following manner. Readings as outlined above in 2, 3, and 4 were taken in a dark room in the direct paths of radiation from an electric heater, and of wind from a fan, and it was possible by means of these observations and previous calibrations, to predict successfully the readings corresponding to the cases when either the heater or the fan or both of them were removed.

The applications of this method are numerous. In particular it should be possible to allow completely for the influence of solar radiation and atmospheric turbulence upon the readings of various instruments which are at present considered unreliable under open air conditions. The comparative analysis of heating by radiation and heating by convection has important physical bearings and may be facilitated by measurements of this kind.

McGILL UNIVERSITY.

GEOMETRICAL PROOF FOR THE WADSWORTH CONSTANT DEVIATION SYSTEM.

BY R. C. GIBBS AND J. R. COLLINS.

BY an analytical method Wadsworth,[1] determined the location of the axis of rotation of a constant-deviation prism-mirror system such that the emergent ray remains fixed in position as the system is rotated. This proof involves a series of long though simple transformations.

The location of this axis can be determined by a short geometrical proof similar to that used by E. Bloch,[2] in finding the corresponding axis of rotation for a constant deviation prism of the Pellin-Broca type.

CORNELL UNIVERSITY,
December, 1921.

A PIEZO-ELECTRIC METHOD FOR GENERATING ELECTRIC OSCILLATIONS OF CONSTANT FREQUENCY.

BY W. G. CADY.

IN a former communication[3] several methods were described whereby the frequency of a vacuum-tube oscillating circuit could be rendered very stable by the use of a piezo-electric resonator of proper dimensions. Further investigation has shown that it is possible, with the aid of amplifiers, to make the piezo-electric resonator serve as a *mechanically tuned feedback*, so that a high-frequency alternating current is generated, whose frequency is determined solely by the mechanical vibrations of the quartz plate. The plate is so mounted as to vibrate freely longitudinally between two pairs of close-fitting metallic "coatings." The first pair of coatings is connected between the output anode of a three-stage resistance amplifier and ground, while the second pair is connected between the input grid and ground.

[1] Astronomy and Astro Physics, Vol. 13, p. 835, 1894.

[2] Journal de Physique, Vol. 7, p. 145, 1917.

[3] PHYSICAL REVIEW, 18, p. 142, 1921. A more complete account of these experiments, together with the theory of the piezo-electric resonator, will appear in the Proceedings of the Institute of Radio Engineers.

Any slight increase in potential of the output anode alters the electric field between the first pair of coatings, and sets the resonator into vibration. The charges thereby excited in the second pair vary the potential of the input grid. This varying potential, by virtue of the amplification taking place in the system, will, if the proper coating is connected to the grid, still further increase the potential variations of the output anode and thus maintain the vibrations of the resonator. The power output is of course very small—of the order of 1/20 watt—but this small power may of course be further amplified. Maximum power is obtained by tuning the output circuit by means of a variable condenser and inductance in parallel. If the resonator functions properly, however, the frequency is found to be practically independent of the electrical constants, the current merely passing through a maximum when in electrical resonance. The forced vibrations which the resonator executes have a frequency which is not entirely without influence from external circumstances; yet it hardly ever differs from the natural frequency of the resonator by more than one part in 10,000, and for wide ranges of the various parameters of the circuit the variation is very much less than this.

By the use of quartz plates 3 cm. long, frequencies of (roughly) either 100,000 or 200,000 may be obtained. I have not yet succeeded in obtaining regeneration with frequencies much higher than these. For frequencies so low that it is impracticable to use quartz plates of sufficient length, flat steel rods have been successfully employed. Such a rod has a small quartz plate cemented to each side at its center, and each of the quartz plates is provided with two separate tinfoil coatings. In this case a five-stage amplifier has been found necessary for regeneration. The frequency is essentially that of the steel rod, the quartz plates serving merely to excite longitudinal vibrations in the steel.

WESLEYAN UNIVERSITY,
MIDDLETOWN, CONN.

THE DISSIPATION OF HEAT IN AIR FROM PLAIN AND BLACKENED BRASS SURFACES FOR MODERATE TEMPERATURE DIFFERENCES.

BY T. S. TAYLOR.

OBSERVATIONS have been made in air, free from convection currents other than those set up by the apparatus itself, of the loss of heat from a flat heater when its surfaces were plain brass and when blackened, for various temperature differences and angular positions relative to the vertical. The energy put into the heater was varied till temperature excesses of the heater's surface were obtained up to 130° C. The surface temperatures were obtained by small copper-constantan thermocouples peened into the metal surface. By temperature excess is meant the difference between the temperature of the heater and that of the surroundings and in particular that of the air before it came into the field of influence of the heater.

Assuming black body radiation for the blackened surface, the heat losses