DESIGN OF TWO-WIRE D-66 LOADED NEGATIVE RESISTANCE REPEATERED TRUNK PLANT

CONTENTS

1. SCOPE

1.1 This section provides REA borrowers, consulting engineers, contractors and other interested parties with technical information for use in the design and construction of REA borrowers' telephone systems. It discusses in particular the design of 2-wire voice frequency trunk plant intended for toll connecting and EAS applications, as well as other special low loss applications, using D-66 loading and E-6 type negative resistance voice frequency repeaters with the most economical cable gauge selection.

1.2 This section does not include information on the application to open wire voice frequency trunk plant or to E-6 type repeaters in intermediate locations. REA TE & CM-444, "Negative Resistance and Negative Impedance Voice Frequency Repeaters and Voice Frequency Repeatered Trunks," discusses these applications and reference should be made to that section. This section also does not provide information on trunk applications on a 4-wire voice frequency basis. At this time, the additional cost inherent with 4-wire voice circuits, despite the utilization of the finer gauge cables which is possible, generally does not allow their usage on an economical basis. From the transmission standpoint, facilities, electronic equipment and techniques exist which allow all normal transmission objectives to be met more economically on the basis of 2-wire operation.

1.3 Because the transmission design herein allows substantial circuit lengths to be treated adequately on a 2-wire basis from both the economic and normal transmission objective standpoints, it will be very difficult to justify 4-wire voice circuits on new construction. On existing systems, this may not be the case. There, poor return loss characteristics due to mixed gauges, irregular spacing, older type distribution wires and other earlier practices may not permit present transmission objectives to be met on a 2-wire basis. In such instances, consideration must be given to operating the circuits on a 4-wire voice frequency basis or by means of cable carrier and carrier frequency repeaters or to make the necessary changes and provide improvement to the plant which will allow the 2-wire design intended herein to be used. Whichever solution is the more economical initially and for the future should be utilized. Improving the performance of the existing plant so that 2-wire voice frequency operation can be retained is further discussed in other paragraphs herein.

1.4 The factors which make it possible to utilize the finer gauge conductors, thus making the design herein economical and which also make it possible to meet all transmission objectives, are the use of D-66 loading and the E-6 type negative resistance repeaters. The D-66 loading is capable of high structural return loss performance. As discussed in REA TE & CM-444, a minimum value of 25 db single frequency structural return loss and 32 db in the echo range is obtained. High values of structural return loss coupled with the inherent higher gain capability of the E-6 type repeater make it possible to serve the shorter distances with the finer gauge cables while very long distances can be served with cables no coarser than 19 gauge. For example, for toll connecting applications using repeatered 24-gauge cable D-66 loaded, it is possible to serve distances of up to 8.5 miles while repeatered 19-gauge cable, D-66 loaded can be used up to 40 miles in length. Because D-66 loaded cables are capable of imparting high return loss performance, there is no need from the transmission standpoint for the more expensive low capacitance type cable (0.062 or .066 microfarads per mile, also known as toll grade). All normal transmission requirements can be met solely on the basis of exchange type cable, of .083 ± 0.004 microfarads per mile as set forth in the REA PE cable specifications.

2. TRANSMISSION OBJECTIVES AND REQUIREMENTS

2.1 The transmission parameters which are generally of interest in toll connecting, EAS and other special trunk applications which the 2-wire design discussed herein takes into consideration are as follows:

2.11 Repeatered or Net Circuit Loss at 1000 cps
2.12 Circuit Frequency Response relative to 1000 cps
2.13 Stability
2.14 Echo Return Loss
2.15 Singing Point
2.16 Noise

The transmission objectives and requirements applicable to the above parameters and met in the 2-wire design herein are discussed in paragraphs 2.2 to 2.7 below:

2.2 Repeatered or Net Circuit Loss at 1000 cps

2.21 A net circuit loss of VNL+2 db for toll connecting trunks in accordance with the objectives in the AT & T Company's "Notes on Distance Dialing" 1961 and 4 db at 1000 cps for direct EAS trunks.

2.3 Circuit Frequency Response

2.31 A net circuit loss of ± 1 db at 2000 cps and + 1 to -3 db at 3000 cps, relative to the 1000 cps loss, as contained in the REA Form 397a, "Performance Requirements for Voice Frequency Repeaters and Voice Frequency Repeatered Trunks."

2.4 Circuit Stability

2.41 Unconditional circuit stability, without the use of idle line circuit terminations or other repeater disabling means, when the repeatered circuit terminal ends are tested under the condition of open-open, short-short, open-short, short-open terminations. This requirement applies equally well to toll connecting and EAS trunks.

2.5 Echo Return Loss

2.51 An echo return loss of at least 18 db on toll connecting trunks measured at the Class-4 (Toll Center) office toward the Class-5 office (End Office), using the W. E. Co. 201B Noise Generator and 3A Noise Measuring Set or equivalent, C-message weighted, between 900 ohm and 2 microfarad terminations as per requirements in the AT & T Company Blue Book, "Notes on Distance Dialing" 1961. There is no comparable requirement on EAS trunks. However, where the design herein is used for both toll and EAS trunks, the EAS trunks are capable of meeting the same return loss performance.

2.6 Singing Point

2.61 A singing point of at least 10 db at any frequency between 300 to 3000 cps on toll connecting trunks measured at the Class-4 office toward the Class-5 office using a W.E. Co. type 2D Singing Point Test Set or equivalent as per the requirements in the AT & T Company's Blue Book, "Notes on Distance Dialing," 1961. There is no comparable requirement on the EAS trunks. However, where the design herein is used for both toll and EAS trunks, the EAS trunks are capable of meeting the same singing point performance.

2.7 Noise

2.71 Circuit noise is an additional consideration. Noise is controlled by proper repeater design, installation and alignment practices, correct cable design and installation procedures, and proper inductive coordination practices. For this reason, noise is not directly associated with the type of loading system or type of repeater used. Nevertheless, where the system has been designed in accordance with practices covered in other sections of the Manual, noise levels of 20 dbrn-C or lower can be expected as maximum values. In connection with buried plants, noise levels of as low as 0 and even -10 dbrn-C have been measured in actual operating systems in REA borrowers' projects.

2.8 Figures 1 to 9 herein are direct measurements in the field on REA borrowers' systems and in the laboratory and are typical of the resulting transmission performance when using D-66 loading and E-6 type negative resistance repeaters on a 2-wire basis. It should be noted that the higher frequency performance of the artificial loaded lines is not as good as that possible when using the actual cables.

3. APPLICATION AND USE OF THE DESIGN CHARTS

3.1 Information has been prepared and shown in Charts I-III herein for designing 2-wire trunk plant using the simplified method of this section. For a given circuit length the charts show the corresponding available repeater gain which meets the required transmission objectives. Both toll connecting and direct EAS trunk applications are shown. It is only necessary that the circuit length be known for the cable gauge under consideration; the Chart furnishes the repeater gain which can be used for this length and gauge. Conversely, for a given transmission objective in either toll or EAS trunk application, the most economical gauge can be selected.

3.2 Design Charts I-III apply to trunk circuits which are derived entirely on a voice frequency basis or which are voice frequency extensions from radio multiplex or carrier equipment. The design applies to one uniform gauge only, to one type of loading system, D-66; that is, 24-D-66 only, 22-D-66 only, 19-D-66 only. Design Charts I-III do not apply to the following situations, though the requirements of paragraphs 3.31 to 3.33 below are met:

3.21 Mixed gauge cables D-66 loaded
3.22 Compensated D-66/H-88 loaded cables using the junction impedance compensator
3.23 Loading systems other than D-66
3.24 Intermediate repeater applications

Where the situations of paragraphs 3.21 to 3.24 above arise, the design procedures in REA TE & CM-444 should be used.

3.3 <u>In new construction</u>, the following requirements must be met by the D-66 loaded outside plant facilities in order that the design Charts shown herein can be used.

3.31 The outside plant is designed, staked and constructed to meet the D-66 load spacing requirements of paragraph 3.04 or 3.05, REA TE & CM-431, "Voice Frequency Loading for Trunk Cables."

3.32 The cable meets the mutual capacitance requirements of .083 $\pm$ .004 microfarads per mile average, in the REA PE cable specifications.

3.33 The 66 mh loading coils meet the requirements in REA PE-26 loading coil specification.

3.34 The structural return loss and facility loss of the outside plant has been measured and meets the requirements set forth in REA TE & CM-445, "How to Make Structural Return Loss Measurements," and REA TE & CM-408, "Facility Requirements for Voice Frequency Repeatered Trunks," respectively.

Paragraphs 3.4 below discusses the procedure to be followed in <u>existing</u> plant for those cases where it may not be possible to meet the requirements of paragraphs 3.31 to 3.33 above.

3.4 <u>In existing plant</u> where both the distance and the gauge are fixed, the above design, if it could be made possible to apply, would enable the trunks to meet improved transmission objectives and operate at presently required values of net loss, frequency response, echo return loss, and singing point. In other instances, special applications may be involved requiring low loss (2 db net loss) operation of the circuits, such as for example, tandem EAS with a connecting company where the over-all loss of both links cannot exceed 4 db. The addition of a second cable, for example, in order to add to the existing cable pairs and convert the circuits to 4-wire operation may mean not only the added investment in cable costs but the elimination of the existing central office trunk equipment as being no longer suitable. Further, while the 4-wire solution, if used, will make it possible to operate the circuits at a lower net loss, it will not improve circuit frequency response characteristics since presumably the type of loading system will remain the same.

3.41 The procedure discussed below may be found considerably more economical than any proposed 4-wire voice or cable carrier solution and therefore its use should be given careful consideration when planning transmission improvement programs for <u>existing</u> systems:

3.411 Measure the mutual capacitance of the cable pairs intended for trunk operation. Use the measuring procedure and test equipment contained in TS-1, "Testing Standards," 1964.

3.412 Lay out a new load spacing system as follows: If the measured capacitance of the pairs does not exceed .083 $\pm$ .004 microfarads average per mile, locate the loading points at 4500 foot intervals using 66 millihenry loading coils and meeting the load spacing deviation requirements in REA TE & CM-431, paragraphs 3.04 or 3.05.

3.413 If the measured average capacitance of the pairs is higher than .083 $\pm$ .004 microfarads, per mile, locate the loading points at 0.071 microfarad intervals, using 66 mh loading coils. (It is ultimately the capacitance which is the important consideration; not the physical length.)

3.414 Measure the structural return loss and facility loss of the completed plant as per paragraph 3.34. A value of structural return loss of 25 db minimum (worst value at single critical frequency in a 300 to 3000 cps band) should be obtained.

3.5 How to Use Charts I-III

3.51 Charts I-III can be used to find the gain which the repeater should be set for (gain - unit gain) to meet the transmission requirement for the particular type of service once the distance and repeater location(s) is known. More important, however, it can be used in reverse. That is, when the distance between offices is known, to select from the charts the minimum gauge and minimum number of repeaters that will meet the objective. The examples discussed below are illustrative on how to use the Charts.

3.511 Assume that toll connecting trunks are to be provided between two offices 4.5 miles apart. There is no EAS between the same two offices. What is the most economical gauge which should be selected to meet transmission objective?

