REPORT NO. R-2266

DATE 14 March 1944

[redacted]

SUBJECT

A Summary of Measurement on Infra-red Decoys for Homing Missiles, October, 1943 to March 1944

FR-2264

Date: 14 March 1944 NRL Report No. H-2266

NAVY DEPARTMENT

Report on

A SUMMARY OF MEASUREMENTS ON INFRA-RED DECOYS FOR HOMING MISSILES, OCTOBER, 1943 TO MARCH, 1944

Naval Research Laboratory
Anacostia Station
Washington 25, D. C.

Number of Pages: Text - 7 Plates - 1 Tables - 1
Authorization: BuShips Project Order No. 2226/42 of 18 March, 1942.

Prepared by: _____
J. A. Sanderson

Reviewed by: _____
E. O. Hulburt, Superintendent
Physical Optics Division

Approved by: _____
A. H. Van Keuren, Rear Admiral, USN
Director

Distribution:
(3) BuShips
(2) BuOrd
(2) BuAero
(1) SONRD

ABSTRACT

This report summarizes recent measurements of the radiant intensity of heat sources of interest as decoys for infra-red-guided missiles, and in particular, the results of measurements of the apparent black body temperatures of gasoline-benzene filled incendiary bombs are discussed. The flames produced by these bombs containing 40 pound charges when ignited on water radiated in the 7.5 to 10 micron infra-red spectrum like 800° K to 900° K black bodies. The emission of heat was computed to be about 300 watts/ft^2 in the 8.5 - 13μ region, and each bomb was estimated to cover about 100 square feet emitting a total of 30 KW in this spectral band. These numbers are a little larger than the results of earlier measurements on similar bombs containing 7 pound charges and radiating 180 watts/ft^2 between 7.5 and 10μ and about 3 KW over about 16 square feet total area.

Examples of total upward radiation based on temperature measurements over several ships are given; the values range from 290 KW for a battleship in sunlight in warm air and cool water to -28 KW for a ship with deck temperature lower than sea temperature. In the first case, perhaps the equivalent of 10 of the bombs measured would be required as decoy; in the second case the controls of an infra-red missile might operate in reverse or be affected by a weak decoy.

A flame thrower discharged on water was not so impressive as when fired on land, and the simple bombs apparently produced equally intense flames.

It is pointed out that spectral transmission measurements of white screening smokes have shown that they may transmit 50 percent of 9μ radiation when thick enough to produce complete hiding in the visible. It is conjectured that heavy black smoke produced by the ship's furnaces may be of larger particle size and, thus, of greater hiding power in the infra-red but that the temperature of the freshly emitted smoke may defeat its use as an infra-red screening agent, Experiments are necessary here.

SUMMARY OF RADIATION MEASUREMENTS ON DECOYS FOR INFRA-RED-GUIDED MISSILES

In connection with the general problem of countermeasures against guided missiles[1], measurements have been made by NRL from time to time on several heat decoys for use against homing missiles presumed to employ infra-red detectors. This report summarizes the results and describes new measurements on gasoline-benzole filled incendiary bombs developed by the Bureau of Ordnance and the Edgewood Arsenal.

Flares

The total radiation from brilliant visible flares[2] was found to be about 1 KW, nearly all of which was in the visible and the infra-red wave-lengths below 3 microns. Since it may be presumed that an enemy target seeking device will probably be blind to visible and short wave-length infra-red light, through the use of filters, to exclude disturbance by reflected sunlight, there has been little further interest in the flares.

Flame Thrower

On 14 October, 1943, measurements were made by NRL at Fort Belvoir of the total radiation from flames produced by portable flame throwers ejecting 4 gallons of fuel in about 15 seconds on the ground[3]. Two fuels were used: gasoline, kerosene and heavy bunker oil, and a jell of Napalm in gasoline. The total radiation of all wave-lengths in the first case was 45 KW and in the second, 40 KW, and the two flames were essentially alike. The measurements were made at a distance of about 100 yards affording a limited amount of filtering of short wave-length emission bands of hot CO_2 and water vapor. Use of a glass filter showed that about 16 KW of the total emission was in the infra-red beyond 3μ, but no means were available at the time for a more complete analysis of the spectrum.

