

NCEL

Technical Note

August 1989

By G.V. Urata and J.O. Franchi

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25-kVA AMORPHOUS METAL-CORE TRANSFORMER DEVELOPMENTAL TEST REPORT

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ABSTRACT NCEL has completed a test and evaluation program for 25-kVA amorphous metal-core transformers. These transformers save energy by reducing no-load losses by 60 to 70 percent. No-load losses are estimated to cost the Navy millions annually and if all of the Navy transformers were replaced by amorphous metal-core transformers, the Navy would save millions a year. The program objective was to evaluate the electrical performance and operational reliability of the amorphous metal-core transformers compared to conventional silicon-steel transformers.

NAVAL CIVIL ENGINEERING LABORATORY PORT HUENEME CALIFORNIA 93043-5003

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

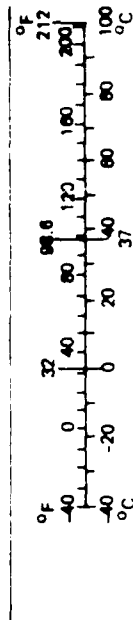
Symbol	When You Know	Multiply by	To Find	Symbol
LENGTH				
m	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
AREA				
in ²	square inches	6.5	square centimeters	cm ²
ft ²	square feet	0.09	square meters	m ²
yd ²	square yards	0.8	square meters	m ²
mi ²	square miles	2.6	square kilometers	km ²
	acres	0.4	hectares	ha
MASS (weight)				
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2,000 lb)	0.9	tonnes	t
VOLUME				
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	ml	ml
fl oz	fluid ounces	30	ml	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft ³	cubic feet	0.03	cubic meters	m ³
yd ³	cubic yards	0.76	cubic meters	m ³
TEMPERATURE (exact)				
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

Approximate Conversions from Metric Measures

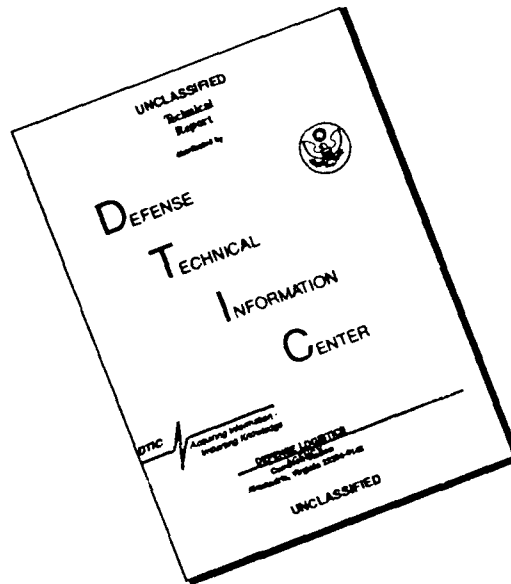
When You Know	Multiply by	To Find	Symbol
LENGTH			
millimeters	0.04	inches	in
centimeters	0.4	inches	in
meters	3.3	feet	ft
meters	.1	yards	yd
kilometers	0.6	miles	mi
AREA			
square centimeters	0.16	square inches	in ²
square meters	1.2	square yards	yd ²
square kilometers	0.4	square miles	mi ²
hectares (10,000 m ²)	2.5	acres	
MASS (weight)			
grams	0.035	ounces	oz
kilograms	2.2	pounds	lb
tonnes (1,000 kg)	1.1	short tons	
VOLUME			
milliliters	0.03	fluid ounces	fl oz
liters	2.1	pints	pt
liters	1.06	quarts	qt
liters	0.26	gallons	gal
cubic meters	35	cubic feet	ft ³
cubic meters	1.3	cubic yards	yd ³
TEMPERATURE (exact)			
Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



*1 in. = 2.54 (exactly). For other exact conversions and more detail tables, see NBS Misc. Publ. 286 Units of Weights and Measures. Price \$2.25, SD Catalog No. C13.10.286.



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INTRODUCTION

The Naval Civil Engineering Laboratory (NCEL) has completed a test and evaluation program for 25-kVA amorphous metal-core transformers. Amorphous metal-core transformers save energy by reducing transformer no-load losses by 60 to 70 percent. No-load losses are the power required to energize the transformer core and are constant regardless of the load on the transformer. No-load losses cost the Navy millions of dollars annually. The Navy operates approximately 79,000 liquid-filled distribution transformers at 150 locations. If all of the Navy transformers were replaced by amorphous metal-core transformers, the Navy would save millions a year. The program objective was to evaluate the electrical performance and operational reliability of the amorphous metal-core transformers compared to conventional silicon-steel transformers. The test and evaluation program was conducted in the following two phases.

Phase I

In Phase I, the electrical and mechanical performance of three General Electric 25-kVA amorphous metal-core transformers was compared with the electrical performance of two General Electric 25-kVA conventional silicon-steel transformers. The testing for this phase was conducted by Westinghouse Electric Corporation using American National Standards Institute (ANSI) and National Electric Manufacturers Association (NEMA) standards, at the Westinghouse Distribution Transformer Division plant, Athens, Georgia.

Phase II

In Phase II, electrical tests, overland transportation tests, and autopsies were conducted by General Electric on five 25-kVA amorphous metal-core transformers. An NCEL devised 3-foot drop test and autopsy was then conducted on three of the transformers. The laboratory testing for this phase was conducted using ANSI and NEMA standards, at the General Electric Distribution Transformer Division plant, Hickory, North Carolina.

BACKGROUND

Amorphous metals are an entirely new class of metallic material whose dominant characteristic is a lack of grain structure. In the process of producing amorphous metals, a proprietary molten alloy of iron, boron, and silicon is cooled rapidly at a rate of about 1 million °C per second so that crystals cannot form. Instead, the constituent atoms arrange themselves in a random fashion, rather than in the crystal lattices found in typical metals. The practical result of this process

is a material that, when used in the core of a transformer, reduces no-load losses to about 30 percent of those in a conventional silicon-steel transformer.

The reliability and performance of amorphous metal-core transformers are expected to be comparable to conventional silicon-steel transformers because virtually no changes have been made in the coil and insulation system. The only difference is the substitution of the more efficient amorphous metal-core material.

PHASE I TESTS

Four types of transformer tests were conducted in Phase I, including the typical commercial, design, ANSI/IEEE C57.12.90-1980 tests, and several additional tests designed by NCEH engineers. The identity, objective, and pass/fail criteria for the Phase I tests are described in the following paragraphs.

Commercial Tests

The commercial tests were performed: (1) to determine the transformer's electrical performance parameters upon initial receipt before testing, (2) to demonstrate compliance with nameplate data or contractual agreements, and (3) to identify any significant changes in transformer performance characteristics after the transformers were subjected to individual stressful tests. For the amorphous metal-core and silicon-steel transformers examined, the tests consisted of the following:

Ratio Test.

- **Objective:** The turns ratio of the transformer is the ratio of turns in the high-voltage winding to turns in the low-voltage winding. The objective of the ratio test was to demonstrate that the ratio of turns in the high-voltage and low-voltage windings was correct, so that a given impressed high voltage would produce the expected low voltage, according to the ratio of high-voltage winding turns to low-voltage turns.
- **Pass/Fail Criteria:** The observed ratio of high voltage to low voltage had to be within 0.5 percent of the transformer nameplate markings.

Polarity Test.

- **Objective:** The objective of the polarity test was to demonstrate that the leads and polarity marks on the transformer reflected the actual arrangement of the transformer windings. These data are particularly important when two or more transformers are operated in parallel.
- **Pass/Fail Criteria:** The polarities of the winding leads, as determined from testing, had to match the polarities shown on the nameplate.

Applied Voltage Tests.

- **Objective:** The objective of the applied voltage tests was to stress the major components of insulation, and the major insulation between the windings and ground. Two types of applied voltage tests were made: High-to-Low-to-Iron-to-Case (HLIC) applied voltage tests, and Low-to-High-to-Iron-to-Case (LHIC) applied voltage tests. In the HLIC tests, the test voltage was applied to the high-voltage transformer bushings (which were tied together), and the low-voltage bushings, which were tied together and grounded. In the LHIC tests, all low-voltage bushings were tied together and connected to the source voltage, and the high-voltage bushings were tied together and grounded. The HLIC tests stressed the insulation of the high-voltage windings. The LHIC tests stressed the low-voltage windings.
- **Pass/Fail Criteria:** There had to be no evidence of arcing, smoke, bubbles, or a sudden increase in test circuit current as a result of the applied potential. If such evidence existed, then troubleshooting was required to locate the source of the problem.

Induced Potential Test.

- **Objective:** The objective of the induced potential test was to stress interwinding insulation structures, as well as portions of the major insulation. The test applied greater than rated volts per turn to the transformer, so that it was run at higher frequency (400 Hz in this case) to avoid core saturation.
- **Pass/Fail Criteria:** There shall be no evidence of arcing, smoke, bubbles, or a sudden increase in test circuit current as a result of applied potential. If such evidence exists, then troubleshooting is required to locate the source of the problem.

No-Load Loss/Exciting Current Test.

- **Objectives:** The objectives of the no-load loss and excitation current tests were to determine: (1) the power loss in the transformer when operating at rated voltage and frequency, but not supplying load; and (2) the excitation current required to maintain the magnetic flux excitation in the transformer core. No-load losses include core loss, dielectric loss, and loss in the windings due to exciting current. Both no-load losses and excitation currents should be determined using sinusoidal sources, or by correcting for the applied source waveforms as described in Section 8 of ANSI/IEEE C57.12.90-1980.
- **Pass/Fail Criteria:** Not applicable because measurements are made and recorded per Section 8 of ANSI/IEEE C57.12.90-1980.

Design Tests

The design tests were performed to compare the amorphous metal-core transformers and the silicon-steel transformers with respect to adequacy of the design of their component parts, ability to meet assigned ratings, and performance under normal operating conditions. The tests consisted of the following:

Full-Wave and Chopped-Wave Impulse-Voltage Tests.

- **Objective:** The objective of the impulse-voltage tests was to determine the ability of the transformer to withstand lightning surges. Voltage waves with a nominal front of 1.5 microseconds and a nominal tail to half value of 40 microseconds were applied to each terminal of an unenergized transformer. The first applied wave was a reduced full wave whose crest value was 50 percent of the transformer's basic insulation level (BIL). This was followed by two chopped waves of 115 percent of the BIL. Chopping was accomplished by using a rod gap in air, adjusted to arc after the crest of the voltage wave. The chopped-wave applications were followed by a full wave at 100 percent of the BIL. The chopped wave stressed insulation between turns near the line end. The full wave stressed insulation between the middle of the winding and ground. Oscillograms were obtained for applied voltage versus time, and for neutral current versus time.
- **Pass/Fail Criteria:** Agreement in voltage and current wave shape between the initial full-wave reduced voltage application and the final 100 percent full-wave application indicated that the transformer had passed without damage. Any unexplainable difference in wave shape indicated a failure in either the windings, the major or minor insulation, or the bushings.

NOTE

In order to provide additional assurance that the amorphous metal-core transformers would withstand lightning surges, the tests were performed on an energized transformer, and additional stress tests were added to the test sequence. The test sequence included (in the following order): reduced full-wave test, chopped-wave test, 400-Hz induced potential test, front-of-wave impulse test (voltage wave is chopped before it crests), 400-Hz induced potential test, full-wave test, 400-Hz induced potential test, and HVIC and LHIC applied voltage tests.

