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SUMMARY

This paper describes the design and performance of a thin-line radiant energy source for calibrating a pressure modulated radiometer (PMR). The line source is an 11.4-cm-long, 0.005-cm-diameter platinum-iridium wire of which 8 cm is an isothermal radiator maintained at 1200 K. Superimposed on the 1200-K "signal" is a ±20-K "signal," oscillating at adjustable frequencies between dc and 20 Hz. The sinusoidal variation of the filament energy provides a source which is able to demonstrate the PMR's capability to distinguish between the atmospheric gas signals of interest and the anticipated signal variation caused by the Earth's background surface. Detailed discussion is provided on the operation, calibration, and maintenance of the source.

INTRODUCTION

An airborne, nadir-viewing pressure modulated radiometer (PMR) (ref. 1) was developed at NASA Langley Research Center to extend the measurements made by the Oxford University stratospheric and mesopheric sensor (SAMS), a limb-scanning instrument, into the troposphere. The infrared sensing PMR, a gas-filter correlation radiometer, is designed to measure the atmospheric concentration of certain trace gases, such as CO. Unfortunately, nadir-viewing gas-filter correlation radiometers are sensitive to changes in the Earth's brightness temperature in addition to changes in the atmospheric line parameters of the target gas. In order to distinguish between atmospheric-gas signal changes and the undesired Earth-surface signal variations, the PMR must be accurately calibrated. To effectively calibrate the PMR, a modulated infrared radiant source was designed and constructed which demonstrated the PMR's capability.

APPARATUS

Modulated Infrared Radiant Source

The modulated infrared radiant source was designed to simulate a nominal Earth background with a 5-percent radiance variation superimposed on it. Additional requirements included an 8-cm-diameter clear aperture and frequency variability between dc and 20 Hz. For the spectral band from 2080 cm^{-1} to 2240 cm^{-1}, calculations of radiant energy showed that radiometric requirements could be satisfied by an 8-cm-long wire of 0.005-cm-diameter operated at 1200 K with a ±20-K modulation superimposed on it. The thin-line source was placed in front of an ambient-temperature blackbody. In order to distribute the radiant energy uniformly across the PMR detector, the optical system imaged the energy source onto the aperture stop and imaged the stop onto the detector. The modulated infrared radiant source (figs. 1, 2, and 3) consists of: a metal housing containing the filament assembly and the photodetector; a flat, honeycomb, blackbody radiator; a power supply module; and a simple signal conditioner.

Filament Assembly

The filament assembly (fig. 2) provides a straight-line source of radiant energy 0.005 cm in diameter. A platinum-iridium wire was used because its suitability for high-temperature applications has been well established in the hot-wire anemometry field (ref. 2). An 11.4-cm-long filament was used to satisfy the design requirement that 8 cm of the filament length be isothermal. This can be observed optically, as shown in figure 4. The filament operates at 1200 K and has a superimposed ±20-K modulation which is variable in frequency between dc and 20 Hz. Previous experience with another filament device (ref. 3) had shown that compensation for thermal expansion was required to keep the filament from sagging. This is done by suspending the filament between two posts, one fixed and the other spring loaded (fig. 2). The spring-loaded post uses jewel bearings of the type found in meter movements to minimize friction. Minimum tension is applied to the spring-loaded post so that the small diameter wire will not be stretched when it is at high temperature. The filament posts are large enough to act as heat sinks so that solder can be used to attach the filament without fear of losing the connection when heated. Power is introduced to the filament through binding posts on the top cover of the housing with the spring on the spring-loaded post used to carry current to that end of the filament.

Several precautions must be taken when using a filament of this type. It must be protected from forced convection since it has so little mass that even small air movements will cause rapid cooling. The filament must be mounted horizontally to be isothermal, as illustrated in figure 4. This figure is a display of the difference in temperature distribution measured along the filament when oriented in the horizontal and vertical positions.

Photodetector

A photodetector (figs. 2 and 3) was chosen to satisfy the design requirement that temperature excursions be monitored. It is a high-sensitivity industrial photodetector with a peak response in the visible and near infrared spectrum. The detector's 200- to 475-K ambient operating range is valuable because of its physical proximity to both the filament and the background radiation source. The photodetector's temperature sensitivity is overcome by calibrating the filament after all components reach their operating temperature. The background radiation of the filament assembly housing is seen by the photodetector, but it is orders of magnitude lower and is insignificant. The transducer views the filament and produces an output proportional to the filament temperature. The photodetector's signal conditioner is located in a separate package to avoid the space limitations and the temperature problems associated with the filament assembly housing.

