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ULTRAVIOLET AND NEAR-INFRARED SPECTRAL ANALYSIS OF A BURNER-CAN BURN-THROUGH FLAME

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16. Abstract

The near-infrared and ultraviolet spectrum of a burner-can burn-through flame was analyzed using a J47 engine to produce the burn-through flame. Charts of the power output of the flame in the near-infrared and ultraviolet were produced for various engine power settings.

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PREFACE

The author wishes to acknowledge the valuable assistance given by Duane Fox, of the Air Force Aero Propulsion Laboratory/SFH, in analyzing the burn-through flame.

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INTRODUCTION

PURPOSE.

The purpose of this project was to determine the power output of a burner-can burn-through flame in the ultraviolet and near-infrared regions.

BACKGROUND.

Fire detectors in service have detected burner-can failures, but some fires have gone undetected and often undiscovered until routine ground inspection. A burn-through impinging on a vital aircraft structure can endanger the entire aircraft when an early detection is not obtained.

The determination of the spectral output of a burn-through flame in the ultraviolet and near-infrared region will give detector manufacturers a guideline on the range and sensitivity needed to detect a burn-through flame using an ultraviolet or infrared detector.

DISCUSSION

EQUIPMENT DESCRIPTION.

A J47 jet engine was used to produce a burn-through flame varying in pressure from 6 inches of Mercury (Hg) gauge to 100 inches of Hg gauge and in temperature from 2300° Rankine (R) to 3500°R (see Figure 1). Two EG and G, model 585, spectroradiometers were used to analyze the ultraviolet and near-infrared spectrum of the burn-through flame, and an X-Y plotter was used to record the data. The spectroradiometer, used in the ultraviolet range, was calibrated between 200 and 300 millimicrons and contained the following items:

1. Monochromotor Housing Assembly, Model 585-11.
2. Monochromotor Grating, Model 585-24.
3. Monochromotor Slits, Entrance 5.36 millimeter (mm), Exit 3.00 mm, Model 585-20-21.
4. Beam Input Optics, Model 585-32.
5. Filters (Corning), Model 585-20-1.
6. High-Sensitivity Detector Head, Model 585-66.

The spectroradiometer used in the near-infrared range was calibrated between 700 and 1200 millimicrons and contained the following items:

1. Monochromotor Housing Assembly, Model 585-11.
2. Monochromotor Grating, Model 585-23.
3. Monochromotor Slits, Entrance 2.68 mm, Exit 1.50 mm, Model 585-20-22.
4. Beam Input Optics, Model 585-31.
5. Filters (Corning), Model 585-20-13.
6. Detector Head, Model 580-23A.

TEST PROCEDURE.

The EG and G spectroradiometer was placed 6 feet from the burn-through hole on a J47 engine and perpendicular to the burn-through flame (see Figure 2). The spectroradiometer was then operated by remote control from a block house, as were the J47 engine and the burn-through flame.

The near-infrared spectrum was recorded during the daylight hours, with a background reading being taken with the engine running and the flame OFF: then the infrared spectrum of the flame was scanned at the same engine power settings. The ultraviolet spectrum was recorded after dark, and the background was essentially zero.

The test procedure for all tests was as follows:

1. The J47 engine was brought up to the predetermined test revolution per minute (r/min) percentage.

2. The Burn-through flame was turned ON.

3. The spectroradiometer scanned the ultraviolet or near-infrared spectrum.

4. The ultraviolet or near-infrared spectrum was plotted on an X-Y recorder.

5. The Burn-through flame was turned OFF, and the J47 engine was shut down.

Ultraviolet tests were run under the conditions shown in Table 1, and the near-infrared tests were run under the conditions shown in Table 2.

DISCUSSION OF RESULTS.

The results of the five ultraviolet test runs can be seen in Figures 3 through 7, with a comparison of all five tests in Figure 8. The graphs show the power in watts per square centimeter for a bandwidth of one millimicron verse wavelength at a distance of 6 feet from the burn-through hole. It can be seen that the only test that does not seem to follow the same pattern as the others is the 30-percent r/min run, which was the only subsonic flame analyzed. Table 3 is a compilation of the total power according to bands of wavelengths and for the entire ultraviolet region analyzed (200 and 300 millimicrons).

The results of the five near-infrared test runs can be seen in Figures 9 through 13 with a comparison of the spectral power above the background shown in Figure 14. This comparison was obtained by determining the difference between the flame-ON and flame-OFF spectrum (as shown in Figures 9 through 13). Table 4 is a compilation of total power above the background

TABLE 1. ENGINE CHARACTERISTICS - ULTRAVIOLET TESTS

r/min (%)	Compressor Pressure (in. Hg gauge)	Stagnation Temperature at Burn-Through Hole (°R)
30	6	2300
60	28	2600
70	48	3000
80	74	3200
90	100	3500

TABLE 2. ENGINE CHARACTERISTICS - INFRARED TESTS

r/min (%)	Compressor Pressure (in. Hg gauge)	Stagnation Temperature at Burn-Through Hole (°R)
30	6	2300
60	28	2600
70	50	3000
80	75	3200
90	100	3500

according to bands of wavelengths and for the entire near-infrared region analyzed (700 - 1100 millimicrons). It should be noted that the figures in this report represent not only the burn-through flame, but also the radiation of the burner-can itself during a burn-through condition. Although this burner-can radiation is felt to have had little effect on the ultraviolet and lower near-infrared data, it had a rather large effect on the 80- and 90-percent r/min near-infrared tests.

In both the ultraviolet and the infrared spectrums for the supersonic flame, as the wavelength increased, the power output also increased. The greater the pressure ratio of the flame, the greater the increase in power output as the wavelength increased.

TABLE 3. TOTAL ULTRAVIOLET POWER BETWEEN 200 AND 300 MILLIMICRONS

Engine r/min Pressure	Spectral Range (Millimicrons) 200-210	210-220	220-230	230-240	240-250	250-260	260-270	270-280	280-290	290-300	Total
30% 6 in. Hg	10.4*	7.3	6.6	9.0	10.0	10.9	14.5	14.5	19.8	21.0	124.0
60% 28 in. Hg	3.2	2.5	2.7	4.1	7.2	12.6	19.5	22.9	34.2	37.1	146.0
70% 48 in. Hg	3.2	2.5	2.7	4.3	7.3	11.1	18.5	22.2	33.4	37.2	142.4
80% 74 in. Hg	5.9	5.8	6.0	7.5	11.6	19.1	26.3	31.2	47.5	49.5	210.4
90% 100 in. Hg	7.5	11.1	14.4	19.6	23.0	25.0	32.1	36.5	52.4	63.4	285.0

* Figures are all Watts/cm^2 x 10^{10} at a distance of 6 feet from the burn-through flame.

