FINAL REPORT

35-Element Cold Gas-Cooled Array

JPL Contract No. 950962
SBRC Project 5778

For - Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, California

10 March 1965

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This work was performed for the Jet Propulsion Laboratory, California Institute of Technology, sponsored by the National Aeronautics and Space Administration under Contract NAS7-100.

10 March 1965

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Project Manager

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Santa Barbara Laboratory

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DESIGN OBJECTIVE

The objective of this program was to design, construct, and test a multi-element (35-detector) PbSe array for use at approximately -80°C to be achieved by using a cold gas flow through the detector mount.

The design was for use in the focal plane of an Ebert type spectrometer, each detector to see a specific portion of the spectrum as reflected from the grating.

DESIGN

The optical design consists of a silicon front lens and a strontium titanate lens with an immersed PbSe detector for -80°C and warmer operation. Both lenses have the sides flattened and mounted in a metal frame with thin side plates applied to form a 3 X 13 mm aperture. Figure 1 shows a view of the detector module with one side plate removed.

The lenses are located and cemented in the metal housing at the correct distance for an f/3 optical system. The side plates are designed with 0.002-inch thickness to minimize optical losses between the detector modules. The aperture surfaces outside the silicon lenses are polished and gold plated; the surface between the silicon and strontium titanate lenses is blackened to minimize internal reflections.

The detector modules are designed with very close tolerances to prevent tolerance build-up over the 35 elements (see Figure 2).

Electrical lead pins of tinned copper are potted with filled epoxy in holes in the bottom of the detector module frame. The heat exchanger design uses all available space for labyrinth passages for the flow of the cold gas which is first channeled under the detectors, around cooling fins to facilitate heat transfer, then returned around both sides to the inlet end, and again

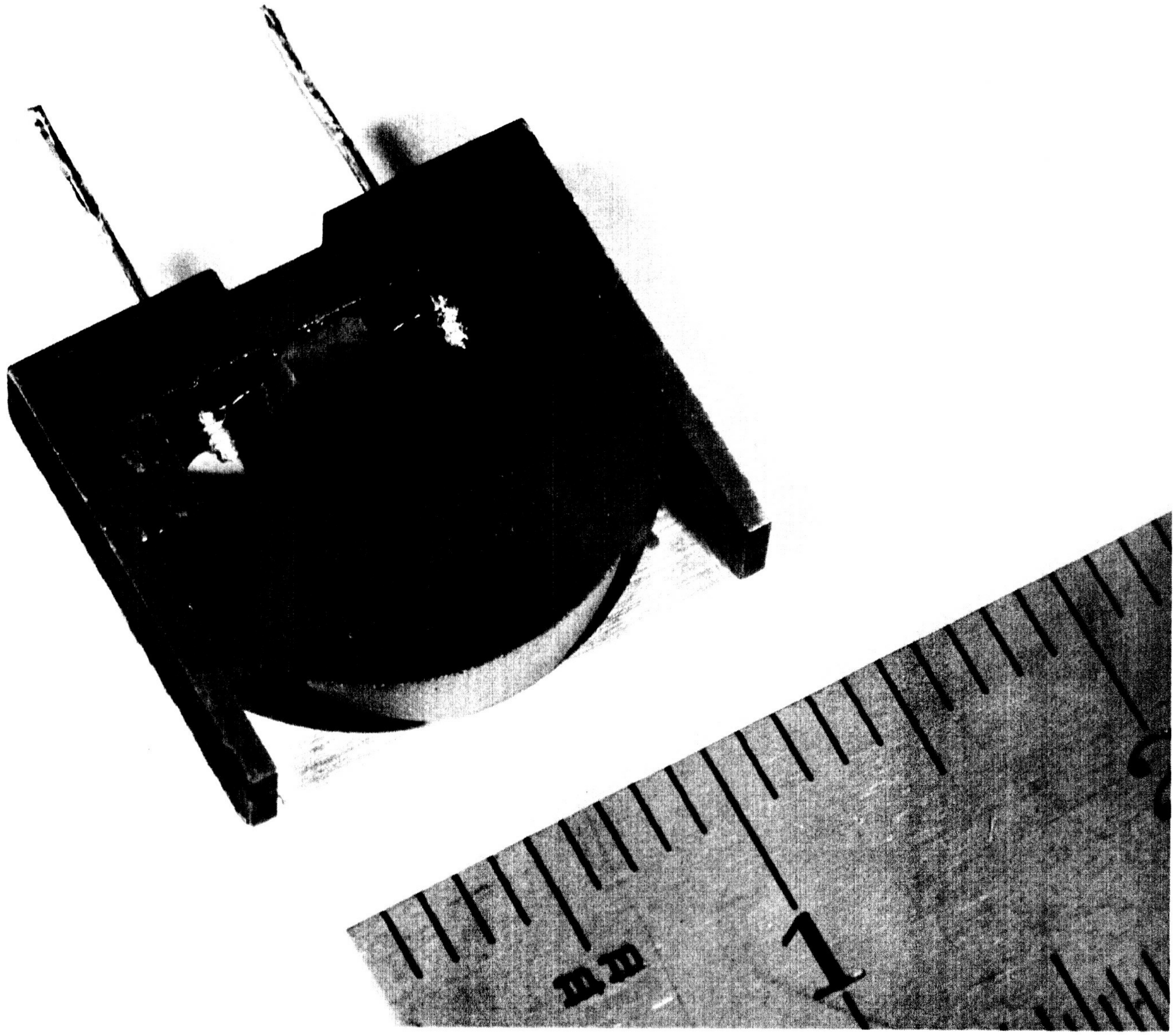

Figure 1. Detector-Optics Module Subassembly (Without Side Plate)

