Rural Electrification Administration
Telephone Engineering & Construction Manual

Section 408
Issue No. 2
November 1965

HOW TO MAKE FACILITY LOSS MEASUREMENTS ON VOICE FREQUENCY LOADED CABLES

CONTENTS

1. GENERAL

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 provides technical information for use when the attenuation (loss) of voice frequency loaded cables must be known. Issue No. 2 of this section supersedes Issue No. 1, August 1960, in its entirety.

1.2 This section is revised to include information on D-66 loaded cables and cables joined with the D-66/H-88 impedance compensator. It provides information to accomplish the following:

1.21 How to measure the facility loss of cables which are D-66 loaded for their entire length.

1.22 How to measure the facility loss of cables which are H-88 loaded for their entire length.

1.23 How to measure the facility loss of D-66 loaded cables connecting to H-88 loaded cables by means of the D-66/H-88 junction impedance compensator.

1.24 The step-by-step measurement procedures.

1.25 Attenuation information for various frequencies so that the measured results can be compared against the computed values.

1.3 The information presented herein can be used to accomplish the following:

1.31 To measure the facility loss of loaded intertoll, toll connecting (VNL + 2), EAS and special application trunks as well as subscriber loops. For measuring subscriber loops the subscriber end-section must be disconnected. The loaded portion only is measured starting at 0.5 end-section at the central office (0.4 to 0.6 is acceptable) and ending at 0.5 end-section after the last loading point (0.4 to 0.6 is acceptable).

1.32 To determine whether (a) the loaded cable meets the transmission requirements to which it has been engineered, (b) the as-built plant is suitable for voice frequency repeater application, (c) corrective measures are required.

1.33 To check periodically the performance of the outside plant on a routine maintenance basis or as a tool for trouble clearing when transmission problems occur.

1.34 As an aid for determining impedance irregularities where structural return loss measurements made in accordance with REA TE & CM-445, "How to Make Structural Return Loss Measurements," indicate low structural return loss values.

1.4 This section does not provide information for determining:

1.41 The facility loss of loading systems other than D-66 and H-88. For loading systems other than these, insertion loss measurements should be made in accordance with REA TE & CM-407, "How to Make Insertion Loss Measurements," paragraph 11.04.

1.42 The attenuation of non-loaded cables and/or open wire conductors. For non-loaded cables the insertion loss procedure in REA TE & CM-407, Example 17 should be used.

1.5 Where no mention of the facility type is made it should be assumed that it refers to loaded cable.

2. DEFINITIONS

2.1 Facility Loss

2.11 The term "Facility Loss" is used throughout this section to describe "attenuation." The general case of facility loss is defined as the loss in a facility or network which is terminated in its <u>characteristic impedance</u>.

2.12 Facility loss for the purpose of the measurements in this section is defined as the loss in db resulting from the insertion of a facility or network having 1000 ohm impedance between a 1000 ohm resistive source and a 1000 ohm resistive load. Further, for the measurements considered in this section, the measuring oscillator and A-C Voltmeter equipment will be of the 600 ohm type, such as are used for making insertion loss type of measurements, but externally modified through an impedance compensator to become 1000 ohm devices.

2.2 Impedance Compensator

2.21 An impedance compensator for the purpose of the measurements described herein is defined as a device which modifies the facility impedance from 300 to 4000 cps to approximately 1000 ohms and in addition modifies conventional 600 ohm measuring equipment to become suitable for 1000 ohm impedance measurements in the same frequency range. The impedance matching properties of the impedance compensator are discussed in paragraph 4 below.

2.3 Insertion Loss

2.31 The general case of insertion loss is defined as the loss in a facility or network which is <u>NOT</u> terminated in its characteristic impedance.

3. THEORY OF FACILITY LOSS

3.1 Insertion loss and facility loss are <u>not</u> the same; facility loss is a special case of insertion loss. The following principle should be helpful in clarifying the difference:

3.11 To measure attenuation or facility loss <u>only</u>, the facility under test must be terminated in its characteristic impedance. If a termination is used which is different from the facility characteristic impedance, the resulting loss is attenuation plus reflection losses. Insertion loss is generally greater than attenuation or facility loss. The two are related as follows:

INSERTION LOSS = ATTENUATION
\+ TERMINAL REFLECTIONS
\+ INTERACTION

3.2 For loaded cables, the characteristic impedance as seen in Figure 1a and measured between one-half end-sections varies considerably in both magnitude and phase from 300 to 4000 cps. If 600 ohm measuring equipment is used to measure a facility having such impedance characteristics, the measurement represents insertion loss since it includes not only attenuation but the resulting reflection losses between the facility and the measuring equipment. If, however, the facility had been measured using an oscillator and A-C Voltmeter whose terminating impedance at each frequency under measurement were equal to the impedance of the line at the same frequency, the reflection loss and the interaction loss of the above expression would have been zero and the insertion loss would equal the attenuation or facility loss. Therefore, attenuation or facility loss can be thought of as the case of minimum insertion loss. This is shown by the flattened impedance curve in Figure 1b.

3.21 Depending on the magnitude and phase relationships of the impedances involved, it is possible to have negative reflections which represents reflection gain.

3.22 Interaction losses are further extensions of reflection losses. They represent the sum total of all possible reflections traveling back and forth in the line as a result of impedance mismatches between the generator, facilities and load as modified by the attenuation of the line. The relationship which describes interaction losses is a highly complex one and unlike simple reflection loss, it is not readily adaptable to computation. For line losses greater than about 10 db, interaction may be safely ignored in insertion loss measurements.

3.3 In summary: The main purpose of making facility loss type of measurements on loaded cable plant rather than insertion loss, with the aid of the impedance compensator is to assure negligible terminal reflection effects due to mismatches between the 600 ohm test equipment and cable impedances at both ends of the line, and to permit an accurate comparison between the computed and measured transmission losses. This also provides a basis for detecting the presence of impedance irregularities. The impedance of a loaded cable "flattened-out" by the impedance compensator is shown in Figure 1b.

4. THE IMPEDANCE COMPENSATOR

4.1 As discussed previously the purpose of the impedance compensator is to minimize the effects of the terminal reflections due to mismatches between the 600 ohm test equipment at both cable ends and the dissimilar impedance of the cable pair under measurement. Specifically, the purpose of the impedance matching network is threefold: (a) it builds the facility under test to 1000 ohms; (b) it builds the 600 ohm oscillator impedance to 1000 ohms; and (c) it builds the 600 ohm A-C Voltmeter load resistance to 1000 ohms.

4.2 Such matched conditions minimize the terminal reflections and interaction losses between the measuring equipment and the facility under test and result in attenuation or facility loss only. This method therefore permits an accurate comparison between the computed and the measured facility losses in the range of 300 to 4000 cps.

4.3 The impedance matching network consists of three main sections: (a) Cable built-out capacitor; (b) Inductor; and (c) Measuring-equipment build-out resistor.

4.4 The purpose of the build-out capacitor is to build-out each cable end-section to approximately 0.8 end-section in order to obtain a resistance component of the cable impedance which is essentially constant over the frequency range.

4.5 The purpose of the inductor is to cancel out most of the capacitive reactance of the cable impedance built-out to 0.8 end-section by the cable build-out capacitor, and thus produce 1000 ohm resistance. The purpose of the equipment build-out resistor is to modify the 600 ohm equipment impedance to 1000 ohms. A facility thus modified is in accordance with the definition of paragraph 4.4. A typical compensated impedance is shown in Figure 1b.

4.6 The impedance matching network described above is readily available at low cost. It can also be constructed locally with the aid of radio parts and loading coils. A schematic diagram of the network, a list of component parts and the method of connection are shown in Figure 5.

5. STEP-BY-STEP MEASUREMENT PROCEDURE

5.1 The actual step-by-step measurement procedure, including the type of test equipment, wiring connections and calibration is shown in Figures 2 and 4. The method basically consists of inserting an impedance compensator at each cable terminal-end between the cable end-section and the oscillator and A-C Voltmeter measuring equipment. The compensator at each cable end of a D-66 loading cable consists of a 36 millihenry loading coil, a 400 ohm resistor and a variable capacitor, termed CBO, with its capacitance calibrated in terms of feet. This is done only for convenience and ease of measurement, since the cable end-section length is normally also expressed in feet so that no conversion is required. A capacitor calibrated in microfarads, instead of feet will give the same results. The terminal end of the impedance compensator that connects to the CBO is always connected to the cable pair and the terminal end with the 400 ohm resistor to the test equipment as in the diagrams, Figures 2 to 4. If the two pairs of terminals are inadvertently reversed, the results of the measurement will be incorrect.

5.2 Two compensators are required for the measurement, one at each cable terminal end. Each CBO in the compensator in a cable which is D-66 or H-88 loaded is set to make the total cable end-section (at the point where it is used) 0.8 of a full section. That is, the cable length between the last loading point and the point of measurement plus the amount of CBO in the compensator should be 0.8 section. For D-66 loaded cables, 0.8 section results in a 3600 foot end-section total, while with H-88 loading it must be 4800 feet. The amount of end-section adjacent to the compensator can be 3600 feet in cable length only (compensator CBO is zero feet), built-out to 3600 feet by the compensator CBO only (cable natural end-section length is zero), or a combination of both. This last one is that which occurs in actual practice. The end-section length of the cable has a certain physical length and the CBO of the compensator furnishes the remainder so that together they add to 3600 feet (for D-66). For example, assume that the physical end-section of a D-66 loaded cable is 1900 feet. The amount of CBO which would be required in the compensator would be 3600-1900 or 1700 feet. By design, the end-sections in new D-66 construction are required to be 0.5 but are allowed to vary between 0.4 and 0.6, which is 1800 feet to 2700 feet respectively. This, however, may not be the case in existing H-88 plant where the end-section can be longer or shorter than this.

5.3 Unlike the impedance compensator used to measure H-88 loaded cables, the compensator used to measure D-66 loaded cables uses one value of inductance coil only; 36 millihenries. This coil in the D-66 compensator can be used for any one gauge or for mixed gauges. For this reason there is no switch for selecting the coil according to the gauge to be measured and this also somewhat simplifies the measurement.

