NATIONAL BUREAU OF STANDARDS REPORT

5747

Problems in the Control of Glare
in Approach- and Runway-Light Systems

By
C. A. Douglas

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

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For
Aeronautical Accessories Laboratory
Wright Air Development Center
Deparment of the Air Force

NBS

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1. INTRODUCTION

Present practice is to control the glare from approach- and runway-light systems by choosing a beam pattern for the lights so that the pilot is outside the main beam of a light when the distance to the light is short, and by changing the current through all lamps in the system thereby reducing the intensity of the system when the visibility is good. Since restricting the beam of the lights reduces the region in which the lights provide guidance and since reducing the intensity of the lights reduces their visual range, some compromise is necessary in the design of the system.

The present trend to lights on the centerline of the approach zone and runway and to narrow-gauge lighting has accentuated these problems.

The increase in the angles at which the pilot views a light as the distance to the light decreases will also be smaller, becoming nearly zero for centerline lights in the touchdown zone. Thus the possibilities of the control of glare of these lights by means of beam pattern are limited. The minimum distances between the pilot and the lights will be smaller, thus requiring lower intensity settings for a given visibility condition.

The reduction in the visual range of the approach lights resulting from this reduction in intensity can have significant effects on the performance of the approach-light system as will now be demonstrated.

2. DESIGN PARAMETERS

In 1940 and 1941 the National Bureau of Standards conducted field studies of approach lighting on Nantucket Island. As part of that work a qualitative system for rating the brilliancy of approach lights was developed. The results of this work are shown in figure 1 which is a plot of the illumination required at night for the various steps used in describing the appearance of the lights.(1) Note that there is a factor of approximately 4 between the brilliancy steps. These data were taken by a stationary observer using a relatively short system of lights. Experience indicates that for the moving pilot, the illuminations corresponding to each step should be increased by a factor of about four. Thus an illumination of 2 mile candles corresponding to

our rating of "Faint" is now used as the pilot's threshold in computing runway visual range from transmissometer measurements. Similarly, a pilot rating of "Very Bright," which is about the maximum useful illumination, requires an illumination of about 2000 mile candles. Thus we have a ratio of about 1000 between the maximum and minimum useful illuminations.

3. VISUAL RANGE OF APPROACH LIGHTS

These values may be used to develop design criteria for the beam pattern and intensity control of approach and runway lights. For example, the maximum useful intensity may be computed as a function of the atmospheric transmittance and the distance between the pilot and the light. The results of this computation are shown in figure 2. The minimum useful illumination is about one-thousandth the intensities shown and the optimum illumination is about one-fortieth of the intensities shown. Note that when the viewing distance is small, the maximum useful intensity is low both in fog and in good visibility and that as the viewing distance increases, the maximum useful illumination in fog increases rapidly. The maximum, and also the optimum and the minimum, useful intensity can be obtained from these curves if the minimum distance between the light and the intersection of its main beam and the path of the airplane is known. In the inner approach zone this minimum distance is of the order of 400 to 600 feet. Hence, when the visibility is 1000 feet, the maximum useful intensity of the main beam is about 1000 candles. Since the present approach-light lamps have an intensity of about 20,000 candles in the beam when operated at full intensity, the lights in the inner part of the approach zone will be glaring if they are operated above 5% of peak intensity. On the other hand, for 1000-foot visibility the minimum distance at which the pilot is within the main beam of the lights in the outer approach zone is of the order of 1200 feet. The maximum useful beam intensity is about 4,000,000 candles. Hence, the minimum useful intensity for the main beam is about 4000 candles. Thus the minimum useful intensity in the outer approach zone is about four times the maximum useful intensity in the inner approach zone.

The situation is even more serious than these figures indicate. When the aircraft is in the outer approach zone, lights closer than about 1000 to 1200 feet can not be seen because of restrictions in the field of view caused by the structure of the aircraft. This effect of cockpit cutoff is illustrated in figure 3. The minimum visual ranges at which the lights will be seen were computed assuming a maximum downward angle of view of 15° and an approach-light system 3000 feet long. With these visual ranges the pilot will have only one-half second to find the light before it disappears under the nose of the airplane. These visual ranges must be increased by

about 500 feet before the pilot will obtain sufficient visual guidance from the lights to fly by visual reference.

