MULTI-FREQUENCY AC OPERATED RINGING EQUIPMENT
MODEL S5 **SUB-CYCLE** RINGING CONVERTER

FOR SYNCHROMONIC RINGING SYSTEMS

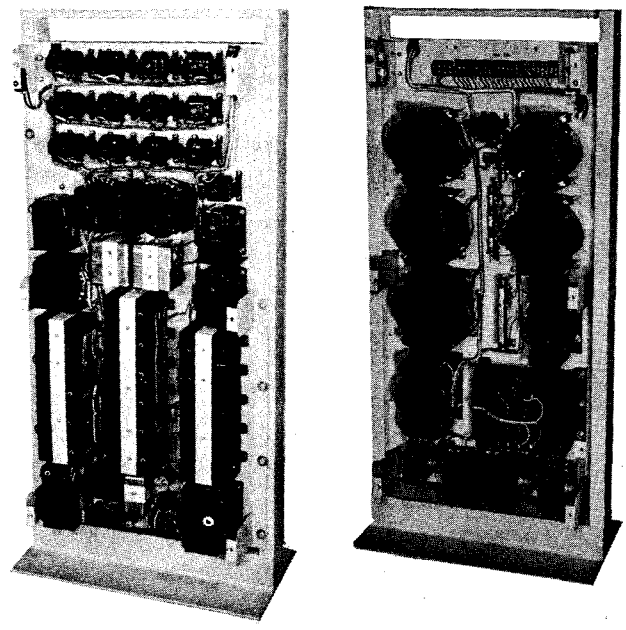
The Synchromonic SUB-CYCLE is a magnetic frequency changer capable of generating the synchromonic series of ringing frequencies of 30, 42, 54 and 66 cycles from the 60 cycle line frequency. Biased Core SUB-CYCLES generating 15 cycles or 20 cycles supply the fifth ringing frequency. The system incorporates a new SUB-CYCLE principle along with basic SUB-CYCLE methods used in the past to give a truly reliable ringing system. The Synchromonic SUB-CYCLE like all other SUB-CYCLES has no moving parts, the output frequencies are locked to the a-c line frequency with a definite ratio and the ringing voltages are regulated.

The circuit components are mounted on the front and back sides of a steel panel which is provided with slots for rack mounting. The arrangement of parts can be seen on the inside Front and Rear Views of the Model S5 as shown in Fig. 1. The circuit elements, saturating transformers, resistors, oil capacitors, and selenium rectifiers are all of the highest quality and are operated conservatively to insure freedom from operating failures. The entire frequency conversion is accomplished by these elements and the circuit does not even require a starting relay. The SUB-CYCLE can therefore be operated satisfactorily on a start-stop basis if desired.

Principle of Operation

The conversion from the 60 cycle line frequency to the ringing frequencies in the synchromonic SUB-CYCLE is accomplished by the frequency changing steps outlined in the functional block diagram shown in Fig. 2. The 30 cycle ringing voltage is obtained from the 60 cycle input voltage through a self-starting frequency divider. The ringing frequencies of 42, 54 and 66 cycles are obtained from a double balance modulator in which two frequencies are added to produce the desired output frequency.

Three modulators are shown in the block diagram, each of which is energized from a common 30 cycle voltage source. The other modulator input frequencies of 12, 24 and 36 cycles are generated in a combination frequency dividing and multiplying system that is energized from the 60 cycle input. The 20 cycle ringing voltage is also obtained from the 60 cycle input by means of the well known biased core SUB-CYCLE. The 15 cycle ringing voltage is obtained by cascading two biased core SUB-CYCLE frequency halvers.



Front view **Back view**

Fig. 1

The relationship of the various circuit components of the Synchromonic SUB-CYCLE is shown on wiring diagram WD-450.

12, 24 and 36 Cycle Generator

The basic components making up the 12 cycle circuit are capacitor C1, saturable inductances L1 and L2, 24 cycle anti-resonant circuit consisting of capacitor C2 and transformer T3 and the 36 cycle anti-resonant circuit consisting of capacitor C3 and transformer T4. Transformer T1 is the input step-up autotransformer which permits the SUB-CYCLE to operate at various line voltages of 110, 120, 210 and 230 volts input. The frequency changing process takes place in the saturable inductances L1 and L2 by reason of their nonlinear characteristics. Saturable inductances L1 and L2 are made nonlinear by saturating the cores with a biasing current supplied from rectifier No. 1.

Rectifier No. 1 is energized from winding 8-9 on the 30 cycle transformer T9 through bias adjustment resistor R2. R1 is a bias stabilizing resistor. The 12 cycle voltage appears across capacitor C1 by means of the step-up action of transformer T2. T2 serves as an isolation transformer and also as a step-up transformer. The 24 cycles which occur from the doubling action of 12 cycles appears across the anti-resonant circuit C2 and T3. T3 serves several purposes, one is an impedance matching device and also as an isolation transformer for the output windings which deliver 24 cycles to the 54 cycle modulator circuit.

