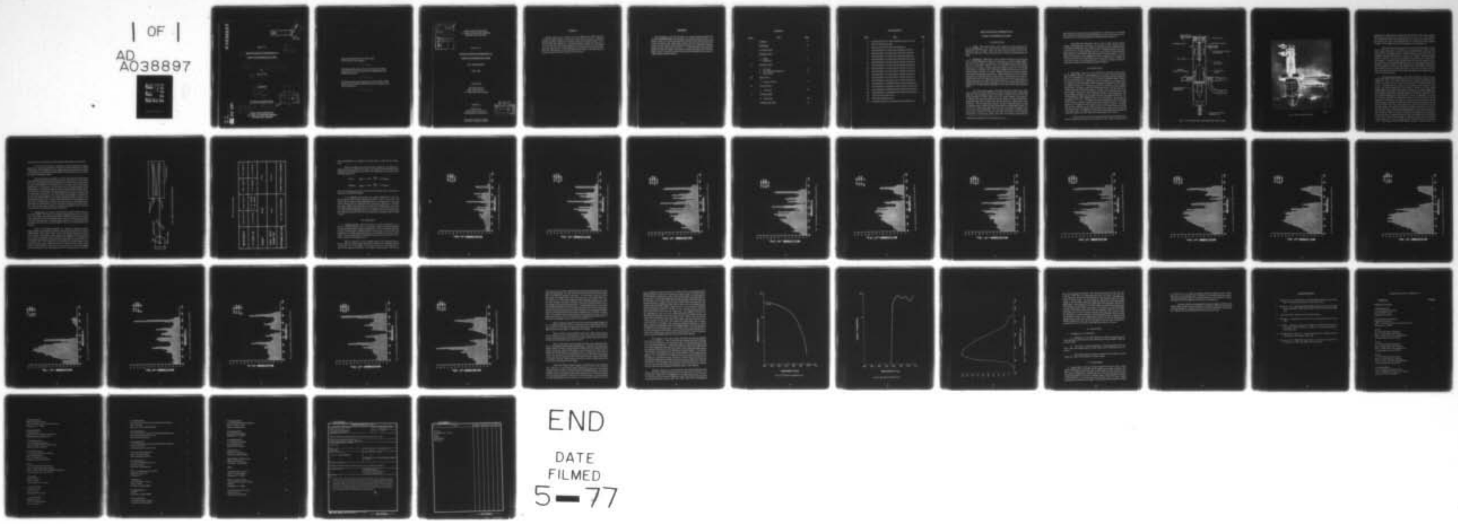
AD-A038 897 ARMY NIGHT VISION LAB FORT BELVOIR VA F/G 7/2
ABSOLUTE SPECTRAL DISTRIBUTION OF CESIUM AND RUBIDIUM ARC LAMPS--ETC(U)
AUG 69 C S FOX
UNCLASSIFIED NVL-6 NL

1 OF 1
AD
A038897



END
DATE
FILMED
5-77

1

NW

Report No. 6

14 NVL-6

6

ABSOLUTE SPECTRAL DISTRIBUTION OF CESIUM AND RUBIDIUM ARC LAMPS

9 Rept. for Feb-Jun 69

by

10 Clifton S. Fox

11 August 1969

12 41p.

401 336

16 1Z662709D466

17 06

NIGHT VISION LABORATORY
U. S. ARMY ELECTRONICS COMMAND
FORT BELVOIR, VIRGINIA

NIGHT VISION LABORATORY
U. S. ARMY ELECTRONICS COMMAND
FORT BELVOIR, VIRGINIA

Report No. 6

ABSOLUTE SPECTRAL DISTRIBUTION OF CESIUM AND RUBIDIUM ARC LAMPS

Task 1Z662709D466-06

August 1969

Distributed by

The Deputy Director
Night Vision Laboratory
U. S. Army Electronics Command

Prepared by

Clifton S. Fox
Light Source Research Team
Optical Radiation Technical Area

This document has been approved for public release and sale; its distribution is unlimited.

SUMMARY

Spectral radiance data in absolute units was obtained from 2-KW cesium and rubidium arc lamps operated at various power levels and vapor pressures to determine optimum operating conditions for maximum visible and near infrared output. The report concludes that rubidium has a favorable distribution at high vapor pressures for use with a pink filter (low density infrared filter) and an S-25 detector in the infrared mode and cesium has a favorable distribution at intermediate pressures for use with a filter with a higher degree of visual security and an S-1 detector. More development of the lamp is needed to increase radiance and total efficiency.

FOREWORD

The investigation covered by this report was conducted under the authority of DA Task 1Z662709D466-06. This investigation was performed during February–June 1969, by Clifton S. Fox, Physicist, Light Source Research Team, under the supervision of Steve B. Gibson, Chief, Light Source Research Team, and under the direction of Stanley M. Segal, Director, Optical Radiation Technical Area, and Benjamin Goldberg, Deputy Director, Night Vision Laboratory, U. S. Army Electronics Command (USA-ECOM), Fort Belvoir, Virginia. The assistance of Keith Lewis, Electronics Technician, Melpar, Division of American Standard, is gratefully acknowledged for his assistance in experimentation and data reduction.

CONTENTS

I INTRODUCTION

II INVESTIGATION

III DISCUSSION

IV CONCLUSIONS

V FUTURE WORK

ILLUSTRATIONS

ABSOLUTE SPECTRAL DISTRIBUTION OF CESIUM AND RUBIDIUM ARC LAMPS

I. INTRODUCTION

1. Subject. This report covers the work conducted to obtain in absolute units the spectral distribution in the visible and near infrared of experimental 2-kilowatt, alkali-metal vapor, arc lamps. Data in the form of spectral radiance curves was obtained at various power levels and vapor pressures of cesium and rubidium plasma arc lamps.

2. Background. High-pressure, xenon, compact arc lamps are now being used by the Army in illumination systems for dual-purpose, overt/covert lighting applications (1).* In the visible, xenon produces a very white light with good color rendition due to its strong visible continuum. In the near infrared, xenon has extremely good output due to continuum emission along with broad-line emission (2). Even though xenon lamps are serving the Army well, lamps with higher luminous efficacy and near-infrared, radiative efficiency are possible. Alkali-metal, vapor arc lamps are among the most efficient thermal light sources known. Alkali metals have low excitation energies and the lowest ionization potentials of all the elements. Alkali metals are strongly electropositive because of their large atomic diameters and single-valence electron—the lone electron being easily removed to form the monopositive ion. Cesium and rubidium are of particular interest for military applications because of their appreciable number of spectral lines with high-transition probability in the visible and near infrared spectral regions.

One of the current projects of the Optical Radiation Technical Area, Night Vision Laboratory (NVOR) is the design, construction, and optimization of alkali metal lamps that will substantially surpass xenon lamps in efficiency and will be at least equally advantageous in other respects such as life, weight, reliability, and ruggedness. In addition to the increased visible and near IR radiation for a given input power, another advantage will be realized which will also decrease the weight and size of the illuminator. This advantage derives from the fact that the spectral output of cesium and rubidium lamps is such that infrared filter problems are substantially reduced. The cut-off of the visual security filter falls in the region of strongly self-absorbed resonance lines of cesium and rubidium. The absence of a large amount of radiation in this region implies a reduction of thickness and weight of the filter used to achieve the same degree of visual security as with a xenon lamp. This reduction in filter thickness

---

*Numbers in parentheses refer to *Literature Cited*, p. 32.

lessens thermal stresses which cause cracking of the filter. This leads to a more reliable filter which passes a higher percentage of IR radiation. The goal of this program is the production of a 2-kw arc lamp which will be fully optimized for military use.

Lamps filled with noble gases such as xenon are made with basic quartz, tungsten, and molybdenum construction. Inert gas will not attack a quartz envelope, so fused quartz ($Si0_2$) with its low coefficient of thermal expansion and high resistance to thermal stress is an ideal envelope for inert gases. Alkali metal lamps, on the other hand, must have an envelope that will resist the corrosive effects of the alkali metals at high temperatures and still have high transmission in the spectral regions of interest. Single-crystal aluminum oxide (sapphire) meets these requirements and is used as the envelope material for these lamps though thermal-stress characteristics of sapphire are not as good as quartz. Recent progress in the cost reduction of sapphire cylinder production has made this material financially feasible for lamp use.

II. INVESTIGATION

3. The Lamps. Figure 1 is a cross sectional view of the type of lamp used in this investigation. Figure 2 is a photograph of one of the lamps. This lamp and others like it were manufactured by RCA in Lancaster, Pennsylvania, under the support and direction of the Night Vision Laboratory on Contract DAAK02-68-C-0061. Much of the external metal structure of the lamp is made of molybdenum. At the high operating temperature of the lamp (600° to 700° Centigrade), molybdenum would be rapidly oxidized if exposed to air. The lamps are, therefore, operated in a vacuum chamber during testing. The lamps are made with molybdenum because of its better coefficient of thermal expansion match with sapphire as compared with metals that will not oxidize as rapidly. Because these lamps will be incorporated into inert gas-filled, sealed-beam housings for military use, the molybdenum presents no oxidizing problem. The overall length of the lamp is approximately 6.5 inches. The sapphire envelope has a 2.5 cm outside diameter, 3.8 cm length, and 0.175 cm wall thickness. The arc gap is approximately 5 to 7 mm. The lamp has an internal cathode heater filament through which a current is passed to heat the cathode for thermionic emission. An external heating wire is wrapped around the metal reservoir to heat the anode area. A sapphire disc is used as a dielectric to electrically insulate the heater input lead from the cathode, DC input lead. The sapphire envelope insulates the cathode from the anode end of the lamp. There is a cooling course on the anode end through which compressed air is passed to dissipate waste heat from electron bombardment on the anode.

To start the lamp, current is passed through both heaters until enough vapor pressure is built up in the lamp and the cathode tip is hot enough to strike an arc by