Selective Radiation Telescope

It seemed of interest to measure the intensity of the radiation in the 8.5 to 13μ region where the flame is not a selective emitter of CO_2 and water bands which are reabsorbed by the atmosphere, and where the atmosphere is transparent, and where a homing device must be sensitive because targets themselves at normal temperatures emit in this region.

Accordingly, a radiation telescope was constructed employing a 10 cm diameter, 20 cm focal length telescope mirror and a secondary plane reflector suitably located on the optic axis to reflect convergent light from the telescope mirror to a focus on a single junction 2 mm diameter (0.6° field of view) thermocouple. When the plane mirror was of aluminized glass the instrument measured total radiation; when a quartz reflector was used the reflected radiation was principally in a band between 7.5 and 10μ with maximum intensity at

about 9μ thus fulfilling the condition of measuring in a part of the spectrum free from selective emission by the flame. The quartz reflector was coated with a powder film of magnesium oxide further to purify the spectrum by eliminating 4 to 8 percent of short wave-length radiation which would be reflected by polished quartz. The reflection curve of the oxide coated quartz is shown in Plate 1.

Incendiary Bombs: 7 Pound Charge

The billowing flames of high intensity produced by the flame thrower had appeared promising for some situations. It appeared, practically, that large containers filled with gasoline and containing a sufficient charge of explosive to disrupt the casing and ignite the fuel without wide dispersion of the flame would be of interest. The construction of such incendiary bombs was successfully undertaken by the Bureau of Ordnance and the Edgewood Arsenal, and the first set containing 7 pounds of fuel in 100 pound incendiary bomb casings were measured at Solomons, Maryland on 22 January 1944(4). These measurements showed that the radiation of the gasoline flames in the 7.5 to 10μ spectral band embraced by the instrument was equivalent to that of a black body at about 500° C, and that it amounted to about 180 watts/foot^2, or about 3 KW total for a typical 7 pound charge producing a little more than 15 square feet of flame. Differences in behavior of individual fuel mixtures were largely lost in widely differing behavior of the bombs upon explosion. It was concluded that larger bombs were required.

Forty Pound Charges

The most recent experiments on 1 March 1944 at Edgewood were made on bombs consisting of 40 pound charges of various mixtures of gasoline and benzole in Napalm, in 100 pound incendiary bomb casings. Again, the apparent black body temperatures in the 7.5 to 10μ region represented in Plate 1 were measured, and from these the radiation in the 8.5 to 13μ region was computed. The temperature measurements are given in Table 1. While distinct differences in black body temperatures and in burning time were observed, it was again true that the individual flame patterns of the eight bombs differed widely enough to make conclusions regarding the fuels difficult. Benzole had been added in each case to increase the amount of hot carbon in the flames thus enhancing the non-selective long wave-length radiation, but it is not possible to say without comparative experiments on fuels without benzole whether the excess black smoke produced by it defeated the purpose.

Maximum black body temperatures in excess of 600° C were recorded, usually 15 to 30 seconds after ignition. Considering a safe average temperature to be 527° C = 800° K and a maximum maintainable temperature to be 627° C = 900° K, it was assumed that the radiation emitted by the flame in the 8.5 to 13μ region, at least, would be effective against infra-red homing devices, and this quantity was evaluated for 800° K and 900° K black bodies. For comparison, the total emission of black bodies at these temperatures relative to a water background temperature of 4° C (observed when the measurements were made) is also given, although the flames probably are not of constant emissivity throughout

the spectrum. But it is not known how much of the spectrum of the flame would be effective; the two figures represent, therefore, maximum and minimum values.

