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(See 6.6)

MILITARY SPECIFICATION

TRANSFORMERS, POWER, DISTRIBUTION, SINGLE PHASE, 400 HERTZ, INSULATION SYSTEM CLASS 220°C, DRY (AIR COOLED) (NAVAL SHIPBOARD USE)

1. SCOPE

1.1 This specification covers dry type, 400 hertz (Hz), single-phase, electric transformers of standard mounting dimensions, used for shipboard electrical distribution.

2. APPLICABLE DOCUMENTS

2.1 The following documents of the issue in effect on date of invitation for bids or request for proposal, forms a part of this specification to the extent specified herein.

SPECIFICATIONS

MILITARY

MIL-W-583 - Wire, Magnet, Electrical.
MIL-S-901 - Shock Tests, H.I. (High-Impact); Shipboard Machinery, Equipment and Systems Requirements For.
MIL-E-917 - Electric Power Equipment, Basic Requirements (Naval Shipboard Use).
MIL-D-1000 - Drawings, Engineering and Associated Lists.
MIL-D-1000/2 - Drawings, Engineering and Associated Lists.
MIL-E-2036 - Enclosures For Electric and Electronic Equipment, Naval Shipboard.
MIL-P-15024 - Plates, Tags and Bands for Identification of Equipment.
MIL-P-15024/5 - Plates, Identification.
MIL-E-16366 - Electrical Clamps, Lug Terminals and Conductor Splices-Pressure Grip.
MIL-W-16878 - Wire, Electrical, Insulated High Temperature.

STANDARDS

MILITARY

MIL-STD-470 - Maintainability Program Requirements (For Systems and Equipments).
MIL-STD-740 - Airborne and Structureborne Noise Measurements and Acceptance Criteria of Shipboard Equipment.
MIL-STD-785 - Requirements for Reliability Program (For Systems and Equipments).

(Copies of specifications, standards, drawings and publications required by suppliers in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

3. REQUIREMENTS

3.1 Qualification. The transformers furnished under this specification shall be products which are qualified for listing on the applicable qualified products list at time set for opening of bids (see 4.1 and 6.4).

3.2 General requirements. The transformers shall be in accordance with the requirements of MIL-E-917, and the requirements of this specification except as otherwise specified in the contract or order. If any requirement specified herein conflicts with the requirements of MIL-E-917, the requirements of this specification shall govern.

3.3 Definitions.

3.3.1 General. The definitions specified in 3.3.2 through 3.3.15 shall apply to the various technical terms shown below whenever such terms appear in this specification.

3.3.2 Transformer. A transformer is an electric device without continuously moving parts which by electromagnetic induction transfers electric energy from one or more circuits to one or more other circuits at the same frequency usually with changed values of voltage and current.

3.3.3 Dry type transformer. A dry type transformer is a transformer cooled by the natural circulation of air and not liquid-immersed.

3.3.4 Primary winding. The primary winding is the winding on the input side.

3.3.5 Secondary winding. The secondary winding is the winding on the output side.

3.3.6 Tap (in a transformer). A tap in a transformer is a connection brought out of a winding at some point between its extremities, usually to permit changing the voltage ratio.

3.3.7 Rated kilovoltampere of a transformer. The rated kilovoltampere (kVA) of a transformer is the output which can be delivered for the time specified at approximately rated secondary voltage and rated frequency without exceeding the specified temperature limitations.

3.3.8 Ratio of a transformer. The ratio of a transformer is the turn ratio of the transformer.

3.3.9 No-load losses of a transformer (excitation losses of a transformer). The no-load losses of a transformer are the losses in a transformer that is excited at rated voltage and frequency but not supplying load.

NOTE: No-load losses include core loss, dielectric loss, and copper loss in the winding due to exciting current.

3.3.10 Load losses of a transformer (impedance losses of a transformer). The load losses of a transformer are those losses in a transformer which are incident to the carrying of load.

NOTE: Load losses include I^2R loss in the windings due to load current, stray loss due to stray fluxes in the windings, core clamps, and so forth, and to circulating currents, if any, in parallel windings.

3.3.11 Total losses of a transformer. The total losses of a transformer are the losses represented by the sum of the no-load losses and the load losses.

3.3.12 Regulation of a transformer. The regulation of a transformer is the change in secondary voltage, expressed in percent of rated secondary voltage, which occurs when rated kVA output at a specified power factor (pf) is reduced from rated value to zero, with the primary impressed terminal voltage maintained constant.

3.3.13 Impedance voltage of a transformer. The impedance voltage of a transformer is the voltage required to circulate rated current through a winding of the transformer when another winding is short circuited, with the respective windings connected for rated voltage operation, and is expressed in percent of the rated voltage of the winding in which the voltage is measured.

3.3.14 Exciting current of a current. The exciting current of a transformer is the current which flows in any winding used to excite the transformer when all other windings are open-circuited, and is expressed in percent of the rated current of the winding in which it is measured.

3.3.15 Lead polarity of a transformer. The lead polarity of a transformer is a designation of the relative instantaneous directions of currents in its leads. Primary and secondary leads are said to have the same polarity when at a given instant the current enters the primary lead in question and leaves the secondary lead in question in the same direction as though the two leads formed a continuous circuit. The lead polarity of a single-phase distribution or power transformer may be either additive or subtractive. If one pair of adjacent leads from the windings in question is connected together and voltage applied to one of the windings:

(a) The lead polarity is additive if the voltage across the other two leads of the windings in question is greater than that of the higher voltage winding alone.
(b) The lead polarity is subtractive if the voltage across the other two leads of the windings in question is less than that of the higher voltage winding alone.

3.4 Basic requirements. Transformers shall conform to the requirements of MIL-E-917.

3.4.1 Insulation system. The insulation system shall be class 220° Celsuis (C). The whole core and coil of each transformer shall have varnish applied by the dipping prodcess or vacuum-pressure process specified by MIL-E-917.

3.4.2 Painting. Painting shall be in accordance with MIL-E-917 except that only one coat of gray enamel need be applied. Marks or scratches made due to handling during fabrication and testing shall be repainted by either complete repainting of equipment or by touch-up method. Parts to be painted shall consist of those not having a corrosion-resisting treatiment or not fabricated of corrosion-resisting materials of the types specified in MIL-E-917 and shall include exterior and interior surfaces of the enclosure.

