

CABLE TESTING

USE OF BALANCING CABLE AND BALANCING UNIT FOR REDUCING QUADDED CABLE CAPACITANCE UNBALANCES

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1. GENERAL

1.01 As seen in Section G72.225, capacitance unbalance test splicing consists of the association of quads having unbalances of similar magnitude but of opposite sign, the effect being the equalization of certain quad capacitances. If there were only one length of cable to be balanced, so that there were no opportunity to test splice one quad to another, the effect of test splicing could be obtained by connecting small external condensers in parallel with the quad condensers having the smallest capacitance. This method of balancing will be briefly reviewed, using first a regular type of condenser for illustration. Practical applications of the method, the use of balancing cable and the balancing unit, will then be taken up.

2. CONDENSER BALANCING

2.01 The formulas for within-quad capacitance unbalances, as discussed in Section G72.225 are:

$$\text{Side-to-Side} = (C_2 + C_4) - (C_1 + C_3)$$

$$\text{Phantom-to-White} = \left(C_1 + C_2 + \frac{C_W}{2} \right) - \left(C_3 + C_4 + \frac{C_{WM}}{2} \right)$$

$$\text{Phantom-to-Black} = \left(C_1 + C_4 + \frac{C_B}{2} \right) - \left(C_2 + C_3 + \frac{C_{BM}}{2} \right)$$

2.02 A diagram of the four wires of a quad showing the place of the various capacitances of these formulas is given by Figure 1.

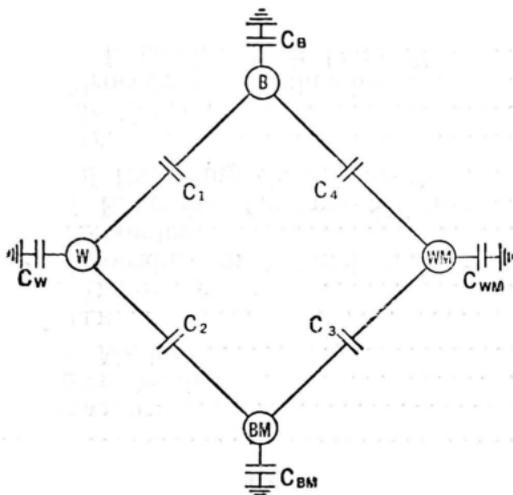


Figure 1.

2.03 As defined, the unbalance is considered (+) when the sum of the capacitances in the first parenthesis is the larger; otherwise, the unbalance is (-). If the side-to-side unbalance of a quad were (+), it could be reduced to zero by connecting an external capacitance, of same value as the unbalance, in parallel with either C_1 or C_3 ; or two condensers, the sum of which equals the value of unbalance, could be connected to the quad, one in parallel with C_1 , and the other in parallel with C_3 . In either case, the resulting value of $(C_1 + C_3)$ would equal $(C_2 + C_4)$. If the phantom-to-white were positive, a condenser could similarly be connected to either C_3 or C_4 or one condenser to each. In the phantom-to-side case the unbalance could also be reduced by connecting the condenser in parallel with C_{WM} . Since the term C_{WM} is divided by 2 in the formula, 40 mmf would, for example, have to be connected in order to

affect the formula 20 mmf: in other words, the external condenser when connected to ground should be twice the value of unbalance.

2.04 As seen from Figure 1 an external condenser may be placed in parallel with C_1 by connecting one of its terminals to wire B and the other terminal to wire W. In parallel with C_w , the condenser would be connected to wire W and to ground (cable sheath).

2.05 It is important to note certain relations between the capacitances of the three formulas, or rather, the occurrence of the same capacitance in all three formulas. C_1 , for example, occurs in all three (each of the wire-to-wire capacitances occurs in all three). Consequently, an external capacitance connected to C_1 for reducing a side-to-side unbalance would likewise affect the two phantom-to-side unbalances. In both cases of phantom-to-side, C_1 is in the positive parenthesis, so that the external capacitance would tend to reduce a (—) unbalance. If the side-to-side unbalance were +20 mmf and each of the phantom-to-side —20 mmf, a 20-mmf condenser connected to C_1 would evidently reduce all three unbalances to zero.

2.06 If it were desired to reduce the side-to-side unbalance and not affect the phantom-to-side, a 10 mmf condenser could be connected to C_1 and another 10 mmf condenser to C_3 (assuming a side-to-side unbalance of +20 mmf). It will be noted that for both phantom-to-side unbalances C_1 is in the positive parenthesis and C_3 is the negative. Adding equal amounts to each parenthesis evidently does not affect the unbalance.

2.07 By further inspection of the formulas it is seen that a phantom-to-side unbalance can be similarly reduced without affecting either the side-to-side or the other phantom-to-side unbalance. Assume a phantom-to-black unbalance of —40 mmf. This could be reduced by connecting a 20 mmf condenser to C_1 and a 20 mmf condenser to C_4 . An 80 mmf condenser to C_B would also reduce this unbalance to zero and not affect the other two unbalances.

2.08 For convenience the quads that require balancing may be divided into two classes: (1) quads requiring only one unbalance each to be corrected, and (2) quads in which more than one unbalance needs to be reduced. For the first class it is desired to correct the unbalance independently, that is, without appreciably altering the other two of the same quad. Considering a side-to-side unbalance this as seen can be accomplished by connecting equal condensers to each of the two wire-to-wire capacitances having opposite signs to the unbalance. For all positive unbalances this means one condenser to wires W-B and one to WM-BM. For all negative unbalances, the condensers must be connected to W-BM and WM-B.

