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For The Atomic Energy Commission
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Chief, Declassification Branch

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BRIEF REPORT OF TYPE II CENTRIFUGE OPERATION
AT
THE UNIVERSITY OF VIRGINIA
FEBRUARY 28, 1944

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The 136" long 7.35" I.D. centrifuge at Virginia has been used with process gas UF_6 in both type I and type II operation. For predicting the operation of a number of centrifuges in cascade, Thompson has shown that type II operation of a single centrifuge is preferable to type I. In view of the fact that the recent results with type II operation are both significant and clear cut, this brief report is submitted at this time. A more detailed report of the complete experiments including both type I and type II will be submitted later.

Type II operation for a stripper is shown schematically in Fig. I. For a single machine a definite amount of L gms/sec ordinary UF_6 (input flow) is fed into the centrifuge in a thin stream with annular cross section, (diam. AA) which flows down the inner walls of the tubular centrifuge along the path AB. At BB it (L gms/sec) is withdrawn from the centrifuge by a centrifugal pump on the centrifuge shaft and pumped to E where the desired product P gms/sec is removed. The remainder of the UF_6 $L - P$ flows to F where an amount of ordinary UF_6 (called make up) equal in mass flow to the product P gms/sec is introduced into the stream. From F the stream of L gms/sec flows back into

Fig. I

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the centrifuge end cap where it is directed from C to D in a thin stream with annular cross section (diam.CC). At DD, L gms/sec is removed from the centrifuge. (D.D. equals approximately one half AA) The flows L entering at A and at C, the product rate P and the make up rate which is equal to P, are measured by thermal flowmeters to about one percent. The change in N_0/N_2 where N_0 is the mole fraction of U_{235} in the ordinary material introduced into the input and into the make up and N_2 is mole fraction of U_{235} in the product withdrawn, was determined to about one percent by Ney, McQueen and Cocke, using the Nier mass spectrometer. With a knowledge of the above quantities together with the rotor speed and rotor temperature the results of the operation obtained can be directly compared with those computed from the ideal Cohen-Thompson theory. Also, which is of great practical importance, from the above measured data, the operation of a cascade of centrifuges can be determined independently of the theory of the internal operation of the single centrifuge.

The centrifuge tube was 11-1/3 ft long, 7.35" I.D. and is very nearly the size contemplated for use in a large plant of centrifuges. However, it was made of forged rather than of extruded Duralumin ST 1 and it is known to contain flaws. As a result, the rotor inside peripheral speed was necessarily limited to 2.01×10^4 cm/sec rather than 2.7×10^4 cm/sec which is the safe speed for the extruded tubes. Nevertheless, our previous experiments as well as the theory have indicated that increased peripheral speed increases stabilization of the concentric flow streams AB and CD, Fig. 1, and hence increases the efficiency of operation; i.e., the efficiency of operation here described is no doubt handicapped to some extent by the reduced speed

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The experimental procedure for a "run" consisted in first evacuating the entire system Fig. 1, and bringing the centrifuge up to speed (inside peripheral speed = 2.01×10^4 cm/sec). The system was then filled with UF_6 and all of the various flows adjusted as soon as possible. The pressure on the axis of the centrifuge varied from run to run, but was usually the order of 1 cm of mercury. The product was taken continuously and samples of this were drawn off for analysis at regular 30 minute intervals from the beginning of the operation, so that a measure of the equilibrium time could be obtained. The enrichment $\epsilon = 1 - \frac{N_o}{N_z}$ as measured by the mass spectrometer in the product P was then plotted vs time as shown in (Graph 1) for a typical operation with all flows constant. It will be observed that the curve becomes a straight line parallel to the time axis in 1.5 hours after the operation is started. In other words, the equilibrium time is less than 1.5 hour which is less than one half the theoretical equilibrium time for this case.

Table I gives the data taken with type II operation. All of the data are included so that they represent actual average operation. The results of Table I are plotted in Graphs II, III, IV and V.

According to the theory of the cascade of centrifuges the so-called "separative work" is proportional to the total length of centrifuges necessary to produce a given amount of U_{235} at a prescribed concentration per unit of time. In graphs II, III and IV the separative work obtained is plotted against the product rate, for input flow rates (L) of 80 mg/sec, 65 mg/sec and 50 mg/sec. It will be observed that in some cases, the experimental points are above the theory. However the efficiency of operation for a given flow L is the ratio of the peak of the experimental curve to that of the theoretical curve. These

values can be read from the scale at the right of each graph. The value of the separative work corresponding to the peak of the theoretical curve is called, W_{fm} . In the lower part of the graphs the separation N_o/N_z is plotted against the product rate.

