DECLASSIFIED

[redacted]

NRL REPORT 3698

FR-3698

THE SPECTRAL AND FREQUENCY RESPONSE OF SEVERAL TYPES OF THERMOPILES

DECLASSIFIED by NRL Contract
Declassification Team
Date: 24 JAN 2017
Reviewer's name: [redacted]
Declassification authority: NAVY DECLASS GUIDE/ NAVY DECLASS MANUAL, 11 DEC 2012

DISTRIBUTION STATEMENT A APPLIES.
Further distribution authorized by UNLIMITED only.

NAVAL RESEARCH LABORATORY

WASHINGTON, D.C.

DECLASSIFIED

[redacted]

DECLASSIFIED

[redacted]

NRL REPORT 3698

THE SPECTRAL AND FREQUENCY RESPONSE OF SEVERAL TYPES OF THERMOPILES

C. F. Bieber

June 20, 1950

Approved by:

Mr. H. L. Clark, Head, Applied Optics Branch
Dr. J. A. Sanderson, Superintendent, Optics Division

NAVAL RESEARCH LABORATORY

CAPTAIN F. R. FURTH, USN, DIRECTOR

WASHINGTON, D.C.

[redacted]

DECLASSIFIED

DISTRIBUTION

BuShips	
Attn: Code 841	5
BuAer	
Attn: Code EL-84	5
Attn: Code TD-4	1
Attn: Code EL-71	1
Attn: Code EL-81	1
BuOrd	
Attn: Code Re4e	5
Attn: Code Re9e	1
CNO	1
CO & Dir., USNEL	2
CDR, USNOTS	
Attn: Reports Unit	2
CO & Dir., USNUSL, New London	
Attn: Infrared Division	1
Wright-Patterson AFB	
Attn: BAU-CADO	1
Attn: CADO-D13	1
Attn: CADO-E1	2
Attn: Ch., Electronics Subdiv., MCREEO-2	1
OCSigO	
Attn: Ch. Eng. & Tech. Div., SIGTM-S	1
CO, SCEL	
Attn: Dir. of Eng.	2
CO, Watson Labs., Red Bank	
Attn: Ch. Eng. Div., WLENG	1
CO, Air Force Cambridge Res. Labs.	
Attn: ERCAJ-2	1
RDB	
Attn: Information Requirements Branch	2
Attn: Navy Secretary	1
Attn: Electronics Committee Infrared Panel	18
Naval Res. Sec., Science Div., Library of Congress	
Attn: Mr. J. H. Heald	2

CONTENTS

 [redacted]

ABSTRACT

The spectral and frequency response of twelve radiation thermopiles, built mainly for use as sensitive elements in infrared detection devices, have been measured.

The frequency responses are presented in two series of curves. The first shows the open-circuit peak-to-peak volts per peak-to-peak watt versus frequency, with the receiver area of the respective thermopiles effectively equivalent to one square millimeter. The second uses the same data but shows the relationship of the responses when the total resistance of each thermopile is effectively equivalent to one ohm.

The spectral responses relative to that of a standard infrared spectrometer thermocouple are shown for the region from 1.5 microns to 15.5 microns.

PROBLEM STATUS

This is an interim report on this problem; work is continuing.

AUTHORIZATION

NRL Problem N07-13R
NR 477-130

 [redacted]

THE SPECTRAL AND FREQUENCY RESPONSE OF SEVERAL TYPES OF THERMOPILES

INTRODUCTION

In the regular course of work under this problem, and in the process of evaluating sensitive elements for current infrared detection problems in which this Laboratory is now engaged,[1,2] the spectral and frequency responses of twelve thermopiles have been measured.

This group of thermopiles is representative of those used as sensitive elements in devices developed in the past, under current development, or for proposed future development. Also included in the group are specimens of all thermopiles which have been submitted to this Laboratory for evaluation.

All of the thermopiles were measured with the same equipments and under identical conditions. On this basis direct comparison between them is justified. The measuring equipments, as well as the procedure followed, will be fully described in another report.[3]

Whenever possible, measurements of frequency response were made for both receivers of the compensated thermopiles, and the spectral response of one receiver of the same thermopile was measured. In this manner, four quantities were determined: (1) The degree of compensation, (2) the sensitivity, (3) the frequency response, and (4) the spectral response. In several cases, however, normal handling had resulted in accidental breakage of leads or internal parts, rendering one set of receivers useless; in others, use of the thermopile in a problem elsewhere prevented one type of measurement from being taken. Finally, it should be noted that most of the thermopiles in the group are special-purpose thermopiles and may not represent the best of these particular types.

