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A PROGRESS REPORT

The Development of Short Bowl Ultracentrifuges

by

Gernot Zippe

Submitted to the

Physics Branch
Division of Research
U.S. Atomic Energy Commission

July 1, 1959

Contract [AT(40-1)-2400]

UNIVERSITY OF VIRGINIA
DEPARTMENT OF PHYSICS
ORDNANCE RESEARCH LABORATORY

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I. INTRODUCTION

A detailed description of a very simple short gas ultra-centrifuge with exceptional performance characteristics has been given in the first progress report on this contract (UVA/ORL-2400-58 PR #1 of December 1, 1958). Because of the inexpensive construction made possible by its simple design, the very low electric power consumption and a novel method for handling the process gas, this device is believed to be superior for large scale separation of uranium isotopes to gaseous diffusion or other known types of gas centrifuges.

The present research program has as its principal objectives, the reproduction of this device, a careful study of its mechanical characteristics and a thorough demonstration of its separating ability as applied to the uranium problem.

II. REPORT ON PROGRESS TO DATE

The work of reproducing the original effort is divided into three parts.

Part I - Construction and lifetime testing of mechanical prototypes.

Part II - Study of the dynamic properties of the scoops using an inert gas. Particular emphasis will be placed upon a determination of power requirements and the pressure developed.

Part III - Use of this centrifuge for the actual separation of uranium isotopes.

At the present time work on Parts I and II is essentially completed. A mass spectrometer is now ready for measurements and as soon as uranium hexafluoride is received and arrangements for handling this gas are completed, work on Part III will commence.

A. Facilities and Supporting Work

This research program has been carried on in a separate building located near the shop of the Physics Department of the University of Virginia which has been made available to

the Ordnance Research Laboratory. The space available has been adequate for the project.

Mr. William H. Dancy, Jr., of the staff of the Ordnance Research Laboratory has given freely of his time in assisting the author in the procurement of materials, supplies and equipment. This assistance is gratefully acknowledged as the author is still quite unfamiliar with such procedures and particularly the availability in the United States.

The instrument shop at the Ordnance Research Laboratory also assisted in the construction of much of the instrumentation needed, e.g., power generators, oscilloscopes and oscillators for speed measurement. Some of the test stands and rotor systems were also constructed in their instrument shops.

A mass spectrometer suitable for routine measurement of isotopic abundance of uranium has been installed. In order to make it possible to do work in the summer time an air conditioning system has been installed. Provisions for handling uranium hexafluoride are now being made. These include the installation of a large exhaust fan and the construction of a special room and device for filling ampules.

B. Lifetime Tests

One important requirement for a gas centrifuge which is intended for use in a production cascade is its reliability and a minimum of maintenance. Because these tests require a long period for completion they were scheduled to start early in the research program. A description of the stands used for life tests of the rotors and bearings is given on pages 9-12 and Figures 2-9 of the first report. The preliminary arrangement in which both stands are connected to a single vacuum fore pump has been changed. Each stand now operates with a single mechanical pump as depicted in Fig. 1. Two stands which will accommodate rotors 11 inches long, 2.7 inches in diameter and a weight of one pound have been in operation since mid-December 1958. Two additional stands of similar construction which are designed for larger rotors (up to 4 inches in diameter and 20 inches long) have been available since April 1959.

Figure 1. Lifetime stands for rotors with 2.7" diameter and 11" length.

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During the progress of a life test the rotors are kept in continuous operation at a speed of 1500 cycles per second (synchronous with the driving frequency). The length of the needle on which the rotor spins (which is the only mechanical contact of rotating parts) is checked periodically to determine wear. The deceleration of the rotor with no driving power is a measure of the total drag torques (bearing plus air friction). This was measured daily by determining the change in rotational speed during a given time interval.

Experimental Results

The failure of a rotor after 300 hours mentioned in the previous report which was ascribed to differential creep between the end cap and rotor has not been repeated.