TABLE 4. TOTAL NEAR-INFRARED POWER BETWEEN 700 and 1100 MILLIMICRONS

Engine r/min Pressure	Spectral Range (Millimicrons) 700-800	800-900	900-1000	1000-1100	Total 700-1100
30% 6 in. Hg	41.2*	69.1	80.0	107.0	297.3
60% 28 in. Hg	5.8	20.4	44.2	83.1	153.5
70% 50 in. Hg	17.4	37.0	90.3	147.5	292.3
80% 75 in. Hg	29.6	108.0	227.7	341.8	707.1
90% 100 in. Hg	76.5	384.2	953.5	1538.0	2952.2

* Figures are all Watts/cm^2 x 10^7 at a distance of 6 feet from the burn-through flame.

SUMMARY OF RESULTS

1. The ultraviolet (200 to 300 millimicrons) and near-infrared (700 to 1100 millimicrons) spectrum of a jet engine burn-through, having pressures of 6-, 28-, 50-, 75-, and 100-inches Hg gauge, was analyzed and graphed.

2. Total ultraviolet and near-infrared power of a burner-can burn-through was determined between 200 and 300 millimicrons and between 700 and 1100 millimicrons.

FIGURE 1. J47 BURN-THROUGH FLAME AT 90 PERCENT R/MIN.

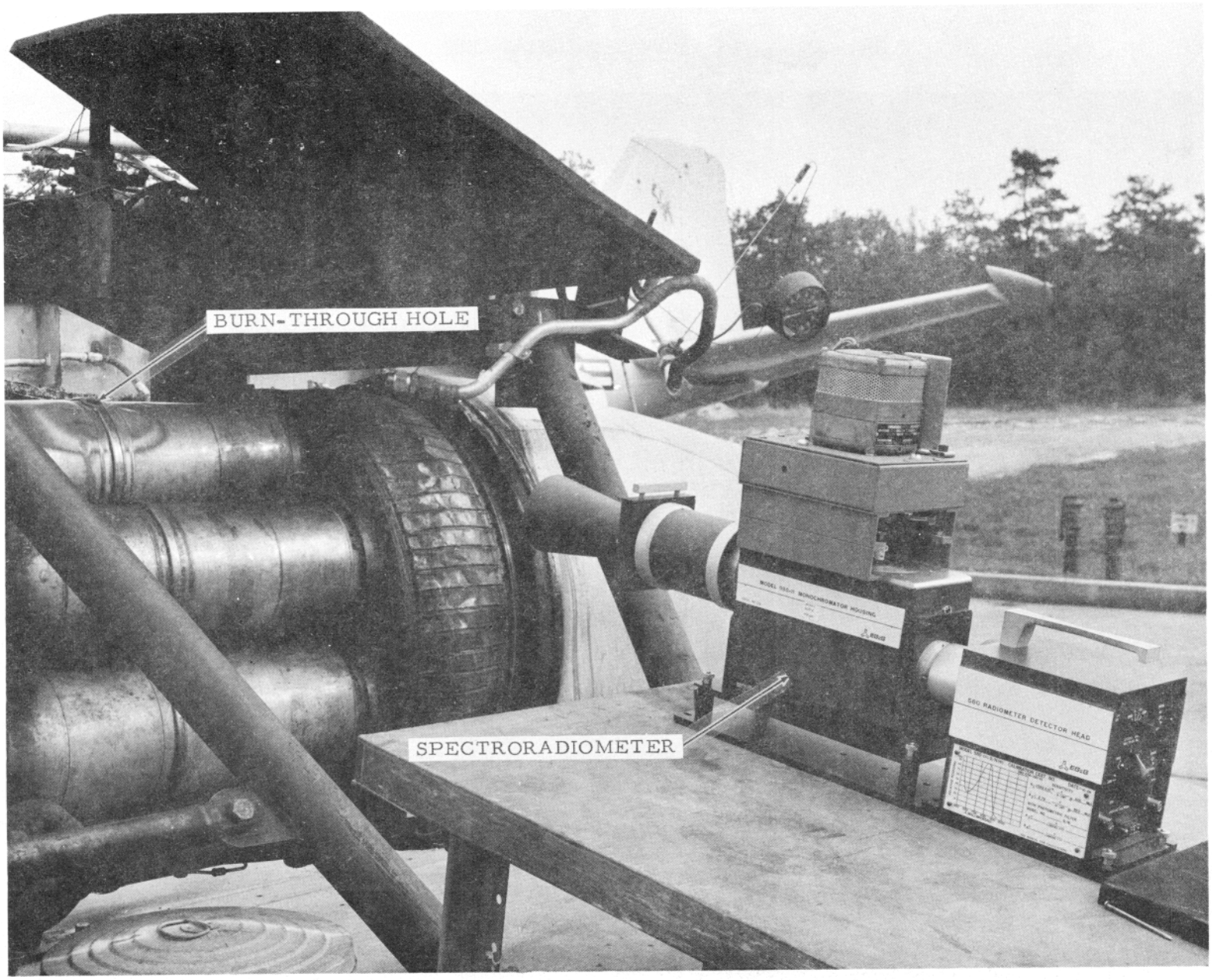

FIGURE 2. J47 ENGINE WITH SPECTRORADIOMETER IN TEST POSITION.

