NATIONAL BUREAU OF STANDARDS REPORT

8327

PROCEDURES FOR PRECISE DETERMINATION
OF THERMAL RADIATION PROPERTIES

PROGRESS REPORT NO. 21

November 1, 1963 - January 31, 1964

Contract No. DO (33-615) 64-1005
Task No. 738103

to

AIR FORCE MATERIALS LABORATORY
Research and Technology Division
United States Air Force
Wright-Patterson Air Force Base, Ohio

NBS

U. S. DEPARTMENT OF COMMERCE
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I. SUMMARY

Malfunctions in the correction circuits of the data-processing attachment to the normal spectral emittance equipment have been corrected. The remaining malfunctions are all concerned with the paper tape recording of the corrected emittance data.

New thermopile detectors have been received for use with the ellipsoidal mirror reflectometer. Working drawings of the laser integrating sphere reflectomer have been completed, and the parts are now being fabricated.

II. NORMAL SPECTRAL EMITTANCE EQUIPMENT

A new vacuum thermocouple detector was received. Tests indicate that it has about 2.5 times the sensitivity of the standard vacuum thermocouple previously used with the Perkin-Elmer equipment. Use of this new detector will be particularly advantageous in the 15 to 35 micron range: , where the energy is very low. There is also a possibility that it may be usable in the 0.3 to 1.0μ range.

The light-tight cover for the portion of the optical path between the chopper and combining optics has been constructed and installed.

III. DATA PROCESSING ATTACHMENT

The manufacturer of the data-processing attachment sent an engineer to the Bureau late in the last report period to correct all remaining malfunctions in the equipment. All of the malfunctions were supposedly corrected at the time of his departure. However, a short time later, series of measurements were made to test the reliability of the equipment. The measurements included recording on punched paper tape the "100% line" and "zero line" calibrations as well as the uncorrected and the corrected specimen lines. The results were then analyzed by the NBS SEAC computer.

The computer corrected the data on the basis of the recorded calibration lines, and it also compared these results to the data obtained by use of the automatic correction feature of the data-processing attachment. This comparison showed that the errors remaining after automatic correction of the data were unacceptably large in those ranges where large calibration corrections were necessary. This was believed to be due to amplifier drift, and rechecking of the static correction circuit alignment revealed that serious drift had occurred. A faulty component was located and replaced. After this replacement, drift in the correction circuits was almost completely eliminated. The data-processing attachment now consistently corrects the recorded data to an accuracy of 0.5% or better.

A second source of trouble developed during the check of the data-processing attachment, which was manifested as incorrectly punched tapes. Two kinds of faults appeared: (1) duplicate punching of some characters, and (2) extra punches in some characters.

The data are punched on eight-channel tape in words of eight characters. The data are recorded in digital notation. The first four channels are used to record the digits 1 to 9 in binary code. The fifth channel is used for the parity bit, the sixth channel for zero, the seventh is not used, and the eighth is a carriage return. Odd parity is used, and a hole is punched in the fifth channel as required to make the total number of holes in the character odd.

The first four characters in a word represent the position of the wavelength drive drum, in units of 0.001 turn. The next three characters represent the pen position in percent of full scale, in units of 0.1 percent.

The automatic data processing equipment cannot be considered to operate successfully until the malfunctions responsible for incorrect punching of the tape are corrected. Methods for doing this are being investigated. In the meantime, any errors in the tape must be corrected before it can be used for direct input to a computer. The errors must be identified before they can be corrected. Consideration is therefore being given to methods of checking the tape either during or shortly after punching. One method of checking for extra punches in the characters is to incorporate a parity checker operating directly from the levers that punch the holes. This check would generate a signal and/or mark the tape whenever an even number of holes in a character appeared. Because of the odd parity built into the recording system, there will always be an odd number of holes when a character is recorded correctly. The presence of duplicate characters will cause a word to consist of more than eight characters. A system designed to generate a signal and/or mark the tape when this occurs can also be designed. Another way to check for extra characters is to transcribe the tape with a rape-reading typewriter, and examine the typewritten output for words of more than seven characters.

IV. SPECTRAL REFLECTANCE

A. Ellipsoidal Mirror Reflectometer

The design of the ellipsoidal mirror reflectometer was described in detail in the last annual summary report. The specimen, located at the first focus of the ellipsoidal mirror, is illuminated near normal by a slightly converging beam of monochromatic radiation which passes through a small opening in the mirror. The ellipsoidal mirror collects the radiation reflected by the specimen into a solid angle of 165° (that reflected at angles greater than 82.5° from the normal is lost) and focuses it onto the detector, which is located at the second focus of the ellipsoid. The linear magnification factor of the ellipsoid is about 5.