The two shorter life test stands have been in continuous operation for several months (December 1958 - June 1959), and it is planned to continue these tests. At intervals of about one thousand hours the length of the flexible axle was measured with an accuracy of two ten-thousandths of an inch, and the oil level in the bearing was checked visually. During the first few hundred hours of operation the hardened tip of the piano wire shaft is ground to fit exactly the depression in the supporting tungsten carbide plate. The decrease in length of the axle which occurred after the initial "grinding in" period for both rotors was determined to be 0.0002 inches which is the same as the precision of the measurement. This corresponds to an operation for 2500 hours for one rotor and 3700 hours for the other. At the present time (June 15, 1959) one rotor has completed almost 3,000 hours and the other more than 4,000 hours of continuous operation (4,380 hours is one half year of uninterrupted operation).

The oil level was found to be unchanged and the deceleration of the coasting rotor measured for a time interval shows only small fluctuations (about 15 percent) which depend on the room temperature and the pressure in the vacuum jacket.

The two additional life test stands mentioned above are completed and in operation. These stands are depicted in Fig. 2. All four lifetime test stands are driven synchronously by the same generator at 1500 cycles per second. The rotors do not have a diameter of 4 inches (as mentioned in the first report) because the material provided for these rotors had a

Figure 2. Lifetime stands for rotors up to 4" diameter and 20" length.

tensile strength yield corresponding to a maximum peripheral speed of 350 meters per second. There was available thin walled tubing three inches in diameter of 7075 aluminum alloy which permits a maximum peripheral speed of 385 meters per second. Since the separating power of a centrifuge is proportional to the fourth power of the peripheral speed (see Appendix A to the first report for elementary theory of the gas centrifuge), the author decided to work with rotors of 3-inch diameter until better tubing of larger diameter is available. At the present time these two additional lifetime stands are being used to test mechanically, rotors which will be used in the separation experiments.

C. Spin Test Stand

Before building the final centrifuge for separation it is essential to know the stress limitations of all the materials to be used. A simple test stand which can be used to rotate a short ring of tubing which has been constructed is depicted in Fig. 3. The maximum peripheral speed is a measure of the ratio of the tensile yield strength to the density of the rotor material. (See Appendix A to the first report). The rotational speed of the ring to be tested is increased until failure occurs. The diameter of the ring and the maximum rotational speed determines the maximum peripheral velocity. The decision to use thin walled rotors of 3-inch diameter was based on measurements made in this manner.

D. Determination of Power Loss of Scoop System

As described on page 6 of the first report three tubes for insertion and extraction of process gas pass through the top of the rotor. The feed tube ends in the middle of the rotor while the other two tubes terminate at opposite ends of the rotor in two pairs of pitot tubes in the plane perpendicular to the axis of rotation. These end sections referred to as scoops make use of the high impact pressure in the vicinity of the periphery for transport of the heavy and light gas fractions. Simultaneously one of the tubes, by means of the reduction of the angular velocity of the gas, induces the desired counter-current flow while the other is shielded by a plate so as not to disturb the flow of the gas.

Figure 3. Spin Test stand.

Two important features of this gas centrifuge design are the fact that transfer of gas from stage-to-stage is accomplished with a very low power consumption without external pumps and that counter-current flow is established without a temperature gradient. The power requirement of the internal scoop system was determined from deceleration measurements made with a gas filled system. At the same time the pressure available for stage-to-stage transport was measured directly. The properties of the counter-current flow induced by the scoops can only be experimentally determined through its effect on separation.

Measurements have been made on ten different scoop systems with three freon gases of varying molecular weight (121, 210, 260). These experiments were completed by the end of April 1959. The qualitative results were satisfactory as a basis for the design of the separation units. A detailed theoretical analysis of this unusual aerodynamical problem is now being made under the direction of Dr. H. M. Parker of the Ordnance Research Laboratory.

It is estimated that the scoop system to be used in the uranium hexafluoride separation experiments will consume about 2.5 watts per millimeter pressure at 1500 cycles per second (corresponding to 350 meters per second peripheral speed) for two pairs of scoops. It is clear from the experiments that the necessary pressure of several millimeters which will be required for stage-to-stage pumping will be obtained. The scoop system which will be used in the separation experiments is depicted in Fig. 4.

