Speed Control of Magnetically Suspended Ultracentrifuge

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Citation: Review of Scientific Instruments **37**, 667 (1966); doi: 10.1063/1.1720281
View online: https://doi.org/10.1063/1.1720281

many channels at high energies as at low energies. Although the logarithmic system provides a considerable improvement, it utilizes 5× the number of channels per peak at low energies compared with high energies. This is due to the inherently poorer resolution of the detector at low energies.

Pulse height response curves for linear, optimum, and logarithmic systems are illustrated on Fig. 1. Also plotted on Fig. 1 are calibration points obtained using the nonlinear amplifier described below to modify the response of a linear RIDL model 24-12 gamma ray spectrometer. Note that the nonlinear amplifier makes it possible to utilize most of the analyzer channels in approximately the optimum manner.

Figure 2 shows a block diagram of the over-all system employed. One of two operational amplifiers contained in the Tektronix type O plug-in unit is used to amplify the output from the preamplifier. The other operational amplifier in the type O unit is modified as described below and used as the nonlinear amplifier which operates on input pulses from about 0.02 to 20 V. The output of the nonlinear amplifier feeds into the internal amplifier system of the multichannel analyzer. Energy range can be varied by adjustments of the multichannel analyzer internal amplifier gain, while the high energy limit is conveniently set by adjustment of either the high voltage on the photomultiplier or the gain of the first operational amplifier.

Figure 3 illustrates the nonlinear amplifier circuit which is basically a modification of a logarithmic amplifier circuit described in the "Tektronix Type O Operational Amplifier Instruction Manual." The amplifier utilizes the logarithmic current-voltage characteristics of G-130 silicon diodes to achieve the desired nonlinearity. As forward voltages from 0.25 to 0.75 V are applied to these diodes, their static resistance varies exponentially from 10^5 to 80 Ω. Since the gain of an operational amplifier is approximately equal to the ratio of feedback to input impedances, the gain can have a logarithmic characteristic if diodes are used as feedback elements and driven over the exponential portion of their characteristic curves. Similarly, diodes can be used in series with resistive elements in a voltage divider at the input to the operational amplifier to provide a logarithmic response. In the circuit shown in Fig. 3, both techniques

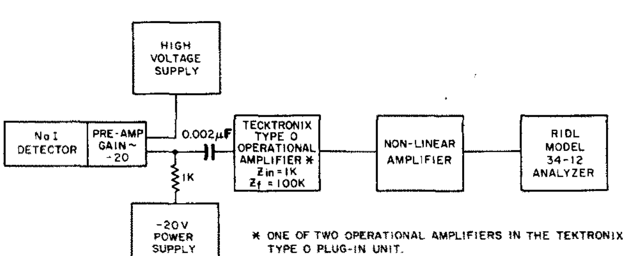
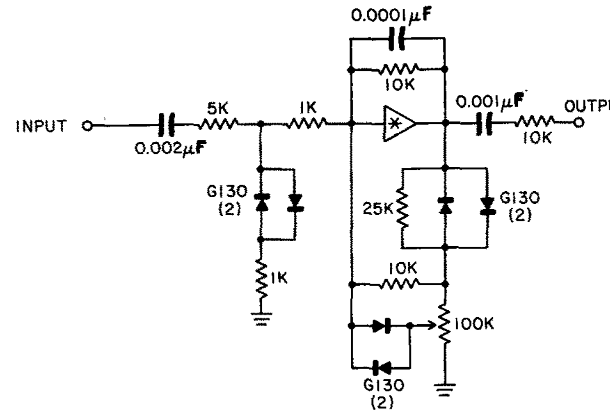


FIG. 2. Block diagram of the nonlinear response system.



* ONE OF TWO OPERATIONAL AMPLIFIERS IN THE TEKTRONIX TYPE O PLUG-IN UNIT, Z_f AND Z_{in} BOTH ON EXTERNAL.

