LARS Information Note 022268
Purdue University

ABSOLUTE SCENE RADIANCE SPECTRA IN THE 4 TO 16 MICRON REGION

The purpose of this information note is to describe the gathering of absolute scene radiance spectra in the 4 to 16 micron region with the Block 195 T interferometer spectrometer.

First, the optical head of the spectrometer system views a conical black body and the resulting interferograms are recorded on the Ampex SP-300 tape recorder in the LARS field van. Over 60 interferograms are recorded and later averaged for noise reduction. The black body is a LARS production of a Texas Instruments design; the black body temperature is usually run at 45°C, sufficiently higher than the instrument bolometer detector temperature for a good signal but not vastly different from the ambient scene temperature. When the averaged interferogram of Fig. 1 is Fourier-transformed the resulting response R_λ of Fig. 2 is related to the black body radiance $N_{\lambda BB}$ and the instrument bolometer radiance $N_{\lambda IB}$ by

$$R_\lambda = K_\lambda (N_{\lambda BB} - N_{\lambda IB})$$

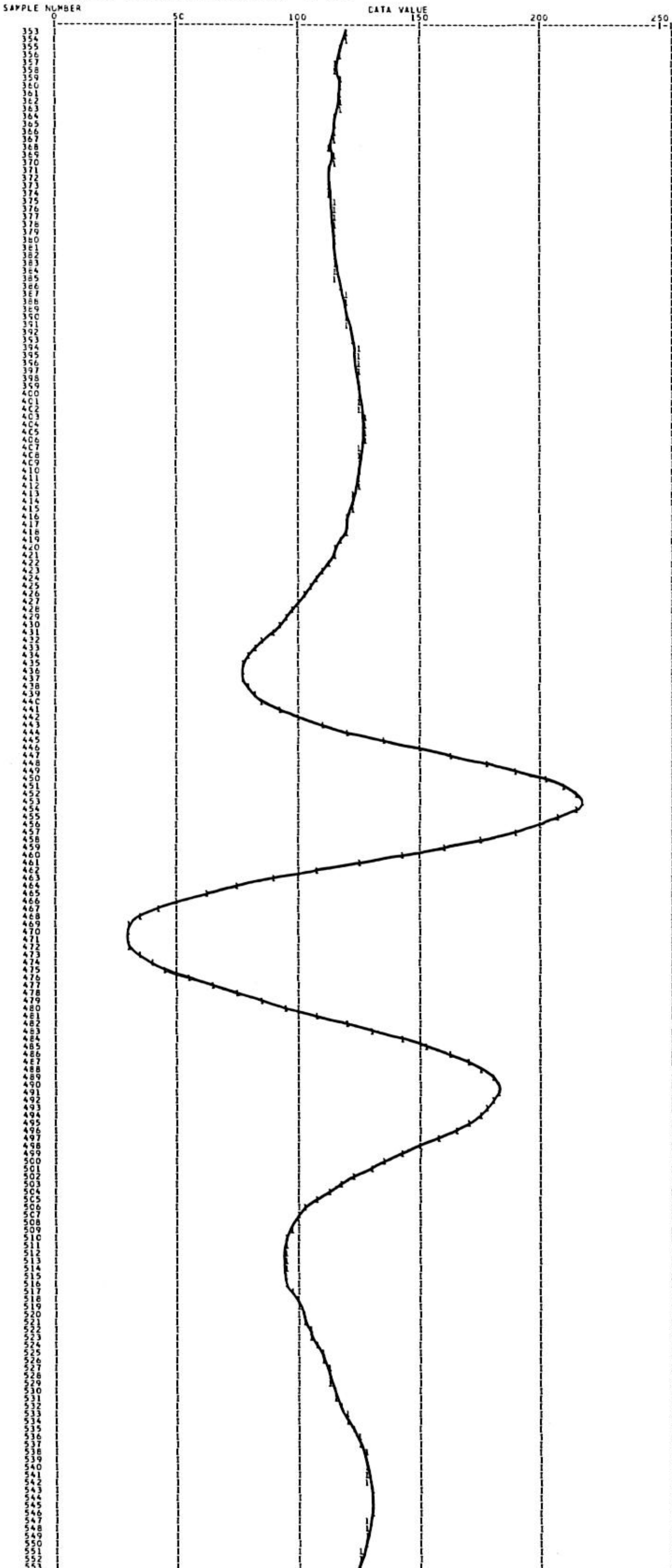
Since $N_{\lambda BB}$ and $N_{\lambda IB}$ are known from black body and instrument bolometer temperature readings, while R_λ is measured, it follows that

$$\frac{1}{K_\lambda} = \frac{N_{\lambda BB} - N_{\lambda IB}}{R_\lambda} \qquad \frac{\dfrac{\text{watts}}{\text{cm}^2\text{-steradian-}\mu}}{\text{volt}}$$

can be calculated. This is shown in Fig. 3 for the limited wavelength range of 6 to 16 microns, though the function is calculated from 2 to 22 microns for the use to be described shortly.

Next, the optical head of the spectrometer system views the desired scene targets, with the tape recorder gain on the signal channel identical to the value used to record the black body interferograms. Throughout the