When the visibility is 1000 feet, the illumination from an approach-light lamp operating at full intensity (20,000 candles in the beam) will be 2 mile candles when the distance to the lamp is about 1400 feet. Thus the pilot should be able to locate the outermost light in the system soon after he comes within 4400 feet of the threshold and will see a 500-foot segment of lights when he comes within 2800 feet of the threshold. However, if the lights are operated at 5% intensity (1000 candles in the beam) in order to reduce glare in the inner approach zone, an illumination of 2 mile candles will not be obtained until the distance to the light becomes slightly less than 1100 feet. Thus the pilot will not see any lights until he comes within 3800 feet of the threshold. The outermost light which can be seen will be a light 1700 feet from the threshold. He will not see 500 feet of lights until he is within 1500 feet of the threshold. Thus a change of only 300 feet in the visual range of the incandescent approach lights would cause these lights in the outer half of the approach zone to be of very little use.

For present aircraft and glide slopes, if the contact distance is not limited by the length of the approach-light system, the change in contact distance will be approximately five times the change in visual range.

The solution to this problem is straightforward: 1) Use of lights in the outer approach zone with as high a beam intensity as is consistent with the required beam spread and permissible power consumption (the use of color filters in this area is precluded); 2) Use of lamps of different intensity and beam pattern in the inner and outer parts of the approach-light systems; 3) Adjustment of the lamps to different relative intensities in conditions of restricted visibility. One arrangement would be the use of the 500-watt, 20-ampere approach-light lamps in the outer 1000 feet of the approach zone and the 200-watt, 6.6-ampere lamps in the rest of the system and setting the intensity of the lights in the outer zone one step higher than those in the inner zone when those in the inner zone are on steps 2, 3, or 4. The transition between the two zones can be smoothed by making the intensity-setting change at a different point from the one at which the lamp types are changed, for example, at 1500 feet from the threshold.

4. CONTROL OF INTENSITY SETTING

It is also important that the relative intensity of an approach- or runway-light system be set at a level which is suitable both for the system and the visibility conditions. This requires first a

knowledge of the suitable intensity and some means of insuring that the system is set at this intensity.

As a part of the NBS approach-light tests at Nantucket and Indianapolis, a generalized formula for the intensity setting of approach and runway lights was developed.[1] Examples of the intensity setting - visibility relation for night conditions are shown in figure 4. The lower curve shows the intensity-setting relation used by the automatic intensity-control system in setting the intensity of the runway lights at the Landing Aids Experiment Station throughout the 1949 test season.[2] The middle curve shows the relation used by the same equipment to control the intensity of the approach lights at the Naval Air Test Center in 1951-1952.[3] The intensity control of both systems was considered satisfactory by the pilots using the systems. The upper step curve shows the current practice.[4] The intensities given by the LAES and NATC curves are for use during approaches with precision electronic aids only. The current practice settings are somewhat higher in order to have intensities outside the main beam sufficiently high for circling and non-precision approaches.

There are a number of methods for obtaining the proper intensity setting which should give better results than are now being obtained. Among these are, 1) a completely automatic system which will compensate for changes in both background brightness and atmospheric transmittance, 2) a meter in the transmissometer indicator circuit which indicates directly the proper intensity setting, and 3) the simple expedient of using a single brightness selector switch and marking the positions of this switch with the visibilities corresponding to the positions instead of with an arbitrary number.

A feasibility model of a completely automatic system developed by NBS was tested at the Landing Aids Experiment Station[2] and the Naval Air Test Center. This system was designed for use with slow-acting induction regulators and it can be simplified somewhat if it is to be used with the present high-speed and step-type regulators.

