An Inverted Air-Driven Ultracentrifuge

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An Inverted Air-Driven Ultracentrifuge

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An air-driven ultracentrifuge is described in which the air turbine is below rather than above the large rotor or centrifuge. The centrifuge is mounted inside a vacuum tight chamber on a flexible shaft which extends vertically downward, through an oil gland that seals the vacuum chamber, to the turbine below the chamber. The rotating parts are supported upon an air cushion below the turbine. The turbine is driven by air jets. The rotation of the centrifuge is very smooth and the maximum speed is limited only by the strength of the centrifuge.

IN the original "vacuum type" of air-driven ultracentrifuge[1] the large rotor or centrifuge in the vacuum chamber was both driven and supported by an air turbine situated outside and vertically above the chamber. The driving turbine was connected to the centrifuge by a small flexible shaft or tube which was coaxial with their axis of rotation and passed through a vacuum tight oil gland that sealed the vacuum chamber. That is, the centrifuge inside the vacuum chamber hung on a flexible shaft from the air supported turbine above the chamber. With this arrangement the rotating centrifuge was very stable and could easily be spun to a speed limited only by the mechanical strength of the centrifuge. In the course of some work, to be described elsewhere, it became necessary to place the air turbine below the vacuum chamber rather than above it. Since this latter arrangement should be of considerable use in many experiments, especially where observing apparatus must be placed directly over the center of the centrifuge or where one rotor is to be spun inside another, etc., it will be briefly described.

Fig. 1 shows a diagram of the apparatus while Fig. 2 shows a photograph with the vacuum chamber removed. In Fig. 1 the rotating parts consist of the turbine *T*, the centrifuge *C* and the flexible shaft *S*. These are supported on an air cushion formed between the Bakelite collar *K* and the under side of the turbine *T*. The air (5 to 20 lb/in.^{2} depending upon the weight of *C*) is supplied to this cushion through the tube *I*. The rotating parts are spun by air supplied through the tube *D* which after passing through the directed channels in the stator impinges upon the flutings of *T*. The oil glands G_1 and G_2 are mounted in round Duprene rings *R* to insure flexibility. G_1 serves to seal the vacuum chamber *V* while G_2 also serves as a vacuum tight bearing when the flexible shaft *S* is a tube instead of a rod and the centrifuge *C* itself is to be evacuated through *U*. These glands G_1 and G_2 are constructed by machining a piece of brass to the shape shown with about $\frac{3}{8}$ in. hole along its axis. The bushings *B* are then fitted into the ends of this tube. Holes in these bushings for the shaft *S* are made with a twist drill smaller in diameter than the shaft and are then made the proper size by a "bit" or special reamer sometimes made of a piece of the shaft itself. The bushings are usually brass, bronze or some type of bearing metal depending upon the material of the shaft. The

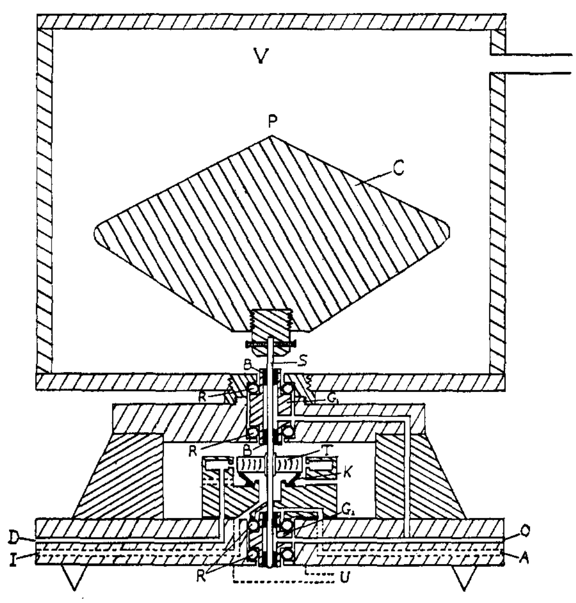

FIG. 1.

