MIL-S-2335
8 August 1950

MILITARY SPECIFICATION

SYNCHROS, 60 CYCLE, 115 VOLT

This specification was approved by the Departments of the Army, the Navy, and the Air Force for use of procurement services of the respective Departments, and supersedes the following specification:

NAVORD OS 671
15 December 1949

This specification consists of this cover sheet and Bureau of Ordnance Specification OS 671, dated 15 December 1949, attached hereto, without modification.

Copies of this specification may be obtained upon application to the Bureau of Supplies and Accounts, Navy Department, Washington 25, D.C., except that activities of the Armed Forces should make application to the Commanding Officer, Naval Supply Center, Norfolk 11, Va. Both the title and identifying number or symbol should be stipulated when requesting copies.

When a request for this specification is received by a supplying activity, it will be necessary to attach this cover sheet to the pertinent specification before issue.

FSC 5930

NAVORD OS 671
71 SHEETS
SHEET 1

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BUREAU OF ORDNANCE

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ORDNANCE SPECIFICATIONS

SYNCHROS

60 CYCLE

115 VOLT

NAVY DEPARTMENT
BUREAU OF ORDNANCE
WASHINGTON D.C.

15 DECEMBER 1949

BY DIRECTION OF THE CHIEF OF BUREAU

REVISIONS			
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OS 671

NAVY DEPARTMENT
BUREAU OF ORDNANCE

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1. SCOPE AND CLASSIFICATION

1.1 This specification covers 115 volt 60 cycle synchros used by the Department of the Navy. The word "Synchro" is a term, analogous to a trade name, used by the Armed Forces, and applies to certain components of self-synchronous systems or units which are listed in 1.2 below. A self-synchronous system is defined as a system composed of electrically connected transmitting, receiving, and auxiliary units which, under all operating conditions, will automatically set up and continuously maintain correspondence between the transmitter and receiver. Rotatable synchro units, i.e., units which consist of a rotor and stator in which the angular position of the rotor with respect to the stator can be varied, are covered by this specification. Auxiliary units consist of synchro capacitors and trouble indicators and are covered in referenced specifications.

1.2 Classification as to Function.--

1.2.1 Synchro Transmitter.--A unit, the rotor of which is mechanically driven, for generating and transmitting electrical information corresponding to angular positions of the rotor. (Previous to Revision E this unit was called a synchro generator).

1.2.2 Synchro Differential Transmitter.--A unit, the rotor of which is mechanically driven, for modifying received electrical angular information and transmitting electrical information corresponding to the sum or difference of the respective angles. (Previous to Revision E this unit was called a synchro differential generator).

1.2.3 Synchro Receiver.--A unit, the rotor of which is free to turn in accordance with the electrical orders received. (Previous to Revision E this unit was called a synchro motor).

1.2.4 Synchro Differential Receiver.--A unit, the rotor of which is free to turn in accordance with the sum or difference of electrical angular information received from two synchro signals. (Previous to Revision E this unit was called a synchro differential motor).

1.2.5 Synchro Control Transformer.--A unit, the rotor of which is mechanically driven until the electrical voltage induced in the rotor from its stator becomes null, or the final

angular position of rotor corresponds to that set up by the transmitter. The voltages induced in the rotor are generally impressed upon grids of thermionic tubes or similar devices used for the control of servo units.

1.3 Classification as to Size.--

Size	Approx. Weight Lbs.	Approx. Length	Approx. Diameter
1	2	3.9 to 4.2 in.	2.25 in.
3	3	5.2 to 5.51 in.	3.1 in.
5	5	6.0 to 6.8 in.	3.39 to 3.625 in.
6	8	6.4 to 7.5 in.	4.5 in.
7	18	8.9 to 9.2 in.	5.75 in.

1.4 Classification Letters.--

Letter	Definition
G	Transmitter
F	Flange mounted receiver (This letter is omitted if letters other than "H" or "S" occur in a receiver's type designation)
D	Differential Receiver
DG	Differential Transmitter
CT	Control Transformer
H	High Speed (1200 rpm for 1500 hours)
B	Bearing Mounted
N	Nozzle Mounted
S	Special Unit (The synchro does not conform to standard specifications in some way)

The above types are for 60 cycle operation. Two frame types are standard - Flange Mounted and Bearing Mounted.

1.5 Type Designation.--A synchro unit is identified by a type designation consisting of the above classifications. The letter symbol or a combination of the letter symbols is preceded by a numerial prefix designating the size e.g., 5DGB designates a size 5 differential transmitter bearing mounted, low operating speed.

1.6 Mark and Modification.--In addition to the type designation, synchro units are further identified by Mark and Modification numbers. The Mark number signifies the design of the particular type that is in accordance with this specification. The Modification numbers indicates the manufacturer and is assigned by the Bureau of Ordnance.

2. APPLICABLE SPECIFICATIONS, OTHER PUBLICATIONS, AND DRAWINGS.

2.1 Specifications.--The following specifications, of the issue in effect on the date of invitation for bids, form a part of this specification.

FEDERAL SPECIFICATIONS
QQ-A-315 - Aluminum-alloy (Al 52): bars, rods, shapes.
QQ-A-318 - Aluminum-alloy (Al 52): plates, sheets.
QQ-A-325 - Aluminum-alloy (Al 61): bars, rods, shapes.
QQ-A-327 - Aluminum-alloy (Al 61): plates, sheets.
QQ-A-591 - Aluminum-Base-Alloy: die-castings.
QQ-S-763 - Steel, corrosion-resisting: bars and forgings (except for reforging).

JOINT ARMY-NAVY SPECIFICATIONS
JAN-I-225, Interference Measurement, Radio, Methods of, 150 Kilocycles to 20 megacycles for components and complete assemblies.
JAN-P-13 - Plastic-materials, laminated, thermosetting: sheets and plates.
JAN-P-14 - Plastic-materials, molded, thermosetting.
JAN-C-76 - Cable (hook-up wire), electric, insulated, radio and instrument.

AIR FORCE-NAVY AERONAUTICAL SPECIFICATIONS
AN-QQ-A-696 - Anodic Films; Corrosion-protective (for) aluminum alloys.

NAVY DEPARTMENT SPECIFICATIONS
Index of Specifications used by the Navy Department for Naval Stores and Material.
General Specification for Inspection of Material.
14G8 (Ord) - Instrument Grease.

14P1 - Petrolatum.
14O20 - Instrument Oil.
15W2 - Wire, Magnet.
17C8 - Cambric, insulating, varnished.
17I11 - Insulation, electrical, paper, fish.
17I13 - Insulation, electrical, slot-cell, composite, armature.
17P8 - Plastic-materials, rigid, thermoplastic.
17T1 - Tape, insulating, rubber.
17T15 - Tape, insulating, linen finish, plain.
17T16 - Tape, insulating, silk.
42S5 - Screws, machine, (cap and set; and nuts).
43B11 - Bolts, nuts, studs, and tap rivets.
46A1 - Aluminum-alloy, light: castings (sand)(resistant to salt water corrosion).
46B14 - Bronze, phosphor, rolled or drawn: bars, plates, rods, sheets, and strips.
46T1 - Tin, pig.
47S20 - Steel, corrosion-resisting: plates, sheets, strips, and structural shapes.
51F1 - Flux, soldering (paste).
52T15 (Ord) - Treatment, Moisture and fungus proofing of elements, components and assemblies, electrical and electronic: general specifications.
52V13 - Varnish insulating (electrical).
52Z3 - Zinc-dust.
66S3 - Shockproof-equipment, class HI (high-impact); and tests for.

BUREAU OF ORDNANCE SPECIFICATIONS
NAVORD OS 445 - General Specification for Fire Control Equipment.
NAVORD OS 3681 - United States Navy Synchro Capacitor Specifications.

BUREAU OF SHIPS SPECIFICATIONS
BuShips Supplementary General Specification for Machinery.
SGS(71) - 119b - Trouble Indicators for self-synchronous motors and generators.

(copies of Federal specifications, National Military Establishment specifications, Joint Army-Navy specifications, and Navy Department specifications may be obtained upon application to the Bureau of Supplies and Accounts, Navy Department, Washington 25, D.C., except that activities of the Armed Forces should make application to the Supply Officer in Command, Naval Supply Center, Norfolk 11, Virginia. Copies of Air

Force-Navy Aeronautical (AN) specifications may be obtained upon application to the Commanding Officer, U.S. Naval Air Development Station, Johnsville, Pennsylvania. Both the title and identifying number or symbol should be stipulated when requesting copies).

2.2 Other Publications.--The following publications, of the issue in effect on date of invitation for bids, form a part of this specification:

NATIONAL BUREAU OF STANDARDS PUBLICATION
Handbook H-28 (1944) - Screw-Thread Standards for Federal Services.
(Copies of Handbook H-28 may be obtained upon application, accompanied by money order, coupon, or cash, to the Superintendent of Documents, Government Printing Office, Washington 25, D.C.).

BUREAU OF ORDNANCE STANDARDS
NAVORD Ordnance Std. No.4 - Standard finishes, Tolerances and Allowances.
NAVORD Ordnance Std. No.52 - Painting of Ordnance Material.

BUREAU OF ORDNANCE PAMPHLETS
OP 400 - General Specifications for Manufacture and Inspection of Ordnance Material for the U.S. Navy.
OP 1303 - U.S. Navy Synchros, Description and Operation.

BUREAU OF ORDNANCE DATA
NAVORD OD 3448 - Instruction for furnishing spare parts.

2.3 Drawings.--The following Bureau of Ordnance drawings, of the issue in effect on date of invitation for bids, form a part of this specification:

(Copies of Bureau of Ordnance specifications, publications and drawings may be obtained upon application to the Bureau of Ordnance, Navy Department, Washington 25, D.C.).

Standard Units

Table I

Synchro	Mark	Type	Mounting	Requisition Drawing	Weight Lbs. (approx.)
Transmitter	14	1HG	Flange	561790	2
Transmitter	10	3HG	Flange	561791	3
Transmitter	6	5HG	Flange	561792	5
Transmitter	7	6HG	Flange	561793	8
Transmitter	9	7HG	Flange	561794	18
Differential Transmitter	13	1HDG	Flange	561790	2
Differential Transmitter	8	3HDG	Flange	561791	3
Differential Transmitter	9	5HDG	Flange	561792	5
Differential Transmitter	10	6HDG	Flange	561793	8
Differential Transmitter	11	7HDG	Flange	561794	18
Receiver	8	1F	Flange	561790	2
Receiver	9	3F	Flange	561791	3
Receiver	4	5F	Flange	561792	5
Receiver	16	3B	Bearing	561795	3
Differential Receiver	1	1D	Flange	561790	2
Differential Receiver	3	3D	Flange	561791	3
Differential Receiver	7	5D	Flange	561792	5
Control Transformer	11	1HCT	Flange	255711	2
Control Transformer	7	3HCT	Flange	561791	3
Control Transformer	6	5HCT	Flange	561792	5
Mount	2	For Size 3 Bearing Mounted	Flange	561796	2

Replacement Units

Table II

(These units are to be manufactured only to replace like units already installed.)

Synchro	Mark	Mod	Type	Mounting	Requisition Drawing	Weight Lbs. (approx.)
Transmitter	8		7SG	Flange	164364	18
Receiver	5		5B	Bearing	164367	6
Receiver	6		5N	Nozzle	164368	5
Receiver		1	5SB	Bearing		6
Receiver		1	5SN	Nozzle		5
Receiver		2	5SB	Bearing		6
Control Transformer	1		5CT	Flange	202423	5
Control Transformer	2		6CT	Flange	202424	8
Control Transformer	4		5CT	Flange		5
Control Transformer		1	5CTB	Bearing		5
Control Transformer		2	1CT	Flange		1
Control Transformer		2	*5SB1	Bearing		7
Control Transformer		2	5SCT	Flange		5
Control Transformer		3	**1CT	Flange		1
Control Transformer		4	5SCT	Flange		5
Control Transformer	8		*5CTB	Bearing	561788	7

* Type 5SB1 Mod 2 has been changed to Synchro Control Transformer Mark 8 Type 5CTB.

** Type 1CT Mod 3 is identical with Synchro Control Transformer Mark 5 Type 1CT and should be replaced with the latter.

Special Units

Table III

(These units are for special engineering designs only and specific approval must be given before any of them may be used.)

Synchro	Mark	Mod	Type	Mounting	Requisition Drawing	Weight Lbs. (approx.)
Transmitter	1		5G	Flange	561792	5
Transmitter	2		6G	Flange	561793	8
Transmitter	3		7G	Flange	561794	18
Transmitter	4		8G	Flange	164363	60
Transmitter	5		1G	Flange	561790	1
Differential Transmitter	1		1DG	Flange	561790	1
Differential Transmitter	3		5DGB	Bearing	561788	5
Differential Transmitter	4		5DG	Flange	561792	5
Differential Transmitter	5		6DG	Flange	561793	8
Differential Transmitter	6		7DG	Flange	561794	18
Differential Transmitter	7		8DG	Flange	164365	60
Receiver	5		5B	Bearing	164367	6
Receiver	6		5N	Nozzle	164368	5
Receiver	14		1HF	Flange	561790	1
Receiver	15		3HF	Flange	561791	3
Receiver		1	5SB	Bearing		6
Receiver		1	5SN	Nozzle		5
Receiver		2	5SB	Bearing		6
Differential Receiver	5		1HD	Flange	561790	1
Differential Receiver	6		3DB	Bearing	561795	3
Differential Receiver	9		5DB	Bearing	561788	6
Control Transformer	5		1CT	Flange	255711	1
Differential Transmitter	16		3DGB	Bearing	561795	3
Control Transformer	12		3CTB	Bearing	561795	3

Table III (Cont'd)

Synchro	Mark Mod	Type	Mounting	Requisition Drawing	Weight Lbs. (approx.)
Receiver	11	5HF	Flange	561792	5
Control Transformer	3	5CT	Flange	561792	5

Table IV

Packaging and Packing Drawings

Synchro Size	BuOrd Drawing
1	515719
3	515719
5	515720
6	515721
7	515722

Auxiliary Units

Table V

Standard Synchro Capacitor Units

Mark	Type	Requisition Drawing	For use with Synchros	Rated total Capacitance Mfd.	Rated Capacitance Per leg.Mfd.
1	3C	216891	5D,5DB,5DG,5DGB, 5HD's,5HDG's,3D, 3DG	30	10
2	6C	216891	6CT	60	20
3	9C	216891	6DG,6HDG	90	30
4	15C	216891	7DG,7HDG	150	50
12	1C	257136	1CT Mk 5 all Mods 5CT Mk 3 all Mods 5HCT Mk 6 all Mods 5CT Mk 1 Mod 4 3HCT Mk 7 all Mods 1HCT Mk 11 all Mods	1.8	0.6
13	2C	257136	5CT Mk 1 Mod 3	4.2	1.4
14	4C	257136	1CT Mod 1 1DG,1HDG 1D,1HD	9	3
*15	7C	216891	6DG,6HDG	75	25

* To be used in lieu of the Mark 3 Capacitor since the total capacitance more nearly approximates the optimum capacitance required for 6DG's and 6HDG's.