The intensity of the incident beam is measured by moving the detector to the specimen position. The reflectance of the specimen, at any one wavelength, is taken as the ratio of the reflected energy to the incident energy, after correction for mirror losses.

A Golay cell has been used as the detector for the reflectometer. Because of the large magnification factor, a cell with a sensitive area one centimeter in diameter was used. This cell proved to be highly microphonic, particularly when it was used with the sensitive diaphragm placed horizontally, which is the normal position for use with the ellipsoidal reflectometer. Satisfactory signal-to-noise ratios have not been achieved with this detector, in spite of elaborate precautions to isolate the detector from noise and building vibrations.

During the last quarter, two newly-developed thermopiles with a viewing area of one square centimeter were procured for use with the equipment. Tests for signal-to-noise ratio and linearity in the 1 to 15 micron wavelength range indicated that they will be satisfactory for the purpose.

Preliminary tests with flowers of sulfur with one of the new detectors at 5 μ gave an uncorrected reflectance of about 50 percent, well below what has been reported by other investigators. This would indicate that mirror losses are more nearly 45% than the 5 to 10% that had been expected. There was reason to suspect that the losses were caused by aberrations of the ellipsoidal mirror, which resulted in some of the energy reflected by the specimen being focused outside the sensitive area of the detector. Photographs were taken of (1) the beam incident on the specimen, which is about 2 mm square, and (2) the beam incident on the detector. By careful adjustment of the positions of the specimen and detector relative to the mirror, it was possible to obtain an image at the detector of the illuminated spot on the specimen that fell entirely within a square one centimeter on a side. However, this careful adjustment did not significantly reduce the mirror losses.

Further investigation revealed that the detector varied significantly in sensitivity over its sensitive area. It is now believed that what appeared to be mirror losses are caused by a difference in sensitivity of the detector for the small beam (2 x 2 mm) when the detector is at the specimen position (first focus) and the larger (10 x 10 mm) beam when the detector is at the second focus when it is measuring the reflected flux.

To quantitatively establish the magnitude of the variation in sensitivity, cooperative tests with the Photometry and Colorimetry Section of NBS have been initiated. Both the Golay Cell and thermopile detectors will be examined in this investigation.

Consideration is being given to the design of a diffusing screen to be placed over the detector window. This screen will help to distribute the incident flux over the entire surface of the detector, and hence reduce the effect of the localized variations in detector sensitivity.

B. Integrating Sphere Reflectometer

The advantages of using an integrating sphere reflectometer with a continuous-wave gas laser as a source were discussed in the last Annual Summary Report (NBS Report 8174). Briefly, the method shows promise of considerably greater precision than can be achieved with direct measurements of emitted flux, particularly at short wavelengths and very high temperatures.

It appears logical for the development program to proceed in six phases, as follows: (1) Design and construction of an integrating sphere reflectometer, and evaluation of its performance at room temperature in an air atmosphere and at 0.632 and 1.15 microns. (2) Design of a specimen heater to permit reflectance measurements to be made in air at temperatures up to 1400°K. (3) Modification of the equipment to permit operation in vacuum or controlled atmosphere. (4) Extension of the operation capabilities of the equipment to 3.39 microns. (5) Extension of the measurements to additional wavelengths, particularly to longer wavelengths, by use of other lasers as sources and (6) Increase in the maximum temperature of operation to 2500°K (4000°F).

While it is contemplated that the phases enumerated above will be completed in the order listed, they will be carried on simultaneously to the extent that it is practicable to do so.

a. <u>Sphere Coatings</u>: Magnesium oxide has been used for many years for coating integrating spheres. Its high diffuse reflectance make it the preferred coating for use in the 0.3 - 2.5 micron wavelength range in spite of its extreme fragility and somewhat laborious application procedures. Information is not readily available on use of MgO coatings in vacuum. Its high surface area may make de-gassing a problem, and because of its fragility it may not stand pumping or release of vacuum without rupturing. These properties will be investigated. The reflectance of MgO coatings decreases rapidly beyond about 2.5 microns, so that in any case another coating must be developed for use at longer wavelengths.

b. <u>Reflectometer Design</u>: The preliminary design of the reflectometer is shown in figure 1. The integrating sphere is of stainless steel, 14 in. in diameter, and has been designed so that it can be operated under vacuum or positive pressure. The specimen mount accommodates a specimen disc which can be heated by induction. The detector for use at 0.632 micron is an RCA 7102 photomultiplier. The source is a helium-neon continuous-wave gas laser with accessories for operation at 0.632 and 1.15 microns. A 3/4-inch diameter detector port in the sphere wall is fitted with a flashed opal glass cover, from which a light pipe directs the light to the detector. Provision is made for filters to be inserted between the detector and sphere, to absorb energy emitted by the hot specimen. The amplifier is a Perkin-Elmer Model 107, operated in conjunction with a synchronous rectifying chopping assembly.