The 36 cycles which occur across the anti-resonant circuit, consisting of capacitor C3 and T4 is supplied to transformer T5, through choke L3. Choke L3 eliminates unwanted modulation products from the 66 cycle modulator from occurring across transformer T4. The oscillations are made self-starting in this type of frequency changer by the fact that 36 cycles, plus 24 cycles equals 60 cycles. With these conditions the oscillations are made self-sustaining by the 12 cycle voltage which is the one-fifth submultiple of the input frequency. The 12 cycles being a submultiple of 60 cycles positively locks the oscillations in step with the 60 cycle line frequency. The only way these oscillations can change is by a change in input frequency. The maximum input frequency deviation that can be tolerated is ± 1 cycle.

30 Cycle Divider

The 30 cycle frequency divider consists of a three-legged saturable transformer T9, capacitor C10, inductor L22, and a portion of rectifier No. 3. A half-wave rectifier, part of Rect. 3 connected between the 60 cycle input and the outer legs of T9 passes direct current pulses

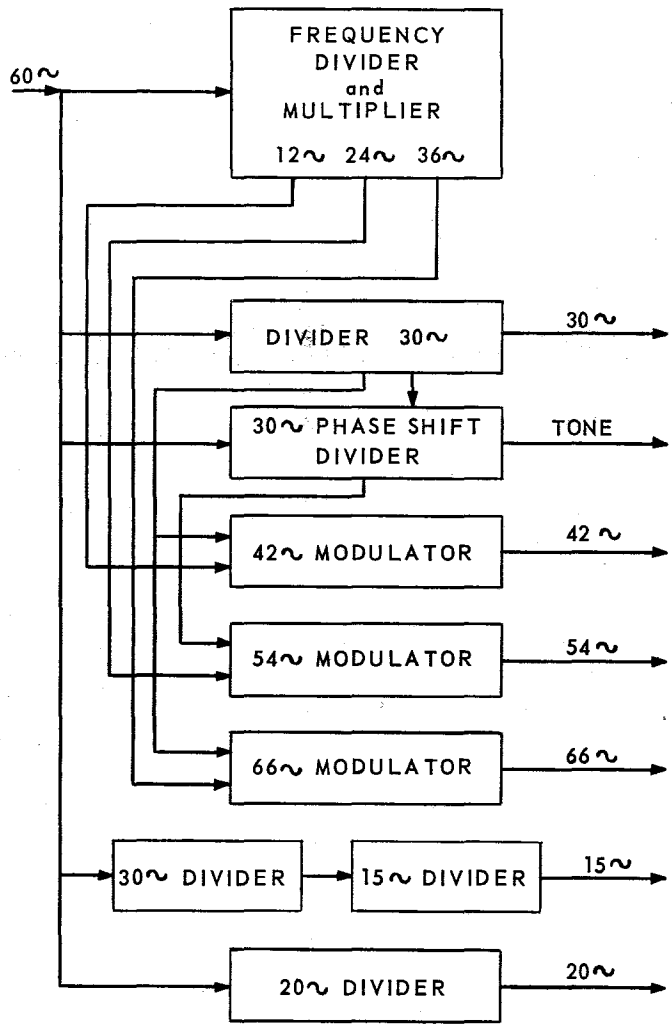


Fig. 2

through the outer leg windings. The voltage induced into the center leg winding is cancelled as long as the two outside legs are equally magnetized. Any current that passes through C10 and the center leg winding combined with the magnetizing effect of the outer legs, unbalances the cancellation of voltage in the center winding. Under the control of current in C10, power is transferred from the 60 cycle input to the circuit of C10, resulting in the self-excited oscillation of C10.

The 30 cycle voltage occurring across capacitor C10 and the center-tapped winding 3-5 is supplied to the three modulator circuits. Regulated voltage is also supplied to rectifier No. 1 and rectifier No. 2. The 30 cycle ringing voltage is taken from isolated winding 10-12 and distributed to the output terminal strip. Resistors R11 and R12 reduce the peak inverse voltage across the sections of rectifier No. 3. Inductor L22 is a stabilizing inductor.

30 Cycle Phase Shift Divider and Tone Circuit

Transformer T10 along with capacitor C11 and a portion of rectifier No. 3 constitute the 30 cycle phase shift divider. The basic operation of this circuit is the same as the 30 cycle divider. In order for the 54 cycle modulator circuit to function properly a phase relation must exist between the 24 cycle and 30 cycle input voltages. The proper phase is established by adding in series two 30 cycle voltages that are 90 degrees out of phase. The 90 degree phase shift occurs since the inputs to T9 and T10 are effectively 180 degrees out of phase. The 30 cycle voltage supplied to the 54 cycle modulator is the resultant combination of the voltage from winding 3-5 on T9 and the voltages from winding 4-5 and winding 6-7 on T10.

