# NATIONAL BUREAU OF STANDARDS REPORT

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By
C. A. Douglas

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By
C. A. Douglas
Photometry and Colorimetry Section
Metrology Division

Prepared For
Meteorological Management Division
Bureau of Naval Weapons
Department of the Navy

and

Instrument Division
Weather Bureau
Washington, D. C.

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# Methods of Modifying the Transmissometer System to Permit its Use during Periods of Very Low Runway Visual Ranges

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## I. INTRODUCTION

As aircraft landing minimums are reduced, the transmissometer pulse rate becomes a limiting factor during periods of low visibility. For example, the minimum pulse rate with a 500-foot baseline transmissometer for the range of transmittances reported as a nighttime RVR, runway visual range, of 1000 feet is about one pulse in 13 seconds. The present RVR converters count the number of pulses in a fixed time interval rather than the time for a known number of pulses. An error of ± 1 in the pulse count is therefore possible because of (a) the random variation in the interval between the start of the interval in which pulses are counted and the occurrence of the first pulse in the interval, and (b) because of the variations in the time between pulses caused by momentary changes in fog density and by minor irregularities in pulse rate produced by the type WL-759 trigger tube (V 202). Hence, the acceptable minimum number of pulses per interval is often considered to be four for the lowest reportable increment of RVR. Even so, when the true transmittance is such that the pulse rate is slightly more than three pulses per interval, four pulses per interval will be counted occasionally. This will, in effect, drop the lower end of the 1000-foot RVR increment by about 50 feet.

Therefore, if RVR's lower than 1000 feet are to be reported, some modification of the transmissometer-converter system is required. The following methods of modifying the system are analyzed in this report.

I. Increase in length of time interval.

II. Modifications of the RVR converter.

III. Increase in the pulse rate by a fixed factor by modifications of the transmissometer.

IV. Reduction of the length of the baseline.

The attached figures have been prepared to assist in the interpretation of the effects of these modifications. Figure 1 shows the relation between transmittance and RVR as a function of the length of the baseline. In preparing this figure an intensity of 10,000 candles and a threshold illuminance of 2 mile candles have been assumed. These curves represent nighttime operation with the lighting system at full intensity. Figure 2 shows the relation between seconds per pulse and RVR as a function of length of the baseline. It was prepared from the data of Figure 1 assuming a pulse rate of 4000 pulses per minute for a transmittance of 1.00. Figure 3 is similar to Figure 2 except that the dependent variable is pulses per minute.

### 2. Method I - Increase in the Length of the Time Interval in which Pulses are Counted.

The present Weather Bureau specifications require that the length of the time interval be in the range of 45 to 55 seconds. If the length of this interval were increased, the transmittance at which four pulses would be produced per interval would be decreased proportionately. However, it is readily apparent from the figures that obtaining a significant decrease in the lowest RVR which could be reported would require intervals of the order of several minutes. For example, assume that the lowest RVR to be reported is 800 feet, and that RVR's in the range 750 to 850 feet are to be reported as 800 feet. The transmittance for a 500-foot baseline corresponding to the lower limit, an RVR of 750 feet, is 0.00025 and the time between pulses is about 65 seconds. Thus, in order to obtain four pulses per time interval, an interval of 270 seconds would be required. This interval is too long.

### 3. Method II - Modification of the RVR Converter.

It is possible to construct an RVR converter that will measure the time between pulses when the transmittance is very low instead of the number of pulses in a fixed interval. With such a converter, there would be no problem of the accuracy of the determination. The converter could be designed so it would have, in effect, an instantaneous re-set and hence would measure each time interval between pulses. The minimum transmittance which could be measured would be determined only by the maximum permissible time between successive RVR readouts or the maximum time between pulses at which the equipment would operate, whichever is the smaller. An RVR of 800 feet could be measured if permissible time between RVR readouts were of the order of 70 seconds. RVR's lower than this could not be reported satisfactorily both because the interval between RVR readouts would become unduly long and because leakage currents in the photopulse unit of the transmissometer usually limit the instrument to transmittances for which the interval between pulses is of the order of 90 seconds.

