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A HOT WIRE RADIANT ENERGY SOURCE FOR MAPPING THE FIELD OF VIEW OF A RADIOMETER

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SUMMARY

This report describes the design and performance of a calibration device that allows the measurement of a radiometer's field of view. The heart of the device is a heated 0.0254-mm (0.001-inch) diameter filament that provides a variable, isothermal line source of radiant energy against a cold background. By moving this discrete line source across the field of view of a radiometer, the radiometer's spatial response can be completely mapped. The use of a platinum filament provides a durable radiation source whose temperature is stable and repeatable to 10 kelvin over the range of 600 to 1200 kelvin. By varying the energy emitted by the filament, the field of view of radiometers with different sensitivities (or multiple channel radiometers) can be totally mapped.

INTRODUCTION

Instrumentation was developed to measure the instantaneous field of view of the LIMS (Limb Infrared Monitoring of the Stratosphere) scanning radiometer for the Nimbus G satellite. A calibration source and its housing were designed to be integrated into the final radiometer calibration apparatus using an existing off-axis parabolic mirror at a focal length of 1016 mm (40 inches) as the collimator. The radiometer's total detector plane subtends 17.6 milliradians in angle and the smallest instantaneous field of view is 0.5 milliradians.

The instrumentation was designed, constructed, and tested as a constant-current hot-wire assembly. The concept, originally formulated by W. D. Hesketh of the Flight Electronics Division, consists of a 0.0254-mm (0.001-inch) line source with a cold background which could best be realized with a hot-wire anemometer in front of a liquid nitrogen cooled plate. However, no anemometers with elements of sufficient length were available. Furthermore, the elements elongate and sag when heated and were no longer straight line sources. Design and construction were undertaken to use the commercially available anemometer power supply to power a resistance filament as a temperature source. By spring loading one end of the resistance filament, the problem of sag was eliminated. The purpose of this paper is to describe this technique and other design, construction, and calibration techniques used to provide the radiant energy source.

SOURCE ASSEMBLY

The physical characteristics of the target assembly were dictated by several factors. First, in order to map the system's smallest instantaneous field of view, 0.5 milliradians at a focal length of 1016 mm (40 inches), the actual target could be no greater than 0.025 mm (0.001 inch) in diameter and at least 19-mm long (0.75-inch) long (for acceptable resolution), and had to be maintained horizontal when heated. Second, the physical assembly size was restricted to 12.7 cm x 12.7 cm x 25.4 cm because of space limitations on the radiometer test bed. Third, a system of baffles to shield the light source was required since the target assembly would be subjected to air currents which were generated when the enclosed radiometer test bed was maintained at a slightly positive pressure by a nitrogen gas purge. Fourth, a background of low radiant energy was required which extended down to liquid nitrogen temperatures in order to essentially eliminate background radiance and maintain a high signal-to-noise ratio. Further design requirements included: Vertical and axial movement of the assembly for optimum positioning, a mask with a 13-mm by 19-mm window (which could be pivoted out of the field of view) having a vertical wire through the center for alinement purposes, and a sensor attached to the LN_2 cooled plate for monitoring background temperature.

To keep within size limitations, a protective housing with baffling was constructed (figs. 1 and 2). The baffles shown in figure 2 proved adequate to damp out transient air movements. The interior of the housing was painted with a high emissivity black paint to minimize reflections from the target filament and other stray light.

Next the filament holder was designed and constructed as shown in figure 2. It was mounted to the inside of the removable top cover of the protective housing. This facilitates changing filaments and making adjustments. The filament is held between two posts, one fixed and the other spring loaded. Spring loading eliminated sagging of the filament due to elongation caused by heating the filament. Minimum tension is applied to the spring-loaded post so that the small diameter wire will not be stretched when it is subjected to high temperatures. The binding post is large enough to act as a heat sink which allows the filament wire to be soldered to it without fear of losing the connection when heated. Power to the filament is introduced through binding posts located on the top cover of the protective housing (figs. 1 and 3).

To meet the requirement for a uniform background of low radiant energy behind the filament, a copper plate with a honeycombed surface was procured commercially and mounted at the rear opening of the protective housing as shown in figures 1 and 2. The copper plate contains a chamber through which liquid nitrogen is pumped to cool the honeycomb surface. A Chromel-Constantan thermocouple was welded to the front of the copper plate at the base of one of the honeycomb cavities at a spot which was not within the field of view.

The source assembly mounting plate consisted of two 19-mm-thick plates welded together to form an inverted "T" (fig. 3). Between the mounting plate and the source assembly was mounted a dual-axis micrometer slide. These slides provide fine vertical and axial adjustments for final alinement of the hot wire filament.

A mask was installed within the target assembly to aline the radiometer with the isothermal portion of the filament. The mask contains a 13 x 19 mm opening and a vertical cross hair for locating the center of the filament. The front side of the mask was painted yellow for easy viewing and a knob on the top cover of the protective housing is used to pivot it out of the field of view after alinement (fig. 2).

SOURCE ASSEMBLY PERFORMANCE

The filament was 0.0254 mm (0.001 inch) pure platinum wire. A hot wire anemometer power supply was used as the current source to heat the filament. There were several problems or limitations associated with this power supply which were noted. First, fast response at some filament tensions cause the filament to vibrate at frequencies that are audible. If air currents are present, high variations in temperature along the filament are noted. These temperature variations were exaggerated because under the constant electrical power, localized air currents cooled parts of the filament and caused sharp increases in the other noncooled sections.

