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FEDERAL COMMUNICATIONS COMMISSION
CLEAR CHANNEL HEARING
DOCKET #6741

January 14, 1946

REPORT AND RECOMMENDATIONS OF COMMITTEE #1
AS TO
"WHAT CONSTITUTES A SATISFACTORY SIGNAL"

PART I

In the Standard Broadcast band, the principal sources of interference are: interference from other broadcast stations; atmospheric noise or "static"; noise generated by various forms of electrical apparatus such as automobile ignition, motors, generators, power line insulation, neon signs, etc., and referred to herein as man-made noise; and spurious emissions by non-communication types of radio frequency generators, such as diathermy and industrial heating devices. The intensities of the interference generated by the latter class of apparatus are frequently much higher than the intensities of atmospheric or man-made noise and in many cases are so high that it becomes impractical to provide signal levels sufficient to override them. Specific frequency assignments outside the standard broadcast band have therefore been provided for the operation of certain types of this class of apparatus, and it is understood that standards for the remainder which do not operate on the assigned frequencies are being considered to reduce their emissions to levels comparable to the prevailing levels of atmospheric and man-made noise. The determination of what constitutes a satisfactory signal in the absence of station interference therefore resolves itself into the evaluation of -

(A) Atmospheric noise levels to be expected throughout the United States.
(B) Levels of man-made noise in towns and cities.
(C) The determination of satisfactory signal to noise ratios for a broadcast service.

Committee 1 has undertaken to assemble and analyze the available information on the above three phases of the work and to make measurements to evolve additional information where necessary. The work has not been completed on all matters under investigation, and in the following detailed breakdown the status of the separate investigations is indicated. Findings and recommendations have been made in those instances where the work has progressed to the point where the Committee feels that the available data warrant making them and where they will not be altered by investigations which are still under way. The Committee feels that it is highly desirable and recommends that the Committee continue to function in its present form and that the several current investigations be carried to completion.

(A) Atmospheric Noise

1. Effective bandwidth of receivers. The available data indicate that 50% of the broadcast receivers in the hands of the public have an effective bandwidth of 4 kc or less. These data are not recent but the trend has been toward narrower bandwidths. In view of this and of the fact that the wider band receivers are generally equipped with tone controls which can be used to reduce the nuisance value of the noise, the Committee recommends that an effective bandwidth of 4 kc be adopted as standard for the purpose of calculating the atmospheric noise accepted by a broadcast receiver and for the purpose of making listener reaction tests for the determination of satisfactory signal to noise ratios.

2. Day noise. The Committee recommends (a) that the determination of day noise levels be based upon all day hours between sunrise and sunset, (b) that noise data be presented in the form of noise contour maps of the United States for frequencies of 530 kc and 1600 kc, (c) that noise levels for frequencies lying between 530 kc and 1600 kc be determined by linear interpolation between the two reference frequencies.

   Annual contour maps of the recommended form showing atmospheric noise levels below which the noise will lie for 90% of the daylight hours during the year are presented in Figures 12 and 13 of the attached report. The decision of the Committee as to whether the 90% annual maps will be recommended for adoption as standard indices of noise levels is awaiting the preparation of similar contour maps for the noisest month and for the quietest month of the year. These are being prepared and should be completed by February 15.

3. Night noise. The Committee recommends (a) that the determination of night noise levels be based upon the second hour after sunset, (b) that noise data be presented in the form of noise contour maps of the United States for frequencies of 530 kc and 1600 kc, (c) that noise levels for frequencies lying between 530 kc and 1600 kc be determined by linear interpolation between the two reference frequencies.

   Annual contour maps of the recommended form showing atmospheric noise levels below which the noise will lie for 90% of the time during the second hour after sunset throughout the year are presented in Figure 13 and 14 of the attached report.

As in the case of day noise, the Committee's recommendation on the use of these maps is awaiting the preparation of contour maps for the noisiest and quietest months, to be available on or before February 15.

(B) Man-made noise

1. Man-made noise measuring equipment and methods. Standard specifications for a meter and for methods of measurement of man-made noise have been developed by the Joint Coordination Committee of the Edison Electrical Institute, the National Electrical Manufacturers Association and the Radio Manufacturers Association. Committee 1 recommends that these specifications be accepted as the most reliable measure of man-made noise presently available. The J.C.C. is now functioning as a standards committee of the American Standards Association with representation from other interested branches of Industry and from various Government Agencies, including the F.C.C. From time to time certain modifications in the above specifications are recommended; however, this is a long term, continuing activity which has no immediate effect, and changes can be adopted as they appear.

2. Man-made noise surveys. Mobile measurements of man-made noise along the streets of cities and towns of various populations were made with J.C.C. meters modified to operate continuous tape recorders. This type of survey and the necessary modification of the meters were not agreed to by all members of Committee 1, some of whom felt that for accurate results the measurements should be made within homes and without modification. Some tests were made which satisfied the majority of the Committee that the impairment of accuracy was not serious, and in the interests of obtaining as much noise data as possible in the available time, it was decided to make the mobile surveys. During the surveys, some tests were made to determine the noise and signal levels inside and outside of homes, so that the noise occurring at street levels could be related to noise voltages appearing at the antenna terminals of radio sets. The latter results were not definitive however, and further tests are being made which are expected to require a period of about three months for completion.

   The results of the street-level mobile noise surveys are summarized in Figures 16 to 20 of the attached report. Figure 20 shows curves of the percentage of measurements falling below fixed noise levels vs population for residential areas near industrial areas. These values are not urged as a standard for the determination of required signal levels and for making population counts, but are referred to as illustrative of a final form in which measurements of man-made noise may be expressed. It may prove to be practical to combine the noise values for the three types of residential areas specified; viz, suburban, crowded and residential, into a single set of curves of this type. The curves may also be affected quantitatively by the current investigation of ratios of inside and outside noise. There are alternative methods of presenting the data, such as the specification of given signal or noise levels for cities in particular population brackets, which should also be given consideration.

(C) <u>Signal to noise ratios</u>

The method of determining satisfactory signal to noise ratios which has been adopted by the Committees consists in making tests of audience reaction when listening to carefully prepared recordings of both speech and music with selected signal to noise ratios.

1. <u>Signal to atmospheric noise ratio</u>. Tests of satisfactory signal to atmospheric noise ratios made at previous times indicated that ratios between 69/1 and 125/1, carrier to 4 kc average atmospheric noise, would be satisfactory. The Committee was unwilling to adopt a ratio on the basis of these tests and decided to make further tests to determine a more reliable ratio. The tests consist in (a) making signal to atmospheric noise ratio recordings for audience reaction tests and (b) simultaneous measurement of atmospheric noise levels by the J.C.C. meter and by continuous recording meters having both average and peak time constants. From the latter test it is hoped that ratios can be established which will permit the designation of a single signal to noise ratio for both atmospheric and man-made noise. The tests have not been completed and, depending upon the availability of atmospheric noise of the desired characteristics of summer atmospherics, may require a period of from three to six months for their completion.

Committee 1 recommends that it be permitted to complete these tests and that no signal to atmospheric noise ratio be adopted prior to their completion.

2. <u>Signal to man-made noise</u>. Signal to man-made noise tests have been completed and the results of the audience reaction tests summarized in Figure 21 of the attached report. It is recommended that a satisfactory signal to man-made noise ratio be determined by reference to that Figure.

FEDERAL COMMUNICATIONS COMMISSION
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REPORT OF COMMITTEE #1, JANUARY 14, 1946

PART II

This is a status report of the three phases of the work of Committee#1

(A) Atmospheric noise levels to be expected throughout the United States, (B) Levels of man-made noise in towns and cities and (C) The determination of satisfactory signal to noise ratios for a broadcast service.

A. Atmospheric Noise Levels.

Atmospheric noise is caused by conditions generally associated with thunderstorms. It therefore exhibits rather well defined diurnal and seasonal characteristics and varies from year to year in accordance with the number and intensity of thunderstorms. For the same reason the intensity of atmospheric noise varies widely between different geographic locations. It is apparent that an adequate sampling, which will permit the prediction of noise levels to be expected on a long term basis, suggests that measurements be made at a sufficient number of well chosen recording points and over a period of time such that a full range of atmospheric conditions will be encountered. As a practical matter, neither of these objectives is obtainable, so that recourse has been made to the measurement of noise for a lesser period of time at a limited number of points and correlating the measured values with thunderstorm data furnished by the U. S. Weather Bureau, which are available in summary form from 1904 to date.

1. Sources of Atmospheric Noise Data.

The data on which this report is based were derived from measurements made at the following locations and frequencies, for the periods of time and by the organizations indicated. It is not possible to measure nighttime atmospheric noise levels in the United States within the Standard Broadcast band because of station occupancy, so that the frequencies chosen are adjacent to, rather than within this band. Where conditions have permitted, measurements have been made at both ends of the band so that interpolation could be made for frequencies within the band.

Recording Site	Frequency	Hours	Period	Recorded By
Allegan, Mich.	530 & 1600	SR to SS+4	8/41-8/43	FCC
Atlanta, Ga.	520	"	9/43-8/44	FCC
Baltimore, Md.	540 & 1575	"	1/39-12/40	FCC
Duluth, Minn.	520 & 1900	"	3/42-12/42	FCC
Grand Is., Neb.	530 & 1580	"	1/39-12/42	FCC
Grand Is., Neb.	"	"	9/43-8/44	FCC
Kingsville, Tex.	540 & 1600	"	7/44-7/45	FCC
Portland, Ore.	530	"	1/40-12/41	FCC

Recording Site	Frequency	Hours	Period	Recorded By
Cincinnati, Ohio	530	Noon, SS+2	6/39-7/45	WLW
Cincinnati, Ohio	1600	Noon, SS+2	6/39-6/41	WLW
Nashville, Tenn.	530 & 1600	Day, Night	5/38	WSM

2. Measuring Equipment.

The measuring equipment consists of a commercial communication type receiver fed from a short vertical antenna and modified so as to operate a recording milliammeter. The IF output of the receiver is rectified by a diode circuit with charge and discharge time constants each approximately 100 seconds, followed by a direct current amplifier which drives the recording milliammeter. Some of the recorders are adapted also for peak recording with circuit constants of approximately 3 seconds charge and 70 seconds discharge. A cam on the recorder chart drive switches the circuit from peak to average recording at twenty minute intervals. A signal generator is provided for regular calibration of the recorder, the recorder and signal generator being supplied from a regulated power source.

The effective height of the recording antenna is determined by measuring the field strength of each of several ground wave fields from broadcast stations having frequencies throughout the broadcast band and measuring each station with the recording equipment to determine the input to the equipment from the recording antenna. The second value divided by the first yields the effective height at a particular frequency. The several values are plotted against frequency, a smooth curve drawn through the points or among the points if scattering is apparent, and the curve extrapolated to the frequency or frequencies at which the noise is recorded.

The recorder is calibrated at regular intervals which are sufficiently short to assure that calibration will be maintained over the interval. This may vary from once a day, for new installations or installations where poor temperature and voltage regulation tend to render the equipment unstable, to once a week for some other installations. To calibrate the equipment, the antenna is disconnected and the signal generator connected to the antenna and ground terminals of the receiver. A sufficient range of signal levels is applied in steps to the receiver, at each step the output of the signal generator being marked on the recorder chart at the level indicated by the recorder pen.

3. Effective Bandwidths of Receivers.

For the purposes of the analysis of noise data, it is necessary to know the effective bandwidth of the recording receiver, which is determined as follows. With the signal generator connected to the input of the receiver and the receiver tuned to the frequency on which the noise is to be recorded, a RF response run is made with the signal generator, carrying it to a sufficient distance on each side of the center frequency to obtain a negligible response. The ratios of the response at other frequencies to the midfrequency response are squared and plotted on linear coordinate paper with frequencies as abscissae and squared response ratios as ordinates. The area under the curve divided by the area of a rectangle 1 kc in width and equal to the midfrequency response in height will give the effective bandwidth in kilocycles. (See Figure 1)

It is also necessary to know the effective bandwidths of the receivers in the hands of the public, in order to determine what the noise intensities accepted by these receivers will be in relation to a measured value of noise with a receiver of known bandwidth. No recent surveys of broadcast receiver response characteristics, other than those reported by Committee II, have been made because of war conditions. The most comprehensive surveys have been those made by the Radio Corporation of America between 1935 and 1938. The most recent of these, like the measurements reported by Committee II, have been made to determine the adjacent channel response and are of little value in determining the effective bandwidth for noise, in which the portions of the response near resonance carry the greatest weight. The most valuable data are found in the RCA License Bulletin #380, in Figure 5 of which the results of measurements made on 182 receivers of various types built between 1930 and 1936 are weighted in accordance with the numbers of receivers of each type in the hands of the public and are shown as response curves for given percentages of receivers. While these data are not as recent as desired, it is the opinion of the Committee that present receivers are of somewhat narrower bandwidth and that the use of 1930-1936 figures result in indicated noise levels somewhat in excess of those actually accepted by corresponding percentages of present day receivers. Calculations of service made thereon will thus be conservative rather than otherwise. In view of this and of the fact that receivers having good response at high audio frequencies are generally equipped with tone controls for further decreasing the nuisance value of the noise, the Committee agreed that the effective bandwidth represented by 50% of the receivers would be a satisfactory standard. When calculated in accordance with the foregoing method, the effective bandwidth was determined to be 4.12 kc in accordance with Figure 1, whereupon the Committees adopted 4 kc as the recommended standard bandwidth.

The atmospheric noise which is accepted by a receiver and which must be overcome by the desired signal is proportional to the square root of the effective bandwidth.* In order to illustrate the effect of bandwidth, the noise accepted by receivers of selected bandwidths has been plotted in Figure 2 in relation to the noise accepted by a receiver of 4 kc effective bandwidth.

* 1. An Experimental Investigation of the Characteristics of Certain Types of Noise, K.G. Jansky, Dec. 1939 Ire, p. 763
2. Static Set Bandwidth Measurements, Engineering Department Crosley Corporation, August 20, 1945.

The selected bandwidths were calculated from frequency response data taken from LB #380 for the corresponding percentages of receivers indicated in Figure 2. This chart is useful for examining the effect of selecting bandwidths or percentages of receivers other than those adopted by the Committees. For example, a noise level of 10 uv/m/4 kc is equivalent to a level of 12 uv/m/6 kc. Thus a signal of one millivolt (1000 uv) under these conditions would provide a signal to noise ratio of 100/1 for 50% of the receivers and a ratio of 83/1 for 80% of the receivers.

4. Method of Analysis of Data.

Two methods of dividing the charts into hours for analysis have been used since the beginning of the recording program in 1938. In the earlier method, the chart was divided throughout the day into hours beginning with the 15 minute time division nearest to sunrise. The night was divided into hours beginning with the time division nearest to sunset. Following the hourly divisions as determined above, each hourly median value of noise intensity for a 1 kc effective bandwidth was determined, using the calibrations previously described, divided by the square root of the effective bandwidth and the value of antenna effective height. The individual hourly values were tabulated on individual daily forms which permitted them to be identified with the time of recording.

In the latter method of analysis, the chart is divided so as to include a sunrise hour, centered on sunrise to the nearest 15 minutes; the following two hours, sunrise plus one and plus two; the noon hour which is centered on local noon to the nearest 15 minutes; the sunset hour centered on sunset to the nearest 15 minutes; the two hours preceding sunset designated sunset minus 1 and minus 2; and the six hours following sunset designated sunset plus 1 to plus 6. The hourly median values are determined as before and tabulated on a monthly summary sheet which permits identification of the time of recording. Thus identified, the data from either the earlier daily sheet or the monthly sheet are readily available for further analysis and the preparation of graphs and studies of the type presented in the following section.

5. Atmospheric Noise Graphs.

The atmospheric noise data taken at the above places and times have been analyzed to show various characteristics of the noise and its relationship to thunderstorms. These are presented in the form of graphs in Figures 3 to 15, attached.

Figures 3 to 6 show graphs of the annual, highest month and lowest month distributions of noise field intensities in uv/m/4 kc bandwidth vs per cent time for day hours and the second hour after sunset for the frequencies recorded at eight of the locations listed above. The data for Nashville, for the month of May 1938, are not shown because they do not cover a period during which a fair sampling of annual weather condition will occur. However, the data have been compared with the corresponding month at other recording sites in order to estimate how the annual value at Nashville compares with the annual values at other sites. The data for Allegan were taken over a period of two years, with the recorder operating about one week out of three on each of three frequencies. These data thus have somewhat less weight than that for a year of continuous recording at the remaining six locations, and no reliable distribution for an individual month is available. These graphs are useful for the determination of annual noise levels for percentages of time other than 90% and for comparing the percentages of time during the best and worst months which correspond in noise intensity to any desired percentage of annual noise.

The graphs were prepared as follows: the data for a given location, period, frequency and hour were tabulated in order of size on distribution sheets. From the total number of hours of data, the time percentage interval corresponding to each hour of recording was determined. The highest value of noise intensity, corrected for a 4 Kc bandwidth by multiplying by the square root of the bandwidth, 2.00, was plotted at the center of the first time percentage interval, the corrected second highest value was plotted at the center of the second time percentage interval, etc. Near the center of the graph, where many values lay in a close group, the points were plotted by groups rather than by individual hourly values. The second hour after sunset designated by these graphs is the hour centered at a time two hours after sunset, in accordance with the recent practice. Consequently, for the locations Baltimore, Duluth, Grand Island and Portland, for which the data were analyzed under the original practice of beginning the night hours with the time of sunset, data for the second and third hours after sunset have been combined. Thus these data are for the two hours centered at a time two hours after sunset.

Figure 7 shows the month to month variation of the level below which the 530 Kc average atmospheric noise intensity will lie for 50% and 90% of the month for the second hour after sunset. These, together with the preceding Figures 3 to 6, should be useful in determining whether any adjustment of night signal to noise ratios is indicated by reason of differences in the month to month distribution of signals and noise. For convenience in comparison with any particular month the annual 50% and 90% values of noise intensities for each of the recording locations are shown at the left.

Figure 8 shows the diurnal variation of average atmospheric noise at 520-545 Kc at various recording locations. The values for each hour were obtained by determining the level below whic the noise lay for 90% of the time during that hour. Each graph represents one year of data, except for Allegan, where two years of intermittent recording have been combined, and Kingsville, where but eight months of data have been analyzed by individual hours. For Baltimore, Portland and Grand Island, where graphs are shown for separate years of recording, significant differences in level and in distribution will be noted. Some of this is due to differences in thunderstorm activity or time of occurrence. All of the differences can not be accounted for in this way, however, as will be shown in connection with later discussion on thunderstorm correlation.

Figure 9 shows the corresponding diurnal variation for 1545-1900 Kc. No noise in this frequency range was recorded at Atlanta and Portland, so that no graphs appear for these locations. In general, the daytime noise is much lower than at 530 Kc and the nighttime noise somewhat lower, with a wider range between day and night levels than at 530 Kc.

In Figure 10 the noise levels for the various recording sites below which the noise will lie for 90% of the time, taken from the annual distribution curves of Figures 3 and 6, have been plotted against the numbers of thunderstorm days reported by the U. S. Weather Bureau for the recording locations during the time of recording. Four sets of correlations are shown: 530 Kc, Day; 1600 Kc, Day; 530 Kc, Night; and 1600 Kc, Night. Noise values for frequencies between 520 and 545 Kc have been plotted on the 530 Kc charts and for frequencies between 1545 Kc plotted on the 1600 Kc chart without making correction for departures from the nominal frequencies of 530 and 1600 Kc. The values for Cincinnati in the day correlations are for the Noon hour alone and are somewhat lower than would be expected for all day. Although considerable scattering of the data is apparent, there is a definite upward trend of noise levels with increasing numbers of thunderstorm days for both day and night conditions at 530 Kc, and straight lines have been drawn through the data to show this trend in each case. At 1600 Kc, the absence of data for Portland and the small spread of the remaining data renders the correlation rather obscure, particularly for the day values. However, by using the slope of the 530 Kc trend line as a guide to the slope to be expected at 1600 Kc, trend lines have been drawn through the points for the latter frequency. The maximum departures of individual points from the trends are about ±3/1. A large amount of scatter was not unexpected when it was appreciated that a thunderstorm day, as defined by the Weather Bureau, is a day on which thunder is heard at the reporting location. Thus a day on which a single peal of thunder occurs will have the same weight with regard to the thunderstorm data as a day on which there is an all day thunderstorm. The effect on the noise level will be vastly different, however. For this reason, it is believed that the individual departures from the trend should not be viewed too critically.

In an attempt to obtain a somewhat closer agreement and to weight the thunderstorm days in duration and intensity, the ratios of the individual noise values to the noise levels indicated by the trend line were correlated with the numbers of inches of rainfall for the months March through September, during which period the rainfall might be assumed to be associated with thunderstorms. For the four years of recording at Grand Island, increasing rainfall showed an increase in the ratio, but considering all recording sites and recording periods, no consistent correlation was obtained. A second study, in which the ratios were plotted against the ground conductivity at the various recording sites, likewise yielded negative results.

Figure 11 is an isoceraunic map of the United States showing contours having equal numbers of annual thunderstorm days averaged over the years 1904-1933. The material for this map was taken from a report prepared by W. H. Alexander of the Weather Bureau Office at Columbus, Ohio, Figure 13 of which is a map, similar to the above, showing contours of equal 30 year totals of thunderstorm days.

Figures 12 through 15 are United States maps showing contours of equal noise intensity below which the noise will lie for 90% of the time throughout the year for day and night conditions at 530 and 1600 kc. These were prepared from the contour map of annual thunderstorm days (Figure 11) by the use of the trend lines of Figure 10, showing the relationship of 90% annual atmospheric noise to thunderstorm days. As an example of the procedure used, the night trend line for 530 kc shows that an annual value of 13.3 thunderstorm days corresponds to a noise level of 5 uv/m. The 5 uv/m contour in Figure 14 is seen to follow the 13.3 thunderstorm day contour of Figure 11. In some other cases, the selected noise levels do not correspond to thunderstorm day values represented by individual contours in Figure 11, and for these the noise contours were determined by interpolation between adjacent thunderstorm contours.

B. Man-Made Noise Levels.

The measurement of man-made noise levels requires a somewhat different technique from the measurement of atmospheric noise. Owing to its many forms and causes, the nuisance value of man-made noise is somewhat difficult to measure. After a prolonged study, lasting several years, the Joint Coordination Committee of the Edison Electric Institute, the National Electrical Manufacturers Association and the Radio Manufacturers Association, developed a standard specification for a noise meter and for methods of noise measurement.* Under war-time conditions, the availability of these meters was very limited, and it was at first proposed by Committee #1 to modify communications type receivers so as to produce noise meters adhering to the J.C.C. specification. After discussion with several members of the J.C.C. who had participated in the formulation of the specification, the Committee abandoned the idea of using receivers and decided to use R.C.A. type 312 Radio Noise Meters, which

*Methods of Measuring Radio Noise-1940,RMA Engineering Bulletin #32.

appeared to be available on loan in limited quantities. After a great deal of delay, eight meters were obtained, three of which had been realigned and recalibrated at the factory. The other five meters were recalibrated against the above three. The meters were modified to operate 1 milliampere Esterline-Angus continuous recorders through a 25,000 ohm resistor, which gave the recording meters very nearly the same response as the panel indicating instruments on noise peaks. During the latter part of August seven meters were shipped to Committee members and other participating engineers for making surveys in the following seven cities; Boston, Philadelphia, Chicago, Cincinnati, Des Moines, Nashville and Lincoln. Accompanying each meter was a detailed set of instructions as to the method of making the surveys and of analyzing and tabulating the measurements. At each of the above locations, a route through cities and towns of various sizes was laid out. In each designated city, mobile surveys were made of street level noise in representative residential areas of three types: suburban residential areas, crowded residential areas and residential areas near industrial plants.

Figures 16, 17 and 18 are plots of the peak noise levels versus the population of cities and towns in which the measurements were made, for each of the three types of residential areas which were surveyed. The noise levels were determined by averaging the ten highest peaks per minute to obtain the quasi-peak values and then taking the average of the individual quasi-peak values over approximately equal increments of distance throughout the area surveyed. The increments to be used in each case were not specified in advance so that the percentage of the surveyed area represented by a dot will differ from town to town in accordance with population and with the judgment of the engineers making the survey of a particular town. The distribution of the dots will, however, give a reliable measure of the noise levels to be encountered along the streets.

Figure 19 is a replot of the data of Figure 18, in which each dot has the same weight in terms of the percentage of the area surveyed. This was done by dividing the measured points for each town into five groups, with an equal number of points in each group and each group lying at a different intensity level, and plotting a single dot at the intensity level represented by the median level of each group.

Figure 20, showing percentages of the weighted peak noise measurements which are equal to or below specified intensities vs population, was derived from Figure 19 in the following manner: The population scale was divided into three intervals per cycle; viz; 2000-5000; 5000-10,000; 10,000-20,000; 20,000-50,000; etc. The percentages of the number of dots in each interval lying on or below the specified intensities of 10, 20, 50, 100 and 500 uv/m were plotted at the centers of the corresponding population intervals in Figure 20. Smooth curves were then drawn among the points corresponding to each of the selected intensities.

In order to utilize these curves as a basis for making counts of population which will be served by signals of known intensit it is necessary to make two assumptions:

First, that the density of population throughout each of the surveyed areas is substantially uniform, so that intensity measurements expressed in terms of the percentages of the measurements, or of the surveyed areas, can be translated into percentages of population. No population surveys have been made to determine the distributions of population within the selected areas and in making the assumption that the percentages of measurements and of population are synonymous, reliance must be placed upon the judgment of the engineers who made the surveys in each case to select areas of uniform residential character and substantially uniform population conditions for each type of area.

Second, that the noise field as measured in the street will bear the same relation to the noise measured at the terminals of a radio receiver as the desired signal field will bear to the signal voltage at the set terminals. Owing to the fact that many noise sources are in the home and that wires entering the home may be closely coupled to external noise sources, it is reasonable to assume that the relation will in many cases be different for noise than for signals. An attempt was made to evaluate this factor during the present surveys by making set terminal measurements and outside measurements of noise and signal levels at homes where access could be had. Owing to the small numbers of measurements which could be made and to the necessity for making the inside and outside measurements in sequence, rather than simultaneously, the results of this phase of the study were not convincing. Further work is being done with duplicate equipment which will permit simultaneous inside and outside measurements and should resolve some of the difficulties found with the previous measurements.

C. Signal to Noise Ratios.

The method of determining satisfactory signal to noise ratios which has been adopted by the Committee consists in making tests of audience reaction when listening to carefully prepared recordings of both speech and music with selected signal to noise ratios. As each passage of the recording is played, each member of the audience marks the corresponding box of a ballot to indicate whether the sample is satisfactory or unsatisfactory. A count of the ballots permits a determination of the percentages of the audience who find the signal satisfactory for each ratio, for both types of program and each type of noise. By holding listening tests at many locations throughout the country a good sampling of listeners is obtained which should be fairly representative of the radio audience.