Inductance L17 and capacitor C12 which are in series with C11 serve two purposes. Firstly, L17 is the tone coil which supplies the audible tone or reverting tone to the terminals marked "Tone". Capacitor C12 across inductance L17 serves to accentuate the harmonic content required at the tone output. Secondly, it also prevents the starting of this unit until the 30 cycle divider T9 has started.

In order to obtain the proper phase relation between the 24 cycles and 30 cycles it is important that the phase shifting divider does not start until after the 30 cycle divider T9 has started. T10 is prevented from starting by itself by the high impedance offered by inductance L17. T10 will not start without the aid of T9.

42 Cycle Modulator

The 42 cycle modulator consists of saturable inductances L4, L5, L6 and L7 along with tuned output transformer T6 and tuning capacitors C4 and C5. Saturable inductances L4 and L5 are connected as a bridge circuit. L6 and L7 are arranged likewise. The modulation process occurs by means of the non-linear characteristic of the magnetic cores. The non-linear characteristic is achieved by saturating the cores with a biasing current from rectifier No. 2.

Saturable inductances L4 and L5 are energized from terminals 3-4 of T9. L6 and L7 are energized from terminals 4-5 of T9. The biasing current is introduced into the center tap lead, terminal 4. Resistor R3 adjusts the biasing current. The 12 cycle voltage is introduced to the modulator bridge units from the secondary winding on T2 through portions of the winding on T6. The 42 cycles, which is the sum of the 12 cycles and the 30 cycles, appears across the tuned output transformer T6. T6 is in resonance with capacitors C4 and C5.

54 Cycle Modulator

The 54 cycle circuit consists of the modulator bridge units L8, L9, L10 and L11 along with output transformer T7 and

associated capacitors C6 and C7. Operation is the same as the 42 cycle modulator. The 30 cycle power supplied to the modulator is supplied from across capacitor C10 through a portion of the windings on the phase shift on transactor T10. The 24 cycle power is supplied from the two secondary windings on transformer T3. Inductance L16 is a bias choke to prevent unwanted modulation components from appearing in the output transformer T7.

NOTE: In some early model SUB-CYCLES a bias adjustment resistor R4 was placed in series with the choke L16, however, this resistor is not included in later model SUB-CYCLES.

66 Cycle Modulator

The 66 cycle modulator consists of inductances L12, L13, L14, and L15 along with the output transformer T8 which is tuned with its associated capacitors C8 and C9. 30 cycles for the modulator is supplied from across capacitor C10. The 36 cycle power is supplied from transformer T5. R5 is a bias adjustment resistor. This modulator is similar to the other previous modulator circuits in that the 36 cycles are added to the 30 cycles to produce the desired output frequency of 66 cycles.

20 Cycle Divider

In the 20 cycle SUB-CYCLE there are two saturable three-legged transformers T11 and T12. Transformer T12 with capacitor C14 operates as a common core SUB-CYCLE. The conversion of the 60 cycle line frequency to the 20 cycles is accomplished through the saturation of the three-legged core of T12. The charging and discharging of capacitor C14 through the windings of T12 saturates the core at a 20 cycle rate and acts as a trigger on the 60 cycle current into the circuit. Thus the 20 cycle oscillations are self-sustaining when once started.

The small saturable inductance L21 and its capacitor C17 generate reverting tone and the inductance L19 acts as a transformer to help cancel out miscellaneous noise from the output voltage and to improve the tone quality. The three-legged saturable transformer T11, inductance L18, capacitor C13 and the full wave rectifier No. 4, function to start the oscillations and put the common core SUB-CYCLE T12 and C14 into operation. The saturable transformer T11 is biased by the current from the rectifier bridge and acts as a magnetic modulator and also as a frequency doubler and divider.

The circuit of C13 and L18 is tuned with T11 to produce 40 cycles which is coupled to the 20 cycle circuit due to frequency dividing or multiplying action of T11. Energized from the 60 cycle source, the 20 cycle and 40 cycle oscillations are mutually self-exciting due to modulating action of T11. As the oscillations build up to a voltage sufficient to saturate T12, the regular SUB-CYCLE action of T12 takes over and supplies the output power. T2 continues to generate 40 cycles and cooperates with T12 to supply regulated voltage at the terminals of T12 and assist in generating the output frequency under overload conditions. Resistors R6 and R8 are stabilizing resistors. Resistor R7 is an adjustable resistor for controlling the d-c biasing current.

15 Cycle Divider

15 cycles is obtained by cascading two frequency halvers. The first frequency dividing stage consists of the three-legged saturable transformer T14, C16 inductance L20 and rectifier No. 6. This circuit constitutes a 30 cycle divider similar to the 30 cycle divider T9. The output of the first frequency divider is fed into the input of a second frequency divider consisting of the three-legged saturable transformer T13, C15 and rectifier No. 5. Resistor R13 aids in the starting of the first frequency dividing stage. R14 and R15 are protective resistors which

help reduce the peak inverse voltage on rectifiers No. 6 and No. 5 respectively. Inductance L20 is a stabilization inductance that helps smooth out the 30 cycle output voltage of transformer T14.

