BELL TELEPHONE LABORATORIES
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COVER SHEET FOR TECHNICAL MEMORANDUM

SUBJECT: Message Circuit Noise Objectives — Distribution Curves
of Bell System Values and Relation to British Post
Office Objectives — Files 36725-1 and 38925-28

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CASE FILE

DATE FILE

AREA CENTRAL FILES (4)

MM— 54-2433-3
DATE January 29, 1954
AUTHOR R. N. Hunter

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ABSTRACT

For the proposed transatlantic cable carrier system it is necessary to consider both Bell System and British Post Office noise objectives. The purpose of this memorandum is to show the relations between these values.

The Bell System and the Post Office values differ both in the noise units used and in the probabilities corresponding to the chosen objectives. In the design of Bell System carrier systems both rms and 0.01% maximum noise objectives have been considered, while the Post Office noise objective represents a value which should not be exceeded for more than 1% of the time. With respect to units the Bell System values are given in dba while the Post Office values are expressed in picawatts.

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Message Circuit Noise Objectives - Distribution Curves of Bell
System Values and Relation to British Post Office Objectives -
Files 36725-1 and 38925-28

MM-54-2433-3

January 29, 1954

MEMORANDUM

1. INTRODUCTION

The purpose of this memorandum is to compare the
message circuit noise objectives used in the design of Bell
System carrier systems with the British Post Office objectives.
The present need for this comparison arises in connection with
the proposed transatlantic cable since consideration must be
given to both Post Office and Bell System requirements.

It has been customary in the Bell System design of
carrier systems to consider both rms and maximum noise objec-
tives, the maximum being taken as a value which should not be
exceeded for more than 0.01% of the busiest hour. The Post
Office has, however, used only one noise objective, this being
defined as a value which should not be exceeded for more than
1% of the busiest hour. For comparison with this Post Office
value it is therefore necessary to obtain a Bell System 1%
objective which is consistent with the usual rms and 0.01%
objectives.

The Post Office noise values are expressed in picawatts
while the Bell System values are given in dba. Relations between
these two types of units are determined and a comparison is made
between the relative severity of the Post Office and Bell System
1% objectives.

2. SUMMARY OF RESULTS

2.1 Distribution Curves of Bell System Noise Objectives

Two different distributions for message circuit noise
objectives, referred to here as the Barstow and the Morris
curves, are discussed in Section 3. The second of these two
will be used for obtaining a 1% noise objective.

If it is assumed that the Barstow distribution is
representative of noise conditions in the present toll plant,
it may be said that the use of the Morris distribution
for engineering purposes constitutes a slight lowering of noise
standards for economic reasons.

2.2 Bell System 1% Noise Objective

The following Table 2-1 shows the proposed 4000-mile 1% noise objective, together with the rms and the 0.01% maximum objectives which have been used in Bell System design work on carrier systems. These values are those shown by the Morris curve.

TABLE 2-1

BELL SYSTEM 4000-MILE MESSAGE
CIRCUIT NOISE OBJECTIVES

| | Noise Objectives in dba | | |
Transmission Level Point	RMS	1.0% Max.	0.01% Max.
-9 db	29	35.6	40
0	38	44.6	49

It will be seen that the 1% objective is 4.4 db less than the 0.01% value and 6.6 db greater than the rms.

As noted below this 1% value is more lenient than the Post Office 1% objective for the same circuit length by 6.5 db.

2.3 Application of Objectives

It should be pointed out that the rms objective as used in the Bell System and the 1% objective as used by the Post Office apply to the over-all noise in a given circuit. The Bell System 0.01% maximum objective has, however, usually been applied to a single type of circuit noise or to a single link in a long circuit. Thus, for the over-all circuit, the probability that this objective will be exceeded may be several times 0.01%.

2.4 Relation Between Post Office and Bell System Noise Objectives

As discussed in Section 6, the Post Office message circuit noise values are given in terms of picawatts where one weighted picawatt (p.w.) corresponds to -6 dba for F1A weighting.

