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Study - Mechanical Attrition
Tests, Termination Report
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SUMMARY

An attrition loop has been constructed to study the mechanical attrition of resin during the operation of a Higgins continuous ion exchange column. The loop was operated for 350 hr with resin in water and 900 hr with resin in mill pulp. Applying the results of these tests to the prediction of the mechanical attrition rate in the 6-in. Higgins column, a probable value of 13%/yr was obtained. The maximum value which could be expected from extrapolation of the data to 6-in. column operation was 45%/yr.

From these data it can be shown that attrition of resin the 6-in. Higgins column due to mechanical action probably would contribute very little to the chemical cost of operating such a column.

Examination of the mechanical factors which contribute to resin attrition indicated that the rate of mechanical attrition in the 12-in. Higgins column would probably be reduced by one order of magnitude from the values predicted for the 6-in. column. The resin attrition due to mechanical action in the 12-in. column would be so slow that it is quite certain that chemical attrition (attrition due to resin swelling and shrinking on chemical loading and unloading) would be the controlling factor.

In order to predict the total attrition rate in large Higgins columns, it will be necessary to study the phenomenon of chemical attrition on a laboratory scale. In addition, it would be very desirable to obtain data on total attrition rates during the forthcoming operations of the 12-in. column at Grand Junction, Colorado.

Contrary to prediction, it was found that circulation of resin in mill pulp through the loop resulted in little difference in mechanical attrition rate compared with resin circulated in water. However, there was an indication that substantial differences in initial attrition rate may exist between various batches of the same resin type.

It is recommended that laboratory tests be developed to determine initial attrition rates of resin batches for control purposes. It is further recommended that future mechanical attrition tests be carried out with resin in water to simplify test operations.

INTRODUCTION

One important problem in the operation of the Higgins-type ion exchange column is the attrition of resin. Excessive resin attrition could seriously affect the economics of the continuous ion exchange process. A hydraulic classifier section in the Higgins column removes small particles of broken resin as well as some of the fines that are fed to the column in the mill pulp. This section is located at a point where the concentration

of the uranium adsorbed on the resin is a maximum. Thus resin attrition would result not only in resin loss but also uranium loss from the column.

The following values are based upon calculations performed by I. R. Higgins of the Chemical Development Section. Resin cost is conservatively estimated to be \$70/cu.ft. Since resin fully loaded with uranium will contain approximately 3.2 lb uranium/cu.ft., the total value of resin and uranium lost from a column classifier section would be approximately \$100/cu.ft.

A continuous ion exchange column containing 64 cu.ft. of resin, capable of processing 100 tons of ore per day, is taken as an example. If all of the resin in the column must be replaced once each year, the resulting contribution to the cost per pound of uranium processed would be \$0.036. On the other hand, resin replacement once per month would increase the contributing cost to \$0.43/lb uranium. For the chemical flowsheet using aqueous ammonium nitrate as the strip solution, the cost for the nitrate would be approximately \$0.18/lb of uranium processed. The nitrate cost is the largest single chemical cost for the process.

Thus resin life on the order of one month would make the resin cost much larger than the largest chemical cost for the process, while resin life of one year or greater would make the resin cost minor compared with chemical costs.

There are two causes for resin attrition, chemical and mechanical. The chemical effect is due to density changes due to particles swelling and shrinking as the resin is loaded and unloaded under restraint in the extraction and stripping sections of the column.

The mechanical effects are due to shear between individual particles and between particles and column equipment either during dense bed flow of the resin or stationary bed operations. The purpose of the present investigation was to study the mechanical causes of resin attrition. The method of study was to set up equipment simulating the mechanical attrition of resin in the Higgins column and to attempt to predict resin life due to mechanical effects in actual column operation.

An attrition loop was constructed to measure resin attrition in the presence and absence of mill pulp as a function of time.

ATTRITION TEST PROCEDURE

The attrition loop used in this investigation is shown in Figure 1. The loop consisted essentially of a circulation system of 2-in. Pyrex pipe, interconnected bronze plug valves, and an Oliver diaphragm pump operating with pressure and vacuum connections.