## 4. Method III Increasing the Pulse Rate

Two methods of increasing the pulse rate of the transmissometer are possible: (1) increasing the sensitivity of the receiver[1], and (2) increasing the intensity of the projector.

### 4.1 Increasing the Sensitivity of the Receiver

Increasing the sensitivity of the receiver is simpler than increasing the intensity of the projector. However, the background pulse rate is increased by the same factor as is the signal pulse rate. Since the background pulse rate is the limiting factor in daylight, increasing the receiver sensitivity would be beneficial only at night. Sensitivity of the receiver could be increased by several methods, among them the following:

a. Increasing the diameter of the receiver lens. The sensitivity (pulse rate) is proportional to the exposed area of the lens. Thus, increasing the lens diameter to 8 inches would increase the pulse rate by a factor of about four.

b. Increasing the sensitivity of the present receiver by changes in electronic circuitry. An increase by a factor of about five could be obtained by this method. The number of phototubes and trigger tubes having sensitivities which are too low would be increased significantly. Tests of a receiver in which the circuitry has been modified to obtain a fivefold increase in pulse rate are now being conducted at NBS.

c. Use of a neon lamp (Type Ne-2) in place of the trigger tube (WL-759). (A neon-lamp-type photopulse unit was used in the first NBS transmissometer.) An increase in sensitivity by a factor of about five could be obtained. Stability of receiver sensitivity would be decreased. Obtaining satisfactory neon lamps would necessitate a tedious selection process.

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[1] Receiver sensitivity is defined as the pulse rate (pulses per minute) divided by the illuminance at the receiver lens.

d. Use of a photomultiplier in place of the present phototube. A several-fold increase in sensitivity could be obtained by this method. Stability would be decreased and the complexity of circuitry increased. A transmissometer is now being modified to use a photomultiplier tube to obtain service experience with this modification.

### 4.2 Increasing the Intensity of the Projector

Increasing the intensity of the projector is the most desirable method of increasing the pulse rate since the background pulse rate is unchanged. The pulse rate could be increased by a factor of about 2 if the operating life of the lamp were decreased from 3000 to 300 hours. The intensity of the projector could be increased by the use of a large aperture reflector and a separate lamp. For example, with a 24-inch reflector and a 100-watt incandescent lamp, the intensity could be increased to about 10 or 20 times the present intensity without reducing lamp life. However, use of such a projector increases the problem of of maintenance markedly. Still greater increases in pulse rate could be obtained if the incandescent lamp were replaced by a high-pressure xenon or mercury lamp with this reflector. This change would increase the problems of maintenance still more. Moreover, the expected life of these lamps is of the order of 500 hours and the cost of a xenon lamp is several hundred dollars. A type H-6 mercury lamp would require forced cooling. The stability of the output of neither lamp is comparable with that of the present incandescent source. Hence, more frequent adjustment of the 100% setting would be required.

4.3 The effects of increasing the pulse rate or the time interval by a constant factor are summarized in Table I.

TABLE I

| Factor by which pulse rate or timing period is increased | Lowest reportable RVR for 500-foot baseline transmissometer [1] (feet) | Minimum RVR in reporting increment (feet) |
|---|---|---|
| 2 | 900 | 850 |
| 5 | 800 | 750 |
| 10 | 750 | 700 |
| 100 | 600 | 550 |
| 1000 | 500 | 450 |

[1] Based on 100-foot reporting increments. Values are approximate.

