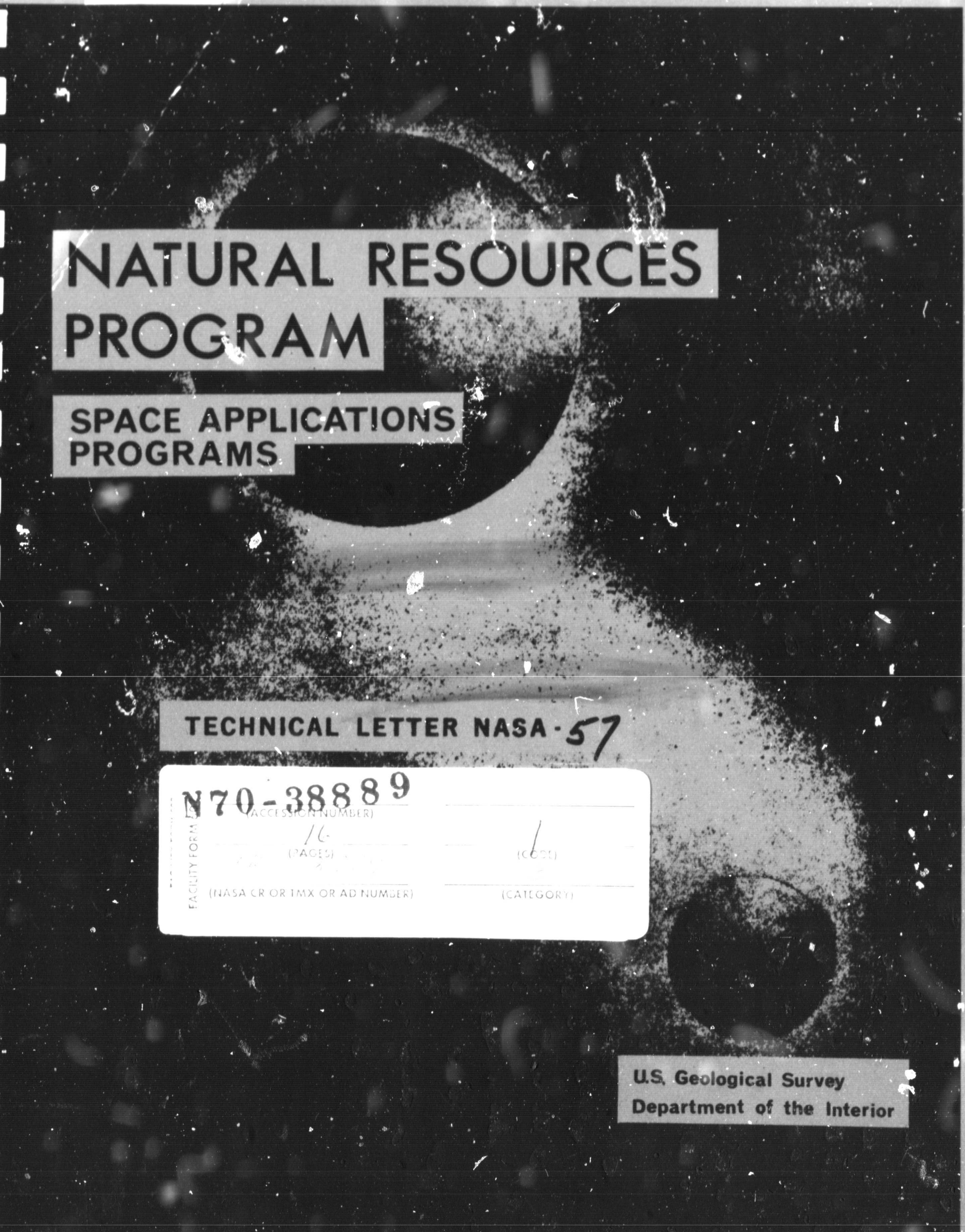

NATURAL RESOURCES PROGRAM

SPACE APPLICATIONS PROGRAMS

TECHNICAL LETTER NASA-57

U.S. Geological Survey
Department of the Interior

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WASHINGTON, D.C. 20242

Technical Letter
NASA - 57
August 1966

Dr. Peter C. Badgley
Chief, Natural Resources Program
Office of Space Science and Applications
Code SAR, NASA Headquarters
Washington, D. C. 20546