EXPERIMENTAL RESULTS

Frequency Response

The range of frequencies covered in the frequency response measurements extended from 2.5 to 100 cycles per second. The temperature of the black body source was held

---

[1] Clark, H. L., NRL Ltr. Report S-3750-540A/50 to BuAer, Code EL-84, June 27, 1950

[2] Bieber, C. F. and Clark, H. L., "The Thermal Discontinuity at the Horizon Observed from High Altitudes," NRL Report 3529 (Confidential), September 12, 1949

[3] Bieber, C. F. and Clark, H. L., "Equipments for the Evaluation of Infrared Sensitive Elements," NRL Report in preparation (Confidential)

within a few degrees of 473°K for nearly all measurements. A small number of measurements was made with the source temperature held within a few degrees of 373°K, and these cases are noted in Table 1, "Details of the Thermopiles Measured."

The radiation from the source was chopped sinusoidally. The response is given in open-circuit peak-to-peak volts per peak-to-peak watt for an irradiated-receiver area equivalent to one square millimeter plotted to a logarithmic scale, all versus frequency in cycles per second plotted to a logarithmic scale (Figure 1).* A second set of curves shows the open-circuit peak-to-peak volts per peak-to-peak watt for an irradiated-receiver area equivalent to one square millimeter and a total thermopile resistance equivalent to one ohm, all versus the frequency; again both are plotted logarithmically (Figure 2).

For the compensated thermopiles in which no center electrical connection was provided and in which both the hot and cold junction remained in the circuit, it was necessary to mask off the incident radiation from one of the pair of receivers while the response of the other receiver was being measured. While this is not an ideal situation, since it tends to lower the sensitivity value slightly, from practice it has been found to be the arrangement least likely to damage the thermopile to the extent that no evaluation can be made. Again, the thermopiles so treated are noted in Table 1, "Details of the Thermopiles Measured."

Spectral Response

The range covered in the spectral response measurements extended from 1.5 to 15.5 microns. The spectral response given in each case is relative to that of the standard Perkin-Elmer A-C thermocouple[4] for use with the 12-C Infrared Spectrometer. In every case, the response of the thermopile being measured was set equal to the response of the P-E thermocouple at the maximum of the globar radiation curve (approximately 2.3 microns). The radiation from the globar source was chopped sinusoidally at the entrance slit, at a frequency of 10 cycles per second, and the response of the standard thermocouple and of the thermopile being measured were recorded simultaneously for each wavelength. The relative spectral responses of the thermopiles are shown in Figures 3 to 7 inclusive.

CONCLUSIONS AND DISCUSSION

Since the noise generated by this type of sensitive element is directly proportional to the square root of its resistance, and inasmuch as the signal-to-noise ratio is the useful quantity in actual use, a truly comparative rating must take into consideration the resistance as well as the receiver area.

When the sensitivities of the various thermopiles are examined on the basis of equivalent receiver area and their respective resistances are ignored (Figure 1), the total spread of values amounts to a factor of 50. This gives the impression that the highest is 50 times better than the lowest. Where the respective total resistances of the thermopiles are made effectively equivalent, however (Figure 2), the relative values of the signal-to-noise ratio are changed, with the total spread closing to a factor of 17 between the lowest and highest values. In other words, for practical use, the best is only 17 times better than the poorest.

---

*All figures appear at the end of the report.

[4] Perkin-Elmer Thermocouple No. 375, rated sensitivity 7.3 μv/μw, resistance 11 ohms, window material potassium bromide