Other Features

The Model S5 SUB-CYCLE always delivers the exact synchromonic ringing frequencies, because its output frequencies are positively locked in a fixed ratio to the 60 cycle input frequency.

Deviations in output frequency will occur only when the 60 cycle line frequency changes. The close regulation of line frequency by the power companies limits deviations of this type to a negligible value.

Typical voltage regulation curves for the Model S5 SUB-CYCLE are shown in Fig. 3. Note the excellent voltage regulation which is obtained on all five ringing frequencies. This is an important factor in the elimination of cross-ring in multi-frequency ringing systems. The output voltages are substantially independent of input voltage variations or load conditions on other ringing frequencies.

The output of the higher frequencies, 42, 54 and 66 cycles, is rated at 0.20 ampere per output frequency. The 30 cycles is rated at 0.40 amperes. The 15 cycles and 20 cycles are rated at 0.20 amperes and 0.30 amperes respectively. The voltage regulation curves show that ample reserve capacity is available beyond the rated values. The 30 cycle voltage is recommended for straight line ringing because of the large reserve of available power. Full rated load can be carried continuously by all five frequencies at the same time, allowing division of the ringing load to handle large exchanges.

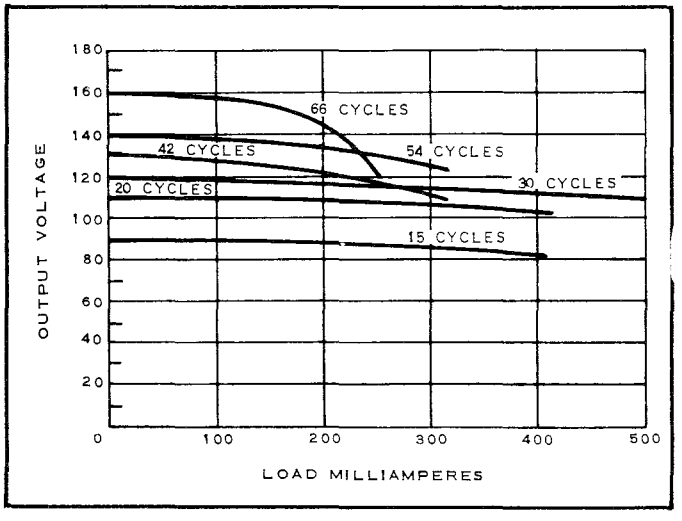


Fig. 3

The input power to the Model S5 SUB-CYCLE with 20 cycles as the fifth frequency is approximately 900 watts with full load on all five frequencies. The no-load consumption is approximately 750 watts. The Model S4 and Model S5 with 15 cycles as the fifth frequency have a power consumption of approximately 750 watts at full load and 600 watts at no load. The input transformer is tapped for 110, 120, 210 and 230 volt 60 cycle single phase operation.

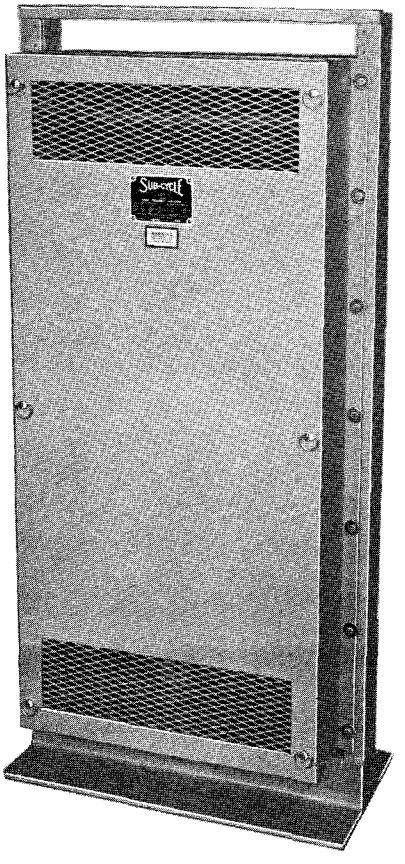


Fig. 4

Because the ringing voltages have smooth wave shapes, a separate tone circuit in the SUB-CYCLE provides the necessary reverting tone for all five frequencies. A wide range of tone levels is available at the output terminal strip. The tone can be used alone or it can be added to the ringing voltage depending on the ringing circuit requirements.

The Model S5-15-23, shown in Fig. 4, includes a floor-standing rack 52 inches high. The floor space required is only 24-3/8 x 15 inches. Space is available at the top to mount a transfer relay assembly which may be obtained as a separate item. The Model S5 is also available on a standard 19 inch relay rack, in which case the number "19" appears at the end of the model number as a suffix. Each SUB-CYCLE is supplied complete with the mounting rack.

