Society of Automotive Engineers, Inc. 29 West 39th Street New York City	AERONAUTICAL RECOMMENDED PRACTICE	ARP 461
SYNCHRO SPECIFICATION		Issued 7-1-55 Revised

1. SCOPE:

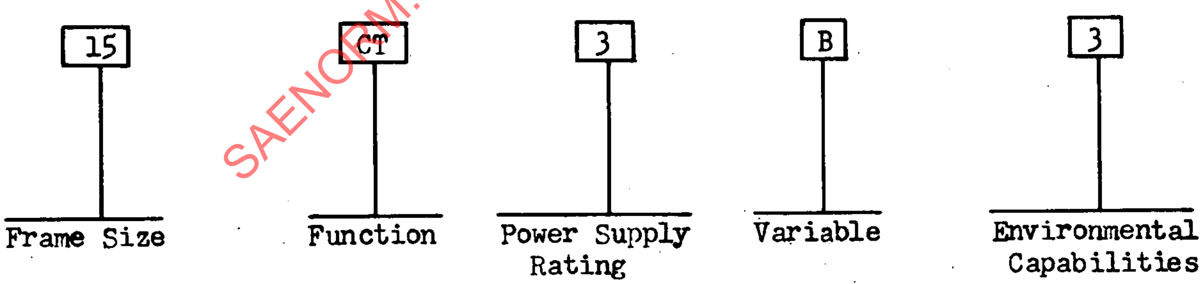
1.1 This specification covers the following general class of synchros:

26 volt, 400 cycle synchros
115 volt, 400 cycle synchros
115 volt, 60 cycle synchros

1.1.1 Under each of the above general classes of synchros the following specific type of synchro is covered by this specification:

Synchro Transmitter - Torque
Synchro Transmitter - Control
Synchro Control Transformer
Synchro Differential Transmitter - Torque
Synchro Differential Transmitter - Control
Synchro Differential Receiver
Synchro Receiver
Synchro Resolver Transmitter
Synchro Resolver Control Transformer
Synchro Resolver Differential

1.2 Code for Type Designation of Synchros: Synchros are classified according to frame size, function, power supply rating, environmental capabilities and the type of shaft and method of electrical connection. This information is contained in the type designation which consists of five blocks of alternate numerals and letters as follows:



1.2.1 Frame Size: The first two numerals of the type designation number consists of two numerals which indicate the maximum diameter of the unit in tenths of an inch. If the diameter is not exactly a whole number of tenths, the next higher tenth is used.

Printed in U. S. A.

Frame Size (2 Numerals)

08	0.701 to .800 inch diameter
10	0.901 to 1.000 inch diameter
11	1.001 to 1.100 inch diameter
15	1.401 to 1.500 inch diameter
16	---- ----
18	1.701 to 1.800 inch diameter
19	---- ----
23	2.201 to 2.300 inch diameter
31	3.001 to 3.100 inch diameter
37	3.601 to 3.700 inch diameter

1.2.2 Function: The second block of the type designation number consists of two letters which indicates the functional applications as follows:

Function (Two Letters)

TX	Transmitter - Torque
CX	Transmitter - Control
CT	Control Transformer
TD	Differential Transmitter - Torque
CD	Differential Transmitter - Control
DR	Differential Receiver
TR	Receiver
RX	Resolver - Transmitter
RC	Resolver - Control Transformer
RD	Resolver - Differential

1.2.3 Power Supply Rating: The third block of the type designation number consists of one numeral which indicates the nominal power supply system utilized as follows:

Power Supply Rating (1 Numeral)

	Nominal Voltage	System Frequency
1	115	60
2	115	400
3	26	400

1.2.4 Variable: The fourth block of the type designation number consists of a letter which indicates a variable applicable to the particular unit such as terminals, leads, shaft, etc. in accordance with the following table:

Variable (One Letter)

A	Terminal connection, smooth shaft
B	Flexible leads, smooth shaft
C	Terminal connection, splined shaft
D	Flexible leads, splined shaft
E	Rotatable - outline figure 3

1.2.5 Environmental Capabilities: The fifth block of the type designation number consists of one numeral to indicate the service conditions which the unit is designed to withstand according to the following table:

Environmental Capabilities
(1 Numeral)

1.	Unexposed	Units which are normally installed within protected areas that do not require more than a 24 hour humidity check, such as sealed instruments or servos.
2.	Exposed	Units which are normally installed in unprotected areas that do require more than a 24 hour humidity check, such as unprotected units in computer racks.
3.	Hi-Temp.	Units which are normally installed in areas subjected to ambients between 71°C. and 150°C. for periods of 24 hours.
4.	Hi Hi-Temp.	Units which are normally installed in areas subjected to ambients between 150°C. and 300°C. for periods of 24 hours.

1.2.6 Illustration: 15CT3B3 indicates a Synchro Control Transformer for use in a 26 volt, 400 c.p.s. system which has a smooth shaft, flexible leads and was designed for operation in ambients above +71°C.

1.3 Definitions:

1.3.1 Definitions of Types:

1.3.1.1 Synchro: A synchro is an electro-magnetic device which is primarily used for transmission, reception or conversion of angular data.

1.3.1.2 Synchro Transmitter: A unit wherein the rotor is mechanically positioned for transmitting electrical information corresponding to angular position of the rotor with respect to the stator.

(a) A torque transmitter is constructed primarily for operation with receivers, torque differential transmitters, and differential receivers.

(b) A control transmitter is constructed primarily for operation with control transformers or control differential transmitters.

1.3.1.3 Synchro Control Transformer: A unit wherein the stator is supplied with electrical angular information and the rotor output is a voltage proportional to the sine of the difference between the electrical input angle and the control transformer rotor angle. This unit is constructed primarily for operation with control transmitters and control differential transmitters.

1.3.1.4 Synchro Differential Transmitter: A unit wherein the rotor is mechanically positioned for modifying electrical angular information received from a transmitter and re-transmitting electrical information corresponding to the sum of difference of the electrical input angle and its rotor position angle depending on the system wiring.

(a) A torque differential transmitter is constructed primarily for operation with torque receivers.

(b) A control differential transmitter is constructed primarily for operation with control transformers.

1.3.1.5 Synchro Differential Receiver: A unit wherein the rotor is free to turn to assume a position with respect to the stator in accordance with the sum or difference of the electrical angular information received. This unit is constructed primarily for operation with two synchro torque transmitters.

1.3.1.6 Synchro Receiver: A unit wherein the rotor is free to turn, to assume a position with respect to the stator in accordance with the electrical information received when the rotor is properly energized. This unit is primarily constructed for operation with torque transmitters and torque differential transmitters.

1.3.1.7 Resolver -- Transmitter: A unit which may have two perpendicular windings on the rotor or stator, that has its rotor mechanically positioned for transmitting electrical information corresponding to angular position of the rotor with respect to the stator.

1.3.1.8 Resolver - Control Transformer: A unit which may have two perpendicular windings on the rotor or stator that transforms electrical angular information from the stator to a voltage proportional to either the sine or cosine of the difference between the electrical input angle and the resolver control rotor angle.

1.3.1.9 Resolver - Differential: A unit which may have two perpendicular windings on the rotor or stator that has its rotor mechanically positioned for modifying electrical angular information received from a transmitter and re-transmitting the electrical information corresponding to the sum or difference of the electrical input angle and its rotor position angle, depending on the system wiring.

1.3.2 Definitions of Terms:

1.3.2.1 Direction of Rotation: Clockwise or counter-clockwise is determined when facing the shaft extension end of the synchro. When two shaft extensions exist, the one opposite the lead or terminal end shall be the one considered for this definition.

1.3.2.2 Rotor Angle: The rotor angle of the synchro is the angular displacement of its rotor from the synchro zero position (see 1.3.2.6) measured as an increasing positive angle in a counter-clockwise direction.

1.3.2.3 Primary and Secondary Windings: The primary winding is the one which receives energizing power from either the supply line (as in transmitters or receivers) or from another synchro (as in control transformers). In the case of differential transmitters and differential receivers, the primary winding is the outer winding.

1.3.2.4 Electrical Angle:

1.3.2.4.1 Transmitter and Receiver: The electrical angle is the angle "a" displaced in a positive direction from synchro zero which satisfies the relative magnitudes and polarities of the secondary voltages of a synchro transmitter or receiver in accordance with the following equations:

$$E\ (S_{13}) = n\ E\ (R_{21})\ \sin\ a$$

$$E\ (S_{32}) = n\ E\ (R_{21})\ \sin\ (a + 120^\circ)$$

$$E\ (S_{21}) = n\ E\ (R_{21})\ \sin\ (a + 240^\circ)$$

Where: n is the ratio between the maximum rms voltage between any two secondary terminals, with the third terminal open, and the primary voltage;

$E\ (R_{21})$ is the voltage between terminals R_2 and R_1.

$E\ (S_{13})$ is the voltage between terminals S_1 and S_3.

Other voltages are similarly defined. These secondary voltages are in time phase with one another and usually displaced a nominal amount in time phase from the primary voltage.

1.3.2.4.2 Control Transformer: The electrical angle "a" is the angle displaced in a positive direction from synchro zero which satisfies the relative magnitudes and polarities of the secondary voltage of a synchro control transformer in accordance with the following equations:

$$E\,(R_{12}) = n\,\left[E\,(S_{13}) \sin(a + 120) - E\,(S_{32}) \sin a\right]$$

$$E\,(S_{13}) + E\,(S_{32}) + E\,(S_{21}) = 0$$

Where: n is the ratio between the maximum rms voltage between any two secondary terminals, with the third terminal open, and the primary voltage:

$E\,(R_{12})$ is the voltage between terminals R_1 and R_2

$E\,(S_{13})$ is the voltage between terminals S_1 and S_3

Other voltages are similarly defined.

1.3.2.4.3 Differential Transmitter and Receiver: The electrical angle "a" is the angle displaced in a positive direction from synchro zero which satisfies the relative magnitudes and polarities of the secondary voltages of a synchro differential transmitter or a differential receiver in accordance with the following equations:

$$E(R13) = n\,\left[E\,(S_{13}) \sin(a + 120) - E\,(S_{32}) \sin a\right]$$

$$E(R32) = n\,\left[E\,(S_{13}) \sin a - E\,(S_{32}) \sin(a + 240)\right]$$

$$E(R21) = n\,\left[E\,(S_{13}) \sin(a + 240) - E\,(S_{32}) \sin(a + 120)\right]$$

$$E\,(S_{13}) + E\,(S_{32}) + E\,(S_{21}) = 0$$

Where: n is the ratio between the maximum rms voltage between any two secondary terminals, with the third terminal open, and the primary voltage:

$E\,(R_{12})$ is the voltage between terminals R_1 and R_2

$E\,(S_{13})$ is the voltage between terminals S_1 and S_3

Other voltages are similarly defined.

1.3.2.4.4 Resolver Transmitter: The electrical angle "a" is the angle displaced in a positive direction from synchro zero which satisfies the relative magnitudes and polarities of the secondary voltages of a resolver transmitter in accordance with the following equations:

$$E\ (S_{13}) = n\ E\ (R_{31}) \sin a$$

$$E\ (S_{24}) = n\ E\ (R_{31}) \cos a$$

Where: n is the ratio between the maximum rms voltage between the secondary terminals and the primary voltage:

$E\ (R_{31})$ is the voltage between terminals R_3 and R_1

$E\ (S_{13})$ is the voltage between terminals S_1 and S_3

Other voltages are similarly defined.

1.3.2.4.5 Resolver Control Transformer: The electrical angle "a" is the angle which displaced in a positive direction from synchro zero satisfies the relative magnitudes and polarities of the secondary voltage of a resolver control transformer in accordance with the following equation:

$$E\ (R_{24}) = n\ \left[E\ (S_{42}) \sin a + E\ (S_{13}) \cos a\right]$$

Where: n is the ratio between the maximum rms voltage between the secondary terminals and the primary voltage:

$E\ (R_{24})$ is the voltage between terminals R_2 and R_4

$E\ (S_{42})$ is the voltage between terminals S_4 and S_2

Other voltages are similarly defined.

1.3.2.4.6 Resolver Differential: The electrical angle "a" is the angle displaced in a positive direction from synchro zero which satisfies the relative magnitudes and polarities of the secondary voltages of a resolver differential in accordance with the following equations:

$$E\ (R_{13}) = n\ \left[E\ (S_{24}) \sin a + E\ (S_{13}) \cos a\right]$$

$$E\ (R_{24}) = n\ \left[E\ (S_{31}) \sin a + E\ (S_{24}) \cos a\right]$$

Where: n is the ratio between the maximum rms voltage between the secondary terminals and the primary voltage:

$E\ (R_{13})$ is the voltage between terminals R_1 and R_3

$E\ (S_{13})$ is the voltage between terminals S_1 and S_3

Other voltages are similarly defined.

1.3.2.5 Time Phase: The time phase at a point in a synchro system is the phase of the voltage at that time with respect to the energizing voltage of the synchro system. The time phase is measured in degrees. Time phase as defined here shall not be confused with electrical angle which is also measured in degrees.

1.3.2.6 Synchro Zero:

1.3.2.6.1 Transmitters and Receiver: The synchro zero position of transmitters and receiver is that position of the rotor with respect to the stator at which minimum voltage is induced in the secondary circuit $S_1 - S_3$ and at which the secondary voltages E (S_{12}) and E (S_{32}) are approximately in time phase with the primary voltage E (R_{21}). The minimum voltage position is defined as the point where the secondary voltage of fundamental frequency that is in time phase with the secondary voltage at maximum coupling is zero.

1.3.2.6.2 Control Transformer: The synchro zero position of a control transformer is that position of the rotor with respect to the stator at which minimum voltage is induced in the secondary circuit $R_1 - R_2$ when the unit is energized by applying 0.866 times the rated voltage between terminal S_2 and the terminal S_1 which is connected to S_3. It is so determined that for small deflections of the rotor counter-clockwise from synchro zero the induced voltage E (R_{12}) is approximately in time phase with the voltage E (S_{21}) or E (S_{23}). The minimum voltage position is defined as the point where the secondary voltage of fundamental frequency that is in time phase with the secondary voltage at maximum coupling is zero.

1.3.2.6.3 Differential Transmitters and Differential Receiver: The synchro zero position of differential transmitters and differential receiver is that position of the rotor with respect to the stator at which minimum voltage is induced in the circuit $R_1 - R_3$ and at which the voltages E (R_{32}) and E (R_{12}) are approximately in time phase with the corresponding voltages E (S_{32}) and E (S_{12}) when the synchro is energized by applying 0.866 times the rated voltage between terminal S_2 and terminal S1 which is connected to S_3. The minimum voltage position is defined as the point where the secondary voltage of fundamental frequency that is in time phase with the secondary voltage at maximum coupling is zero.

1.3.2.6.4 Resolver Transmitter: The synchro zero position of a resolver transmitter is that position of the rotor with respect to the stator at which minimum voltage is induced in the secondary circuit $S_1 - S_3$ when the unit is energized with rated voltage between terminals $R_1 - R_3$. It is so determined that for small deflections of rotor counter-clockwise from synchro zero the induced voltage E (S_{13}) is approximately in time phase with E (R_{31}). The minimum voltage position is defined as the point where the secondary voltage of fundamental frequency, that is in time phase with the secondary voltage at maximum coupling, is zero.

1.3.2.6.5 Resolver Control Transformer: The synchro zero position of the resolver control transformer is that position of the rotor with respect to the stator at which minimum voltage is induced in the secondary circuit $R_4 - R_2$ when the unit is energized with rated voltage between terminals S_2 and S_4. It is so determined that for small deflections of the rotor counter-clockwise from synchro zero the induced voltage E (R_{42}) is approximately in time phase with E (S_{24}). The minimum voltage position is defined as the point where the secondary voltage of fundamental frequency, that is in time phase with the secondary voltage at maximum coupling, is zero.

1.3.2.6.6 Resolver Differential:

1.3.2.7 Transformation Ratio: The transformation ratio of a synchro is the ratio of the no-load maximum fundamental secondary voltage to the fundamental supply voltage applied to the primary.

1.3.2.8 Electrical Error: The error at a given rotor position is defined as the mechanical rotor position minus the electrical position.

1.3.2.9 Units: Unless otherwise specified the units for Angles are degrees, minutes, and seconds. Potential is volts rms. Impedance is ohms. Current is amperes rms.

2. SYNCHRO CHARACTERISTICS:

2.1 Physical:

2.1.1 Envelope Dimensions: Figures 1, 2, 3, and 4, together with its accompanying dimensional chart, gives the synchro envelope dimensions, shaft configurations, and electrical connections.

2.1.2 Lead Wire Identification: For units using lead wires instead of terminals, the following color designation is to be considered standard:

TRANSMITTERS, CONTROL TRANSFORMERS AND RECEIVERS

Rotor	Stator
R_1 - Red	S_1 - Blue
R_2 - Black	S_2 - Black
	S_3 - Yellow

DIFFERENTIAL - (TRANSMITTER, RECEIVER)

Rotor	Stator
R_1 - Yellow	S_1 - Blue
R_2 - Black	S_2 - Black
R_3 - Blue	S_3 - Yellow

RESOLVER - (TRANSMITTER, CONTROL TRANSFORMER AND DIFFERENTIAL)

Rotor	Stator
R_1 - Red	S_1 - Red
R_3 - Black	S_3 - Black
R_2 - Yellow	S_2 - Yellow
R_4 - Black	S_4 - Blue

DIMENSIONAL CHART for FIGURE NO. 1

SYNCHRO SIZES

DIMENSIONS AND LIMITS	08	10	11	15
A ±1/32	7/16	3/8	5/16	1/2
B +.003 -.010	0.750	0.937	1.062	1.437
C +.0000 -.0005	-	0.8123	1.000	1.3120
D +.0000 -.0005	0.5000	0.5000	0.6250	0.5000
E +.0000 -.0005	0.1200	0.0900	0.1200	0.1200
F Max.	*1.658 **1.812	1.246 -	1.687 -	1.627 1.978
G ±.005	0.040	0.038	0.062	0.040
H ±.005	-	0.062	0.062	0.132
I ±.005	0.062	0.062	0.093	0.093
J ±.005	0.062	0.062	0.050	0.078
K Max.	0.630	0.840	0.975	1.315
L	-	3-(2-64)	4-(4-40)	4-(4-40)
M ±.003	-	0.678	0.812	0.875
N	-	0.001	0.001	0.001
P	-	0.001	0.001	0.001

* For unit with flexible leads.

