TRANSISTORIZED PYROMETER

WITH AND WITHOUT FEEDBACK

The measurement of missile and rocket surface temperatures in their operational environments is a frequent requirement in the work of the APL hypersonic research facility. The hazardous nature of this research, together with the short operating times involved, requires that these measurements be automatic and that they be controlled by an operator remote from the test area. To meet these requirements, a completely transistorized recording pyrometer for measuring brightness temperatures was developed by S. A. Elder.* The pyrometer measures surface temperature by sensing the amount of radiation emitted from the surface at a fixed wavelength (1.4 microns). Calibration is performed by means of a "black body" source, an ideal radiator, for which the radiant power spectrum and temperature are related by Planck's law.

The recording pyrometer system consists of the pyrometer, a control box, and connecting cables. The principal components of the pyrometer are a telescope lens, infrared filter, chopper wheel, pinhole, condenser lens, and germanium phototransistor. A narrow pencil of light carries an image of the hot source from the port in the nozzle wall (as small as $\frac{1}{16}$ in.) and feeds it through this system onto the phototransistor. The condenser lens is required to smooth out the photosensitive irregularities of the phototransistor to provide a uniform light-sampling spot. This is the same principle used in photo enlargers to avoid imaging the light filament onto photosensitive paper.

The temperature range of the pyrometer is affected by the dynamic voltage range of the electronics and by the efficiency of the optical system. With the telescope objective wide open, the lowest temperature measurable by the instrument is $\approx 725°$K, with a range extending up to some maximum set by the linear limit of the voltage amplifier. In principle, temperatures in excess of $3000°$K could be measured on the pyrometer by a suitable choice of attenuators, though in practice it has been used only below $2500°$K ($\approx 4000°$F).

This pyrometer system has certain advantages over systems based on phototube detectors; chief among them are its almost complete insensitivity to shock and vibration, and its compactness and low cost. Also, the fact that it operates at infrared wavelengths gives it a wider temperature range than is possible with most phototubes. Under ordinary laboratory conditions, the accuracy of the system is better than $\pm 10°$C. Response times as short as 20 μsec can be achieved with the phototransistor currently in use.

In an improved version of the pyrometer, the electro-optical response of the phototransistor is stabilized by "photofeedback." Here, the phototransistor becomes the first stage of a direct-coupled common-emitter cascade amplifier. The
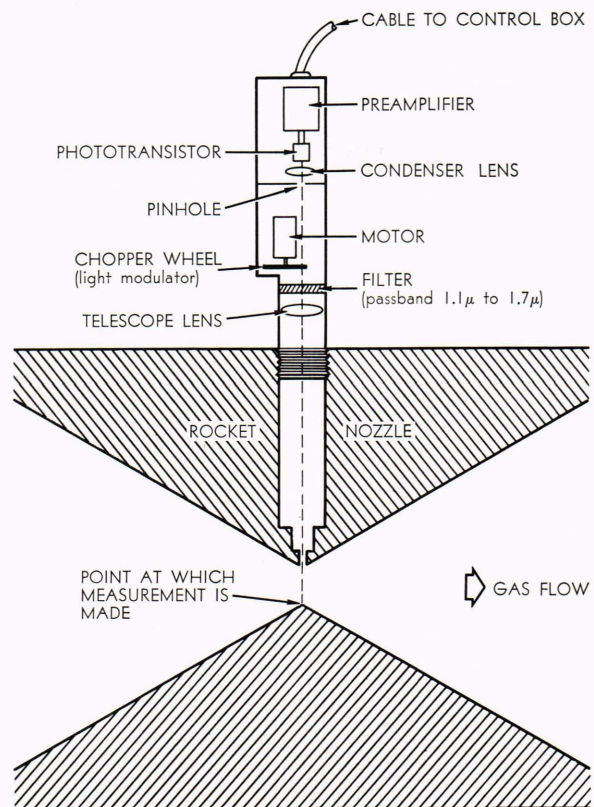

Schematic of a pyrometer screwed into the side of a rocket nozzle for throat-temperature measurement.

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* S. A. Elder, "Designing Phototransistor Pyrometers with and without Feedback," *Electronics*, **34**, 1961, 56–60; and "A Completely Transistorized Recording Pyrometer," *Temperature—Its Measurement and Control in Science and Industry*, **3**, Part 2, 1962, 873–877.

feedback is introduced in the form of an infrared light signal. A subminiature tungsten bulb acting as an electro-optical transducer re-introduces into the window of the phototransistor an optical signal proportional to the electrical signal at the output of the amplifier. Base bias for the phototransistor is supplied by the DC component of the light from the lamp, which is run at a steady 12-ma current.

The photofeedback version of the pyrometer gives greater precision as well as greater calibration stability. The voltage calibration is reproducible to better than 0.1%, giving a temperature that is reproducible to better than $\pm 1°C$ at $1000°$ K and $\pm 4°C$ at $2000°K$. Even greater precision could be achieved by redesigning for a larger amount of feedback, but stability of the feedback lamp characteristics may impose a practical limit. The threshold temperature of this version is $\approx 840°K$.

The most important advantage of the feedback version of the pyrometer, as previously noted, is that after an initial absolute calibration, it needs no further optical calibration and is therefore ready for field use under any conditions. Another advantage is that feedback improves the linearity of the phototransistor response.

An accompanying figure shows how the pyrometer is being used currently to measure throat-
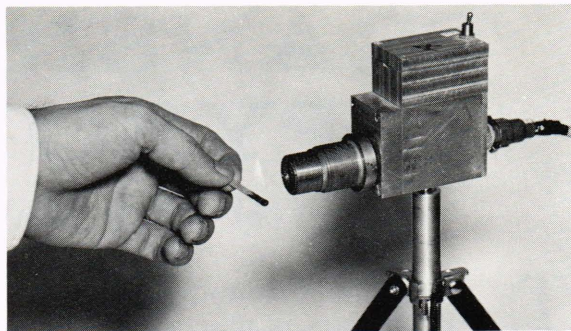
Recording pyrometer designed for use by the Flight Research Group.

surface temperature in a rocket motor. By mounting the pyrometer directly to the rocket-nozzle wall (a capability made possible by its small size and weight), optical alignment errors due to thermal expansion can be avoided. An optical pyrometer is preferable to a thermocouple in this application since it has no thermal lag or lead conduction loss.

Other groups in the Laboratory are finding uses for the transistorized pyrometer. A conveniently sized unit using the same basic optical and electronic design, which has been adapted by J. M. Akridge for use by the Flight Research Group, is illustrated.

SURVIVAL

in

Metropolitan-Area Nuclear Attacks

R. J. Vicars

On May 25, 1961, in his message to Congress on "Urgent National Needs," the President called for a new and revitalized civil defense program to protect the civilian population of the United States from the hazards of nuclear war. Since that time, many pamphlets, books, and articles have appeared urging the population to begin providing the means for shelter-

ing itself from the residual radioactivity ("fallout") that would result from a nuclear attack.

It is agreed* that "fallout shelters" will provide useful protection only

* The author acknowledges that the factual data upon which this study is based were derived from U. S. Government and other publications listed at the conclusion of this paper. The statements herein do not con-

when quite remote from the actual ground zero of a large-yield thermonuclear detonation. They can provide all the immediate protection that is required for a large segment of the population (20 million rural inhabi-

stitute a specific set of recommendations, but are an aggregation of facts from which the reader may determine his own course of action.