AN EVALUATION OF 15KV OUTDOOR VOLTAGE TRANSFORMERS

JULY 1985

METER BUSINESS DEPARTMENT
GENERAL ELECTRIC COMPANY
SOMERSWORTH, NEW HAMPSHIRE 03878

GENERAL ELECTRIC

CONTENTS

15KV INSTRUMENT TRANSFORMER TEST REPORT

I. PERSPECTIVE

High voltage instrument transformers are used by utilities for their largest revenue commercial and industrial customers and for overall systems protection. While long term system reliability and uninterrupted service are extremely important, some utilities and manufacturers have experienced product problems and/or instrument transformer failures that have adversely impacted service and revenue.

II. PROGRAM PURPOSE

With some new instrument transformer designs available and the realization that user's incoming tests aren't necessarily indicative of long term product reliability, General Electric has completed a comprehensive test program to better assess available design attributes and evaluated reliability. With 15 KV being the major class of distribution voltage, this program analyzed the products of manufacturers of dry type 15KV outdoor voltage transformers.

The product samples used in this evaluation were selected entirely at random. Sample sizes were limited; therefore, General Electric encourages users to conduct further test programs to expand this base data.

III. GENERAL SUMMARY HIGHLIGHTS

The General Electric JVW-110 and JVW-5* voltage transformers were evaluated to be superior in performance, electrical tests, resistance to mechanical damage, and product features.

Although all products performed well on applied potential, accuracy, and megger tests, (see description of test in Section VII), some have demonstrated shortcomings on the critical ANSI design tests such as impulse and environmental tests such as mechanical drop tests.

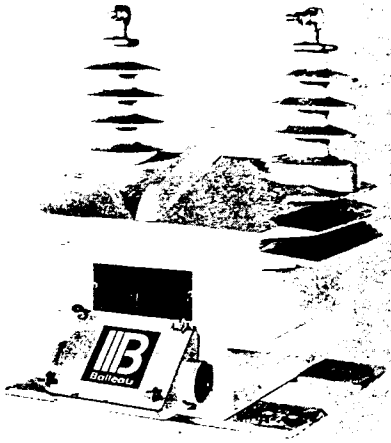
It is evident from these results that typical user incoming tests do not adequately evaluate a product's capability to provide long term, trouble-free service. There *are* measurable differences in product performance between manufacturers as will be illustrated further in this report.

Users should give due consideration to evaluating their instrument transformer suppliers in greater depth than has typically been done in the past and consider reliability objectives as a key factor in establishing individual manufacturer approvals.

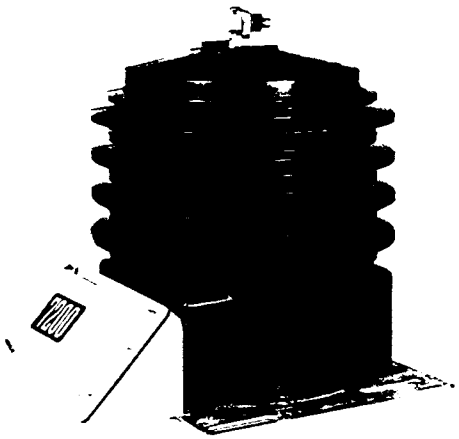
*based on similarity in design to the JVW-110

IV. LIST OF PRODUCTS EVALUATED

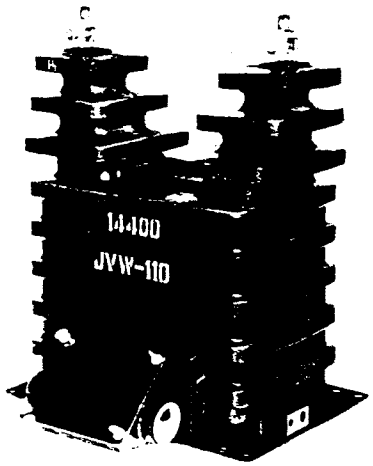
ASSOCIATED ENGINEERING COMPANY PTT-110
THREE (3) UNITS EVALUATED



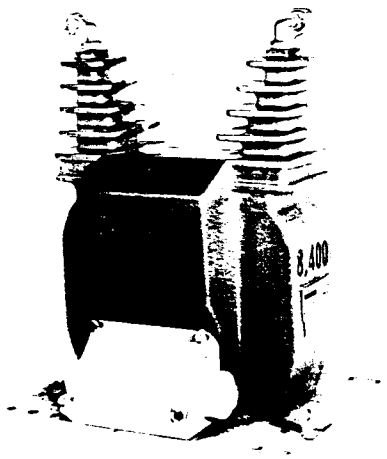
BALTEAU STANDARD INC. VEO1-110
SIX (6) UNITS EVALUATED



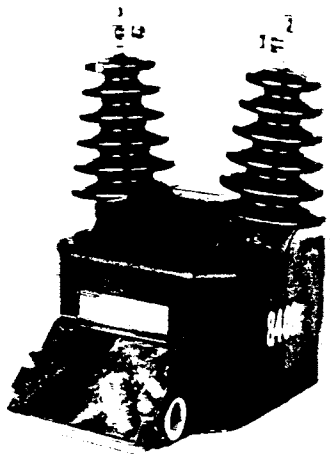
ELECTROMAGNETIC INDUSTRIES • SQUARE D COMPANY
PO5-110
THREE (3) UNITS EVALUATED



GENERAL ELECTRIC COMPANY JVW-110
THREE (3) UNITS EVALUATED



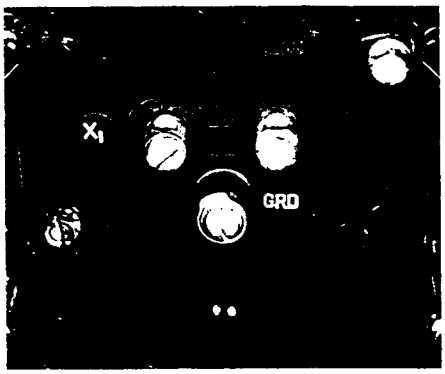
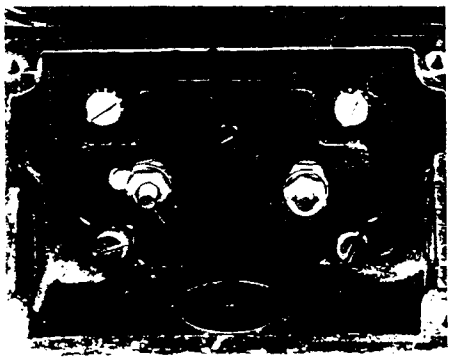
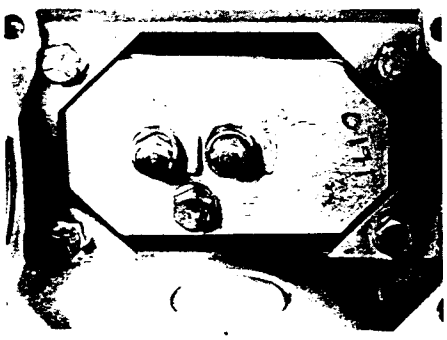
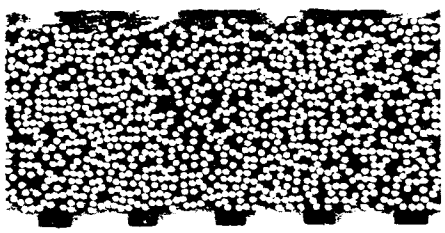
SANGAMO WESTON MEO-1503
SIX (6) UNITS EVALUATED