Ans.: Reference to Chart I for 24-gauge D-66 loaded, indicates that a length of up to 6.6 miles (35 KF) can be used with this gauge and meet VNL+2 transmission objectives using an E-6 type repeater at the Class-5 office. Therefore, the 4.5 miles required can be 24-gauge. Follow the 4.5 mile (23.8 KF) on the horizontal scale of Chart I, until it intersects the curve of interest (VNL+2 db, One term. E-6 at C-5 only, in this example). Refer this point to the vertical scale which gives 4.8 db gain - unit gain.[1] Setting the repeater for this gain will result in a circuit operating at VNL+2 db for the circuit length and no other transmission computations are necessary.

3.512 Assume that an existing toll connecting group of trunks has been redesigned using the criteria of paragraph 3.4 due to upgrading reasons. The existing toll trunks are 7.6 miles of 22-gauge cable. What is the repeater gain which can be used?

Ans.: Enter Chart II for 22-gauge D-66 at 7.6 miles (40.1 KF) on the horizontal scale. The point of intersection between 40.1 KF and the "VNL+2 db, One Term. E-6 Repeater" curve is read on the vertical scale. This gives 4.7 db gain-unit gain. By setting the E-6 repeater for this gain at the Class-5 office the circuit net loss will be VNL+2 db for that length.

3.513 Assume a toll connecting trunk is to be operated as a voice frequency extension off W.E. Co. "ON2" carrier. The length of the v.f. portion is 12.1 miles. What is the minimum gauge which can be used?

Ans.: Reference to Chart II for 22-gauge, D-66 loaded, indicates that VNL+2 objectives can be met up to 78 KF (14.8 miles) if the carrier can be set to operate at a net gain of 3 db for its portion. Therefore the 12.1 miles required can be 22-gauge. Enter the 12.1 miles (64 KF) in the horizontal scale of Table II until it intersects the "VNL+2, One Term. E-6 at C-5, second E-6 at T.C." curve. Read this point on the vertical scale of the curve. This is 5.5 db. Thus, by operating the E-6 repeater at the C-5 office at 5.5 db gain-unit gain with the carrier at a net gain of 3 db for its portion VNL+2 objectives are met. If, for valid reasons, it is not possible to operate the carrier portion at a 3 db net gain some of this additional gain required can be made up in the E-6 repeater at the C-5 office. That is, gains can be transferred. In this particular instance the E-6 can be operated at 5.5+2 = 7.5 db gain, and the carrier at 3-2 = 1 db gain. The total gain, it should be noted, remains the same at 8.5 db (5.5+3.0 = 8.5 db, or 7.5 + 1.0 = 8.5 db) and the limitation on how much gain to transfer to the E-6 repeater is controlled by crosstalk. A gain of 7.5 db for the terminal E-6 must therefore not be exceeded for reasons of crosstalk.

3.514 Assume that EAS service is to be provided between two towns 9.5 miles apart via direct trunks and that the construction is new. How can this be best accomplished?

Ans.: Reference to Chart II for 50 KF of 22-gauge D-66 indicates that one E-6 terminal repeater set at 4.9 db gain will produce a 4 db net loss circuit. Reference to Chart I for 24-gauge D-66 indicates that two E-6 repeaters, one at each office location, set for 5.2 db gain each will also result in a 4 db net circuit loss. Therefore, if there are no other local factors which conflict, the 24-gauge solution with two repeaters will be more economical.

3.515 There is both toll connecting VNL+2 trunks and direct EAS trunks between two offices 10.6 miles apart and the construction is new. How can the transmission be provided?

Ans.: Reference to Chart II for 56 KF of 22-gauge, D-66 loaded indicates that this gauge will meet both toll and EAS requirements. The toll connecting trunk repeaters at the C-5 office set for a 7.0 db gain will result in a VNL+2 db net circuit loss while the EAS trunks need only to be set at 5.8 db to meet the 4 db circuit net loss requirement. From the standpoint of avoiding transmission contrasts, the EAS repeaters can also be set for 7.0 db gain-unit gain. For maintenance reasons, both EAS and toll repeaters should be located at the C-5 office for ease of maintenance.

[1]Refer to REA TE & CM-444, paragraph 6.03.

3.516 There are toll connecting trunks to a connecting company's office and tandem EAS trunks through that office. The connecting company's transmission objective for the tandem EAS is such that each link should not exceed 2 db in order that the overall circuit not exceed 4 db switch-to-switch. The distance is 10.0 miles and construction is new. Find the most economical gauge which will meet the 2 db requirement.

Ans.: Reference to Chart II for 53 KF of 22-gauge, D-66 loaded indicates that VNL+2 db on the toll trunks for this length can be met by setting the E-6 repeater at the C-5 office for 6.6 db. This will result in a net circuit loss of 2.4 + 0.04 x 10 = 2.8 db. Reference to Chart V (discussed in paragraph 5 below) curve 22-D-66, one terminal E-6 indicates that 53 KF of 22-D-66 cannot be operated at a 2 db net loss. The two terminal repeater, however, shows that the 2 db can be met rather easily, with as low as 0.8 db net loss being possible. Therefore, the special, low loss, EAS objectives can be met for this application on a 2-wire basis by using two terminal E-6 repeaters.

3.517 There is both toll connecting and direct EAS trunk service between two towns 16.7 miles apart and the construction is new. How can transmission be provided?

Ans.: Reference to Chart II indicates that for a length of 16.7 miles (88 KF) VNL+2 objectives with 22-gauge cannot be met but EAS objectives could be met by using two terminal E-6 repeaters set for 5.5 db gain-unit gain each. Because toll trunk transmission is controlling the 19 gauge is used. Reference to Chart III for 19-gauge, D-66 loaded, indicates that for 88 KF and one terminal E-6 repeater at the C-5 office a repeater gain of 5.3 db will result in the circuit meeting VNL+2. A gain of 4.4 db for one terminal E-6 repeater at either office (C-5 for ease of maintenance) will result in a net circuit loss of 4 db.

3.6 Basis of Computation for Deriving Charts

3.61 The computations used to derive Charts I-V herein are based on the following:

3.611 Single critical frequency structural return loss of 25 db in a 300 to 3000 cps band.

3.612 Central office losses of 0.5 db at each terminal end.

3.613 E-6 repeater LBO loss of 0.3, 0.4, and 0.5 respectively for 19, 22 and 24-D-66 loaded cables.

3.614 No BOR loss for 19 and 22 gauge, D-66 loaded cables.

3.615 BOR loss of 0.24 db per kilofoot for 24-D-66 only, with a total of 2 KF used per repeater location. (Assumes 0.5 cable end section)

3.616 Terminal E-6 repeaters at Class-5 offices do not exceed a 7.5 db gain-unit gain from crosstalk considerations. (The return loss allows higher repeater gain but crosstalk is controlling)

3.617 The computation procedures have been carried out in accordance with REA TE & CM-444 using the stability design method.

3.62 Where office losses are somewhat greater than the 0.5 db assumed (for example, a toll center COL may well be 0.7 or 0.9 db) or where it becomes necessary to use BOR on 22-gauge, or to remove the BOR from the 24-gauge such minor corrections (is in the order of + 0.5 db) can be reflected by modifying the repeater gains in Charts I-V.

3.7 Location of Repeaters at Toll Centers

3.71 Generally, it becomes difficult for 2-wire toll connecting trunks to meet echo return loss objectives if the repeaters are located at the Class-4 office (toll center). This is due inherently to the poor match possible between the repeater image impedance and that of the cable plant and also because these irregularities are amplified directly (no intervening circuit loss) at the point of measurement. For this reason the AT & T Company Bluebook "Notes on Distance Dialing" 1961 recommends that "For terminal trunks on 2-wire facilities, repeaters (V-type, E-type, etc.) should be located at the Class-5 office or intermediate point . . . . ."

3.72 When the type of loading system used is D-66 and the type of repeater the E-6, it is entirely possible to place the repeater equipment at Class-4 office locations and still meet (and better) the echo return loss requirements in the AT & T Company Bluebook. This comes as a direct result of the better impedance match between the flatter impedance characteristics of the D-66 loading (approximately 900 ohms in series with 2 microfarads in the echo band) and the image impedance of the E-6 repeater which is 900 ohms in series with 2 microfarads by design. Since the test termination specified in the AT & T Company Bluebook for the return loss measurement is also 900 ohms and 2 microfarads, the arrangement of an E-6 repeater at the toll center when operating over D-66 loaded cables, results in good echo return loss. To keep the return loss as high as possible the gain of the E-6 repeater at the toll center is kept to 3 db as a maximum. Also, the first E-6 repeater is always placed at the Class-5 office; it is only the second E-6 repeater, where required, that is placed at the Class-4 office. Where only one repeater is required to meet transmission objectives, it is always placed at the Class-5 office.

3.73 The inherent capability of the E-6 repeater for good echo return loss performance when used in conjunction with D-66 loading makes its use possible at toll center locations is shown in Chart VI. The echo return loss shown is for the repeater gain-unit only (no LBO) in approximately one db steps. For each additional db of repeater gain the echo return loss is reduced by approximately twice the repeater gain. For example, at 1 db repeater gain the echo return loss is 36 db while at 3.0 db gain it is 31 db. This 31 db echo return loss is still substantially higher than the 18 db overall required to be met by the AT & T Company Bluebook. It is for this reason that E-6 repeaters for 3.0 db gain can be used at toll center locations.

3.74 For return loss considerations it is recommended that repeaters other than the E-6 type operating on loading systems other than D-66 be <u>always</u> placed at the Class-5 office or at an intermediate location but never at the Class-4 office.

4. LENGTH-COVERAGE CAPABILITY OF THE 2-WIRE DESIGN

4.1 The capability of the design discussed herein from the standpoint of maximum circuit length for each uniform gauge which meets the VNL+2 objectives for toll connecting trunks and 4 db for direct EAS trunks is shown in Charts I-IV for trunks in new construction and which the requirements of paragraph 3.3 above or existing circuits which have met the requirements of paragraph 3.4 above.

4.2 VNL+2 Toll Connecting Trunks

4.21 For circuits entirely on a voice frequency basis, D-66 loaded and which have one terminal E-6 repeater at the Class-5 office, or for circuits which are voice frequency extensions from radio multiplex or carrier equipment which use an E-6 repeater at the Class-5 office and operate the carrier portion at an 0 db (zero db) net loss, the following distances can be served:

Facility	Length
24-gauge	up to 6.6 miles
22-gauge	up to 10.6 miles
19-gauge	up to 21.8 miles

4.22 For circuits entirely on a voice frequency basis, D-66 loaded with one repeater at the Class-5 office and with a second E-6 repeater at the Class-4 office providing 3 db fixed gain or for circuits which are voice frequency extensions from microwave or carrier equipment which use an E-6 repeater at the Class-5 office and operate the carrier portion at a net gain of 3 db the following distances can be served:

24-gauge	up to 8.5 miles
22-gauge	up to 14.8 miles
19-gauge	up to 29.2 miles

4.3 Direct EAS Trunks

4.31 For circuits entirely on a voice frequency basis, D-66 loaded, and which have one terminal E-6 repeater only located at either office, or for circuits which are voice frequency extensions from radio multiplex or carrier equipment which use an E-6 repeater at the Class-5 office and operate the carrier portion at a 0 db (zero db) net loss, the following distances can be served:

24-gauge	up to 7.8 miles
22-gauge	up to 12.7 miles
19-gauge	up to 24.1 miles

4.32 For circuits entirely on a voice frequency basis, D-66 loaded and which have one terminal E-6 repeater at each office location, the following distances can be served:

24-gauge	up to 13.3 miles
22-gauge	up to 21.6 miles
19-gauge	up to 40.7 miles

4.33 For circuits which are voice frequency extensions off radio multiplex or carrier equipment and which use one E-6 repeater at one office and 2 db of net gain from the carrier portion the following distances can be served:

24-gauge	up to 8.5 miles
22-gauge	up to 14.8 miles
19-gauge	up to 29.2 miles

Operating the carrier equipment at a <u>net gain of 3 db</u> allows distances greater than the ones shown above to be used.