Winding Resistance Test.

- **Objective:** The objective of the winding resistance test was to obtain winding resistance data that will be used later: (1) to calculate the I^2R component of conductor losses, (2) to calculate winding temperatures at the end of a temperature rise test, and (3) to use as a base for assessing possible damage in field operation. The winding resistance test was performed using the procedures in Section 5 of ANSI/IEEE C57.12.90-1980.

- **Pass/Fail Criteria:** Not applicable. Readings were taken, calculations were made to correct for the desired temperature at which the resistance values were to be used, and the data were applied as required.

Impedance Voltage/Load Loss Tests.

- **Objective:** The objective of the impedance voltage/load loss tests was to determine the voltage required to circulate the rated current under short-circuit conditions, and the associated watt loss when the source was connected to the rated voltage taps. The impedance voltage consisted of an effective resistance component corresponding to the load losses and a reactive component corresponding to the leakage flux linkages of the windings.
- **Pass/Fail Criteria:** Not applicable. Measurements were made per Section 9.2.2 of ANSI/IEEE C57.12.90-1980, and calculations of the impedance voltage and load loss watts were made per Section 9.4 of ANSI/IEEE C57.12.90-1980. For these tests, comparisons were made between the performance of the amorphous metal-core transformers and the silicon-steel transformers.

Temperature Rise Test.

- **Objective:** The objective of the temperature rise test was to determine the maximum temperature rise (above the ambient temperature) of the windings and the insulating fluid in the transformer when the transformer was operated at maximum kVA rating. The temperature rise test was conducted in accordance with the procedures in Section 11 of ANSI/IEEE C57.12.90-1980.
- **Pass/Fail Criteria:** The average winding and fluid temperature rise above ambient temperature could not exceed 65 °C or the temperature rise specified on the transformer nameplate (whichever is smaller). The winding hottest spot temperature could not exceed 80 °C.

Audible Sound Level Test.

- **Objective:** The objective of the audible sound level test was to determine the audible sound emitted from the transformer when operated at rated voltage and frequency, and no load. Sound level measurements were significant because excessive sounds from transformers can be an annoyance in residential or other populated areas. Also, excessive sound levels may indicate apparent problems in the transformer core, such as loose or fractured core laminations. A sound level meter with an A-weighting frequency network was used for the measurements, since this type of weighting best represents the ability of a remote listener, with normal hearing, to hear the complex sounds generated by the transformer. The tests were conducted in accordance with the procedures in Section 13 of ANSI/IEEE C57.12.90-1980.

- **Pass/Fail Criteria:** The measured value of the A-weighted (A) sound level had to be no greater than 48 dB (A).

Radio Influence Voltage (RIV) Test.

- **Objective:** The objective of the RIV test was to determine the amount of RIV produced by the corona (local overstress) in transformer insulation. RIV, as the name implies, may cause interference to radio communications. Excessive corona also may be an indication of insulation breakdown. The tests were performed with the methods prescribed in NEMA Publication TR 1. Tests were run at 100 percent and 110 percent of rated voltage.
- **Pass/Fail Criteria:** NEMA Publication TR 1 lists limiting RIV values at about 110 percent of the operating voltage.

Short-Circuit Test.

- **Objective:** The objective of the short-circuit test was to demonstrate the ability of the transformer to withstand the stresses resulting from a short circuit applied to the transformer's primary or secondary terminals. The tests were conducted by either closing a breaker at the faulted terminal to apply a short circuit to a previously energized transformer, or by closing a breaker at the source terminal to apply energy to a previously short-circuited transformer.
- **Pass/Fail Criteria:** The impedance change shall be less than 11.1 percent, and the excitation current change shall be less than 25 percent, when a short-circuit current of 40 times the rated current is applied in accordance with the procedures of Section 12 of ANSI/IEEE C57.12.90-1980. There shall be no discernible damage to the transformer, based on a post-test autopsy.

Additional NCEI Tests

Safe Transit Tests.

- **Objective:** The objective of the safe transit tests was to demonstrate that the transformer could withstand the shocks and vibrations encountered on a cross-country shipment, with no significant mechanical damage, and no significant change in electrical performance characteristics. The tests consisted of: (1) a 4-hour test on the safe transit machine at 160 rpm to simulate two cross-country shipments by truck; and (2) a 4-foot drop of the transformer onto a hard surface (to simulate inadvertent mishandling during transit). Upon completion of the shake and drop tests, the transformer was subjected to the commercial tests to detect any changes in electrical performance; and to an autopsy, in which the transformer core was removed from the tank and inspected for damage.

- **Pass/Fail Criteria:** The commercial tests had to be passed satisfactorily, after completion of the safe transit tests, with no more than a 10 percent increase in measured no-load watts. There had to be no evidence of damage that would impair proper long-term, reliable operation of the transformer.

Infrared Scanning Test (Transformer Energized).

- **Objective:** The objective of the infrared scanning tests was to obtain (by means of an infrared-sensitive detector) a visual indication of the amount of energy required to magnetize the transformer core. In these tests, the infrared scans of the energized amorphous metal-core and silicon-steel transformers were compared.
- **Pass/Fail Criteria:** No quantified criteria. The intensity of the infrared radiation from an amorphous metal-core transformer had to be less than the infrared radiation from a silicon-steel transformer of the same rating when the transformers were operated under the same conditions.

Cold-Load Pickup Test.

- **Objective:** The objective of the cold-load pickup test was to determine whether heavy loading of a cold transformer had any injurious effects, such as thermal instability, on the transformer. The principal concern was that the transformer fluid could become so viscous at low temperatures that it could not circulate and transfer heat generated in the core and windings. This could create hot spots that could cause breakdown of the insulation and possible short circuits. For this test, the following conditions were assumed and simulated:
 - A power outage occurred in a cold (-35 °C) environment.
 - A replacement transformer was obtained from a cold (-35 °C) environment and placed in service.
 - Upon restoration of service, a 200 percent rated load was placed on the transformer for the first 2 hours. This was followed by a 100 percent rated load for the next 6 hours.

Instrumentation was installed and measurements were made as prescribed in Section 9.2.2 of ANSI/IEEE C57.12.90-1980.

- **Pass/Fail Criteria:** There had to be no significant change in winding current during operation at 100 percent rated load or 200-percent rated load. Any such change was evidence of a potential failure that had to be investigated by an autopsy.

Saturation, Regulation, and Efficiency Tests.

- **Objective:** The objective of these tests was to compare the excitation current, no-load loss, load loss, regulation, and efficiency of the amorphous metal-core and silicon-steel transformers under loading conditions of 50 percent, 100 percent,

and 150 percent of rated load. To conduct the tests, the transformers were instrumented as prescribed in Section 8 of ANSI/IEEE C57.12.90-1980, and were operated at the selected fraction of rated load until the top oil temperature stabilized. Immediately following temperature stabilization, voltage, current, and power readings were taken to obtain the data to develop saturation curves and to calculate transformer regulation and efficiency at each loading condition for each transformer type. Regulation and efficiency were calculated using the procedures in Section 14 of ANSI/IEEE C57.12.90-1980. After completion of the saturation, regulation, and efficiency tests, the transformers were subjected to the commercial tests to determine whether any of the operating characteristics of the transformers changed as a result of the tests.

- **Pass/Fail Criteria:** The transformers had to pass the commercial tests after completion of the saturation, regulation, and efficiency tests. The core losses, exciting currents, and percent regulation of the amorphous metal-core transformer had to be less than those for the silicon-steel transformers. Also, the percent efficiency of the amorphous metal-core transformer had to be greater than that of the silicon-steel transformer. At rated input voltage, the no-load losses and load losses had to match the nameplate values. There had to be no change in the operating characteristics of the transformers as a result of the testing.

PHASE II TESTS

An autopsy conducted on two amorphous metal-core transformers during Phase I testing revealed that some amorphous metal particles had broken loose from the amorphous metal core. These particles were found at the bottom of the tank, on the inside of the bottom frame, and on the coils. It was believed that the presence of these particles in the oil would reduce the coil-to-coil insulation margin.

After all Phase I tests were completed, the transformers were returned to the General Electric Company Distribution Transformer plant, Hickory, North Carolina. At the suggestion of NCEL engineers, General Electric made a production-line change to correct the problem. A special device was made that rotated the amorphous metal-core and allowed the core to be sprayed with a special adhesive, which completely encapsulated the core.

The Phase II tests were conducted on five amorphous metal-core transformers. Four of the transformers had fully encapsulated cores. The remaining transformer was unmodified.

Several types of transformer tests were conducted in Phase II, including (in the following order) a cross-country shipping test, commercial transformer tests, an impedance voltage/load loss design test (prescribed in ANSI/IEEE C57.12.90-1980), an untanking and inspection of each transformer, a 3-foot drop test on three of the transformers, and a subsequent untanking and inspection of the three transformers. The identity, objective, and pass/fail criteria for the Phase II tests are described in the following paragraphs.

Cross-Country Shipping Test

- Objective: The objective of the cross-country shipping test was to demonstrate that the fully encapsulated amorphous metal-core transformers could withstand the shocks and vibrations encountered in cross-country shipment by commercial truck with no mechanical damage or change in electrical performance. For this test, five amorphous metal-core transformers were shipped by commercial truck from Hickory, North Carolina, to Port Hueneme, California, and back to North Carolina by commercial truck. Standard commercial packing and handling procedures were used.
- Pass/Fail Criteria: There had to be no visible damage from shipment. After shipment, the transformers had to pass the ANSI/IEEE Commercial tests, the ANSI/IEEE impedance voltage/load loss test, and the untanking and inspection test.

ANSI/IEEE Commercial Tests and Impedance Voltage/Load Loss Tests

- Objectives: The objectives for these tests are described in the corresponding Phase I test descriptions.
- Pass/Fail Criteria: The pass/fail criteria are described in the corresponding Phase I test descriptions.
- Commercial tests consist of the following:
 - Induced potential test per ANSI C57.12.90 - 1980 Sec 10.4.
 - No-load loss/exciting current per ANSI C57.12.90 - 1980 Sec 8.
 - Applied voltage tests per ANSI C57.12.90 - 1980 Sec 10.3.
 - Impulse per ANSI C57.12.90 - 1980 Sec 10.5.
- ANSI/IEEE impedance voltage/load loss test per ANSI C57.12.90 - 1980 Sec 9.

Initial Untanking and Inspection Test

- Objective: The objective of the initial untanking and inspection test was to determine the extent of mechanical damage, if any, to the transformer core or internal structure as a result of the cross-country shipping test.
- Pass/Fail Criteria: The criteria for passing the test was that there had to be no evidence of flaking of the amorphous metal within the transformer. In addition, there had to be no evidence of mechanical damage to the transformer internal structure that would impair the long-term, reliable operation of the transformer as a result of cross-country shipment and return (approximately 5,000 miles).

Drop Test

- Objective: The objective of the drop test was to simulate the shock that the transformer would receive if it were mishandled and inadvertently dropped from a height of 3 feet (from the bottom of the transformer tank) to a hard surface.
- Pass/Fail Criteria: The criteria for passing the test was that the transformer had to pass the subsequent untanking and inspection test, and the post-drop commercial tests.

Post-Drop Untanking and Inspection Test

- Objective: The objective of the post-drop untanking and inspection test was to determine the extent of mechanical damage, if any, to the transformer core or internal structure as a result of the drop test.
- Pass/Fail Criteria: The criteria for passing the test was that there had to be no evidence of flaking of the amorphous metal within the transformer. In addition, there had to be no evidence of mechanical damage to the transformer's internal structures that could impair the long-term, reliable operation of the transformer as a result of the 3-foot drop test.

