CROSSTALK - GENERAL CONSIDERATIONS

Contents

1.0 GENERAL

This section refers to the crosstalk considerations involved in the design, construction and maintenance of the exchange cable plant. As will be noted from the succeeding paragraphs no serious crosstalk reactions may in general be expected in the exchange plant assuming the use of present standard station apparatus and exchange cable facilities. Where somewhat special conditions are involved crosstalk of considerable magnitude may result and in such cases the information given in this section should be helpful. Methods are given for estimating the total crosstalk coupling between message circuits under varying conditions. Also, remedial measures are pointed out which may be followed where crosstalk mitigation is necessary. Only brief references are made to those considerations which are covered elsewhere in more detail.

Inasmuch as experience has indicated few complaints as a result of excess babble in the exchange plant, and calculations indicate that this factor should ordinarily be unimportant, the scope of this section has been confined to the strictly crosstalk phases, that is, those items that must be taken into account when considering the possibilities of hearing intelligible crosstalk.

2.0 CROSSTALK LIMITS

In establishing crosstalk standards for the exchange plant it is necessary to use two values, one for message circuits and one for program circuits. Moreover as will be noted from the following paragraphs somewhat different criteria are used for judging the quality of performance of the two types of service.

2.1 Message Circuits

In arriving at a suitable performance criterion for message facilities the reactions of a large number of observers listening to various values of crosstalk coupling under specified conditions of talker volume, receiving efficiency and room and circuit noise were determined. Such data indicated the per cent. of observers to whom crosstalk is intelligible for various values of crosstalk coupling between the disturbing and disturbed circuits and certain values of room and circuit noise present in the receiver on the disturbed circuit, assuming certain average values of talker volume and receiving efficiency.

Considerable data have been obtained as a result of volume measurements made of talker volume at both local and toll central offices. Estimates have also been made of the variation of receiving efficiency. The talker volume and receiving efficiency data are discussed in considerable detail in Part 3.5 of this Section.

Data have also been obtained on the distribution of near-end crosstalk coupling in the exchange cable plant for various types of facilities. While it is possible for far-end crosstalk to result in exchange plant, experience indicates that usually near-end crosstalk is controlling and for this reason crosstalk coupling data are only given for near-end crosstalk. A detailed discussion of the crosstalk coupling data is given in Part 3 of this Section.

Data are also available which indicate the variation of loop losses, both transmitting and receiving. By properly combining the above data together with data which takes account of the "busy-ness" factor of the particular facilities being considered, crosstalk performance criteria have been determined for both trunk and subscriber plant. As a matter of convenience they have been set up on the basis of crosstalk coupling and for further simplification average values are given.

With the values of crosstalk coupling given below it is believed that there will not be more than a one per cent. chance of a random observer overhearing "intelligible" crosstalk during a single short interval. As used in this practice "intelligible" crosstalk is defined as the overhearing of four consecutive words or the gist of the conversation during an interval of approximately seven seconds. A time analysis of telephone conversations has indicated that seven seconds represents approximately the minimum interval during which there is an appreciable chance of any observer overhearing sufficient words or phrases to get the gist of the conversation.

The values assume that the source of the crosstalk occurs in only one type of plant, that is, the subscriber loop or the trunk plant and no allowance has been made for crosstalk in the toll plant. This appears to be a reasonable assumption since the chance of two circuits being intimately associated with one another simultaneously in more than one type of plant is extremely remote.

Studies have indicated that the hand set consisting of the 395 transmitter and the 557 receiver is better from a crosstalk standpoint than the desk stand. In this connection preliminary information on the new hand set transmitter indicates that when used with the 557 receiver it would be expected to have about the same reaction on crosstalk as the desk stand. This latter matter, however, is being studied further. Since both the hand sets and desk stands are used throughout the plant and also in view of the preliminary information on the new hand set transmitter it is believed desirable in general for the present to use the limit for desk stand sets as a basis for crosstalk considerations.

2.11 Trunk Circuits

The following are the values of average crosstalk coupling at the terminals of the trunks based on the use of desk stand instruments corresponding to a one per cent. chance of overhearing "intelligible" crosstalk. From such data as have already been obtained it is thought that there will be little difficulty in meeting these values where standard practices are followed regarding the use of the various types of cable facilities and station apparatus.

Note: As a matter of interest the corresponding values assuming the use of hand sets (395 Transmitter and 557 Receiver) may be obtained by subtracting 4 db from the above values for sidetone hand sets and 7 db for anti-sidetone hand sets.

The values of crosstalk coupling assume a room noise condition which is the

Type of Subscriber Set	Type of Cable	Average Crosstalk Coupling - db: Direct and Tandem Trunks	Average Crosstalk Coupling - db: Toll Board Trunks
Desk Stand Sidetone	Staggered Twist	74	76
Desk Stand Sidetone	Non-Staggered Twist	88	90
Desk Stand Anti-Sidetone	Staggered Twist	80	82
Desk Stand Anti-Sidetone	Non-Staggered Twist	93	95

approximate equivalent of the typical room noise condition of Drawing 909-2509 which is attached to Section AB43.075 of Bell System Practices. Room noise conditions may be encountered which are different from the typical room noise condition and the effect of a higher value of room noise than the typical condition would be expected to permit of a larger magnitude of average crosstalk coupling, while the effect of a lower value of room noise would act to restrict the crosstalk coupling values to a lower magnitude. This effect is being studied further but in the meantime the effects of higher or lower room noise on crosstalk may be roughly approximated by using the room noise impairments given on Drawing 909-2509 bearing in mind that with each additional db of noise impairment about 1 db more crosstalk coupling may be allowed. The crosstalk coupling values given above assume 21 db or approximately 80 units of line noise measured at the input of the listener's subscriber set with a 1-A Noise Amplifier. It will be noted that the values vary depending upon the type of cable used. The difference between the values for the staggered and non-staggered twist cable takes account of the higher pair to pair capacitance unbalances which are ordinarily present in non-staggered twist cable.

Where it is desired to determine the effect on the crosstalk values of varying the per cent. chance of hearing intelligible crosstalk reference should be made to Drawings 611-187 and 611-188 attached.

2.12 Subscriber Loops

The following are the values of average crosstalk coupling corresponding to a one per cent. chance of overhearing "intelligible" crosstalk. Substantially better performance can ordinarily be expected.

Note: As a matter of interest the corresponding values for hand sets (395 Transmitter and 557 Receiver) may be obtained by subtracting 2 db for sidetone hand sets on staggered twist cable. For non-staggered twist cable 3 db should be subtracted. In the case of anti-sidetone hand sets 6 db should be subtracted for staggered twist cable or for non-staggered twist cable.

The values of crosstalk coupling assume talking volumes and receiving efficiencies equal to those of a zero loop equipped with a 323-144-46 set. The values also assume a condition of room noise which is the approximate equivalent of the typical room noise condition indicated on Drawing 909-2509. Where other values of room noise are encountered the effect on crosstalk may be roughly approximated by using the room noise impairments given on this same drawing. The line noise is assumed to be 21 db or approximately 80 units measured at the input to the subscriber set with a 1-A Noise Amplifier. It will be noted that another variable is introduced in connection with the crosstalk values, namely the type of area under consideration, that is, whether business, combination business and residential or residential which affects the rate of using the telephone and therefore the chance of overhearing intelligible crosstalk in a particular cable. For this purpose a business area is considered as one in which about 75 per cent. or more of the lines are business lines. Likewise, in a residential area it is assumed about 75 per cent. or more of the lines are residential lines. The remaining offices would be classified as combination business and residential.

Where it is desired to determine the effect on the crosstalk values of varying the per cent. chance of hearing intelligible crosstalk reference should be made to Drawings 611-193, 611-194 and 611-195 attached.

2.2 Program Circuits

Where plant conditions indicate the desirability of a crosstalk check before pairs are assigned for program purposes, experience indicates that this check should preferably be carried out by making selective crosstalk coupling measurements. Accordingly values are given below as representing the measured maximum values of crosstalk coupling which should ordinarily be permitted keeping in mind the necessity of guarding against the broadcasting of intelligible crosstalk. The values assume that the crosstalk coupling is measured on the bare cable pairs with a 14-A, 15-A or 16-A oscillator or the 20-C test set as the source of tone. No allowance is included for crosstalk from the toll plant since there is little chance for crosstalk from the same source simultaneously in both the local and toll plant.

Type of Subscriber Set	Type of Cable	Average Crosstalk Coupling - db: Business Areas	Business & Residential Areas	Residential Areas
Desk Stand Sidetone	Staggered Twist	73	72	71
Desk Stand Sidetone	Non-Staggered Twist	86	84	83
Desk Stand Anti-Sidetone	Staggered Twist	79	78	77
Desk Stand Anti-Sidetone	Non-Staggered Twist	92	91	90

PROGRAM CIRCUITS - MEASURED CROSSTALK COUPLING

Type of Crosstalk	Crosstalk Coupling db	Crosstalk Units
Message to Program	75	180
Program to Message	75	180
Program to Program	70	320

Near-end crosstalk is usually controlling in situations involving message-to-program and program-to-message crosstalk. In the case of program-to-program crosstalk either near-end or far-end components may be governing depending, of course, on whether or not the two program circuits in a particular combination operate in the same or opposite directions. Occasionally cases arise where a program circuit may be operated in either direction and the performance in each direction should be scrutinized.

3.0 DETAILED FACTORS INVOLVED IN ESTIMATING TOTAL CROSSTALK COUPLING - MESSAGE CIRCUITS

In estimating the total crosstalk coupling in the exchange plant between two circuits, such items as the type of subscriber sets, length and type of cable making up the loop or trunk facilities and the central office cabling and equipment must be considered. Usually the chance of two circuits being intimately associated with one another in both the outside cable and the central office is very slight so that it is highly improbable that there will be crosstalk between the two circuits in both the outside and inside plant simultaneously. For this reason only the coupling in the outside cable is considered in this section, since it is usually of greater magnitude referred to the subscriber station, than that from the central office equipment and cabling.

3.1 Distribution of Crosstalk Coupling - Outside Cable

The magnitude of the crosstalk coupling in ordinary exchange cable is dependent to a considerable extent upon whether or not the cable is of the staggered twist design. In the case of the non-staggered twist design, the adjacent pairs in a layer have the same length of twist so that crosstalk coupling between the pairs is of greater magnitude per unit length than in the staggered twist design. Staggered twist has been used for about 25 years in 19-gauge cables and has been applied in the case of 22 and 24-gauge to all cables manufactured since 1921. Since 26-gauge was only recently introduced into the plant, all cable of this gauge is of the staggered twist type.

The pairs in exchange cables are, in general, arranged in color groups (101 pairs in the larger sizes) in order to facilitate their identification when splicing. Each color group of a particular cable section is usually spliced as a unit to a single color group in another section. Only in special cases, such as splicing a very small sized cable to a larger sized cable, are the pairs in one color group of a cable section spliced to more than one color group in another section.

The crosstalk coupling between two pairs in an exchange cable is caused by the capacitance unbalance between the two pairs. The phenomena involved are discussed in detail in Section AB94.175 of Bell System Practices and in Section G72.225 of Bell System Practices. Usually the more intimately the conductors are associated in a cable, the higher are these unbalances. Test data have indicated that the highest capacitance unbalances usually occur between combinations within the same 101-pair group, those combinations between different color groups being of little importance. The data discussed below are, therefore, based upon the unbalances which occur between the various combinations of a 101-pair color group.

Drawing 611-171 attached gives the distribution of crosstalk coupling in a 101-pair group for long lengths of various types of non-loaded exchange cable. The drawing gives data for cable of the staggered and non-staggered twist type. Similar curves may be prepared for the various types of loaded facilities. The difference in crosstalk coupling between the various types of facilities having either staggered or non-staggered twist construction is, in general, caused by the variation in the characteristic impedances of the different types of facilities. The average values of crosstalk coupling are indicated by the 50 per cent. points on the curves. Since the values given in Part 2 are in terms of average values of crosstalk coupling, only the average values need be considered in the crosstalk coupling calculations. They are accordingly listed below for the various types of facilities.

As already noted the crosstalk coupling data are based on 101-pair color groups which are used in cables containing 404 pairs or more. For sizes of cable ranging from 101 pairs to 303 pairs inclusive, which are more commonly used in the subscriber loop plant, 50-pair color groups are used and for sizes of cable smaller than 101 pairs a single color group is used in each particular cable. The unbalances in the smaller sizes of cable (303 pairs or less) would be expected to be somewhat more than those involving 101-pair color groups with corresponding increases in crosstalk coupling (smaller db's). With smaller color groups involved the number of circuits busy at a particular instant would correspondingly be smaller and it is believed that the reduction in this number of busy circuits (which is taken into account in the determination of the performance criteria given

AVERAGE NEAR-END CROSSTALK COUPLING VALUES

Exchange Cable - Staggered and Non-Staggered Twist Type

"Long" Lengths

Type of Facility	Average Crosstalk Coupling - db Staggered Twist	Non-Staggered Twist
26 NL	92.5	
24 NL	95	92
22 NL	97.5	94.5
19 NL	100.5	
16 NL	102.5	
24-M-88	92.5	89
24-H-44	93.5	90
24-H-88	91.5	88
24-B-88	89	85
22-H-44	95.5	92.5
22-M-88	93.5	90.5
22-H-88	92.5	89.5
22-H-135	90.5	87.5
22-B-88	89.5	86.5
22-B-135	88.5	85.5
19-CNB-H-44	96	
19-CNB-H-88	92.5	
19-DNB-H-88	92	
19-DNB-H-135) 19-CNB-B-88)	89.5	
19-DNB-B-88) 19-DNB-H-175)	89	
19-CNB-B-135	88.5	
19-DNB-B-135	87	
19-DNB-B-175	86.5	
19-CNB-M-88	94	
19-DNB-M-88	93.5	
16-H-88	91.5	
16-B-88) 16-H-175)	89	
16-B-135	87	
16-B-175	86.5	
16-H-135	89.5	

in Part 2) will tend to offset the larger unbalances encountered. Therefore the average values of crosstalk coupling given above should be a fairly close approximation for the smaller sizes of cables i.e., those having 303 pairs or less.