3.5 Enclosure. Unless otherwise specified in the contract or order, all transformers shall be of dripproof construction, in accordance with MIL-E-2036. The enclosure shall provide for the entrance of the ship's cables. Ready accessibility shall be provided with clearance in the vertical direction for installation and maintenance of electrical connections. Space shall be provided in the terminal compartment for making connections of single phase transformers in closed delta banks. The terminal compartment shall be so constructed that it is possible to disconnect readily a transformer connected in a three-phase bank without disturbing the cable to the remaining transformers or the other units comprising the bank.

3.6 Ambient temperature. The rating of transformers shall be based upon a maximum ambient temperature of 50°C.

3.7 Rating.

3.7.1 Voltage. Transformers shall be designed for the following voltages as specified (see 6.3):

Group 1 - 450 - 120 no-load
Group 2 - 1000 - 120 no-load
Group 3 - 1000 - 450 no-load
Group 4 - Special voltages

3.7.2 Phase. Transformers shall be designed for single-phase operation.

3.7.3 KVA capacity. Transformers shall be designed to have the following kVA capacities as specified (see 6.3):

1.0	7.5	25.0	75.0
3.0	10.0	37.5	100.0
5.0	15.0	50.0	125.0

3.8 Duty. Unless otherwise specified (see 6.3), all transformers shall be designed for continuous duty at 100 percent load.

3.9 Temperature limits. Transformers shall be so designed as not to exceed the values of maximum permissible temperature rises shown in table I.

Table I - Maximum permissible temperature rises at 100 percent load.

Item	Name of part	Insulation system class 220°C
1	Primary winding	1/150
2	Secondary winding	1/150
3	Core	2/150

1/ By change of resistance method.
2/ By thermometer or thermocouple method.

NOTE 1: Top of enclosure temperature shall be included in test report.
NOTE 2: The manufacturer shall also take into account in the design that the transformers, when in place onboard ship, are mounted in banks with a minimum distance of 2 inches between units. Under this condition, the design shall be such that the temperature rises are not exceeded.

3.10 Characteristics. Characteristics of the transformers shall be as shown in table II.

Table II - 150°C rise transformers.

Division 5/	kVA	Maximum weight pounds	Maximum volume cubic inches	Maximum losses		Regulation maximum 4/		Maximum exciting current percent	Maximum peak inrush current amperes 1/
				No-load watts	Total watts 4/	1.0 pf	0.8 pf		
A	1	18	335	25	60	4.0	5.0	15	60
	3	25	470	55	105	2.0	3.5	10	90
	2/5	30	600	70	140	1.5	3.5	10	180
B	7.5	40	800	85	185	1.5	3.5	5	200
	10	50	870	100	225	1.5	3.5	5	215
	15	75	1750	125	315	1.5	3.5	5	275
	2/25	105	2150	160	455	1.5	3.5	5	360
	37.5	140	2750	240	585	1.5	3.5	5	570
C	50	165	3/3775	290	700	1.5	3.5	5	850
	2/75	240	3/4575	375	930	1.5	3.5	5	1300
	100	310	3/7100	440	1200	1.5	3.5	5	1460
	125	410	3/12500	500	1475	1.7	3.7	5	950

1/ Values for inrush current are applicable to transformers with 450-volt primary. For transformers of other voltages maximum inrush current shall be the same percentage of the primary load currents.

2/ Transformer to be submitted from each division for qualification (see 4.3.1).

3/ Spacers used to attain the "F" and "G" dimensions specified in table III.

4/ Regulation impedance and total losses shall be given at 150°C.

5/ See 4.3.1.

3.11 Winding resistance. On a percentage basis, the average of the variations in resistance of the primary and secondary windings for transformers of the same size and design shall be not more than minus 5 percent. The resistance of any one winding shall vary not more than minus 10 percent.

3.12 Safety. The transformers shall be designed for the utmost safety of ship's personnel. The transformers shall conform to the safety requirements of MIL-E-917.

3.13 Ratio. Transformers shall be so designed that the turn ratio shall not vary more that plus or minus 1 percent from the ratio of rated voltages indicated on the idetification plate.

3.14 Polarity. Transformers shall be of additive polarity.

3.15 Operating noise. Transformers shall be designed to meet the noise level requirements specified in 4.6.14.

3.16 Shockproofness. Transformers shall be designed to withstand high impact shock without mechanical damage or failure of parts as specified in MIL-S-901 for grade A, class I, type A (see 4.6.10).

3.17 Short circuit. Transformers shall be designed to withstand short circuit currents as specified in 4.6.13.

3.18 Weight. Transformers complete with case and including wiring and mounting provision shall be so designed and constructed as not to exceed the weights shown in table II.

3.19 Volume. Transformers shall be so designed and constructed that the volume does not exceed the volume in cubic inches shown in table II. The maximum overall dimension in each direction shall be used in determining the volume except as otherwise specified for 50, 75, 100 and 125 kVA transformers in table II.

3.20 Dielectric strength. Transformers shall be designed and constructed so that the insulation of the high-voltage and low-voltage windings shall withstand a dielectric voltage (root mean square (rms) of 4000 volts [illegible] ating current (ac), 60 cycles for a 1 minute period.

3.21 Standard mounting dimensions. The transformers shall be for bulkhead or deck mounting as specified on figures 1 and 2. Mounting dimensions of transformers shall be as shown in table III. Holes provided for mounting and bracing shall not be slotted.

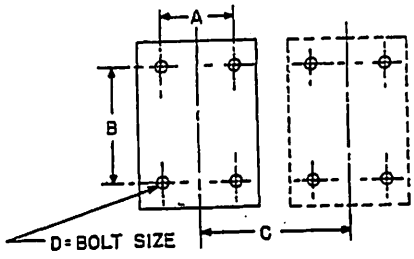

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Figure 1 - Bulkhead mounting.