1. Signal to Atmospheric Noise Ratios.

Recordings with various ratios of signal to atmospheric noise have been made in previous years by Stations WSM* and WLW** and by the FCC. Because the listener reaction tests have not included sufficiently large groups or because the recordings themselves were found to be unsatisfactory in some respects, such as frequency response, modulation percentage, record noise, or the method of measurement of the atmospheric noise, the Committee elected to make new recordings of signal to atmospheric ratios, rather than to rely on these previous recordings. The noise for the WSM records was measured by a meter having time constants differing from the present meter, so that the signal to noise ratios are not directly comparable. The noise for the WLW and FCC records was measured with the present type of meter, and while the tests made with these recordings are not regarded as satisfactory for a final determination of a recommended standard, they should be indicative of its order of magnitude. The listener reaction tests on the WLW records indicated that a signal to average atmospheric noise ratio of 69/1, on the basis of 4 kc effective bandwidth, would be satisfactory, whereas the FCC tests gave a ratio of 125/1.

The signal to atmospheric noise test records have not been completed by the Committee. Until very recently no organization represented on the Committee has been in a position to undertake making the records. At the present time the Crosley Corporation is preparing a set of test records which is expected to be completed in the near future. All of the recordings have of course been made under fall and winter atmospheric noise conditions where the noise sources are likely to be distantly removed from the recording location. The character of the noise is quite different from that of summer day atmospherics, in which the noise sources are local, and somewhat different from summer night noise which is due to a large number of both local and distant sources. In general, the 90% annual level of atmospheric noise which has been used in the preparation of the noise maps is determined by summer noise conditions. For this reason it is necessary to continue this study and to carry it forward into the period when summer noise conditions are available.

2. <u>Signal to Man-Made Noise Ratios</u>.

A test record, containing passages of speech and of music combined with man-made noise in several ratios, was made for the Committee by the Columbia Broadcasting System. The speech consisted of a substantially identical announcement identifying each passage and the music was an identical passage of light classical music of a high average level of modulation. The noise sources were a vacuum cleaner motor, an electric vibrator type razor and a dial phone, representing three widely different noise impulse rates. The program signal from a modulated signal generator was fed into the input of a high quality radio receiver, noise voltages from one of these sources

*FCC Docket #5072A Exhibit #56
**Engineers Experiment Station News, Ohio State University, December 1943

being fed into the input through a calibrated attenuator. The carrier level and the radio frequency noise level at the set input were determined by an RCA 312 type noise meter, the noise level being checked with the carrier off in the pauses between passages. Short passages were recorded for each of speech and music, against noise from each of the three sources, for signal to noise ratios of 100/1, 50/1, 25/1, 12.5/1 and 6.25/1. Twenty-five pressings of this recording were made and distributed among the members of the Committee for the purpose of holding listener reaction auditions. The received ballots were examined in order to determine from the manner of marking whether it was apparent that the listener understood the instructions and whether the inclusion of the ballots would tend to produce anomalous or misleading results. For example, some of the ballots might show a satisfactory mark for a given signal to noise ratio and a particular combination of types of signal and noise, and an unsatisfactory mark for a higher signal to noise ratio for the same combination of signal and noise. Ballots which were defective for this or other apparent reasons were discarded. The remaining ballots, approximately one thousand, were analyzed and the results summarized in the graphs of Figure 21.

Figure 21 shows that, in the case of both speech and music, the noise with higher impulse rates, exemplified by the vacuum cleaner and razor, required a higher ratio than the low impulse rate noise produced by the telephone dial in order to be satisfactory to a given percentage of listeners. The tests show also that a higher signal to noise ratio was required for speech than for music, the ratio to satisfy 50% of the listeners being 25.5/1 for speech and 20/1 for music. The ratio for both speech and music combined was 23/1. The music used in this record was of the light classical type with a fairly uniform high level of modulation, with no low amplitude passages comparable in length to the pauses which occur in speech during which the noise might make itself apparent. This characteristic is believed to be mainly responsible for the differences in the ratios which were found to be satisfactory, so that the use of a musical selection containing some sustained pauses or low passages would undoubtedly have brought the ratios for speech and for music more closely together.

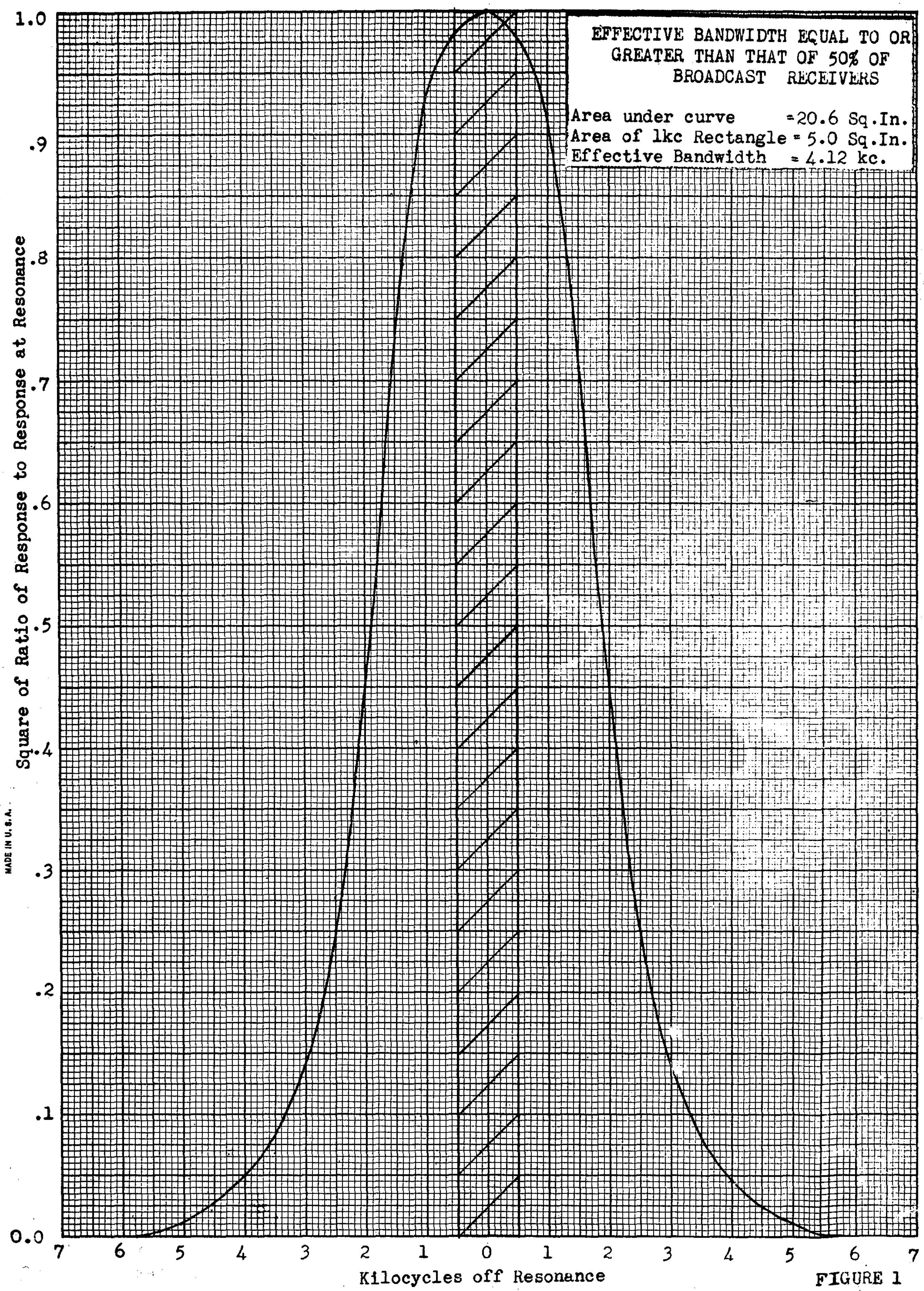

EFFECTIVE BANDWIDTH EQUAL TO OR GREATER THAN THAT OF 50% OF BROADCAST RECEIVERS
Area under curve = 20.6 Sq.In.
Area of 1kc Rectangle = 5.0 Sq.In.
Effective Bandwidth = 4.12 kc.
Square of Ratio of Response to Response at Resonance
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0.0
7
6
5
4
3
2
1
0
1
2
3
4
5
6
7
Kilocycles off Resonance

FIGURE 1

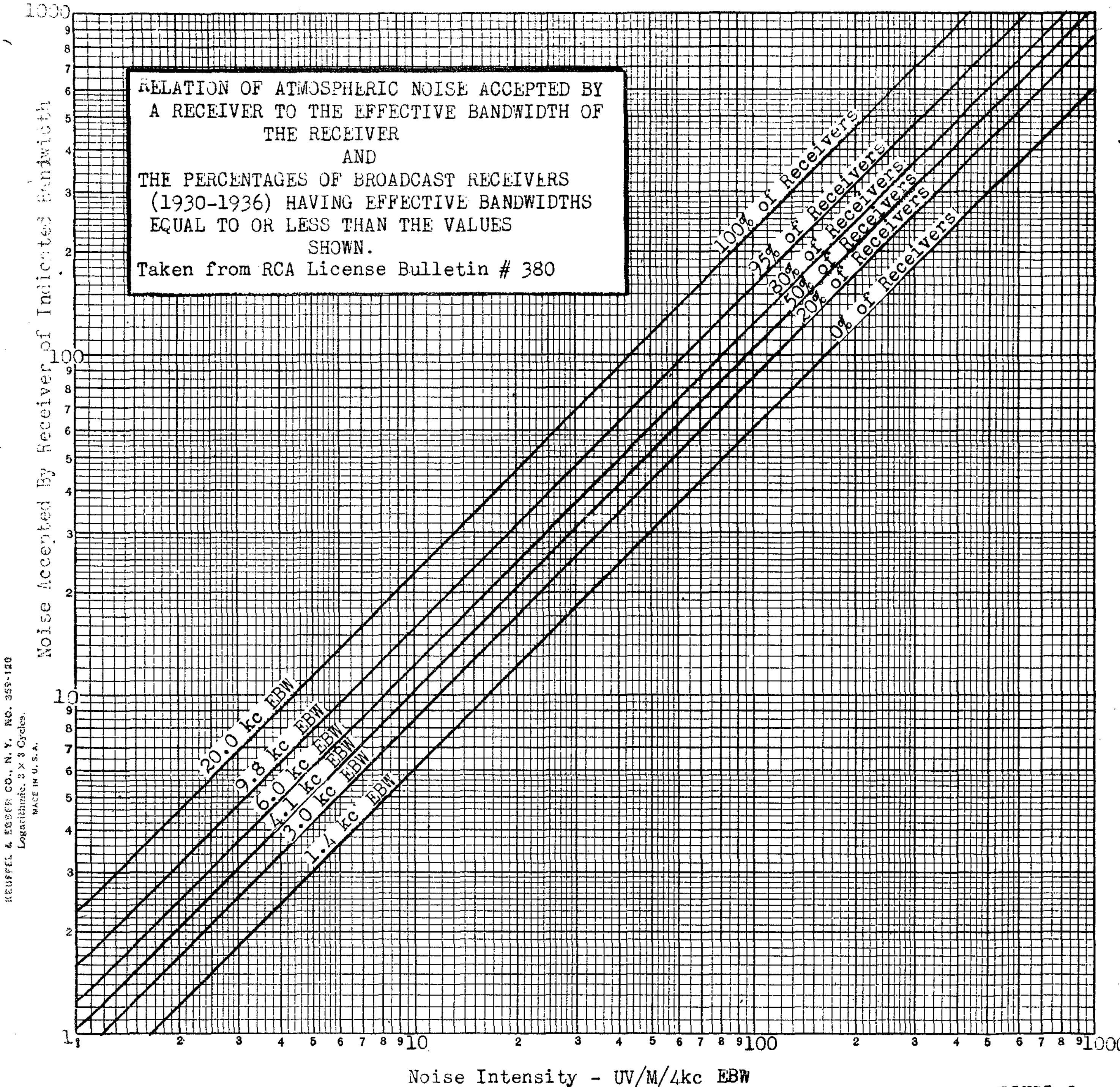

RELATION OF ATMOSPHERIC NOISE ACCEPTED BY A RECEIVER TO THE EFFECTIVE BANDWIDTH OF THE RECEIVER
AND
THE PERCENTAGES OF BROADCAST RECEIVERS (1930-1936) HAVING EFFECTIVE BANDWIDTHS EQUAL TO OR LESS THAN THE VALUES SHOWN.
Taken from RCA License Bulletin # 380
100% of Receivers
95% of Receivers
80% of Receivers
50% of Receivers
20% of Receivers
0% of Receivers
20.0 kc EBW
9.8 kc EBW
6.0 kc EBW
4.1 kc EBW
3.0 kc EBW
1.4 kc EBW
Noise Accepted By Receiver of Indicated Bandwidth
Noise Intensity - UV/M/4kc EBW
1
10
100
1000
KEUFFEL & ESSER CO., N. Y. NO. 359-120
Logarithmic, 3 × 3 Cycles.
MADE IN U. S. A.