5. ULTIMATE CIRCUIT TRANSMISSION CAPABILITY

5.1 The term "ultimate circuit transmission capability" is defined herein as the lowest possible net circuit loss at which the trunk can operate for nontoll connecting, special purpose applications on a 2-wire basis using D-66 loading and E-6 repeaters and the "stability design" method of REA TE & CM-444. Chart V gives the ultimate transmission information at a glance. No transmission computations are required. It is only necessary that the circuit length and gauge be known. This is shown in the horizontal scale. For each particular gauge and number of repeaters the vertical scale gives the lowest possible net circuit loss at which the circuit can operate.

5.2 This information in Chart V will be found extremely useful for the following applications:

5.21 For systems interconnecting with other companies which form one link of a two-link tandem and are required to operate at 2 db net loss per link.

5.22 For determining whether 4-wire voice or carrier operation of circuits must be considered due to low loss circuit requirements.

5.23 When improving existing EAS plant to meet the current 4 db direct trunk EAS objectives.

5.24 To study maximum number of switched links which can be used and still meet overall transmission requirements.

5.25 Other special low loss applications.

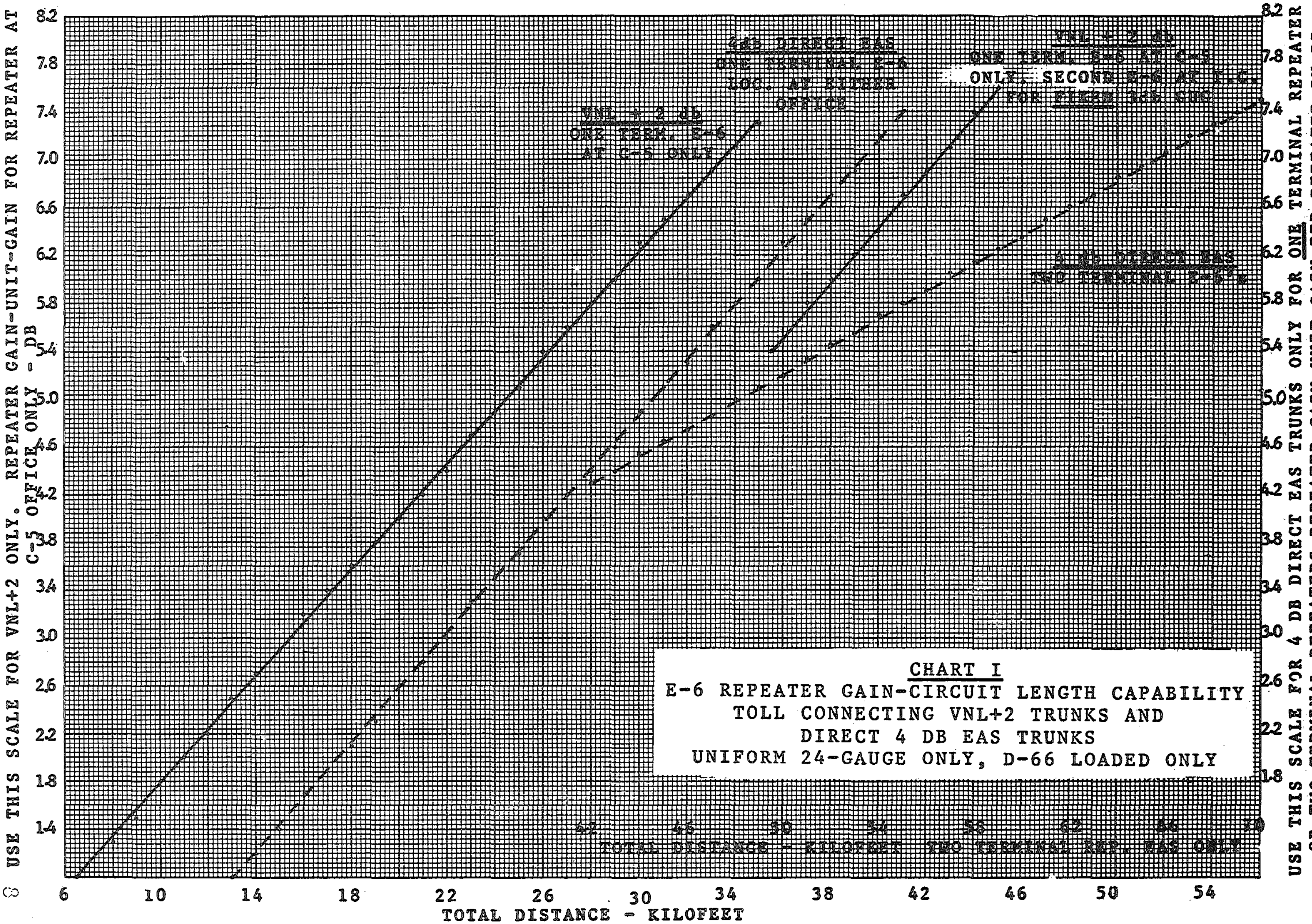
CHART I
E-6 REPEATER GAIN-CIRCUIT LENGTH CAPABILITY
TOLL CONNECTING VNL+2 TRUNKS AND
DIRECT 4 DB EAS TRUNKS
UNIFORM 24-GAUGE ONLY, D-66 LOADED ONLY
USE THIS SCALE FOR VNL+2 ONLY. REPEATER GAIN-UNIT-GAIN FOR REPEATER AT C-5 OFFICE ONLY - DB
USE THIS SCALE FOR 4 DB DIRECT EAS TRUNKS ONLY FOR ONE TERMINAL REPEATER OR TWO TERMINAL REPEATERS-REPEATER GAIN-UNIT-GAIN PER REPEATER IN DB
TOTAL DISTANCE - KILOFEET
TOTAL DISTANCE - KILOFEET TWO TERMINAL REP. EAS ONLY
VNL + 2 db
ONE TERM. E-6
AT C-5 ONLY
4db DIRECT EAS
ONE TERMINAL E-6
LOC. AT EITHER
OFFICE
VNL + 2 db
ONE TERM. E-6 AT C-5
ONLY, SECOND E-6 AT T.C.
FOR FIXED 3db CUC
4 db DIRECT EAS
TWO TERMINAL E-6's
8.2
7.8
7.4
7.0
6.6
6.2
5.8
5.4
5.0
4.6
4.2
3.8
3.4
3.0
2.6
2.2
1.8
1.4
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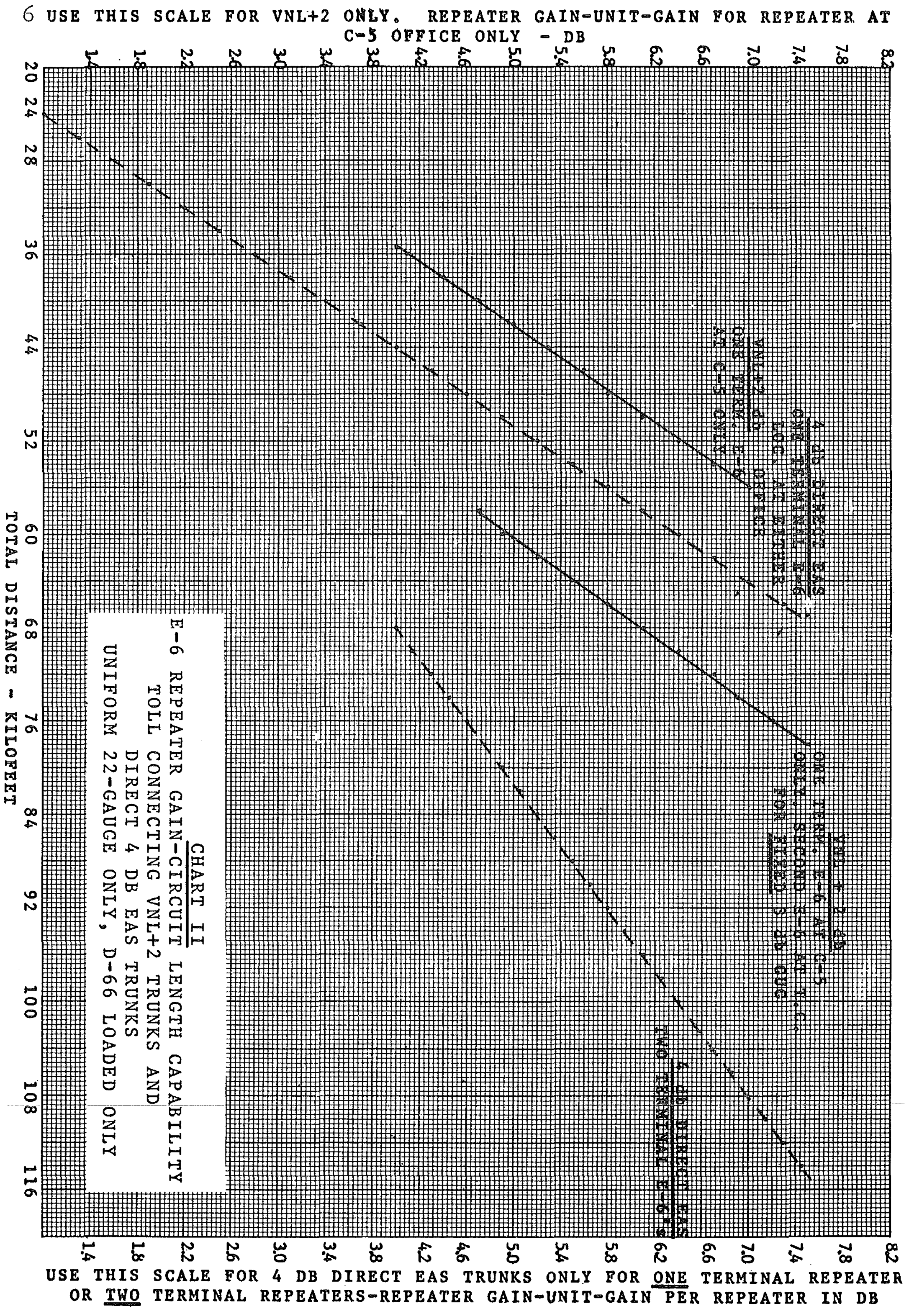

USE THIS SCALE FOR VNL+2 ONLY. REPEATER GAIN-UNIT-GAIN FOR REPEATER AT C-5 OFFICE ONLY - DB
TOTAL DISTANCE - KILOFEET
4 db DIRECT EAS ONE TERMINAL E-6 LOC. AT EITHER OFFICE
VNL+2 db ONE TERM. E-6 AT C-5 ONLY
VNL + 2 db ONE TERM. E-6 AT C-5 ONLY. SECOND E-6 AT T.C.
4 db DIRECT EAS TWO TERMINAL E-6's
CHART II
E-6 REPEATER GAIN-CIRCUIT LENGTH CAPABILITY
TOLL CONNECTING VNL+2 TRUNKS AND
DIRECT 4 DB EAS TRUNKS
UNIFORM 22-GAUGE ONLY, D-66 LOADED ONLY
USE THIS SCALE FOR 4 DB DIRECT EAS TRUNKS ONLY FOR ONE TERMINAL REPEATER OR TWO TERMINAL REPEATERS-REPEATER GAIN-UNIT-GAIN PER REPEATER IN DB