The results are:

	Total Radiation by Black Body	8.5 - 13μ	Ratio
800° K	2070 watts/ft^2	270	0.13
900° K	3300	330	0.10

A value 3000 watts per square foot for the total radiation and 300 watts per square foot in the 8.5 - 13μ region may be adopted for purposes of discussion. The 40 pound charges of these bombs covered about 100 square feet with flame for a useful time. Hence, the total radiation was about 300 KW and the total 8.5 - 13μ radiation was about 30 KW. In view of these results the earlier measurements on flame throwers seem conservative, for the sensation of heat from the flame thrower on land is vastly more impressive than the relatively gentle fires produced by the bombs.

Flame Thrower on Water

A standard portable flame thrower produced flames on water quite unlike those observed at Fort Belvoir. The flame was a long streak about 2 or 3 feet wide. A maximum radiation temperature of 610° C was recorded. The total area of flame did not appear to be greatly in excess of that of a typical bomb.

RADIATION BY SHIPS

The radiation from decoys must be compared with the thermal brightnesses of the targets they are to protect, and here there is almost unlimited variety.

Battleship in Sunlight

Measurements by the Bureau of Ordnance (Lt. Phillip Nolan) on one occasion showed, sea temperature 65° F, ship = air temperature, 80° F. The total radiation relative to the sea of a target 600 feet long and 100 feet wide would be 290 KW.

But if the temperature difference between sea and ship were 1° C and there were not any hot stacks the total radiation would be only 2.4 KW. The intensity of radiation upward from the stacks of ships is not yet fully known.

Destroyer at Night

Recent temperature measurements on the stacks and hull of a destroyer indicated a total radiation intensity of about 24 KW against the horizon sky[5]. Situations could exist when the same intensity would be observed against the sea in daylight or at night.

Computation of ship radiation intensities at night based on measurements at ranges of several miles have indicated 2 to 3 KW total emission for destroyers and other ships(2). In these cases the measurements included only radiation filtered through 2.5 to 6 miles of atmosphere.

Destroyer Tender

This 5200 ton ship was 400 feet long, beam 54 feet. The deck was at 7° C, sea 10° C, and the stack of effective area viewed at 45° from above, about 100 square feet, was at 25° C. A calculation for a detector scanning the scene and encompassing the image of the entire ship on its sensitive element gave the result that the net effective target radiation was -28 K.f. A homing device thus may encounter situations when it must operate against a cold target.

Destroyer Escort at Anchor Under Overcast Sky in Daylight

The sea was at 3.0° C, the deck, 7° C, and a small area about 5 feet square on the stack was at 50° C. Under way, perhaps 100 square feet of stack might be effective. Let the deck area be 6000 square feet. The total upward radiation relative to the sea is then about 13 KW of which 7 KW is from the deck and 6 KW from the stack.

CONCLUSIONS

It cannot be predicted whether gasoline flames will form adequate decoys against infra-red homing missiles. The estimates which have been given indicate that as much as 1000 square feet of flames such as those observed might be required to equal the radiation from a warm battle ship in cool water. This does not necessarily mean that 1000 square feet of the sea must be covered, but that a flame equivalent in radiation to 1000 square feet of flames such as were measured must be used. On the other hand, if the supposed device employed radiation at wave-lengths outside the 8.5 - 13μ region (as it probably would, in view of known filter characteristics) a smaller flame would be adequate, but it could not be more than ten times smaller. Since the estimates given here are subject to wide variations, it is as likely that the equivalent of 10000 square feet might be required.

The bombs which were measured did not spread in a way to make measurements of area easy, but bomb No. 1 covered an area about 12 feet in diameter or 113 = 100 square feet. Ten such bombs might be required in the situation described.

On the other hand, a single bomb might be effective on a cold overcast day when ship and sea are nearly at the same temperature, assuming that the hot stacks of the ship are not too prominent.

The question perhaps cannot be settled finally without recourse to the trying experiment of using such a bomb while under attack by a homing missile. But measurement of target intensities now in progress by the Bureau of Ordnance will contribute to the answer and will permit the direct comparison from the air of target and flame intensities.