5.4 Figures 2 to 4 show that a 120H repeating coil is used for the measurement. This coil is not essential to the measurement and is used only to maintain circuit balance so that noise will not affect or obscure the meter readings. If transistorized, portable oscillator and A-C Voltmeter equipment is used the 120H can be removed from the calibration and measurement. If vacuum tube equipment is used the 120H coil will probably have to be used. A good check to make with any type of test equipment is as follows:

5.41 With the test setup as per Figures 2 to 4 and the DPDT switch in the "measure" position and the cable connected, but without the 120H repeating coil turn off the oscillator power on-off switch. Have the A-C Voltmeter read at the far end. If the reading on the A-C Voltmeter is -45 dbm or greater (that is, -48, -50 dbm, etc.) the 120H repeating coils need not be used. Incidentally, the above procedure is a good check with or without coils since the same noise problem can sometimes exist due to unb unbalances in the cable pair itself under test.

5.5 The actual measurements can be made quite rapidly, without significant sacrifice in accuracy, if the calibration procedure can be made to be simple. This can be done as follows:

5.51 Connect the oscillator to the A-C Voltmeter (as per calibration procedure in Figures 2 to 4) and rotate the oscillator frequency vernier from 300 to 4500 cps. Note the readings in the A-C Voltmeter. If the readings do not vary by more than 0.3 db in this range, there is no need to recalibrate at each frequency of measurement (only periodically). Set the oscillator at this output level (+4.4 dbm) and proceed with the measurement, varying the frequency vernier only.

5.6 The minimum frequencies which should be measured in D-66 loaded cables are 300, 500, 1000, 1500, 2000, 2500, 3000, 3500, 3900, 4000, and 4100 cps and also the frequency where the loaded cable cuts off (-60 dbm or greater in the absence of line noise). For the initial cable runs, it is advisable to take frequency steps even smaller in order to establish the shape of the curve. Some of the oscillators which may be used can have a frequency accuracy of ± 3 percent. At 4000 cps this would be ± 120 cps which is significant. To account for this, the frequencies of 3900 and 4100 cps have been included.

5.7 When making the facility loss measurements, the cable temperature must be known accurately (to within ± 5 degrees, F) so that temperature corrections will not be in error. For aerial cables the thermometer should be placed in the outside air and periodic readings taken throughout the course of the measurements. Sunlight (not in shade) temperature readings should be taken as being more representative of the temperature in the cable sheath. In buried cables proceed as follows:

5.71 Bore a hole approximately 24 to 30 inches in the ground using nothing larger in diameter than a ground rod. Attach the thermometer to a length of rope or string and lower it to the bottom of the hole. Take periodic readings by holding and raising the thermometer by the string. This method has been found to give results representative of the cable-ground temperature.

5.8 The results of the measurements should be plotted on the "Data Sheets - Facility Loss Measurements." This type of data sheet has one significant advantage over the tabular form. The results can be analyzed as the measurement progresses. That is the smoothness of the curve can now be observed and conversely bumps in the response become more evident and at times even some form of a periodic pattern may appear for certain types of irregularities.

5.9 Where the D-66/H-88 junction compensator is used to interconnect D-66 to H-88 loaded cables, it is advisable to check the connections physically at the junction compensator before proceeding with the measurements for assuring that the D-66 side of the compensator is connected to the D-66 loaded cable and the H-88 side to the H-88 cable.

6. EXPECTED MEASURED LOSS

6.1 The purpose in making facility loss measurements is to eliminate reflection losses. The results of the measurements represent the total attenuation of the circuit for the particular length, gauge(s) and type of loading system(s) under test and the cable temperature at the time of measurement. Table I gives attenuation information at 68°F. for various cable gauges (D-66 and H-88 loaded) at various frequencies, so that the expected facility loss of a particular cable layout can be computed at 68°F. or other temperature of interest and compared against the measured values.

6.2 The basic procedure for computing the expected attenuation or evaluating measurement data is as follows:

6.21 For the particular frequency, loading system and temperature, multiply the length of each different gauge by the db per unit length using the information in Table I to obtain the loss. This is the total loss for each gauge for this length. Adding the individual losses for each gauge gives the total circuit attenuation for the particular loading system, frequency of interest and temperature.

6.3 The attenuation information in Table I has been prepared for 68°F. For converting the measured loss to 68°F. use the following percentages for copper conductors:

6.31 For each ± 5°F. change in temperature from 68°F. change the db per mile attenuation (at any frequency) by ± one percent or the results of measurements by ± one percent.

6.4 The measured facility loss for D 66 loaded cables compared to the computed facility loss should be within ± 10 percent at 1000, 2000, and 3000 cps and ± 20 percent at 4000 cps. The computed facility loss is obtained by multiplying the db per mile attenuation values in Table I for exchange type, 0.083 microfarads per mile cable by the facility length as discussed in paragraph 6.2 above.

6.5 The values shown above are upper limits and not the actual normal values expected. In actual practice, the percent limits shown above will be improved at least by a two-to-one ratio. As a guide to the values of facility loss which should be expected with D-66 loaded cables, the information in Examples 1 to 6 should be referred to. These examples show the results of actual measurements in several REA borrowers' systems. It should be noted that the requirements of paragraph 6.4 above are met with a considerable margin.

6.6 The measured facility loss for H-88 loaded cables compared to the computed value of facility loss should be within ± 10 percent at 1000 and 2000 cps and ± 20 percent at 3000 cps. These limits will not normally apply to H 88 plant built under former design practices for non-repeatered circuits due to larger than normal permissible deviation in cable mutual capacitance, load spacing accuracy and loading coil inductance. Therefore, the above limits should be used only as broad guidelines.

6.7 When making facility loss measurements it is essential that the outside plant facility configuration be accurately known, including the manner by which the measurements have been carried out and any measurement adjustments which have been found necessary. This information is necessary in order to analyze the result and determine whether the objectives are being met, whether corrective action is required and the type of correction. Besides serving as a record for initial acceptance measurements, it also provides the plant forces with a powerful tool for performing routine testing on these circuits or for correction problems when they occur. It is extremely difficult to evaluate results of transmission measurements, to make recommendations for correction of transmission problems or to perform routine testing when plant and/or test records are lacking or incomplete. The Form used to record the facility loss measurements and the other information required is shown in "Data Sheet - Facility Loss Measurement."

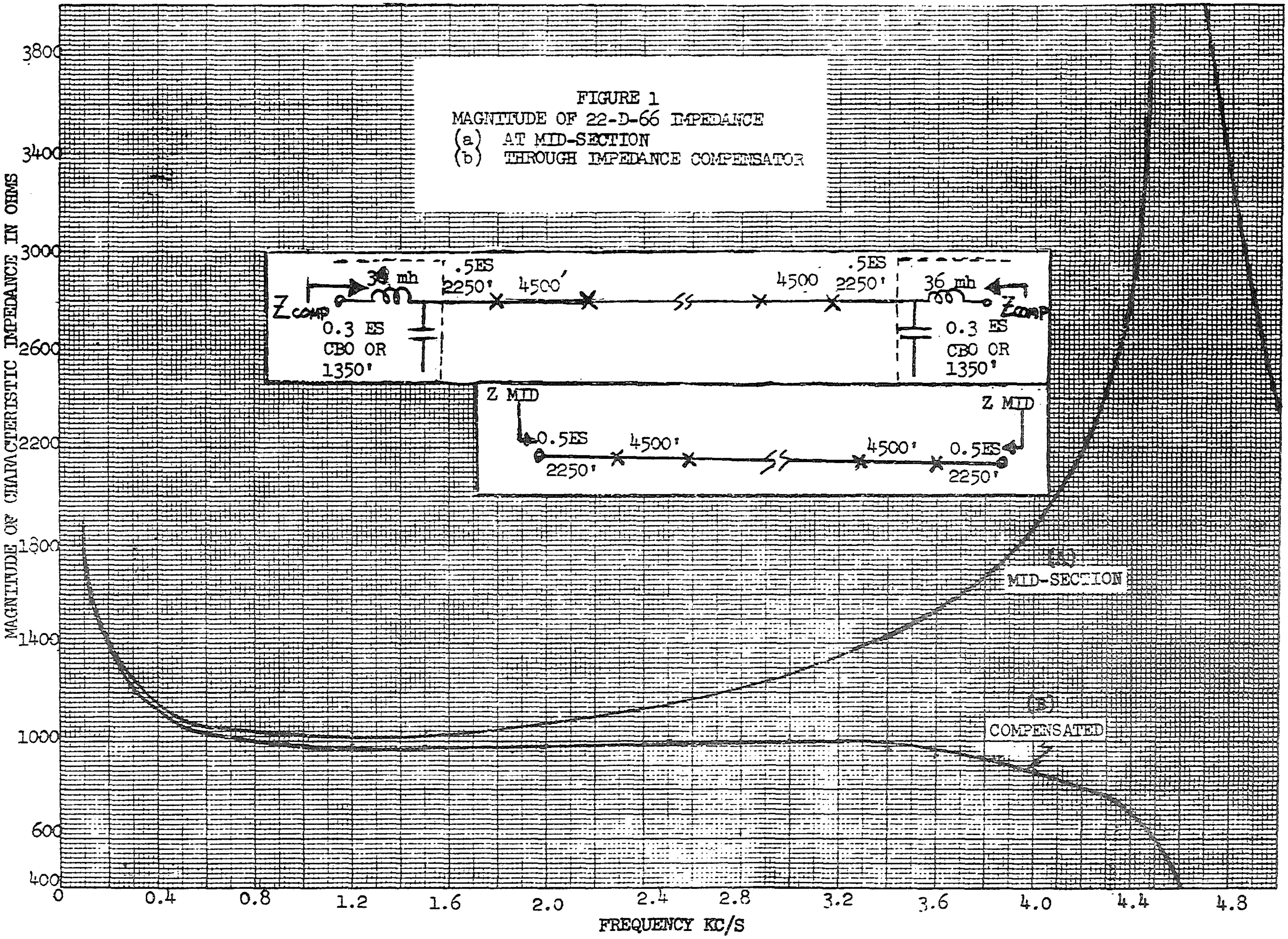
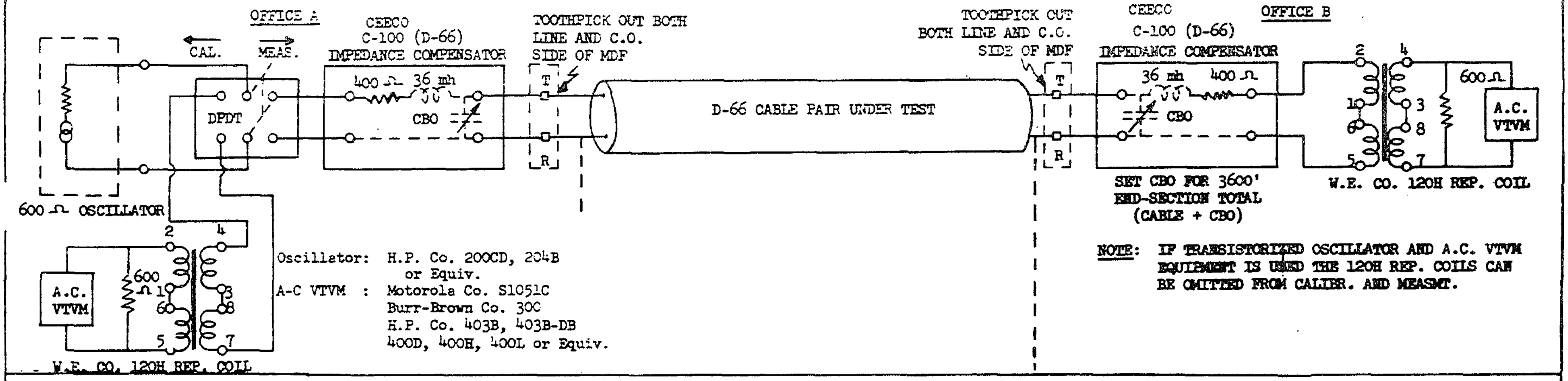