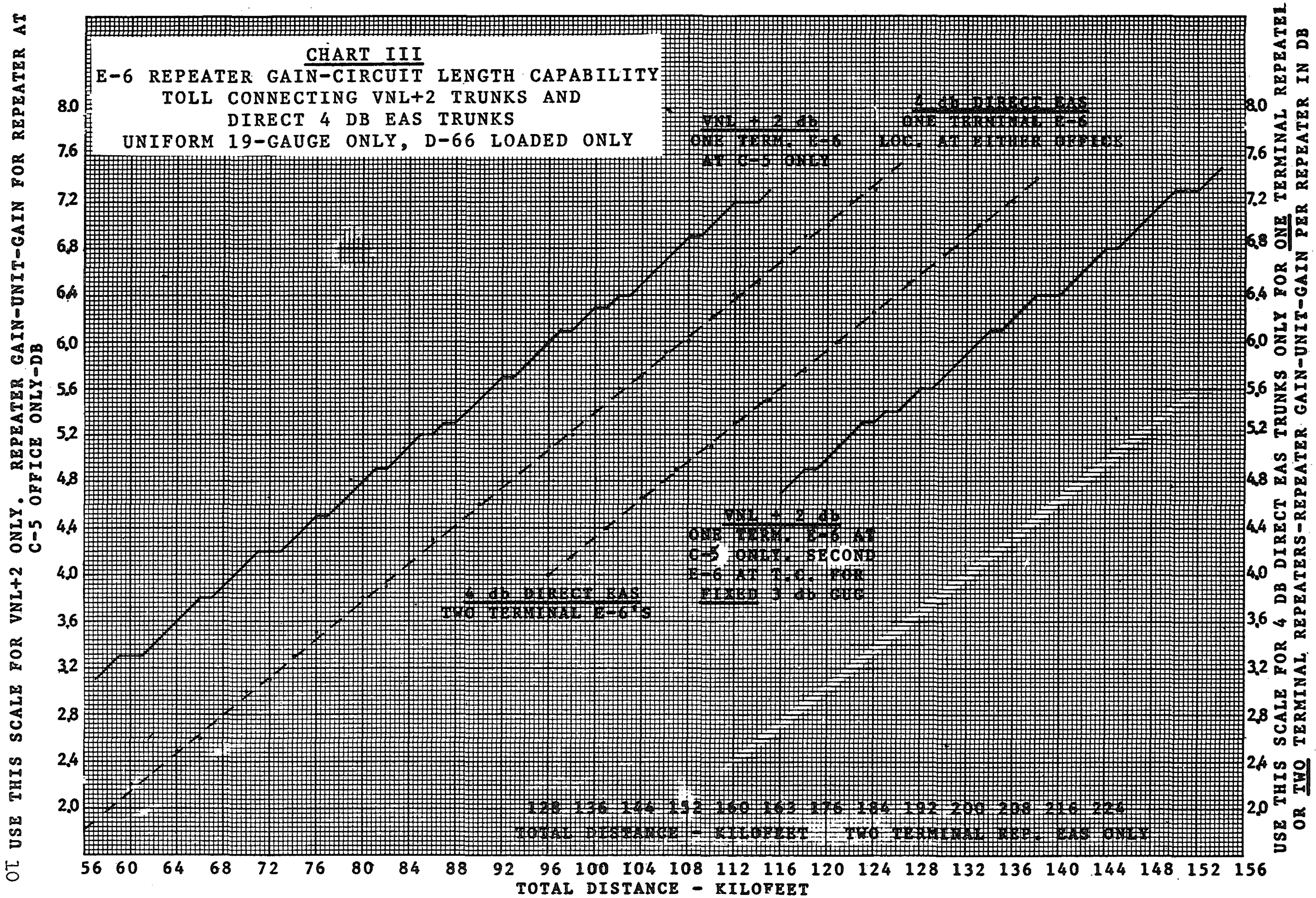
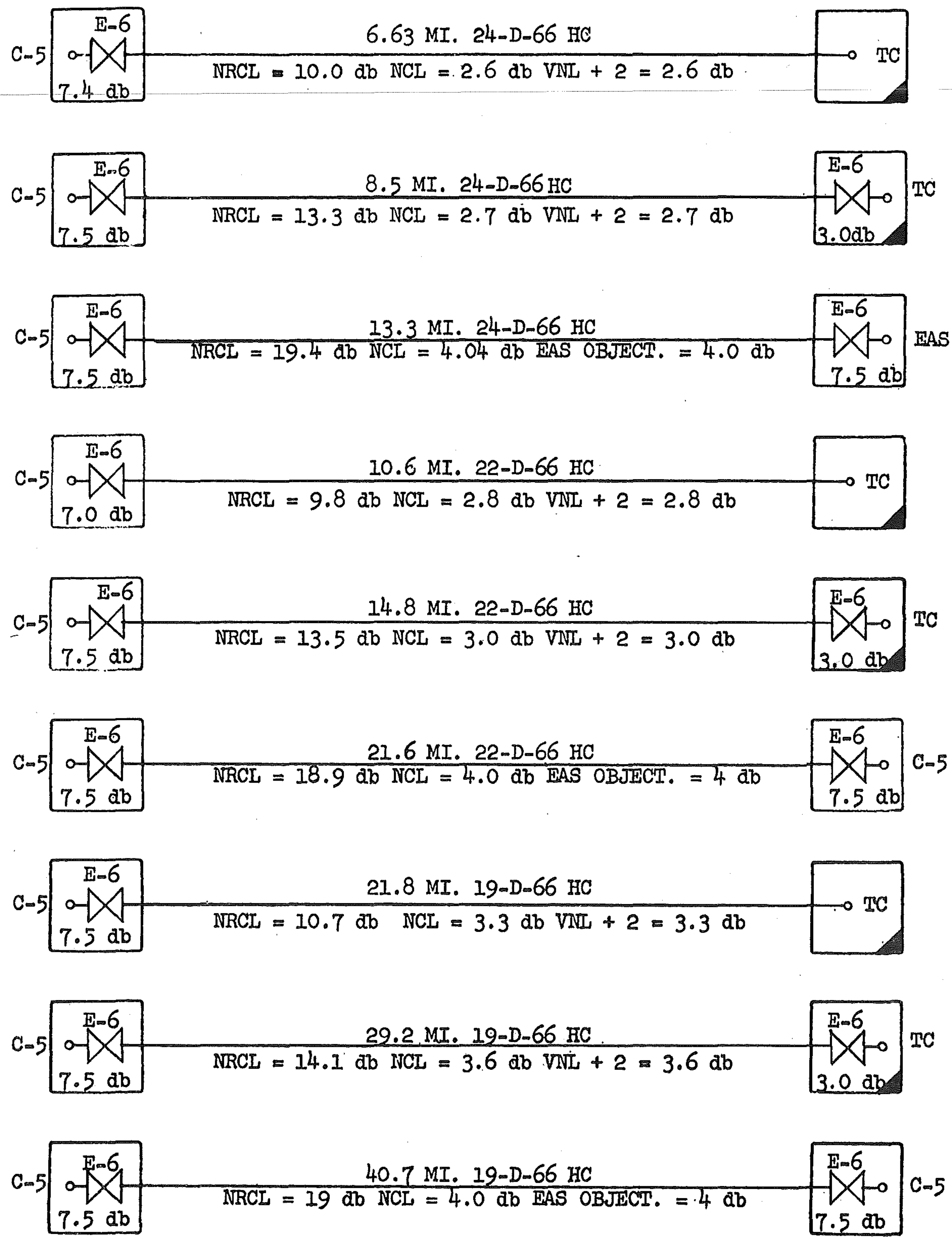


CHART III
E-6 REPEATER GAIN-CIRCUIT LENGTH CAPABILITY
TOLL CONNECTING VNL+2 TRUNKS AND
DIRECT 4 DB EAS TRUNKS
UNIFORM 19-GAUGE ONLY, D-66 LOADED ONLY
USE THIS SCALE FOR VNL+2 ONLY. REPEATER GAIN-UNIT-GAIN FOR REPEATER AT C-5 OFFICE ONLY-DB
USE THIS SCALE FOR 4 DB DIRECT EAS TRUNKS ONLY FOR ONE TERMINAL REPEATER OR TWO TERMINAL REPEATERS-REPEATER GAIN-UNIT-GAIN PER REPEATER IN DB
VNL + 2 db
ONE TERM. E-6
AT C-5 ONLY
4 db DIRECT EAS
ONE TERMINAL E-6
LOC. AT EITHER OFFICE
VNL + 2 db
ONE TERM. E-6 AT
C-5 ONLY. SECOND
E-6 AT T.C. FOR
FIXED 3 db CUC
4 db DIRECT EAS
TWO TERMINAL E-6'S
8.0
7.6
7.2
6.8
6.4
6.0
5.6
5.2
4.8
4.4
4.0
3.6
3.2
2.8
2.4
2.0
128 136 144 152 160 168 176 184 192 200 208 216 224
TOTAL DISTANCE - KILOFEET TWO TERMINAL REP. EAS ONLY
56 60 64 68 72 76 80 84 88 92 96 100 104 108 112 116 120 124 128 132 136 140 144 148 152 156
TOTAL DISTANCE - KILOFEET