Filament Power Supply

The requirement to generate a 1200-K signal that is modulated ±20 K demands a filament power supply that produces an output that both elevates (or biases) the filament temperature to 1200 K and fluctuates (or modulates) it ±20 K.

Power for the filament is provided by a remotely programmable modular power supply with remote sensing capability. The modular power supply is volt-per-volt voltage programmable (i.e., for every volt input to its control circuit, it outputs a volt to the filament). It is, in a sense, a power amplifier. To control the level of its output (bias), a stable and repeatable voltage source is needed. A small voltage calibrator with decade switch settings was used. A function generator with selectable sine- and square-wave outputs provides the modulation. Figure 3 is an illustration of the interconnecting wiring that supplies the programming voltage to the filament power supply to generate the correct output to the filament.

Once the properly biased and modulated signal has been applied to the filament, there still remains the task of determining the temperature of the filament. Measuring the filament temperature at a constant 1200 K can be done with an optical pyrometer. When the filament temperature is modulated, the optical pyrometer measurement must be augmented since the response of the human eye is limited. The solution is to use an optical pyrometer in combination with the photodetector, the function generator, and the oscilloscope. The filament temperature is set to 1200 K using the optical pyrometer and the control power supply. Next, the ±20-K modulation is set at a low frequency using the optical pyrometer and the function generator. A frequency of 0.5 Hz was used, which is well within the ability of the human eye to respond. The output of the photodetector viewing the modulated filament is displayed on the oscilloscope screen as a calibrated amplitude, which is maintained between two preset limits (graticule lines) on the screen. (See appendix.)

Background Blackbody

A flat, copper, honeycomb blackbody (fig. 1) is mounted behind the filament assembly so that the background radiation can be varied. The blackbody plate contains a series of tubing coils so that it can be heated or cooled from 80 to 380 K by pumping a liquid of the proper temperature through it. There are also auxiliary resistance heaters cemented to the copper backplate to allow the temperature of the background radiator to be maintained at any temperature between ambient and 380 K.

RESULTS

A modulated infrared radiant source has been designed, constructed, calibrated, and tested. Results show that the design criteria has been met for an 8-cm straight-line source of radiant energy maintained at 1200 K with a superimposed ±20-K modulation which is variable in frequency between dc and 20 Hz. The measurement of the filament temperature is the only practical limit to this system's accuracy. The filament was isothermal to within ±5 K. This measurement was made with an optical pyrometer with an uncertainty of ±3 K. This corresponds to ±1-percent radiation.

The temperature of the filament can be modulated ±20 K at a frequency between dc and 20 Hz with ease. The system frequency response decreases above

20 Hz such that the magnitude of the modulated temperature must be decreased so that the temperature excursions are approximately ±10 K at 50 Hz.

The spring-loaded filament suspension technique was remarkably successful in view of the relatively long length of the platinum-iridium wire. The filament remained horizontal and no sag could be detected. Occasionally the filament will begin to vibrate. This problem is common in long filaments electrically heated to high temperatures. A momentary decrease in power to the filament is all that is necessary to stop the vibration.

To determine the effect of changing the background blackbody temperature on the filament temperature, a fixed current was passed through the filament while the temperature of the blackbody was varied. By changing the background temperature 100 K, the filament temperature change was measured to be 10 K; while a 75-K increase in background temperature induces an increase of 5.5 K. This change can be attributed to combinations of photodetector temperature coefficient and radiation effects. No effort was made to determine the contribution of each, since these induced errors can be corrected by bringing the background blackbody to its operating temperature before the 1200-K filament temperature is set.

Temperature of the background blackbody was determined with a copper-constantan thermocouple embedded in the honeycomb plate. The accuracy of this thermocouple and its associated readout can be realized to ±1.0 K.

A complete operational procedure for this calibration source can be found in the appendix.

CONCLUDING REMARKS

All design requirements have been met to produce a modulated, isothermal, straight-line radiation source for the calibration of an experimental pressure modulated radiometer. The source employs a spring-loaded filament holder that maintains the horizontal filament physically linear without any detectable sag, even when heated to incandescent temperatures. The filament itself is a 0.005-cm-diameter platinum-iridium wire 11.4-cm long, of which more than 8 cm is observed to be isothermal. The filament operates at 1200 K and has a superimposed, oscillating ±20-K "signal," which is variable in frequency between dc and 20 Hz.

