N92-27723

PROFESSOR JESSE W. BEAMS AND THE FIRST PRACTICAL MAGNETIC SUSPENSION

P. E. Allaire

R. R. Humphris

D. W. Lewis

Mechanical and Aerospace Engr. Dept., University of Virginia, Charlottesville, VA 22901

PRECEDING PAGE BLANK NOT FILMED

INTRODUCTION

Dr. Jesse W. Beams developed the first practical magnetic suspension for high speed rotating devices [1–2]. These devices included high speed rotating mirrors, ultracentrifuges and high speed centrifugal field rotors. Figure 1 shows a photograph of Dr. Beams in his laboratory.

Dr. Beams employed magnetic suspension as a means to carry out extensive experiments on physical properties in areas of isotope separation, biophysics, materials science, and gravitational physics. Typically, he thought of ways to modify and improve experiment equipment. The improved equipment then gave much better experimental results. Building on this advance, he then thought of some new type of experiment that could be performed with the technological advance in equipment and capabilities.

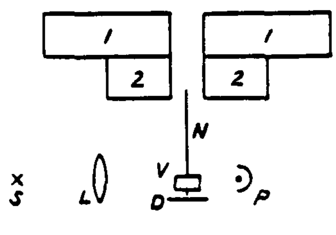
Fig. 1 Professor Jesse W. Beams, 1898–1977

EARLY AXIAL MAGNETIC SUSPENSION FOR ULTRACENTRIFUGES

The interest in high speed rotating devices extended to centrifuges. Around 1924, practical centrifuges were being developed in Sweden. Heavy particles in suspension will settle out more rapidly than light particles. This process can be speeded up by putting the suspension in a high speed centrifuge. However, convection currents caused by friction heating of the rotor surface due to the air outside caused problems. Beams removed this difficulty by placing the rotor in a vacuum.

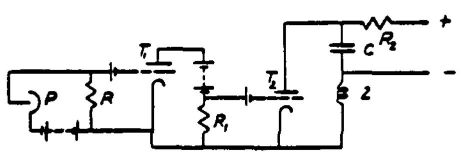
Originally, the rotor was supported axially by compressed air. This was replaced by a magnetic suspension system. A vertical shaft in the centrifuge rotor was attracted upward by a magnetic solenoid coaxial with it. The centrifuge was then radially stable, but axially unstable. Beams and two colleagues, Sheppard Black and Fred Holmes [3–6], devised a system of sensing the vertical position of the centrifuge rotor with a photoelectric cell. The position of the rotor was maintained by changing the current in the solenoid as needed. This type of system is now called automatic feedback control.

The principle was reported in [3]. Figure 2 illustrates the approach employed. "Solenoid 1 carries a steady direct current producing a magnetic field sufficiently strong to support a large fraction of the weight of the needle, N, and the attached cylindrical vane V. A source of light, S, is roughly focused on the upper edge of V so that some of the light passes over V and strikes a photo—cell P. The current from P operates a two-stage d.c. amplifier whose output is fed into a solenoid 2. Thus if N drops too low, the amount of light striking P is increased and the magnetic field is increased: if N rises too high, the field is decreased. In this way, if adequate damping is supplied, N may be automatically maintained at its equilibrium position." Figure 3 gives the circuit diagram for controlling solenoid 2.



N = rotating needle
V = attached vane
1 = steady solenoid
2 = control solenoid
S = source of light
L = lens
P = photocell
D = damping plate

Fig. 2. Schematic of Vertical Magnetic Suspension System Employed by Beams, et. al. [3] in 1937.



P= photocell, PJ23
R = resistor, 5 meg ohm
R1 = resistor, 40 kilo ohm
T1 = vacuum tube, 27
T2 = vacuum tube, 2A3
2 = control solenoid

Fig. 3. Control Circuit [3] Feeding Solenoid 2 in Figure 1.

In a short period of time, the magnetic suspension was employed in an ultracentrifuge and a paper [5] published in 1939 showed the schematic diagram of Figure 4. "... The rotating parts consist of the centrifuge C, an armature D of the electric motor, a small iron rod S, and a flexible shaft A which connects them together. The shaft A passes through vacuum tight oil glands G1, which seals the vacuum chamber, and G2, which serves to center D in the field F."