TABLE 1

Details of the Thermopiles Measured

Note: The gas inside the cases was air at atmospheric pressure unless oth

Name	Manufacturer	Type	Number of Receivers	Area of Each Receiver (sq. mm)	Total Resist-tance (ohms)	Window Material
Eppley 1287	Eppley Laboratory, Inc., Newport, R. I.	Compensated	2	(1.5 x 3.0)	7.0	Sodium chloride
Eppley 1986	Same as above.	Compensated	2	(0.508 x 5.08)	8.4	Sodium chloride
Eppley 1 sq. inch (A)	Same as above.	Uncompensated	250	(0.508 x 508)	0.2	Coated silver chloride
Harris 36	Harris, L. (See Final Report on the Development of Fast Response Thermopiles, M.I.T., BuShips Contract NObs 25391, December 1946)	Compensated	2	(0.194 x 2.45)	32.2	Sodium chloride
Harris 55	Same as above.	Compensated	2	(0.099 x 1.08)	9.7	Sodium chloride
Harris 60	Same as above.	Compensated	2	(0.115 x 1.17)	10.0	Sodium chloride
Harris C_2^3	Same as above.	Compensated	2	(1.09 x 2.54)	41.0	Sodium chloride
Reeder I	Charles M. Reeder & Co., 171 Victor Ave., Detroit 5, Michigan.	Compensated	2	(0.794 x 2.38)	11.0	Sodium chloride
Reeder II	Same as above.	Compensated	2	(0.65 x 3.0)	16.0	Sodium chloride
Reeder 1 sq. inch (A)	Same as above.	Uncompensated	250	(0.508 x 5.08)	2.0	Coated silver chlorid
Reeder 1 sq. inch (B)	Same as above.	Uncompensated	250	(0.508 x 5.08)	2.0	Coated silver chlorid
Schwarz Vacuum Thermopile XGVO/3	Adam Hilger Ltd., 98 St. Pancras Way, Camden Road, London N.W.I., England	Compensated	2	(8.0 x 0.5)	40.0	Calcium fluoride

It is evident from Figure 1 that, taken at the lowest frequency for each case (~ 2.5 cps), the sensitivities of the thermopiles, beginning with the highest, rank as follows:

1. Schwarz XGVO/3
2. Harris C_2^3
3. Reeder I
4. Harris 36
5. Harris 55
6. Harris 60
7. Eppley 1287
8. Eppley 1986
9. Reeder 1 sq. inch (A) and (B)
10. Eppley 1 sq. inch (A)

There is a noticeable grouping in Figure 1 also, and when allowances are made for peculiarities, this grouping appears to fall according to manufacturer. As already noted, the Reeder 1 sq. inch thermopiles without doubt have a lowered sensitivity because of a mistake during application of the "black." The Harris 55 and 60 were built to special order and were successfully constructed only after much difficulty. The result was a sensitivity lower than is normally shown for this type of thermopile. With these two exceptions, the thermopile sensitivities fall into the following groups:

I Schwarz XGVO/3
II Harris C_2^3, Reeder I, and Harris 36
III Eppley 1287, Eppley 1986, and Eppley 1 sq. inch (A)

The Harris 55 and 60 fall in group III for the lower frequencies and 55 (and presumably 60) falls in group II at the higher frequencies. Both Reeder 1 sq. inch thermopiles fall in group III.

However, it is seen in Figure 2 that, again taken at the lowest frequency for each case, the signal-to-noise values of the thermopiles, beginning with the highest, rank in the following manner:

1. Schwarz XGVO/3
2. Reeder I
3. Harris 36
4. Eppley 1 sq. inch (A)
5. Harris C_2^3
6. Reeder 1 sq. inch (A) and (B)
7. Eppley 1287
8. Eppley 1986
9. Harris 55
10. Harris 60

When considered from the standpoint of signal-to-noise ratio, it is evident that distinct grouping does not appear and the relative order of superiority is changed—remarkably so for the Eppley 1 sq. inch (A) because of its unusually low resistance (0.2 ohm), and to a lesser extent for the Reeder 1 sq. inch thermopiles which also have rather low resistances (2.0 ohms each).

