NBSIR 74-580

Spectral Characteristics of Additional Bar Code Readers. II

Julius Cohen

Electronic-Optical Development Section
Measurement Engineering Division
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Supplemental Report

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Office of Postal Technology Research
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U. S. DEPARTMENT OF COMMERCE, Frederick B. Dent, Secretary

NATIONAL BUREAU OF STANDARDS, Richard W. Roberts, Director

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1. Introduction

This report deals with the measured spectral characteristics of two bar code readers submitted by the U.S. Postal Service Laboratory under Task No. 1, Agreement No. 74-02934 (Mod. No. 1). The readers shall be identified here as Reader No. 1 and Reader No. 2 as listed in the Task Statement. Two auxiliary filters, a yellow and a dark red, were supplied with Reader No. 2.

The present work is an extension of previous work at NBS, and details of the experimental approach and procedure have been reported in "Spectral Characteristics of Bar, Half-Bar Code Readers, Final Report" [1]. This report is intended to be supplementary to the former.

2. Objective

The objective is to measure the relative spectral output as a function of wavelength in the interval of approximately 450 to 1200 nm.

3. Experimental Procedure and Apparatus

Radiation emitted from an incandescent tungsten-ribbon filament passes through (1) a limiting aperture; (2) a calibrated, continuously variable filter, or wedge; (3) a discrete bandpass filter(s) (to suppress undesired orders), and finally impinges upon the photodetectors. The photodetectors are then replaced by a thermopile and the measurements repeated. The ratio of photodetector-to thermopile signal is the relative response of the former. The product of the relative response and the relative spectral radiance of the reader's lamp filaments is the relative spectral output of the system.

The present experimental procedure is similar to that previously described [1], but a few changes were made in the measurement apparatus and precedure:

1. The limiting circular aperture was replaced by a narrow slit of reduced width for high spectral purity;

2. An improved calibration of the optical wedge was obtained with the aid of newly acquired filters used for blocking unwanted orders. Table 2 of the Appendix lists the supplemental blocking filter(s) selected for use at various wavelength intervals;

3. A more efficient thermopile shroud, with integral filter box for discrete filters, was used for exclusion of stray thermal and optical radiations;

4. The operating temperature of the reader's lamp filament was measured *in situ* with an optical pyrometer, and the observed temperature converted to so-called true temperature by making a correction for spectral emissivity [2]. The relative spectral radiance of the lamp was obtained from a knowledge of lamp filament operating temperature [3].

Although Reader No. 2 was supplied with two auxiliary filters, a yellow and a dark red, the spectral output of this reader was determined without the use of these auxiliary filters. However, the transmittance of each filter was measured with a spectrophotometer over the region of 450 to 1080 nm; cf Table 4, columns 8 and 9. The product of the spectral output of the reader (unmodified) and the transmittance yielded the spectral output of the reader with auxiliary filter.

3. Results

Figures 1 and 2 are plots of normalized relative spectral outputs vs. wavelength, for Readers No. 1 and 2. Spectral outputs obtained with (1) the wedge-blocking filter combination, and (2) the narrow-band interference filters are shown, and their agreement is seen to be close. The spectral outputs of the readers are seen to be similar. Figure 2 shows also the spectral output which would be obtained if the auxiliary yellow or dark red filter, provided by the U.S.P.S., were used.

The wavelength at which the spectral output peaks, and the wavelengths at which the spectral output is 50% of the peak are tabulated below.

Table 1. Summary of relative spectral output

Reader No.	Wavelength at Peak, nm	50% Wavelengths at response nm
1	850	650; 1015
2	850	635; 1000
2 with yellow filter	660	575; 745
2 with red filter	860	720; 1000

The measured data, arranged sequentially for calculation of spectral output, are given in Tables 3 and 4 of the Appendix.

Appendix

This Appendix consists of three Tables, as follows:

Table 2 lists the supplemental filters used to block the undesired orders transmitted by the wedge.

Table 3 contains the measured data and intermediate calculations used to determine the spectral output of Reader No. 1. Similar information for Reader No. 2 is given in Table 4.