The input terminal panel, input voltage adjustment terminal panel and the output terminal panel are conveniently located at the top rear of the cabinet. Separate bushings are provided for the input and output wiring. Each output frequency is electrically isolated from the power line and from the other output frequencies. The ringing outputs can be used independently or they may be used together with a common ground return.

Electrical Specifications

Electrical specifications for various SUB-CYCLE models are as follows:

Models: S4-19, S4-23, RS4-19, RS4-23

Ringing Output:

Frequency	Volts	Amperes
30 CPS	105/110	0.4
42	90/110/130	0.2
54	110/125/140	0.2
66	125/140/160	0.2

Reverting Tone:

57, 65, 73 Decibels

Input:

Frequency	Volts	Amps	(F.L.) Watts
60 CPS	110/120	12.0	725
	210/230	6.0	725

Models: S5-15-19, S5-15-23, RS5-15-19 RS5-15-23

Ringing Output:

Frequency	Volts	Amperes
15 CPS	75/90	0.2
30	105/120	0.4
42	90/110/130	0.2
54	110/125/140	0.2
66	125/140/160	0.2

Reverting Tone:

56, 65, 73 Decibels

Input:

Frequency	Volts	Amps	(F.L.) Watts
60 CPS	110/120	12.0	750
	210/230	6.0	750

Models: S5-20-19, S5-20-23, RS5-20-19 RS5-20-23

Ringing Output:

Frequency	Volts	Amperes
20 CPS	95/110	0.3
30	105/120	0.4
42	90/110/130	0.2
54	110/125/140	0.2
66	125/140/160	0.2

Reverting Tone:

57, 65, 73 Decibels

Input:

Frequency	Volts	Amps	(F.L.) Watts
60 CPS	110/120	12.5	900
	210/230	6.25	900

Installation

Connect the input power wiring to the (a-c input) terminal block, as shown in Fig. 5. The wire size should be heavy enough to carry the rated input current.

Adjust input voltage tap on T1 to the desired input voltage. See table below for voltage ranges available.

Tap	Voltage Range
110 V	100 V - 120 V
120 V	110 V - 130 V
210 V	190 V - 230 V
230 V	210 V - 250 V

The machine as received from the factory, is set to operate on 210 volts unless otherwise specified by the purchaser.

Input fuses F1, F2 are 8 amp. for the 210/230 volt range and 15 amp. for 110/120 volt range. The 2 amp fuse F3 in the 20 cycle converter input and the 3 amp. fuse F4 in the 15 cycle converter remains the same regardless of the input ranges. These fuses will not blow from overloading the output of the SUB-CYCLE and they should not require replacement unless a line surge or trouble condition occurs.

The output ringing voltages are supplied from separate transformer windings so that any of the ringing circuits may be connected as desired. It is suggested that the lowest ringing voltages be used in systems employing high impedance ringers. The 30 cycles voltage is recommended for straight line ringing because of the large reserve of available power. The output connection block is shown in Fig. 6.

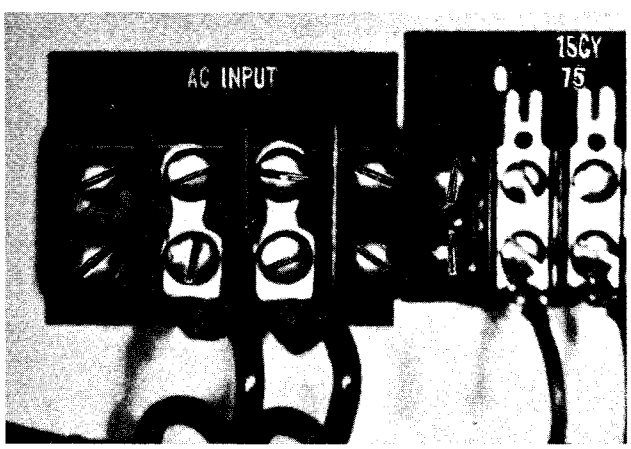


Fig. 5

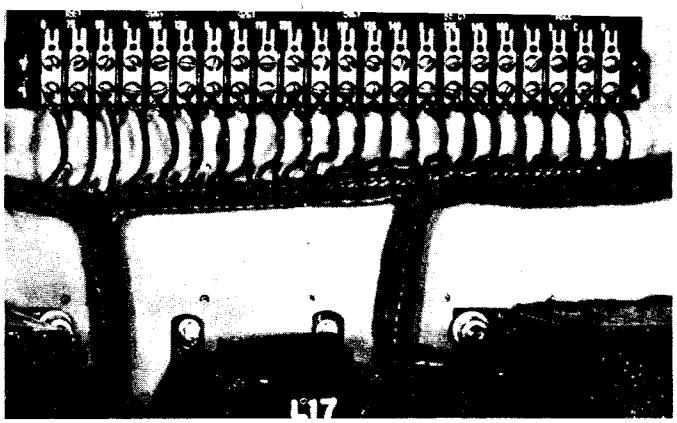


Fig. 6

Because of the smooth wave shape of the ringing voltage, there is insufficient audible tone in the ringing voltage to provide reverting tone. This tone is supplied from a separate circuit and brought out to the terminal marked "Tone". See table below for tone levels and voltages.