The problem associated with the measurement and calibration of the modulated ±20-K component of the source was solved. A technique was developed that made possible an accurate calibration and also provided a simple method for monitoring and adjusting the modulation in normal operation. The filament temperature is calibrated by supplying its modulating power in the form of a 0.5-Hz square wave which can be measured optically and using the output of a built-in photodetector to set a known display on an oscilloscope screen. Once this is done, the wave shape and frequency can be changed and the output of the source can be returned to its calibrated level by adjusting the modulation amplitude to the preset limits on the oscilloscope screen.

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May 11, 1981

APPENDIX

MODULATED INFRARED RADIANT SOURCE CALIBRATION PROCEDURE

The following is a step-by-step procedure describing the calibration and operation of this modulated radiation source. Before starting the calibration, the following precautions must be taken:

1. Protect the calibrator from forced convection.

2. Mount the filament horizontally.

3. Bring the background radiator to the anticipated operating temperature and allow all components to stabilize.

The source filament is now ready to be calibrated as follows:

1. Focus on the filament with an optical pyrometer. Set the pyrometer for 1200 K.

2. Adjust the function generator to deliver a square-wave signal of 0.5 Hz, but keep the output amplitude at zero.

3. Adjust the control power supply until the filament temperature, as viewed in the optical pyrometer, is 1200 K.

4. Set the oscilloscope monitoring the silicon photodetector to the 50 mV-per-division range at a sweep rate of 5 msec per division. Set the oscilloscope mode for "uncalibrated amplitude" in dc response and adjust the zero offset until the input signal is matched with the oscilloscopes center horizontal graticule line.

5. Increase the setting of the optical pyrometer by 20 K to 1220 K.

6. Increase the amplitude of the function generator output until the source filament matches the temperature of the pyrometer filament at the upper end of the square wave.

7. Adjust the amplitude control of the oscilloscope display until the top and bottom of the square wave shown on the screen are matched with convenient upper and lower horizontal graticule lines.

8. Return the function generator to a sine-wave output. The source filament is now producing a 1200-K signal which has a ±20-K oscillation superimposed on it.

9. As the frequency of the ±20-K signal is increased, the amplitude of the signal from the function generator must also be increased. Since the oscilloscope is adjusted to display a ±20-K signal between two graticule lines, all that is necessary after increasing the frequency is to increase the function-generator output amplitude until the signal returns to the two, predetermined

graticule lines. Adjust the time base of the oscilloscope to any sweep rate that simplifies viewing the display.

WARNING!

Before decreasing the frequency, decrease the amplitude of the function generator control signal. If this is not done, the source filament will be overdriven and may be fatigued or destroyed.

Replacement of the filaments is simplified by the heat sink provided by the relatively large mass of the filament posts. Since the filament posts remain cool, solder is used to attach the filament. First, solder the replacement filament to the spring-loaded post. Second, grasp the loose end of the filament and pull on it until the two posts are parallel. Third, solder the filament to the fixed post. Fourth, trim off excess filament material with scissors.