FIGURE 2

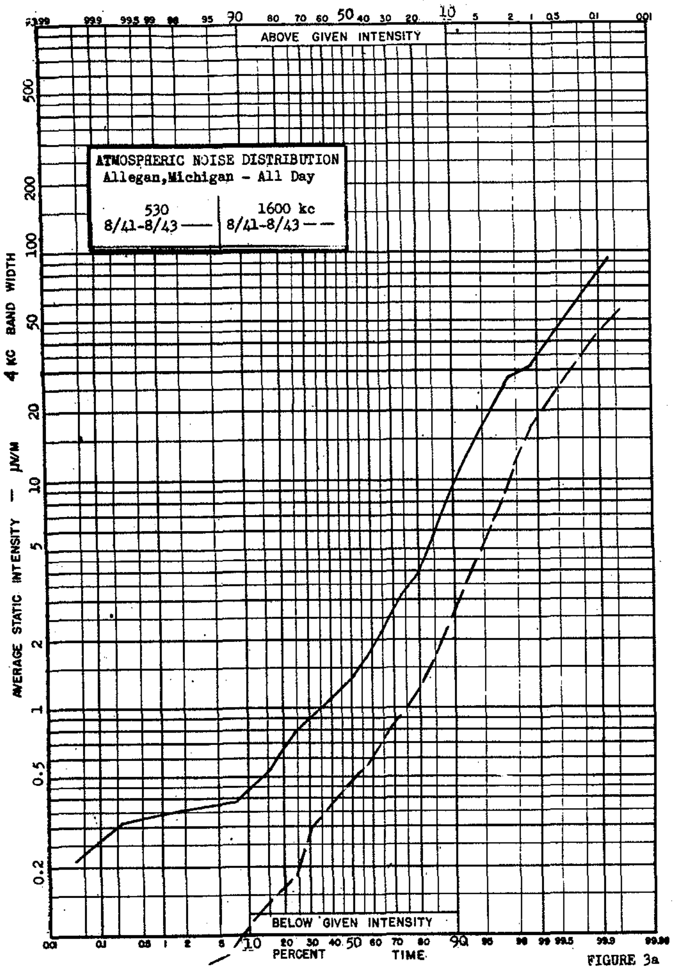


FIGURE 3a

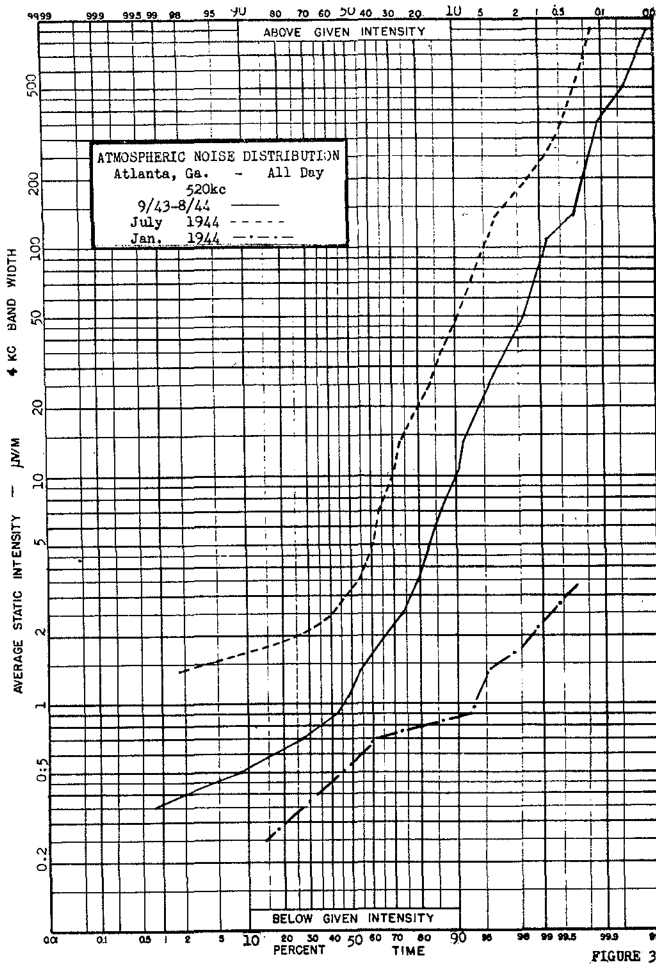


FIGURE 3b

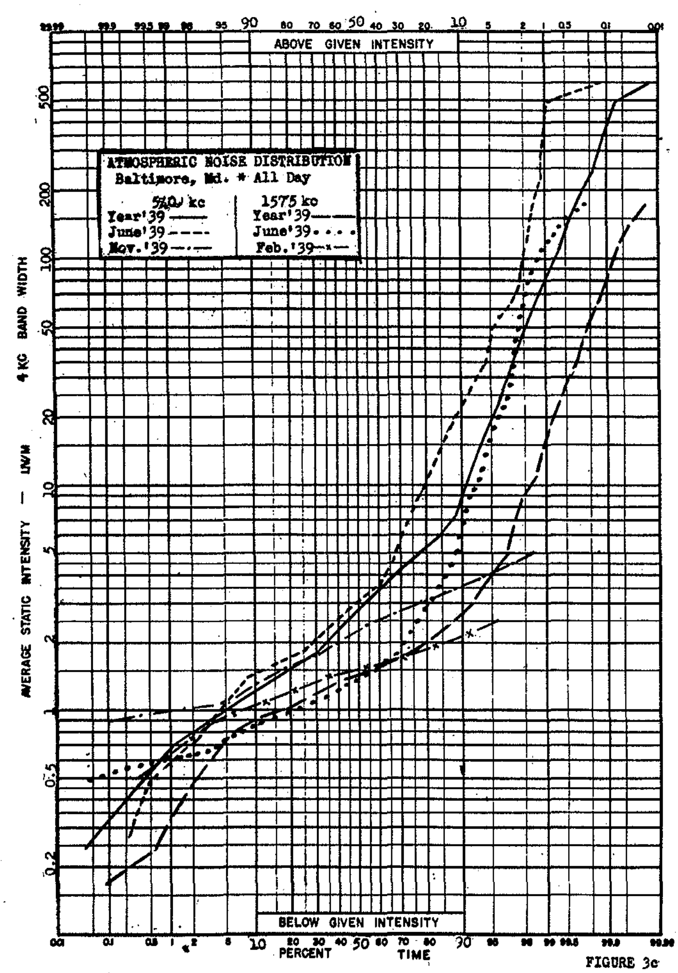


FIGURE 3c

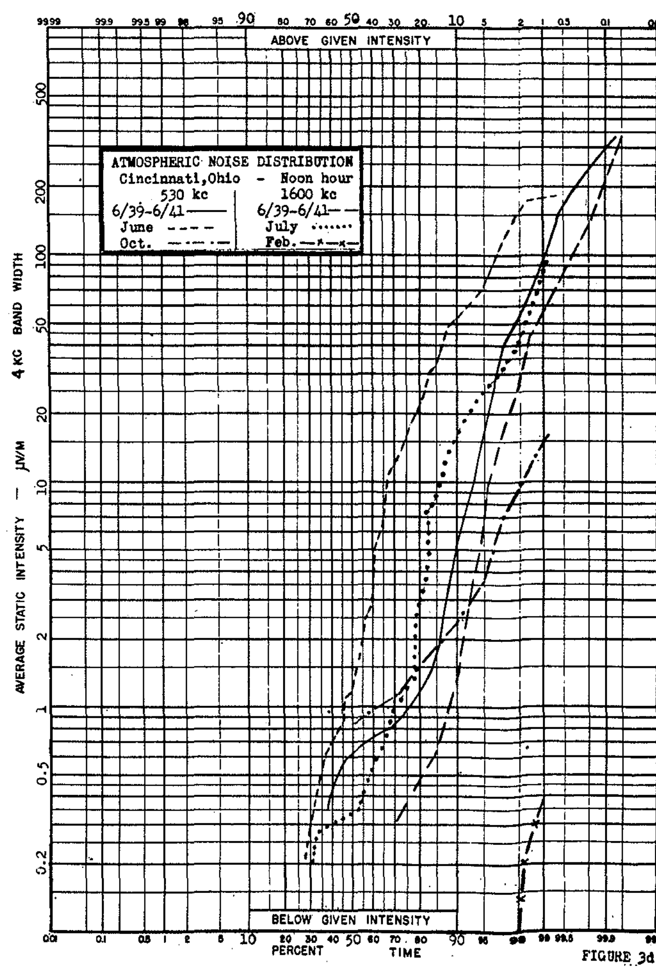


FIGURE 3d

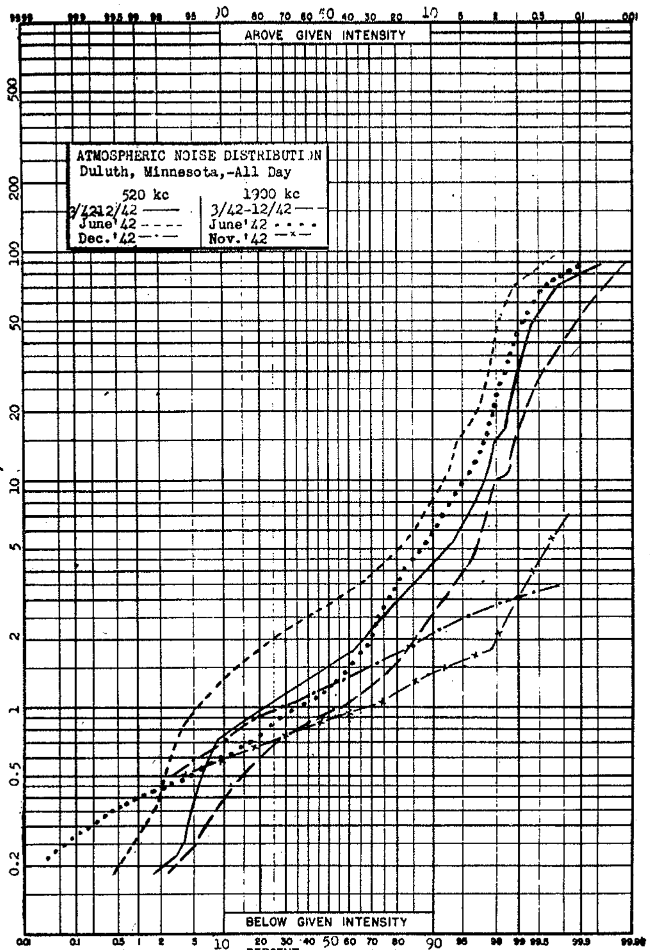


FIGURE 4a

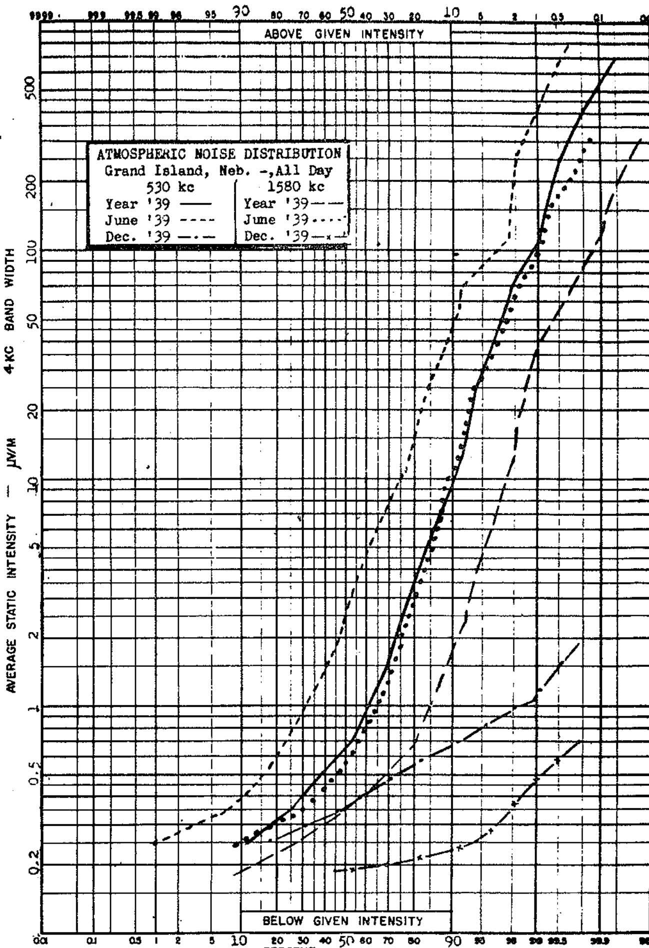


FIGURE 4b

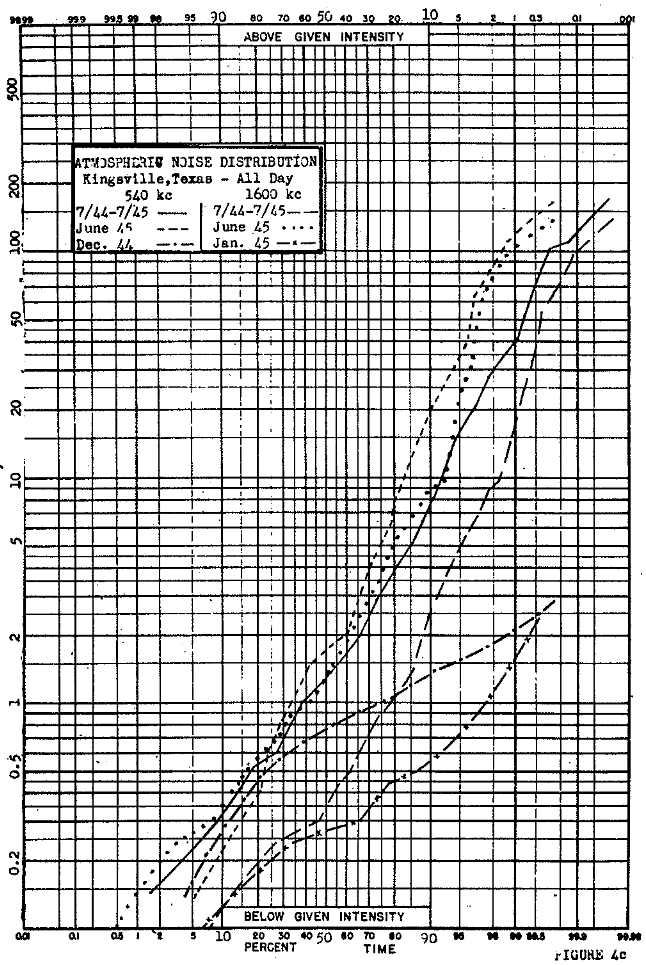


FIGURE 4c

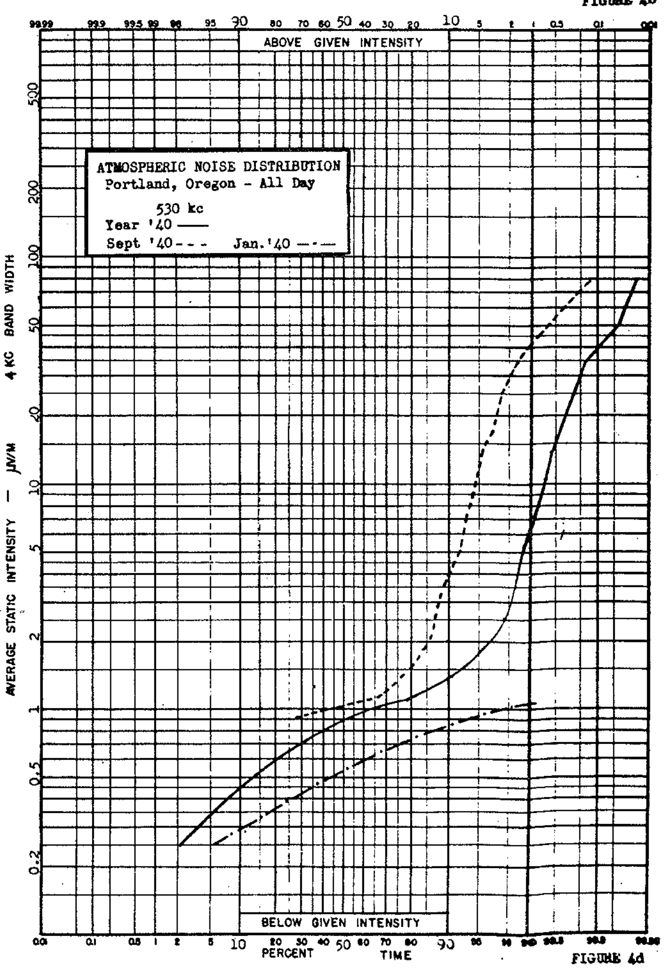


FIGURE 4d

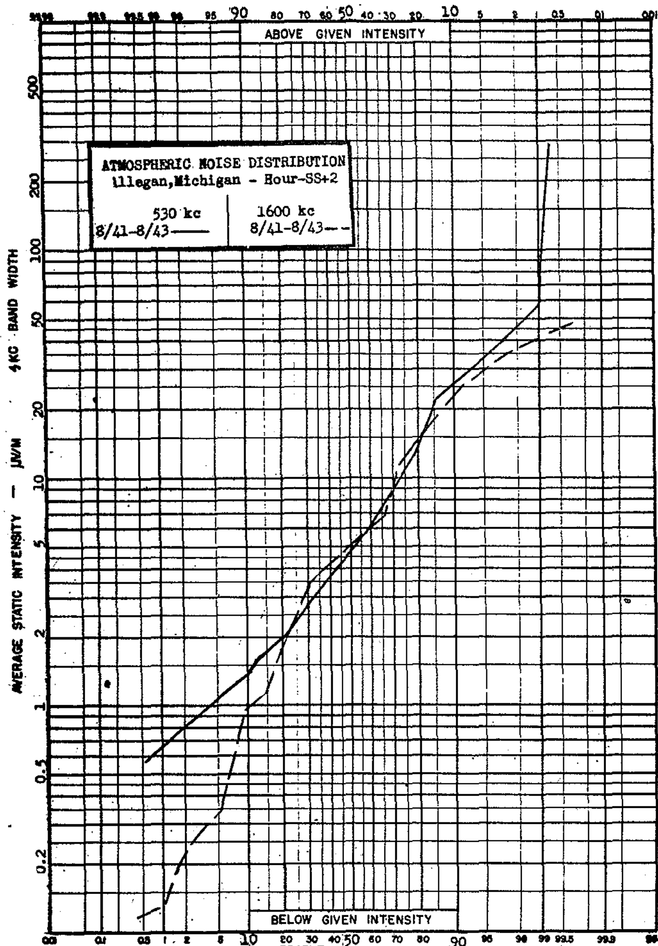


FIGURE 5a

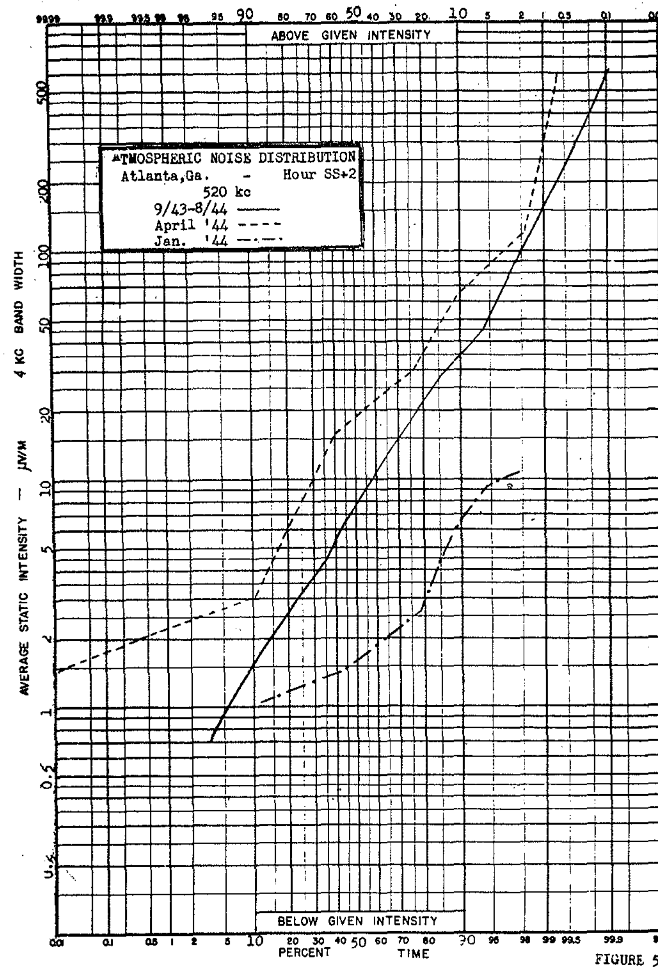


FIGURE 5b

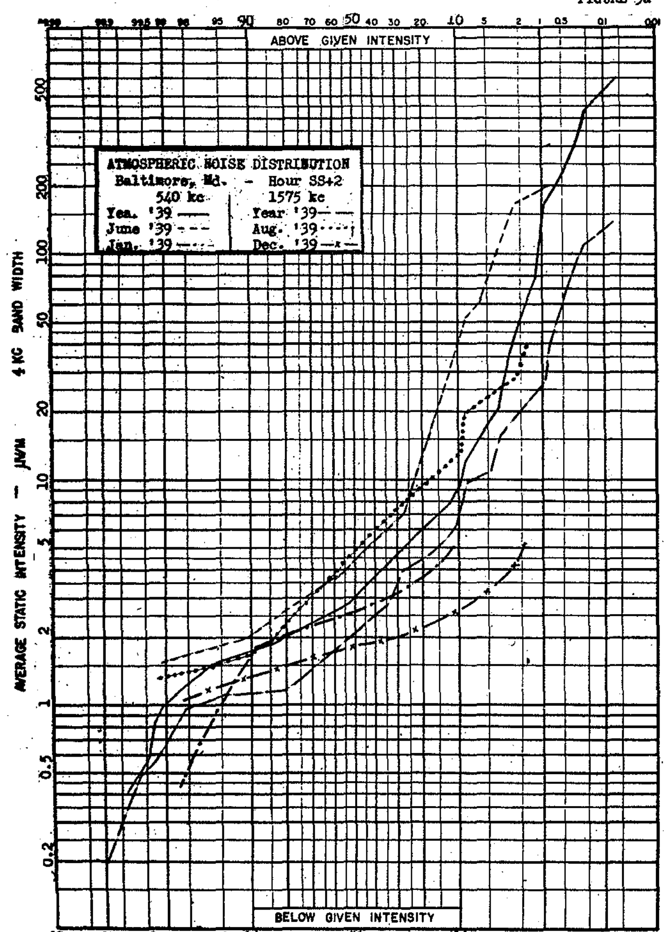


FIGURE 5c

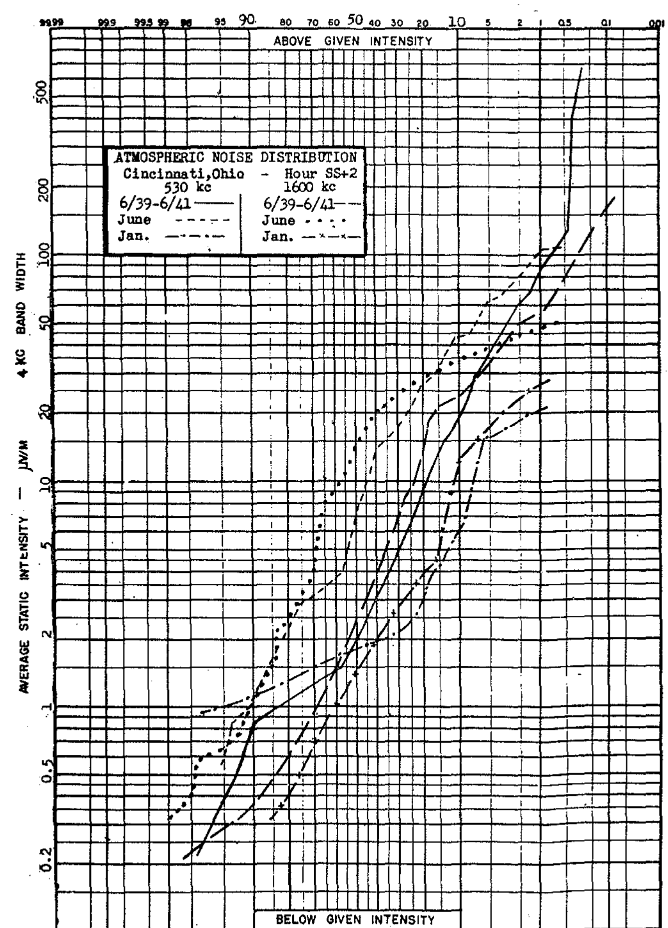


FIGURE 5d

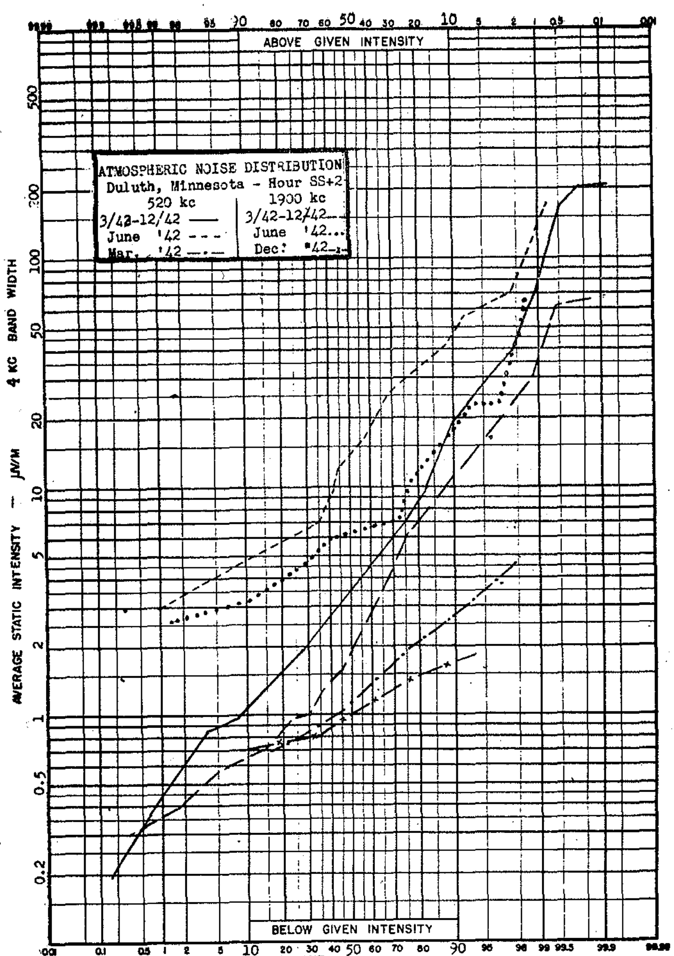


FIGURE 6a

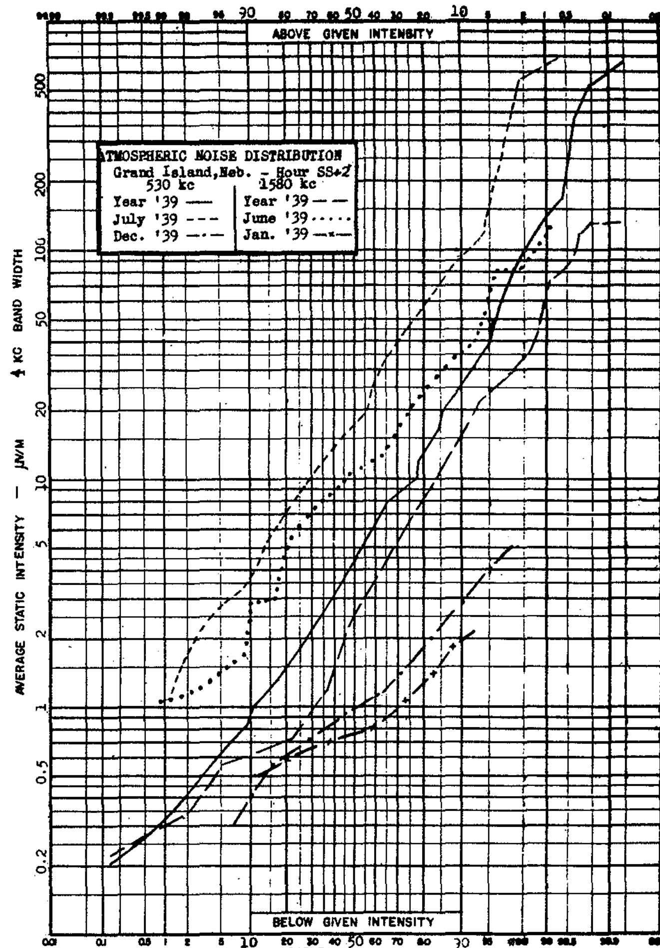


FIGURE 6b

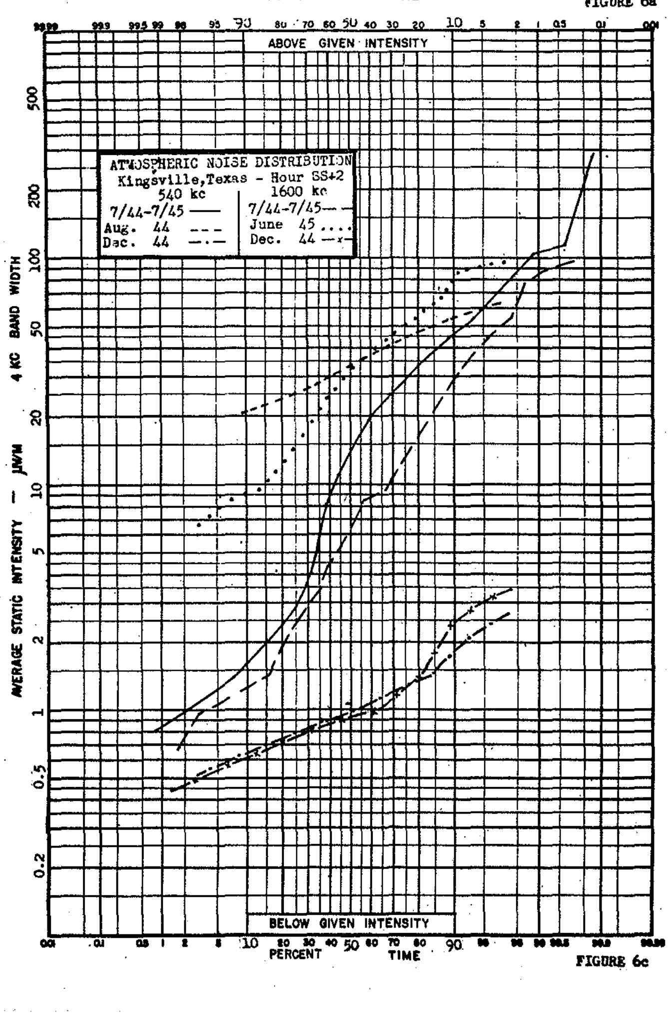


FIGURE 6c

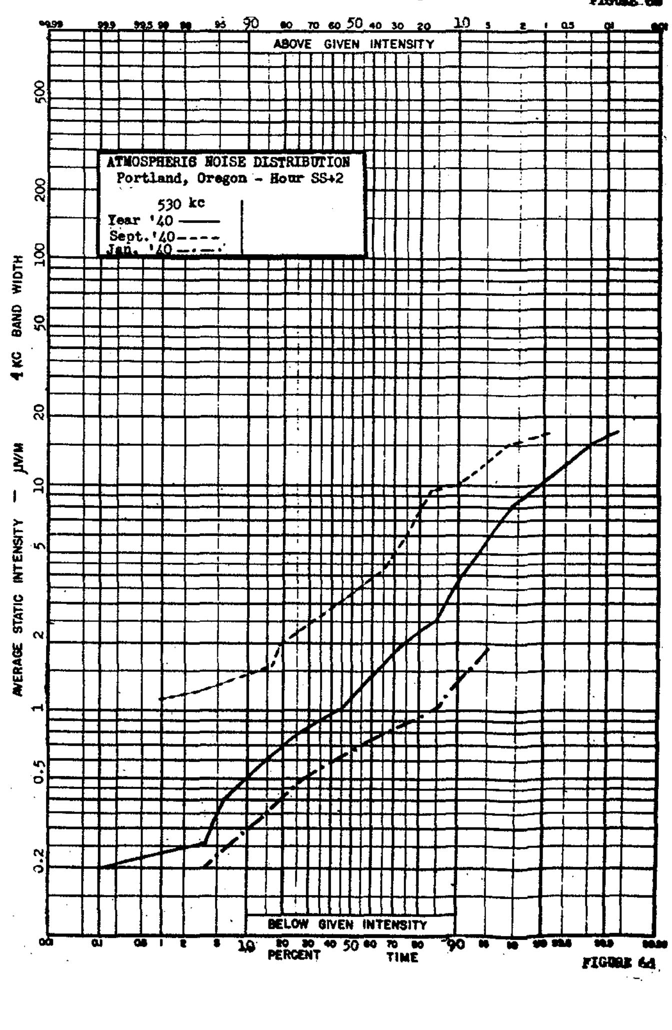
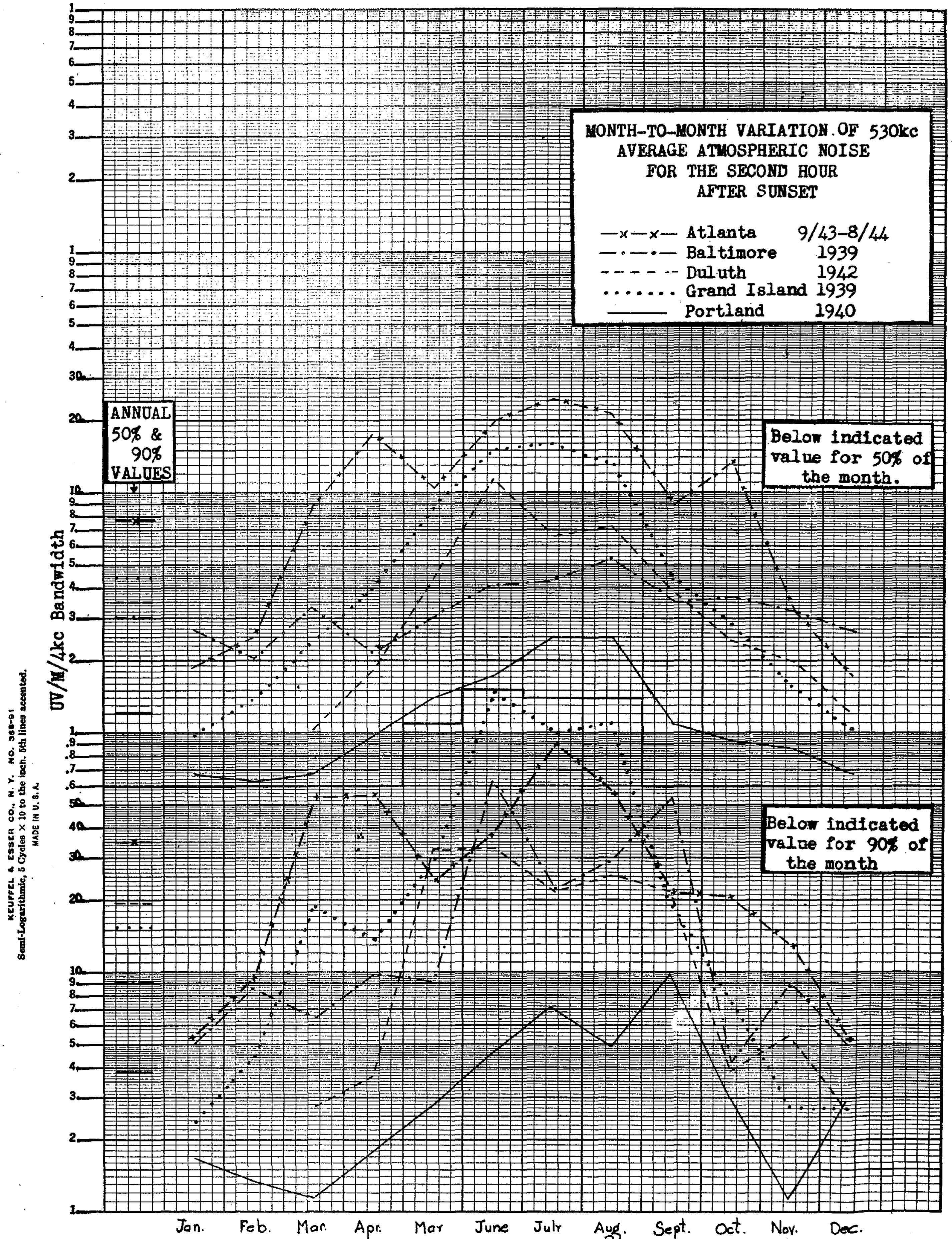


FIGURE 6d



MONTH-TO-MONTH VARIATION OF 530kc
AVERAGE ATMOSPHERIC NOISE
FOR THE SECOND HOUR
AFTER SUNSET
Atlanta 9/43-8/44
Baltimore 1939
Duluth 1942
Grand Island 1939
Portland 1940
ANNUAL 50% & 90% VALUES
Below indicated value for 50% of the month.
Below indicated value for 90% of the month
UV/M/4kc Bandwidth
Jan.
Feb.
Mar.
Apr.
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.
KEUFFEL & ESSER CO., N. Y. NO. 358-91
Semi-Logarithmic, 5 Cycles × 10 to the inch, 5th lines accented.
MADE IN U. S. A.