FIGURE 1
MAGNITUDE OF 22-D-66 IMPEDANCE
(a) AT MID-SECTION
(b) THROUGH IMPEDANCE COMPENSATOR



SET CBO FOR 3600'
END-SECTION TOTAL
(CABLE + CBO)

Oscillator: H.P. Co. 200CD, 204B
or Equiv.
A-C VTVM : Motorola Co. S1051C
Burr-Brown Co. 30C
H.P. Co. 403B, 403B-DB
400D, 400H, 400L or Equiv.

NOTE: IF TRANSISTORIZED OSCILLATOR AND A.C. VTVM EQUIPMENT IS USED THE 120H REP. COILS CAN BE OMITTED FROM CALIBR. AND MEASMT.

A. Calibration of Test Equipment

1. Connect the oscillator, the 600-ohm resistor, the 120 H repeating coil (if used) and A.C. VTVM as shown in the above figure. Do not include the D-66 impedance compensator in the calibration setup.) Throw DPDT switch to "CALIBRATE" position.

2. Set the oscillator to a convenient frequency such as 2000 cycles. Adjust the oscillator output level control to read +4.4 dbm on the A.C. VTVM.

3. Do not change the oscillator output level. Vary the oscillator frequency from 300 to 4500 c.p.s. The reading of the A.C. VTVM should not change appreciably from that obtained in step (2). If varying the frequency changes the reading on the A.C. VTVM by more than 0.3 db, calibration at each frequency is required before measuring.

4. The calibration is now complete. Do not change the oscillator output level settings.

NOTE: Check the a.c. VTVM before measurement. This may be conveniently accomplished by paralleling the two A.C. VTVM's terminated in one 600-ohm resistor across the oscillator output terminals. In the frequency range of 300 to 4500 cycles the readings of the two A.C. VTVM's should be within 0.3 of a db of each other.

B. Measurement Procedure

5. The facility loss measurement is made on the line side of the office with the protector opened at the line and central office terminals. (The central office equipment and associated wiring must not be included in the measurement.)

6. Adjust the CBO in each impedance compensator to build out its respective end section to 3600 feet total (cable length plus CBO).

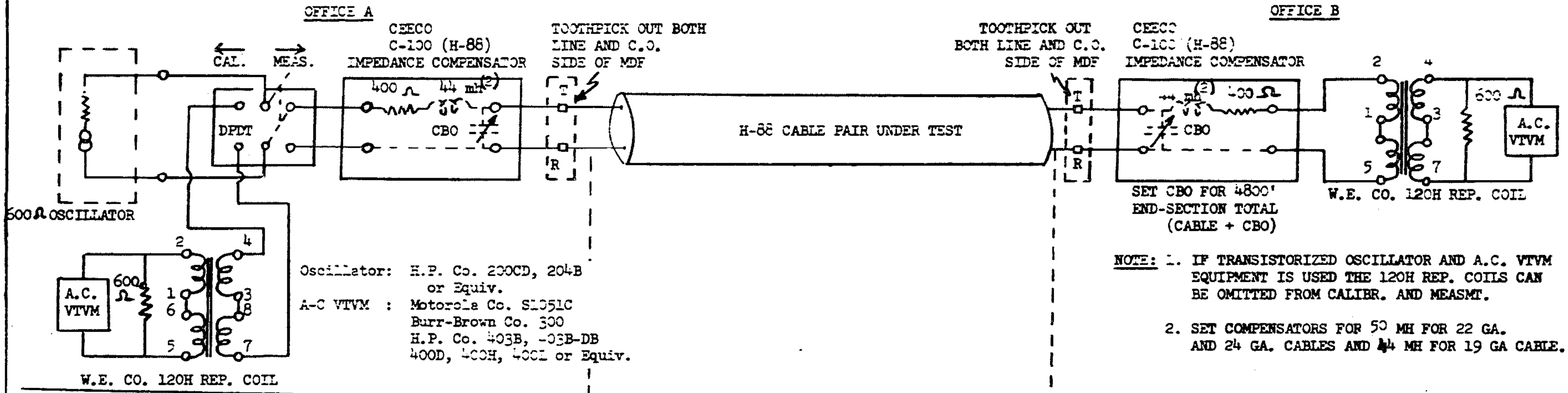
7. Throw DPDT switch to "MEASURE" position.

8. Have personnel at the receiving end read the a.c. VTVM. The reading in minus dbm of the A.C. VTVM at the oscillator frequency represents the loss in db of the facility at the same frequency.

9. Repeat the above procedure for the remainder of the frequencies under test. Measurements are made at the frequencies of 300, 500, 1000, 1500, 2000, 2500, 3000, 3500, 3900, 4000, 4100 and the frequency where the loss is 50 db or greater.

10. Enter the results of the measurements for each individual trunk according to frequency in the "Data Sheet—Facility Loss Measurements."

FIGURE 2. CALIBRATION AND MEASUREMENT OF D-66 LOADED CABLE "FACILITY LOSS" USING THE D-66 IMPEDANCE COMPENSATOR



Oscillator: H.P. Co. 200CD, 204B
or Equiv.

A-C VTVM : Motorola Co. S1051C
Burr-Brown Co. 300
H.P. Co. 403B, -03B-DB
400D, 400H, 400L or Equiv.

NOTE: 1. IF TRANSISTORIZED OSCILLATOR AND A.C. VTVM EQUIPMENT IS USED THE 120H REP. COILS CAN BE OMITTED FROM CALIBR. AND MEASMT.

2. SET COMPENSATORS FOR 50 MH FOR 22 GA. AND 24 GA. CABLES AND 44 MH FOR 19 GA CABLE.

A. Calibration of Test Equipment

1. Connect the oscillator, the 600-ohm resistor, the 120 H repeating coil (if used) and A.C.-VTVM as shown in the above fugure. (Do not include the H-88 impedance compensator in the calibration setup.) Throw DPDT switch to "CALIBRATE" position.

2. Set the oscillator to a convenient frequency such as 2000 cycles. Adjust the oscillator output level control to read +4.4 dbm on the A.C.-VTVM.

3. Do not change the oscillator output level. Vary the oscillator frequency from 300 to 4000 c.p.s. The reading of the A.C. VTVM should not change appreciable from that obtained in Step (2). If varying the frequency changes the reading on the A.C.-VTVM by more than 0.3 db, calibration at each frequency is required before measuring.

4. The calibration is now complete. Do not change the oscillator output level settings.

NOTE: Check the A.C.-VTVM before measurement. This may be conveniently accomplished by paralleling the two A.C.-VTVM's terminated in one 600-ohm resistor across the oscillator output terminals. In the frequency range of 300 to 4000 cycles the readings of the two A.C. VTVM's should be within 0.3 of a db of each other.

B. Measurement Procedure

5. The facility loss measurement is made on the line side of the office with the protector opened at the line and central office terminals. (The central office equipment and associated wiring must not be included in the measurement.)

6. Adjust the CBO in each impedance compensator to build out its respective end section to 4800 feet total (cable length plus CBO).

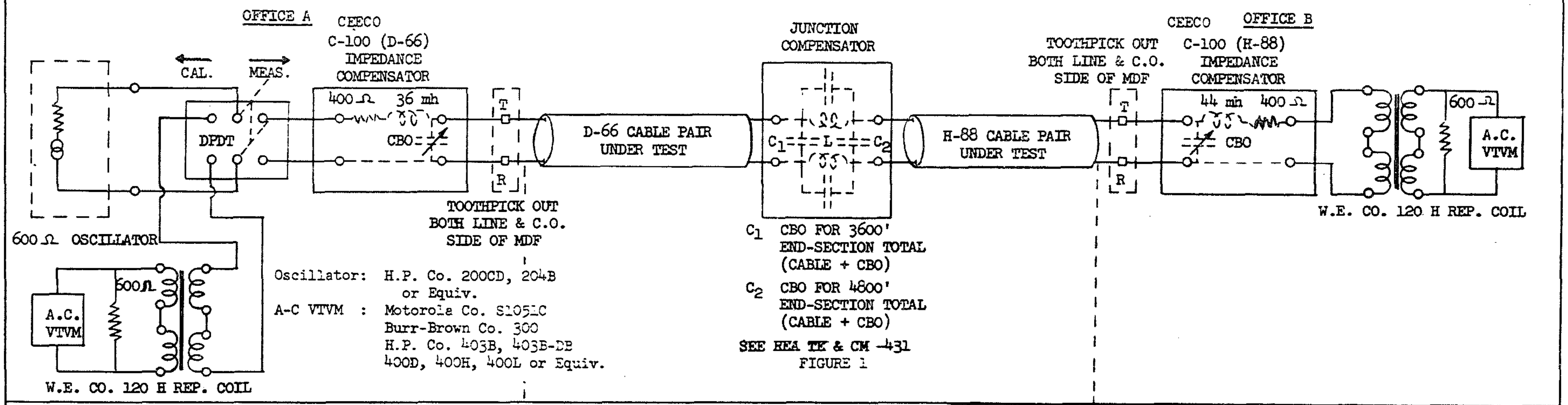
7. Throw DPDT switch to "MEASURE" position.

8. Have personnel at the receiving end read the A.C.-VTVM. The reading in minus dbm of the A.C.-VTVM at the oscillator frequency represents the loss in db of the facility at the same frequency.

9. Repeat the above procedure for the remainder of the frequencies under test. Measurements are made at the frequencies of 300, 500, 1000, 1500, 2000, 2500, 2600, 2700, 2800 2900, 3000, 3100, 3200, 3300, 3400, and the frequency where the loss is 50 db or greater.