WESTINGHOUSE ELECTRIC CORPORATION VOZ-11
THREE (3) 1981 UNITS EVALUATED
SIX (6) 1984 UNITS EVALUATED

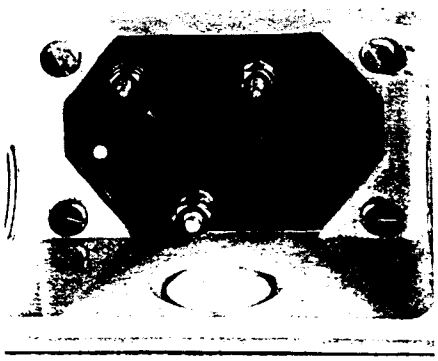
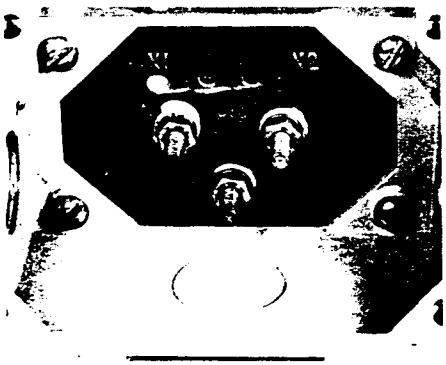
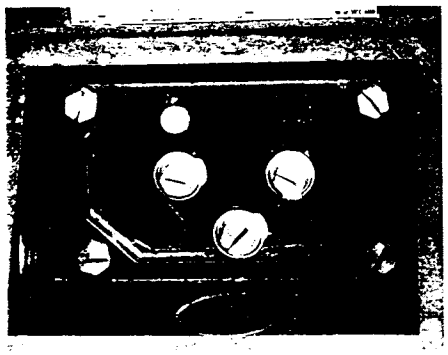
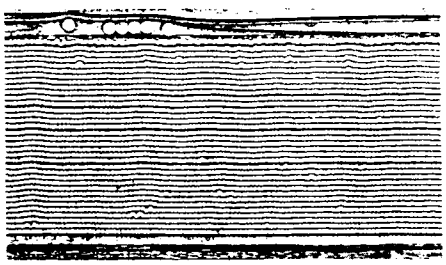
V. NAMEPLATE DATA AND VISUAL OBSERVATIONS

MANUFACTURER	TYPE	BIL (KV)	VOLTAGE RATIO	PRIMARY BUSHINGS	WEIGHT LBS.	QUOTED ANSI ACCURACY 0.3W THRU-	QUOTED THERMAL RATING VA AT 30C AMB.	EXTERNAL INSULATION	NAMEPLATE MATERIAL	NAMEPLATE GROUNDED
ASSOCIATED ENGINEERING	PTT-110	110	7200:120	2	138	Y (75VA)	1500	Butyl	St. Steel	No
BALTEAU STANDARD	VEO1-110	110	7200:120	2	127	Z (200VA)	1500	Epoxy (1)	St. Steel	No
ELECTROMAGNETIC IND.	PO5-110	110	7200:120	1	67	Y (75VA)	750	Epoxy (1)	St. Steel	Yes
GENERAL ELECTRIC	JVW-110	110	8400:120	2	103	Y (75VA)	1200	Butyl	St. Steel	Yes
GENERAL ELECTRIC	JVW-5	110	8400:120	2	105	Z (200VA)	1500	Butyl	St. Steel	Yes
SANGAMO WESTON	MEO-1503	110	8400:120	2	68	Y (75VA)	1200	Epoxy (1)	Aluminum	No
WESTINGHOUSE (1981)	VOZ-11	110	8400:120	2	73	Z (200VA)	1500	Epoxy (2)	St. Steel	No
WESTINGHOUSE (1984)	VOZ-11	110	8400:120 7200:120	2	73	Z (200VA)	1500	Epoxy (2)	St. Steel	No

JVW-110 GENERAL ELECTRIC	PTT-110 ASSOCIATED ENGINEERING	VEO1-110 BALTEAU STANDARD
		
Secondary Terminal Area	Secondary Terminal Area	Secondary Terminal Area
		
Cross Section of Primary Coil	Cross Section of Primary Coil	Cross Section of Primary Coil

Notes: (1) Cycloaliphatic epoxy.
(2) "WESTINGHOUSE EPOXY", "SATURATED EPOXIES".
(3) Soldered to H_2 connection strap.
(4) No external ground provided independent of the H_2 terminal.

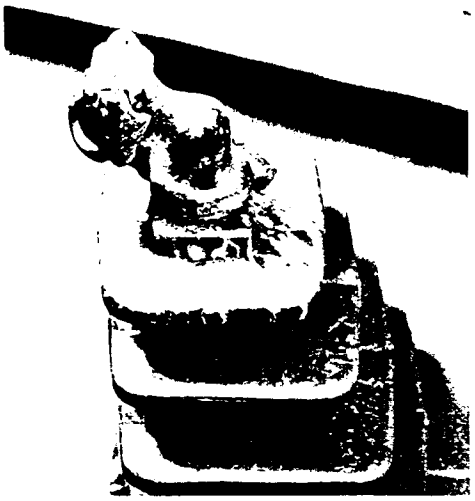
BASEPLATE							PRIMARY COIL DESIGN		
MATERIAL	REMOVABLE	CONDUIT BOX MATERIAL	GROUND TERMINAL NEAR SECONDARY	EXTERNAL GROUND	SECONDARY HARDWARE	CREEPAGE DISTANCE	# SECTIONS	WINDING METHOD	EPOXY IMPREGNATED
St. Steel	No	Aluminum	No	Yes	Studs	Exceeds ANSI	2	Layer w/paper	Yes
Steel	Yes	Aluminum	Yes	Yes	Bolts	Exceeds ANSI	2	Layer w/paper	No
St. Steel	(3)	Plastic	Yes	No(4)	Studs	Exceeds ANSI	1	Layer w/paper	Yes
St. Steel	No	Aluminum	Yes	Yes	Clamp	Exceeds ANSI	2	Lattice	Yes
St. Steel	No	Aluminum	Yes	Yes	Clamp	Exceeds ANSI	2	Lattice	Yes
Steel	Yes	Aluminum	Yes	Yes	Studs	Exceeds ANSI	1	Layer w/paper	Yes
Aluminum	Yes	Plastic	Yes	Yes	Screws	Exceeds ANSI	4	Random	Yes
Aluminum	Yes	Aluminum Plastic	Yes	Yes	Screws	Exceeds ANSI	2	Layer w/paper	Yes

PO5-110 ELECTROMAGNETIC IND	MEO-1503 SANGAMO WESTON	VOZ-11 WESTINGHOUSE
		
Secondary Terminal Area	Secondary Terminal Area	Secondary Terminal Area
		
Cross Section of Primary Coil	Cross Section of Primary Coil	Cross Section of Primary Coil 1984 PRODUCTION

VI. TEST RESULTS

		TYPICAL UTILITY TEST ON INCOMING					
	TYPE	PRI HIPOT	SEC HIPOT	PRI MEGGER	SEC MEGGER	PRI PF	ACCURACY
ASSOCIATED ENGINEERING	PTT-110	OK	OK	OK	OK	OK	OK
BALTEAU STANDARD	VEO1-110	OK	OK	OK	OK	OK	OK
ELECTROMAGNETIC INDUSTRIES	PO5-110	OK	OK	OK@	OK	—	OK
GENERAL ELECTRIC COMPANY	JVW-110	OK	OK	OK	OK	OK	OK
SANGAMO WESTON	MEO-1503	OK	OK	OK	OK	OK	OK
WESTINGHOUSE (1981)	VOZ-11	OK	OK	OK	OK	OK	OK
WESTINGHOUSE (1984)	VOZ-11	OK	OK	OK	OK	Over 2%	OK

@ based on Secondary Megger to base and H_2

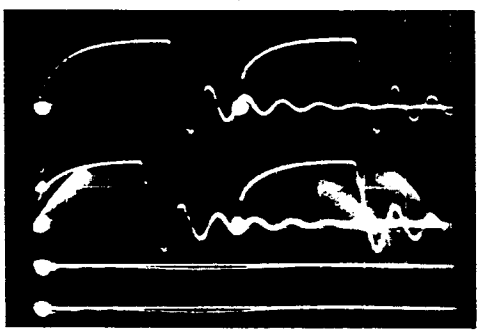


SANGAMO WESTON
MEO-1503
SALT FOG TEST RESULTS

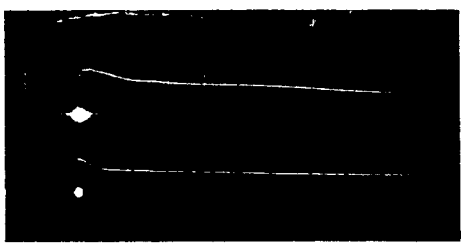
BALTEAU STANDARD
VEO1-110
DROP TEST RESULTS

