particles which obey the Stokes-Cunningham law. Intense dark field illumination of the particles allows photography of a number of vibrating particles in a small fraction of a second. Our present apparatus employs standing waves of 5-kc frequency, generated by the type of oscillator described by H. F. St. Clair (*12*), and is applicable to particles from 1 to 5 μ in diam, while a 40-kc frequency will cover the range from 0.1 to 1 μ.

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A Contact Modulated Amplifier and Some of Its Laboratory Uses

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Developed to measure d-c signals on the order of a few hundredths of a microvolt, this amplifier employs motor-driven contacts to modulate the input signal (*2*). It features ruggedness, portability, stability, low noise level, and insensitivity to vibration.

Direct-current input signals are converted to a-c (80 cycles) by means of a mechanical breaker, stepped up in

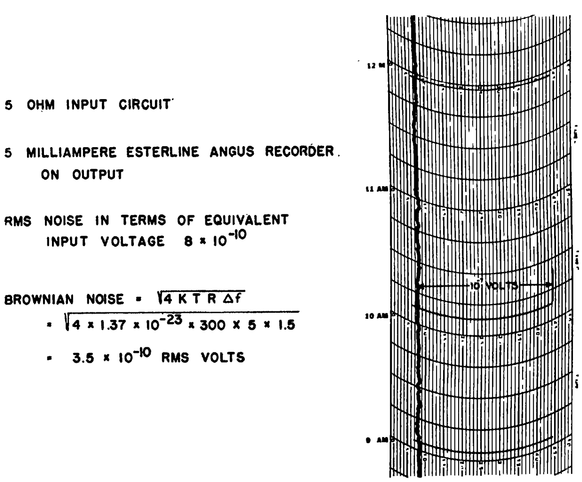

Fig. 1. Amplifier noise level and drift over a 3-hr period.

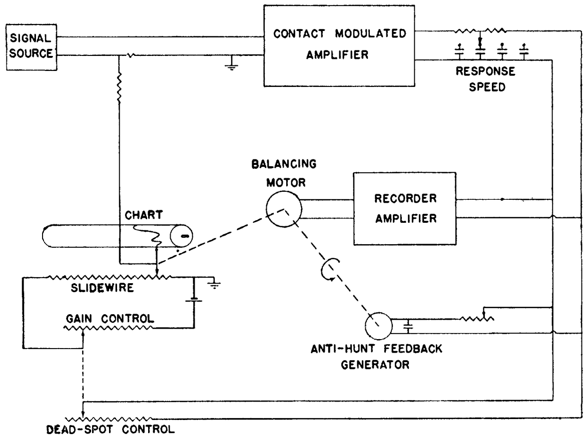

Fig. 2. Infrared spectrograph recording circuit.

voltage by a transformer, amplified with several vacuum tube stages, and finally rectified by another breaker driven synchronously with the input breaker. This arrangement reduces the effect of random variations in the amplifier and favors the wanted signals introduced at the input.

Drift due to small temperature differences between components in the input circuit has been minimized by careful construction and selection of materials. Thermoelectric coefficients of the copper components in this part of the amplifier are matched and junctions are soldered with a special solder (70% Cd, 30% Sn) having a low thermo emf with respect to copper. The input transformer is magnetically shielded with multiple, concentric layers of Mumetal and soft iron.

Fig. 1 shows a performance record of the amplifier. A test signal of 10^{-7} v applied to the 5-ohm input circuit provides calibration from which the random noise level can be measured. An interesting comparison is made in Fig. 1 between the observed noise of 8×10^{-10} rms v and the Brownian noise due to thermal agitation in the input circuit. In the expression for Brownian noise:

K = Boltzman constant
T = Temperature in degrees Kelvin
R = Resistance of input circuit
Δf = Over-all band width (cycles) of amplifier and recorder.

The observed noise is only a little more than twice the theoretical minimum.