Smoke Screens

The spectral transmission of typical white smoke screens was measured at this Laboratory some time ago(6), and it was found that these smokes of fine particles may transmit the 9μ region of the spectrum quite well while hiding the scene completely in the visible spectrum. It seems probable that thin smoke screens of this type would not completely screen the ship from a far infra-red detector. Generation of black smoke by the ship's own furnaces might be more effective and should be tried, with observation from the air. This smoke would be hot at the point of emergence from the stack and its screening action might be offset by its temperature.

It has been surmised that an infra-red homing device would be blind to reflected sunlight. If it is sensitive to all wave-lengths, then sunlight reflected from a white smoke screen could possibly block its positive action. Black smoke from the stacks may contain larger particles and hence be more opaque to long wave-length infra-red light, but it is not known surely that this is true.

[redacted]

REFERENCES

1. Coord. ltr. (SC)A13-7 of 8 January 1943 to BuShips.

2. NRL ltr. S-S70-4(1)(422) of 14 October, 1943 to BuShips, "Radiation from Flares and Infra-Red Radiation from Ships."

3. Coord. ltr. HGD:mk (SC) of 26 October 1943 to Deputy Chief of Naval Operations (Air): Encl. (A), "Report of 16 October 1943 Conference on Decoys for Homing Type Missiles."

4. NRL ltr. S-F42-1/84 RCM(422WRH) of 3 February 1944 to BuShips: Encl. A, Memorandum on Radiation Measurements on Incendiary Bombs.

5. NRL Report No. H-2248 of 29 February 1944, "Tests at Sea of the General Motors Radiant Heat Detector in Tracking a Destroyer."

6. NRL Report No. H-1602 of 25 March 1940, "The Attenuation of Light by Smoke Screens."

[redacted]

Table 1. Apparent black-body temperatures for 7.5 - 10μ radiation of gasoline-benzole filled incendiary bombs.

No.	Composition	Time after ignition	Apparent black body temperature	
1	12% Napalm in 50% Quartermaster Gasoline 50% benzole Total: 40 lbs.	00:10^{s}	470	The blaze was uniform over a 12 foot diam. area at maximum intensity.
		00:20	665	
		00:40	680	
		00:50	660	
		1^{m}:15^{s}	635	
		2:00	510	
		2:30	460	
		3:00	510	
2	4% Napalm in 50% Conoco Narrow cut; 50% benzole Total: 40 lbs.	00:15^{s}	650	A ring about 15 ft. diam., center dark.
		00:25	610	
		00:45	630	
		00:60	585	
3	4% Napalm in 50% QM; 50% benzole Total: 40 lbs.	00:30	660	
		00:45	430	
		00:60	585	
		1:30	515	
		2:00	595	
		3:45	430	
4	4% Napalm in 50% Conoco; 50% benzole Total: 40 lbs.	00:30	590	At maximum temp. the flame was a ring about 30 ft. in diameter
		00:45	605	
		00:60	410	
		1:30	410	
		2:00	340	
		3:00	195	widely scattered
5	12% Napalm in 50% QM; 50% Casinghead gasoline Total: 40 lbs.	00:15	430	Exploded in air; widely scattered after 1 minute.
		00:30	330	
		1:15	150	
		1:30	290	
		2:00	290	
6	12% Napalm in 50% Casinghead; 50% benzole Total: 37.5 lbs.	00:15	280	Fired deep in water. Not smoky. Flames scattered and weak after 2 minutes.
		00:30	330	
		1:00	295	

[redacted]

Table 1 (Continued)

No.	Composition	Time after ignition	Apparent black body temperature	
7	12% Napalm in 50% QM; 50% benzole Total: 40 lbs		560 590	A quick explosion. The flames spread into a ring about 30 feet in diam.
8	40 lbs: 4% Napalm in 50% QM; 50% benzole	00:15 00:30 00:45	470 630 660	Very smoky. At 45 sec. the flames were in a ring about 15 ft. in diameter.
	Flame thrower		610 to 580	A long narrow streak of flame quite unlike behavior on land.