FIG. 3. Nonlinear amplifier circuit.

are employed. However, resistive elements are used in series with the input diodes and in both series and parallel with the output diodes to provide a response characteristic which falls between linear and logarithmic as shown in Fig. 1. The feedback diodes attached to the center top of the 100 k potentiometer are included to permit fine adjustment of the high energy end of the response curve. The response curve shown in Fig. 1 was obtained by adjusting the 100 k potentiometer in the feedback circuit to give 5 V peak-to-peak output pulses from 20 V peak-to-peak square wave pulses at the input to the nonlinear circuit. Capacitive feedback across the operational amplifier serves to eliminate high frequency oscillations.

Thermal stability of the nonlinear circuit elements shown in Fig. 3 (excluding the operational amplifier) was studied over the range 16 to 42°C. Maximum energy shifts occurred at about the middle of the energy scale and amounted to $-0.3\%/\mathrm{C}°$.

* Work done under the auspices of the U. S. Atomic Energy Commission and the U. S. Public Health Service.

[1] D. Meader, Rev. Sci. Instr. **26**, 805 (1955).
[2] W. H. Bradley, R. H. Huebner, and F. H. Wichman, "Nuclear Spectrometer Applications" (Nuclear Measurements Corp., Indianapolis, Indiana, 1962).
[3] J. S. Lundsford, Rev. Sci. Instr. **36**, 461 (1965).
[4] D. DeSoete and J. Hoste, Nucleonics **20**, No. 4, 72 (1962).

Speed Control of Magnetically Suspended Ultracentrifuge*

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(Received 9 December 1965; and in final form, 10 January 1966)

IN the magnetically suspended equilibrium ultracentrifuge,[1] the deceleration of the rotor is so small that it is allowed to "coast" during the experiment. In this way

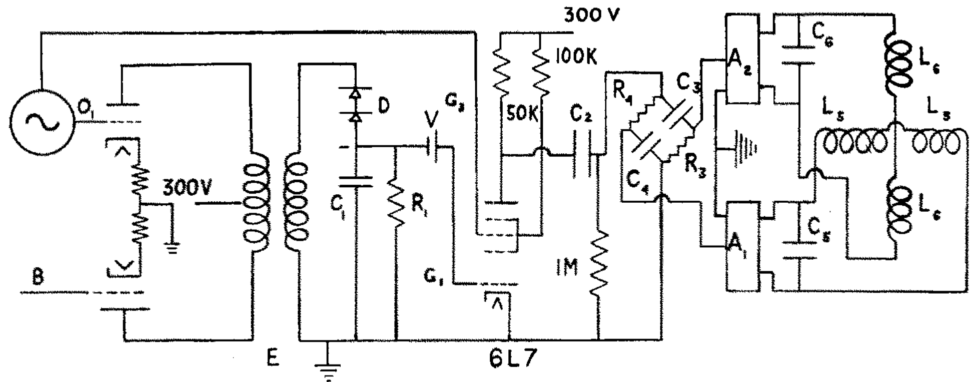

FIG. 1. Control circuit.

the disturbing effects of hunting are eliminated and a close approximation to true equilibrium is obtained. However, in some experiments it is advantageous to hold the rotor speed as constant as possible. This is especially important in the measurement of very large molecular weight compounds. In this paper, a method of speed control is described which holds the centrifuge rotor speed constant to the order of 1 ppm and at the same time is free of hunting. Figure 1 shows a schematic of the circuit, and Fig. 2 the sensing circuit for determining the speed of the rotor. In Fig. 1, the output of a commerical piezoelectric oscillator O_1 with frequency dividers giving frequencies of 100, 10, 5, and 2.5 kc is fed to the control grid of one of the tubes in a difference amplifier E. The output from the sensing device which gives a multiple frequency of the rotor speed is impressed on the grid of the other tube at B. The output of the amplifier E is connected through rectifier diodes D (1N47) to a condenser C_1. The rectified potential across C_1 is connected through a biasing battery V to the control grid G_1 of the mixer amplifier 6L7 tube. It is observed that if the waveform of the standard oscillator O_1 and the speed signal from the rotor are roughly similar in shape and magnitude and if they have exactly the same frequency the magnitude of the emf across C_1 is small. However, if their frequencies differ then it increases, i.e., a very slight change in rotor speed turns the 6L7 tube off or on. The 2.5 kc or the 5 kc frequency of O_1 impresses the drive frequency on the grid G_3. The output signal from the 6L7 is connected to a resistance capacity phase splitting bridge. One signal from the bridge is connected to the input of amplifier A_1, and the other signal to the input of the amplifier A_2. The bridge is designed so that these two signals differ in phase by 90°. The output of A_1 is connected across the resonant circuit C_6 and field coils L_6 while the output of A_2 is connected across the resonant circuit C_5 and field coils L_5. When it is only necessary to hold the rotor speed constant to a few parts in 10^4, the 60 cycle ac with its harmonics may be used as the oscillator O_1. The circuit E was constructed by connecting O_1 and B to the control grids of the two tubes in the circuit of a commercial audio-frequency amplifier. Also, A_1 and A_2 were similar 50 W loud speaker amplifiers. Furthermore, an amplifier with its control grid biased by the emf across C_1 may be used to replace the 6L7 circuit.