** For unit with terminals (exclusive of screws)

DIMENSIONAL CHART for FIGURES NOS. 2 and 3

SYNCHRO SIZES

DIMENSIONS & LIMITS	11	15	16(a)	18
A *±.005 **±.010	*0.555	**0.540	**0.540	**0.540
B +.000 -.003	1.062	1.437	1.437	1.750
C +.000 -.0005	1.000	1.3120	1.3120	1.5620
D +.0000 -.0005	0.6250	0.8750	0.8750	0.9375
E +.000 -.001	0.185	0.185	0.185	0.185
F Max.	1.775	1.770 * 1.93	2.593	*2.67 2.52
G ±.003	0.062	0.040	0.040	0.040
H ±.003	0.062	0.132	0.132	0.132
I ±.003	0.093	0.093	0.093	0.093
J ±.005	0.050	0.078	0.078	0.078
K ±.003	0.975	1.312	1.312	1.625
L	4-(4-40)	4-(4-40)	4-(4-40)	4-(4-40)
M ±.003	0.812	1.100	1.100	1.250
N	1.318	1.646	1.646	1.959
P	0.0015	0.0015	0.001	0.0015
R	0.001	0.001	0.001	0.001
S +.010 -.005	0.292	0.263	0.263	0.263
T +.010 -.005	0.355	0.200	0.200	0.200
U	21	21	21	21

DIMENSIONAL CHART
for
FIGURES NOS. 2 and 3
(Con't)

SYNCHRO SIZES

DIMENSIONS & LIMITS	11	15	16(a)	18	19
V	120	120	120	120	120
W +.000 -.002	0.175	0.175	0.1750	0.1750	0.1750
Y +.0000 -.0002	0.1872	0.1872	0.1872	0.1872	0.1872
Z Max.	0.155	0.155	0.155	0.155	0.155
AA	20°	20°	20°	20°	20°
AB	10-32NF-2	10-32NF-2	10-32NF-2	10-32NF-2	10-32NF-2
AC ±.001	0.125	0.125		0.125	
AD ±.003	0.062	0.062		0.062	
AE +.000 -.005	0.505	0.665		0.810	
AF	45°	45°		45°	
AG ±.005	0.170	0.281		0.281	
AH +.000 -.005	0.125	0.100		0.100	
AJ			0.281		
AK Max.			0.325		
AL			0.565		
AM +.000 -.002			1.451		
AN			96		
AP			72		
AR +.0000 -.0005			1.3333		

*DIFFERENTIAL
(a) Dimensions for Control Transformers only.

DIMENSIONAL CHART
for
FIGURES NOS. 2 and 3
(Con't)

SYNCHRO SIZES

DIMENSIONS & LIMITS	11	15	16(a)	18	19
AS +.0000 -.0005			1.3611		
AT MAX.			1.2959		
AU			20°		
AV ±.005			1.537		

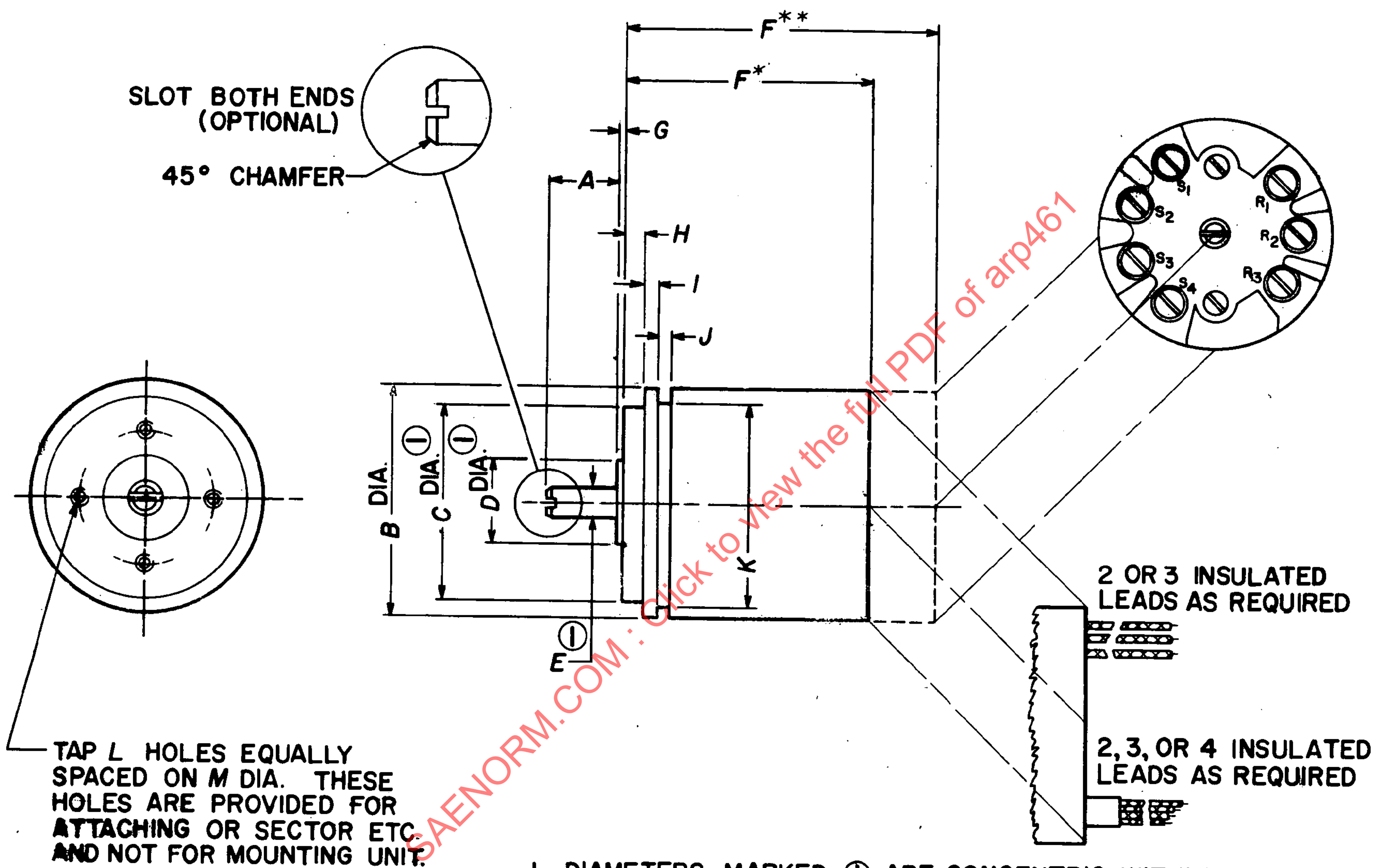
DIMENSIONAL CHART FOR FIGURE NO. 4
SYNCHRO SIZES

DIMENSION	23	31
A	0.719 +.000 -.026	0.676 +.000 -.015
B	1.990 +.000 -.005	2.700 Max.
C	2.250 +.000 -.001	3.100 +.000 -.002
D	1.9995 +.0000 -.0005	2.750 ±.001
E	1.990 +.000 -.005	2.700 Max.
F	0.2405 +.000 -.001	0.2405 +.000 -.001
G	3.580 *3.830 Ref.	4.524 Ref.
H	0.422 +.000 -.012	0.990 +.001 -.006

DIMENSIONAL CHART FOR FIGURE NO. 4

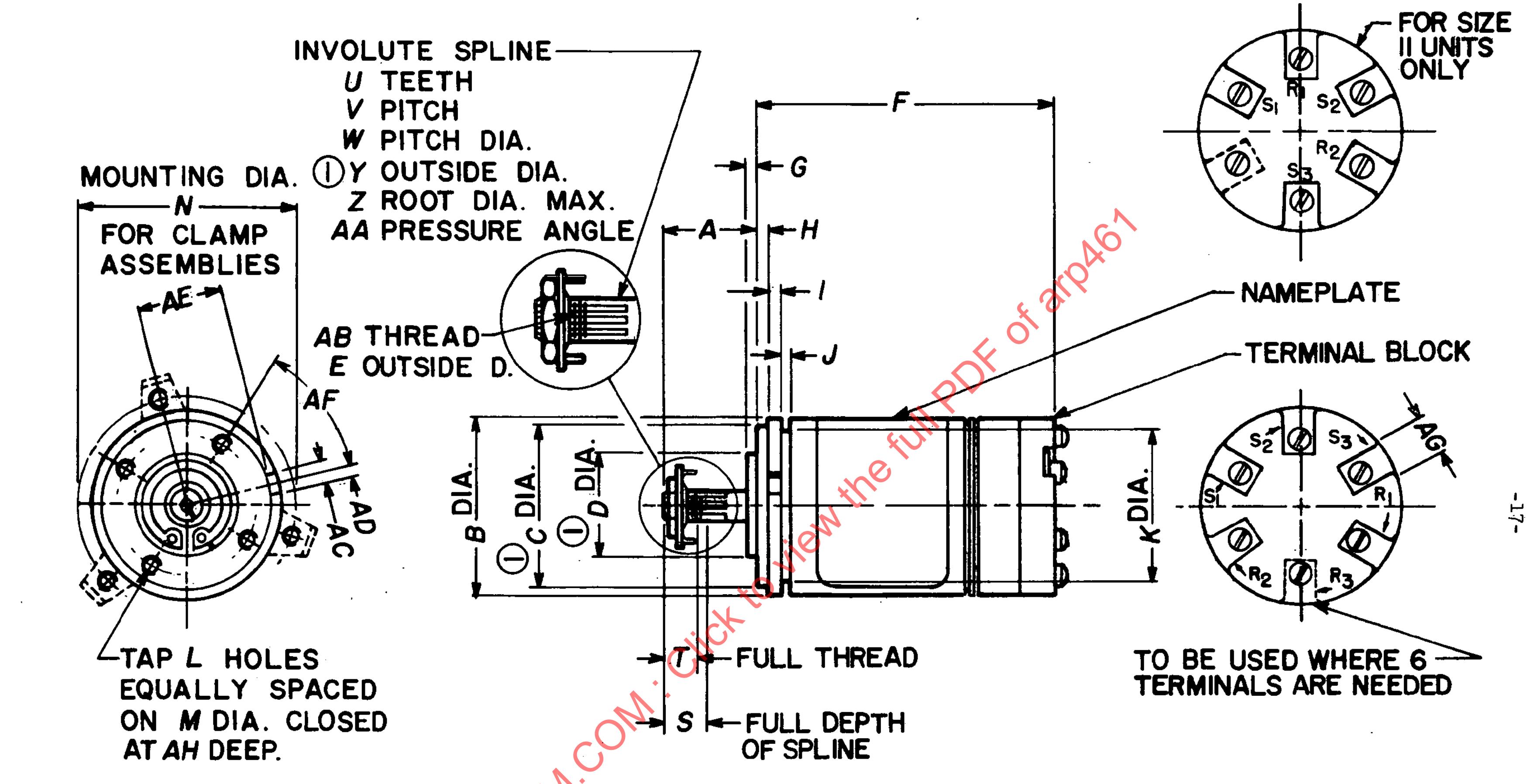
SYNCHRO SIZES

DIMENSION	23	31
I	0.420 +.000 -.005	0.625 +.000 -.003
J	0.250 +.000 -.002	0.250 ±.001
K	0.203 ±.005	0.250 ±.005
L	1.9995 +.0000 -.0010	2.750 ±.001
M	0.005	0.002
N	0.002	0.002
P	0.001	0.001
R	0.001	0.001
S	0.267 ±.015	0.267 ±.015
T	0.387 +.005 -.000	0.468 Max.
U	22	22
V	96	96
W	0.2291 +.0000 -.0020	0.2291 +.0000 -.0020
AA	0.2405 +.0000 -.0002	0.2405 +.0000 -.0002
AB	0.205 Max.	0.205 Max.
AC	20°	20°
AD	1/4-28UNF-2A	1/4-28UNF-2A
AE	0.125 ±.001	-
AF	0.062 ±.003	-
AG	0.064 +.010 -.000	-
AH	45 ±1°	-



1. DIAMETERS MARKED (I) ARE CONCENTRIC WITHIN *N* FULL INDICATOR READING.
2. RUNOUT AT END OF SHAFT WILL NOT EXCEED *P* FULL INDICATOR READING.
3. DIAMETER MARKED *B* IS EXCLUSIVE OF NAMEPLATE WHICH SHALL NOT EXCEED .010 THICKNESS.

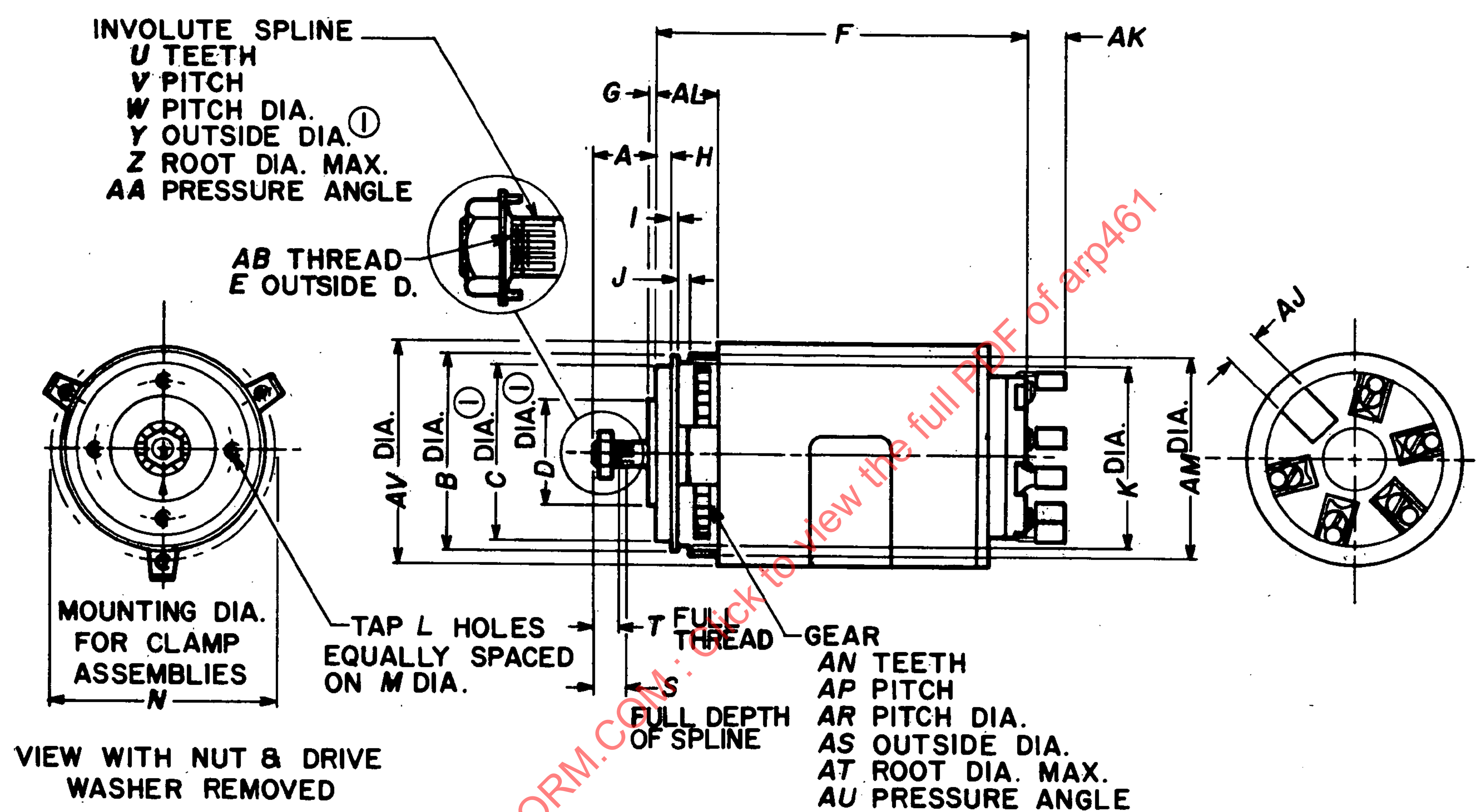
FIGURE 1



VIEW WITH NUT & DRIVE WASHER REMOVED

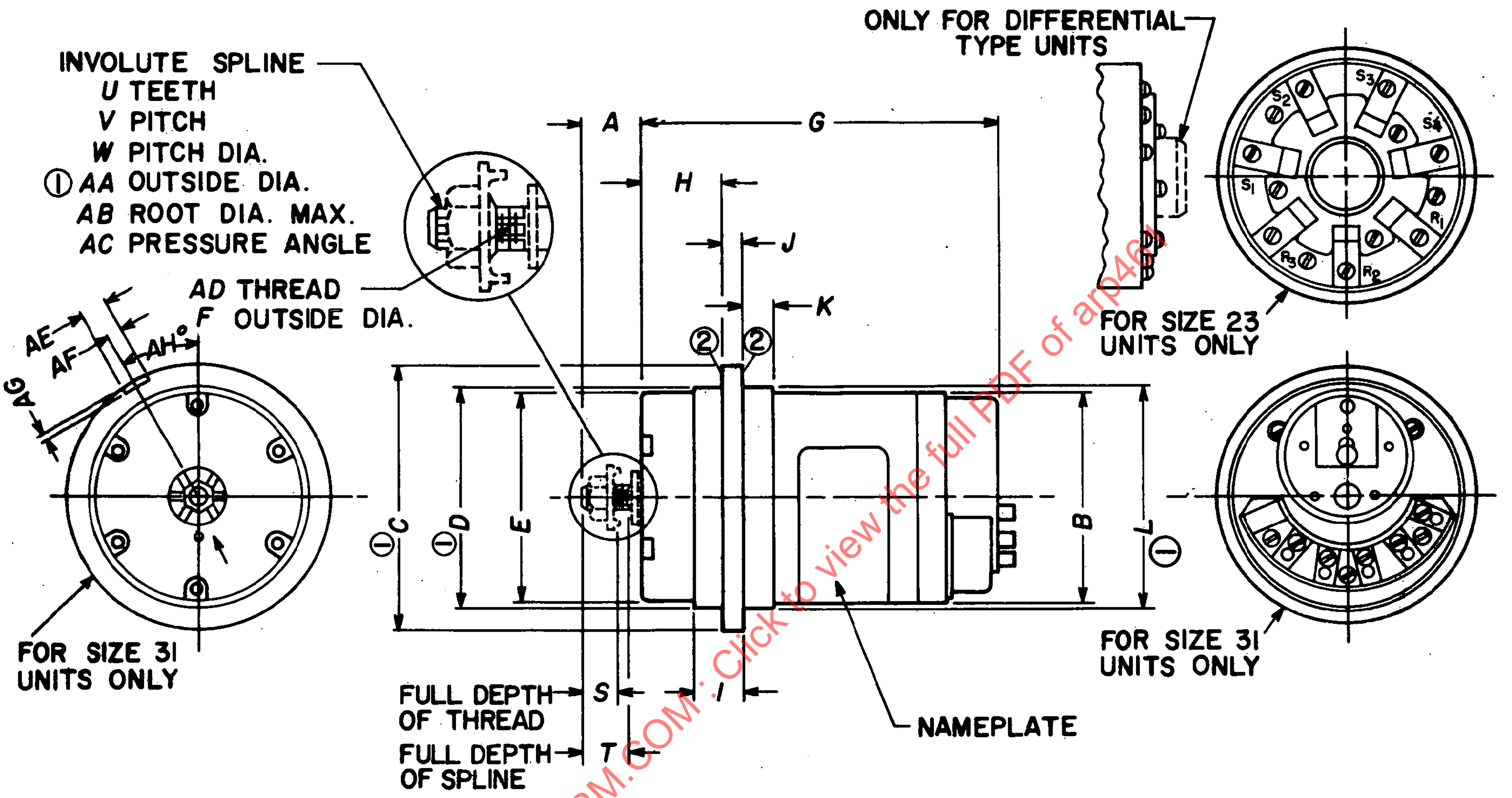
1. DIA. MARKED *B* IS EXCLUSIVE OF NAMEPLATE WHICH SHALL NOT EXCEED .010 THICKNESS.
2. END PLAY OF SHAFT MUST BE *R* MAX. & MUST BE MEASURED WITH THE SHAFT AT REST IN ONE POSITION UNDER ONE POUND FORCE TO THE AT REST POSITION UNDER A ONE POUND FORCE IN THE OPPOSITE DIRECTION.
3. DIAMETERS MARKED (1) ARE CONCENTRIC WITHIN *P* FULL INDICATOR READING.
4. WHEN MARK ON SHAFT END IS IN LINE WITH ARROW ON FRONT OF HOUSING, THE UNIT IS SET ON ELECTRICAL ZERO.
5. THE FINISH ON THE HOUSING IS NATURAL ANODIZE.