"... The rotating members are supported by an electromagnet consisting of an iron core M and windings L. The current through L is so adjusted that the magnetic attraction between M and the small iron rod S, rigidly attached to and coaxial with A, is just greater than necessary to lift S, A, D, and C."

The new magnetic suspension system had several advantages. First, the vertical rotor position was controlled to such an extent that no vertical motion could be detected by a 100 power microscope. Second, the power losses were so low that very high rotating speeds could be produced. Figure 5 shows a photograph of the magnetically supported centrifuge. In 1940, Skarstrom and Beams reported on an improved ultracentrifuge [6] as shown in Fig. 6. A viscous damper was added at the bottom to reduce lateral shaft vibrations. Figure 7 shows machinist P. Sommer in Dr. Beams' laboratory standing next to an ultracentrifuge.

As early as 1937, Beams and colleagues showed that the isotopes of elements could be purified by centrifuges. Further work was reported in [6]. During World War II, the Department of Physics conducted work on a long cylindrical centrifuge for the separation of uranium isotopes. A pilot plant was operated at Bayway, NJ starting early in the war for separating uranium 235 from uranium 238. However, this method was not employed for production of uranium 235 during the war. After the war, Dr. Beams continued to work with a classified project at the University to develop the centrifuge for eventual use in the production of uranium supplied to electric power reactors. The project continued until 1988.

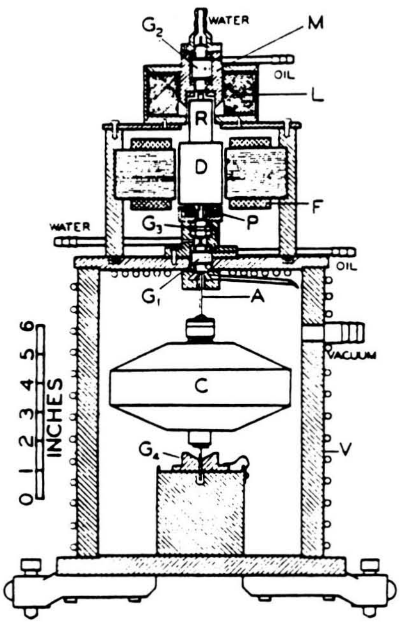


Figure 4. Drawing of Vacuum–Type Self–Balancing and Magnetically Supported Ultracentrifuge (1939).

C = centrifuge rotor
D = motor armature
S = iron rod
M = electromagnet iron core
L = electromagnet windings
A = flexible shaft
G1 = oil gland
G2 = oil bearing
F = field for rotation
N = clutch

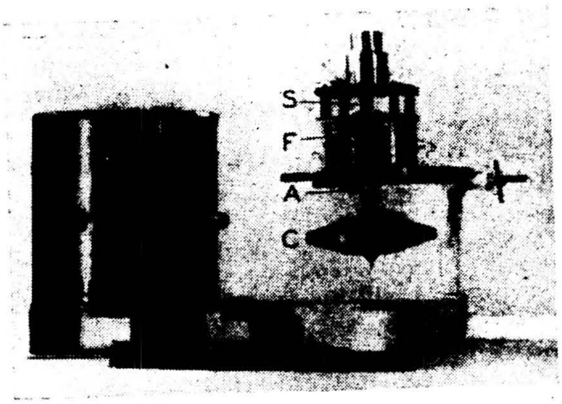
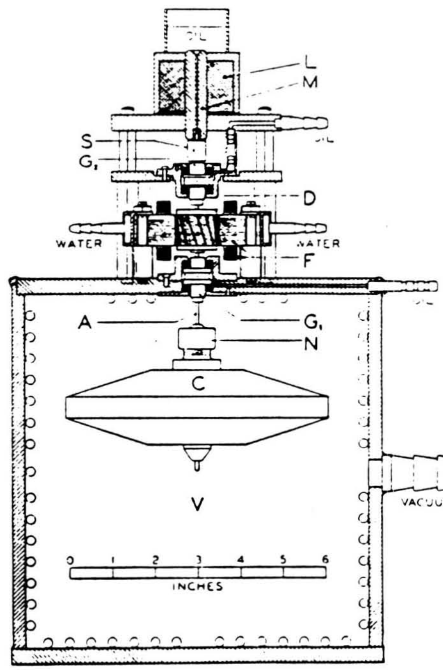


Figure 5. Photograph of Early Ultracentrifuge.