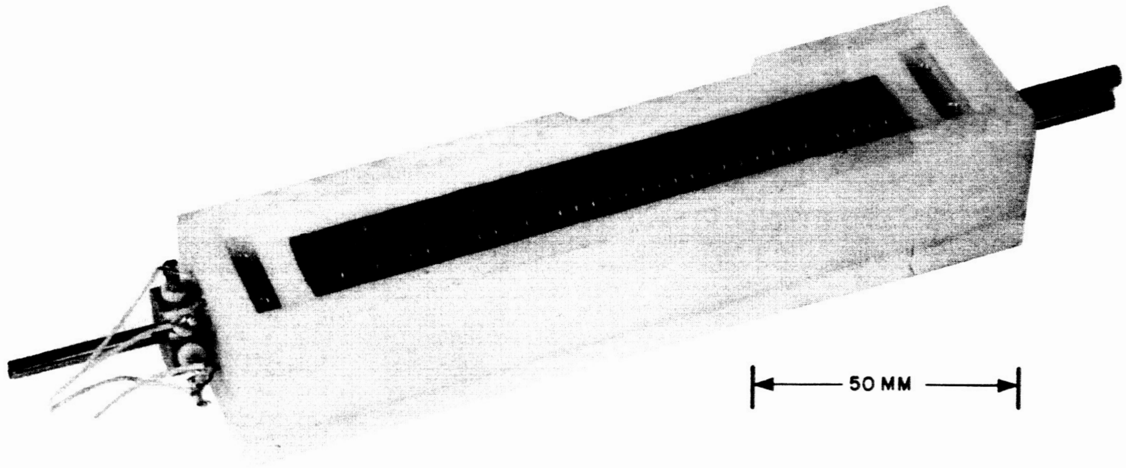

Figure 2. 35-Element Detector, Modular Lens and Cell Array, Filter Removed

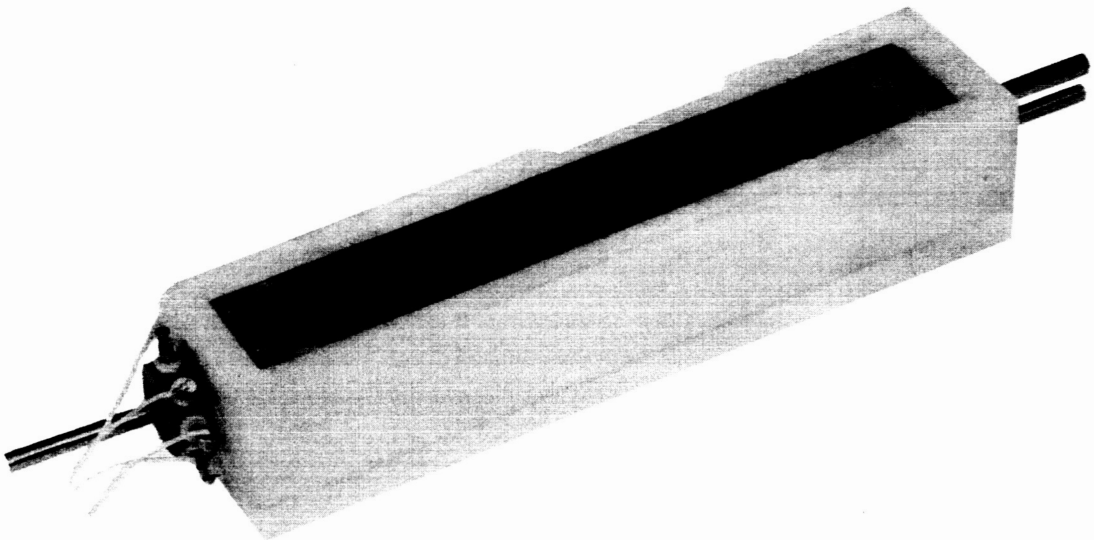

Figure 3. 35-Element Detector, Modular Lens and Cell Array, Filter in Place

circulated up and back to the exhaust through a larger tube in the same end as the inlet tube. The completed assembly is shown in Figures 3 and 4.

Thermo-ribbon temperature sensors made by Minco Products, Inc. (4.100 inches in length to fit a cavity 0.025-inch thick by 0.125-inch wide with a resistance of 676 ohms at 25°C) were cemented to the heat sink. One is placed under the detectors and one placed on the side of the heat sink. Figure 5 demonstrates the resistance versus temperature of the bottom thermo ribbon. Both of the sensor resistances are within 1.0 ohm. The sensor leads are attached to terminals mounted on the flushing tube.