Dear Peter:

Transmitted herewith are 2 copies of:

TECHNICAL LETTER NASA-57

LIQUID NITROGEN BLACKBODY FOR

SPECTRAL EMITTANCE STUDIES*

by

D.L. Daniels and A.E. Stoddard

Sincerely yours,

William A. Fischer
Research Coordinator
Earth Orbiter Program

*Work performed under NASA Contract No. R-146-09-020-006

[redacted]

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

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by

D.L. Daniels and A.E. Stoddard

July 1966

These data are preliminary and should
not be quoted without permission

Prepared by the Geological Survey
for the National Aeronautics and
Space Administration (NASA)

Liquid nitrogen blackbody for

Spectral emittance studies

by

D.L. Daniels and A.E. Stoddard

INTRODUCTION

This letter reports preliminary considerations and experiments concerning use of a blackbody maintained at liquid nitrogen temperature in the study of spectral emittance of rocks in situ or in the laboratory. Providing that the sample studied and a reference blackbody assume the same arbitrary temperature, the method provides a rather simple, absolute determination of spectral emissivity utilizing the Block interferometer type spectrometer.

THEORY

Radiation incident upon the bolometer detector of the Block Interferometer consists of two parts, each varying at an audio frequency ω proportional to the wavenumber ν of the radiation. The first part arises from radiation entering the instrument from outside, and is given by:

$$I_\nu = H_\nu I_\nu^i \ (1+\cos\omega t)$$

I_ν^i is the intensity of radiation incident upon the instrument at the wavenumber ν and I_ν is the transmitted intensity incident upon the bolometer. H_ν is the so-called "modulation efficiency," a proportionality constant. The second part arises from radiation from the bolometer detector which is "reflected" back onto itself by the interferometer. At the same wavenumber the intensity of this radiation is shifted in phase by 180° with respect to the "transmitted" radiation, and is given by:

$$I_\nu = H_\nu I_\nu^d \ (1-\cos\omega t)$$

The bolometer responds to the sum,

$$H_\nu \ (I_\nu^i + I_\nu^d) + H_\nu \ (I_\nu^i - I_\nu^d) \ \cos\omega t$$

of these incident intensities.

The output of the Block Interferometer is proportional to the amplitude of the second, or audio frequency term in the radiation intensity incident upon the bolometer. Denoting this output by A_ν, the amplitude of the chart recorder trace at wavenumber ν, then

$$A_\nu = R_\nu |I^i_\nu - I^d_\nu|$$

Where R_ν, the "responsivity," is a proportionality constant consisting of H_ν and the gain settings of the interferometer.

Three measurements of A_ν are required to determine emissivity. First, the incident intensity with the instrument directed at the rock surface is given by:

$$I^r_\nu + (1-\varepsilon_\nu)\, I^s_\nu$$

where I^r_ν is the thermal emission of the rock, ε_ν its emissivity and I^s_ν the radiation from the sky reflected by the rock into the instrument. Normally $I^s_\nu \sim 0.1\ I^r_\nu$ in the 8-14μ band and $\varepsilon_\nu \sim 0.8$ so that the second term is $\sim 0.02\ I^r_\nu$ and may be neglected. Under these conditions this measurement yields

$$A^r_\nu = R_\nu |I^r_\nu - I^d_\nu|$$

Second, the incident intensity with the instrument directed at a reference blackbody at the temperature of the rock is I^{bb}_ν, giving a recorder output of

$$A^{bb}_\nu = R_\nu |I^{bb}_\nu - I^d_\nu|$$

Third, the incident intensity with the instrument directed at a cold blackbody at liquid nitrogen temperature is essentially zero. The recorder output amplitude with this blackbody filling the field of view is thus,