Note that the transmissometer receiver and indicator as presently designed will not operate at pulse rates faster than about 60,000 pulses per minute even though the intensity of the projector is sufficient to produce pulse rates higher than this. Note also that if a 500-foot baseline transmissometer were modified — by using a xenon lamp in a large aperture reflector — so that it would produce, for example, one pulse in 15 seconds when the nighttime RVR was 500 feet, the clear-weather pulse rate would be 4,000,000 pulses per minute. Recording of transmittances varying from 1.00 to $10^{-6}$ would be required. Recording over so wide a range presents a number of difficulties. For example, if the transmittance were recorded on a logarithmic scale, the lower half of the scale would be used only when the RVR was below 1000 feet (the transmittances for 500 feet were $10^{-3}$ and lower), and the transmittance reading would be in the upper fifth of the scale whenever the RVR was above 2000 feet (the transmittance was above 0.07).

## 5. Reduction in Length of Baseline

For a fog of constant density, the pulse rate is an exponential function of the length of the baseline. Hence, shortening the baseline will produce a significant increase in the pulse rate in very dense fogs as is demonstrated by the figures. The lower limit of operation as a function of the length of the baseline is summarized in Table II.

TABLE II

| Length of Baseline (feet) | Lowest Reportable RVR (feet) | Minimum RVR in reporting increment (feet) |
|---|---|---|
| 1000 | 1800 (1) | 1700 |
| 750 | 1400 (1) | 1300 |
| 500 | 1000 (1) | 900 |
| 400 | 800 (1) | 750 |
| 300 | 650 (1) | 600 |
| 250 | 550 (1) | 500 |
| --- | --- | --- |
| 250 | 400 (2) | 350 |

(1) Based on a pulse rate of 4000 pulses per minute when T = 1.00

(2) Based on a pulse rate of 40,000 pulses per minute in clear weather.

Note: In computing the lowest reportable RVR a 200-foot increment is assumed for RVR's of 1000 feet and higher. A 100-foot increment is assumed for RVR's below 1000 feet. Thus, RVR's in the interval 900 to 1100 feet would be reported as RVR's of 1000 feet.

If no changes are made in the intensity of the projector or the sensitivity of the receiver, the clear-weather pulse rate with the new baseline will be equal to the product of the clear-weather pulse rate with the former baseline and the square of the ratio of the length of the new baseline to the length of the former baseline. Hence, a clear-weather pulse rate of 16,000 pulses per minute would be obtained by changing from a 500-foot to a 250-foot baseline if no changes were made in the sensitivity of the receiver. If the sensitivity of the photopulse unit is increased to about the maximum possible and the diameter of the receiver lens is increased to about 6 inches, a clear-weather pulse rate of 40,000 pulses per minute could be obtained for a 250-foot baseline.

The primary difficulties involved in the use of a shorter baseline are the reduction in the length of the sample measured and the decrease in the maximum RVR which can be indicated with satisfactory accuracy. There are several possible methods of compensating, at least in part, for these difficulties; Among these are: (1) the use of two transmissometers "end-to-end", (2) the use of a double-baseline transmissometer, and (3) the use of a composite baseline transmissometer.

## 6. Discussion

### 6.1 "End-to-end" Transmissometers

If two transmissometers are used end-to-end with their outputs combined so that the product of the two transmittances is indicated, the problem of decreased length of sample will be eliminated.

It should be noted that the two transmissometers need not be located so the two baselines form a continuous line. The two baselines need not, and should not, be precisely colinear. A deviation of several degrees in the orientation of baselines is desirable. Nor are the two baselines required to be so located that one starts where the other ends. An interval as long as one or two baselines may be left between the end of the first baseline and the start of the second. For example, if two 250-foot baseline instruments were installed with a gap of about 500 feet between the two baselines, a very good sample of a 1000-foot path would be obtained under relatively homogeneous fog conditions. In addition, a good measure of the homogeneity of the fog could be obtained by comparing the outputs of the individual instruments. The redundancy of instrumentation would permit operation with one instrument should the other be out of service and would, in addition, be a significant aid in trouble shooting and maintenance. One of the primary difficulties of this method is the cost of the required dual instrumentation and the additional instrumentation required to combine the outputs of the two instruments. However, it is believed that the cost of a very high intensity projector of the type described in Section 4.2 would be greater than the cost of the second transmissometer. The second difficulty is the limitation in accuracy in the indications of the higher RVR's where instrumental accuracy is the limiting factor. The errors produced by instrumental inaccuracies

in RVR's obtained from the two 250-foot "end-to-end" transmissometers would be intermediate between the errors of a single 250-foot transmissometer and those of a 500-foot transmissometer.