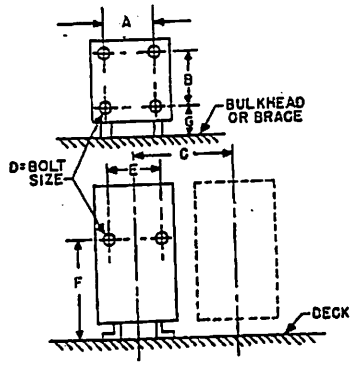

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Figure 2 - Deck mounting.

Table III - Standard mounting dimensions.

kVA	A 1/	B 1/	C 2/	D 3/	E 1/	F 1/	G 1/
1	5-1/2	4	8-3/4	3/8	---	---	---
3	6	4-1/3	9-1/4	3/8	---	---	---
5	6-1/2	4-3/8	9-3/4	3/8	---	---	---
7-1/2	6-3/4	4-1/2	10-1/4	3/8	---	---	---
10	7-1/4	4-5/8	10-1/2	3/8	---	---	---
15	8	6	11-1/2	3/8	---	---	---
25	8-7/8	6-1/2	12-1/2	3/8	---	---	---
37-1/2	10	7-3/8	13-1/2	3/8	---	---	---
50	9	10-1/2	14	5/8	10-1/2	12	5
75	10	12	16	5/8	11	13	5
100	12	14	18	5/8	12-1/2	14	5
125	14	16	22	11/16	14	16	5

1/ Tolerance: plus or minus 1/32 inch.

2/ Recommended minimum spacing for drilling plan of adjacent units (includes a minimum of 2 inches between units).

3/ Hole diameter shall equal bolt size plus or minus 1/16 inch.

3.22 Spot welding or tack welding. Spot welding or tack welding shall not be used for structural parts of transformers subject to stress or shock.

3.23 Lifting means. Transformers of 10 kVA capacity and over shall be provided with means for lifting and handling by use of a rope sling.

3.24 Windings.

3.24.1 The transformers shall have separate primary and secondary windings insulated from each other, and from metal parts.

3.24.2 The windings shall be so supported that mechanical stresses caused by short circuits (see 4.6.14) and shock will be reflected in the weakening of the insulation, permanent deformation of the windings, or other mechanical or electrical injury.

3.24.3 Taps shall not be permitted.

3.24.4 Magnet wire for transformers shall be in accordance with MIL-W-583.

3.25 Core. The laminations shall be properly insulated from each other. In the assembly of the core, care shall be taken to remove all burrs or projecting laminations which might result in injury to the coils. The laminations shall be clamped together in such a manner as to insure a tight core. Where use on butt jointed cores is contemplated specific Naval Ship Engineering Center (NAVSEC) acceptance shall be obtained prior to design and development of transformers. During the process of manufacture the assembled core shall be given a varnish dip. All laminations shall be annealed for stress relieving after punching or forming.

3.26 Transformer plates.

3.26.1 General. Identification plates shall be as shown on figure 3 and in accordance with MIL-P-15024 and MIL-P-15024/5. The plates shall be installed on and furnished as a part of each transformer. They shall be located so that they can be easily read at all times without danger to personnel. Unless otherwise specified in the contract or order, the identification plates shall be located on the front of the enclosure.

3.26.2 Connection diagram plates. Two plates shall be mounted on each transformer. The plate mounted on the front of the transformer enclosure shall indicate a delta-delta connection diagram schematically showing the acutal connections for three phase operation, instructions for connecting in open delta and the percent kVA capacity for open delta to be provided as shown on figure 3. The plate mounted on the top of the transformer enclosure shall indicate a delta-wye connection diagram schematically showing the actual connections for three phase operation with the primary windings connected in delta and the secondary windings in wye as shown on figure 3.

3.27 Terminal boards shall not be used.

3.27.1 The transformer leads shall be secured by the use of an insulated support and arranged in such a manner that the connections to ship's cables may be made by the use of solderless connnectors conforming to MIL-E-16366. Solderless connectors shall be furnished by the shipbuilder.

3.28 Cable compartments.

3.28.1 The cable compartments for 1 through 37.5 kVA transformers shall be at the bottom of the transformer enclosure. The compartments for 50 through 125 kVA transformers shall be at the top of the transformer enclosure.

3.28.2 The size of cable compartments shall be as shown in table IV.

Table IV - Cable compartments.

kVA size	Minimum distance between lead supports and cover
	Inches
1	4
3	4
5	5
7.5	6-1/2
10	6-1/2
15	8-1/2
25	8-1/2
37.5	8-1/2
50	10-1/2
75	11-1/2
100	13
125	15

3.29 Cable leads. Cable leads for transformers shall be type FF as specified in MIL-W-16878 and as shown in table V. The minimum length of the leads shall be the height of the wiring compartment.

Table V - Cable for transformer coil leads.

kVA	Approximate outside bare diameter in inches		
	1000 volts	450 volts	120 volts
1	0.111	0.111	0.111
3	.111	.111	.111
5	.111	.111	.111
7-1/2	.111	.111	.167
10	.111	.111	.266
15	.111	.111	.266
25	.167	.167	.477
37-1/2	.266	.266	.601
50	.266	.266	.601
75	.335	.335	1/ .477
100	.378	.378	1/ .477
125	.378	.628	.477

1/ Denotes two leads in parallel.

3.29.1 Cable lead substitution. Any other cable leads shall be subject to acceptance of NAVSEC or agency concerned.

3.29.2 Cable lead markings. The transformer primary leads shall be marked H1 and H2 and the secondary output leads shall be marked X1 and X2. The markings shall be stamped on aluminum cable bands.

3.30 Drawings. Unless otherwise specified (see 6.3), drawings and certification data sheets shall be furnished. Drawings shall conform to MIL-D-1000, category A, F, G and form 2 and MIL-D-1000/2, type II(b). Certification data sheets shall conform to MIL-D-1000/2, type III. Figure 3 is a typical transformer drawing. NAVSEC is the acceptance activity for drawings and the ordering activity is the acceptance activity for certification data sheets.