FIGURE 7

Diurnal Variation of 520-545kc Average Atmospheric Noise

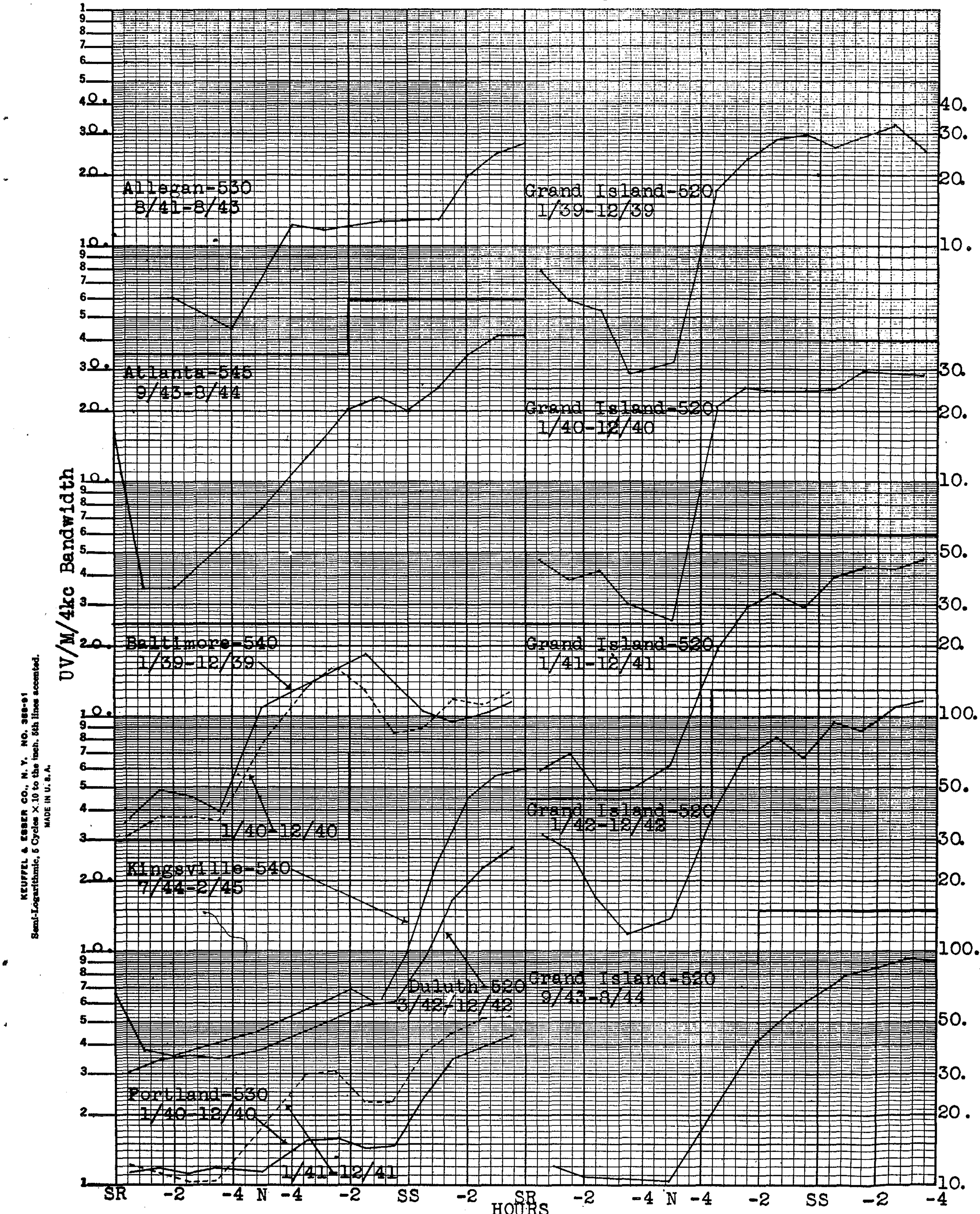


FIGURE 8

Diurnal Variation of 1545-1900kc Average Atmospheric Noise

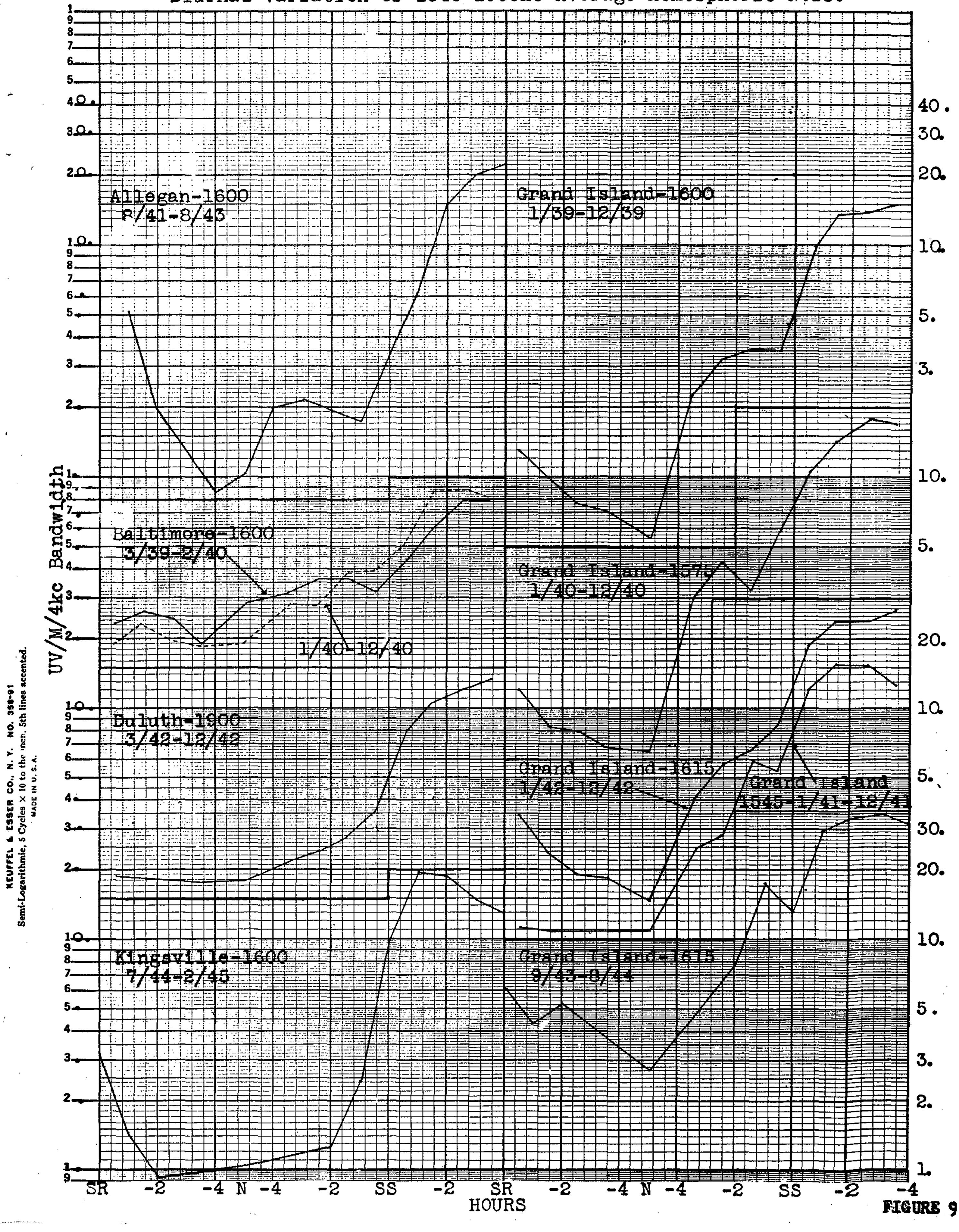


FIGURE 9

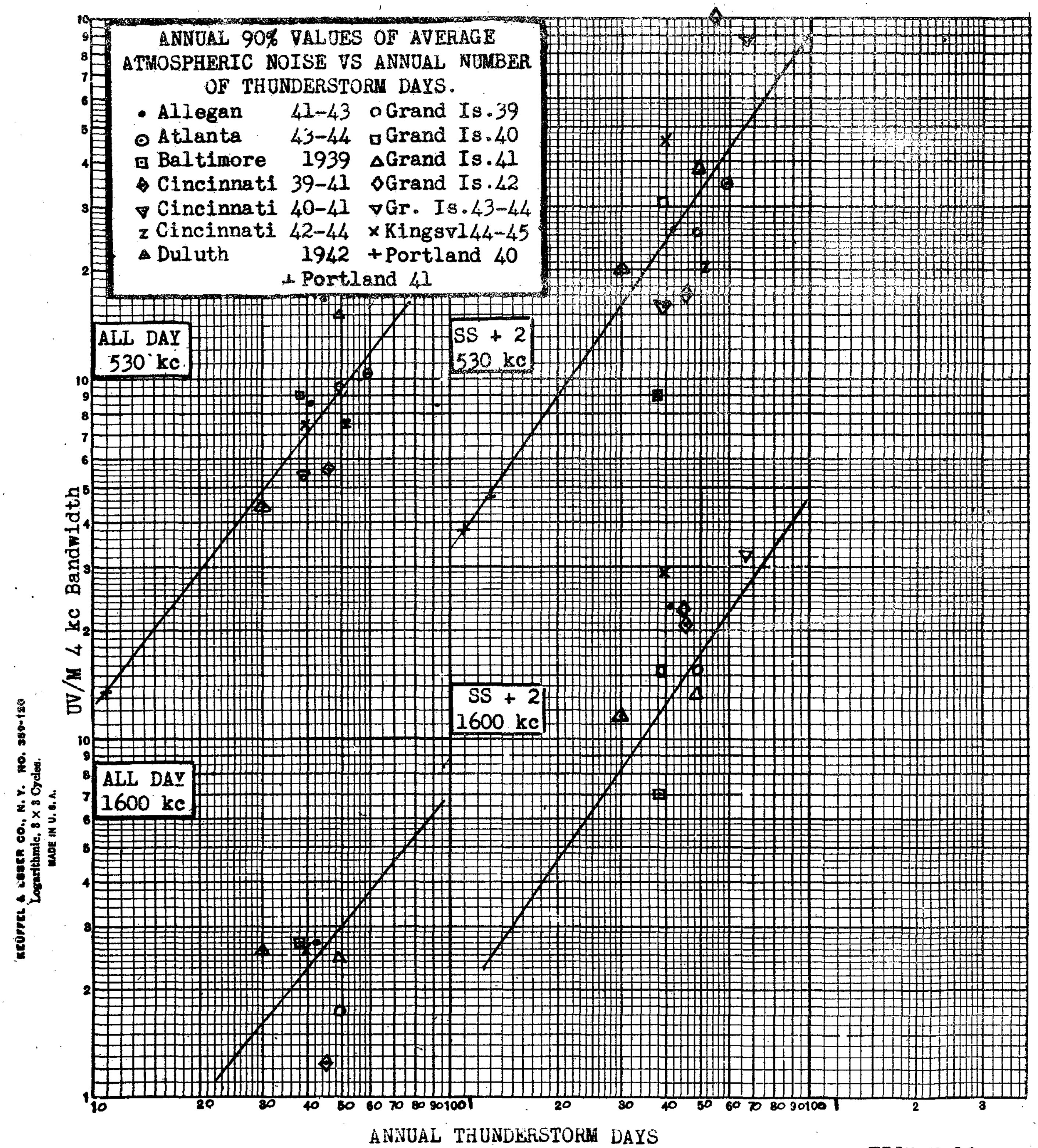
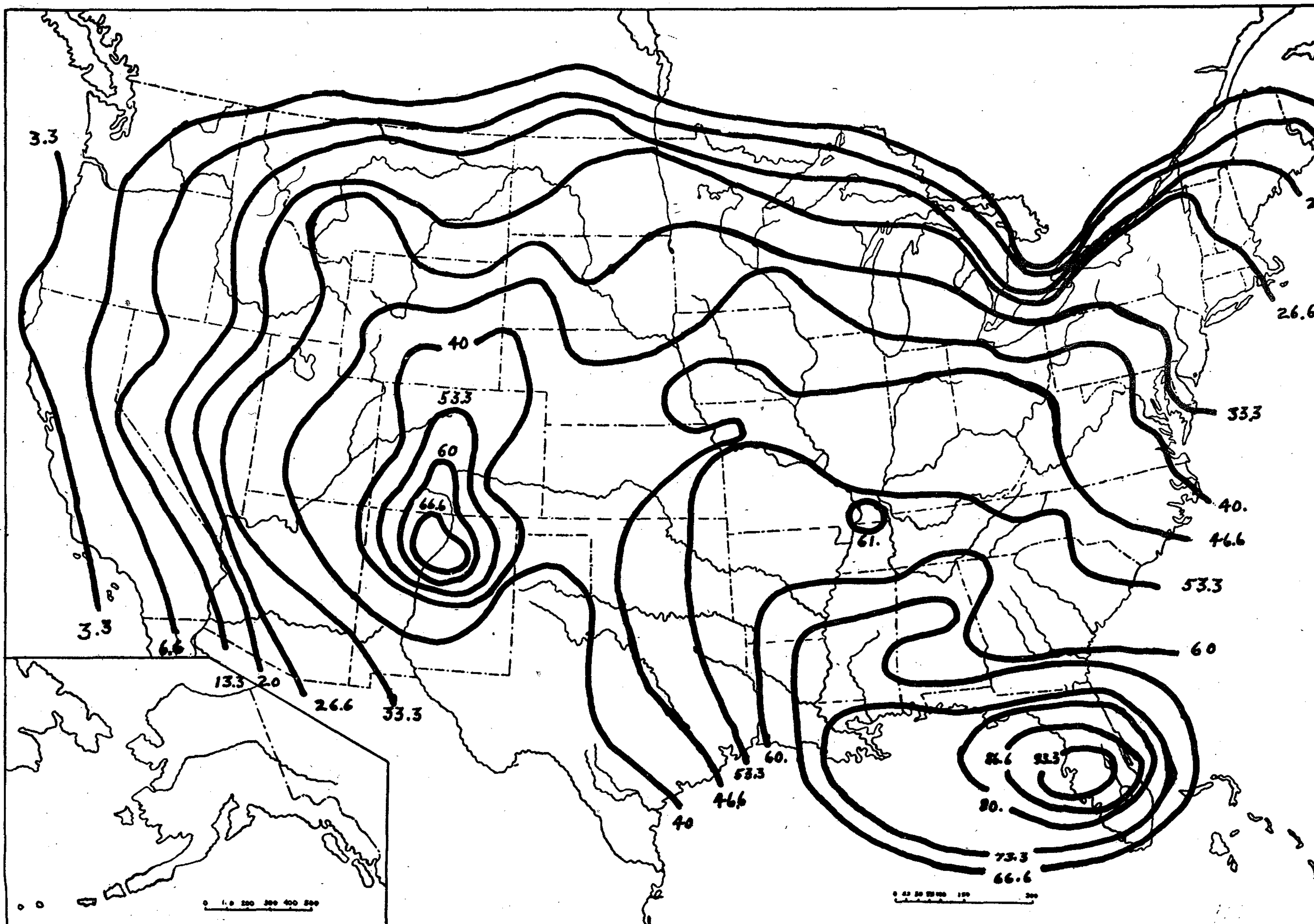

ANNUAL 90% VALUES OF AVERAGE ATMOSPHERIC NOISE VS ANNUAL NUMBER OF THUNDERSTORM DAYS.
• Allegan 41-43
⊙ Atlanta 43-44
Baltimore 1939
Cincinnati 39-41
Cincinnati 40-41
z Cincinnati 42-44
Duluth 1942
o Grand Is.39
Grand Is.40
Δ Grand Is.41
◊ Grand Is.42
Gr. Is.43-44
× Kingsvl44-45
+ Portland 40
Portland 41
ALL DAY 530 kc
SS + 2 530 kc
SS + 2 1600 kc
ALL DAY 1600 kc
UV/M 4 kc Bandwidth
ANNUAL THUNDERSTORM DAYS
KEUFFEL & ESSER CO., N.Y. NO. 359-120
Logarithmic, 3 × 3 Cycles.
MADE IN U.S.A.

FIGURE 10



UNITED STATES
ANNUAL AVERAGE NUMBER OF THUNDERSTORM DAYS, 1904 - 1933.

FIGURE 11

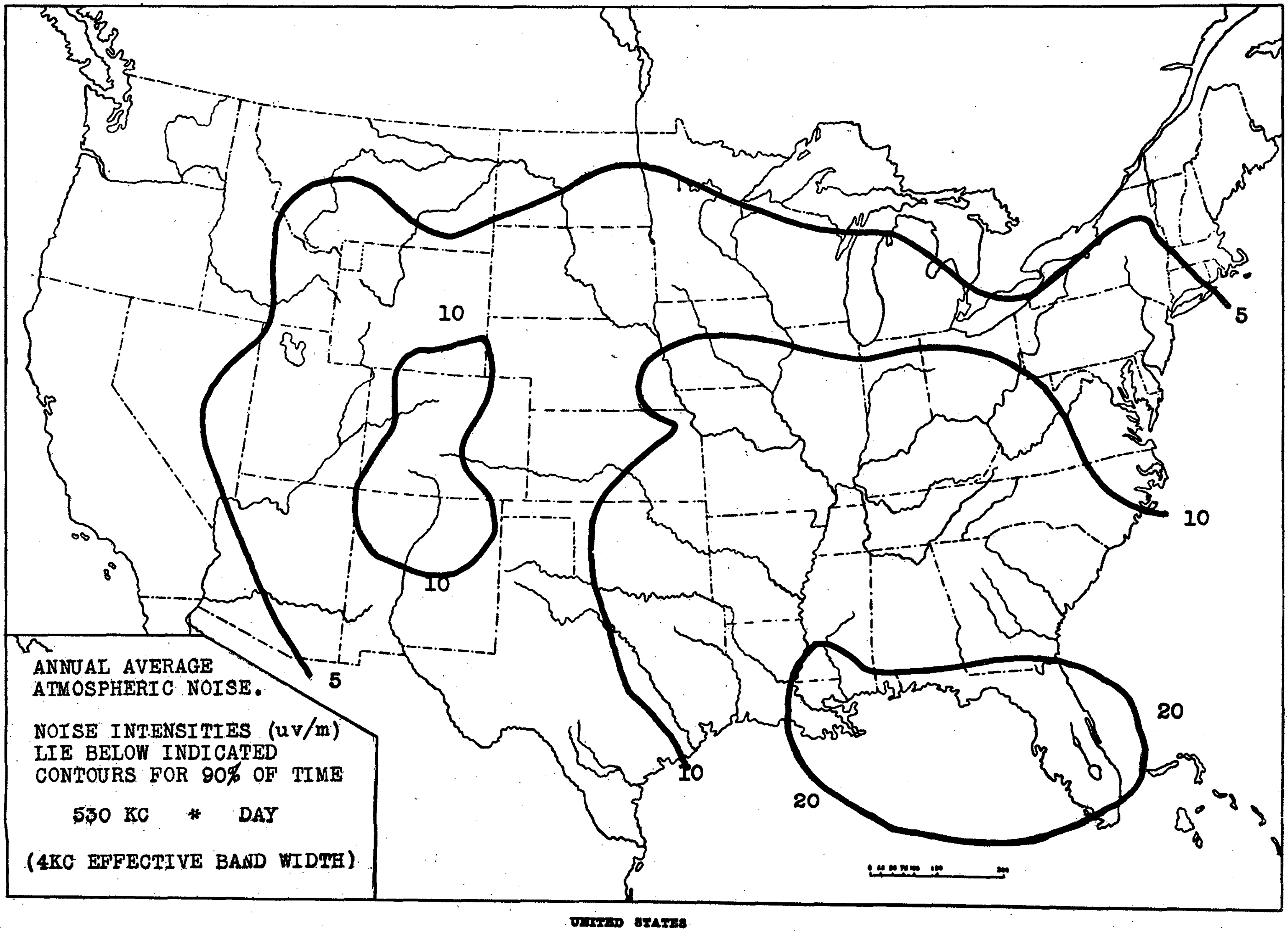
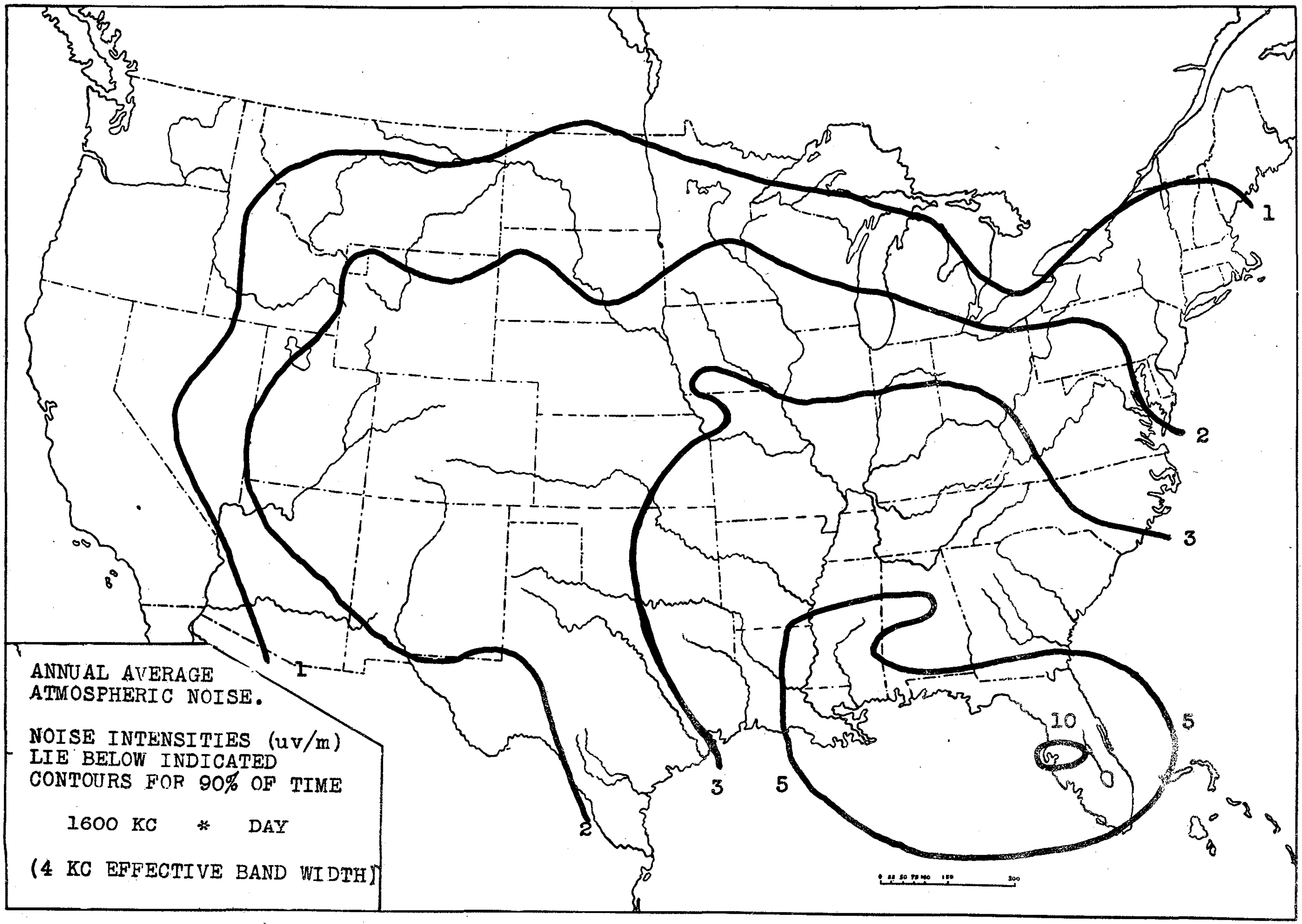
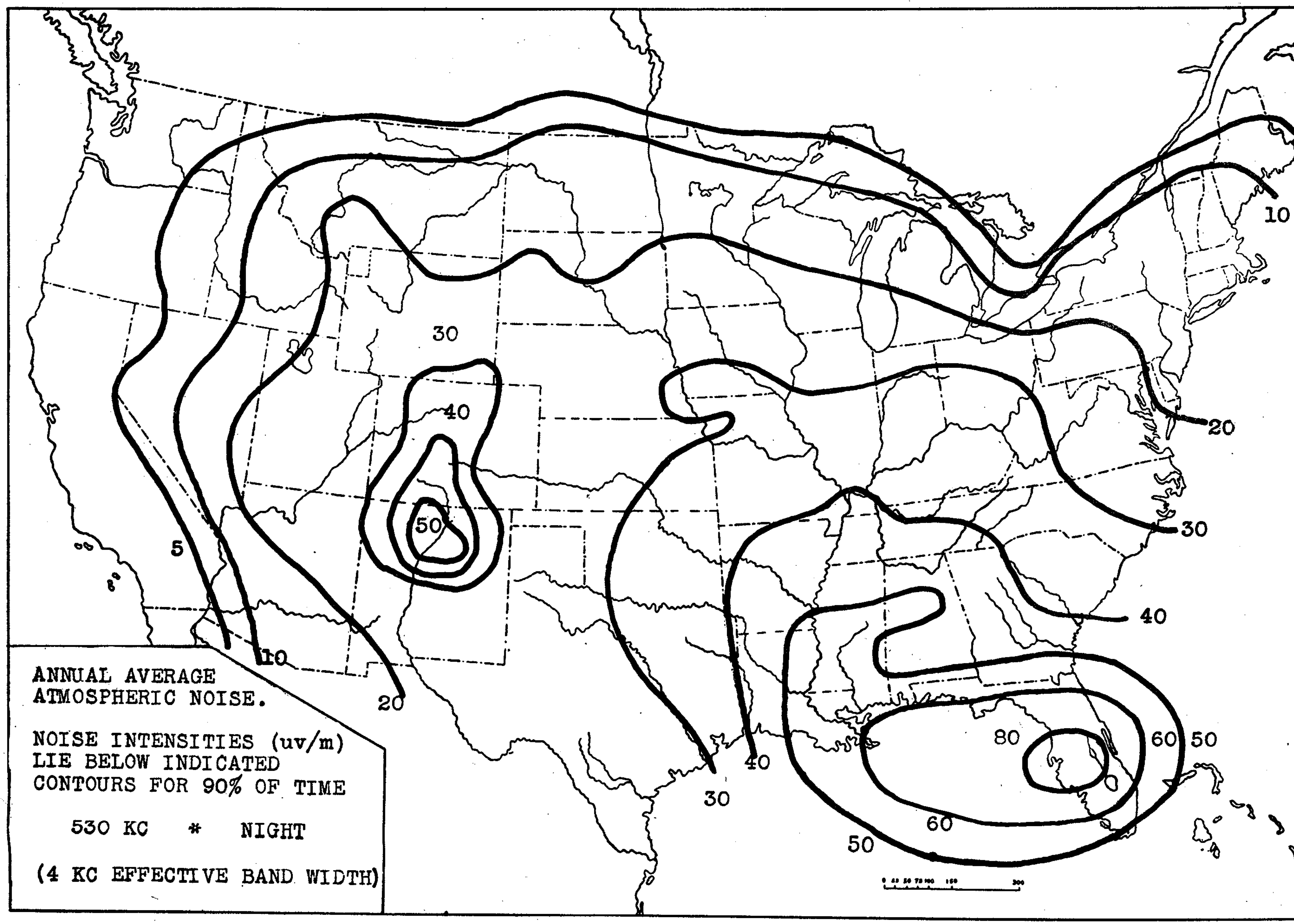

ANNUAL AVERAGE
ATMOSPHERIC NOISE.
NOISE INTENSITIES (uv/m)
LIE BELOW INDICATED
CONTOURS FOR 90% OF TIME
530 KC * DAY
(4KC EFFECTIVE BAND WIDTH)
5
10
10
10
5
10
10
20
20
UNITED STATES

FIGURE 12



UNITED STATES

FIGURE 13



UNITED STATES

FIGURE 14

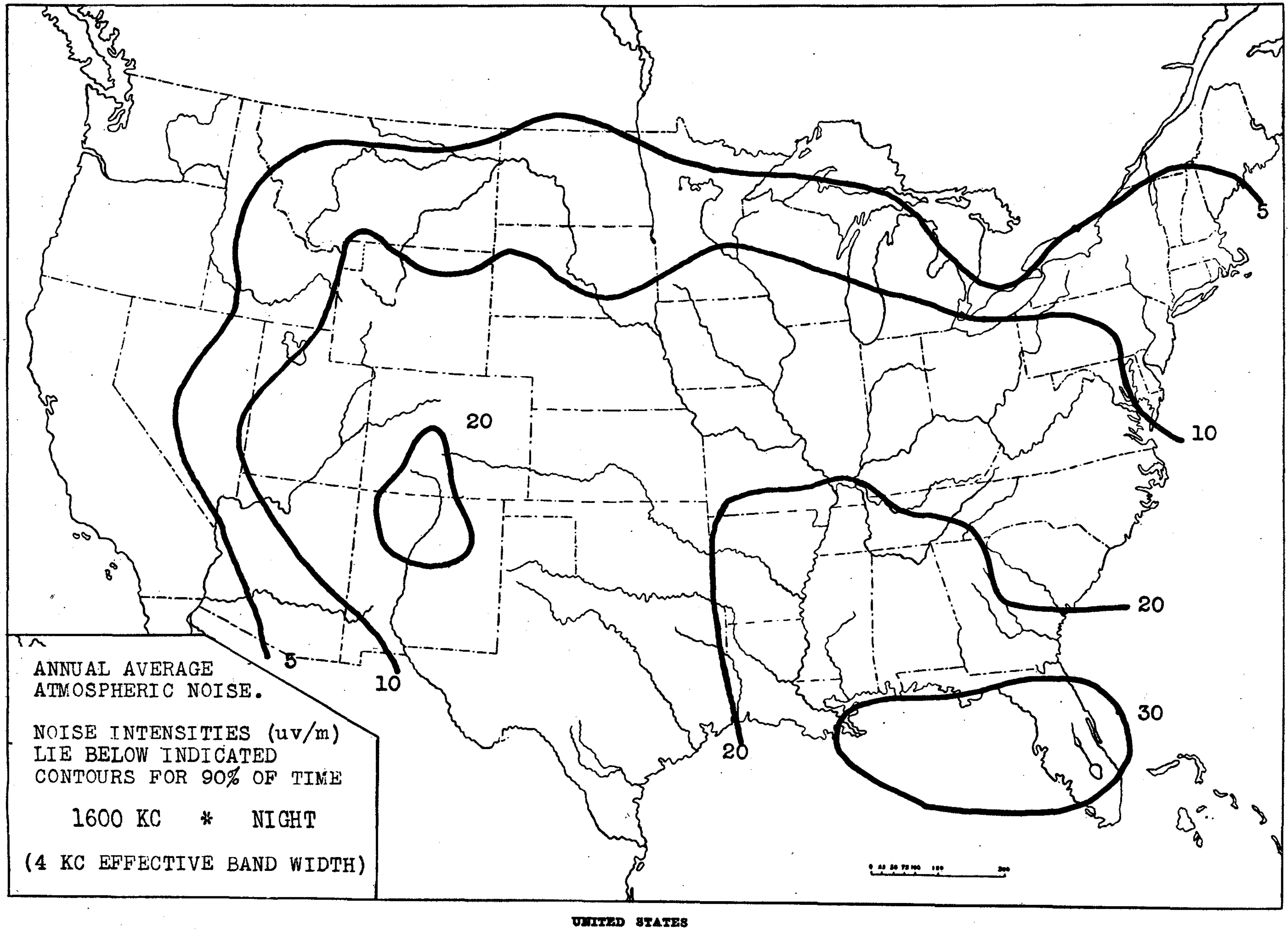

ANNUAL AVERAGE
ATMOSPHERIC NOISE.
NOISE INTENSITIES (uv/m)
LIE BELOW INDICATED
CONTOURS FOR 90% OF TIME
1600 KC * NIGHT
(4 KC EFFECTIVE BAND WIDTH)
5
10
20
30
5
10
20
20
UNITED STATES