The metal heat exchanger is then potted in a mold to form an insulating jacket of polyurethane foam which is also used as a means of anchoring the attachment plates for the spectral filter. The foam is then painted with a flat black paint to minimize any possible radiation transmission or scattering in the foam.

The spectral filter was ordered as a long-wavelength pass filter on 0.010-inch thickness optically polished quartz. The transmission was to be no less than 70 percent from 3.3 to 4.6 microns with the transmission to be less than 0.01 percent at 2.3 microns and shorter wavelengths.

Spectral response curves are attached. Figure 6 shows the transmission curve of the filter. Figure 7 shows the relative response curve of the detector-filter assembly.

The final assembly's spectral response was checked on a Model 112A Perkin-Elmer spectrometer with less than a 1-inch air gap between the exit aperture of the spectrometer and the dry nitrogen flushed test box. An expanded spectral transmission curve in the region of most interest between 4.21 and 4.5 microns was run at 0.01-micron intervals. The expanded transmission curve is demonstrated in Figure 8.

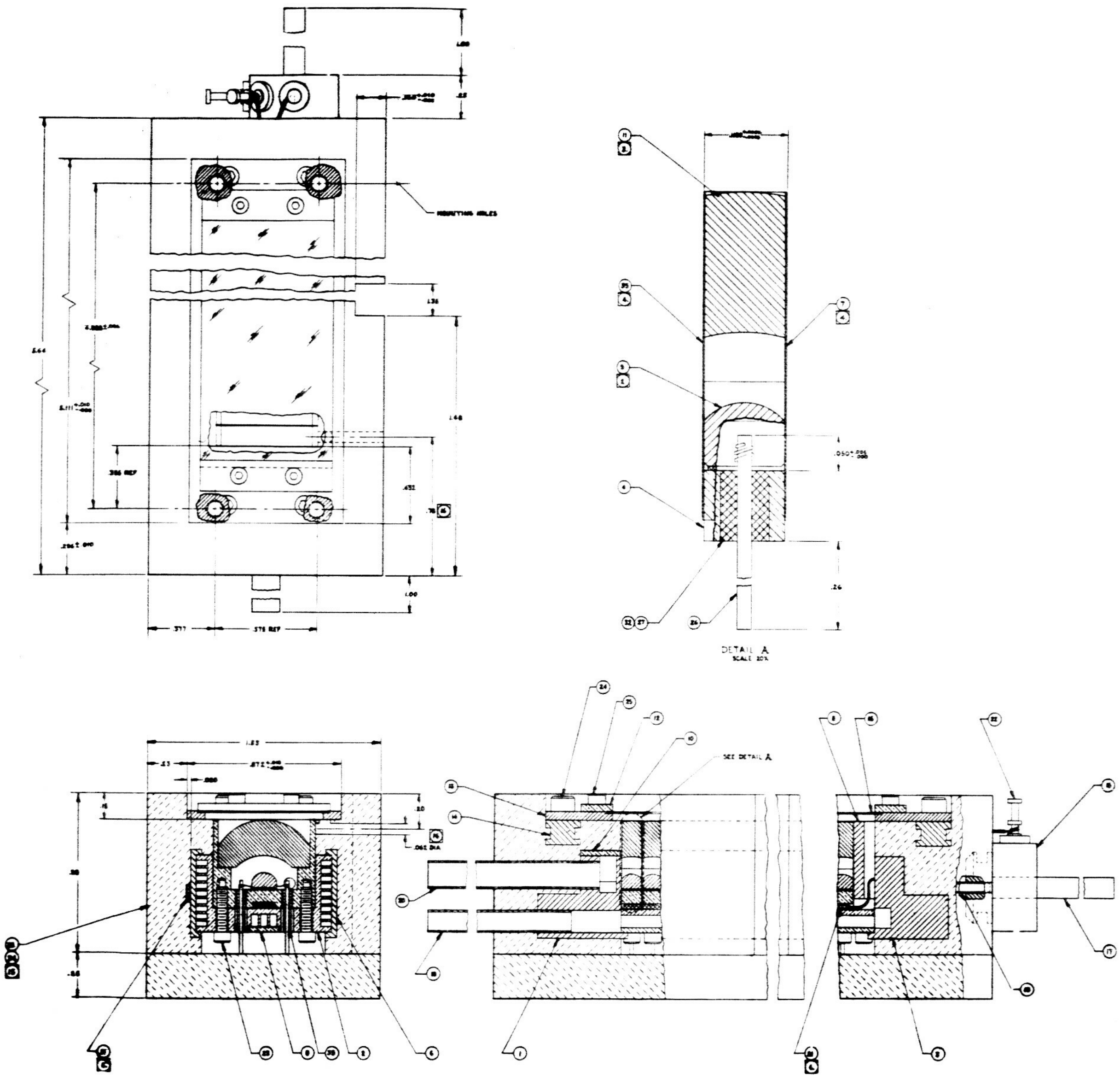

Figure 4. 35-Element Detector Assembly (SBRC Engineering Drawing 21437)