GRAPH OF INTERFEROGRAM AVERAGED OVER 75 SCANS

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FOURIER TRANSFORM PROG. ENTERED.
CA210I PROGRAM INTERRUPT( ) OLD PSW IS    FF05000DA2008078
OA210I PROGRAM INTERRUPT( ) OLD PSW IS    FF05000DA200996A
CA210I PROGRAM INTERRUPT( ) OLD PSW IS    FF05000DA2009976
PROG. CHK. ERRORS DUE TO UNDERFLOW CONDITION CAUSED BY SMALL VALUES OF DATA.
THIS CONDITION IS ACCEPTABLE.
TRANSFORM COMPLT.
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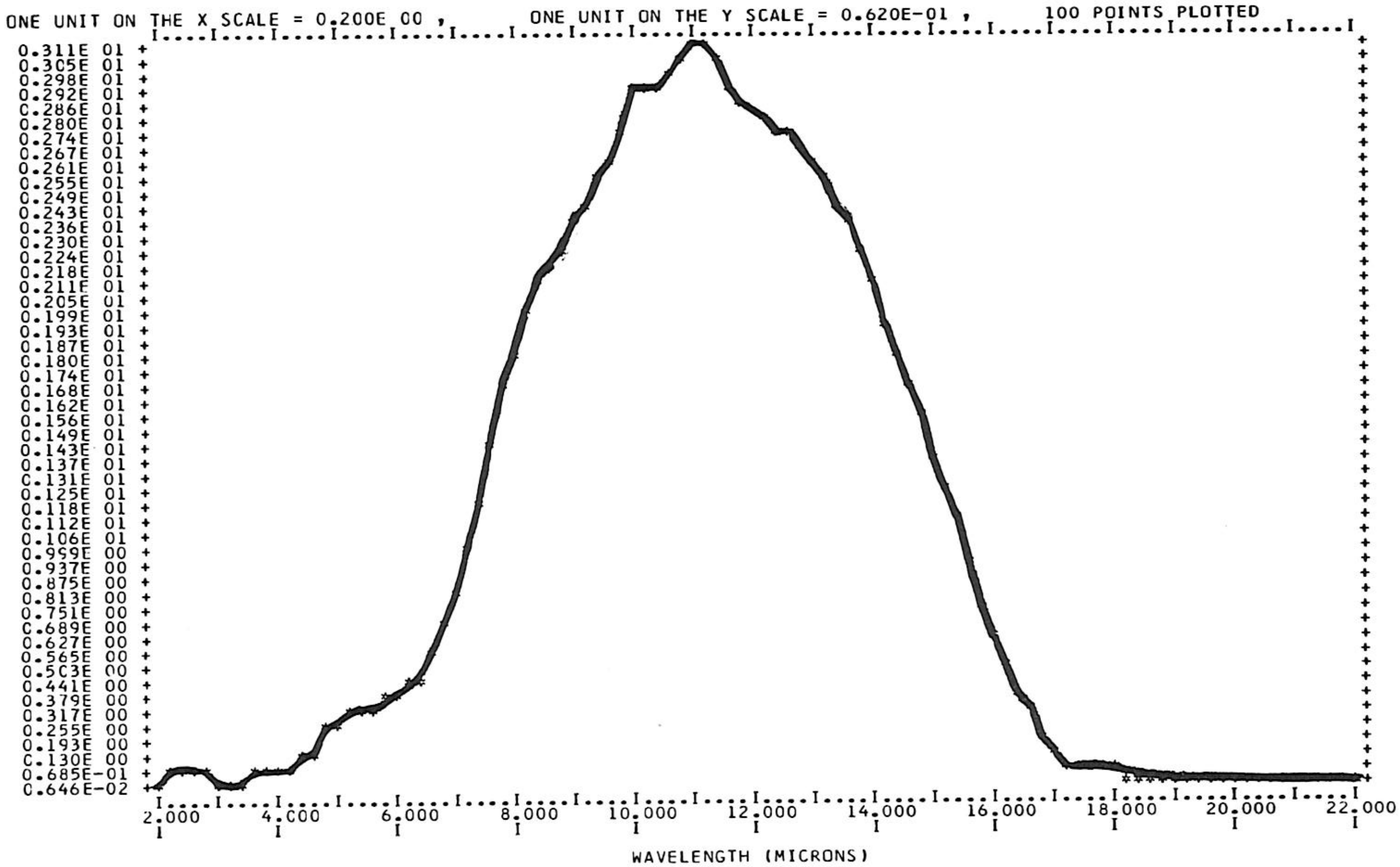
FIG. 1 A 75-SCAN AVERAGE INTERFEROGRAM FROM A 43.3°C BLACK BODY.