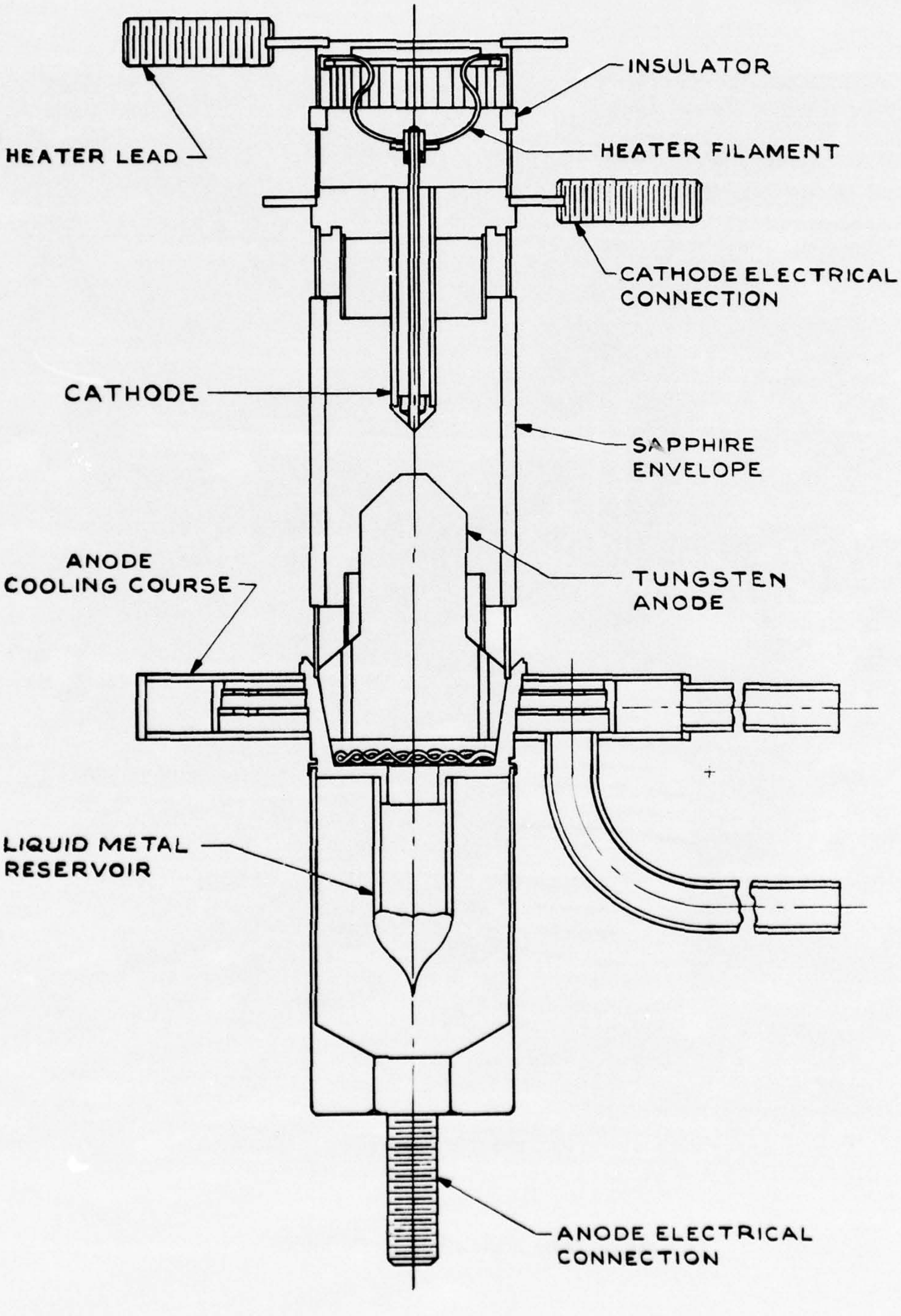
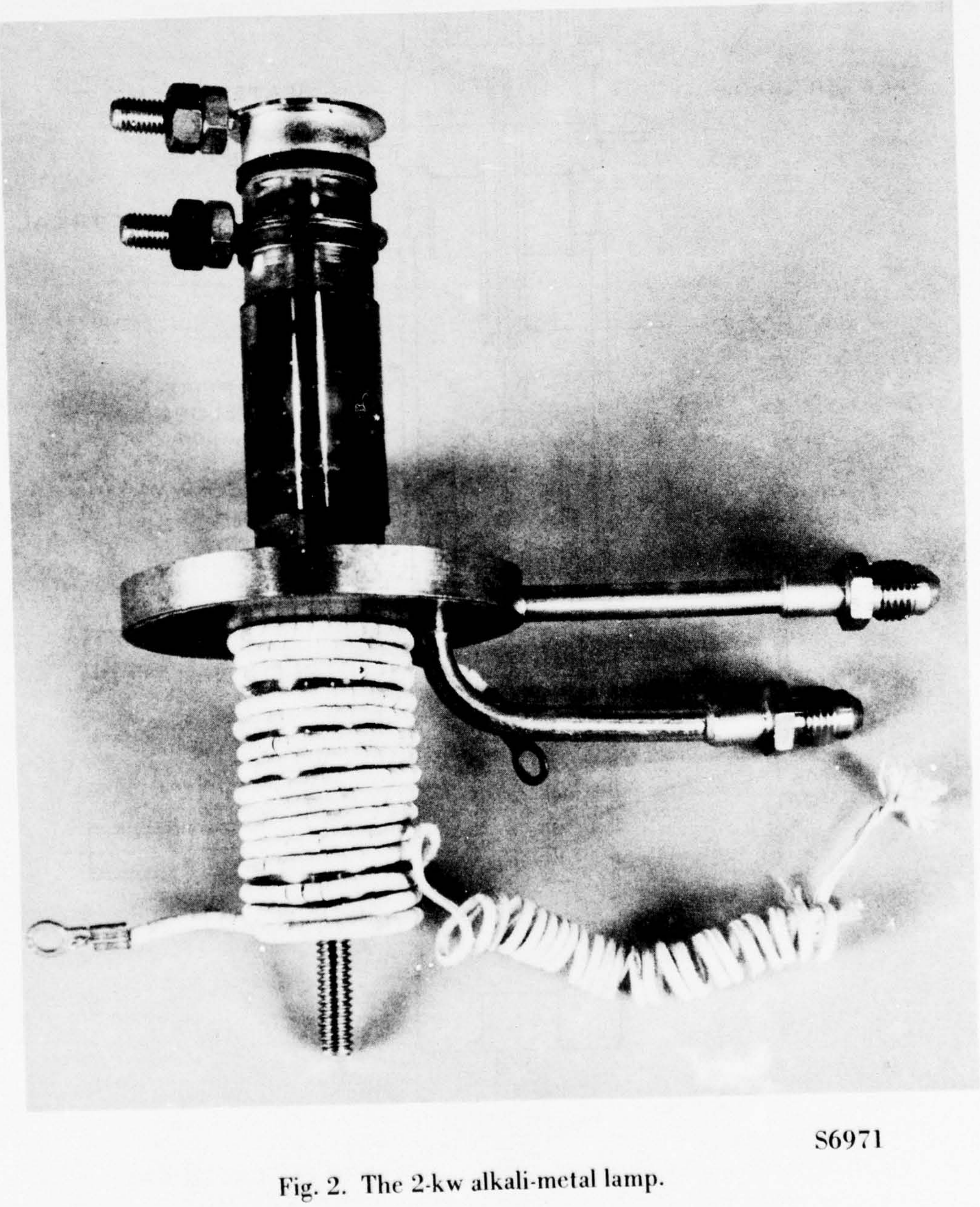


Fig. 1. Cross sectional view of 2-kw alkali-metal, vapor arc lamp.



S6971

Fig. 2. The 2-kw alkali-metal lamp.

applying a low voltage (typically 4 volts) across the electrodes. If the voltage is applied before the lamp has built up a vapor pressure of at least a few torr, a glow discharge fills practically the whole volume inside the envelope. As the vapor pressure increases, the discharge passes from a wall-stabilized stage to a voluminous, electrode-stabilized discharge. At even higher pressure, the discharge becomes a constricted arc.

Alkali metal lamps have been made before, but most of them differ from this type in several major respects. This lamp is an electrode-stabilized, compact arc lamp with a sapphire envelope and is made for continuous operation. Most other alkali metal lamps are of the wall-stabilized variety with relatively long arc gaps, and they use polycrystalline aluminum oxide (Lucalox or Vistal) as an envelope. The polycrystalline aluminum oxide has a much lower transmission in the visible and near infrared than clear sapphire. It usually has better transmission in the far infrared regions, however, and is therefore used to good advantage for far IR work. The polycrystalline oxide is translucent instead of transparent. The transparency of clear sapphire is important to the NVL lamp because of narrow-beam projection. The effective emitter area is the arc itself instead of the whole envelope because the envelope does not disperse the radiation as the translucent form does. Many of the other lamps are also used for pulsed instead of continuous operation.

4. The Experimental Equipment. The alkali-metal lamps are operated in a specially designed stainless steel vacuum chamber with a 3-inch diameter sapphire window. Sapphire was chosen as the window material instead of quartz so that measurements could be extended in the future to the far infrared regions. The interior of the chamber has a very high emissivity coating to absorb radiation so that reflections do not interfere with optical measurements. The chamber is cooled by cold water flowing through copper coils brazed to the outside of the housing. The lamp is supported inside the chamber by a cantilever beam attached to the back plate which is bolted to the main housing and sealed with a disposable aluminum seal. The back plate has all necessary insulated feedthroughs for lamp operation. Electrical feedthroughs are provided for AC power to the internal cathode heater filament and reservoir heater (a ceramic insulated coil of Nichrome wire). Water-cooled, high-current feedthroughs are provided for DC power to the lamp. Feedthroughs are also provided for compressed air to be piped to and from the anode cooling course and are sealed to the back plate with copper gasket flanges. The compressed-air line has a regulator valve in line to vary the airflow rate and thereby control the operating temperature and metal vapor pressure inside the lamp. Chromel and alumel feedthroughs are provided on the back plate so that four thermocouples can monitor the lamp and the lamp chamber temperatures. Lamp temperature is monitored on both the anode and cathode seal areas and on the metal reservoir. The fourth thermocouple is attached to the back plate of the chamber. A high-vacuum bellows valve is brazed to the side of the main housing section for evacuation. A diffusion pump with a liquid nitrogen cold trap is connected to the valve,

and the vacuum is monitored by a standard thermocouple gauge and control unit.

AC power to the heaters is controlled by variable transformers of appropriate value. A step-down transformer is used in series with a 10-ampere Variac for the cathode heater due to its high-current, low-voltage characteristic. DC power is supplied to the lamp by a Hewlett-Packard Model 6475A current-controlled, 10-kw power supply capable of 100-ampere output.

The lamp chamber is mounted on a 2-meter optical bench with the window on axis with the lamp and other optical components as shown in Fig. 3. A quartz lens with a 30-cm focal length is positioned 50 cm in front of the lamp, and the entrance slit of the monochromator is 75 cm from the lens. An image of the arc with a linear magnification of 1.5 is projected on the entrance slit of the monochromator during lamp operation. Color filters are placed in the optical path immediately before the entrance slit of the monochromator. Optical stops are used on the lens to adjust intensity for various parts of the spectral runs. Photomultipliers are attached to a flange on the exit slit of the monochromator. The output of the photomultiplier is recorded on a Hewlett-Packard Model 7000 AM X-Y recorder modified for strip-chart operation. The monochromator/spectrometer is a Hilger Engis Model 1000 of the symmetrical Czerny-Turner type. One grating is used for the entire spectral range. It has 1,200 lines/mm and is blazed at 7,500 Angstroms (Å) for the first-order spectrum (3,750 Å second order). The spectrometer has a solid-state, controlled-wavelength drive with a precision, ten-turn pot for very reproducible scan-speed adjustment.

5. Measurements. The sequence of filters and other optical settings is shown in the enclosed Table. The entrance and exit slits of the spectrometer were set at 15 microns. The portion of the spectrum from 4000 Å to 5800 Å in the visible was scanned in the second order for increased dispersion and resolution. Resolution was well below 1 Å for the whole spectrum. A reducing wedge was used to mask off the image of the electrodes on the slit so that the total length of the arc was examined between the electrodes.

First, the experimental apparatus was calibrated by placing an Eppley, tungsten-filament, spectral-radiance standard in the same position that the cesium and rubidium lamps would be placed, and a run was made with all settings at the positions to be used later. The sapphire window of the vacuum chamber was also in the optical path so that its transmission would be included in the calibration. The resulting curve was integrated by planimetry in 10-mμ intervals, and the data was corrected for recorder sensitivity scale. The resulting values were divided into the actual radiance values obtained from the Eppley calibration certificate to obtain correction factors for the cesium and rubidium data. Experiments were then run on the cesium and rubidium lamps at various power levels and vapor pressures. The resulting data was corrected for

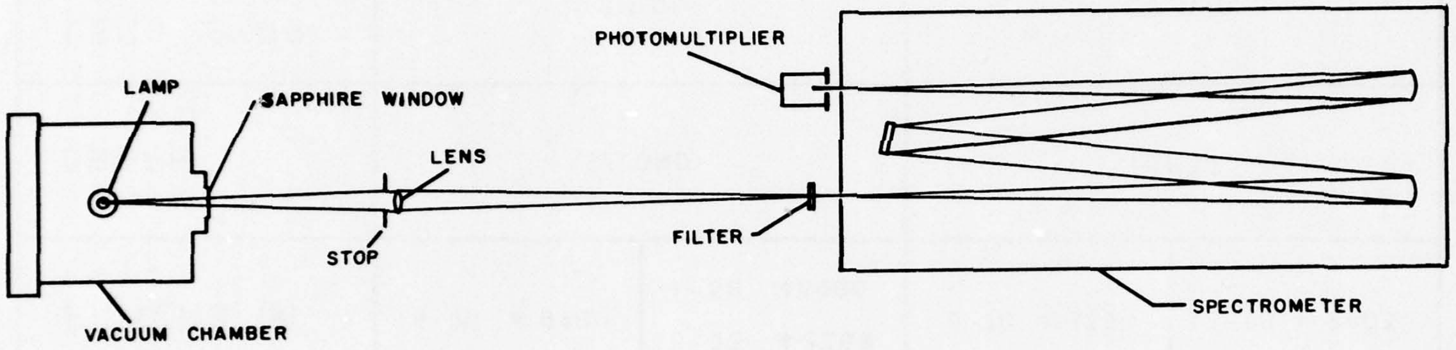


Fig. 3. Diagram of experimental optical arrangement.

Table. Spectroscopic Program

WAVELENGTH	4000-5000 Å	5000-5800 Å	5800-7600 Å	7000-10500 Å
FILTERS (3)	4-76 #9780	3-73 #3389 1-58 #3965	3-70 #3384	2-58 #2403
ORDER	SECOND		FIRST	
LENS STOP DIAMETER	5 m.m.		20 m.m.	
PHOTOMULTIPLIER	RCA IP28 (S-5 RESPONSE)		DUMONT INFRARED (S-1 RESPONSE)	

scale and multiplied by the calibration correction factors to obtain the true radiance values.

Figures 4 through 18 are the results of the experiments. The input power, voltage, and current are written on each curve. The vapor pressure listed is the pressure determined by substituting the value of the lowest temperature on the lamp into the following equations (4):

$$\text{Cesium:} \qquad \log_{10} P = 11.38 - \frac{4075}{T} - 1.45 \log_{10} T$$

$$\text{Rubidium:} \qquad \log_{10} P = 12.00 - \frac{4560}{T} - 1.45 \log_{10} T$$

where P is the vapor pressure and T is the temperature in degrees Kelvin. The data was obtained between 400 and 1050 mμ.

It was originally planned that curves would be obtained for four or five vapor pressures at power levels of approximately 0.6 kw, 1.0 kw, 1.3 kw, 1.7 kw, and 2.0 kw. Because of power-supply limitations, however, the upper power levels could not be reached. Curves were obtained for runs requiring up to 100 amperes. Sufficient curves were obtained from both lamps at the 0.6 kw level. Higher power curves from the rubidium lamp would require too much current due to its relatively short arc gap. Curves for power levels higher than 0.6 kw were obtained from the cesium lamp at relatively high vapor pressures, but the lower vapor pressures would again require too high a current.