3.30.1 Drawing contents. The drawing requirements specified in 3.30 shall include the following minimum data:

(a) Manufacturer's name.
(b) List of descriptive data including:
Enclosure.
Rating (kVA, phase, Hz)
Duty.
Maximum temperature rise.
Maximum ambient temperature.
Shock classification.
Mounting.
Polarity.
Manufacturer's catalog number for each voltage rating.
Insulation system class.
Federal Supply Catalog.
(c) Weight and volume of equipment.
(d) Finish, including method of treatment of enclosure for painting, color and applicable specification of paint.
(e) Method of impregnation of windings including step by step procedure.
(f) Table of coil lead data with corresponding volts, bare wire diameter, insulated wire diameter, number of wires in stranding, size of wire and insulation.
(g) Sectional view of windings and insulation.
(h) A table of insulation indicating the location, insulation material, thickness and type used and the applicable specifications and remarks.
(i) Description of the application of insulating materials, where used, including location and manner of application of tape, cord, or sleeving.
(j) Outline with cutaway half sections and essential details of the equipment. The front and side views shall be shown. The top view shall also be shown, if necessary, for understanding the drawing. The center of gravity shall be shown and dimensioned.
(k) Elementary wiring diagram showing lead markings.
(l) Table of design performance data with corresponding groups, primary no-load voltage, primary rated amperes, secondary no-load voltage, secondary rated amperes, no-load watts loss, total watts loss, regulation at 1.0 pf, regulation at 0.8 pf, percent exciting current, percent impedance and maximum peak inrush current.

(m) Table of winding data with corresponding group number, winding, number of coils, turns, turns per layer, layers, length of layer, dimensions of bare conductor, area of conductor, dimensions of insulated conductor, applicable specification of conductor, weight of conductor, and resistance of winding.
(n) Diagram of connections for three phase operation of delta-delta and delta-wye connections.
(o) Cutaway pictorial view of wiring compartment showing method of connecting leads to ship's cable.
(p) Table of approval status with date and file number of NAVSEC or agency concerned acceptance letter.

3.30.2 Certification data sheet contents. The requirements of MIL-D-1000/2, type III shall include the following:

Transformer.
kVA rating.
Primary volts.
Secondary volts.
Frequency.
Insulation system class.
Class shock.
Single phase.
Weight.
Manufacturers catalog No.
Federal stock number.
Maximum ambient temperature.
Maximum temperature rise in °C.

3.31 Reliability and maintainability program. A prerequisite to qualification shall be the submittal of a reliability and maintainability plan covering all equipment that will be supplied against this specification. The plan shall be submitted to NAVSEC for acceptance. MIL-STD-785 and MIL-STD-470 shall be used as guidelines in preparing the reliability and maintainability program. The minimum plan shall require the manufacturer to accomplish the following:

(a) Define the equipment covered by the program plan (for example: 400 Hz transformers for use on Naval shipboard).
(b) List the military specifications which govern the equipment furnished under this plan such as MIL-T-17221, MIL-E-917 and others.
(c) Describe the inspection system which will be followed.
(d) Indicate the system which will be used to insure reliability of suppliers' and subcontractors' products.
(e) Describe training to be provided to manufacturing personnel to permit these personnel to keep pace with improved methods and materials.
(f) Identify personnel responsible for the reliability and maintainability program.
(g) Indicate that design reviews will be conducted, identifying personnel involved and stating frequency of review sessions. Reviews shall include these topics:
    (1) Reliability
    (2) Design
    (3) Value engineering
    (4) Safety engineering
    (5) Standardization of parts
    (6) Means of reducing maintenance
    (7) Improvements in methods and materials
    (8) Inspection procedures
(h) Indicate the system which will be used to improve parts reliability and maintainability of equipment.
(i) Indicate techniques that will be used in arriving at reliability and maintainability data.
(j) Indicate life-cycle cost estimates and cost effectiveness studies which have been, and will be, performed.
(k) Include a copy of the Technical Manual Preventive Maintenance Form.

3.32 Workmanship. All metal surfaces shall have a smooth finish and all details of manufacture, including the preparation of parts and accessories, shall be in accordance with the best practice for high quality electrical equipment. Particular attention shall be given to neatness and thoroughness of wiring, impregnation of coils, marking or parts, plating, finishes, riveting, welding, clearance between connections, ruggedness, and suitability of enclosure.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all requirements as specified herein. Except as otherwise specified in the contract or order, the supplier may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.2 Classification of inspection. The examination and testing of transformers shall be classified as follows:

(a) Qualification tests (see 4.3).
(b) Quality conformance inspection (see 4.4).

4.3 Qualification test.[1/] Qualification tests shall be conducted at a laboratory satisfactory to the Naval Ship Engineering Center (NAVSEC). Qualification tests shall consist of the examination and tests specified in 4.3.1.

4.3.1 Sampling for qualification inspection. One representative transformer of each of the divisions shown in table II shall be submitted for examination and test. The size transformer required as representative for each division is marked with a superior two in table II. For the purpose of obtaining comparative data on transformer representative of different manufacturer's practices it is highly desirable that all manufacturers submit transformers of the same capacity for test. When such practice is impracticable because the size shown will not be representative of the given division, consideration will be given to the manufacturer's request for test of a size of transformer more representative of that division. A qualification sample selected from table II shall be submitted for the qualification inspection specified in table VI.

4.3.2 Test records for qualification inspection. Three copies of the test report shall be submitted to NAVSEC for acceptance action. A separate report shall be prepared for each transformer including a report number, date and authentication by the DCAS. The report shall show the tests in sequence as shown in the specification and in a table form. The table shall show the test, test value recorded and the applicable specification limit. Supplemental sheets shall show calculations for various tests such as regulation, heating, inrush current, short circuit and etc.

Table VI - Qualification and quality conformance inspection.

Inspection	Qualification inspection	Quality conformance inspection			Requirement paragraph	Inspection paragraph
		Group A	Group B	Group C		
General examination	X	-	X	-	3.32	4.5
Winding resistance	X	-	X	-	3.11	4.6.1
Polarity	X	-	X	-	3.14	4.6.2
Ratio	X	-	X	-	3.13	4.6.3
Impedance	X	-	-	X	----	4.6.4
Losses - no load	X	-	-	-	3.10	4.6.5.1
Losses - total	X	-	-	X	3.10	4.6.5.2
Exciting current	X	-	X	-	3.10	4.6.6
Regulation	X	-	-	X	3.10	4.6.7

[1/] Application for Qualification tests shall be made in accordance with "Provisions Governing Qualification" (see 6.4 and 6.5). An applicable transformer drawing in accordance with 3.30 shall be submitted with the request for authorization of testing.