3. REQUIREMENTS

3.1 Material and Workmanship.--

3.1.1 General.--

3.1.1.1 Suitability.--All materials used in the construction of synchro units shall be in accordance with the referenced specifications and of the quality best suited for the purpose intended. Material used shall be the lightest practicable, consistent with safety and reliability.

3.1.1.2 Reference Specifications.--Where specifications are referred to for a given material, it is the intent to require that the quality of material used shall be at least equal to that covered in the referenced Navy Department specifications.

3.1.1.3 Departures from Reference Specifications.--The use of materials differing from the referenced Navy Department specifications will be considered when it can be clearly demonstrated that an improvement in operating characteristics, or a saving in weight without sacrifice in reliability can be accomplished thereby. Specific approval by the Bureau of Ordnance shall be obtained where departures are made from the referenced specifications.

3.1.2 Stability of Materials.--Any varnish, lacquer or paint employed in the manufacture of synchro units shall be chemically stable to the extent that, under the extreme range of temperatures, gases or vapors shall not be emitted in sufficient quantity to form an explosive, toxic or corrosive mixture inside any instrument nor shall there be a distillation of varnish products that might settle on the bearings or slip rings. The use of rubber or any compound containing sulphur in appreciable quantity is prohibited.

3.1.3 Use of Aluminum Alloys.--

3.1.3.1 Light Weight.--Approved corrosion-resisting aluminum alloys shall be used for the manufacture of low-stressed or unstressed structural parts insofar as the design and limitations of the available alloys permit. The purpose of the use of aluminum is to save weight.

3.1.3.2 Bolting.--Through bolting shall be used wherever practicable, unless otherwise approved by the Bureau of Ordnance. All bolts, nuts and screws shall be positively fastened to

avoid loosening under vibration and shock. See Ordnance Sketch 58366 for a list of approved fastenings.

3.1.3.3 Dissimilar Metals.--Contact of dissimilar metals shall be avoided as much as practicable in the assembly of parts in which aluminum alloys are used.

3.1.4 Protection against Corrosion and Fungus Growth.--All parts of the equipment shall, when practicable be adequately protected against deterioration due to corrosion and fungus growth. All bolts, nuts, studs, pins, screws, terminals, springs, washers shall be where practicable of an approved corrosion-resisting material, or be of a suitable material treated in an approved manner to render it adequately resistant to corrosion and treated for fungus growths in accordance with specification 52T15.

3.1.5 Soldering.--All soldering shall be performed with an approved non-corrosive flux. Immediately after the completion of soldering operations all excess flux shall be removed.

3.1.6 Interchangeability.--

3.1.6.1 All standard units of the same Mark and Type shall be interchangeable.

3.1.6.2 All possible parts of units of the same Mark, Mod and Type shall be interchangeable. All possible parts of synchros of a given Mod and size shall be interchangeable without fitting.

3.1.7 Threaded Parts.--

3.1.7.1 National screw-thread standards.--All screw threads used in the construction of the equipment shall be in accordance with the National Bureau of Standards Handbook H-28 (1944) - Screw Thread Standards for Federal Services.

3.1.7.2 Screw-thread series.--Unless otherwise specified or specifically approved by the Bureau of Ordnance, the number of threads and general dimensions shall be those specified for the American National coarse-thread series or the American National fine-thread series. Threads of the coarse-thread series are preferred, except where definite improvements in design or operating characteristics would be affected by use of the fine-thread series.

3.1.7.3 Screw-thread fits.--For both the coarse-thread and the fine-thread series, the screw-thread fits as approved by the Inter-departmental Screw-thread Committee are to be applied on the equipment as follows:

Class 1 (loose) fit is not to be specified or used.

Class 2 (free) fit may be specified or permitted for electrical terminals and fittings, wiring appliances, connection studs, and other electrical parts where a moderate amount of play or shake is not objectionable and ease of assembly is essential. Except as indicated above, this fit is not to be used without the specific approval of the Bureau of Ordnance.

Class 3 (medium) fit is required for all types of equipment for which a good grade of interchangeable threaded work is necessary. This fit is to be used as the general all-round machinery fit.

Class 4 (close) fit precludes strict interchangeability, and is therefore not to be specified or used.

3.1.7.4 Forms and dimensions of screw heads, bolt heads, nuts, and wrench openings shall conform to the standards approved by the Inter-departmental Screw Thread Committee, except on specific approval. All screws used for electrical terminal connections shall be of a standard slotted head type.

3.1.8 Plastics.--All molded and laminated plastic materials shall be mineral filled and natural color only.

3.1.9 Workmanship.--The workmanship shall be first class in every particular.

3.2 General Requirements.--

3.2.1 Definitions.--

3.2.1.1 Angular Measurement.--All positive angles are measured in a counterclockwise direction from the electrical zero position. All directions of rotations and observations of synchro units given in this specification are considered as viewed from the shaft extension end.

3.2.1.2 Heading.--The heading of a unit is its angular displacement from the electrical zero position measured counterclockwise.

3.2.2 Vibration and Shock.--All units shall be so designed that vibration or shock as defined by test herein will not markedly affect the accuracy or operation of the unit.

3.2.3 Differential Expansion.--All equipment shall have provision to prevent binding of moving parts due to differential expansion as a result of temperature changes.

3.2.4 Speeds of Rotation.--All low speed synchro units shall be designed to operate up to 300 rpm continuously for 500 hours and still meet all the requirements of this specification. All high speed units shall be designed to operate up to 1200 rpm continuously for 1500 hours and still meet all the requirements of this specification.

3.2.5 Position of Operation.--All equipment covered by this specification shall operate in any position within the specified accuracies.

3.2.6 Rotor Shafts.--Rotor shafts shall be of approved corrosion resisting steel or, in lieu thereof, of carbon or chrome nickel-steel of suitable magnetic properties. Carbon steel shall be suitably protected against corrosion. The shafts shall be heat-treated to an elastic limit of at least 100,000 pounds per square inch and a tensile strength of at least 115,000 pounds per square inch. The elongation of a test sample shall be not less than 8 percent in 2 inches after heat treatment. Lathe centers shall be preserved if practicable.

3.2.7 Rotor and Stator Cores, Stacking.--Rotor and stator cores shall be stacked of high grade non-aging electrical sheet steel.

3.2.8 Impregnation.--All rotor and stator core assemblies shall be dried in a vacuum of at least 25 inches of mercury at a temperature between 100°C. and 110°C. for at least an hour; then without exposure to the air, shall be impregnated with a baking type insulating compound of an approved polymerizing type in accordance with Navy Department Specification 52V13 Type M varnish or an approved equivalent so that after curing, subsequent heating will not cause it to flow. The time, temperature, pressure and procedure for curing the compound shall be in accordance with the recommendation of the manufacturer of the compound. Finished windings shall show no localized collections of varnish. Deep drying or solventless type varnishes will be considered for this application subject to test of a manufacturer's particular type of unit. If a manufacturer desires to use such varnish, approval shall be obtained from the Bureau of Ordnance.

3.2.9 Insulation Distances.--The distance between uninsulated live parts to ground or to uninsulated live parts of opposite polarity shall be not less than .10 inches through air and .1875 inches across surface for mineral filled phenolics. If a surface material (such as mineral filled melamine or silicone) is used which will not provide a permanent low resistance path after arcing, the distance between uninsulated live parts may be reduced to .10 inches across surface.

3.2.10 Nameplates.--Nameplates shall be positively secured to the synchro. They shall include the following data:

U.S. Navy - Bureau of Ordnance

Synchro_____

Mark _____ Mod_____ Type_____

Weight_____ Serial No._____

Manufacturer's Name

_____/_____V., 60 cycle Ord.Dr._____

3.2.11 Ambient and Operating Temperatures.--Equipment covered by this specification shall be capable of operating without damage at ambient temperatures from -25°C to +65°C and maintain the specified accuracy requirements within 5%.

3.2.12 Voltage and Frequency Rating.--Synchro units shall be designed for operation from a basic power supply of 115 volts, 60 cycle, single phase alternating current, but shall be capable of satisfactory performance within the following limits of voltage and frequency variation:

Voltage: 115 ±7 volts
Frequency: 60 ±5 cycles per second

3.3 Detail Requirements.--

3.3.1 Synchro Transmitter.--The function of a synchro transmitter is to transmit orders electrically, by impressing upon the three wire secondary circuits, three voltages the values of which are dependent upon the angular position of the rotor.

A synchro transmitter consists of a stator and rotor inductively coupled and rotatable with respect to each other. The rotor is the primary, and is provided with a single phase winding having two emerging leads marked R1 and R2. The primary (rotor) winding is connected to the supply circuit, normally 115 volts, 60 cycles single phase, A.C. The stator is the secondary and is provided with a symmetrical three-phase winding having terminals marked S1, S2 and S3. When viewed from the shaft the stator markings shall be S1, S2, and S3, increasing in a counterclockwise direction. On open circuit with rated voltage applied to the primary winding, the stator is so wound as to give at its terminals three single phase voltages of magnitudes:

$$E(S13) = 90 \sin a,$$
$$E(S32) = 90 \sin (a + 120^{o}),$$
$$E(S21) = 90 \sin (a + 240^{o}).$$

where "a" is the counterclockwise angular displacement of the rotor from electrical zero.
E(S13) is the voltage between terminals S1 and S3. Other voltages are similarly defined.

The design of synchro transmitters and receivers in which the stator is the primary and the rotor is provided with a symmetrical three-phase winding having leads S1, S2 and S3, is approved, provided this design results in the production of units that are equal or superior in their individual and system characteristics to the synchro receiver and transmitter described herein.

3.3.2 Synchro Differential Transmitter.--The function of a synchro differential transmitter is to receive at its primary terminals an order from a synchro transmitter, modify this order by an angle equal to the rotor displacement from the electrical zero and transmit the modified order from its secondary terminals to other synchro units. A synchro differential transmitter consists of a stator and rotor inductively coupled and rotatable with respect to each other. The rotor and stator are each provided with a symmetrical three-phase winding. The stator normally receives the magnetizing current from a synchro transmitter and capacitor and is considered the primary; its terminals are marked S1, S2 and S3, in counterclockwise order, viewed from the shaft end. The rotor is normally driven mechanically to modify the received order and is considered the secondary; its terminals are marked R1, R2 and R3, in counterclockwise order, viewed

from the shaft end. The primary receives from a synchro transmitter three single-phase voltages of magnitudes:

$$90 \sin a,$$
$$90 \sin (a + 120^{\circ}),$$
$$90 \sin (a + 240^{\circ}).$$

(where a is the counterclockwise angular displacement of the transmitter rotor from its electrical zero position.) The secondary has induced in it voltages of magnitudes $90 \sin (a - b)$, $90 \sin (a - b + 120^{\circ})$, $90 \sin (a - b + 240^{\circ})$ where b is the counterclockwise angular displacement of the differential rotor from its electrical zero position.

3.3.3 Synchro Receiver.--The function of a synchro receiver is to rotate in response to an impressed order and position an indicating dial. A displacement of the receiver rotor from a position of correspondence with the transmitter rotor creates a condition of electrical unbalance in the secondary circuit and currents are thereby caused to flow, which, by the torque produced, tend to restore the receiver rotor to the position of correspondence, at which position the three voltages induced in the receiver secondary become equal and opposite to those induced in the transmitter secondary. Under such a condition minimum current flows and there is no torque developed. Since the rotor is free to turn, it has a tendency to operate as an induction motor. It is therefore necessary to provide suitable damping devices to prevent "spinning" and excessive oscillation about the position of correspondence. A synchro receiver is electrically similar to a synchro transmitter.

3.3.4 Synchro Differential Receiver.--The function of a synchro differential receiver is to receive two electrical orders, one of which is impressed on the stator and one on the rotor, causing its rotor to assume a position that corresponds to the sum or difference of the two orders received and to position an indicating dial. The principle of operation of the synchro differential receiver is similar to that of a synchro receiver in respect to the balancing of voltages in the secondary circuits and the equilibrium position of minimum current and zero torque. Since the receiver is free to turn, it must be provided with a suitable damping device to prevent spinning or excessive oscillation. A synchro differential receiver is electrically similar to a synchro differential transmitter.

3.3.5 Synchro Control Transformer.--A synchro control transformer consists of a stator and a rotor inductively coupled and rotatable with respect to each other. The stator normally receives the magnitizing current and is considered the primary; it has a three-phase symmetrical winding and is connected to three emerging leads marked S1, S2, and S3. The primary receives a synchro signal consisting of three single-phase voltages of magnitudes: 90 sin(a), 90 sin (a +120°), 90 sin (a +240°) (where a is the heading of the synchro signal). The secondary shall have a single phase winding and the open circuit voltage E(R12) induced in the secondary shall be (57 ±3) sin (a-c) (where c is the angular displacement counterclockwise of the control transformer rotor from its position of electrical zero). The secondary voltage shall be designed to be impressed on a circuit whose impedance shall not be less than 10,000 ohms for size 3 and 5 control transformers and 15,000 ohms for size 1 control transformers. The output voltage E(R12) induced in the secondary of a control transformer is approximately in phase with the primary supply voltage E(R12) of the synchro system when the unit is directly connected and displaced counterclockwise from its electrical zero position.