A design study has been made of the problems involved in the use of an intensity-setting meter in the transmissometer circuit. This study indicates that there will be sufficient separation of intensity setting steps 3, 4, and 5 on the meter if a logarithmic movement is used.

No problems are anticipated in the introduction of the third method of control.

The choice of method of intensity control is an operational one and is determined by the degree of automation desired and the complexity of the instrumentation required.

5. CONCLUSION

Operating the present approach-light systems at reduced intensity in order to reduce glare in the inner approach zone can seriously reduce the effectiveness of the outer part of the approach-light system. Modification of the system so that the lights in the outer zone have considerably higher intensity than those in the inner zone appears desirable.

Improvement should be made in the means of obtaining the proper intensity setting. Several methods of obtaining improved intensity control are feasible.

References

(1) F. C. Breckenridge and C. A. Douglas, Development of Approach- and Contact-Light Systems. Illuminating Engineering 40, 785 (1945)

(2) Landing Aids Experiment Station 1949 Final Report, pages 36 and 121

(3) Naval Air Test Center Report AE 2201, EI 311-292, Installation and Test of Automatic Light Intensity Control Systems for Approach and Runway Lights, April 9, 1954

(4) Air Force Technical Order 35F8-14-1

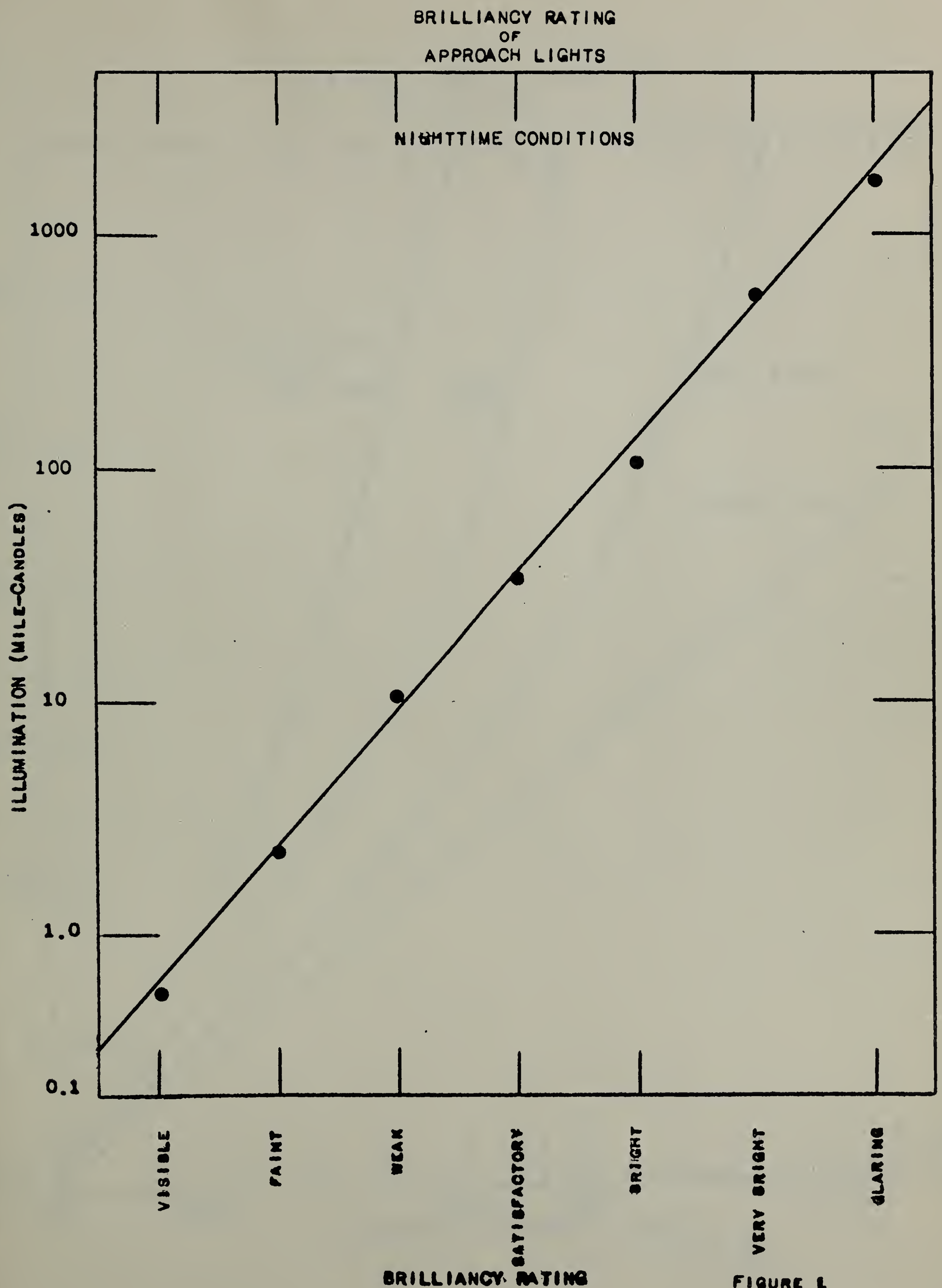

BRILLIANCY RATING
OF
APPROACH LIGHTS
NIGHTTIME CONDITIONS
ILLUMINATION (MILE-CANDLES)
1000
100
10
1.0
0.1
VISIBLE
FAINT
WEAK
SATISFACTORY
BRIGHT
VERY BRIGHT
GLARING
BRILLIANCY RATING