$$A^n_\nu = R_\nu I^d_\nu$$

Generally the detector will be at a common temperature with the reference blackbody and rock surface. Then $I_\nu^{bb} \gtrsim I_\nu^d \gtrsim I_\nu^r$, so that:

$$A_\nu^r = R_\nu(I_\nu^d - I_\nu^r)$$

$$A_\nu^{bb} = R_\nu(I_\nu^{bb} - I_\nu^d)$$

$$A_\nu^n = R_\nu I_\nu^d$$

Eliminating I_ν^d and R_ν, and rearranging,

$$\frac{I_\nu^r}{I_\nu^{bb}} \equiv \varepsilon_\nu = \frac{A_\nu^n - A_\nu^r}{A_\nu^n + A_\nu^{bb}}$$

It is observed, under these conditions, that A_ν^{bb} is very nearly zero due to the near cancellation of I_ν^{bb} and I_ν^d. To this approximation only two measurements are required and:

$$\varepsilon_\nu \cong 1 - \frac{A_\nu^r}{A_\nu^n}$$

The liquid nitrogen blackbody

The liquid nitrogen temperature blackbody was constructed by spraying 3M Velvet Coating black paint over the interior of a 2 3/4" I.D. by 9 1/4" overall height, one pint pyrex dewar. This paint is quite resistant to thermal shock, whereas Parson's Black flakes at low temperature. Other paints may be found which are superior. The dewar was filled with liquid nitrogen to within a half inch of the top and viewed directly by the interferometer at a distance of approximately two inches. In this configuration a thin, broken water cloud wavers over the liquid surface. This cloud could be eliminated by proper design, but it was observed not to reflect infrared from a hot soldering iron into the interferometer.

The recorder amplitude when the instrument views this blackbody should depend only upon the detector temperature, and should increase as the detector temperature is increased. Runs with the detector at 29, 34, 40, 45 and 50°C showed this effect. Figure 1 show the ratio of the recorder amplitudes with the detector at elevated temperatures to the amplitude at 29°C for selected wavelengths. The increase is greater than the corresponding ratios of the intensity of detector emission at these temperatures as calculated from the Planck formula. It had been anticipated that amplitude ratios smaller than corresponding emission ratios would measure the reflection of room radiation by the cold blackbody. The reverse behavior is apparently due to an increase in responsivity of the detector with temperature. The necessary increase in responsivity is also shown in figure 1 and is, as yet, unexplained.

Results

Two polished samples, a microcline feldspar single crystal (260) and quartz monzonite (316), and a Parson's Black coated aluminum block were placed in the shade on the roof of the building. The sample and detector were so oriented that any reflected radiation reaching the detector was from the clear sky. The interferometer output for these sources and the cold blackbody are shown in figure 2. The data was reduced according to the expression

$$\varepsilon_\nu \approx 1 - \frac{A^r_\nu}{A^n_\nu}$$

with the results shown in figure 3. The emissivity curves for these samples compare favorably with those determined by the laboratory procedure given by Daniels (1966).

Reference

Daniels, D.L., 1966, Infrared spectral emittance of rocks from the Pisgah Crater and Mono Craters areas, California: U.S. Geological Survey Technical Letter NASA-13. (in preparation)