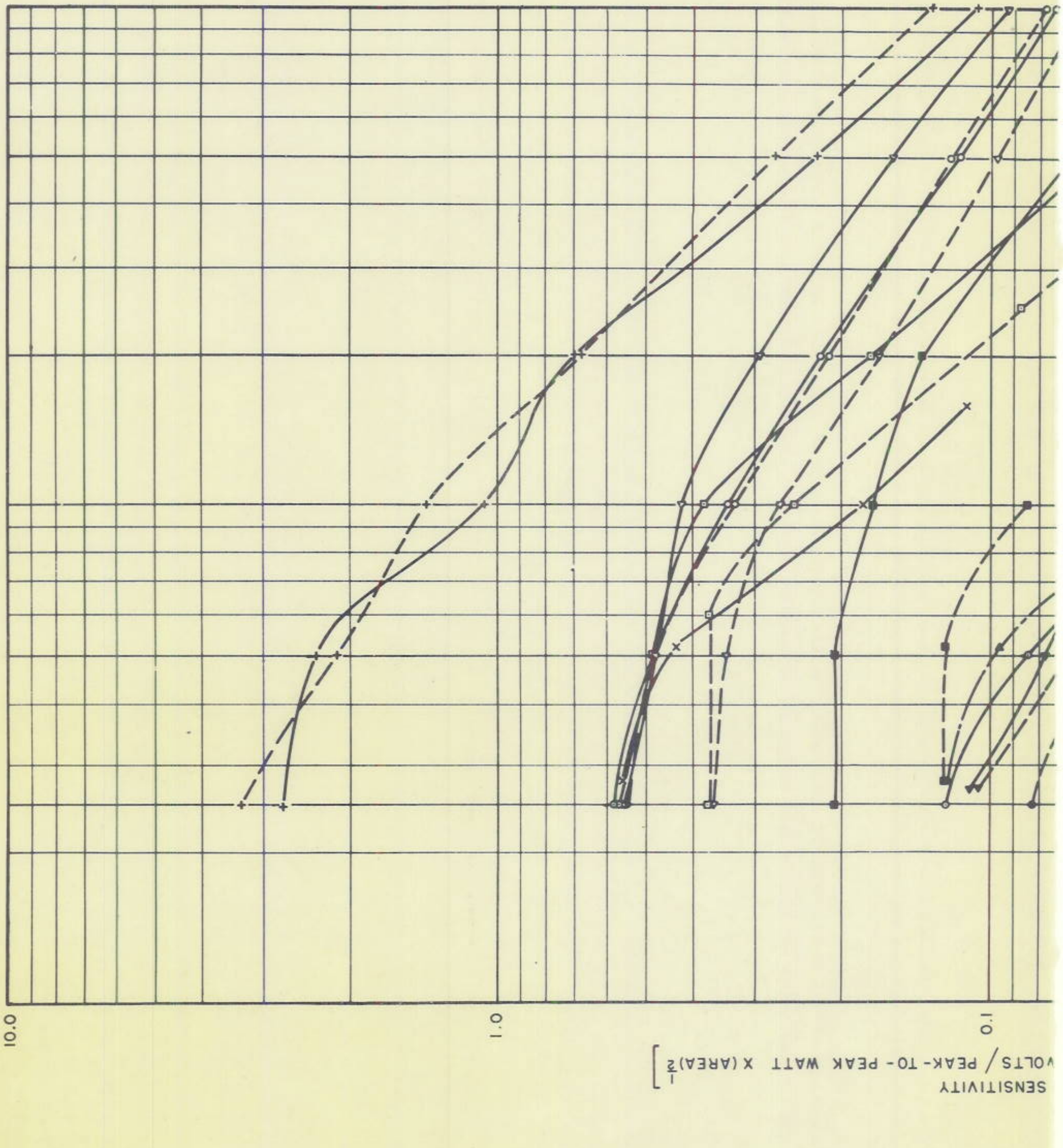
* * *

[redacted]

[redacted]

[redacted]