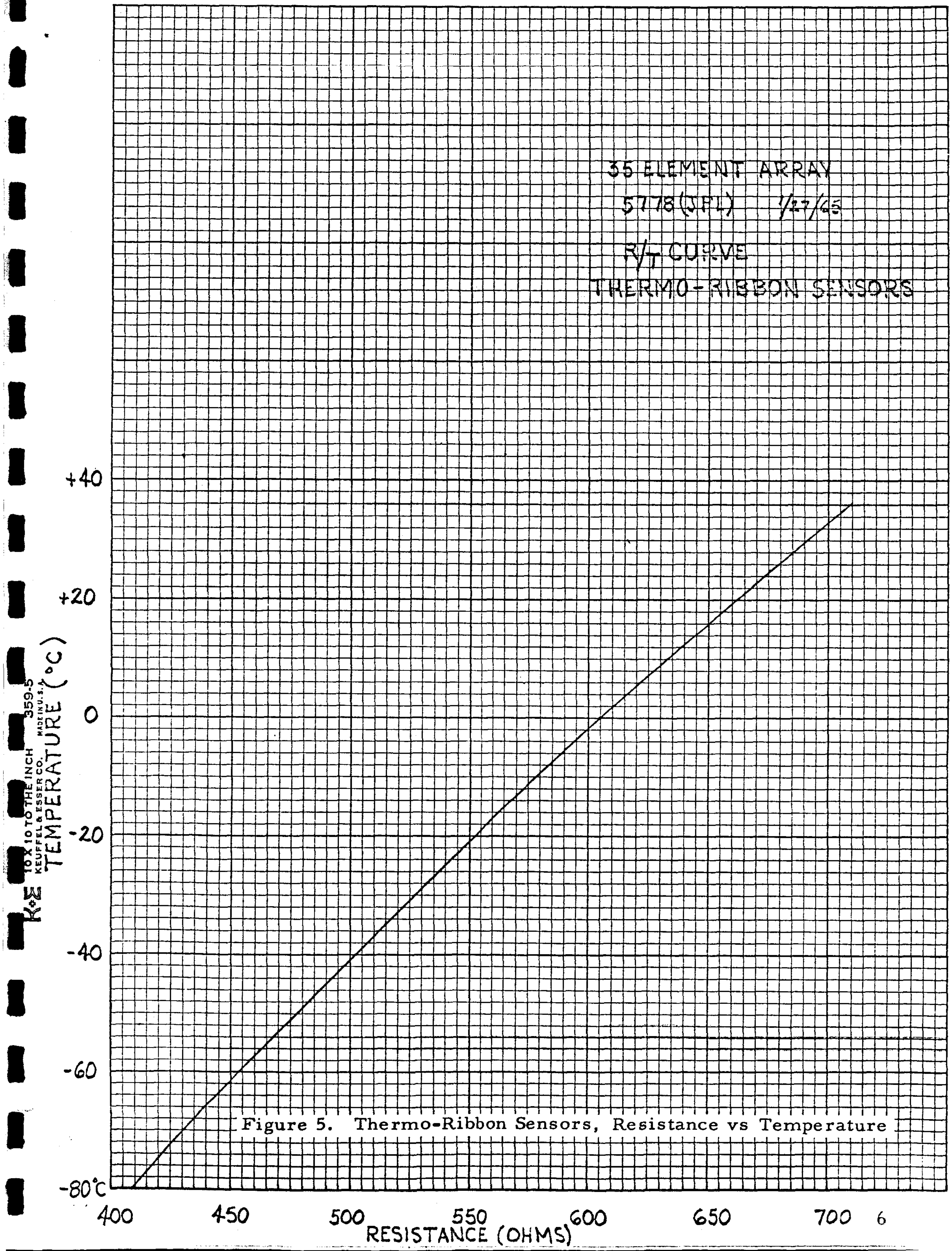

Figure 5. Thermo-Ribbon Sensors, Resistance vs Temperature

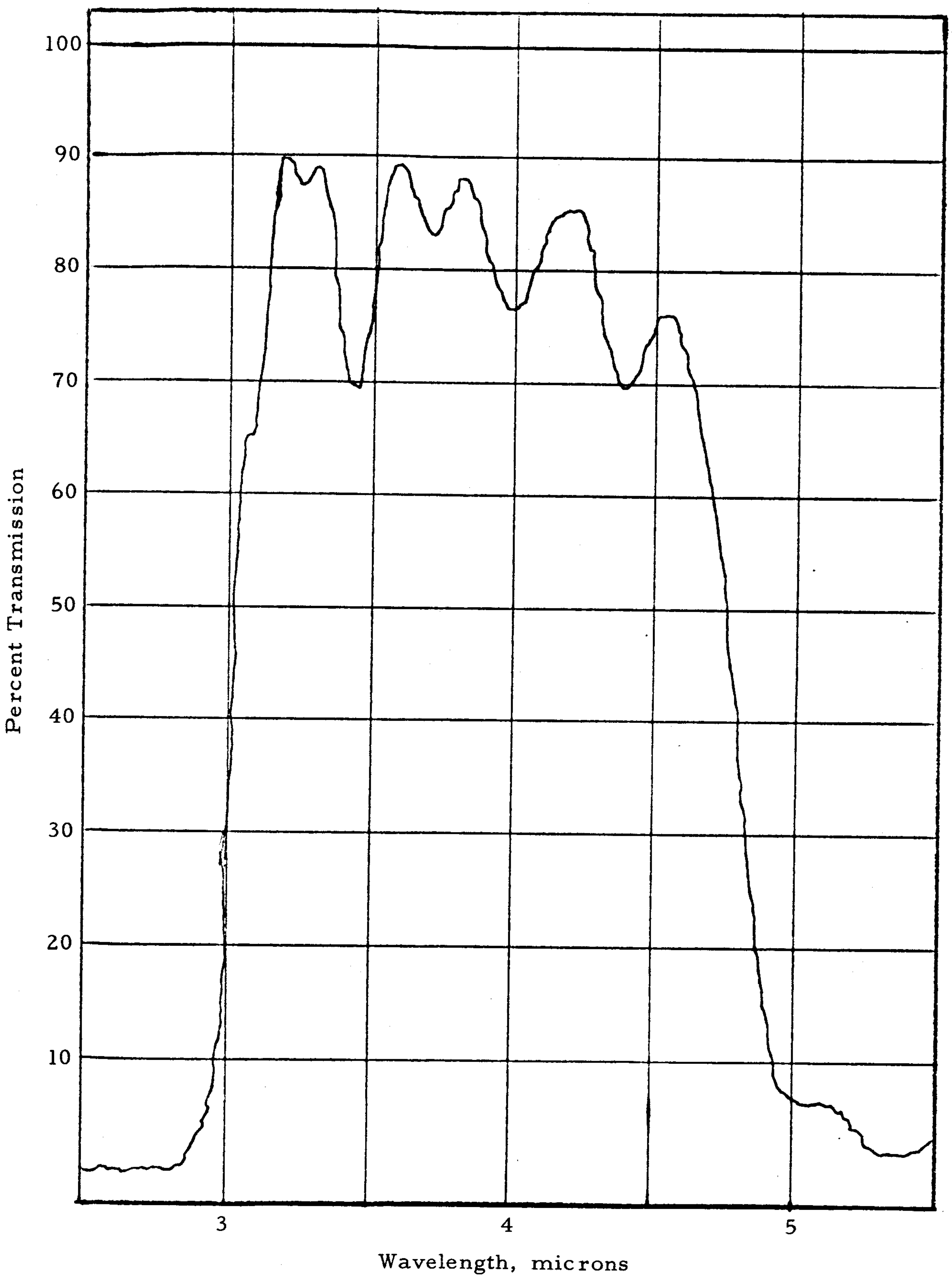

Figure 6. Spectral Response of Filter

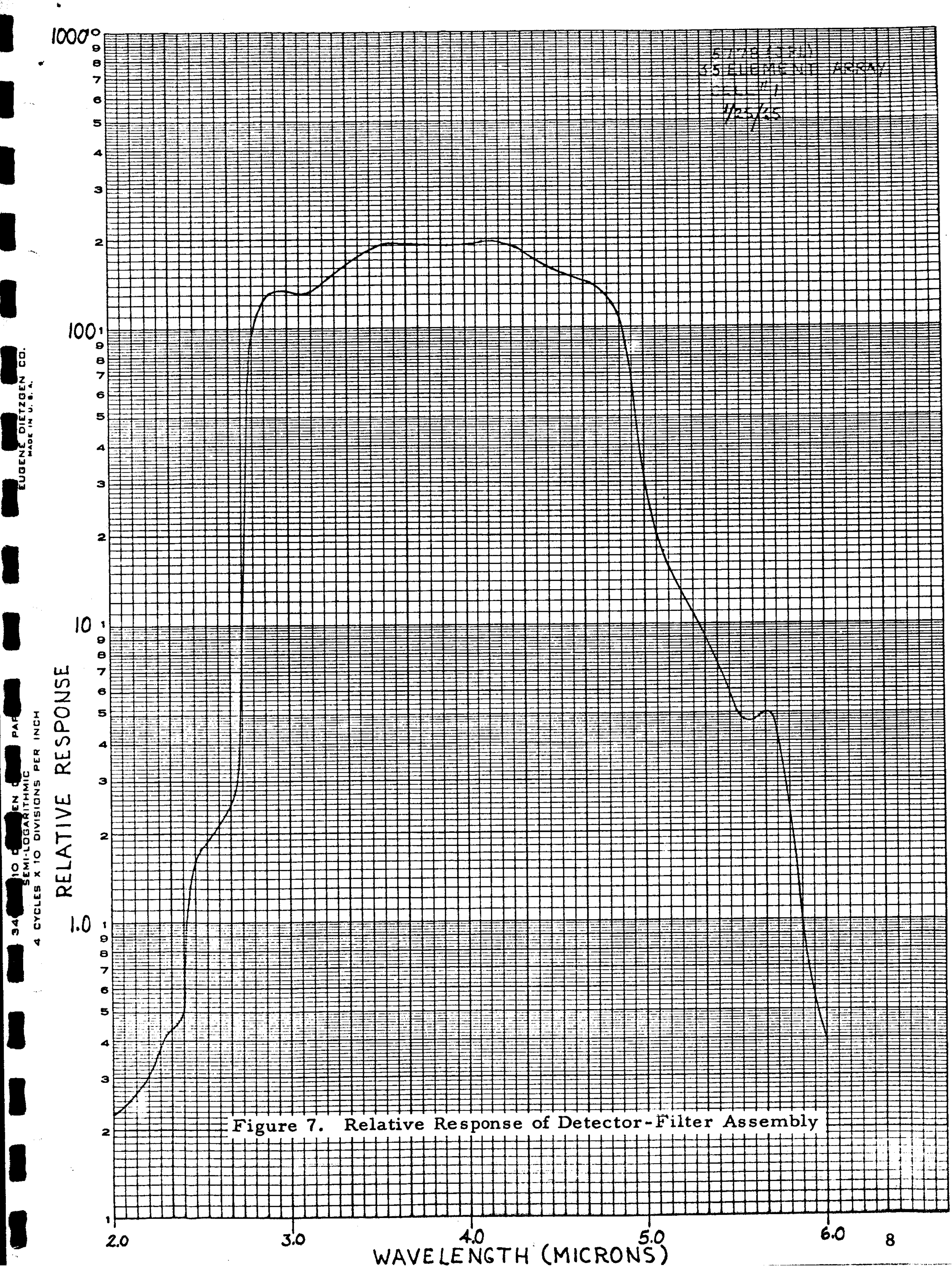

Figure 7. Relative Response of Detector-Filter Assembly

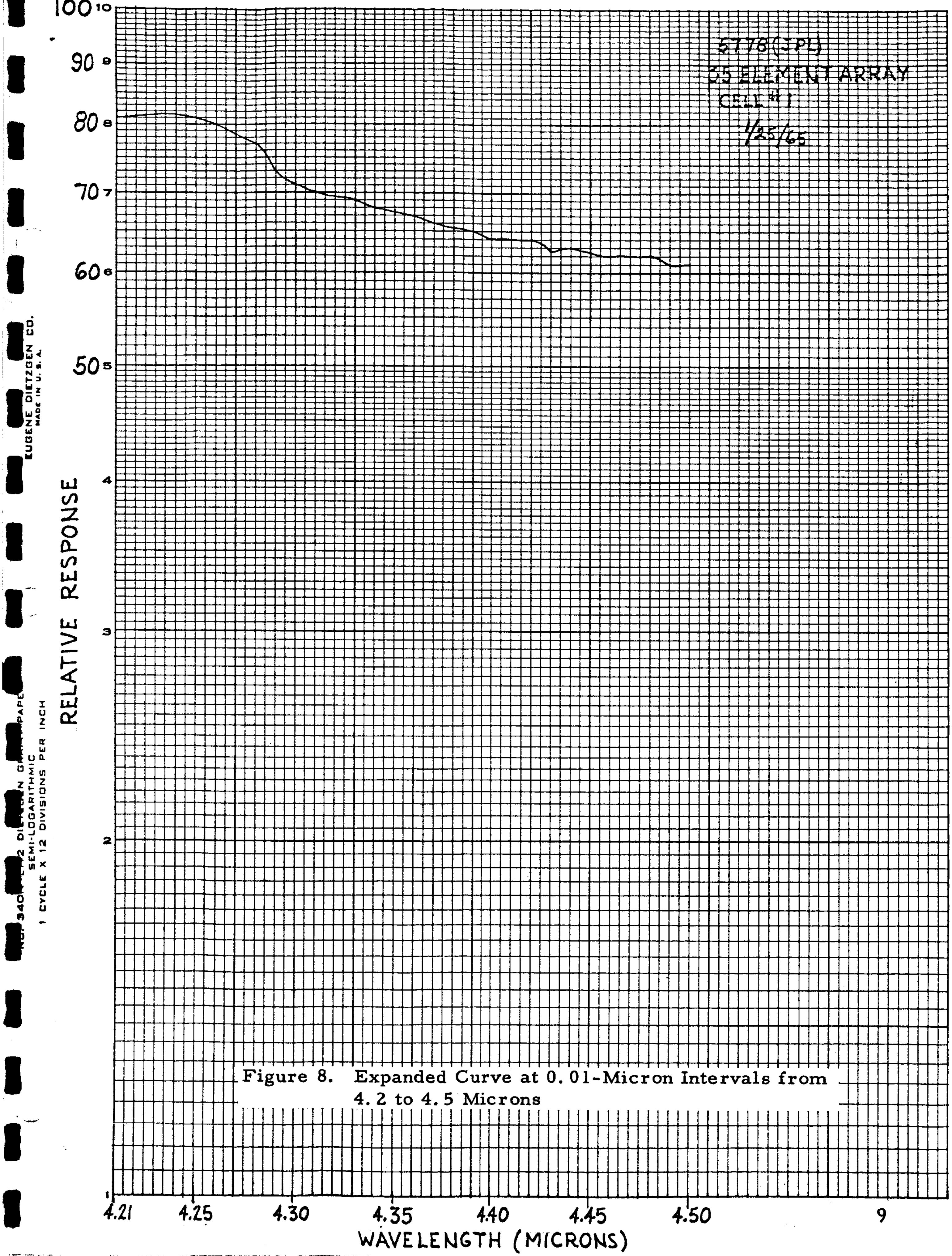

Figure 8. Expanded Curve at 0.01-Micron Intervals from 4.2 to 4.5 Microns

TEST PROCEDURES

To simulate the final optical test conditions it was necessary to devise a means to illuminate the entire sensitive surface of the detector by irradiating a diffuse reflective surface which was the same size as the f/3 field of view in the spectrometer.

Several methods were explored with the resultant use of a beaded screen which had been aluminized by vacuum deposition from several