Second, when power supply response is slow, air currents cause the filament to heat or cool at the rate of 3 to 5 hertz. The expansion and contraction of the filament is large enough to cause the spring-loaded binding post to pulsate. The pulsations stress the filament causing it to fatigue and become nonisothermal. The temperature distribution across a fatigued filament is shown in figure 4. These two problems were corrected by adjusting the response control on the anemometer power supply to an intermediate rate.

Third, the anemometer power supply exhibited instability as shown in figure 5. To maintain a constant current and therefore a constant temperature across the filament, a four-terminal shunt was placed in the circuit and the voltage drop across the shunt was held constant by varying the power supply controls.

FILAMENT TEMPERATURE CALIBRATION

Where the filament temperature was high enough to be incandescent, the temperature versus current relationship could be established with an optical pyrometer. However, much of the temperature range of interest was in the nonincandescent range. To measure the temperature in the range between 600 and 1400 kelvin, a commercial radiometer was optically modified so that the filament would fill the apparent field of view. Since the optics had been changed, it was now necessary to calibrate the radiometer with a known source which duplicated the size, shape, and materials of the source assembly filament.

A technique was developed to establish the relationship between the filament current and the filament temperature. To do this, a separate platinum filament was used as both the temperature source and the temperature sensing element by attaching wires to the filament (fig. 6) in such a way that the platinum element between two Chromel leads acts as the sensing element of a four-wire resistance thermometer. First, the platinum filament was welded between 0.1023 cm Nichrome support wires as shown. The support wires were clamped in electrical binding posts, one fixed and the other spring loaded to provide a constant tension to the filament as it expands with heat. The binding posts were mounted on laboratory jacks located at either end of a 30.5-cm-long, 2.54-cm-diameter furnace.

Second, Chromel potential leads were welded to the platinum heater filament as shown in figure 6 using a capacitance discharge spot welder with tweezer welder attachment.

Third, the platinum filament with potential leads was lowered into the tube furnace with the lab jacks and the furnace was closed after potential leads were insulated electrically from the furnace shell. A calibrated thermocouple was positioned at the same point within the furnace as the filament.

Fourth, the furnace was heated while a 1-milliampere current was maintained through the platinum filament. The temperature was measured with the thermocouple at the same time that the voltage drop was measured across the platinum filament with the Chromel leads. By varying the furnace throughout the temperature range of interest, the temperature versus resistance relationship was established for the platinum filament.

Fifth, the platinum filament was now ready to be used as a calibration source. The furnace was opened and the filament heated with known currents while simultaneously measuring the voltage drop across the platinum filament and the output of the modified commercial radiometer which had been focused on the filament. By relating the voltage drop measured and the known current in this measurement to the basic resistance values, the temperature of the platinum filament was derived.

After this calibration, the commercial radiometer was now available to calibrate the source assembly filament. This was done by measuring the voltage drop across the shunt which had been installed in the filament circuit and generating the curve of figure 7, which shows shunt voltage drop versus temperature over the temperature range 600 to 1300 kelvin. An excellent filament calibration over the temperature range was implied when data taken using a thermocouple in the furnace and measurements made using the optical pyrometer agreed to within 5 kelvin. This strongly indicates that the filament calibration at the lower temperature is equally as good.

The temperature distribution about the center of the filament was measured and the results are shown in figure 8. The total length of the filament was 32 mm and the isothermal temperature portion is more than 20 mm in length which exceeds the 19 mm requirement. Temperature stability with time was measured and is presented in figure 9. Both the stability of the filament temperature and the length of the stable filament exceeded all requirements.

Further tests indicate that the stability of the filament would be degraded if its temperature exceeds 1200 kelvin. Figure 10 displays the filament instability caused by higher temperatures. However, little calibration instability is exhibited over a 6-hour period if temperature is maintained below 1200 kelvin as shown in figure 9.

CONCLUSION

A high resolution isothermal line radiation source of variable temperature for radiometer instantaneous field-of-view measurements was constructed and calibrated. The technique successfully employed a spring-loaded hot-wire anemometer-type element of 0.0254-mm-diameter platinum wire which was electrically heated. Physical linearity of the filament was an important factor in the overall effectiveness of the method of mapping the field of view, and spring loading held the filament horizontal without detectable sag. Although extremely fragile, the filament proved to be isothermal, stable, durable, and repeatable to within 10 kelvin over the temperature range from 600 to 1200 kelvin.

The problem of the temperature measurement of a wire this small at levels below incandescence was solved by modification of the optics of a radiometer to view very small targets. This radiometer was calibrated with another 0.0254-mm-diameter platinum element whose temperature was known. The temperature of this other element had been determined by comparison of the resistance of its heated portion by measuring the voltage drop when heated in a furnace and when heated electrically. Filament temperature calibration data using a thermocouple and using an optical pyrometer agreed to within 5 kelvin. The 20-mm length of the filament isothermal temperature zone and its stability with time exceeded the design requirements.