10. Enter the results of the measurements for each individual trunk according to frequency in the "Data Sheet - Facility Loss Measurements."

FIGURE 3. CALIBRATION AND MEASUREMENT OF H-88 LOADED CABLE "FACILITY LOSS" USING THE H-88 IMPEDANCE COMPENSATOR



A. Calibration of Test Equipment

1. Connect the oscillator, the 600-ohm resistor, the 120 H repeating coil (if used) and A.C. VTVM as shown in the above figure. (Do not include the D-66 impedance compensator in the calibration setup.) Throw the DPDT switch to "CALIBRATE" position. Set the oscillator to a convenient frequency such as 2000 cycles.

2. Adjust the oscillator output level control to read +4.4 dbm on the A.C. VTVM.

3. Do not change the oscillator output level. Vary the oscillator frequency from 300 to 3500 c.p.s. The reading of the A.C. VTVM should not change appreciably from that obtained in step (2). If varying the frequency changes the reading on the A.C. VTVM by more than 0.3 db, calibration at each frequency is required before measuring.

4. The calibration is now complete. Do not change the oscillator output level settings.

NOTE: Check the A.C. VTVM before measurement. This may be conveniently accomplished by paralleling the two A.C. VTVM's terminated in one 600-ohm resistor across the oscillator output terminals. In the frequency range of 300 to 3500 cycles the readings of the two A.C. VTVM's should be within 0.3 of a db of each other.

B. Measurement Procedure

5. The facility loss measurement is made on the line side of the office with the protector opened at the line and central office terminals. (The central office equipment and associated wiring must not be included in the measurement.)

6. Adjust the CBO of the compensator at the D-66 cable measuring end to build out this end section to 3600 feet total. Adjust the CBO of the compensator at the H-88 cable measuring end to build out this end section to 4800 feet total.

7. Throw the DPDT switch to the "MEASURE" position.

8. Have personnel at the receiving end read the A.C. VTVM. The reading in minus dbm of the A.C. VTVM at the oscillator frequency represents the loss in db of the facility at the same frequency.

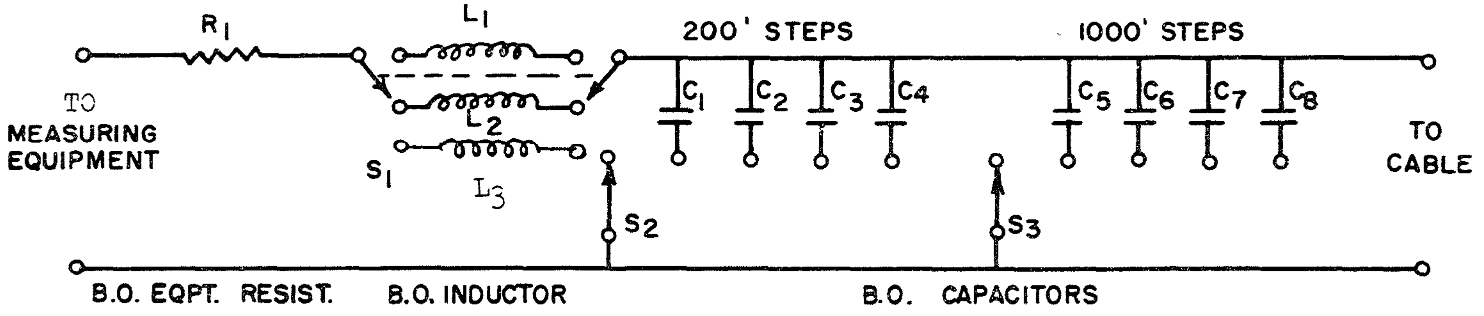
9. Repeat the above procedure for the remainder of the frequencies under test. Measurements are made at the frequencies of 300, 500, 1000, 1500, 2000, 2500, 2600, 2700, 2800 2900, 3000, 3100, 3200, 3300, 3400, and the frequency where the loss is 50 db or greater.

10. Enter the results of the measurements for each individual trunk according to frequency in the "Data Sheet -Facility Loss Measurements."

FIGURE 4. CALIBRATION AND MEASUREMENT OF D-66/H-88 LOADED CABLE "FACILITY LOSS" USING THE IMPEDANCE COMPENSATOR

SCHEMATIC DIAGRAM & CONSTRUCTION DETAILS OF IMPEDANCE COMPENSATOR

FOR D-66 OR H-88 LOADING (SEE FIG. 2 FOR APPLICATION)



L_3 - 36 MH LOADING COIL (FOR D-66 ONLY)

PARTS LIST

R_1	—	400 OHM	1 WATT ± 1%	CARBON RESISTOR		AEROVOX TYPE CPI OR EQUIV.
L_1	—	44 MH	LOADING COIL —	FOR 19—H—88 CABLES		W.E. CO., CEECO. OR EQUIV.
L_2	—	55 MH	" " —	" 22—H—88 "		" " " "
C_1	—	PAPER OR MICA	CAPACITOR	0.003 MF ± 3%	500 V DCW	EL MENCO-ARCO CO. OR EQUIV.
C_2	—	" " "	"	0.006 " "	" "	"
C_3	—	" " "	"	0.010 " "	" "	"
C_4	—	" " "	"	0.013 " "	" "	"
C_5	—	" " "	"	0.016 " "	" "	"
C_6	—	" " "	"	0.032 " "	" "	"
C_7	—	" " "	"	0.045 " "	" "	"
C_8	—	" " "	"	0.064 " "	" "	"

FIGURE 5

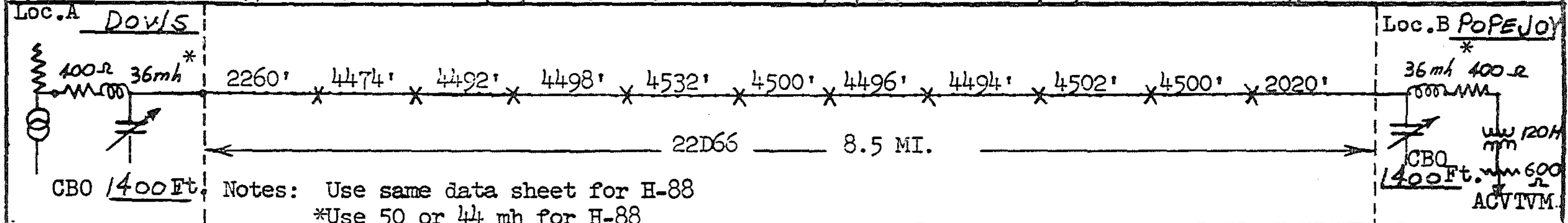
TABLE I
FREQUENCY ATTENUATION IN DB/MI @ 68°F.
D-66 AND H-88 LOADED CABLES
EXCHANGE CABLE .083 MF PER MILE

FREQUENCY CPS	D-66				H-88			
	19GA	22GA	24GA	26GA	19GA	22GA	24GA	26GA
200	0.39	0.65	0.90	1.20	0.39	0.65	0.90	1.20
300	0.40	0.71	1.00	1.39	0.40	0.71	1.00	1.39
400	0.41	0.74	1.08	1.52	0.41	0.74	1.08	1.52
500	0.42	0.76	1.13	1.61	0.42	0.76	1.13	1.61
800	0.42	0.79	1.19	1.77	0.42	0.79	1.19	1.77
1000	0.42	0.79	1.21	1.83	0.42	0.79	1.21	1.83
1500	0.42	0.80	1.23	1.89	0.42	0.80	1.23	1.89
2000	0.42	0.80	1.23	1.90	0.42	0.80	1.23	1.90
2500	0.43	0.80	1.23	1.90	0.43	0.81	1.23	1.90
2800	0.43	0.80	1.23	1.90	0.45	0.82	1.24	1.90
3000	0.44	0.80	1.23	1.90	0.48	0.86	1.31	2.00
3100	0.44	0.80	1.23	1.90	0.51	0.90	1.36	2.07
3200	0.44	0.80	1.23	1.90	0.56	0.97	1.46	2.20
3400	0.45	0.81	1.24	1.91	0.86	1.42	2.01	2.80
3600	0.46	0.82	1.26	1.93				
3800	0.48	0.85	1.29	1.98				
3900	0.50	0.87	1.31	2.01				
4000	0.51	0.89	1.34	2.05				
4100	0.54	0.93	1.39	2.12				
4200	0.57	0.98	1.46	2.21				
4300	0.62	1.05	1.56	2.34				
4400	0.71	1.18	1.72	2.55				
4500	0.87	1.42	2.03	2.90				
4600	1.35	2.01	2.66	3.51				