angles to assure that a diffuse reflecting surface was obtained. The beaded reflector was enclosed with a nonreflecting frame to form the f/3 field of view.

Calibration tests of the reflected radiation were made by using a 7 X 7 mm detector with a known NEP with a flat silicon window at the same distance and using the same reflective screen area as that used for final acceptance tests with the blackbody irradiation calculated from the relative signal levels. The temperature of the blackbody in the test set was 800°K and the blackbody energy was calculated to be 1.45×10^{-7} watts/cm^2 at the detector.

The detectors were first screened in evacuated test bottles to determine acceptability, then mounted in the detector module frame with lenses in place, placed in a test dewar, evacuated and tested with the reflective beaded screen. No filter was used during this test; resistance values during this test were well within the 10 megohm specification.

The detectors were then tested in the final assembly with the spectral filter in the heat exchanger using cold gas cooling to determine final electrical performance. The best detectors were selectively located in the No. 10 to 18 positions to concur with JPL's request. Figure 9 relates the module number to cell position number. Each module is identified with a number scribed in the slot cut in the bottom to clear the thermo ribbon. The resistance values during this test were in some cases higher than specification,

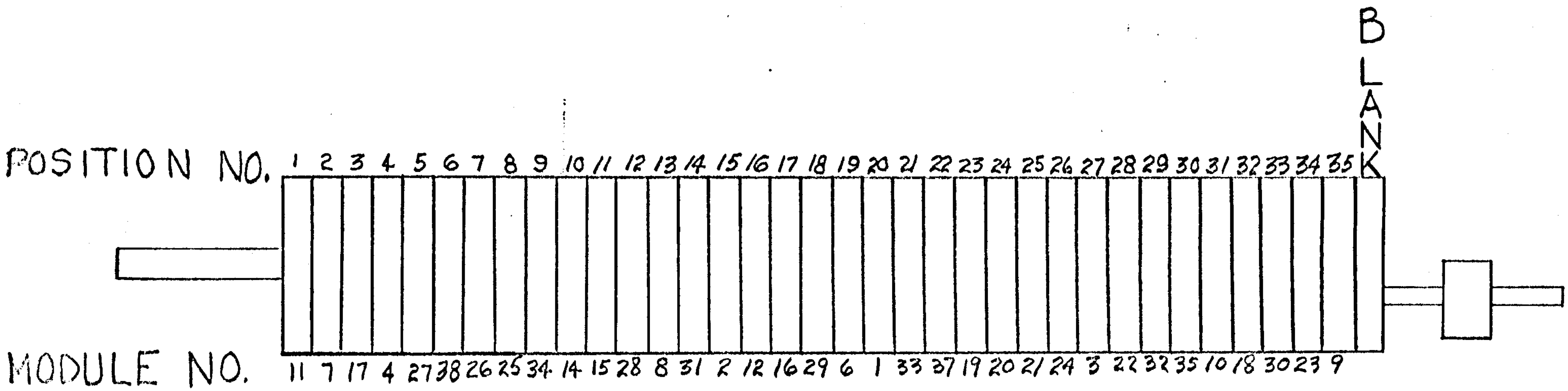

Figure 9. Relative Module Numbers with Cell Position

partially due to spectral shielding and probably due to better control of detector temperature.

The final checks were conducted in a special test box (constructed for this test) that was flushed with dry nitrogen gas to prevent condensation on the detector assembly. The test box was fitted with a Corning No. 9752 coated glass window having an average transmission of 89 percent in the spectral band between 3.0 and 4.8 microns.

The NEP calculations given in Table 1 compensate for the transmission loss attributable to the above window in the test box.

COOLING TESTS

Cooling tests were first conducted on the final assembly using the cold nitrogen gas boiled off by an immersed heater in liquid nitrogen in a closed dewar. It was found almost impossible to control the temperature closely by this approach so this method was abandoned.