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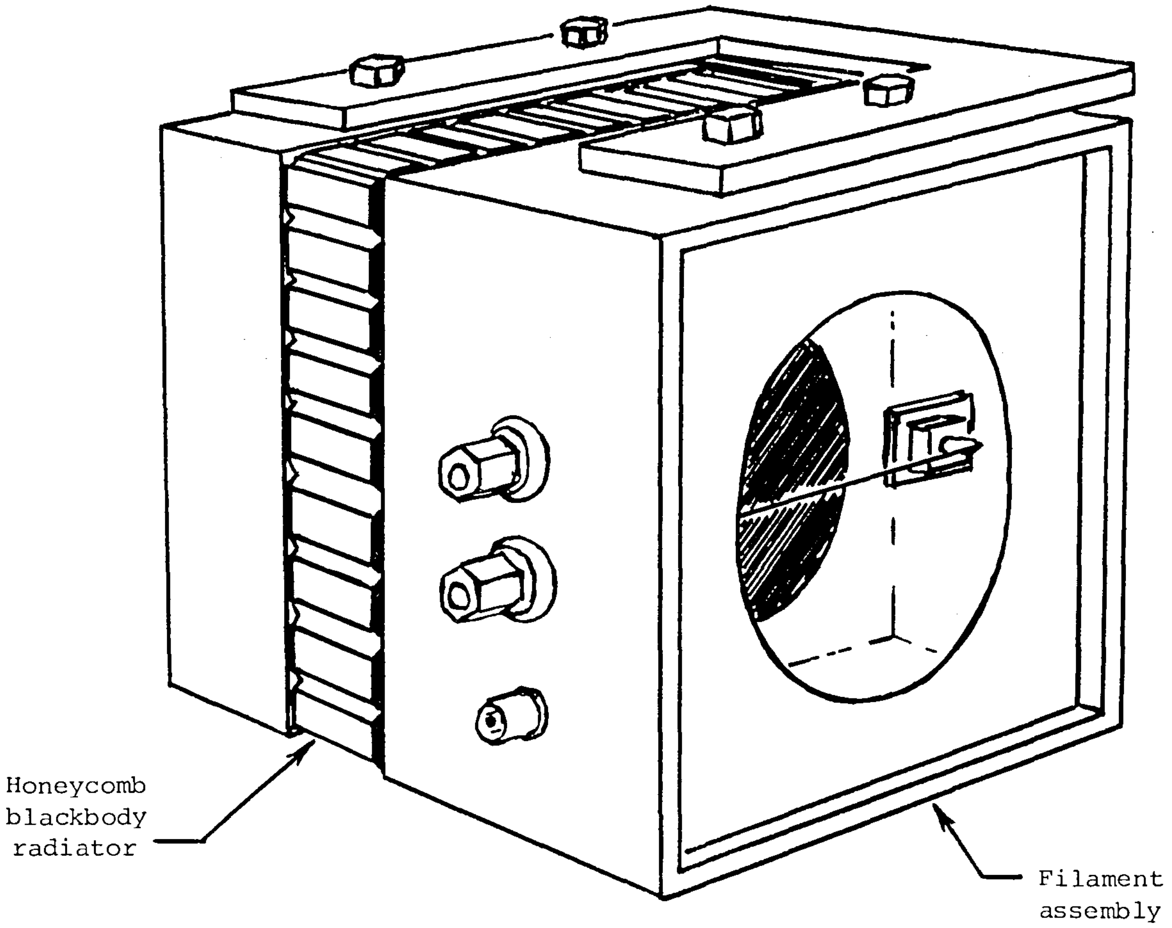

Figure 1.- Modulated infrared radiant source.