E. Performance of Spiral Molecular Pump

In order to reduce the drag on the wall of the spinning rotor it is necessary for it to operate in a vacuum. The maintenance of this vacuum is an important part of the power requirement of conventional gas centrifuges. As described in the first report, screw type grooves in the wall of the vacuum jacket in combination with the rotating tube act as a molecular pump to maintain a vacuum around the rotor.

Measurements have been made with a model pump using gases of different molecular weights and different rotational

Figure 4. Scoop assembly for handling gas inside the rotor and parts of rotor.

speeds. The preliminary experiments have been completed with satisfactory results. A detailed study of these pumps is being conducted by two graduate students at the Ordnance Research Laboratory.

Fig. 5 is a picture of the pump which will be used in the centrifuge designed for separation experiments. The expected performance of the pump was estimated from the qualitative results obtained with a model pump of identical geometry.

F. Electric Drive Motor.

The flat 3-phase drive motor in use for the new lifetime stands, the spin test stand and the separation stands are of the same type as described on page 11 and shown in Fig. 5 of the first report.

Instead of a laminated iron core, as shown in Fig. 6 of this report, ferrite rods and rings are used. This material has less magnetic losses, is easier to assemble and can be used inside the vacuum chamber.

G. Separation Tests

Perhaps the most important experiment to be conducted is a direct measurement of the ability of the gas centrifuge to separate uranium isotopes. Essentially the data to be obtained is the measurement of separation factor as a function of flow rate for various pressures and scoop geometrics.

One stand designed for conduct of separation experiments has been completed (June 15, 1959). The construction of the gas handling system is not finished because of delay in delivery of certain component parts (flowmeter, pressure meter for UF_6 , metering valves, etc.). The mass spectrometer which has recently been installed is now believed to be ready to make abundance measurements. A second separation test stand will be completed after obtaining some experience with the first one. The most important parts for the second unit are completed.

The design of the vacuum jacket and the driving motor are identical to those used in the mechanical life test stands described above. The rotor which will be used for separation and the upper bearing assembly with the ring shaped support magnets are depicted in Fig. 7.

Figure 5. Molecular pump and rotor.

Figure 6. Powdered iron magnetic core, completed stator, and driven end of rotor showing steel plate and supporting needle.

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Figure 7. Upper magnetic bearing, rotor, and top of scoop assembly.

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III. OUTLINE OF WORK TO BE COMPLETED BEFORE AUG. 28, 1959

The principal effort for the period from July 1, 1959 to Aug. 31, 1959 will be the performance of separation tests using UF₆. It is impossible to predict when these will start, but within the next two weeks all equipment should be ready and if the UF₆ is here the experiments should be underway.

As indicated in Section II-G above, this program, which is expected to require 3 to 4 months, will consist of the measurement of the separation factor as a function of flow rate for various pressures and scoop geometrics.

In addition mechanical lifetime tests will continue.

Finally it is hoped that there will be sufficient time and funds available to permit a preliminary look at the problems involved in engineering the ultracentrifuge to a form suitable for production in small quantities.

IV. GENERAL ADMINISTRATIVE REPORT

A. <u>Report of Expenditures</u>	Total to May 31, 1959	For period Mar. 1, 1959- May 31, 1959
1. Direct salaries and labor	\$ 23,142.34	\$ 7,069.33
2. Travel	1,137.92	124.92
3. Materials & supplies	9,949.02	4,529.99
4. Equipment	6,139.60	2,574.36
5. University charges	9,208.35	2,817.88
Total	\$ 49,577.23	\$ 17,116.48
B. Estimated expenditures, 1 June 1959 - Aug. 28, 1959		\$ 19,435.00
C. Estimated funds remaining in contract - Aug. 28, 1959		None

D. Changes Between Actual and Proposed Rates of Activity

Essentially the rate of effort has been pretty much as anticipated. However, due to delays in obtaining a mass spectrometer and difficulties in obtaining UF₆ it is now estimated that the separation experiments will need approximately one additional month beyond the expiration date before they are completed.

E. Incident Report

1. Serious Incidents - None
2. Fires, explosions, lightning, windstorms, floods and sprinkler leakage - None
3. Other property damage accidents - None
4. Personnel injuries - None

F. Technical Reports and Publications

The first three sections of this document are being released as a progress report. Otherwise there have been no publications or reports.

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