FIGURE 15

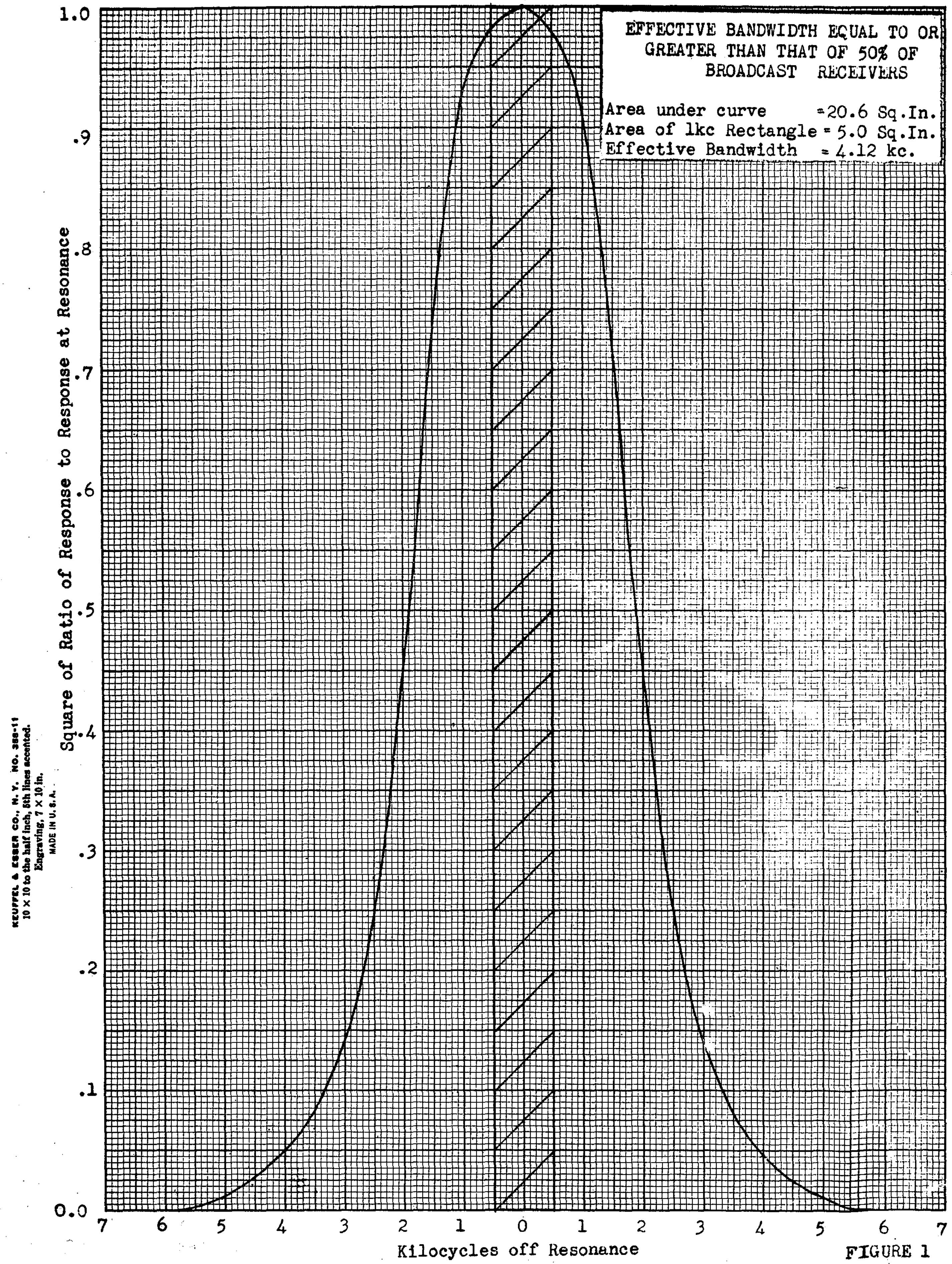

EFFECTIVE BANDWIDTH EQUAL TO OR GREATER THAN THAT OF 50% OF BROADCAST RECEIVERS
Area under curve = 20.6 Sq.In.
Area of 1kc Rectangle = 5.0 Sq.In.
Effective Bandwidth = 4.12 kc.
Square of Ratio of Response to Response at Resonance
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0.0
7
6
5
4
3
2
1
0
1
2
3
4
5
6
7
Kilocycles off Resonance
KEUFFEL & ESSER CO., N. Y. NO. 358-11
10 X 10 to the half inch, 5th lines accented.
Engraving, 7 X 10 in.
MADE IN U.S.A.

FIGURE 1

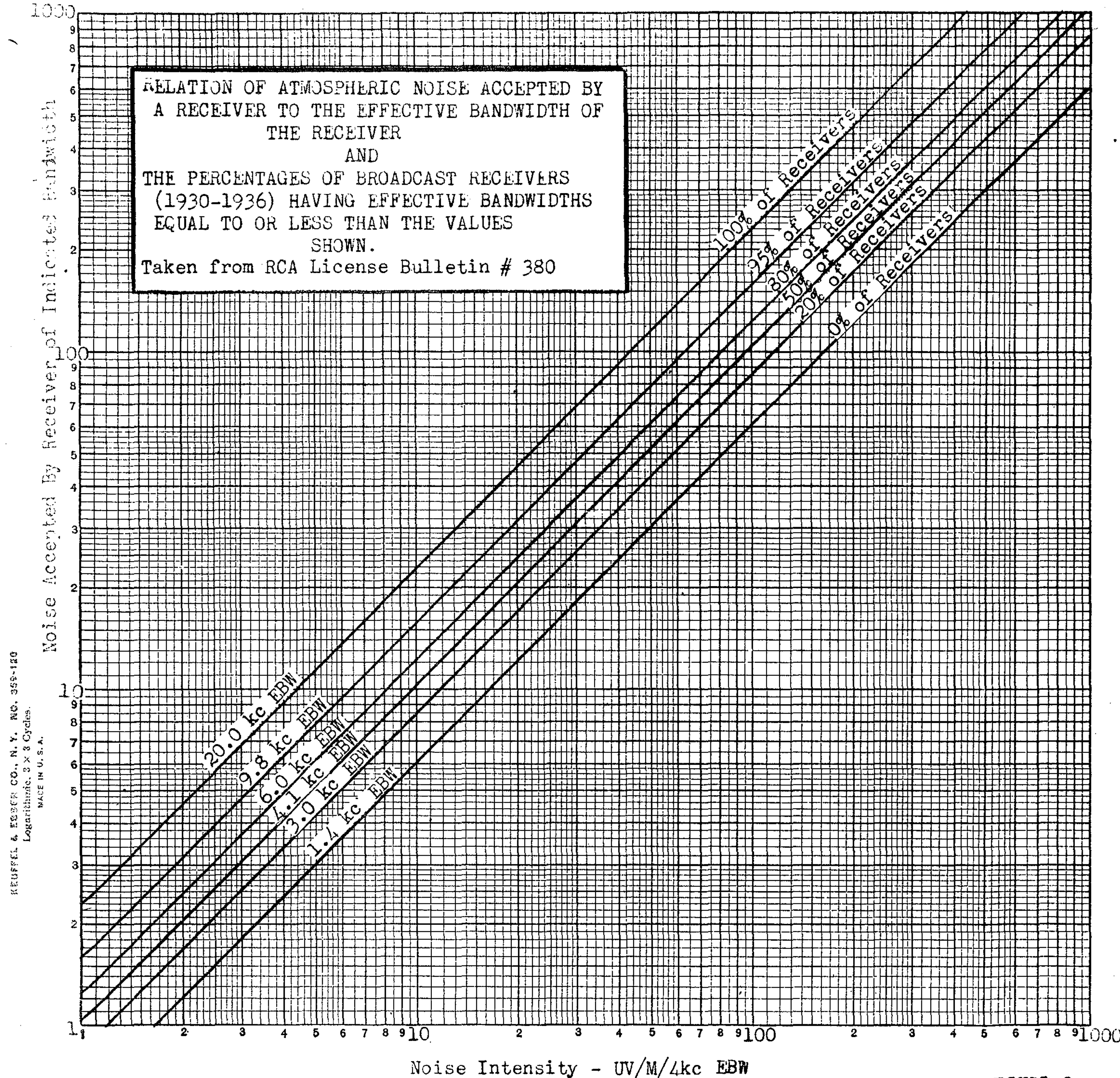

RELATION OF ATMOSPHERIC NOISE ACCEPTED BY A RECEIVER TO THE EFFECTIVE BANDWIDTH OF THE RECEIVER
AND
THE PERCENTAGES OF BROADCAST RECEIVERS (1930-1936) HAVING EFFECTIVE BANDWIDTHS EQUAL TO OR LESS THAN THE VALUES SHOWN.
Taken from RCA License Bulletin # 380
100% of Receivers
95% of Receivers
80% of Receivers
50% of Receivers
20% of Receivers
0% of Receivers
20.0 kc EBW
9.8 kc EBW
6.0 kc EBW
4.1 kc EBW
3.0 kc EBW
1.4 kc EBW
Noise Accepted By Receiver of Indicated Bandwidth
Noise Intensity - UV/M/4kc EBW
1
10
100
1000
KEUFFEL & ESSER CO., N. Y. NO. 359-120
Logarithmic, 3 x 3 Cycles.
MADE IN U. S. A.