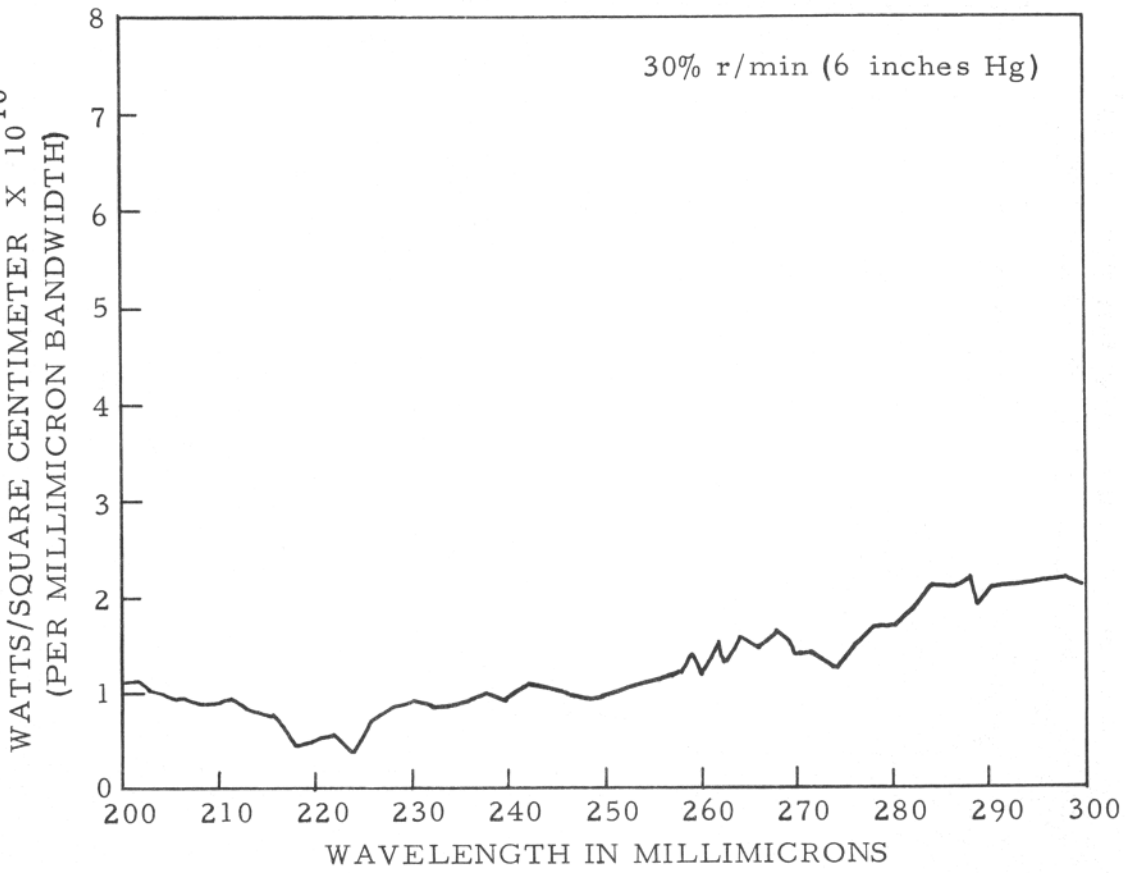

FIGURE 3. ULTRAVIOLET SPECTRUM OF J47 ENGINE AT 30 PERCENT R/MIN, 6 FEET FROM BURN-THROUGH FLAME.

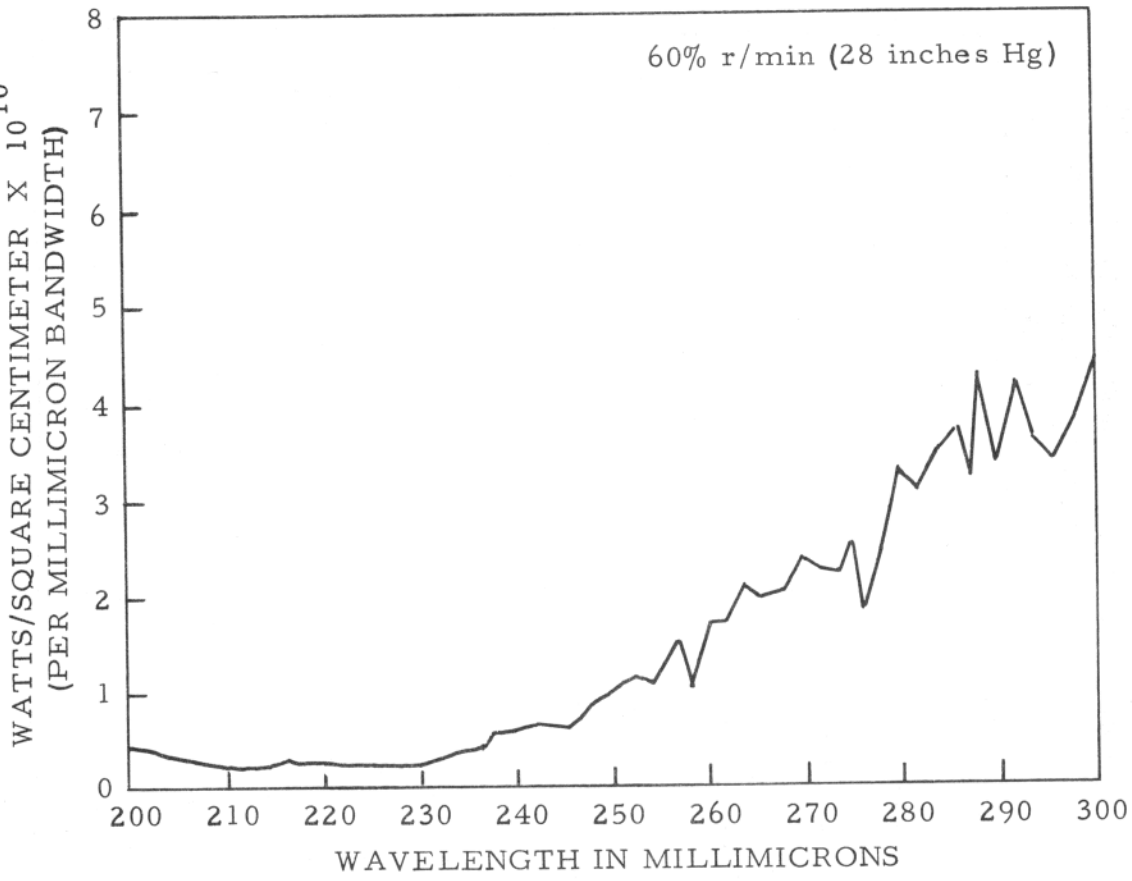

FIGURE 4. ULTRAVIOLET SPECTRUM OF J47 ENGINE AT 60 PERCENT R/MIN, 6 FEET FROM BURN-THROUGH FLAME.