TEST SEQUENCING

Proper test sequencing was an important aspect of the test program. In order to minimize potential damage to the transformers during testing, the resistance, polarity, phase relation, ratio, no-load loss and excitation current, impedance, load loss, and temperature rise tests were conducted before the dielectric tests (which test the transformer insulation levels) were performed. Also, in this transformer test program, the commercial tests were performed upon initial receipt of the transformers at the test facilities and after each group of tests in which stressful conditions were imposed.

Phase I Test Sequence

In Phase I, three 25-kVA amorphous metal-core transformers and two 25-kVA silicon-steel transformers were tested. The test sequence for each transformer is listed in Table 1.

Phase II Test Sequence

In Phase II, four 25-kVA amorphous metal-core transformers with fully encapsulated cores and one 25-kVA amorphous metal-core transformer without an encapsulated core were tested. The test sequence for the transformers is listed in Table 2.

RESULTS AND CONCLUSIONS

Phase I

The identity, objectives, and pass/fail criteria for the Phase I tests are described in the Phase I test descriptions. The sequence of testing for each transformer tested in Phase I is described in the section on test sequencing. The results and conclusions from the Phase I tests are provided in the following paragraphs.

Commercial Tests. These tests were performed: (1) to determine the electrical performance parameters of the transformers upon initial receipt before testing; (2) to demonstrate compliance with nameplate data or contractual agreements; and (3) to identify any significant changes in transformer performance characteristics after the transformers were subjected to individual stressful tests.

- Commercial Test Results: The results of the commercial tests are tabulated in Appendix A. All of the transformers passed the commercial tests because they met the test criteria specified for the applicable tests. For the amorphous metal-core transformers, the largest average change in no-load loss, load loss, efficiency, and regulation between the initial tests and the tests that imposed stressful conditions was 2.4 percent. The maximum change in any of these parameters was a 7.0 percent increase in no-load loss for amorphous metal-core transformer serial number P217060-YZA after the 170 percent temperature rise test.
- Commercial Test Conclusions: The conclusions from the results of the commercial tests were that the transformers demonstrated compliance with the nameplate data upon initial receipt, and there were no significant changes in transformer electrical characteristics after being subjected to tests that caused significant stresses.

Temperature Rise Tests. These tests were performed to determine the maximum temperature rise (above the ambient temperature) of the windings and the insulating fluid in the transformer when the transformer was operated at loads equal to, and greater than, the nameplate kVA rating. The amorphous metal-core transformers were operated at 100 percent and at 170 percent of nameplate load. The silicon-steel transformers were operated at 100 percent and 150 percent of nameplate load.

- Temperature Rise Test Results: The detailed results of the temperature rise tests are shown in Appendix B. The summarized results are listed in Table 3 and illustrated in Figure 1.

- Temperature Rise Test Conclusions: The conclusions to be drawn from the results of the temperature rise tests are as follows:
 - At 100 percent of rated load, both the amorphous metal-core and the silicon-steel transformers passed the temperature rise test. Both of the transformer types had temperature rises of less than the ANSI/NEMA requirement of 65 °C temperature rise above ambient.
 - At 100 percent of rated load, the temperature rise in the amorphous metal-core transformer oil, low-voltage windings, and high-voltage windings was significantly less than the corresponding temperature rises in the silicon-steel transformers.
 - The temperature rises in the amorphous metal-core transformers at 170 percent of rated load were roughly comparable to the temperature rises in the silicon-steel transformers at 150 percent of rated load.

The significance of the lower temperature rises in the amorphous metal-core transformers is that, other factors being equal, amorphous metal-core transformers should have longer reliable operating lives compared to silicon-steel transformers.

Audible Sound Level Test. The audible sound level test was conducted to determine the audible sound emitted from the transformer when operated at rated voltage and frequency and no-load. Sound level measurements are significant because excessive sounds from transformers can be an annoyance in residential or other populated areas. Also, excessive sound levels may indicate apparent problems in the transformer core, such as loose or fractured core laminations.

- Audible Sound Level Test Results: The audible sound level tests were conducted on amorphous metal-core transformer serial number P217059-YZA at 100 percent and 110 percent of rated voltage, after the transformer had been subjected to short-circuit testing. This worst-case condition was chosen to give an indication of any possible loosening or fracturing of core laminations as a result of the short-circuit test. The detailed test data are shown in Appendix B. The summarized audible sound level test data are listed below, and illustrated in Figure 2:

Sound Level at 100%	
of Rated Voltage	32.4 dB(A)
Sound Level at 110%	
of Rated Voltage	37.3 dB(A)

The ANSI/NEMA sound level limit at 100 percent of rated voltage is 48 dB(A). There is no ANSI/NEMA sound level limit at 110 percent of rated voltage.

- Audible Sound Level Test Conclusions: The conclusions from the test results were that the tested amorphous metal-core transformer operated at a sound level that was substantially lower than the ANSI/NEMA limit. The low sound level indicated that no core damage was incurred as a result of the previously conducted short-circuit test.

Radio Influence Voltage Test. The objective of the RIV test was to determine the amount of RIV produced by the corona (local overstress) in transformer insulation. RIV, as the name implies, may cause interference to radio communications. Excessive corona also may be an indication of insulation breakdown.

- RIV Test Results: The test produced no radio influence voltage at 100 percent and 110 percent of rated voltage.
- RIV Test Conclusion: The conclusion from the test results was that operation of the tested amorphous metal-core transformer at 100 percent of rated voltage or 110 percent of rated voltage would not interfere with radio transmission or reception.

Short-Circuit Test. The short-circuit test was conducted to demonstrate the ability of the transformer to withstand the stresses resulting from a short circuit applied on the transformer's primary or secondary terminals. The test may be conducted by closing a breaker at the faulted terminal, which would apply short circuit to a previously energized transformer, or by closing a breaker at the source terminal, which would apply energy to a previously short-circuited transformer.

- Short-Circuit Test Results: The detailed test results are shown in Appendix B. The summarized short-circuit test results are listed below and illustrated in Figure 3 for amorphous metal-core transformer serial number P217059-YZA when subjected to a short-circuit current of 40 times the rated current.

	<u>Impedance Change</u>	<u>Exciting Current Change</u>
As observed in before/after commercial tests	5.3%	1.0%
As allowed per ANSI/IEEE C57.12.90-1980	11.1%	25.0%

Measurements were also made of the first and sixth peak of the magnetizing in-rush current. These values were 28.8 and 12.8 times the normal magnetizing current. The transformer passed the commercial tests both before and after the short-circuit test. No damage attributable to the short-circuit test was found in a post-test autopsy.

- Short-Circuit Test Conclusion: The conclusion from the short-circuit test results was that the amorphous metal-core transformer can be expected to withstand short-circuit current of at least 40 times the rated current, without damage or significant change in electrical performance parameters.

Full-Wave and Chopped-Wave Impulse Voltage Tests. These tests were conducted to determine the ability of the transformer to withstand lightning surges. The test descriptions and pass/fail criteria are contained in the Phase I test descriptions. The chopped wave stressed insulation between turns near the line end. The full wave stressed insulation between the middle of the winding and ground. Oscillograms were obtained for applied voltage versus time and for neutral current versus time.

- Full-Wave and Chopped-Wave Impulse Voltage Test Results: The detailed test results are contained in Appendix B. The test sequence included the following tests: reduced full-wave test, chopped-wave test, 400-Hz induced potential test, front of wave impulse test (voltage wave is chopped before it crests), 400-Hz induced potential test, full-wave test, 400-Hz induced potential test, and HLIC and LHIC applied voltage tests. In order to provide additional assurance that the amorphous metal-core transformers could withstand lightning surges, the tests were performed on an energized transformer, and additional stress tests were added to the test sequence.

As stated in the Phase I test descriptions, agreement in voltage and current wave shape between the initial full-wave reduced voltage application and the final 100 percent full-wave application indicates that the transformer has passed without damage. Any unexplainable difference in wave shape indicates a failure in either the windings, the major or minor insulation, or the bushings.

As described in Paragraph 7 of Appendix B, two anomalies arose in the full-wave impulse tests. To determine if the anomalies indicated a failure in the insulation, the transformer was subjected to an induced voltage test at 400-Hz and the HLIC and LHIC applied voltage tests. The transformer passed these auxiliary tests. Therefore, the transformer was considered to have passed the full-wave and chopped-wave impulse voltage tests.

- Full-Wave and Chopped-Wave Impulse Voltage Test Conclusions: From the test results, it was concluded that the tested amorphous metal-core transformer was able to withstand simulated lightning surges, even when it was energized. It is noteworthy that these tests were more severe than the unenergized tests prescribed in ANSI/IEEE C57.12.90-1980.

Infrared Scanning Test (Transformer Energized). This test was conducted to obtain, by means of an infrared-sensitive detector, a visual indication of the amount of energy required to magnetize the transformer core. The infrared scans of an energized amorphous metal-core transformer and a silicon-steel transformer were compared.

- Infrared Scanning Test Results (Transformer Energized):
Photographs of the infrared scan of the amorphous metal-core transformer and the silicon-steel transformer are contained in Appendix C. It can be seen that the intensity of radiation from the amorphous metal-core transformer is less than the intensity of radiation from the silicon-steel transformer. Also, there are no visible hot spots in the infrared scan of either transformer.
- Infrared Scanning Test Conclusions (Transformer Energized):
The test results confirm the results of the commercial tests, which indicate that the core losses in the amorphous metal-core transformer are less than the core losses in the silicon-steel transformer.

Cold-Load Pickup Test. This test was conducted to determine whether heavy loading of a cold transformer had any injurious effects, such as thermal instability, on the transformer. The conditions that the test was designed to simulate are described in the Phase I test descriptions. For this test, the transformer was placed in a cold chamber until the oil temperature reached -34°C . Then the transformer was energized at 200 percent load for 2 hours. This was followed by 6 hours of operation at 100 percent load. Watt loss was measured throughout the test.

- Cold-Load Pickup Test Results: The detailed test results are contained in Appendix B. In summary, within a relatively short time, the losses stabilized at both loading conditions and remained fairly constant throughout the remainder of each test iteration. Subsequently, the transformer passed the commercial test.
- Cold-Load Pickup Test Conclusions: From the results of the tests, it was concluded that the tested amorphous metal-core transformer can satisfactorily withstand being subjected to a 200 percent cold load when the transformer oil temperature is -34°C . Further, the transformer can operate satisfactorily for an extended period at 100-percent load after the 200 percent load period. This realistic test demonstrated that the transformer design is sufficient to adequately circulate the transformer oil during a cold load. No damage to the transformer insulation is likely to occur as a result of hot spots caused by poor transformer circulation.

Saturation, Efficiency, and Regulation Tests. These tests were conducted to compare the excitation current, no-load loss, load loss, regulation, and efficiency of the amorphous metal-core and silicon-steel transformers under loading conditions of 50 percent, 100 percent, and 150 percent of rated load. The tests were run as described in the Phase I test descriptions.