FIGURE 2



1. DIMENSION V IS FULL DEPTH OF THREAD.
2. DIMENSION U IS FULL DEPTH OF SPLINE.
3. DIAMETERS MARKED (1) ARE CONCENTRIC WITHIN R FULL INDICATOR READING.
4. SHAFT EXTENSION SHALL RUN TRUE IN SHAFT BEARINGS WITHIN P FULL INDICATOR READING.
5. DIAMETER MARKED AV IS EXCLUSIVE OF NAME-PLATE WHICH SHALL NOT EXCEED .010 THICKNESS.
6. TO SET SYNCHRO AT APPROX. ELECT. ZERO, LOCK INNER AND OUTER HOUSING WITH A .060 PIN. WHEN ARROW AND SHAFT MARK ARE IN LINE SYNCHRO IS AT APPROX. ELECT. ZERO.

FIGURE 3



1. MARK ARROW AS SHOWN TO INDICATE ELECTRICAL ZERO WITH REFERENCE TO MARK ON SHAFT.
2. END PLAY SHALL NOT EXCEED *M*.
3. DIAMETERS MARKED ① TO BE CONCENTRIC TO ROTOR SHAFT WITHIN *N* FULL INDICATOR READING – INDICATOR MOUNTED ON SHAFT.
4. SURFACES MARKED ② TO BE PERPENDICULAR TO ℄ WITHIN *P* FULL INDICATOR READING.
5. SHAFT EXTENTION SHALL RUN TRUE IN SHAFT BEARING WITHIN *R* FULL INDICATOR READING.
6. DIAMETER MARKED *B* IS EXCLUSIVE OF NAME-PLATE WHICH SHALL NOT EXCEED .010 THICKNESS.

FIGURE 4

2.1.3 Coarse Synchro Zero Marking: When required by the detail specification, synchro zero shall be approximately located to within 10° by providing an arrow stamped on the frame and an index mark on the shaft extension.

2.2 Electrical:

2.2.1 High Potential Tests: The synchro shall withstand satisfactorily a specified sinusoidal potential at a frequency of 60 cycles per second applied for 15 seconds between windings and case and between windings insulated from each other, but on the same iron structure. The applied potential shall be raised from zero to the specified value in not less than 5 seconds and reduced to zero at the same rate. Synchros having nominal ratings of 115, 90 and 57.5 volts shall be tested at 900 volts R.M.S. and those rated at 26 and 11.8 volts shall be tested at 500 volts R.M.S. The High Potential test shall be performed only once on the completed synchro. Repeated High Potential tests, made by any agency after shipment from point of manufacture, are to be made at values not to exceed 80% of those specified for the completed unit.

2.2.2 Insulation Resistance: The insulation resistance of the synchro shall be measured at ambient temperature of $22 \pm 3^{\circ}C$. and a barometric pressure of 29.92 inches of mercury before and after the high potential test. The measurement made at 500 volts d-c for one minute between windings and frame shall not be less than 20 megohms.

2.2.3 Open Circuit Current and Power: The input current and power shall be measured with the synchro energized as described under para. 2.2.8 and with the secondary leads open. The primary current and power shall not exceed the values given in the following table. The measurements shall be made with the synchro at normal operating temperature. The open circuit current and power shall not vary by more than 2 percent as the rotor is turned through a complete revolution.

SYNCHRO CURRENT - POWER TABULATION

	115 VOLT 60C		115 VOLT 400C		26 VOLT 400C	
	I AMPS	W WATTS	I AMPS	W WATTS	I AMPS	W WATTS
TRANSMITTER - TORQUE						
8						
10						
11						
15						
16						
18						
19						
23						
31						
37						
TRANSMITTER - CONTROL						
8						
10						
11						
15						
16						
18						
19						
23						
31						
37						
CONTROL TRANSFORMER						
8						
10						
11						
15 CT3B2					0.072	0.31
16						
18						
19						
23						
31						
37						

SYNCHRO CURRENT - POWER TABULATION

	115 VOLT 60C		115 VOLT 400C		26 VOLT 400C	
	I AMPS	W WATTS	I AMPS	W WATTS	I AMPS	W WATTS
DIFFERENTIAL TRANS. - TORQUE						
8						
10						
11						
15						
16						
18						
19						
23						
31						
37						
DIFFERENTIAL TRANS. - CONTROL						
8						
10						
11						
15						
16						
18						
19						
23						
31						
37						
DIFFERENTIAL RECEIVER						
8						
10						
11						
15						
16						
18						
19						
23						
31						
37						

SYNCHRO CURRENT - POWER TABULATION						
	115 VOLT 60C		115 VOLT 400C		26 VOLT 400C	
	I AMPS	W WATTS	I AMPS	W WATTS	I AMPS	W WATTS
RECEIVER						
8						
10						
11						
15						
16						
18						
19						
23						
31						
37						
RESOLVER - TRANSMITTER						
8						
10						
11						
15						
16						
18						
19						
23						
31						
37						
RESOLVER - CONT. TRANSFORMER						
8						
10						
11						
15						
16						
18						
19						
23						
31						
37						
RESOLVER - DIFFERENTIAL						
8						
10						
11						
15						
16						
18						
19						
23						
31						
37						

2.2.4 Synchro Zero: Measurements of all angular displacements of the rotors of synchros shall be referred to a standard position which will be designated as "Synchro Zero", as defined in paragraph 1.3.2.6. Caution should be taken in testing units without dampers to prevent their spinning. External friction may be applied or the voltage made very low at first and then increased to normal after the rotor has come to rest. The values of applied voltages for types are tabulated below:

Nominal System Volts	Applied Volts					
	Figures					
	5-6	7-8	9-10	11-12	13-14	15-16
115	115	78	78	115	90	90
26	26	10.2	10.2	26	11.8	11.8

2.2.4.1 Synchro Zero of Transmitters and Receiver: The synchro zero position of a transmitter or receiver shall be determined by connecting the primary and secondary as shown in figure 5.

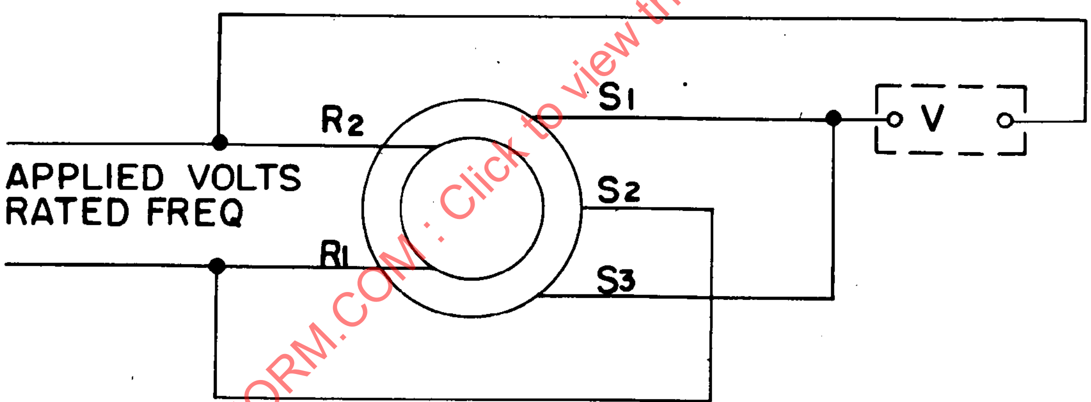


Figure 5

The synchro shaft will rotate to either of two positions which are 180° apart. The correct approximate position is that one which produces the smaller voltage reading in V. The synchro zero position should be accurately determined as follows: Without rotating the synchro shaft, reconnect synchro as shown in figure 6.

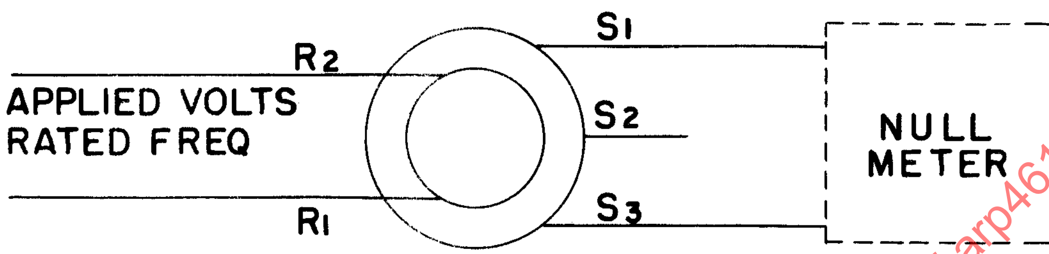


Figure 6

Rotate the synchro shaft through the smaller angle that will produce a zero reading on the null meter. That position is the synchro zero position.

2.2.4.2 Synchro Zero of Control Transformers: The synchro zero position of a control transformer shall be determined by connecting the synchro as shown in figure 7.

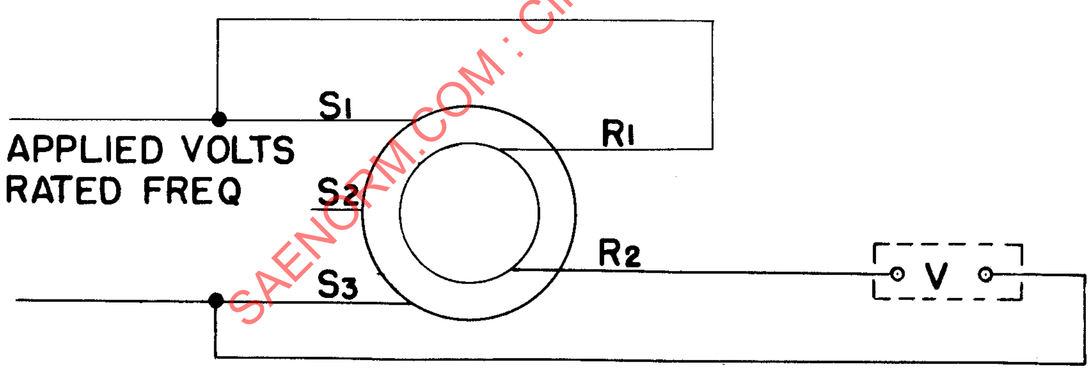


Figure 7

The synchro zero position is approximately at the minimum voltage position. This position should be accurately located by connecting the synchro as shown in figure 8, without rotating the synchro shaft.

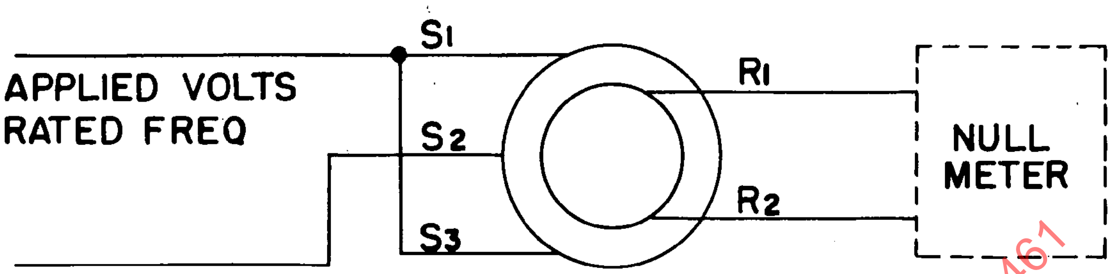


Figure 8

Rotate the synchro shaft through the smallest angle that will produce a zero reading on the null meter. That position is the synchro zero position.

2.2.4.3 Synchro Zero of Differential Transmitters and Differential Receiver: The synchro zero position of a differential transmitter or receiver shall be determined by connecting the synchro as shown in figure 9.

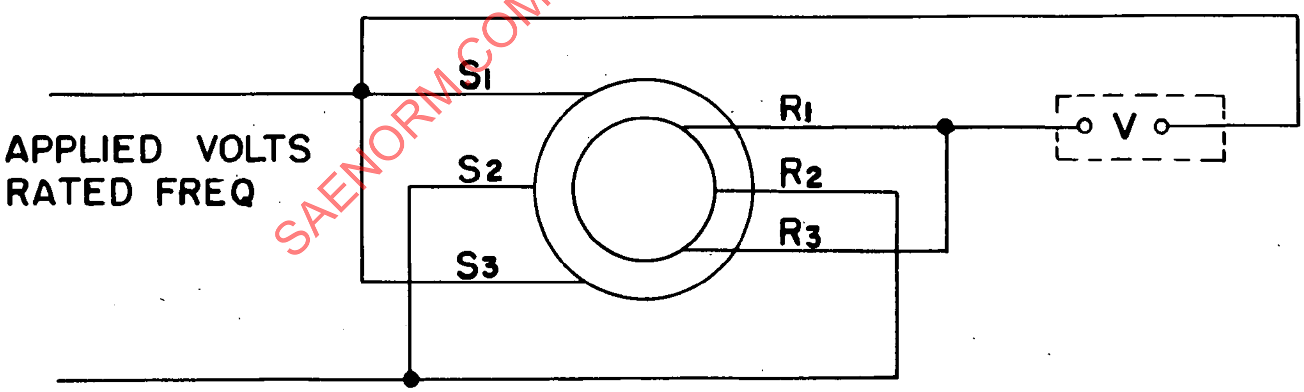


Figure 9

The synchro shaft will rotate to either of two positions which are 180° apart. The correct approximate position is the one which produces the smaller voltage reading in V. The synchro zero position should then be accurately determined as follows: Without rotating the shaft, reconnect the synchro as shown in figure 10.

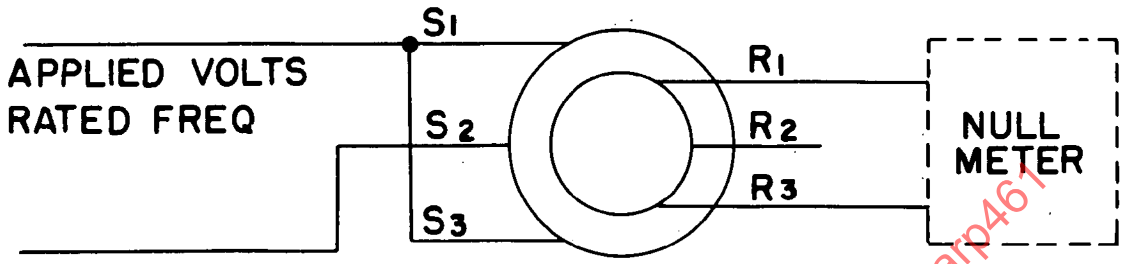


Figure 10

Rotate the synchro shaft through the smallest angle that will produce a zero reading of the null meter. That position is the synchro zero position.

2.2.4.4 Synchro Zero of Resolver Transmitter: The synchro zero of a resolver transmitter shall be determined by connecting the primary and secondary as shown in figure 11.

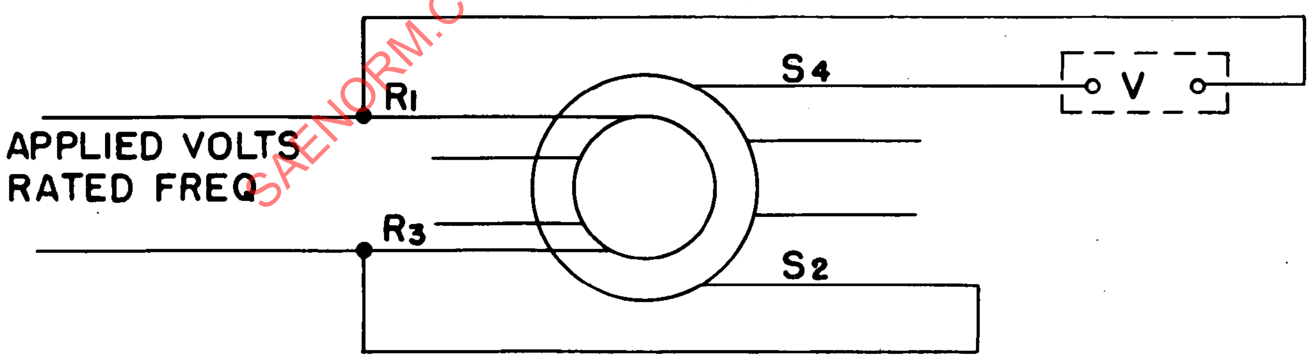


Figure 11

The resolver shaft shall be rotated to the position that produces the smallest reading in V. The synchro zero position should then be accurately determined as follows: Without rotating the resolver shaft, reconnect the resolver as shown in figure 12.

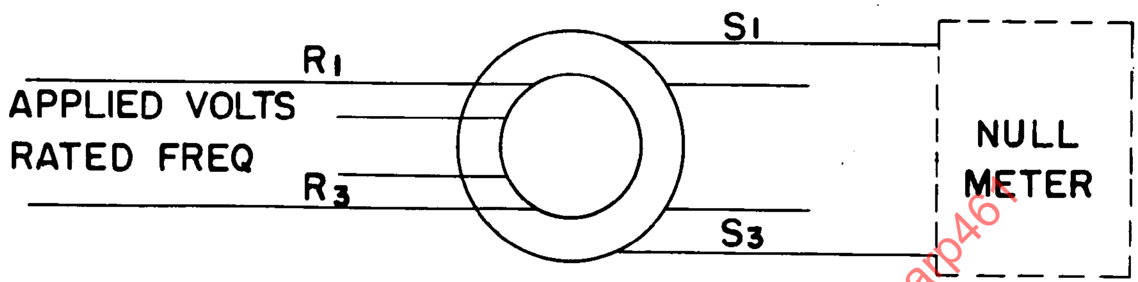


Figure 12

Rotate the resolver shaft through the smaller angle that will provide a zero reading on the null meter. That position is the synchro zero position.

2.2.4.5 Synchro Zero of Resolver Control Transformer: The synchro zero of a resolver control transformer shall be determined by connecting the primary and secondary as shown in figure 13.