10

CHART IV

LIMITING CIRCUIT LENGTHS WHICH MEET VNL + 2 OBJECTIVES FOR TOLL CONNECTING TRUNKS AND FOR 4 DB DIRECT EAS TRUNKS



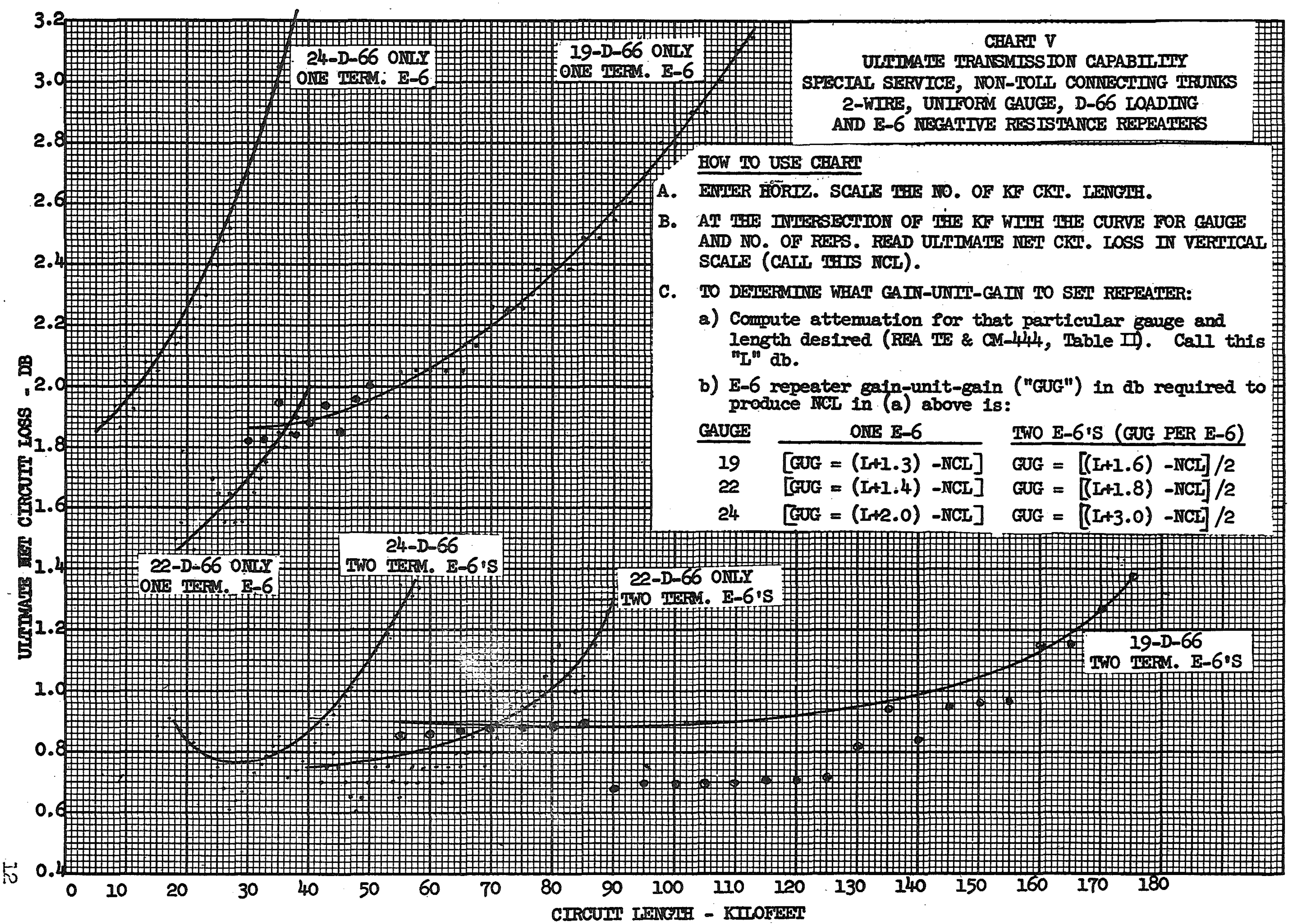
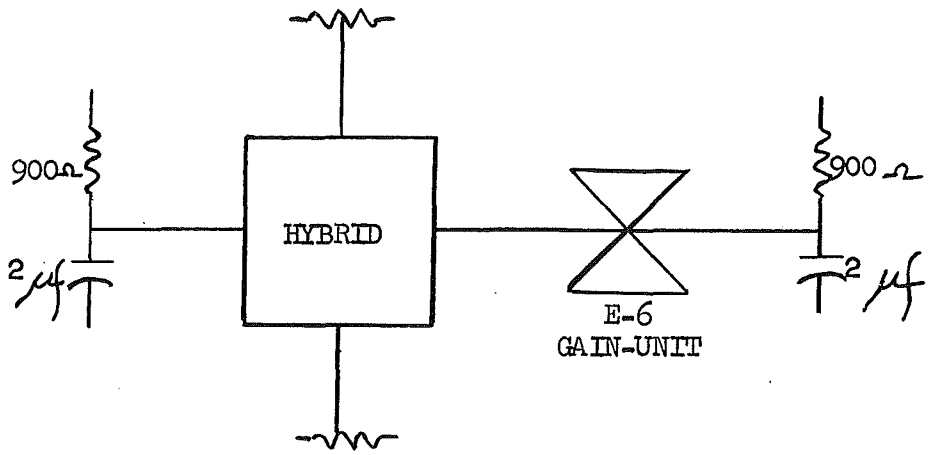


CHART V
ULTIMATE TRANSMISSION CAPABILITY
SPECIAL SERVICE, NON-TOLL CONNECTING TRUNKS
2-WIRE, UNIFORM GAUGE, D-66 LOADING
AND E-6 NEGATIVE RESISTANCE REPEATERS
HOW TO USE CHART
A. ENTER HORIZ. SCALE THE NO. OF KF CKT. LENGTH.
B. AT THE INTERSECTION OF THE KF WITH THE CURVE FOR GAUGE AND NO. OF REPS. READ ULTIMATE NET CKT. LOSS IN VERTICAL SCALE (CALL THIS NCL).
C. TO DETERMINE WHAT GAIN-UNIT-GAIN TO SET REPEATER:
a) Compute attenuation for that particular gauge and length desired (REA TE & CM-444, Table II). Call this "L" db.
b) E-6 repeater gain-unit-gain ("GUG") in db required to produce NCL in (a) above is:
GAUGE | ONE E-6 | TWO E-6'S (GUG PER E-6)
19 | [GUG = (L+1.3) -NCL] | GUG = [(L+1.6) -NCL]/2
22 | [GUG = (L+1.4) -NCL] | GUG = [(L+1.8) -NCL]/2
24 | [GUG = (L+2.0) -NCL] | GUG = [(L+3.0) -NCL]/2
24-D-66 ONLY ONE TERM. E-6
19-D-66 ONLY ONE TERM. E-6
22-D-66 ONLY ONE TERM. E-6
24-D-66 TWO TERM. E-6'S
22-D-66 ONLY TWO TERM. E-6'S
19-D-66 TWO TERM. E-6'S
ULTIMATE NET CIRCUIT LOSS - DB
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180
CIRCUIT LENGTH - KILOFEET

CHART VI
E-6 REPEATER GAIN UNIT-ECHO RETURN LOSS CHARACTERISTICS



REPEATER GAIN STEP-DB	ECHO RETURN LOSS-DB
1	36
2.1	34.5
3.0	31
4.0	28.5
5.1	25.5
6.0	23
7.0	20
8.0	17.5
9.0	14.5
10.0	10.5

NOTE: [1]Input power to repeater approximately 90 dbrn-c for repeater gain steps 1 to 6 db. 80 dbrn-c for 7 to 10 db gain steps.

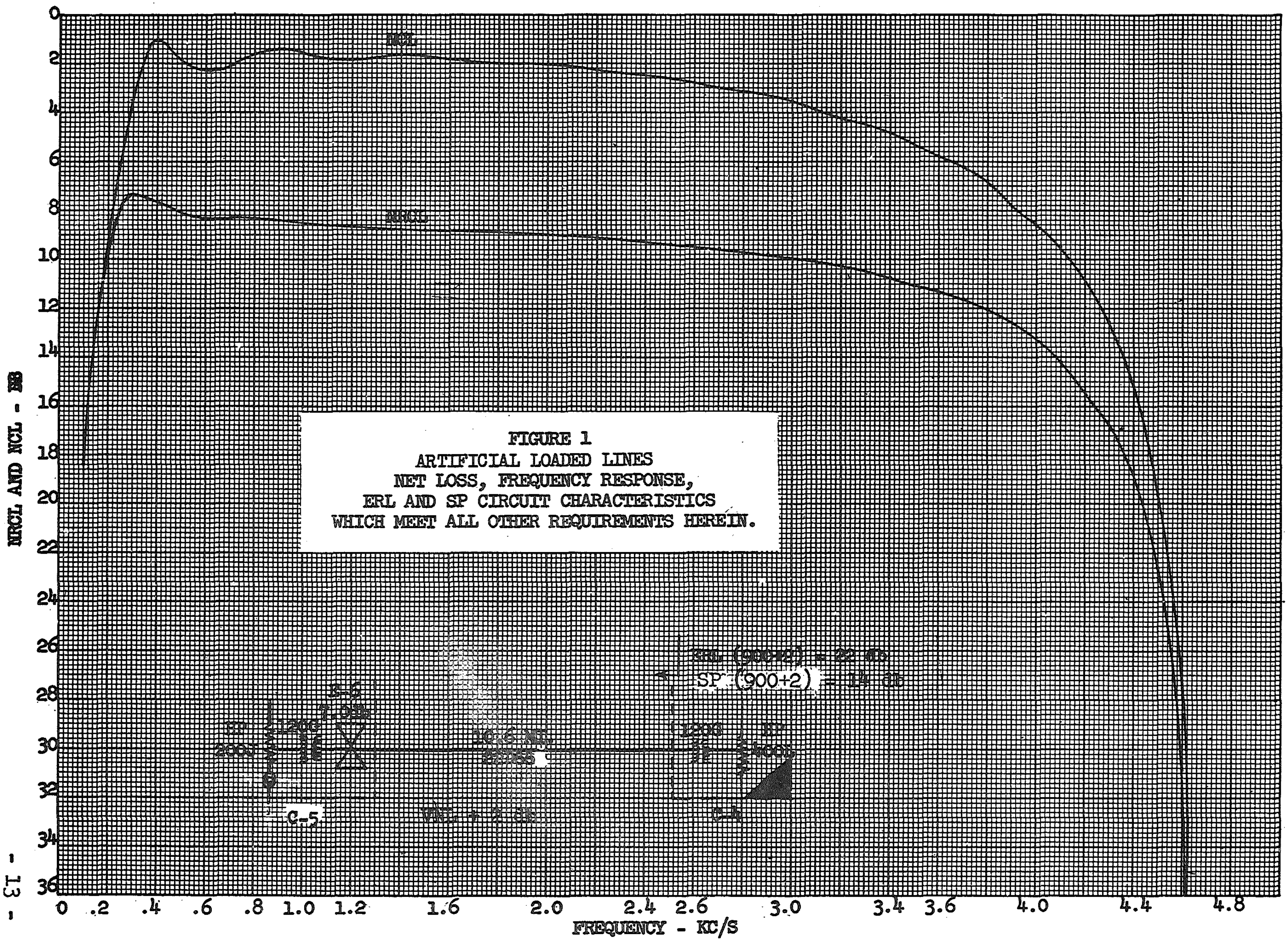


FIGURE 1
ARTIFICIAL LOADED LINES
NET LOSS, FREQUENCY RESPONSE,
ERL AND SP CIRCUIT CHARACTERISTICS
WHICH MEET ALL OTHER REQUIREMENTS HEREIN.