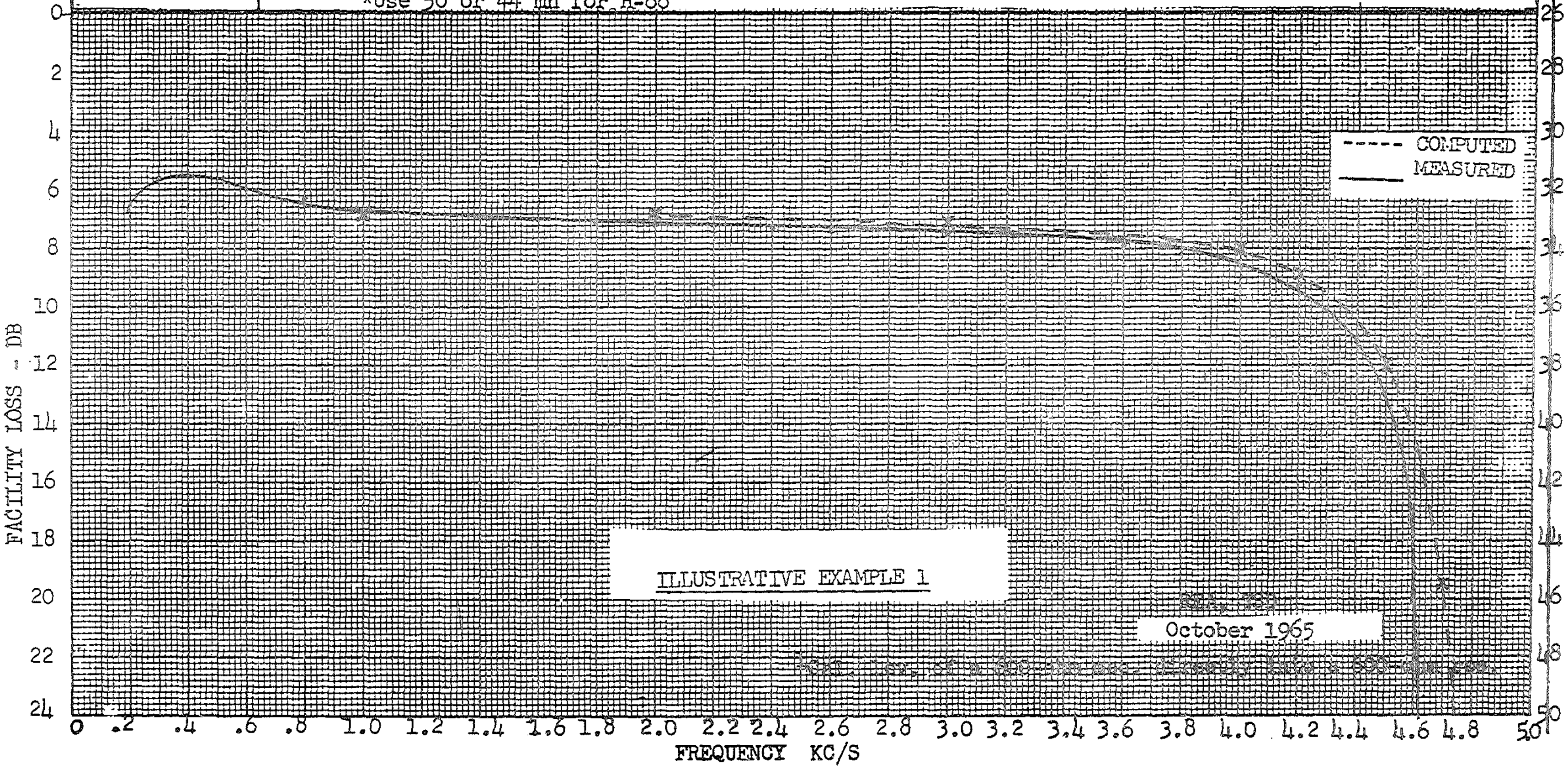
NOTE: TO CONVERT DB PER MILE ABOVE FOR TEMPERATURE OTHER THAN 68°F CHANGE VALUES SHOWN BY ± 1 PERCENT FOR EVERY CHANGE OF ± 5°F FROM 68°F.

DATA SHEET - FACILITY LOSS MEASUREMENTS FOR D-66

(1) REA PROJ. DESIGN. Iowa 501-D Dows (2) ~~TRK.~~ GROUP Dows TO ALDEN (3) TOLL, [✓ EAS] SPEC. (Circle One)
(4) MEASURING BETWEEN Dows TO POPEJOY (5) ~~TRUNK NO. LOC.~~ A —, LOC. B — (6) PAIR NO. LOC. A 3/6, LOC. B 3/6
(7) TEMP. AIR 68 °F (If Aerial), GD. ___ °F (If Buried) (8) TESTERS PGL & HFP (9) DATE MEASMS. JULY 1963
In line diagram below show: (10) Type of loading system, (11) All gauges and length of each, (12) As-build length of each full-loading section, (13) As-built length of each end-section, (14) CBO, amount and location, (15) Junction Compensator, if used, (16) Plant buried or aerial, (17) Plant new or existing, (18) Age of plant if existing.
(19) TYPE OSC. HP 200 J (20) OSC. CAL. LEVEL[1] +4.4 dbm DBM (21) TYPE AC VTVM HP 400L



Notes: Use same data sheet for H-88
*Use 50 or 44 mh for H-88



ILLUSTRATIVE EXAMPLE 1

October 1965

---

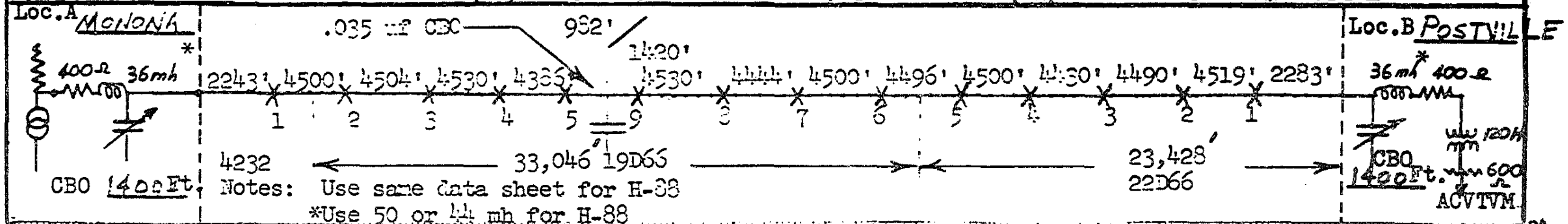
[1] Cal. Lev. of a 600-ohm osc. directly into a 600-ohm res.

DATA SHEET - FACILITY LOSS MEASUREMENTS FOR D-66

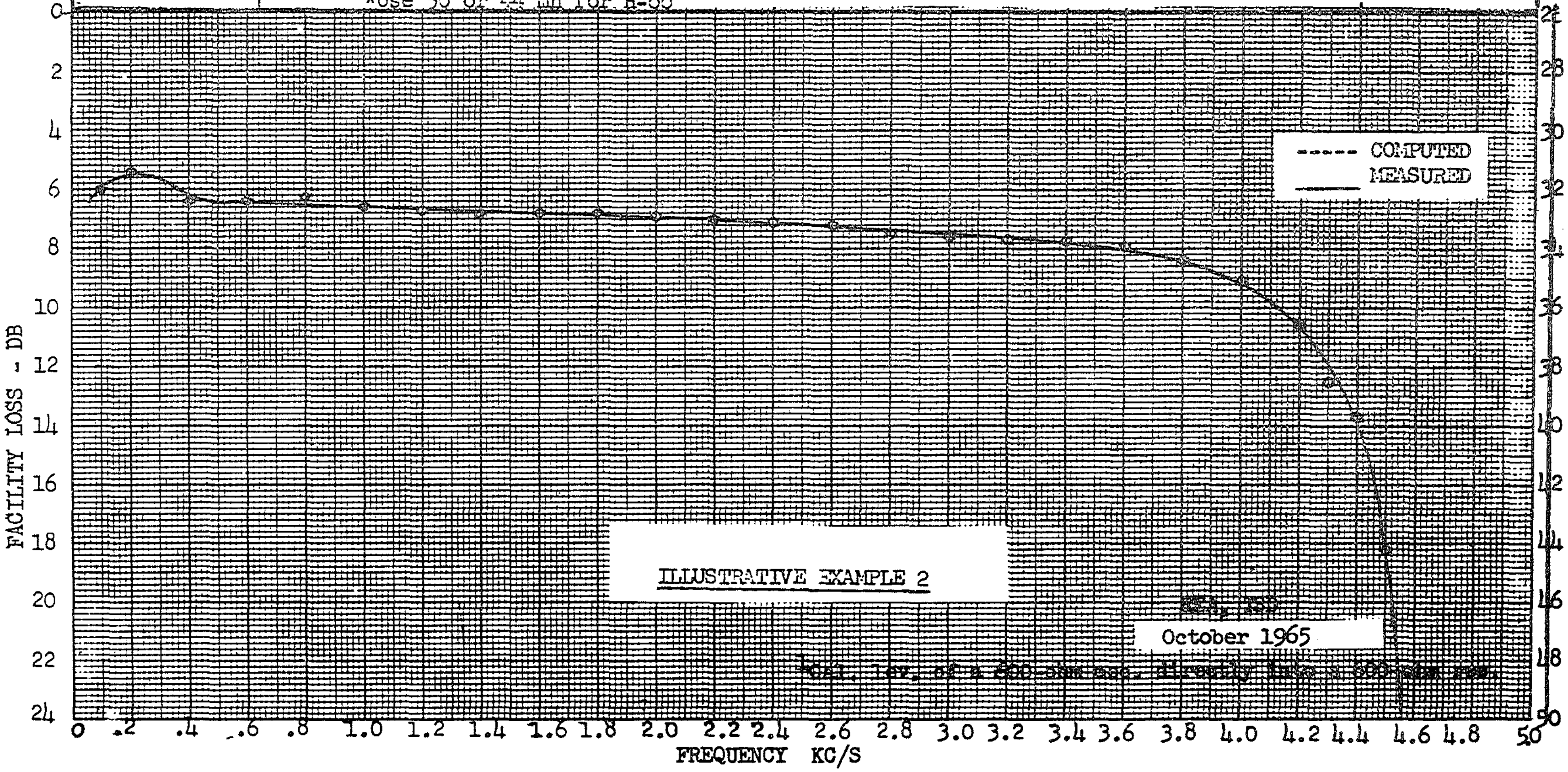
(1) REA PROJ. DESIGN. Iowa 583-A Postville (2) TRK. GROUP Monona TO Postville (3) TOLL, [✓ EAS] SPEC. (Circle One)
(4) MEASURING BETWEEN Monona TO Postville (5) TRUNK NO. LOC. A —, LOC. B — (6) PAIR NO. LOC. A 1257 LOC. B 1257
(7) TEMP. AIR 70 °F (If Aerial), GD. 55 °F (If Buried) (8) TESTERS FSL, HPP (9) DATE MEASMS. July 1963

In line diagram below show: (10) Type of loading system, (11) All gauges and length of each, (12) As-build length of each full-loading section, (13) As-built length of each end-section, (14) CBO, amount and location, (15) Junction Compensator, if used, (16) Plant buried or aerial, (17) Plant new or existing, (18) Age of plant if existing.

(19) TYPE OSC. H.P. 200 J (20) OSC. CAL. LEVEL[1] +4.4 dbm DBM (21) TYPE AC VTVM H.P. 400L



Notes: Use same data sheet for H-88
*Use 50 or 44 mh for H-88



ILLUSTRATIVE EXAMPLE 2

REA, TSD
October 1965

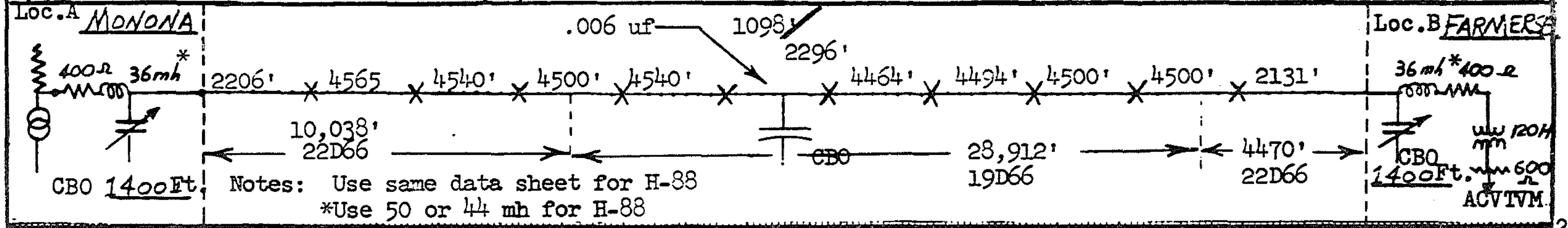
[1] Cal. lev. of a 600-ohm osc. directly into a 600-ohm res.