FIGURE 1

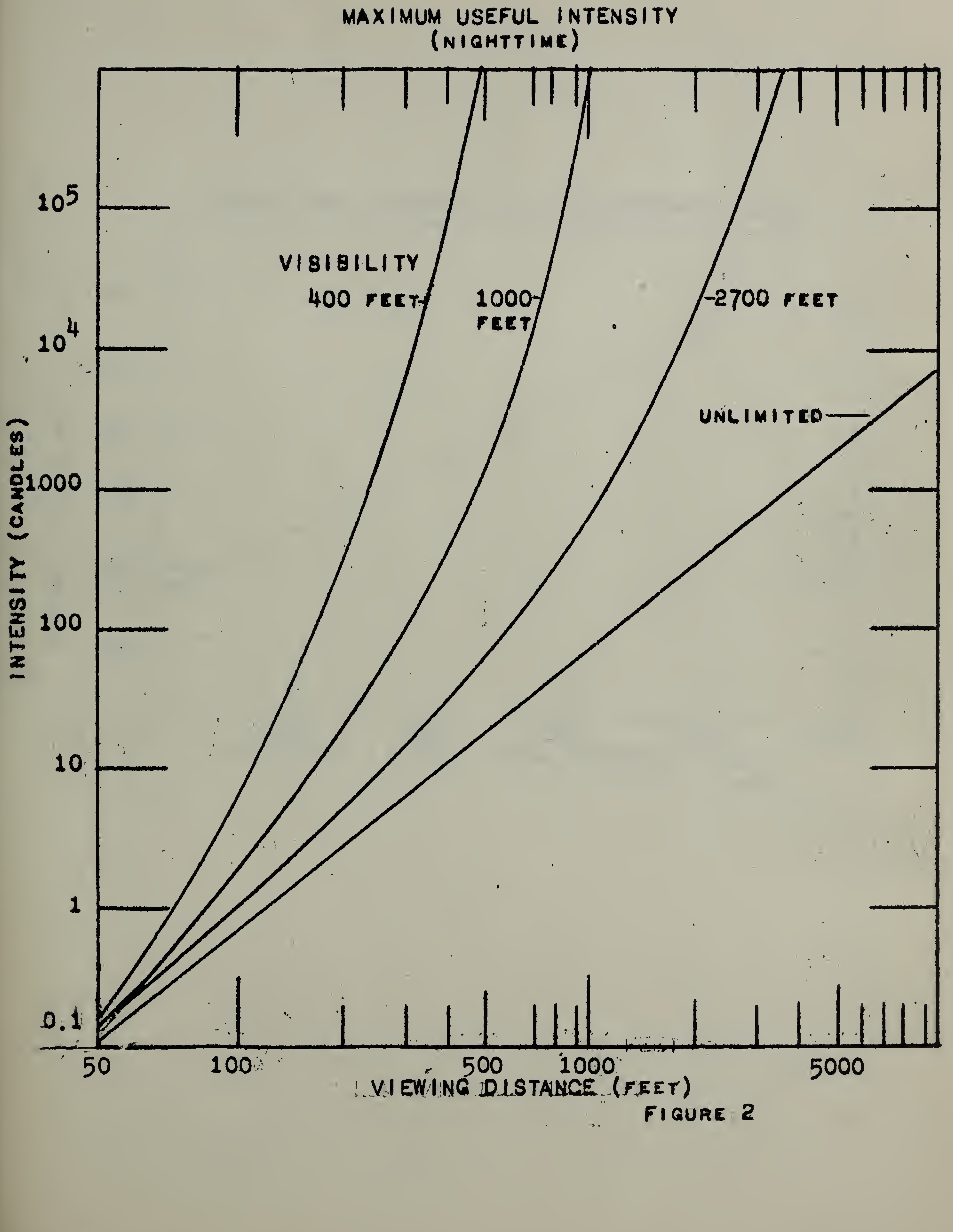

MAXIMUM USEFUL INTENSITY
(NIGHTTIME)
VISIBILITY
400 FEET
1000 FEET
2700 FEET
UNLIMITED
INTENSITY (CANDLES)
10^5
10^4
1000
100
10
1
0.1
50
100
500
1000
5000
VIEWING DISTANCE (FEET)