3.2 Effect of Length of Cable on Magnitude of Crosstalk Coupling

Section AB94.175 of Bell System Practices describes in detail how the magnitude of near-end crosstalk coupling for a particular type of facility varies with the length of that facility. While the discussion is given primarily from the standpoint of quadded cable the principles may be applied in the case of exchange cables, both loaded and non-loaded. Analyzing these principles it will be noted that in general the magnitude of near-end crosstalk coupling for a particular facility increases with increasing length up to a certain length where it becomes a constant value. The length at which the magnitude of the crosstalk coupling becomes a constant value is arbitrarily termed the "long length" for that particular facility.

The average crosstalk coupling data given in Part 3.1 are based on a "long length" of cable. However, with the aid of Drawings 611-178, 179, 180, 181 and 182 the average crosstalk coupling may be determined for any length of cable. The drawings cover all types of facilities, both loaded and non-loaded and may be used for both staggered and non-staggered twist cable. From the data given on the drawings the "long length" for each type of facility may be determined. As indicated on the Drawings for distances less than the "long lengths" the values of crosstalk coupling may be determined by adding the db indicated for the particular length of facility to the average values given in Part 3.1. For example in determining the average crosstalk coupling for a group of non-loaded 22-gauge staggered twist trunk circuits 2-1/2 miles long, the value of 97.5 db is found from the table given in Part 3.1 and from Drawing 611-178 a correction factor of 0.5 db is found. Hence, the average crosstalk coupling is 97.5 + 0.5 db, or 98 db.

3.3 Conditions Involving More Than One Type of Cable Facility

It frequently happens, particularly in the case of subscriber loops, that the outside cable facility is made up of more than one type of plant, that is, a particular loop may contain more than one gauge of conductors, or may be made up of the same gauge throughout its length but loaded for a part of the length. Where such conditions are encountered the total crosstalk coupling caused by the two types of facilities may be determined as outlined in Section AB94.175 of Bell System Practices, by correcting the individual values of crosstalk coupling for the types of facilities in the circuit to the proper circuit terminal and then adding them according to the root sum square law. As an illustration, assume it is desired to find the actual average crosstalk coupling of a group of trunks at point A due to a length ABC, Section AB consisting of 2.5 miles of 22-gauge staggered twist and Section BC consisting of one mile of 24-gauge staggered twist. From Part 3.1 the average crosstalk coupling for a long length of 22-gauge cable is 97.5 db and for a long length of 24-gauge cable is 95 db. From Drawing 611-178 it is noted that the correction factors for the shorter lengths are 0.5 db for 22-gauge and 2 db for 24-gauge cable. In effect then, the crosstalk coupling at A due to Section AB is 98 db and that at B due to Section BC is 97 db. The crosstalk coupling at B due to Section BC must be corrected to the circuit terminal at A. This may be done by simply adding twice the value of the 1,000-cycle loss (see Section AB94.175 of Bell System

Practices) in the Section AB to the value of the crosstalk coupling for Section BC. The coupling then at A due to Section BC is 97 + 2 x 2.5 x 1.8 = 106 db.

Drawing 611-192 attached has been prepared to facilitate adding any number of values of crosstalk coupling by the root sum square method taking two values at a time. The chart simply shows the number of db to be subtracted from the lower numerical value in db of crosstalk coupling for various differences in db between the two values of crosstalk coupling under consideration. It should be noted that where the difference between the two values of crosstalk coupling is more than approximately 10 db, the higher value in db may be neglected with an error of less than .5 db. Using the chart then the coupling at A caused by Sections AB and BC is 98 - .6, or approximately 97.5 db.

In the case of loaded trunks or loaded subscriber loops, end sections in excess of one-half loading section may be considered as non-loaded facilities when determining the crosstalk coupling. This is an approximation since the impedance of the non-loaded end section is affected by the impedance of the loaded section. For instance, consider an M-88 loaded trunk 9 miles long between points A and B. Suppose the end section on the A end of the trunk is 6000 feet and that on the B end is 5500 feet and it is desired to find the total crosstalk coupling at A. With a 6000-foot end section at A, 6000-4500 or 1500 feet should be considered as a non-loaded section. The crosstalk coupling caused by this non-loaded section may be determined directly in the manner already outlined. Next, the coupling of 45,000 feet of loaded trunk should be determined. However, as already pointed out, it must be corrected to point A since it really ends at a point 1500 feet from A. Lastly, the coupling of the non-loaded section at the B end of the trunk 5500-4500, or 1000 feet in length should be determined and corrected to the A end of the trunk. The three values of coupling may then be combined by the root sum square method in the manner already outlined.

As will be noted from the crosstalk coupling values given in Part 2.0, different values are required for staggered and non-staggered twist cable. At present a simple method of precisely determining the overall value for a condition involving both staggered and non-staggered twist cable is not available. However, where a particular facility is made up of largely one type of cable located adjacent to the terminal from which the coupling is being considered, the effect of the other type of facility can for all practical purposes be neglected. For other cases it is believed that the information given in Part 5.11 will suffice.

3.4 Effect of Connecting Two or More Pairs in Parallel on Crosstalk Coupling

Cases sometimes arise, where it is desired to connect two cable pairs in parallel for certain types of subscriber loops. Where this is employed quite extensively in a color group in a particular cable, an increase in the crosstalk coupling (smaller number of db) results. The crosstalk coupling values given in Part 3.1 assume a single disturbing pair and a single disturbed pair. The expected effect of more than one disturbing pair connected in parallel and also more than one disturbed pair connected in parallel may be estimated by subtracting from the average crosstalk coupling values given in Part 3.1 the db corresponding to the current ratio which is equivalent to the square root of the number of pairs connected in parallel forming the disturbing circuit and also subtracting the db corresponding to the current ratio which is equivalent to the square root of the number of pairs connected in parallel to form the disturbed circuit. For example if a case involved a long length of 22-gauge staggered cable the coupling between a disturbing circuit consisting of two pairs connected in parallel and a disturbed circuit also consisting of two pairs connected in parallel would be estimated as follows: The average crosstalk coupling for a long length of 22-gauge staggered twist cable is 97.5 db. Then the expected effect on coupling may be estimated by subtracting from 97.5 db the db corresponding to a current ratio of $\sqrt{2}$ to allow for the disturbing circuit and to also subtract a similar amount to allow for the disturbed circuit or, in effect, 97.5 - 3 - 3 = 91.5 db.

In cases involving group talking arrangements (covered in greater detail in Part 5.32) a number of pairs may be bridged at the main station and from a coupling standpoint may be considered connected in parallel. In such cases the crosstalk coupling may be estimated by increasing (reducing the number of db) the crosstalk coupling values given in Part 3.1 by the db corresponding to the current ratio which is equal to the square root of the number of pairs connected in parallel. For 4 pairs connected in parallel 6 db should be subtracted from the values of Part 3.1, 9 pairs 9.5 db, 16 pairs 12 db, etc.

3.5 Distribution of Talking Volume and Receiving Efficiency

The crosstalk coupling values outlined in Part 2.0 of this Section of Practices are, as previously stated, based on an average talking volume and receiving efficiency. Talking volume measurements have been made at central offices for different types of subscriber instruments. In addition, the receiving efficiencies have been estimated. The table below gives the average talking volumes and receiving efficiencies for manual, panel and step-by-step central offices and toll connections. They assume the typical room noise condition and are based on zero loops with the exception of that for the 337 transmitter which cannot ordinarily be used on loops having less than 150 ohms. While as pointed out in Part 2 the use of desk stand instruments should ordinarily be assumed, the values for hand sets are included as they may be helpful in specific problems. It should be noted that the receiving efficiency data are on an effective basis thus taking into account the effects of sidetone. Data are also given in the table on the average talking volume and receiving efficiency for various types of local battery subscriber sets used in common battery areas. Since local battery sets are usually used on long loops in common battery areas, the data have been set up on such a basis. They may, however, be used for any length of loop with a fair degree of accuracy.

The talking volume data given in the table represent the actual talking level at the subscriber set on a zero loop with respect to reference volume. The receiving efficiency data indicate the effective gain or loss with respect to a zero loop operating from a No. 1 switchboard and equipped with a 323-144-46 standard subscriber set.

3.6 Variation of Talking Volume and Receiving Efficiency with Length

Since loops of varying lengths may be encountered in the plant, the effect of the length of loop on talking volume and receiving efficiency needs to be considered. In a common battery area, the longer the loop the lower is the battery supply to the subscriber instrument tending to a lower talking volume and in general in lower room noise sidetone effects. As the pertinent values are the talking volume at the set terminals and the receiving efficiency of the set only, the corrections to allow for length of loop can be approximated by using the battery supply data given in Section AB43.075 of Bell System Practices. These data have been put together in a form which it is believed can readily be interpreted for any length of loop. Drawings 611-189, 190 and 191 attached cover conditions for No. 1 and No. 10 manual, panel and step-by-step offices, both local and toll connections. The variations in receiving efficiency and talking volume are given in terms of crosstalk gains and losses and the curves simply indicate the gain or loss in db for each length of loop which should be added to the average value of the talking

AVERAGE TALKING VOLUMES AND RECEIVING EFFICIENCIES - ZERO LOOP

Basis Talking Volume vs Reference Volume
Receiving Efficiency vs Receiving Efficiency
of 323-144-46 Subscriber Set on Zero Loop
No. 1 Switchboard

+ Values Indicate Gains
- Values Indicate Losses

Type of Subscriber Set	Type of Connection	Type of Central Office	Average Talking Volume in db	Average Receiving Efficiency in db
323-144-46-STD	Local	#1 & #10 Manual Panel M.S.	-14	0
395-557-46-STD	"	"	-18	+2.5
*337-144-46-STD	"	"	-14	+ .5
323-144-AST	"	"	- 8.5	+2
395-557-AST	"	"	-15	+4.5
*337-144-AST	"	"	- 7.0	+3
323-144-46-STD	"	Step-by-Step M.S.	-13.5	+2.5
395-557-46-STD	"	"	-18	+5.0
*337-144-46-STD	"	"	-13	+1.5
323-144-AST	"	"	- 8.5	+3.5
395-557-AST	"	"	-15	+6.0
*337-144-AST	"	"	- 7.0	+4.0
323-144-46-STD	Toll		-12	0
395-557-46-STD	"		-16	+1.5
*337-144-46-STD	"		-12	0
323-144-AST	"		- 6.5	+1.5
395-557-AST	"		-13	+4.5
*337-144-AST	"		- 4.5	+3.0
**337 or 323-144-13	Local or Toll		-13	-1.5
**395-557-13	"		-17	+2
**337-567A-62-AST	"		- 7.5	+3
**395-574A-62-AST	"		-12.5	+5.5

* 150-ohm Loop
** Long Loop
AST Anti-Sidetone Set
STD Standard Connection

volume and receiving efficiency given in Part 3.5, to give the actual talking volume and receiving efficiency for the particular length of loop under consideration. As an illustration of how the curves may be used, assume it is desired to find the average talking volume and receiving efficiency on a local connection for a 22-gauge loop three miles long equipped with a 337-144-46 subscriber set in a panel office. From Part 3.5 the average talking volume and receiving efficiency for a 150-ohm loop equipped with a 337-144-46 subscriber set are found to be -14 db and +.5 db, respectively. Three miles of 22-gauge cable is approximately 510 ohms. From Drawing 611-189 it is found that, with a loop of this length, the talking volume should be decreased approximately 2 db and the receiving efficiency increased approximately 1.3 db. Hence, the average talking volume for the 510-ohm loop is -16 db and the receiving efficiency is +1.8 db. The value of -16 db represents the level on the loop at the subscriber set and the receiving efficiency of +1.8 db indicates the gain of the particular station apparatus over the reference condition.

3.7 Effect of Talking Volume and Receiving Efficiency on Crosstalk Coupling - Subscriber Loops

The crosstalk coupling values for subscriber loops given in Part 2.12 assume certain specified average talking volumes and receiving efficiencies. Conditions will be encountered in practice which are not the equivalent of these reference conditions and hence the variation in talking volume and receiving efficiency from the reference conditions will need to be taken into account when determining the total corrected crosstalk coupling. The talking volume and receiving efficiency for any length loop and for various types of subscriber instruments may be determined as outlined in Part 3.6. If the combined effect of the talking volume and receiving efficiency gives a loss with respect to the reference condition (323 transmitter and 144 receiver on zero loop), the deviation in db from the reference value should be added to the value of the average crosstalk coupling given in Part 3.1. If the combined effect gives a gain with respect to the reference condition the deviation in db should be subtracted from the average crosstalk coupling given in Part 3.1. The resultants can then be compared with the values given in Part 2.12. The following example illustrates the manner in which the variation in talking volume and receiving efficiency from the reference condition may be taken into account in computing the total corrected crosstalk coupling. Assume that the average crosstalk coupling (on the bare cable pairs) of a group of subscriber loops equipped with desk stand sidetone subscriber sets is 94.5 db and the talking volume and receiving efficiency for this group are -16.8 db and +2.2 db and it is desired to know the total corrected crosstalk coupling so it may be compared with the values of Part 2.12. The talking volume and receiving efficiency for the reference condition are respectively -14 db and 0 db. It may be seen that 16.8 - 14 or 2.8 db more coupling may be allowed on account of the lower talking volume and that 2.2 - 0 or 2.2 db less coupling may be allowed on account of the better receiving efficiency. In other words 2.8 - 2.2 or 0.6 db more coupling may be allowed taking into account both the talking volume and the receiving efficiency. Then the total crosstalk coupling is 94.5 + 0.6 = 95.1 db which is substantially within the values suggested in Part 2.12.