### 6.2 Double-Baseline Transmissometer

Another means of improving the sampling is the use of a double-baseline transmissometer, that is, two receivers at different distances from a projector. A switch-over device would be included so that the longer baseline is used whenever the fog density is such that operation with this baseline is feasible. (Such instruments were used in the initial transmissometer installation at Nantucket and also at the Landing Aids Experiment Station.) Because of the limited field of view of the receiver, the use of two receivers with a single projector is preferable to the converse. Although this method requires less instrumentation and would be less costly than the "end-to-end" transmissometer, it is considered less desirable for the following reasons:

(a) During periods when use of the short-baseline section is required, a less adequate sample of fog is used with this method.

(b) This method provides a less satisfactory means of indicating the variations in a non-homogeneous fog.

(c) There is no redundancy in the instrumentation during periods when the use of the short baseline is required. The only redundancy in good weather (when the long baseline should be used) is the possibility of using the short baseline should the long-baseline receiver fail.

This method would, however, provide more accurate RVR indications for the higher RVR's than will the "end-to-end" transmissometers. If the length of the "long" baseline is made more than 500 feet, this method will provide higher accuracy during periods of high RVR's than does the present 500-foot instrument. It should be noted that, if the "long" baseline is increased to more than 750 feet, a projector of higher intensity than the present projector would be required unless a more sensitive receiver were used.

### 6.3 Composite Baseline Transmissometer

An instrument of this type is similar to a double-baseline instrument using two projectors, except that in this instrument the projectors would be operated simultaneously. The primary advantage of this system is that no switch-over between baselines is required. However, its accuracy would be inferior to that of a double-baseline instrument for all RVR's.

### 6.4 Scattered-Light Errors

In a fog, a telephotometer such as the transmissometer receiver will receive, in addition to the light which passes directly from the source to the receiver, some light which, though radiated by the source, would not reach the receiver in clear weather. This scattered light constitutes an error in the transmittance measurement. In dense fogs this error may become large, especially when the size of the fog droplets is small. In the transmissometer the error is minimized by keeping the field of view of the receiver and the beam spread of the projector as small as possible. Measurements made at the NBS Field Laboratory, Arcata, California, indicate that with the present transmissometer the errors caused by scattered light do not cause significant errors in the indicated visibility or RVR when the transmittance per 500 feet is higher than $10^{-4}$. However, this error may become significant in very dense fogs and a correction for it may be required.

## 7. Conclusion

When operation of the transmissometer is required in fogs in which the runway visual range is lower than 1000 feet, modification of the instrument will be required. The choice of type of modification is dependent upon the maximum fog density (minimum RVR) at which operation is required. For operation in RVR's lower than about 800 feet, a reduction in length of baseline is the preferred modification. Compensation can be made for the decreased length of sample incurred with this reduction in baseline length by the use of two short-baseline transmissometers in an essentially "end-to-end" position. If the minimum RVR for which transmissometer operation is required is about 800 feet, increase in both the sensitivity of the receiver and the intensity of the projector should provide satisfactory operation.