Table VI - Qualification and quality conformance inspection (cont'd.).

Inspection	Qualification inspection	Quality conformance inspection			Requirement paragraph	Inspection paragraph
		Group A	Group B	Group C		
Heating	X	X	-	-	3.9	4.6.8
Weight and volume	X	-	-	X	3.18 and 3.19	4.6.9
Shock	X	-	-	-	3.16	4.6.10
Post shock	X	-	-	-	3.16	4.6.10.3
Dielectric	X	-	X	-	3.20	4.6.11
Inrush current	X	X	-	-	3.10	4.6.12
Short circuit	X	X	-	-	3.17	4.6.13
Noise	X	X	-	-	3.15	4.6.14

4.4 Quality conformance inspection. At 3 year intervals after qualification inspection a transformer kVA rating shall be selected from the applicable qualification division and subjected to the quality conformance, group A tests shown in table VI. This requirement is based on quantity production. If it appears that more than 3 years will elapse from the last quality conformance group A test before the manufacturer will again supply a transformer rating in the particular qualification division, the tests shall be conducted on an applicable transformer of the subsequent contract or order. Each production line transformer shall be subjected to all the tests shown in table VI in the quality conformance, group B tests. In addition, production line transformers shall also be subjected to the quality conformance group C tests on the selection basis shown in table VII.

Table VII - Sampling for quality conformance, group C tests.

Number of transformers on order	Minimum number of transformers to be tested
1 to 30	None
31 to 65	3
66 to 110	5
111 to 180	7
181 to 300	10

4.5 General examination. Each transformer shall be subjected to a through examination to ascertain that the material, workmanship, and design or conformance with this specification as well as with the applicable drawing.

4.6 Tests.

4.6.1 Resistance. The resistance of both the primary and secondary windings shall be accurately measured. The ambient temperature at which the resistance readings are taken shall also be recorded.

4.6.2 Polarity. The polarity of each transformer shall be determined by either of the methods specified in 4.6.2.1 and 4.6.2.2.

4.6.2.1 Polarity by alternating voltage. The left-hand side (facing the low voltage side of the transformer) high-voltage and low-voltage outlet leads shall be connected together. Any convenient value of alternating voltage not exceeding rated voltage shall be applied to the high-voltage winding. Readings of the applied voltage and voltage between the right-hand adjacent high-voltage and low-voltage leads shall be observed. If the latter voltage reading is less than the former (indicating the approximate difference in voltage between that of the high-voltage and low-voltage windings) the polarity is subtractive. If the latter is greater than the former, the polarity is additive.

4.6.2.2 Polarity by standard transformer. A standard transformer of known polarity and having the same ratio as the transformer to be tested may be used. The high-voltage windings of both transformers shall be connected in parallel. The left-hand side low-voltage leads (facing the low-voltage side) of both transformers shall be connected together. The right-hand side leads shall be left free. With these connections apply a reduced value of voltage to the high-voltage windings and measure the voltage between the two free leads. A zero or negligible reading of the voltmeter will indicate that the relative polarities of both transformers are identical.

4.6.3 Ratio. The turn ratio between the primary and the secondary windings shall be accurately determined by either of the methods specified in 4.6.3.1 through 4.6.3.2.2.

4.6.3.1 Voltmeter method. The ratio test shall be made with rated or lower voltage at rated or higher frequency applied to either the high or low voltage leads of the transformer. Simultaneous readings of a voltmeter in the high-voltage winding and a voltmeter in the low-voltage winding shall be taken and recorded. The meters shall be interchanged and another set of readings obtained, the average of these two sets of readings shall be used in checking the ratio.

4.6.3.2 Standard transformer method. The transformer to be tested shall be connected in parallel with a standard transformer of the same nominal ratio. The secondaries shall also be connected in parallel but with a voltmeter or detector in the connection between two terminals of similar polarity and so arranged as to read the difference between the two secondary voltages. If the manufacturer desires, the voltages in each secondary winding may be obtained. Where this method is used, however, the voltmeters shall be interchanged and a second set of readings shall be obtained. The average of the results shall be used in determining the ratio.

4.6.3.2.1 The connections for the ratio test by comparison with standard transformer are shown on figures 4 and 5.

4.6.3.2.2 The variation of the value of ratio between transformers of the same size, and design shall be within plus or minus 1/2 of 1 percent of turns ratio shown on applicable drawing.

4.6.4 Impedance. Either the primary or the secondary winding shall be short circuited and voltage at rated frequency applied to the other winding and adjusted to circulate rated current in the winding. With current and frequency adjusted to rated values, simultaneous readings shall be taken on the ammeter, voltmeter, wattmeter and frequency meter. The actual design value appears on the drawings. The impedance values for transformers of the same size, and design may vary from the value shown on the drawings by not more than plus or minus 7-1/2 percent.

4.6.5 Losses.

4.6.5.1 No-load losses. The no-load losses shall be accurately determined. Rated voltage shall be applied to either the primary or secondary windings. The frequency shall be 400 Hz. Simultaneous readings shall be made of frequency, voltage, watts (low power factor wattmeter), and amperes. The actual design value appears on the drawings. The no-load loss for transformers of the same size, design, and type may exceed the value shown on the drawing by 10 percent; however, in no case shall the no-load losses exceed the maximum allowable no-load losses shown in table II.

4.6.5.2 Total losses. From the data obtained in the impedance test and no-load loss test, the total losses shall be determined. The actual design value appears on the drawings. The total loss for transformers of the same size, and design may exceed the value for full load loss watts shown on the drawing by 6 percent, but in no case shall the value exceed the value for full load losses shown in table II.

4.6.6 Exciting current. The exciting current shall be determined during the no-load loss test, and shall not exceed the maximum allowable value of exciting current shown in table II.