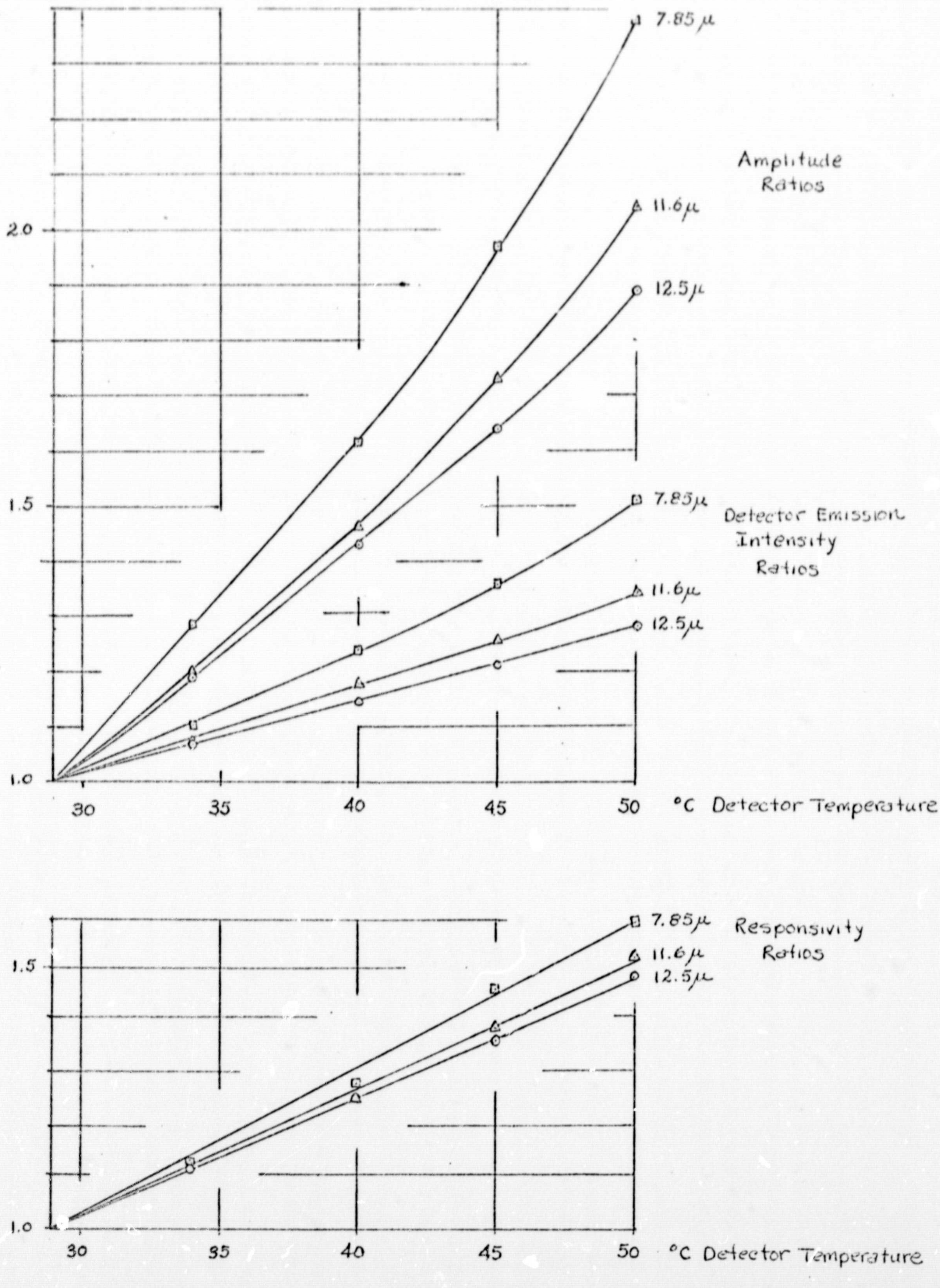