The Post Office 1% objective is 10,000 p.w. in 2500 kilometers while the Bell System 1% value (from Table 2-1) is 44.6 dba in 4000 miles. As may be seen from Table 6-1, the

Post Office 1% objective, for the same over-all circuit length, is more severe than the Bell System value by 6.5 db.

3. NOISE OBJECTIVES BASED ON DISTRIBUTIONS PROPOSED BY BARSTOW AND MORRIS

3.1 General

Two somewhat different distributions of message circuit noise, referred to here as the Barstow and the Morris distributions are, shown on attached drawing ES-931620.

The rms and 0.01 maximum values represented by the Morris curve have been used in the design of Type L carrier and TD-2 microwave systems. The Barstow curve represents a sufficient, rather than a necessary, condition. In practice, the application of the rms and 0.01% values of the Morris curve on a 4000-mile basis to systems with a large number of channels has not been the cause of any known noise difficulties. Thus the Morris curve will be used here for determining a 1% noise objective for the transatlantic carrier system.

3.2 Barstow Curve

The Barstow curve shows a cumulative distribution of message circuit noise taken from drawing ES-841436 attached to a memorandum by J. M. Barstow.*

This curve was based on a considerable number of noise measurements made by the Long Lines Department on toll circuits. It has an rms value of 26.1 dba and a 0.01% maximum value of 40 dba, both values being expressed at the -9 db transmission level.**

The Barstow curve was obtained by combining a steady noise of 20 dba with the distribution based on the field measurements. The actual test data showed values below 20 dba but, because of the effect of local room and circuit noise, there appeared to be no advantage in showing a distribution going down to very low values.

The test data were obtained on circuits ranging in length from 400 to 1800 miles. It is noted in the memorandum, however, that the results showed no definite tendency for greater noise values in the longer circuits.

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*MM-40-3400-32, April 17, 1940, Tentative Message Circuit Noise Objectives for Toll Plant Engineering - Case 36725-1.
**Actually, the values on this and the Morris distribution curve are given in db above reference noise (dbRN) with the older "144 weighting", but for present purposes it is assumed that the noise in dba (F1A weighting) would be numerically equal to the older value.

3.3 Morris Curve

The Morris curve is a cumulative distribution of message circuit noise taken from sheet 3 of drawing ES-819055 attached to a memorandum by L. H. Morris.*

It is stated in the Morris memorandum that this curve gives an example of a satisfactory distribution when the 4000-mile objectives are 29 dbRN for the rms and 40 dbRN for the 0.01% maximum. (These are the objectives given in the older Dixon memorandum referred to below.) The Morris curve has the same 0.01% maximum (40 dba) as the Barstow distribution but the rms is 29 dba which is more lenient than the Barstow value by 2.9 db. The rms and the 0.01% maximum values for the Morris distribution have been used in the design of the L carrier systems, the TD-2 microwave system, and the proposed transatlantic cable system.

Other distributions could of course be drawn with an rms of 29 dba and a 0.01% maximum of 40 dba. It seems unlikely however, that the 1% value obtained from such curves would differ much from the value of 35.6 dba shown by the Morris curve.

3.4 Dixon Objectives

The use of a 29-dba objective (expressed either in dbRN or in the earlier form of 200 noise units) antedated the Morris memorandum by many years. However, the use of this value as an rms may have first been covered in a memorandum by J. T. Dixon.**

In the Dixon memorandum, the over-all busy hour noise objectives for 4,000-mile J, K or L carrier systems were given as 29 dbRN for the rms and 40 dbRN for the 0.01% maximum, both values being those measured at the -9 db transmission level.

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*MM-47-3500-48, May 16, 1947, Coaxial Repeater Development - 7-12 Mc Repeater Systems - Telephone Message Cross-Modulation and Noise Requirements for Broadband Carrier Systems - Case 35552-12X.
**Memorandum entitled Carrier Telephone Development - Transmission Objectives for Carrier Telephone Systems - File 36674-1 - February 4, 1938.

