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ABSTRACT

A radio telemetry system for use with analytic or preparative ultracentrifuge rotors is described. Capable of sustained high-speed operation, this modulated FM system simultaneously transmits with precision both rotor speed and rotor temperature.

Previous methods developed to measure the temperature of a rapidly spinning ultracentrifuge rotor (1-4) have either been impractical for routine laboratory analyses, have had certain technical limitations, or have relied on rotating contacts requiring critical adjustment. An example of previous radio telemetry is the technique devised by Robinson and Beams[3] for use with magnetically suspended rotors. Although providing accurate temperature monitoring, their device involved a somewhat complex blocking-oscillator frequency-ratio circuit, which to our knowledge has not been used for high-speed rotors, either analytic or preparative. This communication describes the application of a simplified radio telemetry system which has essentially none of these shortcomings, and is capable of routine operation at rotor speeds of 52 640 rpm.

A transistorized Colpitts oscillator, which operates in the standard FM band, is inserted into a hole in the bottom of the rotor, as shown in Fig. 1. The frequency of the transmitter increases with temperature at a rate of approximately 60 kcs/°C, because of the high negative temperature coefficient of the ceramic capacitors used in the tuned circuit. We have found the frequency to be quite reproducible with respect to temperature. The entire transmitter and antenna-loop assembly is potted in thermally conductive epoxy. thereby providing great mechanical rigidity. Power for the transmitter comes from two small mercury cells (Mallory type 6RM-312) mounted in the rotor above the transmitter. These batteries power the transmitter for more than 25 hours of continuous operation in the spinning rotor.

The signal from the transmitter is coupled to a stationary pickup coil mounted about 2 cm below the transmitter in the rotor chamber. The coupled signal is fed via coaxial cable to the receiver, consisting of an ordinary high-fidelity FM tuner (Eico Model HF-90A). The dc voltage output of the tuner's discriminator is then proportional to the temperature excursion of the transmitter mounted in the rotor. This signal is either read on a panel meter, or fed to a strip chart recorder. The system may be initially calibrated by simultaneously measuring the temperature of the rotor while at rest with a separate device of acknowledged accuracy, such as a calibrated digital thermometer (Digitec Model 502). Thus, a thermistor probe and bridge serve as a practical reference for this telemetry system.

The dc signal from the discriminator has been used as the input for a negative-feedback temperature-control system, which employs a refrigerated rotor chamber in conjunction with a controlled 200-watt heater, as shown in Fig. 2. Although not extensively tested, this arrangement should provide more accurate control of rotor temperature than available with the usual Spinco RTIC unit.[5]

The temperature of a Spinco aluminum analytical rotor, type An-D, was measured as it underwent a normal analytical run including full-speed operation at 52 640 rpm. Figure 3 shows the sharp temperature drop on acceleration, the slow rise due to frictional effects, and finally, the sharp rise on deceleration. These results are similar to those obtained previously by Waugh and Yphantis,[2] using a radiation thermocouple to measure the temperature of the bottom of the rotor. We estimate that our technique indicates the actual temperature of the center of the rotor with an error of approximately ±0.05°C. Gropper and Boyd[6] have measured the temperature gradient from the sample cells, near the periphery of the rotor, to the center of the rotor, and have found it to be both small and constant for a given type of rotor. We therefore expect to be able to correct our observed temperature readings to the actual sample temperature in the analytic cell.

Precise rpm measurement is achieved from the sinusoidal amplitude-modulated signal produced by the varying coupling between transmitter and receiver antennas during rotation. The frequency of the sine wave is the rotational frequency of the rotor, and is counted for either 0.6, 6.0, or 60 seconds by a Hewlett-Packard Preset Counter Model 5214L, depending on the time period over which it is desired to integrate rpm. This measurement provides a continuous digital display of rotor rpm, having far greater accuracy than that obtainable with the usual ultracentrifuge tachometer. When five-digit accuracy is desired in a shorter counting time, the period of the sine wave may be measured.

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FOOTNOTES AND REFERENCES

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FIGURE CAPTIONS

Fig. 1. Modified analytic rotor, showing the telemetry transmitter, pickup coil, and temperature-control heater.

Fig. 2. Block diagram of the radio telemetry temperature measurement and control system. Schematic drawing of the transmitter is shown in the lower left.

Fig. 3. Recording of rotor temperature during a typical analytical run. No temperature control was used for this run.