4.6.7 Regulation. The regulation of a transformer shall be determined by calculation based on the measured values of impedance volts and impedance watts, corrected to 150°C. Either of the following formulae may be used in the calculation of the regulation:

Formula I:

(a) When the load is lagging

$$\text{Regulation} = pr + qx + \frac{(px - qr)^2}{2}.$$

(b) When the load is leading

$$\text{Regualtion} = pr - qx + \frac{(px + qr)^2}{2}.$$

Formula II:

$$\text{Regulation} = a - 1/2a^2 + 1/2a^3 - 5/8a^4 + 7/8a^5$$

Where:

$p = \cos\theta$ = power factor of load.

$q = +\sqrt{1 - p^2}$.

θ = phase angle of load current, positive for leading current, negative for lagging current.

ϕ = impedance angle of transformer.

r = resistance factor = $\frac{\text{impedance loss in kw.}}{\text{rated kva}}$

z = impedance factor = $\frac{r}{\cos\phi}$

x = reactance factor = $+\sqrt{z^2 - r^2}$.

$a = z\cos(\phi + \theta) + \frac{z^2}{2}$.

The quantities of regualtion are on a per unit basis so that the result must be multiplied by 100 to get the regulation in percent.

4.6.8 Heating.

4.6.8.1 General. Heating tests on transformers shall be made under conditions equivalent to normal operating conditions, that is, rated voltage, rated frequency, rated current, and the duty specified. The test methods to be employed and the precautions to be observed shall be as specified in 4.6.8.2 through 4.6.8.5.3.

4.6.8.2 Assembly of transformer. The heating test shall be made only on the completely assembled transformer.

4.6.8.3 Duration of test. The heating test for transformer shall be continued until constant temperatures have been attained in all parts of the transformer.

4.6.8.4 Method of loading. The following methods of loading transformers for the heating test are acceptable:

(a) The transformer may be loaded directly. That is, with rated voltage applied to the primary and sufficient load on the secondary to load the transformer to rated kVA capacity.

(b) Duplicate single-phase transformers may be tested in banks of two by connecting both the high-voltage and low-voltage windings in parallel and by applying rated excitation voltage at rated frequency to one set of paralleled windings, as shown on figure 6. The connections of the other pair of windings shall be opened at one point and a voltage impressed across the break just sufficient to circulate rated currents through the windings. The circulated current should preferably be at rated frequency.

Note: If other than rated frequency is applied to the opened windings the value of the current should be adjusted to yield the true impedance watts of the transformer.

4.6.8.5 Measurement of the ambient temperature. Unless otherwise specified in the contract or order, transformers may be tested at any convenient room temperature above 10°C. With a minimum distance of 2 inches between units, the maximum permissible temperature rises specified shall not be exceeded. In order to avoid errors due to time lag, air stratification, and drafts, precautions as specified in 4.6.8.5.1 through 4.6.8.5.3 shall be observed.

4.6.8.5.1 The ambient or room temperature shall be measured by means of two or more thermometers placed at different points around and on level with the transformers and at a distance of 3 to 6 feet therefrom. The room temperature thermometers shall be inserted in oil-filled cups, not less than 1-inch external diameter and 2 inches high, and shall be protected from drafts and from abnormal heat radiation. The value to be adopted for the ambient or room temperature during the tests shall be the mean of the readings of the several thermometers (placed as stated) taken at 4 equal intervals of time during the last quarter of the duration of the test.

4.6.8.5.2 The test room temperature shall not vary significantly during tests. During a 6 hour period, the temperature variation shall never exceed 10°C. If the room temperature is very irregular during a test or changes rapidly at the end, the test shall be repeated.

4.6.8.5.3 In determining temperature rise, no correction shall be made for barometric pressure, humidity; however, a correction will be made for a fluctuation in ambient temperature between the cold resistance reading and the ambient temperature occurring in the last quarter of the load run test.

4.6.9 Weight and volume. The weight and volume of a transformer shall be taken and recorded. The design weight appears on the drawing. The weight of transformers of the same size, and design may exceed the value shown on the drawing by 5 percent but in no case shall the weight exceed the value shown in table II.

4.6.10 Shock.

4.6.10.1 General. The shock test shall be in accordance with MIL-S-901, grade A, class I, type A.

4.6.10.2 Mounting. The transformers shall be mounted on the shock machine in the following manner:

(a) Light-weight machine - figure 4A of MIL-S-901 (1 thru 37.5 kVA).
(b) Medium-weight machine - figure 9-1 of MIL-S-901 (50 thru 125 kVA).

4.6.10.3 Inspection of transformer after shock test. After the shock test the transformer shall be carefully inspected for damage. The details of all damage shall be recorded. If there are any appreciable injuries it will be considered that the transformer has failed to meet the requirements of this test.

4.6.10.3.1 Electrical tests. After the mechanical inspection, the transformer shall be submitted to the following electrical tests in the order listed:

(a) No-load loss (see 4.6.5.1).
(b) Exciting current (see 4.6.6).
(c) Short circuit (see 4.6.14).
(d) Dielectric (see 4.6.11).

If the values of no-load loss watts and the exciting current amperes differ by more than plus or minus 5 percent and 10 percent, respectively, from the original values, it will be a cause for rejection. Failure of the transformer to meet the requirements of the short circuit test or the dielectric test will also be sufficient cause for rejection.

4.6.11 Dielectric strength test.

4.6.11.1 General. The dielectric strength test shall be performed following completion of all but the weight and shock tests. This test shall be made on the completely assembled transformer at equipment temperature between 10° and 50°C.

4.6.11.2 Applied potential. The test voltage shall be applied successively between each winding with all other windings and metal parts grounded.

4.6.11.2.1 Test voltage. The test voltage shall approximate a true sine wave. The insulation of the high-voltage winding shall withstand a dielectric test voltage (rms) of 4,000 volts ac 60 Hz, or a period of 1 minute with the low-voltage winding and case and core

grounded. The low-voltage winding insulation shall withstand a dielectric test voltage (rms) of 4,000 volts ac, 60 Hz, for a period of 1 minute with the high-voltage winding and case and core grounded.