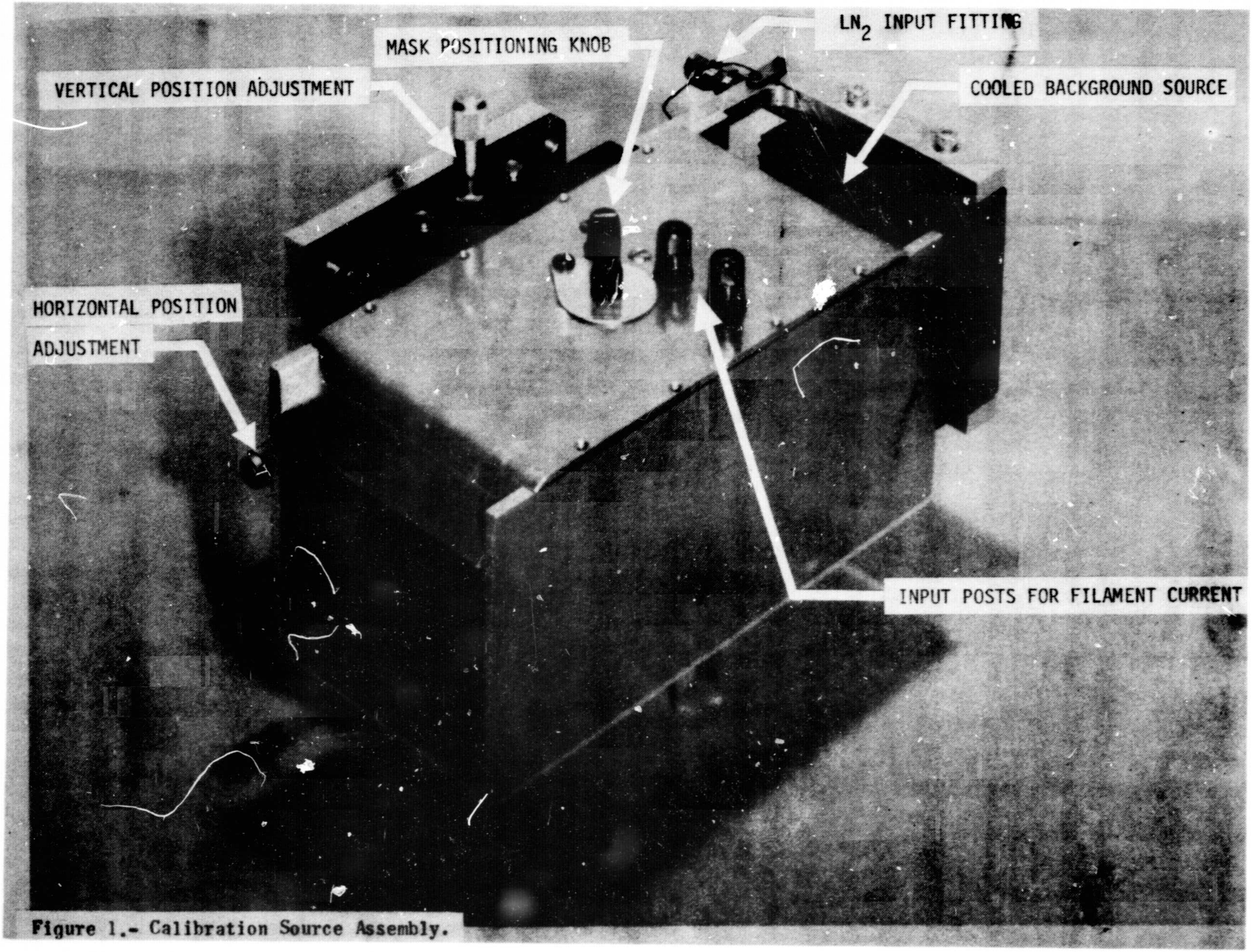

Figure 1.- Calibration Source Assembly.