3.8 Effect of Repeaters on Crosstalk Coupling

Transmission considerations sometimes necessitate the use of repeaters on certain tandem and toll board trunks. In such cases the repeaters are usually installed at the tandem and the toll board ends of the trunks. As pointed out in Section AB94.175 of Bell System Practices the introduction of repeaters in the trunk circuits results in increasing the near-end crosstalk coupling at the tandem and toll board ends of the trunks by an amount equivalent to the gain introduced by the repeaters. As an illustration of the effect of repeaters on crosstalk coupling, consider a large terminal repeatered trunk group consisting of a long length of 19-CNB-M-88 facilities in the same 100-pair group. Assume that the repeaters are operating at 6 db gains in each direction and that it is desired to know the crosstalk coupling within this trunk group at the ends of the trunks adjacent to the repeaters. From Part 3.1, the crosstalk coupling for a long length of 19-CNB-M-88 trunk group is found to be 94 db. Since the coupling is, in effect, increased by the repeaters 6 + 6, or 12 db, the corrected value becomes 94 - 12, or 82 db.

As noted above the crosstalk coupling on tandem trunks repeatered at the tandem switchboard end is greater at the tandem end than at the subscriber end of the trunk. However the crosstalk at the tandem switchboard is attenuated by an amount equal to the sum of the equivalents of the trunks to which both the disturbing and disturbed circuits are connected. Furthermore usually only a small proportion of the total pairs in a particular 100-pair group will be repeatered so that the net effect on the average crosstalk coupling will be materially less than the sum of the repeater gains. In view of these facts it is believed that for all practical purposes, the crosstalk coupling on tandem trunks repeatered at the tandem switchboard need be determined at the tandem end only in those cases where more than about 25 pairs in a particular 100-pair group are repeatered. In all other cases the limiting condition will in general be that at the subscriber end of the repeatered tandem trunk.

Where repeaters are located at intermediate points on tandem or toll board trunks and in cases of terminal repeaters located at local offices on small trunk groups the crosstalk coupling depends upon the proportion of the circuits being repeatered, the gains employed and the location of the repeaters with respect to the subscriber end of the trunk. In general where such a practice is followed an increase in the average crosstalk coupling would be expected. It is suggested that if such cases arise they be handled on a special basis.

4.0 OUTLINE OF STEP-BY-STEP PROCEDURE FOR ESTIMATING TOTAL CROSSTALK COUPLING

4.1 Trunk Circuits

The various steps which are involved in determining the total crosstalk coupling are given below. It is suggested that they be carried out in the order listed in order to facilitate the calculations:

1. Knowing the type of facility concerned, determine the average crosstalk coupling for a long length using the data given in the table of Part 3.1.

2. Knowing the length of the facility concerned, correct the average crosstalk coupling for the long length in the manner indicated in Part 3.2 to obtain the average crosstalk coupling for the length under consideration.

3. Where more than one type of facility is involved in a trunk group, proceed as outlined in Part 3.3, bearing in mind that:

   a. In the case of direct trunks, the crosstalk coupling should be determined at both ends of the trunks, and the largest of the two values used as representative of the total crosstalk coupling.

   b. For tandem and toll board trunks, the crosstalk coupling should be determined at the subscriber end of the trunk only, with the exception as noted in Part 3.8.

4. By comparing the average figures of crosstalk coupling, estimated by the procedure outlined above, with those given in Part 2.11, it can readily be determined whether or not the proposed layout will give more than a one per cent. chance of obtaining intelligible crosstalk. If a chance somewhat higher than one per cent. is to be permitted, the corresponding values of crosstalk coupling may be estimated as outlined in the last paragraph of Part 2.11.

4.2 Subscriber Loops

The various steps involved in determining the crosstalk coupling on subscriber loops are listed below. It is suggested that the steps be carried out in the order given to facilitate the calculations:

1. Knowing the type of facility concerned, determine the average crosstalk coupling for a long length using the data given in Part 3.1.

2. Knowing the length of the facility concerned, correct the average crosstalk coupling, for the long length, in the manner indicated in Part 3.2.

3. Where more than one type of facility is involved, proceed as outlined in Part 3.3. The crosstalk coupling need only be determined for the subscriber end of the loop.

Note: The crosstalk coupling obtained as outlined in Steps 2 and 3 is the coupling on the bare cable pairs.

4. Knowing the type of central office and the type of subscriber apparatus, determine the average talking volume and receiving efficiency on a local connection for the particular loop in the manner outlined in Parts 3.5, 3.6 and 3.7.

5. Correct the crosstalk coupling on the bare cable pairs by taking into account the variation in the probable average talking volume and receiving efficiency from the reference condition.

6. Determine the type of area served by the loops being investigated i.e., determine whether business, combination business and residential or residential.

7. By comparing the average figures of crosstalk coupling, estimated by the procedure outlined above, with those given in Part 2.11, it can readily be determined whether or not the proposed layout will give more than a one per cent. chance of obtaining intelligible crosstalk. If a chance somewhat higher than one per cent. is to be permitted, the corresponding values of crosstalk coupling may be estimated as outlined in the last paragraph of Part 2.11.

It will be noted that Step 4 suggests that the talking volume and receiving efficiency should be determined on the basis of a local connection. The combined (algebraic sum) talking volume and receiving efficiency on a toll connection is in general of higher value from a gain standpoint than that for a local connection for the same loop. However, since the number of toll conversations being carried on during a busy toll period is relatively small compared with the number of local conversations during the busy local hour, the resulting effect on the average talking volume would in general be negligible.

5.0 LIMITATION OF CROSSTALK COUPLING

5.1 Message Circuits - Trunk Circuits and Subscriber Loops

In general where the present standard types of cable and subscriber sets (both sidetone and anti-sidetone sets) are used, the crosstalk coupling on trunk circuits and subscriber loops are probably within the values suggested in Part 2.0. There is still a considerable amount of non-staggered twist cable in the exchange plant and certain restrictions are necessary in connection with its use. Some of these restrictions have already been recommended, as referred to later, and a few supplemental ones are recommended below.

5.11 Use of Non-Staggered Twist Cable

5.111 Trunk Circuits

Where non-loaded, non-staggered twist cable is employed in the trunk plant, there are, in general, no limitations from a crosstalk standpoint. The limitations on the use of loaded non-staggered twist cable are based on so locating the non-staggered twist section with respect to the trunk circuit terminals that the total crosstalk coupling for the particular trunk group in kept within suitable values. The restrictions in regard to the use of loaded non-staggered twist cable in various types of trunk circuits and for both sidetone and anti-sidetone subscriber sets are covered in detail in Section AB22.125 of Bell System Practices.

Where it is impracticable to carry out the recommendations given in Section AB22.125, it may be possible to make cable rearrangements so as to place the non-staggered twist cable in a non-loaded trunk group, or in a better relative location with respect to the circuit terminals in another loaded trunk group.

5.112 Subscriber Loops

Calculations and a limited amount of experimental evidence indicate that ordinarily no restrictions need to be observed in the use of non-loaded, non-staggered twist cable in subscriber loops. In those cases where loaded non-staggered twist cable is to be employed, restrictions are apparently necessary only in the cases involving the use of local battery talking sets as follows:

1. With any type of central office where there are 3 or more miles of 22-M-88, 22-H-88 or 24-H-44 non-staggered twist facilities in loops equipped with local battery anti-sidetone subscriber sets there should be preferably at least a 1,000-cycle loss of 1.5 db between the loaded non-staggered twist cable and the subscriber set in those few cases involving business areas. In combination business and residential areas and residential areas, other conditions remaining the same, the 1,000-cycle losses respectively, should be at least 1 db and 0.5 db.

2. Where there are 2 or more miles of 24-M-88 or 24-H-88 non-staggered twist facilities in loops equipped with local battery anti-sidetone subscriber sets there should be preferably at least a 1,000-cycle loss of 2 db between the loaded non-staggered twist cable and the subscriber set in business areas. In combination business and residential areas and residential areas, other conditions being the same, the 1,000-cycle losses should be 1.5 db and 1 db respectively.

5.12 Use of Repeatered Trunks

As already discussed, repeaters when used on tandem or toll trunks are usually installed at the tandem or toll offices. With the exception of those cases where tandem trunks equipped with repeaters are connected to short inner area trunks, the use of repeaters on tandem and toll board trunks would be expected to have little effect on the crosstalk heard by the subscriber. In connection with the exception just mentioned, no serious crosstalk reactions should result if the gain of the repeaters is limited to 6 db.

In the case of toll board trunks, the effect of repeaters would result in increasing the crosstalk between toll operators when using the trunks. Since the present field of use of such repeaters appears to be on 19-gauge facilities, which are in general of the staggered twist type, and since operator-to-operator crosstalk should be considered from the standpoint of noise impairment rather than secrecy impairment, it appears that crosstalk will not be a limiting factor when specifying desired repeater gains.

5.2 Program Circuits

In selecting exchange pairs for program circuits, crosstalk will not usually be a limiting factor although it will ordinarily require attention. Where non-staggered twist cable is involved, suitable crosstalk selection tests may be necessary. Where several program circuits are required along a particular route, crosstalk tests are highly desirable to insure satisfactory message-to-program and program-to-program crosstalk conditions. In such cases also, it will be found desirable to distribute program pairs in a particular cable throughout the different color groups in so far as practicable.

5.3 Special Circuits

5.31 Subscriber Special Service Lines

Subscriber special service lines, which include foreign exchange lines, off-premise extensions, P.B.X. tie lines, L.D. loops, and private lines may involve the trunk plant, the loop plant, or both. The crosstalk conditions in connection with such lines may be checked using the methods outlined for subscriber loops, and trunk circuits. Usually any type of plant which is satisfactory for subscriber loops or trunk circuits will also be satisfactory for special service lines and the same limitations regarding the use of non-staggered twist cable apply.

In certain instances, particularly those involving trunk facilities, repeaters may be necessary in order to provide satisfactory transmission. Repeaters in such cases are usually placed in some central office along the route of the special service line, the particular location being determined from the standpoint of overloading, crosstalk, circuit layout, maintenance reactions, etc. The use of repeaters makes it necessary to exercise certain precautions as regards the desirable gains to be used, having in mind the effect on crosstalk as well as overloading. The limiting crosstalk condition will ordinarily be one involving trunk facilities in the section or sections adjacent to the repeater.

In order to reduce the number of calculations necessary for estimating the desirable gains for operating repeaters on special service lines, methods are given in Section AB22.326 of Bell System Practices by which they may be readily determined. Section AB22.326 also outlines certain precautions which should be taken in regard to the use of non-staggered twist cable in repeatered circuits.

5.32 Group Talking Arrangements

There are in general two types of group talking arrangements employed in the exchange plant, the particular type used depending on the number and length of lines and stations involved, etc. Where only a small number of lines and stations is involved it is often practicable to provide satisfactory transmission by employing special station sets and without the aid of an amplifier in the transmitting element of the main station. Where a large number of lines and stations is involved, an amplifier may be necessary. In cases where no amplifier is used, the limiting crosstalk condition will ordinarily be crosstalk from the group talking lines into other circuits in the particular cable. The effect of an increase in the number of bridged circuits would be expected to result in a correspondingly larger magnitude of crosstalk coupling, as outlined in Part 3.4, assuming all of the pairs to be within a particular color group in a cable. This larger magnitude of crosstalk coupling would be offset to a great extent by the lower talking volume on each of the pairs, this latter being brought about by the bridging loss of the lines bridged at the main station. It is believed that the loop portion of such circuits will usually be the only part requiring attention from a crosstalk standpoint. Since in general there will only be a single group talking arrangement served in a particular 100-pair group and as the calling rate for such a circuit is usually less than that of a normal business line, somewhat larger crosstalk coupling than that where ordinary subscriber loops are involved may be permitted. The values for the various conditions are given below.

Subscriber Set	Type of Cable	Crosstalk Coupling - db
*Hand Set Sidetone	Staggered Twist	63
Desk Stand Sidetone	Staggered Twist	65
*Hand Set Sidetone	Non-Staggered Twist	72
Desk Stand Sidetone	Non-Staggered Twist	74
*Hand Set Anti-Sidetone	Staggered Twist	66
Desk Stand Anti-Sidetone	Staggered Twist	72
*Hand Set Anti-Sidetone	Non-Staggered Twist	75
Desk Stand Anti-Sidetone	Non-Staggered Twist	81

* 395 Transmitter, 557 Receiver.

