Westinghouse

Type CI
Synchro-Verifier

INSTRUCTION BOOK

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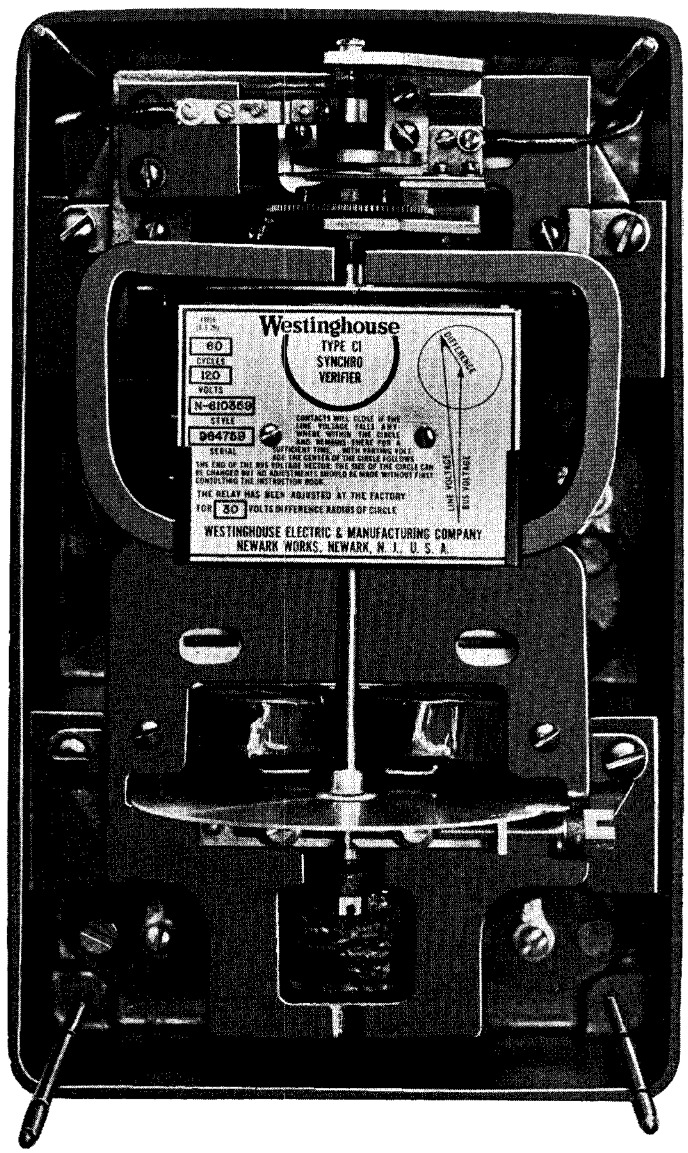

Fig. 1—Type CI Synchro-Verifier, (Cover removed)

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Type CI Synchro-Verifier

Introduction

1. The type "CI" synchro-verifier has been developed to perform a particular and limited function. It is to be used to verify the condition of synchronism existing between two system voltages and will close its contacts when these voltages are, within set limits, equal, in phase, and of the same frequency. If the two systems have been split apart, so that a beat frequency exists across the open circuit breaker used to tie the two systems together, the synchro-verifier will not close its contacts unless this beat frequency is approximately $^1/_{45}$ cycle or less.

2. The type "CI" synchro-verifier is not an automatic synchronizer and should not be confused with the type "XY-11" and "XY-12" automatic synchronizers. The latter two types have the feature of closing ahead of synchronism at an angle of phase advance proportional to the beat frequencies and determined by the speed of operation of the circuit breaker so that the two systems are connected right on synchronism. The type "CI" synchro-verifier does not have this feature and consequently cannot be used as an automatic synchronizer.

Description

3. The type "CI" synchro-verifier shown on Figures 1 and 2 operates on the induction principle. The rotating element consists of two solid copper discs fastened on a hollow steel shaft. There is an inverted cup-shaped jewel on the lower end of the shaft which rests on a hardened and polished steel ball. The steel ball is carried on another cup-shaped jewel mounted in the lower bearing screw. The clearance between the upper jewel support and the lower jewel bearing screw is very small so as to prevent the shaft from tilting and thus eliminate the possibility of the discs binding in the air gaps under very heavy torque conditions. Since there is only a few thousandths of an inch clearance between the jewel support on the shaft and the bearing screw, the possibility of dust and other foreign matter settling on these jewels is greatly reduced. The upper jewel and its support can be readily removed from the shaft if replacement is necessary. The upper bearing is of the pin type and is constructed so as to reduce tilting of the shaft and end play to a minimum. The upper bearing screw is screwed down until there is a clearance of approximately .002″ between it and the upper end of the shaft. It is then locked securely in place. This bearing design results in a very rugged construction with a minimum of wear and friction. The rotating element is made as light as possible, yet gives the necessary strength and operating characteristics, so as to reduce the duty on its bearings.

4. The synchro-verifier has single pole contacts which are made of pure silver. The moving contact is mounted on a counter shaft which is geared to the shaft of the main rotating element. A hardened and polished steel pin in the lower end of the counter shaft runs on a jewel bearing. The upper bearing is of the pin type. The gear on the counter shaft and the pinion on the main shaft have special depth teeth in order to prevent their coming out of mesh and also to reduce friction to a minimum. The counter shaft is covered with a moulded insulation hub around which the moving contact arm is clamped. When the synchro-verifier is completely de-energized, the moving contact is held firmly against the stationary contact by means of a spiral spring, except when this spring may be reversed as discussed in paragraph #17. The inner end of this spring is fastened to the moving contact arm and the outer end is fastened to a spring adjuster. The spring adjuster allows the initial tension on the spring to be changed without changing the strength of the spring. To change the spring tension it is only necessary to loosen one screw, rotate the adjuster until the desired tension is obtained, and then tighten the screw again. The moving contact, counter shaft, bearings and bearing bracket, and the spiral spring and spring adjuster can be removed as a unit by removing three screws and disconnecting the lead to the moving contact. This lead is securely fastened to the spring adjuster by means of a screw and washer and it is, therefore, not necessary to open any soldered connections when removing the moving contact assembly.

5. The stationary contact is mounted on a flat spring and is provided with a stop screw for adjusting the contact pressure. The travel of the moving contact is limited by a small aluminum stop riveted on the disc. The maximum contact opening is approximately ⅛″. This is sufficient to prevent the contacts accidentally closing should the synchro-verifier be subjected to extremely heavy jars or vibration.

6. In order to secure the proper amount of time delay a certain amount of damping of the movement of the disc is necessary. This damping is secured by means of a permanent magnet mounted in front of the upper element so as to act on the front half of the upper disc.

7. The two electro-magnets are designated as elements A and B. Element A operates on the back half of the upper disc and element B operates on the back half of the lower disc. The laminated iron circuit of each electro-magnet is made in two sections. This construction is necessary in order to assemble the form wound coils on the two upper poles. The two sections are built up and wound separately. The potential coil, which is a machine wound coil, is assembled on the lower or main pole punchings. It is a normal 120 volt coil but will operate satisfactorily on any voltage between 100 and 135. The phasing coils, which are made up of a large number of turns of small wire, are machine wound. One of the phasing coils is placed on each of the two upper poles of each upper pole assembly and secured in place. After the potential and phasing coils have been placed on the iron, the two sections of each electro-magnet are assembled as a unit. The two complete electro-magnets are then impregnated with insulating varnish, thoroughly baked and assembled on the movement frame. Figure 3 shows the coils and internal connections of the synchro-verifier.

General Application

8. The principal application of the synchro-verifier will probably be in connection with automatic reclosing equipment on loop systems fed by generating stations at two or more points. On such a system, when a section of line goes out, it is sometimes desirable to reclose on it and should the section "stay in" when it is energized from one end, the breaker on the other end should be reclosed provided the system has not been pulled apart at the other connecting points. A system of relays for such an application is suggested in Figure 9. This system of relays has been worked out so that it will fulfill three conditions. These are:

1. The breaker should close when the bus is alive and the line is dead.
2. The breaker should close when the line is alive and the bus is dead.
3. The breaker should close when the bus and line are both alive when their respective voltages are approximately equal, in phase, and of the same frequency.

Referring to the diagram, it may be seen that the type "CI" synchro-verifier functions only under the third condition, while the type "GR" automatic reclosing relay and the two type "CV" relays with undervoltage and overvoltage contacts function under the other two conditions.

9. Another possible application of the type "CI" synchro-verifier is shown on Figure 10. This figure also gives the correct external connections for the synchro-verifier.

10. It will be noted that on both of these application diagrams a type "CV" time delay relay is used in connection with the synchro-verifier. The purpose of this "CV" relay is two-fold. If the synchro-verifier is adjusted for operating characteristics as per adjustment No. 1 in Fig. 10, the "CI" contacts will be in the closed position in the moment the synchro-verifier is connected to give control. Consequently, due to the damping of the "CI" synchro-verifier, the breaker closing relay which operates instantaneously, would be energized and the breaker would be closed independent of how the frequency and phase-angle conditions might be. By introducing the time delay of the "CV" relay in the closing sequence, faulty breaker closure will not occur since the "CI" contacts will assume the proper position corresponding to the phase-angle displacement before the "CV" relay would close its contacts. The other function of the "CV" relay is to provide additional time delay when the "CI" synchro-verifier is operating at a frequency difference. If the frequencies of the two systems are erratic, and the synchro-verifier is adjusted to close at a wide phase displacement angle, for example 20 degrees, and assuming that the type "CV" relay is not used, it is possible that the breaker closing relay may be energized 20 degrees late and at an instantaneous frequency considerably higher than $\frac{1}{45}$ cycle, so that when the breaker contacts finally close, the phase displacement may be too large. When the "CV" relay is being used, the highest frequency difference at which the breaker would be closed would be considerably lower than $\frac{1}{45}$ cycle, and the probability of obtaining breaker closure off synchronism would be considerably minimized. For this reason it is recommended always to supply a "CV" relay in connection with the "CI" synchro-verifier as shown in figures 9 and 10, whether adjustment No. 1 or adjustment No. 2 is being used, if the transmission system layout is such that the two sides of the breaker can be expected to belong to two independent systems. Summing up