FIGURE 2

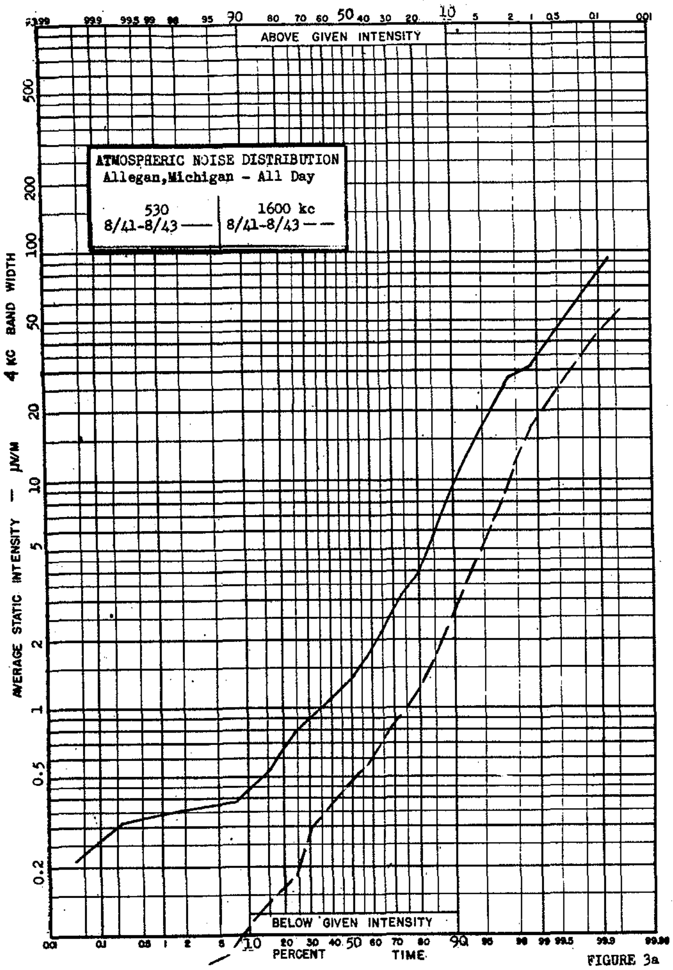


FIGURE 3a

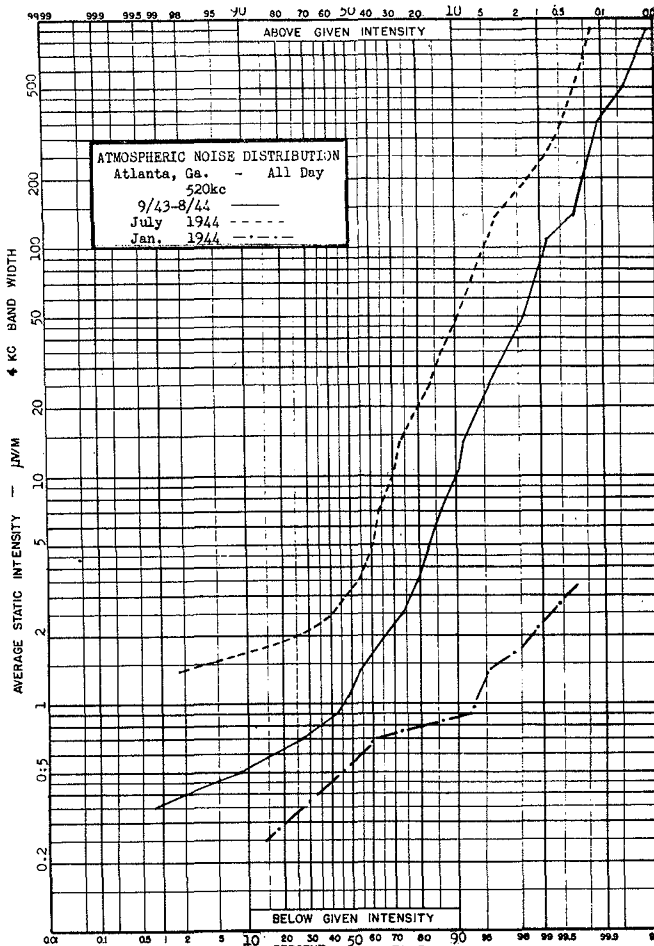


FIGURE 3b

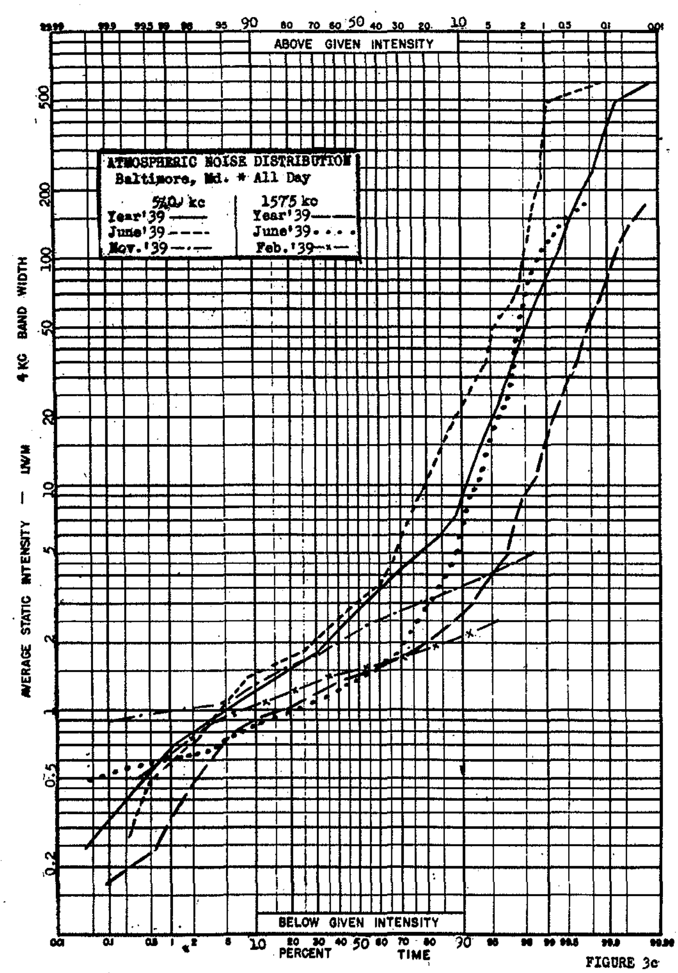


FIGURE 3c

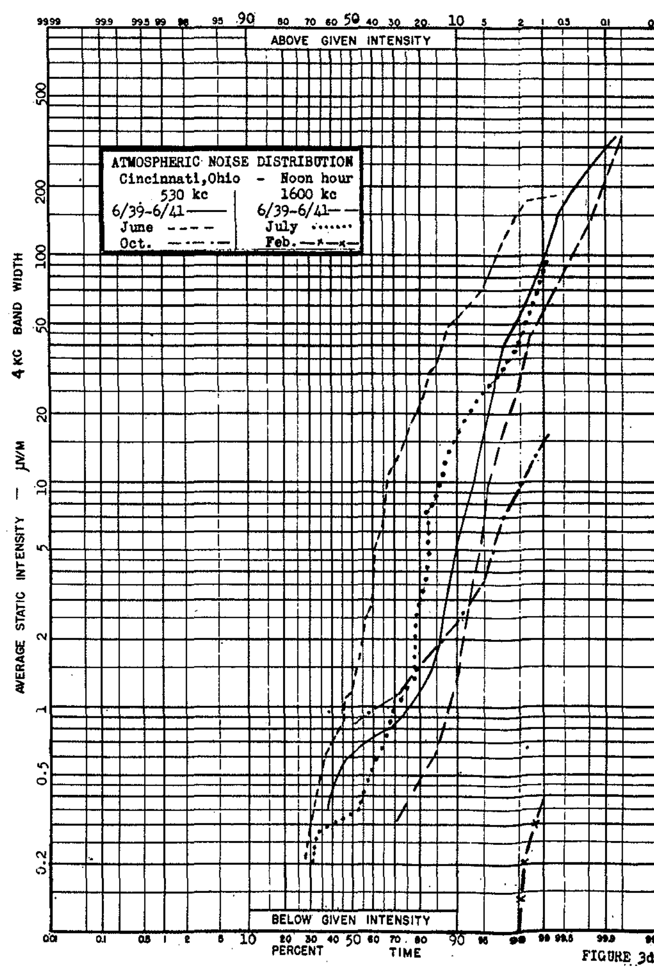


FIGURE 3d

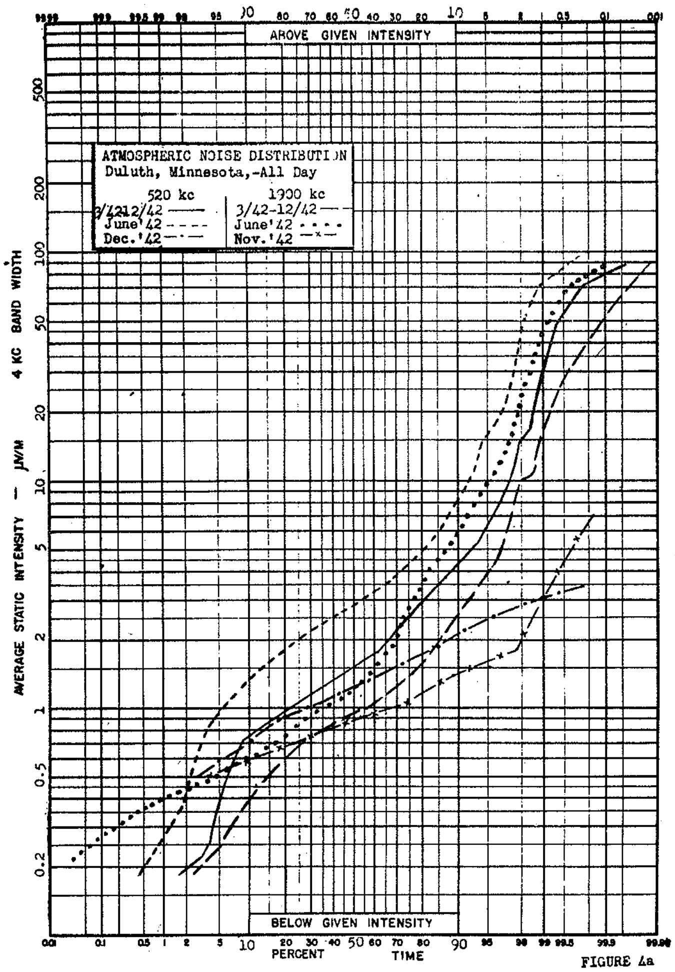


FIGURE 4a

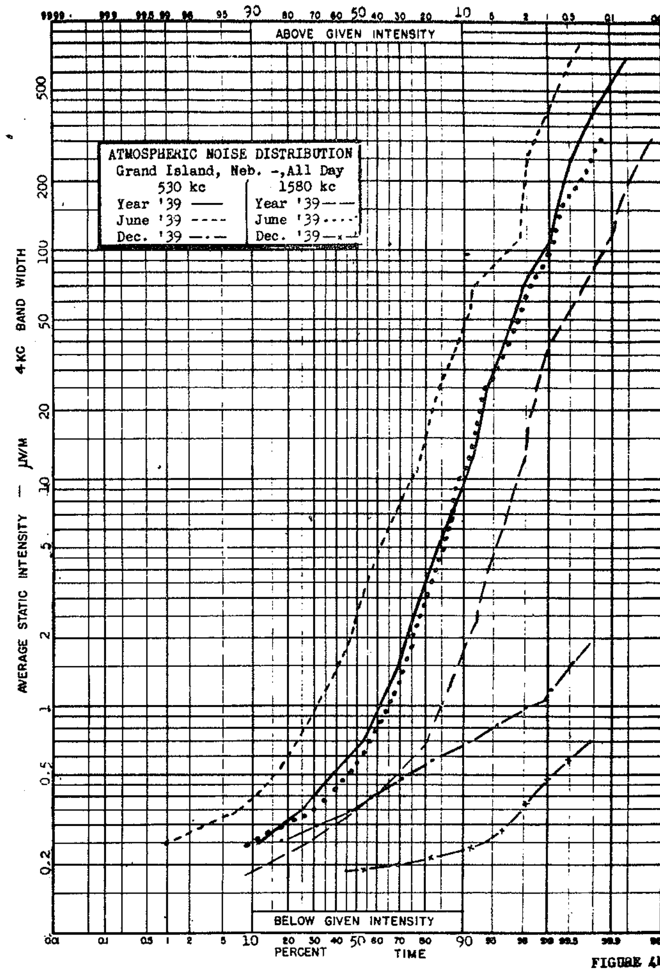


FIGURE 4b

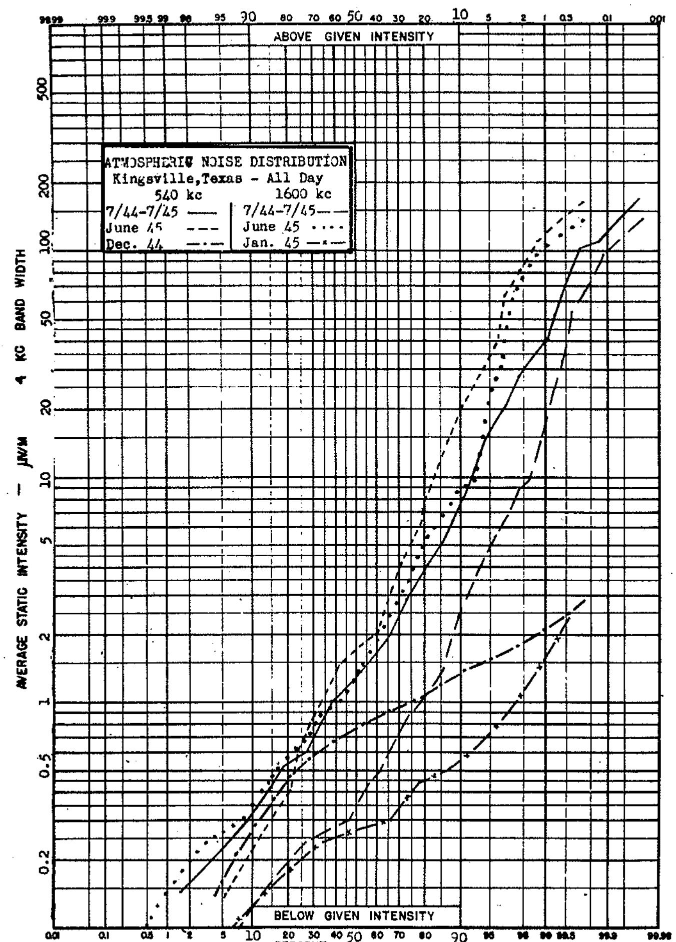


FIGURE 4c

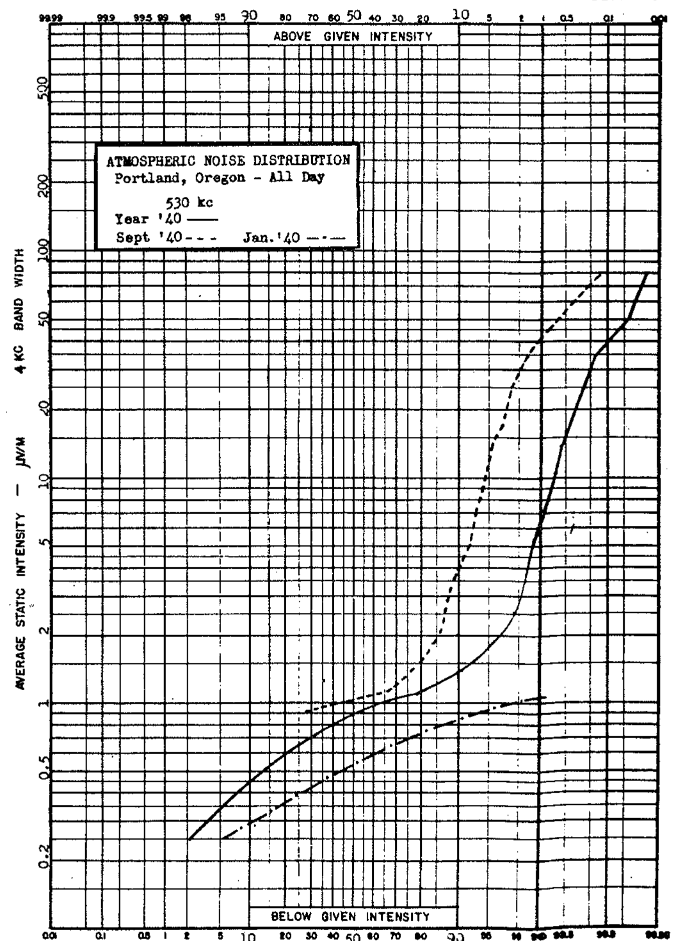


FIGURE 4d

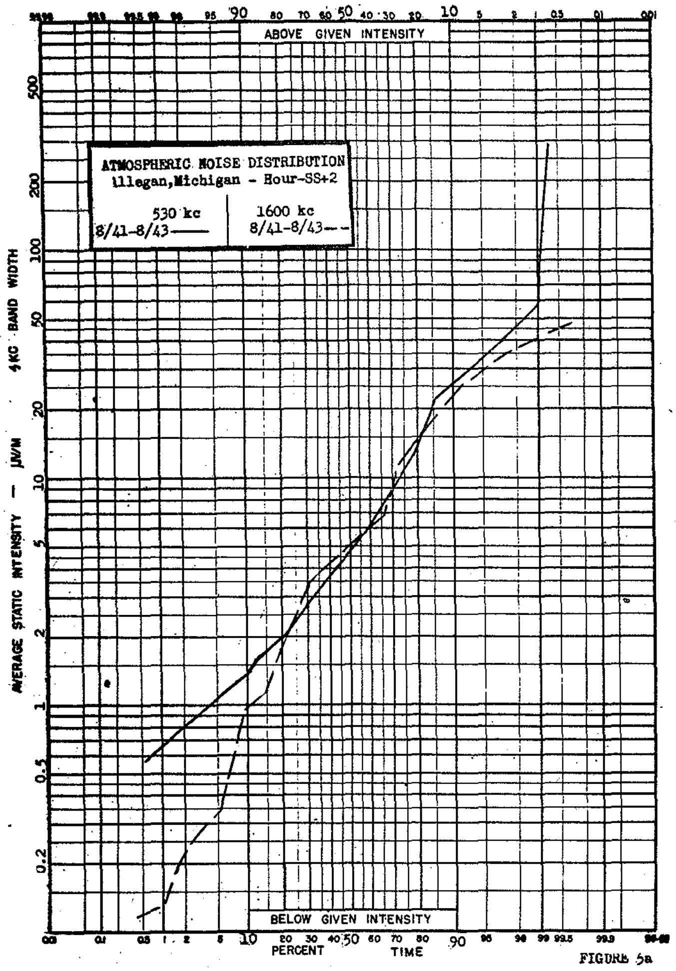


FIGURE 5a

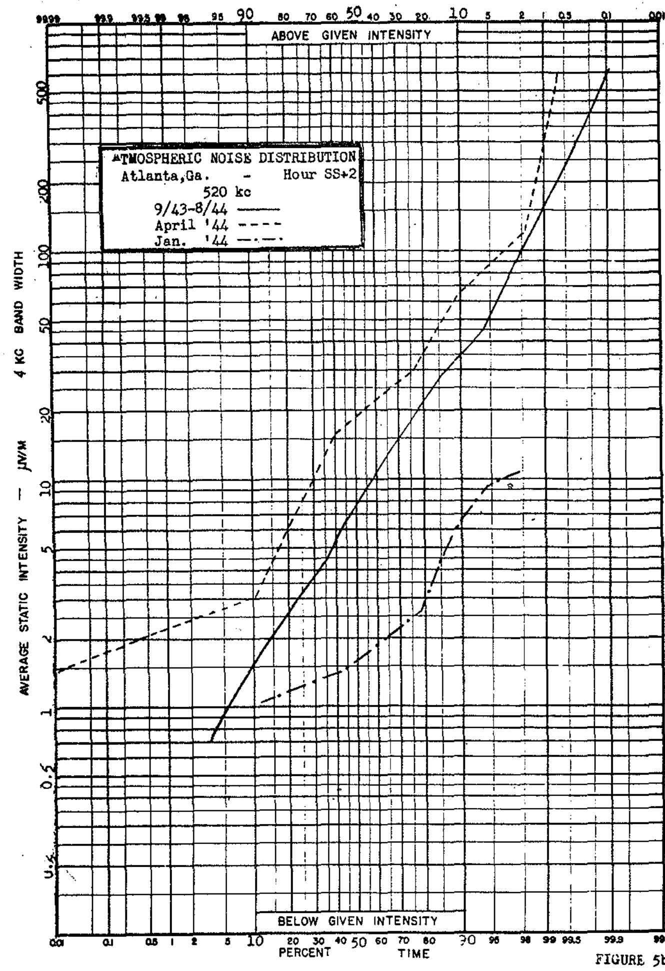


FIGURE 5b

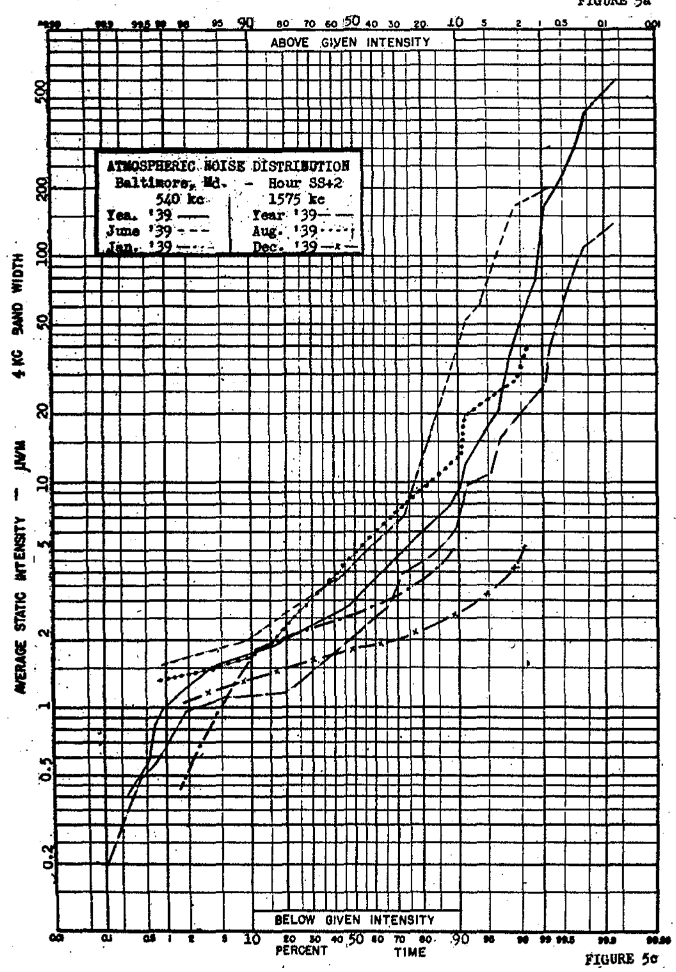


FIGURE 5c

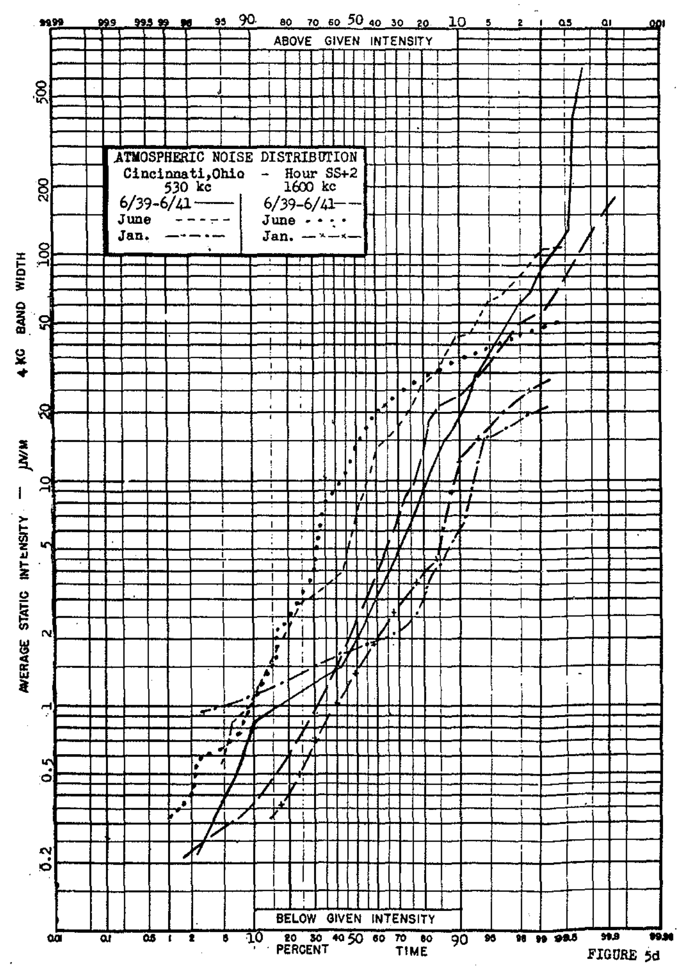


FIGURE 5d

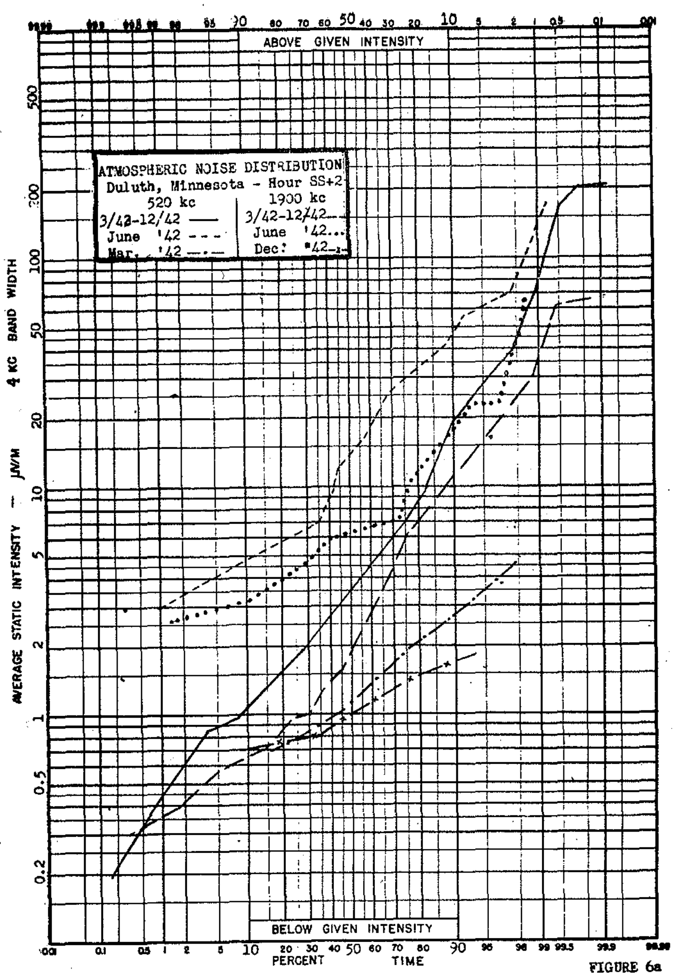


FIGURE 6a

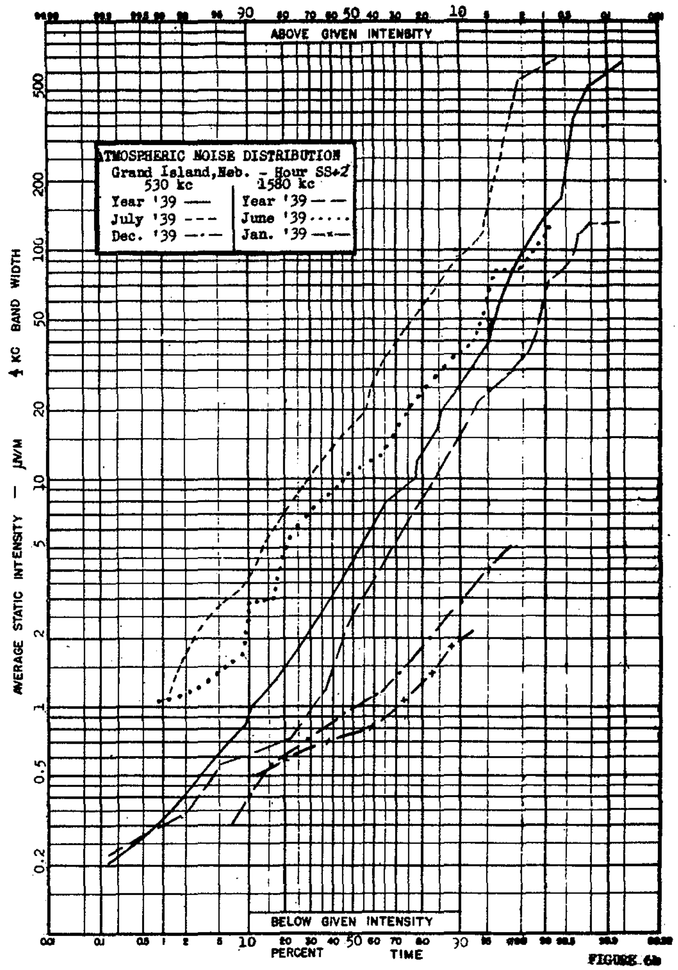


FIGURE 6b

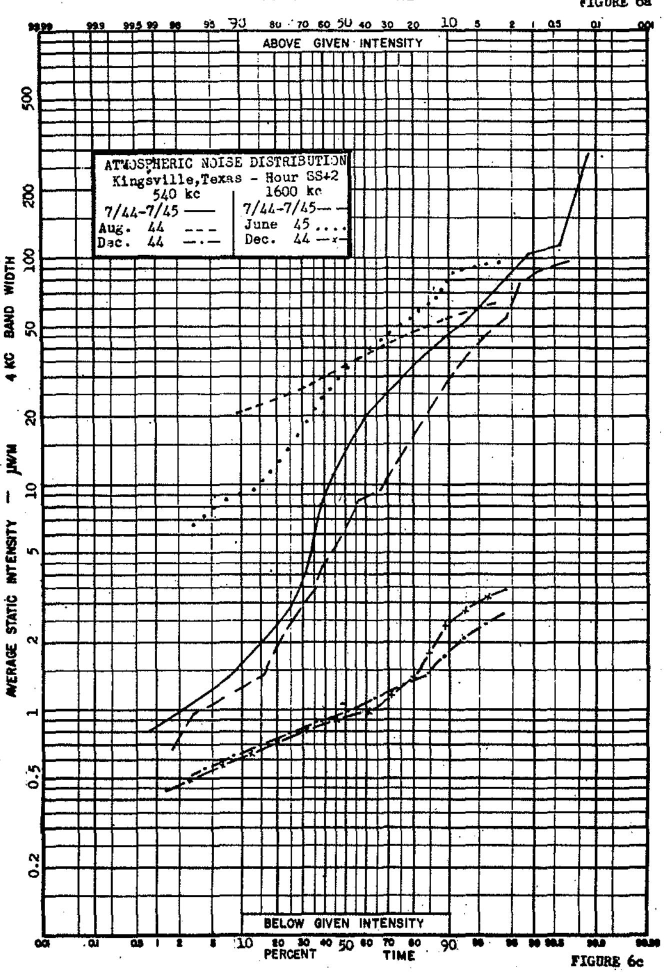


FIGURE 6c

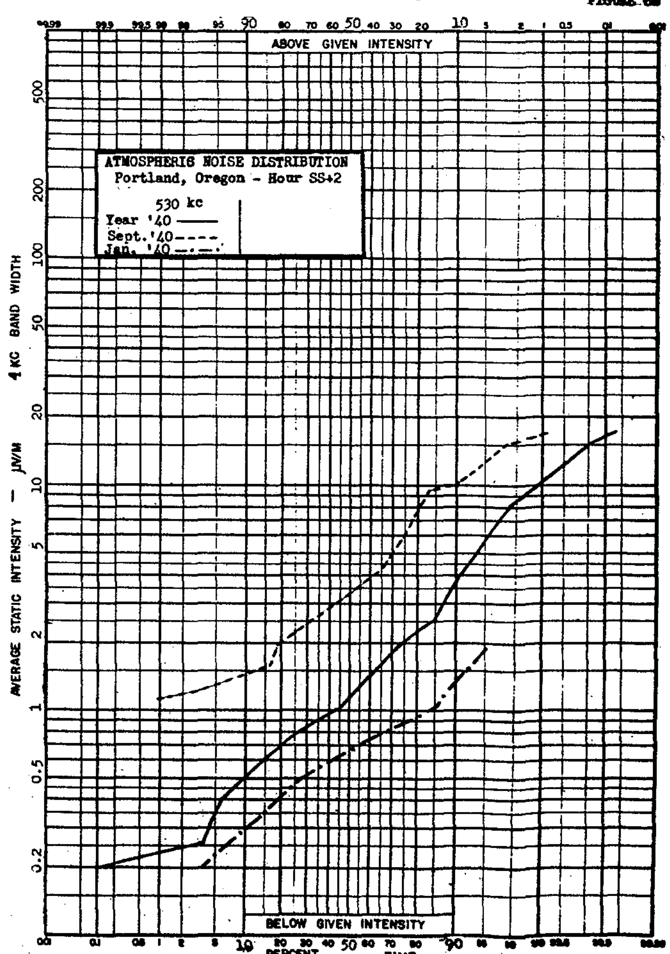


FIGURE 6d

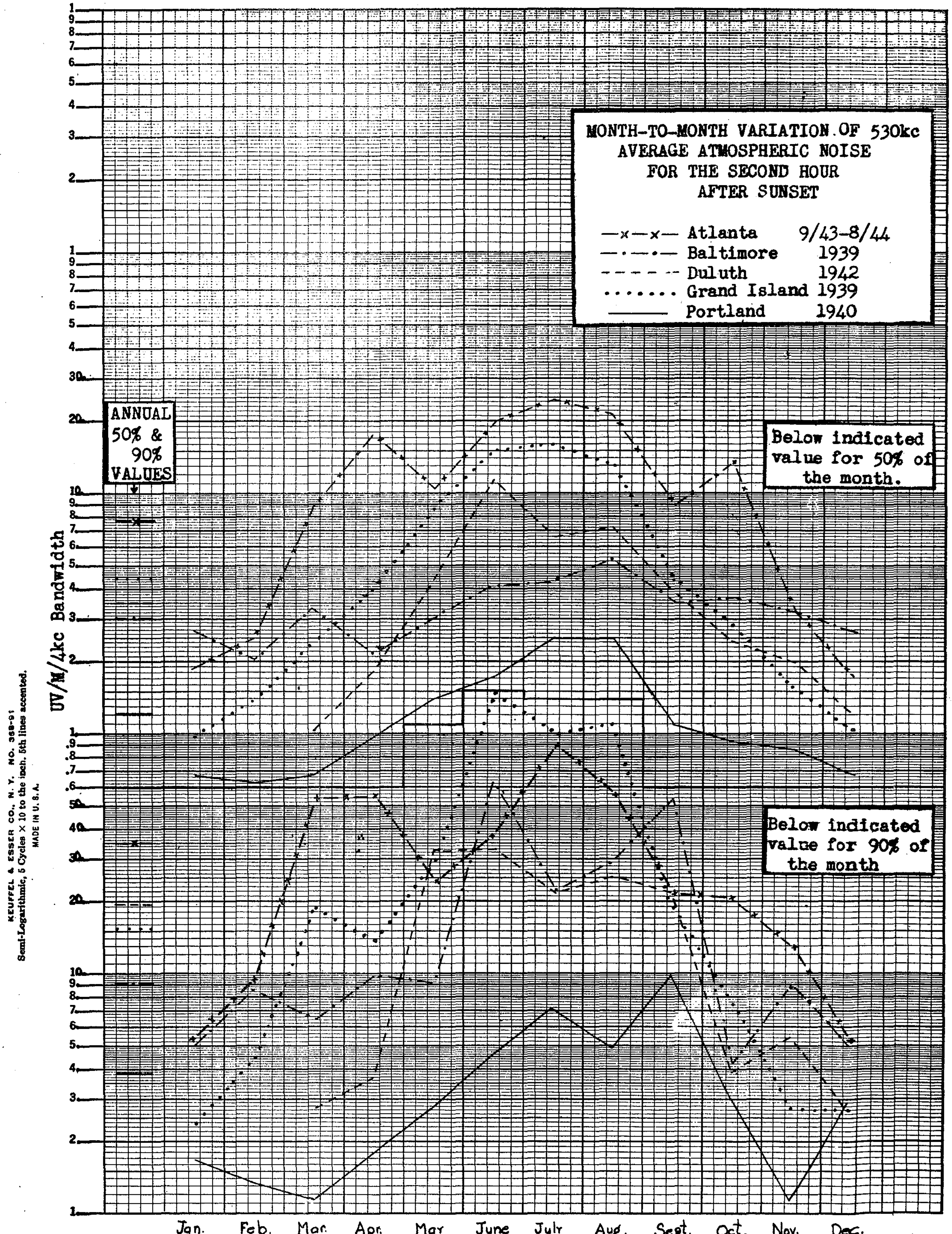
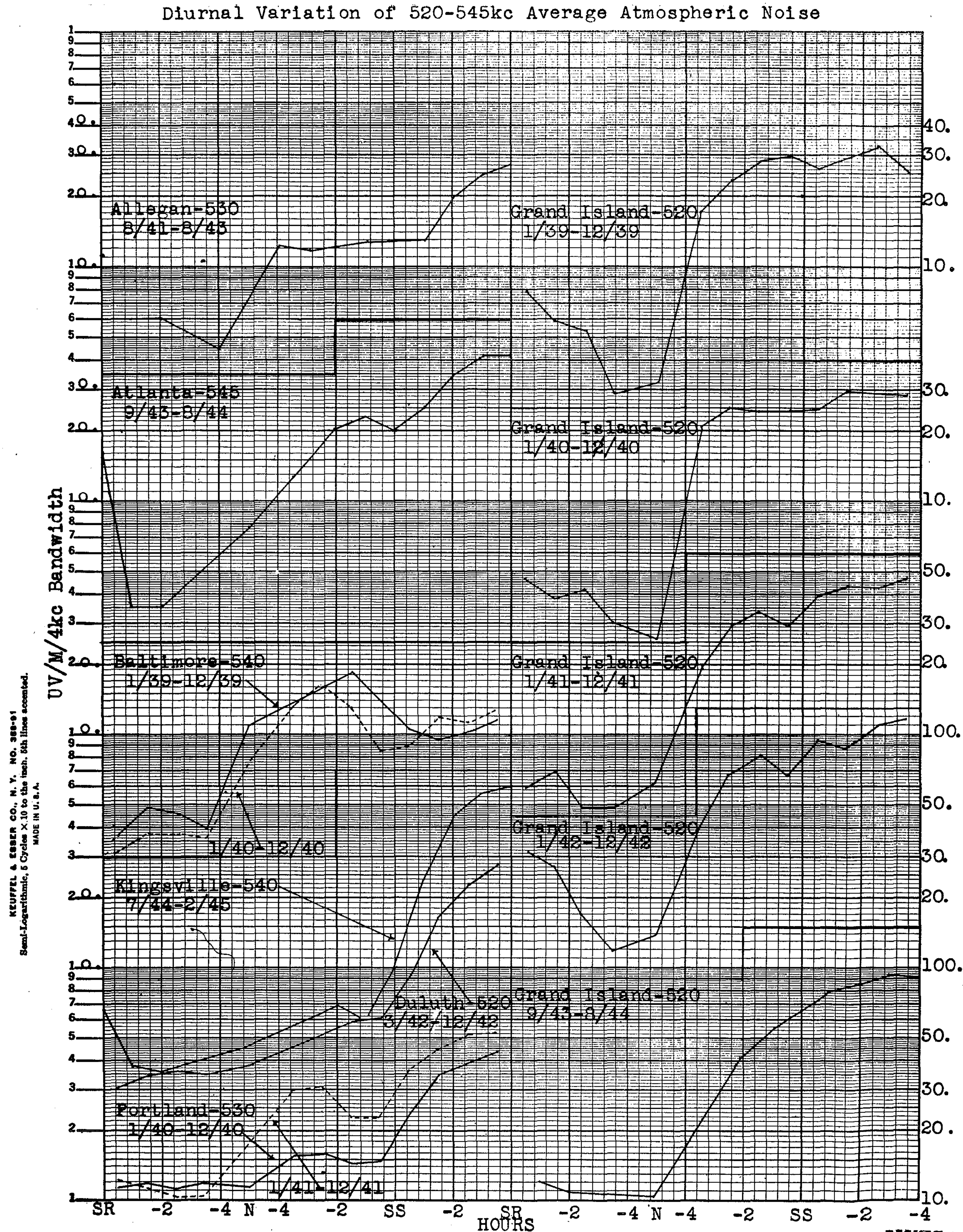
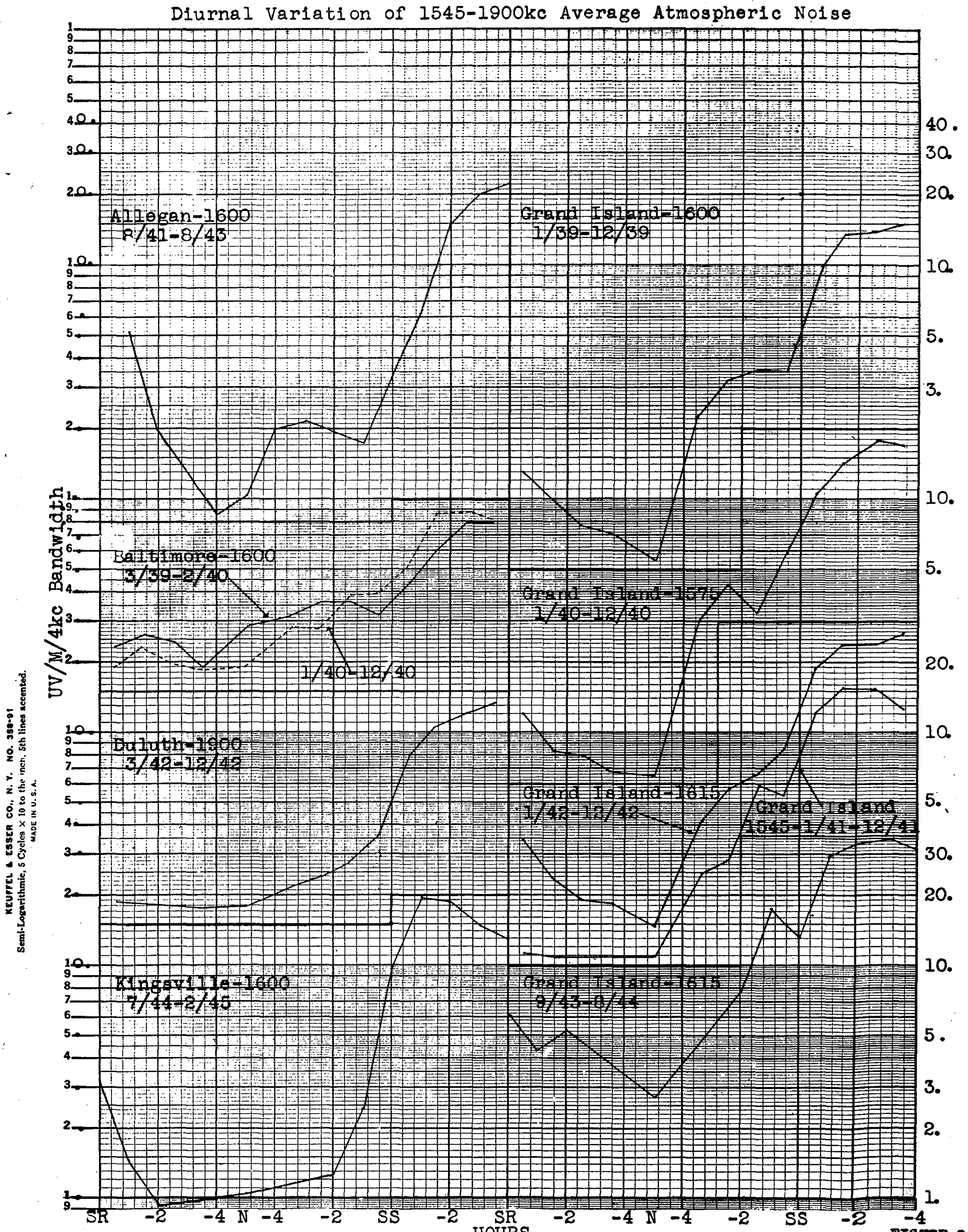

MONTH-TO-MONTH VARIATION OF 530kc
AVERAGE ATMOSPHERIC NOISE
FOR THE SECOND HOUR
AFTER SUNSET
—x—x— Atlanta 9/43-8/44
—·—·— Baltimore 1939
- - - - - Duluth 1942
.... Grand Island 1939
——— Portland 1940
ANNUAL 50% & 90% VALUES
Below indicated value for 50% of the month.
Below indicated value for 90% of the month
UV/M/4kc Bandwidth
Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec.
KEUFFEL & ESSER CO., N. Y. NO. 358-91
Semi-Logarithmic, 5 Cycles × 10 to the inch, 5th lines accented.
MADE IN U. S. A.