The above crosstalk coupling values are based on the same general assumptions as those given for subscriber loops in Part 2.12. With such values of crosstalk coupling it is believed that there will not be more than a one per cent. chance of hearing intelligible crosstalk. For other per cent. chances reference should be made to Drawing 611-196 attached. The total crosstalk coupling for situations involving group talking arrangements may in general be determined as outlined for subscriber loops in Part 4.2. It should be noted that where more than one bridged line is involved the talking volume will need to be corrected to take account of the bridging loss.

Where an amplifier is used in the transmitting station of a group talking arrangement, it is necessary that the level on the various bridged pairs be kept at a lower value than would be the case where only a very few pairs were involved. In cases where the cable facilities of the special service lines are of the staggered twist type, it is believed that no serious crosstalk reactions will result if the level on the bridged pairs is kept below approximately -10 db with respect to reference volume. In situations where there is a considerable length of non-staggered twist cable adjacent to the main station serious crosstalk may result on loops equipped with anti-sidetone subscriber sets even with a level of -10 db. If such situations arise it is suggested that they be given specific consideration.

5.33 Loud Speaking Station Equipment

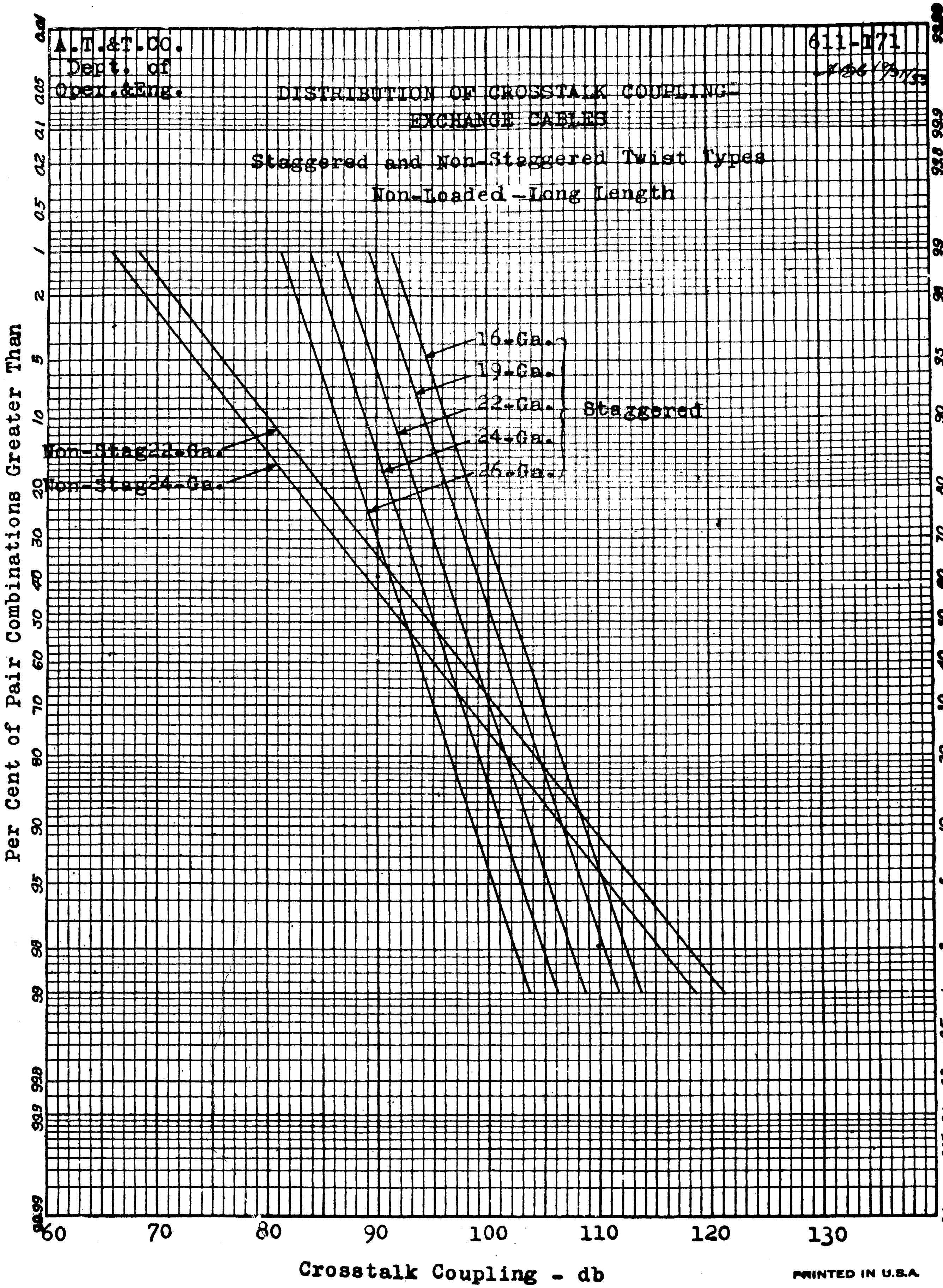
In cases where loud speaking station equipment such as the 100 type Loud Speaker Set or the D-95507 Loud Speaking Telephone Outfit are used a considerable amount of gain may be introduced. It is perfectly possible for a customer in a silent interval to increase the amplification of the loud speaker to a point making prominent in many cases the babble on the telephone circuit as well as any intelligible crosstalk which may in rare cases be encountered. Such effects would be produced by the misuse rather than by the use of the set and it is believed that under normal operating conditions they will seldom be observed by the customers.

In some cases where a one-way or two-way loud speaker arrangement is to be used primarily in talks from a particular station a 615-A transmitter is used at the distant station. Since the output of this transmitter is about the same as that of a 395 transmitter no serious crosstalk reactions would be expected as a result of the use of this transmitter.

Attached:

Drawings: 611-171, 611-178 to 611-182 Inclusive

611-187 to 611-196 Inclusive


A.T.&T.CO.
Dept. of
Oper.&Eng.
611-171
DISTRIBUTION OF CROSSTALK COUPLING-
EXCHANGE CABLES
Staggered and Non-Staggered Twist Types
Non-Loaded - Long Length
16-Ga.
19-Ga.
22-Ga.
24-Ga.
26-Ga.
Staggered
Non-Stag22-Ga.
Non-Stag24-Ga.
Per Cent of Pair Combinations Greater Than
Crosstalk Coupling - db
60
70
80
90
100
110
120
130
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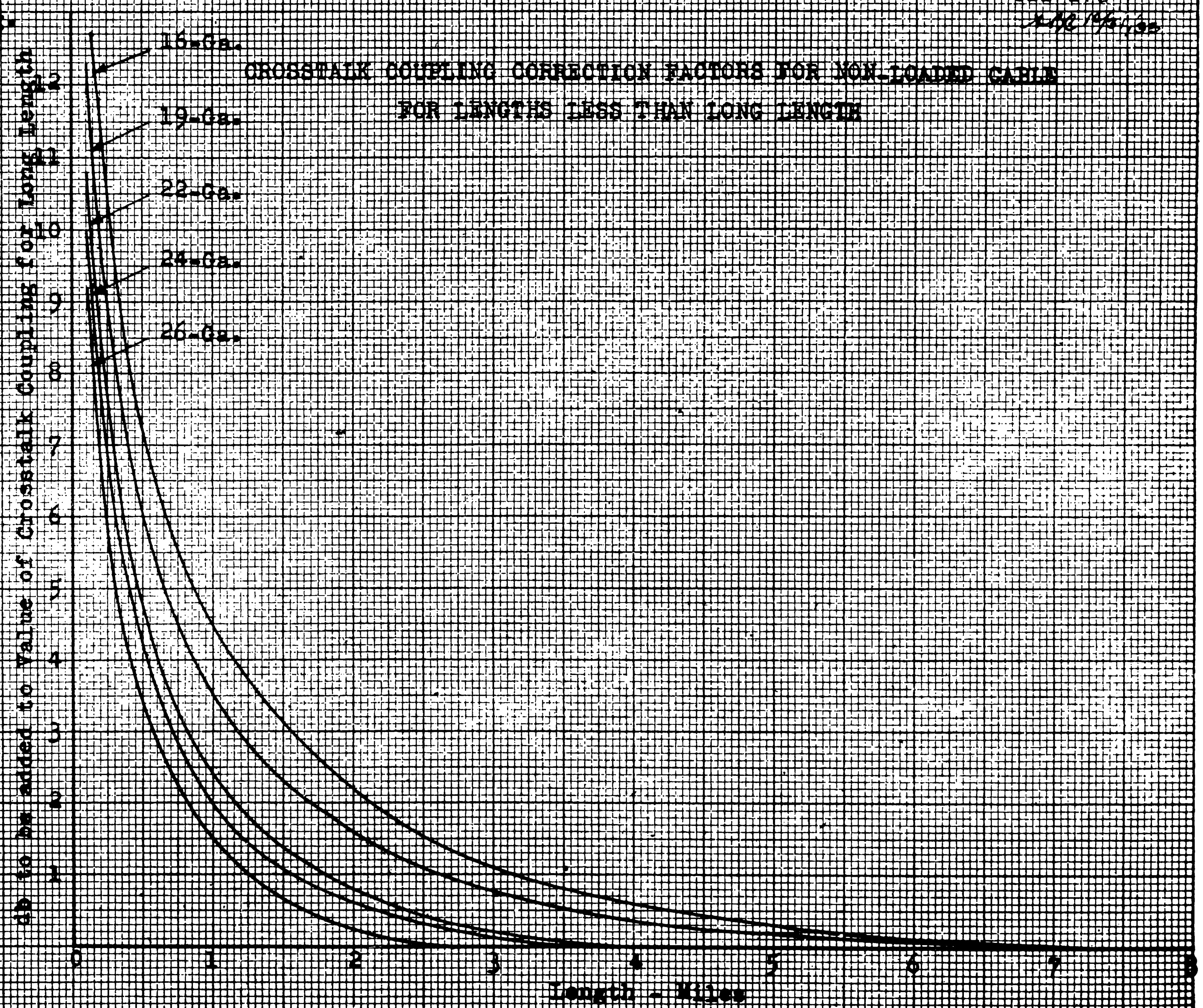
A. T. & T. CO.
Dept. of
Oper. & Eng.

611-178



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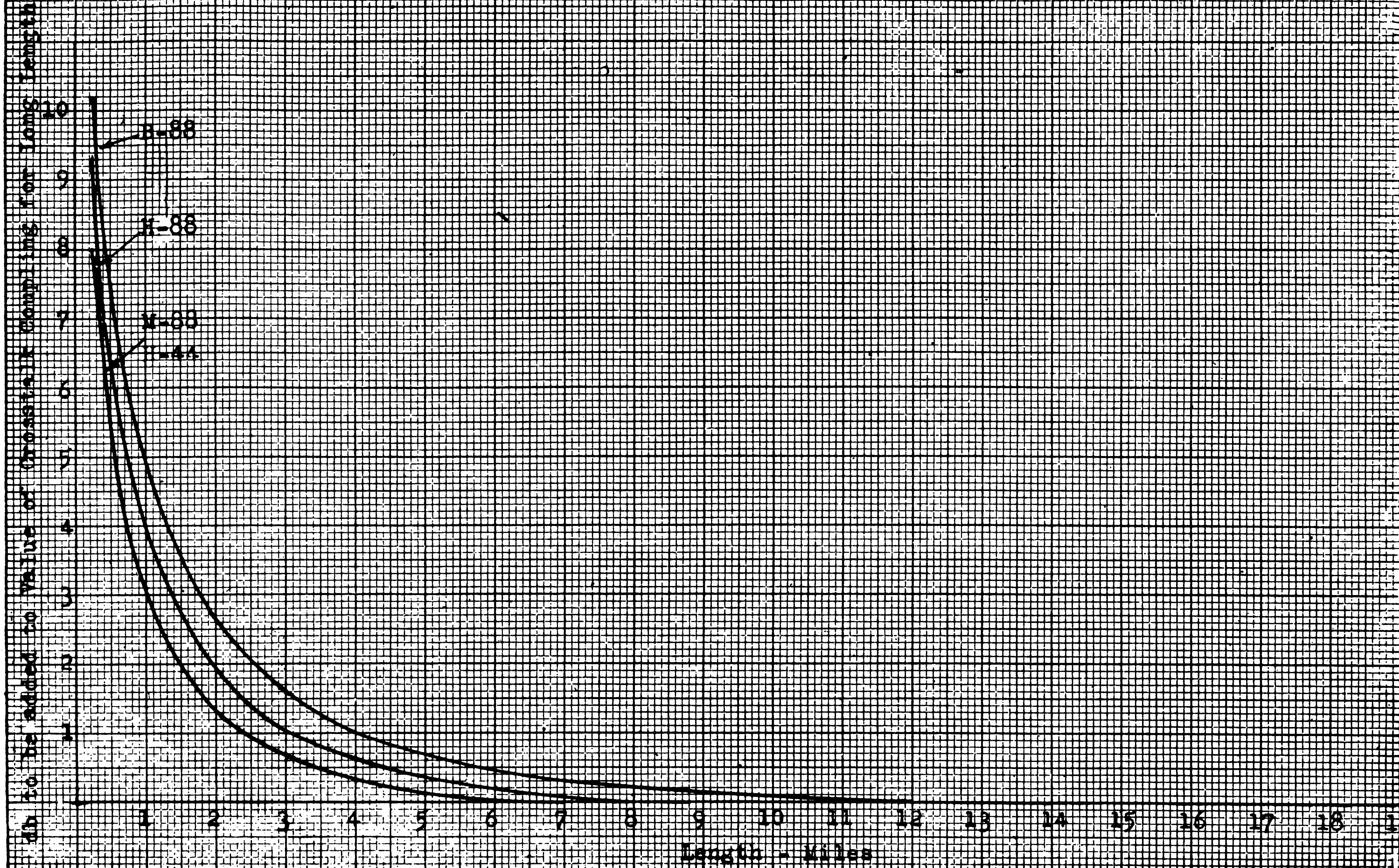
611-179