ELECTROMAGNETIC INDUSTRIES
PO5-110
DROP TEST RESULTS

ELECTROMAGNETIC INDUSTRIES
PO5-110
NORMAL IMPULSE OSCILLOGRAMS



GENERAL ELECTRIC
JVW-110
NORMAL IMPULSE OSCILLOGRAMS

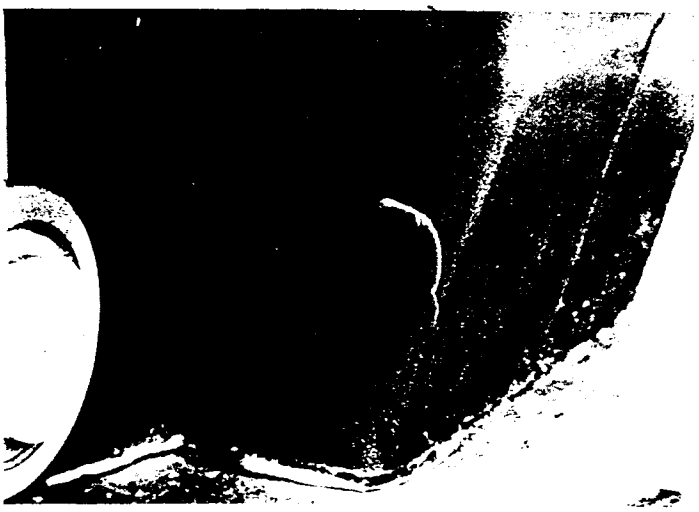


ASSOCIATED ENGINEERING
PTT-110
IMPULSE OSCILLOGRAMS
CONNECTION #2 & #3
CWV FAILURE*

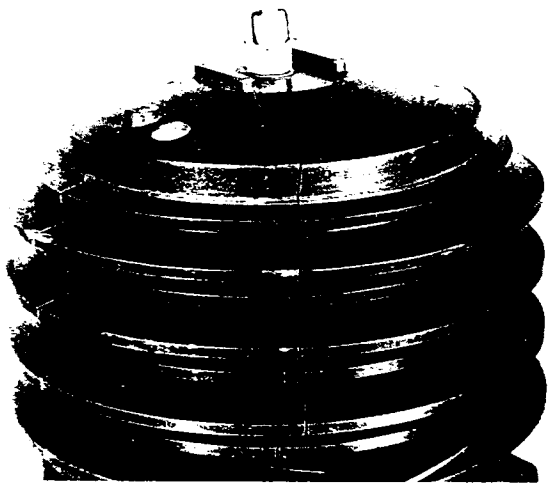
CORONA OR PARTIAL DISCHARGE	INDUCED VOLTAGE	ANSI DESIGN TESTS		ENVIRONMENTAL TESTS			
		IMPULSE	TEMP. RISE	SALT FOG	THERMAL SHOCK	ACCEL LIFE TEST	DROP TEST
OK	OK	100% Failed*	>55°C	—	—	OK	OK
OK	OK	100% Failed*	>55°C	OK	OK	OK	Damaged
OK	OK	OK	<55°C	OK	Cracked	OK	Damaged
OK	OK	OK	<55°C	OK	OK	OK	OK
OK	OK	OK	>55°C	Erosion	OK	Early Failure#	Damaged
OK	OK	67% Failed*	<55°C	OK	OK	OK	OK
High #	OK	OK	<55°C	—	—	—	—

*Based on GE interpretation of oscillogram.

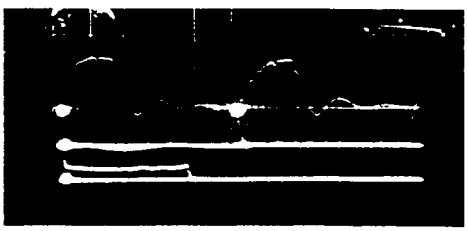
Compared to other units in this evaluation.



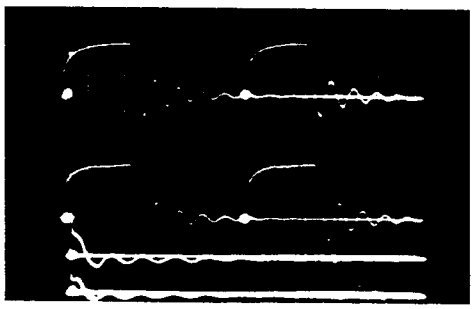
SANGAMO WESTON
MEO-1503
DROP TEST RESULTS



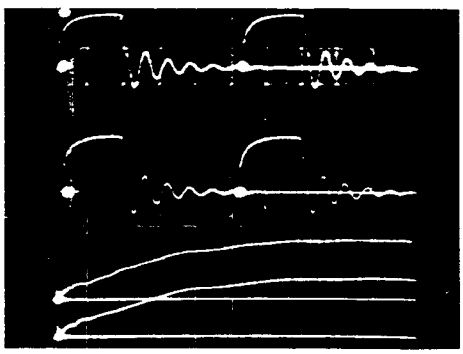
ELECTROMAGNETIC INDUSTRIES
PO5-110
THERMAL SHOCK TEST RESULTS



BALTEAU STANDARD
VEO1-110
IMPULSE OSCILLOGRAMS
CONNECTION #2 & #3
CWV FAILURE *
CONNECTION #3
FWC FAILURE*



SANGAMO WESTON
MEO-1503
NORMAL IMPULSE OSCILLOGRAMS



WESTINGHOUSE
VOZ-11
IMPULSE OSCILLOGRAMS
CONNECTION #2 & #3
CWV NORMAL
CONNECTION #2 & #3
FWC FAILURE*

VII. TESTS DESCRIPTION AND SIGNIFICANCE

(NOTE: All test connections are shown in Appendix 1)

A. Primary insulation power factor— measured at 2.5 and 10.0kV, except it was not measured on the PO5-110 as the H_2 terminal is permanently connected to the base. This is a key test for liquid-immersed apparatus, and a test which has been used as an indicator of insulation quality in solid-insulated instrument transformers. Some observations typically causing concern would be:

1) A change in power factor with time.
2) Tip-up (power factor increases with test voltage).
3) "Power factors" exceeding 2%, a level of commercial interest since those users establishing a flat limit for solid-insulated units typically select 2%. For purposes of this report, power factors below 2% will be considered both technically and commercially acceptable.

B. Accuracy—Tested per ANSI C57.13 at 60 hertz at 100 and 110% of rated voltage, no load, and at rated voltage with the heaviest burden where the accuracy is rated 0.3. This permits evaluation of accuracy versus quoted ratings. The requirement is to meet quoted accuracy.

C. Impulse test—typically consisted of 2 chopped wave shots (voltage detection) on connection #2 and #3 at 130kV crest as defined by ANSI, and 1 full wave shot (current detection) on connection #2 and #3 at 110kV crest, to check the ability to meet the published 110 kV BIL. The requirement is that chopped wave voltage oscillograms, and full wave current oscillograms be typical of those obtained in an unfailed unit of the type.
Note: Only connection #2 is used for single bushing units.

Impulse tests evaluate the quoted capability to withstand voltage waves which may be applied as a result of lightning, and also indicate to some extent, capability of withstanding waves from other disturbances. Failure to meet impulse levels indicates a probability that, in time and in general, a design will experience a greater percentage of failures from voltage surges than would occur if quoted capability was provided.

ANSI C57.13 does not require impulse testing as a 100% production test. GE believes 100% impulse testing is a good manufacturing practice on products where a high impulse test failure rate is anticipated. General Electric also believes type testing and production sampling should be used to provide assurance that quoted impulse strength is met by a very high percentage of each 15kV voltage transformer design.

Impulse strength is one of the quoted ratings pertinent to product life. The design, evaluation, and product costs to assure desired impulse strength may be substantial.