Terminal	Tone Level	Tone Voltage
A-B	57 Db	4.6 Volts RMS
A-C	65	11.5
A-D	73	27.8

This tone may be used with ringing frequencies of 15, 30, 42, 54 and 66 cycles. The 20 cycle ringing voltage has superimposed on it, a high frequency reverting tone designed to transmit through carrier telephone systems. Typical tone connection options for typical S4 and S5 SUB-CYCLES are as follows:

S4 SUB-CYCLE - Fig. 7

S5-15 SUB-CYCLE - Fig. 8

S5-20 SUB-CYCLE - Fig. 9

Connect terminals X2 and X2 of remote control relays to source of 48 volts d-c to provide remote control connection for all models identified with the prefix R.

Parallel operation of two SUB-CYCLES is accomplished by connecting in phase, the input and output terminals. Before connecting the outputs, the no-load output voltages of each paralleled frequency should be adjusted as closely as possible to insure equal division of load and to minimize circulating currents. Fine adjustment of the 20, 42, 54 and 66 cycle voltages is accomplished by moving the adjustable leads (with arrows) on units T12, T6, T7 and T8 respectively. Connect an equalizing lead between terminal

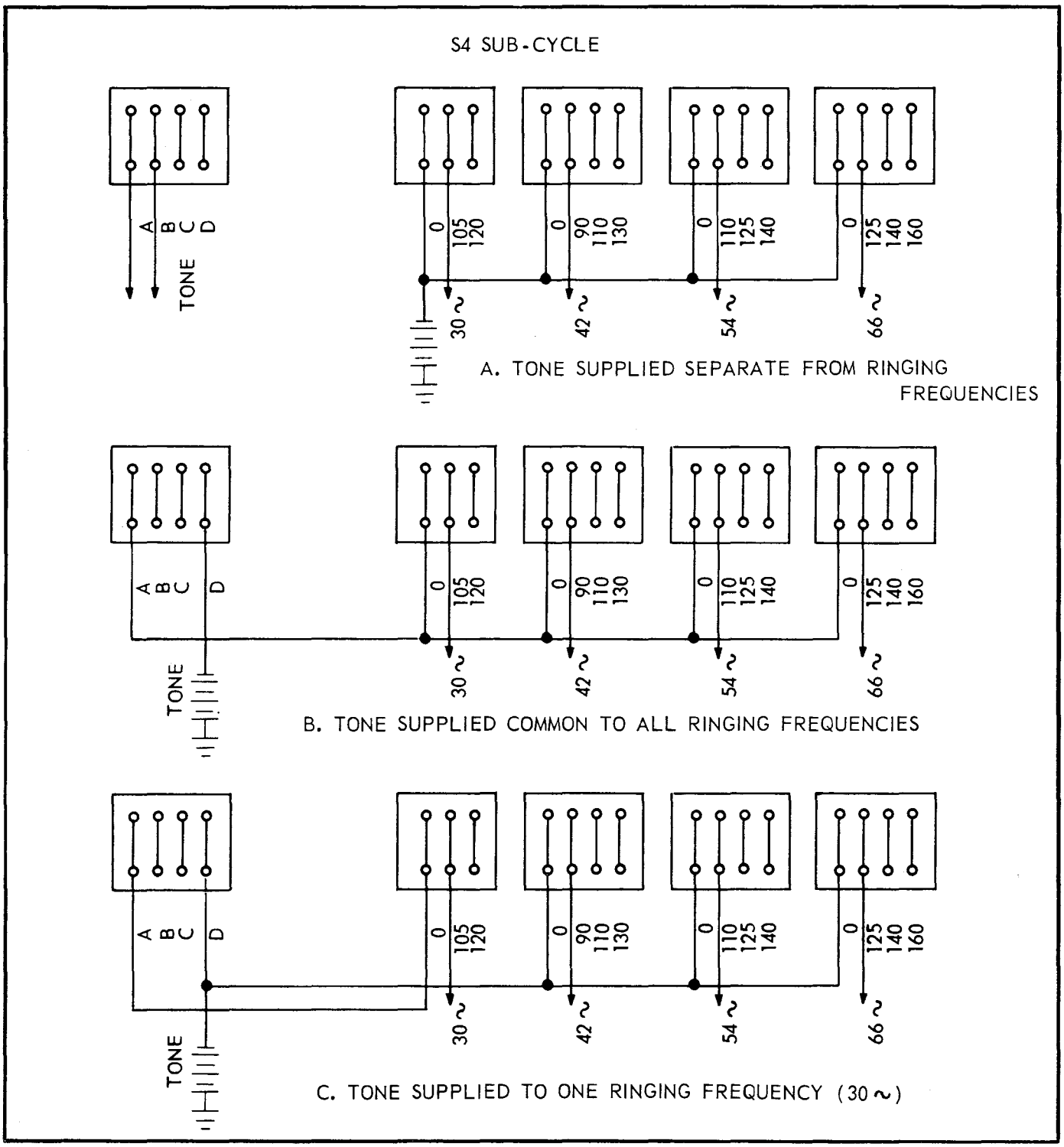


Fig. 7

4 of T3 to corresponding terminal on other SUB-CYCLE. This lead should be No. 16 or heavier and insulated for 600 volts.