The suggested division of the 29 dbRN rms objective between the principal noise components was as shown in Table 3-1.

TABLE 3-1

RMS NOISE OBJECTIVES
FOR 4000-MILE CARRIER SYSTEMS
AS PROPOSED BY J. T. DIXON

Noise Source	dbRN at -9 db Level		
	Type J	Type K	Type L
Terminals	20	20	23
Line and repeaters	26	24	25
Repeater modulation	22	24	24
Unintelligible line crosstalk and babble	21	23	15
Total	29	29	29

It was stated in the memorandum that the maximum objective of 40 dbRN should not be exceeded by the noise from any one of the four sources given above for more than 0.01% of the time in any one hour.

3.5 Comparison of Barstow and Morris Distributions

A comparison of various points on the Barstow and Morris distributions is given in the following Table 3-2. Except for the 0.01% point it will be assumed that these values apply to the over-all noise in a 4000-mile circuit. As discussed in Section 4.2 below, the 0.01% value is usually applied to each of several components of the total noise.

TABLE 3-2

COMPARISON OF VARIOUS POINTS ON THE
BARSTOW AND MORRIS NOISE DISTRIBUTIONS

Point on Distribution Curve	Noise in dba at -9 db Level		Difference in db
	Barstow Curve	Morris Curve	
99%	20.2	24.0	3.8
50	23.9	28.4	4.4
rms	26.1 (28)*	29.0 (42)*	2.9
10	29.0	32.4	3.3
1	33.6	35.6	2.0
0.1	37.1	38.0	1.0
0.01	40.0	40.0	0

*The values in parentheses represent the per cent point of the distribution at which the rms values occur.

4. USE OF RMS AND 0.01% MAXIMUM OBJECTIVES IN BELL SYSTEM

4.1 RMS Objective

The rms noise objective of 29 dba at the -9 db level (or 38 dba at zero level) is commonly taken for design purposes as applying to the over-all busy hour noise in the worst channel of the system.

4.2 Maximum Objective

As already indicated, it was proposed in the Dixon memorandum of 1938 that the 40-dba 0.01% maximum objective be applied to each of four sources of noise. Thus if in any particular case this objective were just met for each type of noise, the probability of exceeding 40 dba would be 0.04%.

This four fold increase in probability is actually not **very** important since the Morris distribution shows that the difference between the 0.01% and the 0.04% values is about 1.1 db. Thus, if the 40 dba objective were assigned to the total noise resulting from the four equal sources, the requirement on each source would be made more severe by only 1.1 db.

In a similar manner it has been assumed in the case of the transatlantic cable circuit that all of the 0.01% maximum objective may be applied to any type of intermodulation noise in the submarine cable link between Newfoundland and Scotland. Similar maximum objectives would be applied to other portions of an over-all circuit including the transatlantic cable.

5. OTHER INFORMATION ON BELL SYSTEM NOISE OBJECTIVES

A detailed review of the available information on the noise objectives which have been used or proposed for message channels on carrier systems was covered in MM-52-3800-31.*

It is of interest to note that in the information transmitted to the field (in the form of Bell System Practices for the J and K carrier systems) the term rms has not been used and no reference has been made to a 0.01% maximum objective. Instead, the value of 29 dba at the -9 level (which is the 42% value for the Morris distribution and the 10% value for the Barstow distribution) is given as an objective which should be exceeded on only a small number of telephone connections.

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*Review of Message Circuit Noise Objectives for Carrier Systems - File 36725-1, July 24, 1952 by R. N. Hunter.

6. RELATION BETWEEN POST OFFICE AND BELL SYSTEM NOISE OBJECTIVES

The Post Office objective for message circuit noise in carrier channels is 10,000 picawatts (abbreviated here as p.w.) at the 0-db level. This objective applies to a 2500-kilometer system; it represents a value which should not be exceeded for more than 1% of the busiest hour.