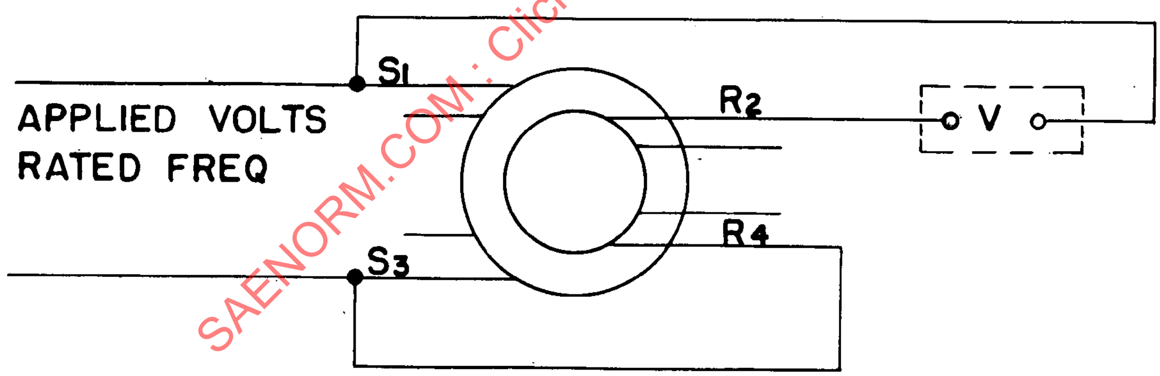


Figure 13

The resolver shaft shall be rotated to the smaller peak voltage position as read in V. The synchro zero position should then be accurately determined as follows: Without rotating the resolver shaft, reconnect the resolver as shown in figure 14.

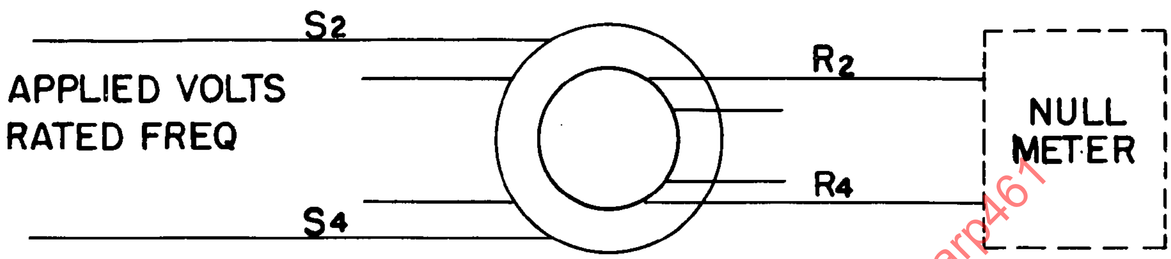


Figure 14

Rotate the resolver shaft through the smaller angle that will provide a zero reading on the null meter. That position is the synchro zero position.

2.2.4.6 Synchro Zero of Resolver Differential: The synchro zero of a resolver differential shall be determined by connecting the primary and secondary as shown in figure 15.

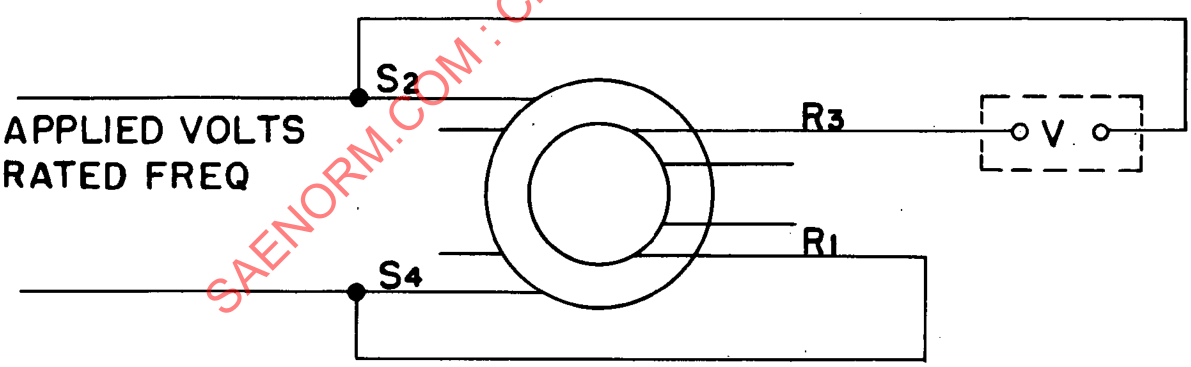


Figure 15

The resolver shaft shall be rotated to the position that produces the smallest reading in V. The synchro zero position shall then be accurately determined as follows:

Without rotating the resolver shaft, reconnect the resolver as shown in figure 16.

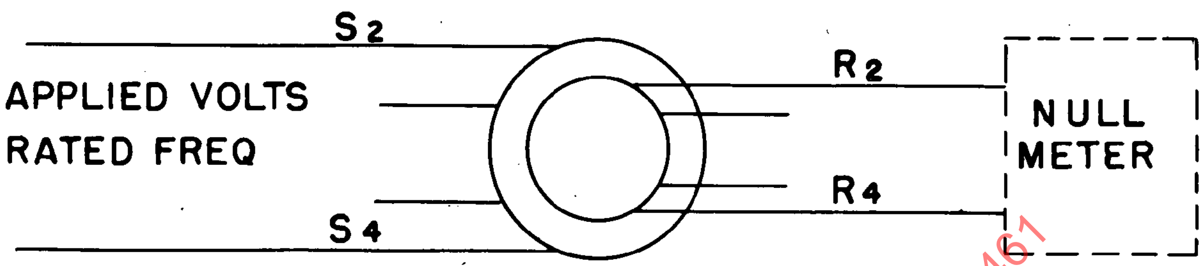


Figure 16

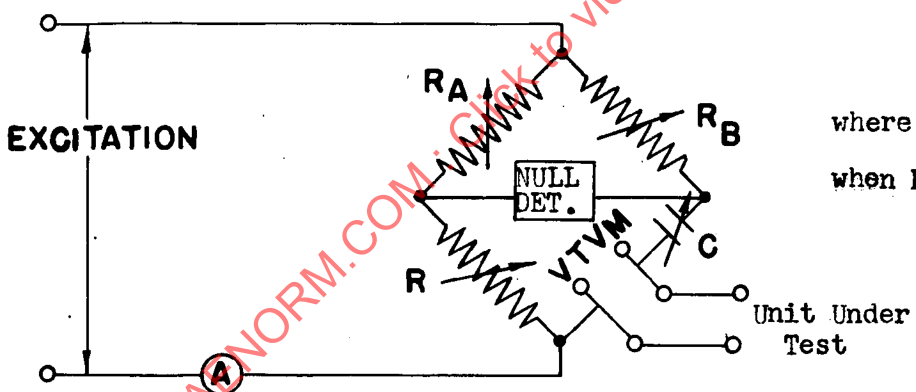
Rotate the resolver shaft through the smaller angle that will provide a zero reading on the null meter. That position is the synchro zero position.

2.2.5 Impedance:

2.2.5.1 General: The synchro shall be mounted centrally in a square aluminum plate as shown in figure No. 17. The synchro shall be held in place by recommended mounting clamps. All surfaces of the plate shall be finished with black anodize (MIL-A-8625A). The plate shall be mounted on supports which allow approximately 1/4" clearance from other surfaces at the base and held in an upright position by 2 supporting arms. The base and upright supports are to be made of any suitable heat insulating material. The unit shall be maintained at 22°C. $\pm$ 3°C. until unit reaches a state of equilibrium. Then the unit and its mounting shall be located to assure minimum effect from air currents and ambient temperature rise.

2.2.5.1.1 Mounting Plates: The mounting plates, bases and supports are shown in figures 17, 18 and 19.

2.2.5.1.2 Circuit: Impedance readings shall be taken after the synchro has been excited for one hour or has reached a stable temperature condition. The unit shall be set at synchro zero except as noted below. The impedance value in ohms shall be determined with a series resonance bridge circuit figure 20.

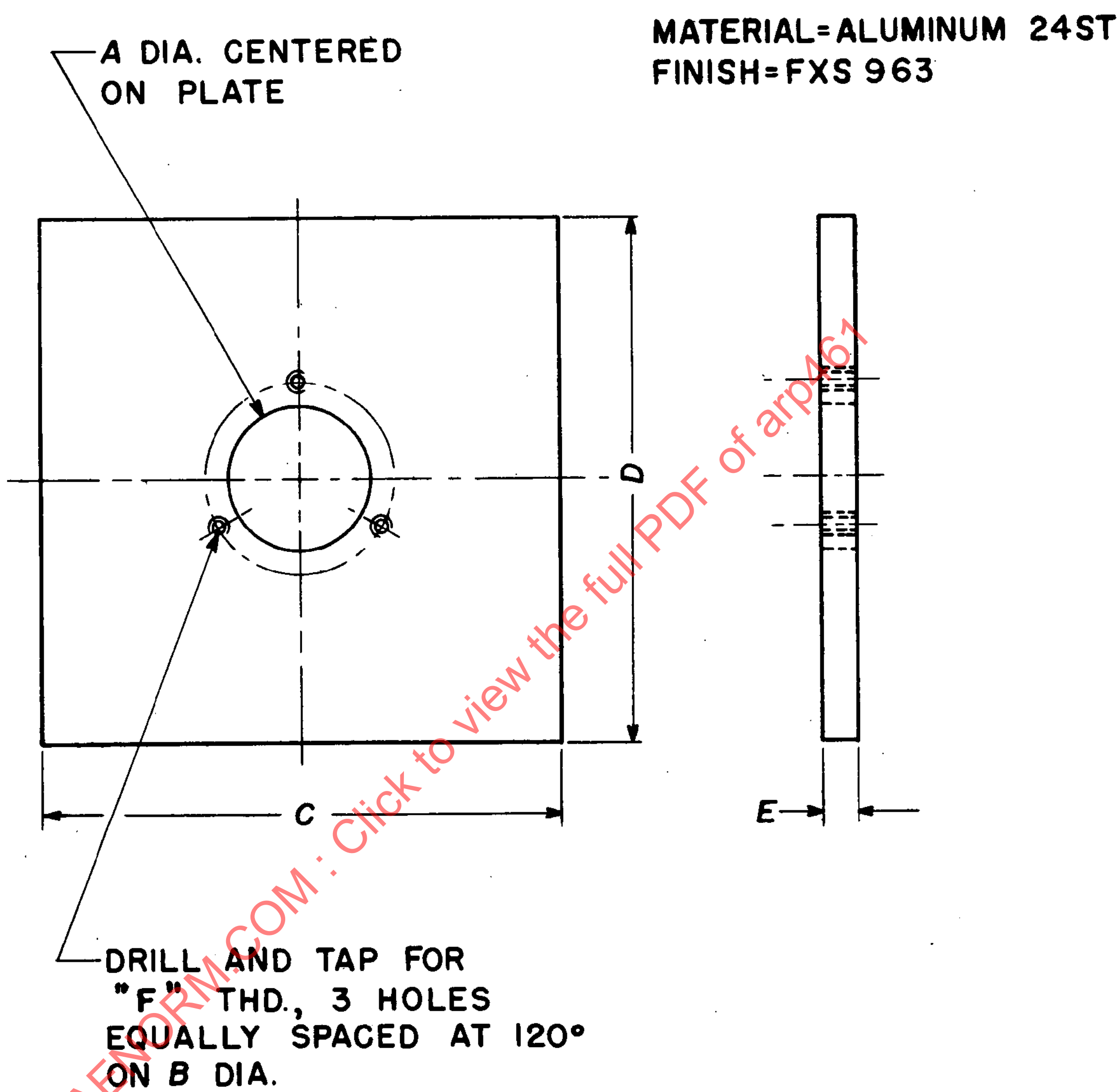


where $Z = R + j\frac{1}{2\pi fC}$

when $R_A = R_B \approx R$

Figure 20

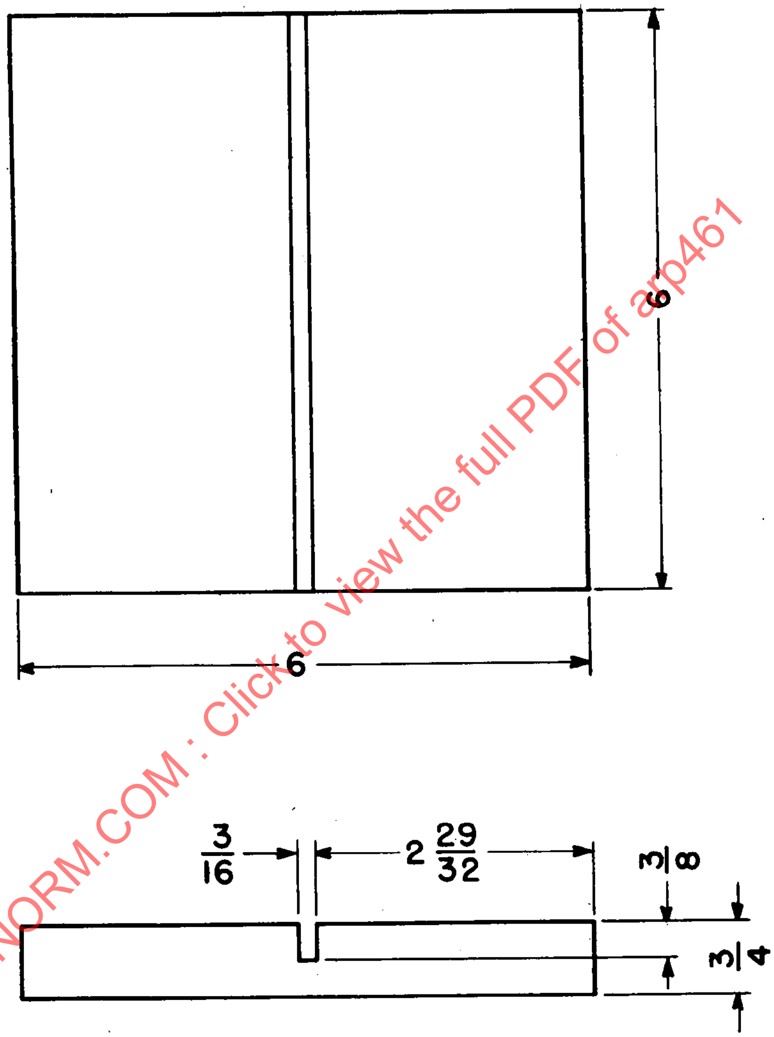
FIGURE NO. 17



SYNCHRO MOUNTING PLATES

Frame Size	A +.001 -.000	B ± .002	C	D	E	F
	Dimensions - inches					
8	0.501	0.875	2.25	2.25	0.1875	3-56
10	0.812	1.187	2.80	2.80	0.1875	3-56
11	1.001	1.375	3.20	3.20	0.1875	3-56
15	1.313	1.688	4.30	4.30	0.1875	3-56
18	1.563	1.956	5.25	5.25	0.1875	3-56
23	2.001	3.00	6.75	6.75	0.3125	6-32
31	2.751	3.50	9.30	9.30	0.3125	6-32

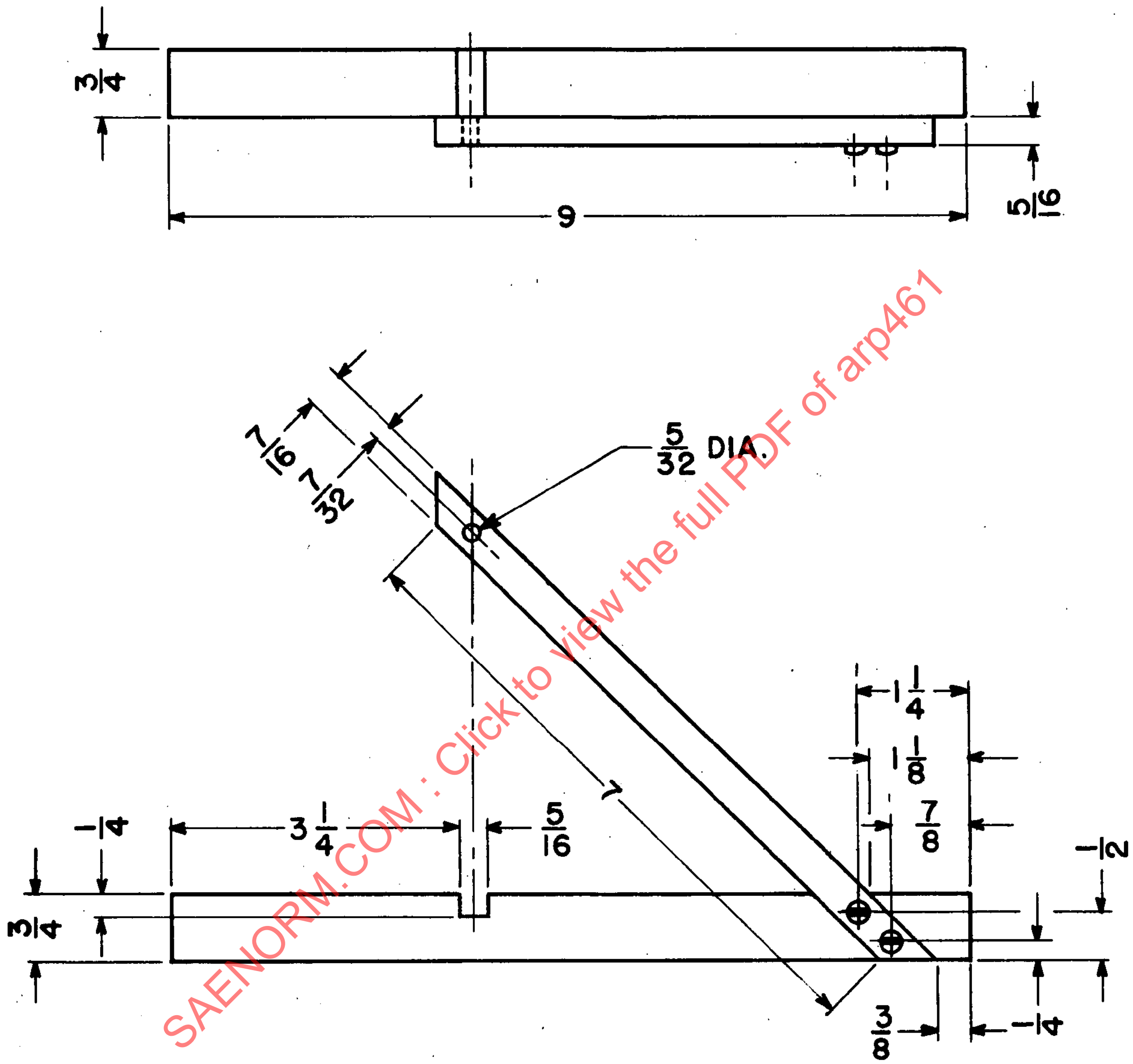
FIGURE NO. 18



MATERIAL= LINEN LAMINATED BAKELITE OR
OTHER SUITABLE INSULATING MATERIAL

INSULATING BASE FOR
SIZE 8, 10, 11, 15, 16, 18 & 19 SYNCHRO MOUNTING PLATES

FIGURE NO. 19



MATERIAL = LINEN LAMINATED BAKELITE OR
OTHER SUITABLE INSULATING MATERIAL

INSULATING STAND FOR
SIZE 23 & 31 SYNCHRO MOUNTING PLATES

2.2.5.2 Transmitters, Control Transformers, Receiver:

The following impedance measurements are to be made:

(a) Impedance Z_{RO}

Excite rotor at nominal rated excitation, see Section 2.2.8, with stator open circuited.