During the studies it was necessary to operate the loop for prolonged periods. The loop was equipped with automatic timing controls,

LEGEND

A—ADAPTER—1" PYREX TO 1" I.P.S. SS FITTING
N—NIPPLE—1" SS
R—REDUCER—PYREX
V—VALVE

Figure 1
ION EXCHANGE RESIN TEST LOOP

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activating alternately the solenoid valves on the Oliver pump and the pneumatic piston. It was found that the loop could be operated continuously for several days with a minimum of attention.

Samples were taken every one-hundred hours of loop operation. The resin was photographed at 25-power magnification and the particles were counted to determine the percentage of broken particles. The following equation was used to calculate the per cent broken:

$$\text{Per cent broken} = \frac{A + B/2}{A + B/2 + C} \times 100$$

where: A = broken particles larger than half-spheres.
B = broken particles smaller than half-spheres.
C = whole resin particles.

RESULTS OF ATTRITION TESTS

Two series of tests were carried out with the attrition loop: Test Series "A" - resin circulated in water, and Test Series "B" - resin circulated in mill pulp. The results of these tests are shown graphically in Figure 2, and the data are listed in Table I. In Table II is presented the initial resin particle size distribution for Test Series "A" and "B".

As may be seen from the figure, the attrition curve may be considered to have three separate sections: an initial-rate period, a constant-rate period, and an increasing-rate period. The initial-rate period is probably the result of the high initial breakup of particles which were cracked or weakened during the manufacture of the resin.

Note that there was a higher initial breakup rate during Test Series "A" than during Test Series "B". The resin for these two tests were from two separate shipments from the manufacturer. It is probable that there was a significant difference in the percentage of structurally-sound particles between the two shipments.

The constant-rate period probably represents the rate of attrition of structurally-sound resin particles containing a small percentage of broken pieces. Note that the constant-rates for the two test series were essentially equal. Obviously there was little effect of the mill pulp present in Test Series "B" on the constant-rate attrition.

Finally, the increasing-rate period may be the result of broken particles contributing to the mechanical abrasion of the whole particles. The broken particles would behave as catalysts for the attrition reaction and the rate would be expected to increase as the catalyst concentration increased. (According to this argument there would be no true constant-rate period; however, the slope change in this period was not detectable experimentally).

As was mentioned previously, the Higgins column contains a classification section, the purpose of which is to remove among other things broken

Fig. 2. The Effect of Operating Time on Resin Attrition.

Table I
Results of Attrition Tests

a. Test Series "A"

Liquid: Water - 8 liters (approximation)
Resin: Permutit S.K. (10-20 mesh^a)-12 liters

Operating Cycle: 2 cycles/min.

<u>Time - Hr.</u>	<u>Per Cent Broken</u>
0	0
100	6.0
200	7.0
300	9.0

b. Test Series "B"

Liquid: Mill Pulp Slurry^b - 6 liters
Resin: Permutit S.K. (10-20 mesh^a)-12 liters

Operating Cycle: 2 cycles/min.

<u>Time - Hr.</u>	<u>Per Cent Broken</u>
0	0.0
100	3.4
200	4.7
300	5.6
400	7.1
500	10.8
600	19.2
700	29.
800	36.
900	57.

^aInitial resin particle size distributions are shown in Table II.

^bSlurry - 10% solids, 1% of which greater than 325 mesh.

Table II

Initial Resin Particle-Size Distribution

Size (mm)	Test Series "A" % of Total	Test Series "B" % of Total
0.60	---	.46
0.64	1.6	----
0.72	---	.46
0.80	3.9	3.1
0.84	10.9	3.1
0.88	14.8	8.8
0.92	4.7	2.7
0.96	7.0	6.0
1.00	4.7	10.6
1.04	9.4	9.2
1.08	8.6	5.6
1.12	7.8	10.1
1.16	3.9	4.1
1.20	3.9	6.5
1.24	3.1	1.4
1.28	3.1	4.1
1.32	---	.46
1.36	2.3	4.1
1.40	1.6	2.3
1.44	1.6	3.7
1.48	1.6	1.8
1.52	1.6	3.2
1.56	2.3	1.4
1.60	0.8	6.3

resin particles. Therefore, the catalytic effect of broken particles on mechanical attrition in a column would probably be minimized. Thus, the probable long term attrition rate in a system with continuous broken particle removal would be an extension of the constant-rate period, shown in Figure 1 as a dashed line.