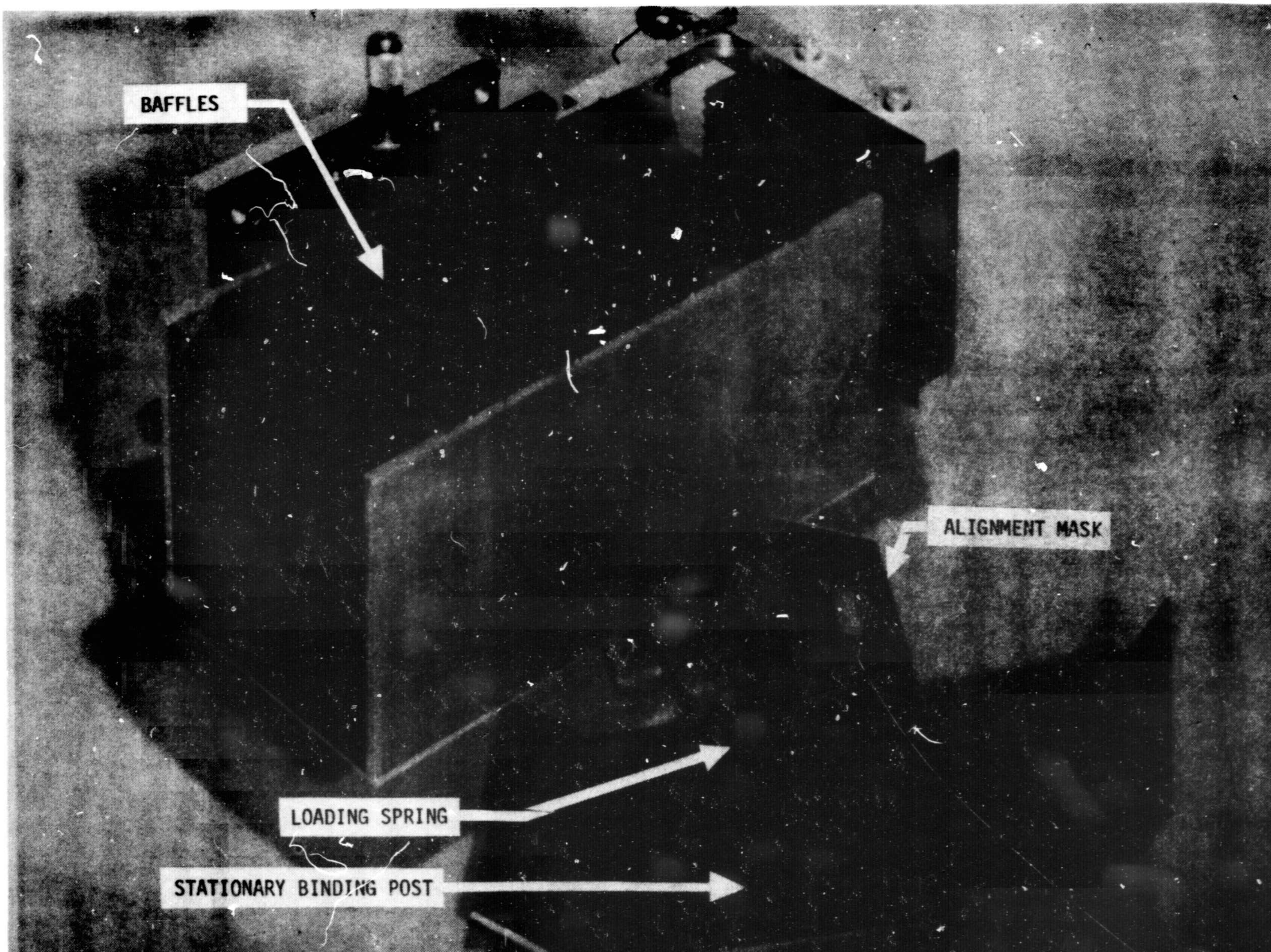

Figure 2.- Calibration Source interior.