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2.09 When the unbalance is a phantom-to-side, it can be reduced independently by connecting a condenser between one wire of the side involved and ground. The wire is in every case the "Wire" (W or B) of that side for a negative unbalance and the "Mate" (WM or BM) for a positive unbalance. Independent reduction of a phantom-to-side unbalance can also be made by connecting equal condensers between each of the two wire-to-wire capacitances of opposite signs to the unbalance. For all negative unbalances, this would mean the connection of a condenser from the "Wire" of the pair involved to each of the wires of the other pair; and for positive unbalances, the connection of a condenser from the "Mate" of the pair to each of the wires of the other pair.

2.10 When more than one unbalance in a quad requires reduction, the reduction can be obtained by treating each unbalance independently as discussed above. One condenser may, however, be used to reduce more than one unbalance. This latter procedure is desirable because, as will be seen under the discussion of balancing cable, it requires the use of fewer balancing cable pairs than the independent method and it also requires fewer connections to the cable quads.

Wire-to-Ground Method

2.11 In order to save as many connections to the cable quads as possible, it is desirable to employ both the independent and dependent methods of unbalance reduction where balancing cable is used. In most cases such a procedure will involve connections to ground and further discussion of these two methods as applied to balancing cable will be referred to as the "wire-to-ground method."

2.12 It is convenient in applying the independent and dependent methods to divide quads requiring unbalance reduction into two groups, positive quads and negative quads. A positive quad is one, the product of the three unbalance signs of which is plus (+), and a negative quad is one, the product of the three unbalance signs of which is negative (-).

2.13 The INDEPENDENT method should be employed in the reduction of all NEGATIVE quad unbalances. The various combinations of signs forming the negative quads and the connections and magnitudes to be employed for these combinations are given in the following table. The magnitudes of the capacitance required for the reduction of phantom-to-side unbalances given below are based on the methods of setting up the constants of the balancing cable given in paragraph 3.04. This method takes account of the factor 2 discussed in the latter part of paragraph 2.03.

UNBALANCE SIGNS—NEGATIVE QUADS		
Ph-W	Ph-B	S-S
+	+	-
+	-	+
-	-	-
-	+	+

METHOD OF REDUCTION

Reduce +Ph-W by adding capacitance equal to Ph-W from WM to G.

Reduce -Ph-W by adding capacitance equal to Ph-W from W to G.

Reduce +Ph-B by adding capacitance equal to Ph-B from BM to G.

Reduce -Ph-B by adding capacitance equal to Ph-B from B to G.

Reduce +S-S by adding capacitances equal to $\frac{S-S}{2}$ from W to B and WM to BM.

Reduce -S-S by adding capacitances equal to $\frac{S-S}{2}$ from W to BM and WM to B.

2.14 The DEPENDENT method should, in general, be employed in the reduction of all positive quad unbalances. The various combinations of signs forming the positive quads are:

UNBALANCE SIGNS—POSITIVE QUADS		
Ph-W	Ph-B	S-S
-	-	+
-	+	-
+	+	+
+	-	-

As a first step in the unbalance reduction, the smallest unbalance should be reduced as closely as possible to zero by connecting a balancing capacitance approximately equal to the smallest capacitance as shown below:

UNBALANCE SIGNS			METHOD OF REDUCTION
Ph-W	Ph-B	S-S	
-	-	+	Connect balancing capacitance from W to B.
-	+	-	Connect balancing capacitance from W to BM.
+	+	+	Connect balancing capacitance from WM to BM.
+	-	-	Connect balancing capacitance from WM to B.

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Next compute the resultant unbalances after adding the balancing capacitances. The resultant unbalances should then be reduced by the INDEPENDENT method as discussed in the latter part of paragraph 2.13. As an illustration suppose it is desired to effect unbalance reduction using balancing cable of a quad with the following unbalances, Ph-W -70, Ph-B -70 and S-S +55. As a first step the S-S +55 value is reduced by connecting a balancing capacitance of 55 mmf to W-B. The resulting unbalances are then Ph-W -20, Ph-B -20 and S-S 0. These remaining unbalances may then be reduced to zero using the INDEPENDENT method by connecting balancing capacitances of 20 mmf each respectively to W-G and B-G.

2.15 In cases where the smallest unbalance of a positive quad referred to in paragraph 2.14 is zero or so near zero that it is not practical to reduce it any further, the unbalance reduction should be effected by the INDEPENDENT method.

Wire-to-Wire Method

2.16 While, as pointed out in paragraph 2.11, the wire-to-ground method of obtaining phantom-to-side unbalance reduction is usually preferable where balancing cable is employed, however, the physical and electrical characteristics of the balancing unit have been so designed as to permit the use of the wire-to-wire method.

2.17 As indicated in paragraphs 2.06 and 2.07, in order to correct a single unbalance without affecting the other two using the wire-to-wire method, it is necessary to employ two balancing units of equal value. For example, if a phantom-to-white side unbalance of +100 mmf were to be balanced without changing the other two unbalances in the quad, balancing units of 50 mmf each should be connected in multiple with C_2 and C_4 . (See Figure 1.) These balancing units would reduce the phantom-to-white unbalance to zero and cause no change in the phantom-to-black and side-to-side unbalances since the connection of the balancing unit in multiple with C_2 would add -50 mmf to the latter unbalances, and the balancing unit in multiple with C_4 would add +50 mmf, or the net effect would be zero.