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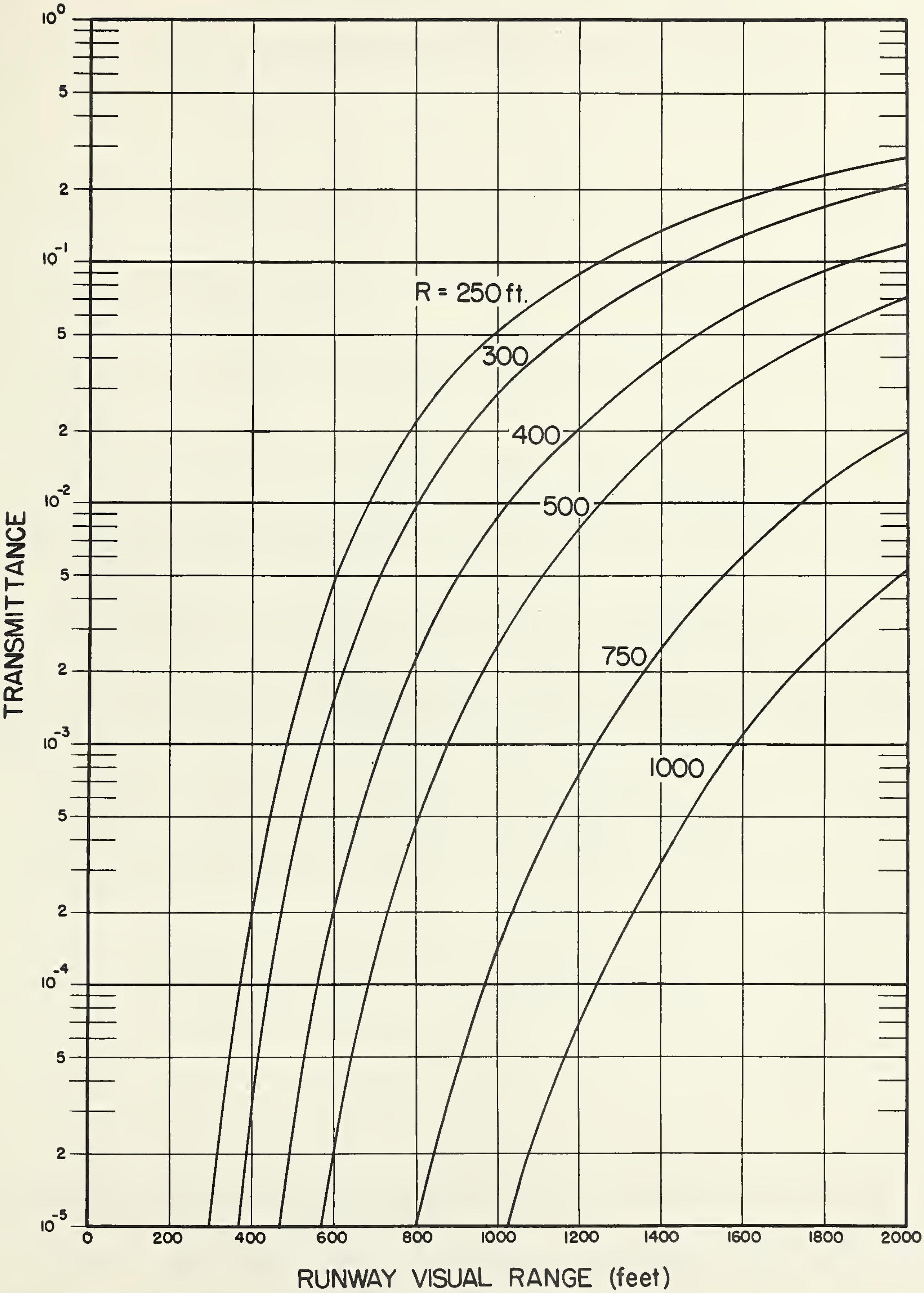
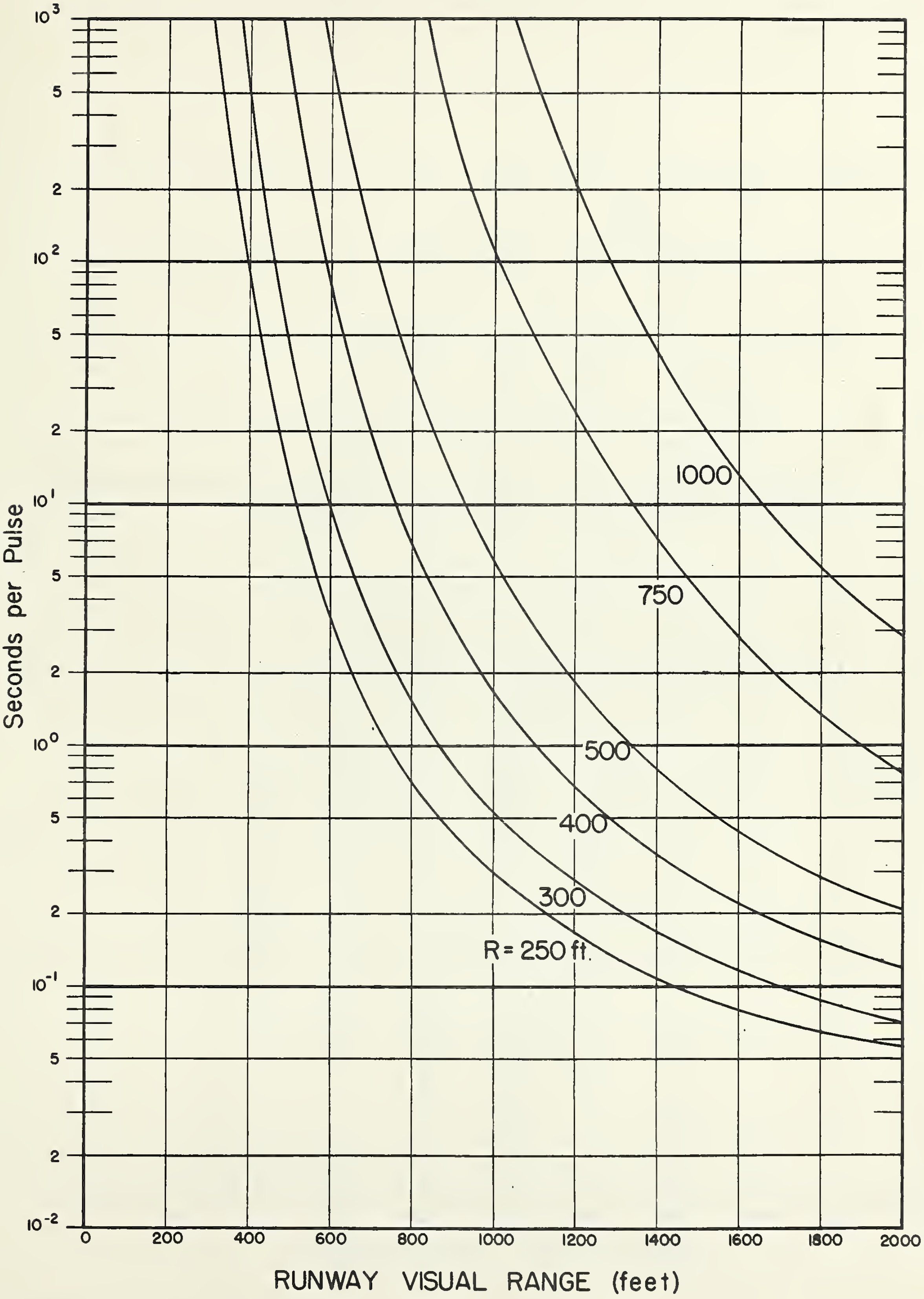
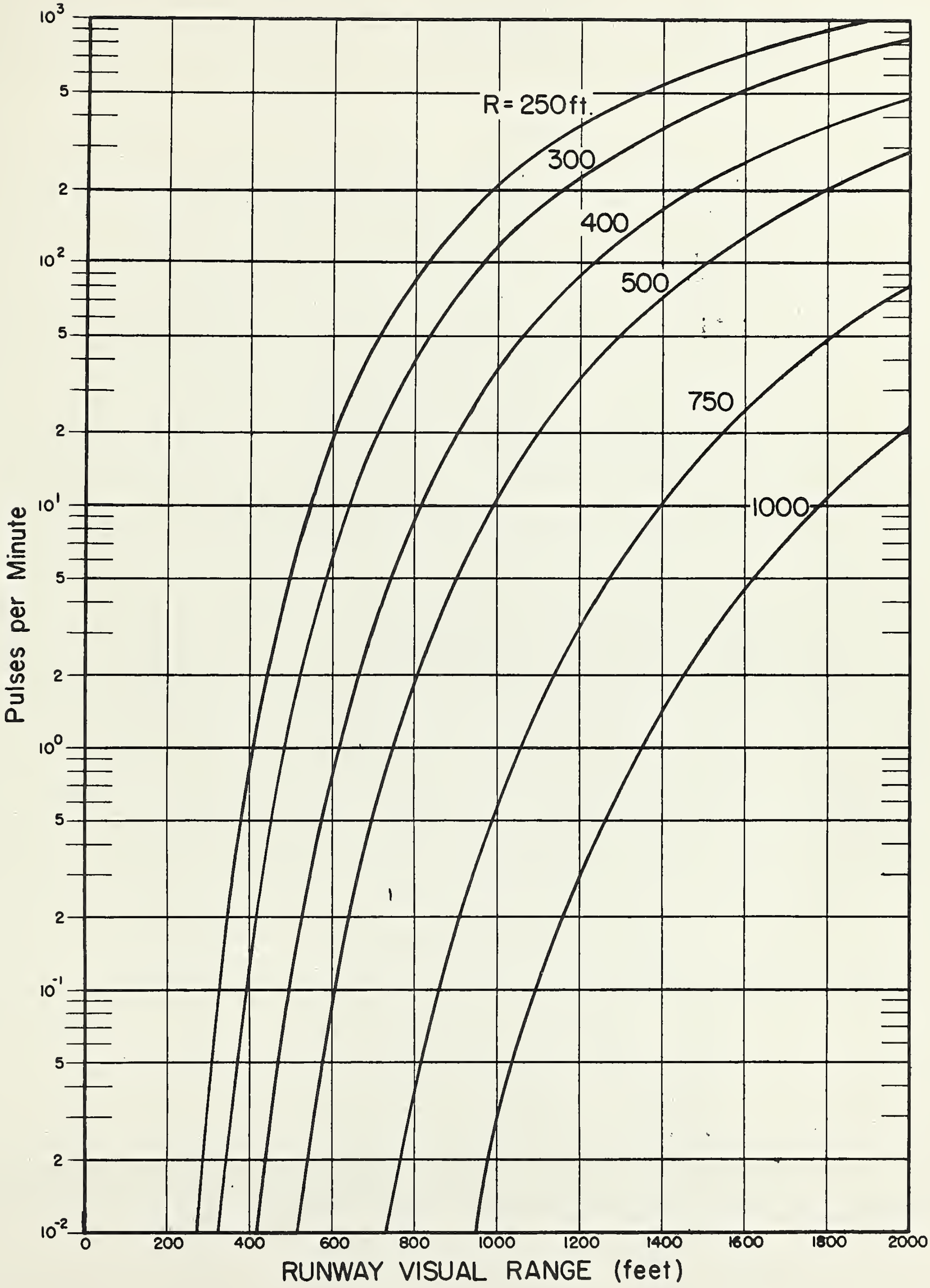


**NBS REPORT 8188** **FIGURE 1**



**NBS REPORT 8188** **FIGURE 2**



R = 250 ft.
300
400
500
750
1000
Pulses per Minute
10³
5
2
10²
5
2
10¹
5
2
10⁰
5
2
10⁻¹
5
2
10⁻²
0
200
400
600
800
1000
1200
1400
1600
1800
2000
RUNWAY VISUAL RANGE (feet)

**FIGURE 3**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