D = motor armature
R = mag. support core
M = cm iron core
L = support solenoid
C = rotor
A = shaft
G1 = oil bearing
G2 = oil bearing
G3 = oil bearing
G4 = viscous damper
P = pick up coil
F = motor stator
V = vacuum chamber

Fig. 6. Drawing of Assembled Electric Ultracentrifuge in 1940.

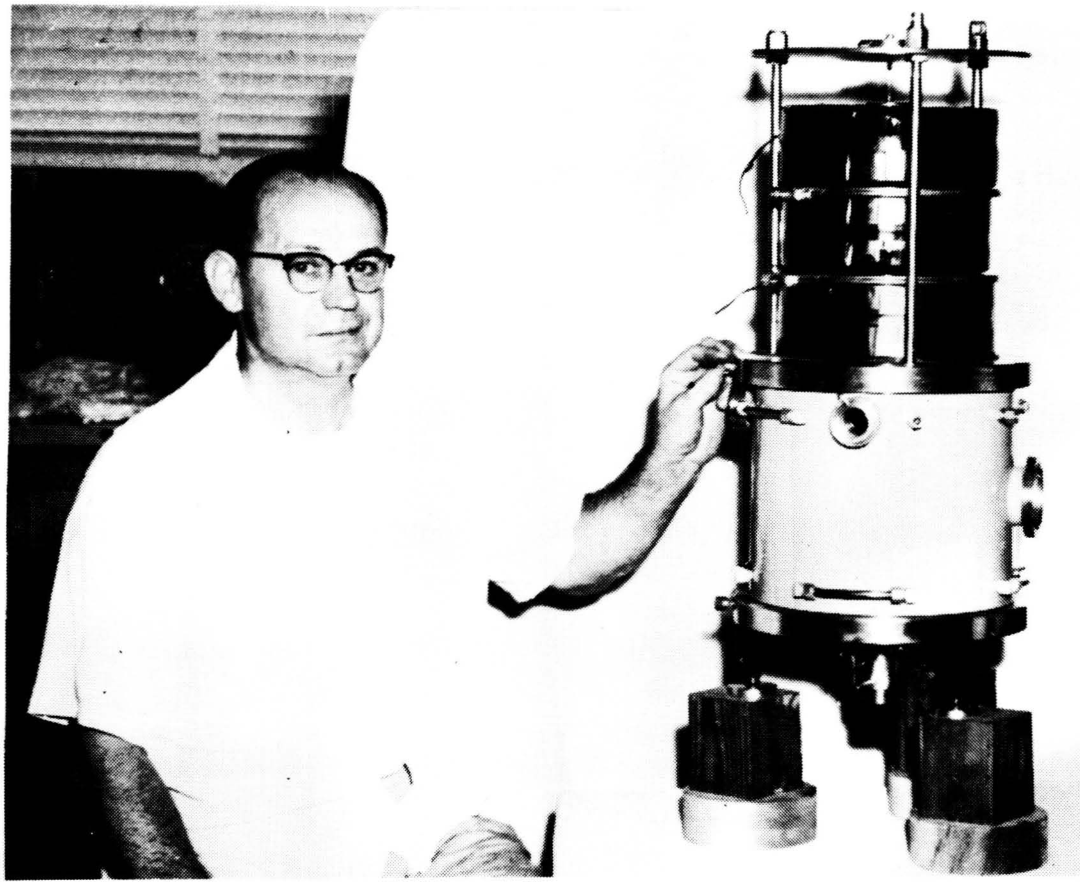


Fig. 7. Beams' Machinist, P. Sommer, with Early Version of Magnetically Supported Ultracentrifuge

In 1968, the National Medal of Science was presented to Dr. Beams by President Lyndon Johnson for his gas centrifuge work. Also, the Atomic Energy Commission in 1972 cited Dr. Beams for his outstanding contributions to the U. S. atomic energy program.

MAGNETIC SUSPENSION FOR HIGH CENTRIFUGAL FIELDS

Dr. Beams' interest in centrifugal effects continued after World War II. Small steel balls, in this case 1/32 of an inch, were spun up to 386,000 revolutions per second [7]. In other works [8,9,10,11], he reported small balls rotating at speeds up to 800,000 revolutions per second. He and his co-workers filed for a patent on this device [12]. The electronic circuitry was constructed of vacuum tubes. He later received another patent with a rotational speed of 4,000,000 revolutions per second.