2.18 When correction of two or three of the unbalances in a quad is to be made, the method outlined in paragraph 2.17 would result in the use of four or six balancing units. Two or three of these units might be in multiple between the same pair of wires and could be combined into one unit. If this is done, there would be no more than four units in multiple with the four capacitances C_1 to C_4 of Figure 1. Each of the four units could be reduced in capacitance by the capacitance of the smallest unit without changing the unbalances. This is based on the fact that like capacitances connected in multiple with

each of the four direct capacitances between wires of a quad have no effect on the unbalances within the quad. By the same reasoning, the four direct capacitances between the wires of a quad could each be reduced by the same amount without changing the unbalances within the quad. The correction of three of the unbalances will, therefore, require three balancing units. A close approximation to the correction of three unbalances can sometimes be made with two units or with one unit.

2.19 An example of the calculation of the magnitudes and method of connecting three balancing units to correct three unbalances is given below. The pairs of wires between which the units may be connected are represented by W-B, W-BM, etc. The signs under W-B, etc., indicate whether the connection of a balancing unit will introduce a plus or minus unbalance. A pair of balancing units is calculated for each unbalance and the total capacitance needed between each pair of wires is then calculated as shown.

UNBALANCES		BALANCING UNITS			
Comb.	Value	W-B (C ₁)	W-BM (C ₂)	WM-BM (C ₃)	WM-B (C ₄)
Ph-W	-100	+	+	-	-
		50	50		
Ph-B	+ 50	+	-	-	+
			25	25	
S-S	+ 16	-	+	-	+
		8		8	
Totals		58	75	33	

2.20 In many cases, as indicated in paragraph 2.19, the method of calculating the balancing units to correct three unbalances will result in initially calculating the four balancing units as illustrated below.

Comb.	Value	W-B (C ₁)	W-BM (C ₂)	WM-BM (C ₃)	WM-B (C ₄)
Ph-W	-100	+	+	-	-
		50	50		
Ph-B	+ 80	+	-	-	+
			40	40	
S-S	- 40	-	+	-	+
			20		20
First total		50	110	40	20
Smallest unit		-20	- 20	-20	-20
Second total		30	90	20	0

The four units are, therefore, reduced to three by subtracting from all four the magnitude of the smallest unit.

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2.21 It sometimes happens that one or two of the three calculated balancing units have such small values that they may be omitted. An example of this is given below.

Comb.	Value	W-B (C ₁)	W-BM (C ₂)	WM-BM (C ₃)	WM-B (C ₄)
Ph-W	+100	+	+	—	—
Ph-B	— 92	+	—	—	+
		46			46
S-S	— 90	—	+	—	+
			45		45
First total		46	45	50	141
Smallest unit		—45	—45	—45	— 45
Second total		1	0	5	96

The resultant unbalances are given below for the above example after each balancing capacitance shown in the "Second total" is added so that individual effects may be observed. These are taken in the order C₄, C₃ and C₁.

	Ph-W	Ph-B	S-S
Original Unbalances	+100	— 92	— 90
Add 96 mmf to WM-B	+ 4	+ 4	+ 6
Add 5 mmf to WM-BM	— 1	— 1	+ 1
Add 1 mmf to W-B	0	0	0

It will be noted that the omission of one balancing unit causes all three unbalances to assume its value i.e., omitting 1 mmf causes all three to become 1 mmf. The omission of two units causes one unbalance equal to the sum of the capacitances of the two units and two unbalances equal to the difference of the two capacitances i.e., omitting balancing units of 1 and 5 mmf causes one to become 6 mmf and two to become 4 mmf. Calculated balancing units of 5 mmf or less should be omitted inasmuch as the average unbalances for an entire group of quads will be little affected.

3. BALANCING CABLE

3.01 The balancing cable is one method of providing the necessary balancing condensers and is used where a large number of quads are to be balanced. It is an ordinary lead-sheathed cable usually containing 202 or 606 non-quadded pairs of wire. The two wires of a pair constitute the plates of a condenser, the capacitance of which depends on the length of the wires, that is, the length of the balancing cable. Usually, a fixed length of cable is used in a particular instance, so that

the capacitance of the balancing condenser for a given quad is varied by connecting several pairs in parallel to form a balancing group. There is a difference between the balancing cable and the regular condenser, in that the cable has capacitance between each wire and the sheath in addition to the capacitance between the wires. These capacitances are illustrated in Figure 2. The capacitance between the wires of a pair is designated "a" and that between wire and sheath, "b."

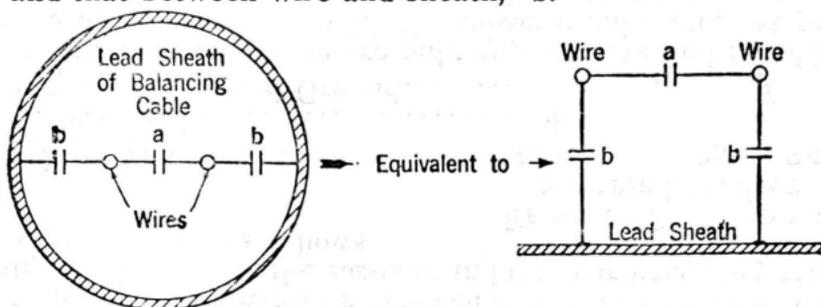


Figure 2.