[redacted]

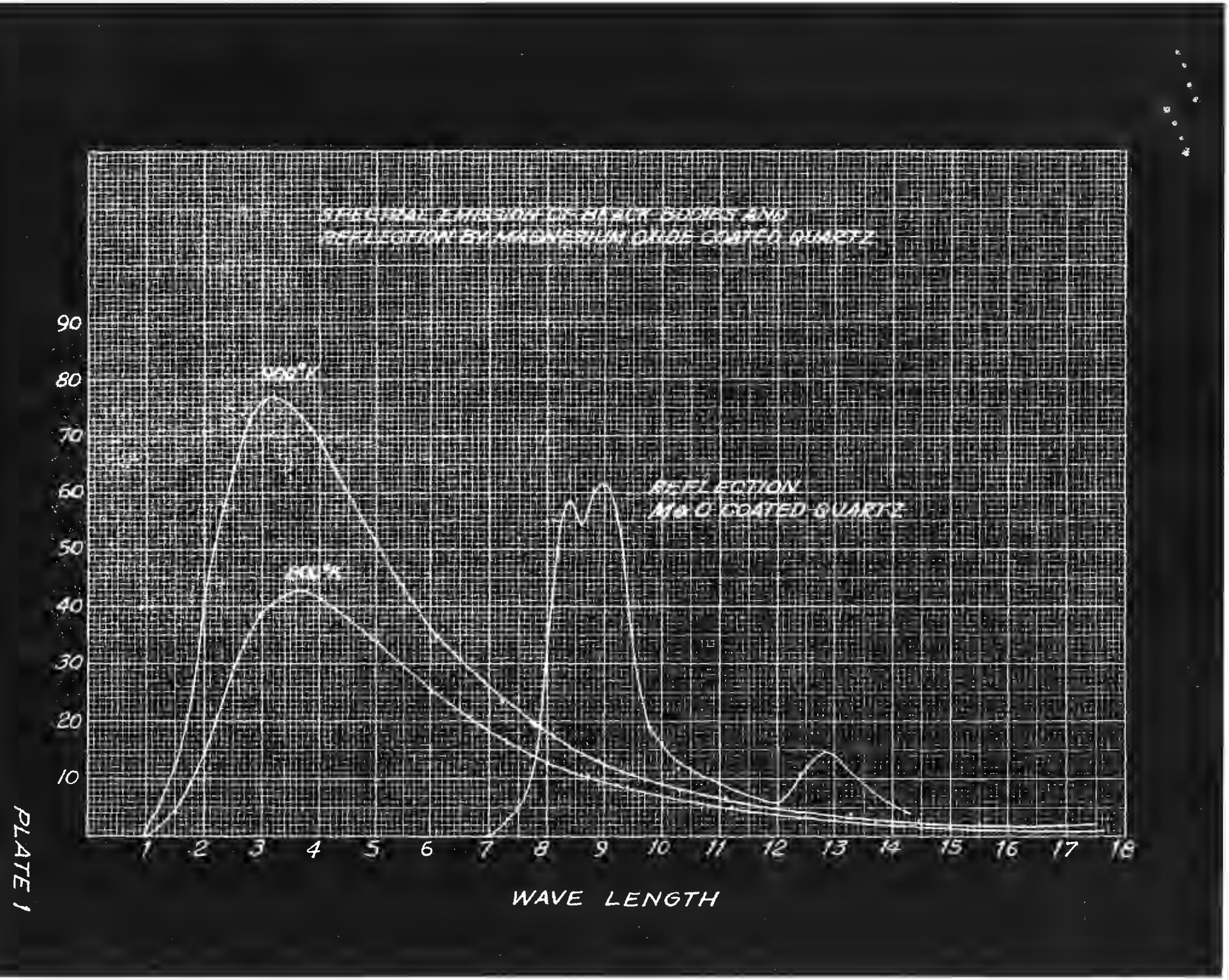

PLATE 1