- Saturation, Efficiency, and Regulation Test Results:

- Saturation: The excitation current in the amorphous metal-core transformer was significantly lower (0.25 to 0.5) than the excitation current in the silicon-steel transformer for all loading conditions and all values of secondary voltage. The test data are listed in tabular form in Appendix D, and illustrated in Figures 4 through 7.
- No-load losses: The no-load losses of the amorphous metal-core transformer were significantly lower than the no-load losses of the silicon-steel transformer for all loading conditions and all values of secondary voltage. At 100 percent of rated flux voltage, the no-load loss of the amorphous metal-core transformer was 27 percent of the no-load loss for the silicon-steel transformer. The actual values closely approximated the nameplate values for both transformers. The test data are provided in tabular form in Appendix D and in Figures 8 through 11.
- Regulation: Both the measured and calculated percent regulation of the amorphous metal-core transformer was better (lower) than the measured or calculated percent regulation of the silicon-steel transformer at 50 percent, 100 percent, and 150 percent load for both 0.8 and 1.0 power factors. The test data are provided in tabular form in Appendix B for all loading conditions, and illustrated in Figure 12 for 100 percent loading.
- Efficiency: Both the measured and calculated efficiency of the amorphous metal-core transformer was better (higher) than the measured or calculated efficiency of the silicon-steel transformer at 50 percent, 100 percent, and 150 percent load for both 0.8 and 1.0 power factors. The test data are provided in tabular form in Appendix B and illustrated in Figure 13 for 100 percent loading.

The electrical parameters of the amorphous metal-core transformer showed very little variation from previous values after the saturation, efficiency, and regulation tests were completed. See Appendix A for the detailed results of the commercial tests conducted before and after the saturation, efficiency, and regulation tests.

- Saturation, Efficiency, and Regulation Test Conclusions: The amorphous metal-core transformer performed better in all tests than the silicon-steel transformer. There were no significant changes in the electrical parameters of the amorphous metal-core transformer as a result of the testing.

Safe Transit (Shake and Drop) Tests. These tests were conducted to demonstrate that the transformer could withstand the shocks and vibrations encountered during a simulated cross-country shipment, with no significant

mechanical damage and no significant change in electrical performance characteristics. Two tests were run: (1) a 4-hour test on the safe transit machine at 160 rpm to simulate two cross-country shipments by truck, and (2) a 4-foot drop of the transformer onto a hard surface (to simulate inadvertent mishandling during transit). After the shake and drop tests, the transformer was subjected to the commercial tests to detect any changes in electrical performance and to an autopsy where the transformer core was removed from the tank and inspected for damage. The pass/fail criteria are described in the Phase I test descriptions.

- Safe Transit (Shake and Drop) Test Results: The transformer passed the shake and drop tests with no significant external damage. When the shake and drop tests were completed, the amorphous metal-core transformer was subjected to the commercial tests. The transformer passed the tests with a 3 percent drop in no-load loss, which was substantially less than the allowed 10 percent drop. There were no significant changes in the other electrical performance parameters of the transformer (see Appendix A).
- Safe Transit (Shake and Drop) Test Conclusions: The preliminary conclusion from the shake and drop tests was that the transformer passed the tests. See the autopsy test results in the following paragraph for further discussion of the test results.

Post-Shake and Drop Test Autopsy. The post-drop untanking and inspection was done to determine the extent of mechanical damage, if any, to the transformer core or internal structures as a result of the drop test.

- Post-Shake and Drop Test Autopsy Results: When the transformer was untanked, minor mechanical damage to the tank bottom (a bowed core/coil and cracked core/coil pressure plates) was found. In addition, amorphous metal-core particles were found on the bottom of the tank, on the inside of the bottom frame, and on the coils. See Figure 1 in Section 8 of Appendix B.
- Post-Shake and Drop Test Autopsy Conclusions: The criteria for passing the test were that there had to be no evidence of the amorphous metal flaking in the transformer core and there had to be no evidence of mechanical damage to the transformer internal structures that could impair the long-term, reliable operation of the transformer as a result of the drop test. The mechanical damage to the exterior of the tank and to the internal core/coil support structures was not considered to be serious considering the severity of the test.

The presence of amorphous metal particles in the tank, on the coils, and in the tank oil was considered serious. The presence of these particles would reduce the coil-to-coil insulation margin of the transformer. Therefore, it was concluded that the transformer had not passed the post-test autopsy.

NOTE

After all Phase I tests were completed, the transformers were returned to the General Electric Company Distribution Transformer Division plant, Hickory, North Carolina. At the suggestion of NCEL engineers, General Electric devised a production-line change to completely encapsulate the core and correct the problem.

Phase II

The identity, objectives, and pass/fail criteria for the Phase II tests are described in the Phase II test descriptions. The sequence of testing for each transformer tested in Phase II is set forth in the Phase II test sequence. The General Electric Company test data are contained in Appendix E. The results and conclusions from the Phase II tests are provided in the following paragraphs.

Cross-Country Test. The cross-country test was conducted to demonstrate that the amorphous metal-core transformers could withstand the shocks and vibrations encountered in cross-country shipment by commercial truck with no mechanical damage or change in electrical performance. For this test, five 25-kVA amorphous metal-core transformers were shipped by commercial truck from Hickory, North Carolina, to Port Hueneme, California, and back to North Carolina by commercial truck. Standard commercial packing and handling procedures were used.

- **Cross-Country Test Results:** From the results of the post-transport untanking of the transformers, there was no visible damage from the approximately 5,000-mile truck transport of the transformers. The results of the before and after commercial tests indicated no changes in electrical performance parameters that were outside the allowed variations. There was no indication of amorphous metal particle flaking in the four encapsulated transformers. Fifteen small amorphous metal particles were found in the bottom containment box of the nonencapsulated transformer.
- **Cross-Country Test Conclusions:** All five transformers passed the cross-country test, and the subsequent commercial and untanking and autopsy tests (see Appendix A for the commercial test results). It was further concluded that the amorphous metal-core transformers could withstand the typical shocks and vibrations encountered in cross-country truck shipment without physical damage or significant change in electrical parameters.

3-Foot Drop Test. The 3-foot drop test was conducted on three of the transformers to simulate the shock that the transformer would receive if it was mishandled, and inadvertently dropped, from a height of 3 feet (from the bottom of the transformer tank) to a hard surface. The test procedure, test data, and test photographs are contained in Appendix E.

- 3-Foot Drop Test Results: The results of the drop test were as follows:
 - In all three transformers, the tank bottom had bulged and the bottom clamp had been bent, but none of the embossed areas of the containment tray were punctured.
 - The top and bottom clamp assemblies of all three units were very clean. There was no evidence of amorphous metal particles.
 - There were seven small amorphous metal particles in the bottom of the nonencapsulated transformer containment box.
 - There were four small amorphous metal particles inside the bottom containment box of one of the encapsulated transformers (serial number P265882-YOB).
 - There was one small amorphous metal particle inside the bottom containment box of the other encapsulated transformer (serial number P265883-YOB).
 - There were no amorphous metal particles in the oil or the inside of the transformer tank of all three transformers.
- 3-Foot Drop Test Conclusions: From the 3-foot drop test results, it was concluded that the encapsulated transformers passed the test. The significance of the test results is that the amorphous metal flaking problem experienced in the drop tests of Phase I has been solved.

DISCUSSION

NCEL successfully verified the reliability and performance of amorphous metal-core transformers over a 5-month test period. The amorphous metal-core transformers met or exceeded the ANSI/IEEE or NEMA standard for all tests conducted. The amorphous metal-core transformers performed better in all tests when compared to conventional silicon-steel transformers. In addition, NCEL verified that the no-load losses of the amorphous metal-core transformers were equal to or lower than the values claimed by the transformer manufacturer.

During Phase I testing, a problem was discovered with amorphous metal particles breaking loose from the transformer core. These particles were found in the bottom of the tank, on the inside of the bottom frame, and on the coils of the transformer. Consequently, the amorphous core transformers failed the safe transit tests. NCEL suggested a production-line change to General Electric, recommending complete encapsulation of the transformer core. This recommendation was implemented by the General Electric Company. Subsequent testing in Phase II demonstrated that the amorphous metal flaking problem had been resolved through complete encapsulation of the amorphous transformer core.

CONCLUSIONS

In every electrical performance test, the amorphous metal-core transformers met or exceeded the ANSI/IEEE or NEMA standard for the test.

The amorphous metal-core transformers also passed other more stress-inducing tests, such as the energized impulse voltage tests, the front of wave impulse test, the safe transit test, and the cold-load pickup test.

In every test where the electrical performance of amorphous metal-core and silicon-steel transformers was compared, the amorphous metal-core transformers performed better than the silicon-steel transformers.

The no-load losses of the amorphous metal-core transformers were equal to or lower than previous predictions made by the transformer manufacturer.

The amorphous metal flaking problem discovered in the Phase I tests appears to have been solved effectively by the production-line modification made at the suggestion of NCEL engineers.

Based on the test results, it is reasonable to expect that the amorphous metal-core transformers will operate with equal or better reliability than the silicon-steel transformers over the nominal lifetime of a transformer.

RECOMMENDATIONS

Based on the results of the tests, the following recommendations are made:

1. Up to 500 kVA amorphous metal-core transformers should be procured as replacements based upon life-cycle cost analysis for up to 500 kVA polychlorinated biphenyl (PCB) contaminated transformers and for replacement of other transformers through 500 kVA requiring replacement due to age, loading, or maintenance.
2. The development and commercial availability of larger kVA-capacity amorphous metal-core transformers should be closely followed.
3. As larger kVA-capacity transformers become commercially available, they should be procured as replacements for similar size PCB-contaminated transformers, and for replacement of other similar-size transformers requiring replacement due to age, loading, or maintenance.
4. All amorphous transformer cores should be specified as fully encapsulated in order to eliminate metallic flaking.

Executive Summary of Test Results

Phase I Testing	25 kVA/75 kV BIL Amorphous Metal Test Status	25 kVA/75 kV BIL Silicon Steel Test Status	Test Object Pass/Fail Criteria Description	Test Standard Used
ANSI "Routine" Testing				
Ratio	P	P	Page 2	ANSI C57.12.90 - 1980 Sec. 7
Polarity	P	P	Page 2	ANSI C57.12.90 - 1980 Sec. 6
Applied Voltage HLIC Test	P	P	Page 3	ANSI C57.12.90 - 1980 Sec. 10.3
Applied Voltage LMIC Test	P	P	Page 3	ANSI C57.12.90 - 1980 Sec. 10.3
Induced Potential Test	P	P	Page 3	ANSI C57.12.90 - 1980 Sec. 10.4
No-Load Loss/Exciting Current	C	C	Page 3	ANSI C57.12.90 - 1980 Sec. 8
ANSI "Design" Tests				
Full-Wave J-ulse	P	P	Page 4	ANSI C57.12.90 - 1980 Sec. 10.5
Chopped-Wave Impulse	*	X	Page 4	ANSI C57.12.90 - 1980 Sec. 10.5
Winding Resistance	C	C	Page 4	ANSI C57.12.90 - 1980 Sec. 9
Impedance/Load Loss	C	C	Page 5	ANSI C57.12.90 - 1980 Sec. 9
Temperature Rise	P	P	Page 5	ANSI C57.12.90 - 1980 Sec. 11
Sound Level	P	X	Page 5	ANSI C57.12.90 - 1980 Sec. 13 ANSI/IEEE Std. 141 - 1986 NEMA TR1 - 1980
ANSI "Other" Tests				
Radio Influence Voltage (RIV)	P	X	Page 6	NEMA TR1-1980 Revision 2 Sec. 0.03 (Limits) NEMA 7.01 (Test Code)
Short Circuit	P	X	Page 6	NEMA 107 - 1964 Reaffirmed 1981 Test Methods ANSI C57.12.90 - 1980 Sec. 12