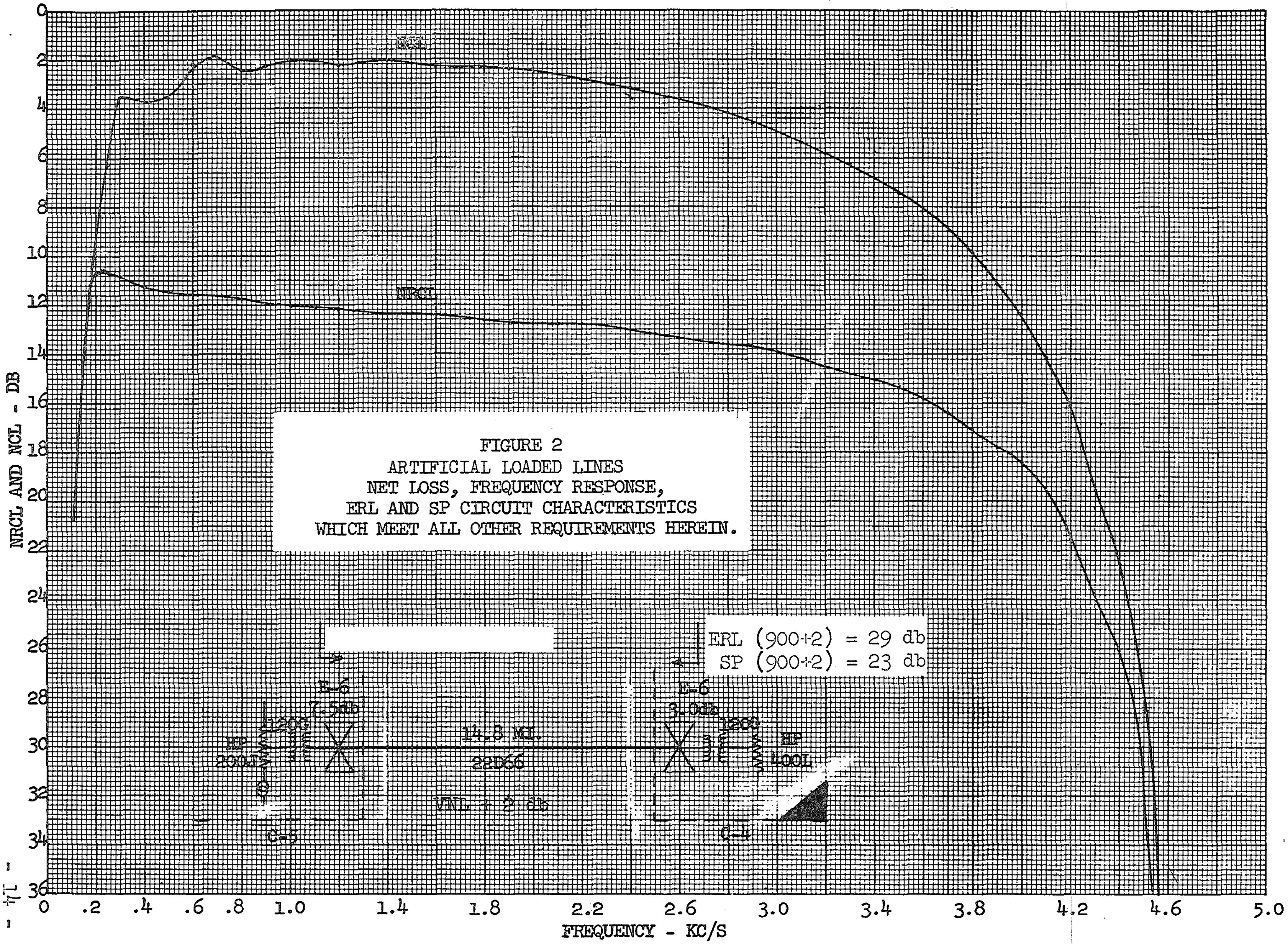


FIGURE 2
ARTIFICIAL LOADED LINES
NET LOSS, FREQUENCY RESPONSE,
ERL AND SP CIRCUIT CHARACTERISTICS
WHICH MEET ALL OTHER REQUIREMENTS HEREIN.

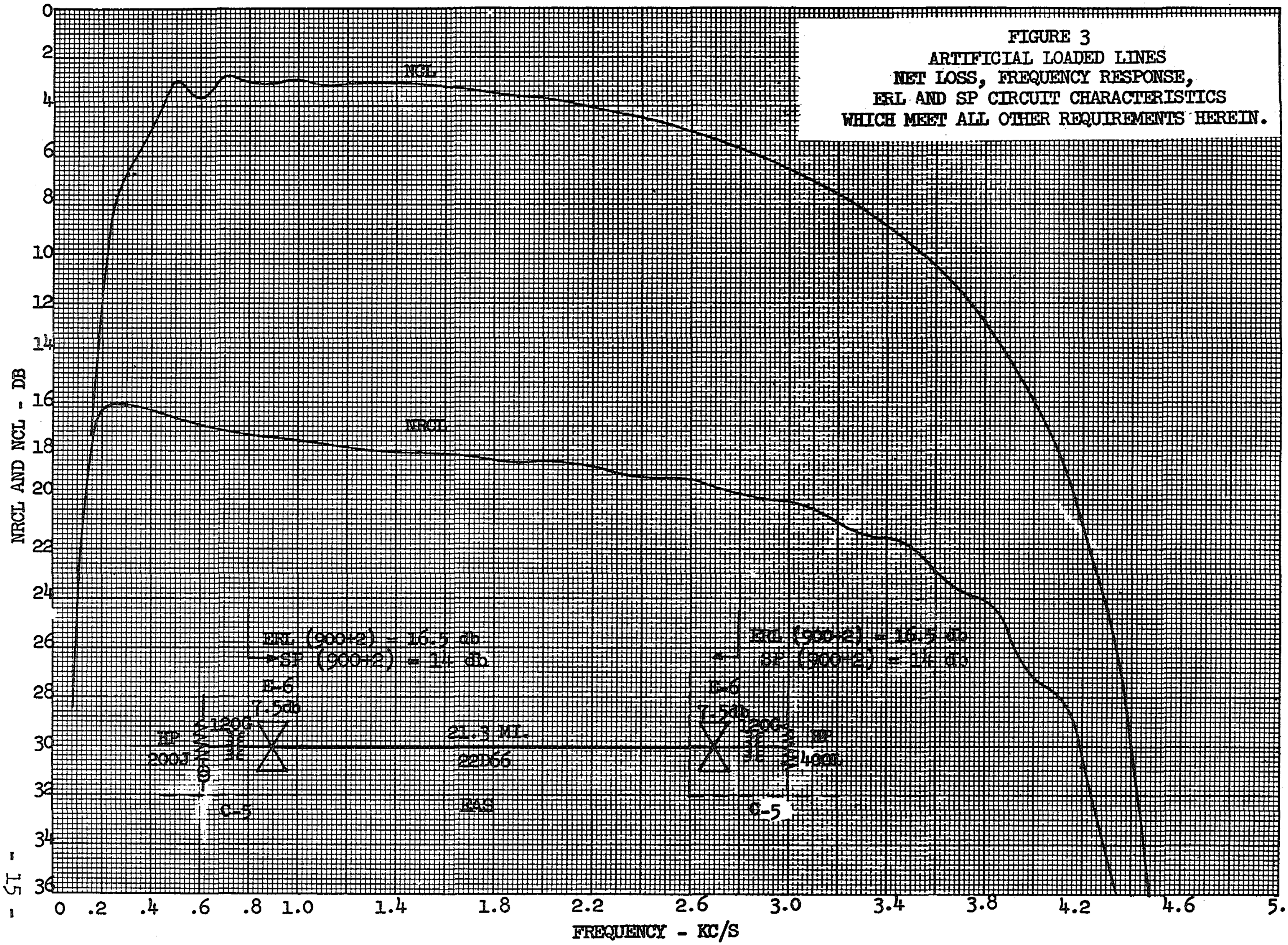


FIGURE 3
ARTIFICIAL LOADED LINES
NET LOSS, FREQUENCY RESPONSE,
ERL AND SP CIRCUIT CHARACTERISTICS
WHICH MEET ALL OTHER REQUIREMENTS HEREIN.
NCL
NRCL
NRCL AND NCL - DB
FREQUENCY - KC/S
0 .2 .4 .6 .8 1.0 1.4 1.8 2.2 2.6 3.0 3.4 3.8 4.2 4.6 5.0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36
ERL (900+2) = 16.5 db
SP (900+2) = 14 db
E-6
7.5db
120G
HP
200J
C-5
21.3 MI.
22D66
BAS
400C

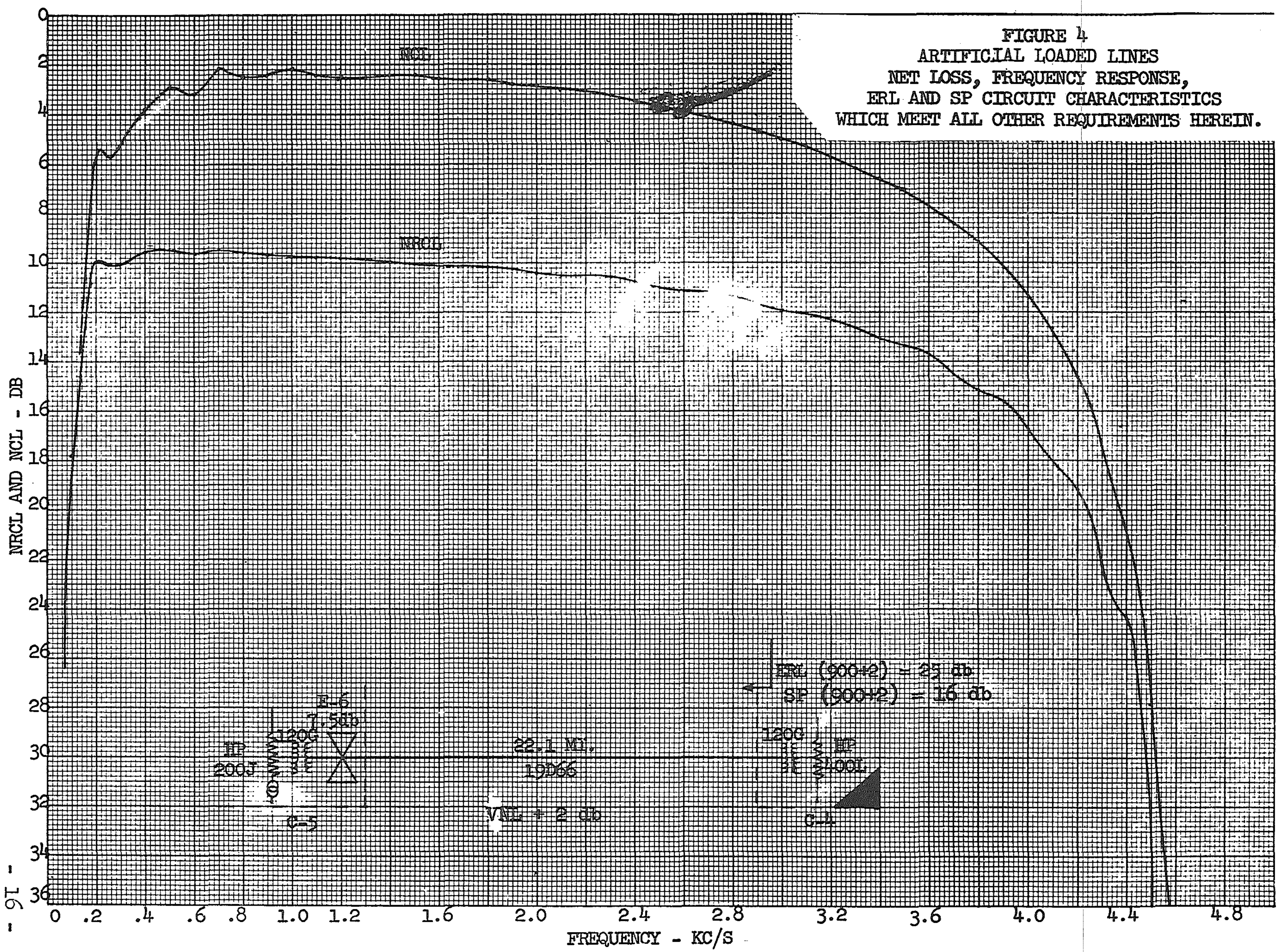


FIGURE 4
ARTIFICIAL LOADED LINES
NET LOSS, FREQUENCY RESPONSE,
ERL AND SP CIRCUIT CHARACTERISTICS
WHICH MEET ALL OTHER REQUIREMENTS HEREIN.