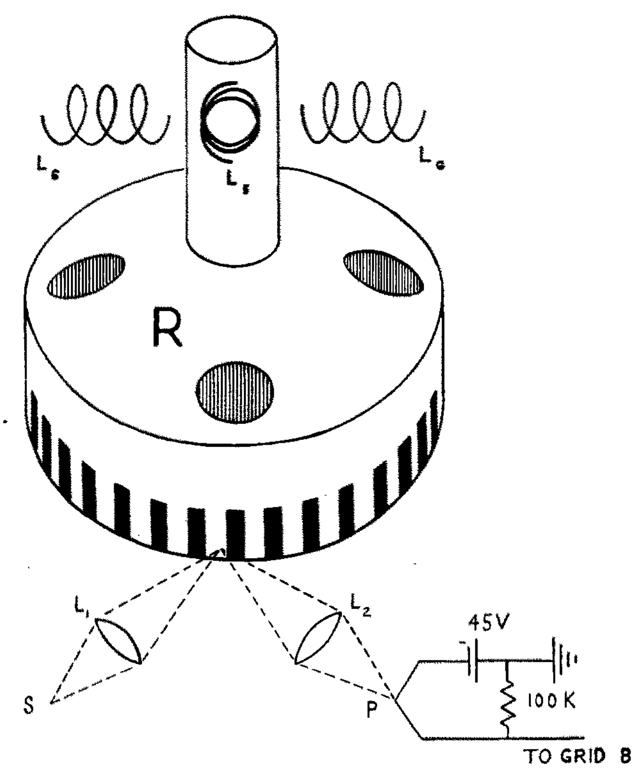

FIG. 2. Diagram of method of multiplying rotor frequency. Each of the four drive coils L_5 and L_6 is bunch wound with 150 turns of No. 16 enameled copper wire. The maximum diameter of each coil is 6.35 mm less than the 11.43 cm long rotor neck. The drive coils function as the field and the rotor neck as the armature of an induction motor. The exact size of these coils is not critical.

For the relatively low rotor speeds used with the equilibrium ultracentrifuge it is advantageous to multiply the rotor frequency many times before applying it at the grid B. This may be done with frequency multipliers but the method shown in Fig. 2 has proven satisfactory. The cadmium plated steel ultracentrifuge rotor R which weighs 13 kg and is 20 cm in diameter has its circumference laid out in 180 equal spaces. Alternate spaces are blackened with Aquadag. Light from a filament source S is focused by a lens L_1 on the rotor surface. The illuminated rotor surface is focused by the lens L_2 on a photodiode (1N2175) P. When the rotor spins the signal from P is impressed on the grid at B in Fig. 1. Sometimes the desired rotor speed cannot be made to match the frequency of O_1. In such cases, the rotor circumference is divided into a larger or smaller number of light and dark bands. This makes it possible to match essentially all of the rotor speeds required in practice.