CROSSTALK COUPLING CORRECTION FACTORS FOR LOADED 24-GA. CABLE
FOR LENGTHS LESS THAN LONG LENGTHS



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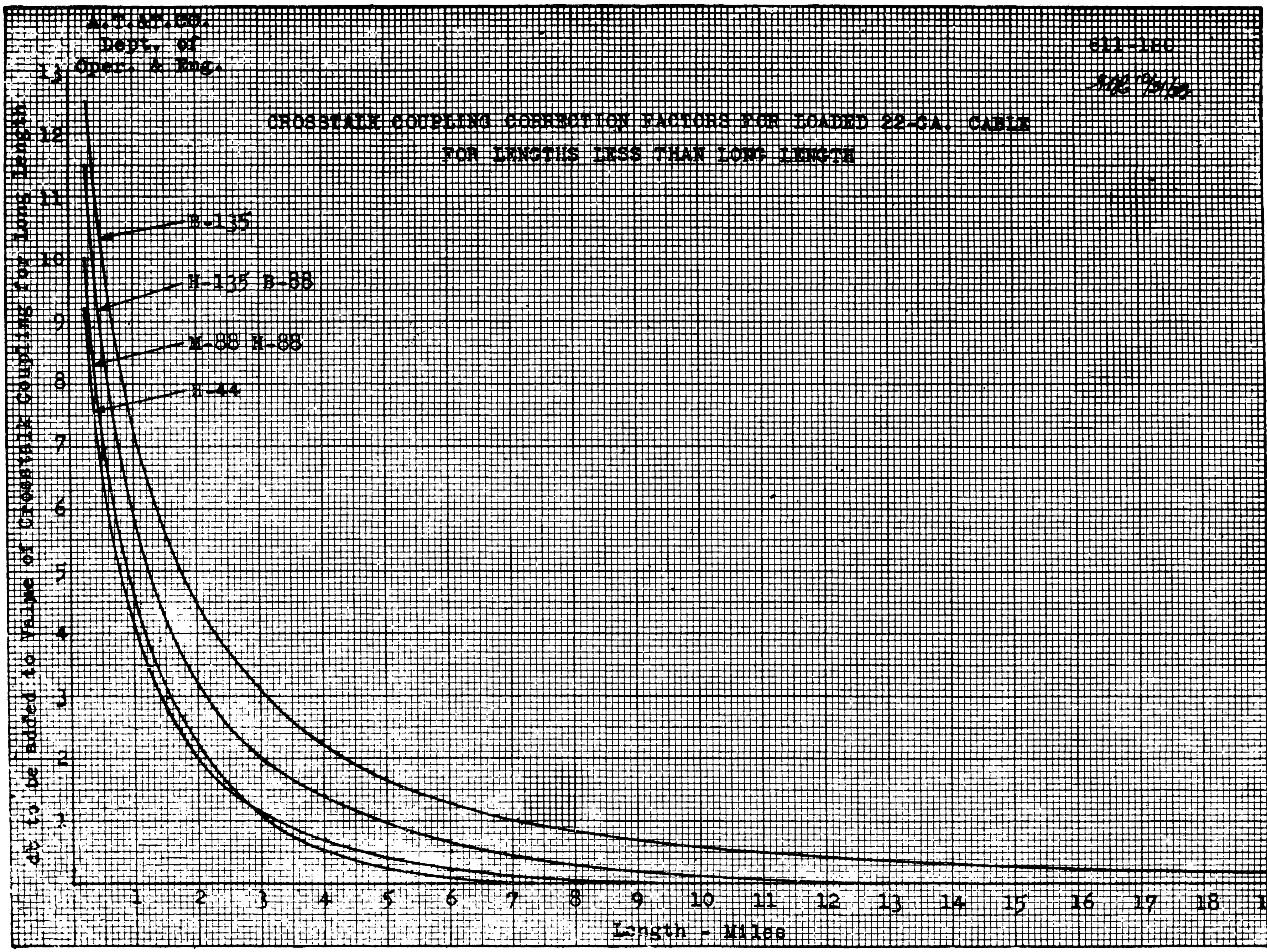
A.T.&T.Co.
Dept. of
Oper. & Eng.
611-180
CROSSTALK COUPLING CORRECTION FACTORS FOR LOADED 22-GA. CABLE
FOR LENGTHS LESS THAN LONG LENGTH
db to be Added to Value of Crosstalk Coupling for Long Length
B-135
H-135 B-88
M-88 H-88
H-44
Length - Miles
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19

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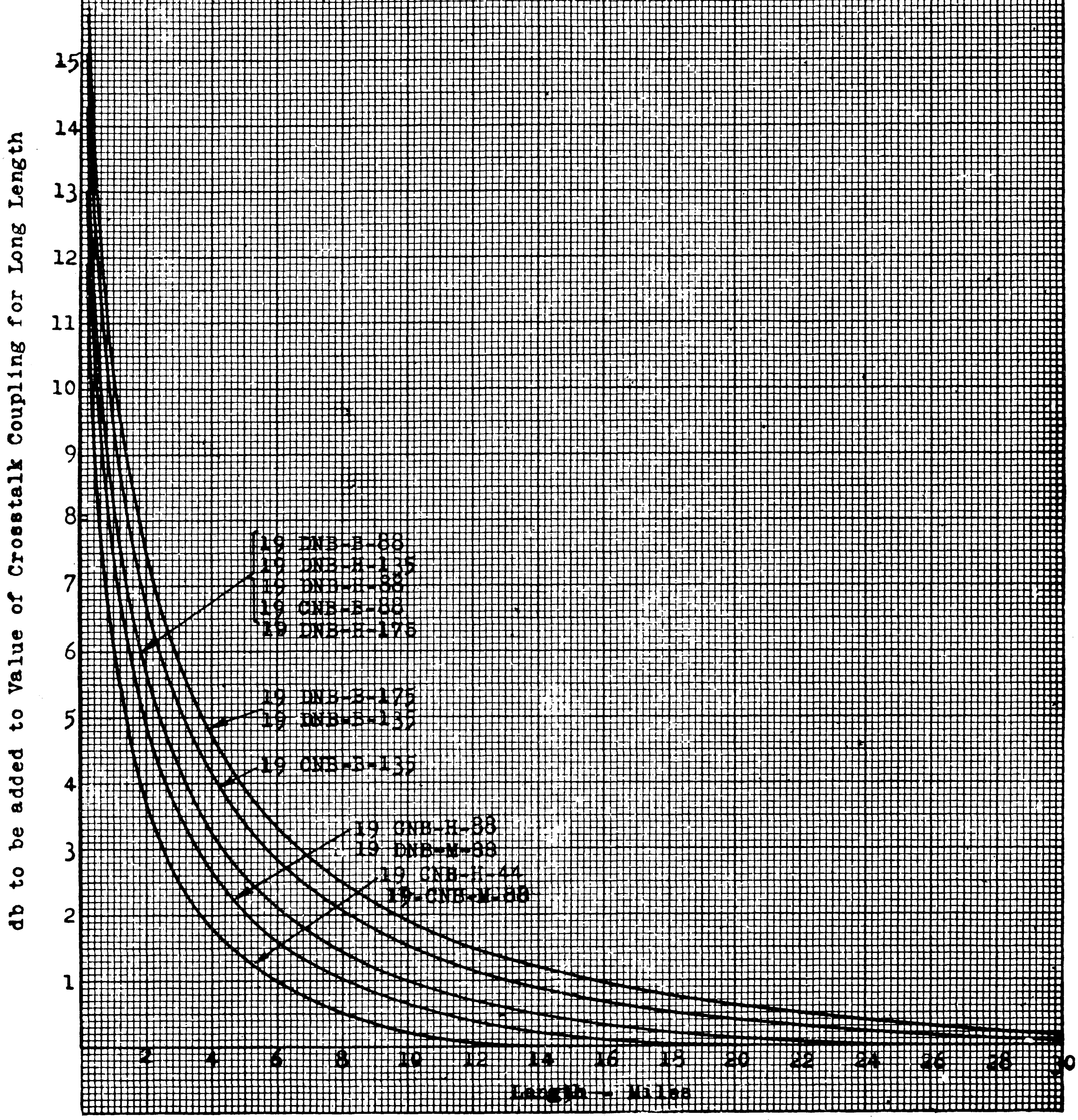
611-181

CROSSTALK COUPLING CORRECTION FACTORS FOR LOADED 19-GA. CABLE FOR LENGTHS LESS THAN LONG LENGTH



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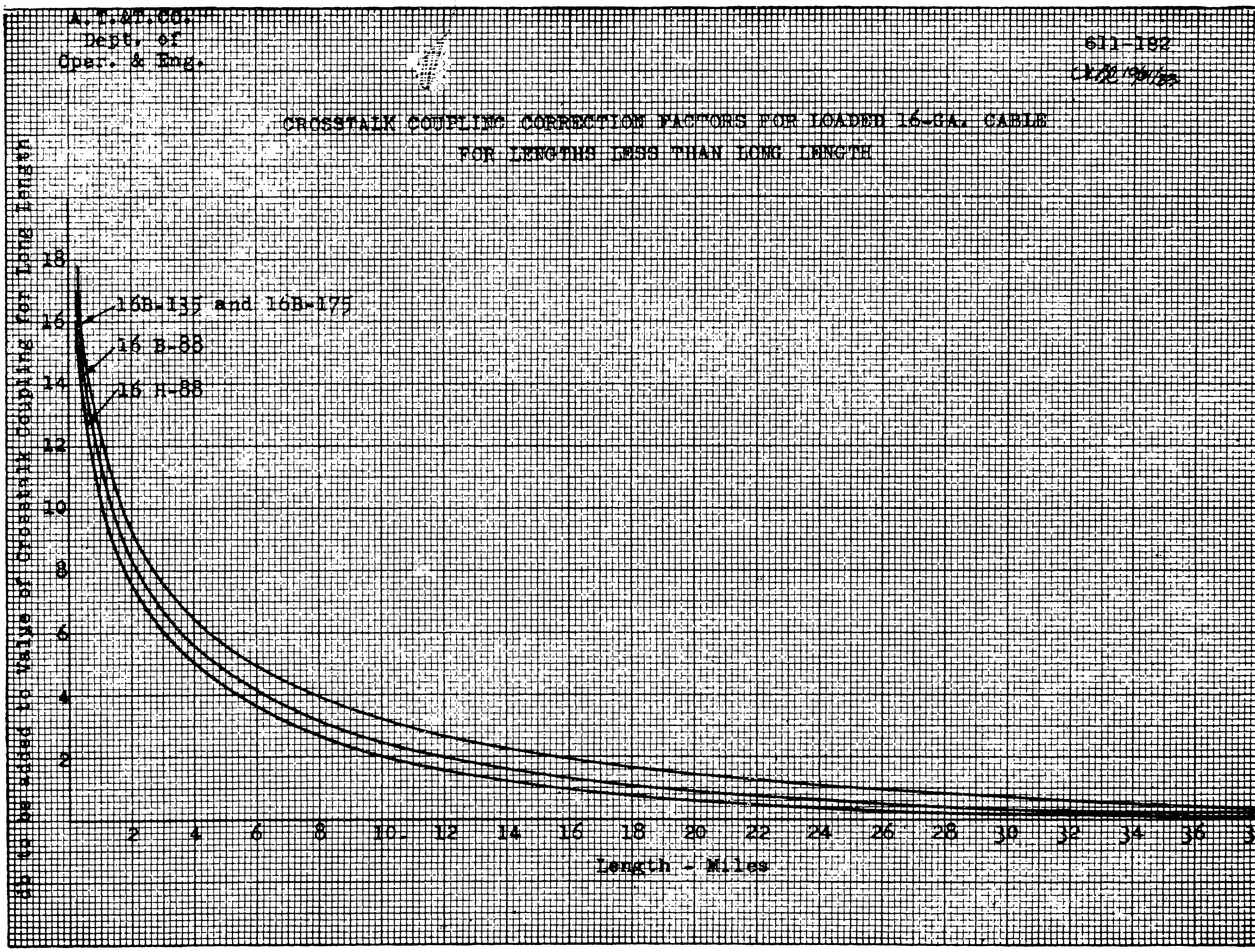
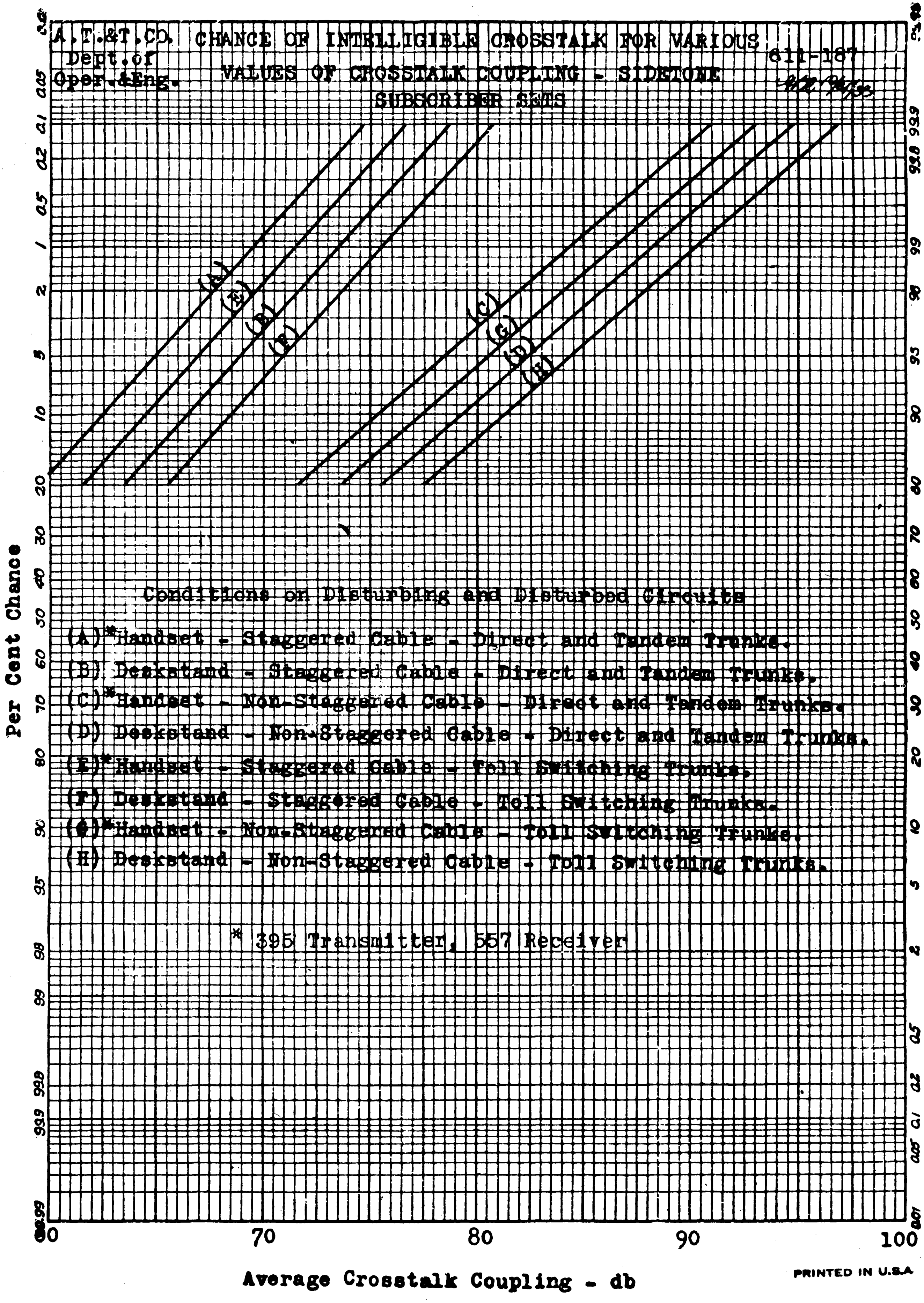