As of the end of the report period all of the equipment required for Phase 1 above is on hand or has been ordered. Fabrication of the sphere and related components is nearly completed.

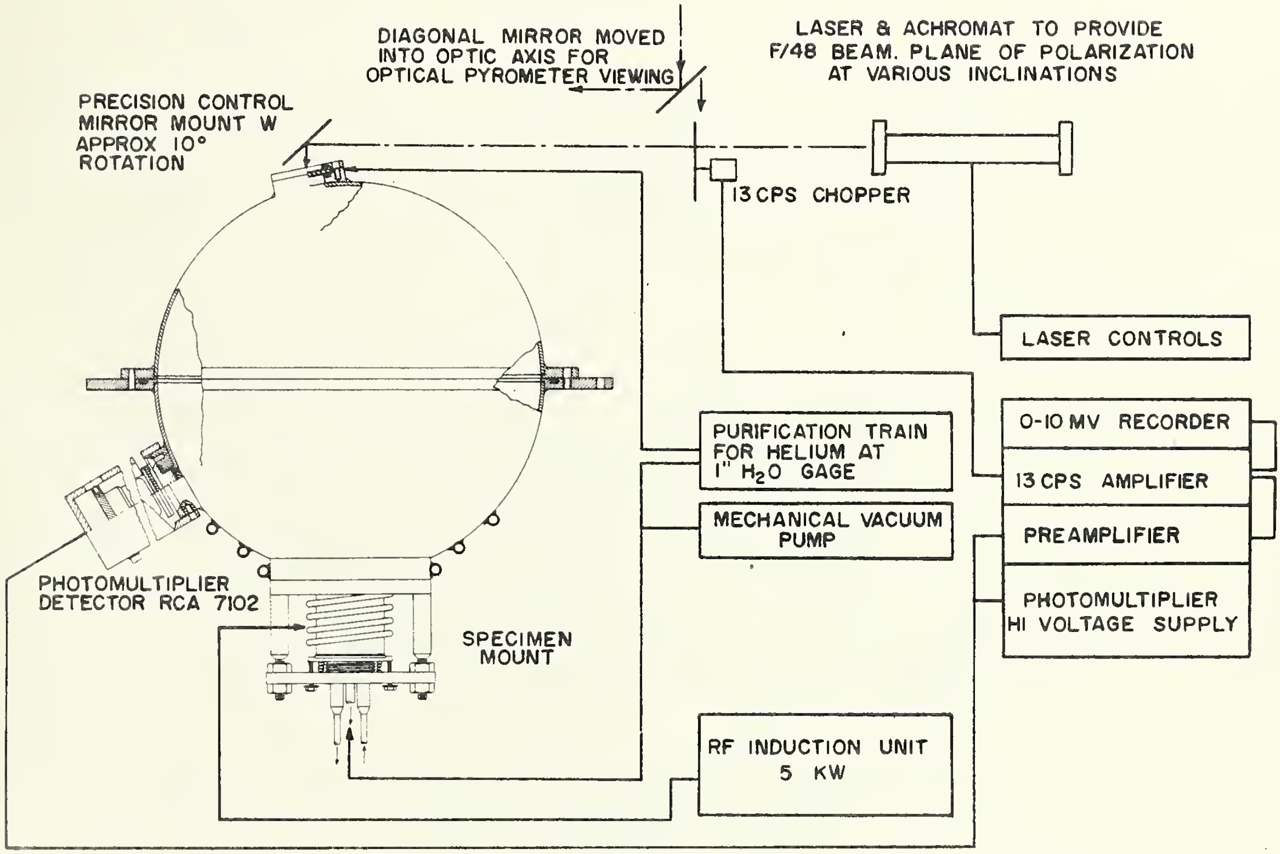

Figure 1. Drawing of integrating sphere for reflectometer, with schematic diagram of accessory equipment.

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