FOURIER TRANSFORM OF INTERFEROMETER DATA
WAVELENGTH PLOT



RUN NUMBER = 1013168006 SOURCE INSTRUMENT - 195T

DATA SOURCE - BLACKBODY SOURCE NO 1 -- TEMP = 43.3C -- DETECTOR TEMP = 21.0C

DATE OF RUN - 1/31/68 WAVELENGTH BAND - 2.00 TO 16.00 MICRONS

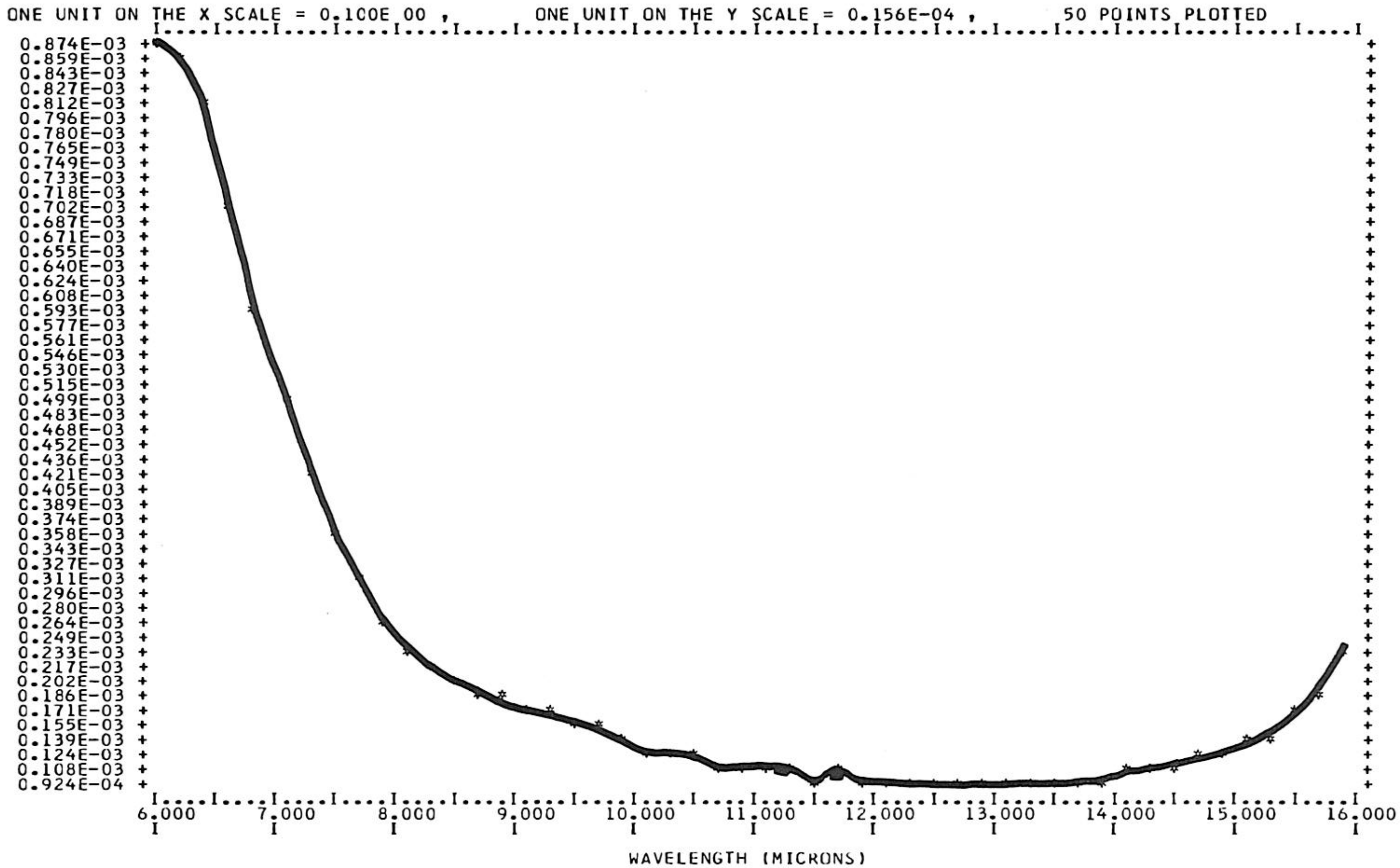
SWEEP TIME SETTING = 1.100 SEC. SWEEP LENGTH SETTING = 542.00 MICRONS

NUMBER OF SAMPLES TRANSFORMED = 1024 DATA AVERAGED OVER 75 SCANS

MEAN SQUARE VALUE OF DATA = 228.421 MEAN SQUARE VALUE OF TRANSFORM = 228.424

FIG. 2 THE FOURIER TRANSFORM OF FIG. 1, THE RAW INSTRUMENT RESPONSE R_λ.

INSTRUMENT TRANSFER FUNCTION FOR THE 195T INTERFEROMETER
WAVELENGTH BAND - 6.00 TO 16.00 MICRONS



TRANSFER FUNCTION COMPUTED FROM RUN NUMBER 1013168006 DATED 1/31/68

DATA SOURCE - BLACKBODY SOURCE NO 1 -- TEMP = 43.3C -- DETECTOR TEMP = 21.0C

SOURCE TEMPERATURE = 43.3C (316.4K) INSTRUMENT TEMPERATURE = 21.0C (294.1K)

SWEEP TIME SETTING = 1.100 SEC. SWEEP LENGTH SETTING = 542.00 MICRONS

NUMBER OF SAMPLES TRANSFORMED = 1024 DATA AVERAGED OVER 75 SCANS

MEAN SQUARE VALUE OF DATA = 228.421 MEAN SQUARE VALUE OF TRANSFORM = 228.424

FIG. 3 THE INSTRUMENT TRANSFER FUNCTION DETERMINED FROM FIG. 2 AND $N_{\lambda BB} - N_{\lambda IB}$.

entire playback and A/D conversion process the black body interferogram and scene interferograms go through identical or calibrated ratio gain systems. Thus, the outcome of the Fourier transformation is a set of scene responses, $R_{\lambda\ scene}$, which are related to scene radiances by

$$R_{\lambda\ scene} = K_{\lambda}(N_{\lambda\ scene} - N_{\lambda IB})$$

Thus, if $R_{\lambda\ scene}$ is multiplied by $1/K_{\lambda}$, the result is a curve of $(N_{\lambda\ scene} - N_{\lambda IB})$ in watts/cm^2-steradian-μ. The R_{λ} curve for wet grass is shown in Fig. 4. The net spectral radiance referenced to the instrument bolometer radiance, $(N_{\lambda\ scene} - N_{\lambda IB})$, is shown in Fig. 5.