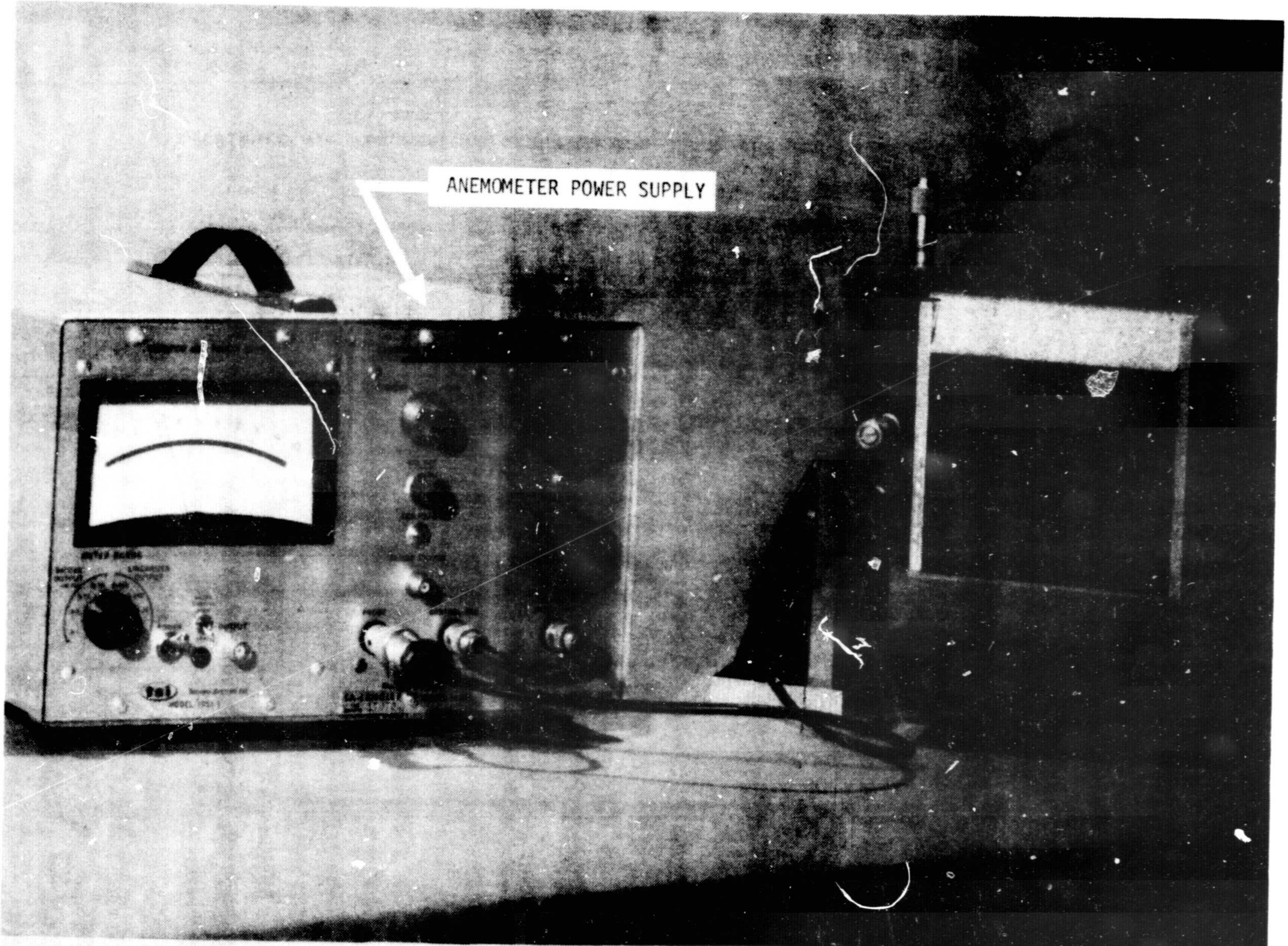

Figure 3.- Calibration Source with filament heated to incandescence.

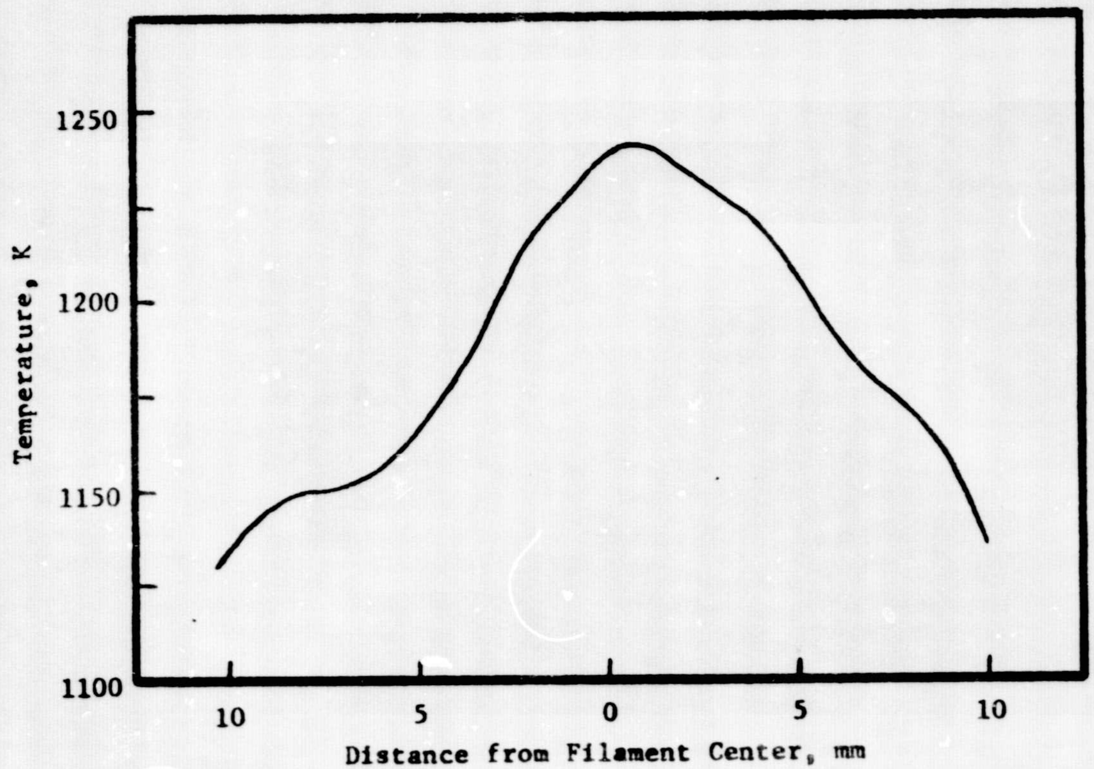

Figure 4.- Temperature distribution along the length of a fatigued filament.