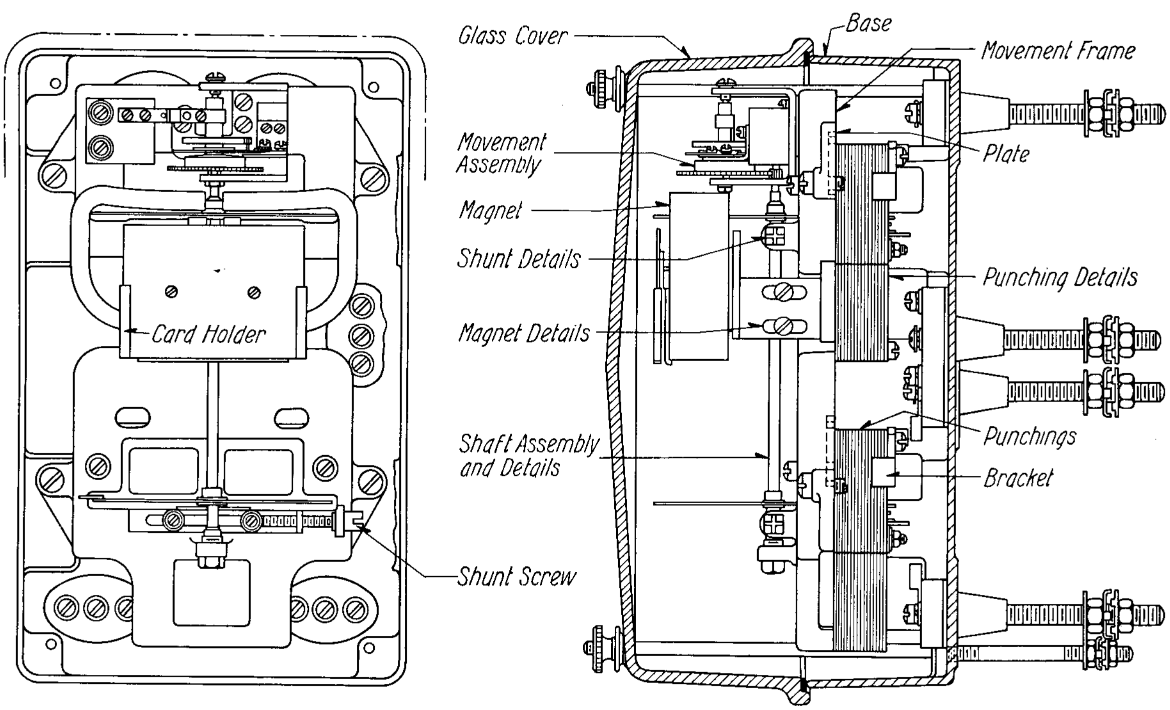

Fig. 2—Type CI Synchro-Verifier

these considerations, it will appear that the "CV" relay should always be applied except when the "CI" synchro-verifier is adiusted for operating characteristics as per adjustment No. 2, (See Figure 10) and at the same time the system layout is such that a frequency difference cannot be expected between the two sides of the breaker.

11. If the application is made in line with Figure 10, it is not necessary to protect against potential transformer fuse failures. If open delta connected potential transformers are used with a fuse in the common primary lead, it is necessary to guard against improper operation, resulting from failure of this fuse, which may occur if the voltage is low on the system other than the one where the fuse failure occurred. This protection is also necessary when an open delta transformer connection is being used even if no common fuse is applied in the middle leg, if a three phase load is connected across the secondaries of the potential transformers. Type "MC" relays are recommended as protective relays. The relays should be adjusted to open if the voltage drops below 65% normal. One "MC" relay should be connected across the secondary of each of the two potential transformers and the make contacts of the "MC" relays should be connected in series with the operating coil of the breaker closing relay so that it cannot be closed if the voltage across one potential transformer is too low. When a type "CV" relay is being used with the synchro-verifier, as outlined in paragraph 10, one type "MC" relay will be sufficient. This "MC" relay should be connected across the potential transformer to which the "CV" relay is not connected. The "CV" relay should be adjusted to close its contacts at a voltage not lower than 65% normal voltage.

12. As the circuit in Figure 9 is arranged to automatically close the circuit breaker upon a dead bus or line, it is obvious that faulty closing of the breaker could occur upon failure of a fuse in either the primary or secondary leads of the potential transformers. The possibility of such incorrect operation may be greatly reduced by the omission of fuses in the primary leads, with small hazard to the potential transformers. The fuses in the secondary leads of the potential transformers may also be omitted; or additional protection provided, according to conditions encountered and protection desired when applying the synchro-verifier. The possibility of incorrect operations occuring upon the failure of the secondary fuses, may be avoided by connecting type "MC" relays across the fuses, with the break contacts of the relays connected in series with the operating coil of the circuit breaker closing relay. Relay Style #423428, or any 110 volt, 60 cycle "MC" with a suitable contact arrangement may be used. It should be adjusted to operate on 40 volts. Only the ungrounded secondary lead of the potential transformer should be fused. If open delta connected potential transformers are used, additional protection, in line with the preceeding paragraph, should be provided.

Installation

13. After the synchro-verifier has been unpacked, it should be closely examined to see that none of the parts have been bent or broken during shipment. See that it is free from friction and that the contacts are properly adjusted as previously described. It is advisable to make a complete check test of the synchro-verifier as outlined under "Adjustments and Tests" before placing it in service in order to make sure that none of the parts have been broken or damaged in shipment and that none of the fixed adjustments have been changed.

Operation

14. Figure 4 shows the schematic diagram of connections of the type "CI" synchro-verifier. The synchro-verifier should close its contacts when the bus voltage E_1, and the line voltage E_2, are, within set limits, equal, in phase and of the same frequency. The potential coil of element A is energized by the voltage E_1, the potential coil of element B is energized by the voltage E_2, and the phasing coils of both elements are energized by the difference between these two voltages. Assuming that the synchro-verifier is being used with the spiral spring wound up in the direction to close the contacts, the contacts will close when E_1 and E_2 are equal, in phase, and of the same frequency. Under this condition the difference between these two voltages is zero and no electrical torque will