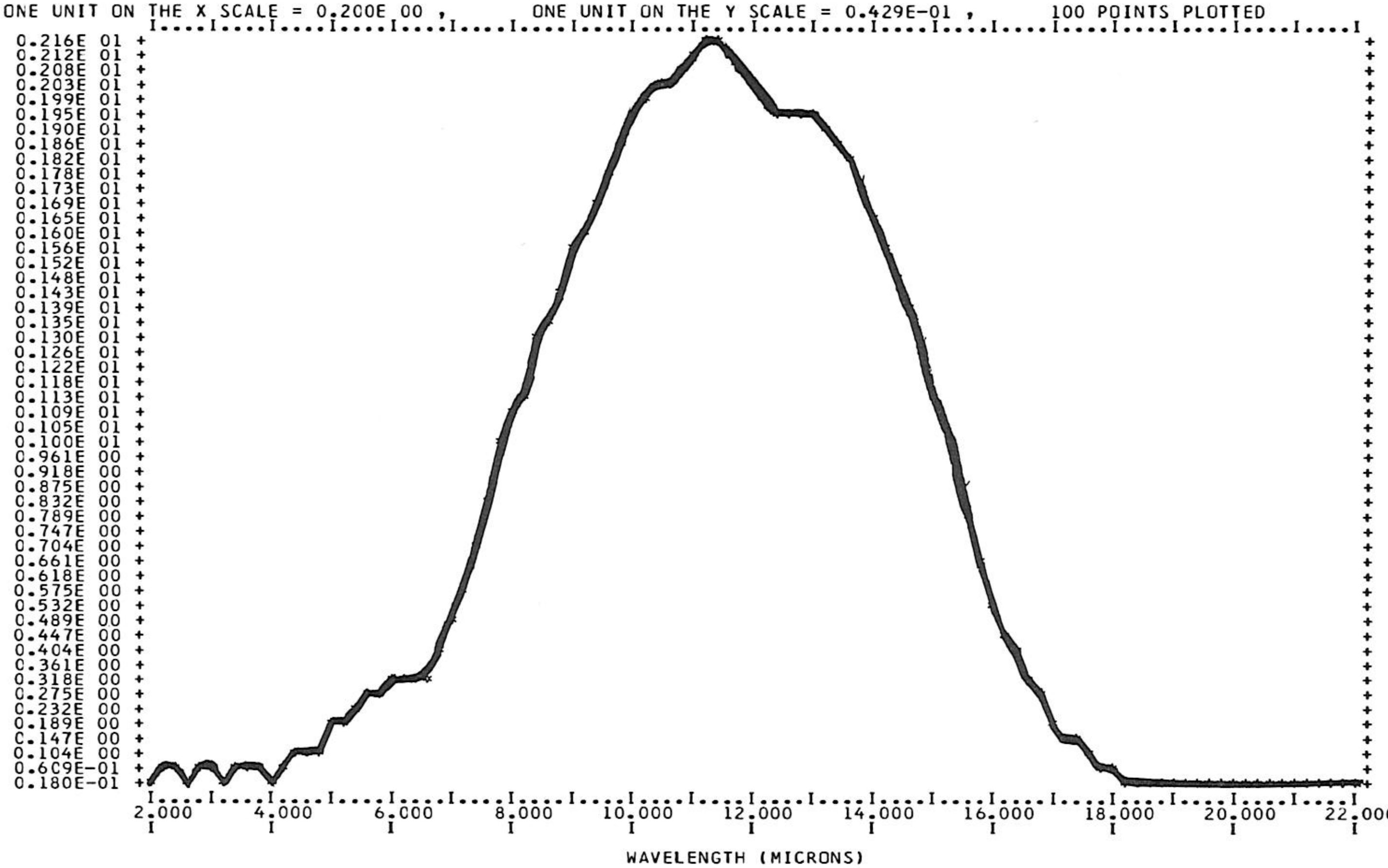
Finally, knowledge of the instrument bolometer temperature is sufficient to calculate $N_{\lambda IB}$, providing the bolometer has unity emissivity. Assuming that $\epsilon_{IB} = 1$ for the moment, the curve $N_{\lambda\ scene} - N_{\lambda IB}$ is added to a curve of $N_{\lambda IB}$, yielding $N_{\lambda\ scene}$.

Figures 6 through 9 show the absolute radiance, $N_{\lambda\ scene}$, for four scenes. The background set of curves are radiance spectra that would be obtained for black bodies at the indicated temperatures. It is clear that the four scenes shown have a nearly black or gray body character on the whole. The day was very damp with intermittent showers and heavy overcast. At approximately the time at which these data were taken the air temperature was between 3° and 3.5°C. If the instrument bolometer emissivity is slightly lower than 1, these radiance curves would be shifted downward.

Figure 10 shows a radiance spectrum for a packed sandy gravel road. A Barnes PRT-4 radiometer measurement was made at the same time, the value being 105°F or 40.6°C. Optical phonon absorption typical of silicates occurs between 8 and about 9.5 microns, while water absorption is apparent from about 5.5 to about 7.5 microns. Carbon dioxide absorption appears at about 14.5 microns. The instrument-to-scene distance was about 10 meters for

FOURIER TRANSFORM OF INTERFEROMETER DATA
WAVELENGTH PLOT

ONE UNIT ON THE X SCALE = 0.200E 00 ,   ONE UNIT ON THE Y SCALE = 0.429E-01 ,   100 POINTS PLOTTED



RUN NUMBER = 1013168002

SOURCE INSTRUMENT - 195T

DATA SOURCE - WET GRASS -- IT = 22.0C

DATE OF RUN - 1/31/68

WAVELENGTH BAND - 2.00 TO 16.00 MICRONS

SWEEP TIME SETTING = 1.100 SEC.