DATA SHEET - FACILITY LOSS MEASUREMENTS FOR D-66

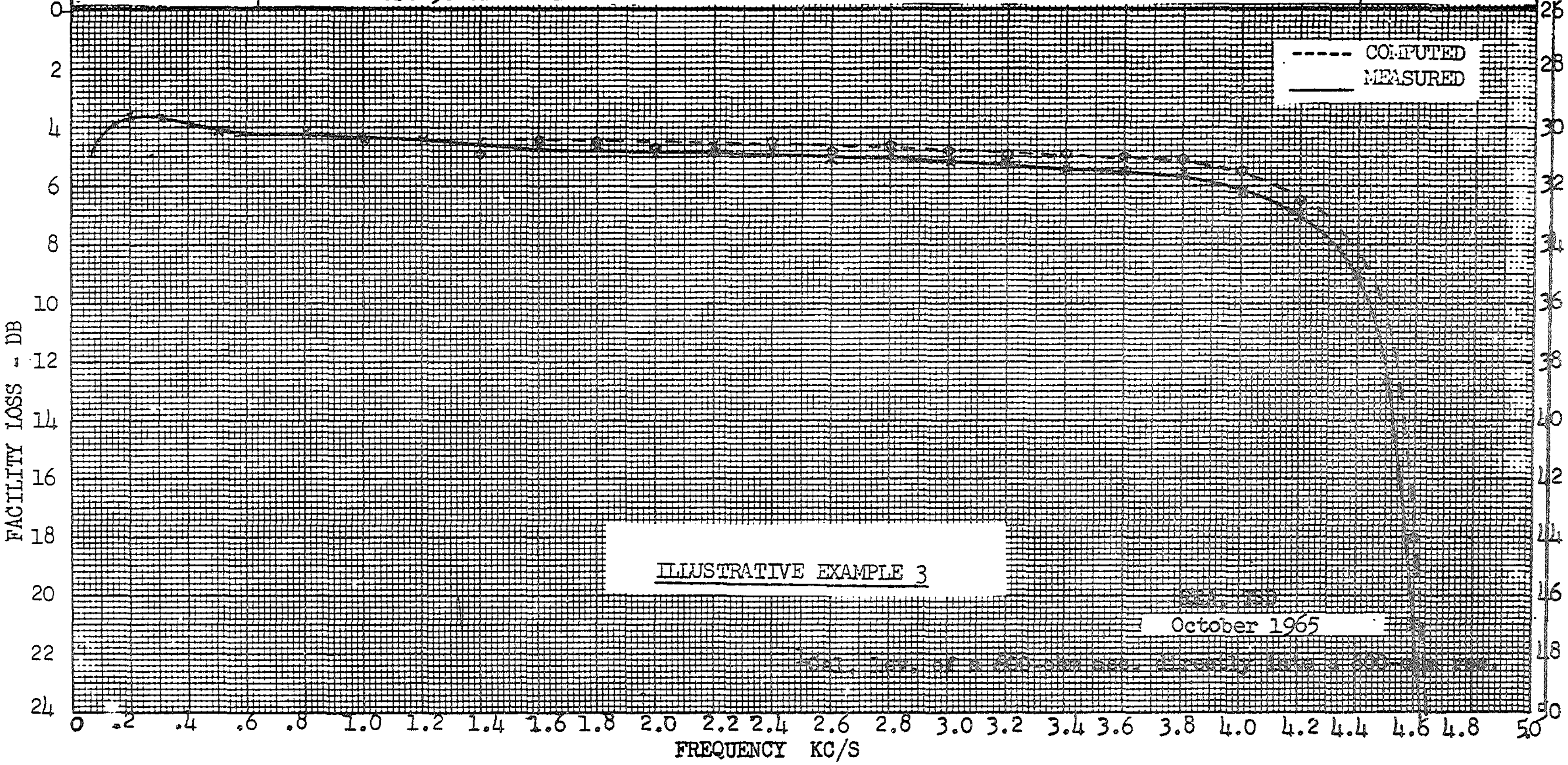
(1) REA PROJ. DESIGN. Iowa 583-A Monona (2) TRK. GROUP Monona TO FARMERSBURG (3) TOLL, [✓ EAS], SPEC. (Circle One)
(4) MEASURING BETWEEN Monona TO FARMERSB. (5) TRUNK NO. LOC. A —, LOC. B — (6) PAIR NO. LOC. A 776/782, LOC. B 33/26
(7) TEMP. AIR 70 °F (IF Aerial), GD. 55 °F (If Buried) (8) TESTERS PGL, HPP (9) DATE MEASMS. JULY 1963

In line diagram below show: (10) Type of loading system, (11) All gauges and length of each, (12) As-build length of each full-loading section, (13) As-built length of each end-section, (14) CBO, amount and location, (15) Junction Compensator, if used, (16) Plant buried or aerial, (17) Plant new or existing, (18) Age of plant if existing.

(19) TYPE OSC. H.P. 200 J (20) OSC. CAL. LEVEL[1] +4.4 DBM (21) TYPE AC VTVM H.P. 400 L



Notes: Use same data sheet for H-88
*Use 50 or 44 mh for H-88



ILLUSTRATIVE EXAMPLE 3

REA, TSD
October 1965

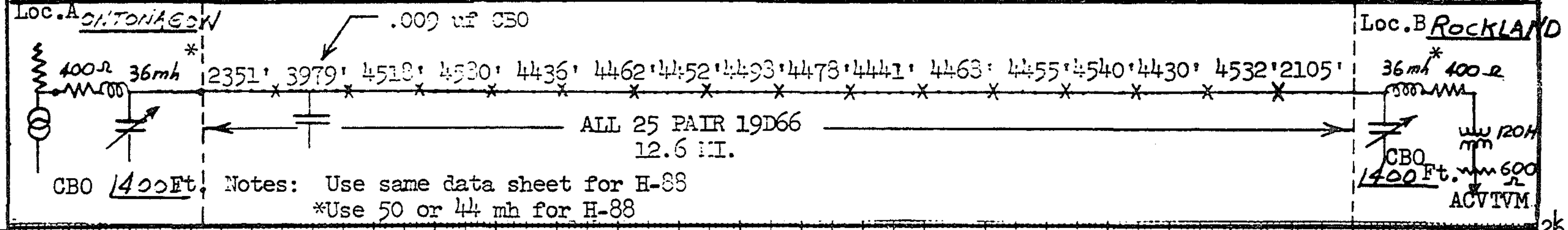
[1] Cal. Lev. of a 600-ohm osc. directly into a 600-ohm [illegible]

DATA SHEET - FACILITY LOSS MEASUREMENTS FOR D-66

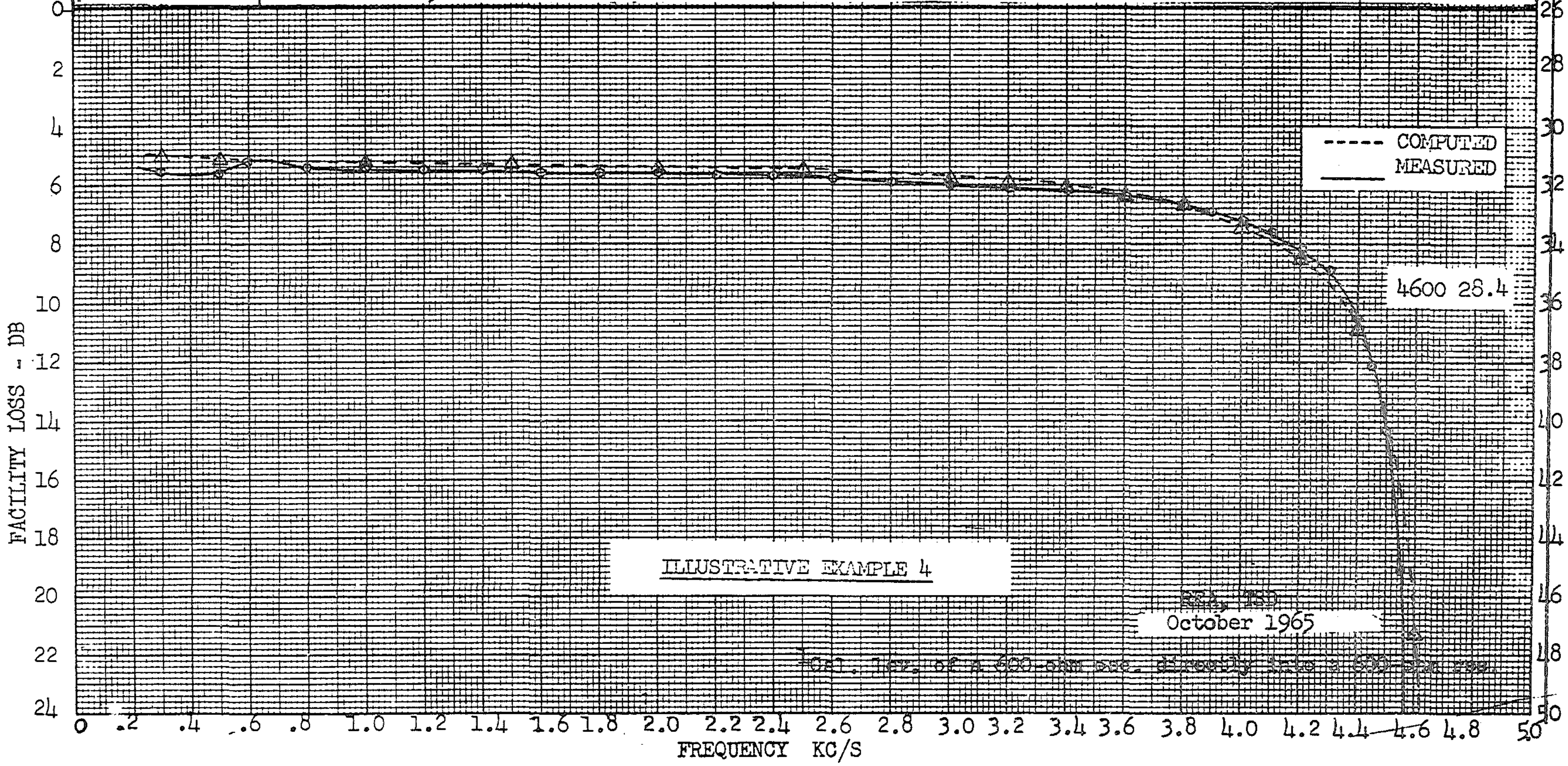
(1) REA PROJ. DESIGN. MICHIGAN 529 (2) TRK. GROUP ONTONAGON TO IRON MTN. (3) [✓ TOLL] EAS, SPEC. (Circle One)
(4) MEASURING BETWEEN ONTONAGON TO ROCKLAND (5) TRUNK NO. LOC. A – , LOC. B – (6) PAIR NO. LOC. A 21 , LOC. B 21
(7) TEMP. AIR 75 °F (IF Aerial), GD. 65 °F (If Buried) (8) TESTERS PGL, WFP (9) DATE MEASMS. AUG. 13, 1963

In line diagram below show: (10) Type of loading system, (11) All gauges and length of each, (12) As-build length of each full-loading section, (13) As-built length of each end-section, (14) CBO, amount and location, (15) Junction Compensator, if used, (16) Plant buried or aerial, (17) Plant new or existing, (18) Age of plant if existing.