D. Induced voltage test—On two-bushing VT's, 2 times rated secondary voltage is applied at 400 Hz for 18 seconds, with the primary winding open as specified by ANSI C57.13. On one-bushing VT's, the secondary voltage corresponding to a 34kV primary voltage is applied at 400 Hz for 18 seconds with H_1 open and H_2 grounded. The requirement is that the exciting current not exceed a magnitude judged to be typical for the design.

E. Primary applied voltage (hipot) test—On two bushing VT's, this test is run per ANSI at 34kV, 60Hz, for 60 seconds. Ionization (corona) levels, were recorded. The requirements are that the test equipment not be tripped out, which would indicate failure, and that the ionization levels not be clearly excessive.

F. Secondary applied voltage (hipot) test—run at 2.5kV, 60Hz, 60 seconds per ANSI. Requirements are as in Section E.

G. Temperature rise test—made at rated voltage at the quoted thermal burden rating for 30°C ambient. The ANSI requirement is that the temperature rise not exceed 55°C based on the average temperature rise of a secondary winding established by resistance measurement.

H. Salt fog tests—operation at 9 or 9.5 kV in the salt fog chamber. Two-bushing VT's are connected with both primary terminals at the same potential, whereas one-bushing VT's, such as the PO5-110, are connected realistically in the intended connection for application. The connection on two-bushing VT's does not simulate exactly the intended line-to-line connection, but has significance for evaluation of line-to-ground voltages.

The judgement here is made by comparison of results with experience in testing GE designs. The test procedure and the evaluation are not covered by industry standards. Evidence of problems would be surface erosion, surface tracking, or an extreme tendency to draw high current scintillations and tripout.

I. Megger Test—measurement of primary to ground insulation resistance, and subsequently secondary to ground insulation resistance, at 1000 volts DC. Readings exceeding 20,000 megohms are considered acceptable in this evaluation.

Test results would typically be satisfactory on new units. On units which have been in storage, or in service, reduced readings may occur as a result of moisture admission, surface moisture, or incipient failures through the insulation or along an insulation surface.

J. Thermal shock—ten cycles of thermal shock, each cycle consisting of 16 hours in the −40°C box, 8 hours in the +75°C box, with immediate transfer between temperature boxes. At about the midpoint of this procedure, the units were subjected to an ionization test and primary hipot test as soon as possible after removal from +75°C, and similarly from −40°C, with the objective of detecting any problems existing only at temperature. At the conclusion of the test the units were required to pass impulse test, induced voltage test, primary and secondary hipot, ionization and accuracy test; all tests are at 100% levels.

K. Accelerated life test—operation with the primary floating, with 180% rated voltage, 400hz, applied to the secondary. The objective was to accelerate life history within the primary winding, without comparable acceleration of life in the primary-to-ground or primary-to-secondary insulation. 400 hz was used to avoid core saturation, and was not intended or considered to be a significant factor in the acceleration achieved.

Failure during the test, or failure on the subsequent testing at 100% levels would indicate possible problems. Target test time was 1,800 hours.

The rate of acceleration achieved during this test may not be the same for all designs.

L. Drop test—the procedure consists of a series of drops unpacked, first of 15" and then of 30", onto a steel plate. To compensate for irregular body shapes, the unit was blocked so that the base plate plane was horizontal, or vertical, as the unit sat on the hinged platform of the drop test machine. Each unit was dropped with the base down, with the conduit box up, with one side down, and in some cases with the other side down.

M. **Partial discharge test**—the test was performed using connections 1,2,3 and cross-winding, except that connections 1, 3 and cross-winding could not be run on the PO5-110 since H_2 was common with the base. The test levels and limits used were those which we could consider applicable to the JVW-110. There are no U.S. industry standards governing test procedure or limits on partial discharge test of these instrument transformers. Arbitrary assignment of partial discharge limits to all insulation systems is not appropriate because of the variations between insulation systems.

The partial discharge tests indicate discharges bridging portions of the insulation under electrical stress. Discharges which are excessive for a particular insulation system can lead to reduced life.

The results are measured in units of crest volts. Start and stop are defined as 0.01CV and any lower CV is considered 0.

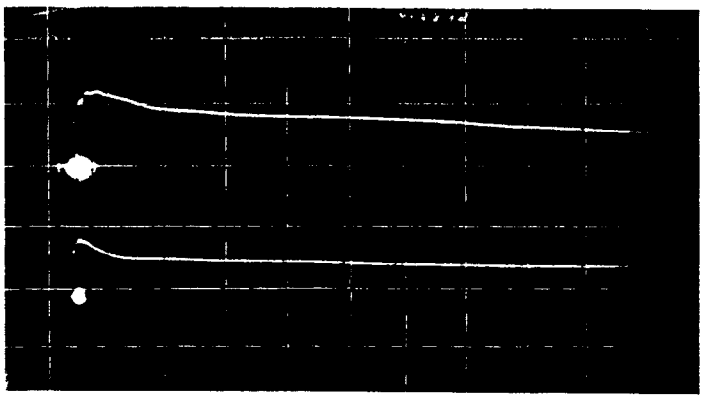
The conversion factor "C" for Q=CV in conversion of crest volts to pico coulombs of apparent charge is not known, however, experience with the GE designs tested in GE equipment suggests C=500 and thus 0.05CV indicates 25 pico coulombs. This does not suggest that this value of "C" is authoritative for non-GE designs tested in GE equipment.

VIII. DETAILED EVALUATION BY INDIVIDUAL MANUFACTURER

ASSOCIATED
ENGINEERING COMPANY

PTT-110

Impulse Test: Based on General Electric's interpretation of the wave form shown on the test oscillograms,* the three (3) units tested were considered to have failed this test.



Chopped wave oscillogram PTT-110 Impulse failure

Quantity Tested	
3	**Induced voltage test:** 100% passed. Current drawn: 0.32A avg.
1	**Temperature rise:** 68.4%°C Rise.
3	**Primary Hipot:** 100% passed.
3	**Secondary Hipot:** 100% passed.
2	**Primary Megger:** Passed. Readings > 20,000 megohms avg.
2	**Secondary Megger:** Passed. Readings > 20,000 megohms avg.
3	**Primary Power Factor:** Passed. % power factor @ 10KV=0.50 avg.
3	**Accuracy:** Passed.

Average Readings:

120V No Load		132V No Load		120V Y Burden	
RCF	PA	RCF	PA	RCF	PA
0.9979	+0.2	0.9981	−0.1	1.0010	−6.2

Quantity Tested	
0	**Salt Fog:** Test not performed. Expected performance comparable to the JVW-110.
0	**Thermal Shock:** See comments above.
1	**Accelerated life test:** Passed. **Test time:** 1892 hours.
1	**Drop test:** No damage indicated.

Partial discharge test: Passed.

Average Readings:

Conn #	Start KV	Start CV	Measured crest volts (CV) for specific KV test levels					Stop KV	Stop CV
1	11.0	0.12	KV	15.5	15.0	12.0	9.3	9.8	0
			CV	.38	.15	.13	.005		
2	10.5	0	KV	10.5	9.3	8.4	5.4		
			CV	0	0	0	0		
3	10.5	0	KV	10.5	9.3	8.4	5.4		
			CV	0	0	0	0		
X-wdg.	12.6	0							

Discussion of visual observations, tests and teardown:

The approximate 139 lb. weight of this unit is the highest of all manufacturers. With this unit meeting only 0.3 Y accuracy, as quoted, the weight appears excessive in comparison to lighter units meeting 0.3Z accuracy.