SWEEP LENGTH SETTING = 542.00 MICRONS

NUMBER OF SAMPLES TRANSFORMED = 1024

DATA AVERAGED OVER 65 SCANS

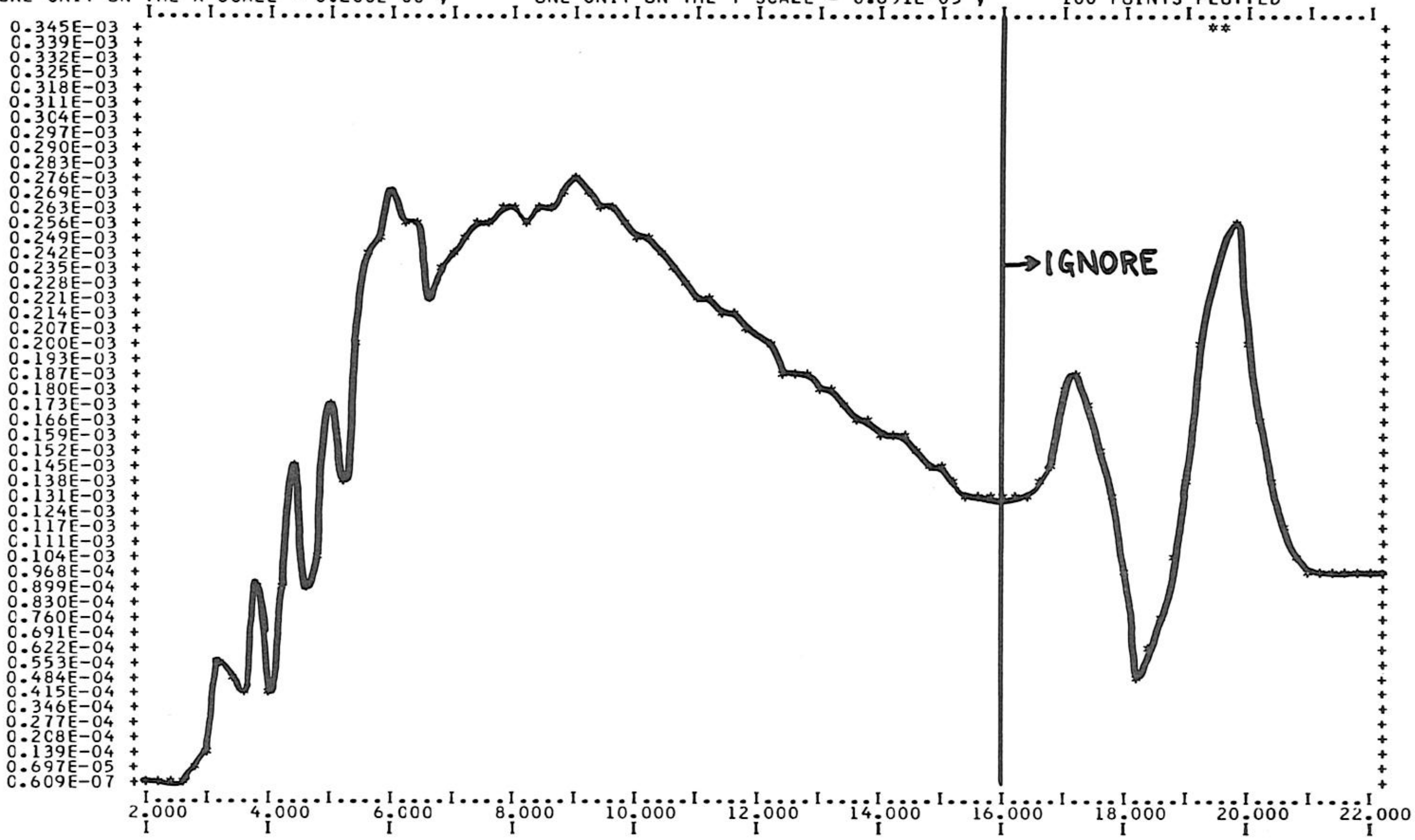
MEAN SQUARE VALUE OF DATA = 109.034

MEAN SQUARE VALUE OF TRANSFORM = 109.043

FIG. 4 RAW INSTRUMENT RESPONSE FOR A WET GRASS SCENE.

RELATIVE SPECTRAL RESPONSE CURVE
WAVELENGTH PLOT

ONE UNIT ON THE X SCALE = 0.200E 00 ,   ONE UNIT ON THE Y SCALE = 0.691E-05 ,   100 POINTS PLOTTED



RUN NUMBER = 1013168002   SOURCE INSTRUMENT - 195T

DATA SOURCE - WET GRASS -- IT = 22.0C

DATE OF RUN - 1/31/68   WAVELENGTH BAND - 2.00 TO 16.00 MICRONS

SWEEP TIME SETTING = 1.100 SEC.   SWEEP LENGTH SETTING = 542.00 MICRONS

NUMBER OF SAMPLES TRANSFORMED = 1024   DATA AVERAGED OVER 65 SCANS

MEAN SQUARE VALUE OF DATA = 109.034   MEAN SQUARE VALUE OF TRANSFORM = 109.043

SPECTRAL RESPONSE CURVE COMPUTED FROM INSTRUMENT TRANSFER FUNCTION - 1013168006

FIG. 5 NET RADIANCE SPECTRUM FOR WET GRASS. THE GRAPH IS MEANINGLESS BEYOND 17 MICRONS DUE TO OPTICAL COMPONENT ABSORPTION.