A.T.&T.CO.
Dept. of
Oper. & Eng.
611-182
CROSSTALK COUPLING CORRECTION FACTORS FOR LOADED 16-GA. CABLE
FOR LENGTHS LESS THAN LONG LENGTH
db to be added to Value of Crosstalk Coupling for Long Length
18
16
14
12
10
8
6
4
2
16B-135 and 16B-175
16 B-88
16 H-88
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
Length - Miles



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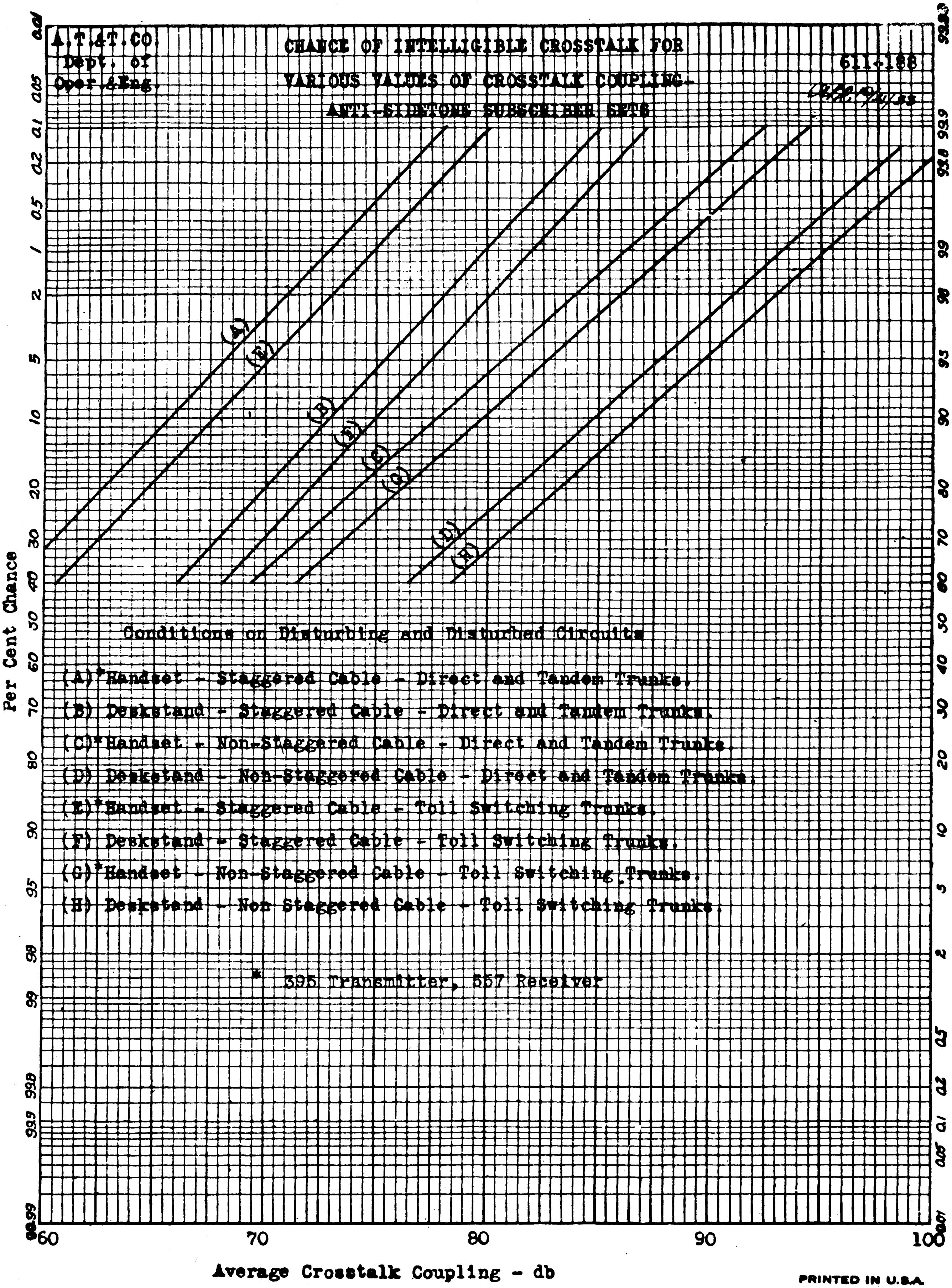
A.T.&T.CO.
Dept. of
Oper.&Eng.
CHANCE OF INTELLIGIBLE CROSSTALK FOR
VARIOUS VALUES OF CROSSTALK COUPLING-
ANTI-SIDETONE SUBSCRIBER SETS
611-188
(A)
(E)
(B)
(F)
(C)
(G)
(D)
(H)
Conditions on Disturbing and Disturbed Circuits
(A)*Handset - Staggered Cable - Direct and Tandem Trunks.
(B) Deskstand - Staggered Cable - Direct and Tandem Trunks.
(C)*Handset - Non-Staggered Cable - Direct and Tandem Trunks.
(D) Deskstand - Non-Staggered Cable - Direct and Tandem Trunks.
(E)*Handset - Staggered Cable - Toll Switching Trunks.
(F) Deskstand - Staggered Cable - Toll Switching Trunks.
(G)*Handset - Non-Staggered Cable - Toll Switching Trunks.
(H) Deskstand - Non Staggered Cable - Toll Switching Trunks.
* 395 Transmitter, 557 Receiver
Per Cent Chance
60
70
80
90
100
Average Crosstalk Coupling - db

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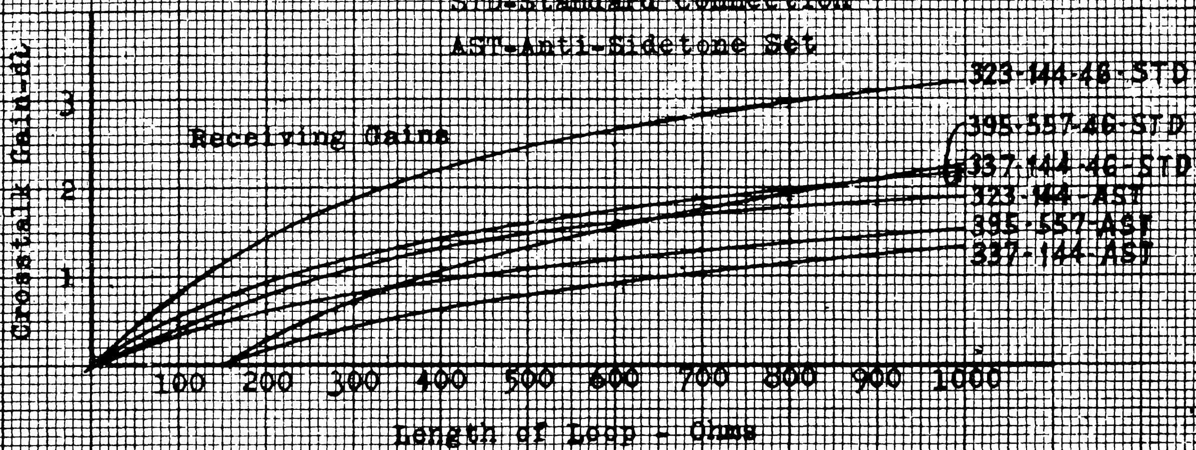
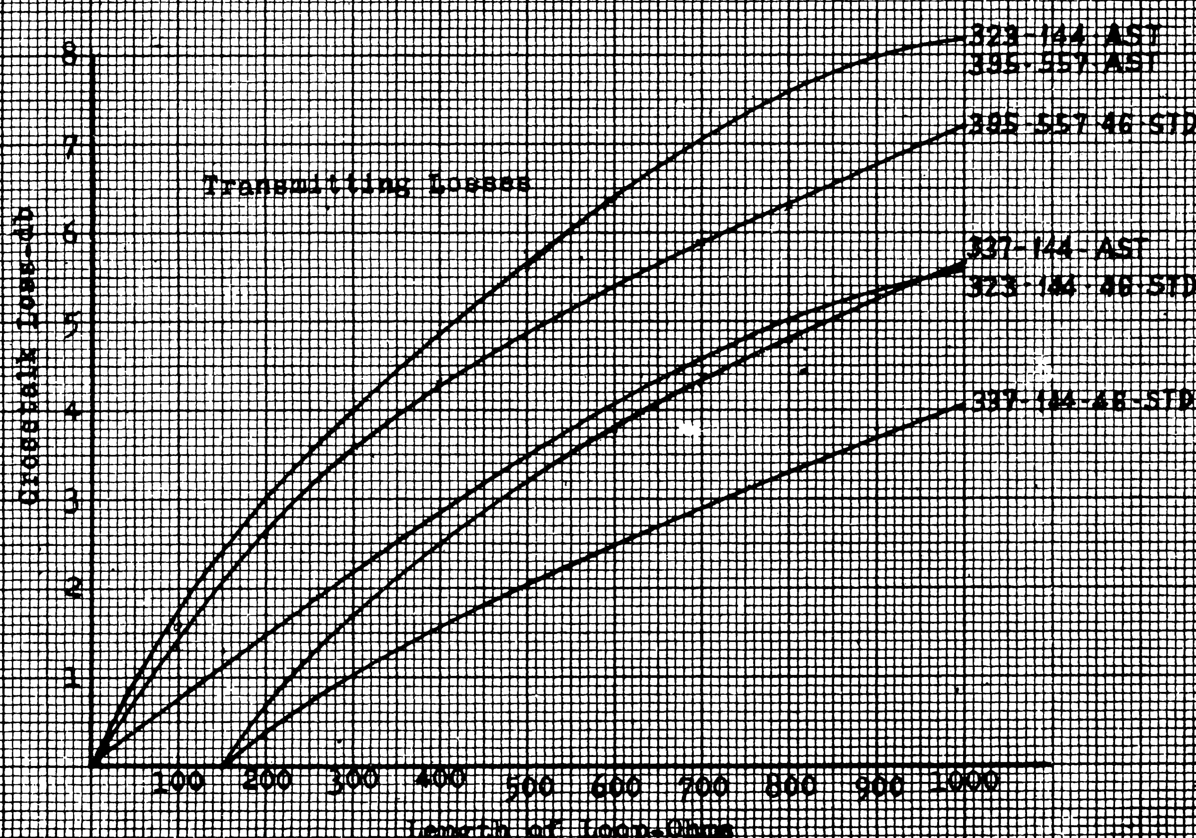
611-189

TRANSMITTING AND RECEIVING CROSSTALK LOSSES AND GAINS FOR VARIOUS LOOPS

No. 1 and No. 10 Manual and Panel M.S.