III. DISCUSSION

6. Analysis of Results. Extensive self-reversal of atomic transition lines is evident even on the low-pressure curves. The only lines which are not heavily absorbed are the upper-level transitions and some impurity lines. At the intermediate and higher pressures, self absorption is definitely the rule and few lines are not reversed. The strongest lines of sodium and potassium show up as impurities on the curves of both lamps. The most persistent lines of rubidium are present on the cesium curves and cesium lines appear on the rubidium curves.

Figures 4 through 8 are the integrated results of the experimental curves taken on the cesium lamp at approximately 0.6 kw input power. The high-resolution, experimental curve corresponding to Fig. 4 shows self reversal of all cesium lines except for some upper-level transitions, even though the vapor pressure is only 39 torr.

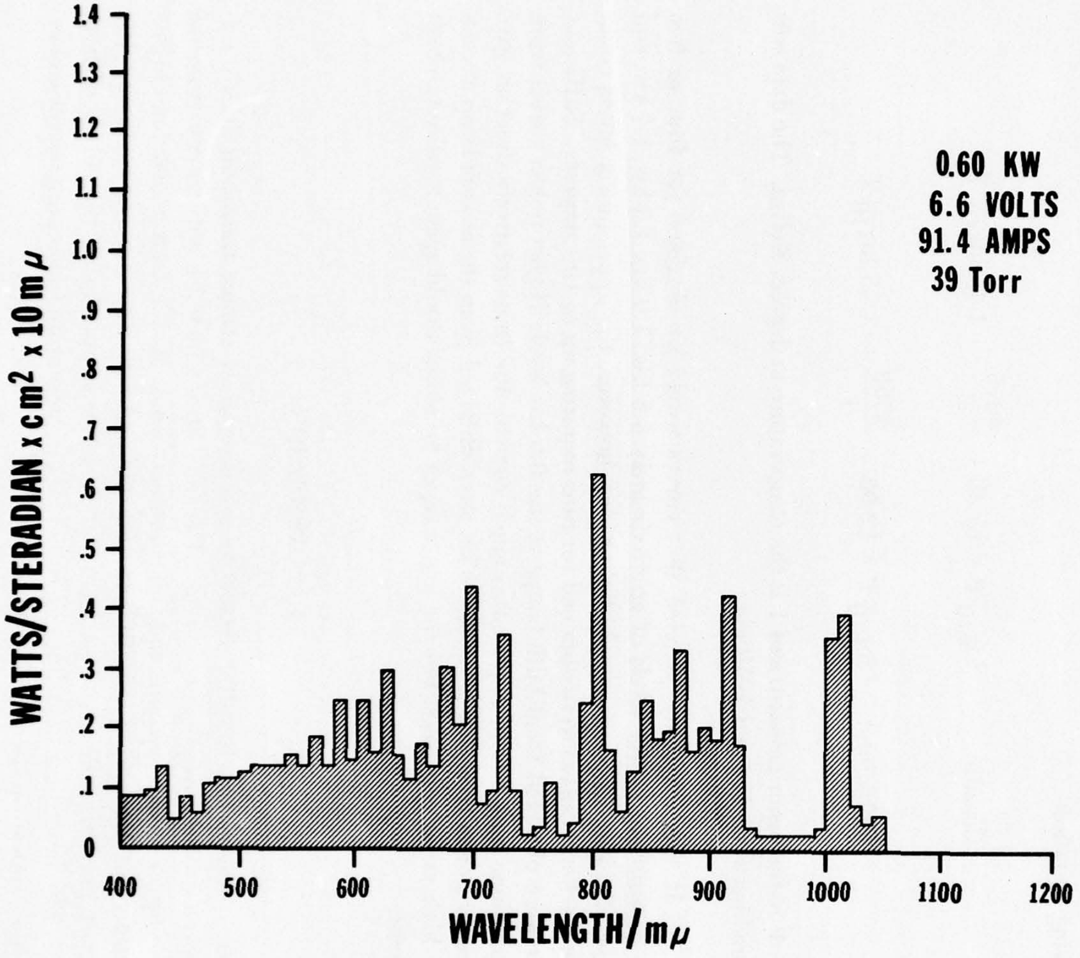


Fig. 4. Spectral radiance of cesium lamp at 0.60 kw and 39 torr.

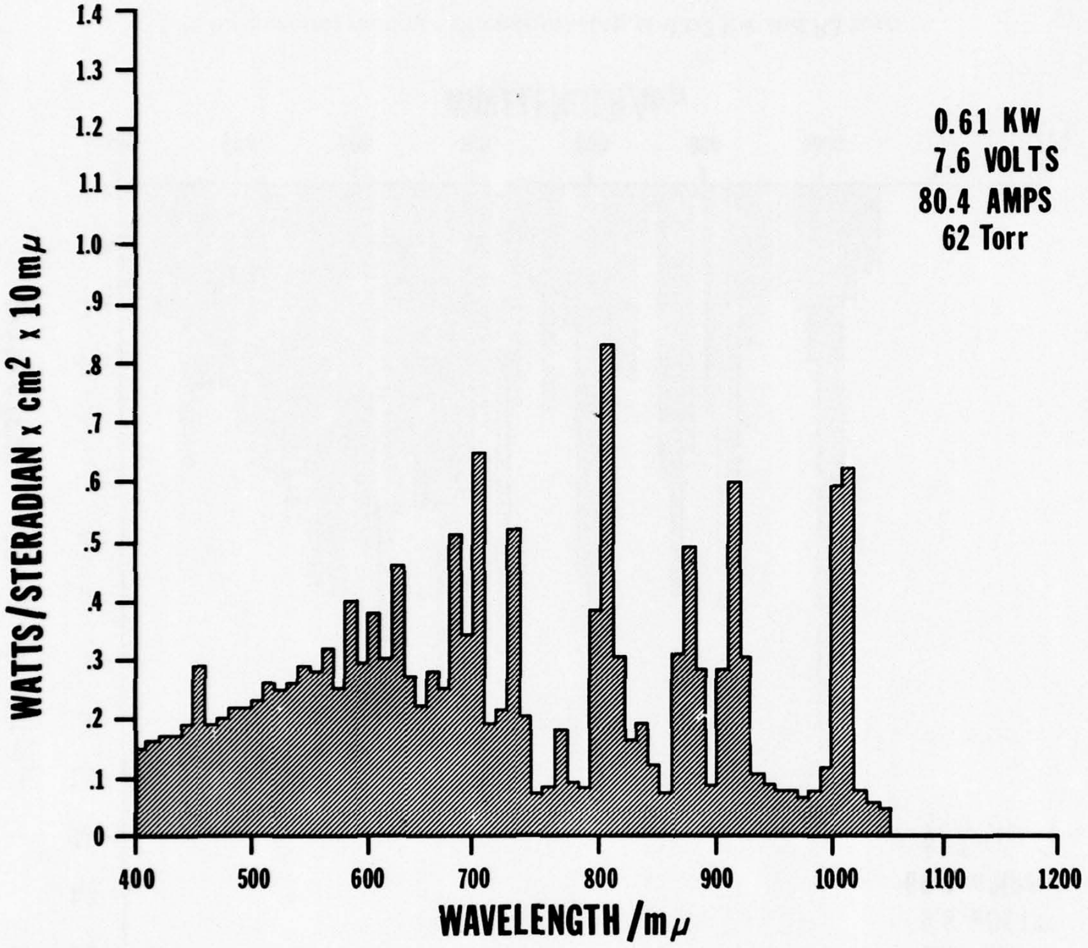


Fig. 5. Spectral radiance of cesium lamp at 0.61 kw and 62 torr.

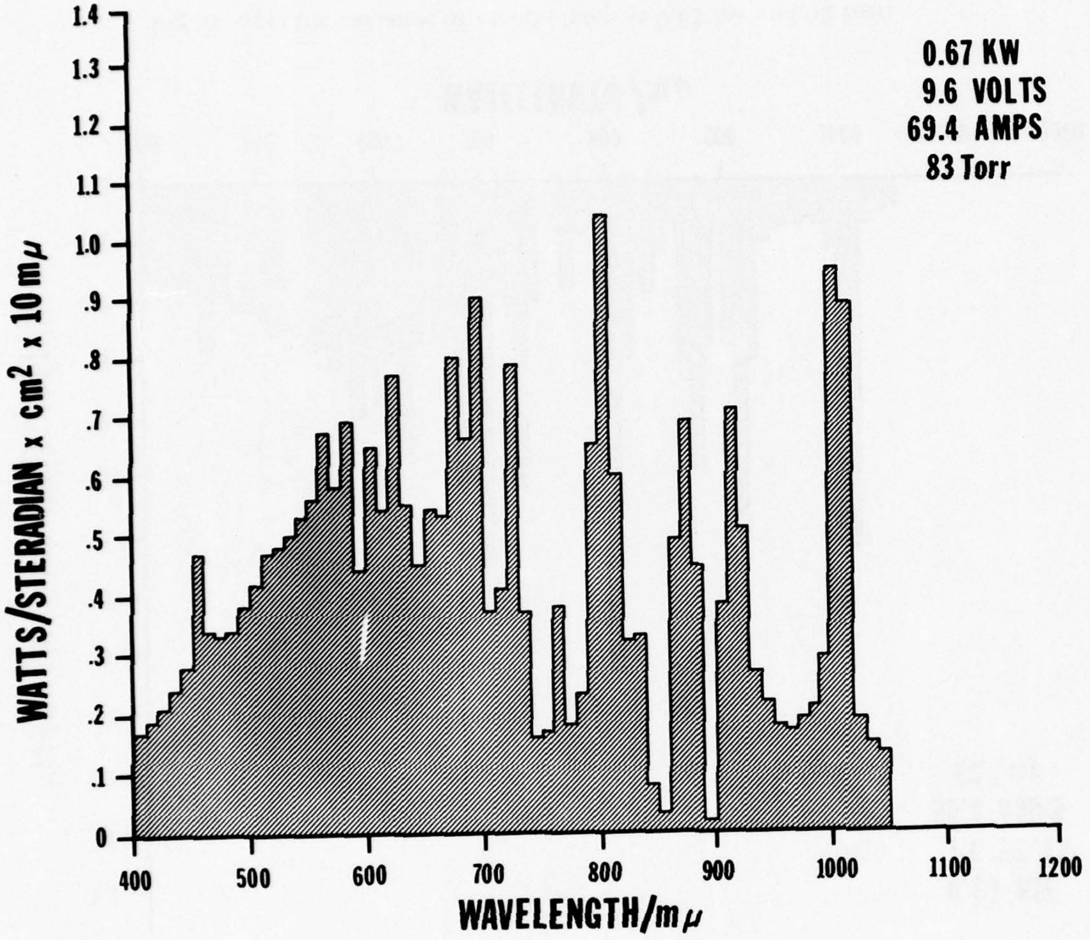


Fig. 6. Spectral radiance of cesium lamp at 0.67 kw and 83 torr.

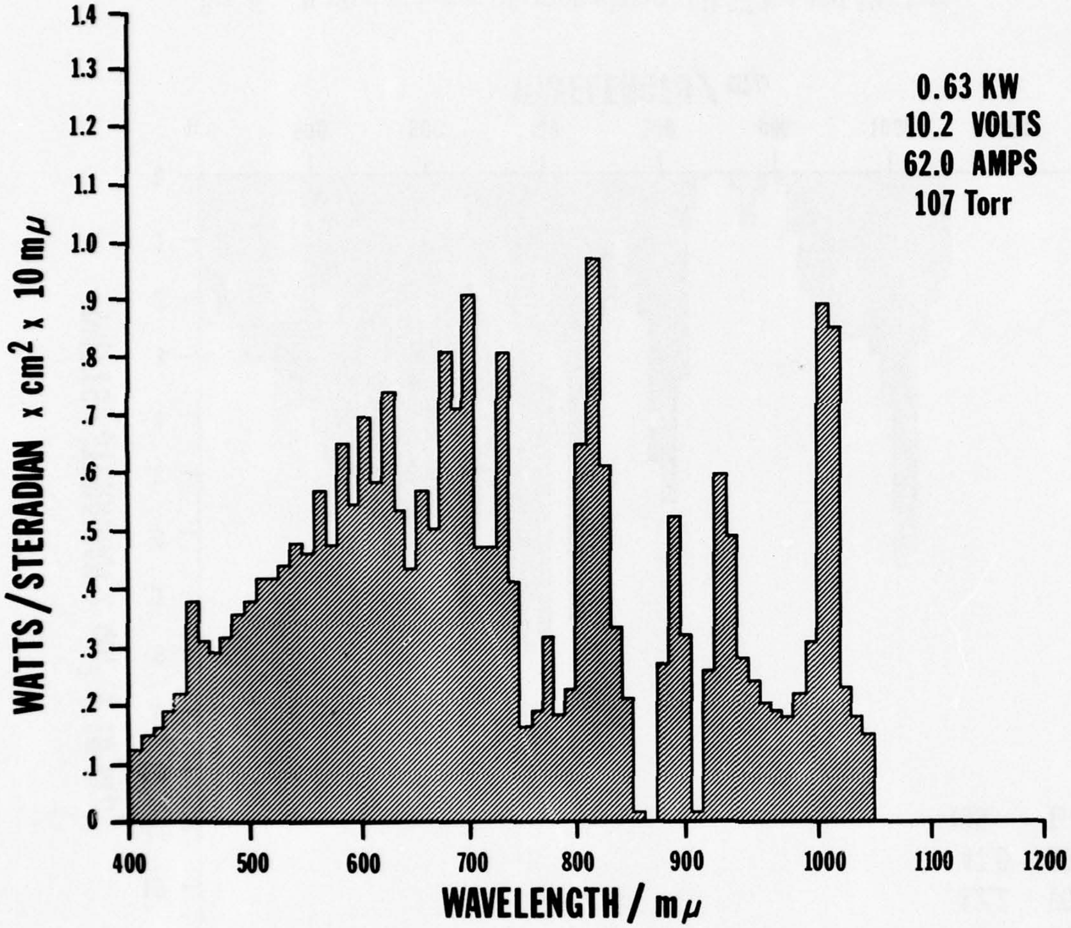


Fig. 7. Spectral radiance of cesium lamp at 0.63 kw and 107 torr.