Means should be provided to disconnect the defective machine to prevent overloading of the good machine in the event that the input fuses of either machine blow.

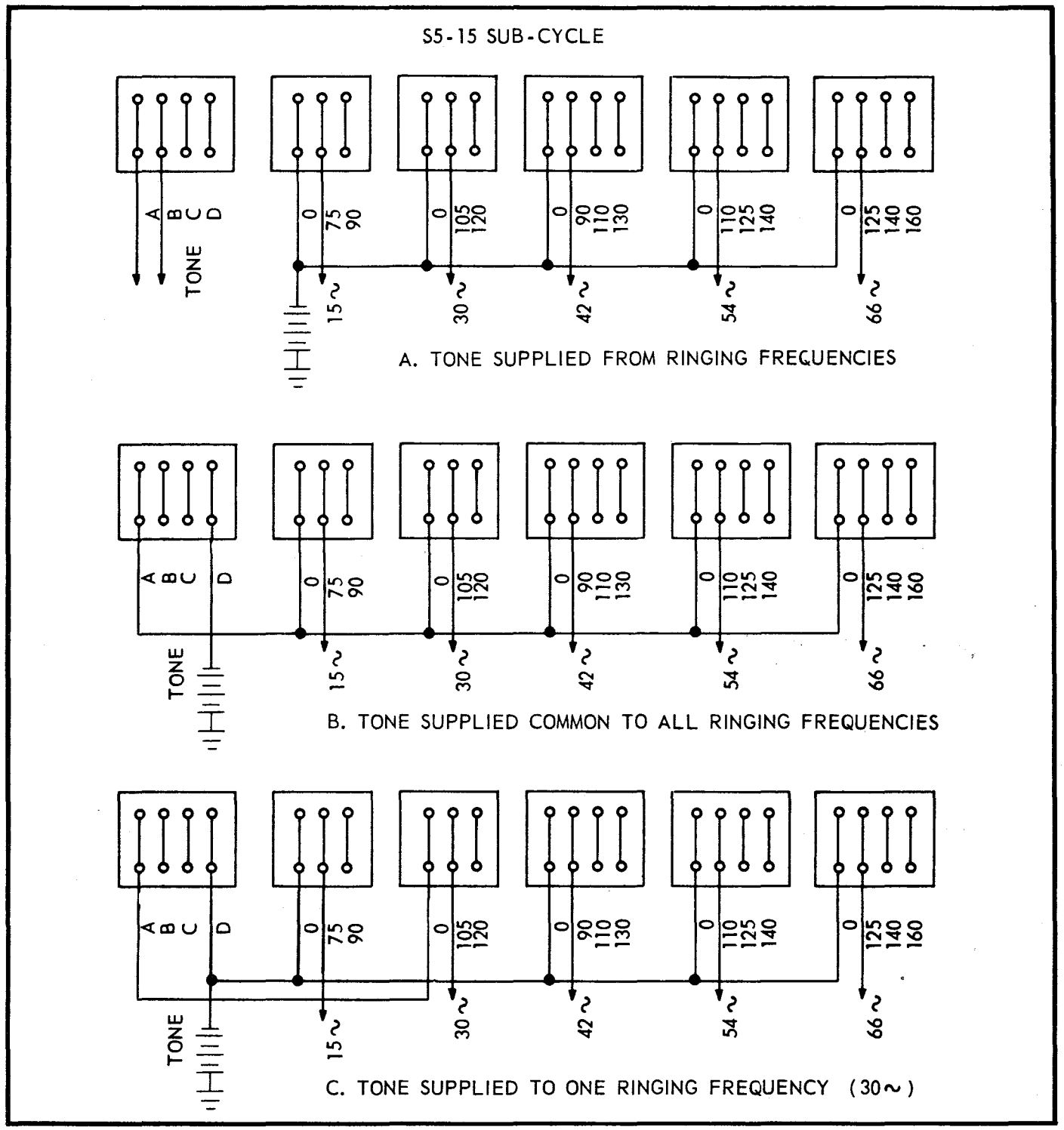
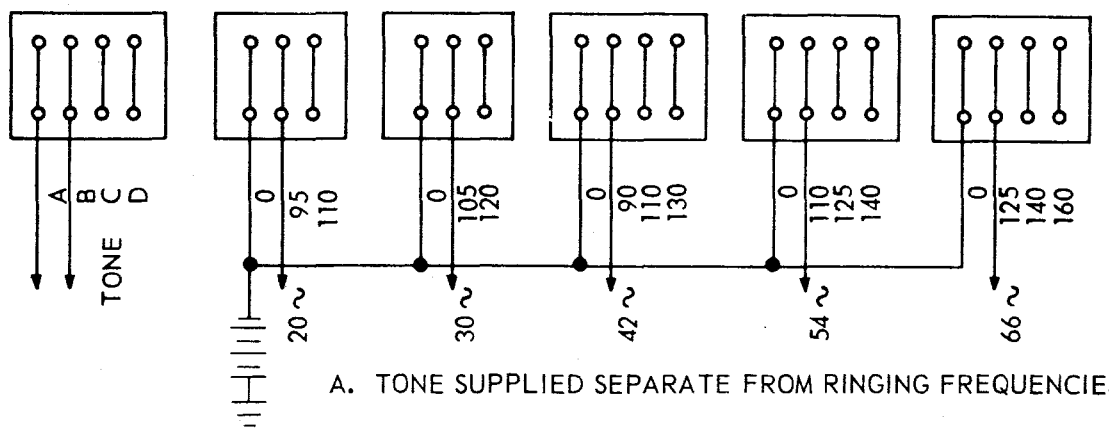
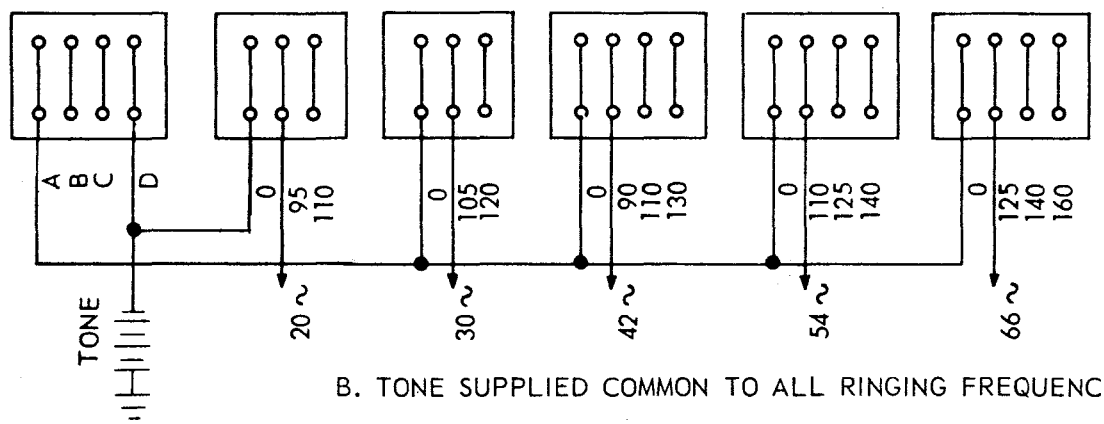