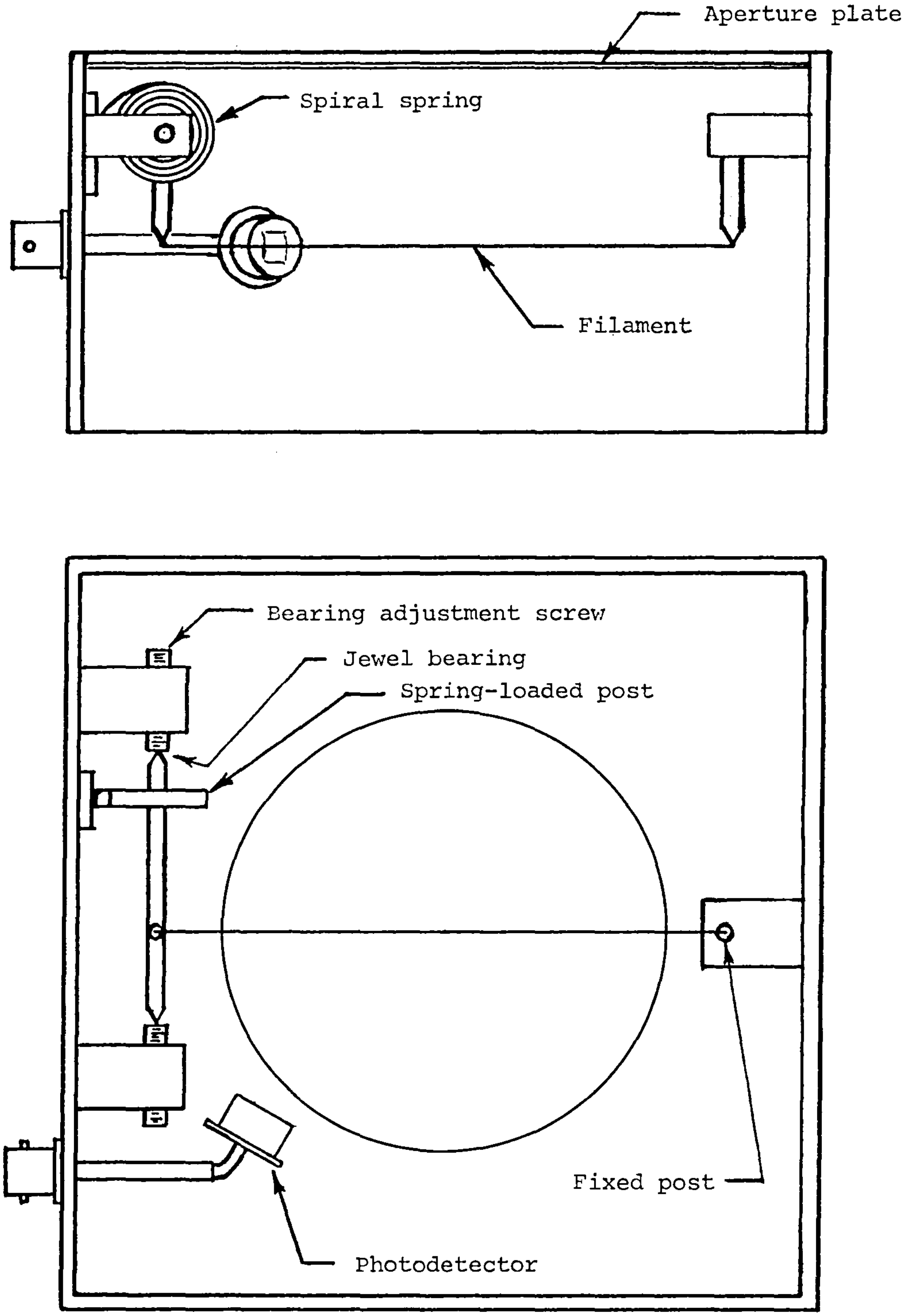

Figure 2.- Filament assembly with front aperture plate removed.