It may be noted that this work was not without risk of personal injury. During one experiment, the metal ball came out of support while spinning at an extremely high speed. The ball went through a railroad tie that was employed as the stationary barrier and through Dr. Beams' neck, just missing the carotid artery. He might easily have been killed. However, he was treated at the local hospital and was back at work in a few days.

CONCLUSIONS

While many others had speculated on the development of magnetic suspension of rotating devices, Dr. Beams was the first researcher to develop a practical magnetic suspension system. Work in his laboratory on magnetic bearings went on for many years. The later works of Dr. Beams and the laboratory that he founded in the Physics Department at the University of Virginia are not discussed in this brief paper.

On the morning of July 23, 1977, Dr. Beams had an idea and described to his wife, in great detail, how to construct what he felt would be the best gyroscope in the world. After dinner, he discussed current research with colleagues. At eight o'clock, he died. He lived a very full life.

Currently, magnetic suspension research continues at the University of Virginia in the Physics Department under Beams' colleague, Rogers Ritter. In the Nuclear Engineering and Engineering Physics Department, there is a strong program on magnetically supported medical devices, conducted by former student George Gilles. Also, the Mechanical and Aerospace Engineering Department has continued the work on magnetic bearings for rotating machines. This research program has become the Center for Magnetic Bearings.

For his pioneering work in the field, Dr. Jesse W. Beams deserves to be called the "Father of Magnetic Bearings."

BIOGRAPHY

In [redacted], Jesse Beams was born in [redacted]. He obtained a Ph. D. from the Department of Physics at the University of Virginia in 1925. After three years at Yale University, he returned to the University of Virginia as an Associate Professor of Physics. He became a Professor in 1930, Chairman of the Physics Department in 1948, and Smith Professor of Physics in 1953. He retired as Professor Emeritus in 1969 and continued to work in his laboratory at the University until his death on July 23, 1977.

Professor Beams was a kind and gentle man, always willing to discuss technical questions with anyone. Many of his experiments required intricate machining. He listened to his machinists' suggestions and often listed them as co-authors. He authored or co-authored 246 articles. The bibliographical records on Dr. Beams in the University library indicate 2.75 meters of information, including 14 patents.

Beams first worked on the timing of the emission of light by atoms excited by electric discharge in a device called a Kerr cell. He made improvements on a rapidly rotating mirror employed to detect the light. His first paper on this subject appeared in 1930.

REFERENCES

1. "Jesse Wakefield Beams," Obituary, 1977.
2. Leyh, C. H., "A Brief History for the Precision Measurement Group at the University of Virginia," Proceedings of 1983 Symposium on Precision Measurement and Gravity Experiment, Taipei, China, 1983.
3. Holmes, F. T., "Axial Magnetic Suspensions," Review of Scientific Instruments, Vol. 8, Nov. 1937, pp. 444–447.
4. Holmes, F. T. and Beams, J. W., "Frictional Torque of an Axial Magnetic Suspension," Nature, Vol. 140, July 3, 1937, pp. 30–31.
5. Beams, J. W., and Black, S. A., "Electrically-Driven Magnetically-Supported Vacuum-Type Ultracentrifuge," Vol. 10, Feb. 1939, pp. 59–63.

6. Skarstrom, C. and Beams, J. W., "The Electrically-Driven Magnetically Supported Vacuum Type Ultracentrifuge," Review of Scientific Instruments, Vol. 11, Dec. 1940, pp. 398–403.
7. Beams, J. W., Young, J. L., and Moore, J. W., "The Production of High Centrifugal Fields," Journal of Applied Physics, Vol. 17, Nov. 1946, pp. 886–890.
8. Beams, J. W., "Experiments With High Speed Rotors," Science, Vol. 107, 1948, p. 646.
9. Dillon, J. F., and Beams, J. W., "An Improved Axial Magnetic Suspension," Physics Review, Vol. 74, 1948, p. 117.
10. Beams, J. W., "Magnetic Suspension Balance," Physics Review, No. 78, 1950, p. 471.
11. Beams, J. W., "Magnetic Suspension for Small Rotors," Review of Scientific Instruments, Vol. 21, No. 2, 1950, pp. 182–184.
12. Beams, J. W., Kinsey, E. E., and Snoddy, L. E., "Magnetically Supported Rotating Bodies," U.S. Patent No. 2,691,306, 1951.