This amplifier has found one of its most important applications in the field of infrared spectroscopy. It is

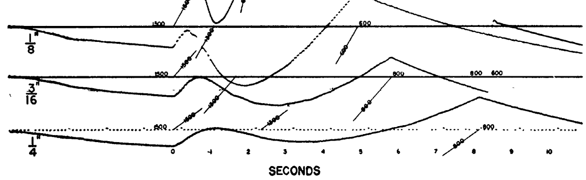

Fig. 3. Record obtained from end-quenched 1020 steel bar.

used with a variety of recording circuits (*4*) in several types of infrared spectrographs. The recording circuit shown in Fig. 2 employs the amplifier as a preamplifier

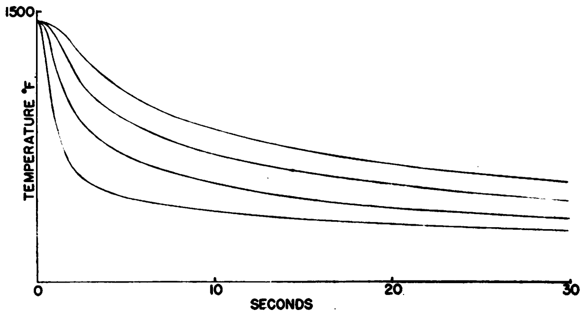

FIG. 4. Cooling curves as recomposed from data of Fig. 3.

for a self-balancing potentiometer type recorder. The features provided are: null balance, wide range of gain control, selection of response speed or band width, and antihunt control. A degree of sensitivity with stability is obtained which permits the recording of infinitesimal quantities of energy on recording instruments of the type commonly used in severe industrial surroundings such as steel mills and foundries.

In a system for studying quench processes in the heat treatment of steel, the amplifier is used with another recording circuit. Time-temperature cooling curves produced by thermocouples at four different locations on a steel bar are recorded during a quench. A method is employed wherein only small differential signals are recorded so that all four curves can be obtained simultaneously on a chart of convenient size while using high sensitivity for accuracy. The major portion of the signal from each thermocouple is bucked out by an opposing emf, which is continuously varied, approximately to cancel the thermocouple signal. During the initial rapid cooling period of the quench, the bucking signal is reduced linearly by a potentiometer driven synchronously with the drum carrying the chart. Fig. 3 shows the first ten sec of a quench record made in this manner. Zero time, as indicated on the time axis (horizontal) of the record, marks the beginning of the quench. The traces prior to zero time represent the cooling of the test bar as it was brought from the 1500° F furnace to the quenching bath. After completion of a quench the actual cooling curves as shown in Fig. 4 are obtained by combining the recorded difference deflections with the bucking signals employed. Cooling rates up to 1200° F per sec have been recorded.

In the oxyhemograph (*1, 3*), a device for recording directly the percent oxygen saturation of the hemoglobin of the blood, photocell signals are applied to the contact modulated amplifier. A photocell, placed on the opposite side of the pinna of the ear from a small light source,

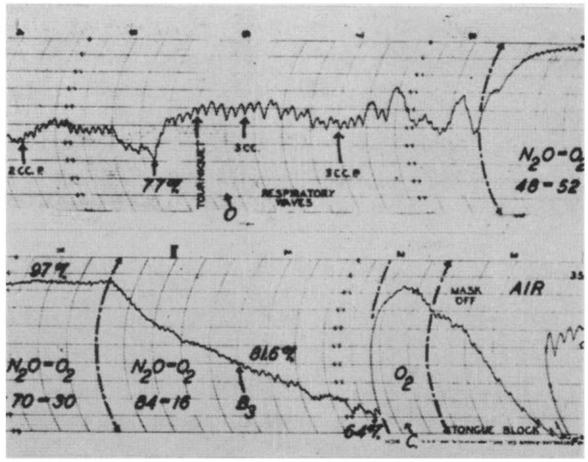

FIG. 5. Oxyhemograph record made with patient under anesthesia for surgery.

responds to changes in the light-transmitting property of blood, which varies with the percent oxygen saturation of the hemoglobin. The oxyhemograph has been found especially useful in the operating room during anesthesia for surgery. Fig. 5 shows sections of a record made in the operating room of the Henry Ford Hospital. The time between each vertical line on the chart is 30 sec. The upper edge of the chart represents 100% oxygen saturation of the blood, the lower edge 60%; below 60% is a dangerously low oxygen content. Each peak in the record on the top section of chart represents one respiration of the patient. The general level of blood oxygen content is low here (lowest point 77%), due to the action of the anesthetic. However, it is increased subsequently by permitting the patient to breathe a mixture of nitrous oxide and oxygen. It was learned, early in the work with the oxyhemograph, that strain on the patient is lessened if the blood oxygen saturation is maintained near normal (95%) during the operation.

The bottom section of the chart shows how the patient's changing condition during the final critical phases of the operation is quickly reflected by the instrument. Blood oxygenation values fluctuate so rapidly and so widely that intermittent gas analysis determinations are inadequate.

The amplifier has found many other uses where high sensitivity is required in the neighborhood of vibration and disturbance.

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