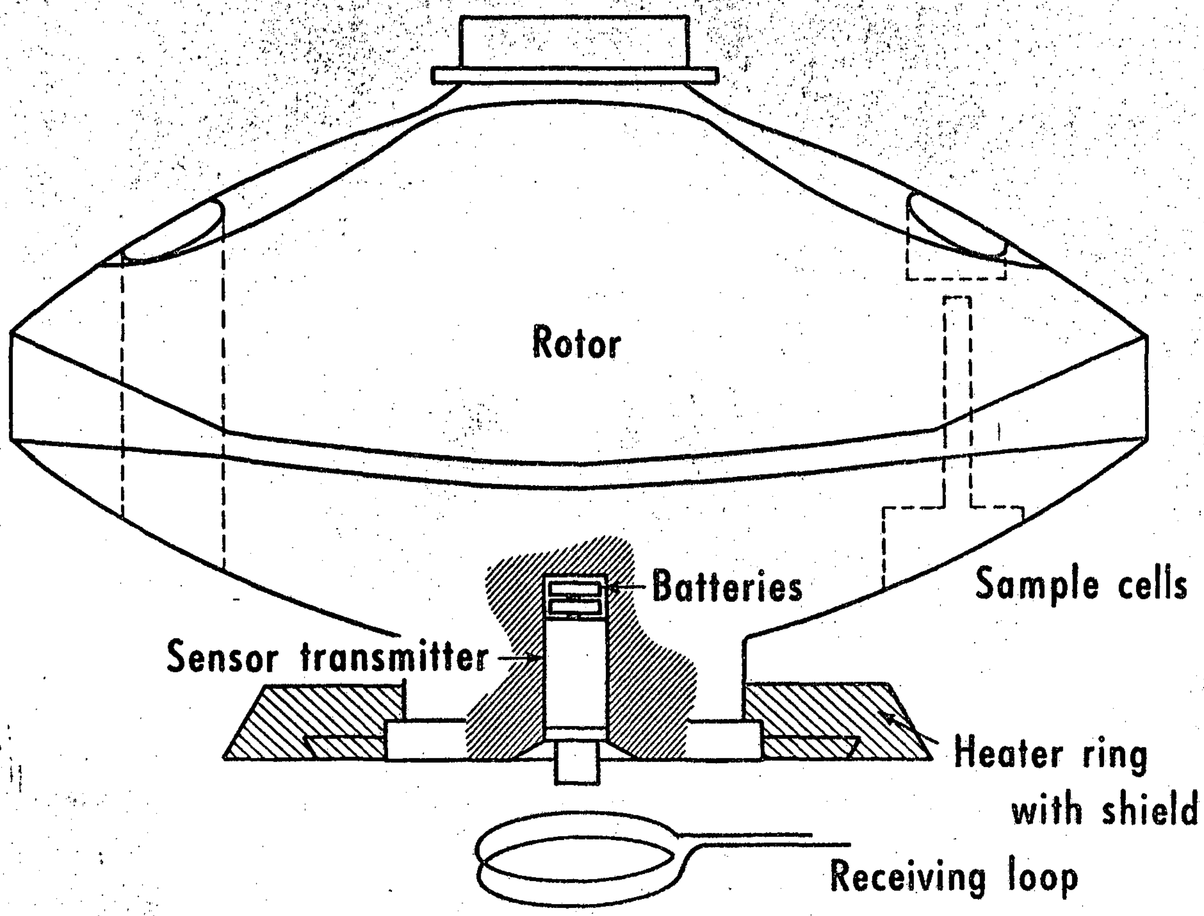

Fig. 1

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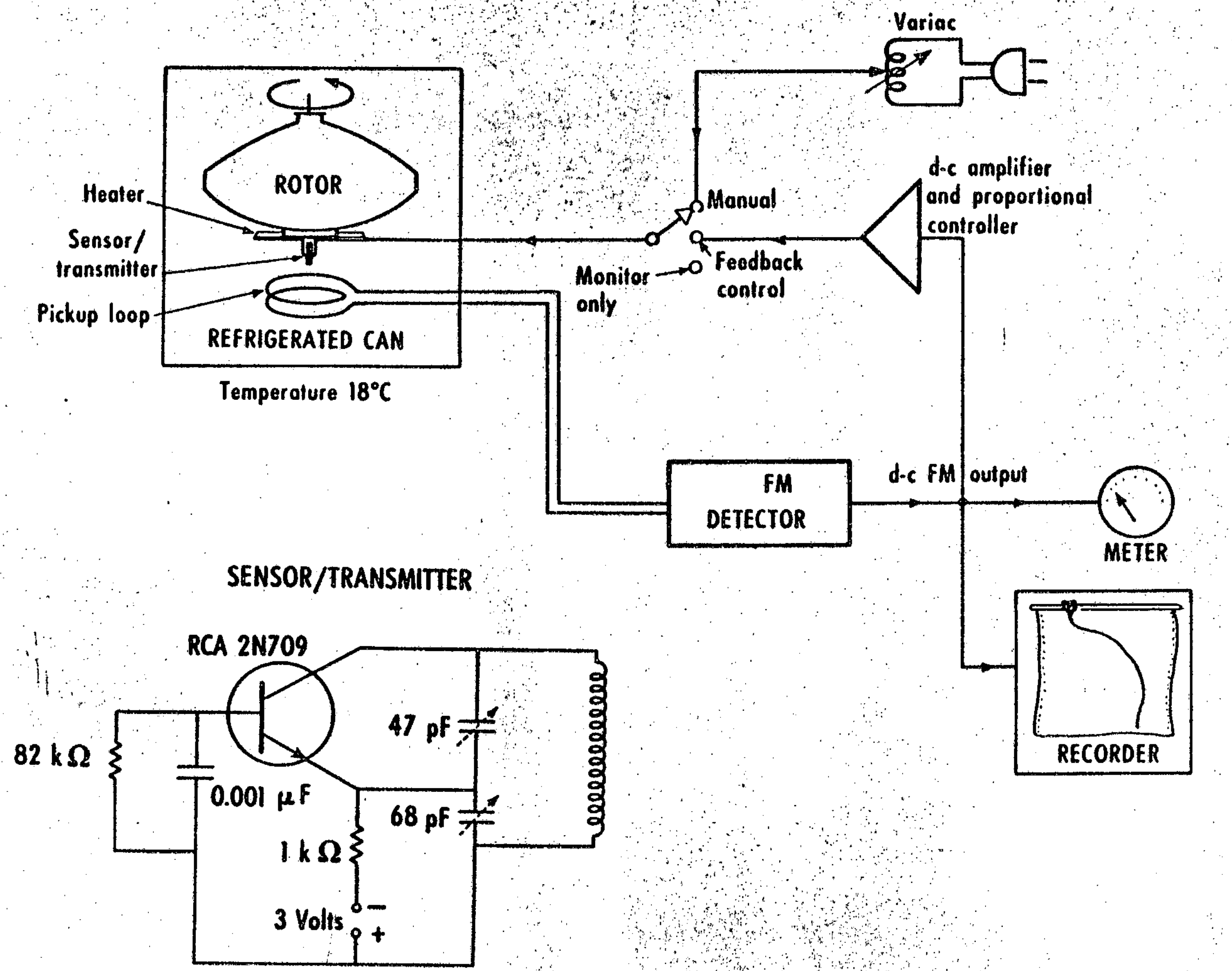

Fig. 2