3.02 The effect of these various capacitances when the pair is connected between two wires of a quad (wires W and BM for illustration) is shown by Figure 3.

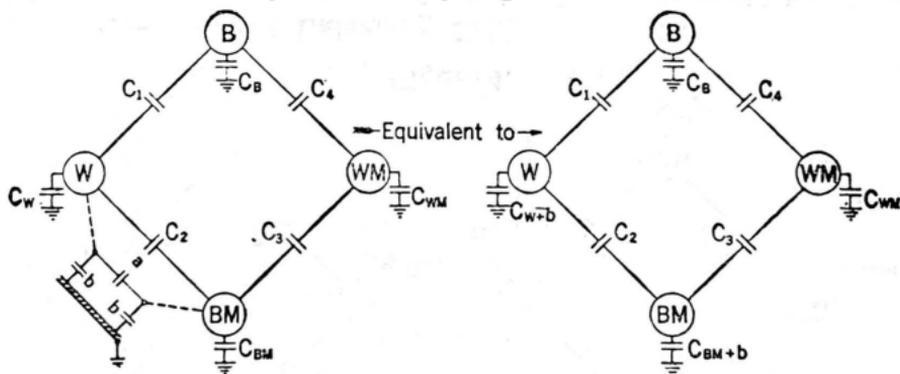


Figure 3.

Referring to the left-hand figure, "a" is evidently in parallel with C_2 , one "b" in parallel with C_W , and the other "b" in parallel with C_{BM} . The addition of these capacitances is shown on the right-hand figure. Knowing the values of a and b for a given length of pair and by referring to the formulas of unbalance, we could easily determine what effect the pair would have. On the side-to-side the effect would be $+a$, meaning the capacitance "a" is added to the positive parenthesis, this tending to neutralize or to reduce a negative unbalance. Remembering that a phantom-to-side unbalance is

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affected by only one half the capacitance added between wire and ground, the effect on the phantom-to-white is $+a + b/2$, and on the phantom-to-black, $-a - b/2$.

3.03 The connection of a pair between wire W and ground is shown by Figure 4. The effect on the phantom-to-white is $+a/2 + b/2$, with NO EFFECT on the other two unbalances.

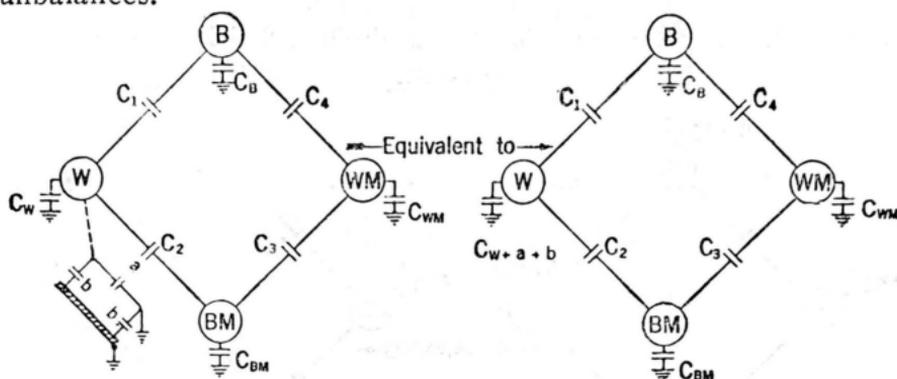


Figure 4.

Constants of Balancing Cable

3.04 While the constants of a balancing cable could be given in terms of "a" and "b," it facilitates the practicable application of balancing cables to have the constants indicate the number of mmf by which one-foot of a pair will affect unbalances as read by a capacity unbalance set, when the pair is connected between wires or between a wire and ground. Constants of this kind for the 202-pair and 606-pair balancing cables are approximately as follows:

Connection	EFFECT ON SET READINGS MMF PER PAIR FOOT	
	S-to-S	Ph-to-Sd
Between Wires.....	4	12
Between Wire and Ground.....	0	9

The constants given above are only approximate and should be checked by measurement with the capacity unbalance set prior to an actual installation and after the balancing cable has been prepared as mentioned in paragraph 3.07. They may be used, however, for computation of balancing cable lengths as discussed later. With the constants, a pair in a balancing cable can be regarded as a regular condenser, and the general principles of Part 2 followed. One difference, however, is that the magnitude of capacitance depends on the way the pair is connected.

3.05 While the constants for one pair of a balancing cable of given length can be obtained by multiplying the pair-foot constants by the cable length, the constants for several pairs forming a balancing group as later discussed may be somewhat different from the sum of the constants of the individual pairs. The reason for this may be seen from the following example. Suppose a side-to-side unbalance which it is desired to reduce is so large as to require a balancing capacitance about twice that afforded by one pair of a balancing cable. If this balancing capacitance is all to be connected in parallel with the same wire-to-wire capacitance of the quad the natural thing to do is to connect two pairs and thus obtain twice the direct capacitance (2a) of a single pair for balancing purposes. Such a connection is shown in Figure 5.