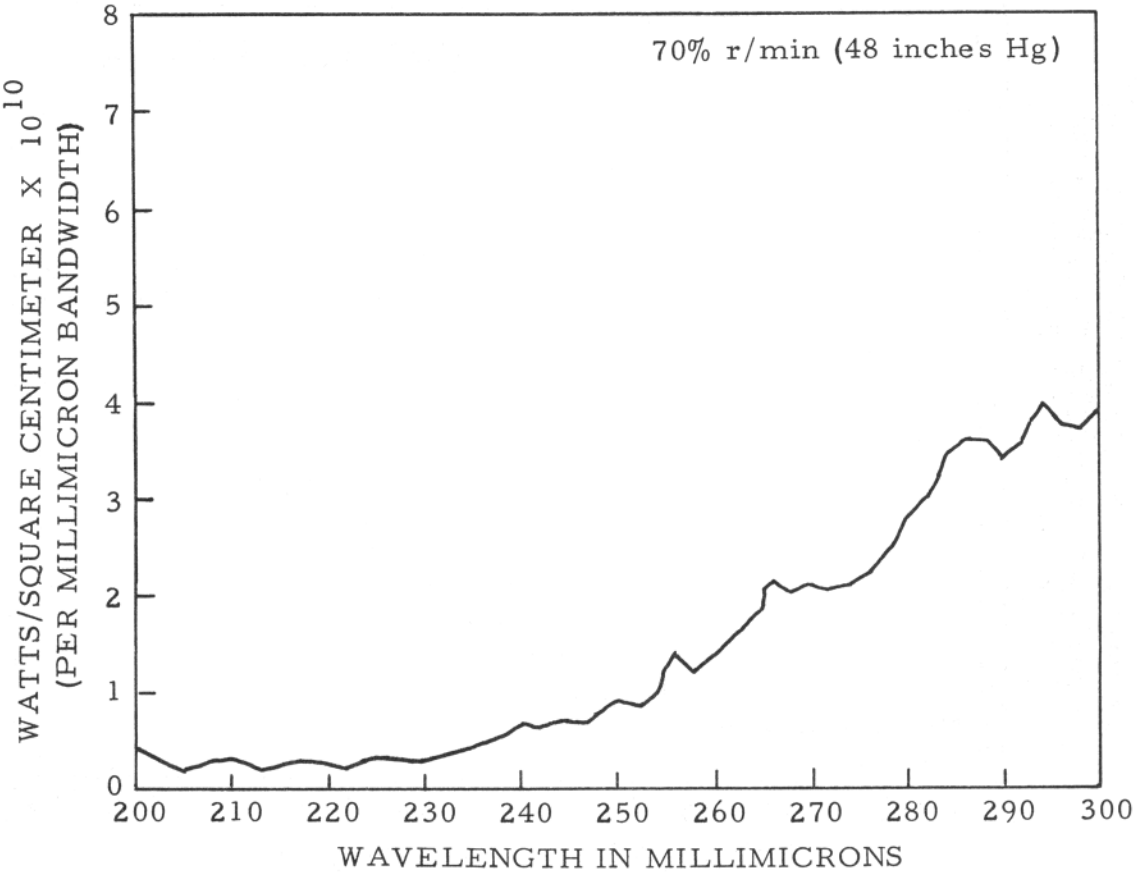

FIGURE 5. ULTRAVIOLET SPECTRUM OF J47 ENGINE AT 70 PERCENT R/MIN, 6 FEET FROM BURN-THROUGH FLAME.

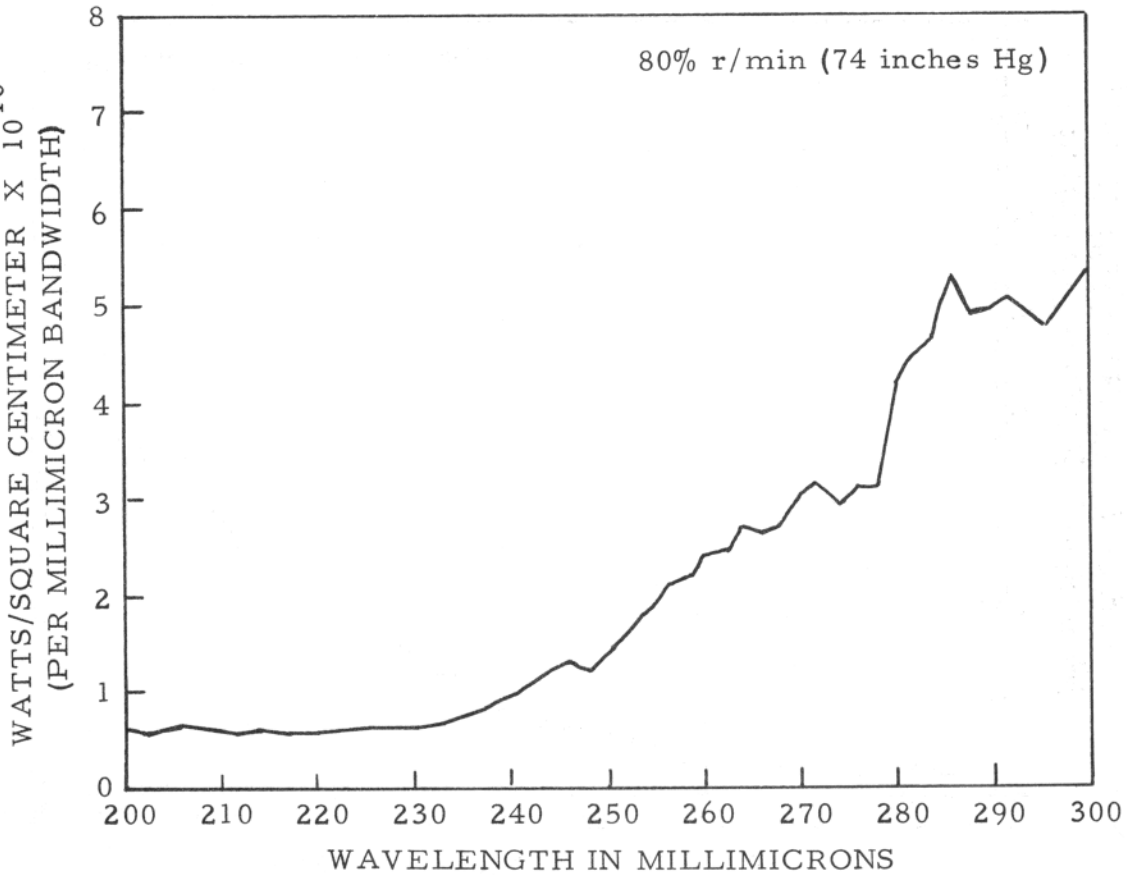

FIGURE 6. ULTRAVIOLET SPECTRUM OF J47 ENGINE AT 80 PERCENT R/MIN, 6 FEET FROM BURN-THROUGH FLAME.