(19) TYPE OSC. H.P. 200 J (20) OSC. CAL. LEVEL[1] +4.4 dbm DBM (21) TYPE AC VTVM H.P. 400L



Notes: Use same data sheet for H-88
*Use 50 or 44 mh for H-88



ILLUSTRATIVE EXAMPLE 4

REA, TSD
October 1965

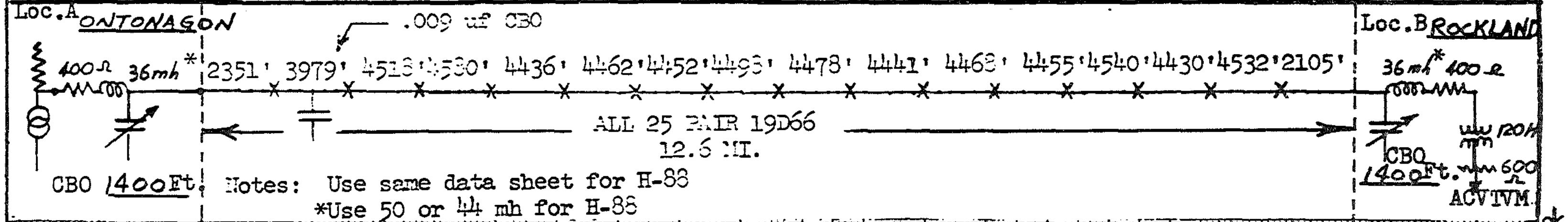
[1] Cal. lev. of a 600-ohm osc. directly into a 600-ohm res.

DATA SHEET - FACILITY LOSS MEASUREMENTS FOR D-66

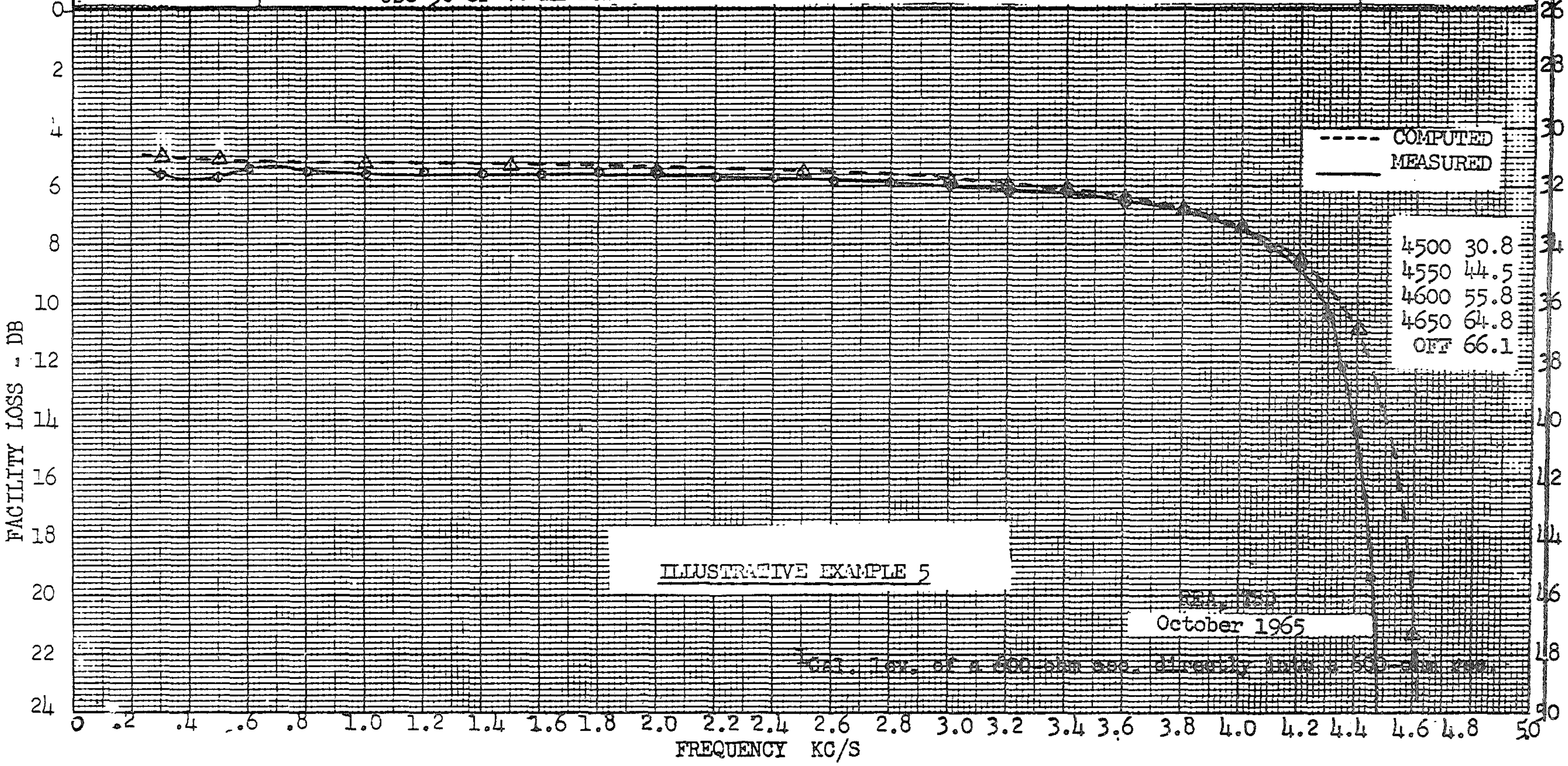
(1) REA PROJ. DESIGN. MICHIGAN 529 (2) TRK. GROUP ONTONAGON TO IRON MTN (3) [✓ TOLL] EAS, SPEC. (Circle One)
(4) MEASURING BETWEEN ONTONAGON TO ROCKLAND (5) TRUNK NO. LOC. A —, LOC. B — (6) PAIR NO. LOC. A 8, LOC. B 8
(7) TEMP. AIR 75 °F (IF Aerial), GD. 65 °F (If Buried) (8) TESTERS PGL, HP, HD (9) DATE MEASMS. AUG 19, 1963

In line diagram below show: (10) Type of loading system, (11) All gauges and length of each, (12) As-build length of each full-loading section, (13) As-built length of each end-section, (14) CBO, amount and location, (15) Junction Compensator, if used, (16) Plant buried or aerial, (17) Plant new or existing, (18) Age of plant if existing.

(19) TYPE OSC. HP 200 J (20) OSC. CAL. LEVEL¹ +4.4 DBM (21) TYPE AC VTVM HP 400L



Notes: Use same data sheet for H-88
*Use 50 or 44 mh for H-88



4500	30.8
4550	44.5
4600	55.8
4650	64.8
OFF	66.1

ILLUSTRATIVE EXAMPLE 5

REA, TESD
October 1965

---

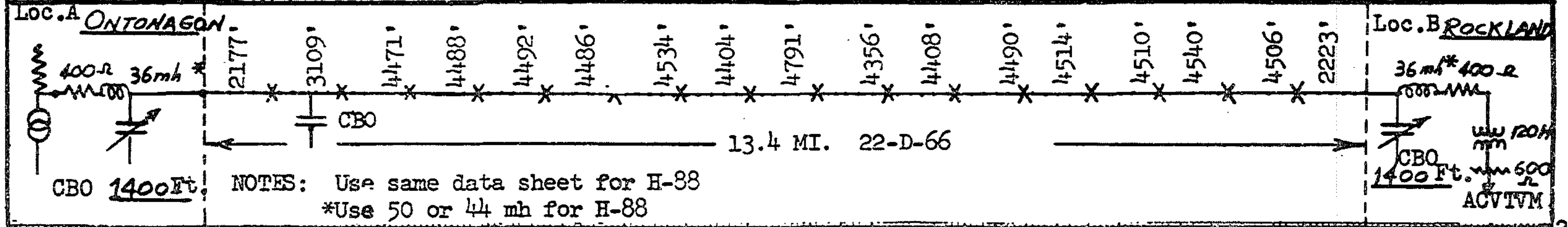
¹Cal. lev. of a 600-ohm osc. directly into a 600-ohm rec.