Executive Summary of Test Results (Continued)

Phase I Testing	25 kVA/75 kV BIL Amorphous Metal Test Status	25 kVA/75 kV BIL Silicon Steel Test Status	Test Object Pass/Fail Criteria Description	Test Standard Used
**Additional Tests				
Front of Wave Impulse	*	X	Page 4	
Full-Wave Impulse-Energized	P	X	Page 4	
Chopped-Wave Impulse-Energized	P	X	Page 4	
Front of Wave Impulse-Energized	P	X	Page 4	
Safe Transit Test (Shake & Drop)	P	X	Page 6	
Infrared Scanning-Energized	C	C	Page 7	
Cold-Load Pickup	P	X	Page 7	
Saturation Curves	C	C	Page 7	
Regulation & Efficiency	C	C	Page 7	

P = Passed Test

F = Failed Test

C = Testing Completed - No Pass/Fail Criteria Available

* = See Same Test With Unit Energized

Q = Qualified Pass

X = This Test Not Part of Test Program for Silicon Steel Units

** = These Tests are not defined or required by ANSI and/or IEMA Standards.

These tests were defined by NCEL

Executive Summary of Test Results

Phase II Testing	25 kVA 75 kV BIL/kVA Amorphous Metal Test Status	Test Objective Pass Fail Criteria Description	Standards Used
Cross-Country Shipping Test*	P	Page 9	ANSI C57.12.90 - 1980 Section 4, 8, 9, 10.3, 10.5
Drop Test*	P	Page 10	ANSI C57.12.90 - 1980 Sections 4, 8, 9, 10.3 10.5
Post-Drop Test*	P	Page 10	

P = Passed Test

F = Failed Test

C = Testing Completed - No Pass/Fail Criteria Available

* = These Tests are not defined or required by ANSI and/or NEMA Standards.
These Tests were defined by NCEL

FUTURE WORK

Amorphous metal-core transformers are an emerging new technology that will meet the typical wide swings in Navy transformer load requirements of no-load to full load. Currently, 25-kVA through 75-kVA production-grade amorphous metal-core transformers are commercially available. Pilot-line 75-kVA through 500-kVA amorphous metal-core transformers are also available. Industry projections indicate that amorphous metal-core transformers will be price comparable in the 1990s and will eventually dominate the transformer market.

NCEL will focus efforts on low core loss transformer technology due to the potential of large Navywide energy savings. Eight three-phase, pad-mounted, amorphous metal-core transformers (three 75-kVA units and five 150-kVA units) are currently being field tested by NCEL at Pearl Harbor, Hawaii. NCEL plans to field test a 300-kVA unit at the Pacific Missile Test Center, Point Mugu, California.

ACKNOWLEDGMENTS

The authors wish to acknowledge Mr. Gregg V. Jones of the Westinghouse Electric Corporation and Mr. Albert C. Lee of General Electric for their assistance in analyzing and interpreting the test data.

Table 1. Phase I Transformer Test Sequences

Amorphous Metal-Core Transformer Test Sequence		
Serial Number P217059-YZA	Serial Number P217060-YZA	Serial Number P217061-YZA
Commercial Tests ^a Short-Circuit Test Sound Level Test RIV Test Commercial Tests ^a 4-hour Shake Test Commercial Tests ^a 4-Foot Drop Test Commercial Tests ^a Autopsy	RIV Test Commercial Tests ^a 100% Temperature Rise 170% Temperature Rise Commercial Tests ^a Impulse Tests ^b (Energized) Infrared Scan	RIV Test Commercial Tests 100% Temperature Rise 170% Temperature Rise Commercial Tests ^a Cold-Load Pickup Test Commercial Tests ^a Regulation Tests Efficiency Tests Saturation Tests Commercial Tests ^a
Silicon-Steel Transformer Test Sequence		
Serial Number P239216-YOB	Serial Number P239217-YOB	
Infrared Scan 100% Temperature Rise 150% Temperature Rise Commercial Tests ^a Regulation Tests Efficiency Tests Saturation Tests ^a Commercial Tests ^a	100% Temperature Rise 150% Temperature Rise Commercial Tests ^a	

^aThe commercial tests included the ratio test, full-wave impulse test, applied potential tests (HLIC and LHIC), induced potential (400-Hz) test, no-load/exciting current test, winding resistance test, and impedance voltage/load loss test.

^bThe impulse tests (with the transformer energized) were conducted in the following order: reduced full-wave test, chopped-wave test, 400-Hz front-of-wave test, 400-Hz full-wave test, and 400-Hz HLIC and LHIC tests.

Table 2. Phase II Transformer Test Sequences

Serial Number P217059-YZA ^a	Serial Number P217060-YZA ^a	Serial Number P217061-YZA ^a
Commercial Test Cross-Country Test Commercial Test Autopsy	Commercial Test Cross-Country Test Commercial Test Autopsy	Commercial Test Cross-Country Test Commercial Test Autopsy 3-Foot Drop Test Autopsy
Serial Number P265882-YOB ^a		Serial Number P265885-YOB ^a
Commercial Test Cross-Country Test Commercial Test Autopsy 3-Foot Drop Test Autopsy		Commercial Test Cross-Country Test Commercial Test Autopsy 3-Foot Drop Test Autopsy

^a Amorphous metal-core transformer with encapsulated core.

Table 3. Summary of Temperature Rise Results

Amorphous and Silicon Transformers at 100% of Rated Load				
Serial Number	Core Material	Top Oil Temp Rise (°C)	HV Winding Temp Rise (°C)	LV Winding Temp Rise (°C)
P217060-YZA	Amorphous	39.1	48.9	47.5
P217061-YZA	Amorphous	39.4	51.7	50.4
P239216-YOB	Silicon	53.7	60.2	58.8
P239217-YOB	Silicon	52.1	59.6	60.8
Avg Silicon Temp Rise (°C)		52.90	59.90	59.80
Avg Amorphous Temp Rise (°C)		39.25	50.30	48.95
Temp Rise Difference (°C)		13.65	9.60	10.85
Amorphous at 170% Rated Load and Silicon at 150% Rated Load				
P217060-YZA	Amorphous	101.71	127.5	122.4
P217061-YZA	Amorphous	101.71	129.2	123.4
P239216-YOB	Silicon	102.1	120.6	112.5
P239217-YOB	Silicon	99.81	118.8	110.2
Avg Amorphous Temp Rise (°C)		101.70	128.35	122.90
Avg Silicon Temp Rise (°C)		100.95	119.70	111.35
Temp Rise Difference (°C)		0.75	8.65	11.55

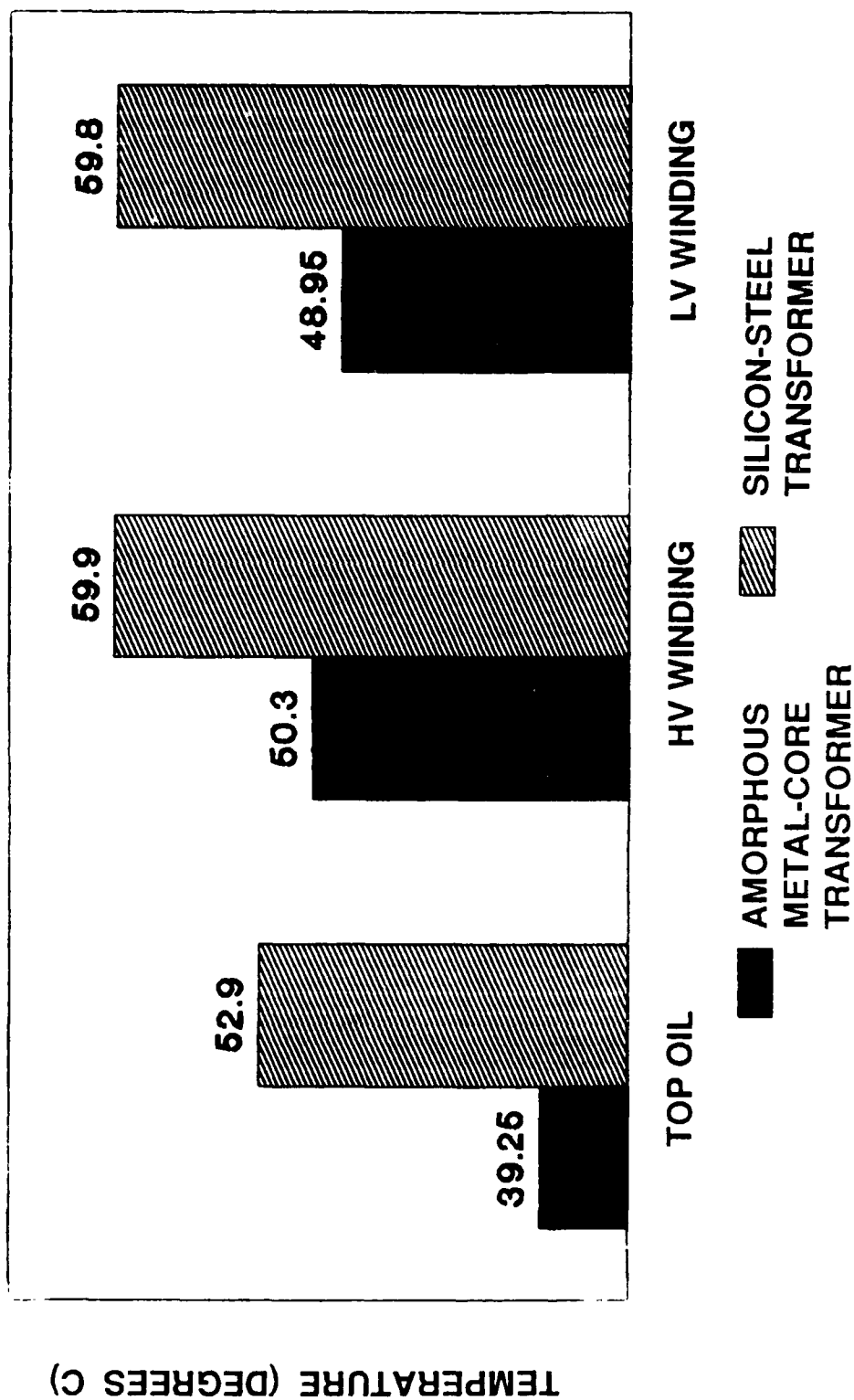


Figure 1. Temperature rise test at 100% load.