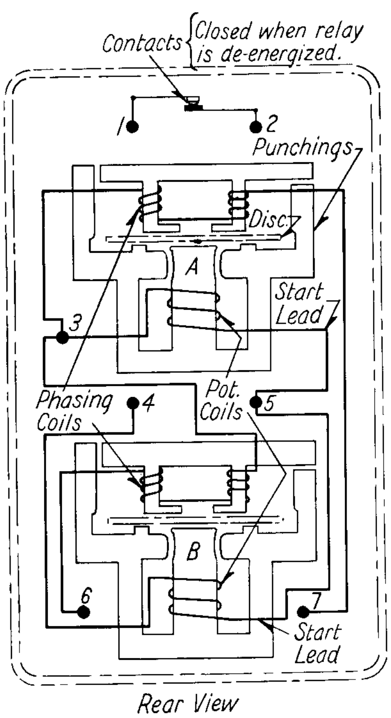

FIG. 3—WIRING DIAGRAM

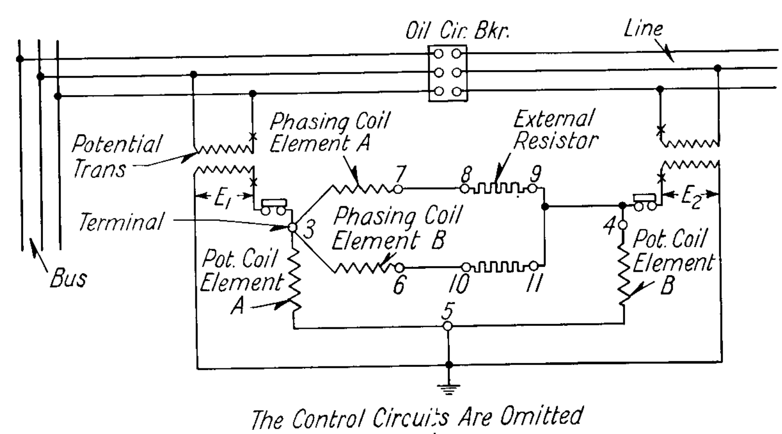

FIG. 4—SCHEMATIC DIAGRAM OF CONNECTIONS TYPE CI SYNCHRO-VERIFIER

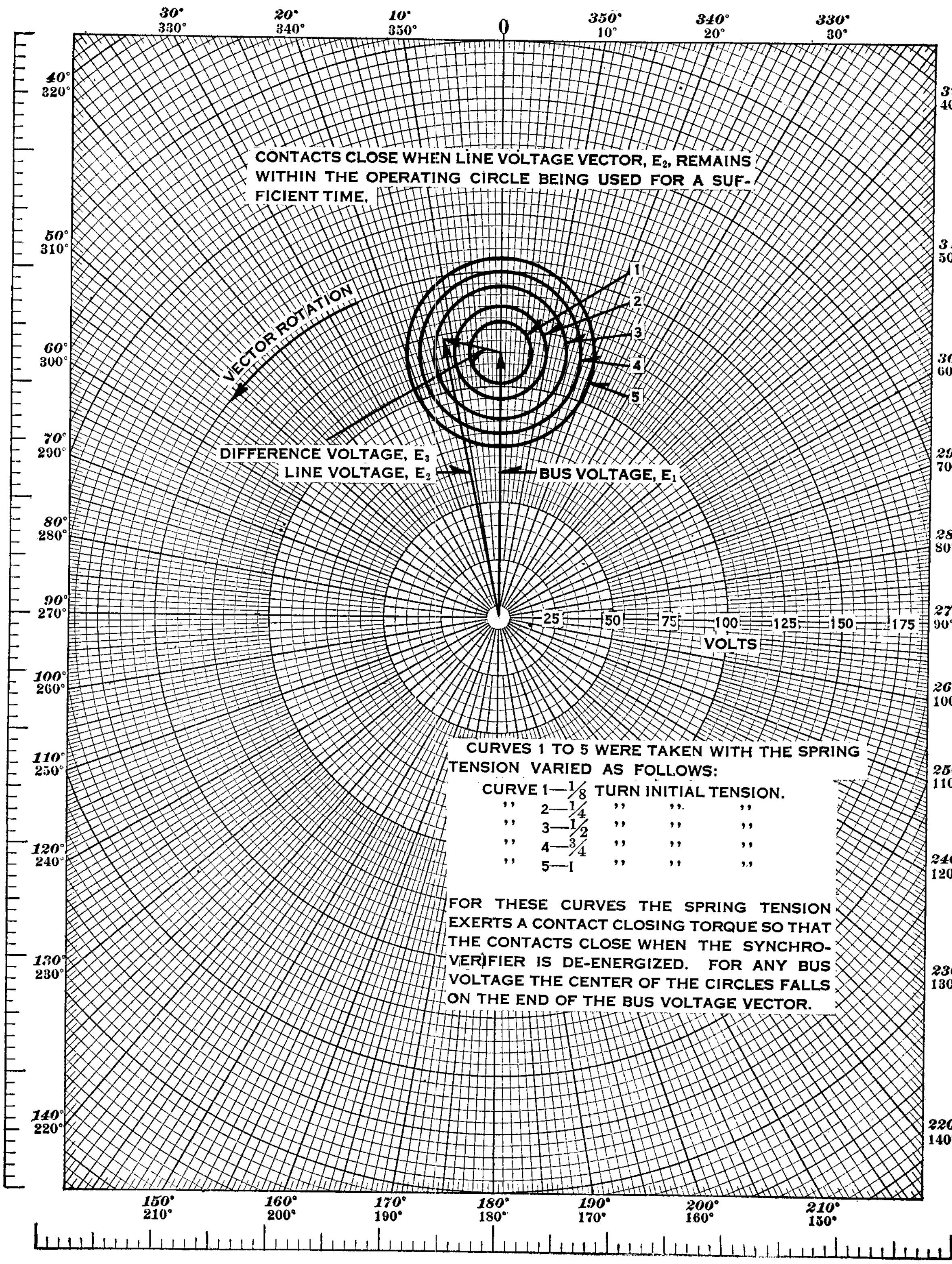

Fig. 5—Operating Characteristics of the Type CI Synchro-Verifier

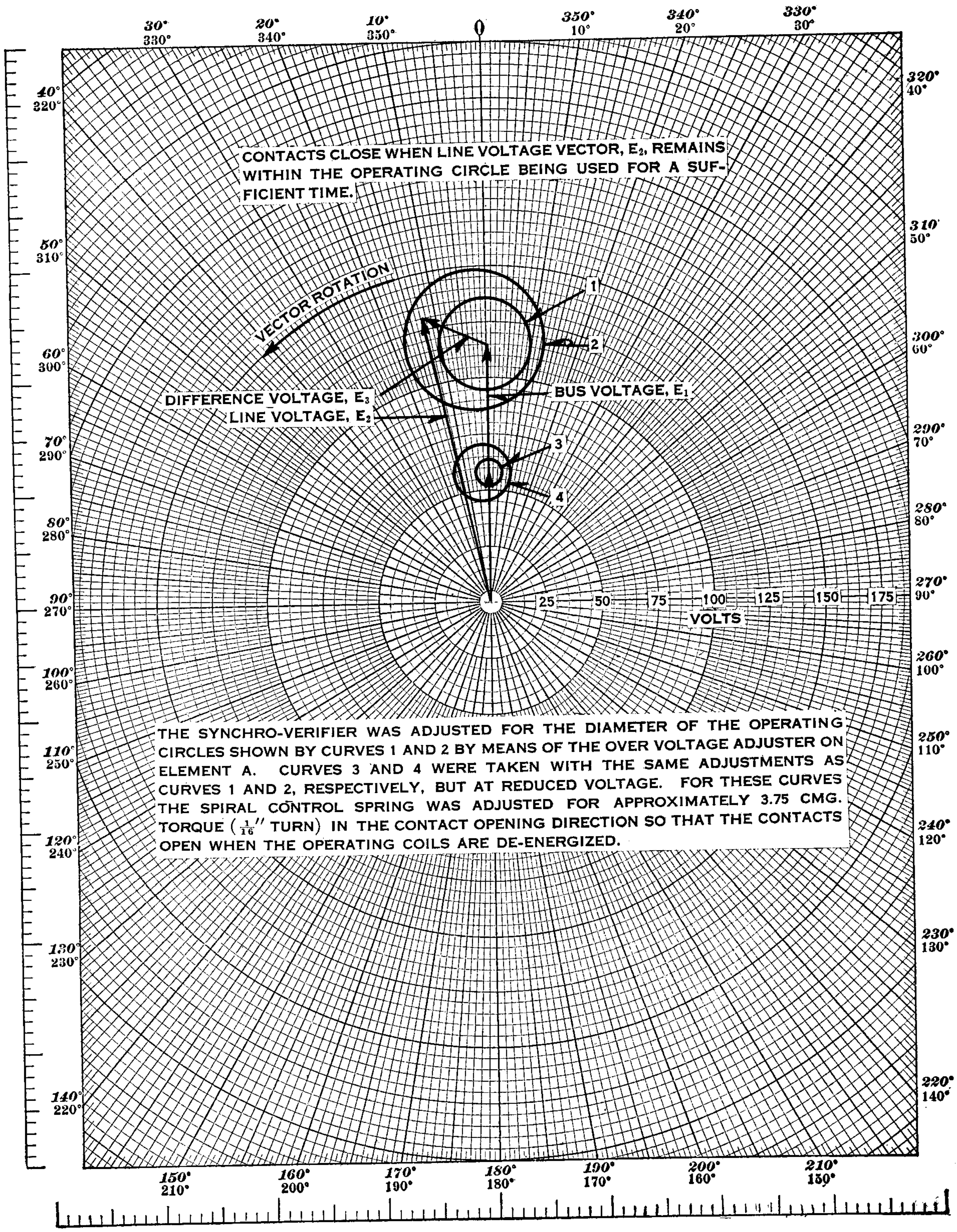

Fig. 6—Operating Characteristics of the Type CI Synchro-Verifier

be produced because neither element will produce any torque unless its potential coil and phasing coil are both energized. Consequently when there is no difference voltage impressed across the phasing coil circuit, the contacts will be closed by the action of the spiral spring alone. In general, the two electro-magnets A and B, produce opposing torques on the two discs and these torques increase as the voltage difference between the two voltages E_1 and E_2 increases. The net electrical torque acting on the disc assembly is always in the contact opening direction and increases as the voltage difference increases so that when the voltage difference exceeds a predetermined amount the net electrical torque becomes greater than the torque exerted by the spiral spring so that the contacts will be opened.

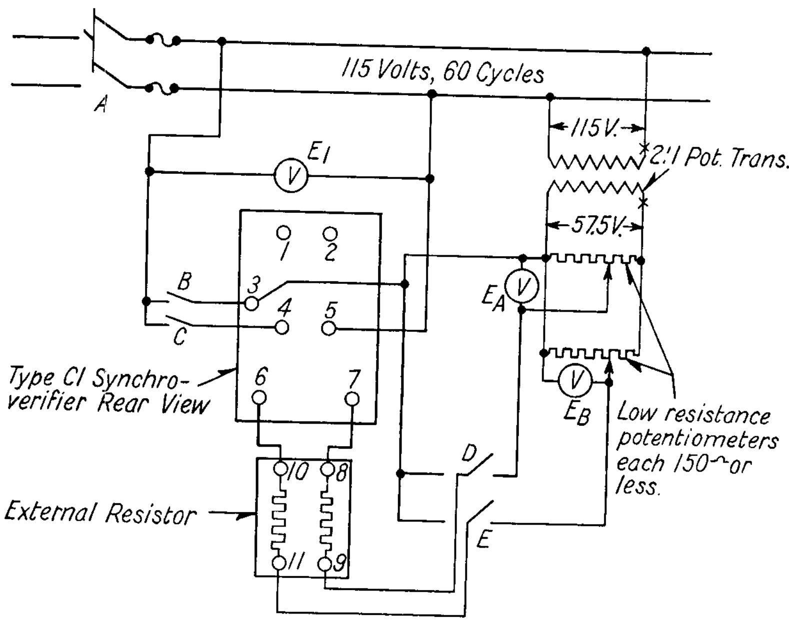

FIG. 8—DIAGRAM OF TEST CONNECTIONS—TYPE CI SYNCHRO-VERIFIER FOR BALANCING ELEMENTS A AND B

15. The usual operating characteristics of the synchro-verifier are shown on Figure 5 although operating characteristics as shown on Figure 6 may be obtained if desired. The operating circles of Figure 5 were obtained by using five different values of spring tension, respectively. Operating circle #5 was obtained by using one whole turn tension on the spring which is about the maximum which can be used without distorting the spring. Operating circle #1 has about the minimum diameter which can be used and still give reliable operation of the synchro-verifier. This curve was obtained using ⅛ turn tension on the spring.

16. The curves of Figure 5 were taken with a constant bus voltage E_1 and represent the locus of the line voltage E_2 which will just produce a balance condition in the synchro-verifier. Assuming that curve #5 is being used, the contacts will not move in either direction if the line voltage E_2 terminates on any point of this circle. If the line voltage E_2 terminates within curve #5 and remains there for a sufficient length of time the contacts will close. The vector diagram given on Figure 5 is given as an illustration and represents the condition where the bus voltage E_1 is used as the reference voltage and is equal to 115 volts, the line voltage E_2 is 123 volts and leads the bus voltage by 12° and the difference voltage E_3 is equal to 26 volts and leads the bus voltage by 78°. Assuming that the system conditions are such that these voltages will remain fixed at these values the contacts will close if either of the operating circles 3, 4 or 5 are used and will not close if either curves #1 or #2 are used. When the synchro-verifier has been adjusted for any given radius of operating circle as shown on Figure 5 by means of the spiral spring adjuster, the radius of this circle will not vary regardless of variations in the reference voltage E_1. This statement is true, providing the overvoltage adjusters have been correctly adjusted for these characteristics as given under "Adjustment and Tests".

17. As previously stated, when characteristics as shown on Figure 5 are used, the contacts of the synchro-verifier will be closed when it is completely de-energized. Should it be essential that the

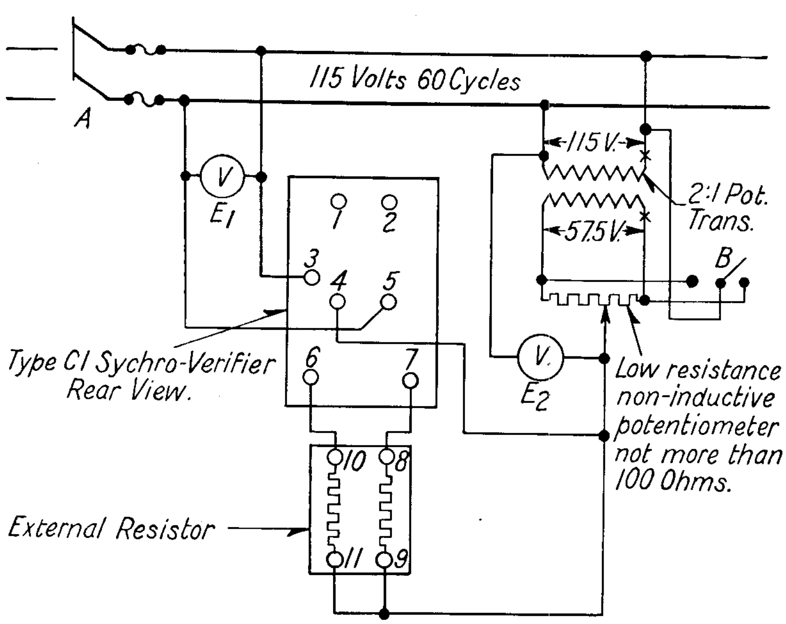

FIG. 7—DIAGRAM OF TEST CONNECTIONS—TYPE CI SYNCHRO-VERIFIER FOR ADJUSTMENT OF OPERATING CHARACTERISTICS

contacts remain open when the operating coils are completely de-energized this may be accomplished by giving the spiral spring a slight amount of tension in the contact opening direction and obtaining the desired radius of operating circle by means of the overvoltage adjustment on element A. (See Adjustments and Tests) When the radius of the operating circle is obtained in this way the characteristics of the synchro-verifier will be as shown on Figure 6. On this figure it may be noted that the center of the operating circles do not coincide with the end of the reference voltage E_1 and also that the radius of the operating circle decreases as the reference voltage E_1 is decreased. Both of these effects are inherent in the design of the synchro-verifier when this type of adjustment is used.