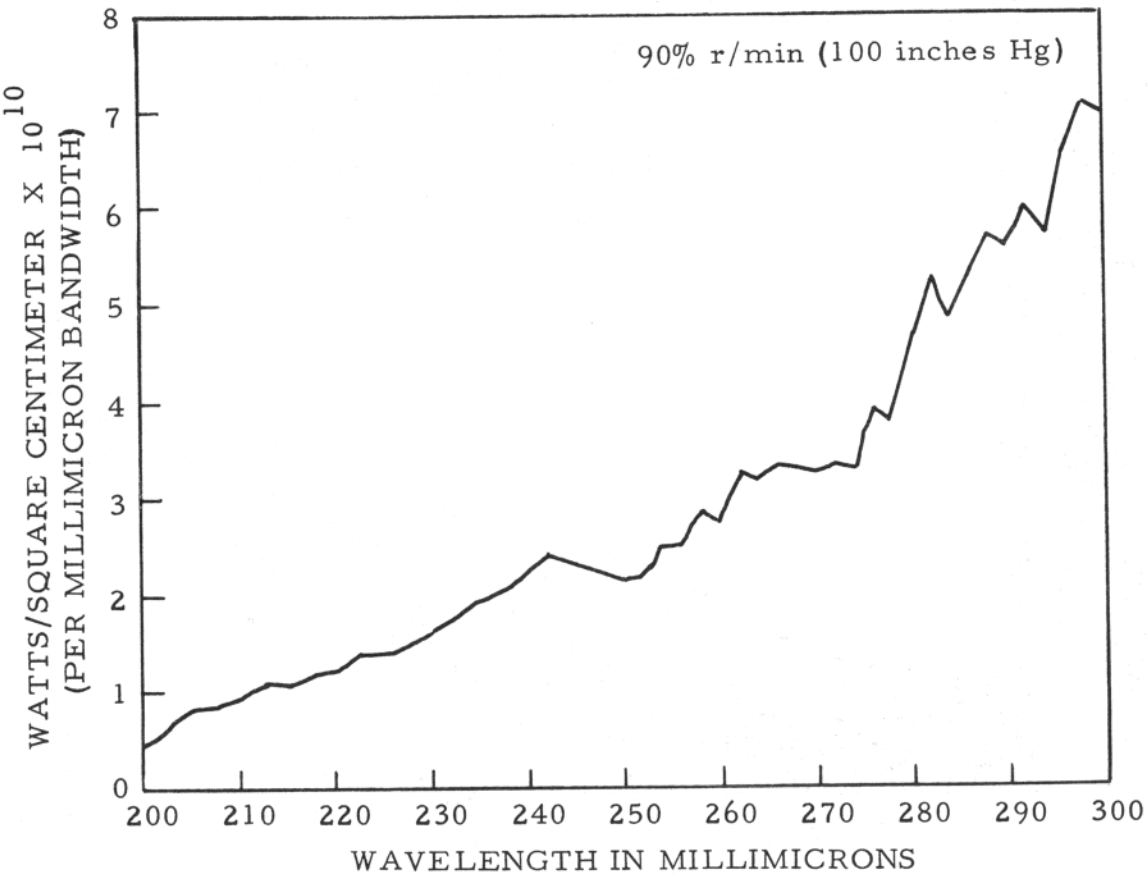

FIGURE 7. ULTRAVIOLET SPECTRUM OF J47 ENGINE AT 90 PERCENT R/MIN, 6 FEET FROM BURN-THROUGH FLAME.

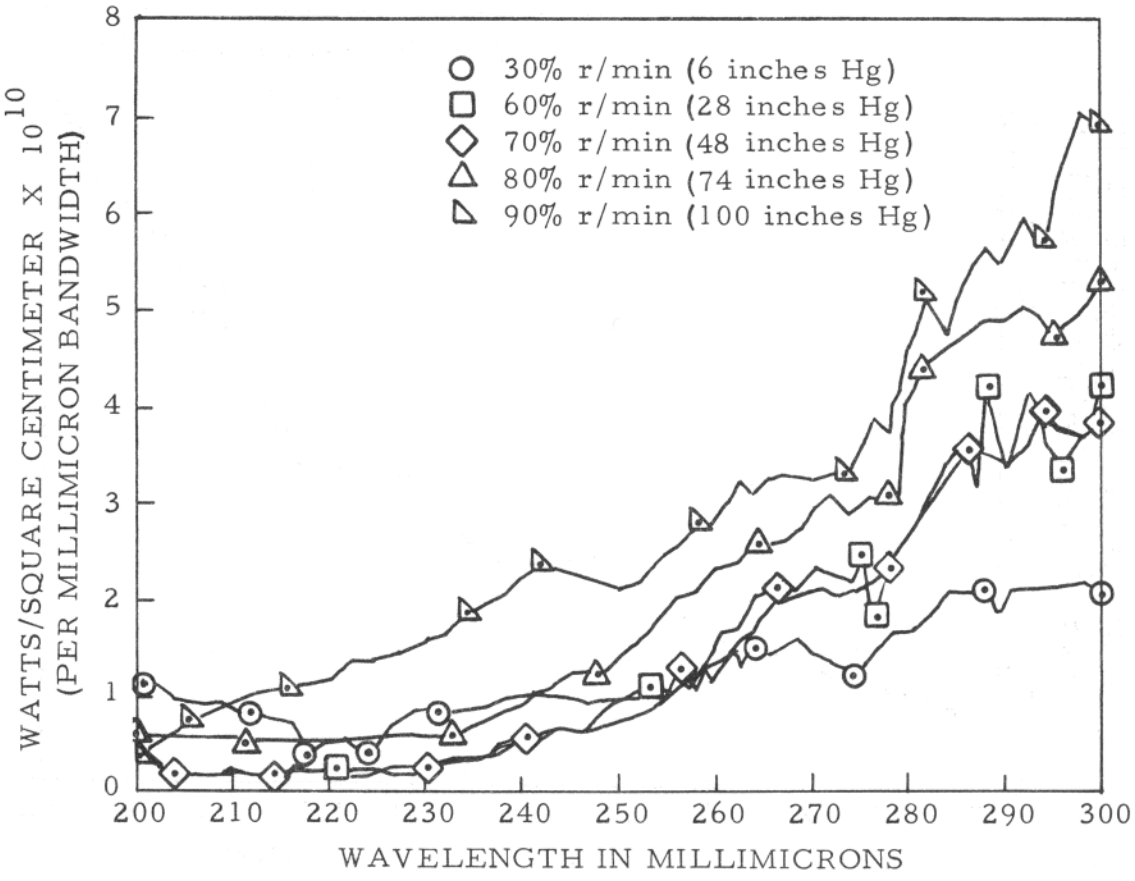

FIGURE 8. A COMPARISON OF THE ULTRAVIOLET SPECTRUM OF A J47 ENGINE AT VARIOUS POWER SETTINGS, FROM A DISTANCE OF 6 FEET FROM THE BURN-THROUGH FLAME.