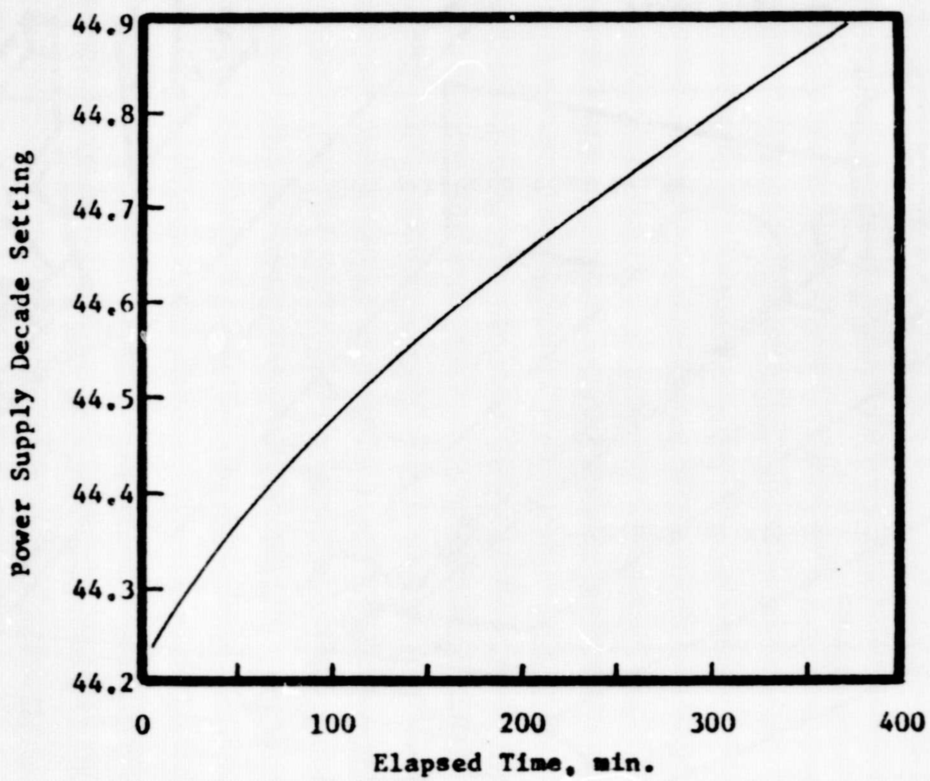

Figure 5.- The change required in power supply decade setting over a 6 hour period to maintain a constant current in the filament circuit. The change in output represented a temperature variation in excess of 100 kelvin.

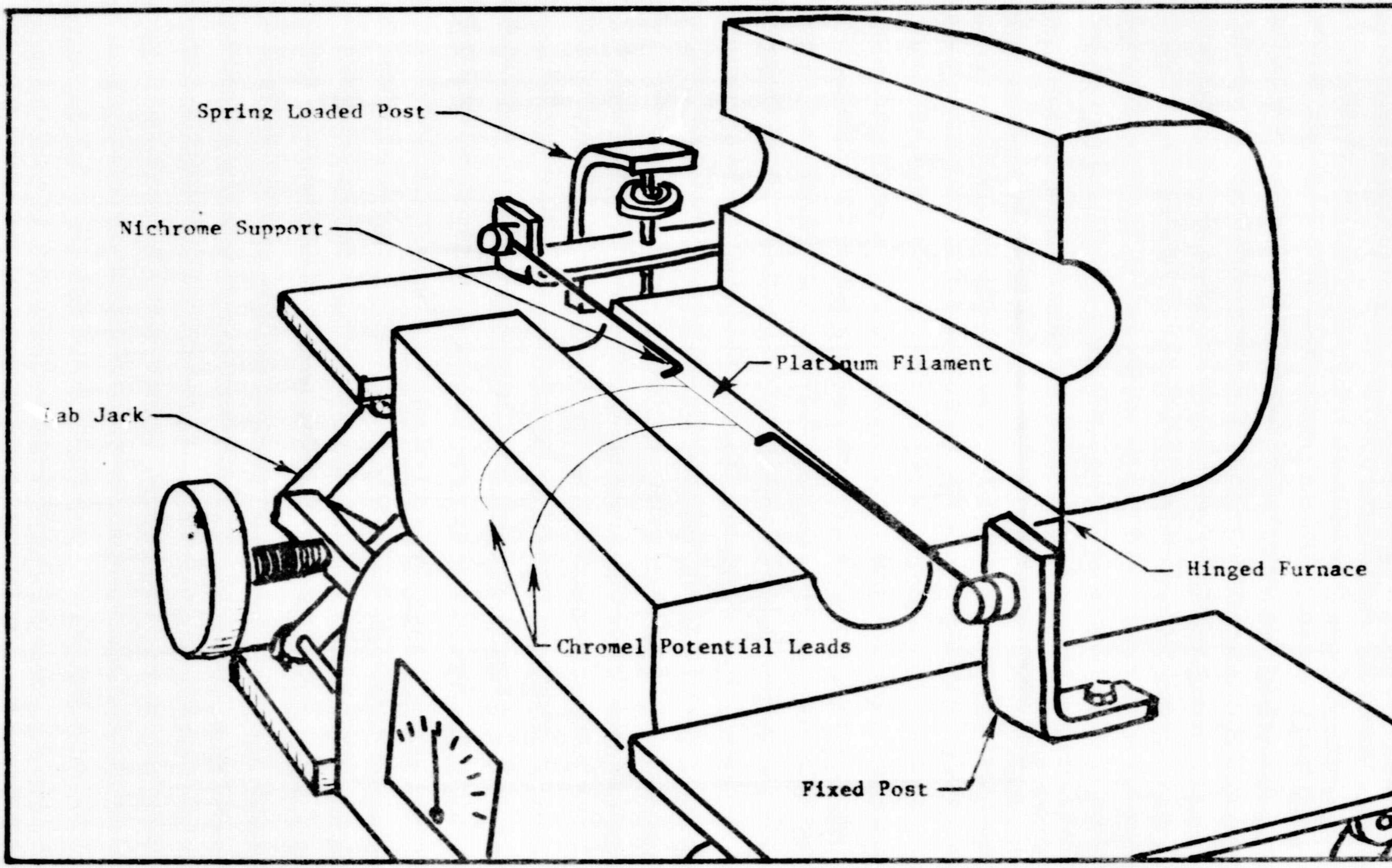

Figure 6.- Sketch of the apparatus used to calibrate the optically modified commercial radiometer.