On the abscissa in Figure 1, along with the time of operation of the attrition loop, is plotted the equivalent operating time of the 6-in. Higgins column. The factor which relates loop operating time to column operating time, as far as mechanical attrition of resin is concerned, was obtained in the following way.

Four types of mechanical action were considered to contribute to resin attrition: (1) the action of plug valves on resin particles as the valves rotate through a stationary resin bed, (2) the contraction of a flowing resin stream as it passes in dense bed flow between pipe sections of decreasing cross-section, (3) the interaction of resin particles with each other under constant cross-section flow (typified by total feet of travel per unit time), and (4) the interaction of resin particles with pipe walls (represented by surface area per unit time and volume).

The four factors are listed in Table III. It was necessary for comparison purposes to evaluate valve action, flow contraction, and pipe surface effects on a per cubic foot of resin basis, since these factors did not affect all of the resin in the three unit simultaneously. However, resin travel per unit time could be compared directly.

The units are shown in the table, and the calculated values are listed for each type of equipment. Under the heading "Factors", the ratios of the calculated values are indicated, with the values for the 6-in. column arbitrarily defined as unity.

It may be seen that the mechanical factors for the attrition loop range from 6.2 to 21. Since all factors are on a common time basis, these factors indicate that the mechanical attrition of resin in the attrition loop should be approximately 6 to 20 times as fast as the mechanical attrition in the 6-in. column. Obviously, the actual value would depend upon the relative importance of each factor.

It was assumed for the purposes of this report that a factor of ten represented the comparative attrition rates in the two pieces of equipment. The two abscissas in Figure 2 are plotted on this basis.

Based on an extension of the constant-rate attrition period and a time factor of ten, the probable per cent resin attrition in the 6-in. column after one year's operation would be 13. The maximum value would be obtained from an intersection with the increasing-rate period curve at a value of approximately 45% per year.

It may also be seen from Table III that there should be a decrease of approximately one order of magnitude in the mechanical attrition rate in the 12-in. column. Such a slow attrition rate would be predicted,

Table III

Mechanical Factors Contributing to Resin Attrition

Mechanical Action	Units	Attrition Loop	6" Column	12" Column	Factors
Valve Action	$\frac{\text{Plug Valve Rotation}}{(\text{min})(\text{cu.ft. of resin})}$	5.6	0.9	0.08	6.2/1/0.09
Resin Flow Contrac-tion	$\frac{\text{Resin Contractions}}{(\text{min})(\text{cu.ft. of resin})}$	8.4	1.2	0.11	7.0/1/0.09
Resin Flow Rate	$\frac{\text{ft}}{\text{min}}$	1.67	0.083	0.021	20/1/0.25
Pipe Sur-face Effect	$\frac{\text{Sq. ft of pipe surface}}{(\text{min})(\text{cu.ft. of resin})}$	1.46	0.07	0.007	21/1/0.1

that chemical attrition (attrition from density changes under chemical loading and unloading) would undoubtedly be the controlling factor in resin attrition.

In order to predict accurately the overall attrition rate in the 12-in. and 6-in. columns, it will be necessary to extend attrition studies to an investigation of the chemical effects on resin life.

PHOTOGRAPHIC MEASUREMENTS OF RESIN ATTRITION

Figures 3 through 6 are photomicrographs of samples of resin taken from the attrition loop at 0, 300, 600, and 900 hr of Test Series "B". The pictures show qualitatively the resin attrition as a function of time. For statistically significant data, it was necessary to count broken and unbroken particles on a large number of photographs at each sampling period.

JCB:CWH/mj

Unclassified
Photo M-1673

Figure 3. Initial Resin Particles Before Test Series "B". Permutit SK (10-20 Mesh). 25X.

Figure 4. After 300 hr of Attrition Loop Operation. Test Series "B". 25X.

Figure 5. After 600 hr of Attrition Loop Operation. Test Series "B". 25X.

Figure 6. After 900 hr of Attrition Loop Operation. Test Series "B". 25X.