(b) Impedance Z_{SO}

Excite stator single phase at nominal rated excitation, see Section 2.2.8, with the rotor open circuited. For this test, connect terminals S_1 and S_3 together and apply excitation between the strapped S_1 - S_3 terminals and S_2.

(c) Impedance Z_{RSS}

Excite the rotor, with the stator short circuited, at the current value obtained in measurement Z_{RO}.

(d) Impedance Z_{SO} - 90 (For Salient Pole Synchros)

Apply nominal rated excitation, see Section 2.2.8, to terminal S_2 and S_1. Connect S_3 to S_1. Rotor terminals shall be open circuited. Rotor to be positioned 90° from synchro zero.

2.2.5.3 Differentials - Transmitters, and Receiver:

The following impedance measurements are to be made:

(a) Impedance Z_{RO}

Apply nominal rated excitation, see Section 2.2.8, to terminals R_2 and R_1. Connect R_3 to R_1. Stator terminals to be open circuited.

(b) Impedance Z_{SO}

Excite the stator single phase at nominal rated excitation, see Section 2.2.8, with the rotor open circuited. For this test, connect terminals S_1 and S_3 together and apply excitation between the strapped S_1 - S_3 terminals and S_2.

(c) Impedance Z_{RS}

Connect R_3 to R_1 and excite the rotor terminals R_1 and R_2, with the stator short circuited, at the current value obtained in measurement Z_{RO}.

2.2.5.4 Resolvers - Transmitter, Control Transformer and Differential:

The following impedance measurements are to be made:

(a) Impedance Z_{RO}

Excite rotor terminals R_1 and R_3 at nominal excitation, see Section 2.2.8, with the stator open circuited. For this test connect rotor terminals R_2 to R_4.

(b) Impedance Z_{SO}

Excite stator terminal S_1 - S_3 at nominal rated excitation, see Section 2.2.8, with the rotor open circuited.

(c) Impedance Z_{RSS}

Excite the rotor terminals R_1 and R_3, with the stator short circuited, at the current value obtained in measurement Z_{RO}. For this test connect rotor terminals R_2 to R_4.

(d) Repeat steps (a), (b), and (c), but exciting the other phase windings R_2 - R_4 (etc.).

2.2.5.5 Tabulating Impedance Values:

2.2.5.5.1 Impedance - For 115 Volt, 60 CPS Synchros:

	IMPEDANCE - OHMS			
SIZE	$Z_{ro} = R + JX$	$Z_{so} = R + JX$	$Z_{rss} = R + JX$	$Z_{so-90} = R + JX$
TRANSMITTER - TORQUE				
8				
10				
11				
15				
16				
18				
19				
23				
31				
37				
TRANSMITTER - CONTROL				
8				
10				
11				
15				
16				
18				
19				
23				
31				
37				
CONTROL TRANSFORMER				
8				
10				
11				
15				
16				
18				
19				
23				
31				
37				

2.2.5.5.1 Cont'd

IMPEDANCE - OHMS

SIZE	$Z_{ro} = R + JX$	$Z_{so} = R + JX$	$Z_{rss} = R + JX$	$Z_{so-90} = R + JX$
DIFFERENTIAL TRANS. - TORQUE				
8				
10				
11				
15				
16				
18				
19				
23				
31				
37				
DIFFERENTIAL TRANS. - CONTROL				
8				
10				
11				
15				
16				
18				
19				
23				
31				
37				
DIFFERENTIAL RECEIVER				
8				
10				
11				
15				
16				
18				
19				
23				
31				
37				

2.2.5.5.1 Cont'd

IMPEDANCE - OHMS

SIZE	Z_{ro} = R + JX	Z_{so} = R + JX	Z_{rss} = R + JX	Z_{so-90} = R + JX
RECEIVER				
8				
10				
11				
15				
16				
18				
19				
23				
31				
37				
RESOLVER - TRANSMITTER				
8				
10				
11				
15				
16				
18				
19				
23				
31				
37				
RESOLVER - CONT. TRANSFORMER				
8				
10				
11				
15				
16				
18				
19				
23				
31				
37				
RESOLVER - DIFFERENTIAL				
8				
10				
11				
15				
16				
18				
19				
23				
31				
37				

2.2.5.5.2 Impedance - 115 Volt, 400 CPS Synchros:

	IMPEDANCE - OHMS			
SIZE	Z_{ro} = R + JX	Z_{so} = R + JX	Z_{rss} = R + JX	Z_{so-90} = R + JX
TRANSMITTER - TORQUE				
8				
10				
11				
15				
16				
18				
19				
23				
31				
37				
TRANSMITTER - CONTROL				
8				
10				
11				
15				
16				
18				
19				
23				
31				
37				
CONTROL TRANSFORMER				
8				
10				
11				
15				
16				
18				
19				
23				
31				
37				

2.2.5.5.2 Cont'd

IMPEDANCE - OHMS

SIZE	$Z_{ro} = R + JX$	$Z_{so} = R + JX$	$Z_{rss} = R + JX$	$Z_{so-90} = R + JX$
DIFFERENTIAL TRANS. - TORQUE				
8				
10				
11				
15				
16				
18				
19				
23				
31				
37				
DIFFERENTIAL TRANS. - CONTROL				
8				
10				
11				
15				
16				
18				
19				
23				
31				
37				
DIFFERENTIAL RECEIVER				
8				
10				
11				
15				
16				
18				
19				
23				
31				
37				

2.2.5.5.2 Cont'd

IMPEDANCE - OHMS

SIZE	$Z_{ro} = R + JX$	$Z_{so} = R + JX$	$Z_{rss} = R + JX$	$Z_{so-90} = R + JX$
RECEIVER				
8				
10				
11				
15				
16				
18				
19				
23				
31				
37				
RESOLVER - TRANSMITTER				
8				
10				
11				
15				
16				
18				
19				
23				
31				
37				
RESOLVER - CONT. TRANSFORMER				
8				
10				
11				
15				
16				
18				
19				
23				
31				
37				
RESOLVER - DIFFERENTIAL				
8				
10				
11				
15				
16				
18				
19				
23				
31				
37				

2.2.5.5.3 Impedance - 26 Volt, 400 CPS Synchros:

SIZE		IMPEDANCE - OHMS Z_{ro} = R + JX	Z_{so} = R + JX	Z_{rss} = R + JX	Z_{so-90} = R + JX
TRANSMITTER - TORQUE					
8					
10					
11					
15					
TRANSMITTER - CONTROL					
8					
10					
11					
15					
CONTROL TRANSFORMER					
8					
10					
11					
15	CT3B2	70+j400	13.2+j76.5	77.8+j51	
DIFFERENTIAL TRANS. - TORQUE					
8					
10					
11					
15					

2.2.5.5.3 Cont'd

IMPEDANCE - OHMS

SIZE	$Z_{ro} = R + JX$	$Z_{so} = R + JX$	$Z_{rss} = R + JX$	$Z_{so-90} = R + JX$
DIFFERENTIAL TRANS. - CONTROL				
8				
10				
11				
15				
DIFFERENTIAL RECEIVER				
8				
10				
11				
15				
RECEIVER				
8				
10				
11				
15				
RESOLVER - TRANSMITTER				
8				
10				
11				
15				

2.2.5.5.3 Cont'd

IMPEDANCE - OHMS

SIZE	Z_{ro} = R + JX	Z_{so} = R + JX	Z_{rss} = R + JX	Z_{so-90} = R + JX
RESOLVER - CONTROL TRANSFORMER				
8				
10				
11				
15				
RESOLVER - DIFFERENTIAL				
8				
10				
11				
15				

2.2.6 Accuracy:

2.2.6.1 Electrical Error - Proportional Voltage Method: Before testing the synchro for electrical error by the proportional voltage method, the synchro zero position of the synchro under test shall be accurately determined as described in 1.3.2.6 as applicable. The synchro zero shall be determined under open circuit conditions and shall not be adjusted before performing electrical error test.

2.2.6.1.1 This method consists in comparing the actual position of the synchro rotor with the electrical position of the synchro. The electrical angle, a, of the synchro is related to the equivalent position ϕ, by the following expression:

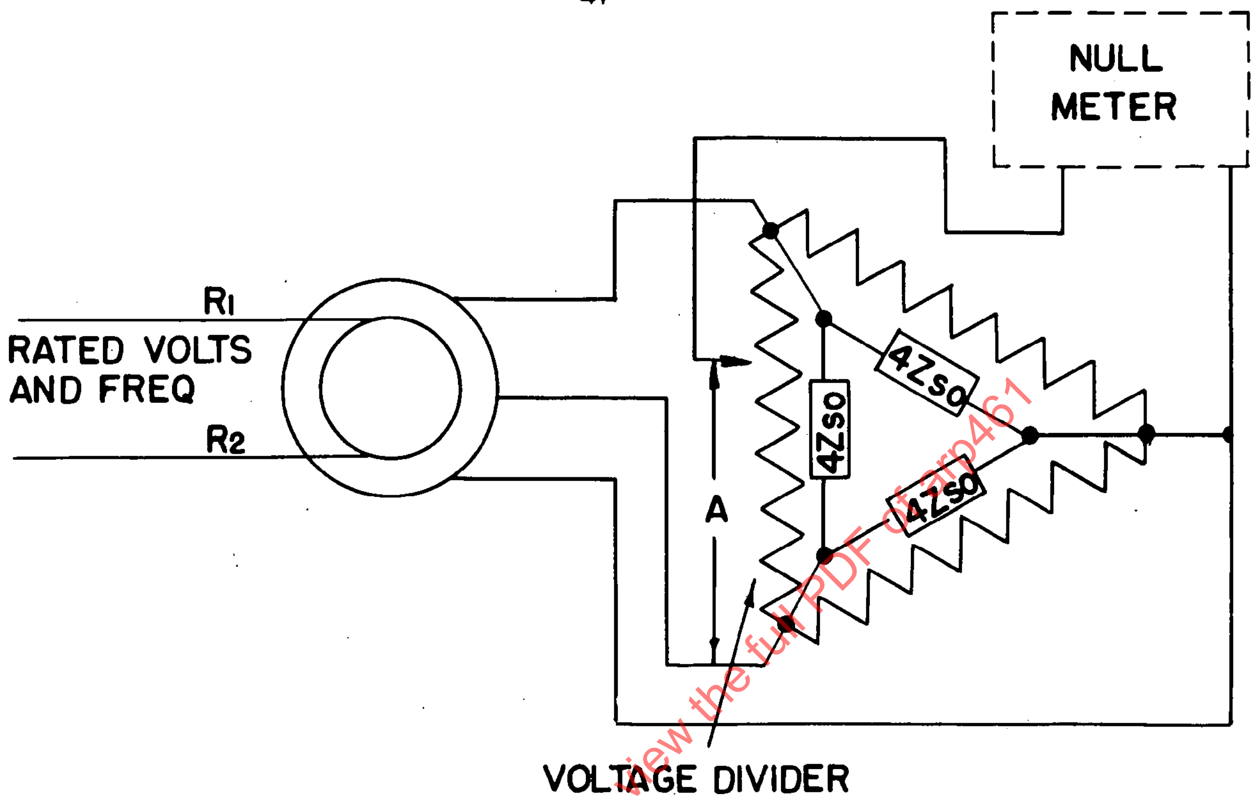
$$a = \text{Electrical angle} = \phi + (N + 3M)\, 60^\circ$$
$$R = 1/2 - 1/2\sqrt{3}\ \cot(\phi + 60^\circ)$$

$$R = \frac{\text{one of the smaller secondary voltages}}{\text{largest secondary voltage}} = \frac{A}{10000} \text{ ohms}$$

M = 0 when Voltage E (S_{13}) is in time phase with voltage E (R_{21}).
M = 1 when Voltage E (S_{13}) is 180° out of time phase with voltage E (R_{21}).
and N is determined from the following tables:

Terminals Giving Largest Secondary Voltage	Terminals Giving Smallest Secondary Voltage	Value of N
$S_2 - S_1$	$S_1 - S_3$	0
$S_1 - S_3$	$S_3 - S_2$	1
$S_3 - S_2$	$S_2 - S_1$	2

The basic circuit employed for electrical error testing of synchro transmitters is shown in figure 21. The unit shall be energized with rated voltage and frequency across $R_1 - R_2$.



NOTE: The $4Z_{so}$ delta connected loads may be replaced by an equivalent wye connected load.

Figure 21

Basic Circuit Employed for Electrical Error Test of Synchro Transmitters and Receivers

Three 10,000 ohm resistors shall be connected in delta across the output circuits S_1, S_2 and S_3. These resistors shall be capable of being tapped. The resistors shall be equal to within 0.01%. The voltage divider shall be linear to within 0.01% and produce a phase shift of no more than 10 minutes. Impedances shown as 4 Z_{so} shall be four times the value of Z_{so} + 15% of the type of unit under test (ref. paragraph 2.2.5.2). This load shall be such that when three error curves are made, each at one of the three possible connections of the load, the maximum difference in the error curves shall not exceed 10% of the allowable transmitter error. With maximum output voltage of unit under test applied across one of the impedances, the maximum pickup across either of the other 2 impedances shall not exceed 0.005% of the applied voltage. The voltage divider shall be connected across the secondary terminals giving the largest voltage, and the resistors shall be connected across the terminals giving the smaller voltages. The variable tap on the divider shall be connected to the common terminal of the two fixed resistors through a sensitive electronic voltmeter having an impedance not less than that of a 500,000 ohm resistance shunted by a capacity of 30 mmfd, and shall be capable of indicating 0.2 minute displacement of the unit under test from a null position. It shall also be able to discriminate against a value of quadrature of 1% of maximum output voltage of the unit under test so as to produce a meter reading less than that produced by a 0.2 minute displacement from the null position of the unit under test. The voltage divider shall be set at the proper ratio (R in the formula) for the desired electrical position and the synchro shaft shall be turned until a zero reading of the null meter is obtained. The position of the rotor is then recorded. The error at a given rotor position is defined as the mechanical rotor position minus the electrical position. To facilitate the settings of the voltage divider, a table of values of R corresponding to various value of ϕ is given in following table:

Values of R for Various Values of Angle ϕ

ϕ	R
0	.00000
5	.09617
10	.18479
15	.26795
20	.34730
25	.42423
30	.50000
35	.57577
40	.65270
45	.73205
50	.81521
55	.90383
60	1.00000

The maximum error, in absolute value, of transmitters shall not exceed those given for its classification in tabulation under section 2.2.6.5.

2.2.6.1.2 Control Transformers: The basic circuit for electrical error testing of control transformers is shown in Figure 22. The stator terminals of the control transformer shall be connected to the corresponding stator terminals of a matching control transmitter operated at rated voltage and frequency. The output terminals $R_1 - R_2$ of the control transformer shall be connected to the null meter. The energizing transmitter shall be turned until its electrical position, measured as described in 2.2.6.1.1, is at the desired value. The mechanical rotor position of the unit under test that produces a zero reading of the null meter shall be determined. The error at a given rotor position is the mechanical rotor position minus the electrical position. The maximum errors, in absolute value, of control transformers shall not exceed the limits given in 2.2.6.5. (When required, coding may be added to define the angular position of the second harmonic error.)

2.2.6.1.3 Differential Transmitters:

2.2.6.1.3.1 Differential Transmitter Rotors: The basic circuit for electrical error testing of the rotor windings of differential synchros is shown in Figure 23. The unit shall be energized at rated frequency with 0.866 times the rated voltage across terminal S_2 and terminal S_1 which is connected to S_3. The electrical position of the rotor is obtained from the following equation:

$$\text{Electrical position} = \phi + (N + 3M)\,60^\circ$$

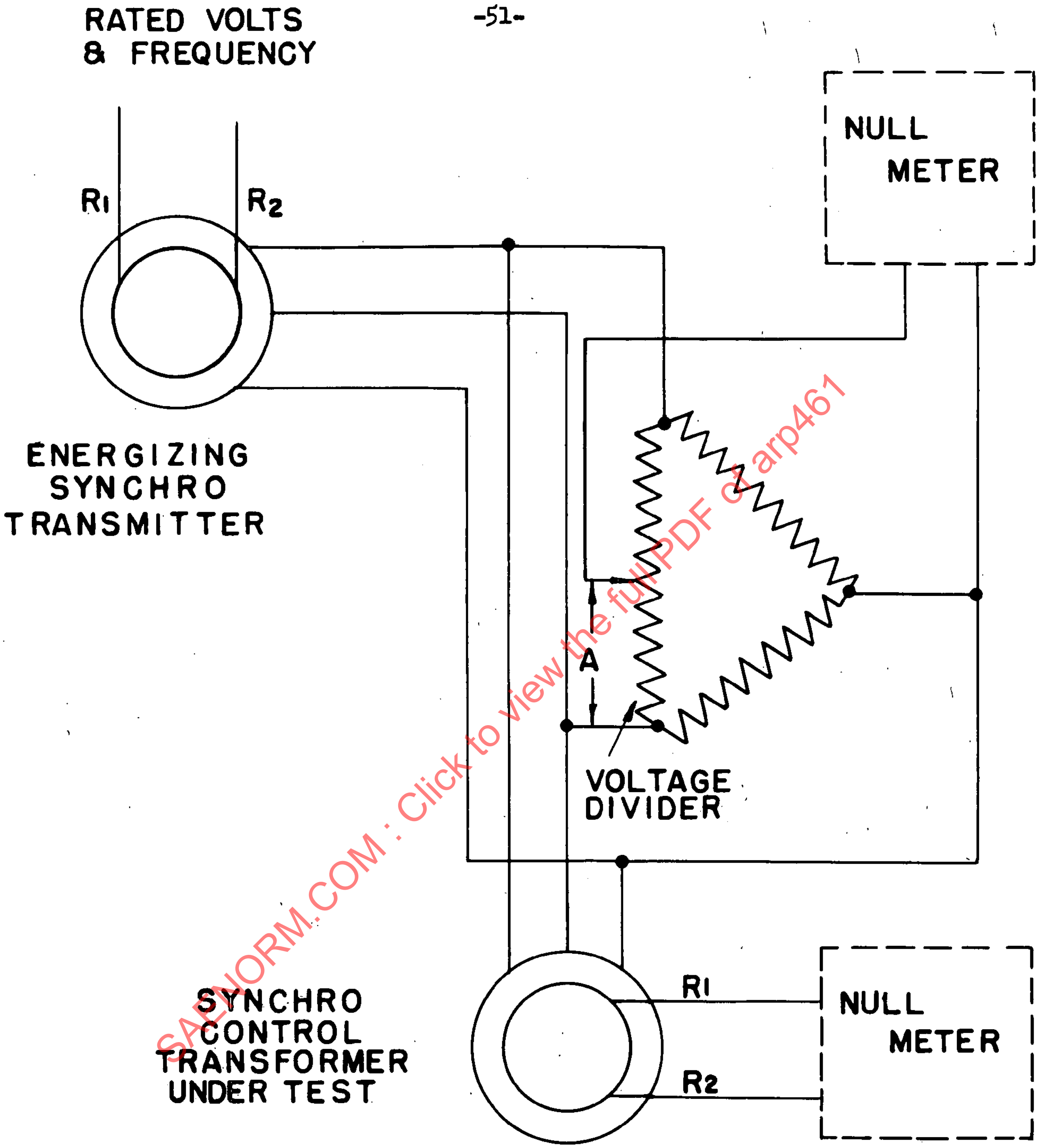
where ϕ is determined as described in Section 2.2.6.1.1.