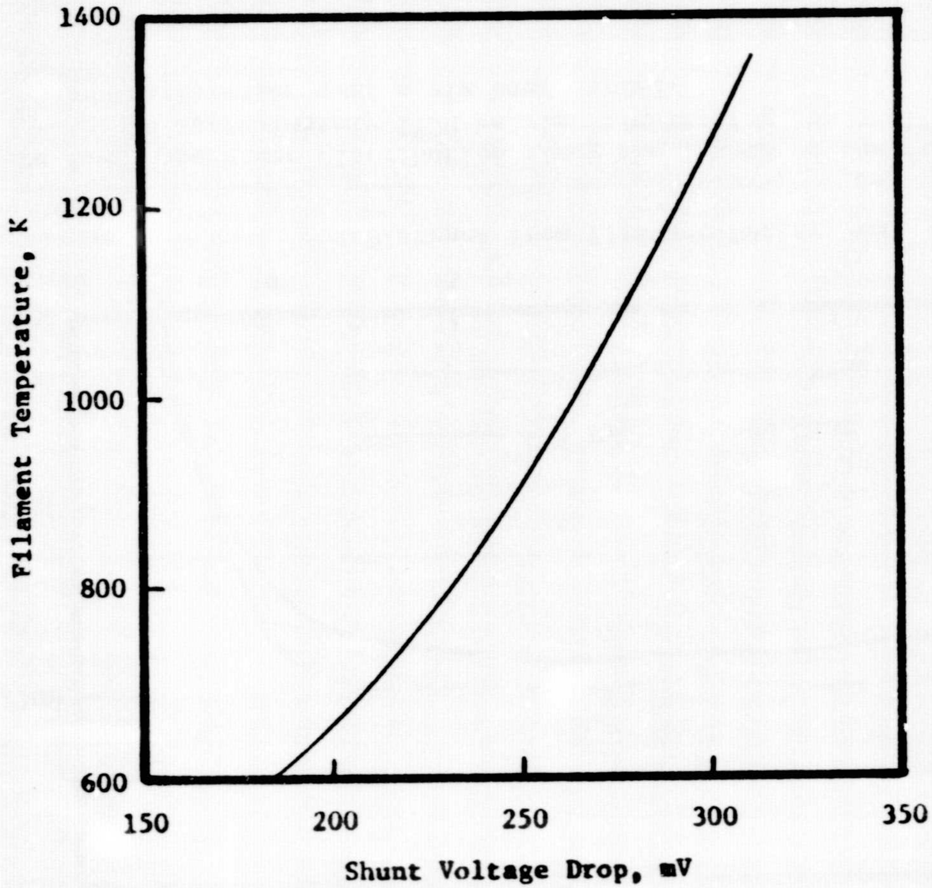

Figure 7.- Filament temperature versus shunt voltage drop when the filament is 0.0254 mm diameter platinum wire.

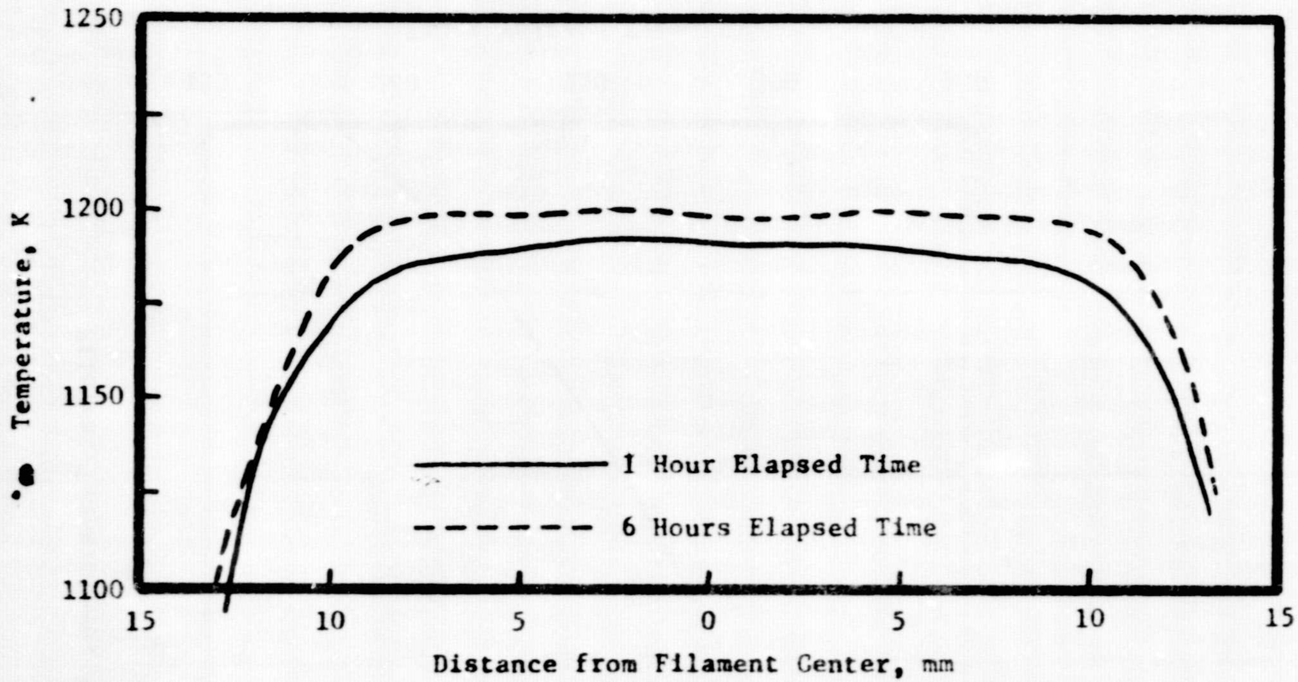

Figure 8.- Temperature distribution along the length of the filament when heated to approximately 1200 kelvin illustrating the small change in calibration over a six hour period.