3.3.6 Electrical Zero.--

3.3.6.1 Synchro Transmitters and Receivers.--The electrical zero position of transmitters and receivers is that position of the rotor with respect to the stator in which minimum voltage is induced in the secondary circuit S1-S3 and in which the secondary voltages E(S21) and E(S23) are approximately in phase with the primary voltage E(R12).

3.3.6.2 Synchro Differential Transmitters and Differential Receivers.--The electrical zero position of differential transmitters and differential receivers is that position of the rotor with respect to the stator in which minimum voltage is induced in the circuit R1-R3 and in which the voltages E(R13), E(R32) and E(R21) are approximately in phase with the corresponding voltages E(S13), E(S32) and E(S21) when the unit is energized by applying 78 volts A.C. between S2 and connected terminals S1 and S3.

3.3.6.3 Synchro Control Transformer.--The electrical zero position of a control transformer is that position of the rotor with respect to the stator in which minimum voltage is induced in the secondary circuit R1-R2 when the unit is energized by applying 78 volts A.C. between S2 and connected terminals S1

and S3, and so determined that for small deflection of the rotor counterclockwise from electrical zero the induced voltage E(R12) is approximately in phase with the voltage E(S21) or E(S23).

3.3.7 Collector Rings and Brush Rigging for Mechanically Driven Rotors (Transmitters, Differential Transmitters and Control Transformers).--

3.3.7.1 General.--Collector rings, brushes and brush rigging shall be designed in proportion to the unit on which they are to be used. All new units shall be designed for high speed continuous operation. Not more than one collector ring shall intervene in any leg of either stator or rotor circuit between the winding and the final external connection. The stator and rotor brushes of all bearing mounted synchros shall be held in a brush holder mounted on a fixed support and the brushes shall bear on collector rings which are connected to the respective windings.

3.3.7.2 Rotor Ring Construction.--Rotor collector rings shall be surfaced with not less than 1/64 inch hard rolled or hard drawn silver, 99 plus per cent fine, or other approved material, molded into (or otherwise firmly secured to) an approved plastic material of the type best adapted to this use. The finished ring shall be as hard as practicable and not less than Vickers No.70. Collector rings shall be smooth and polished with no abrasives imbedded, indentations, or irregularities in the surface.

3.3.7.3 Stator Ring Construction.--Stator collector rings for bearing mounted units shall be surfaced with 99 plus per cent fine silver, or other approved material, not less than 1/64 inch in thickness, rolled or drawn as hard as practicable from stock material not less than Vickers No.70. Collector rings shall be smooth and polished with no abrasives imbedded, indentations, or irregularities in the surface.

3.3.7.4 Brushes.--Brushes shall consist of a formed block of silver graphite composition or other material of suitable composition possessing self-lubricating properties.

3.3.7.5 Brush Rigging.--Brush rigging shall be so designed as to insure the maintenance of the initial brush pressure indefinitely under service conditions. The brush pressure shall not result in scoring of collector rings. The brush rigging shall be so designed as to maintain the brushes at

all times in a fixed position, and at the same time prevent any tendency toward chattering.

3.3.7.6 Brush Rigging Approval.--The approval of a particular design of brush or brush rigging shall be on the same basis as that provided for synchro units and shall also apply to any change in the design of such rigging which may have had prior approval.

3.3.8 Collector Rings and Brush Rigging for Free Rotors (Receivers and Differential Receivers).

3.3.8.1 General.--Not more than one collector ring shall intervene, in any leg of either stator or rotor circuit, between the winding and the final external connection. The stator and rotor brushes of all bearing mounted synchros shall be held in a brush holder mounted on a fixed support and the brushes shall bear on collector rings which are connected to the respective windings.

3.3.8.2 Rotor Ring Construction.--Rotor collector rings shall be surfaced with not less than 1/64 inch hard rolled or hard drawn silver, 99 plus per cent fine, or other approved material, molded into (~~or otherwise firmly secured to~~) an approved plastic material of the type best adapted to this use. The finished ring shall be as hard as practicable and not less than Vickers No. 70. Collector rings shall be smooth and polished with no abrasives imbedded, indentations or irregularities in the surface.

3.3.8.3 Stator Ring Construction.--Stator collector rings for bearing mounted units shall be surfaced with 99 plus per cent fine silver, or other approved material, not less than 1/64 inch in thickness, rolled or drawn as hard as practicable from stock material not less than Vickers No. 70. Collector rings shall be smooth and polished with no abrasives imbedded, indentations, or irregularities in the surface.

3.3.8.4 Brushes.--Each brush shall consist of a button of annealed pure silver or other approved material. For high speed operation the brush material shall be suitable for the purpose intended.

3.3.8.5 Brush Springs.--Brush springs shall not have sharp bends and shall have physical characteristics and mounting such as to insure the maintenance of the initial brush pressure indefinitely under service conditions. The stator and

rotor brushes of ball bearing mounted units shall be held in a brush holder mounted on a fixed support and the brushes shall bear on collector rings which are connected to the respective windings.

3.3.8.6 Brush Wiping Action.--Brush shall be designed to provide wiping action between the brush and collector ring.

3.3.9 Windings.--

3.3.9.1 Assemblies.--Rotor and stator core assemblies shall be wound with Formvar insulated wire or an approved equal. The leads from the stationary windings and the brushes shall be brought out to terminal blocks. Bearing mounted synchros shall have terminals carried by the brushholder.

3.3.10 Ball Bearings.--

3.3.10.1 Selection.--Ball bearings of the radial or radial thrust type of standard size as given in the requisition drawings, shall be used. Any modification of ball bearings by the synchro manufacturers such as using special races, special ball separators, etc. must be approved and the bearing must be interchangeable with commercial type bearings. It is the intent of this specification to insure that standard unmodified commercially available ball bearings be used. Of primary consideration are the qualities of uniformity, low friction and ease of replacement. Bearings shall be especially selected for minimum friction. Extreme care shall be exercised in cleaning the bearings before assembly and every precaution taken to prevent the entrance of dust or foreign matter or the development of corrosion into the bearings. Grade I (precision) ball bearings in accordance with Navy Department Specification 42B5 are required for receivers and differential receivers. Other type bearings may be used in transmitters, differential transmitters and control transformers if approved by the Bureau of Ordnance.

3.3.10.2 Lubrication.--All synchro transmitters, differential transmitters and control transformers shall be lubricated with grease. The grease shall conform with Navy Department Specification 14G8 (Ord). Any variation from this grease shall require prior approval by the Bureau of Ordnance. All synchro receivers and differential receivers shall be lubricated with oil. The oil shall conform with Navy Department Specification 14020. Any variation from this oil shall require prior approval by the Bureau of Ordnance.

3.3.11 Breathing.--The design shall be such as to prevent the collection of dust or moisture in bearings or the inside of synchro units. Collector ends and brush covers shall be designed to protect the unit against the entrance of dust and to permit checking the brush tension. No breathing holes shall be provided which allow breathing through the bearings. Bearing knock-out holes when provided, shall be suitably closed. Two (2) breathing holes 1/16 inch in diameter shall be provided. They shall be located in a suitable place so that there is no breathing through the bearings.

3.3.12 Limits of Tolerances.--Tolerances given on requisition drawings shall be measured as total indicator readings.

3.3.13 Balance.--Balancing of rotors by the addition of varnish or other material which may shift position when heated, is not permissible.

3.3.14 Limiting Values for Synchro Units

3.3.14.1 Transmitters

Type of Synchro	1G or 1HG	3G or 3HG	5G or 5HG	6G or 6HG	7G or 7HG
Static Accuracy Maximum Error (minutes)	18	18	18	18	18
Torque Gradient - Minimum (oz-in/deg)	0.06	0.25	0.40	1.2	3.4
Secondary Peak Voltage Limits Minimum Voltage Maximum Voltage	 88.2 91.8	 88.2 91.8	 88.2 91.8	 88.2 91.8	 88.2 91.8
Primary Current (amperes)(max)	0.30	0.40	0.60	1.3	3.0
Primary Power (watts)(max)	4.8	5.5	7.0	15.0	22.0
Secondary load Current (amperes)(max)	0.04	0.20	0.35	0.70	1.50
Temperature Rise (^{o}C)(max)	50	50	50	50	50

3.3.14.2 Receivers

Type of Synchro	1HF 1F	3F 3HF 3B	5F 5HF 5B
Static Accuracy Maximum Error (degrees)	1.50(1F) 2.50(1HF)	0.60(3F,3B) 1.0(3HF)	0.60(5F,5B) .75(5HF)
Torque Gradient (oz-in/degree) Minimum	0.06	0.25	0.40
Secondary Peak Voltage Limits Minimum Voltage Maximum Voltage	88.2 91.8	88.2 91.8	88.2 91.8
Primary Current (amperes) Maximum	0.30	0.40	0.60
Primary Power (watts) Maximum	4.8	5.5	7.0
Secondary Load Current (amperes)(max)	.04	.20	.35
Temperature Rise (^{o}C)(max)	50	50	50

3.3.14.3 Differential Transmitters

Type of Synchro	1DG 1HDG	3HDG	5DG or 5HDG	6DG or 6HDG	7DG or 7HDG
Static Accuracy Maximum Error (minutes)	18	18	18	18	18
Torque Gradient - Minimum (oz-in)	.035	0.15	0.3	1.4	4.0
Secondary Peak Voltage Limits					
Minimum Voltage	88.2	88.2	88.2	88.2	88.2
Maximum Voltage	91.8	91.8	91.8	91.8	91.8
Primary Current (Amperes)Maximum					
Without capacitor	0.3	0.7	1.0	2.0	3.5
With capacitor	0.15	0.20	0.25	0.55	0.55
Primary Power (Watts)Maximum	8.0	13.0	15.0	23.0	30.0
Secondary Load Current (amperes)(max)	0.020	0.18	0.25	0.80	2.00
Temperature Rise (^{o}C)(max)	50	50	50	50	50

3.3.14.4 Differential Receivers

Type of Synchro	1D,1HD	3D	5D
Static Accuracy Maximum Error (degree)	3.0	1.35	0.9
Torque Gradient (oz-in) Minimum	.035	0.15	0.30
Secondary Peak Voltage Limits Minimum Voltage Maximum Voltage	88.2 91.8	88.2 91.8	88.2 91.8
Primary Current (amperes)(maximum) With capacitor Without capacitor	0.15 0.30	0.20 .70	0.25 1.0
Primary Power (watts)(maximum)	8.0	13.0	15.0
Secondary Load Current (amperes)(maximum)	0.020	0.18	0.25
Temperature Rise (^{o}C)(maximum)	50	50	50

3.3.14.5 Control Transformers

Type of Synchro	1CT 1HCT	3HCT	5CT, 5CTB or 5HCT
Static Accuracy Maximum Error (minutes)	18	18	18
Voltage Gradient (volts per degree)	1.0±5%	1.0±5%	1.0±5%
Null Voltage (maximum) (volts r.m.s.)	above null 0.06	above null 0.04	above null 0.04
Primary Current (amperes)(maximum)			
Without capacitor	.035	.035	.035
With capacitor	0.020	0.020	0.020
Secondary Peak Voltage Limits			
Minimum Voltage	54	54	54
Maximum Voltage	60	60	60
Primary Power (watts)(maximum)	.7	.7	.7
Rotor Impedance (maximum)(nominal) ohms	950	400	200

3.3.15 Drawings.--

3.3.15.1 Preliminary Drawings.--Preliminary drawings with bids will not be required inasmuch as all synchro units proposed in the bids, including the drawings of these units, must have previous type approval before they will be considered on bids. All bids shall state whether or not any changes are contemplated in synchro units, types of which have been previously approved and furnished by the bidder under this specification. The bidder shall submit with his bid four (4) copies of the proposed spare parts lists where spare parts are required to be furnished under the contract.

3.3.15.2 Approval Drawings.--Two (2) complete sets of prints showing and describing sufficient details of construction to judge the unit including winding data and connection diagrams shall be submitted by each manufacturer for each Mark, Mod and type of synchro unit for type approval. These plans shall be submitted to the Bureau of Ordnance prior to or at the time of submission of synchro units for type approval tests. In general, these plans shall be in accordance with the requirements of Ordnance Pamphlet 400. Approximately full size photographs of the synchro units shall be submitted as part of the descriptive matter.

3.3.15.3 Record Drawings.--Manufacturers of synchro units will be required to furnish a complete set of reproducible tracings, including wiring and connection diagrams, assembly and detail drawings for each Mark, Mod and Type of unit. These plans shall be in accordance with the requirements of "Drawings for Record" set forth in Ordnance Pamphlet 400.

4. SAMPLING, INSPECTION, AND TEST PROCEDURES

4.1 Tests shall be divided into the following:

(a) Type Approval Tests.
(b) Inspection Tests at Manufacturer's Plant.

4.2 Type Approval Tests.--

4.2.1 All synchro units specified herein shall be tested for Type Approval at a Government Activity. Material to be acceptable for purchasing purposes shall satisfactorily pass the Type Approval Tests prior to opening of bids.

4.2.2 For Type Approval Tests three (3) synchro units of each Mark, Mod, Type and Design shall be submitted together with approval drawings to the Bureau of Ordnance. No unit shall be considered for purchase unless such unit is identical in electrical and mechanical characteristics and interchangeable with units which have passed the above-mentioned Type Approval Tests. Type units, including drawings, of new design shall be submitted for Type Approval Tests not less than 120 days prior to the opening of bids for these units. The manufacturer shall state and clearly indicate in the drawings or descriptive matter accompanying the units submitted for Type Approval Tests and respects, if any, in which the units differ from the requirements of this specification. Approval of the unit shall include approval of said drawings and descriptive specification and approval of all departures from the specifications indicated therein.

4.2.3 General.--

4.2.3.1 Electrical Zero.--Measurements of all angular displacements of the rotors of standard units shall be referred to a standard position which will be designated as "Electrical Zero". This angular position can be ascertained as described below. Caution should be taken in testing units without dampers to prevent their spinning. External friction may be applied or the applied voltage made very low at first and then increased to normal after the rotor has come to rest.