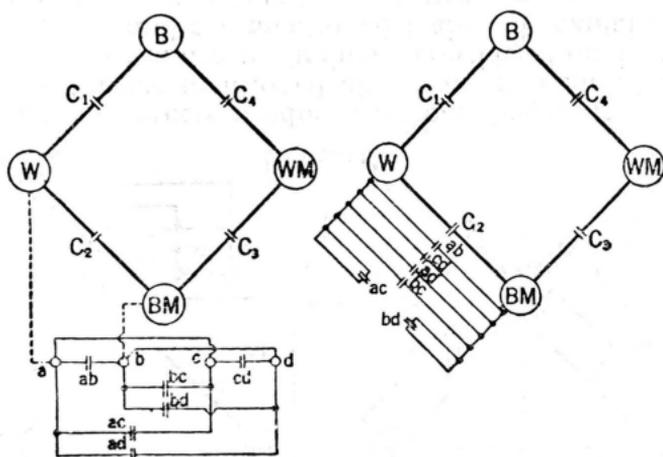


Figure 5.

The wires of one balancing pair are designated a and b, and those of the other c and d. In addition to the direct capacitance between the two wires of each pair, there are four other capacitances involved which may be termed pair-to-pair capacitances, these being one from each wire of one pair to each wire of the other pair. These capacitances are designated in Figure 5 by the two letters corresponding to the two wires between which the capacitance exists: thus, ac is the pair-to-pair capacitance between wires a and c. The direct capacitance of the pairs, "a" of previous discussions, are labeled ab and cd. By converting the detail diagram to the equivalent simplified diagram shown on the right of Figure 5 it is seen that two of the four pair-to-pair capacitances are short-circuited but that the other two are added in parallel with the wire-to-wire capacitance of the quad, thus increasing the balancing effect of the two pairs. If instead of connecting the two pairs in parallel with

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the same wire-to-wire capacitance of the quad, one were connected to this capacitance and one to the other wire-to-wire capacitance in the same parenthesis of the formula for side-to-side unbalance, it can be seen that two of the four pair-to-pair capacitances would be added to the wire-to-wire capacitances of the quad having the same sign as the unbalance. In this case, therefore, these two capacitances would decrease the balancing effect of the two pairs. The other two of the four capacitances would be connected between wires of the same pairs of the quad and would therefore have no effect on the unbalances. This condition is illustrated by Figure 6.

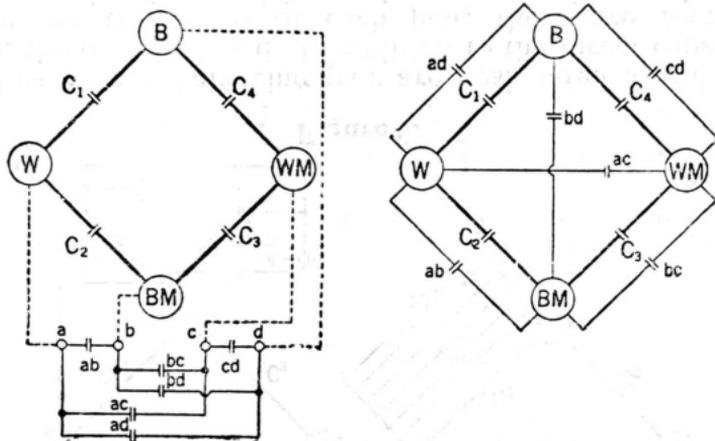


Figure 6.

3.06 Balancing effects produced by pair-to-pair capacitances of the nature mentioned above are in general not sufficiently large to require preliminary consideration in the balancing procedure and are mentioned mainly to explain possible discrepancies between calculated and measured resultants that might be observed when the balancing procedure is worked out on the basis of single pair constants. The magnitude and direction of these effects for various conditions will be indicated as the balancing work in a given instance progresses, and such indications will suggest any need for additional balancing work that might occasionally be needed. This seems a better procedure than to evaluate the effects for all conditions and to take account of these from the outset.

Method and Procedure of Balancing

3.07 Prior to the balancing work the two ends of the balancing cable should be cleared and boiled out. During the balancing work the sheath of the balancing cable and a number of pairs in various locations in the core should be kept tem-

porarily grounded, that is, connected to the main cable sheath and to the ground post of the capacity unbalance set. These precautions will insure that the resultant unbalances obtained during the balancing work will represent the conditions that will exist after the work is completed and the cable sleeve is in place. The provision of shielding quads during the progress of the work as later discussed will finally take place of the temporarily grounded pairs and on completion of the work the cable sleeve will, of course, serve to bond together the sheaths of the main and balancing cables.

3.08 The method and procedure for balancing by means of balancing cable are in general the same as those outlined in Part 2 for condenser balancing. As previously mentioned the balancing capacitance is adjusted by connecting pairs in parallel when one pair is insufficient. Where great precision is required, a number of pairs, preferably in the outer layers, can be opened at an intermediate point in the balancing cable, so as to provide less than full length pairs for fine adjustment.

Illustrative Examples

3.09 For illustrating the balancing procedure assume a 5-foot balancing cable, the constants of which have been found by measurement to be about the same as those given in paragraph 3.04. The constants for a 5-foot pair would then be:

Connection	EFFECT ON SET READINGS	
	MMF PER 5 FT. PAIR	
	S-to-S	Ph-to-Sd
Between Wires.....	20	60
Between Wire and Ground.....	0	45

3.10 In the table below are given assumed initial unbalances of several quads, the number of 5-foot pairs connected to the quads to reduce the unbalances and where connected, and the resultant unbalances on completion of the connections. The reason for the particular connections made will not be discussed to any great length for these will be more or less apparent from previous discussion. In all of the examples the resultant unbalances are given after each balancing group (or pair) is added so that the individual effects may be observed as the balancing of a quad progresses. The final resultants are those shown opposite the last balancing group in each example.