DECLASSIFIED



DECLASSIFIED

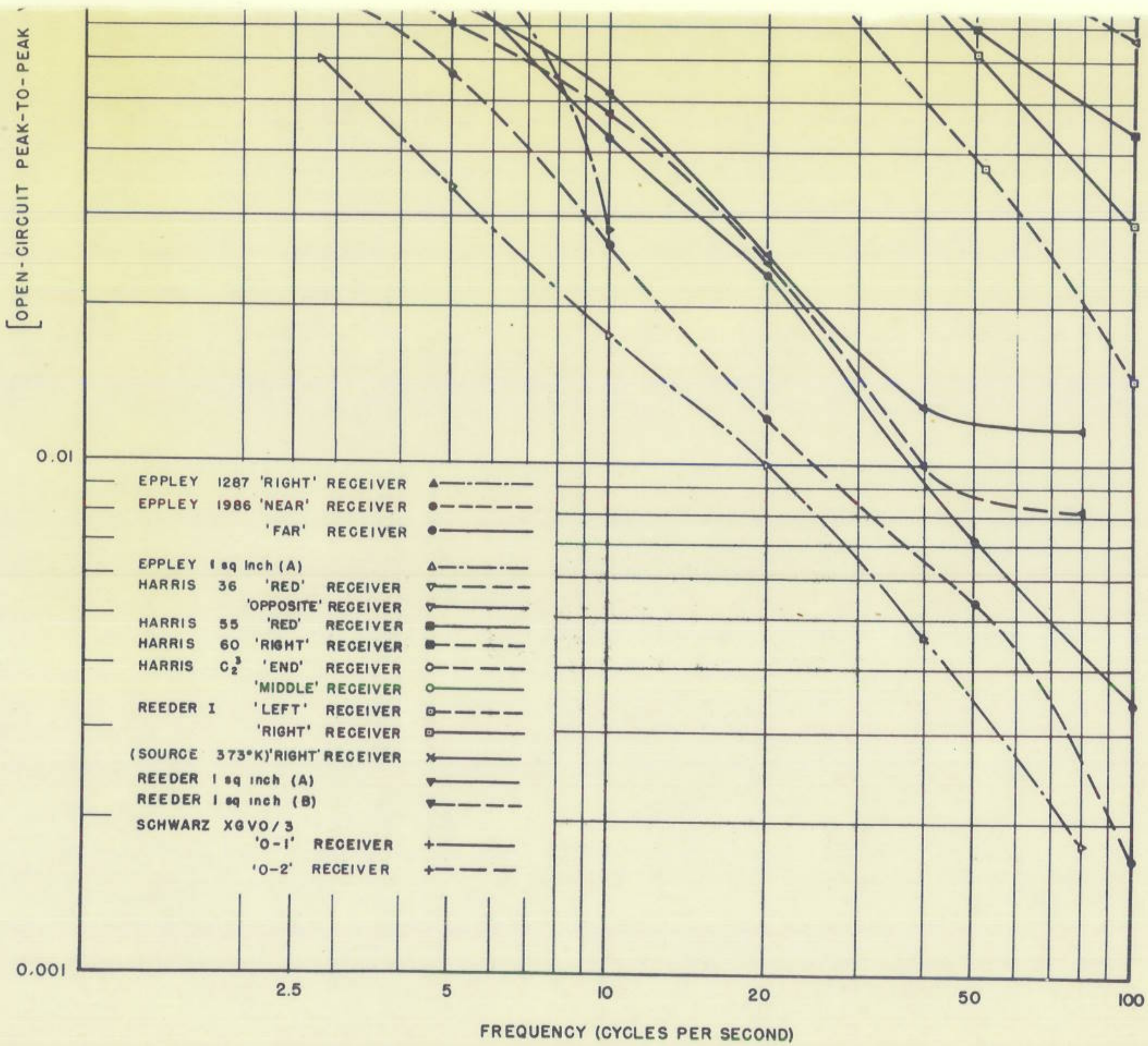