FIGURE 7


Diurnal Variation of 520-545kc Average Atmospheric Noise
UV/M/4kc Bandwidth
Allegan-530
8/41-8/43
Atlanta-545
9/43-8/44
Baltimore-540
1/39-12/39
1/40-12/40
Kingsville-540
7/44-2/45
Portland-530
1/40-12/40
1/41-12/41
Duluth-520
3/42-12/42
Grand Island-520
1/39-12/39
Grand Island-520
1/40-12/40
Grand Island-520
1/41-12/41
Grand Island-520
1/42-12/42
Grand Island-520
9/43-8/44
SR -2 -4 N -4 -2 SS -2 SR -2 -4 N -4 -2 SS -2 -4
HOURS
KEUFFEL & ESSER CO., N. Y. NO. 358-91
Semi-Logarithmic, 5 Cycles × 10 to the inch, 5th lines accented.
MADE IN U.S.A.
FIGURE 8



Diurnal Variation of 1545-1900kc Average Atmospheric Noise
UV/M/4kc Bandwidth
Allegan-1600
8/41-8/43
Baltimore-1600
3/39-2/40
1/40-12/40
Duluth-1900
3/42-12/42
Kingsville-1600
7/44-2/45
Grand Island-1600
1/39-12/39
Grand Island-1575
1/40-12/40
Grand Island-1615
1/42-12/42
Grand Island
1545-1/41-12/41
Grand Island-1615
9/43-8/44
SR -2 -4 N -4 -2 SS -2 SR -2 -4 N -4 -2 SS -2 -4
HOURS
KEUFFEL & ESSER CO., N. Y. NO. 359-91
Semi-Logarithmic, 5 Cycles × 10 to the inch, 5th lines accented.
MADE IN U. S. A.

FIGURE 9

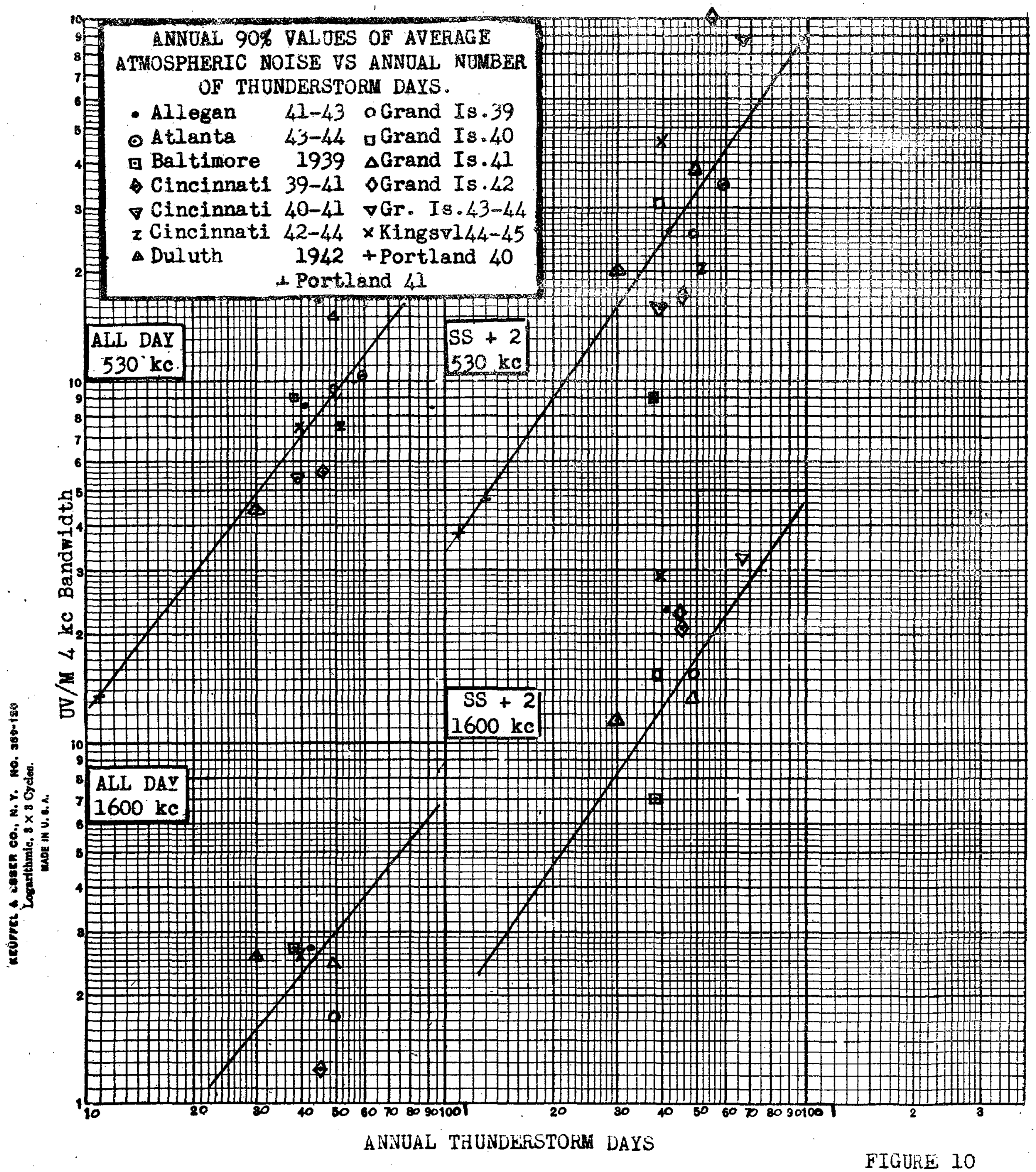

ANNUAL 90% VALUES OF AVERAGE ATMOSPHERIC NOISE VS ANNUAL NUMBER OF THUNDERSTORM DAYS.
• Allegan 41-43
⊙ Atlanta 43-44
Baltimore 1939
Cincinnati 39-41
Cincinnati 40-41
Cincinnati 42-44
Duluth 1942
○ Grand Is. 39
□ Grand Is. 40
△ Grand Is. 41
◇ Grand Is. 42
▽ Gr. Is. 43-44
× Kingsvl 44-45
+ Portland 40
Portland 41
ALL DAY 530 kc
SS + 2 530 kc
SS + 2 1600 kc
ALL DAY 1600 kc
UV/M 4 kc Bandwidth
ANNUAL THUNDERSTORM DAYS
KEUFFEL & ESSER CO., N. Y. NO. 359-120
Logarithmic, 3 × 3 Cycles.
MADE IN U. S. A.

FIGURE 10

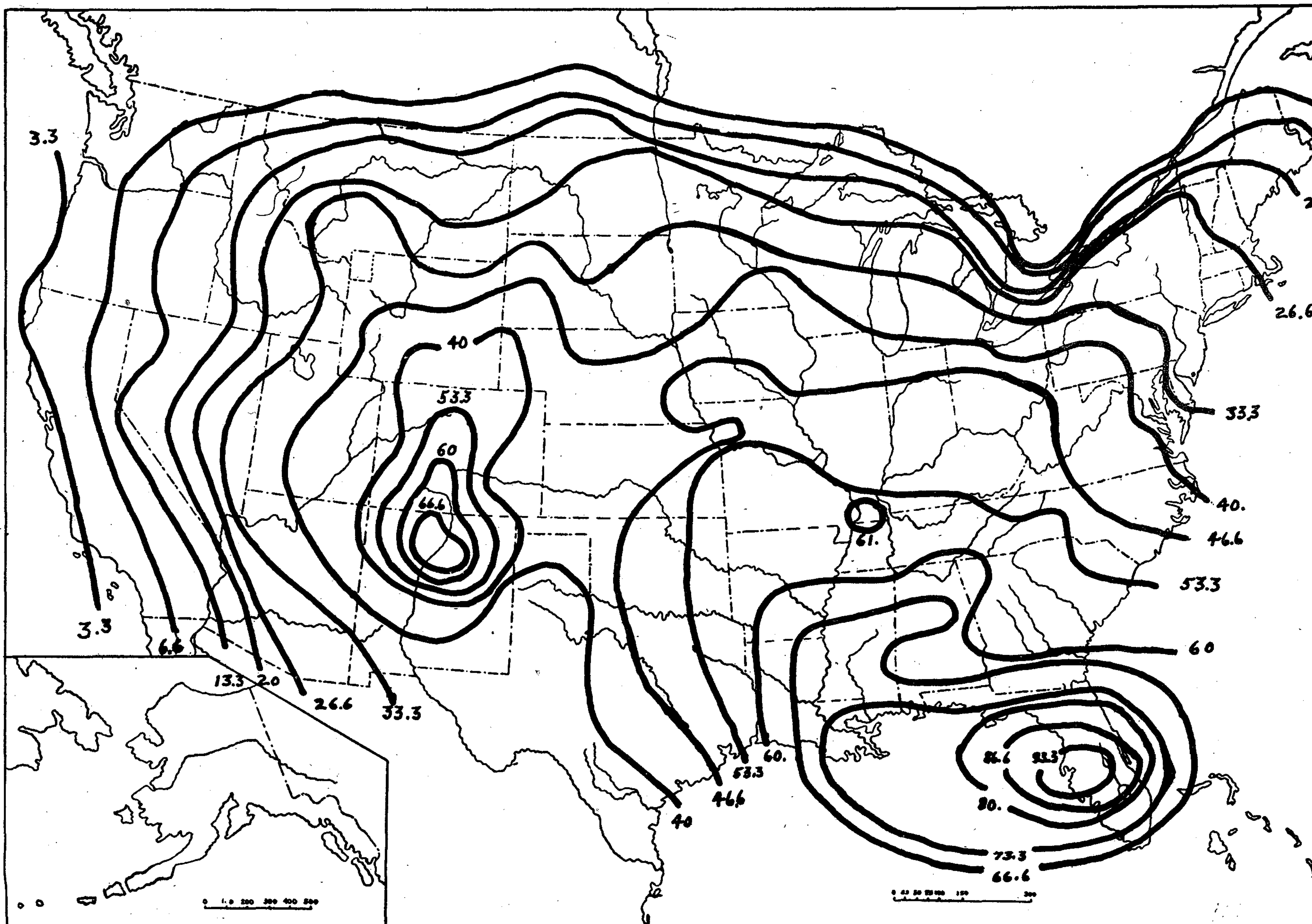
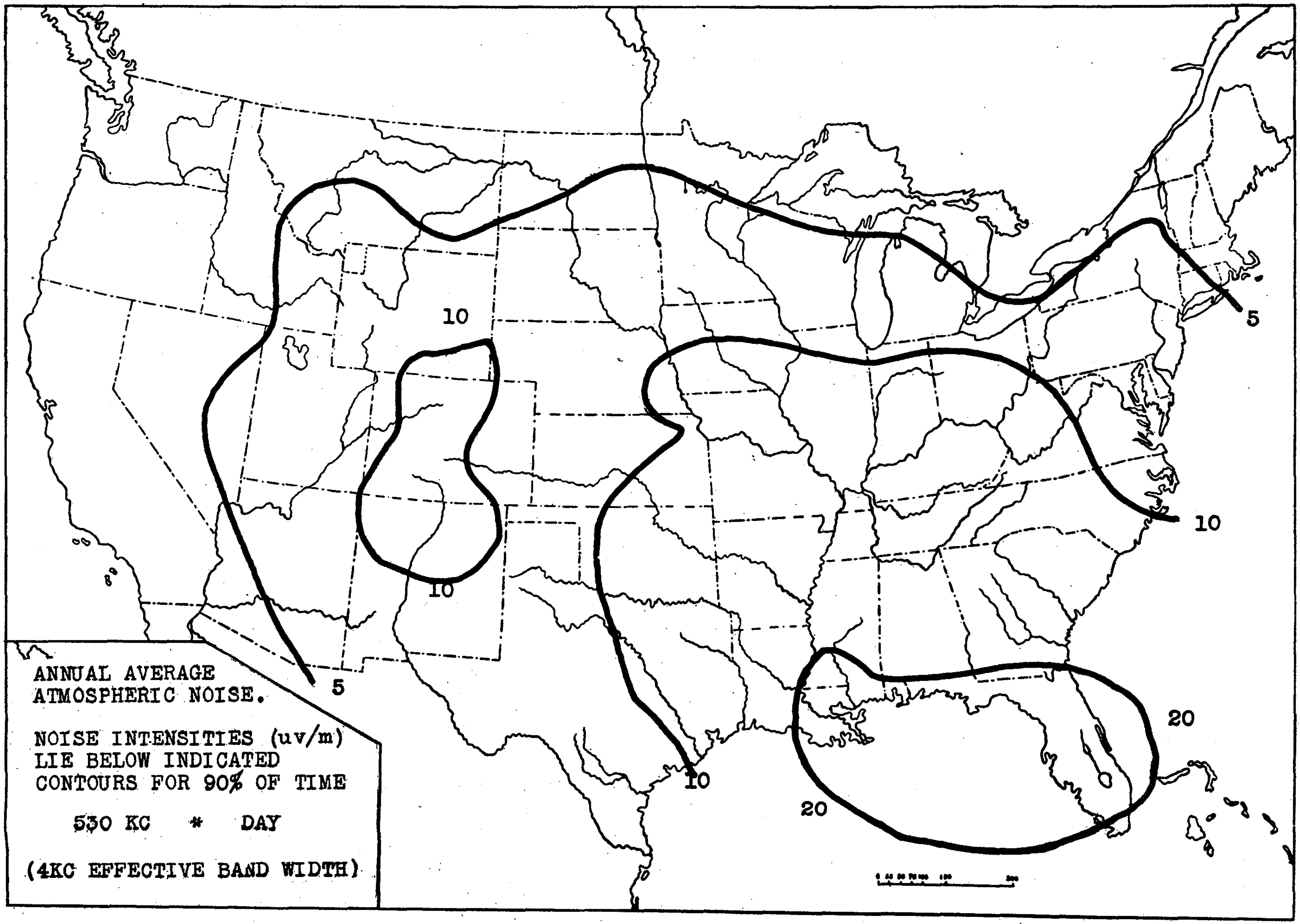


FIGURE 11

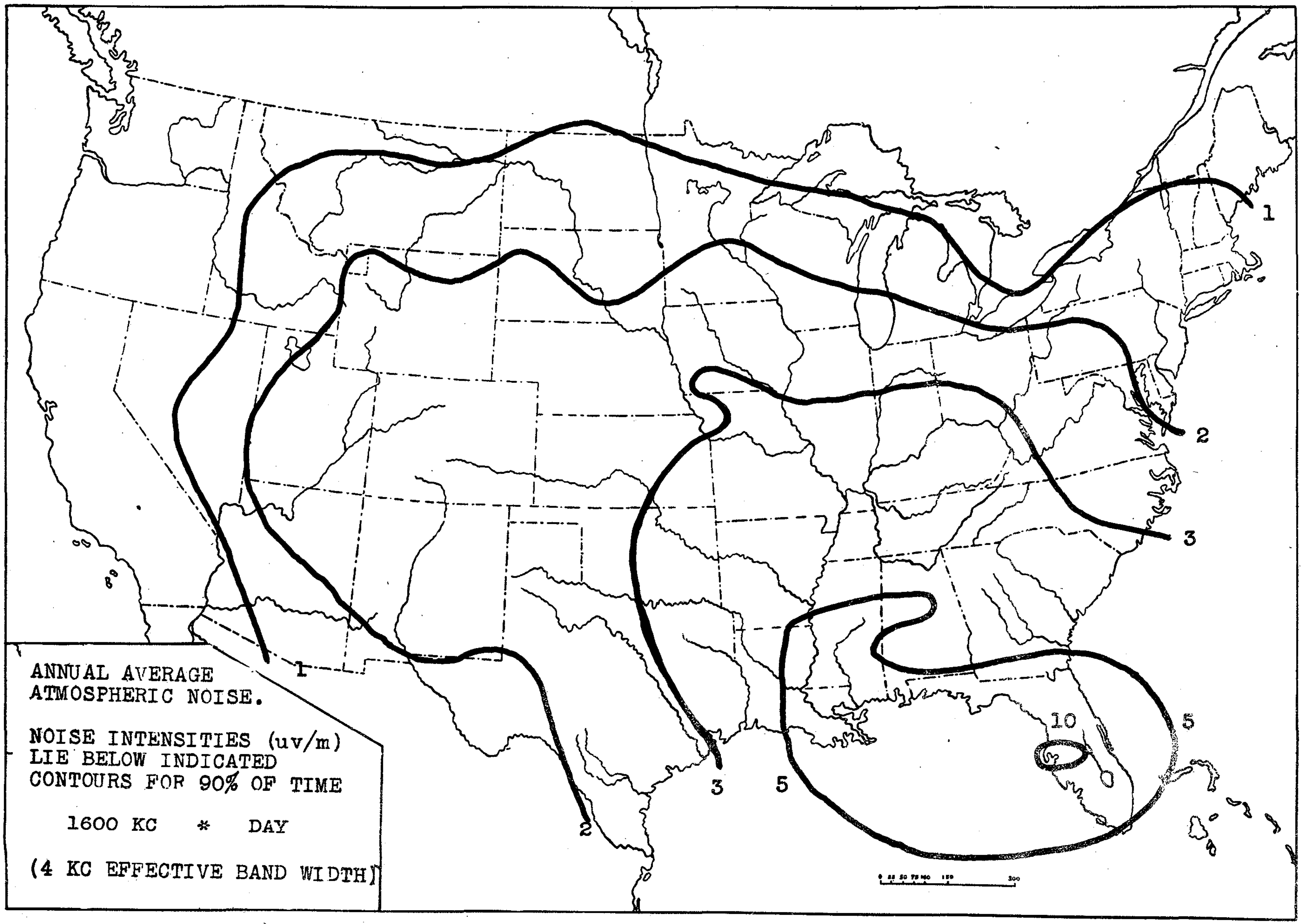
UNITED STATES

ANNUAL AVERAGE NUMBER OF THUNDERSTORM DAYS, 1904 - 1933.