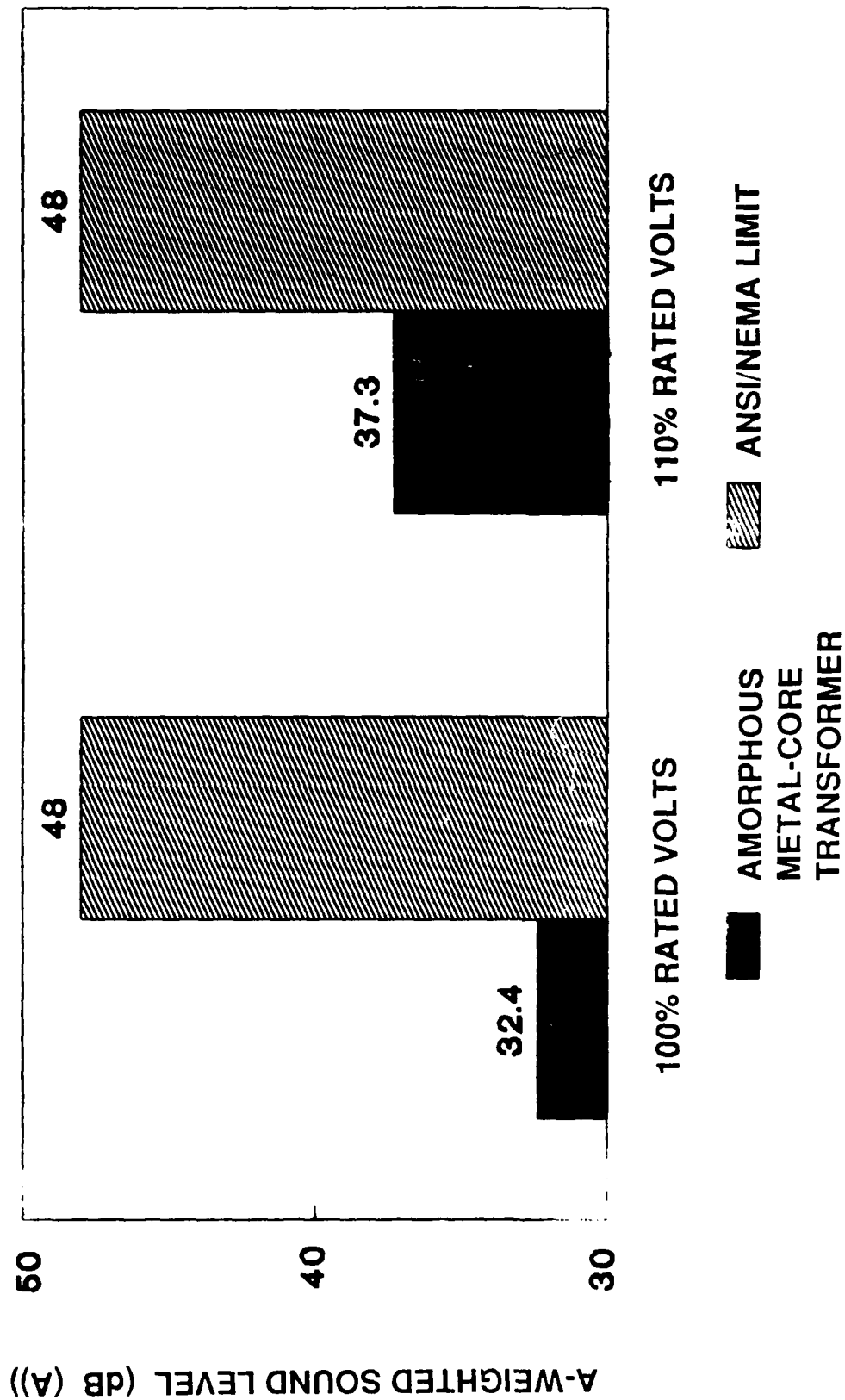


Figure 2. Audible sound level test.

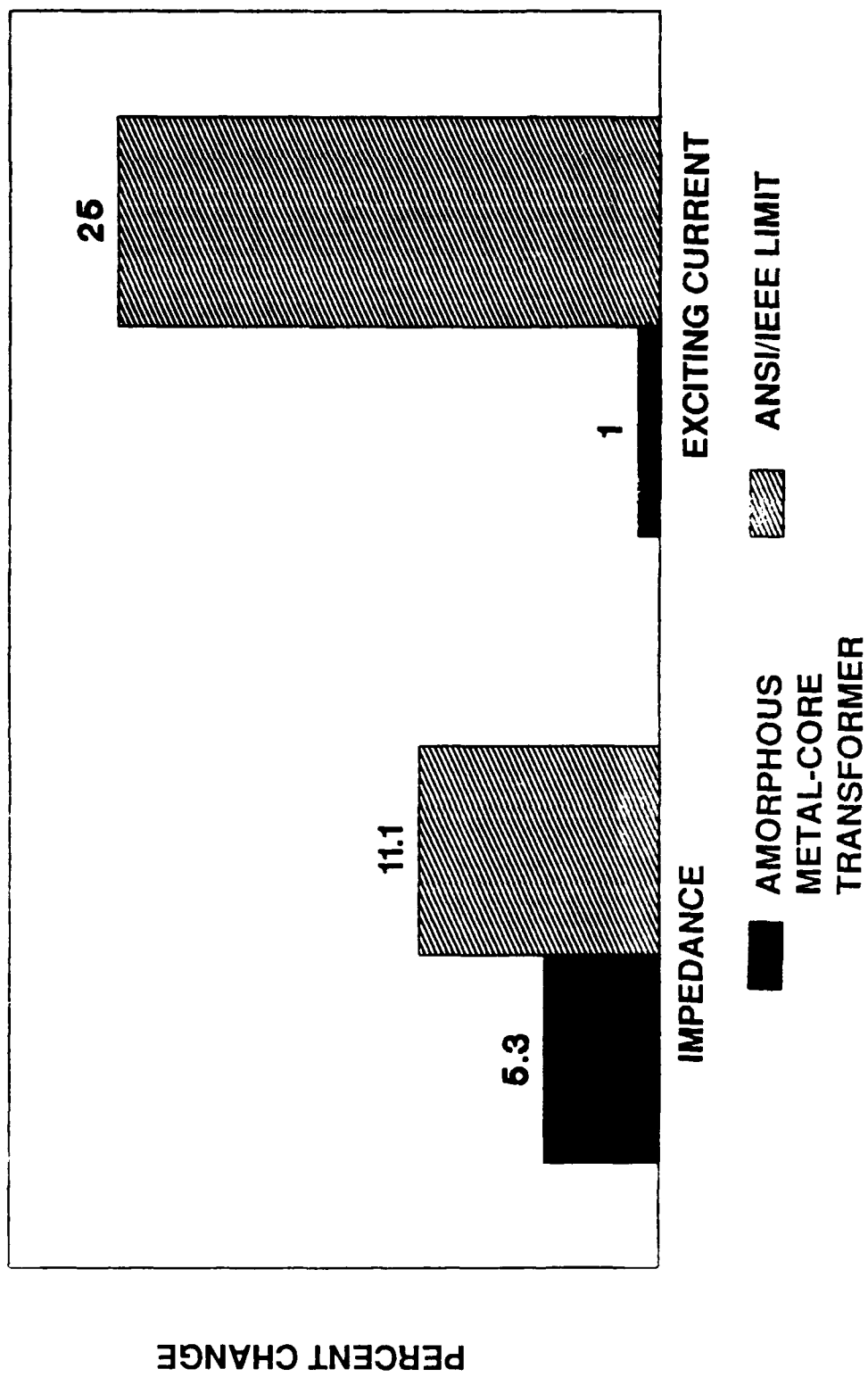


Figure 3. Short-circuit test.

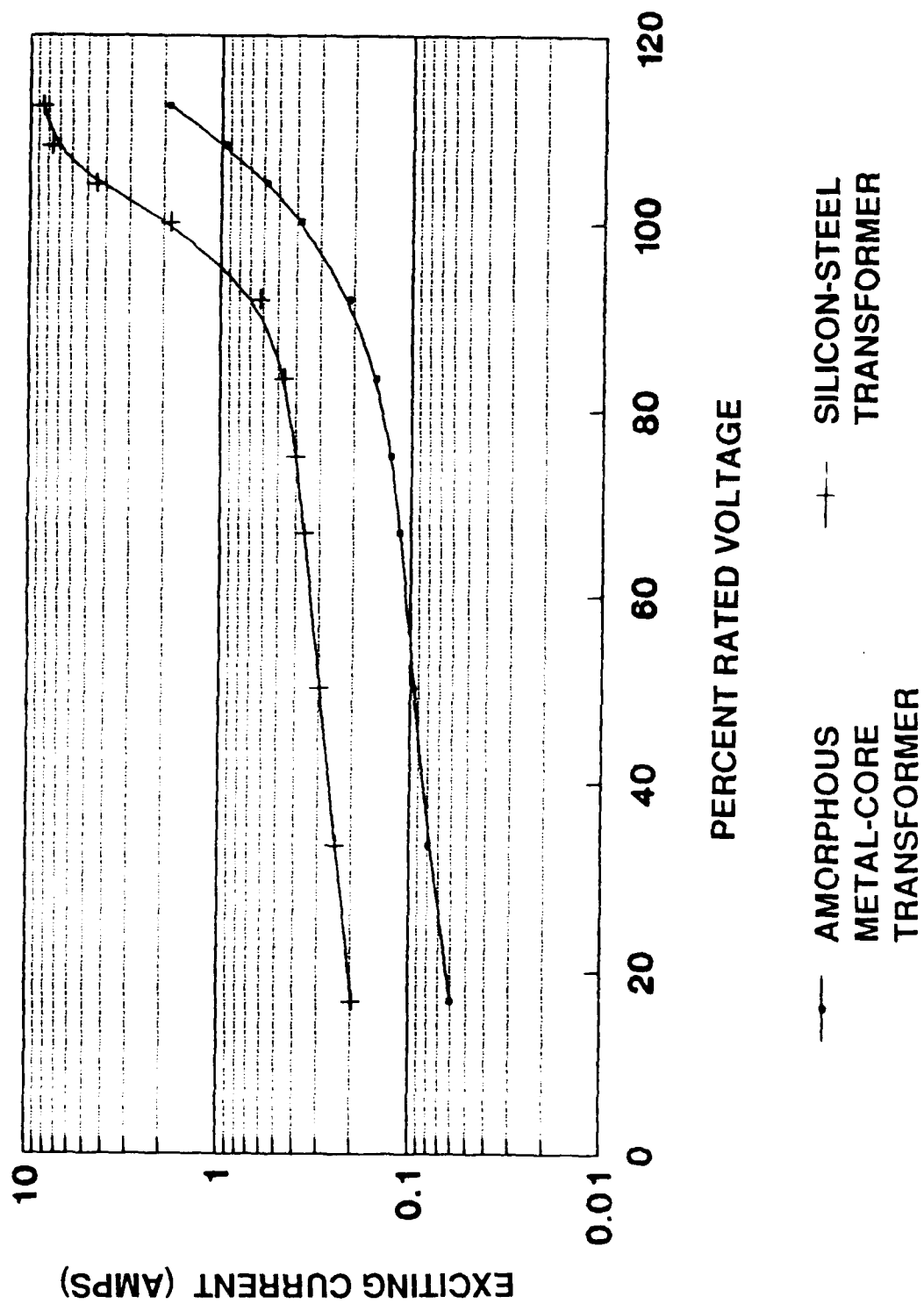


Figure 4. Exciting current versus % rated flux volts at no-load condition.