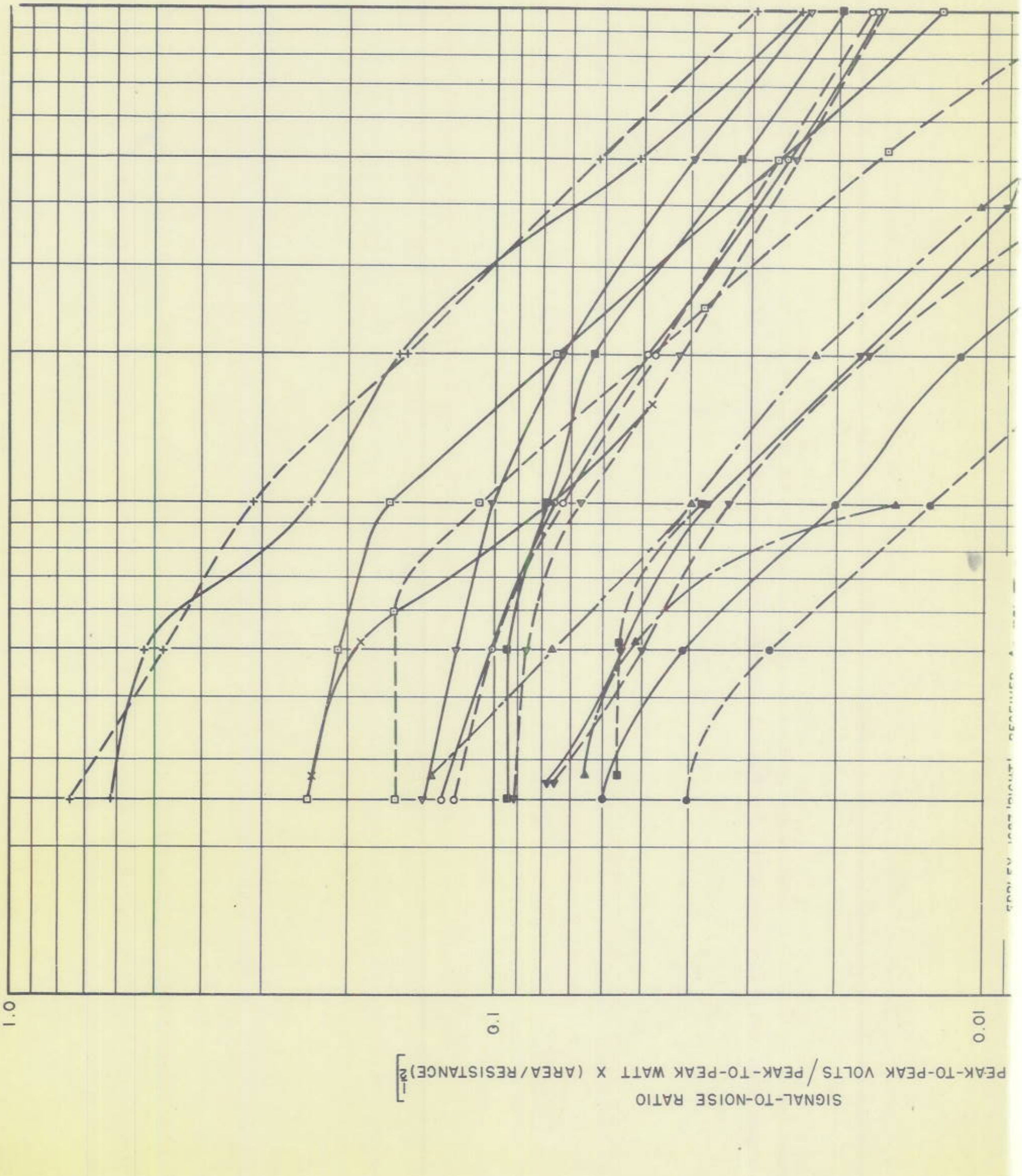