DATA SHEET - FACILITY LOSS MEASUREMENTS FOR D-66

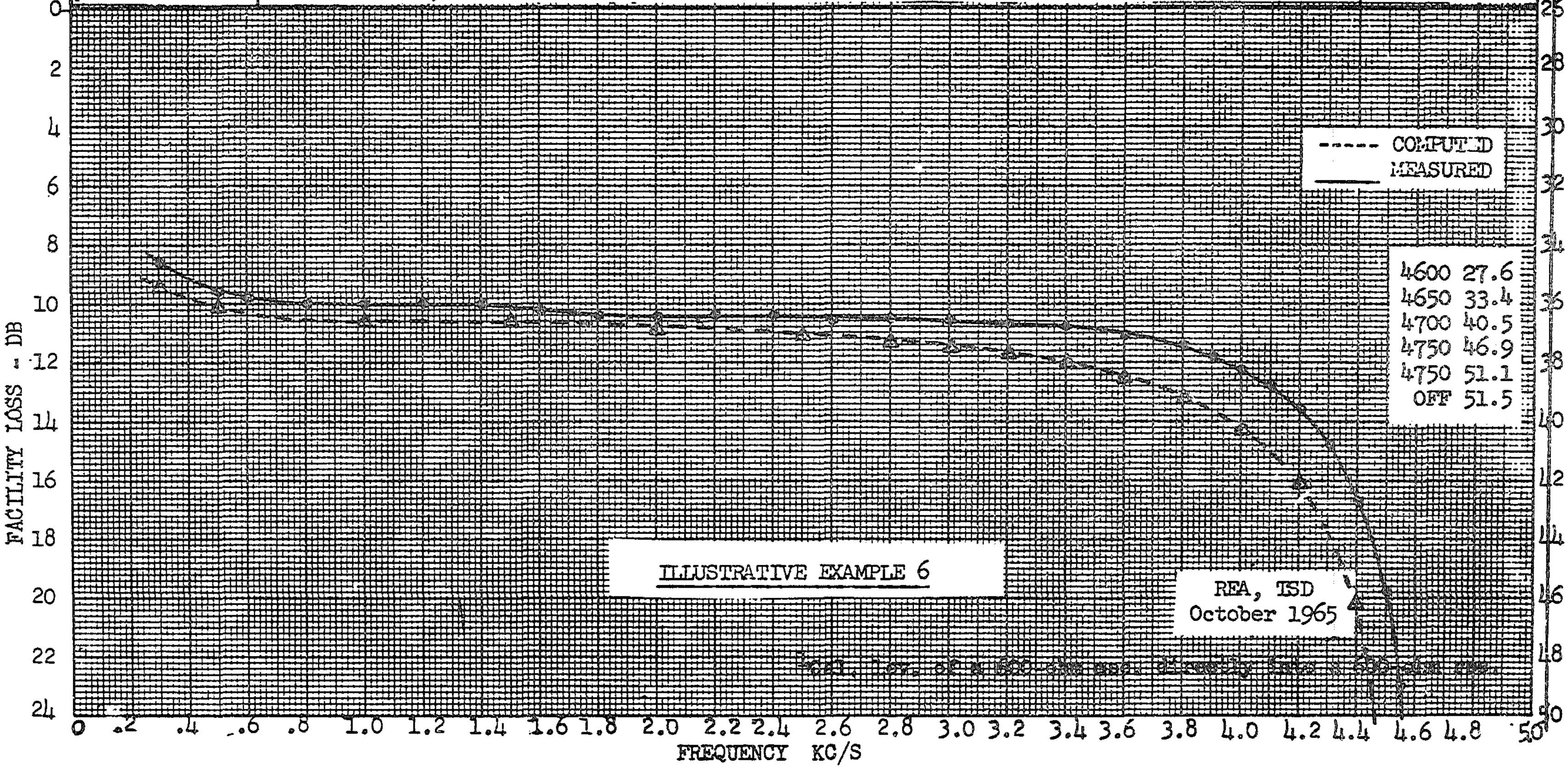
(1) REA PROJ. DESIGN. MICHIGAN 529 (2) TRK. GROUP ONTONAGON TO ROCKLAND (3) TOLL, [✓ EAS], SPEC. (Circle One)
(4) MEASURING BETWEEN ONTONAGON TO ROCKLAND (5) TRUNK NO. LOC. A 2, LOC. B 2 (6) PAIR NO. LOC. A 752, LOC. B 2
(7) TEMP. AIR 70 °F (If Aerial), GD. 65 °F (If Buried) (8) TESTERS PGL, LM (9) DATE MEASMS. AUG 1963

In line diagram below show: (10) Type of loading system, (11) All gauges and length of each, (12) As-build length of each full-loading section, (13) As-built length of each end-section, (14) CBO, amount and location, (15) Junction Compensator, if used, (16) Plant buried or aerial, (17) Plant new or existing, (18) Age of plant if existing.

(19) TYPE OSC. HP 200 J (20) OSC. CAL. LEVEL[1] +4.4 DBM (21) TYPE AC VTVM HP 400L



NOTES: Use same data sheet for H-88
*Use 50 or 44 mh for H-88



ILLUSTRATIVE EXAMPLE 6

REA, TSD
October 1965

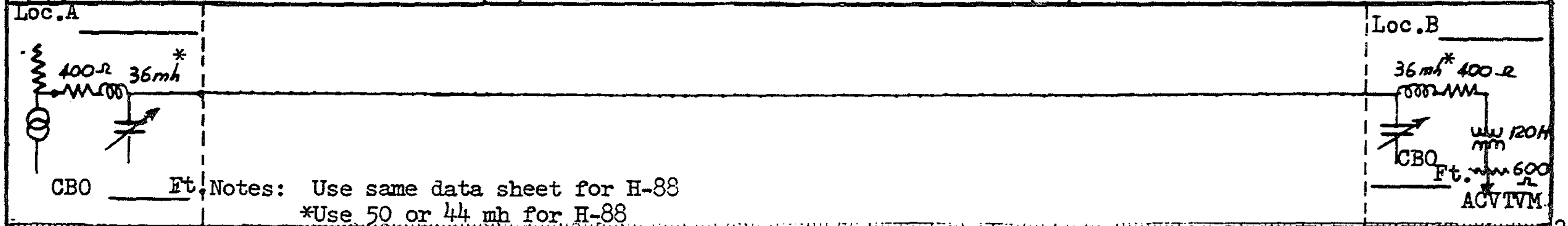
[1] Cal. Lev. of a 600 ohm osc. directly into a 600 ohm rec.

DATA SHEET - FACILITY LOSS MEASUREMENTS FOR D-66

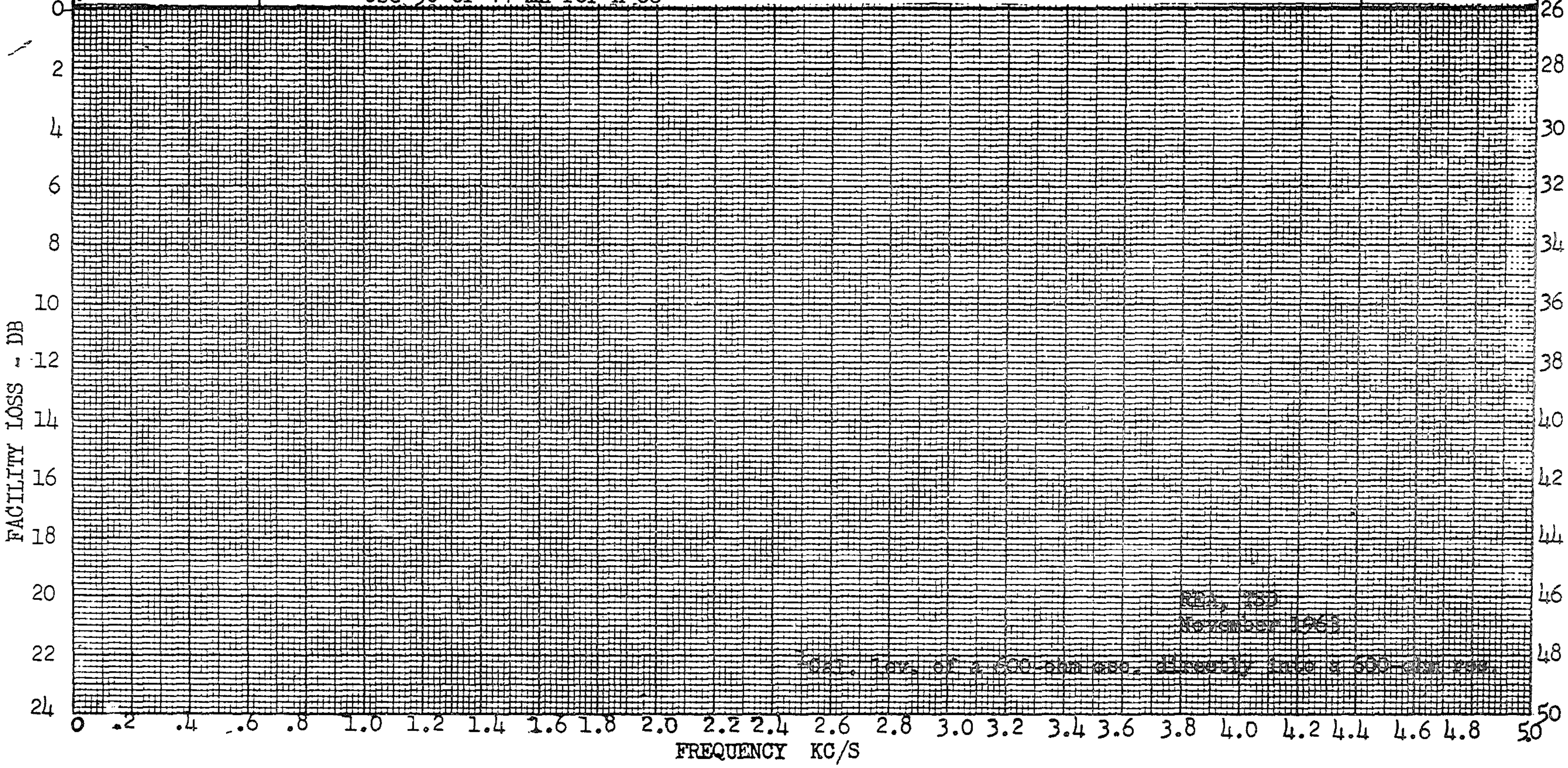
(1) REA PROJ. DESIGN.________________ (2) TRK. GROUP ________ TO ________ (3) TOLL, EAS, SPEC. (Circle One)
(4) MEASURING BETWEEN ________ TO ________ (5) TRUNK NO. LOC. A ___,LOC. B ___ (6) PAIR NO. LOC. A ___,LOC.B ___
(7) TEMP. AIR ____ °F (IF Aerial), GD. ___ °F (If Buried) (8) TESTERS __________ (9) DATE MEASMS. ________

In line diagram below show: (10) Type of loading system, (11) All gauges and length of each, (12) As-build length of each full-loading section, (13) As-built length of each end-section, (14) CBO, amount and location, (15) Junction Compensator, if used, (16) Plant buried or aerial, (17) Plant new or existing, (18) Age of plant if existing.

(19) TYPE OSC. ________ (20) OSC. CAL. LEVEL[1] ______ DBM (21) TYPE AC VTVM ______



Notes: Use same data sheet for H-88
*Use 50 or 44 mh for H-88



REA, TSD
November 1963

[1] Cal. Lev. of a 600-ohm osc. directly into a 600-ohm res.