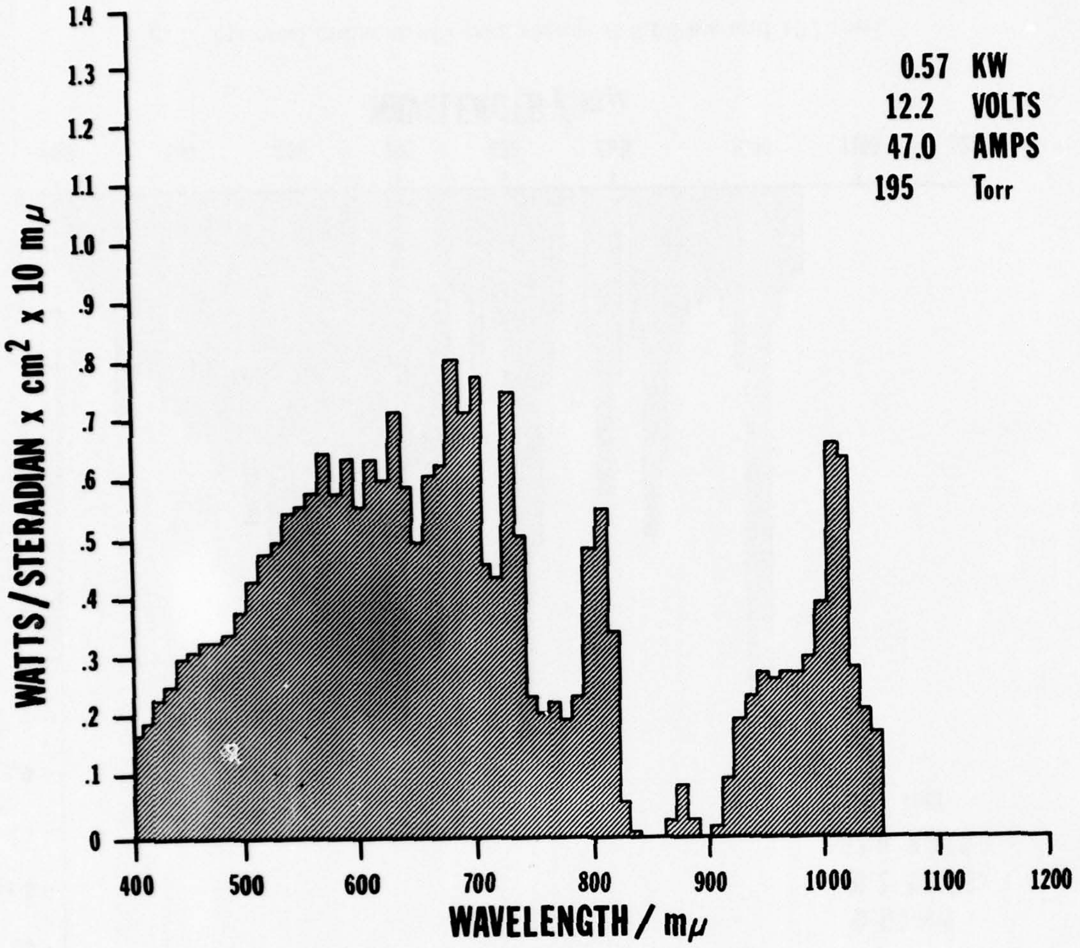


Fig. 8. Spectral radiance of cesium lamp at 0.57 kw and 195 torr.

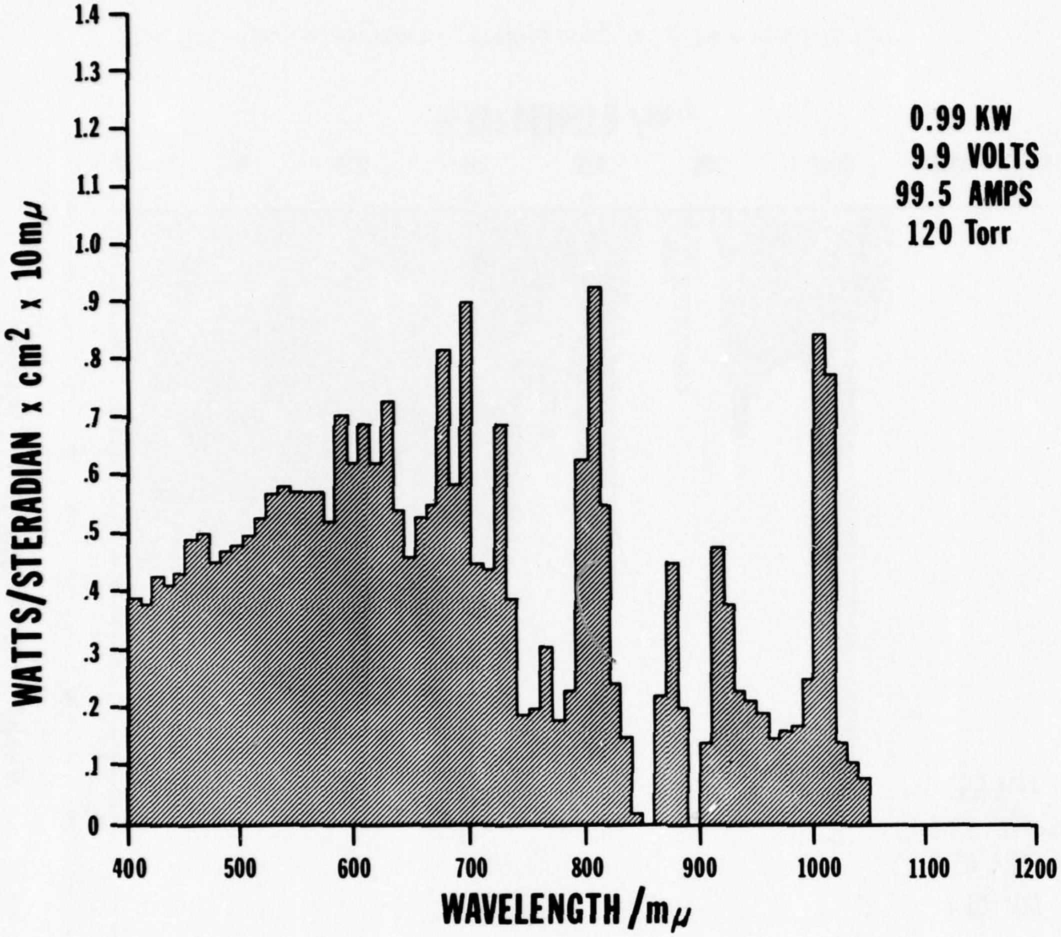


Fig. 9. Spectral radiance of cesium lamp at 0.99 kw and 120 torr.

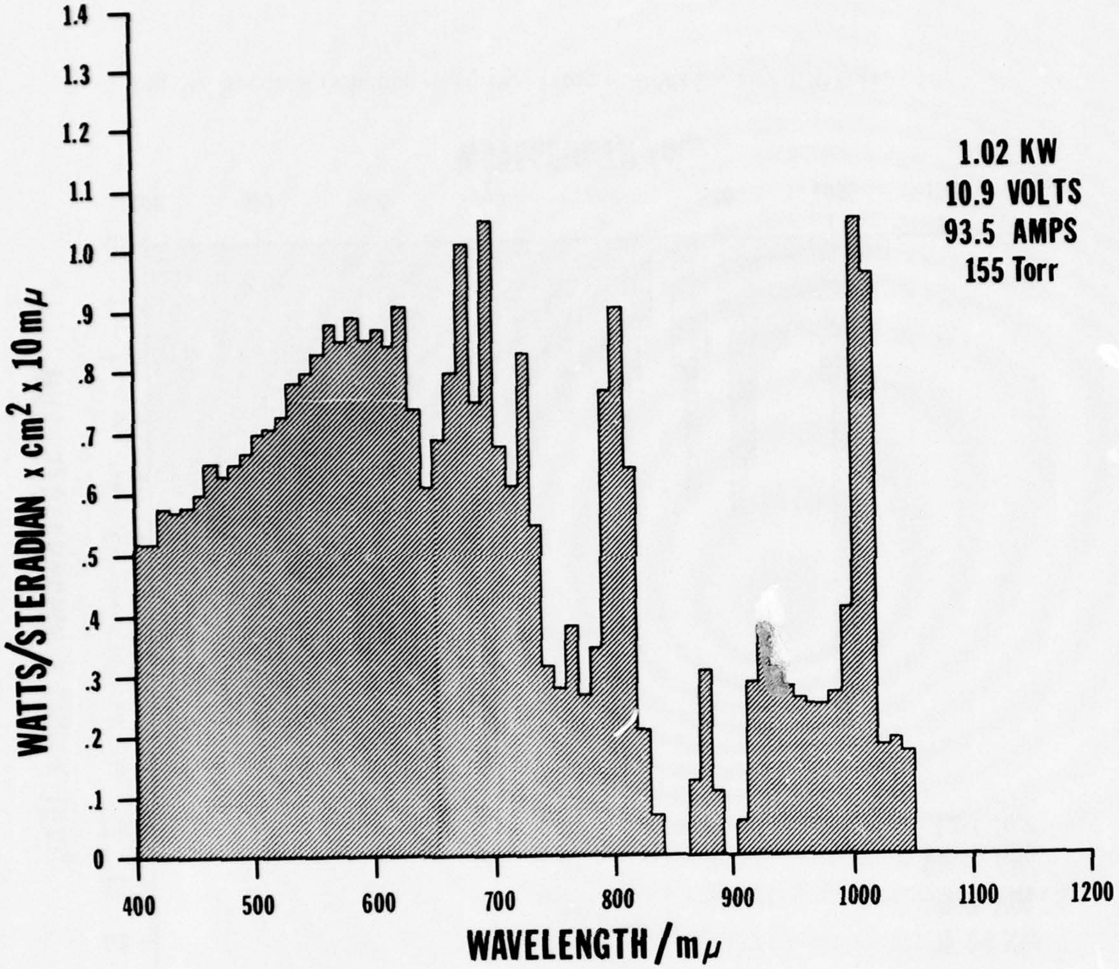


Fig. 10. Spectral radiance of cesium lamp at 1.02 kw and 155 torr.

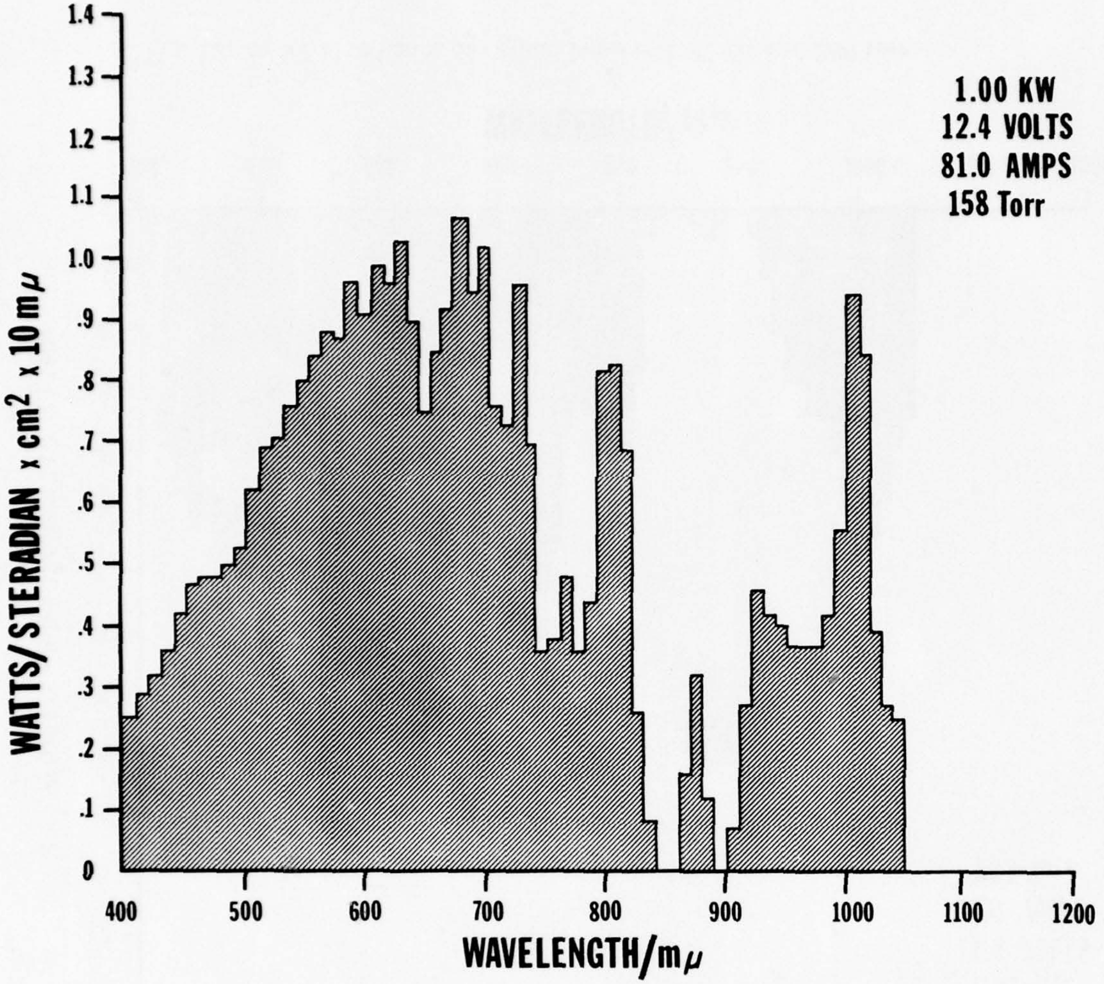


Fig. 11. Spectral radiance of cesium lamp at 1.00 kw and 158 torr.