FIGURE 2

VISUAL RANGE REQUIRED TO SEE APPROACH LIGHTS

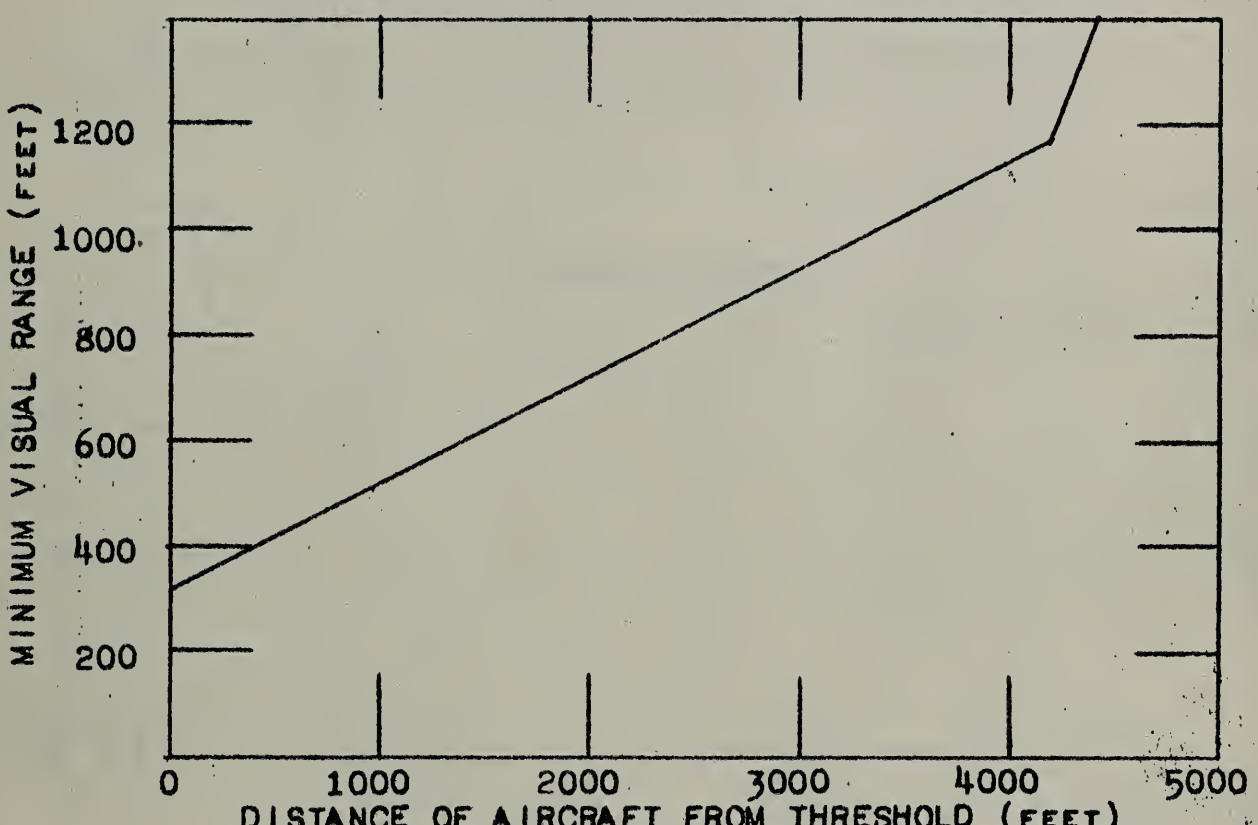
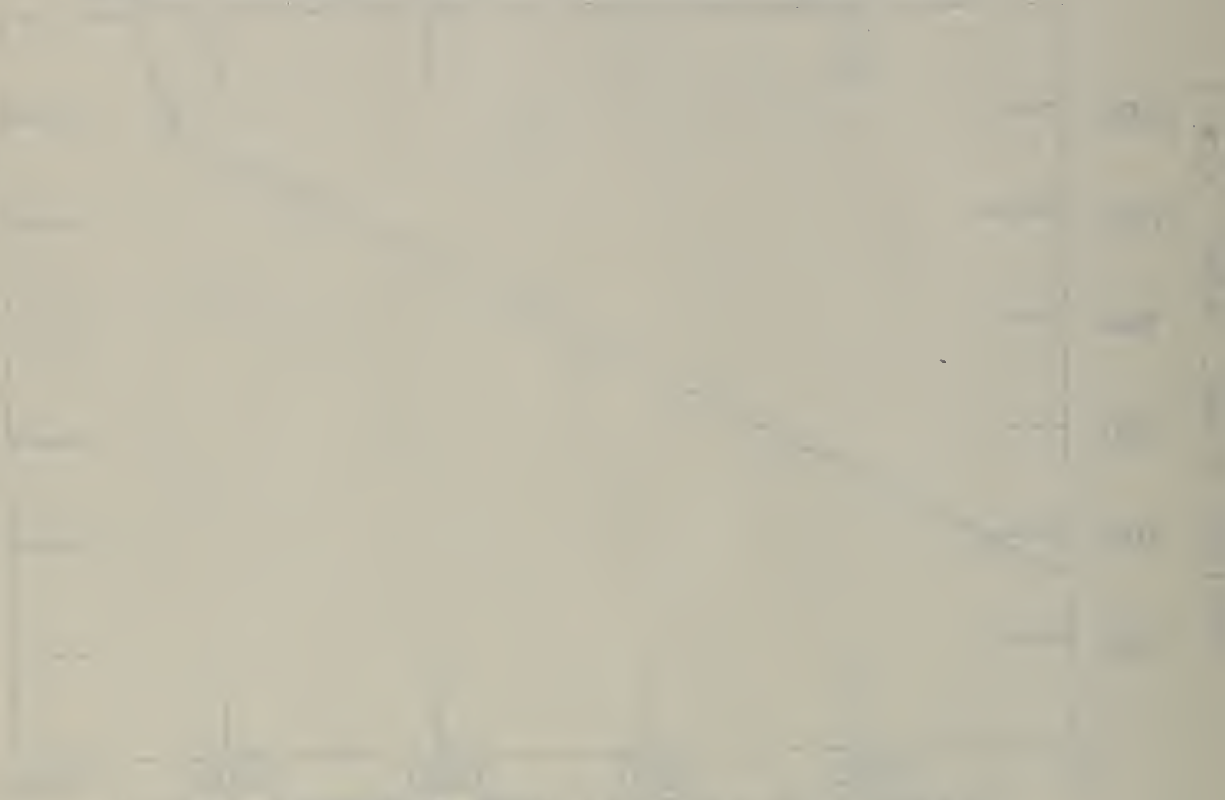