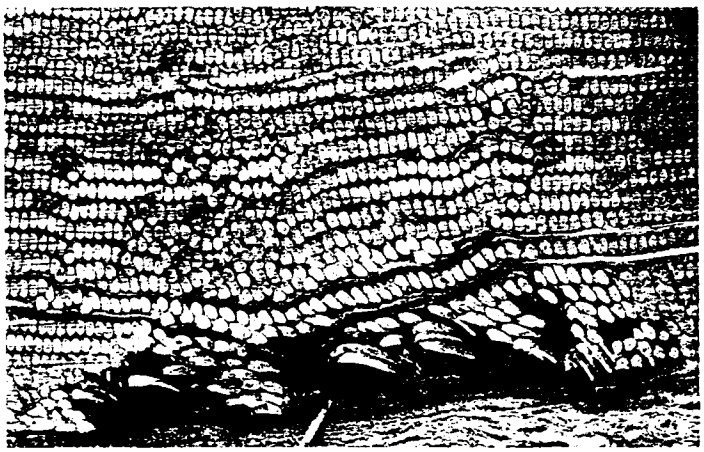
The stainless steel nameplate is ungrounded, adhered to the butyl surface above the aluminum conduit box. This box and the four mounting screws were not consistently in good electrical contact with the base. No ground terminal is provided in the secondary terminal area.

A temperature rise test made on one unit at rated VA of 1500 at 120 volts, with an indicated temperature rise of 69.5°C, exceeds the 55°C target.

*One unit was not impulse tested until after accelerated life test. The judgement was that the impulse test failure did not result from degradation on life test.

All units failed impulse test based on the waveform shown on the test oscillograms.

Teardown shows the primary coil to have two side by side sections with layer paper, cast and impregnated in epoxy. The impulse failure was found in the inner layers of one primary coil section. Winding impregnation appeared good except that there was circumferential evidence of a void coincident with the failure. This void may have contributed to (or resulted from) the failure and subsequent excitation.



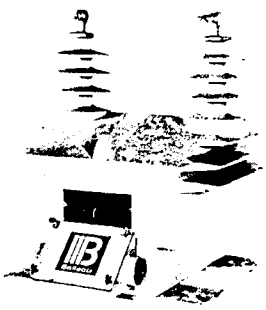
Location of impulse failure within primary coil.

In summary, the design has a high ratio of weight to performance, and appears to have significantly lower impulse strength and greater temperature rise, than some other designs tested.

The manufacturer's literature states "It is recommended that the high voltage bushings be side by side instead of one above the other when the transformer is mounted in the horizontal plane. This is to prevent outages due to ice and snow formations." GE does not make this restriction on the JVW-110 or JVW-5.

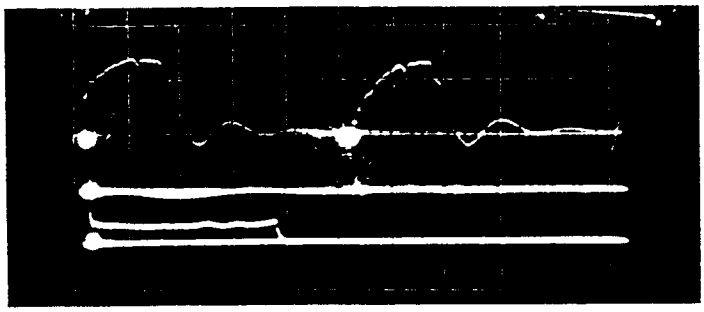
The overall height of approximately 19 15/16" exceeds the 18½" maximum per NEMA Standards Pub. EI 21.1—1983.

BALTEAU
STANDARD INC



VEO1-110

Impulse test: Based on General Electric's interpretation of the waveform shown on the test oscillograms*, the six units tested were considered to have failed this test.



2 chopped wave and 2 full wave oscillograms VEO1-110 impulse failure

Quantity Tested	
6	**Induced voltage test:** 100% passed. current drawn: 0.31A avg.
2	**Temperature rise:** 62.3°C Avg. rise.
6	**Primary Hipot:** 100% passed.
6	**Secondary Hipot:** 100% passed.
3	**Primary Megger:** Passed. Readings > 20,000 megohms avg.
3	**Secondary Megger:** Passed. Readings > 20,000 megohms avg.
5	**Primary Power Factor:** Passed. % power factor @ 10KV=0.57 avg.
6	**Accuracy:** Passed.

Average Readings:

120V No Load		132V No Load		120V Z Burden	
RCF	PA	RCF	PA	RCF	PA
.9980	−0.5	.9983	+0.5	1.0024	−9.7

Quantity Tested	
1	**Salt Fog:** No significant damage or erosion evident.
1	**Thermal Shock:** No damage evident.
1	**Accelerated Life Test:** Passed. **Test time:** 1892 hours.
1	**Drop test:** Damage sustained on both the 15" and the 30" test.

Chipped epoxy on top bushing skirt after 30" drop test.

Partial Discharge Test: Passed. (Quantity Tested—six (6))

Average Readings:

Conn #	Start KV	Start CV	Measured crest volts (CV) for specific KV test levels					Stop KV	Stop CV
1	14.4	.02	KV	15.5	15.0	12.0	9.3	10.5	0
			CV	.02	.02	.01	0		
2	10.5	0	KV	10.5	9.3	8.4	5.4		
			CV	0	0	0	0		
3	10.5	0	KV	10.5	9.3	8.4	5.4		
			CV	0	0	0	0		
X-wdg.	12.0	0							

*One unit was not impulse tested until after accelerated life test. The judgement was that the impulse test failure did not result from degradation on life test. The oscillograms obtained on VEO1-110 were unusual in GE experience, and would be considered failures if occurring on the GE JVW-110.

Discussion of visual observations, tests and teardown:

The approximate 126 lb. weight of this unit is in the high end of the range among the group tested. The unit meets the quoted 0.3 Z accuracy.

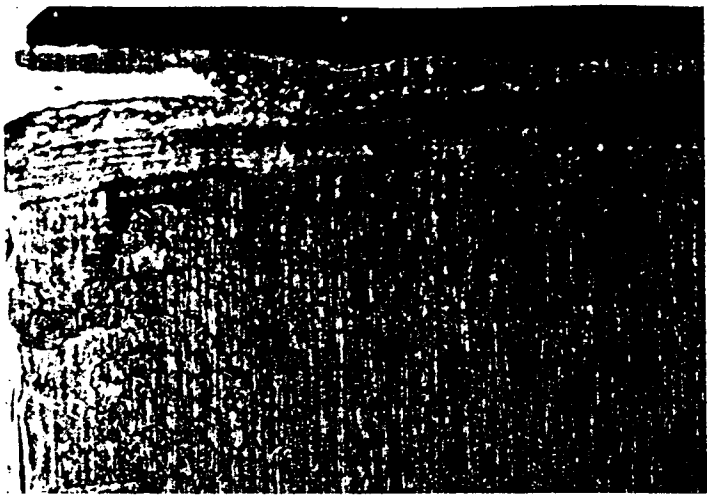
The stainless steel nameplate is ungrounded, screwed or riveted to the epoxy body above the grounded aluminum conduit box. No primary voltage digits are provided on body. The base straps are very magnetic, apparently mild steel.

A temperature rise test was made on two units at rated VA of 1500 at 120 volts with an average indicated temperature rise of 62.3°C, exceeding the 55°C target.

All units failed impulse test based on GE interpretation of the waveform shown on the test oscillograms. Note only one chopped wave shot was performed on each connection due to the unusual waveshapes obtained on all units tested.

On the 15" drop test, a minor (¼" × 1/16") epoxy chip occurred. On the 30" drop test, a substantial piece chipped off the top skirt. The piece was approximately ¾ × ½ × ⅛" thick.

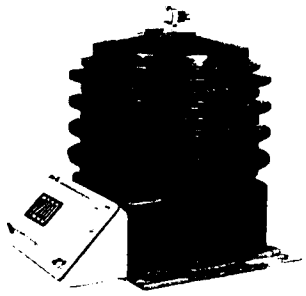
Teardown shows the primary coil has two side-by-side sections. Each primary section is encompassed with approximately 1/16" thick insulation. There appear to be substantial voids at the sides of the primary sections inside this wrap. Primary-to-secondary radial positioning and insulation is provided by "wraps" of other insulation, building up to 7/32" thickness. There is apparantly one epoxy casting stage with the cores, secondary and primary present but protected from the epoxy. The primary winding has layer paper but no solid or liquid impregnant.