4.2.3.1.1 Receivers and Transmitters.--The electrical zero position of a receiver or transmitter shall be determined by connecting the primary and secondary as shown in Figure 1. An auto-transformer is used to supply 78 ±2 volts to the terminals of the secondary winding. The rotor will assume

approximately the electrical zero position. The electrical zero position, should then be accurately determined as follows: The primary should be energized by impressing 115 volts across terminals R1 and R2 with S1, S2, and S3 open. The rotor should be turned slowly until a minimum indication of the fundamental component of the voltage E(S13) is obtained on a voltmeter after filtering this voltage. The low pass filter shall have a minimum attenuation of 35 db for the 2nd and higher harmonics. The voltmeter shall have a sensitivity of 1 millivolt and a minimum input impedance of 500,000 ohms.

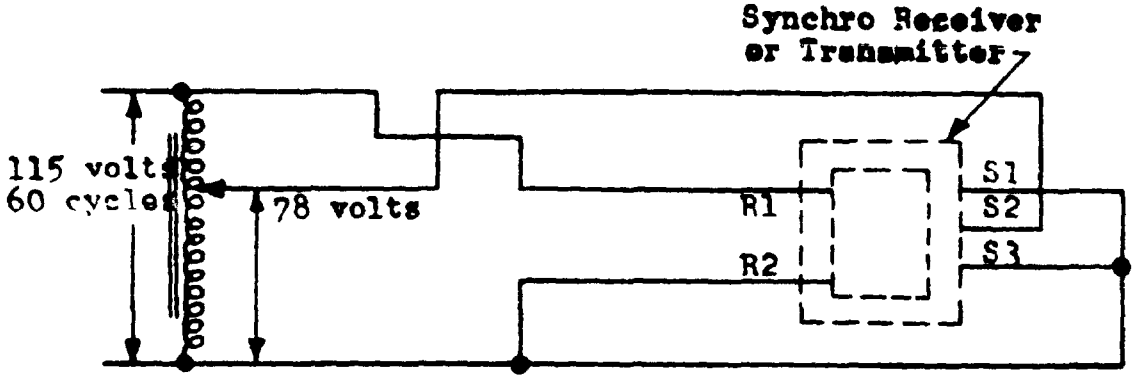


FIGURE 1

4.2.3.1.2 Differential Receivers and Differential Transmitters.--The electrical zero position of a differential receiver or transmitter shall be determined by connecting the primary and secondary to a source of 78 ±2 volts as shown in Figure 2. The rotor will assume approximately the electrical zero position. The electrical zero position of a differential unit should then be accurately determined in a manner similar to that given in 4.2.3.1.1, the 78 volts being applied across terminal S2 and connected terminals S1 and S3. The filter and voltmeter are connected across the R1-R3 terminals.

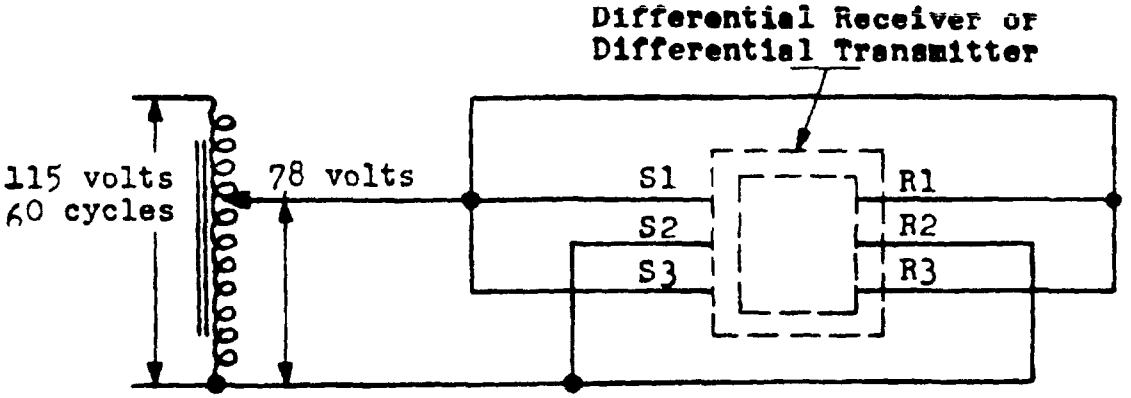


FIGURE 2

4.2.3.1.3 Control Transformer.--The electrical zero position of a control transformer shall be determined by connecting the control transformer to a source of approximately 78 volts in the manner shown in Figure 3. As the rotor is turned the instrument indication will vary from a maximum to a minimum. The electrical zero setting is approximately at the minimum voltage position. This position should be accurately located by connecting 78 volts across terminal S2 and connected terminals S1 and S3, disconnecting R1 and R2 from S1 and S3, respectively, connecting the filter and voltmeter described in 4.2.3.1.1 across R1 and R2, and adjusting the rotor (or stator) until a minimum reading of the fundamental voltage is obtained across R1 and R2.

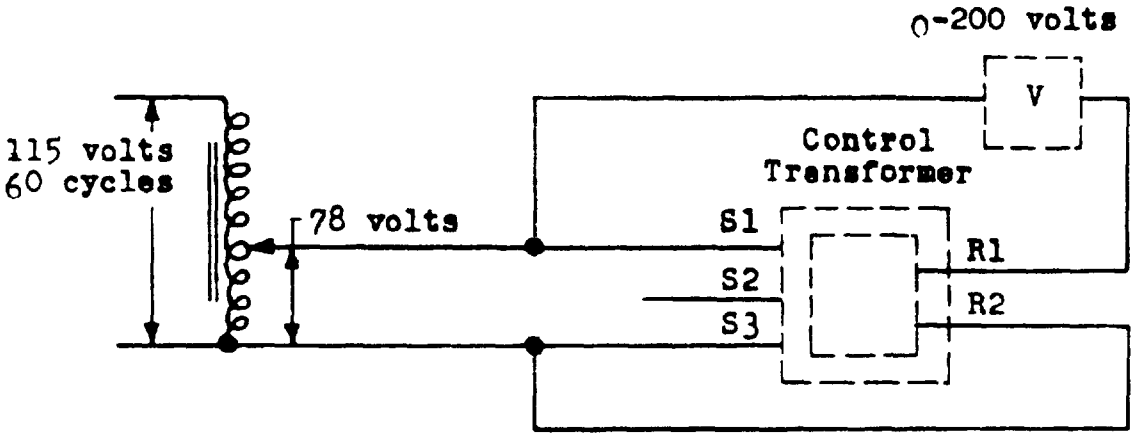


FIGURE 3

4.2.3.2 Calibrated Synchro Unit.--A calibrated synchro unit is one in which the error between the angular position and the electrical position has been accurately determined and a calibration chart plotted. All synchros used as calibrated synchros shall pass the requirements of this specification.

4.2.3.3 Test Power Supply.--All tests shall be made at a line voltage of 115 ±1 volt and at a line frequency of 60 ± 1/2 cycles unless otherwise specified.

4.2.3.4 Test Apparatus.--

4.2.3.4.1 Dials for static accuracy tests.--Dials may be used in making static accuracy tests. When dials are used they shall be in accordance with Bureau of Ordnance Sketch 81883. Readings in all static accuracy tests shall be accurate to at least 3 minutes except for receivers and differential receivers in which case the readings shall be accurate to at least 6 minutes. When dials are not used on receivers the weight and moment of inertia of the device placed on the shaft shall not exceed that of the static accuracy dial shown on Bureau of Ordnance Sketch 81883.

4.2.3.4.2 Dials for synchronizing time tests.--Dials for use in synchronizing time tests shall be in accordance with the dynamic test dial shown on Bureau of Ordnance Sketch No. 81883.

4.2.3.4.3 Dials for spinning tests.--Dials for use in making spinning tests shall be in accordance with the dynamic test dial shown on Bureau of Ordnance Sketch No. 81883.

4.2.3.4.4 Pulley for Torque measurement.--A pulley of at least 3 inches diameter and provided with clamping arrangement suitable for attaching the pulley securely to the shaft of the unit shall be used in the measurement of torque. The synchro unit shall be placed so that the shaft is horizontal and a thread of as great a flexibility as possible consistent with the strength required, secured to the pulley in such a way that weights attached to the other end will cause it to unwind from the pulley. The diameter of the pulley shall be accurately known and in calculating the torque the lever arm used shall be half this diameter. The pulley assembly shall be carefully balanced.

4.2.3.4.5 Synchro Transmitter Loads.--All synchro receivers used as loads for test purposes shall have passed an inspection test.

4.2.3.5 Electrical Instruments.--

4.2.3.5.1 Measurements.--Voltage, current and power measurements shall be made with standard approved calibrated meters of appropriate range so that the readings shall constitute a major portion of full scale deflection except for tests in which series of readings of a variable quantity are being made, e.g., a voltage characteristic test. In such a test the full scale deflection shall be no greater than 1.7 times the largest reading.

4.2.3.5.2 Calibration.--The meters shall be calibrated at sufficiently frequent intervals. The Bureau of Ordnance reserves the right to check the calibration of these meters at frequent intervals.

4.2.3.5.3 Connections.--When a combination of instruments is used in a test, the frequency meter shall be connected on the supply side of all other instruments. The voltage gradient of control transformers shall be measured with a vacuum tube voltmeter responsive to the average value of the rectified wave and with a minimum impedance of 500,000 ohms. The meter shall be calibrated immediately after each reading to give an accuracy of at least 2 percent.

4.2.3.6 Dial Wrenches.--The following dial wrenches shall be used for mounting and adjusting dials and gears on synchro units. For size 3 and size 5 units see Bureau of Ordnance Drawing No. 8-Z-940. For size 1 units, except type 1CT, see Bureau of Ordnance Sketch 81883. For type 1CT units see Bureau of Ordnance Sketch 127068.

4.2.4 Synchro units shall be required to pass the tests designated in the following table for Type Approval:

TABLE VI

Type Approval Tests	Functional Classification					Reference Paragraph	Sheet No.
	G	DG	F	D	CT		
Static Accuracy	X	X	X	X	X	4.2.5	38
Secondary Voltage	X	X	X	X	X	4.2.6	48
Open Circuit Current and Power	X	X	X	X	X	4.2.7	49
Impedance					X	4.2.8	50
Voltage Gradient					X	4.2.9	50
Minimum Voltage					X	4.2.10	50
Capacitance Curve for power factor correction		X		X	X	4.2.11	51
Spinning			X	X		4.2.12	51
Synchronizing Time			X	X		4.2.13	52
Torque Gradient	X	X	X	X		4.2.14	53
Resistance of Windings	X	X	X	X	X	4.2.15	54
Temperature Rise	X	X	X	X		4.2.16	54
Noise	X	X	X	X		4.2.17	56
Vibration	X	X	X	X	X	4.2.18	57
High Potential and Insulation Resistance	X	X	X	X	X	4.2.19	57
Dielectric Test	X	X	X	X	X	4.2.20	58
Shock	X	X	X	X	X	4.2.21	58
Endurance	X	X	X	X	X	4.2.22	58
Mechanical Inspection	X	X	X	X	X	4.2.23	60

4.2.5 Static Accuracy Test.--

4.2.5.1 All synchro transmitters, differential transmitters, and control transformers will be tested for static accuracy by the proportional voltage method. Synchro receivers and differential receivers will be tested for static accuracy against calibrated transmitters of the same size as the receivers.

4.2.5.2 The errors shall be determined for at least every three (3) degree position of the rotor. The unit shall be subject to test in any of the following positions: 0°, 45°, 90°, 135°, 180°, from the vertical. Also each unit submitted for Type Approval Tests shall pass the standard Inspection Tests.

4.2.5.3 Proportional Voltage Method.--Transmitters.-- This method consists in 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:

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

$$\text{where } \Phi = \cot^{-1} \frac{1-2R}{\sqrt{3}} - 60^{\circ}$$

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

M = 0 when voltage E(S13) is in phase with voltage E(R21)
M = 1 when voltage E(S13) is 180 out of phase with voltage E(R21)
and N is determined from the following tables:

Terminals giving largest secondary voltage.	Terminals giving small secondary voltage.	Value of N
S2-S1	S1-S3	0
S1-S3	S3-S2	1
S3-S2	S2-S1	2

The basic circuit employed for static accuracy testing of synchro transmitters is shown in Figure 4. The unit shall be energized with 115 volts 60 cycles across R1-R2. Two 10,000 ohm resistors and a non-inductive decade voltage divider of $10,000 \pm 1$ ohms shall be connected in delta across

the output circuits S1, S2 and S3. The voltage divider shall be accurate to 1 ohm in 10,000 ohms. 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 voltage 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. 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 minimum reading of the electronic voltmeter for the fundamental is obtained. The position of the rotor is then recorded. The error is defined as the rotor position minus the electrical position. The maximum error of a transmitter in absolute value shall not exceed the value given in 3.3.14.1. In addition a positive maximum of the 2nd harmonic of the error shall occur in the 0° to 120° sector. This is done in order to minimize system errors. To facilitate the settings of the voltage divider a table of values of Φ corresponding to various values of R is given in Table VII.