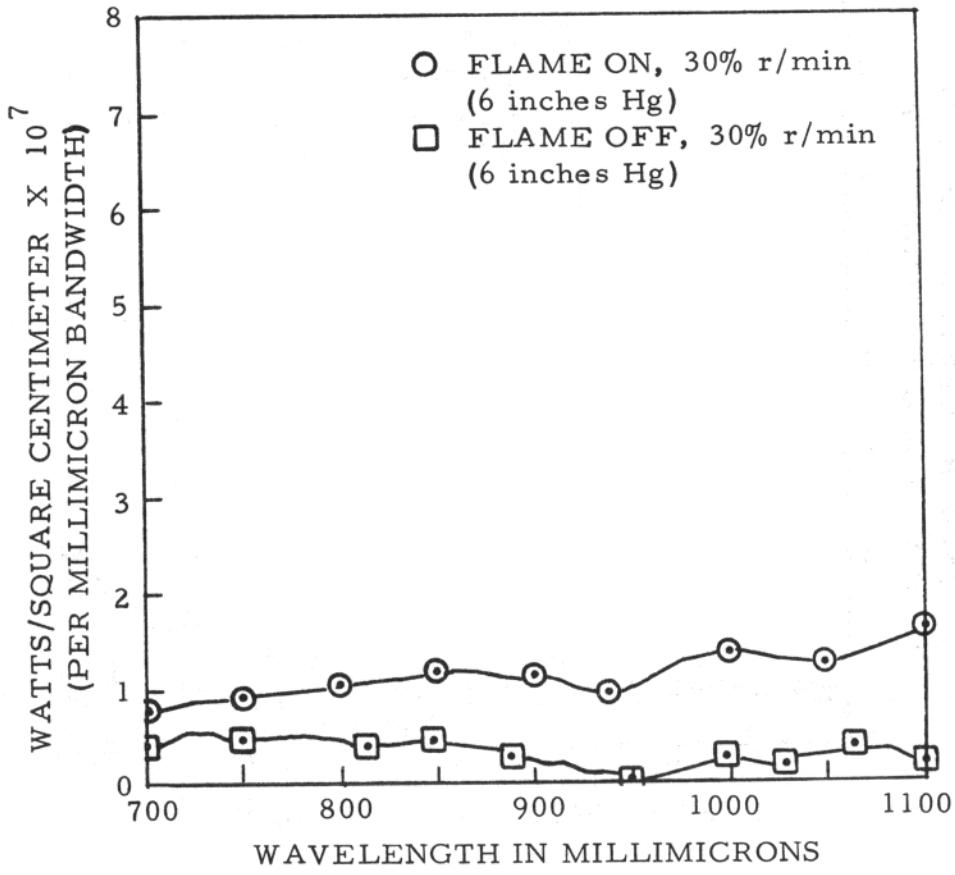

FIGURE 9. NEAR-INFRARED SPECTRUM OF A J47 ENGINE AT 30 PERCENT R/MIN, WITH AND WITHOUT A BURN-THROUGH, FROM 6 FEET.

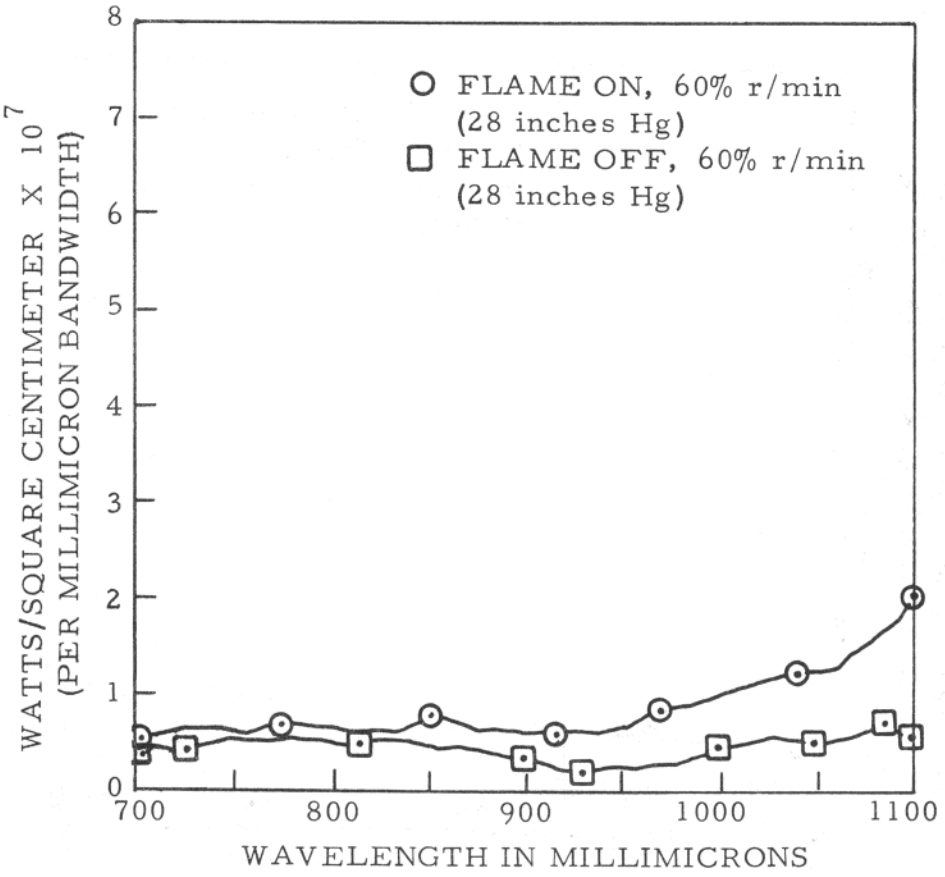

FIGURE 10. NEAR-INFRARED SPECTRUM OF A J47 ENGINE AT 60 PERCENT R/MIN, WITH AND WITHOUT A BURN-THROUGH, FROM 6 FEET.