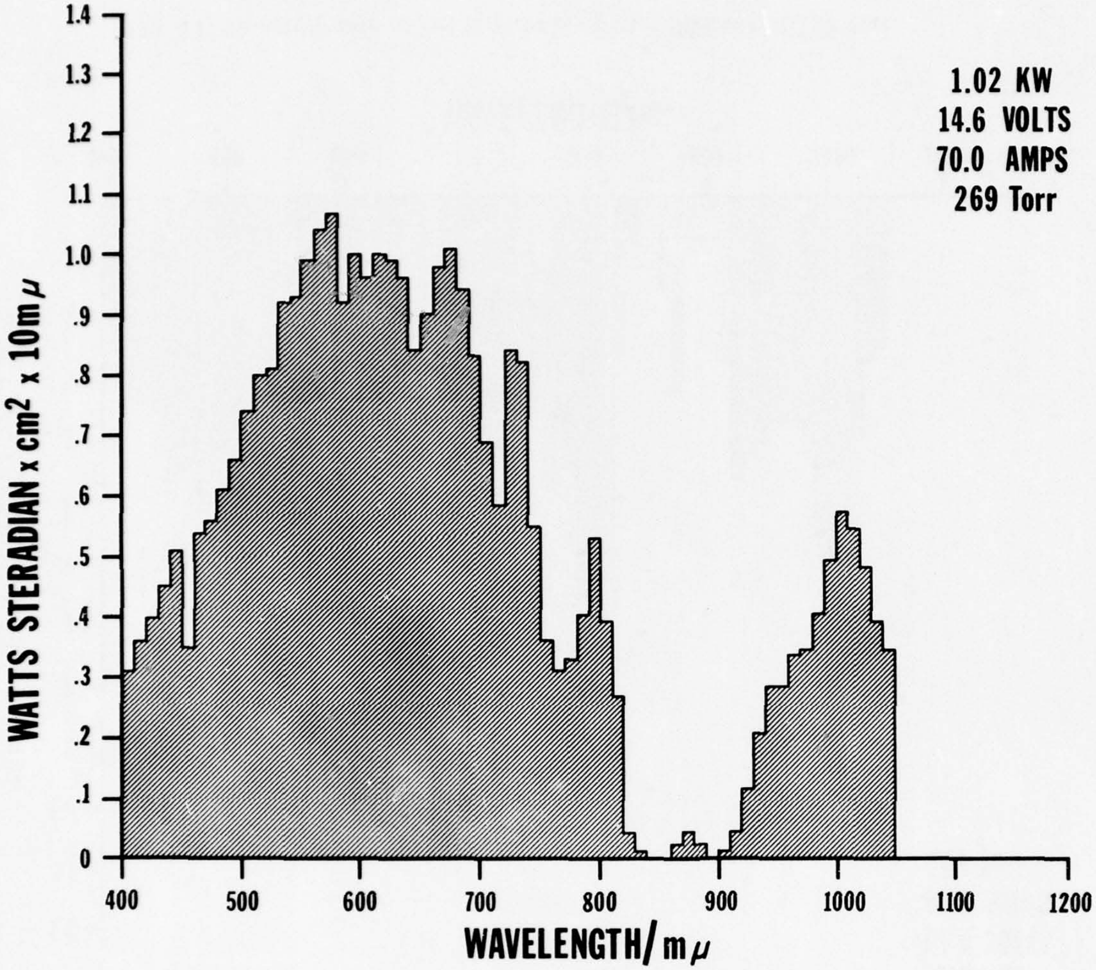


Fig. 12. Spectral radiance of cesium lamp at 1.02 kw and 269 torr.

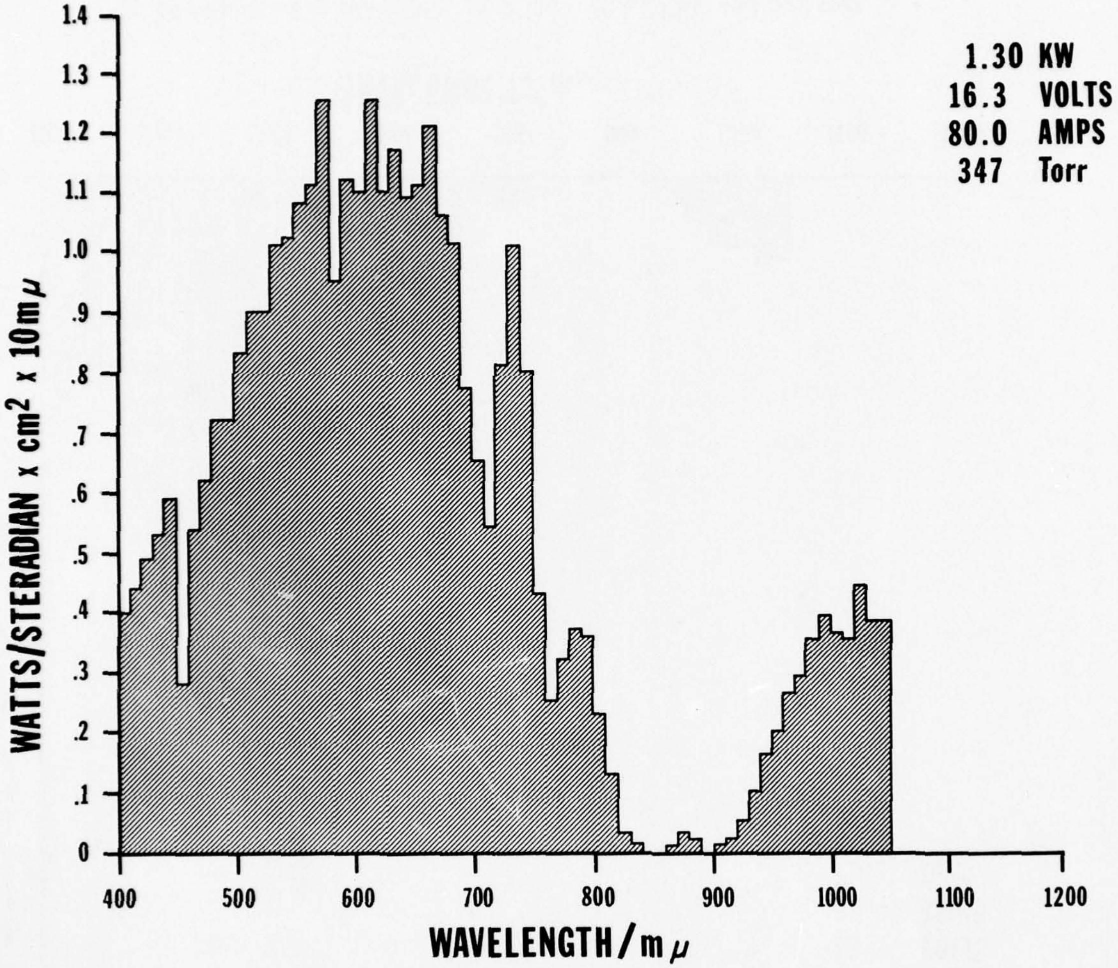


Fig. 13. Spectral radiance of cesium lamp at 1.30 kw and 347 torr.

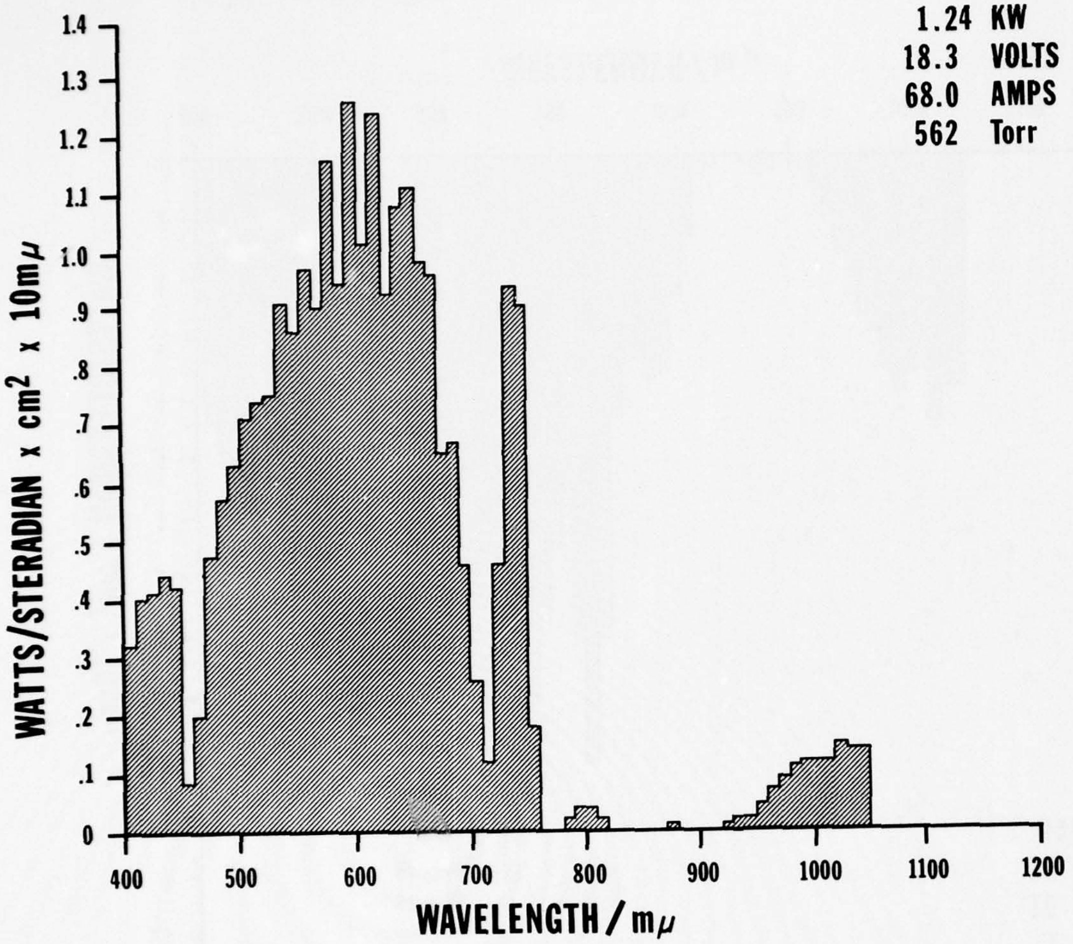


Fig. 14. Spectral radiance of cesium lamp at 1.24 kw and 562 torr.