TABLE VII

Values of R for Various Values of Angle ϕ

ϕ°	R
0	.00000
3	.05874
6	.11442
9	.16756
12	.21861
15	.26795
18	.31592
21	.36284
24	.40898
27	.45461
30	.50000
33	.54539
36	.59102
39	.63717
42	.68408
45	.73205
48	.78139
51	.83244
54	.88558
57	.94126
60	1.00000

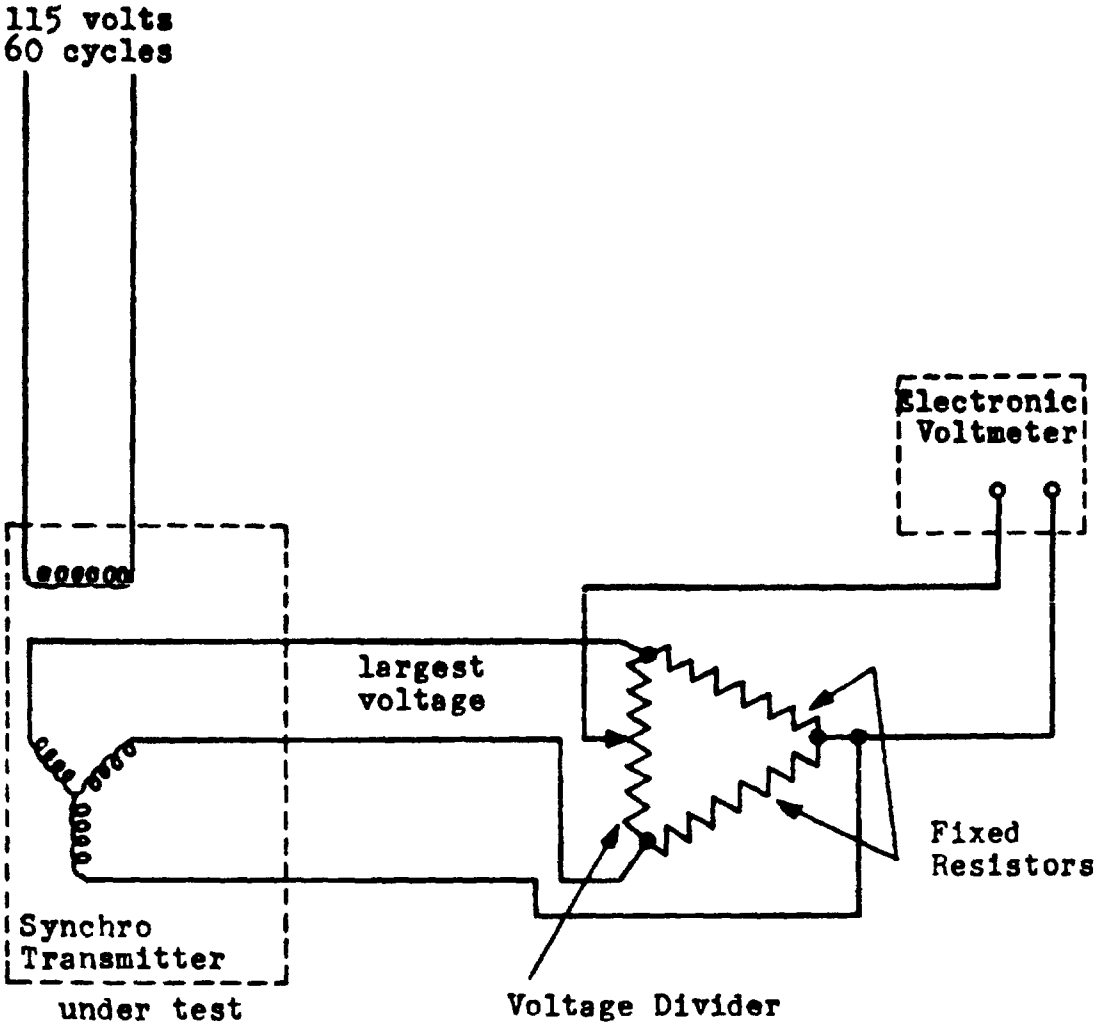


FIGURE 4

Basic Circuit Employed For Static Accuracy Test of Synchro Transmitters.

4.2.5.4 Control Transformers.--The basic circuit for static accuracy testing of control transformers is shown in Figure 5. The unit shall be energized from a size 5 or larger synchro transmitter operated at rated voltage and frequency. The output terminals R1-R2 of the control transformer shall be connected to an electronic voltmeter having an impedance greater than 150,000 ohms. The energizing transmitter shall be turned until its electrical position, measured as described in 4.2.5.3, is at the desired value. The angular position of the unit under test that produces the minimum output voltage shall be determined. The null position shall be so chosen that for a small counterclockwise deflection of the rotor from this position, the output voltage E(R21) is in phase with the voltage E(R21) of the energizing synchro transmitter. The error is defined as the rotor position minus the electrical position. The maximum error of a control transformer in absolute value shall not exceed the value given in 3.3.14.5. In addition a positive maximum of the 2nd harmonic of the error shall occur in the 0° to 120° sector.

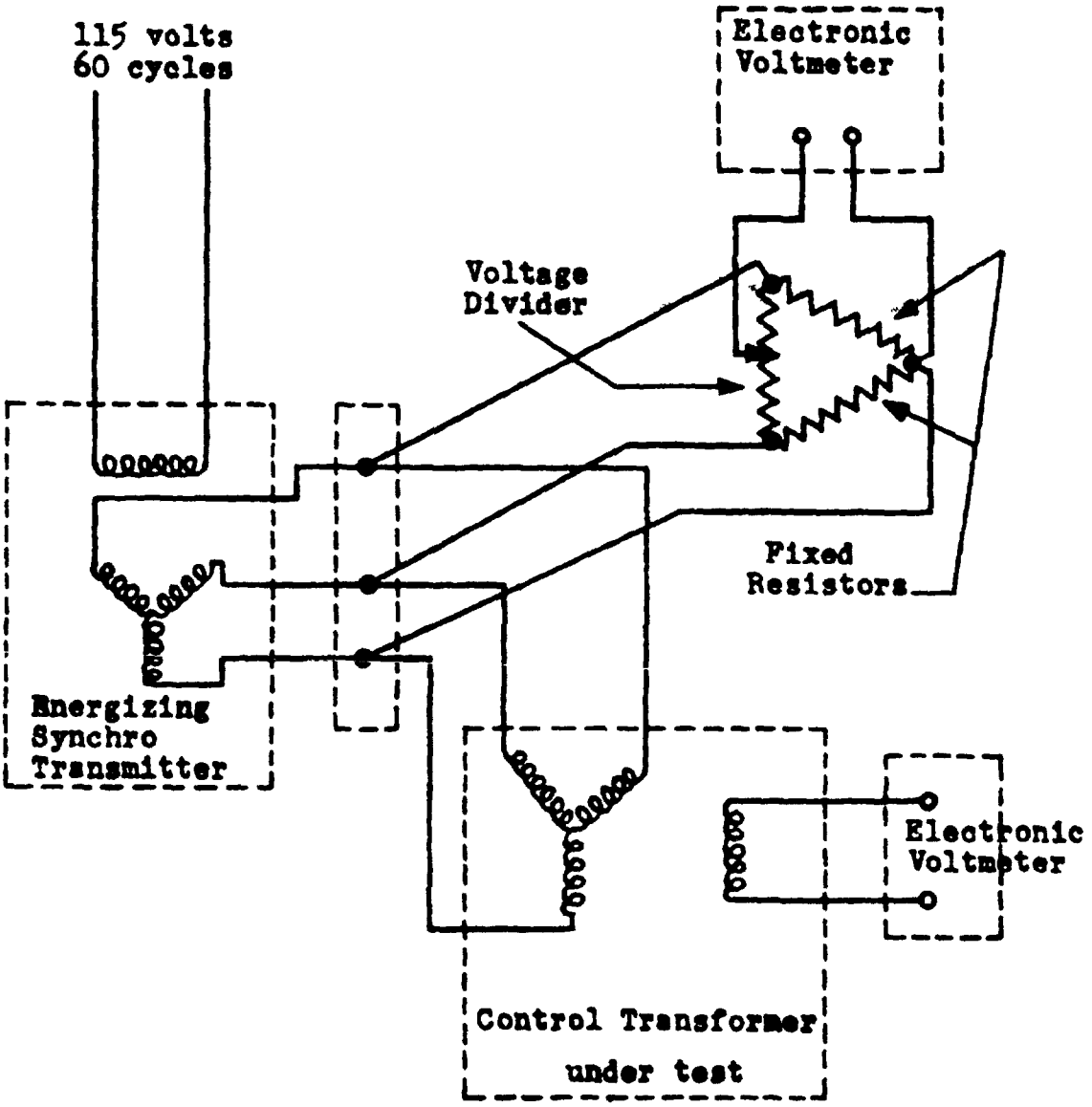


FIGURE 5

Basic Circuit Employed for Static Accuracy Test of Control Transformers.

4.2.5.5 Differential Transmitters.--The static accuracy of both the rotor and the stator shall be determined.

4.2.5.5.1 The basic circuit for static accuracy testing of the rotor windings of differential transmitters is shown in Figure 6. The unit shall be energized with 78 volts 60 cycles across terminals S2 and S1 S3 connected together. 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 4.2.5.3

M = 0 when voltage E(R13) is in phase with voltage E(S23)
M = 1 when voltage E(R13) is 180° out of phase with voltage E(S23)
and N is obtained from the following table:

Terminals giving largest secondary voltage.	Terminals giving small secondary voltage.	Value of N
R2-R1	R1-R3	0
R1-R3	R3-R2	1
R3-R2	R2-R1	2

The error is equal to the sum of the actual position of the rotor plus the electrical position minus 360 degrees. The maximum error in absolute value shall not exceed the value given in 3.3.14.3. In addition a positive maximum of the 2nd harmonic of the error shall occur in the 0° to 120° sector.

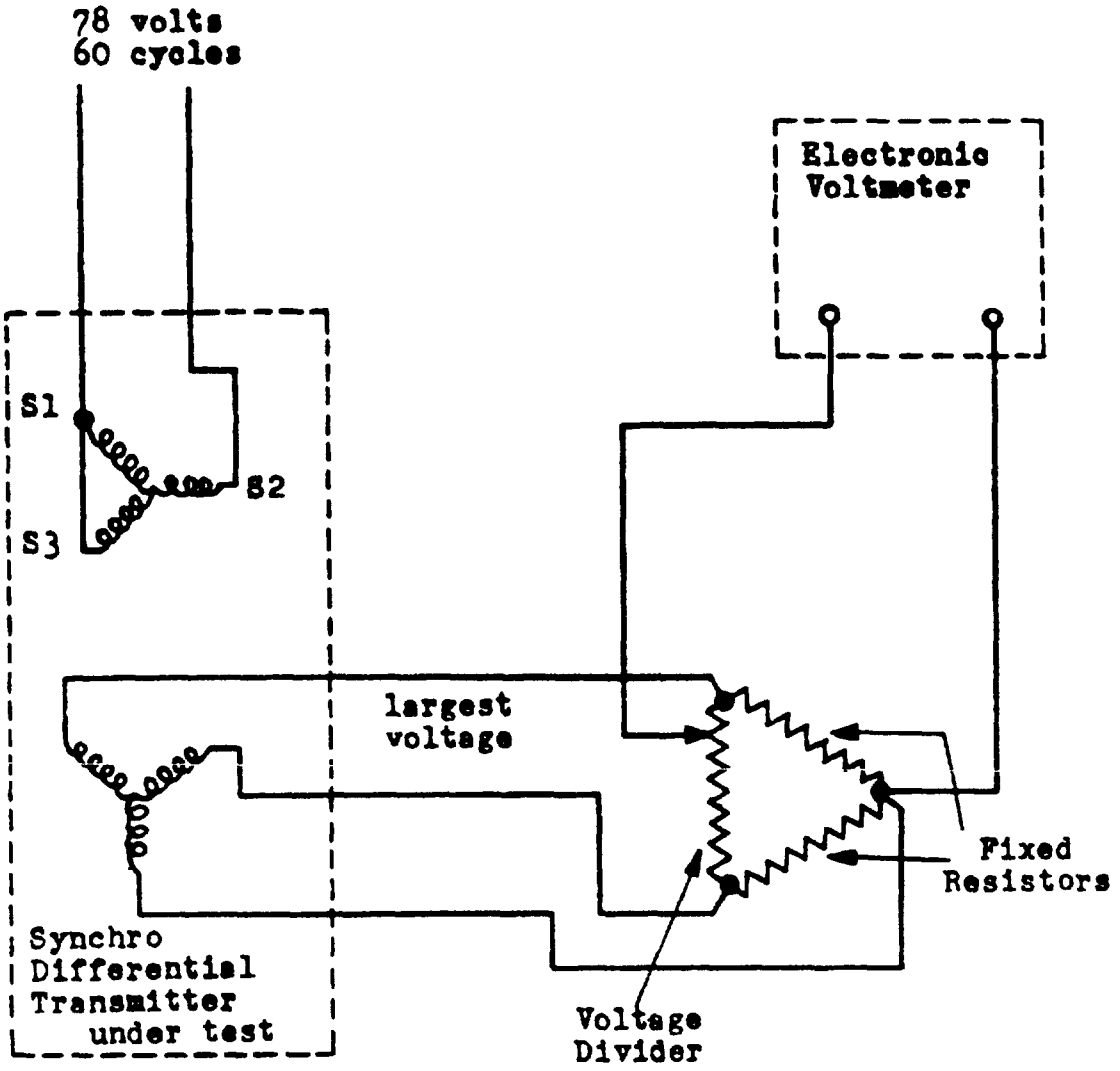


FIGURE 6

Basic Circuit Employed for Static Accuracy Test of the Rotor Windings of Differential Transmitters.

4.2.5.5.2 The basic circuit for static accuracy testing of the stator windings of differential transmitters is shown in Figure 7. The unit shall be energized from a synchro transmitter of equal or larger size than the unit under test but in no case by a transmitter smaller than a 5G. The energizing synchro transmitter shall be operated at rated voltage and frequency. Rotor terminals R1-R3 of the differential transmitter shall be connected to an electronic voltmeter having an impedance greater than 150,000 ohms. The energizing transmitter shall be turned until its electrical position, measured as described in paragraph 4.2.5.3, is at the desired value. The angular position of the unit under test that produces the minimum output voltage shall be determined. The null position shall be so chosen that for a small counterclockwise deflection from the null the voltage E(R13) is in phase with the voltage E(R12) of the energizing transmitter. The error is defined as the rotor position minus the electrical position. The maximum error in absolute value shall not exceed the value given in 3.3.14.3. In addition a positive maximum of the 2nd harmonic of the error shall occur in the 0^{o} to 120^{o} sector.