18. Referring again to Figure 5, assume that E_2 is equal to E_1, is in phase with E_1, and is of the same frequency so that the two vectors shown for E_2 and E_1 coincide. Under this condition the synchro-verifier will close its contacts from the extreme open position in approximately 5 seconds if operating circle #5 is being used. Under this condition no electrical torque is produced and the maximum closing torque developed by the spiral spring is effective in closing the contacts at the greatest possible speed. Under the same electrical conditions the contacts would close at a much slower rate if operating circle #1 was being used due to the decrease amount of spring tension. Assume that E_2 is numerically equal to E_1 but of a different frequency so that it slowly moves through operating circle #5 at a uniform rate of speed so that approximately 5 seconds are required for it to move from 20° lagging, to 20° leading with respect to E_1. Under this condition the contacts will not close if operating circle #5 is being used because the contact closing torque is zero when E_2 is approximately 20° out of phase with E_1 and is at its maximum when E_2 is in phase with E_1. Since 5 seconds are required for the contacts to close when E_2 is equal to E_1 and is exactly in phase with it, a longer time will be required for the contacts to close if E_2 is of different frequency than E_1. The time of 5 seconds required for E_2 to move through the operating circle #5 at a uniform rate of speed corresponds to a beat frequency of approximately $\frac{1}{45}$ cycle so that a beat frequency of less than $\frac{1}{45}$ cycle is required before the contacts will close if operating circle #5 is being used and correspondingly lower beat frequencies are required if operating circles with smaller diameter than #5 are being used.

Adjustments and Tests

19. Ordinarily the only adjustments which it will be necessary to make or check in the field is that for the desired radius of operating circle as shown on Figure 5. In order to check this adjustment it will be necessary to set-up a test circuit as shown on Figure 7. When the synchro-verifier is first received from the factory, the fixed adjustments should be checked to see that they have not changed and for this purpose a test set-up as shown in Figure 8 is necessary. If it should ever be necessary to replace one of the electro-magnets the fixed adjustments would have to be rechecked. An outline of the complete test procedure is given here although it will not be necessary to perform the complete tests as given when checking the adjustments of the synchroifieevn the field.

20. Carefully level the synchro-verifier before making any tests. Remove the gear and contact assembly from the relay. Then set-up a test circuit as shown on Figure 8. Close switches A and B, and close switch D to the left hand side. This places 115 volts on the potential coil of element A and short-circuits the phasing coil circuit of element A. Adjust the overvoltage adjustment on element A so that the stop on the disc balances at a point mid-way of its travel. The over-voltage adjuster is the sliding lag plate which is mounted on the movement frame and extends into the air-gap between the lower potential pole and the disc. It may be moved to the right or left by means of the adjusting screw provided for this purpose. The two locking screws which hold the overvoltage adjuster in place should not be loosened when this adjustment is made. Moving the overvoltage adjuster to the right of the center line of the potential pole as the synchro-verifier is viewed from the front causes it to lag a part of the potential coil flux so that a contact opening torque is produced, while moving it to the left of the center line of the potential pole causes a conact closing torque to be developed. This test is made to balance out all torque which may be caused by voltage on the potential coil only.

21. Open switch B, close switch C and close switch E to the left-hand side. This places 115 volts, 60 cycles on the potential coil of element B and short circuits the phasing coil circuit of element B. Thd overvoltage ad;uster of element B should be adjusted in a similar manner to that of element A so that the disc

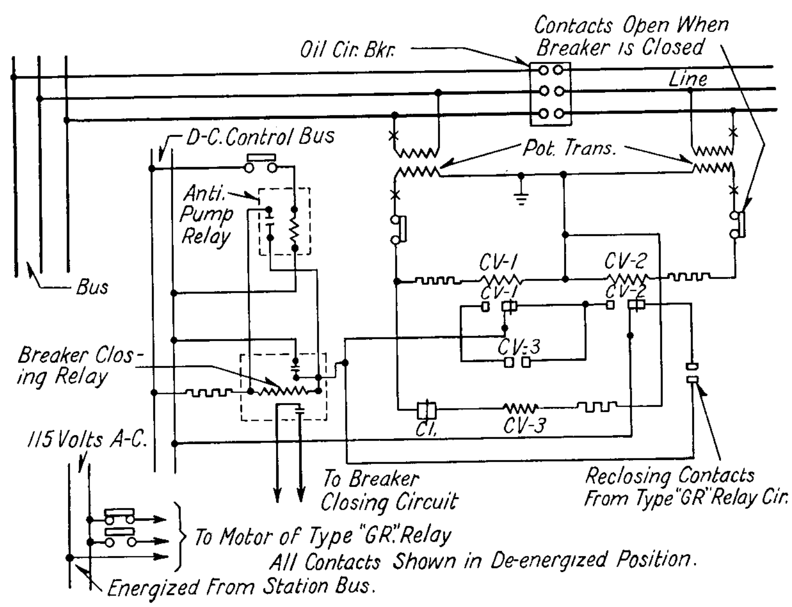

FIG. 9—SCHEMATIC DIAGRAM FOR A PARTICULAR APPLICATION OF THE TYPE CI-SYNCHRO-VERIFIER

will balance at a point mid-way of its travel.

22. Leaving switch A and switch C closed, close switch B and close switch D and E to the right-hand side. This places 115 volts, 60 cycles on each potential coil and places the voltage Ea and Eb on the phasing coil circuits. Set the voltage Ea to 15 volts by means of the potentiometers and then adjust Eb by means of its potentiometer until the disc just balances with its stop mid-way in its travel. If the two electro-magnets do not produce an equal amount of torque under the same conditions then the voltage Eb will differ from the voltage Ed by an amount depending upon the unbalance between the two electro-magnets. When this balance has been obtained the electro-magnet which shows the lowest voltage reading for Ea or Eb has the strongest torque. The two electro-magnets should balance within ½ volt at 15 volts, that is, when Ea is set for 15 volts, Eb should read between the limits of 14.5 and 15.5 volts. If the two electro-magnets do not balance within these limits they should be readjusted with respect to each other by raising or lowering the upper pole assemblies by means of the adjustment provided for this purpose. Raising or lowering the upper pole assembly will disturb the overvoltage adjustment which has been made previously and consequently each time the upper pole assembly is raised or lowered it will be necessary to reset the overvoltage adjuster so that no torque is produced, that is, the disc will balance in the mid-way position when the voltage coil alone is energized and the phasing coil circuit is short-circuited. Since this adjustment must be made by the "cut and try" method and may have to be repeated several times the first adjustments may be made more roughly than the final adjustment. The two electro-magnets may be considered balanced with respect to each other when at the end of the test they will perform as follows:

1. The disc will remain in a position mid-way of its travel when element A is energized with 115 volts, 60 cycles on the potential coil and the phasing coil circuit is short-circuited.
2. The disc will remain at a point mid-way of its travel when element B potential coil is energized at 115 volts, 60 cycles and element B phasing coil circuit is short-circuited.
3. With both potential coils energized at 115 volts, 60 cycles and with 15 volts impressed across the phasing circuit of element A the torque of elements A and B should be balanced so that the disc will remain at a point mid-way of its travel when the voltage impressed across the phasing coil circuit of element B falls at some value between the limits of 14.5 and 15.5 volts.

23. Replace the gear and contact mechanism on the synchro-verifier after making sure that all adjustments which were made in the previous test will remain unchanged or, in other words, see that all screws which lock the adjustments in place are tight.

24. Adjust the position of the stationary contact so that the contacts make when the stop on the disc is between 1″ and 1¼″ from the movement frame on the right-hand side. When the stop on the disc is at the extreme right end of its travel the stationary contact should not be deflected to such an extent that it rests against its own back stop. If this adjustment is not readily obtained the gear and contact assembly may be loosened from the movement frame and the mesh between the pinion and gear changed by one tooth.

25. See that the synchro-verifier is free from friction and then adjust the spring adjuster so that it exerts no torque tending to move the contacts one way or the other just at the point where the

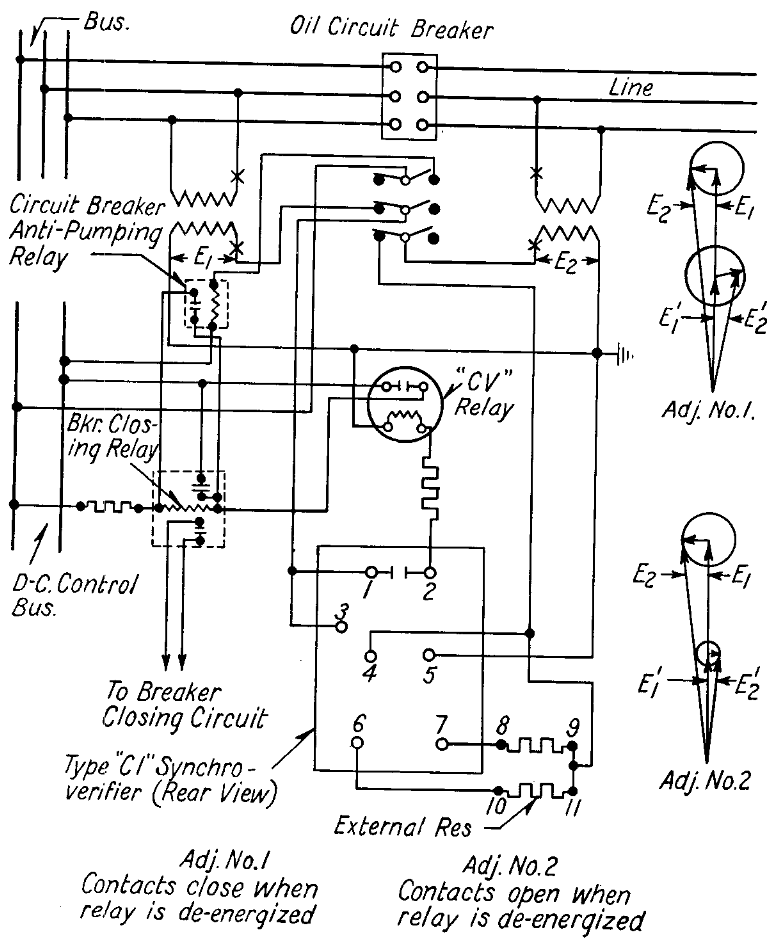

Fig. 10—When the "CI" Synchro-Verifier is Adjusted for Operating Characteristics as per Adjustment #1, the "CV" Relay Should be Used for Additional Time Delay, When Adjusted for Characteristics as Per Adjustment #2, the "CV" Relay May be Omitted

contacts make. Reference marks should then be placed on the spring adjuster and its supporting piece in pencil to indicate the position of the spring adjuster which gives zero initial tension on the spiral spring.

26. Connect the synchro-verifier for tests as shown on Figure 7. Close switch A. This places 115 volts 60 cycles, E_1 on the potential coil circuit of element A. Close switch B to the left-hand side. This places a variable voltage E_2 on the potential coil of element B and the difference between E_2 and E_1 is the voltage impressed on the two phasing coil circuits. Adjust the potentiometer until E_2 reads 145 volts, which is 30 volts greater than E_1. Then adjust the spiral spring adjuster in the direction to wind up the spiral control spring so that it tends to close the contacts. The tension on the spring should be increased until the contacts will close from the extreme open position when E_2 is 145 volts and will not close from the extreme open position when E_2 is 147 volts. A two volt limit is thus allowed on the voltage difference adjustment. Approximately one-half turn initial tension on the spring should be sufficient to make this adjustment, although this will vary some with different synchro-verifiers. Securely lock the spring adjuster in position by means of the locking screw provided and then change switch B to the right-hand position. Then adjust the potentiometer so that E_2 reads approximately 85 volts, which is 30 volts less than E_1.