24-Volts
STD-Standard Connection
AST-Anti-Sidetone Set





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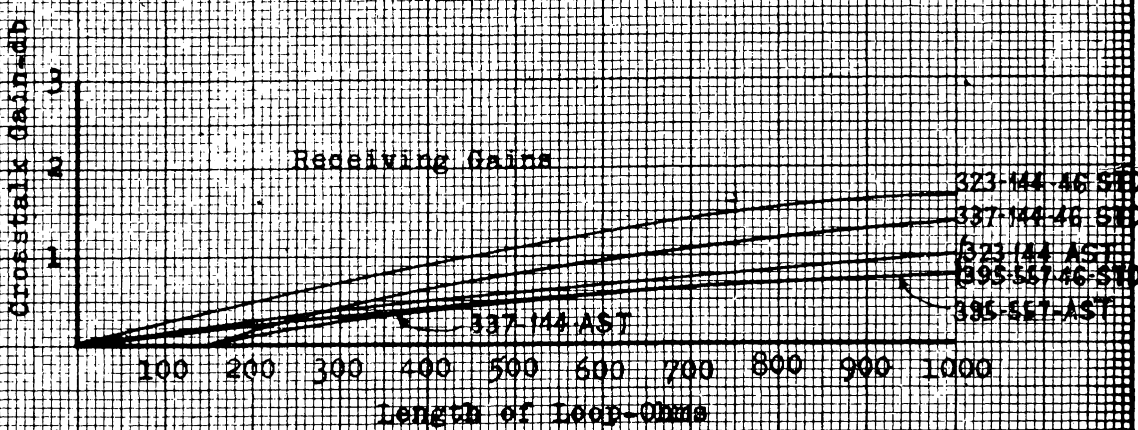
611-190

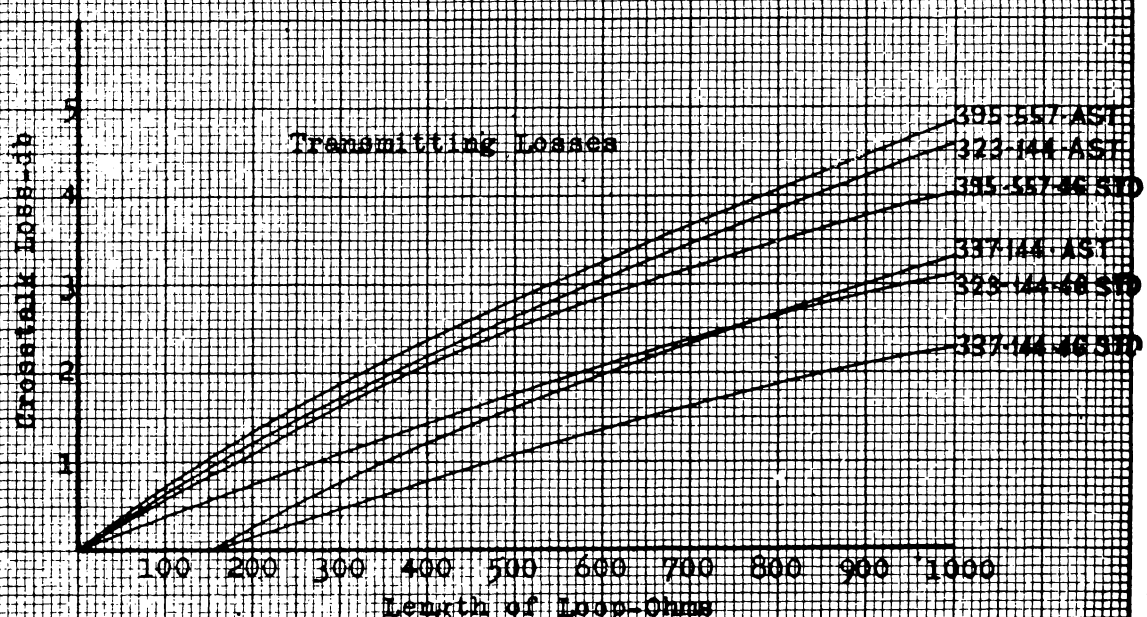
TRANSMITTING AND RECEIVING CROSSTALK LOSSES AND GAINS FOR VARIOUS LOOPS

48-Volt Step-by-Step M.S.

STD-Standard Connection

AST-Anti-Sidetone Set





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Dept. of
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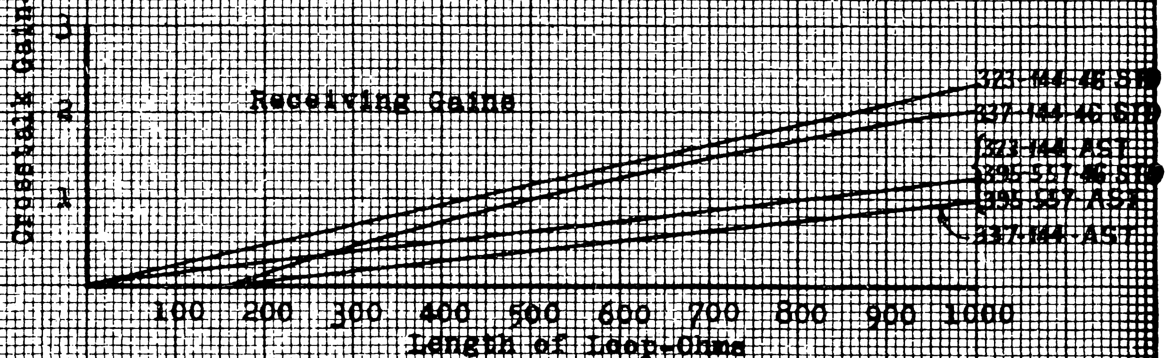
611-191

TRANSMITTING AND RECEIVING CROSSTALK LOSSES AND GAINS FOR VARIOUS LOOPS

48-Volt Toll Connection
STD-Standard Connection
AST-Anti-Sidetone Set



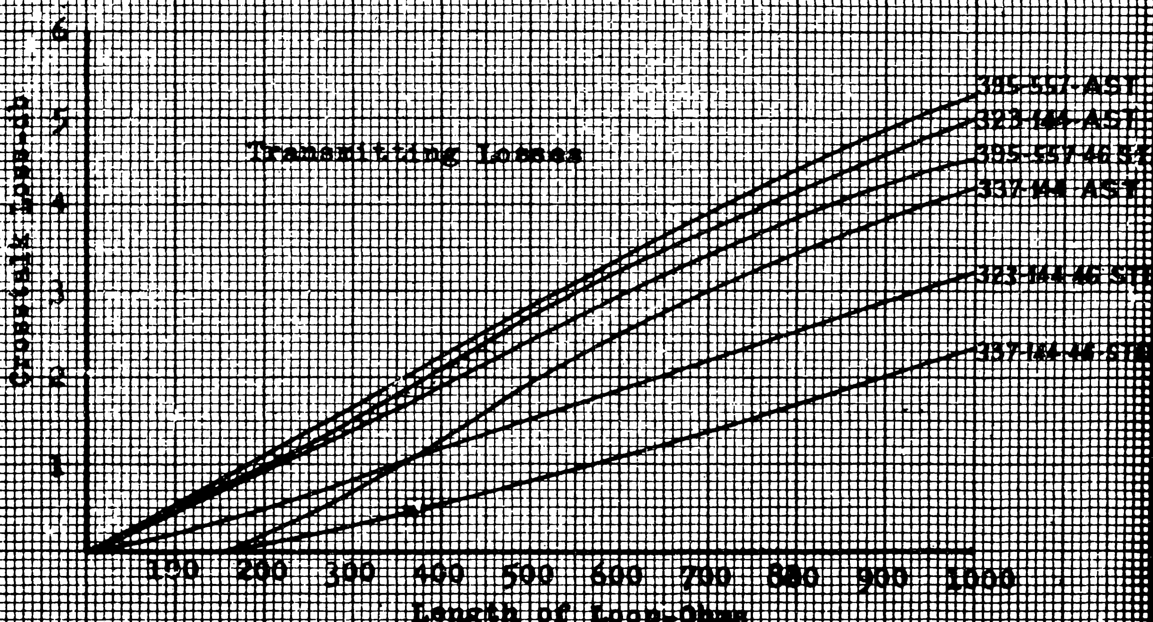


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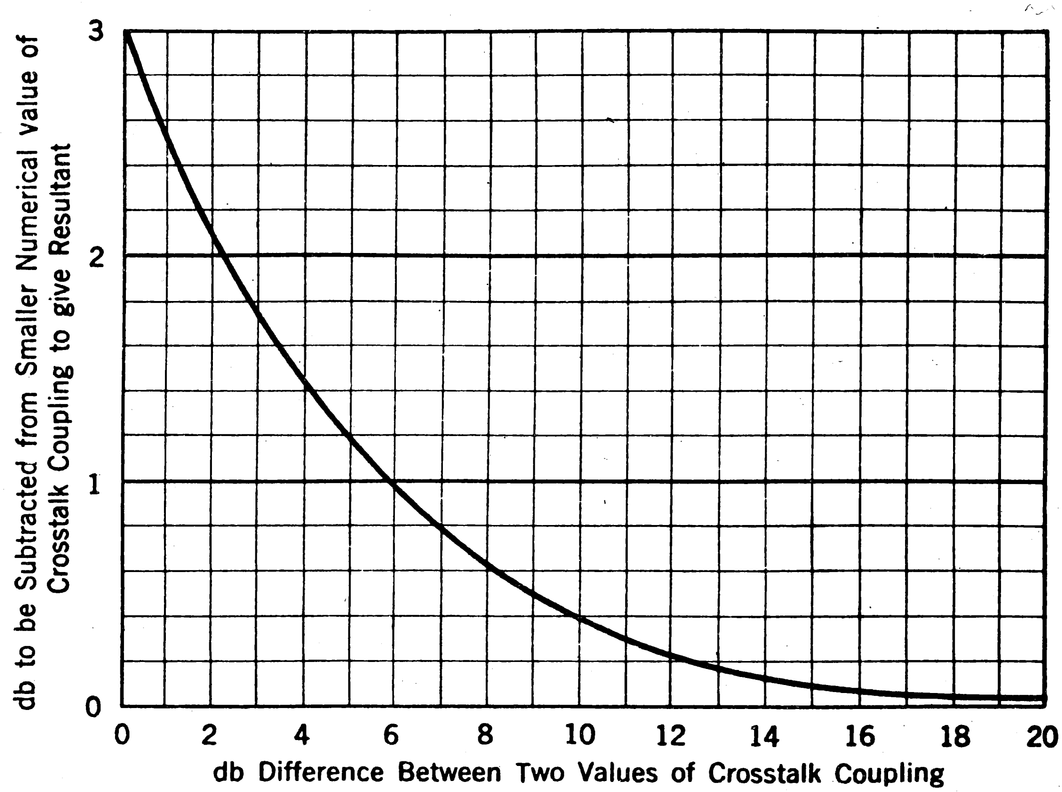
CHART FOR R. S. S. SUMMATION OF TWO VALUES OF CROSSTALK COUPLING IN DB



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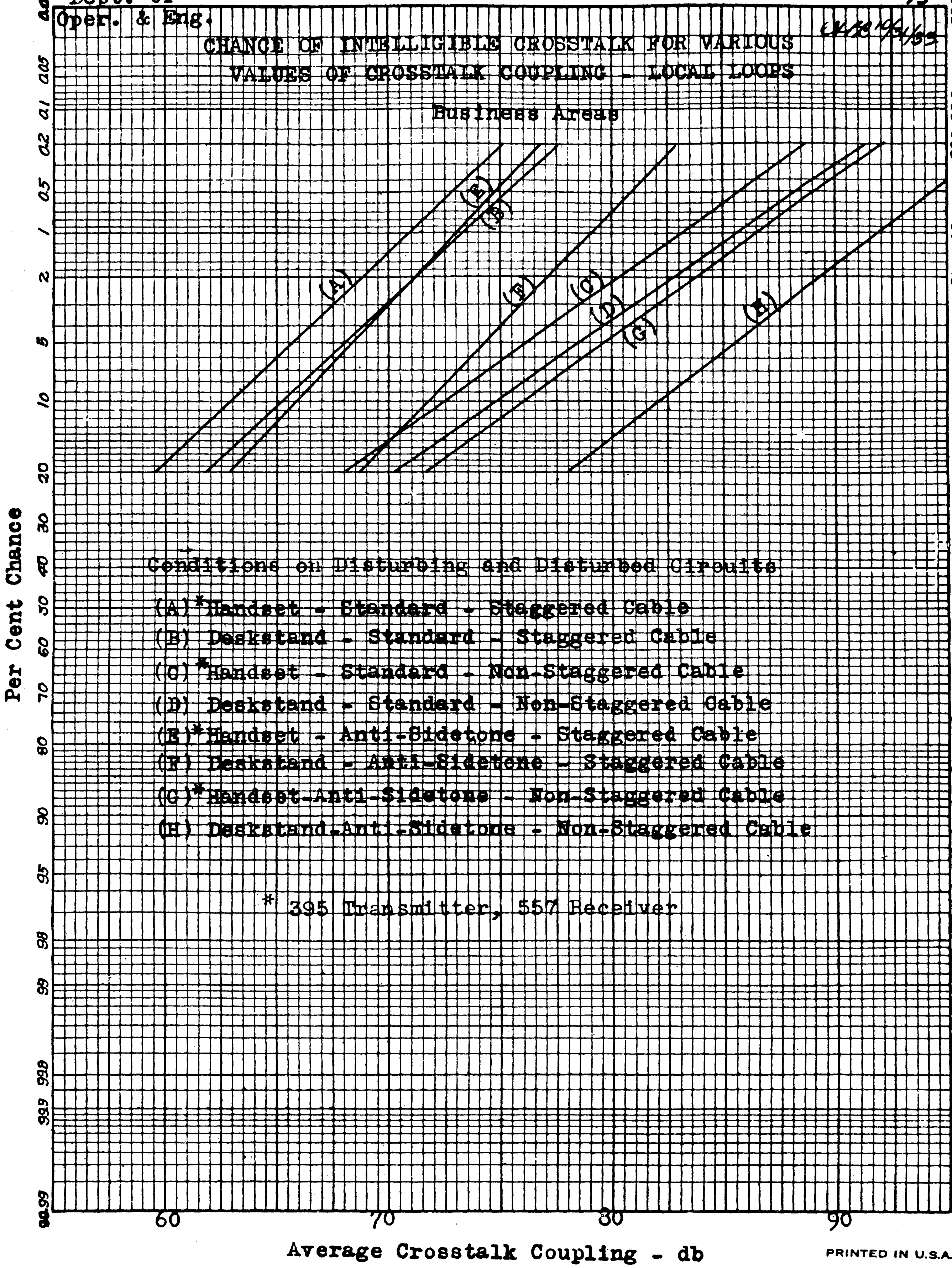
611-193