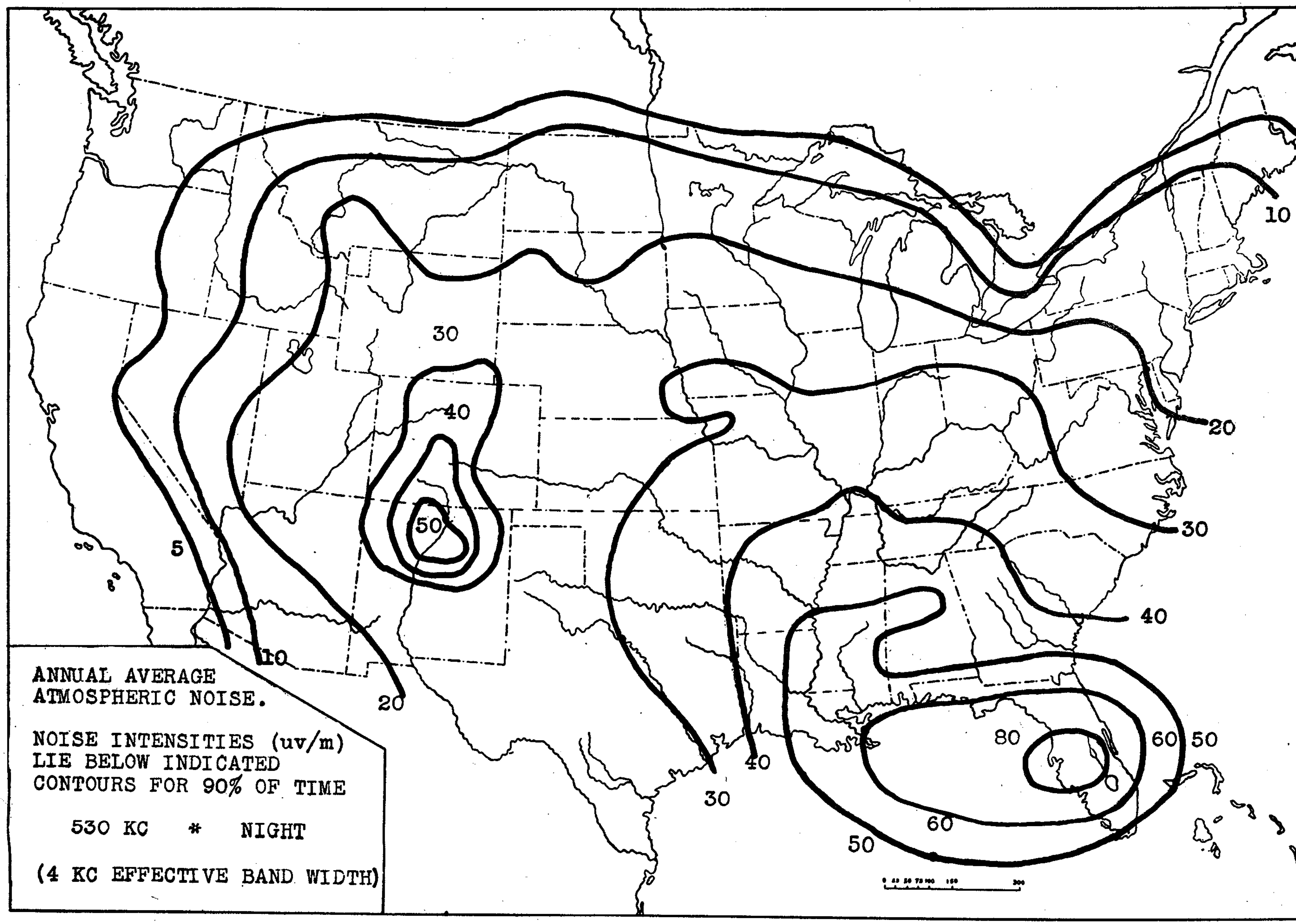
UNITED STATES

FIGURE 12



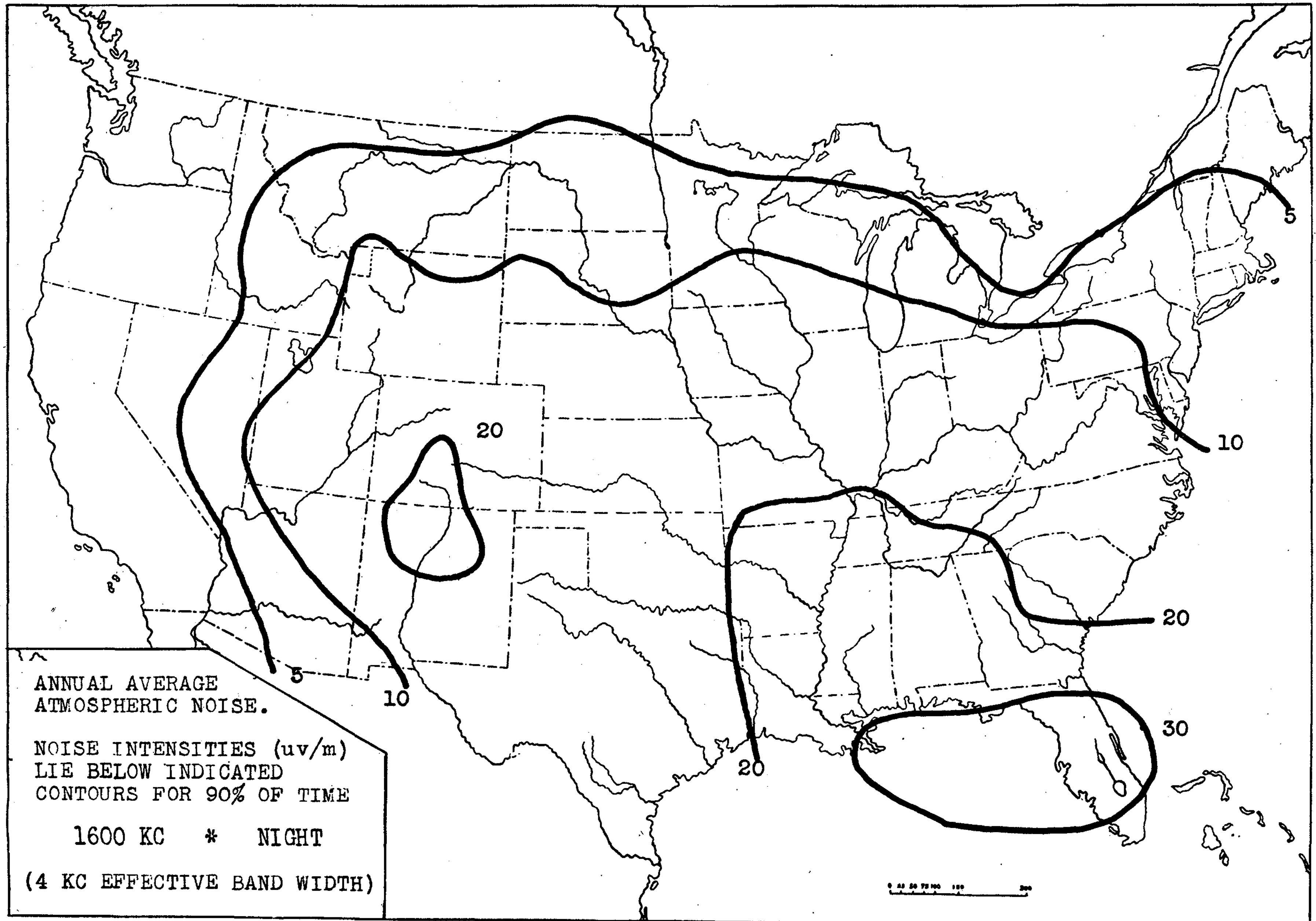
UNITED STATES

FIGURE 13



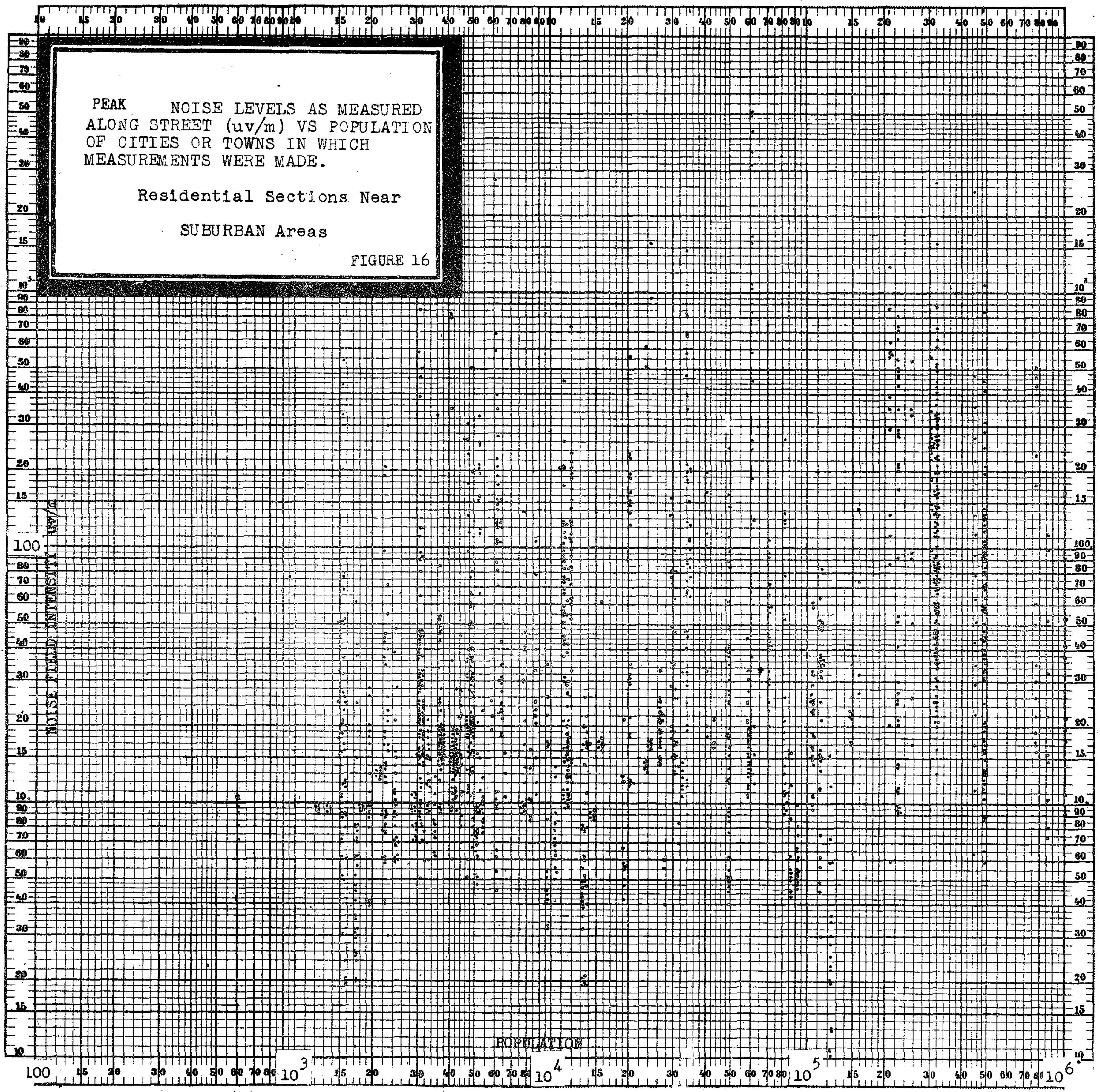
UNITED STATES

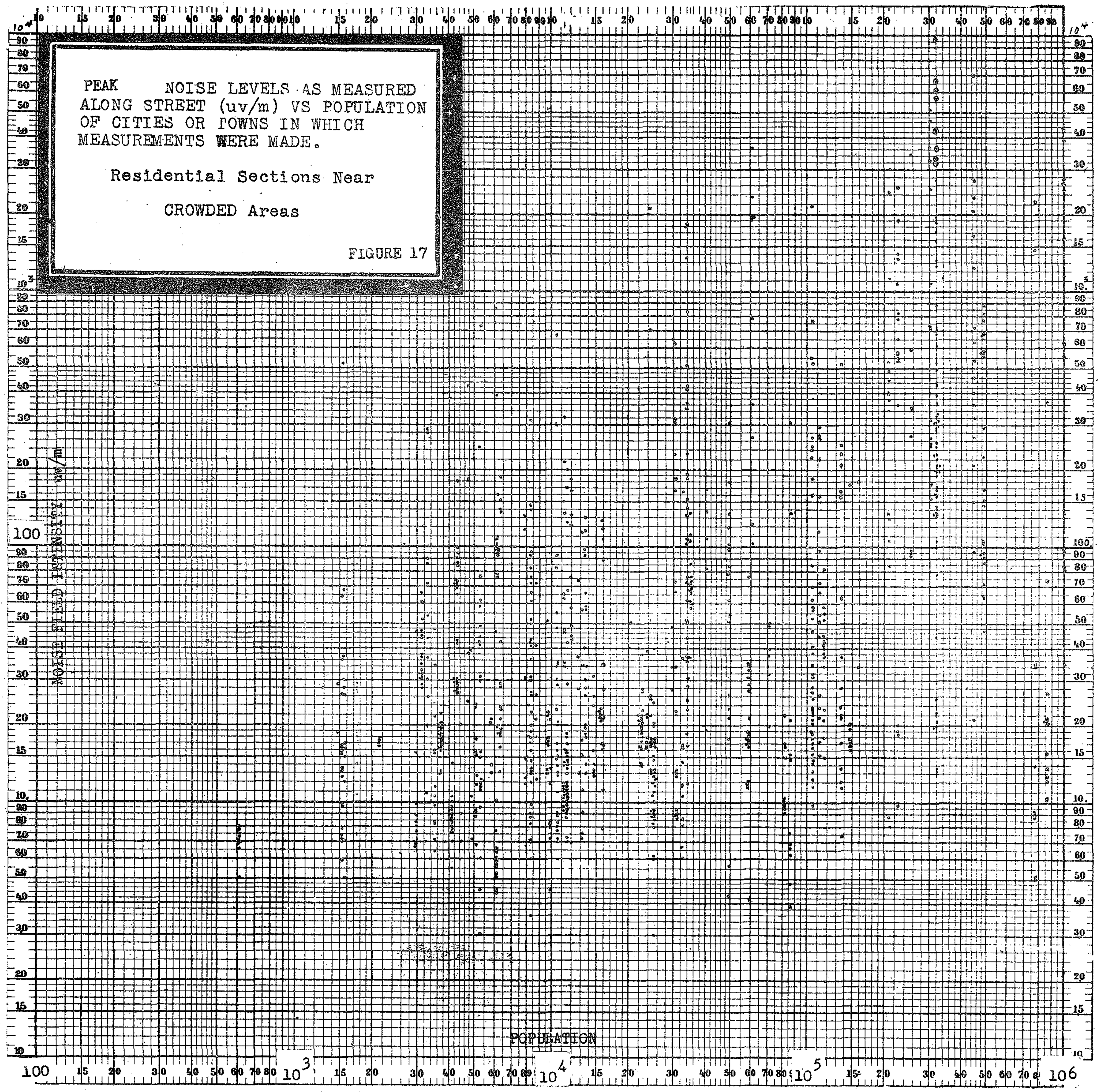
FIGURE 14

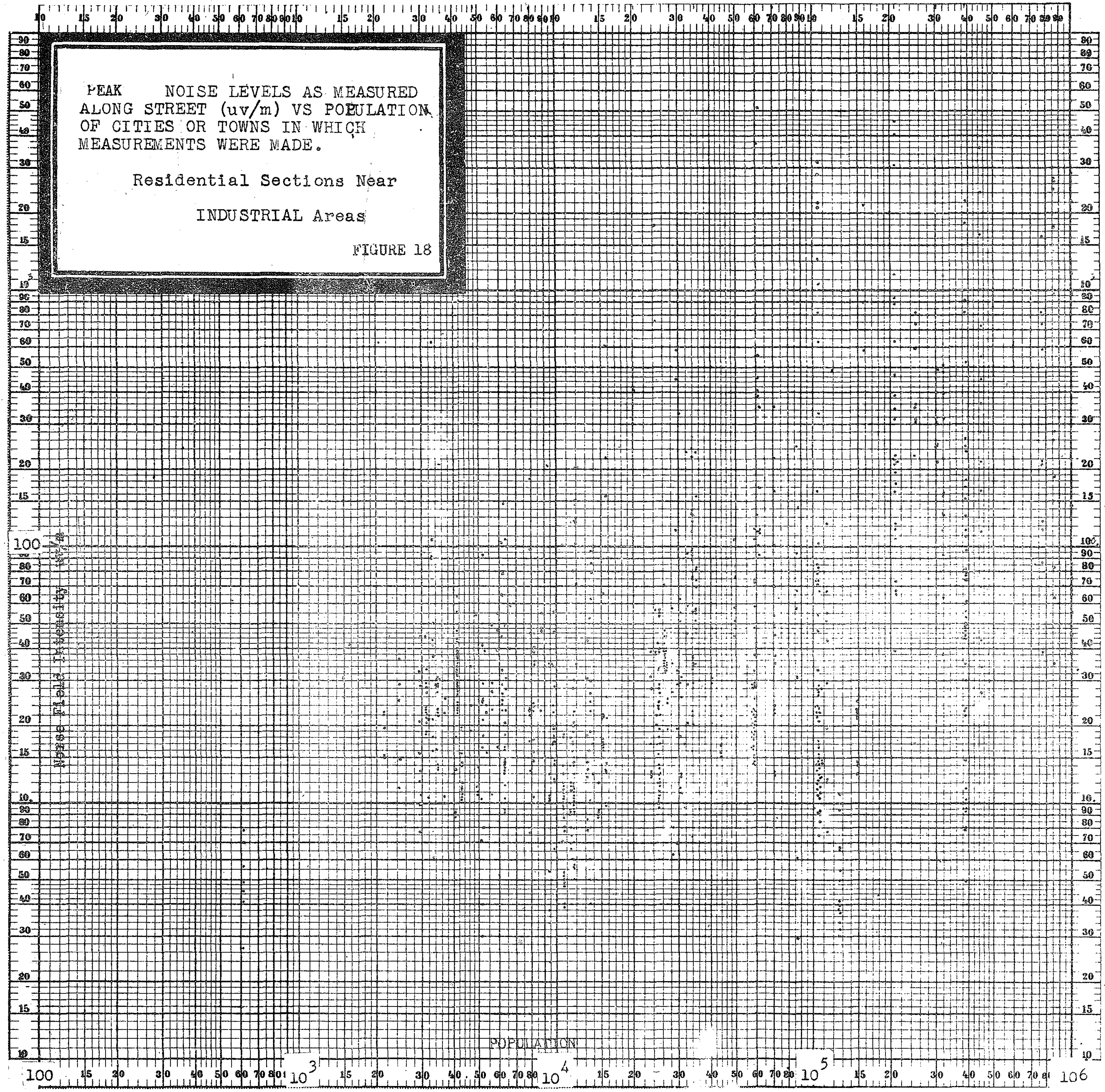


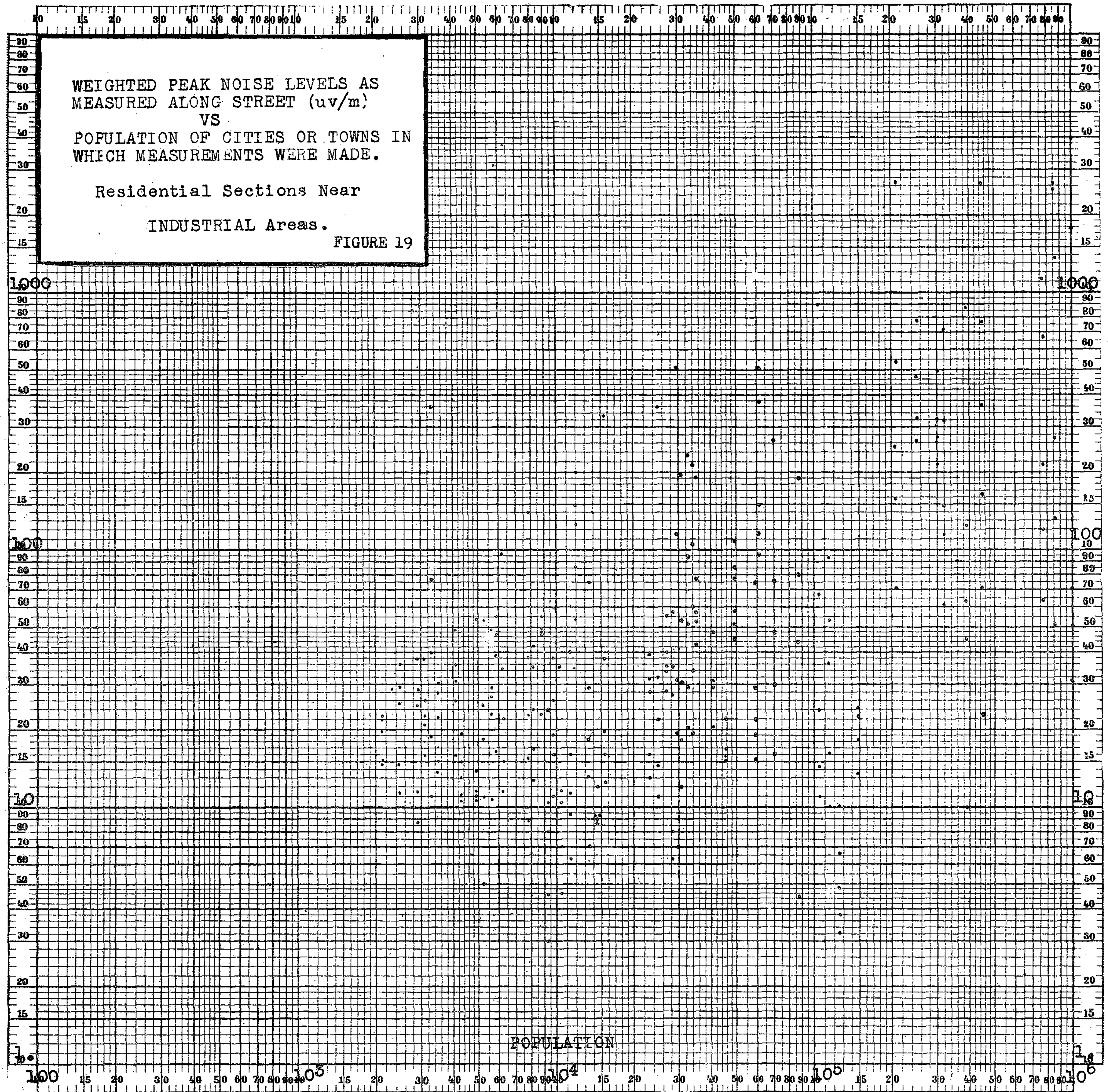
UNITED STATES

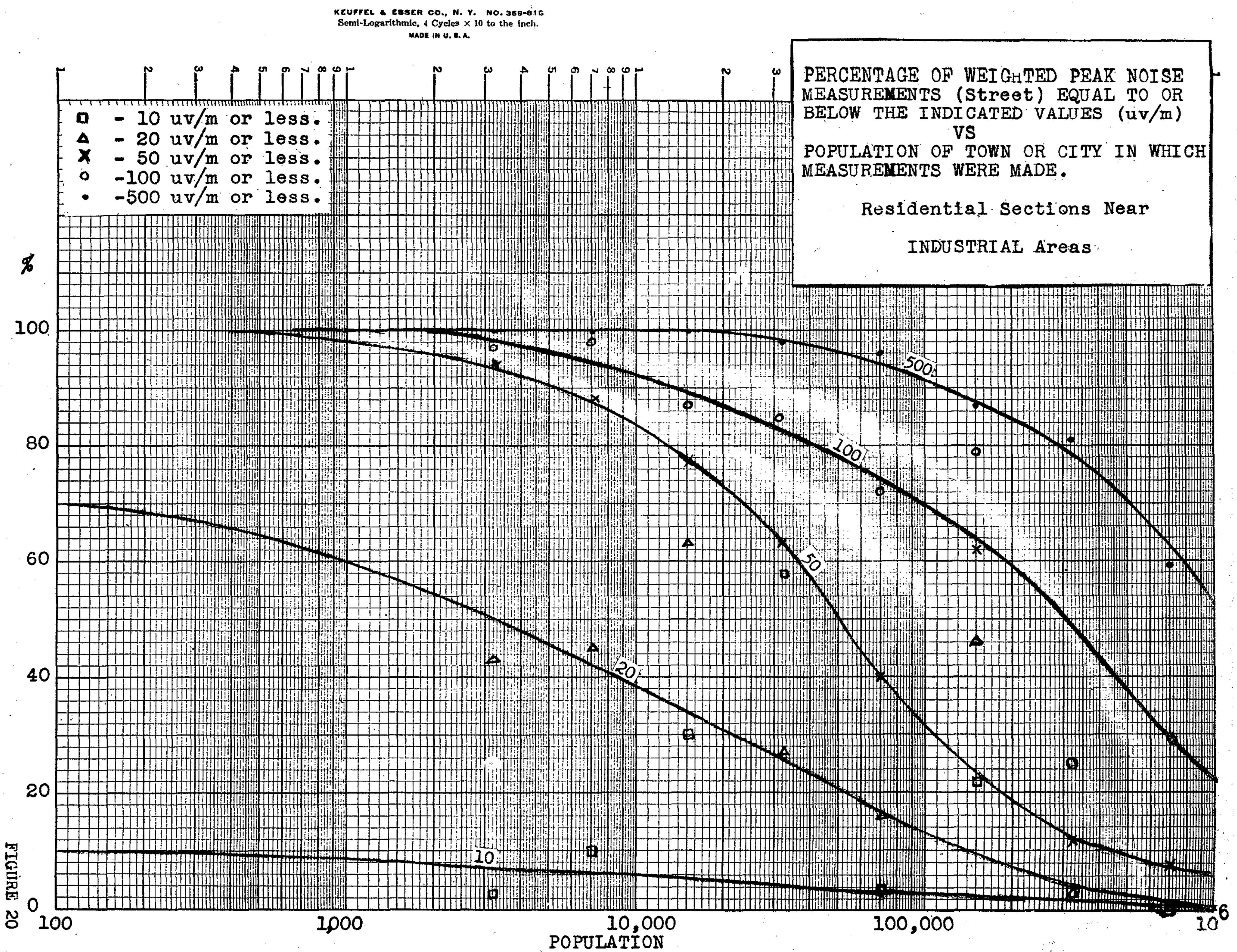
FIGURE 15

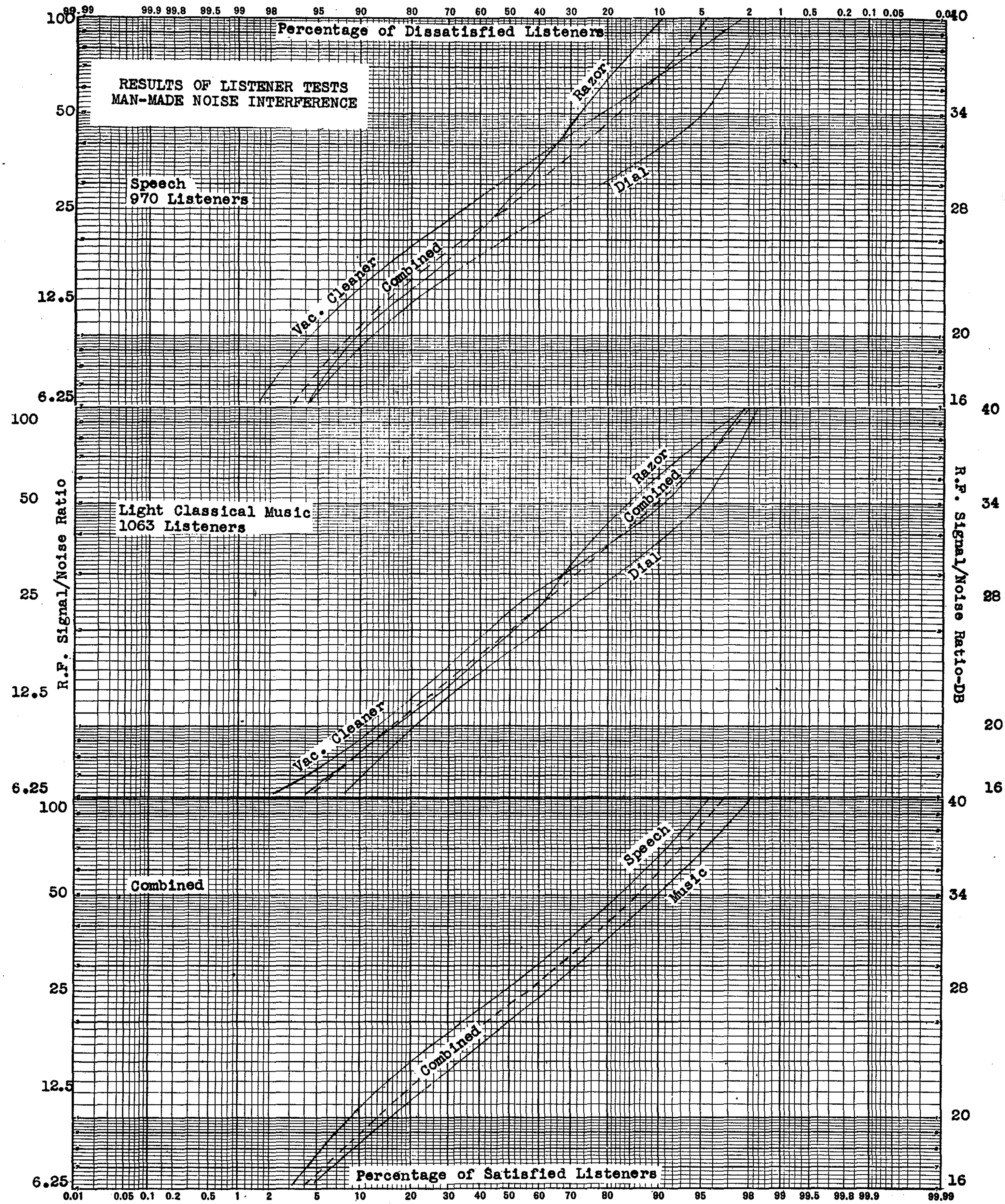

PEAK NOISE LEVELS AS MEASURED ALONG STREET (uv/m) VS POPULATION OF CITIES OR TOWNS IN WHICH MEASUREMENTS WERE MADE.
Residential Sections Near
SUBURBAN Areas
FIGURE 16
NOISE FIELD INTENSITY uv/m
POPULATION
100
10^3
10^4
10^5
10^6


PEAK NOISE LEVELS AS MEASURED ALONG STREET (uv/m) VS POPULATION OF CITIES OR TOWNS IN WHICH MEASUREMENTS WERE MADE.
Residential Sections Near
CROWDED Areas
FIGURE 17
NOISE FIELD INTENSITY uv/m
POPULATION
100
10^3
10^4
10^5
10^6


PEAK NOISE LEVELS AS MEASURED ALONG STREET (uv/m) VS POPULATION OF CITIES OR TOWNS IN WHICH MEASUREMENTS WERE MADE.
Residential Sections Near
INDUSTRIAL Areas
FIGURE 18
Noise Field Intensity uv/m
POPULATION
100
10^3
10^4
10^5
10^6


WEIGHTED PEAK NOISE LEVELS AS MEASURED ALONG STREET (uv/m)
VS
POPULATION OF CITIES OR TOWNS IN WHICH MEASUREMENTS WERE MADE.
Residential Sections Near
INDUSTRIAL Areas.
POPULATION
100
10^3
10^4
10^5
10^6
1000
100
10
1
FIGURE 19


KEUFFEL & ESSER CO., N. Y. NO. 359-81G
Semi-Logarithmic, 4 Cycles × 10 to the inch.
MADE IN U. S. A.
PERCENTAGE OF WEIGHTED PEAK NOISE MEASUREMENTS (Street) EQUAL TO OR BELOW THE INDICATED VALUES (uv/m)
VS
POPULATION OF TOWN OR CITY IN WHICH MEASUREMENTS WERE MADE.
Residential Sections Near
INDUSTRIAL Areas
- 10 uv/m or less.
- 20 uv/m or less.
- 50 uv/m or less.
-100 uv/m or less.
-500 uv/m or less.
%
100
80
60
40
20
0
100
1,000
10,000
100,000
10^6
POPULATION
500
100
50
20
10
FIGURE 20



Percentage of Dissatisfied Listeners
RESULTS OF LISTENER TESTS
MAN-MADE NOISE INTERFERENCE
Speech
970 Listeners
Razor
Dial
Combined
Vac. Cleaner
Light Classical Music
1063 Listeners
Razor
Combined
Dial
Vac. Cleaner
Combined
Speech
Music
Combined
Percentage of Satisfied Listeners
R.F. Signal/Noise Ratio
R.F. Signal/Noise Ratio-DB

FIGURE 21