27. An adjustment for 30 volts difference between E_1 and E_2 has been specified. If a different value for this voltage difference adjustment is desired it may be made in the same way with the same limiting value of plus or minus 2 volts on the check test made with E_2 less than E_1.

28. As a further check on the correct operation of the relay, E_2 should be made equal to E_1 and under this condition the relay should develop a positive contact closing torque, and with E_2 radically more than 30 volts different from E_1 the relay should develop a strong contact opening torque.

29. When the adjustments have been made as outlined above the contacts of the synchro-verifier will close when the operating coils are totally de-energized.

30. As previously stated, the contacts may be made to remain open when the operating circuits are de-energized by giving the spiral control spring a slight amount of tension in the contact opening direction and obtaining the desired radius of operating curve by means of the over-voltage adjustment on element A. Operating circles as shown on Figure 6 are obtained in this manner and the two elements are balanced at the desired voltage difference by means of the over-voltage adjuster on element A instead of by means of adjusting the tension on the spiral control spring as previoulsy outlined. The negative spring tension used should be just sufficient to insure that the contacts will always open when the operating coils are de-energized.

Maintenance

31. The mechanical construction of the type "CI" synchro-verifier is simple and rugged; with small assemblies made as accessible as possible to facilitate repairs and reduce maintenance to a minimum. After being properly adjusted and installed, it will require little attention. When making periodic inspections as are maintained on this type of equipment it would be well to examine the synchro-verifier to see that it is free from friction and that the contacts are properly adjusted and in good operating condition.

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Type CI Synchro-Verifier

INSTRUCTIONS

Introduction

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2. The type "CI" synchro-verifier is not an automatic synchronizer and should not be confused with the type "XY-11" and "XY-12" automatic synchronizers. The latter two types have the feature of closing ahead of synchronism at an angle of phase advance proportional to the beat frequencies and determined by the speed of operation of the circuit breaker so that the two systems are connected right on synchronism. The type "CI" synchro-verifier does not have this feature and consequently cannot be used as an automatic synchronizer.

Description

3. The synchro-verifier operates on the induction principle. The rotating element consists of two solid copper discs fastened on a hollow steel shaft. There is an inverted cup-shaped jewel on the lower end of the shaft which rests on a hardened and polished steel ball. The steel ball is carried on another cup-shaped jewel mounted in the lower bearing screw. The clearance between the upper jewel support and the lower jewel bearing screw is very small so as to prevent the shaft from tilting and thus eliminate the possibility of the discs binding in the air gaps under very heavy torque conditions. Since there is only a few thousandths of an inch clearance between the jewel support on the shaft and the bearing screw, the possibility of dust and other foreign matter settling on these jewels is greatly reduced. The upper jewel and its support can be readily removed from the shaft if replacement is necessary. The upper bearing is of the pin type and is constructed so as to reduce tilting of the shaft and end play to a minimum. The upper bearing screw is screwed down until there is a clearance of approximately .002" between it and the upper end of the shaft. It is then locked securely in place. This bearing design results in a very rugged construction with a minimum of wear and friction. The rotating element is made as light as possible, yet gives the necessary strength and operating characteristics, so as to reduce the duty on its bearings.

4. The synchro-verifier has single pole contacts which are made of pure silver. The moving contact is mounted on a counter shaft which is geared to the shaft of the main rotating element. A hardened and polished steel pin in the lower end of the counter shaft runs on a jewel bearing. The upper bearing is of the pin type.

The counter shaft is covered with a moulded insulation hub around which the moving contact arm is clamped. When the synchro-verifier is completely de-energized, the moving contact is held firmly against the stationary contact by means of a spiral spring, except when this spring may be reversed as discussed in paragraph #17. The inner end of this spring is fastened to the moving contact arm and the outer end is fastened to a spring adjuster. The spring adjuster allows the initial tension on the spring to be changed without changing the strength of the spring. To change the spring tension it is only necessary to loosen one screw, rotate the adjuster until the desired tension is obtained, and then tighten the screw again. The moving contact, counter shaft, bearings and bearing bracket, and the spiral spring and spring adjuster can be removed as a unit by removing three screws and disconnecting the lead to the moving contact. This lead is securely fastened to the spring adjuster by means of a screw and washer and it is, therefore, not necessary to open any soldered connections when removing the moving contact assembly.

5. The stationary contact is mounted on a flat spring and is provided with a stop screw for adjusting the contact pressure. The travel of the moving contact is limited by a small stop riveted on the disc. The maximum contact opening is approximately ⅛". This is sufficient to prevent the contacts accidentally closing should the synchro-verifier be subjected to extremely heavy jars or vibration.

6. In order to secure the proper amount of time delay a certain amount of damping of the movement of the disc is necessary. This damping is secured by means of a permanent magnet mounted in front of the upper element so as to act on the front half of the upper disc.

7. The two electro-magnets are designated as elements A and B. Element A operates on the back half of the upper disc and element B operates on the back half of the lower disc. The laminated iron circuit of each electro-magnet is made in two sections. This construction is necessary in order to assemble the form wound coils on the two upper poles. The two sections are built up and wound separately. The potential coil, which is a machine wound coil, is assembled on the lower or main pole punchings. It is a normal 120 volt coil but will operate satisfactorily on any voltage between 100 and 135. The phasing coils, which are made up of a large number of turns of small wire, are machine wound. One of the phasing coils is placed on each of the two upper poles of each upper pole assembly and secured in place. After the potential and phasing coils have been placed on the iron, the two sections of each electro-magnet are assembled as a unit. The two complete electro-magnets are then impregnated with insulating varnish, thoroughly baked and assembled on the movement frame. Figure 1 shows the coils and internal connections of the synchro-verifier.

General Application

8. The principal application of the synchro-verifier will probably be in connection with automatic reclosing equipment on loop systems fed by generating stations at two or more points. On such a system, when a section of line goes out, it is sometimes desirable to reclose on it and should the section "stay in" when it is energized from one end, the breaker on the other end should be reclosed provided the system has not been pulled apart at the other connecting points. A system of relays for such an application is suggested in Figure 7. This system of relays has been worked out so that it will fulfill three conditions. These are:

1. The breaker should close when the bus is alive and the line is dead.
2. The breaker should close when the line is alive and the bus is dead.
3. The breaker should close when the bus and line are both alive when their respective voltages are approximately equal, in phase, and of the same frequency.

Referring to the diagram, it may be seen that the type "CI" synchro-verifier functions only under the third condition, while the type "GR" automatic reclosing relay and the two type "CV" relays with undervoltage and overvoltage contacts function under the other two conditions.

9. Another possible application of the type "CI" synchro-verifier is shown on Figure 8. This figure also gives the correct external connections for the synchro-verifier.

10. It will be noted that on both of these application diagrams a type "CV" time delay relay is used in connection with the synchro-verifier. The purpose of this "CV" relay is two-fold. If the synchro-verifier is adjusted for operating characteristics as per adjustment No. 1 in Fig. 8, the "CI" contacts will be in the closed position in the moment the synchro-verifier is connected to give control. Consequently, due to the damping of the "CI" synchro-verifier, the breaker closing relay which operates instantaneously, would be energized and the breaker would be closed independent of how the frequency and phase-angle conditions might be. By introducing the time delay of the "CV" relay in the closing sequence, faulty breaker closure will not occur since the "CI" contacts will assume the proper position corresponding to the phase-angle displacement before the "CV" relay would close its contacts. The other function of the "CV" relay is to provide additional time delay when the "CI" synchro-verifier is operating at a frequency difference. If the frequencies of the two systems are erratic, and the synchro-verifier is adjusted to close at a wide phase displacement angle, for example 20 degrees, and assuming that the type "CV" relay is not used, it is possible that the breaker closing relay may be energized 20 degrees late and at an instantaneous frequency considerably higher than $\frac{1}{45}$ cycle, so that when the breaker contacts finally close, the phase displacement may be too large. When the "CV" relay is being used, the highest frequency difference at which the breaker would be closed would be considerably lower than $\frac{1}{45}$ cycle, and the probability of obtaining breaker closure off synchronism would be considerably minimized. For this reason it is recommended always to supply a "CV" relay in connection with the "CI" synchro-verifier as shown in figures 7 and 8, whether adjustment No. 1 or adjustment No. 2 is being used, if the transmission system layout is such that the two sides of the breaker can be expected to belong to two independent systems. Summing up

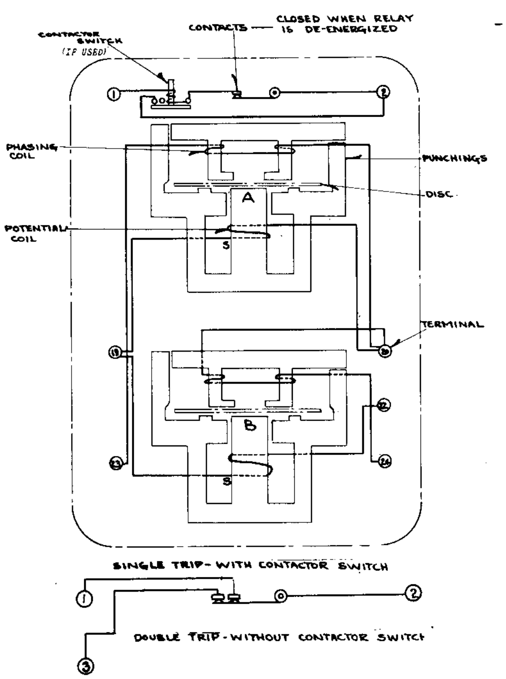


Fig. 1 Internal Wiring Diagram

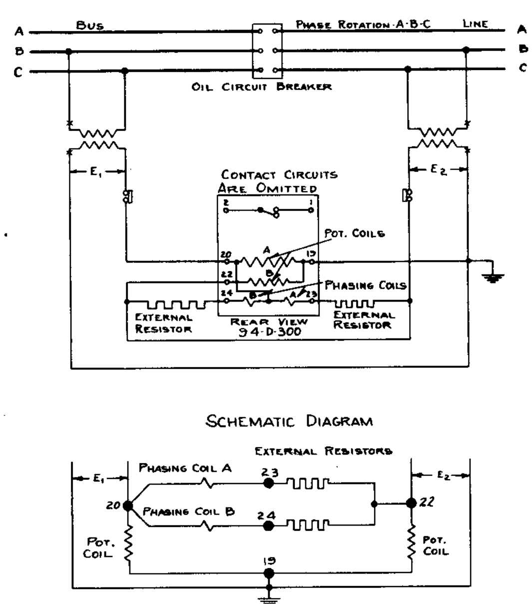


Fig. 2 External Diagram of Connections

these considerations, it will appear that the "CV" relay should always be applied except when the "CI" synchro-verifier is adiusted for operating characteristics as per adjustment No. 2, (See Figure 8) and at the same time the system layout is such that a frequency difference cannot be expected between the two sides of the breaker.