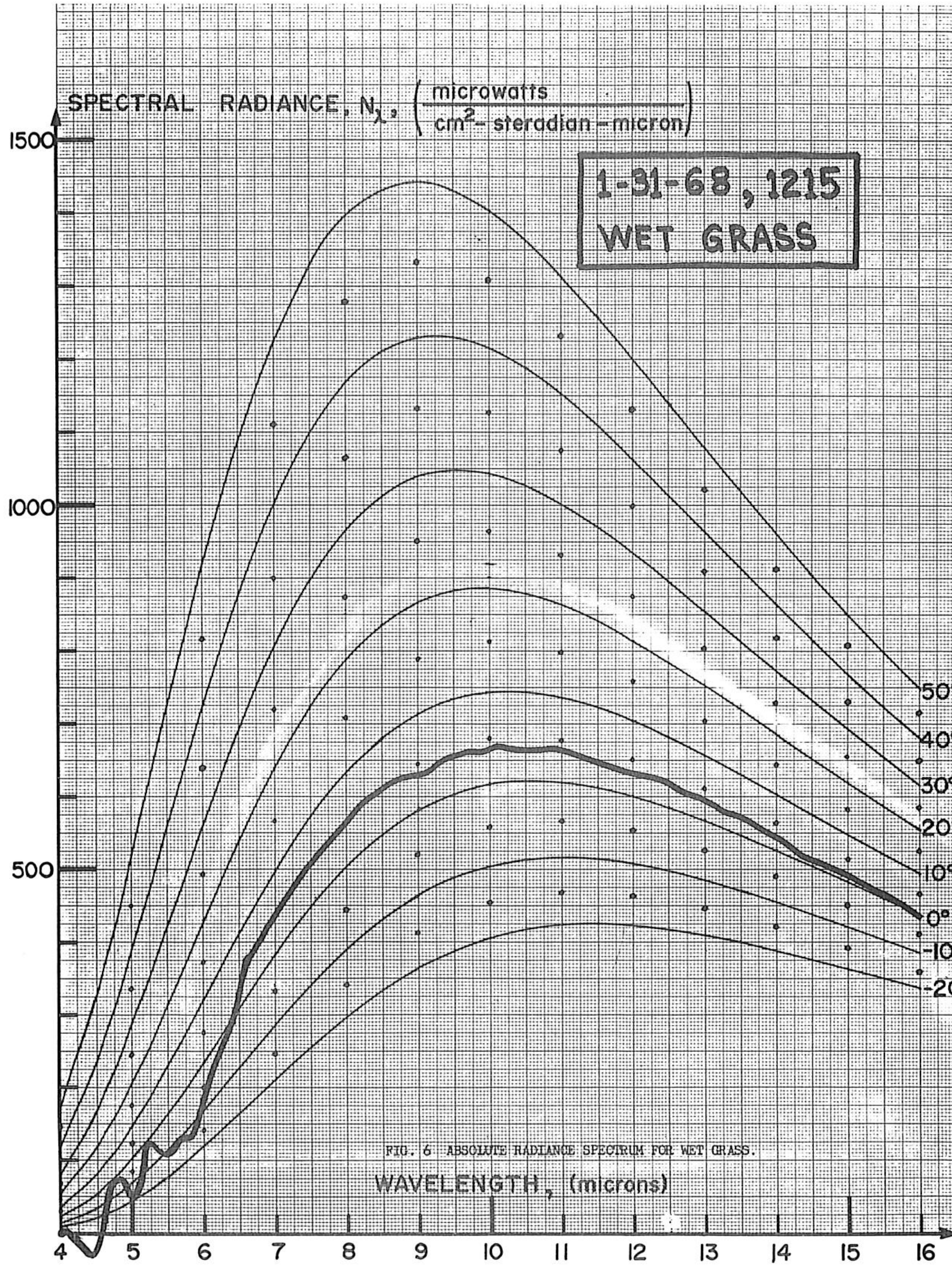


FIG. 6 ABSOLUTE RADIANCE SPECTRUM FOR WET GRASS.

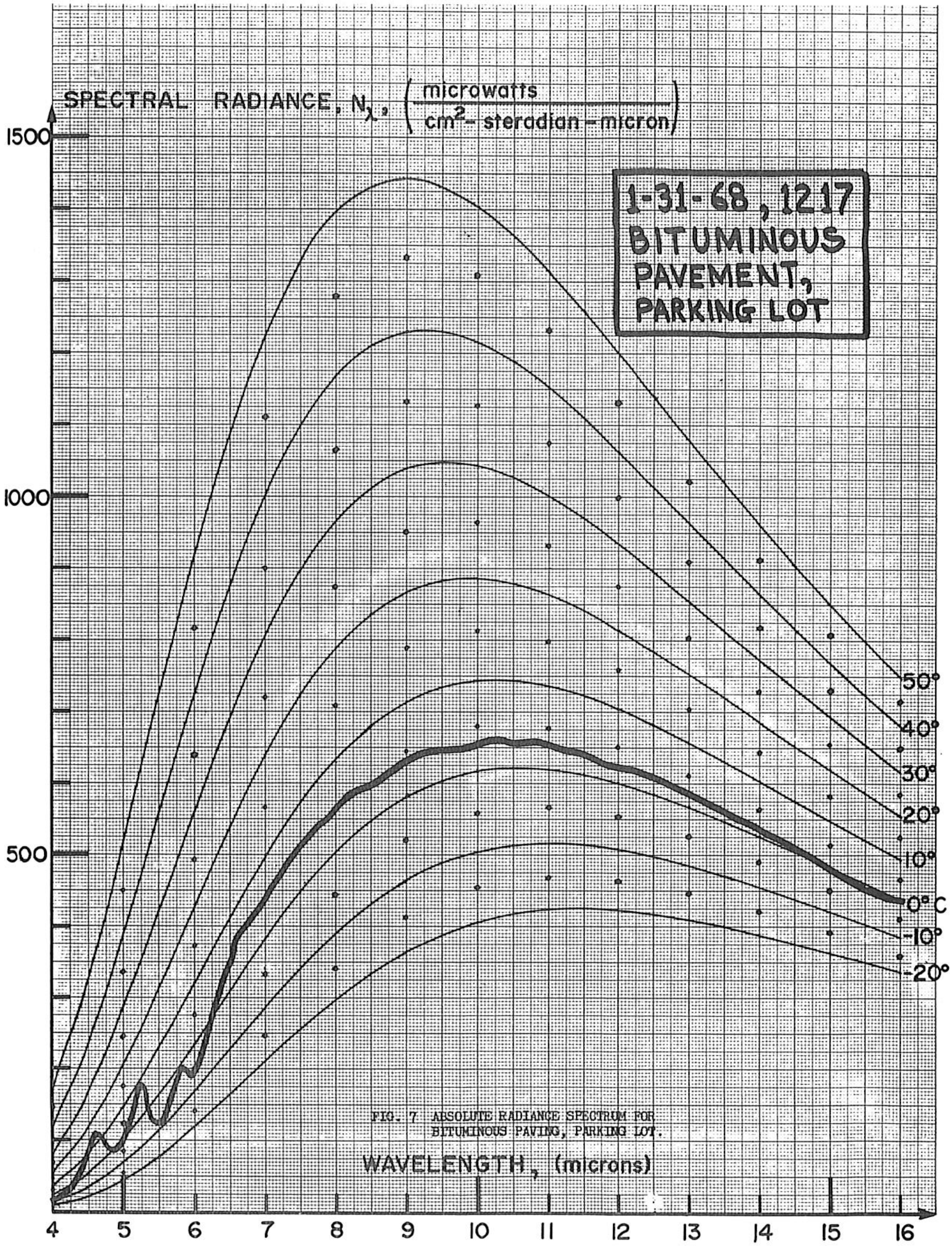


FIG. 7 ABSOLUTE RADIANCE SPECTRUM FOR
BITUMINOUS PAVING, PARKING LOT.

