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PHOTOELECTRIC TACHOMETER FOR PRECISE CENTRIFUGE SPEED DETERMINATION[1]

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Abstract

Certain chemical and physical investigations such as the mechanical analysis of soils by centrifugation require that the speed of rotation of the centrifuge be precisely determined. For a cost of approximately $40.00, when used with instrumentation normally available in research laboratories, the system outlined provides a vivid, unambiguous indication of the speed of rotation, the accuracy of which is limited only by the frequency standard used.

Additional Key Words for Indexing: **mechanical analysis of soil, noncontact speed determination, Lissajous figures.**

CERTAIN chemical and physical investigations require that the rotation speed of a centrifuge be determined exactly. One example of this is the mechanical analysis of soils by centrifugation based upon Stokes law as outlined by Jackson[3]. In this process, both speed of revolution and time of centrifugation are parameters of critical importance.

Most centrifuges have built-in tachometers of the panel meter type but have neither sufficiently finely calibrated dials nor enough accuracy (varying ±10% depending upon the general range of speed used) to be of much use when centrifuge rotation speed is of great importance. Static build-up on the plastic faces of these meters also adds to their inaccuracies. Small hand-held dial tachometers having a rubber drive spindle which is placed on the central shaft of the centrifuge were found to be much more accurate. This type of tachometer requires that mechanical energy be transferred from the centrifuge shaft to the tachometer, which means that the speed indicated by the tachometer may not be the speed at which the centrifuge will run when the tachometer is removed. For these reasons, an ideal tachometer for critical speed measurement should have no physical contact with the centrifuge and be of sufficient accuracy to allow the maximum sensitivity of the centrifuge speed adjustment to be utilized.

The electrical schematic of the basic unit for such a tachometer is shown in Fig. 1. The neon lamp and photoresistor are mounted side by side about 5 mm apart in a hard, opaque, plastic cube about 3 cm in dimension to form the sensor. A ¼-inch mounting hole is drilled through the plastic cube for a rod.

Since the neon lamp is DC excited, only one electrode will glow, so the plane of the two electrodes must be at right angles to the surface being viewed and the polarity of the input current correct to make the electrode closer to the surface glow.

The sensor is positioned by adjusting the mounting rod so that the side of the cube where the photoresistor and neon lamp are located is approximately parallel to some surface of the centrifuge head at a distance of some 3 to 5 cm. This may be the top surface of the head, in which case the armor can be closed and the sensor and the rod inserted through the central hole in the top of the armor; or it may be the slanting side of the head, in which case the mounting rod will have to be bent to such an angle that will allow the face of the cube where the photoresistor is to be parallel with the surface of the head. The mounting rod is secured to a ringstand or other upright, which does not allow the sensor to vibrate excessively when the centrifuge is running. When the sensor is positioned in this manner, the longitudinal axis of the field of view of the photoresistor is approximately perpendicular to the surface of the centrifuge head, as is the axis of the cone of light from the neon lamp. In this manner, a minimal amount of room light is reflected onto the photoresistor, increasing its sensitivity to changes in the intensity of the reflected light from the neon lamp.

Parts List

Number	
1	115 VAC × 115 VAC isolation transformer
1	2.3 Hy 150 ma filter reactor
1	20 μf, 20 μf 200 VDC can capacitor
1 ea.	0.01 μf 200 VDC, 1.0 μf 50 VDC, 1.5 μf 12 VDC, 10 μf 50 VDC, and 20 μf 12 VDC capacitors
1 ea.	33 Ω, 68 Ω, 470 Ω, 1 KΩ, 2.2 KΩ, 15 KΩ. 22KΩ ½ W 10% resistors
2	100 KΩ, ½ W 10% resistors
1	5 KΩ 10 W resistor
1	NE-2H neon lamp
1	NE-51H neon lamp + holder (optional, for pilot lamp)
1	Clairex[4] CL603AL photoresistor
1	International Rectifier[4] 18DB2A full wave bridge
1 ea.	2N333 and 2N1304 transistors
1	1N1522A Zener diode
1	4-contact plug (Cinch-Jones[4] CCT series, or equivalent)
1	4-contact chassis socket (Cinch-Jones[4] AB series, or equivalent)
1	SPST toggle switch
1	Fuse holder
1	10 inch × 6 inch × 3.5 inch minibox
3 ft	22/4 cable (Belden[4] 8741 or equivalent)

A large black mark is made on the head of the centrifuge with a felt-tip marker where it will pass directly in front of the sensor. Each time this mark passes the sensor, the photoresistor changes resistance as a result of decreased light reflected from the centrifuge head. This produces a pulse which is amplified by the transistors in the circuit.

The amplified output from the photoresistor is applied to the vertical input of an oscilloscope. A frequency stan-

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[3] Jackson, M. L. 1956. Soil Chemical Analysis—Advanced Course (2nd printing, 1965). Published by the author, Department of Soil Science, University of Wisconsin, Madison.