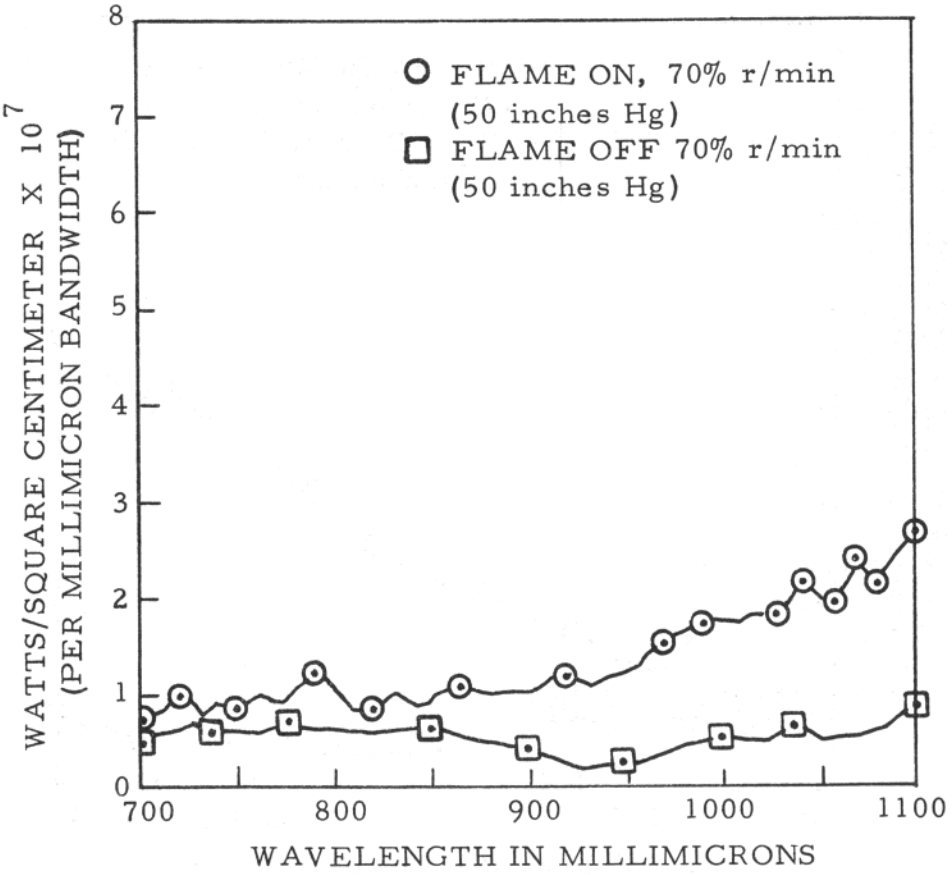

FIGURE 11. NEAR-INFRARED SPECTRUM OF A J47 ENGINE AT 70 PERCENT R/MIN, WITH AND WITHOUT A BURN-THROUGH, FROM 6 FEET.

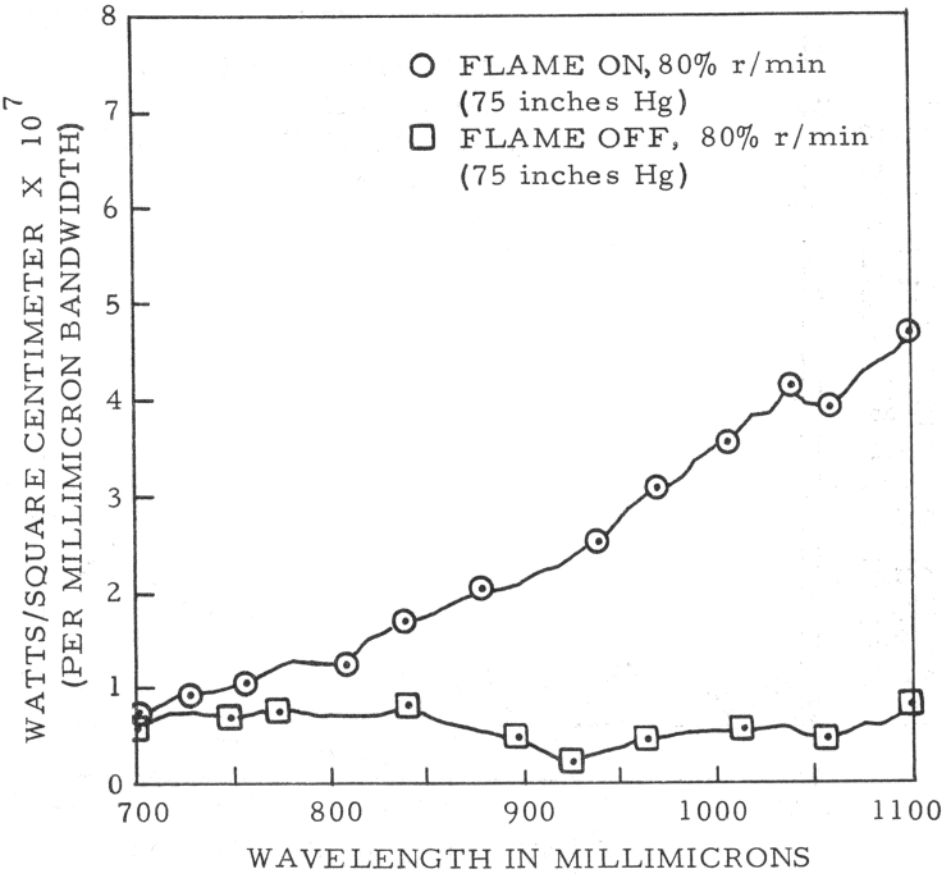

FIGURE 12. NEAR-INFRARED SPECTRUM OF A J47 ENGINE AT 80 PERCENT R/MIN, WITH AND WITHOUT A BURN-THROUGH, FROM 6 FEET.