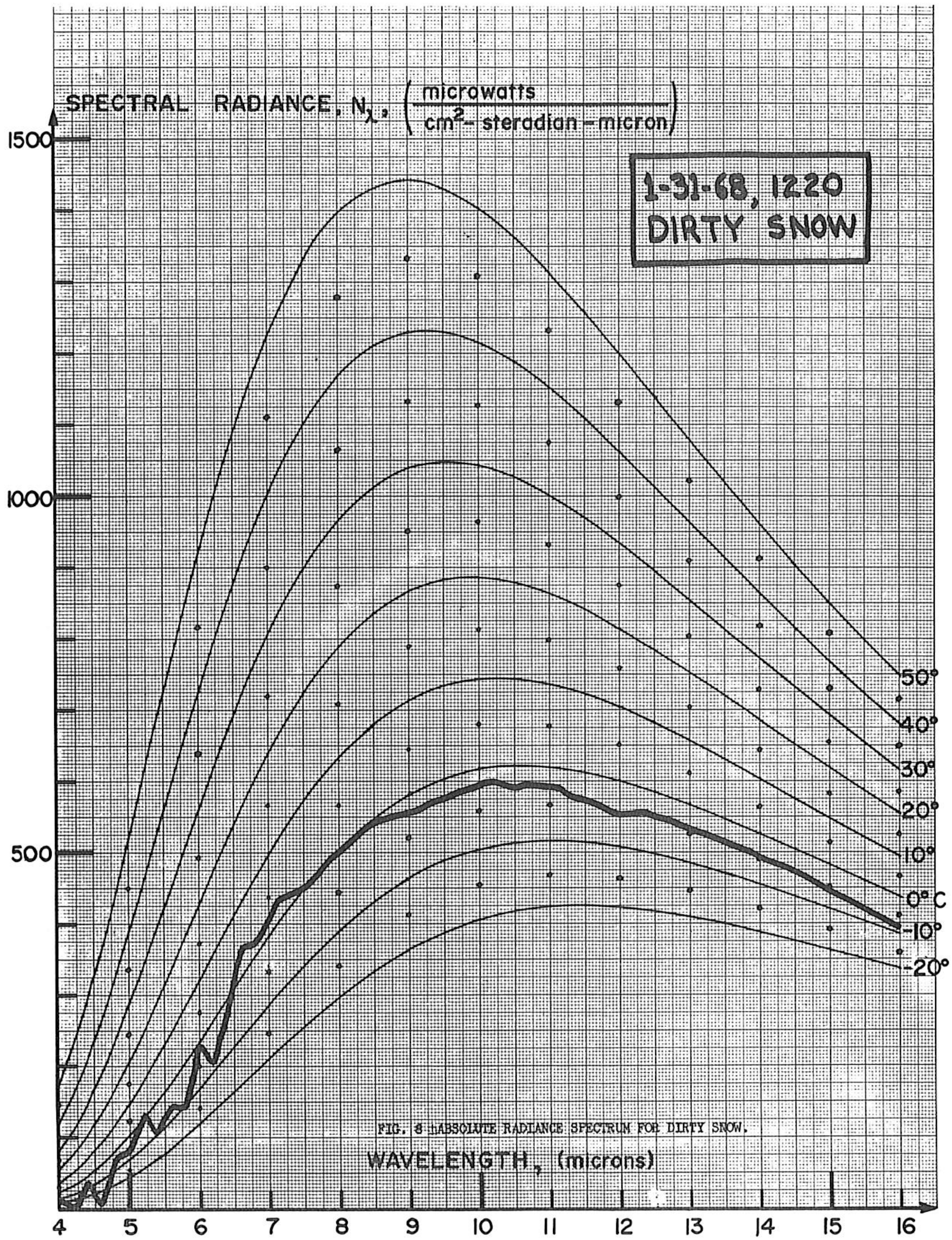


FIG. 8 ABSOLUTE RADIANCE SPECTRUM FOR DIRTY SNOW.