FIGURE 3



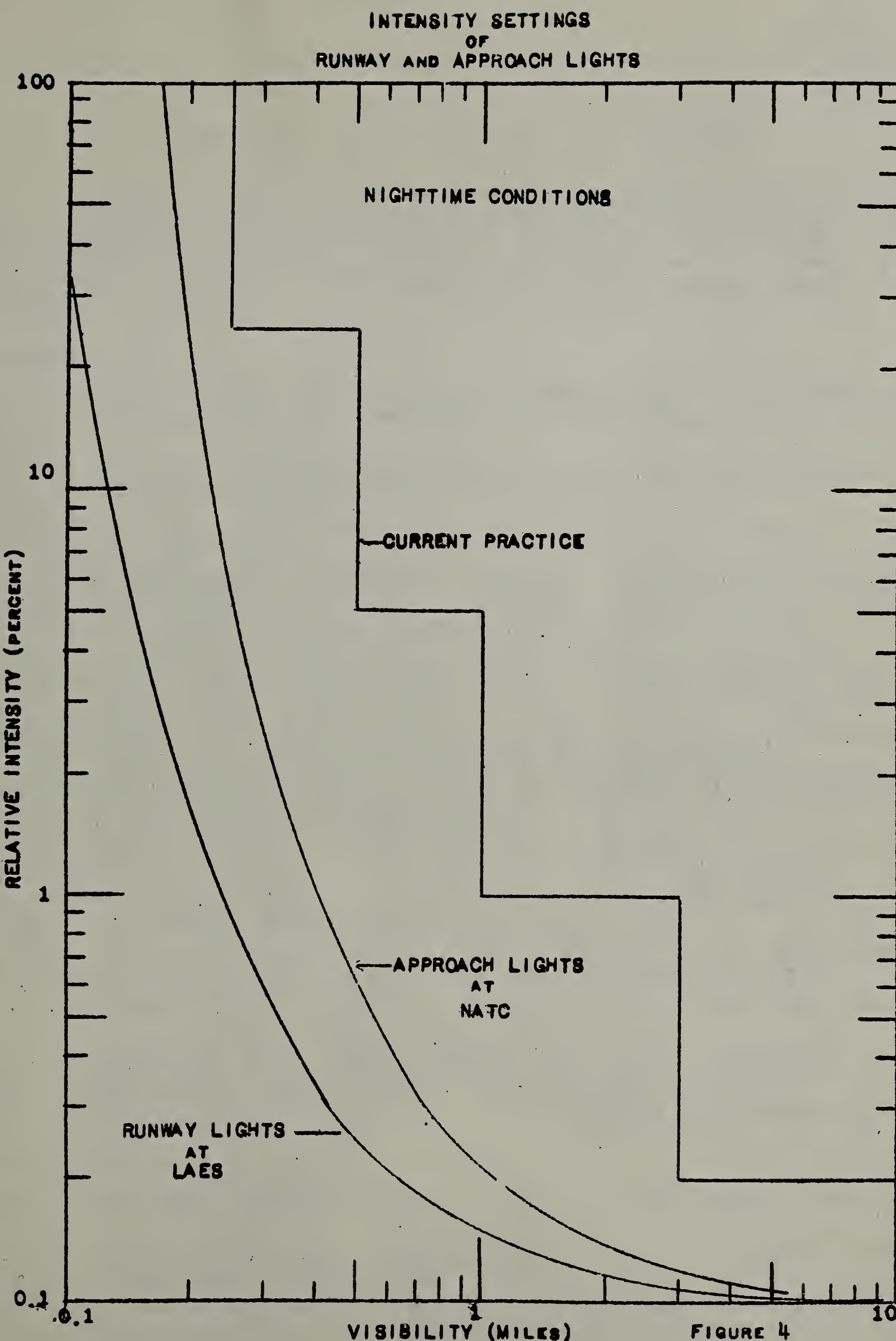

INTENSITY SETTINGS
OF
RUNWAY AND APPROACH LIGHTS
NIGHTTIME CONDITIONS
CURRENT PRACTICE
APPROACH LIGHTS
AT
NATC
RUNWAY LIGHTS
AT
LAES
100
10
1
0.1
.0.1
1
10
RELATIVE INTENSITY (PERCENT)
VISIBILITY (MILES)

FIGURE 4

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Sinclair Weeks, *Secretary*

NATIONAL BUREAU OF STANDARDS
A. V. Astin, *Director*

THE NATIONAL BUREAU OF STANDARDS

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WASHINGTON, D. C.

Electricity and Electronics. Resistance and Reactance. Electron Tubes. Electrical Instruments. Magnetic Measurements. Dielectrics. Engineering Electronics. Electronic Instrumentation. Electrochemistry.

Optics and Metrology. Photometry and Colorimetry. Optical Instruments. Photographic Technology. Length. Engineering Metrology.

Heat and Power. Temperature Physics. Thermodynamics. Cryogenic Physics. Rheology and Lubrication. Engine Fuels.

Atomic and Radiation Physics. Spectroscopy. Radiometry. Mass Spectrometry. Solid State Physics. Electron Physics. Atomic Physics. Nuclear Physics. Radioactivity. X-rays. Betatron. Nucleonic Instrumentation. Radiological Equipment. AEC Radiation Instruments.

Chemistry. Organic Coatings. Surface Chemistry. Organic Chemistry. Analytical Chemistry. Inorganic Chemistry. Electrodeposition. Gas Chemistry. Physical Chemistry. Thermochemistry. Spectrochemistry. Pure Substances.

Mechanics. Sound. Mechanical Instruments. Fluid Mechanics. Engineering Mechanics. Mass and Scale. Capacity, Density, and Fluid Meters. Combustion Controls.