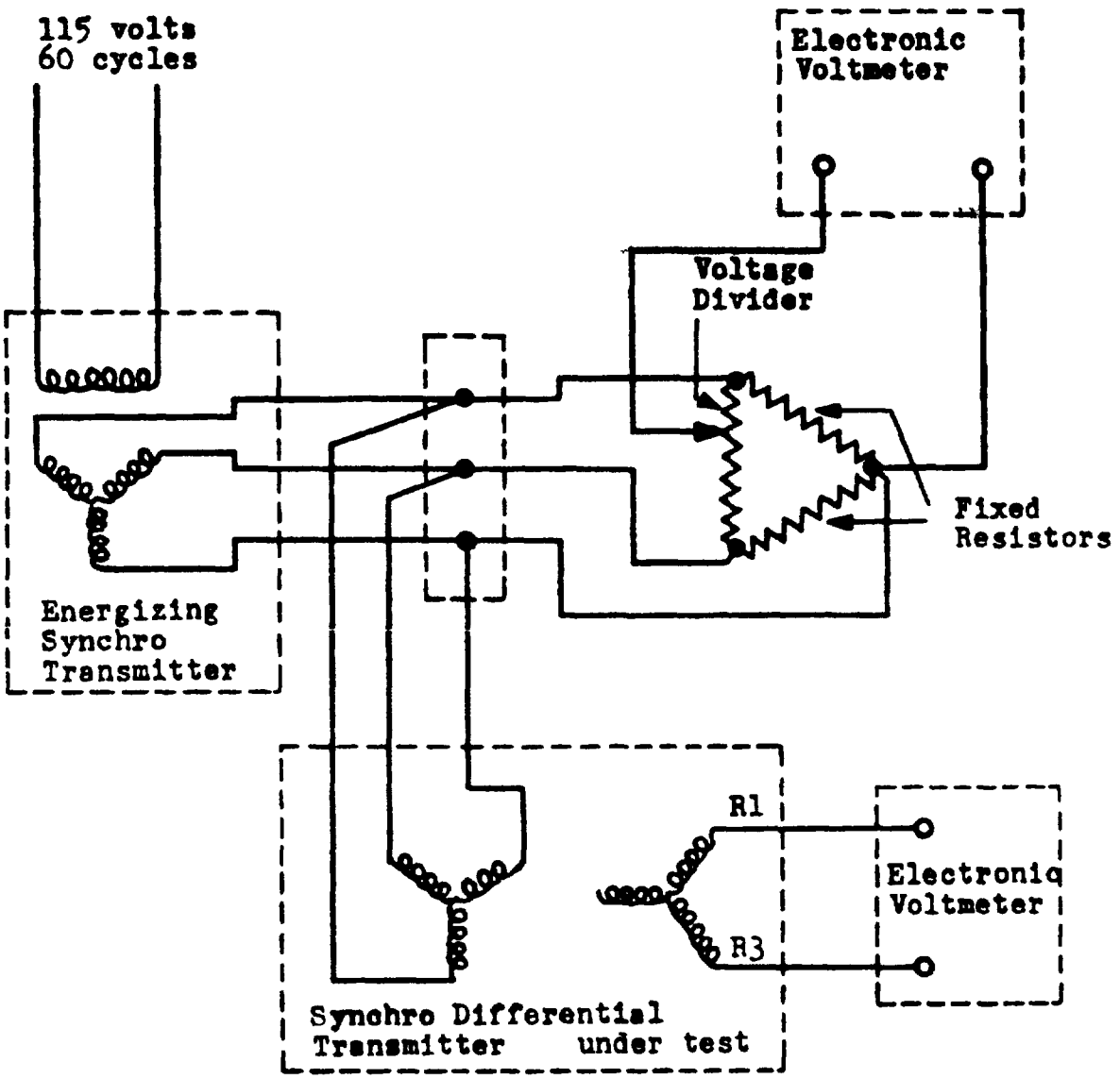


FIGURE 7

Basic Circuit Employed for Static Accuracy Test of the Stator Windings of Differential Transmitters

4.2.5.6 Receivers.--Receivers shall be tested against calibrated size 5 transmitters. The static accuracy shall be determined for both clockwise and counterclockwise rotations. The errors corrected for the calibration errors shall not exceed those given in 3.3.14.2.

4.2.5.7 Differential Receivers.--All sizes of differential receivers shall be tested against two calibrated size 5 synchro transmitters, one connected to the rotor of the differential receiver and the other connected to the stator of the differential receiver with a standard synchro capacitor included in the circuit. Two complete sets of accuracy measurements in each direction of rotation shall be taken.

4.2.5.7.1 Lock one transmitter on electrical zero and vary the setting of the other transmitter in three (3) degree steps recording the angular position assumed by the differential receiver.

4.2.5.7.2 Repeat the above test but with the other transmitter clamped on electrical zero and vary the setting of the transmitter in three (3) degree steps as before.

4.2.5.7.3 The errors corrected for the calibration errors shall not exceed those given in 3.3.14.4.

4.2.6 Secondary Voltage.--

4.2.6.1 The maximum induced secondary voltage shall be determined for the secondary windings, the primary being energized at rated voltage and frequency. In the case of a differential unit, and a control transformer, 78 volts 60 cycles shall be applied across terminal S2 and connected terminals S1 and S3. A high resistance voltmeter of at least 1000 ohms per volt shall be employed so as to avoid any appreciable voltage drop in the secondary winding. A static accuracy dial (Bureau of Ordnance Sketch No. 81883) shall be fitted to the rotor and the unit set accurately to electrical zero. Voltage readings shall be made in the secondary on open circuit when the dial is set to the various angles as required in the following tables:

Receivers and Transmitters

Winding	Angle
S1-S2	30° and 210°
S2-S3	150° and 330°
S1-S3	90° and 270°

Differential Receivers and Transmitters

R1-R2	150° and 330°
R2-R3	30° and 210°
R1-R3	90° and 270°

Control Transformers

R1-R2	90° and 270°

4.2.6.2 The variations from rated values in induced secondary voltages shall not exceed the limits given in 3.3.14.

4.2.7 Open Circuit Current and Power.--With the secondary leads open and the unit under test energized at rated voltage and frequency, the input current and power to the unit shall be measured and recorded. For a differential unit and a control transformer the rated voltage is 78 volts, 60 cycles, which shall be applied across terminal S2 and connected terminals S1 and S3. The measurements shall be made with the unit at normal operating temperature. This may be effected by energizing the unit with normal excitation current for two hours prior to the test. The primary current and power shall not exceed the values given in 3.3.14. The open circuit amperes or watts shall not vary more than 2 percent as the rotor is turned through a complete revolution. The open circuit amperes or watts of each Mark, Mod and Type unit in production lots shall not increase from the value approved in the Type Approval Tests by more than the amount indicated in the following table:

Allowable % increase in Power	Temperature Rise on Type Approval Test
15	40°C
12	42°C
9	44°C
6	46°C
3	48°C
0	50°C

If the primary current or power deviates by more than the allowable amount in the table, the inspector may require a temperature rise test and if 50°C is not exceeded, the unit shall be acceptable.

4.2.8 Impedance Measurements (control transformers).--

4.2.8.1 The stator impedance of control transformers shall be computed from the measurements outlined in 4.2.7. The stator impedance of control transformers shall not be less than the values given in 3.3.14.5.

4.2.8.2 The control transformer shall be energized by applying 78 volts between terminal S2 and connected terminals S1 and S3. An instrument as specified in paragraph 4.2.3.5.3 shall be connected across R1 and R2. The transformer shaft shall first be rotated to a position of minimum voltage and then clamped at a position of 10° from the position of minimum voltage. A variable resistance shall now be introduced in parallel with the instrument. This resistance shall be varied until the voltage as read on the instrument becomes one-half of what it was without the resistor and this resistance shall be called the impedance. The rotor impedance of the control transformer shall not exceed the value given in 3.3.14.5.

4.2.9 Voltage Gradient (Control Transformers).--

4.2.9.1 To determine the voltage gradient of a synchro control transformer, the unit shall be accurately positioned with respect to electrical zero when energized by 78 volts from an autotransformer connected across terminal S2 and connected terminals S1 and S3. An instrument as specified in paragraph 4.2.3.5.3 shall be calibrated and used to measure the voltages in increments of 1° from electrical zero to ±10° and a curve shall be plotted with the displacements as the abscissae and the voltages as the ordinates.

4.2.9.2 The voltage gradient for ±10° from electrical zero shall be as specified in 3.3.14.5.

4.2.10 Minimum (Null) Voltage.--The minimum voltage shall be measured at the six null headings obtained by applying 78 volts across one stator lead and the other two connected together. The null shall be determined by rotating the rotor about its correspondence point until a voltage of minimum peak value, as observed on a cathode ray oscilloscope, is obtained.

The cathode ray oscilloscope shall be calibrated in rms volts from a sine wave source. The minimum voltage shall be recorded in terms of this calibration and shall not exceed the values specified in 3.3.14.5.

4.2.11 Capacitance Curve for Power Factor Correction.--

4.2.11.1 This test is required of differential transmitters, differential receivers and control transformers. The unit shall be energized by applying 78 volts across terminal S2 and connected terminals S1 and S3. A variable capacitor shall be connected in S1-S3, S2 circuit on the line side of the synchro. The capacitance shall be varied until a minimum current is obtained and the value noted. Values from zero correction to twice the value of capacitance at the minimum correction shall be recorded in not less than ten steps to permit drawing the capacity curve. This capacitance is twice the optimum capacity per leg or 2/3 of the total capacitance required and hence the value observed must be multiplied by 1.5 to obtain the total capacitance.

4.2.11.2 The design shall be such that the synchro will not draw current to exceed the value of primary current in 3.3.14.5.

4.2.12 Spinning Test.--

4.2.12.1 General.--The purpose of this test is to determine whether the rotor of a receiver or differential receiver will come to rest at the position of synchronism from any initial angular position without spinning. A dynamic test dial shall be mounted on the rotor. The transmitter (or transmitters) shall be locked on electrical zero position. The rotor of the unit under test shall be displaced $\pm 179^{\circ}$ from electrical zero and the units energized at 126 volts 60 cycle alternating current. This procedure shall be performed 5 times for a clockwise displacement and 5 times for a counterclockwise displacement.

4.2.12.2 Spinning Test of Receivers.--

4.2.12.2.1 A size 1 receiver shall be tested against a size 6 transmitter in accordance with the procedure given in 4.2.12.1

4.2.12.2.2 A size 3 or 5 receiver shall be tested against a size 7 transmitter in accordance with the procedure given in 4.2.12.1.

4.2.12.2.3 The receiver shall be considered to have failed the spinning test if it failed to synchronize in any of the 10 trials.

4.2.12.3 Spinning test of differential receivers.--

4.2.12.3.1 A size 1 differential receiver shall be tested against two size 6G transmitters in accordance with the procedure given in 4.2.12.1. A synchro capacitor of the proper size shall be used in the stator circuit of the differential receiver.

4.2.12.3.2 A size 3 or 5 differential receiver shall be tested against two size 7 transmitters in accordance with the procedure given in 4.2.12.1. A synchro capacitor of the proper size shall be used in the stator circuit of the differential receiver.

4.2.12.3.3 The differential receiver shall be considered to have failed the spinning test if it fails to synchronize in any of the 10 trials.

4.2.13 Synchronizing Time.--

4.2.13.1 General.--The unit under test shall be connected terminal to terminal to an identical unit. A dynamic test dial shall be mounted on the rotor of the unit selected as indicator. The rotor of the other unit shall be locked on electrical zero. The synchronizing time is defined as the length of time required for the receiver rotor to synchronize and remain in synchronism within 0.1 degree after energizing the system at the specified voltage and frequency. The synchronizing time shall be measured for initial displacements of $\pm 36^{\circ}$ and $\pm 179^{\circ}$ by means of an oscillograph. The synchronizing time shall be recorded as the average of three successive tests.

4.2.13.2 Synchronizing Time Test of Receivers.--

4.2.13.2.1 Receivers shall be energized by supplying 115 volt 60 cycle alternating current to the R1-R2 leads of both units and tested in accordance with 4.2.13.1.

4.2.13.2.2 The synchronizing time of receivers shall not exceed 1 second for a 36° displacement and 2 seconds for a 179° displacement.

4.2.13.3 Synchronizing time test of differential receivers.--

4.2.13.3.1 Differential receivers shall be energized by supplying 78 volts 60 cycle alternating current between S1-S3 and S2 of both units and tested in accordance with 4.2.13.1.

4.2.13.3.2 The synchronizing time of differential receivers shall not exceed 1 second for a 36 degree displacement and 2 seconds for a 179 degree displacement.

4.2.14 Torque Gradient Test.--

4.2.14.1 General.--The unit shall be energized under standard conditions and shall be at normal operating temperature. This may be effected by energizing the unit with normal excitation current for 2 hours prior to the test. Torques shall be applied to the unit by suspending weights from a thread attached to the rim of a torque pulley on the rotor shaft. (See 4.2.3.4.4). Predetermined weights of equal increments shall be applied that will cause deflections of approximately 2,4,6,8,9 and 10 degrees in both a clockwise and counterclockwise direction and the corresponding deflections recorded. A torque-deflection curve shall be plotted as the straight line best fitted to the observed points and the torque gradient shall equal 1/2 the slope of this line and expressed in terms of ounce-inches per degree.

4.2.14.2 Transmitters.--Transmitters shall be energized by supplying 115 volt 60 cycle alternating current to the R1-R2 leads of the unit. Terminals S1 and S3 shall be connected together and the unit tested in accordance with 4.2.14.1. The torque gradient of the transmitter shall conform to the limits given in 3.3.14.1.

4.2.14.3 Differential Transmitters.--Differential transmitters shall be energized by supplying 78 volts 60 cycle alternating current, between terminal S2 and connected terminals S1 and S3. Terminals R1 and R3 shall be connected together and the unit tested in accordance with 4.2.14.1. The torque gradient of the differential transmitter shall conform to the limits given in 3.3.14.3.

4.2.14.4 Receivers.--Receivers shall be energized by supplying 115 volt 60 cycle alternating current to the R1-R2 leads of the unit. Terminals S1 and S3 shall be connected together and the unit tested in accordance with 4.2.14.1. The torque gradient of the receiver shall conform to the limits given in 3.3.14.2.

4.2.14.5 Differential Receivers.--Differential receivers shall be energized by supplying 78 volts 60 cycle alternating current between terminal S2 and connected terminals S1 and S3. Terminals R1 and R3 shall be connected together and the unit tested in accordance with 4.2.14.1. The torque gradient of the differential receiver shall conform to the limits given in 3.3.14.4.

4.2.15 Resistance of Windings.--The D.C. resistance of all windings shall be measured by means of a Wheatstone Bridge. The measurement shall be made when the windings are at a temperature of approximately 21°C. The temperature of the unit shall be recorded with the resistance measurements.