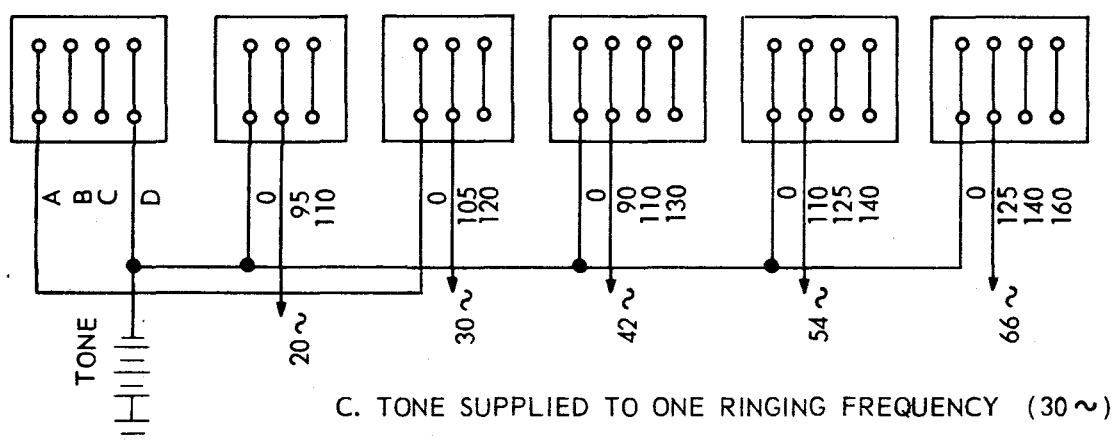
Fig. 8



A. TONE SUPPLIED SEPARATE FROM RINGING FREQUENCIES



B. TONE SUPPLIED COMMON TO ALL RINGING FREQUENCIES



C. TONE SUPPLIED TO ONE RINGING FREQUENCY (30 ~)

Fig. 9