Cross section of primary coil with voids at the sides.

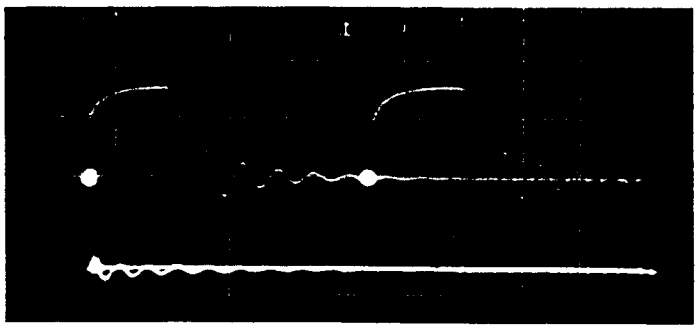
In summary, the VEO1-110 is heavier than most of the designs tested and appears to have significantly lower impulse strength and greater temperature rise than some other designs tested. It does not have solid epoxy as primary-to-secondary insulation or as primary winding impregnant.

The overall depth (front-to-back) of approximately 16¾" exceeds the 15½" maximum per NEMA Standard Pub. El 21.1—1983.



PO5-110

Impulse Test: 100% passed. (Quantity tested—three (3))



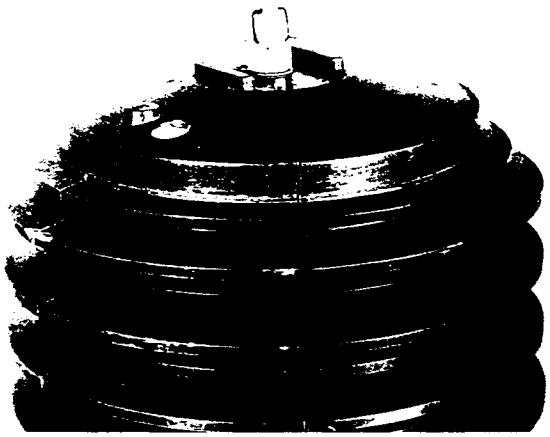
Normal impulse oscillograms PO5-110

Quantity Tested	
3	**Induced voltage test:** 100% passed. **Current drawn:** 0.82A avg.
1	**Temperature rise:** 45.1°C rise.
3	**Primary Hipot:** 100% passed. (Induced method)
3	**Secondary Hipot:** 100% passed.
1	**Primary Megger:** Passed. Not individually tested, but H_2 is connected to the base during the secondary megger test.
1	**Secondary Megger:** Passed. Readings>20,000 megohms avg.
0	**Primary Power Factor:** Test could not be performed due to H_2 being permanently connected to the baseplate.
3	**Accuracy:** Passed.

Average Readings:

120V No Load		132V No Load		120V Y Burden	
RCF	PA	RCF	PA	RCF	PA
.9991	+2.0	.9993	+3.0	1.0009	+2.0

Quantity Tested	
1	**Salt Fog:** No significant damage or erosion evident.
1	**Thermal Shock:** Cracking observed after the fifth cycle from the H_1 terminal down to the main body below the lowest skirt. This unit had been subjected to drop test prior to thermal shock.



Cracking after 5th Cycle
PO5-110 Thermal Shock Damage.

Accelerated life test: Passed. **Test Time:** 1892 hours. (Quantity tested—One (1))

Drop test: Damaged. (Quantity tested—One (1)) On the 15" drop test, a minor chip occurred on the top bushing OD, and the H_2 connector separated from the base with a small adjacent chip of the epoxy. This "separation" involved partial failure of the solder bond on the portion of the H_2 strap protruding from the body. Electrical continuity to the base was maintained. On the 30" drop test, a

substantial piece of epoxy was chipped from the top major skirt, this piece being 2¾" × 1" × 3/16" thick.

Epoxy chipped PO5-110 drop test damage

Partial discharge test: Passed. Note: Connection #1 and #3 and X-wdg not performed due to H_2 permanently tied to the base.

Average Readings:

Conn #	Start KV	Start CV	Measured crest volts (CV) for specific KV test levels					Stop KV	Stop CV
1			KV						
			CV						
2	9.0	0	KV	9.0	8.0	7.2			
			CV	0	0	0			
3			KV						
			CV						
X-wdg.									

Discussion of visual observations, tests and teardown:

The test units were of the single bushing design where all other manufacturers products were two bushing designs. This supplier does not have a two bushing product available, thus limiting the application versatility of the product. Also, with the H_2 permanently connected to the base, it is impossible for users to perform the ANSI primary hipot test, an independent primary megger, or the connection #1 power factor test.

The environmental test results indicated this product has less resistance to thermal shock and drop testing than some of the designs tested.

The PO5-110 has a plastic conduit box and cover. No external ground connection is provided except for the H_2 terminal. The ungrounded nameplate is on the back surface.

Teardown showed that construction uses one circular core, and a circular primary and secondary. The primary is in one section, with layer paper. The core is in continuity with the base, with a band strap around the core, and a ground terminal in the secondary area. The four base mounting inserts are ungrounded except as tied in by the mounting screws and base. The inside (H_2) end of the primary winding has less insulation from the secondary than other designs evaluated since H_2 is connected to the base. There apparently is one epoxy casting, with the core present but protected, and with the primary and secondary well impregnated during the casting.

In summary, there is a greater tendency to crack on both drop tests and thermal shock in comparison to other units tested.

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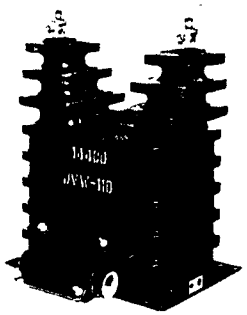
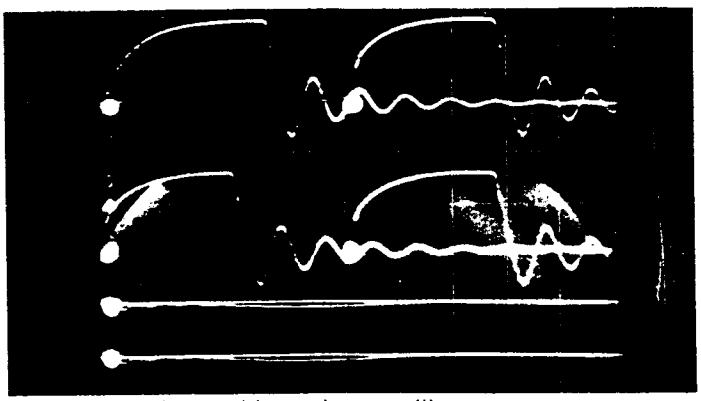


JVW-110

Impulse test: 100% passed. (Quantity tested—three (3))



Normal impulse oscillograms
JVW-110

Quantity Tested	
3	**Induced voltage test:** 100% passed. **Current drawn:** 0.75A avg.
1	**Temperature rise:** 42.0°C rise.
3	**Primary Hipot:** 100% passed.
3	**Secondary Hipot:** 100% passed.
3	**Primary Megger:** Passed. Readings > 20,000 megohms avg.
3	**Secondary Megger:** Passed. Readings > 20,000 megohms avg.
3	**Primary Power Factor:** Passed. % power factor @ 10KV = 0.70
3	**Accuracy:** Passed.

Average Readings:

120V No Load		132V No Load		120V Y Burden	
RCF	PA	RCF	PA	RCF	PA
.9991	+2.3	.9993	+3.0	1.0009	+2.0

Quantity Tested	
1	**Salt Fog:** No significant damage or erosion evident.
1	**Thermal shock:** No damage evident.
1	**Accelerated life test:** Passed. Test time 2027 hours.
1	**Drop test:** Passed. Slight non destructive damage to the baseplate.