The time constant R_1C_1 is the order of a second. If the air pressure around the rotor is below 10^{-6} Torr heating of the rotor produced by radiation from the coils and induced eddy currents is negligible. However, acceleration of the rotor from rest to operating speed in a reasonable time produces sufficient heat to disturb the experiments so that the rotor is accelerated from rest in the usual manner.[1] When the rotor is allowed to coast freely without the drive it loses less than 1 rps/day. The rotor speed is recorded by a photoelectric pickup and is compared with a standard broadcast frequency from a NBS radio station.[1]

* Supported by U. S. Public Health Grant No. GM 11630-06 and Applied Physics Laboratory/Johns Hopkins Subcontract 230533.

[1] J. W. Beams, R. D. Boyle, and P. E. Hexner, Rev. Sci. Instr. 32, 645 (1961); and J. Polymer Chem. 57, 161 (1962).

Modification of Cone-Plate Viscometer to Eliminate Slip Caused by Wall Effects*

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(Received 25 October 1965; and in final form, 16 December 1965)

THE design and utilization of a rather large cone-plate viscometer (30 cm diam) for determining the flow curves of low density foams revealed some interesting characteristics of the flow mechanism and some unsuspected shortcomings of this type of viscometer. As discussed by, among others, Wilkinson,[1] the major merit of the cone-plate viscometer is that since both the gap and the velocity at the surface of the plate vary linearly in the radial direction, the rate of shear strain is constant throughout the sample and is a simple function of the rate of rotation. Thus if the material being tested has a unique or single valued flow curve, then the shear stress must also be constant throughout the sample and is a simple function of the torque on either the cone or the plate.

One difficulty that occurred when using such a viscometer on foam was that regardless of the speed of rotation, nearly all of the flow occurred in two thin liquid layers; one adjacent to the plate and one adjacent to the cone. These two layers formed when the foam came in contact with the smooth surfaces of the viscometer, causing an effective lubrication and thus violating the assumption of zero velocity at the boundaries of the sample. In other words, due to the presence of a wall effect the material did not have a unique flow curve.

In order to determine the flow curve for these foams with a cone and plate viscometer it was necessary to introduce features to control or eliminate the wall effect. This was first attempted by using coarse water proof sandpaper glued to the surfaces of the cone and plate. Slippage at the surface was reduced but not sufficiently to obtain flow only in the body of the foam. When thin plastic vanes were glued to both the cone and the plate (Fig. 1), the wall effect was eliminated and slow motion photography confirmed that uniform flow did indeed occur throughout the entire sample. The sample was considered to extend from the upper edges of the vanes on the plate to the lower edges of the vanes on the cone.

At high rotational speeds a second difficulty arose in that cross or radial velocities developed in the sample. Due to centripetal forces, the foam tended to flow out of

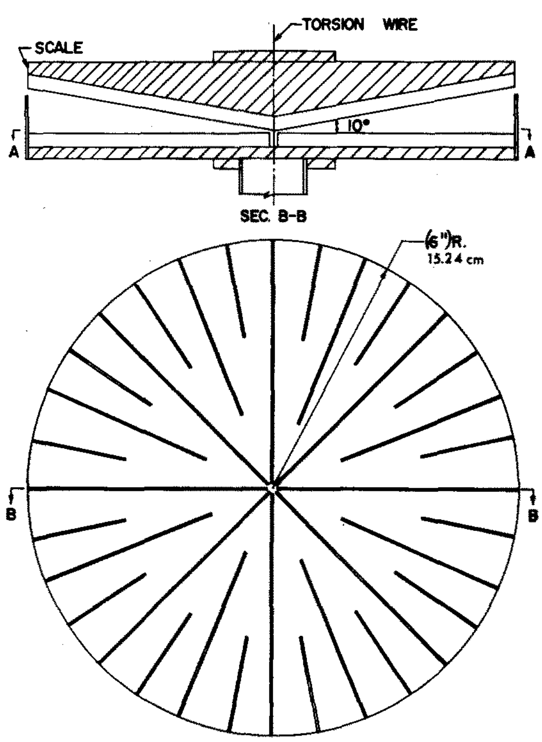

FIG. 1. Cone and plate viscometer.