The relation between weighted picawatts and the corresponding Bell System values in dba was discussed in a memorandum by R. J. Halsey of the British Post Office.* In obtaining this relation we note first that the shape of the Post Office (and CCIF) message weighting curve is the same as the Bell System F1A weighting shown on attached Table I, with the exception that the reference frequency is 1000 cps in the Bell System and 800 cps in the CCIF case.

For the F1A weighting a power of 10^{-12} watt (or -90 dbm) at a frequency of 1000 cps corresponds to a noise value of -5 dba. At 800 cps however the weighting is about 1 db ** and hence 10^{-12} watt at this frequency corresponds to -6 dba.

In the CCIF or British Post Office case, a power of 10^{-12} watt at 800 cps corresponds to one picawatt. Thus one p.w. at 800 cps (or 1 weighted p.w. at any frequency) corresponds to -6 dba, or zero dba corresponds to 3.98 p.w. (approximately 4 p.w.) Since the shapes of the Post Office and Bell System weighting curves are the same, these relations between p.w. and dba will hold for any type of noise provided the dynamic characteristics of the noise meters are the same.

The following Table 6-1 shows the relations between the Bell System and the Post Office noise objectives both for the Bell System "maximum" length of 4000 miles and the Post Office or CCIF "maximum" length of 2500 kilometers. The table applies mainly to the 1% objectives, the Bell System value being that obtained from the Morris distribution (Tables 2-1 and 3-2). The Bell System rms objectives are also shown for comparison.

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*Memorandum entitled Transatlantic Telephone Cable Circuit - Allowable Levels of Intermodulation, December 11, 1953. (This memorandum was attached to minutes of December 10 meeting of Bell System and Post Office engineers).
**Actually the weighting is 0.9 db but the CCIF has used 1 db as an approximate figure.

TABLE 6-1

RELATION BETWEEN POST OFFICE AND BELL SYSTEM
MESSAGE CIRCUIT NOISE OBJECTIVES

| Overall Length of Circuit | | | Zero-Level Noise Objectives | | |
Miles	Km	Noise	Bell System In dba	Converted to p.w.	Post Office In p.w.
4000	6440	rms	38	25,200	-
"	"	1%	44.6	115,000	25,800
1550	2500	rms	33.9	9,780	-
"	"	1%	40.5	44,700	10,000

A comparism between the two sets of 1% values shows that for the same over-all circuit length the Post Office objectives are more severe than those used in the Bell System by 6.5 db.

R. N. HUNTER

2445-RNH-FW

Attached
Table I
Drawing ES-931620

TABLE I

F1A MESSAGE CIRCUIT NOISE WEIGHTING*

Frequency in cps	Weighting in db Referred to 1000 cps
180	-25.0
240	-16.0
300	-11.5
360	- 8.6
420	- 6.5
480	- 4.9
540	- 3.8
660	- 2.1
720	- 1.5
780	- 1.0
900	- 0.4
1000	0
1020	- 0.05
1060	- 0.2
1080	- 0.4
1140	- 0.7
1260	- 1.3
1380	- 1.8
1440	- 2.0
1500	- 2.3
1620	- 2.7
1740	- 3.2
1800	- 3.4
1860	- 3.6
1980	- 3.9
2100	- 4.2
2160	- 4.3
2340	- 4.8
2520	- 5.3
2700	- 5.8
2880	- 6.3
3000	- 6.6
3500	- 9.5
4000	-16.0
5000	-37.0

*Engineering Report No. 45, Joint D. & R. Subcomm.,
Edison Elec. Institute & Bell System

ES-931620

QNH 12-17-53

Message Circuit Noise Objectives

A — Barstow curve from ES-841436
(designated as "proposed design
objective for distribution of noise
on toll circuits")