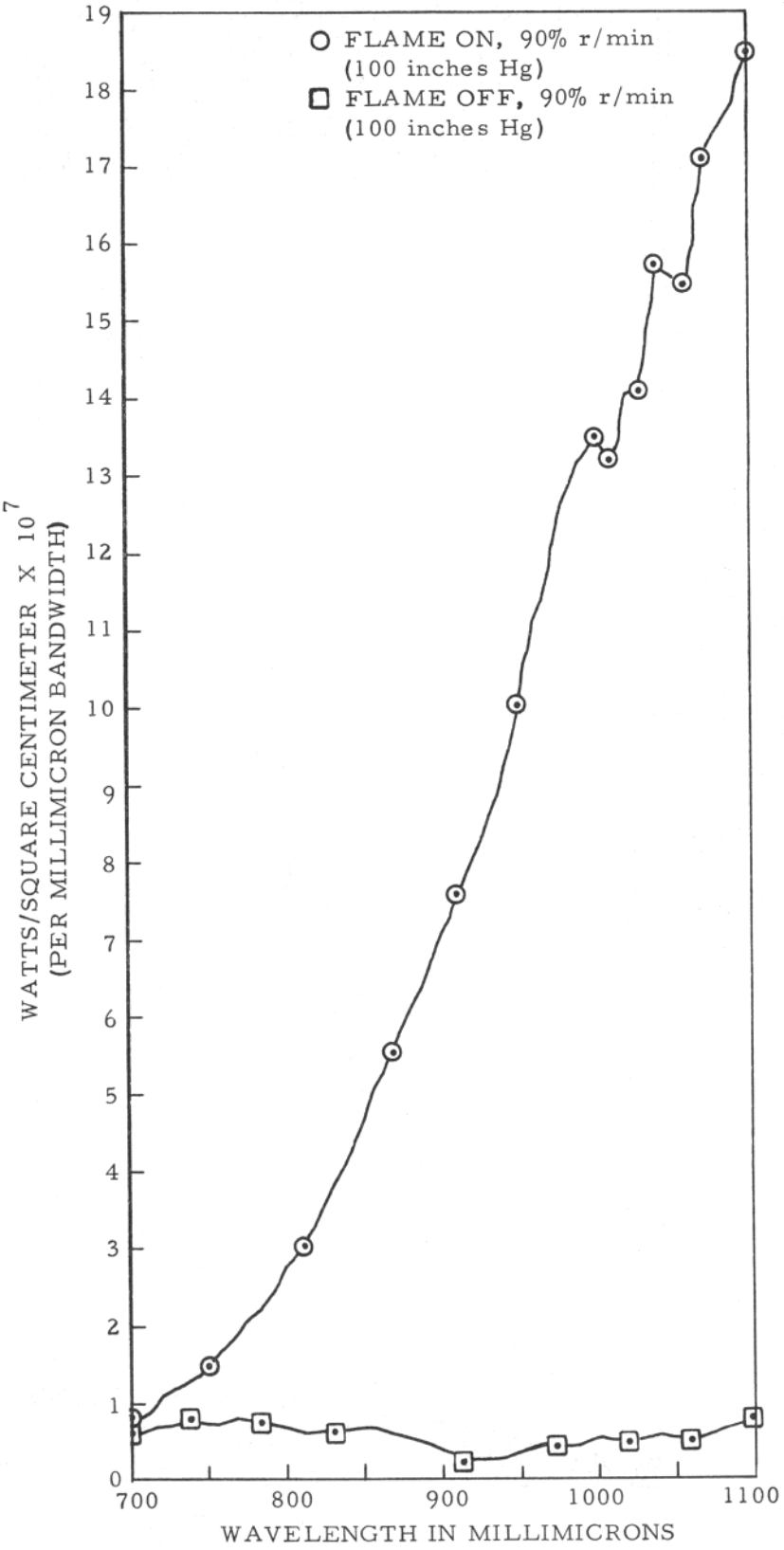

FIGURE 13. NEAR-INFRARED SPECTRUM OF A J47 ENGINE AT 90 PERCENT R/MIN, WITH AND WITHOUT A BURN-THROUGH, FROM 6 FEET.

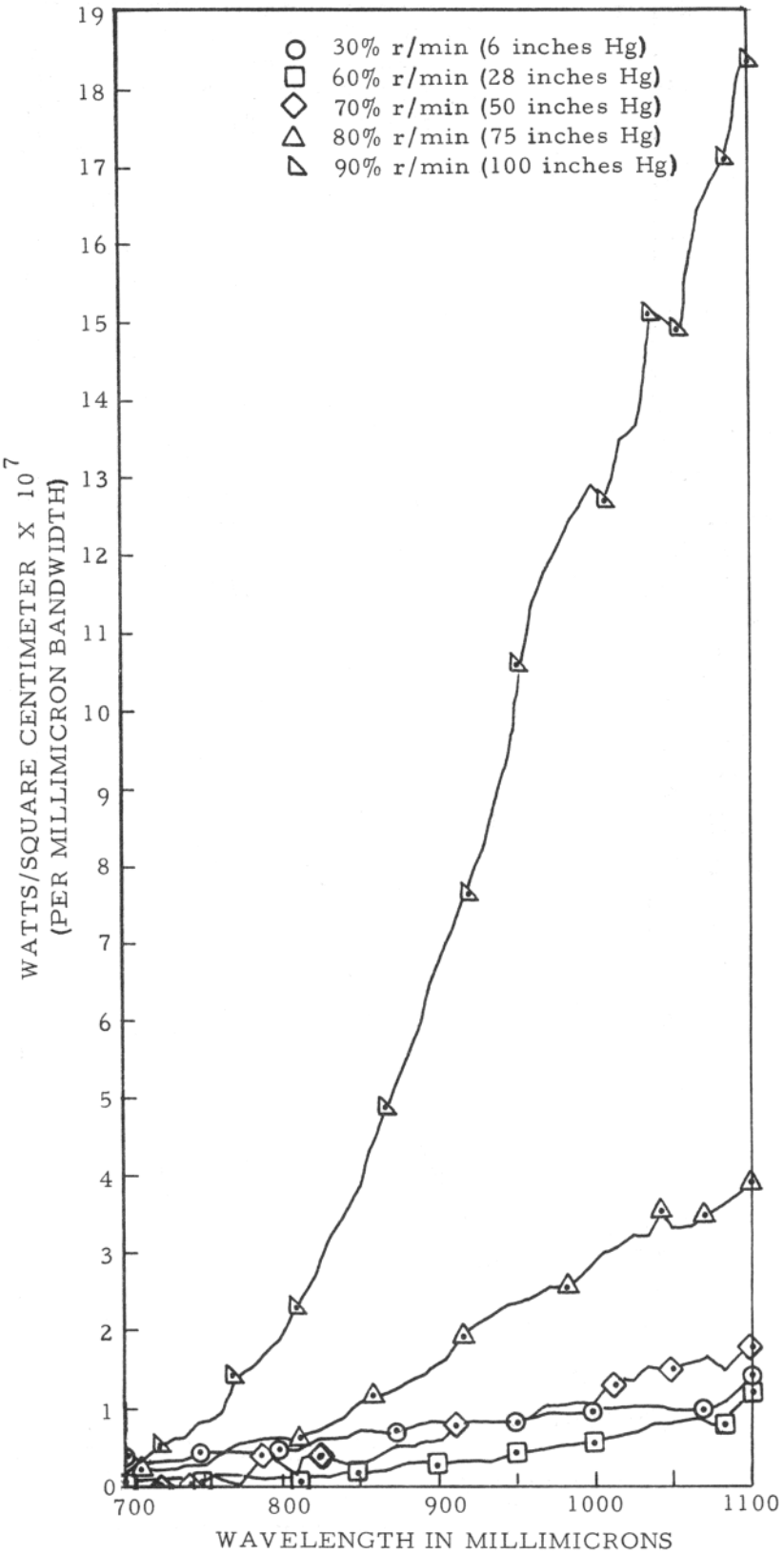

FIGURE 14. A COMPARISON OF THE NEAR-INFRARED SPECTRUM, ABOVE THE BACKGROUND, OF A J47 ENGINE AT VARIOUS POWER SETTINGS, FROM A DISTANCE OF 6 FEET.