Partial discharge test: Passed. (Quantity tested—three (3))

Average Readings:

Conn #	Start KV	Start CV	Measured crest volts (CV) for specific KV test levels					Stop KV	Stop CV
			KV	15.5	15.0	12.0	9.3		
1	13.8	.02	CV	.03	.02	0	0	13.5	0
			KV	10.5	9.3	8.4	5.4		
2	10.5	0	CV	0	0	0	0		
			KV	10.5	9.3	8.4	5.4		
3	10.5	0	CV	0.1	0	0	0	10.1	0
X-wdg.	12.6	0							

Discussion of visual observations, tests and teardown:

Electrical and environmental test results showed this product to be superior to the others in the test group. The design of the unit has two cores, a two section **lattice wound** primary coil with high voltage shields. The primary is cast in epoxy to impregnate the winding and provide major insulation. The assembly is molded in butyl rubber for external insulation.

The lattice primary coil construction is unique to GE and is a major factor in the ability of the product to exhibit excellent impulse withstand, accelerated life test and partial discharge test results, all extremely pertinent to long product life.

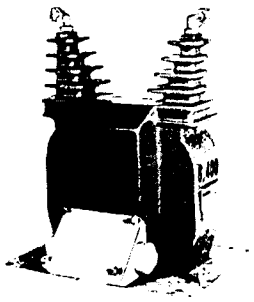
The butyl rubber external insulsation is a major contributor to the excellent results achieved on salt fog, thermal shock and the mechanical drop tests.

The 15" and 30" drop tests in total reduced the distance between the primary terminals by only 3/16", and the right side of the baseplate was deformed approximately 7/16" in front and 1/8" in back. These effects are considered non-destructive.

The JVW-110 provides good electrical continuity between the nameplate, the base, the conduit box, the cores, and the ground shield on the primary casting. A separate ground terminal is provided in the secondary compartment for user convenience.

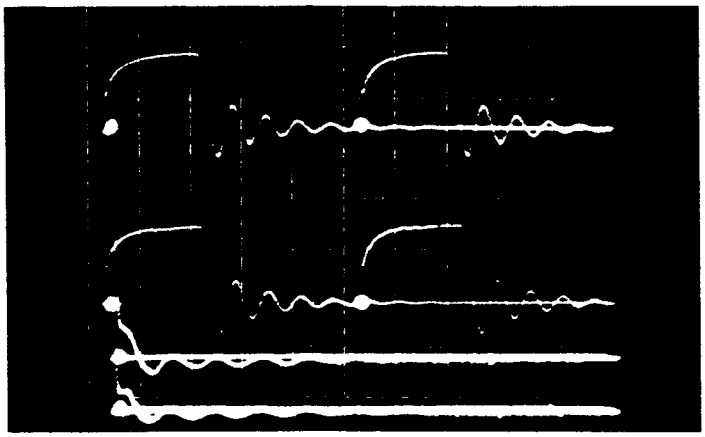
The secondary terminal design is of the clamp type, also unique to GE. This design has been considered superior to stud or bolt type hardware in our specification and design work.

SANGAMO
WESTON

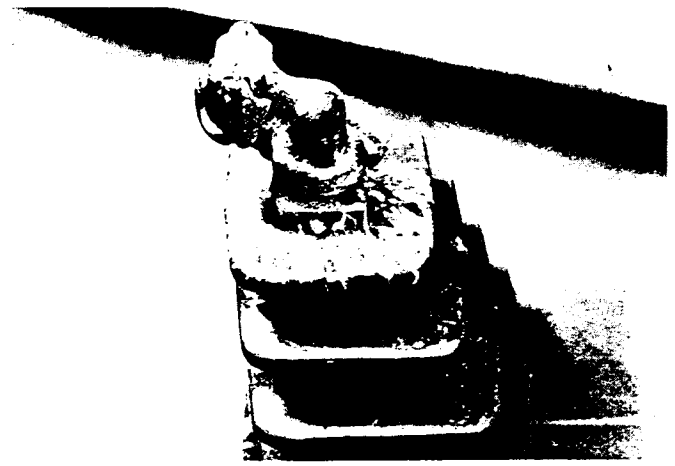


MEO-1503

Impulse test: 100% passed. (Quantity tested—six (6))



Normal impulse oscillograms
MEO-1503



MEO-1503 Salt Fog results

Quantity Tested	
6	Induced voltage test: 100% passed. Current drawn: 0.52A avg.
1	Temperature rise: 65.6°C rise.*
6	Primary Hipot: 100% passed.
6	Secondary Hipot: 100% passed.
6	Primary Megger: Passed. Readings > 20,000 megohms avg.
6	Secondary Megger: Passed. Readings > 20,000 megohms avg.
6	Primary power factor: Passed. % power factor @ 10KV=0.45 avg.
6	Accuracy: Passed.

Average Readings:

120V No Load		132V No Load		120V Y Burden	
RCF	PA	RCF	PA	RCF	PA
.9978	+.8	.9981	+1.2	1.0004	−1.2

1	Salt Fog: Erosion and carbon deposits on upper bushing skirts.

Quantity Tested	
1	Thermal shock: No damage evident.
4	Accelerated life test: Early failures in three (3) units. Test time: 200–697 hours before failures. Fourth unit was still operating at 1345 hours.
1	Drop test: Epoxy body cracked on the right front corner on the 30" drop test.

Drop test damage MEO-1503

*Average of two (2) heat runs.

Partial discharge test: Passed.

Average Readings:

Conn #	Start KV	Start CV	Measured crest volts (CV) for specific KV test levels					Stop KV	Stop CV
			KV	15.5	15.0	12.0	9.3		
1	15.1	.05	CV	.06	.05	0	0	14.3	0
			KV	10.5	9.3	8.4	5.4		
2	10.1	.01	CV	.01	.01	.01	0	10.0	0
			KV	10.5	9.3	8.4	5.4		
3	10.2	.02	CV	.04	.03	.02	0	10.0	0
X-wdg.	12.6	0							

Discussion of visual observations, tests and teardown:

The 68# weight of this unit appears appropriate for the quoted capability of 0.3Y and 1200 VA.

Two temperature rise tests were made on one unit at rated VA of 1200, at 120 volts, with an average indicated temperature rise of 65.6°C, far exceeding the 55°C rise target.

The salt fog testing resulted in some erosion and carbon deposits on the upper bushing skirts. The evaluation is that the MEO-1503 is the only unit of this group to show significant erosion in salt fog test.

Three MEO-1503's subjected to accelerated life test, failed at 200, 329, and 697 hours respectively. The fourth unit was still operating at 1345 hours. These failure times appear quite short compared to the approximately 1800 hours without failure accumulated on each of the other types. After failure on life test, each indicated failure within a winding.

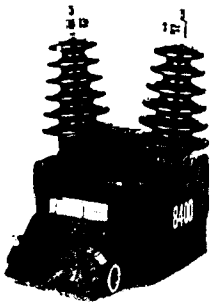
On the 30" drop test, the right front corner of the epoxy body cracked from the base upwards for about 2".

The MEO-1503 has a galvanized mild steel base, ungrounded nameplate, and grounded aluminum conduit box.

Teardown of one unit showed that the MEO-1503 has one core, and a single primary section with layer paper. The primary and secondary are rectangular. The primary impregnation appears good.

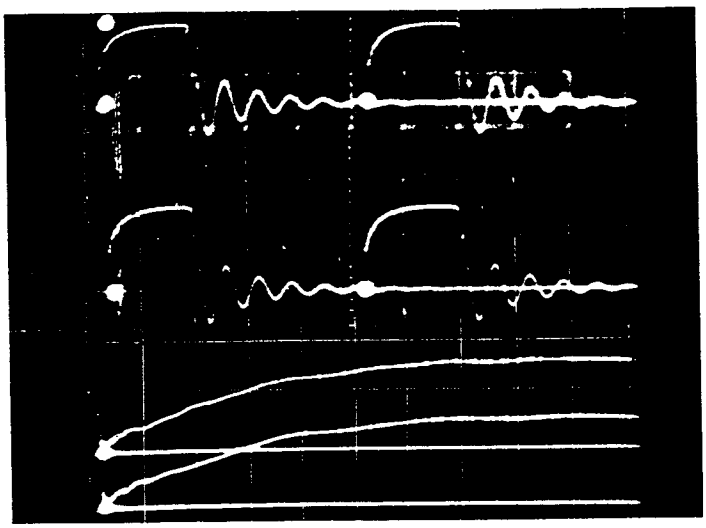
In summary, the MEO-1503 has an appropriate weight for useful quoted capabilities, but tests indicate greater temperature rise; shorter life on accelerated life test; greater erosion in salt fog test; and greater tendency to crack on drop test than some of the other units tested.