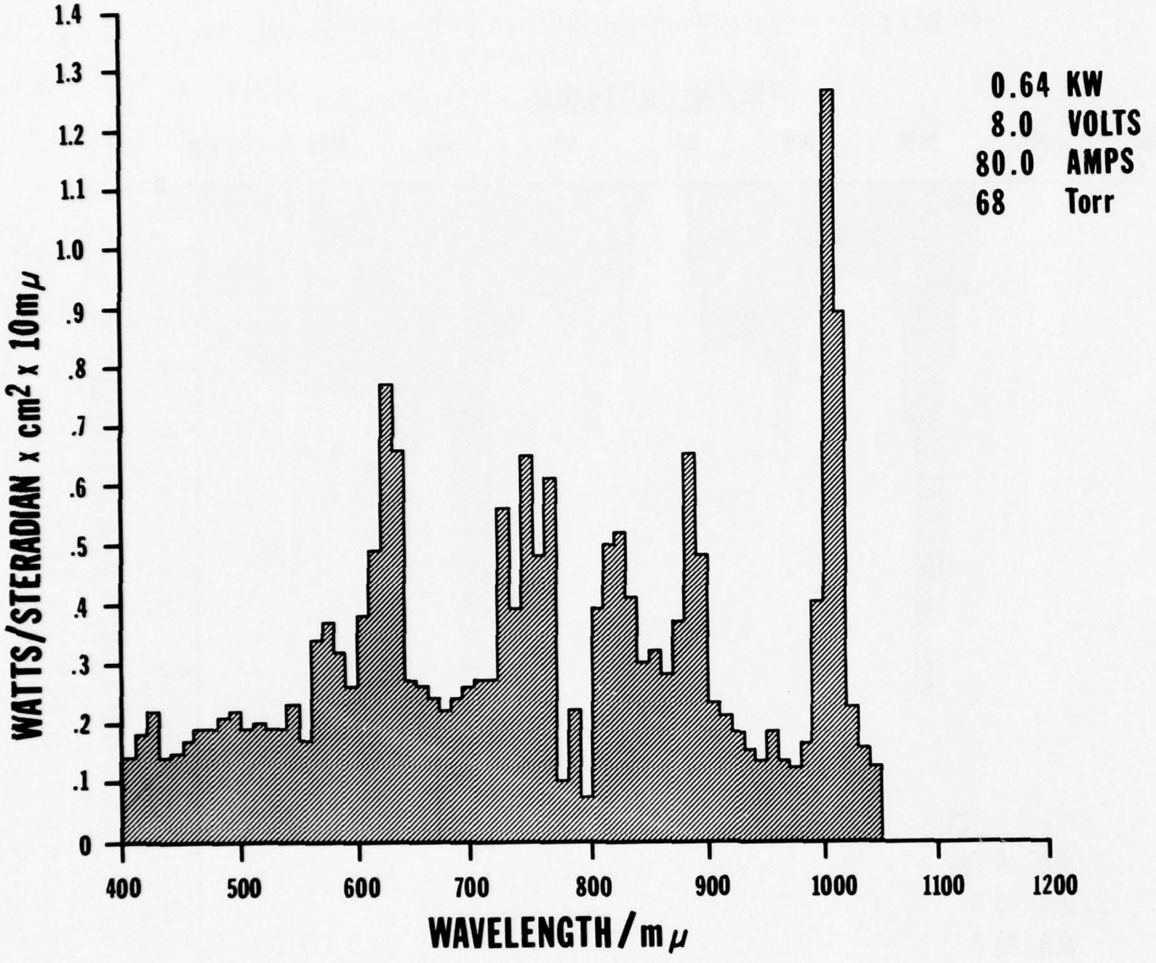


Fig. 15. Spectral radiance of rubidium lamp at 0.64 kw and 68 torr.

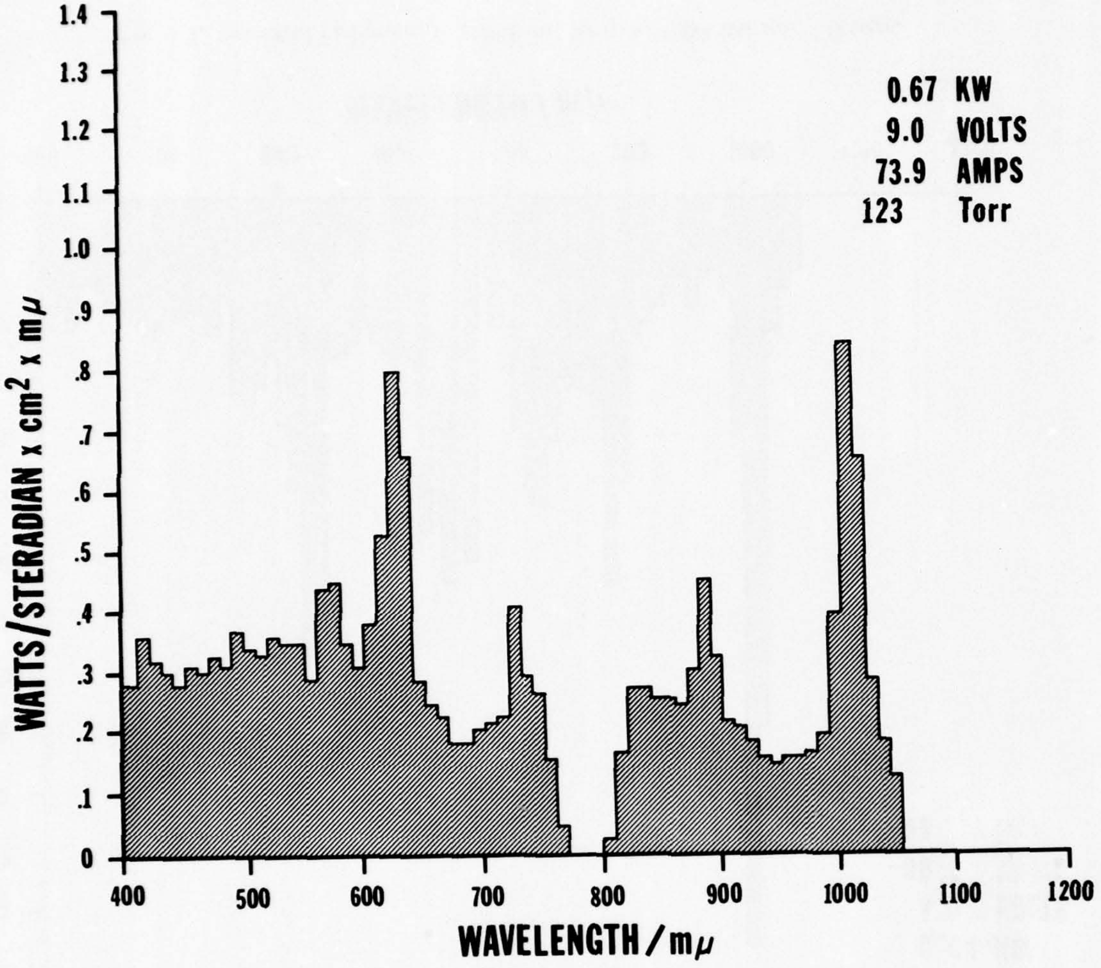


Fig. 16. Spectral radiance of rubidium lamp at 0.67 kw and 123 torr.

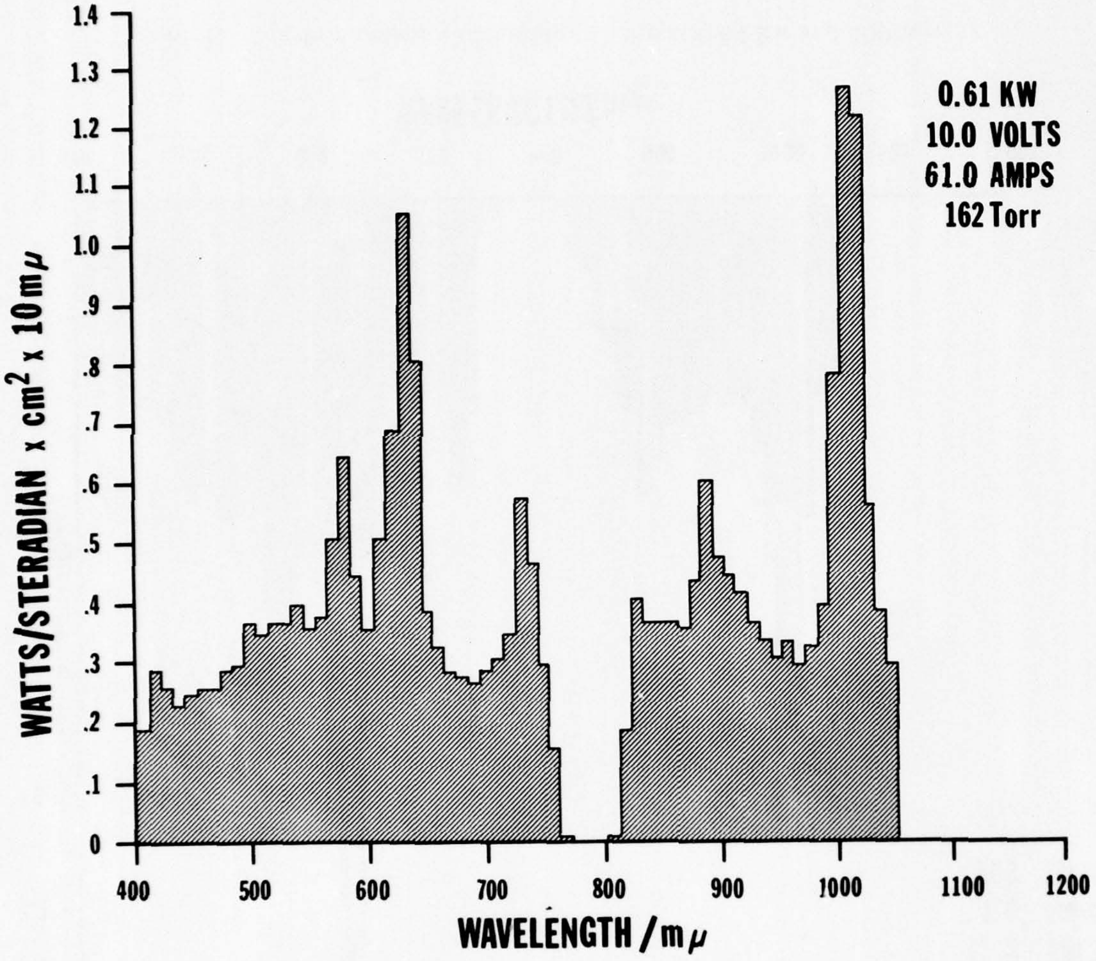


Fig. 17. Spectral radiance of rubidium lamp at 0.61 kw and 162 torr.

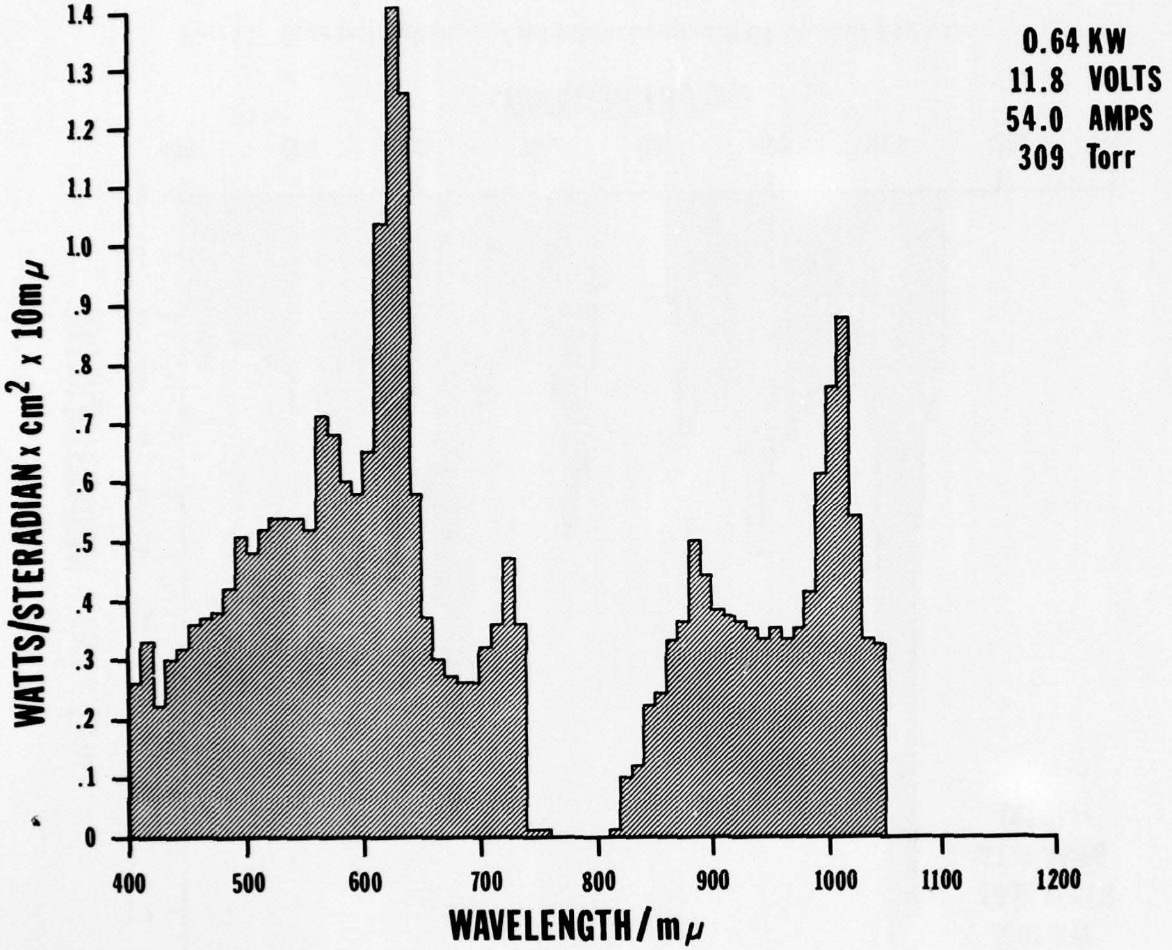


Fig. 18. Spectral radiance of rubidium lamp at 0.64 kw and 309 torr.