4.6.11.2.2 Measurement of test voltage. The voltmeter method shall be used. In measuring the voltage, the voltmeter shall derive its voltage from the high voltage circuit either directly or through an auxiliary ratio transformer placed across the testing transformer.

4.6.11.3 Induced potential. The test voltage shall be applied to either winding and shall approximate a true sine wave. The insulation of the low-voltage and the high-voltage windings shall withstand a voltage applied to either winding of twice normal operating voltage at a frequency of not less than 800 Hz or a period of not less than 7,200 cycles at the frequency of the applied test voltage.

NOTE: The frequency of the voltage should be such that the exciting current is not in excess of 30 percent of rated load current.

4.6.12 Inrush currents. Oscillograph measurements of the maximum inrush currents to the primary winding shall be obtained with rated frequency - applied to the primary winding to determine conformance with table II. The secondary winding shall be open-circuited. The following procedure shall be used in conducting this test:

(a) Apply direct current (dc) to primary winding. The value of dc shall be equal in amperes to the crest value of the ac exciting current.
(b) Gradually remove dc from primary winding.
(c) Apply rated value ac voltage to primary winding. Provision shall be made to insure that the voltage is applied when the voltage wave is passing through zero (plus or minus a maximum of 15 degrees is permissible) in the direction that adds to the residual magnetism.
(d) Record inrush current, primary voltage and secondary voltage waves on oscillograms. Copies of the oscillograms shall be in the test report.

4.6.13 Short circuit. The short circuit test shall be performed in a 60 Hz or 400 Hz test facility. Rated voltage and frequency shall be applied to one winding. The other winding shall be short-circuited. The short-circuit current and duration of short-circuit test shall be as specified in table VIII for the corresponding impedance:

Table VIII - Short circuit test.

Percent impedance	Rms symmetrical short circuit current to be withstood	Time period
		Seconds
4 or less	25 times rated current	2
5	20 times rated current	3
6	16.6 times rated current	4
7 or more	100/percent impedance	5

Intermediate values may be determined by interpolation. There shall be no evidence of shifting of coils or cores or damage to the insulation or loosening of the core.

4.6.14 Noise. Noise tests shall be conducted in accordance with the requirements of MIL-STD-740 for type 3 and grade C equipment (see 3.15). The transformer shall be operated at rated load and voltage (see 4.6.8.4). Short test reports as defined in MIL-STD-740 shall be furnished.

5. PREPARATION FOR DELIVERY

(The preparation for delivery requirements specified herein apply only for direct Government procurements. For the extent of applicability of the preparation for delivery requirements of referenced documents listed in section 2, see 6.6.)

5.1 Preservation, packaging, packing and marking. Transformers shall be preserved and packaged level A or C; packed level A or B and marked as specified in accordance with MIL-E-17555.

6. NOTES

6.1 Intended use. Transformers are used in shipboard electrical systems in order to step-down or step-up the voltage normally available.

6.2 Repair parts. Repair parts for transformers are not required.

6.3 Ordering data.

6.3.1 Procurement requirements. Procurement documents should specify the following:

(a) Title, number, and date of this specification.
(b) Voltage required for transformers (see 3.7.1).
(c) kVA capacity required for transformers (see 3.7.3).
(d) Duty (see 3.8).
(e) Drawings and certification data sheets required (see 3.30).

6.3.2 Contract data requirements. Data generated by this document are not deliverable unless specified on the Contract Data Requirements List (DD Form 1423) or the contract schedule. The data required by this specification include, but are not restricted to the following:

(a) Drawing and certification data sheets (see 3.30).

6.4 With respect to product requiring qualification, awards will be made only for products which are at the time set for opening of bids, qualified for inclusion in applicable Qualified Products List QPL-17221 whether or not such products have actually been so listed by that date. The attention of the suppliers is called to this requirement, and manufacturers are urged to arrange to have the products that they propose to offer to the Federal Government tested for qualification in order that they may be eligible to be awarded contracts or orders for the products covered by this specification. The activity responsible for the Qualified Products List is the Naval Ship Engineering Center, Prince George's Center, Center Building, Hyattsville, Maryland 20782, and information pertaining to qualification of products may be obtained from that activity. Application for Qualification tests shall be made in accordance with "Provisions Governing Qualification SD-6" (see 6.5).

6.5 Copies of "Provisions Governing Qualification SD-6" may be obtained upon application to Commanding Officer, Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, Pennsylvania 19120.

6.6 Sub-contracted material and parts. The preparation for delivery requirements of referenced documents listed in section 2 do not apply when material and parts are procured by the supplier for incorporation into the equipment and lose their separate identity when the equipment is shipped.

Preparing activity:
Navy - SH
(Project 6120-N015)