WESTINGHOUSE
ELECTRIC CORPORATION



VOZ-11

Impulse test: Based on General Electric's interpretation of the wave form shown on the test oscillograms,* two of the three units tested from 1981 production were considered to have failed this test. All six 1984 units tested passed.



VOZ-11 FWC Impulse failure—1981 manufacture

Quantity Tested	
8	Induced voltage test: 100% passed. Current drawn: 0.37A avg.
2	Temperature rise: 53.8°C rise on 1984 manufacture 60:1. 49.2°C rise on 1984 manufacture 70:1
9	Primary Hipot: 100% passed.
9	Secondary Hipot: 100% passed.
9	Primary Megger: Passed. Readings >20,000 megohms avg.
9	Secondary Megger: Passed. Readings >20,000 megohms avg.
3	Primary power factor: 1981—Passed. % power factor @ 10KV = 1.58 average.

Quantity Tested	
6	Primary power factor: 1984—High. % power factor @ 10KV = 3.4 average.
8	Accuracy: Passed.

Average Readings:

120V No Load		132V No Load		120V Z Burden	
RCF	PA	RCF	PA	RCF	PA
.9981	+1.1	.9983	+1.6	1.0021	−1.4

Quantity Tested	
1	Salt fog: No significant damage or erosion evident.†
1	Thermal shock: No damage evident.
1	Accelerated life test: Passed. Test time 2027 hours.
1	Drop test: No damage evident.
2	Partial discharge test: 1981—passed.
6	Partial discharge test: 1984—High compared to the other units in the test group.

Average Readings (1984 70:1)

Conn #	Start KV	Start CV	Measured crest volts (CV) for specific KV test levels					Stop KV	Stop CV
1	6.5	.25	KV	15.5	15.0	12.0	9.3	2.0	0
			CV	1.33	1.33	.60	.51		
2	7.0	.13	KV	10.5	9.3	8.4	5.4	3.5	0
			CV	.26	.26	.24	.51		
3	7.3	.10	KV	10.5	9.3	8.4	5.4	3.8	0
			CV	.30	.30	.26	.11		
X-wdg.	12.6	0							

*One unit was not impulse tested until after thermal shock. The judgement is that the impulse test failure did not result from degradation on thermal shock.

†Tests at 15kV indicated performance would be satisfactory at 9–9.5kV.

Discussion of visual observations, tests and teardown:

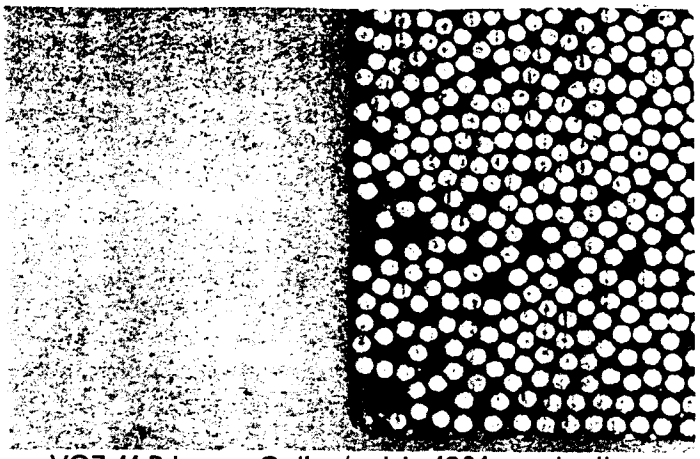
The approximate weight of 73 pounds is relatively low for a two-bushing unit quoted as and meeting 0.3Z and 1500VA.

Based on GE interpretation of the wave form shown on the test oscillograms,* two thirds of the units from 1981 production failed impulse test. All of the units from 1984 production passed impulse. (In a separate evaluation of one Westinghouse VOG-11, the unit failed impulse.

Primary insulation power factor on the 1981 units was acceptable. Primary insulation power facts on 1984 production averaged 2.57% at 2.5 kV, and 3.41% at 10.0 kV, higher than all other units tested.

Some of the VOZ-11's had a plastic conduit box, whereas others had an aluminum box.

Cut-up of a 1981 product indicated than an initial epoxy casting operation created a four section primary winding form and provided substantial epoxy thicknesses at the end flanges and on the inside, between primary and secondary. The secondary was then wound (without layer paper) into the four sections created by the first casting, and apparently impregnated during the second casting which provides the remainder of the epoxy body. Examination of faces cut perpendicular to primary wires indicated presence of voids at some surfaces to the winding form, and within most section faces.



VOZ-11 Primary Coil w/voids, 1981 production

Cut-up of a 1984 product showed a primary coil consisting of two side-by-side layer wound sections with layer paper. It appeared that the primary was impregnated during the epoxy casting of the main body. There was no pre-cast winding form, however, there appeared to be a pre-cast piece providing primary-to-secondary insulation and positioning.

In summary, the 1984 VOZ-11 voltage transformers had higher primary insulation power factors and higher partial discharge magnitudes than the other units evaluated.

RECOMMENDATIONS

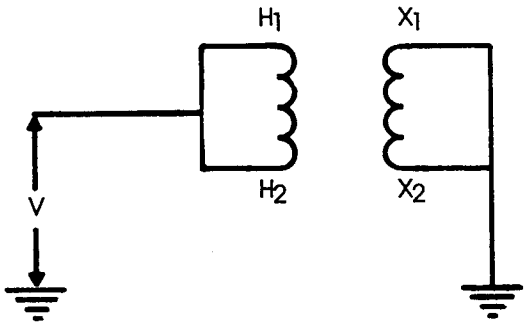
The results of this study indicate significant product feature and performance differences do exist among the manufacturers' products tested. General Electric believes both environmental tests and the ANSI design tests are pertinent to product reliability.

To better protect a user's best interest in terms of product reliability, supplier evaluation programs are recommended and strongly encouraged.

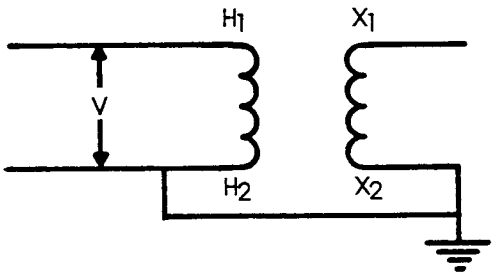
APPENDIX

Wiring diagram for test connections #1, 2, 3 & Cross Winding

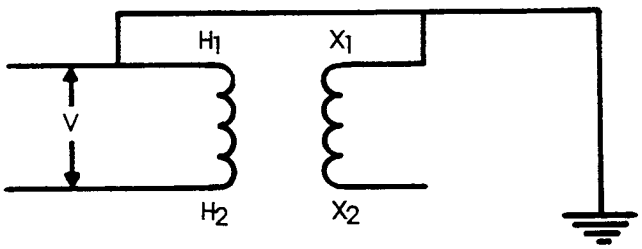
Connection #1



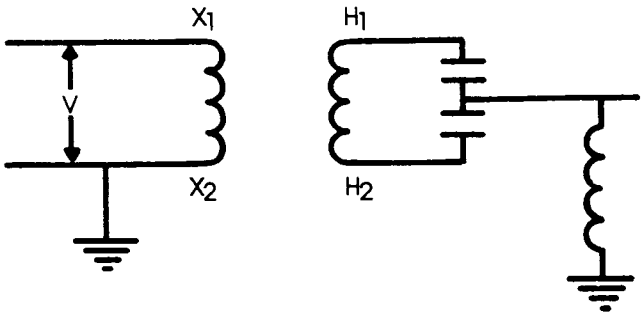
Connection #2



Connection #3



Cross Winding



GENERAL ELECTRIC

5M (7/85)