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Example	INITIAL UNBALANCES			BALANCING GROUP CONNECTIONS	RESULTANT UNBALANCES		
	Ph-W	Ph-B	S-S		Ph-W	Ph-B	S-S
(1)	+ 55	-125	+ 80	1 pr. to WM-G 3 prs. to B-G 2 prs. to W-B 2 prs. to WM-BM	+ 10 + 10 + 50 + 10	-125 + 10 + 50 + 10	+ 80 + 80 + 40 0
(2)	+345	- 90	-200	2 prs. to WM-B 5 prs. to WM-G 1 pr. to BM-G 4 prs. to W-BM 4 prs. to WM-B	+225 0 0 +240 0	+ 30 + 30 - 15 -255 - 15	-160 -160 -160 - 80 0
(3)	-170	-185	+ 70	3 prs. to W-B	+ 10	- 5	+ 10
(4)	- 75	+ 10	+ 5	2 prs. to W-G	+ 15	+ 10	+ 5
(5)	- 60	-125	- 5	1 pr. to W-G 3 prs. to B-G	- 15 + 15	-125 + 10	- 5 - 5
(6)	- 40	+ 5	- 30	1 pr. to W-G 1 pr. to W-BM 1 pr. to WM-B	+ 5 + 25 + 5	+ 5 - 15 + 5	- 30 - 10 + 10

3.11 Example (1) represents a negative quad and from paragraph 2.13 the INDEPENDENT method of unbalance reduction should be employed. The various steps involved and the resultant unbalances are given in the order suggested in the method of reduction in paragraph 2.13. It will be noted that eight pairs are required for reduction.

3.12 Example (2) is a positive quad and hence should be treated by the DEPENDENT method. It will be noted that the first step taken was the reduction of the smallest unbalance, Ph-B -90, to as near zero as possible by connecting balancing capacitance consisting of two pairs to WM-B. The resultant unbalances, Ph-W +225, Ph-B +30 and S-S -160, are then reduced by the INDEPENDENT method starting with the Ph-W +225, etc. Example (3) is also a positive quad and hence is treated by the DEPENDENT method. It will be noted that the reduction of all three unbalances has been obtained by the use of a single balancing group. Example (6) is also a positive quad. However, the smallest unbalance is very near zero and hence this example is treated directly by the INDEPENDENT method, as discussed in paragraph 2.15.

Formation of Balancing Groups—Shielding

3.13 The balancing cable procedure will require the use of single pairs for reducing some unbalances and the use of balancing groups to reduce others, a balancing group consisting of a number of pairs bridged together for the purpose of obtaining greater balancing effect for the treatment of high unbalances. The pairs forming a group should consist as far as practicable of adjacent pairs in the same layer and, for shielding, one pair should be left dead and grounded between groups used for balancing different quads. Adjacent layers may be used for balancing. The omission of shielding between groups used for balancing the same quad and between layers may lead to some error because of the pair-to-pair capacitance effects. One type of such effects encountered within a single balancing group has already been discussed. The effects between groups used for balancing either the same quad or different quads are somewhat similar. Thus, if two adjacent pairs were used for balancing independently (connected between wire and ground) the two Ph-S unbalances of a quad it would be found that the S-S unbalance would be altered to some extent by the pair-to-pair capacitances. The Ph-S values also would be affected by these capacitances. These effects are usually relatively small, depending on the length of the balancing cable for one thing, and do not warrant complete shielding, particularly if the provision for complete shielding would necessitate the use of a larger cable than it is desired to employ or a longer cable than would permit adequately close adjustment of the balancing capacitance. The following general rules should ordinarily be satisfactory:

- (a) Form a balancing group from adjacent pairs in the same layer to the extent practicable.
- (b) Use adjacent groups in the same layer as far as possible for balancing a given quad.
- (c) Leave dead and grounded one pair between groups used for balancing different quads.
- (d) Provide no shielding layer between layers used for balancing.

3.14 Departures from these rules might under certain circumstances be necessary and in such cases if there is any question as to what the reactions might be, this could be determined by noting the effect on the capacitance unbalances of or between the quads involved.

Computation of Balancing Cable Lengths

3.15 The computation of balancing cable length for application in a specific instance need be only approximate and for practical purposes the method below should be satis-

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factory. Balancing groups are formed by bridging together the proper number of adjacent pairs in a layer, and one pair is usually left dead and grounded between the groups used for separate quads. This amount of shielding is provided for in the formula given below, but if it should be desired in any case to provide for greater shielding the necessary modifications will suggest themselves. The 202-pair balancing cable, and the constants given for this cable in paragraph 3.04 are assumed. Independent reduction of unbalances is, for convenience, also assumed. This assumption will tend to provide some excess of balancing capacitance.