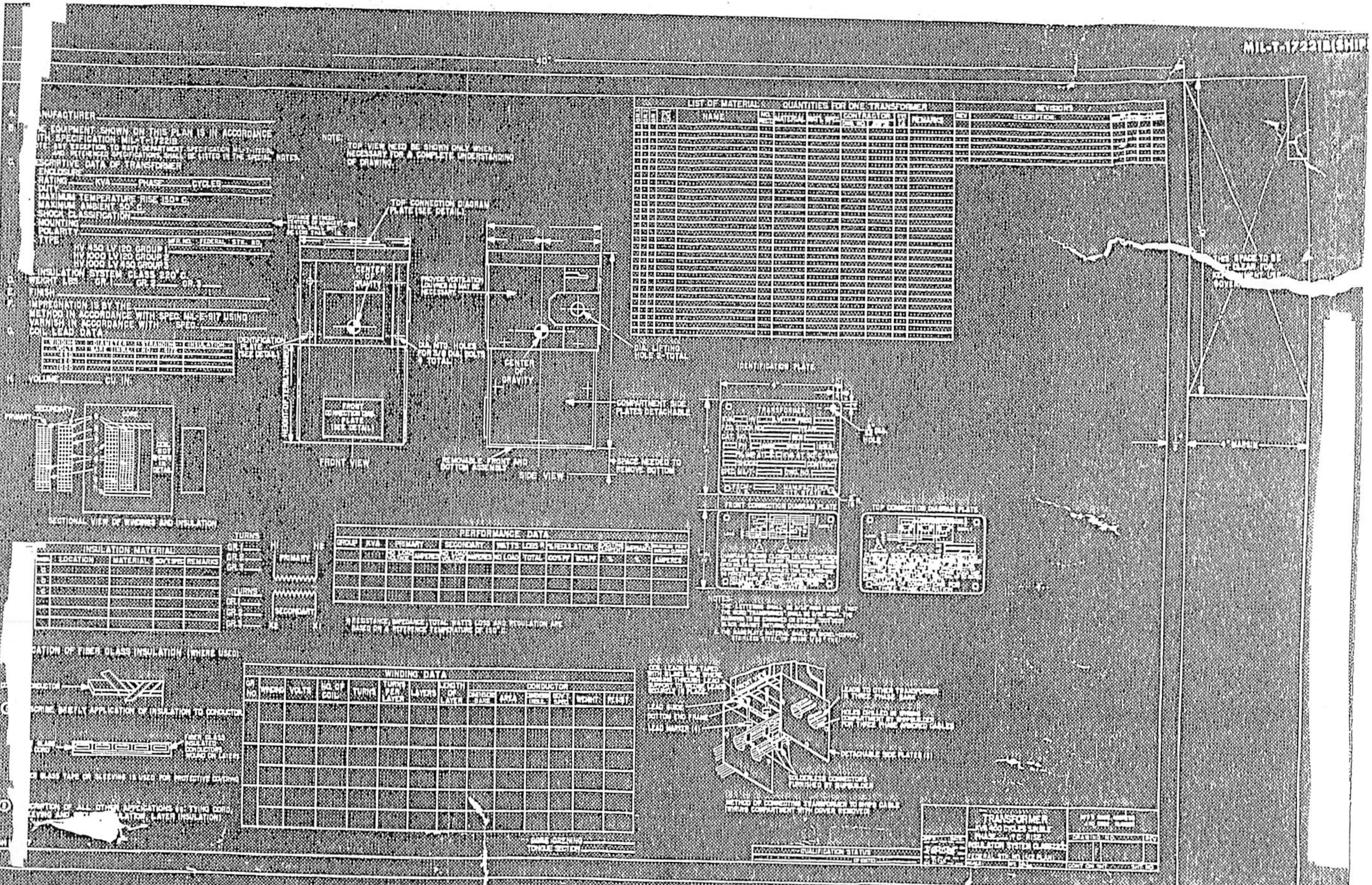
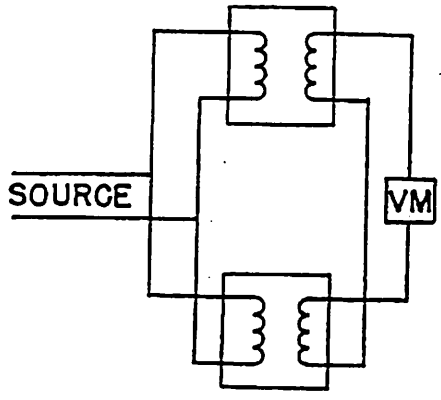
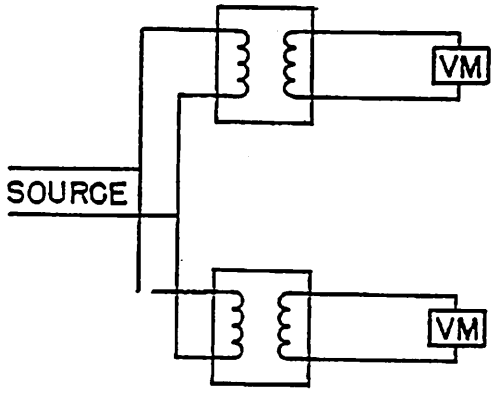


Figure 3 - Typical plan.



SH10528

VOLTMETER ARRANGED TO READ THE DIFFERENCE BETWEEN THE TWO SECONDARY VOLTAGES.



SH 10529

VOLTMETER ARRANGED TO READ THE TWO SECONDARY VOLTAGES. THE READINGS ARE REPEATED AFTER INTERCHANGING VOLTMETERS.

Figure 4 - Transformer under test.

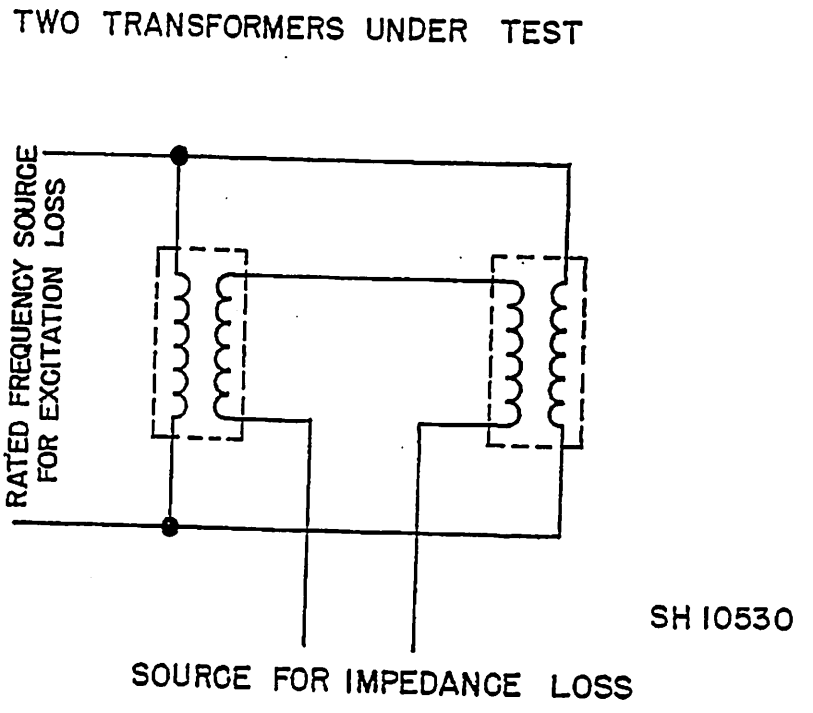


Figure 5 - Method of loading transformers for the heating test.