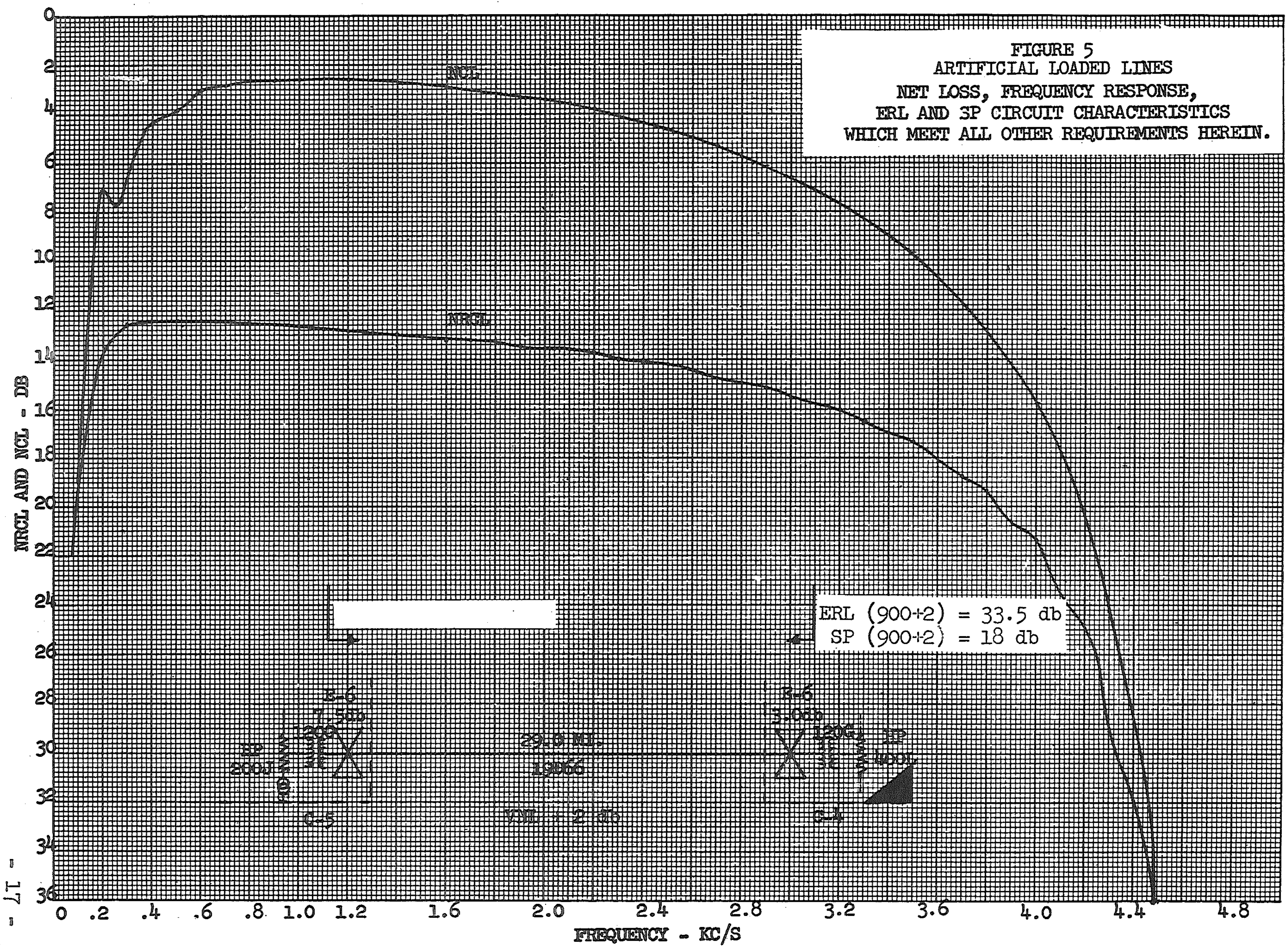
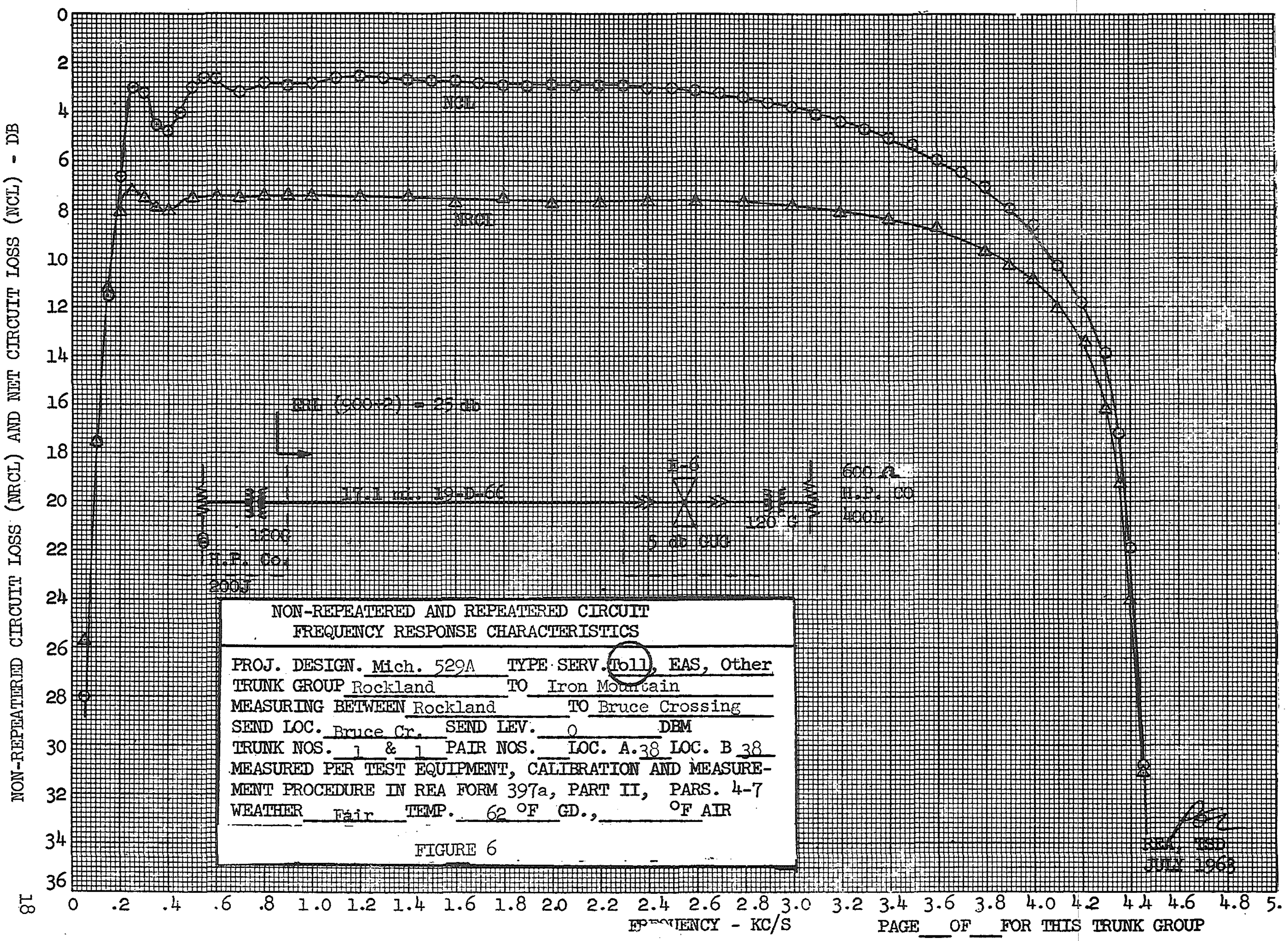


FIGURE 5
ARTIFICIAL LOADED LINES
NET LOSS, FREQUENCY RESPONSE,
ERL AND SP CIRCUIT CHARACTERISTICS
WHICH MEET ALL OTHER REQUIREMENTS HEREIN.

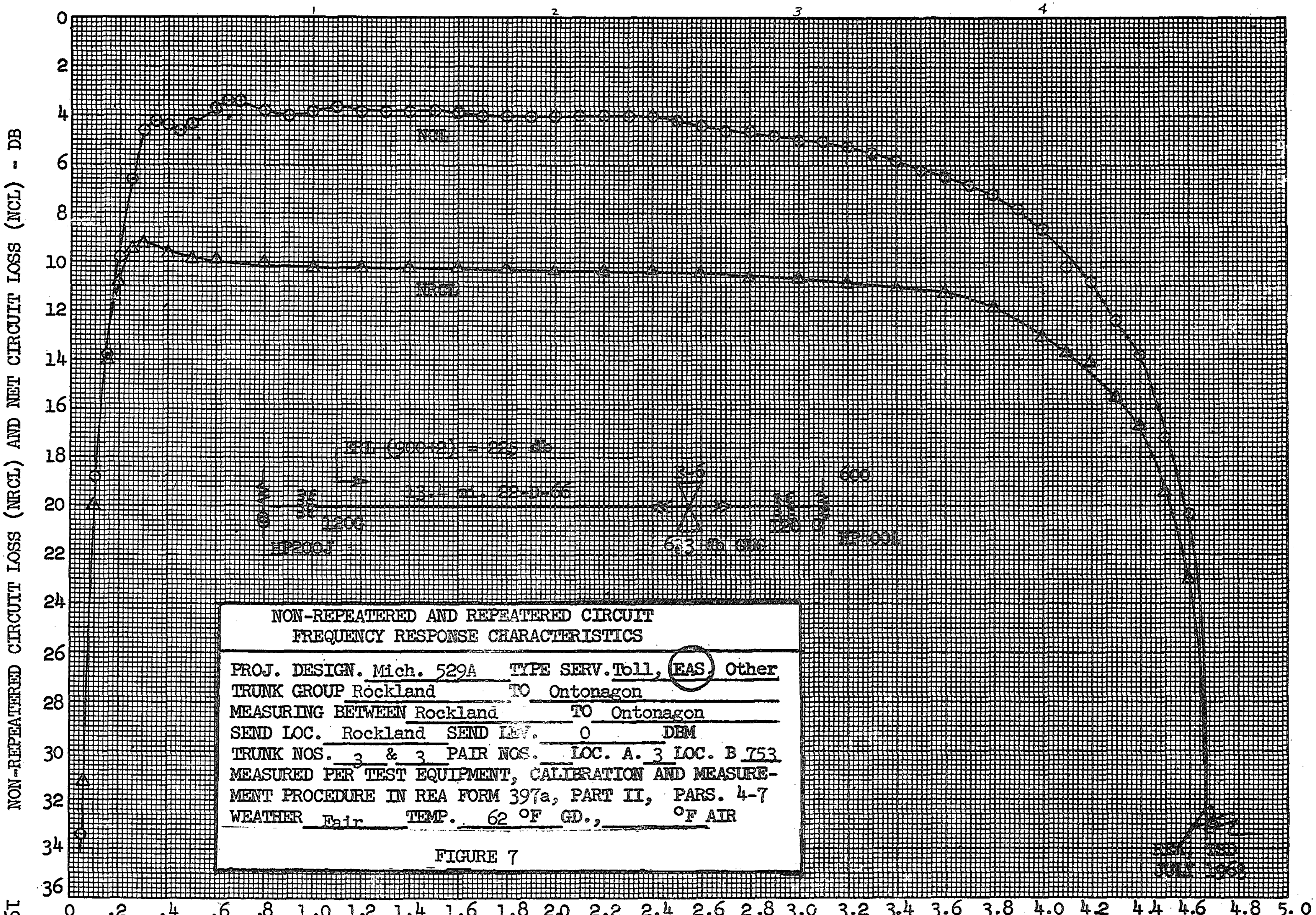


NON-REPEATERED AND REPEATERED CIRCUIT
FREQUENCY RESPONSE CHARACTERISTICS

PROJ. DESIGN. Mich. 529A TYPE SERV. Toll, EAS, Other
TRUNK GROUP Rockland TO Iron Mountain
MEASURING BETWEEN Rockland TO Bruce Crossing
SEND LOC. Bruce Cr. SEND LEV. 0 DBM
TRUNK NOS. 1 & 1 PAIR NOS. LOC. A. 38 LOC. B 38
MEASURED PER TEST EQUIPMENT, CALIBRATION AND MEASUREMENT PROCEDURE IN REA FORM 397a, PART II, PARS. 4-7
WEATHER Fair TEMP. 62 °F GD., °F AIR