Letting: N = number of quads requiring unbalance correction
 S = average S-S unbalance
 P = average Ph-S unbalance
 $S \times N$

Then: $\frac{4}{S \times N}$ = Pair feet required for S-S correction

$\frac{P \times 2N}{9}$ = Pair feet required for Ph-S correction

$$\text{Length of Cable} = \frac{\frac{S \times N}{4} + \frac{P \times 2N}{9}}{202-N}$$

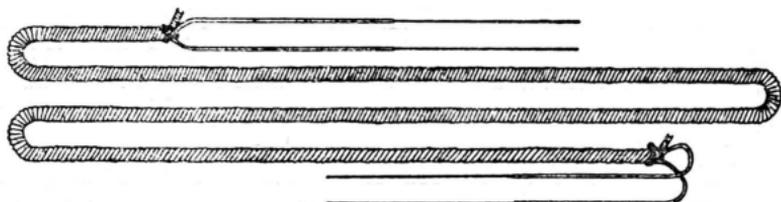
3.16 The application of the approximate formula given above requires a knowledge of the magnitudes of unbalances to be dealt with. In some cases an approximate idea of these can be obtained from data on other similar projects or from general information on cables. In others it may be practicable to defer cutting the balancing cable to length until after the unbalances have been read.

3.17 With a given length of balancing cable, it will evidently be impossible in some cases to reduce occasional unbalances to values less than about one half the constant of one of the balancing cable pairs. Assuming a 10-ft. length of the 202-pair cable, the wire-to-ground constant is approximately 10×9 or 90 mmf. A single Ph-S unbalance of such value as 45 or 135 cannot of course be reduced to less than 45. In specific cases this might suggest opening a few pairs at an intermediate point in the stub in order to obtain lower unbalances. It is generally preferable if practicable, however, to use shorter cables which in turn might necessitate a larger stub or more than one. Conditions surrounding a specific project should in general suggest the preferable procedure.

4. BALANCING UNIT

4.01 The balancing unit, as shown in Figure 7, consists of a cord center about which are wrapped helically two parallel insulated 22-gauge wires.

CAPACITANCE BALANCING UNIT



Note:-

Approx. capacitance of Wrapped Section - 60 m-m-f - per foot
One foot when connected to "W" and "B" terminals of capacitance unbalance set will cause a set reading of about 60 phantom - to - side or side - to - side.

Approx. Dimensions

Diameter of wrapped Section $\frac{1}{8}$ "

Length of wrapped Section 24"

Length of Non - wrapped Section 15"

Figure 7.

4.02 The balancing units are approximately 38 inches long. To facilitate installation approximately 7 inches of non-wrapped wires are left at each end of the unit. The length of the wrapped unit between non-wrapped portions is two feet. When used the wires should be cut in the wrapped portion so that two units are formed.

4.03 The insulation of the balancing unit is designed to make the conductance between wires of the units so small that the coupling introduced between two circuits is practically all due to the capacitance of the unit. The balancing units should be boiled out on the day that they are to be installed in order to obtain sharp balances on the capacity unbalance set.

Balancing Unit Constant

4.04 The direct capacitance between the two wires of the balancing unit is expected to be approximately 60 mmf per foot after it has been boiled out in paraffin at standard temperature and allowed to cool.

Method and Procedure of Balancing

4.05 The quad number, magnitude and sign of the resultant unbalances after the matching process for those quads to which balancing units are to be applied should be entered in the first four columns on Form E-2017, a sample of which is shown in Figure 8.

4.06 As a matter of convenience a calculation chart based on the discussion given in paragraphs 2.16 to 2.21 is given on Form E-2017 for various sign combinations of unbalances. Making use of this chart, determine the value of the capacitance units which should be multiplied with the direct capacitances of the cable quads. Record these values in the proper columns under the heading "Add Capacitances To."

4.07 As an illustration of how the calculation chart of Form E-2017 is to be interpreted assume that for a particular quad the unbalances are as follows: PH-W = -20, PH-B = +50, S-S = -10. Reference to Form E-2017 indicates that capacitance units of the following values should be connected to the quad:

$$\begin{aligned}C_1 - W \text{ to B} &= 10 \text{ mmf} \\C_2 - W \text{ to BM} &= 40 \text{ mmf} \\C_3 - WM \text{ to BM} &= 25 \text{ mmf} \\C_4 - WM \text{ to B} &= 5 \text{ mmf}\end{aligned}$$

4.08 Following the processes outlined in paragraph 2.21, however, the four units indicated in paragraph 4.07 can be reduced to three by reducing each unit by the value of the smallest unit which, in this case, is 5 mmf. Accordingly, the three units which would give the same results as the four are:

$$\begin{aligned}C_1 - W \text{ to B} &= 5 \text{ mmf} \\C_2 - W \text{ to BM} &= 35 \text{ mmf} \\C_3 - WM \text{ to BM} &= 20 \text{ mmf} \\C_4 - WM \text{ to B} &= 0 \text{ mmf}\end{aligned}$$

In this case only two units need be connected since if the third unit of 5 mmf were connected the three unbalances would each be zero while the omission of the third unit would result in the three unbalances each becoming 5 mmf.

4.09 Measure the direct capacitance of a foot of the balancing unit (after it has been boiled out) with the capacity unbalance set. In making these measurements the wires of the balancing unit should be connected, respectively, to the "white" and "black" posts of the capacity unbalance set. A side-to-side measurement should be made. As indicated in paragraph 4.04 a value of approximately 60 mmf per foot should be read.