Figure 1 - Frequency response of thermopiles for irradiated-receiver area equivalent to 1 square millimeter

[redacted]

DECLASSIFIED



[redacted]

DECLASSIFIED

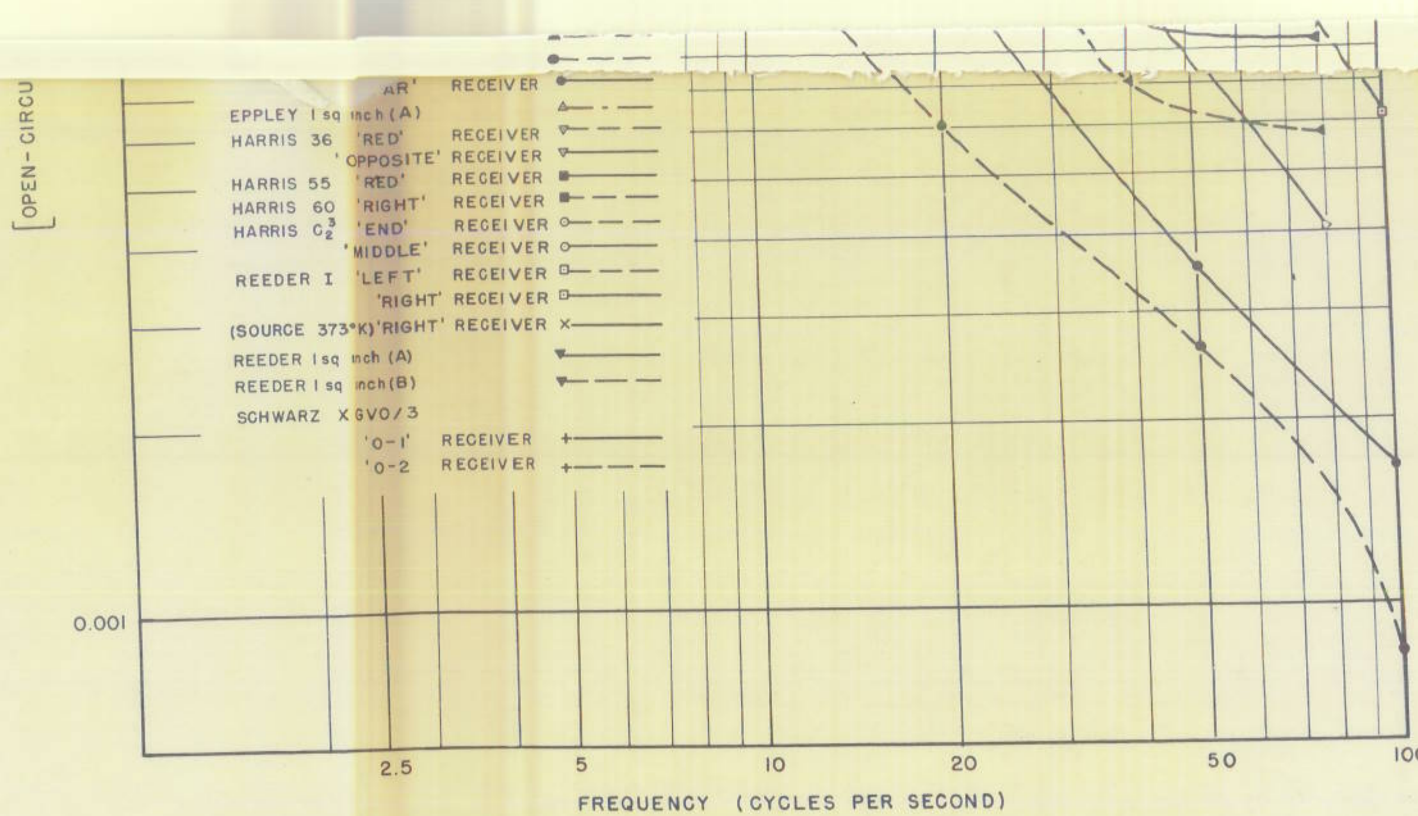


Figure 2 - Frequency response of thermopiles for irradiated-receiver area equivalent to 1 square millimeter and total resistance of thermopile equivalent to 1.0 ohm

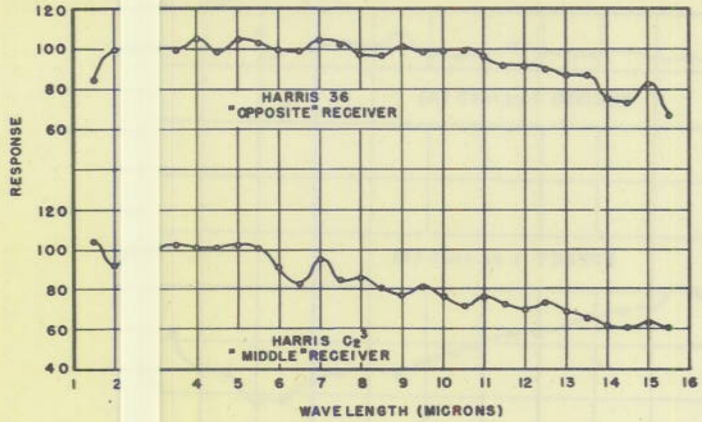


Figure 3 - Spectral response of Harris 36 and Harris C_2^3 thermopiles, relative to Perkin-Elmer No. 375

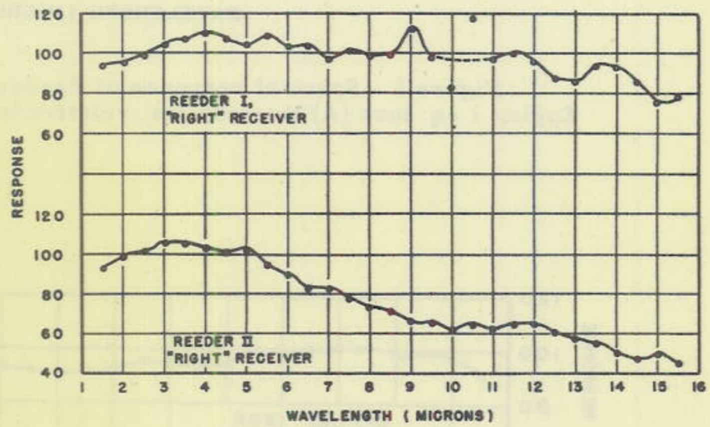


Figure 4 [illegible]pectral response of Reeder I [illegible]d Reeder II thermopiles, re[illegible]ve to Perkin-Elmer No. 375