11. If the application is made in line with Figure 8, it is not necessary to protect against potential transformer fuse failures. If open delta connected potential transformers are used with a fuse in the common primary lead, it is necessary to guard against improper operation, resulting from failure of this fuse, which may occur if the voltage is low on the system other than the one where the fuse failure occurred. This protection is also necessary when an open delta transformer connection is being used even if no common fuse is applied in the middle leg, if a three phase load is connected across the secondaries of the potential transformers. Type "MC" relays are recommended as protective relays. The relays should be adjusted to open if the voltage drops below 65% normal. One "MC" relay should be connected across the secondary of each of the two potential transformers and the make contacts of the "MC" relays should be connected in series with the operating coil of the breaker closing relay so that it cannot be closed if the voltage across one potential transformer is too low. When a type "CV" relay is being used with the synchro-verifier, as outlined in paragraph 10, one type "MC" relay will be sufficient. This "MC" relay should be connected across the potential transformer to which the "CV" relay is not connected. The "CV" relay should be adjusted to close its contacts at a voltage not lower than 65% normal voltage.

12. As the circuit in Figure 7 is arranged to automatically close the circuit breaker upon a dead bus or line, it is obvious that faulty closing of the breaker could occur upon failure of a fuse in either the primary or secondary leads of the potential transformers. The possibility of such incorrect operation may be greatly reduced by the omission of fuses in the primary leads, with small hazard to the potential transformers. The fuses in the secondary leads of the potential transformers may also be omitted; or additional protection provided, according to conditions encountered and protection desired when applying the synchro-verifier. The possibility of incorrect operations occuring upon the failure of the secondary fuses, may be avoided by connecting type "MC" relays across the fuses, with the break contacts of the relays connected in series with the operating coil of the circuit breaker closing relay. Relay Style #423428, or any 110 volt, 60 cycle "MC" with a suitable contact arrangement may be used. It should be adjusted to operate on 40 volts. Only the ungrounded secondary lead of the potential transformer should be fused. If open delta connected potential transformers are used, additional protection, in line with the preceeding paragraph, should be provided.

Installation

13. After the synchro-verifier has been unpacked, it should be closely examined to see that none of the parts have been bent or broken during shipment. See that it is free from friction and that the contacts are properly adjusted as previously described. It is advisable to make a complete check test of the synchro-verifier as outlined under "Adjustments and Tests" before placing it in service in order to make sure that none of the parts have been broken or damaged in shipment and that none of the fixed adjustments have been changed.

Operation

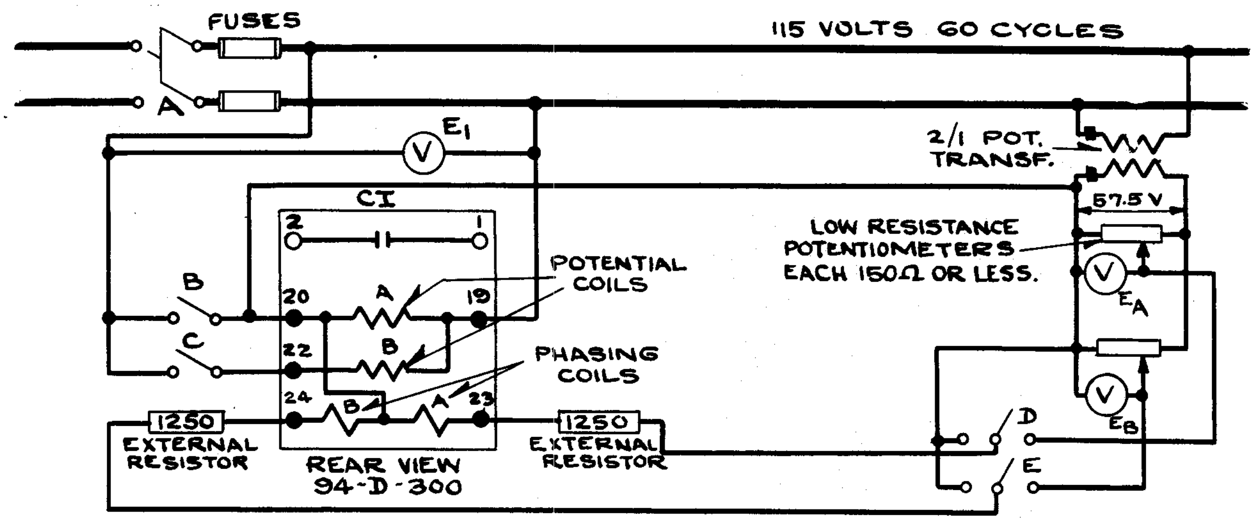
14. Figure 2 shows the schematic diagram of connections of the type "CI" synchro-verifier. The synchro-verifier should close its contacts when the bus voltage E_1, and the line voltage E_2, are, within set limits, equal, in phase and of the same frequency. The potential coil of element A is energized by the voltage E_1, the potential coil of element B is energized by the voltage E_2, and the phasing coils of both elements are energized by the difference between these two voltages. Assuming that the synchro-verifier is being used with the spiral spring wound up in the direction to close the contacts, the contacts will close when E_1 and E_2 are equal, in phase, and of the same frequency. Under this condition the difference between these two voltages is zero and no electrical torque will be produced because neither element will produce any torque unless its potential coil and phasing coil are both energized. Consequently when there is no difference voltage impressed across the phasing coil circuit, the contacts will be closed by the action of the spiral spring alone. In general, the two electro-magnets A and B, produce opposing torques on the two discs and these torques increase as the voltage difference between the two voltages E_1 and E_2 increases. The net electrical torque acting on the disc assembly is always in the contact opening direction and increases as the voltage difference increases so that when the voltage difference exceeds a predetermined amount the net electrical torque becomes greater than the torque exerted by the spiral spring so that the contacts will be opened.

15. The usual operating characteristics of the synchro-verifier are shown on Figure 3 although operating characteristics as shown on Figure 4 may be obtained if desired. The operating circles of Figure 3 were obtained by using five different values of spring tension, respectively. Operating circle #5 was obtained by using one whole turn tension on the spring which is about the maximum which can be used without distorting the spring. Operating circle #1 has about the minimum diameter which can be used and still give reliable operation of the synchro-verifier. This curve was obtained using 1/8 turn tension on the spring.

16. The curves of Figure 3 were taken with a constant bus voltage E_1 and represent the locus of the line voltage E_2 which will just produce a balance condition in the synchro-verifier. Assuming that curve #5 is being used, the contacts will not move in either direction if the line voltage E_2 terminates on any point of this circle. If the line voltage E_2 terminates within curve #5 and remains there for a sufficient length of time the contacts will close. The vector diagram given on Figure 3 is given as an illustration and represents the condition where the bus voltage E_1 is used as the reference voltage and is equal to 115 volts, the line voltage E_2 is 123 volts and leads the bus voltage by 12° and the difference voltage E_3 is equal to 26 volts and leads the bus voltage by 78°. Assuming that the system conditions are such that these voltages will remain fixed at these values the contacts will close if either of the operating circles 3, 4 or 5 are used and will not close if either curves #1 or #2 are used. When the synchro-verifier has been adjusted for any given radius of

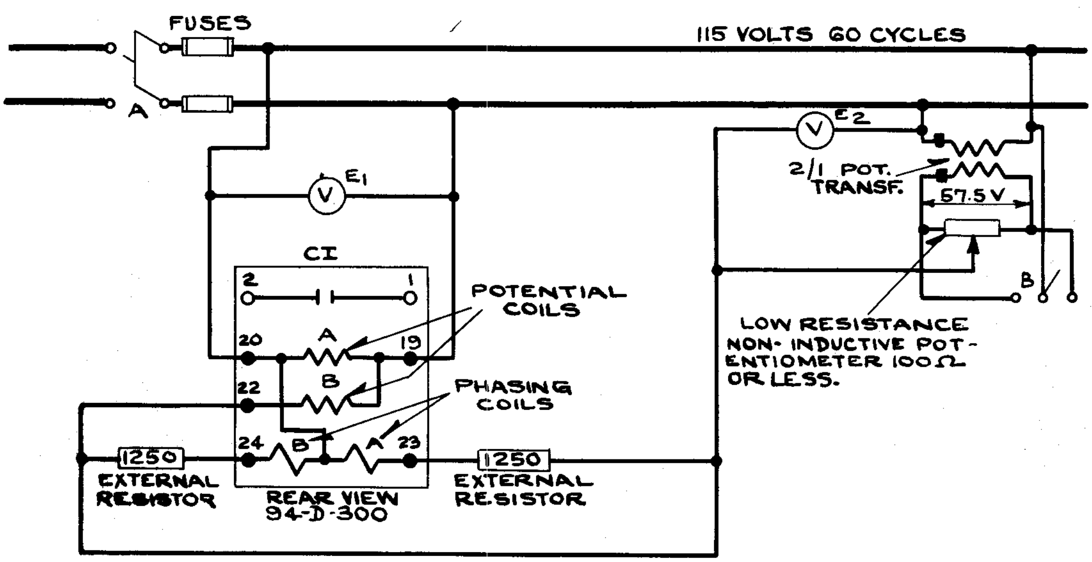
operating circle as shown on Figure 3 by means of the spiral spring adjuster, the radius of this circle will not vary regardless of variations in the reference voltage E_1. This statement is true, providing the overvoltage adjusters have been correctly adjusted for these characteristics as given under "Adjustment and Tests".

17. As previously stated, when characteristics as shown on Figure 3 are used, the contacts of the synchro-verifier will be closed when it is completely de-energized. Should it be essential that the



-Test For Balancing Elements A & B.