B — Morris curve from ES-819055
(designated as "an acceptable
distribution curve for busy-hour
noise")
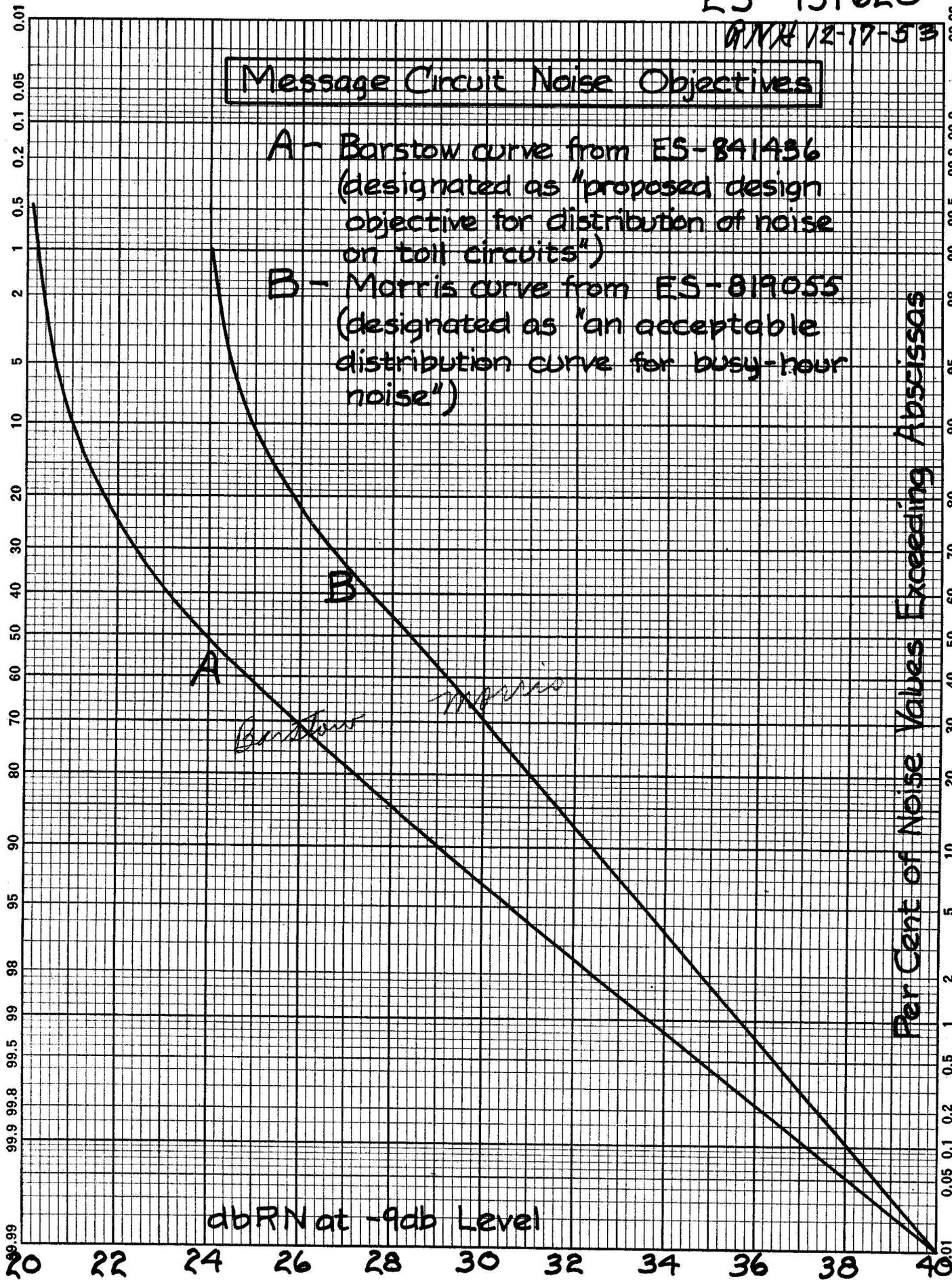
Per Cent of Noise Values Exceeding Abscissas

dbRN at -9db Level