$M = 0$ when voltage $E\ (R_{13})$ is in time phase with voltage $E\ (S_{23})$.
$M = 1$ when voltage $E\ (R_{13})$ is 180° out of time phase with voltage $E\ (S_{23})$.
and N is obtained from the following table:

Terminals Giving Largest Secondary Voltage	Terminals Giving Smallest Secondary Voltage	Value of N
$R_3 - R_2$	$R_1 - R_3$	0
$R_1 - R_3$	$R_2 - R_1$	1
$R_2 - R_1$	$R_3 - R_2$	2

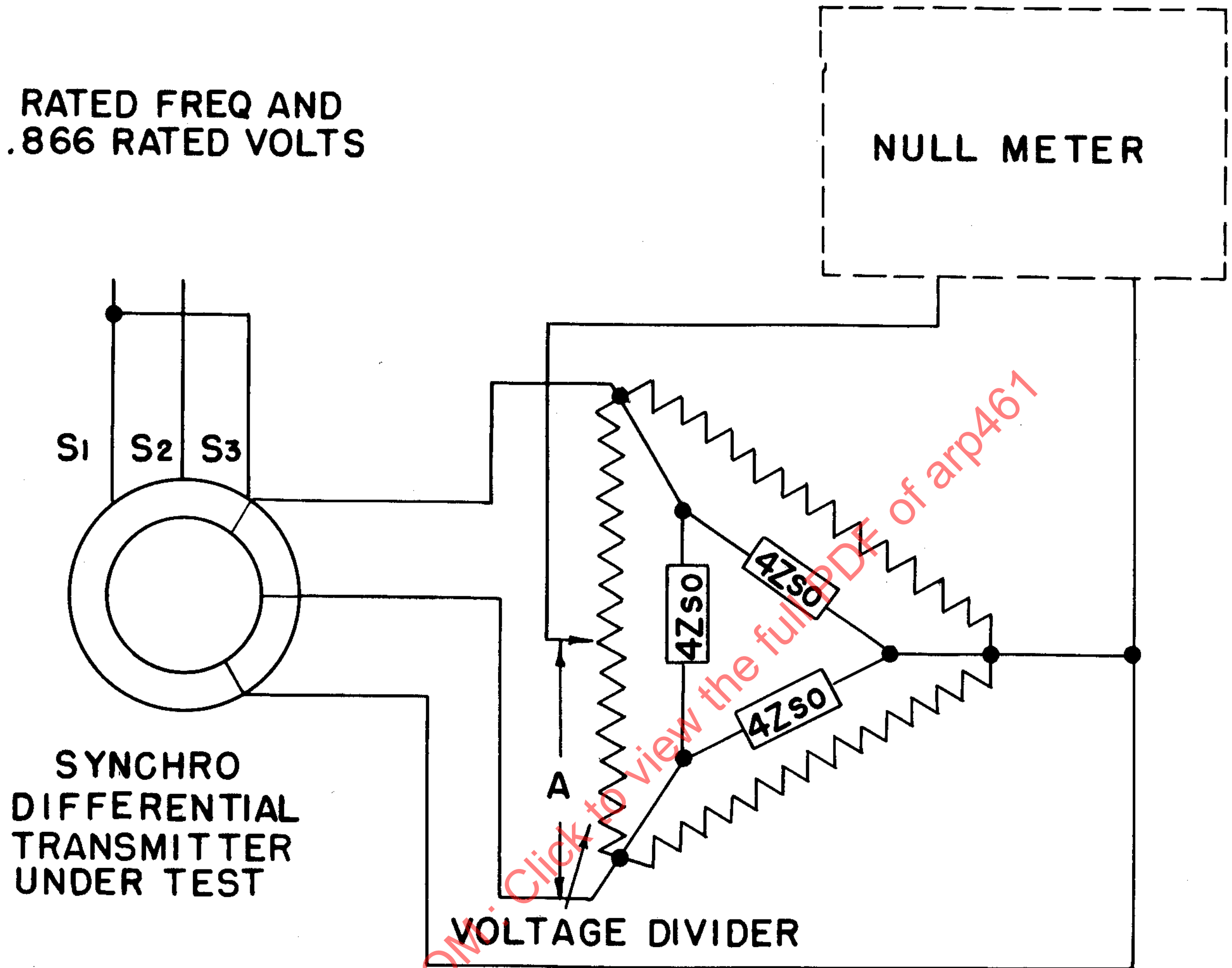
The error at a given rotor position is equal to the mechanical position of the rotor minus the electrical position. The maximum errors, in absolute value, of differential transmitters shall not exceed the limits given in section 2.2.6.5.

2.2.6.1.3.2 Differential Transmitter Stators: The basic circuit for electrical error testing of the stator windings of differential synchros is shown in Figure 24. The stator terminals of the synchro under test shall be connected to the corresponding stator terminals of a synchro transmitter of equal or larger size, operated at rated voltage and frequency. Rotor terminals R_1 - R_3 of the differential transmitter shall be connected to a null meter. The energizing transmitter shall be turned until its electrical position, measured as described in 2.2.6.1.1, is at the desired value. The angular position of the unit under test that produces a zero reading of the null meter shall be determined. The error at a given rotor position is defined as the mechanical rotor position minus the electrical position. The maximum errors, in absolute value, of differential transmitters shall not exceed the limits given in section 2.2.6.5.



BASIC CIRCUIT EMPLOYED FOR ELECTRICAL ERROR TEST OF CONTROL TRANSFORMERS

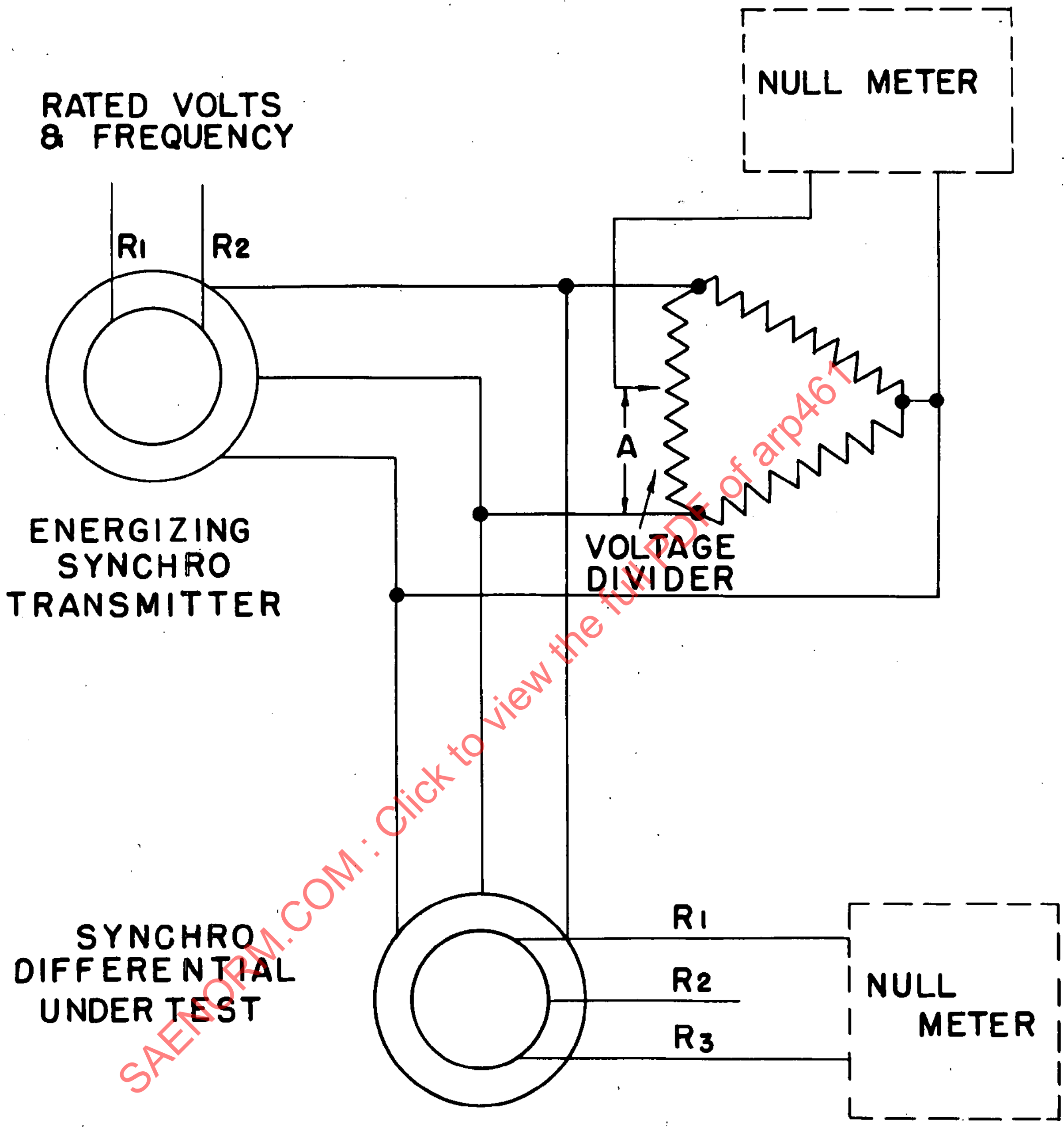
Figure 22



NOTE: The $4Z_{so}$ delta connected loads may be replaced by an equivalent wye connected load.

BASIC CIRCUIT EMPLOYED FOR ELECTRICAL ERROR TEST OF THE ROTOR WINDINGS OF THE DIFFERENTIAL TRANSMITTERS

Figure 23



BASIC CIRCUIT EMPLOYED FOR ELECTRICAL ERROR TEST OF THE STATOR WINDINGS OF THE DIFFERENTIAL TRANSMITTERS

Figure 24

2.2.6.1.4 <u>Resolver Transmitter:</u> This method consists of comparing the actual position of the synchro rotor with the electrical position of the synchro. The electrical position of the synchro is obtained from the following equation:

Electrical Position = $P\,\emptyset + (N + 1/2 - P/2 + 4M)\,45^{\circ}$

$\emptyset = \tan^{-1} R$

R = smaller secondary voltage/larger secondary voltage = $\frac{A_1}{A_2}$

$A_1 + A_2$ = 10,000 ohms

M = 0 when E (S_{13}) is in time phase with voltage E (R_{31})

M = 1 when E (S_{13}) is 180° out of time phase with voltage E (R_{31})

N is determined as follows:

N = 3 when V_3 is larger or equal to V_2 and V_1 is larger or equal to V_3.

N = 2 when V_2 is larger or equal to V_3 and V_1 is larger or equal to V_2.

N = 1 when V_2 is larger or equal to V_3 and V_1 is smaller or equal to V_2.

N = 0 when V_3 is larger or equal to V_2 and V_1 is smaller or equal to V_3.

P = + 1 when R increases with increasing positive angle.

P = - 1 when R decreases with increasing positive angle.

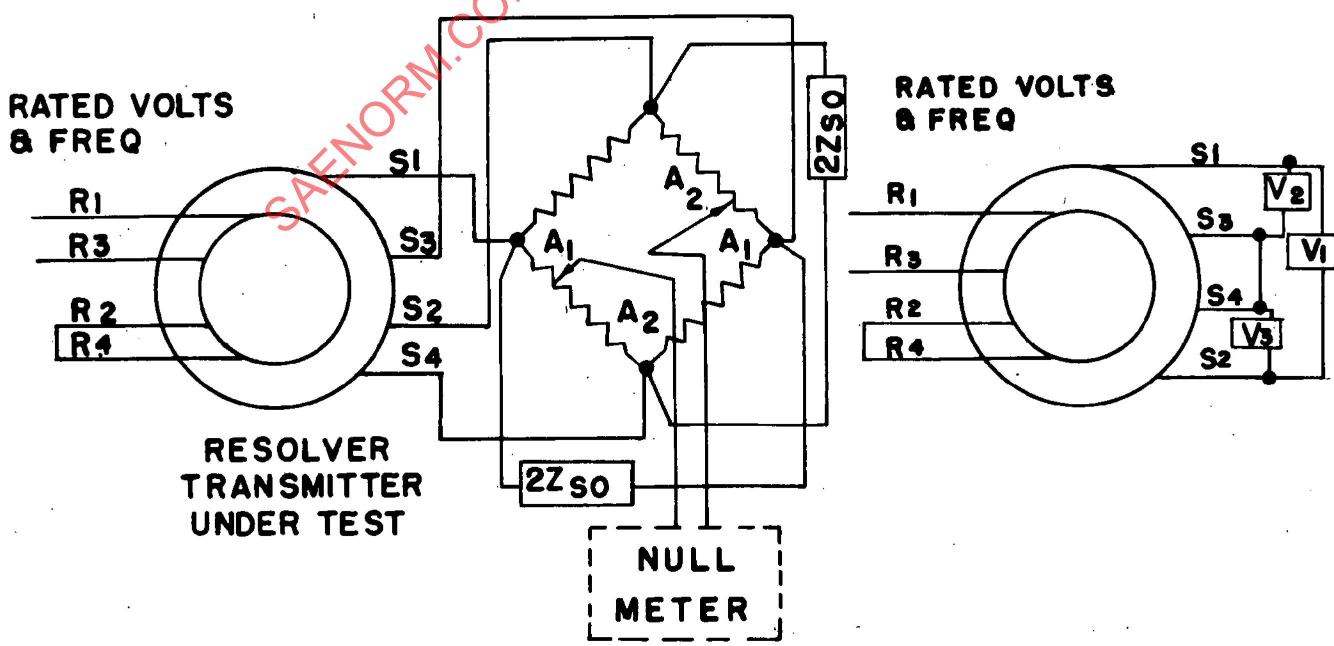


Figure 25

Four non-inductive voltage dividers of 10,000 ohms each shall be connected across the output circuits S_1-S_3, S_2-S_4 as shown in Figure 25. Impedances shown as 2 Z_{so} shall be two times the value of Z_{so} $\pm$ 15% of the type of unit under test (ref. paragraph 2.2.5). This load shall be such that four error curves are made, each at one of the four possible connections of the load, the maximum difference in the error curves shall not exceed 10% of the allowable transmitter error. With maximum output voltage of unit under test applied across one of the impedances the maximum pickup across the other impedance shall not exceed 0.005% of the applied voltage. The voltage dividers shall be equal to within 0.01% and produce a phase shift of no more than 10 minutes. The variable tap shall be connected to a null meter having an impedance not less than that of a 500,000 ohm resistor shunted by a 30 mmf capacitance and shall be capable of indicating 0.2 minutes displacement of the unit under test from a null position. It shall also be able to discriminate against a value of quadrature of 1% of maximum output voltage of the unit under test so as to produce a meter reading less than that produced by a 0.2 minute displacement from the null position of the unit under test. The voltage divider shall be set at the proper ratio (R in the formula) for the desired electrical position and the synchro shaft shall be turned until a zero reading of the null meter is obtained. The position of the rotor is then recorded. The error at a given rotor position is defined as the mechanical rotor position minus the electrical position.

Values of R for Various Values of Angle Ø

Ø	R
0	.00000
5	.08749
10	.17633
15	.26795
20	.36397
25	.46631
30	.57735
40	.83910
45	1.00000

The maximum errors, in absolute value, of resolver transmitter shall not exceed those given in section 2.2.6.5.

2.2.6.1.5 Resolver Control Transformers: The basic circuit for electrical error testing of resolver control transformers is shown in Figure 26.

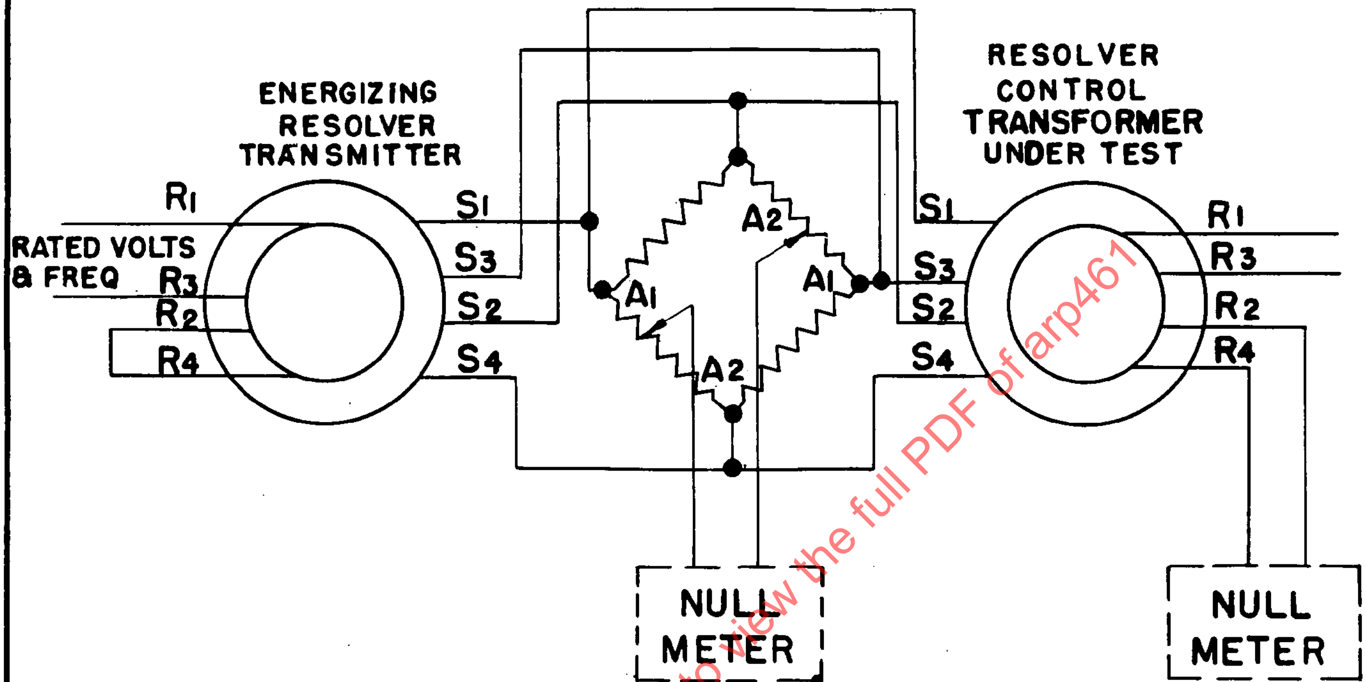


Figure 26

The stator terminals of the resolver transformer shall be connected to corresponding stator terminals of a resolver transmitter operated at rated voltage and frequency. The output terminals R_2 R_4 of the resolver control transformer shall be connected to the null meter. The energizing transmitter shall be turned until its electrical position, measured as described in 2.2.6.1.4, is at the desired value. The angular position of the unit under test that produces a zero reading of the null meter shall be determined. The error at a given rotor position is the mechanical rotor position minus the electrical position. The maximum errors, in absolute value, of resolver control transformers shall not exceed the limits given in section 2.2.6.5.