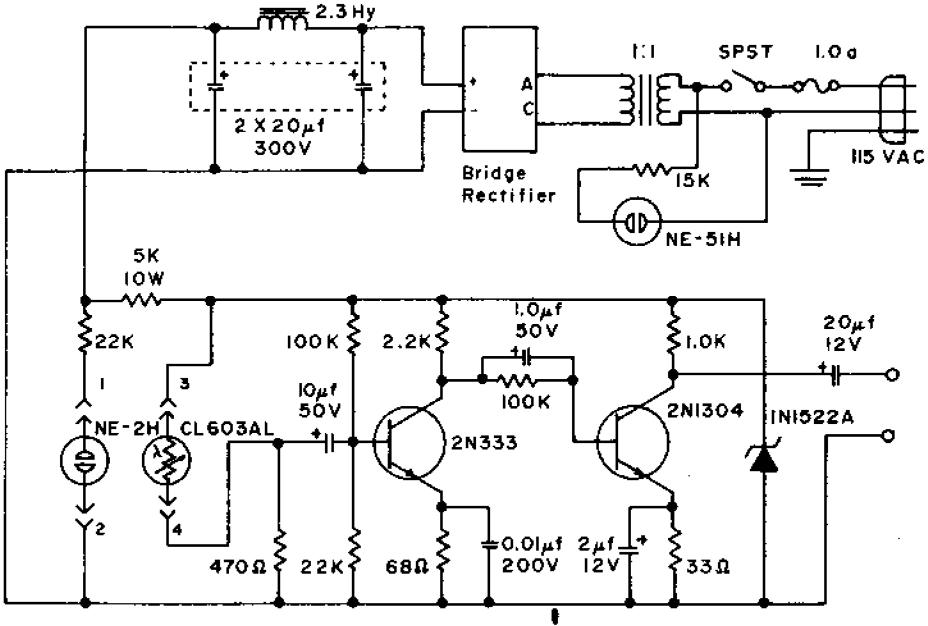

Fig. 1—Power supply, sensor, and amplifier for photoelectric tachometer.

dard such as a sine wave generator is applied to the horizontal input of the oscilloscope. The desired number of revolutions per minute of the centrifuge is divided by 60 to obtain the revolutions per second. The number of revolutions per second is set as the frequency of the standard and the speed of the centrifuge adjusted until the fundamental or first-order Lissajous figure appears on the oscilloscope, meaning that the frequency of the pulses produced by the photoresistor in the sensor is equal to the frequency of the standard applied to the horizontal input.

With this approach, the limiting factor in the accuracy of the tachometer is the accuracy of the frequency standard. Almost any oscilloscope will perform satisfactorily since 30,000 rpm is only 500 revolutions per second, which is well within the bandwidth of even the least expensive student-grade oscilloscope. For example, the authors used a Hewlett-Packard[4] Model CD Wide Range Oscillator in conjunction with an ancient Dumont[4] Model 208-B Oscilloscope for their measurements. This resulted in a tachometer whose accuracy exceeded the ability of the centrifuge to be set at a particular speed because of the coarseness of the control and line voltage fluctuations.

If the speed of the centrifuge in revolutions per second is to be always an integral multiple or fraction of 60, then the line frequency can be utilized as a frequency standard at considerable reduction in cost for the system. However, this necessitates finding the correct harmonic or subharmonic Lissajous figure, as outlined by Lenk.[5] If the oscilloscope used has a vertical deflection sensitivity of 100 mv or more, then the amplifier circuit may be omitted; however, the amplifier does increase the quality of the signal, since it will amplify the pulses from the photoresistor well above the level of the 60 Hz "fuzz" produced by room light being reflected onto the photoresistor.

The photoelectric tachometer outlined above is a simple noncontact device whose accuracy in determining the speed of revolution of a centrifuge is limited only by the accuracy of the frequency standard used. For a nominal cost of $40, with a good signal generator and almost any oscilloscope, the system produces a vivid, unambiguous indication of the speed of revolution of the centrifuge to a degree of accuracy exceeding the sensitivity of adjustment of most centrifuges.

Since photoelectric tachometers having approximately ±1% accuracy are commercially available at reasonable cost, the system outlined above becomes feasible only when an oscilloscope and signal generator are already available. The cost of this associated instrumentation is prohibitive if intended for just this specific use. However, when an oscilloscope and signal generator are readily available, the method becomes simple and inexpensive, and the accuracy of the system is the accuracy of the generator which generally is better than ±1% for high quality laboratory oscillators.

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[4] Trade names and company names are included for the benefit of the reader and do not imply any endorsement or preferential treatment of the product listed by the USDA.

[5] Lenk, John D. 1968. Handbook of oscilloscopes. Prentice Hall, Inc., Englewood Cliffs, N.J, p. 88–91.