 2.14 | 17.5 | 3.210 |
| 250 | 13.2 | 34.5 | 15 | 429 | 6.13 | 13.4 | 0.860 |
| 251 | 9.2 | 20.5 | 10 | 286 | 5.47 | 8.5 | 0.611 |
| 252 | 10.4 | 41.4 | 9 | 257 | 12.27 | 5.5 | 0.176 |
| 253 | 10.0 | 24.0 | 18 | 514 | 3.56 | 21.8 | 2.409 |
| 254 | 9.0 | 32.2 | 15 | 429 | 5.72 | 17.6 | 1.210 |
| 255 | 10.4 | 29.2 | 17 | 486 | 4.59 | 19.7 | 1.688 |
| 256 | 9.8 | 33.8 | 19 | 543 | 4.74 | 23.8 | 1.974 |
| 257 | 6.4 | 21.2 | 6 | 171 | 9.43 | 4.2 | 0.175 |
| 258 | 11.0 | 29.9 | 8 | 229 | 9.97 | 3.2 | 0.126 |
| 259 | 8.8 | 17.9 | 8 | 229 | 5.97 | 5.4 | 0.355 |
| 260 | 10.6 | 18.7 | 13.5 | 386 | 3.71 | 13.3 | 1.411 |
| 261 | 10.8 | 23.3 | 14 | 400 | 4.43 | 14.0 | 1.241 |
| 262 | 9.6 | 16.4 | 19.5 | 557 | 2.25 | 24.9 | 4.355 |
| 263 | 8.2 | 15.8 | 7 | 200 | 6.05 | 4.2 | 0.273 |
| 264 | 11.6 | 53.2 | 11 | 314 | 12.91 | 7.8 | 0.237 |
| 265 | 11.0 | 25.1 | 11 | 314 | 6.10 | 8.4 | 0.541 |
| 266 | 12.4 | 35.4 | 10 | 286 | 9.45 | 5.3 | 0.220 |
| 267 | 13.8 | 12.2 | 18 | 514 | 1.81 | 18.0 | 3.908 |
| 268 | 3.6 | 52.8 | 10 | 286 | 14.09 | 14.1 | 0.393 |
| 269 | 9.6 | 64.6 | 8 | 229 | 21.56 | 4.6 | 0.083 |
| 270 | 10.2 | 19.1 | 12 | 343 | 4.26 | 11.0 | 1.016 |
| 271 | 10.6 | 20.0 | 9 | 257 | 5.92 | 5.3 | 0.352 |
| 272 | 10.4 | 24.4 | 16 | 457 | 4.06 | 17.9 | 1.732 |
| 273 | 11.2 | 9.8 | 14 | 400 | 1.87 | 13.6 | 2.863 |
| | | Set No. 17 | Filtrol in Tube No. 3 | | | | |
| 274 | 28.6 | 46.6 | 22 | 0.629 | 5.64 | 10.3 | 0.717 |
| 275 | 20.4 | 49.4 | 17 | 486 | 7.74 | 9.7 | 0.492 |
| 276 | 22.6 | 47.5 | 16 | 457 | 7.91 | 5.7 | 0.283 |
| 277 | 18.2 | 72.6 | 21 | 600 | 9.21 | 18.9 | 0.807 |
| 278 | 21.2 | 52.5 | 20 | 571 | 7.00 | 14.4 | 0.809 |
| 279 | 20.6 | 50.8 | 16 | 457 | 8.46 | 7.7 | 0.358 |
| 280 | 20.4 | 47.9 | 19 | 543 | 6.72 | 13.2 | 0.772 |
| 281 | 7.6 | 78.0 | 11 | 314 | 18.91 | 11.8 | 0.245 |
| 282 | 17.6 | 54.8 | 16 | 457 | 9.13 | 10.7 | 0.461 |
| 283 | 7.6 | 61.6 | 16 | 457 | 10.27 | 21.7 | 0.831 |
| 284 | 23.8 | 43.2 | 19 | 543 | 6.06 | 9.8 | 0.636 |

| Run No | Manometer cm $H_2O$ | Flow Rate g/sec | Quan in Tube grams | Apparent Sp Gr | Velocity V ft/sec | $\Delta P$ due to flow cm $H_2O$ | $\Delta P/V$ $\frac{\text{in } H_2O}{\text{ft/sec}}$ |
|---|---|---|---|---|---|---|---|
| 285 | 22.2 | 46.7 | 17 | 0.486 | 7.32 | 7.9 | 0.424 |
| 286 | 13.6 | 54.4 | 12 | 343 | 12.09 | 7.6 | 0.247 |
| 287 | 8.6 | 44.2 | 8 | 229 | 14.73 | 5.6 | 0.149 |
| 288 | 19.6 | 48.0 | 21 | 600 | 6.09 | 17.5 | 1.130 |
| 289 | 11.6 | 77.9 | 18 | 514 | 11.54 | 20.2 | 0.689 |
| 290 | 17.4 | 66.8 | 11 | 314 | 16.19 | 2.0 | 0.048 |
| 291 | 15.6 | 49.6 | 6 | 171 | 22.04 | -5.0 | |
| 292 | 21.6 | 50.9 | 22 | 629 | 6.17 | 17.3 | 1.103 |
| 293 | 22.6 | 49.4 | 22 | 629 | 5.98 | 16.3 | 1.071 |
| 294 | 17.0 | 87.7 | 14 | 400 | 16.70 | 7.8 | 0.183 |
| 295 | 17.6 | 55.6 | 6 | 171 | 24.71 | -7.0 | |
| 296 | 14.6 | 53.9 | 13 | 371 | 11.05 | 8.4 | 0.299 |
| 297 | 20.4 | 59.0 | 18 | 514 | 8.74 | 11.4 | 0.513 |
| 298 | 21.2 | 53.9 | 21 | 600 | 6.84 | 15.9 | 0.914 |
| | | Set No. 18 | | Filtrol in Tube No. 1 | | | |
| 299 | 47.6 | 82.3 | 88 | 0.568 | 3.92 | 18.8 | 1.885 |
| 300 | 50.8 | 121.4 | 86 | 555 | 5.92 | 14.0 | 0.930 |
| 301 | 49.4 | 151.0 | 85 | 549 | 7.45 | 14.7 | 0.776 |
| 302 | 48.4 | 149.3 | 78 | 504 | 8.03 | 10.5 | 0.514 |
| 303 | 47.4 | 115.6 | 87 | 562 | 5.57 | 18.3 | 1.291 |
| 304 | 43.8 | 197.2 | 71 | 458 | 11.66 | 9.7 | 0.327 |
| 305 | 47.4 | 142.6 | 82 | 529 | 7.30 | 14.4 | 0.776 |
| 306 | 44.4 | 129.6 | 61 | 394 | 8.91 | 1.6 | 0.070 |
| 307 | 55.4 | 88.0 | 90 | 581 | 4.10 | 12.5 | 1.198 |
| 308 | 49.4 | 113.8 | 90 | 581 | 5.30 | 18.5 | 1.372 |
| 309 | 47.4 | 116.8 | 88 | 568 | 5.57 | 19.0 | 1.342 |
| 310 | 50.4 | 125.4 | 92 | 594 | 5.72 | 19.0 | 1.307 |