4.2.16 Temperature Rise.--

4.2.16.1 General.--The unit shall be tested when lying on its side in a ceramic trough. Prior to the temperature tests, the unit shall be maintained at 20°C ±2° for not less than 24 hours. This ambient temperature shall be controlled by air circulating at a constant rate over heating and refrigerating units, and shall be maintained throughout the test for temperature rise. The temperature rise of both the rotor and the stator of a unit shall be measured by the resistance change method. Measurements of resistance shall be recorded at intervals of time not exceeding one hour in length until equilibrium is attained. The equilibrium temperature shall be judged to have been reached when three successive temperature rise values have been obtained which do not differ by more than ±1°C. The following formula shall be used for calculating the temperature:

$$\text{Temperature Rise } {}^{o}C = 254.5 \frac{Rt - R20}{R20}$$

Where R_t = resistance of winding at the equilibruim temperature
R20 = resistance of winding at 20°C.

4.2.16.2 Circuit.--A schematic diagram of the circuit to be used is shown in Figure 8. Switch SW1 connects the bridge to the rotor or stator as desired. Switch SW2 is coupled mechanically to the bridge switch (not shown in figure) and closes when the bridge switch is closed. When switch SW2 is closed the relay is energized disconnecting the synchro excitatic· voltage and the load, at the same time connecting

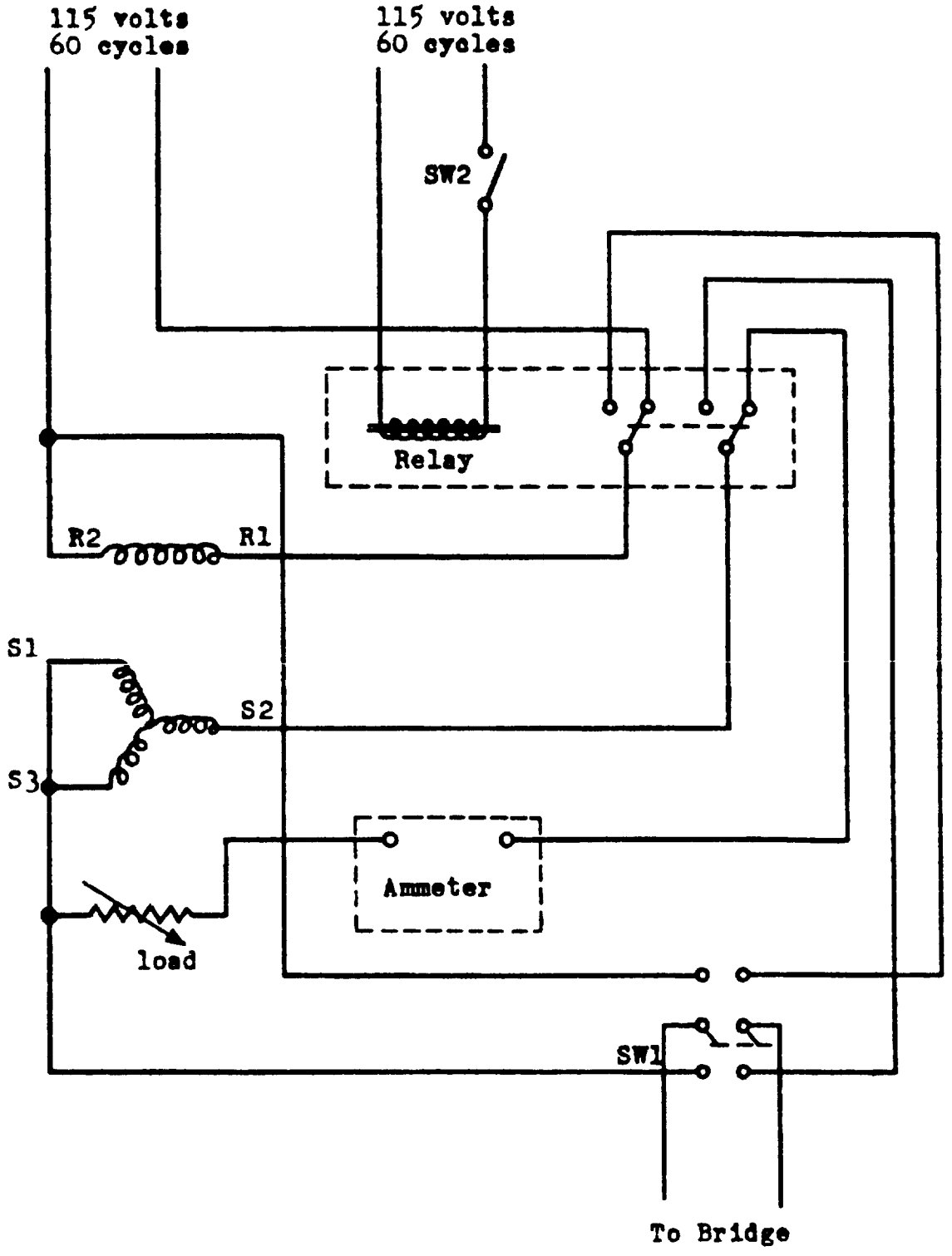


FIGURE 8

Circuit for Measuring Resistance Changes in Synchros

the bridge to the rotor or the stator, depending upon the position of SW1. The relay has mercury contacts with a maximum variation in contact resistance of approximately ±0.004 ohm. This arrangement allows the bridge to be balanced in the conventional manner. Since the bridge switch and SW2 are closed just long enough to determine the deflection of the galvanometer needle, no significant cooling of the synchro occurs while the measurement is being made.

4.2.16.3 Temperature Rise Test of Transmitters and Receivers.--

4.2.16.3.1 The transmitter or receiver rotor shall be set on electrical zero and locked by a thermal non-conductor connecting the shaft and an end bell screw. A variable resistance load together with an ammeter shall be connected across the output terminals S1-S3 and S2 of the transmitter. With the unit energized by supplying 115 volt 60 cycle alternating current to its R1-R2 leads the variable load shall be adjusted to obtain a load current of the magnitude specified in 3.3.14.1 or 3.3.14.2. This load current shall be maintained throughout the test by varying the load resistance.

4.2.16.3.2 The temperature rise of any winding of the transmitter or receiver shall not exceed 50°C in this test.

4.2.16.4 Temperature Rise Test of Differential Transmitters and Differential Receivers.--

4.2.16.4.1 The rotor of the differential transmitter or receiver shall be set on electrical zero and locked. A variable resistance load together with an ammeter shall be connected across the output terminals R1-R3 and R2 of the unit under test. With the unit energized by supplying 78 volts 60 cycle alternating current between S1-S3 and S2 the variable load shall be adjusted to obtain a load current of the magnitude specified in 3.3.14.3 or 3.3.14.4. This load current shall be maintained throughout the test by varying the load resistance. The temperature rise shall be determined in accordance with 4.2.16.1.

4.2.16.4.2 The termperature rise of any winding of the differential transmitter or receiver shall not exceed 50°C in this test.

4.2.17 Noise Test.--

4.2.17.1 General.--A block diagram of this test is given in Figure 9. The noise test shall be performed nine (9) times with the unit being disturbed between tests by being lifted up and replaced on a piece of sponge rubber. During each test the unit shall be in a horizontal position on the sponge rubber and be rotated as a receiver at 15 rpm through at least five (5) complete revolutions. A proper size noise test ring, Ordnance

Dr. 809633, shall be fitted on the synchro, and a crystal pick-up, Ordnance Dr. 809639, shall be attached to the noise test ring. The pickup is to be laid on the noise test ring platform with a medium weight oil film between them, a rubber band placed tightly around them to hold the pickup in place. The pickup shall have a sensitivity of 24 microvolts/cm/sec^2 ± 5%. The output of the crystal, after passing through a preamplifier and an amplifier, shall be recorded on a Sound Apparatus Recorder Model FR or equivalent. The preamplifier shall have a gain of 37 db at 100 cps and include a low pass filter with a cutoff frequency of 3000 cps. The amplifier shall be the equivalent of a Ballantine vacuum tube voltmeter model 300-A. In interpreting the readings of the recorder, zero (0) db is equivalent to .1 volt on the Ballantine voltmeter or equivalent.

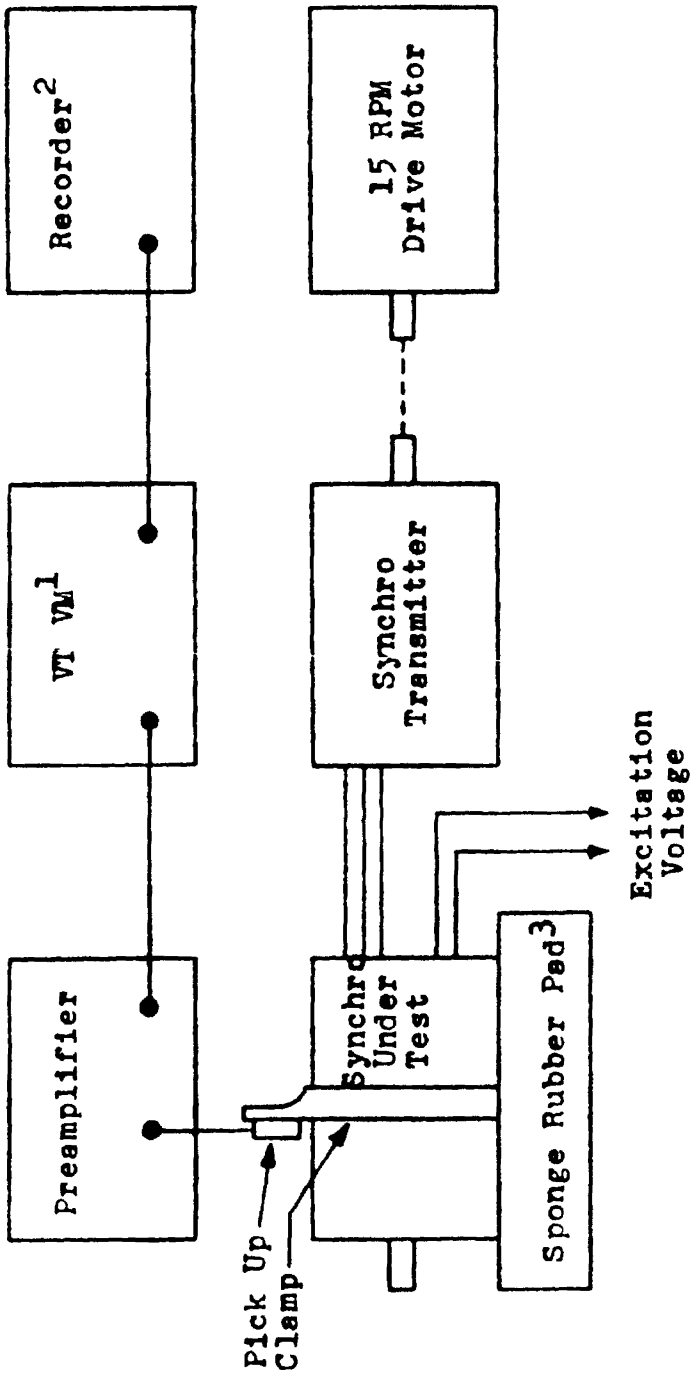
4.2.17.2 Receivers and Transmitters.--Receivers and transmitters shall be driven as receivers by the same size transmitter.

4.2.17.3 Differential Receivers and Transmitters.--Differential receivers and transmitters shall have 78 volts applied across terminal R2 and terminals R1 and R3 connected together. They shall be driven as receivers by means of transmitters of the same size connected to the stator terminals.

4.2.17.4 The synchro shall be rejected if two or more of the nine tests indicate maximum values equal to 11 db or above.

4.2.18 Vibration Test.--The unit to be tested shall be securely clamped to the table of a vibrator with its axis horizontal, and vibrated for a total of 24 hours in three mutually perpendicular directions, one being paralled to the axis of the rotor. During vibrations, the table and synchro shall move in a plane defined by two of these principal directions; and the vibration in each plane shall be continued for 8 hours. In each plane, the frequency of vibration shall be held constant for one hour at each of the frequencies 800, 900, 1000, 1100, 1200, 1300, 1400, and 1500 cycles per minute. At all frequencies the amplitude of vibration shall be 0.030 inch (0.060 inch total displacement). The unit shall not be damaged by this test, nor shall any of the parts loosen as a result of the test. The unit shall be capable of passing the accuracy test after vibration.

4.2.19 High Potential and Insulation Resistance Test.--Synchro units shall pass a high voltage test of 900(+ 0, -30) volts (rms) applied from each winding to the frame and from winding to winding. In all high voltage tests, the



1. Equivalent of Ballantine Laboratories Inc. Model 300A AC Electronic Voltmeter.
2. Equivalent of Sound Apparatus Co. Recorder Model FR.
3. Three-Inch Thickness, Soft Sponge Rubber.

BLOCK DIAGRAM OF SYNCHRO NOISE TEST

Figure 9

voltages shall be raised slowly to the specified value and held at that value for one minute. This test may be repeated as often as required. The peak voltage of the supply throughout this test shall not exceed 1.42 times the specified rms voltage. Immediately after satisfactorily withstanding the high potential test the insulation resistance of the electrical circuits shall be measured by means of a megohm bridge at 500 volts D.C. between each winding and the case and between the primary and secondary windings. The insulation resistance shall be greater than 10 megohms.

4.2.20 Dielectric Test.--Each synchro shall have twice the rated voltage at twice the rated frequency impressed upon its primary winding, with secondaries open. The voltage shall be raised slowly to the specified value and held at that value for one minute. The rotor shall be rotated at less than 2 rpm, making at least one revolution throughout the period of the test. There shall be no indication of insulation breakdown as exhibited by a tendency of the rotor to seek a preferred position. Such a tendency may be accompanied by sporadic changes in the primary current.

4.2.21 Shock Test.--

4.2.21.1 Each unit shall be mounted in a special shock test fixture shown in Bureau of Ordnance Sketch No. 95216 and shall be subjected to six (6) blows of 2000 ft. lb. with the high intensity shock machine. Three (3) blows shall be struck in the vertical and three (3) blows in the horizontal direction. The synchro shall be energized in the usual manner during the test. The special shock test fixture shall be bolted to a standard 34" x 26" x 1/2" thick mounting plate which is fastened to the shock testing machine anvil plate by two (2) 4" channels. The test fixture shall be mounted so that the synchro shaft is in a vertical position. The synchro unit shall be clamped to the test fixture so that a line between the brushes makes an angle of approximately 45° with the mounting plate. All synchro receivers shall have a standard type dial (see Bureau of Ordnance Sketch No. 81883) or equivalent load mounted on the shaft during the test.