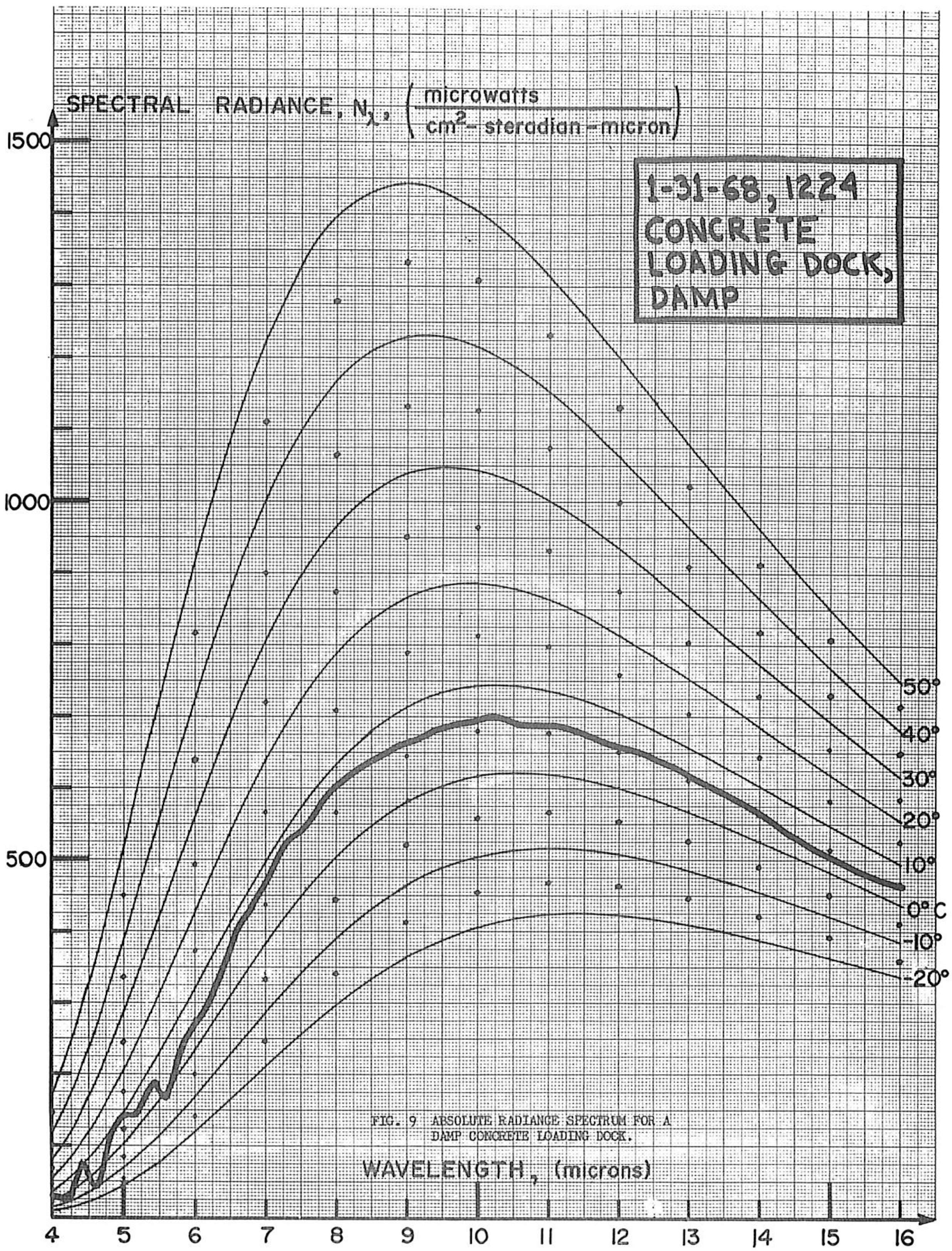


FIG. 9 ABSOLUTE RADIANCE SPECTRUM FOR A DAMP CONCRETE LOADING DOCK.

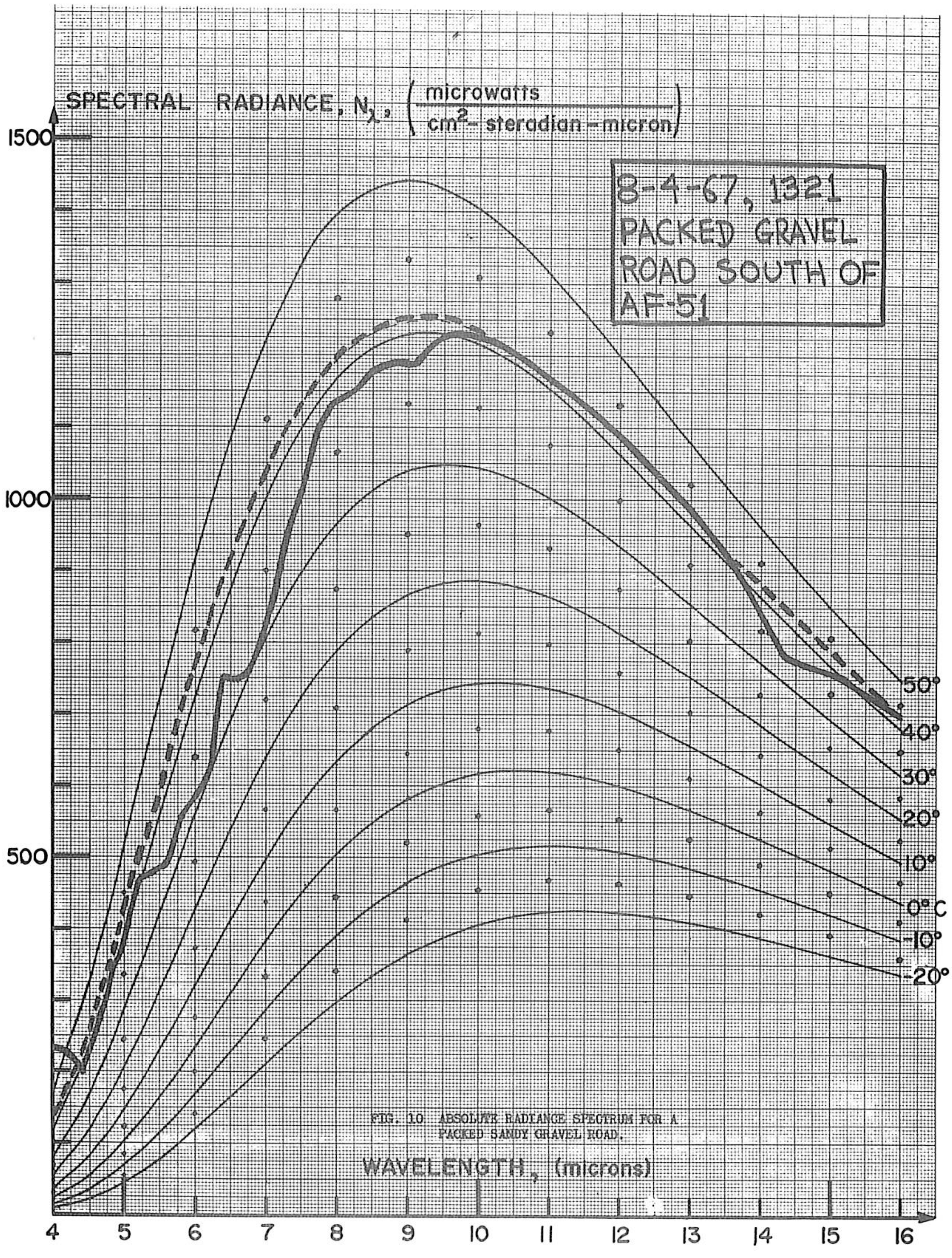


FIG. 10 ABSOLUTE RADIANCE SPECTRUM FOR A PACKED SANDY GRAVEL ROAD.

Fig. 10, but only about 1 to 1.5 meters for Figs. 6 through 9.

The data digitization process is now developed so that a day's data tapes can be processed into absolute radiance spectra in a few hours each evening. Most of the time is taken up by the operator's separation and coding of separate scene runs. This part can also be automated when requirements for more data warrants it.

Figure Captions

Fig. 1 A 75-scan average interferogram from a 43.3°C black body.

Fig. 2 The Fourier transform of Fig. 1, the raw instrument response R_λ.

Fig. 3 The instrument transfer function determined from Fig. 2 and $N_{\lambda BB}-N_{\lambda IB}$.

Fig. 4 Raw instrument response for a wet grass scene.

Fig. 5 Net radiance spectrum for wet grass. The graph is meaningless beyond 17 microns due to optical component absorption.

Fig. 6 Absolute radiance spectrum for wet grass.

Fig. 7 Absolute radiance spectrum for bituminous paving, parking lot.

Fig. 8 Absolute radiance spectrum for dirty anow.

Fig. 9 Absolute radiance spectrum for a damp concrete loading dock.

Fig. 10 Absolute radiance spectrum for a packed sandy gravel road.