Fig. 5 Diagram of Test Connections



-Test For Adjustment Of Operating Characteristics

Fig. 6 Diagram of Test Connections

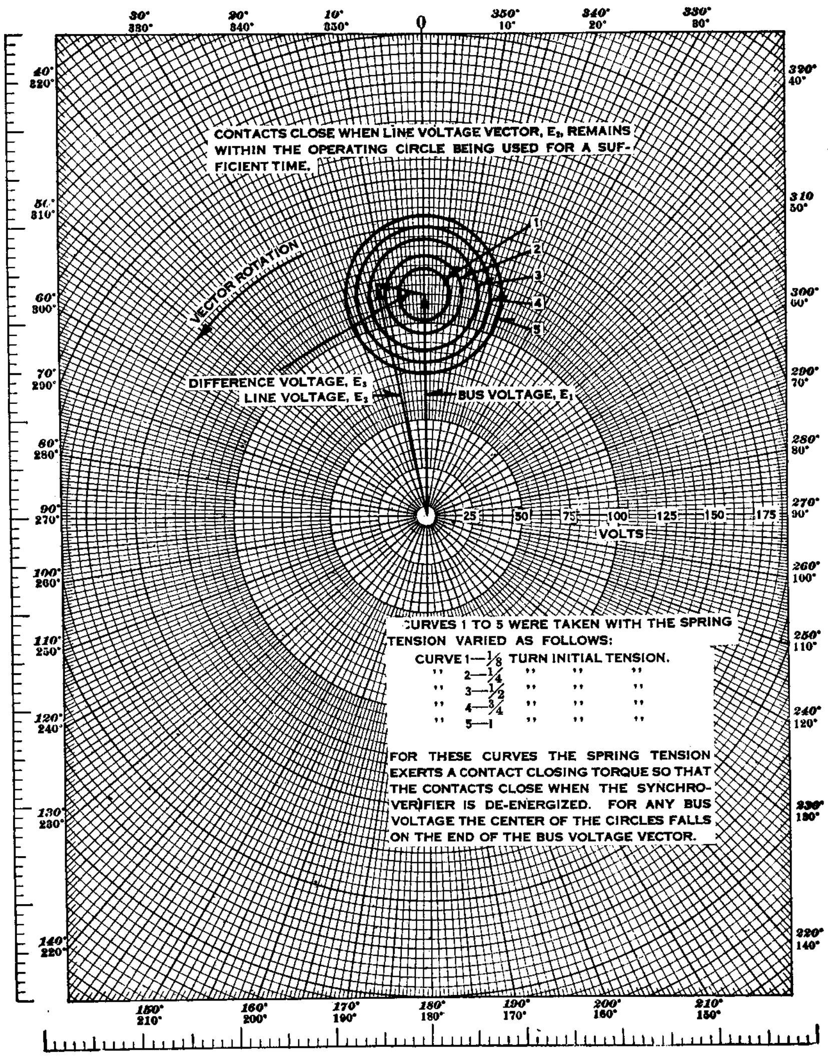


Fig. 3 Operating Characteristics of the Type CI Synchro-Verifier

ELEMENTS BALANCED

Both voltages zero - contacts closed

One voltage zero - contacts open

Both voltages within circle - contacts close

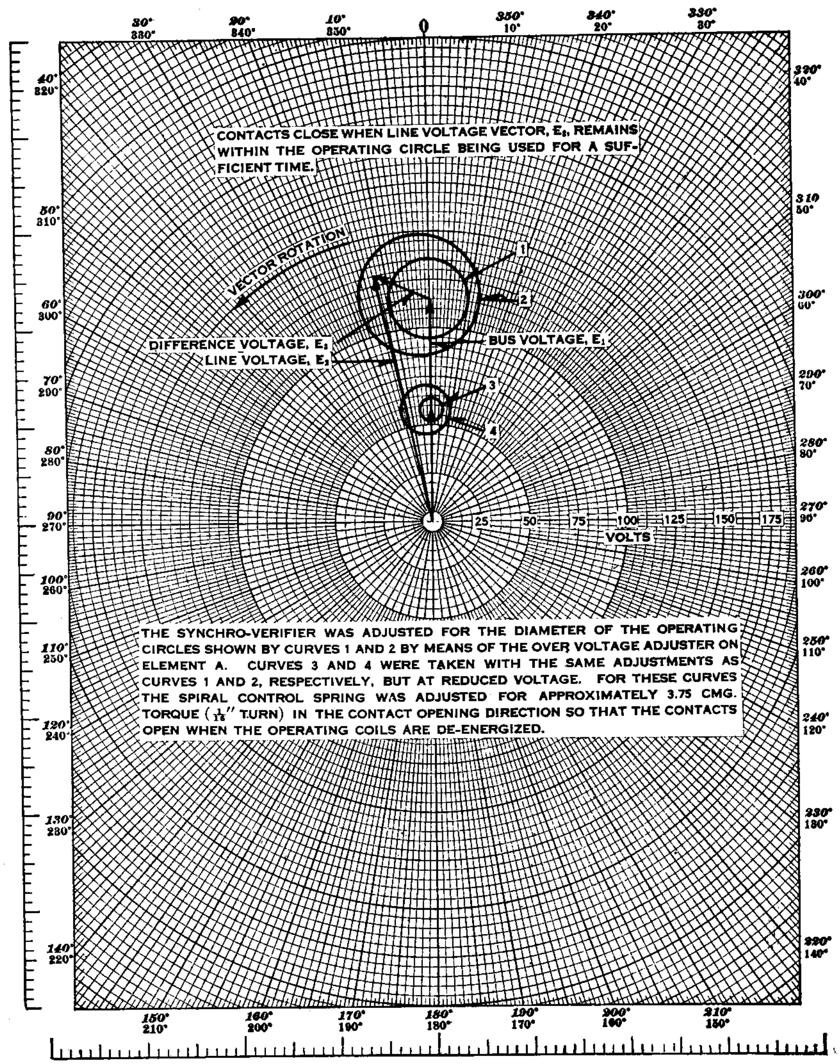


Fig. 4 Operating Characteristics of the Type CI Synchro-Verifier

ELEMENTS UNBALANCED BY VOLTAGE BIAS

Both voltages zero - contacts open

One voltage zero - contacts open

Both voltages within circle - contacts close contacts remain open when the operating coils are completely de-energized this may be accomplished by giving the spiral spring a slight amount of tension in the contact opening direction and obtaining the desired radius of operating circle by means of the overvoltage adjustment on element A. (See Adjustments and Tests) When the radius of the operating circle is obtained in this way the characteristics of the synchro-verifier will be as shown on Figure 4. On this figure it may be noted that the center of the operating circles do not coincide with the end of the reference voltage E_1 and also that the radius of the operating circle decreases as the reference voltage E_1 is decreased. Both of these effects are inherent in the design of the synchro-verifier when this type of adjustment is used.

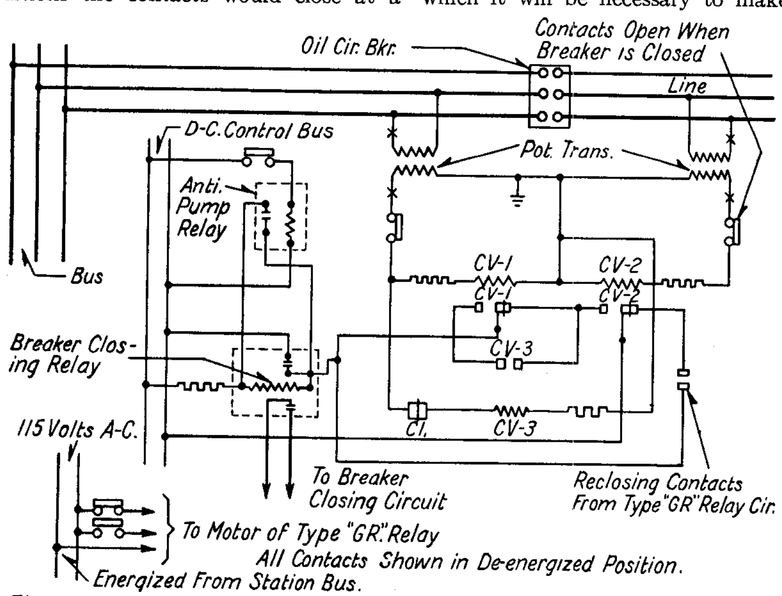
18. Referring again to Figure 3, assume that E_2 is equal to E_1, is in phase with E_1, and is of the same frequency so that the two vectors shown for E_2 and E_1 coincide. Under this condition the synchro-verifier will close its contacts from the extreme open position in approximately 5 seconds if operating circle #5 is being used. Under this condition no electrical torque is produced and the maximum closing torque developed by the spiral spring is effective in closing the contacts at the greatest possible speed. Under the same electrical conditions the contacts would close at a much slower rate if operating circle #1 was being used due to the decrease amount of spring tension. Assume that E_2 is numerically equal to E_1 but of a different frequency so that it slowly moves through operating circle #5 at a uniform rate of speed so that approximately 5 seconds are required for it to move from 20° lagging, to 20° leading with respect to E_1. Under this condition the contacts will not close if operating circle #5 is being used because the contact closing torque is zero when E_2 is approximately 20° out of phase with E_1 and is at its maximum when E_2 is in phase with E_1. Since 5 seconds are required for the contacts to close when E_2 is equal to E_1 and is exactly in phase with it, a longer time will be required for the contacts to close if E_2 is of different frequency than E_1. The time of 5 seconds required for E_2 to move through the operating circle #5 at a uniform rate of speed corresponds to a beat frequency of approximately $\frac{1}{25}$ cycle so that a beat frequency of less than $\frac{1}{25}$ cycle is required before the contacts will close if operating circle #5 is being used and correspondingly lower beat frequencies are required if operating circles with smaller diameter than #5 are being used.

Adjustments and Tests*

19. Ordinarily the only adjustments which it will be necessary to make or check in the field is that for the desired radius of operating circle as shown on Figure 3. In order to check this adjustment it will be necessary to set-up a test circuit as shown on Figure 6. When the synchro-verifier is first received from the factory, the fixed adjustments should be checked to see that they have not changed and for this purpose a test set-up as shown in Figure 5 is necessary. If it should ever be necessary to replace one of the electro-magnets the fixed adjustments would have to be rechecked. An outline of the complete test procedure is given here although it will not be necessary to perform the complete tests as given when checking the adjustments of the synchro-verifier in the field.

20. Carefully level the synchro-verifier before making any tests. Remove the gear and contact assembly from the relay. Then set-up a test circuit as shown on Figure 5. Close switches A and B, and close switch D to the left hand side. This places 115 volts on the potential coil of element A and short-circuits the phasing coil circuit of element A. Adjust the overvoltage adjustment on element A so that the stop on the disc balances at a point mid-way of its travel. The over-voltage adjuster is the sliding lag plate which is mounted on the movement frame and extends into the air-gap between the lower potential pole and the disc. It may be moved to the right or left by means of the adjusting screw provided for this purpose. The two locking screws which hold the overvoltage adjuster in place should not be loosened when this adjustment is made. Moving the overvoltage adjuster to the right of the center line of the potential pole as the synchro-verifier is viewed from the front causes it to lag a part of the potential coil flux so that a contact opening torque is produced, while moving it to the left of the center line of the potential pole causes a conact closing torque to be developed. This test is made to balance out all torque which may be caused by voltage on the potential coil only.

21. Open switch B, close switch C and close switch E to the left-hand side. This places 115 volts, 60 cycles on the potential coil of element B and short circuits the phasing coil circuit of element B. Thd overvoltage adjuster of element B should be adjusted in a similar manner to that of element A so that the disc



The Contacts only, of the Synchro-Verifier are shown in this diagram.

Fig. 7 Schematic Diagram For A Particular Application of the Type CI-Synchro-Verifier

*CAUTION - When Relay is in service with one line completely deenergized, b be sure that this open line is grounded before making adjustments.

will balance at a point mid-way of its travel.