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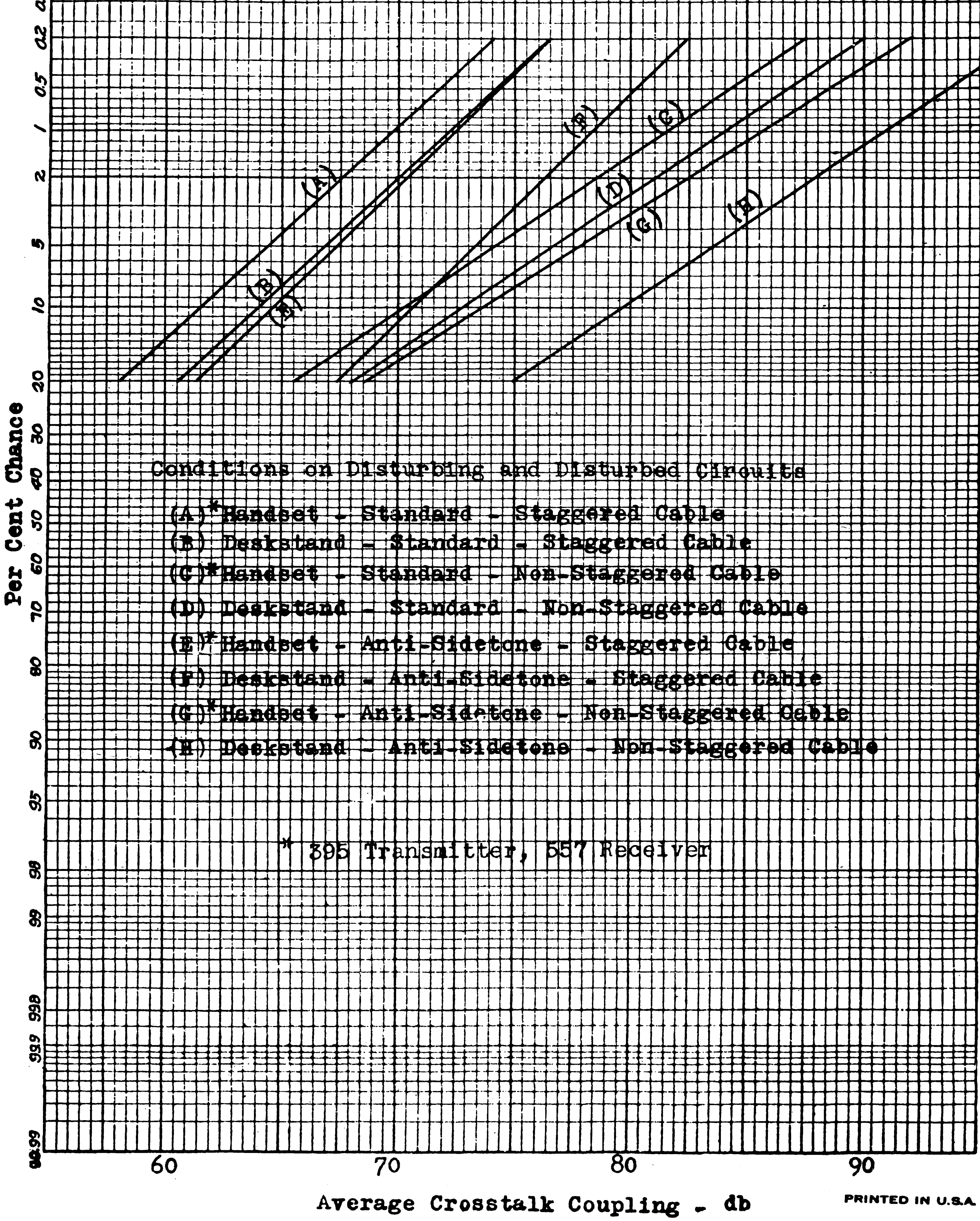
611-194

CHANCE OF INTELLIGIBLE CROSSTALK FOR VARIOUS VALUES OF CROSSTALK COUPLING - LOCAL LOOPS

Combination Business & Residential Areas



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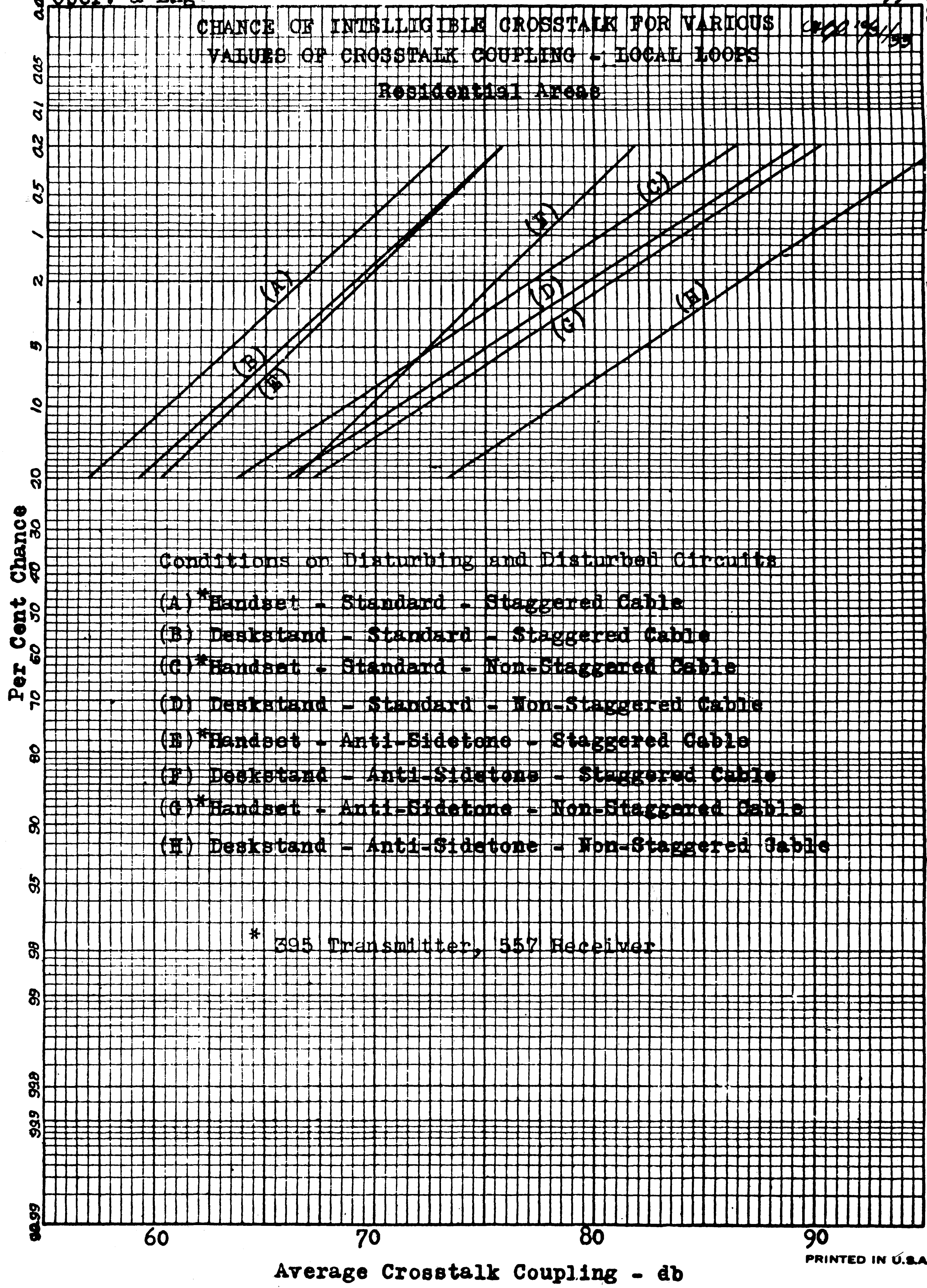

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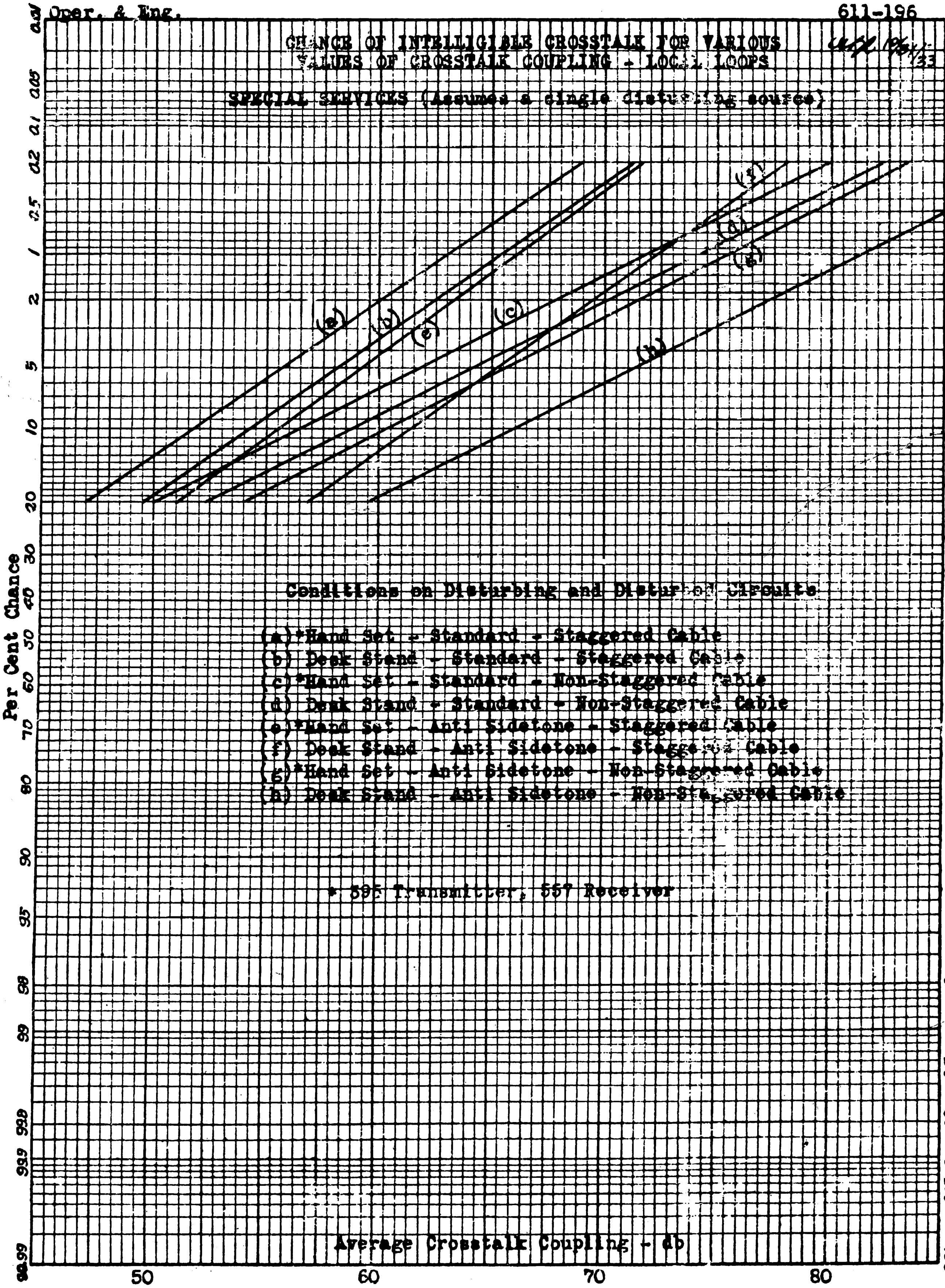
611-196



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