4.2.21.2 The unit shall not be damaged or deranged by this test. In addition the errors in static accuracy at the end of the test shall not exceed the values given in 3.3.14.

4.2.22 Endurance Test.--

4.2.22.1 Driven Units.--

4.2.22.1.1 General.--Low speed transmitters, differential transmitters and control transformers shall be given a continuous endurance run of 500 hours at 300 rpm. High speed units of the above types shall be given a continuous endurance run of 1500 hours at 1200 rpm. The first 64 hours of this test shall be made in an ambient temperature of minus 25°C with the shaft of the unit horizontal. The next 96 hours of the test shall be made in an ambient of 65°C and the unit shall be operated in each of the following positions for 24 hours:

(1) Shaft vertical, upward.
(2) Shaft inclined 45° upward.
(3) Shaft inclined 45° downward.
(4) Shaft vertical, downward.

The time remaining of the test shall be consumed by running the unit with the shaft horizontal and at room temperature. The units shall be completely disassembled 24 hours after the endurance test and carefully checked for any evidence of undue wear, deterioration of windings, and deposits of distillates. Type approval static accuracy tests shall be made both before and after the endurance test.

4.2.22.1.2 Transmitters.--Transmitters shall be energized by supplying 115 volts 60 cycle alternating current to the R1-R2 terminals. The rotor shall be turned mechanically at the speed required in 4.2.22.1.1. The secondary winding shall be loaded by a balanced Y connected resistive load so as to draw a maximum current in each stator lead equal to the secondary current listed in 3.3.14.1.

4.2.22.1.3 Differential Transmitters.--Differential transmitters shall be energized by applying 78 volts 60 cycle alternating current between S1-S3 and S2. The rotor shall be turned mechanically at the speed required in 4.2.22.1.1. The secondary winding shall be loaded by means of a balanced Y connected resistive load to circulate the maximum secondary current specified in 3.3.14.3.

4.2.22.1.4 Control Transformers.--Control transformers shall be energized by applying 78 volts 60 cycle alternating current between S1-S3 and S2. The rotor shall be driven mechanically as required in 4.2.22.1.1. A load of 10,000 ohms shall be connected across R1-R2. (15,000 ohms for 1CT).

4.2.22.2 Free Rotor Units.--

4.2.22.2.1 General.--All low speed receivers or differential receivers shall be given a continuous endurance run of 500 hours at 300 rpm. The test shall be made at room temperature. After the endurance test, the units shall be completely disassembled after 24 hours and carefully checked for any evidence of undue wear, deterioration of windings, and deposits of distillates. Type approval static accuracy tests shall be made before and after the endurance test.

4.2.22.2.2 Receivers.--Receivers shall be driven by a standard synchro transmitter as described in 4.2.22.2.1. The rotor shall be fitted with a dynamic test dial shown on Bureau of Ordnance Sketch No. 81883.

4.2.22.2.3 Differential Receivers.--Differential receivers shall be driven by two synchro transmitters (one of which is locked on electrical zero) as described in 4.2.22.2.1. The rotor shall be fitted with a dynamic test dial shown on Bureau of Ordnance Sketch No. 81883. A synchro capacitor of standard size shall be used in the stator circuit of the differential receiver.

4.2.22.2.4 High Speed Receivers.--Receivers or differential receivers designed as high speed units shall be driven by standard high speed synchro transmitters as in 4.2.22.2.2 and 4.2.22.2.3, respectively. The transmitters should be driven at 1200 rpm for 1000 continuous hours.

4.2.23 Mechanical Inspection.--

4.2.23.1 The units shall be inspected to determine conformity with:

(1) The pertinent requirements of section 3 of this specification.
(2) The appropriate drawings listed under section 2.
(3) The approval drawings required by 3.3.15.2.

4.2.23.2 Side-shake.--

4.2.23.2.1 The side-shake shall be measured at approximately 21°C as the displacement from high point to low point measured on a dial indicator gage graduated to 0.0001. The gage shall be mounted rigidly and in a position such that the actuating button will contact the shaft of the synchro at a point half way between the hardened steel washer shoulder and the slotted washer shoulder. A force of one-half pound shall

be applied by a string to the end thread of the shaft, horizontally first in one direction and then in the opposite direction. The difference between these two indicator readings shall be considered the side-shake. The synchro unit shall be mounted with the stator rigidly clamped.

4.2.23.2.2 The side-shake shall not exceed 0".0005 for driven units other than size 1. For size 1 units and all receivers the side shake shall not exceed ".001.

4.2.23.3 Bearing Seat Run-out on Bearing Mounted Synchros.--

4.2.23.3.1 The run-out between exterior bearing surfaces on all bearing mounted synchros shall be measured by mounting the synchro vertically in a ring fixture having a flat ground top surface square with the axis of its bore, which is accurately ground to fit the exterior bearing of the collector-end end-bell. The synchro is then rotated in this fixture and the run-out measured by a dial indicator radially contacting the exterior bearing on the shaft-end end-bell.

4.2.23.3.2 The run-out shall not exceed 0.005 inch.

4.2.23.4 Shaft End Play.--The shaft end play shall be measured at approximately 21°C, as the total displacement resulting from a force of three (3) pounds being applied to the shaft in a pushing and pulling direction. The line of action of the force shall coincide with the rotor axis. The unit shall be mounted so that the shaft is in a horizontal position and the stator rigidly clamped. The motion of the shaft in a direction parallel to its axis, shall be measured by means of a dial gage capable of reading directly to 0.001 inch. The end play shall not exceed 0.008 inch (0.015 inch for size 1 units) before shock test and should not exceed 0.015 inch after shock test.

4.3 Production Tests.--

4.3.1 Production tests shall be made at the place of manufacture.

4.3.2 A complete examination shall be made of the materials, workmanship and general assembly of the equipment to determine its meeting the requirements of this specification.

4.3.3 The following tests shall be made during production tests on all units offered for acceptance under this specification.

TABLE VIII

Production Test	Functional Classification G	DG	F	D	CT	Reference Paragraph	Sheet No.
Static Accuracy for Production Test	X	X	X	X	X	4.3.4	63
Secondary Voltage	X	X	X	X	X	4.2.6	48
Open Circuit Current and Power*	X	X	X	X	X	4.2.7	49
Minimum Voltage					X	4.2.10	50
Spinning*			X	X		4.2.12	51
Synchronizing Time**			X	X		4.2.13	52
Noise	X	X	X	X		4.2.17	57
High Potential and Insulation Resistance	X	X	X	X	X	4.2.19	57
Dielectric	X	X	X	X	X	4.2.20	58
Mechanical Inspection	X	X	X	X	X	4.2.23	60

*If the open circuit power exceeds the value given in paragraph 3.3.14 the unit may at the discretion of the Inspector be subjected to a Temperature Rise Test (see 4.2.16). If the unit passes the Temperature Rise Test it shall be considered satisfactory in regard to the Open Circuit Power Test.

**These tests are not required for transmitters, differential transmitters or control transformers. The synchronizing time may be determined by a cycle counter or other method accurate to within ±2 seconds.

4.3.4 Static Accuracy for Production Test.--

4.3.4.1 Transmitters.--Transmitters shall be tested against size 5 control transformers calibrated by the proportional voltage method as described in 4.2.5.4. The transmitter under test shall be energized by applying 115 volts 60 cycles to the rotor. Its stator leads shall be connected to the stator leads of the calibrated control transformer in the following manner: S1 to S3, S3 to S1, and S2 to S2. Its rotor shall be coupled mechanically to the rotor of the control transformer so that both units are at electrical zero together. The rotor voltage of the control transformer is a measure of the static error of the transmitter. This voltage shall be recorded for a complete revolution by means of a recording voltmeter. The static accuracy record shall be corrected if necessary to account for the errors of the calibrated control transformer. The error is defined as the transmitter position minus the corrected position of the control transformer. The errors in absolute value shall not exceed those given in 3.3.14.1. In addition, a positive maximum of the 2nd harmonic of the error shall occur in the 0° to 120° sector.

4.3.4.2 Differential Transmitters.--The static accuracy of both the rotor and the stator shall be determined.

4.3.4.2.1 Rotors.--Rotors of differential transmitters shall be tested against size 5 control transformers calibrated by the proportional voltage method as described in 4.2.5.4. The unit under test shall be energized by applying 78 volts 60 cycles between terminal S2 and connected terminals S1 and S3. Its rotor leads shall be connected to the stator leads of the calibrated control transformer in the following manner: R1 to S3, R3 to S1, and R2 to S2. Its rotor shall be coupled mechanically to the rotor of the control transformer so that both units are at electrical zero together. The static errors, corrected if necessary for the calibration of the control transformer, shall be determined by means of a recording voltmeter as described in 4.3.4.1. The error is defined as the differential transmitter position minus the position of the control transformer. The errors in absolute value shall not exceed those listed in 3.3.14.3. In addition, a positive maximum of the 2nd harmonic of the error shall occur in the 0° to 120° sector.

4.3.4.2.2 Stators.--Stators of differential transmitters shall be tested against size 5 control transformers calibrated by the proportional voltage method as described in 4.2.5.4.

The unit under test shall be energized by applying 78 volts 60 cycles between terminal R2 and connected terminals R1 and R3. The static accuracy shall be determined as described in 4.3.4.1 for transmitters. The errors in absolute value shall not exceed those listed in 3.3.14.3. In addition, a positive maximum of the 2nd harmonic of the error shall occur in the 0° to 120° sector.

4.3.4.3 Control Transformers.--Control transformers shall be tested against size 5 transmitters calibrated by the proportional voltage method as described in 4.2.5.3. The transmitter shall be energized by applying 115 volts 60 cycles to its rotor. The stator leads of the control transformer under test shall be connected to the stator leads of the calibrated transmitter in the following manner: S1 to S3, S3 to S1, S2 to S2. Its rotor shall be coupled mechanically to the transmitter rotor so that both units are at electrical zero together. The rotor voltage of the control transformer is a measure of its error. The static errors, corrected if necessary for the calibration of the transmitter, shall be determined by means of a recording voltmeter as described in 4.3.4.1. The error is defined as the control transformer position minus the corrected transmitter position. The errors in absolute value of control transformers shall not exceed those listed in 3.3.14.5. In addition, a positive maximum of the 2nd harmonic of the error shall occur in the 0° to 120° sector.

4.3.4.4 Receivers.--Receivers shall be tested by means of the Synchro Tester Mark 1 Mod 1 as supplied by the Bureau of Ordnance. The errors of receivers shall not exceed those listed in 3.3.14.2.

4.3.4.5 Differential Receivers.--Differential receivers shall be tested by means of the Synchro Tester Mark 1 Mod 1 as supplied by the Bureau of Ordnance, and a second calibrated size 5 transmitter which is locked on electrical zero. The errors of differential receivers shall not exceed those listed in 3.3.14.4.

5. PREPARATION FOR DELIVERY

5.1 Packaging.--Each synchro unit shall be packaged in accordance with the applicable drawing listed in Section 2, Table IV.

5.2 Packing.--Synchros packaged in accordance with 5.1 shall be packed in accordance with the applicable drawing listed in Section 2, Table IV.

5.3 Labeling and Marking.--In addition to any special marking required by the contract or order, marking shall conform to the requirements of the applicable packaging and packing drawings and the Navy Shipment Marking Handbook.

6. NOTES

6.1 All questions pertaining to these specifications shall be referred to the Bureau of Ordnance for consideration and decision. All questions as to the design, manufacture, tests and applications of synchros covered by these specifications are under the cognizance of the Bureau of Ordnance.

6.2 The right is reserved to reject any bids on equipment covered by this specification which have not been subjected to the required tests and found satisfactory. The attention of the manufacturers is called to this requirement and they are urged to forward samples of the equipment which they propose to offer to the Navy in the future in order that tests may be made. These tests will be conducted at the expense of the Government. The samples shall be sent to the Bureau of Ordnance. It is to be understood that the manufacturers shall pay all transportation charges to the Bureau of Ordnance and from the point where tests are made to the manufacturer's plant. In the case of failure of the sample or samples submitted to prove satisfactory, consideration will be given to the requests of the manufacturers for additional tests only after it has been clearly shown that changes have been made in the product with reference to design, method of manufacture, etc., which the Bureau of Ordnance considers sufficient to warrant conducting additional tests.

6.3 Guaranty.--The contractor shall guarantee all synchro units, including spare parts, furnished by him against any and all defects in design, materials, and workmanship which are not detected prior to acceptance but which may develop within two years after delivery of the material, such defects to be made good by and at the expense of the contractor.

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PECIFICATION ANALYSIS SHEET

Form Approved
Budget Bureau No. 22-R004

INSTRUCTIONS

This sheet is to be filled out by personnel either Government or contractor, involved in the use of the specification in procurement of products for ultimate use by the Department of Defense. This sheet is provided for obtaining information on the use of this specification which will insure that suitable products can be procured with a minimum amount of delay and at the least cost. Comments and the return of this form will be appreciated. Fold on lines on reverse side, staple in corner, and send to preparing activity *(as indicated on reverse hereof)*

SPECIFICATION

ORGANIZATION *(Of submitter)*	CITY AND STATE

CONTRACT NO.	QUANTITY OF ITEMS PROCURED	DOLLAR AMOUNT
		$

MATERIAL PROCURED UNDER A

☐ DIRECT GOVERNMENT CONTRACT ☐ SUBCONTRACT

1. HAS ANY PART OF THE SPECIFICATION CREATED PROBLEMS OR REQUIRED INTERPRETATION IN PROCUREMENT USE?

A. GIVE PARAGRAPH NUMBER AND WORDING.

B. RECOMMENDATIONS FOR CORRECTING THE DEFICIENCIES.

2. COMMENTS ON ANY SPECIFICATION REQUIREMENT CONSIDERED TOO RIGID

3. IS THE SPECIFICATION RESTRICTIVE?

☐ YES ☐ NO IF "YES", IN WHAT WAY?

4 REMARKS *(Attach any pertinent data which may be of use in improving this specification. If there are additional papers, attach to form and place both in an envelope addressed to preparing activity)*

SUBMITTED BY *(Printed or typed name and activity)*	DATE

DD FORM 1426