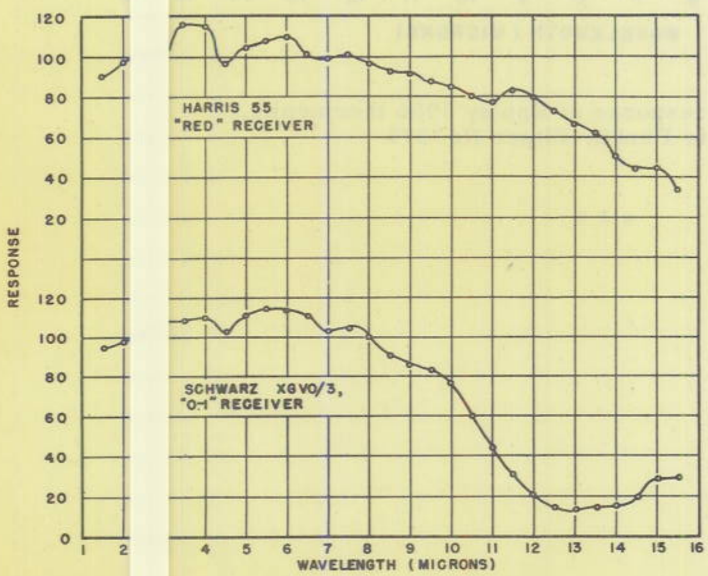


Figure 5 - Spectral response of Harris 55 and Schwarz XGVO/3 thermopiles, relative to Perkin-Elmer No. 375

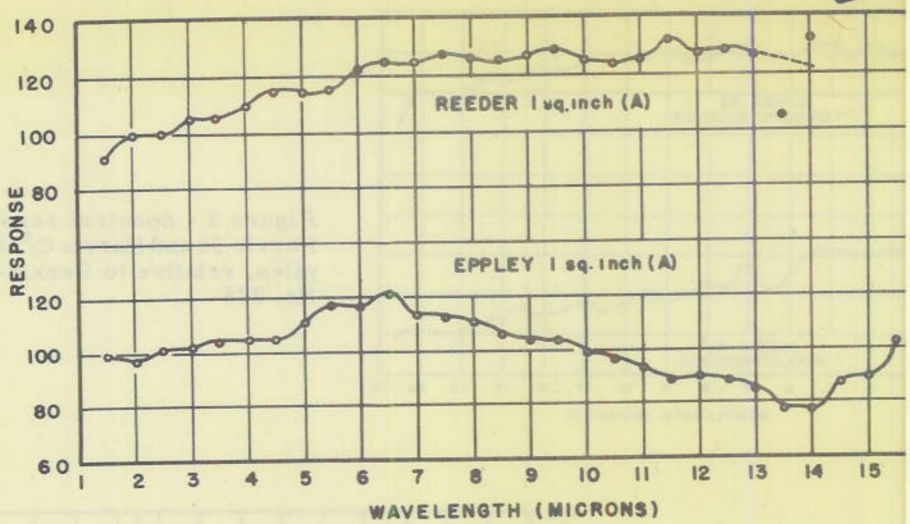


Figure 6 - Spectral response of Reeder 1 sq. inch (A) and Eppley 1 sq. inch (A) thermopiles, relative to Perkin-Elmer No. 375

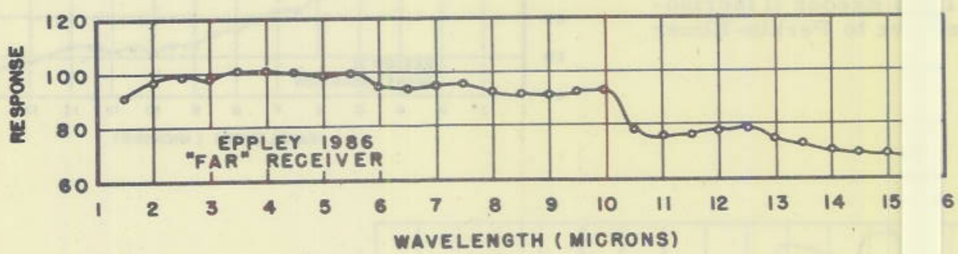


Figure 7 - Spectral response of Eppley 1986 thermopile, relative to Perkin-Elmer No. 375

* * *