The resonance lines at 8521 Å and 8943 Å (the 6p to 6s transitions) show up as broad wells with strong flanks. The wells are 58 Å and 43 Å wide at the 50% points for the 8521 Å and 8943 Å transitions, respectively. As the pressure increases at constant input power, the voltage increases, the current decreases, and the total radiance rises. The widths of reversed lines grow larger while their flanks grow broader. The resonance line wells grow even wider. Continuum radiation and line broadening grow markedly stronger with increasing vapor pressure as noted by Schmidt (5) in his work on wall-stabilized discharges in alumina envelopes. The high visible emission is due mainly to the broad, lower-level lines of the 6p-ms, 6p-md, and 5d-nF series superimposed upon the strong continuum caused by Stark broadening and overlapping of the higher level lines of the 6p-ms and 5d-nF series and recombination (free to bound) continuum (6)(7). The effects of the increased emission with vapor pressure can be seen in the progression from Figs. 4 to 8. In Fig. 8, the heavy absorption in the region of the resonance lines is beginning to make one large valley instead of two.

Figures 9 through 12 are the results of the cesium runs at approximately 1.0 kw. In going from 120 torr to 158 torr, a dramatic increase in visible and near IR radiance is observed. As the pressure is increased to 269 torr, the visible radiance increases slightly but the near IR radiance to 1050 mμ decreases slightly.

Figures 13 and 14 are for data taken near 1.3 kw. Figure 13 for cesium at 347 torr shows an increase in visible radiance over Fig. 12 but the near infrared output is lower. At 562 torr, Fig. 14 shows that visible output is approximately the same as at 347 torr but near infrared has gone down even more.

Figures 15 through 18 are the integrated results of the experimental curves taken on the rubidium lamp at approximately 0.6 kw. Absorption and emission phenomena similar to cesium are observed for the rubidium lamp. In the progression from 68 torr to 162 torr, visible and IR radiance is increased and the resonance lines at 7800 Å and 7948 Å (the 5p to 5s transitions) form a well that widens as pressure increases. The resonance lines of rubidium form one large well at fairly low vapor pressure because they are much nearer each other than the cesium resonance lines (148 Å as compared to 422 Å). When pressure is increased to 309 torr, visible output still increases but near IR output decreases slightly.

Both lamps exhibit a dramatic change in operating modes as the vapor pressure is increased. At moderately low operating pressures, the arc is very constricted and sometimes has wings on it depending on the operating parameters. The wings are probably caused by convection currents within the cylindrical envelope. The cathode jet drives the gas downward toward the anode, and the junction of the downward flow and the returning upward flow around the arc forms the wings. At a pressure dependent upon the input power, the arc switches to a less constricted or "bushy" mode. It is hard to stabilize the lamps in one mode or the other near the pressure that the mode change takes place; and, in fact, the lamp can be made to pulse or oscillate between the two modes at a periodic rate. If the current is held constant, the voltage jumps approximately 1 or 2 volts (depending upon input power) higher in going from the constricted mode to the "bushy" mode, and the voltage jumps lower when the pressure is decreased and the arc switches from the "bushy" mode to the constricted mode. The radiance values do not differ appreciably from one mode to the other at approximately the same input power and pressure. Figures 10 and 11 are curves taken at about the same power and vapor pressure. The Fig. 10 curve was taken from the constricted mode and the Fig. 11 curve, from the "bushy" mode. The integrated radiance values are appreciably the same, but on the experimental curves differences can be seen. Many sharp emission lines are present for the constricted mode which do not show up at all on the experimental curve for the "bushy" mode. All lines on the curve for the "bushy" mode are reversed. The reason for the high number of emission lines in the constricted-mode curve is that the current density is very much higher; the arc temperature is, therefore, much higher; and, consequently, high-level transitions are excited although they do not add appreciably to the integrated output. The reason for the two arc modes is not now known for sure. It is tentatively felt, however, that the balance between field emission and thermionic emission is involved, and the percentage of coverage of the cathode by the cesium metal is an influencing factor. The low work function of cesium and rubidium affects the emission from the hot cathode.

The absorption wells in the resonance line regions of cesium and rubidium are an asset for military use. The cut-off of the visual security filter used for illumination in the infrared mode comes in this general region. The filter thickness and weight can be reduced substantially if no appreciable radiation is emitted by the lamp in that area. Xenon lamps have a large amount of emission in the range between 820 and 850 mμ which must be filtered out with a thick filter or passed with substantially reduced visual secrutiy. A commonly used infrared filter is Corning's 2540 glass. A 2-mm thickness cuts off to 10% transmission at approximately 870 mμ and 1% at approximately 820 mμ. Now, consider Fig. 11. The pressure for this run is such that visible and near IR radiance are near their maximum. The pressure is high enough so that visible continuum is high resulting in a white light, but the pressure is not so high that near IR emission decreases. The absorption well is suited for a 2540 glass filter because of the relatively low emission in the region of 820 to 870 mμ. An S-1 surface detector could then be used to detect the passed radiation including the peaks beyond 1000 mμ.

Though S-1 detectors are now being used in some military night observation devices, detectors with higher sensitivities are more widely used. One of these is the S-25 detector. Figure 19 is a semi-logarithmic curve of the sensitivity of an S-25 detector. However, it does not extend to 1000 mμ. Another filter currently being used with xenon lamps by the Army is the so-called "pink" filter. Figure 20 is a semi-logarithmic

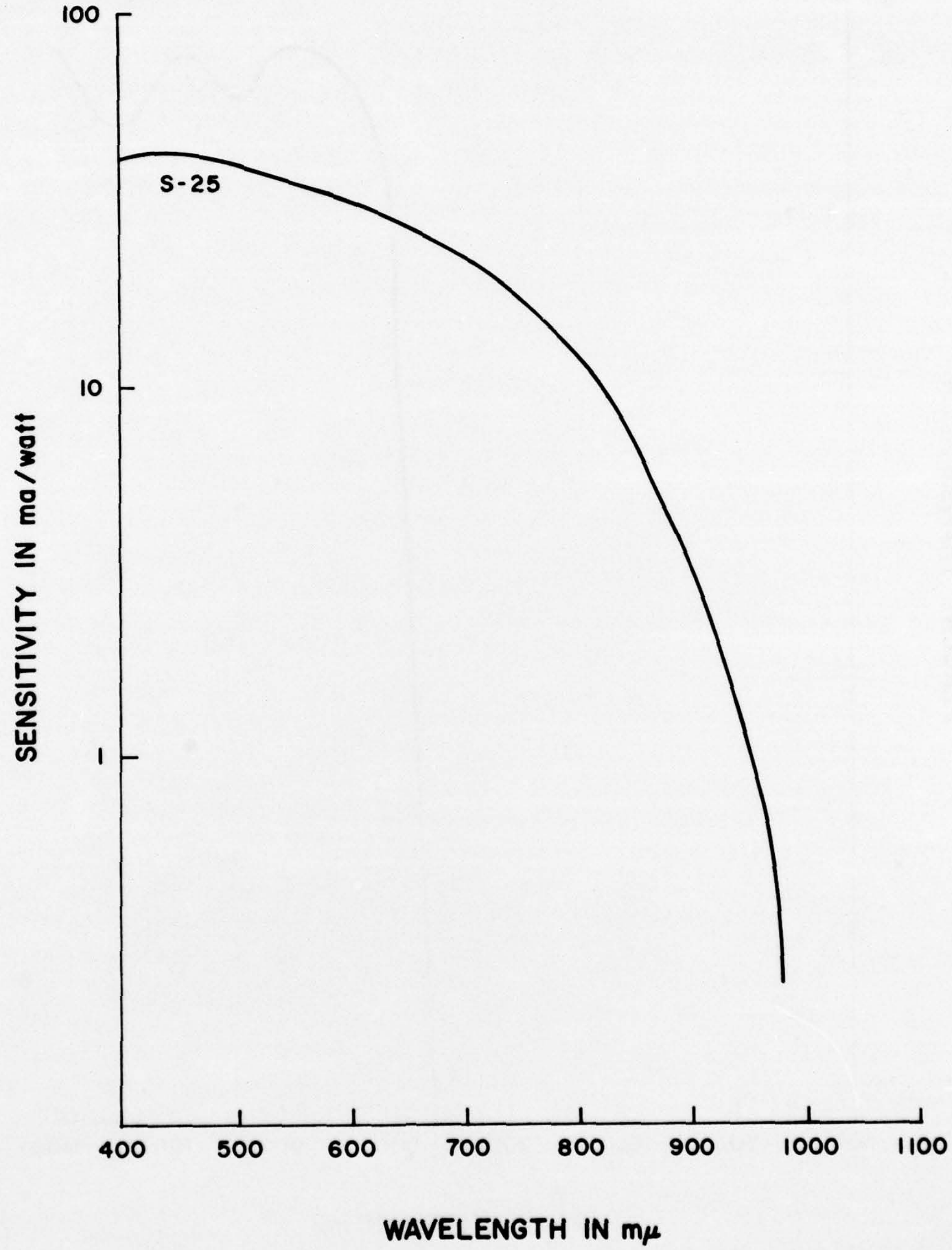


Fig. 19. S-25 detector sensitivity curve.

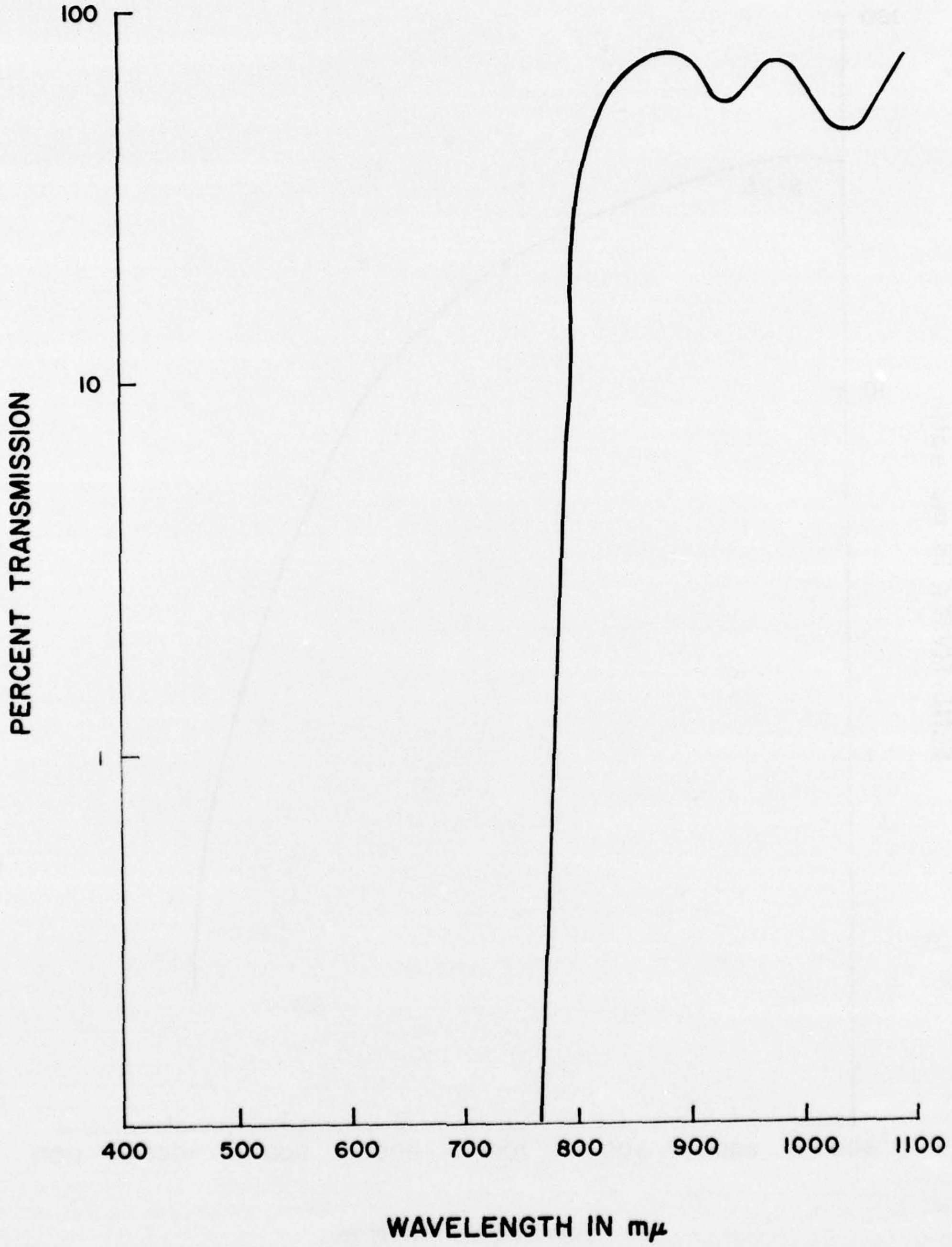


Fig. 20. Pink filter transmission curve.