Table 2. Supplemental filters used with wedge

Wavelength interval, nm	Filter No.
450 - 580	CS 4-96 and CS 1-69
600 - 720	CS 3-68 and CS 1-69
740 - 1100	CS 7-69

Table 3. Computation of spectral characteristic of Reader No. 1

(1) Wavelength, nm	(2) Detector reading, arbitrary units	(3) Thermopile reading, arbitrary units	(4) Ratio (2)/(3)	(5) Source relative radiance (T=2620K)	(6) System spectral output (relative)	(7) System spectral output (normalized)
Wedge data						
450	0.010	0.118	0.085	0.272	0.023	2.5
520	.064	.30	.21	0.682	.14	15.4
580	.028	.11	.25	1.177	.29	31.6
600	.21	.705	.30	1.361	.41	43.8
620	.24	.77	.31	1.552	.48	51.7
640	.26	.825	.32	1.747	.56	60.0
660	.27	.84	.32	1.942	.62	66.7
680	.27	.84	.32	2.136	.68	73.5
700	.25	.80	.31	2.328	.72	77.6
720	.22	.74	.30	2.514	.75	81.0
740	.39	1.28	.30	2.694	.81	86.8
760	.41	1.46	.28	2.866	.80	86.1
780	.41	1.48	.28	3.030	.85	91.1
810	.40	1.45	.27	3.256	.88	94.4
860	.37	1.41	.26	3.581	.93	100.0
900	.31	1.35	.23	3.791	.87	93.7
940	.26	1.26	.20	3.956	.79	85.0
960	.21	1.18	.18	4.023	.72	77.8
1000	.11	0.80	.13	4.127	.54	57.7
1020	.080	.70	.11	4.164	.46	49.2
1040	.035	.49	.071	4.193	.30	32.0
1060	.015	.295	.051	4.213	.22	23.1
1080	.006	.186	.032	4.226	.14	14.5
1100	.003	.105	.029	4.231	.12	13.2
Filter data						
450	0.020	0.17	0.12	0.272	0.033	3.5
520	.087	.48	.18	0.682	.12	13.2
580	.093	.338	.28	1.177	.33	35.5
700	.75	2.20	.34	2.328	.79	85.1
810	1.14	3.98	.29	3.256	.94	101.4
900	0.68	2.90	.23	3.791	.87	93.7
1000	.31	2.45	.13	4.127	.54	57.7

Table 4. Computation of spectral characteristics of Reader No. 2

(1) Wave length, nm	(2) Detector reading, arbitrary units	(3) Thermopile reading, arbitray units	(4) Ratio (2)/(3)	(5) Source relative spectral radiance (T=2960K)	(6) System spectral output (relative)	(7) System spectral output (normalized)	(8) Yellow Filter		(9) Red Filter	
							Transmittance	System spectral output (normalized)	Transmittance	System spectral output (normalized)
Wedge data										
450	0.04	0.118	0.34	0.358	0.12	4.3				
520	.13	.30	.43	.743	.32	11.5	0.085	0.97		
580	.05	.11	.45	1.132	.51	18.3	.857	15.7		
600	.59	.705	.84	1.263	1.06	38.0	.81	30.8		
620	.69	.77	.90	1.392	1.25	44.8	.78	35.0		
640	.79	.825	.96	1.518	1.46	52.3	.75	39.3		
660	.85	.84	1.01	1.638	1.65	59.1	.72	42.6		
680	.86	.84	1.02	1.752	1.79	64.2	.655	42.0		
700	.86	.80	1.08	1.859	2.01	72.0	.535	38.5	0.007	0.50
720	.80	.74	1.08	1.959	2.12	76.0	.38	28.9	.50	38.0
740	1.34	1.28	1.05	2.050	2.15	77.1	.25	19.3	.83	64.0
760	1.68	1.46	1.15	2.133	2.45	87.8	.165	14.5	.885	77.7
780	1.73	1.48	1.17	2.208	2.58	92.5	.11	10.2	.90	83.2
810	1.70	1.45	1.17	2.303	2.69	96.4	.06	5.8	.905	87.3
860	1.62	1.41	1.15	2.422	2.79	100.0	.03	3.0	.910	91.0
900	1.40	1.35	1.04	2.483	2.58	92,6			.910	84.2
940	1.14	1.26	0.90	2.516	2.26	81.0			.913	74.0
960	0.92	1.18	.78	2.524	1.97	70.6			.912	64.4
1000	.44	0.80	.55	2.523	1.39	49.8			.915	45.6
1020	.31	.70	.44	2.516	1.11	39.8			.915	36.4