Organic and Fibrous Materials. Rubber. Textiles. Paper. Leather. Testing and Specifications. Polymer Structure. Organic Plastics. Dental Research.

Metallurgy. Thermal Metallurgy. Chemical Metallurgy. Mechanical Metallurgy. Corrosion. Metal Physics.

Mineral Products. Engineering Ceramics. Glass. Refractories. Enameled Metals. Concreting Materials. Constitution and Microstructure.

Building Technology. Structural Engineering. Fire Protection. Heating and Air Conditioning. Floor, Roof, and Wall Coverings. Codes and Specifications.

Applied Mathematics. Numerical Analysis. Computation. Statistical Engineering. Mathematical Physics.

Data Processing Systems. SEAC Engineering Group. Components and Techniques. Digital Circuitry. Digital Systems. Analogue Systems. Application Engineering.

- Office of Basic Instrumentation
- Office of Weights and Measures

BOULDER, COLORADO

Cryogenic Engineering. Cryogenic Equipment. Cryogenic Processes. Properties of Materials. Gas Liquefaction.

Radio Propagation Physics. Upper Atmosphere Research. Ionospheric Research. Regular Propagation Services. Sun-Earth Relationships.

Radio Propagation Engineering. Data Reduction Instrumentation. Modulation Systems. Navigation Systems. Radio Noise. Tropospheric Measurements. Tropospheric Analysis. Radio Systems Application Engineering.

Radio Standards. Radio Frequencies. Microwave Frequencies. High Frequency Electrical Standards. Radio Broadcast Service. High Frequency Impedance Standards. Calibration Center. Microwave Physics. Microwave Circuit Standards.

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