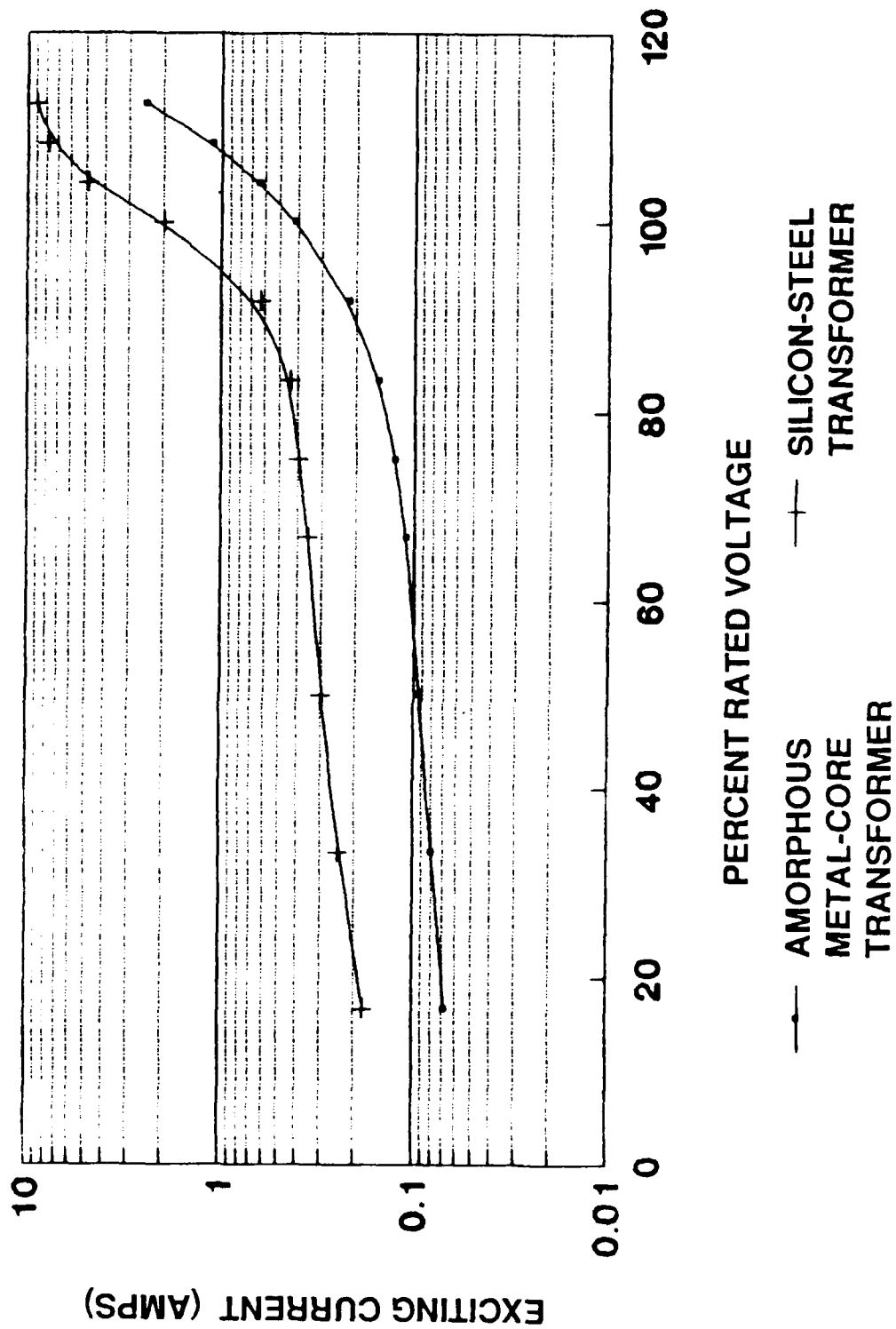


Figure 5. Exciting current versus % rated flux volts at 50% load condition.

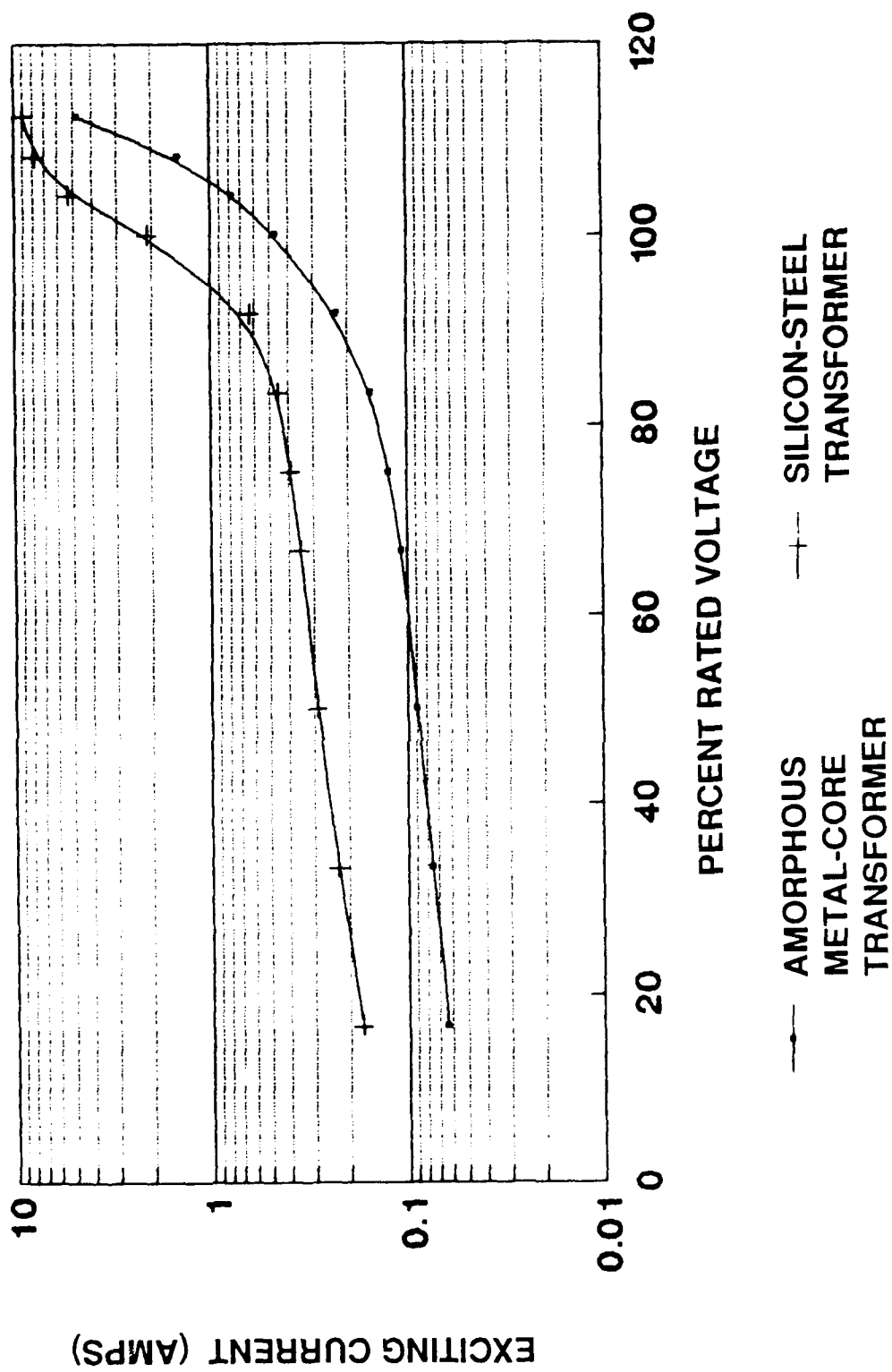


Figure 6. Exciting current versus rated flux volts at 100% load condition.

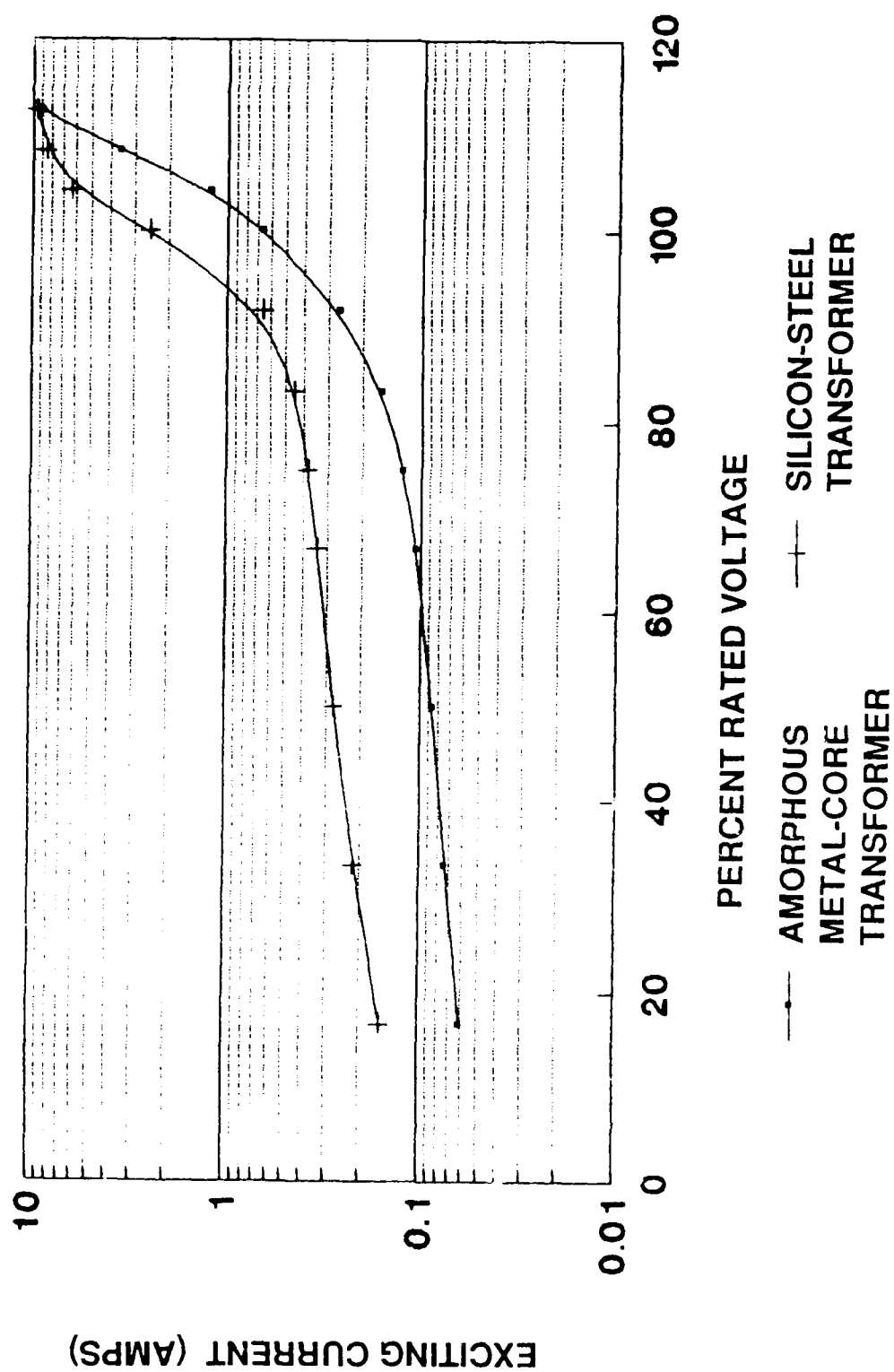


Figure 7. Exciting current versus rated flux volts at 150% load conditions.