The use of warm dry nitrogen gas routed through a heat exchanger tube immersed in liquid nitrogen gave very good control by adjusting the pressure and flow rate. The following data was taken by monitoring the temperature of the cold gas at the entrance and exit of the detector mount as well as the temperature of the heat exchanger using the thermo-ribbon element.

Cooling Gas Flow Rate (Warm) (cfh)	Inlet Gas Pressure (in. Hg)	Inlet Gas Temperature (°C)	Outlet Gas Temperature (°C)	*Detector Temperature (°C) 406.3 ohms
12.6	2.58	-138.2	-74.4	-81.25

*406.3 ohms thermo-ribbon resistance

Table 1. Detector Performance Data Sheet

35-ELEMENT DETECTOR ARRAY		TEST DATE January 28, 1965	
Detector Construction		**Conditions of Measurement**	
Type	PbSe	Blackbody Temp. (°K)	800
Filter Material	Quartz (Interference)	Chop Frequency (cps)	300
Window Material	Silicon Lens	Bandwidth (cps)	6
Field of View	f/3	Detector Temp. (°C)	-80
Area of Aperture	$3.9 \times 10^{-1} cm^2$	Load Resistance (ohms)	1 Meg
Thermo Ribbon (See Curve)	676 ohms @ 25°C	Applied Voltage (Detector + Load)	40
		Blackbody Flux Density (Microwatts/cm^2)	1.45×10^{-7}

Cell No.	Dynamic Resistance (Megohms)	Cell I in μ A	Noise in μ V	Signal in μ V	S/N Ratio	Noise Equivalent Power (watts) $\times 10^{-11}$
1	16.65	2.0	.20	315	1575	1.46
2	15.4	2.0	.23	130	562	4.12
3	14.3	2.1	.6	315	526	4.4
4	7.7	3.2	.5	414	828	2.79
5	12.5	2.5	.45	432	958	2.41
6	5.12	4.5	.35	234	668	3.46
7	11.35	2.7	.38	576	1512	1.54
8	8.0	3.5	.50	792	1598	1.44
9	14.3	2.2	.22	252	1143	2.0
10	8.7	3.6	.39	684	1755	1.31
11	8.7	3.4	.21	369	1755	1.31
12	7.7	4.4	.4	810	2025	1.15
13	14.3	2.0	.17	315	1854	1.28
14	9.1	3.2	.35	657	1972	1.17
15	8.0	3.0	.20	396	1980	1.16
16	16.65	1.8	.19	459	2412	.95
17	18.2	1.4	.23	414	1800	1.28
18	12.5	2.5	.31	558	1800	1.28

Table 1. Detector Performance Data Sheet (Cont)

Cell No.	Dynamic Resistance (Megohms)	Cell I in μ A	Noise in μ V	Signal in μ V	S/N Ratio	Noise Equivalent Power (watts) $\times 10^{-11}$
19	18.2	1.7	.24	302	1260	1.86
20	9.52	3.5	.30	513	1710	1.35
21	8.0	3.2	.26	396	1521	1.52
22	28.6	1.2	.2	342	1810	1.27
23	11.8	2.5	.35	504	1440	1.6
24	11.8	2.0	.40	504	1360	1.69
25	10.0	3.4	.41	558	1360	1.69
26	7.7	2.9	.60	720	1215	1.9
27	6.67	3.4	.48	720	1498	1.54
28	20.0	1.4	.26	414	1593	1.44
29	8.33	2.9	.30	342	1141	2.1
30	9.1	2.6	.30	432	1440	1.6
31	8.33	2.7	.17	252	1485	1.55
32	13.35	2.5	.31	396	1278	1.8
33	14.3	2.0	.31	333	1071	2.15
34	40.0	1.0	.25	173	691	3.32
35	10.0	3.4	.55	297	540	4.26

NOTES: 1. Formula for determining dynamic resistance

$$\frac{DV}{DI} \text{ where } \begin{array}{l} V = \\ I = \end{array} \begin{array}{l} \underline{\text{45-35 volts}} \\ \text{difference in current} \\ \text{at the above voltages} \end{array}$$

2. Conversion factor blackbody to peak: 3.204 @4.10 microns

Prior to all tests in the test box, the detector assembly was purged by flowing 2 cfh dry nitrogen gas through the flushing tube (very low pressure 0.5 to 3 psi). If higher pressures are used, internal pressure will develop on the filter and break it.

ELECTRICAL TESTS

Table 1 demonstrates the performance of the detectors delivered in the complete assembly including the spectral filter and under the test conditions as shown.

The NEP values need to have the 3.204 gain applied to convert blackbody values to peak values. The conversion factor was calculated on the IBM 1620 computer from an actual spectral response of the detector-filter combination integrated with the 800°K blackbody curve.

HANDLING PRECAUTIONS

The detector assembly should be cooled down in a dry gas atmosphere or vacuum, and warmed up to ambient temperatures under the same conditions before subjecting to normal atmospheric moisture. Although the detectors are sealed, excess condensation of water may adversely affect the detectors due to moisture causing electrical noise.

The dry gas to be used for flushing around the detectors should be kept below 3 psi.