Table 4. (continued)

(1) Wave length, nm	(2) Detector reading, arbitrary units	(3) Thermopile reading, arbitrary units	(4) Ratio (2)/(3)	(5) Source relative spectral radiance (T=2960K)	(6) System spectral output (relative)	(7) System spectral output (normalized)	(8) Yellow Filter		(9) Red Filter	
							Transmittance	System spectral output (normalized)	Transmittance	System spectral output (normalized)
Wedge data										
1040	.15	.49	.31	2.504	0.78	28.0			.915	25.6
1060	.09	.295	.31	2.489	.77	27.6			.915	25.3
1080	.05	.186	.27	2.470	.67	24.0			.915	22.0
1100	.02	.105	.19	2.448	.47	16.9			.915	15.4
Filter data										
450	.08	.17	.47	.358	.17	6.1				
520	.28	.48	.58	.743	.43	15.4	.085	1.3		
580	.24	.338	.71	1.132	.80	28.7	.857	24.6		
700	2.30	2.20	1.05	1.859	1.95	69.9	.535	37.4		
810	4.80	3.98	1.21	2.303	2.79	100	.06	6.0	.905	90.5
900	2.70	2.90	.93	2.483	2.31	82.8			.910	75.3
1000	1.22	2.45	.50	2.523	1.26	45.2			.915	41.3

References

1. Greenough, M. L., et al, "Spectral Characteristics of Bar, Half-Bar Code Readers, Final Report, NBS Report 10 943, October 1972).

2. "Handbook of Chemistry and Physics," 44th ed., p. 3098 (The Chemical Rubber Publishing Co., Cleveland, Ohio, 1962-1963).

3. Pivovonsky, M., and Nagel, M. R., "Tables of Blackbody Radiation Functions," pp. 69 and 90 (The Macmillan Co., New York, N. Y., 1961).