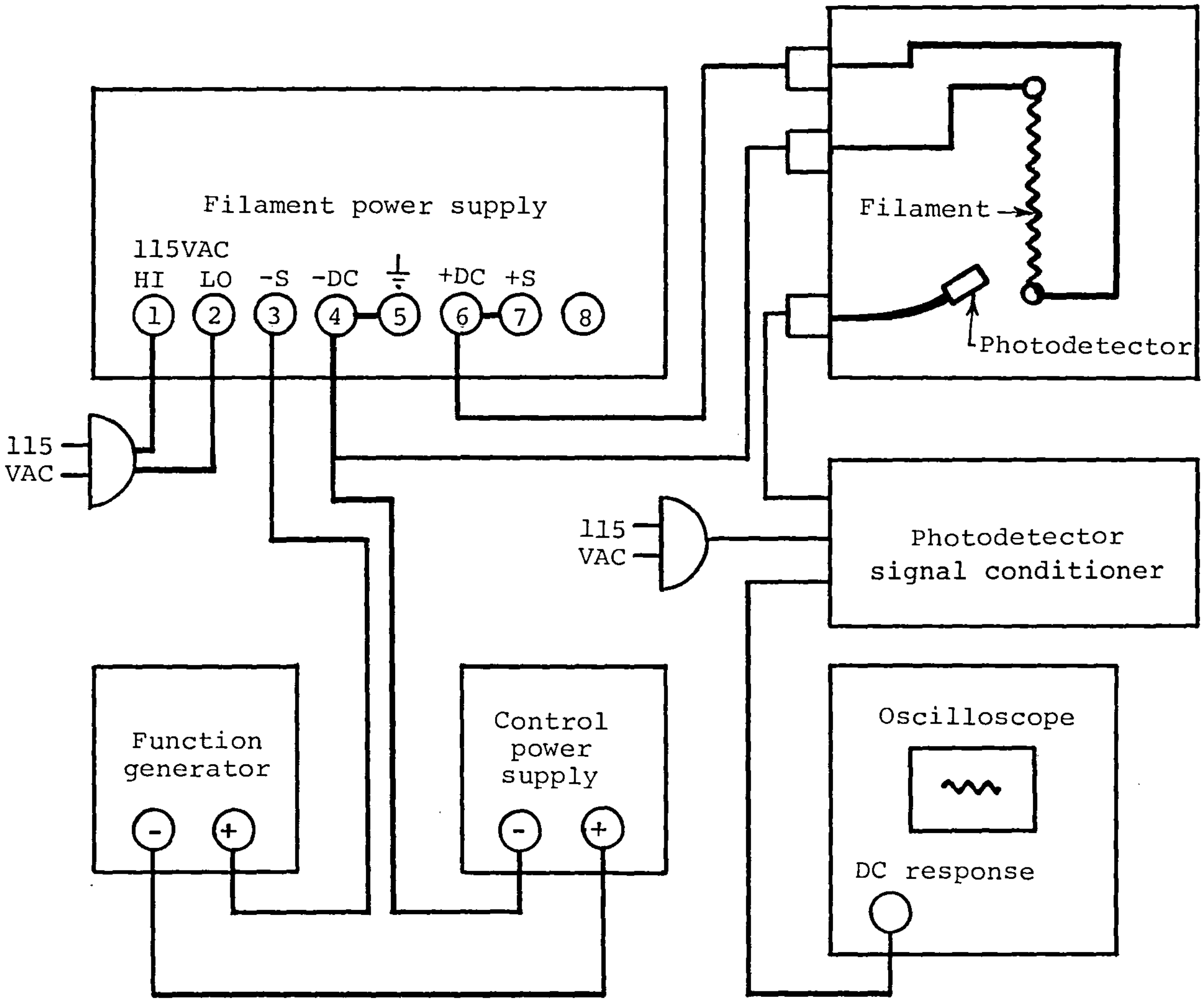

Figure 3.- Modulated infrared radiant source components with interconnecting cables.

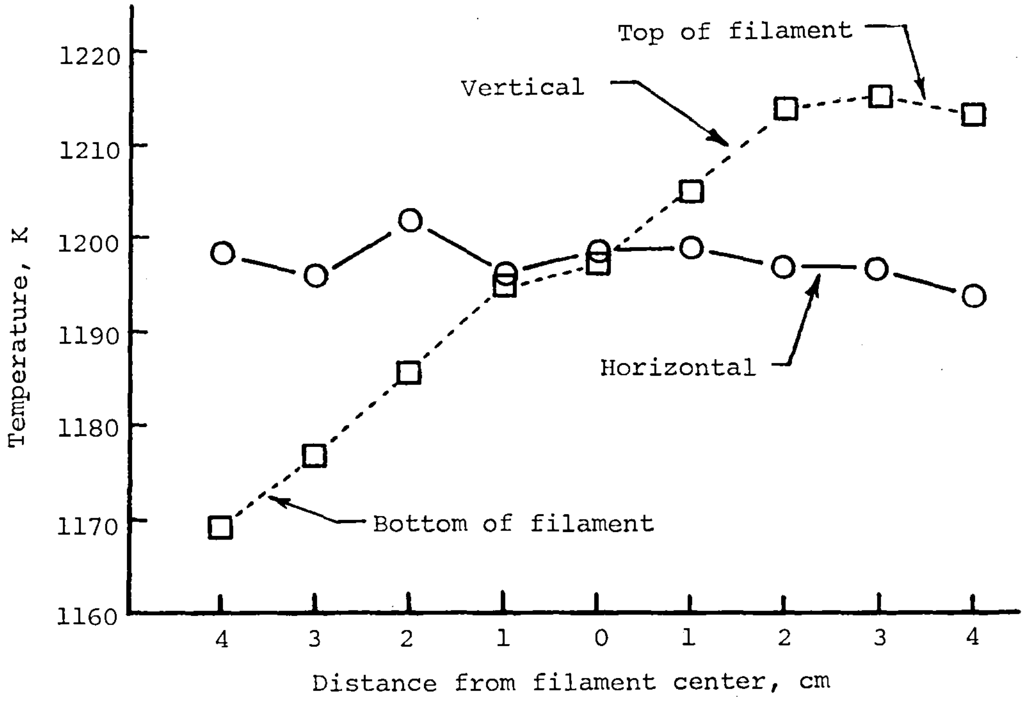

Figure 4.- Temperature distribution along length of sample filament.

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16. Abstract

A modulated, infrared radiant energy source was developed to calibrate an airborne nadir-viewing pressure modulated radiometer to be used to detect from Earth orbit trace gases in the troposphere. The technique used an 8-cm-long, 0.005-cm-diameter platinum-iridium wire as an isothermal, thin-line radiant energy source maintained at 1200 K. A ±20-K "signal," oscillating at controllable frequencies from dc to 20 Hz, was superimposed on it. This periodic variation of the line-source energy was used to verify the pressure modulated radiometer's capability to distinguish between the signal variations caused by the Earth's background surface and the signal from the atmospheric gases of interest.

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