22. Leaving switch A and switch C closed, close switch B and close switch D and E to the right-hand side. This places 115 volts, 60 cycles on each potential coil and places the voltage Ea and Eb on the phasing coil circuits. Set the voltage Ea to 15 volts by means of the potentiometers and then adjust Eb by means of its potentiometer until the disc just balances with its stop mid-way in its travel. If the two electro-magnets do not produce an equal amount of torque under the same conditions then the voltage Eb will differ from the voltage Ed by an amount depending upon the unbalance between the two electro-magnets. When this balance has been obtained the electromagnet which shows the lowest voltage reading for Ea or Eb has the strongest torque. The two electro-magnets should balance within ½ volt at 15 volts, that is, when Ea is set for 15 volts, Eb should read between the limits of 14.5 and 15.5 volts. If the two electro-magnets do not balance within these limits they should be readjusted with respect to each other by raising or lowering the upper pole assemblies by means of the adjustment provided for this purpose. Raising or lowering the upper pole assembly will disturb the overvoltage adjustment which has been made previously and consequently each time the upper pole assembly is raised or lowered it will be necessary to reset the overvoltage adjuster so that no torque is produced, that is, the disc will balance in the mid-way position when the voltage coil alone is energized and the phasing coil circuit is short-circuited. Since this adjustment must be made by the "cut and try" method and may have to be repeated several times the first adjustments may be made more roughly than the final adjustment. The two electro-magnets may be considered balanced with respect to each other when at the end of the test they will perform as follows:

1. The disc will remain in a position mid-way of its travel when element A is energized with 115 volts, 60 cycles on the potential coil and the phasing coil circuit is short-circuited.
2. The disc will remain at a point mid-way of its travel when element B potential coil is energized at 115 volts, 60 cycles and element B phasing coil circuit is short-circuited.
3. With both potential coils energized at 115 volts, 60 cycles and with 15 volts impressed across the phasing circuit of element A the torque of elements A and B should be balanced so that the disc will remain at a point mid-way of its travel when the voltage impressed across the phasing coil circuit of element B falls at some value between the limits of 14.5 and 15.5 volts.

23. Replace the gear and contact mechanism on the synchro-verifier after making sure that all adjustments which were made in the previous test will remain unchanged or, in other words, see that all screws which lock the adjustments in place are tight.

24. Adjust the position of the stationary contact so that the contacts make when the stop on the disc is between 1" and 1¼" from the movement frame on the right-hand side. When the stop on the disc is at the extreme right end of its travel the stationary contact should not be deflected to such an extent that it rests against its own back stop. If this adjustment is not readily obtained the gear and contact assembly may be loosened from the movement frame and the mesh between the pinion and gear changed by one tooth.

25. See that the synchro-verifier is free from friction and then adjust the spring adjuster so that it exerts no torque tending to move the contacts one way or the other just at the point where the contacts make. Reference marks should then be placed on the spring adjuster and its supporting piece in pencil to indicate the position of the spring adjuster which gives zero initial tension on the spiral spring.

26. Connect the synchro-verifier for tests as shown on Figure 6. Close switch A. This places 115 volts 60 cycles, E_1 on the potential coil circuit of element A.

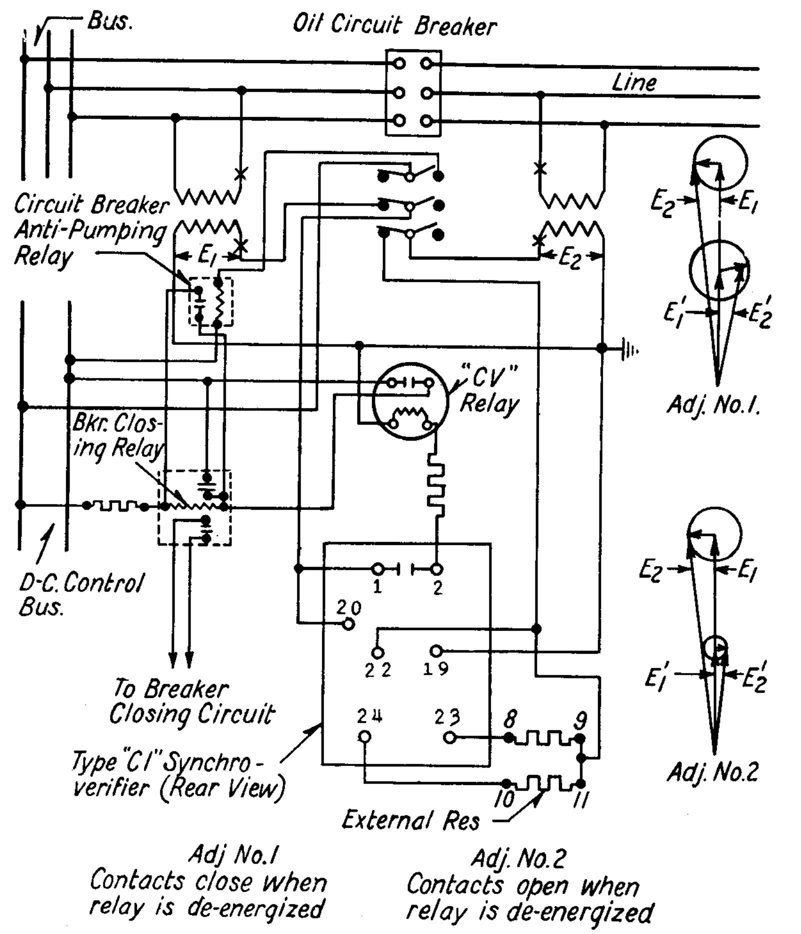


Fig. 8 When the "CI" Synchro-Verifier is Adjusted for Operating Characteristics as per Adjustment #1, The "CV" Relay should be Used for Additional Time Delay, When Adjusted for Characteristics as per Adjustment #2, The "CV" Relay May be Omitted.

Close switch B to the left-hand side. This places a variable voltage E_2 on the potential coil of element B and the difference between E_2 and E_1 is the voltage impressed on the two phasing coil circuits. Adjust the potentiometer until E_2 reads 145 volts, which is 30 volts greater than E_1. Then adjust the spiral spring adjuster in the direction to wind up the spiral control spring so that it tends to close the contacts. The tension on the spring should be increased until the contacts will close from the extreme open position when E_2 is 145 volts and will not close from the extreme open position when E_2 is 147 volts. A two volt limit is thus allowed on the voltage difference adjustment. Approximately one-half turn initial tension on the spring should be sufficient to make this adjustment, although this will vary some with different synchro-verifiers. Securely lock the spring adjuster in position by means of the locking screw provided and then change switch B to the right-hand position. Then adjust the potentiometer so that E_2 reads approximately 85 volts, which is 30 volts less than E_1.

27. An adjustment for 30 volts difference between E_1 and E_2 has been specified. If a different value for this voltage difference adjustment is desired it may be made in the same way with the same limiting value of plus or minus 2 volts on the check test made with E_2 less than E_1.

28. As a further check on the correct operation of the relay, E_2 should be made equal to E_1 and under this condition the relay should develop a positive contact closing torque, and with E_2 radically more than 30 volts different from E_1 the relay should develop a strong contact opening torque.

29. When the adjustments have been made as outlined above the contacts of the synchro-verifier will close when the operating coils are totally de-energized.

30. As previously stated, the contacts may be made to remain open when the operating circuits are de-energized by giving the spiral control spring a slight amount of tension in the contact opening direction and obtaining the desired radius of operating curve by means of the over-voltage adjustment on element A. Operating circles as shown on Figure 4 are obtained in this manner and the two elements are balanced at the desired voltage difference by means of the over-voltage adjuster on element A instead of by means of adjusting the tension on the spiral control spring as previoulsy outlined. The negative spring tension used should be just sufficient to insure that the contacts will always open when the operating coils are de-energized.

Maintenance

31. The mechanical construction of the type "CI" synchro-verifier is simple and rugged; with small assemblies made as accessible as possible to facilitate repairs and reduce maintenance to a minimum. After being properly adjusted and installed, it will require little attention. When making periodic inspections as are maintained on this type of equipment it would be well to examine the synchro-verifier to see that it is free from friction and that the contacts are properly adjusted and in good operating condition.

ENERGY REQUIREMENTS

The burden of the relay at 115 volts, 60 cycles is as follows:

	Z Ohms	R Ohms a-c.	X Ohms	Watts	Volt Amperes	P.F.
Potential Coil	385	57	380	5.14	34.4	81.4° Lag
Phasing Coil & Resistor	1660	1536	628	7.4	8.0	22° Lag

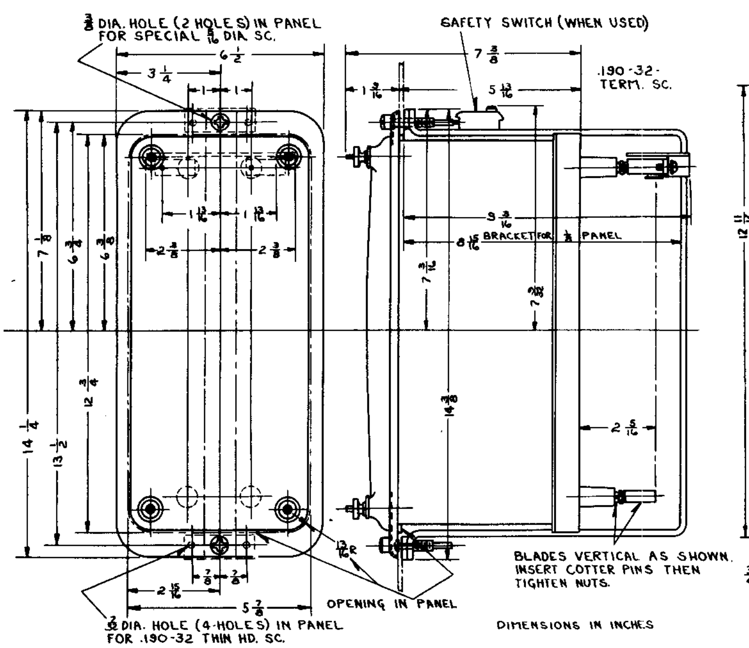


Fig. 9 Outline and Drilling Plan for the Plug-in Semi Flush Type Case for 1/8" Panel Mounting.

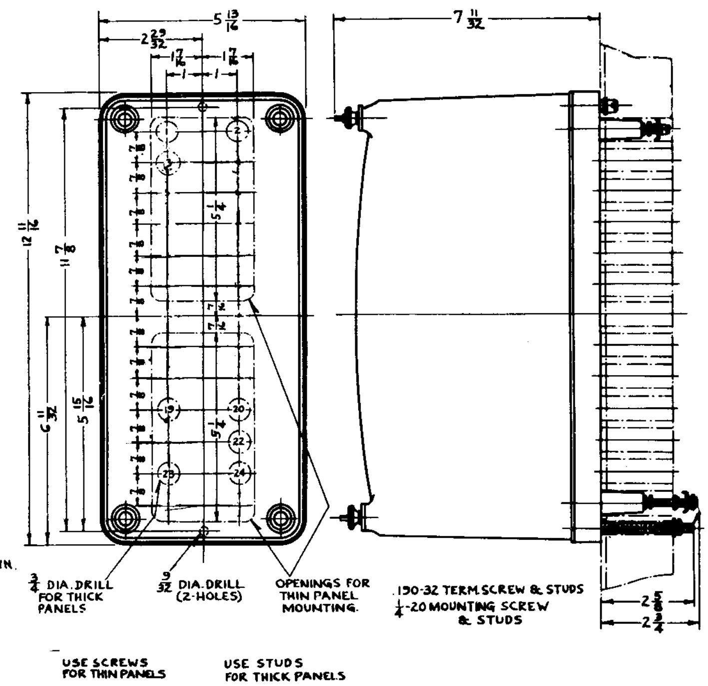


Fig. 10 Outline and Drilling Projection Type Case