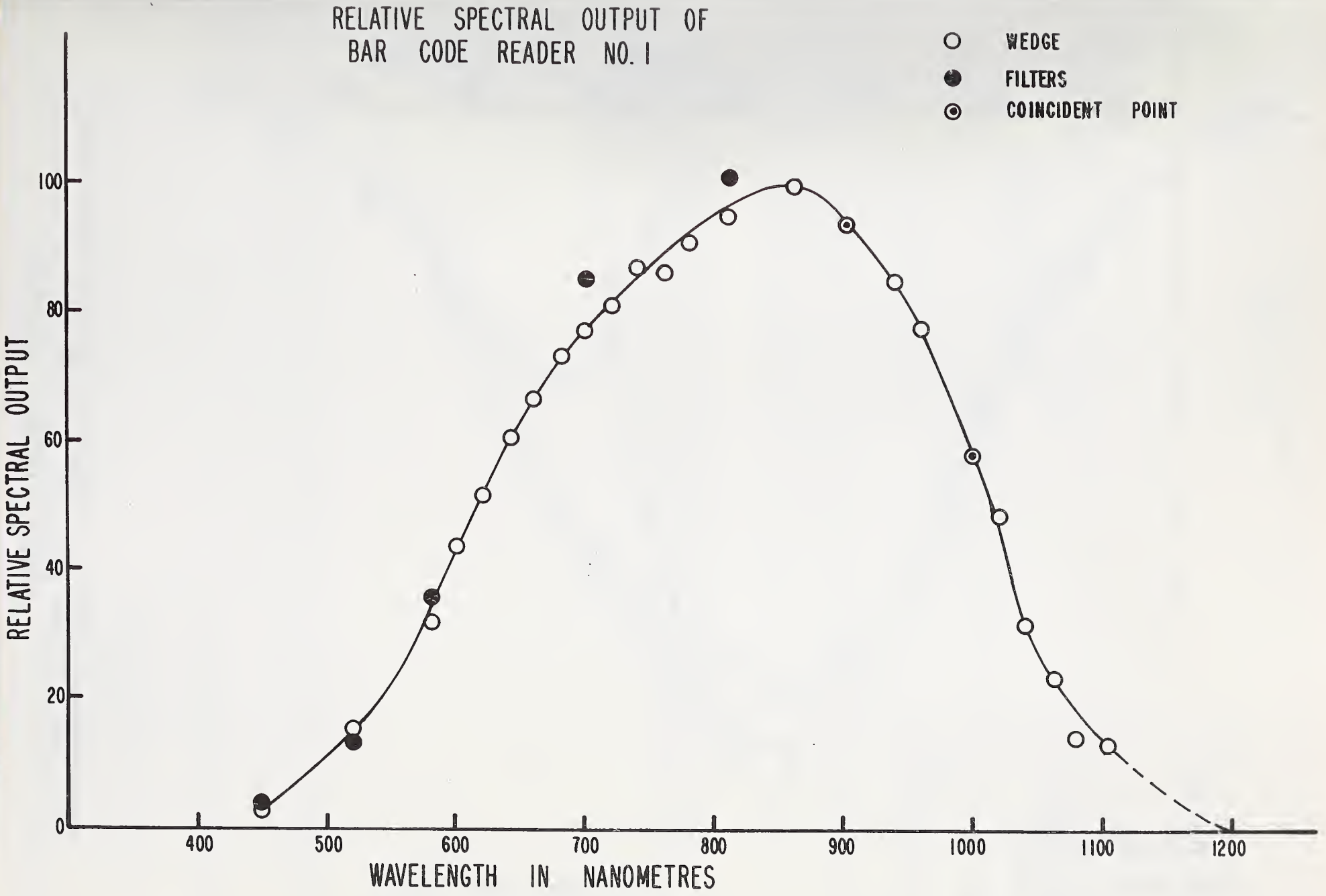

Figure 1. Relative Spectral Output of Bar Code Reader No. 1

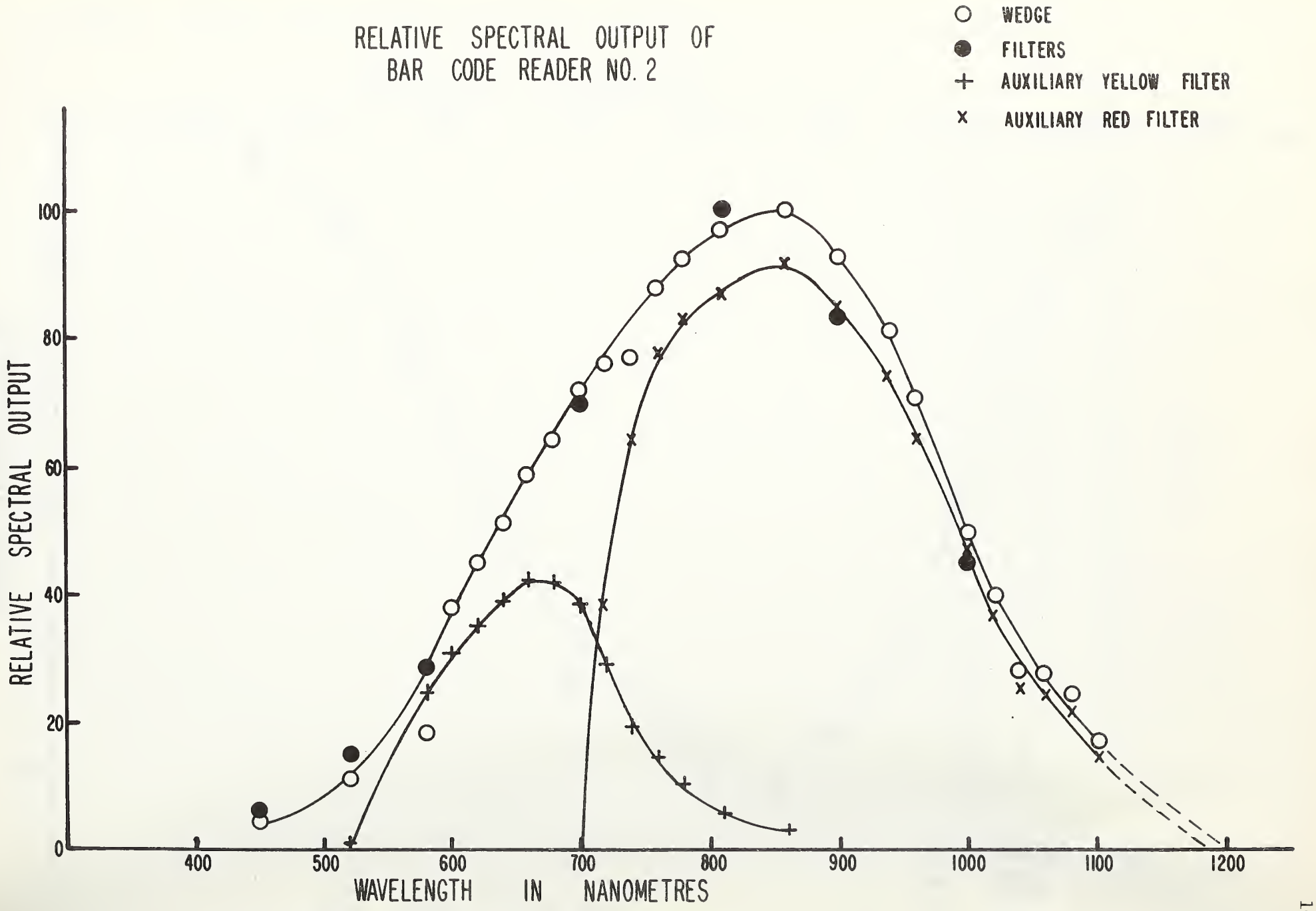

Figure 2. Relative Spectral Output of Bar Code Reader No. 2

NBS-114A (REV. 7-73)

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET	1. PUBLICATION OR REPORT NO. NBSIR 74-580	2. Gov't Accession No.	3. Recipient's Accession No.

4. TITLE AND SUBTITLE

SPECTRAL CHARACTERISTICS OF ADDITIONAL BAR CODE READERS. II

5. Publication Date: September 1974

6. Performing Organization Code

7. AUTHOR(S)
Julius Cohen

8. Performing Organ. Report No.

9. PERFORMING ORGANIZATION NAME AND ADDRESS

NATIONAL BUREAU OF STANDARDS
DEPARTMENT OF COMMERCE
WASHINGTON, D.C. 20234

10. Project/Task/Work Unit No. 4460447

11. Contract/Grant No.

12. Sponsoring Organization Name and Complete Address (*Street, City, State, ZIP*)

Office of Postal Technology Research
U. S. Postal Service
Rockville, Maryland 20852

13. Type of Report & Period Covered: Supplemental

14. Sponsoring Agency Code

15. SUPPLEMENTARY NOTES

This report is supplementary to " Spectral Characteristics of Bar, Half-Bar Code Readers, Final Report,"NBS Report 10 943 (October 1972).

16. ABSTRACT (*A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.*)

The spectral characteristics of two bar code readers (submitted by the U.S. Postal Service under Task No. 1, Agreement No. 74-02934 [Mod. No. 1]) have been measured as a function of wavelength in the approximate interval of 450 to 1200 nm.

17. KEY WORDS (*six to twelve entries; alphabetical order, capitalize only the first letter of the first key word unless a proper name; separated by semicolons*)

Bar code reader; filters; optical wedge; photodetector; relative spectral output; wavelength

18. AVAILABILITY [X] Unlimited

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[ ] Order From National Technical Information Service (NTIS) Springfield, Virginia 22151

19. SECURITY CLASS (THIS REPORT): UNCLASSIFIED

21. NO. OF PAGES: 11

20. SECURITY CLASS (THIS PAGE): UNCLASSIFIED

22. Price

USCOMM-DC 29042-P74


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1776-1976