From the table and graphs the following points should be noted:

1. The separative work efficiency in every case is between 80 and 85 percent of the maximum possible value calculated from theory.
2. The maximum of the experimental curves for separative work vs. product rate occur at higher product rates than those of the corresponding theoretical curves.
3. The maximum of the experimental curves for product rate vs. separative work are much flatter than those of the corresponding theoretical curves. This is of utmost importance because it means that the absolute value of the product rate need not be carefully controlled in a large plant or cascade of centrifuges for good operation. Also graph V shows that curve of the flow rate L vs separative work is very flat which means that the absolute value of the flow is not critical. In other words, the flow control problem for a large cascade of centrifuges should be comparatively easy.
4. The data (of which graph I is an illustration) show that the so-called experimental equilibrium time is less than half as long as theory would predict. This also is of importance because it means that the cascade of centrifuges would start producing material much more quickly than theory would predict.
5. The data given above are for a stripper. This taken with the available data (from G.S.P. Plant at Bayway) for an enricher shows that the separation with a centrifuge is practically independent of

the relative concentration of the isotopes N_0 . This means that the centrifuge method can be used to produce U_{235} of any concentration up to practically pure material without loss of efficiency. Also it is important to note that the short equilibrium time (mentioned in 4 above) makes the method especially adaptable for the upper stages of a plant producing comparatively pure U_{235} .

6. The data were taken with a centrifuge of essentially the same dimensions and under similar conditions as those proposed for the large cascade plant. With the exception that this experimental set-up employed a buffer gas seal system which allowed a very small amount of nitrogen seal gas to enter the process gas system. This latter factor however is believed to have had negligible influence upon the experimental results. Also all data taken were included in the calculations so that the data represent operational conditions. Finally one further point should be mentioned concerning the mechanical operation of the centrifuge. It was observed that when the machine reached full speed little or no observable wear in the bearings, etc., occurred. This is in accord with our previous experience with high speed centrifuges and results from the fact that the high speed centrifuge must be designed so that practically complete hydrodynamic lubrication takes place, i.e., there is no metal to metal contact in the bearing. Obviously this reduces wear almost to zero and accounts for what at first sight might seem like a paradox; namely, that a very high speed machine does not wear out as rapidly as one running at a low speed.

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Date	Input flow (L)mg/ sec	Product (P)mg/ sec	N _o /N _z		Separative Work mg/sec		Max. theo. Sepa- ration for flow (W _{fm})mg/ sec	Efficiency E _{fm} (= $\frac{W}{W_{fm}}$ x 100)
			Obt'd	Theo.	Obt'd (W)	Theo. (W _{fmp})		
12/15	80.7	25.65	1.039	1.0394	.0376	.0383		72.5
12/17	79.5	19.52	1.0475	1.0480	.0420	.0429		80.9
2/21	79.3	15.06	1.0535	1.0574	.0409	.0469		78.7
2/23	79.7	10.64	1.0605	1.0714	.0367	.0506		70.7
2/28	79.6	5.35	1.0725	1.101	.0262	.0496	.0519	50.5
/1	64.3	19.80	1.0470	1.0424	.0418	.0341		81.5
/4	65.4	14.90	1.0535	1.0534	.0405	.0403		79.0
/6	65.2	9.70	1.0695	1.0722	.0438	.0472		85.4
/19	64.9	24.83	1.0415	1.0355	.0411	.0302		80.0
/21	65.2	15.11	1.0525	1.0528	.0396	.0400		77.2
/24	65.2	10.26	1.0670	1.0695	.0432	.0463	.0513	84.2
/26	50.0	19.72	1.0435	1.0359	.0358	.0245		71.5
/29	49.8	15.03	1.0515	1.0445	.0379	.0285		75.8
/31	50.3	10.12	1.0665	1.0626	.0420	.0373	.0500	84.0

Note: (1) The notation "W_{fmp}" is the theoretical separative work for the particular flow pattern ("f"), flow rate ("m"), and product flow ("p") used. W_{fm} is the maximum possible value of W_{fmp}.

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In a large project the summary of which appears in this report it is very difficult to give each worker his proper credit. Also since a more comprehensive report is to appear later in which the apparatus as well as the data will be described, it will suffice only to record the names of the workers here in alphabetical order, who obtained the above data:

The work was under the direction of:

Beams, J. W.

Snoddy, L. B.

The collaborators were:

Bader, Frank

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Mann, Alfred K.

Moore, John W.

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Randolph, Malcolm L.

Simons, Charles S.

Young, James L. III

The above workers are indeed very greatly indebted to Dr. B. C. Belden of the Standard Oil Development Company, who not only served as Liaison with the G.S.P. Plant in Bayway, but has rendered most valuable help with the analysis of the data.

Signed: _____

J. W. Beams, Prof. of Physics
University of Virginia
February 29, 1944

GRAPH I

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ENRICHMENT $I - N_0/N_2$ IN PERCENT

MEASURED ENRICHMENT
VS
TIME AFTER BEGINNING OF RUN

INPUT FLOW = 79.7 MG/SEC.
PRODUCT = 10.64 MG/SEC.

TIME AFTER BEGINNING OF RUN IN HOURS

GRAPH II

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GRAPH III

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GRAPH IV

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GRAPH V