[1] Beams and Pickels, R. S. I. **6**, 299 (1935).

shaft is usually polished. Vacuum pump oil from the supply tank is forced into G_1 and G_2 through the channels O. If the bushings B are properly made only a fraction of a cubic centimeter of oil flows through them per hour. The oil escaping from G_2 is blown out through the tube A into an inclosed reservoir (not shown) with a small air leak. The resulting air pressure on this reservoir may in turn be used to apply the pressure to the oil tank.

The size of the turbine T and the shaft S is determined by the size and weight of the centrifuge C, i.e., both the diameter of S and T should be increased when C is increased. However, the same sizes of S and T will serve for a considerable range in the size of C. For the 4 in. Duralumin centrifuge C shown in Fig. 2 the turbine T is also made of Duralumin and is 13/16 in. in diameter. It is driven by air jets (issuing through ten 1-mm channels) impinging on its periphery. The shaft is either $\frac{1}{16}$ in. drill rod or stainless steel hypodermic needle tubing gauge 15. With stainless steel shaft, Babbit metal bushings are used. The collar K is usually made of Bakelite although light metals such as Duralumin serve almost equally well. K is supported upon a flexible Duprene washer.

Before starting the centrifuge the axis of rotation is made vertical by the leveling screws and care is taken to see that the shaft is straight. The supporting air pressure is then applied to I. This air in escaping between K and T forms a thin film and supports the rotating parts. When the proper pressure (5 to 20 lb/in.^{2} in Fig. 2) is applied to I the rotor turns freely. This working pressure range is not critical and is easily determined by trial. The driving pressure is then applied to D and the centrifuge starts spinning. If the chamber V is evacuated, the centrifuge shown in Fig. 2, will explode under its own centrifugal forces with about 20 to 25 lb/in.^{2} (2 to 3 cubic ft. per min.) driving air pressure.

It will be noted that the rotating centrifuge C mounted on S has some of the properties of both the inverted pendulum and the ordinary spinning top. Consequently when the centrifuge is first started it passes through two speeds in which it may wobble considerably. The first speed is critical and depends upon the length and stiffness

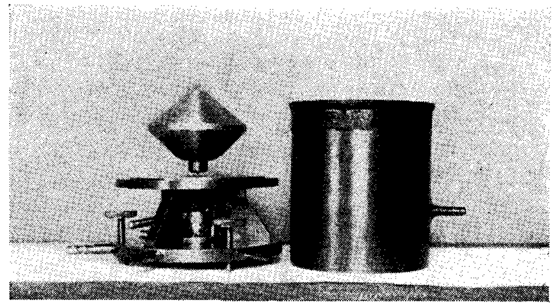

FIG. 2. Picture of centrifuge with the vacuum chamber removed.

of S and the dimensions and weight of C. It is approximately equal to the period observed when the centrifuge, while not spinning, is displaced and allowed to vibrate. The second speed is less critical (band of frequencies) and has a much smaller amplitude than the first. Above these speeds (about 100 r.p.s. in apparatus of Fig. 2) the centrifuge spins smoothly ("sleeps"). If trouble from wobbling is encountered in starting, the centrifuge may be steadied by touching it at P with a pointed wire until it passes the critical speeds, or if desirable a small flexible shaft may be attached through an oil gland in the top of V. However, we always have found it easy to get the centrifuge through these disturbances by suddenly turning on the driving air to 40 or 45 lb/in.^{2}. The centrifuge is accelerated so rapidly that it passes the troublesome speeds before the amplitudes of the disturbances can build up to appreciable magnitude. After passing these speeds the driving pressure may be reduced to give the desired rate of increase in rotational speed. The rotation of the centrifuge is so stable and smooth that, in bringing it up to working speed (when V, Fig. 1 is evacuated), care should be taken to avoid exceeding the bursting speed of the centrifuge. In no case should the centrifuge be spun in a vacuum without a strong enough barricade surrounding it to stop the flying pieces should an explosion occur.

Obviously many other types of turbines and air cushion supports may be used instead of that described above. Also in addition to the air drive the above arrangement may be adapted to the electrical or steam drives now being developed in this laboratory.