FIGURE 6

PAGE__OF__FOR THIS TRUNK GROUP

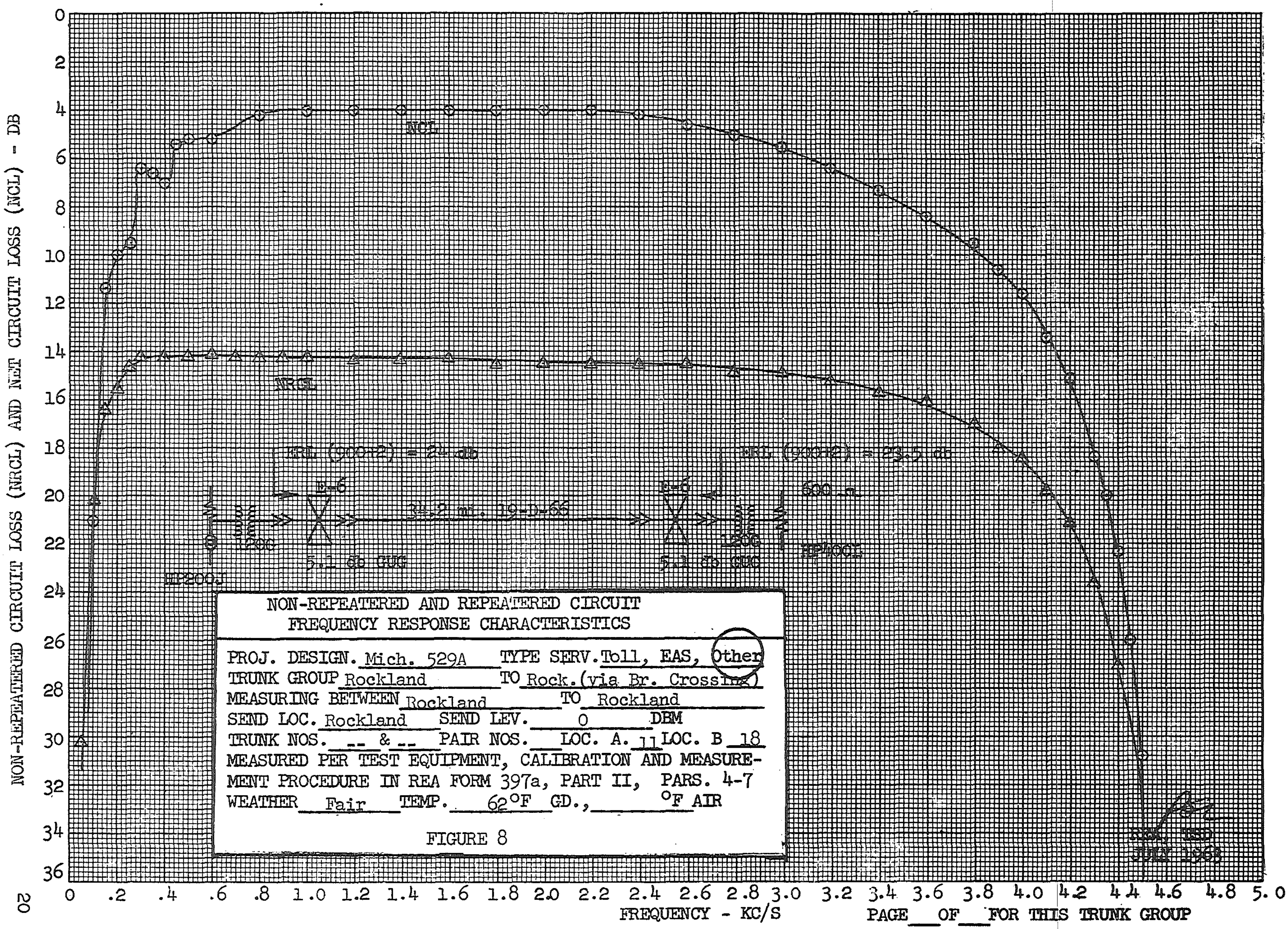


NON-REPEATERED AND REPEATERED CIRCUIT
FREQUENCY RESPONSE CHARACTERISTICS

PROJ. DESIGN. Mich. 529A TYPE SERV. Toll, (EAS) Other
TRUNK GROUP Rockland TO Ontonagon
MEASURING BETWEEN Rockland TO Ontonagon
SEND LOC. Rockland SEND LEV. 0 DBM
TRUNK NOS. 3 & 3 PAIR NOS. __ LOC. A. 3 LOC. B 753
MEASURED PER TEST EQUIPMENT, CALIBRATION AND MEASUREMENT PROCEDURE IN REA FORM 397a, PART II, PARS. 4-7
WEATHER Fair TEMP. 62 °F GD., ____ °F AIR

FIGURE 7

PAGE __ OF __ FOR THIS TRUNK GROUP



NON-REPEATERED CIRCUIT LOSS (NRCL) AND NET CIRCUIT LOSS (NCL) - DB
FREQUENCY - KC/S
NCL
NRCL
ERL (900~) = 24 db
ERL (900~) = 23.5 db
E-6
34.2 mi. 19-D-66
600 Ω
1206
HP200J
HP400CL
5.1 db GUG
NON-REPEATERED AND REPEATERED CIRCUIT
FREQUENCY RESPONSE CHARACTERISTICS
PROJ. DESIGN. Mich. 529A TYPE SERV. Toll, EAS, Other
TRUNK GROUP Rockland TO Rock. (via Br. Crossing)
MEASURING BETWEEN Rockland TO Rockland
SEND LOC. Rockland SEND LEV. 0 DBM
TRUNK NOS. -- & -- PAIR NOS. LOC. A. 11 LOC. B 18
MEASURED PER TEST EQUIPMENT, CALIBRATION AND MEASUREMENT PROCEDURE IN REA FORM 397a, PART II, PARS. 4-7
WEATHER Fair TEMP. 62°F GD., °F AIR
REA, TSD
JULY 1968
PAGE __ OF __ FOR THIS TRUNK GROUP

FIGURE 8

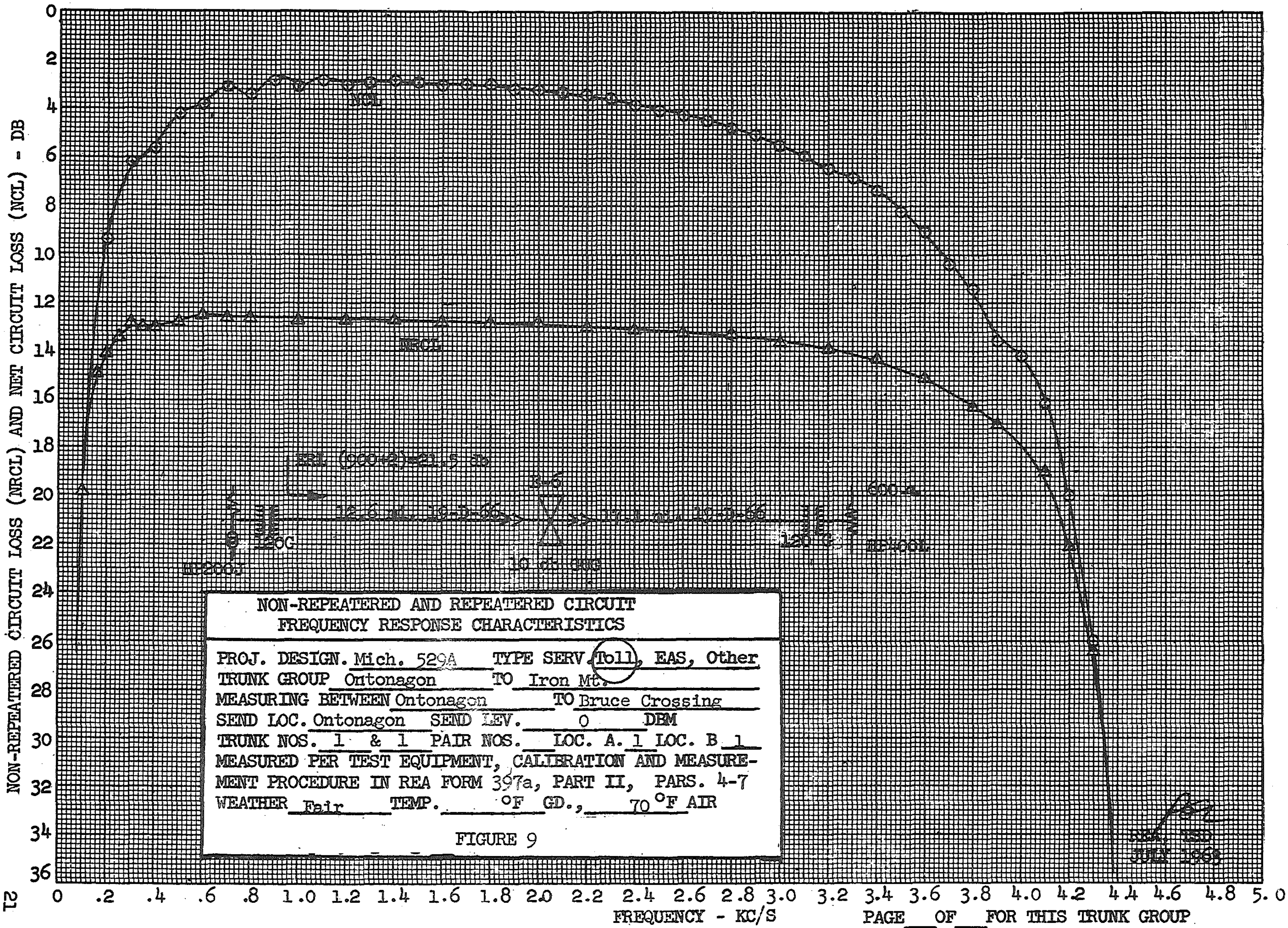

NON-REPEATERED CIRCUIT LOSS (NRCL) AND NET CIRCUIT LOSS (NCL) - DB
NCL
NRCL
ERL (900+2)=21.5 db
HF200J
120G
10 db GWG
600 Ω
HF400L
NON-REPEATERED AND REPEATERED CIRCUIT
FREQUENCY RESPONSE CHARACTERISTICS
PROJ. DESIGN. Mich. 529A TYPE SERV. Toll, EAS, Other
TRUNK GROUP Ontonagon TO Iron Mt.
MEASURING BETWEEN Ontonagon TO Bruce Crossing
SEND LOC. Ontonagon SEND LEV. 0 DBM
TRUNK NOS. 1 & 1 PAIR NOS. LOC. A. 1 LOC. B 1
MEASURED PER TEST EQUIPMENT, CALIBRATION AND MEASUREMENT PROCEDURE IN REA FORM 397a, PART II, PARS. 4-7
WEATHER Fair TEMP. °F GD., 70 °F AIR
REA, TED
JULY 1963
FREQUENCY - KC/S
PAGE ___ OF ___ FOR THIS TRUNK GROUP

FIGURE 9