4.10 Using the data given in paragraphs 4.05 to 4.08 determine with the aid of the chart of Figure 9 the lengths of the various balancing units in inches and record these lengths in the columns headed "Lgth. In" opposite their respective capacitance values. The chart of Figure 9 shows the length in inches of balancing unit required for reducing various values of mmf. Curves are given for various values of a foot of balancing unit covering the range from 50 to 70 mmf in steps of 5 mmf to care for those cases where the measured capacitance of a foot of balancing unit varies 5 or more mmf from the value of 60 mmf.

BALANCING UNIT

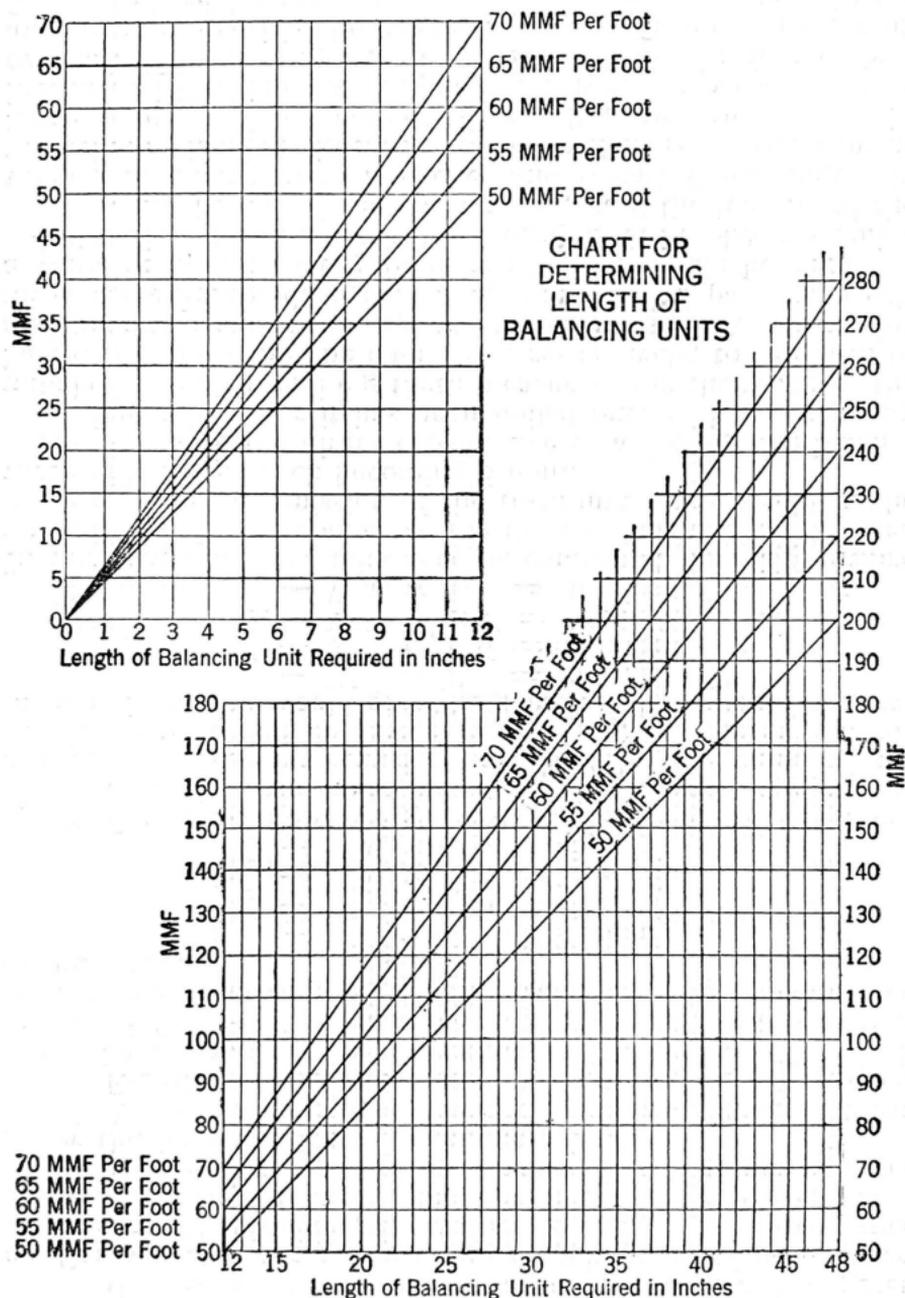


Figure 9.

4.11 After the balancing units have been installed check tests should be made on the quads and the observed resultant unbalances recorded in the last three columns of Form E-2017 in order to make sure that the proper neutralization of unbalances has been accomplished.

Supplementary Balancing Unit Data Sheet

4.12 Some mention has already been made of Form E-2017, Figure 8, for recording the supplementary balancing unit data. The form is 8-1/2" x 11" in size and is printed on light green paper.

4.13 At the top are spaces for recording the number of the loading section where the balancing units are to be installed, the location of the test point, the name of the cable route, the estimate number assigned to the work, and the number of the print (if this is used) showing the splicing procedure for the particular test point. At the bottom are spaces for recording the names of the splicers and testers involved in the work, etc. A space designated "Calculator" is provided for those cases where someone other than the tester determines the number, length and proper connection of the balancing units required. Spaces are also provided for recording the type of tests, whether final or semi-final and for recording the number of quads by gauge and group on which the balancing units are used. Any other data pertaining to the work should be recorded under the heading "Remarks."