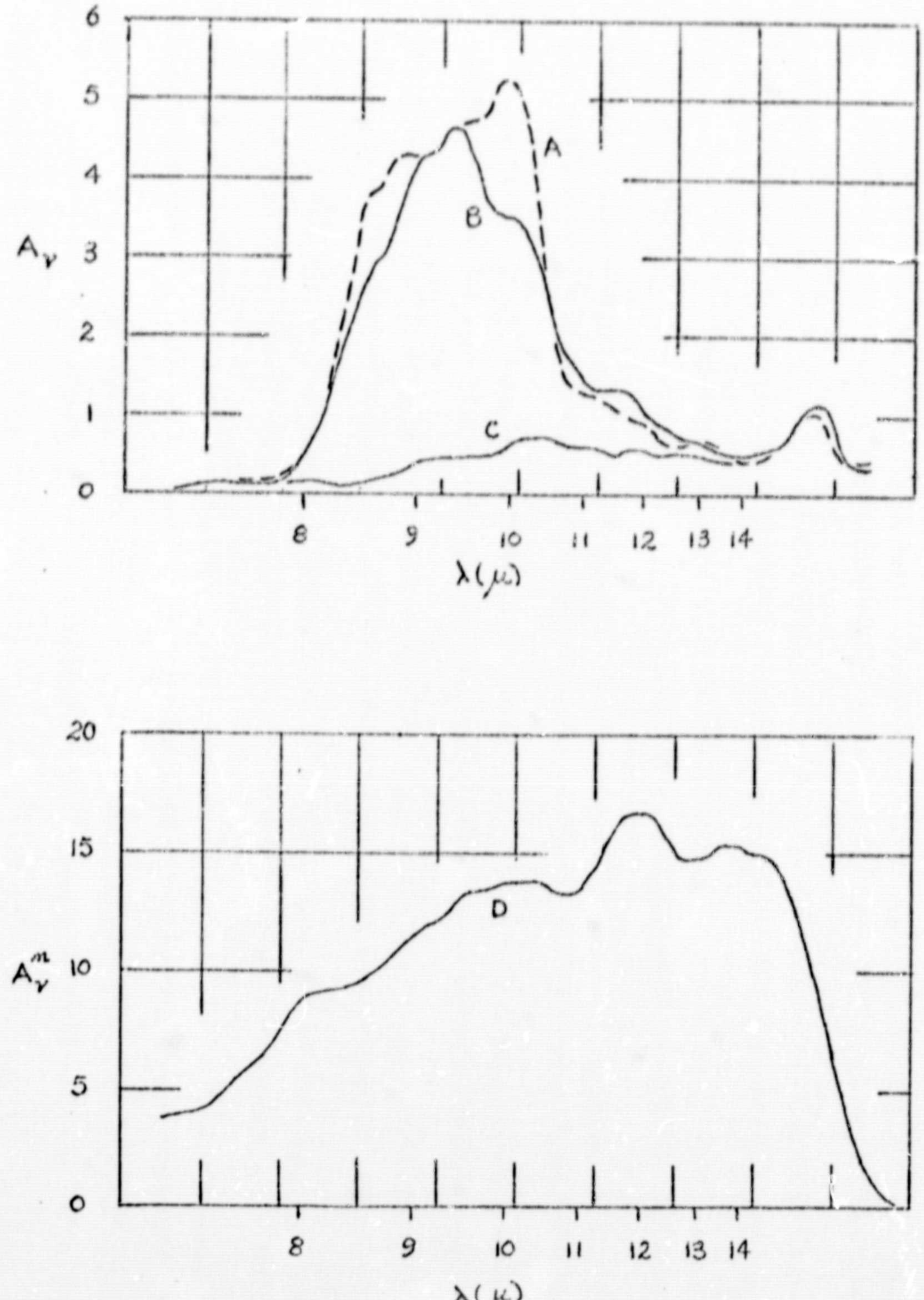