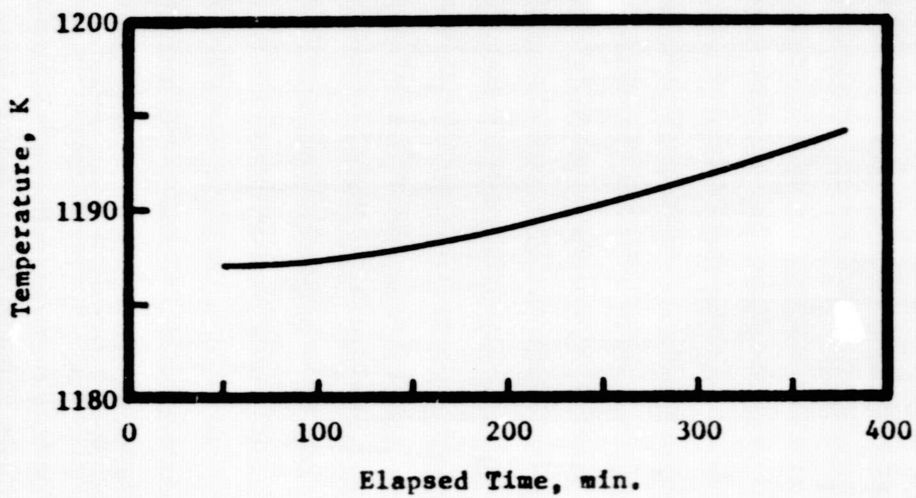

Figure 9.- Calibration drift experienced over a six hour period at a constant current when the temperature is limited to 1200 kelvin.

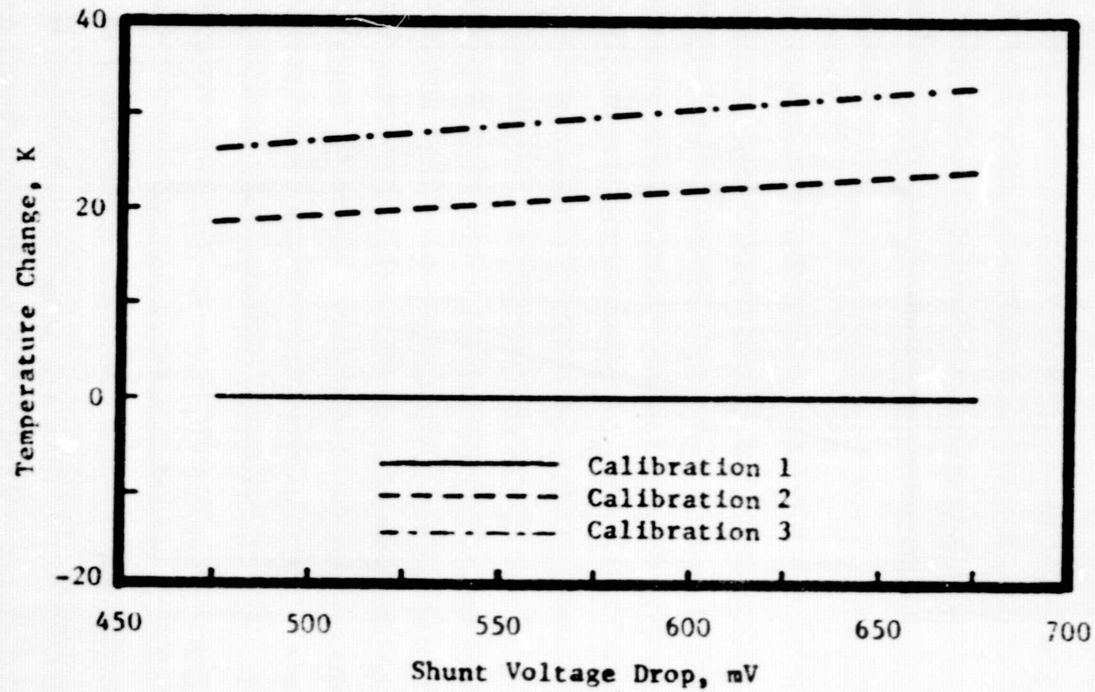

Figure 10.- Instability of the calibration caused by elevating the filament temperature to 1550 kelvin during three successive calibrations.

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16. Abstract

This report describes the design and performance of a calibration device that allows the measurement of a radiometer's field of view. The heart of the device is a heated 0.0254-mm (0.001-inch) diameter filament that provides a variable, isothermal line source of radiant energy against a cold background. By moving this discrete line source across the field of view of a radiometer, the radiometer's spatial response can be completely mapped. The use of a platinum filament provides a durable radiation source whose temperature is stable and repeatable to 10 kelvin over the range of 600 to 1200 kelvin. By varying the energy emitted by the filament, the field of view of radiometers with different sensitivities (or multiple channel radiometers) can be totally mapped.

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