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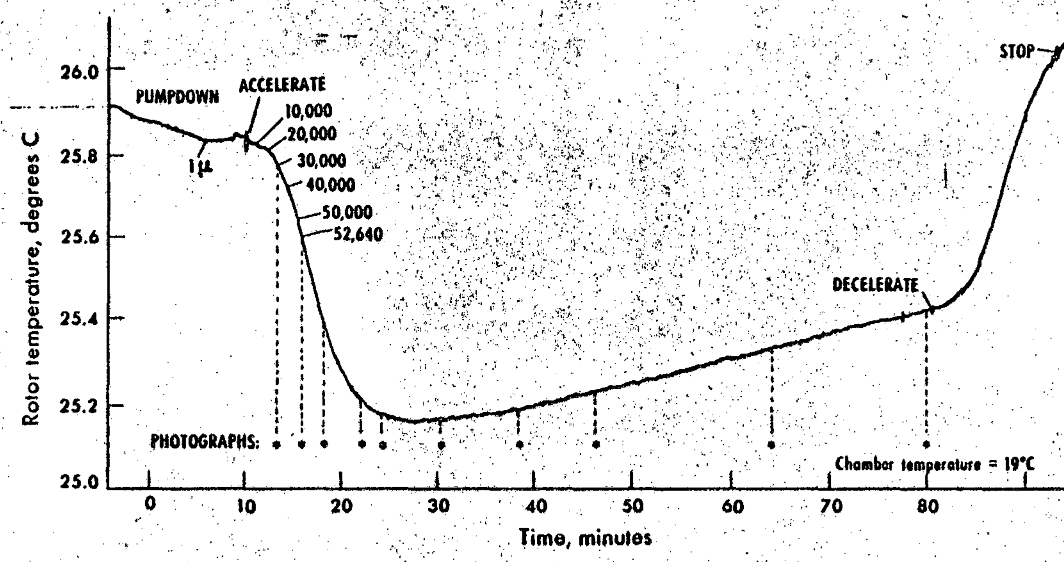

Fig. 3

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