7.85 μ
Amplitude Ratios
11.6 μ
12.5 μ
2.0
1.5
7.85 μ
Detector Emission Intensity Ratios
11.6 μ
12.5 μ
1.0
30
35
40
45
50
°C Detector Temperature
7.85 μ
Responsivity Ratios
11.6 μ
12.5 μ
1.5
1.0
30
35
40
45
50
°C Detector Temperature

Figure 1



A - sample no. 260
B - sample no. 316
C - reference black body
D - cold black body (scale change)

Figure 2.

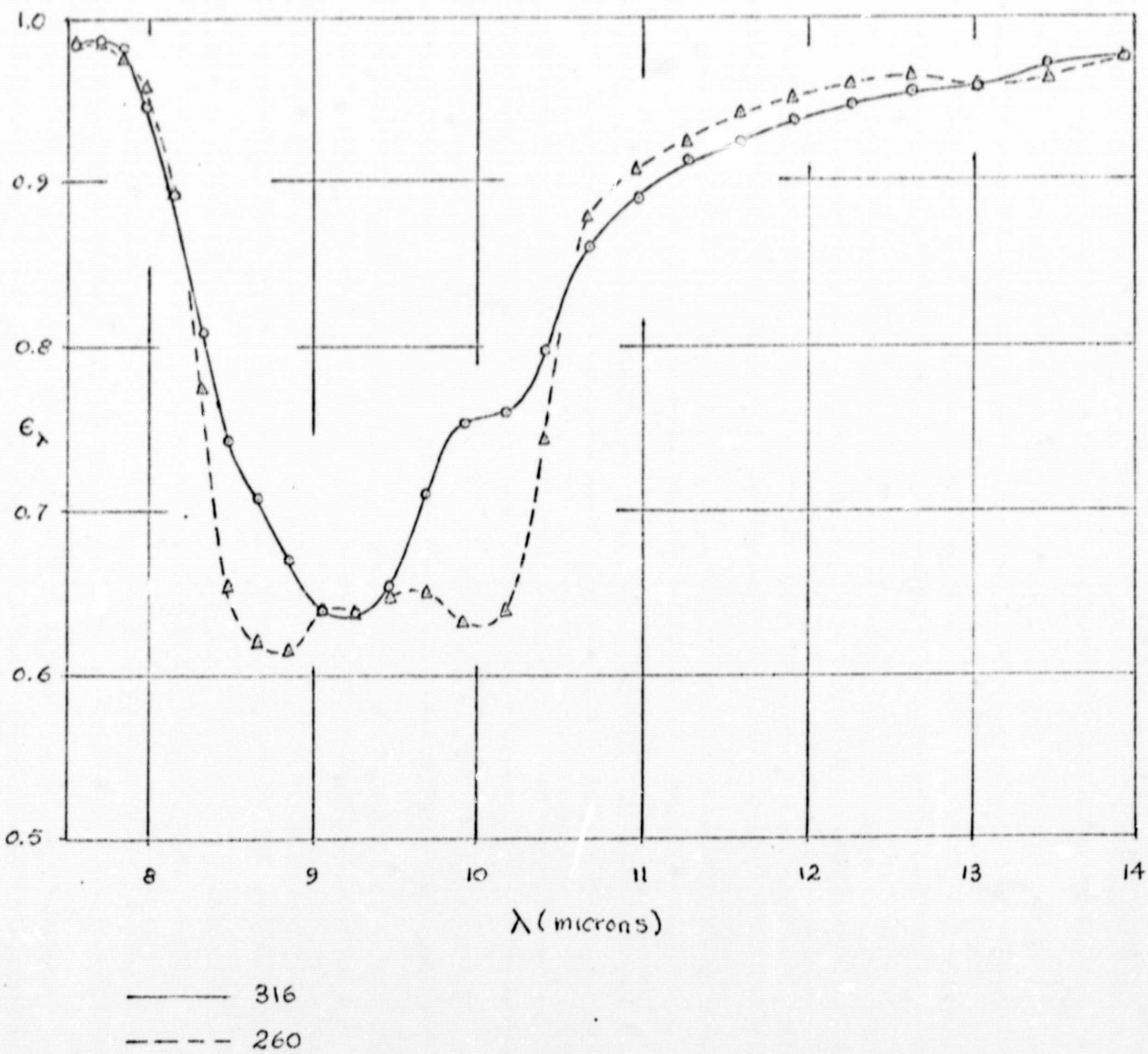

1.0
0.9
0.8
0.7
0.6
0.5
ϵ_λ
8
9
10
11
12
13
14
λ (microns)
316
260

Figure 3.