2.2.6.1.6 Resolver Differential:

2.2.6.1.6.1 Resolver Differential-Rotor:

Figure 27 (assigned)

2.2.6.1.6.2 Resolver Differential-Stator:

Figure 28 (assigned)

2.2.6.2 Electrical Error - Comparison Method: Before testing the synchro for electrical error by the comparison method, the synchro zero position of the synchro under test shall be accurately determined as described in 1.3.2.6 as applicable. The synchro zero shall be determined under open circuit conditions and shall not be adjusted before performing electrical error test.

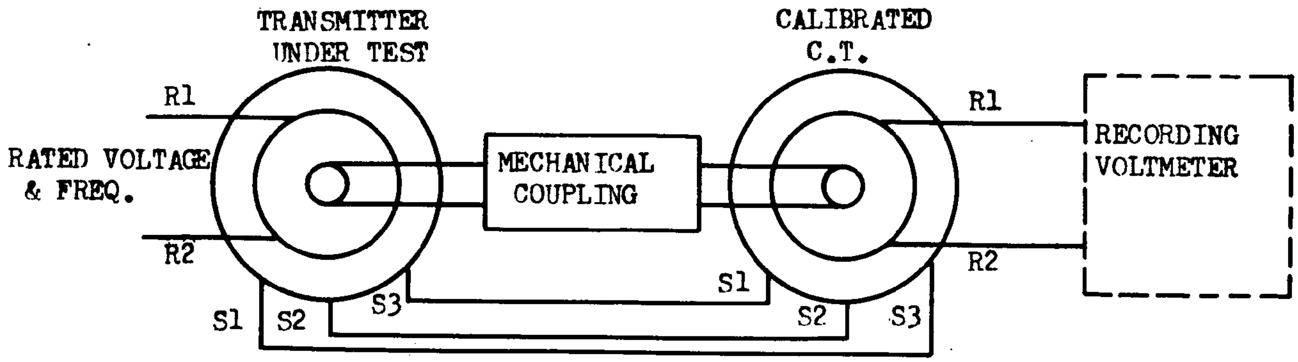
2.2.6.2.1 Transmitters: Transmitters shall be tested as shown in Figure 29 using control transformers, calibrated by the proportional voltage method as described in 2.2.6.1.2. The calibrated C.T. shall have an open circuit input impedance (Z_{so}) two times the open circuit impedance of the output winding (Z_{so}) of the transmitter under test. The synchro under test shall be excited with rated voltage and frequency to the rotor. Its stator leads shall be connected to the stator leads of the calibrated control transformer in the following manner: S_1 to S_3, S_3 to S_1, and S_2 to S_2; and its rotor shall be mechanically coupled to the rotor of the control transformer so that both units are at synchro zero. The rotor voltage of the control transformer is a measure of the electrical error of the synchro system (calibrated C.T. error plus unit error under test). This voltage shall be recorded for a complete revolution by means of a recording voltmeter with the same requirements as the null meter described in 2.2.6.1.1. The electrical error record shall be corrected, if necessary, to account for the errors of the calibrated control transformer. The maximum errors, in absolute value, of the transmitters shall not exceed the limits given in section 2.2.6.5.

2.2.6.2.2 Control Transformers: Control transformers shall be tested as shown in Figure 30 using transmitters, calibrated by the proportional voltage method as described in 2.2.6.1.1. The transmitter shall have an output winding impedance with the rotor short circuited and fully coupled to the output winding no greater than 2% of the open circuit input impedance (Z_{so}) of the control transformer under test. The transmitter shall also have the proper transformation ratio so that with rated voltage applied to the transmitter the control transformer will receive its rated excitation. The stator leads of the calibrated transmitter shall be connected to the stator leads of the control transformer in the following manner: S_1 to S_3, S_3 to S_1, and S_2 to S_2; and their rotors shall be mechanically coupled so both units are at synchro zero. The rotor voltage of the control transformer is a measure of the electrical error of the synchro system (control transformer error under test plus calibrated transmitter error). This voltage shall be recorded for a complete revolution by means of a recording voltmeter with same requirements as the null meter described in 2.2.6.1.1. The electrical error record shall be corrected, if necessary, for the errors of the calibrated transmitter. The maximum errors, in absolute value, of the control transformer shall not exceed the limits given in section 2.2.6.5.

2.2.6.2.3 Differential Transmitters:

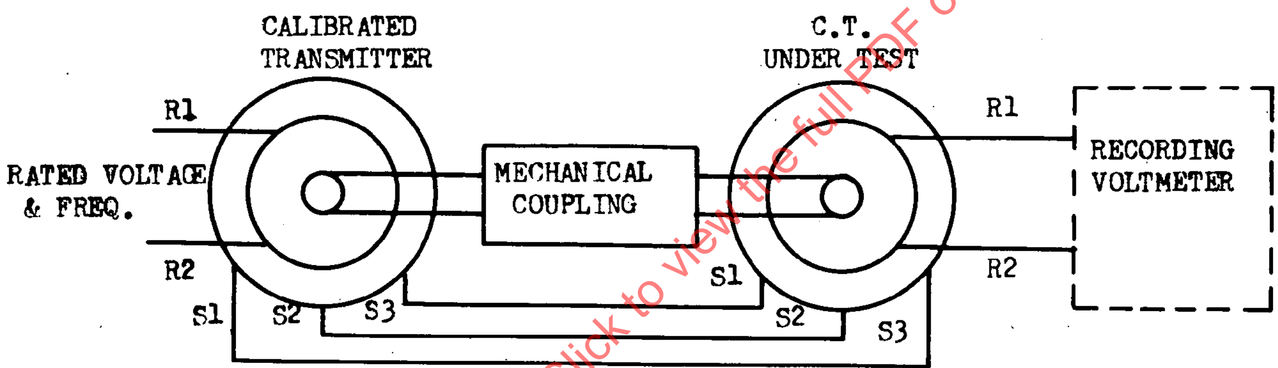
2.2.6.2.3.1 Differential Transmitter Rotor: Differential transmitter rotors shall be tested as shown in Figure 31 using control transformers, calibrated by the proportional voltage method as described in 2.2.6.1.2. The calibrated C.T. shall have an open circuit input impedance (Zso) two times the open circuit impedance of the output winding (Zro) of the transmitter under test. The synchro under test shall be excited **at rated frequency and 0.866 rated voltage applied** between S_2 and S_1-S_3 shorted together. Its rotor leads shall be connected to the stator leads of the calibrated control transformer in the following manner: R_1 to S_1, R_2 to S_2, and R_3 to S_3. Its rotor shall be mechanically coupled to the rotor of the control transformer so that both units are at synchro zero. The rotor voltage of the control transformer is a measure of the electrical error of the synchro system (control transmitter error plus differential rotor error under test). This voltage shall be recorded for a complete revolution by means of a recording voltmeter with the same characteristics as the null meter described in 2.2.6.1.2. The electrical error record shall be corrected, if necessary, for the errors of the calibrated control transformer. The maximum errors, in absolute value, of the differential rotors shall not exceed the limits given in section 2.2.6.5.

2.2.6.2.3.2 Differential Transmitter Stator: Differential transmitter stators shall be tested as shown in Figure 32 using transmitters, calibrated by the proportional voltage method as described in 2.2.6.1.1. The transmitter shall have an output winding impedance with the rotor short circuited and fully coupled to the output winding no greater than 2% of the open circuit input impedance (Zso) of the differential under test. The transmitter shall also have the proper transformation ratio so that with rated voltage applied to the transmitter the differential will receive its rated excitation. The stator leads of the calibrated transmitter shall be connected to the stator leads of the differential in the following manner: S_1 to S_3, S_2 to S_2, and S_3 to S_1, and their rotors shall be mechanically coupled so that both units are at **synchro zero. The rotor voltage E (R_{13}) of the differential is a measure of the electrical error of the synchro system (differential** stator error under test plus calibrated transmitter error). This voltage shall be recorded by means of a recording voltmeter with the same requirements as the null meter described in 2.2.6.1.1. The synchro error record shall be corrected, if necessary, for the errors of the calibrated transmitter. The maximum errors, in absolute value, of the differential stator shall not exceed the limits given in section 2.2.6.5.



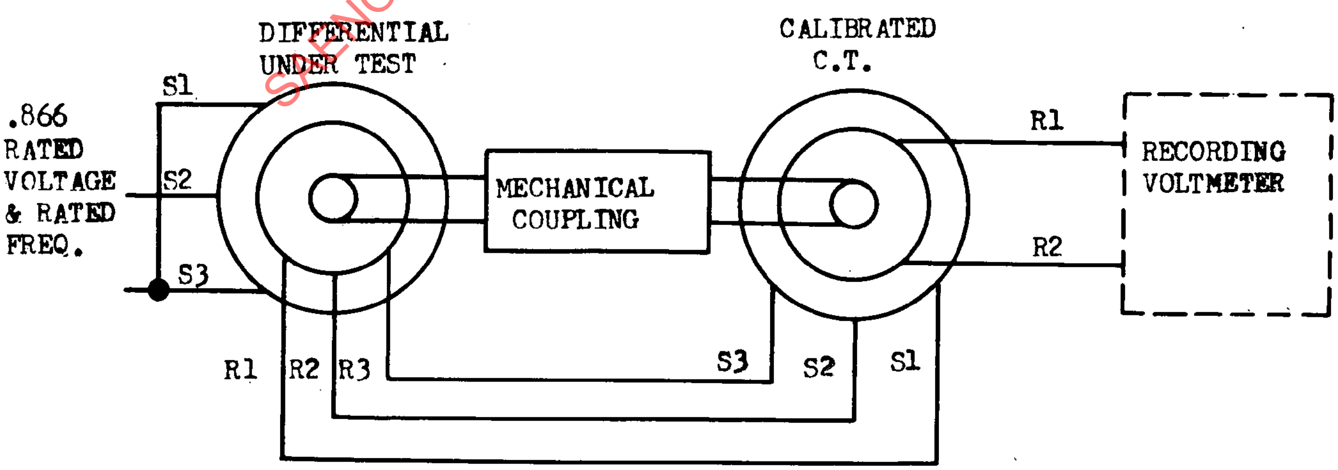
COMPARISON METHOD FOR ELECTRICAL ERROR OF TRANSMITTERS

Figure 29



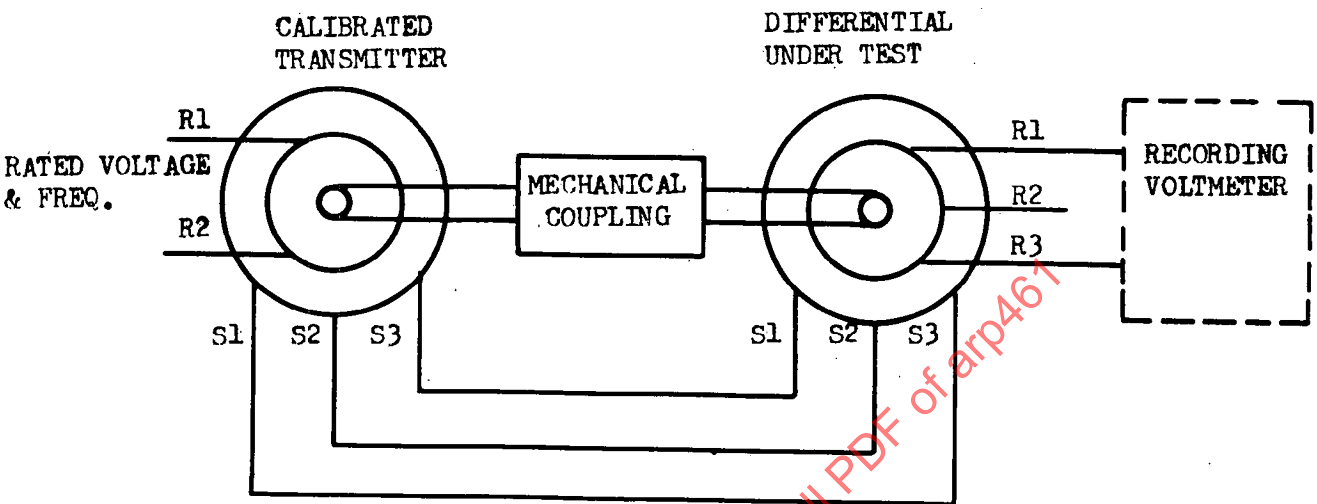
COMPARISON METHOD FOR ELECTRICAL ERROR OF CONTROL TRANSFORMER

Figure 30



COMPARISON METHOD FOR ELECTRICAL ERROR OF DIFFERENTIAL TRANSMITTER ROTORS

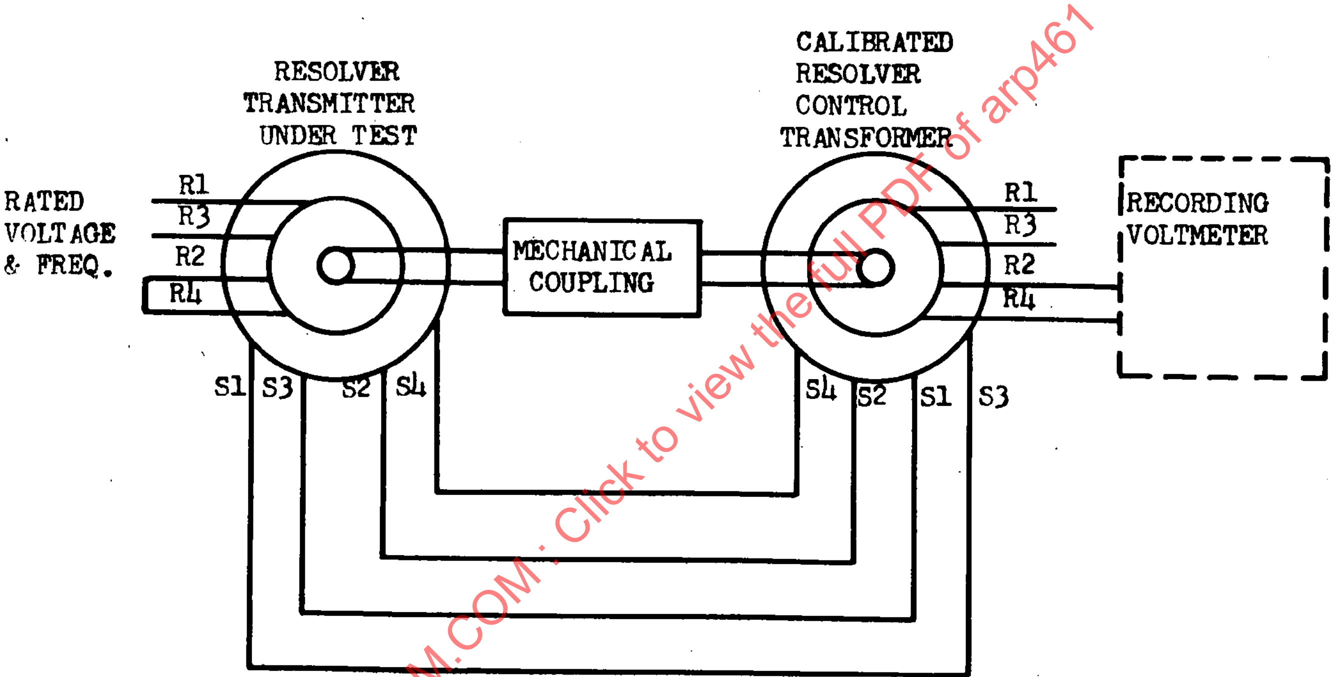
Figure 31



COMPARISON METHOD FOR ELECTRICAL ERROR OF DIFFERENTIAL TRANSMITTER STATORS

Figure 32

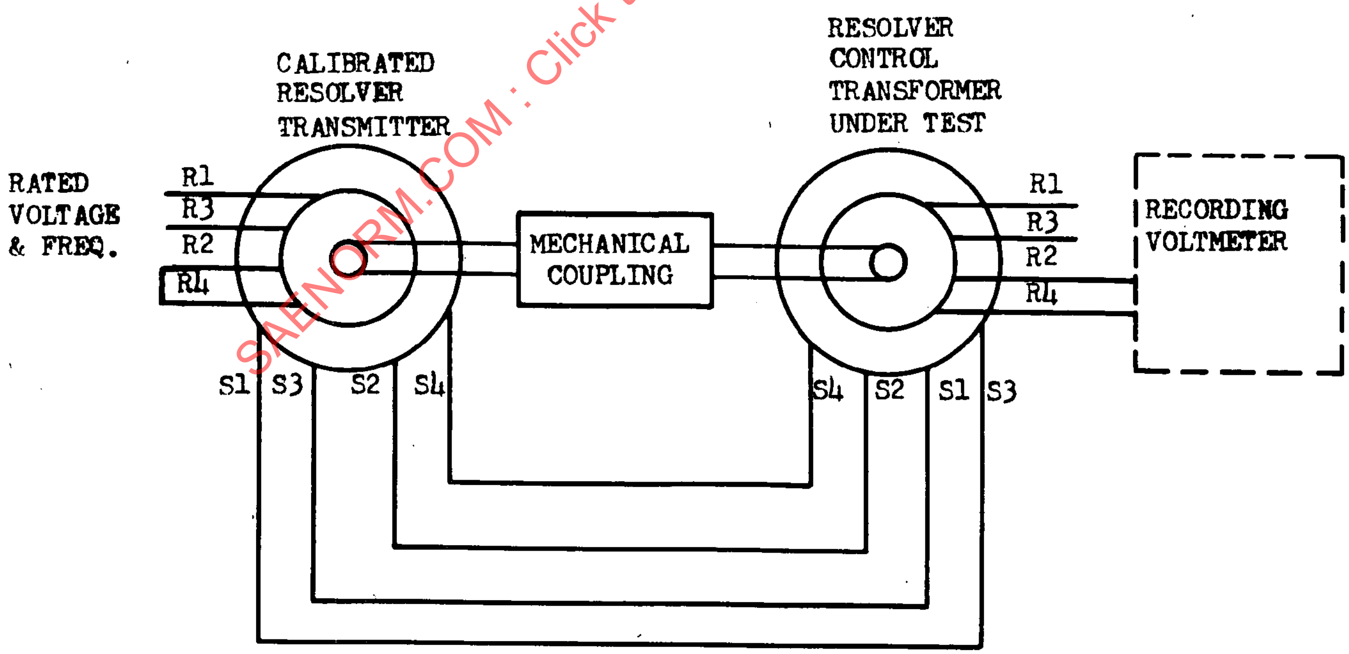
2.2.6.2.4 Resolver Transmitters: Resolver transmitters shall be tested as shown in Figure 33 using resolver control transformers, calibrated by the proportional voltage method as described in 2.2.6.1.5. The calibrated resolver C.T. shall have an open circuit input impedance two times the open circuit impedance of the output winding (Zso) of the resolver transmitter under test. The resolver transmitter under test shall be excited with rated voltage and frequency to the rotor winding R_1R_3 and R_2R_4 shall be shorted together. Its stator leads shall be connected to the stator leads of the calibrated resolver control transformer in the following manner: S_2 to S_2, S_4 to S_4, S_1 to S_3, and S_3 to S_1; and its rotor shall be mechanically coupled to the rotor of the resolver control transformer so that both units are at synchro zero. The rotor voltage across R_2R_4 of the resolver control transformer is a measure of the electrical error of the synchro system (calibrated resolver C.T. error plus resolver transmitter error under test). This voltage shall be recorded for a complete revolution by means of a recording voltmeter with the same requirements as the null meter described in 2.2.6.1.1. The electrical error record shall be corrected, if necessary, to account for the errors of the calibrated resolver control transformer. The maximum errors, in absolute value, of the resolver transmitter shall not exceed the limits given in section 2.2.6.5.