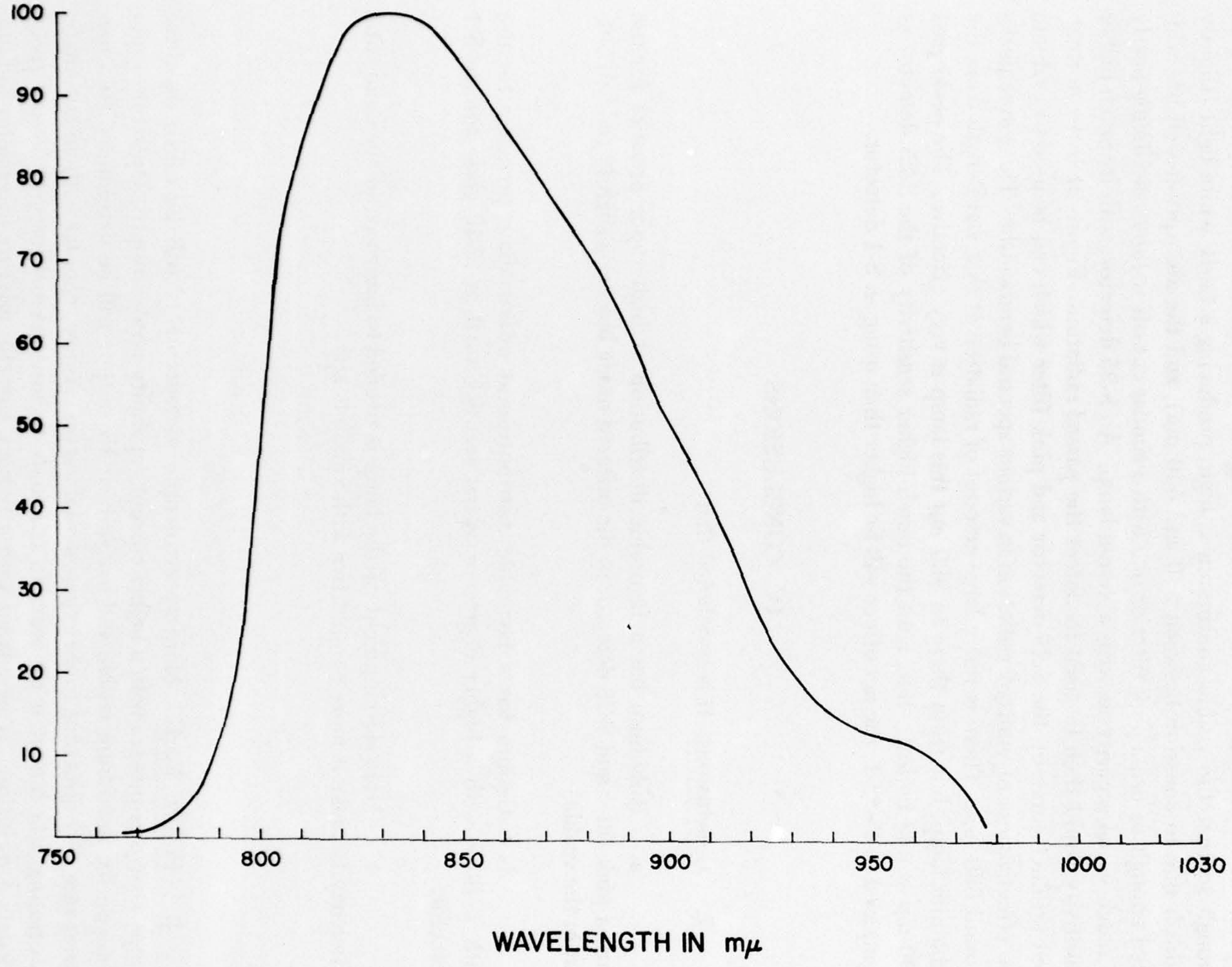


Fig. 21. Normalized product curve of pink filter and S-25 detector.

plot of the transmission of this filter. The reason for the waves on the top of the curve is that the "pink" filter is an interference-type filter. This filter is used to pass the xenon radiation in the region of 820 to 850 mμ as well as the longer wavelengths at the expense of visual security. Now, consider Fig. 18. The pressure for this curve is high enough so that the visible continuum is high, producing a fairly white light (slightly reddish due to emission between 610 and 640 mμ), and the absorption well has widened enough to use a pink filter or one with a similar cut-off without sacrificing nearly as much visual security as with a xenon lamp. An S-25 detector, with its much higher sensitivity could then be used to detect the passed radiation. Figure 21 is the normalized product curve of the S-25 detector and pink filter which can be used to evaluate the effectiveness of emitted radiation in various spectral bandwidths. This curve peaks around 830 mμ. There is not a large amount of radiation at that wavelength from the rubidium lamp, but from there to 980 mμ this lamp is very effective. The peaks past 980 mμ would be lost; but, with the much higher sensitivity of the S-25 detector as compared to the S-1, the net effect will be higher than using an S-1 detector.

IV. CONCLUSIONS

7. Conclusions. It is concluded that:

a. Rubidium has a favorable distribution at high vapor pressure for use with a pink filter and S-25 detector in the infrared mode but has a slightly reddish output in the visible.

b. Cesium has a favorable distribution at intermediate pressures for use with a filter with a higher degree of visual security such as 2540 glass and an S-1 detector.

c. More development of the lamp is needed to increase radiance and total efficiency to make it more competitive with xenon lamps.

V. FUTURE WORK

8. Future Work. More spectroscopic measurements will be taken on these lamps at higher powers with a higher current capability power supply. Optimum vapor pressure for maximum visible and usable near IR output will be determined to a narrower range by obtaining more experimental curves. A new recorder with an automatic integrating attachment is on order to eliminate tedious manual integration and speed up data acquisition. A new lamp with a ternary eutectic mixture of cesium, sodium, and potassium as fill will also be evaluated. Measurements will eventually be extended

to 5 microns by use of a light beam chopper and lock-in amplifier system, an alkali-halide lens, a coarser grating, and a cryogenically cooled indium antimonide detector. The lamp design will be improved for increased radiance and total efficiency. It will be redesigned for increased ruggedness and resistance to thermal stress.

Presently, methods are being explored for improved sapphire cylinder growth with less inherent strain caused by machining. Growth from a melt and vacuum casting are being investigated. An alkali metal lamp is now being made with a xenon starting gas to eliminate the internal cathode heater and provide a quick start.

LITERATURE CITED

1. Gibson, S. B., et al, "Characteristics of a 20 KW, Liquid-Cooled Xenon Arc Searchlight," NVL Report 2, Fort Belvoir, Virginia, March 1967.

2. Fromm, D. C. R., "Absolute Spectral Distribution Measurements of Xenon High-Pressure Discharges," ERDL Report 1837, Fort Belvoir, Virginia, November 1965.

3. "Glass Color Filters," Bulletin CF-3, Corning Glass Works.

4. Smithells, C. J., *Metals Reference Book,* Vol. I, p. 262, Plenum Press, New York, 1967.

5. Schmidt, K., "Radiation Characteristics of High Pressure Alkali Metal Discharges," *Proceedings, Sixth International Conference on Ionization Phenomena in Glass,* Paris, 1963.

6. Finkelnburg, W., and Peters, T., "Kontinuierliche Spektren," *Handbuch der Physik,* XXVIII, p. 183, Springer, Berlin, 1957.

7. Fromm, D. C. R., "Alkali Metal Vapor Studies," *Army Science Conference Proceedings,* Vol. I, 18-21 June 1968, p. 274, AD 837 118.

DISTRIBUTION FOR NVL REPORT NO. 6

ADDRESSEE	NUMBER
Department of the Army	
Commanding General U. S. Army Materiel Command ATTN: AMCRD–RP–E Washington, D. C. 20315	1
Chief, Research & Development Department of the Army ATTN: Dr. Robert B. Watson, Army Research Office Washington, D. C. 20315	1
Director U. S. Army Electronics Laboratories HQ, U. S. Army Electronics Command ATTN: AMSEL–RD–PF, Dr. Harold Jacobs Fort Monmouth, New Jersey 07703	1
Director U. S. Army Electronics Laboratories HQ, U. S. Army Electronics Command ATTN: AMSEL–RD–P, Mr. Bernard Louis Fort Monmouth, New Jersey 07703	2
Director U. S. Army Electronics Laboratories HQ, U. S. Army Electronics Command ATTN: AMSEL–RD–PFM, Mr. Frank Brand Fort Monmouth, New Jersey 07703	1
Commanding Officer U. S. Army Materials Research AGency ATTN: AMXMR–EC, Mr. Raymond L. Farrow Watertown, Massachusetts 02172	1

Commanding Officer Harry Diamond Laboratories ATTN: AMXDO–RCB, Mr. Harold F. Gibson Washington, D. C. 20438	1
Commanding Officer Frankford Arsenal ATTN: SMUFA 1310-64, Dr. Sidney Ross Philadelphia, Pennsylvania 19137	1
Commanding General U. S. Army Natick Laboratories ATTN: AMXRE–PRD, Dr. John M. Davies Natick, Massachusetts 01762	1
Commanding General U. S. Army Research Office–Durham Box CM, Duke Station ATTN: Dr. Robert J. Lontz Durham, North Carolina 27706	1
Director U. S. Army Electronics Laboratories HQ, U. S. Army Electronics Command ATTN: AMSEL–RD–SMA, Dr. Helmut Weickmann Fort Monmouth, New Jersey 07703	1
Commandant Army War College ATTN: Library Carlisle Barracks, Pennsylvania	1
Commanding Officer Frankford Arsenal ATTN: Library Philadelphia, Pennsylvania	1
Commanding Officer Picatinny Arsenal ATTN: Technical Library Dover, New Jersey	2

Commanding Officer U. S. Army Chemical Research & Development Laboratories ATTN: Librarian Edgewood Arsenal, Maryland 21010	1
Commanding Officer U. S. Army Electronics Research & Development Laboratories ATTN: Technical Documents Center Fort Monmouth, New Jersey	1
Commanding Officer U. S. Army Electronics Research & Development Laboratories ATTN: SELRA/LNO Fort Monmouth, New Jersey 07703	1
U. S. Army Natick Laboratories ATTN: Technical Library Natick, Massachusetts 01762	2
Commanding Officer U. S. Army Materials Research Lab Watertown Arsenal Watertown 72, Massachusetts	1
Chief of Communications–Electronics Department of the Army Washington, D. C.	1
Commandant U. S. Army Engineer School ATTN: Library Fort Belvoir, Virginia 22060	2
Commanding Officer USAETL Fort Belvoir, Virginia 22060	1
Commanding Officer U. S. Army Engineer CD Agency Fort Belvoir, Virginia 22060	1

Commanding Officer 1
U. S. Army Materials Research Agency
ATTN: Tech Info Center
Watertown, Massachusetts

Commanding Officer 2
Harry Diamond Laboratory
Washington, D. C. 20438

Commanding Officer 1
U. S. Army Research Office
Box CM Duke Station
Durham, North Carolina

Deputy Director 2
Night Vision Laboratory
Fort Belvoir, Virginia 22060

Optical Radiation Technical Area 60
Night Vision Laboratory
Fort Belvoir, Virginia 22060

Others

Assistant Secretary of Defense 1
ATTN: Technical Library
Washington, D. C. 20301

Office, Secretary of Defense 1
Advanced Research Projects Agency
Pentagon
Washington, D. C. 20301

Defense Documentation Center 20
Cameron Station
Alexandria, Virginia 22314

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Night Vision Laboratory U. S. Army Electronics Command Fort Belvoir, Virginia 22060	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP N/A

3. REPORT TITLE

ABSOLUTE SPECTRAL DISTRIBUTION OF CESIUM AND RUBIDIUM ARC LAMPS

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Interim Technical Report February – June 1969

5. AUTHOR(S) (First name, middle initial, last name)

Clifton S. Fox

6. REPORT DATE August 1969	7a. TOTAL NO. OF PAGES 38	7b. NO. OF REFS 7
8a. CONTRACT OR GRANT NO. b. PROJECT NO. 1Z662709D466-06 c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) 6 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)	

10. DISTRIBUTION STATEMENT

This document has been approved for public release and sale; its distribution is unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Night Vision Laboratory U. S. Army Electronics Command Fort Belvoir, Virginia 22060

13. ABSTRACT

Spectral radiance data in absolute units was obtained from 2-KW cesium and rubidium arc lamps operated at various power levels and vapor pressures to determine optimum operating conditions for maximum visible and near infrared output. The report concludes that rubidium has a favorable distribution at high vapor pressures for use with a pink filter (low density infrared filter) and an S-25 detector in the infrared mode, and cesium has a favorable distribution at intermediate pressures for use with a filter with a higher degree of visual security and an S-1 detector. More development of the lamp is needed to increase radiance and total efficiency.

DD FORM 1 NOV 65 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Arc Lamps						
Alkali Metal Vapor Arc Lamps						
Cesium						
Rubidium						
Spectral Radiance						
Plasma Physics						