COMPARISON METHOD FOR ELECTRICAL ERROR OF RESOLVER TRANSMITTER

Figure 33

2.2.6.2.5 Resolver Control Transformer: Resolver control transformers shall be tested as shown in Figure 34 using resolver transmitters, calibrated by the proportional voltage method as described in 2.2.6.1.4. The resolver transmitter shall have an output winding impedance with the rotor short circuited and fully coupled to the output winding no greater than 2% of the open circuit input impedance (Zso) of the resolver control transformer under test. The resolver transmitter shall also have the proper transformation ratio so that with rated voltage applied to the resolver transmitter the resolver control transformer will receive its rated excitation. The stator leads of the calibrated resolver transmitter shall be connected to the stator leads of the resolver control transformer in the following manner: S_2 to S_2, S_4 to S_4, S_1 to S_3, and S_3 to S_1; and their rotors shall be mechanically coupled so that both units are at synchro zero. The rotor voltage across R_2R_4 of the resolver control transformer is a measure of the electrical error of the synchro system (error of resolver control transformer under test plus calibrated resolver transmitter error). This voltage shall be recorded for a complete revolution on a recording voltmeter with the same requirements as the null meter described in 2.2.6.1.1. The electrical error record shall be corrected, if necessary, for the errors of the calibrated resolver transmitter. The maximum errors, in absolute value, of the resolver control transformer shall not exceed the limits given in section 2.2.6.5.

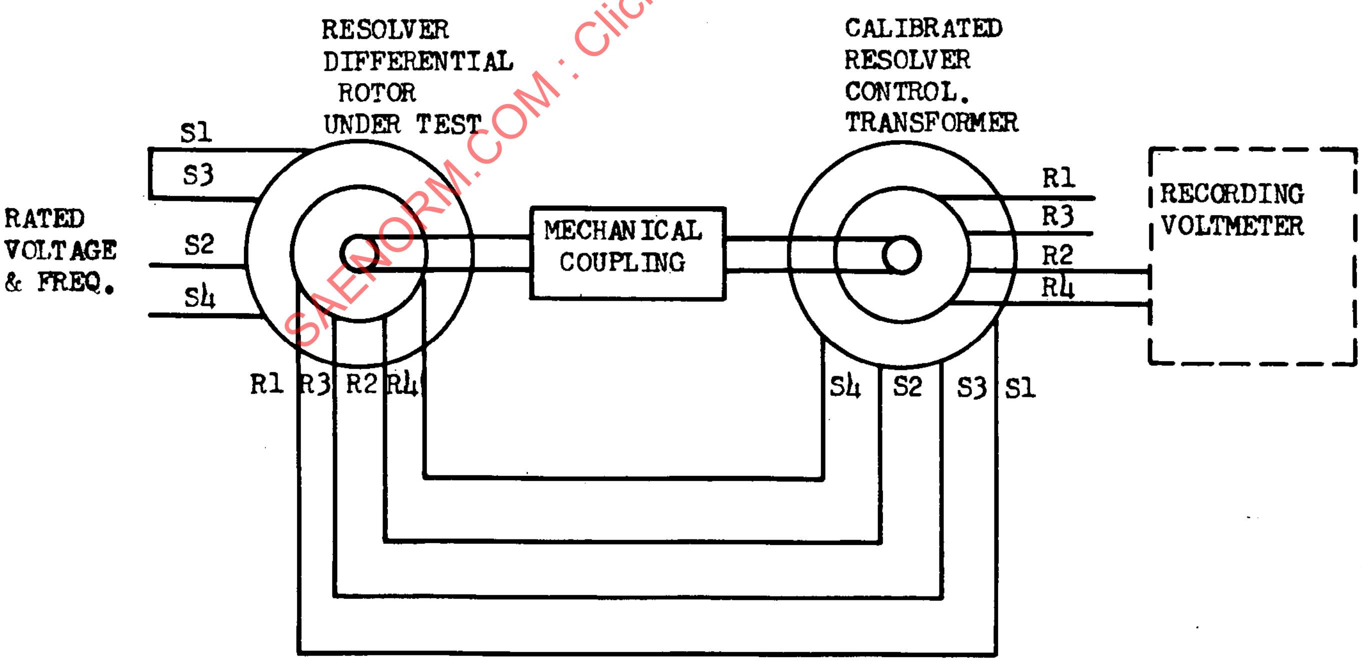


COMPARISON METHOD FOR ELECTRICAL ERROR OF RESOLVER CONTROL TRANSFORMER

Figure 34

2.2.6.2.6 Resolver-Differential:

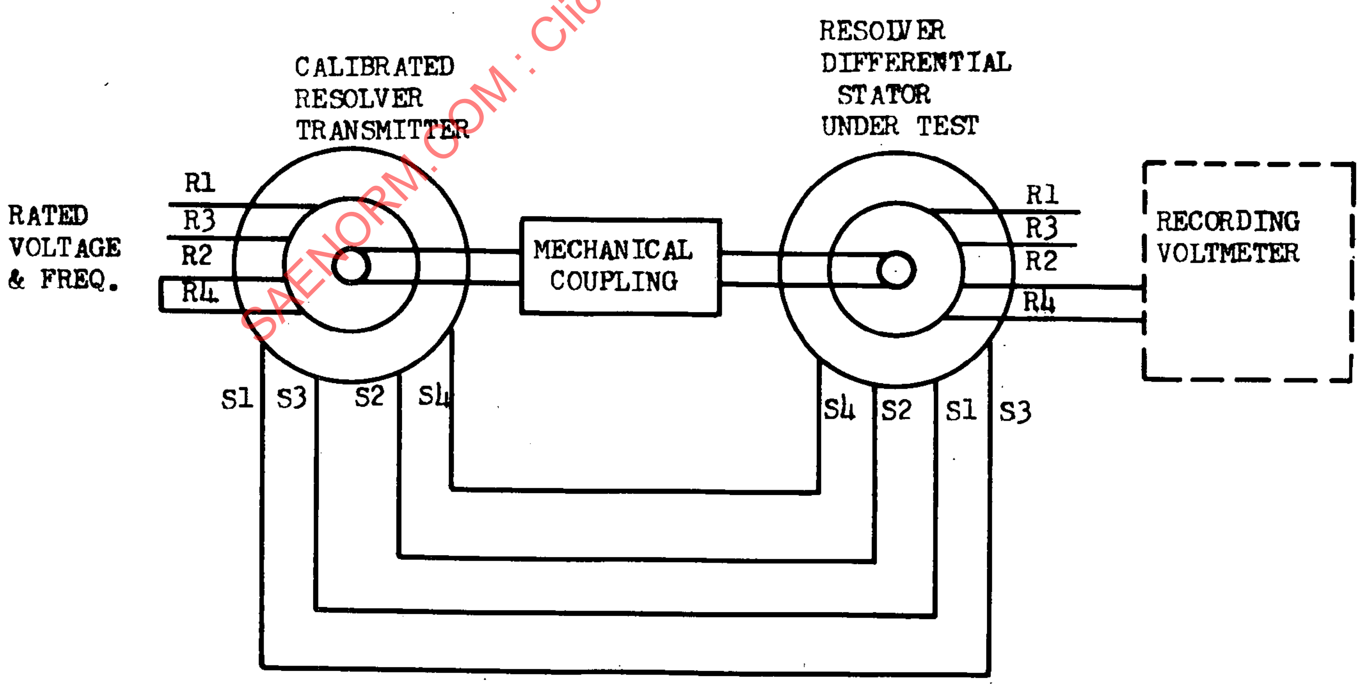
2.2.6.2.6.1 Resolver Differential Rotors: Resolver differential rotors shall be tested as shown in Figure 35 using resolver control transformers, calibrated by the proportional voltage method as described in 2.2.6.1.5. The calibrated resolver C.T. shall have an open circuit input impedance two times the open circuit impedance of the output winding (Zro) of the resolver differential under test. The resolver differential under test shall be excited with rated voltage and frequency to the stator winding S_2S_4 and S_1S_3 shall be shorted together. Its rotor leads shall be connected to the stator leads of the calibrated resolver control transformer in the following manner: R_2 to S_2, R_4 to S_4, R_1 to S_1, and R_3 to S_3; and its rotor shall be mechanically coupled to the rotor of the resolver control transformer so that both units are at synchro zero. The rotor voltage across R_2R_4 of the resolver control transformer is a measure of the electrical error of the synchro system (calibrated resolver C.T. error plus error of resolver differential rotor under test). This voltage shall be recorded for a complete revolution by means of a recording voltmeter with the same requirements as the null meter described in 2.2.6.1.1. The electrical error record shall be corrected, if necessary, to account for the errors of the calibrated resolver control transformer. The maximum errors, in absolute value, of the resolver differential rotor should not exceed the limits given in section 2.2.6.5.



COMPARISON METHOD FOR ELECTRICAL ERROR OF RESOLVER DIFFERENTIAL ROTOR

Figure 35

2.2.6.2.6.2 Resolver Differential Stators: Resolver differential stators shall be tested as shown in Figure 36 using resolver transmitters, calibrated by the proportional voltage method as described in 2.2.6.1.4. The resolver transmitter shall have an output winding impedance with the rotor short circuited and fully coupled to the output winding no greater than 2% of the open circuit input impedance (Zso) of the resolver differential under test. The resolver transmitter shall also have the proper transformation ratio so that with rated voltage applied to the resolver transmitter, the resolver differential will receive its rated excitation. The stator leads of the calibrated resolver transmitter shall be connected to the stator leads of the resolver differential in the following manner: S_2 to S_2, S_4 to S_4, S_1 to S_3, and S_3 to S_1; and their rotors shall be mechanically coupled so that both units are at synchro zero. The rotor voltage across R_2R_4 of the resolver differential is a measure of the electrical error of the synchro system. (Error of resolver differential stator under test plus calibrated resolver transmitter error.) The voltage shall be recorded for a complete revolution on a recording voltmeter with the same requirements as the null meter described in 2.2.6.1.1. The electrical error record shall be corrected, if necessary, for the errors of the calibrated resolver transmitter. The maximum errors, in absolute value, of the resolver differential stator shall not exceed the limits given in section 2.2.6.5.



COMPARISON METHOD FOR ELECTRICAL ERROR OF RESOLVER DIFFERENTIAL STATOR

Figure 36

2.2.6.3 Receiver Error:

2.2.6.3.1 Dynamic: Receivers shall be tested against torque transmitters of equal size. The receiver error shall be determined for continuous rotation of the transmitter both clockwise and counter-clockwise. The receiver errors, corrected for the calibration errors of the transmitter, shall not exceed those given in section 2.2.6.5.

2.2.6.3.2 Static:

2.2.6.4 Differential Receiver:

2.2.6.4.1 Dynamic: All sizes of differential receivers shall be tested against two torque transmitters of the same size, one connected to the rotor of the differential receiver and the other connected to the stator of the differential receiver. Two complete sets of error measurements in each direction of rotation shall be taken.

Lock one transmitter on synchro zero and vary the setting of the other transmitter continuously recording the angular position assumed by the differential receiver.

Repeat the above test but with the other transmitter clamped on synchro zero and vary the setting of the transmitter continuously as before.

The errors, corrected for the calibration errors of the transmitters, shall not exceed those given in section 2.2.6.5.

2.2.6.4.2 Static:

2.2.6.5 Tabulation of Allowable Error:

2.2.6.5.1 115 Volt, 60 CPS Synchros:

Maximum in Minutes

Electrical Error

Type	8	10	11	15	16	18	19	23	31	37
Transmitter - Torque						10	10	8	8	
Transmitter - Control						8		8		
Control Transformer						8	8	6		
Diff. Trans. - Torque - Stator								8	8	
Diff. Trans. - Torque - Rotor								8	8	
Diff. Trans. - Control - Stator								8		
Diff. Trans. - Control - Rotor								8		
Resolver - Transmitter										
Resolver - Cont. Transformer										
Resolver - Differential - Rotor										
Resolver - Differential - Stator										

Receiver Error

Type	18	19	23	31	37
Receiver	60	60	60	48	
Differential Receiver - Stator			60		
Differential Receiver - Rotor			60		

2.2.6.5.2 115 Volt, 400 CPS Synchros:

Maximum in Minutes

Electrical Error

Unit Size

Type	8	10	11	15	16	18	19	23	31	37
Transmitter - Torque				12	12	8	8	8	8	
Transmitter - Control			12	12	12	8	8	8		
Control Transformer			10	10	10	8	8	6		
Diff. Trans. - Torque - Stator				10	10	10	10	8	8	
Diff. Trans. - Torque - Rotor				10	10	10	10	8	8	
Diff. Trans. - Control - Stator				10	10	8	8	8		
Diff. Trans. - Control - Rotor				10	10	8	8	8		
Resolver - Transmitter										
Resolver - Cont. Transformer										
Resolver - Differential - Rotor										
Resolver - Differential - Stator										

Receiver Error

Unit Size

Type	8	10	11	15	16	18	19	23	31	37
Receiver				60	60	60	60	60	48	
Differential Receiver - Stator								60	48	
Differential Receiver - Rotor								60	48	

2.2.6.5.3 26 Volt, 400 CPS Synchros:

Maximum in Minutes

Electrical Error

Type	8	10	11	15	16	18	19	23	31	37
Transmitter - Torque		15	12	15						
Transmitter - Control	10	15	12	15						
Control Transformer	10	15	10	15						
Diff. Trans. - Torque - Stator										
Diff. Trans. - Torque - Rotor										
Diff. Trans. - Control - Stator		18	10	20						
Diff. Trans. - Control - Rotor		18	10	20						
Resolver - Transmitter		18		20						
Resolver - Cont. Transformer		18		20						
Resolver - Differential - Rotor										
Resolver - Differential - Stator										

Receiver Error

Type	8	10	11	15	16	18	19	23	31	37
Receiver			120	60						
Differential Receiver - Stator										
Differential Receiver - Rotor										

2.2.7 Minimum Voltage: The minimum voltage and the fundamental component of the minimum voltage shall be determined by employing the circuit of Figure 37. These voltages shall be read on a vacuum tube voltmeter indicating the average value of the voltage wave in terms of the rms value of an equivalent sine wave. The synchro shall be connected as indicated in the table of Figure 37. The minimum voltage readings shall be made with the synchro at the electrical angles shown in the table. With the switch in position (1) the rotor shall be turned to determine the value of the fundamental voltage. Without further turning of the rotor, the switch shall be changed to position (2) and the minimum voltage shall be read. The maximum values of the minimum voltage and of the fundamental component of the minimum shall not exceed the values specified in 2.2.7.1. The value of the fundamental voltage shall have been corrected for the attenuation of the filter used. The filter shall have a minimum input impedance of 10 times the maximum open circuit impedance of the secondary of the unit under test.

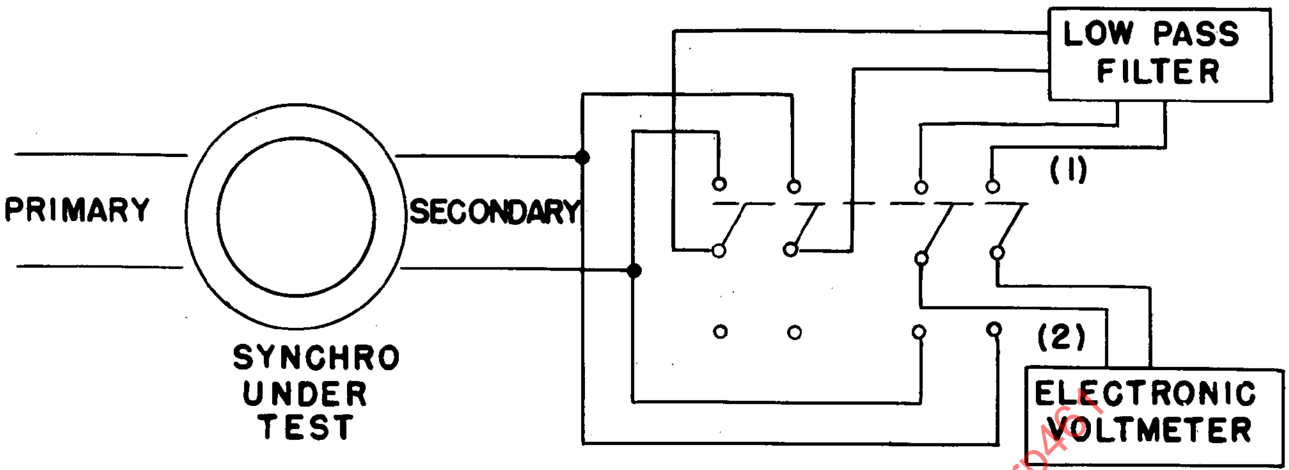


Figure 37

Table of Connections

Table of Connections (Cont'd)

2.2.7.1 Tabulation of Allowable Voltages:

2.2.7.1.1 115 Volts, 60 CPS Synchros:

Type		Minimum Voltage (Millivolts - Max.) Unit Size 18	19	23	31	37
Transmitter - Control	TSV		125	100		
	FSV		75	75		
Control Transformer	TSV		90	60		
	FSV		60	40		
Diff. Trans. - Torque	TSV					
	FSV					
Diff. Trans. - Control	TSV		125	100		
	FSV		75	75		
Resolver - Transmitter	TSV					
	FSV					
Resolver - Cont. Transformer	TSV					
	FSV					
Resolver - Differential	TSV					
	FSV					

2.2.7.1.2 115 Volt, 400 CPS Synchros:

Type		Minimum Voltage (Millivolts - Max.) Unit Size 8	10	11	15	16	18	19	23	31	37
Transmitter - Control	TSV			125	125	125	115	115	100	100	
	FSV			75	75	75	65	65	50	50	
Control Transformer	TSV			90	75	75	65	65	60		
	FSV			60	40	40	35	35	30		
Diff. Trans. - Torque	TSV										
	FSV										
Diff. Trans. - Control	TSV				125	125	115	115	100		
	FSV				75	75	65	65	50		
Resolver - Transmitter	TSV										
	FSV										
Resolver - Cont. Transformer	TSV										
	FSV										
Resolver - Differential	TSV										
	FSV										