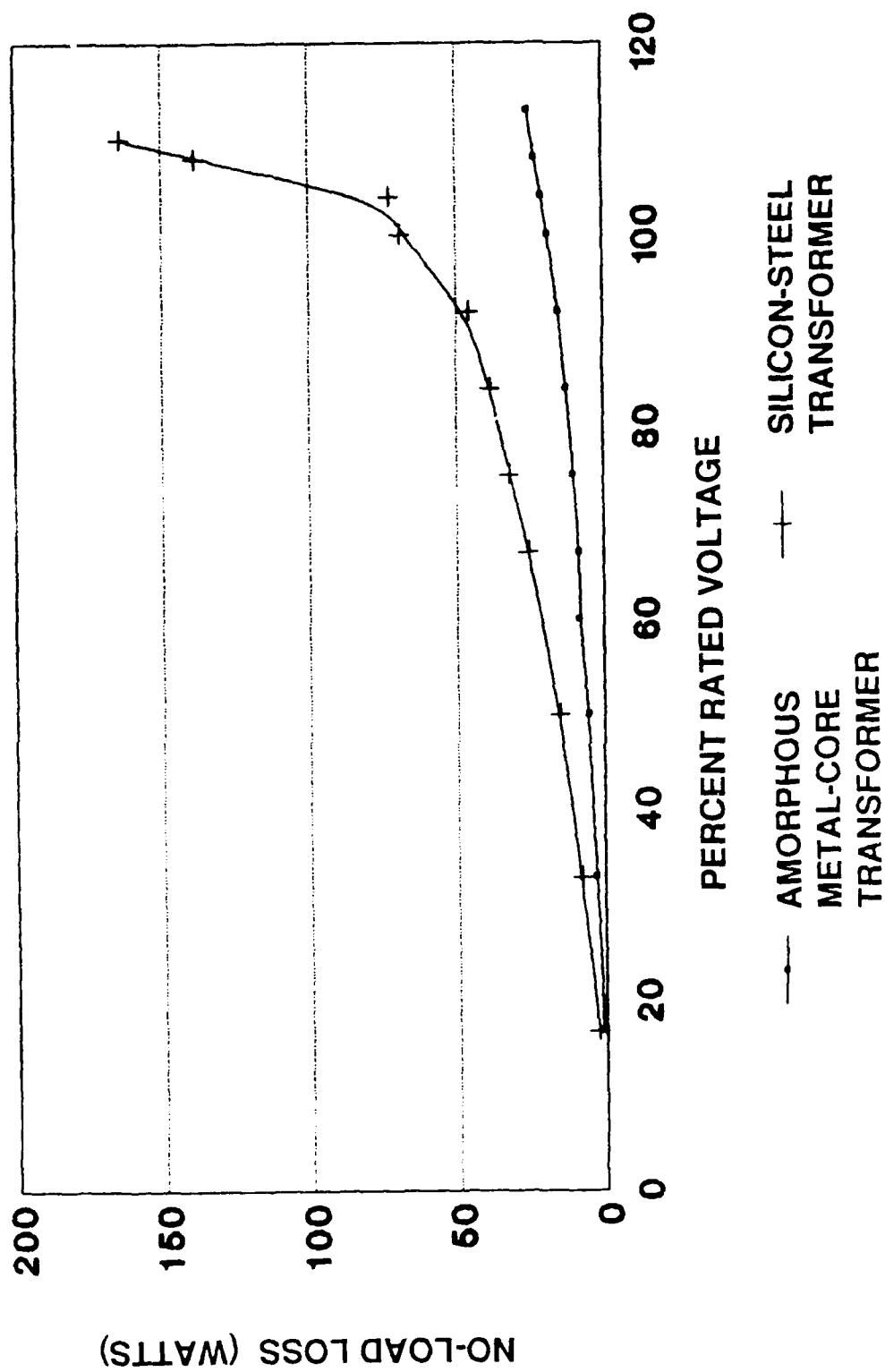


Figure 8. No load loss versus % rated flux voltage at no-load condition.

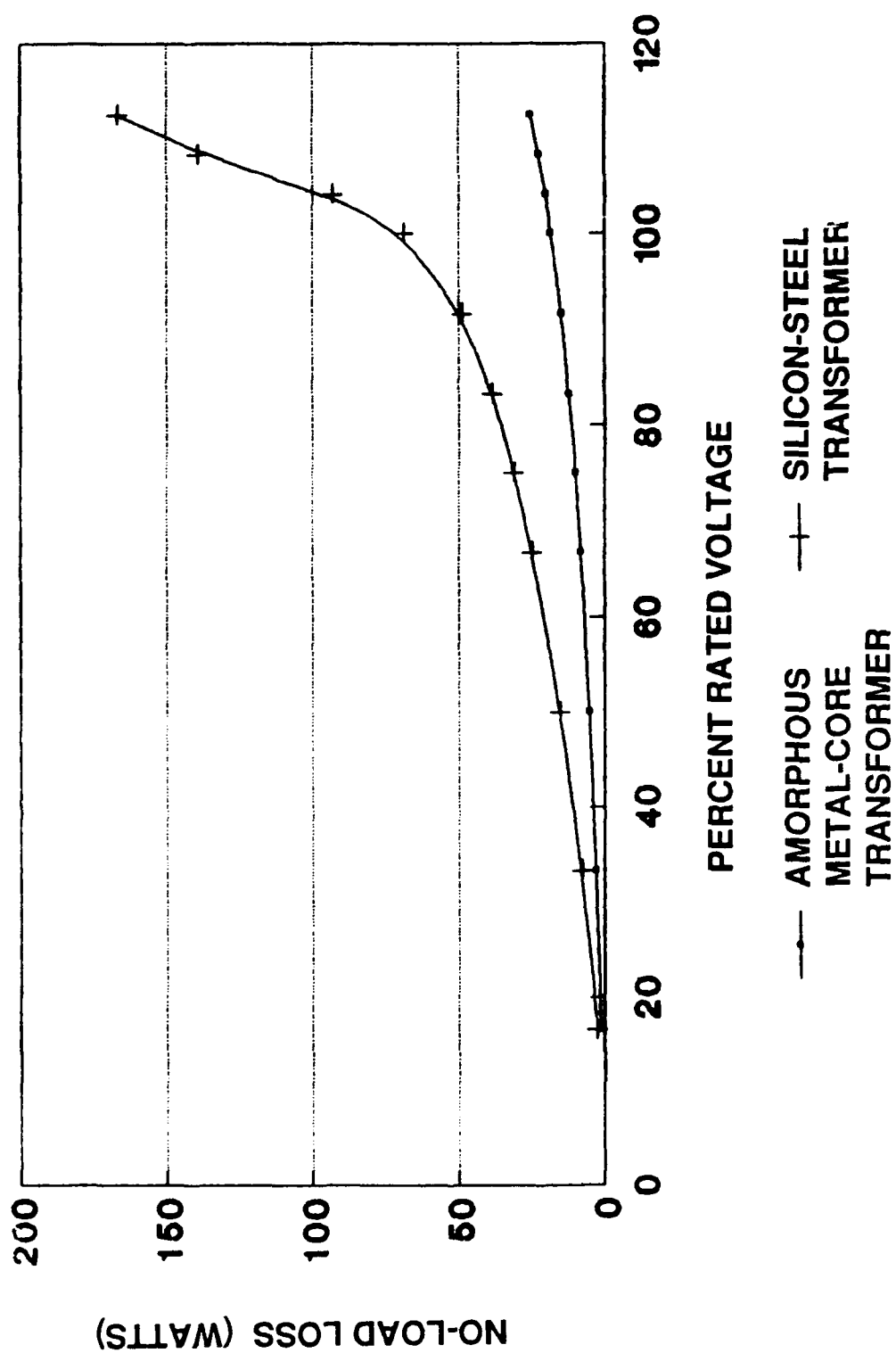


Figure 9. No-load loss versus % rated flux voltage at 50% load condition.

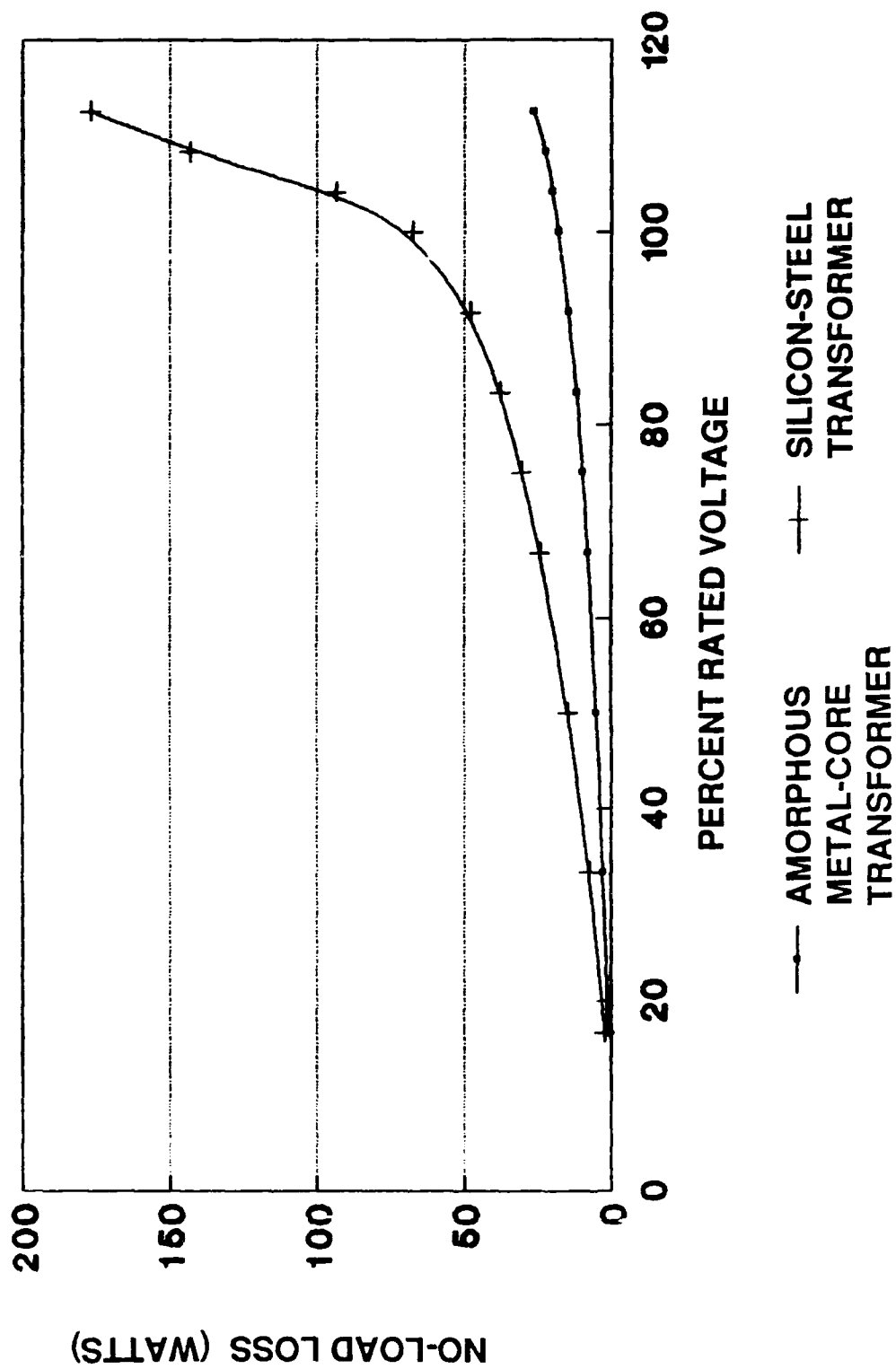


Figure 10. No-load loss versus % rated flux voltage at 100% load condition.

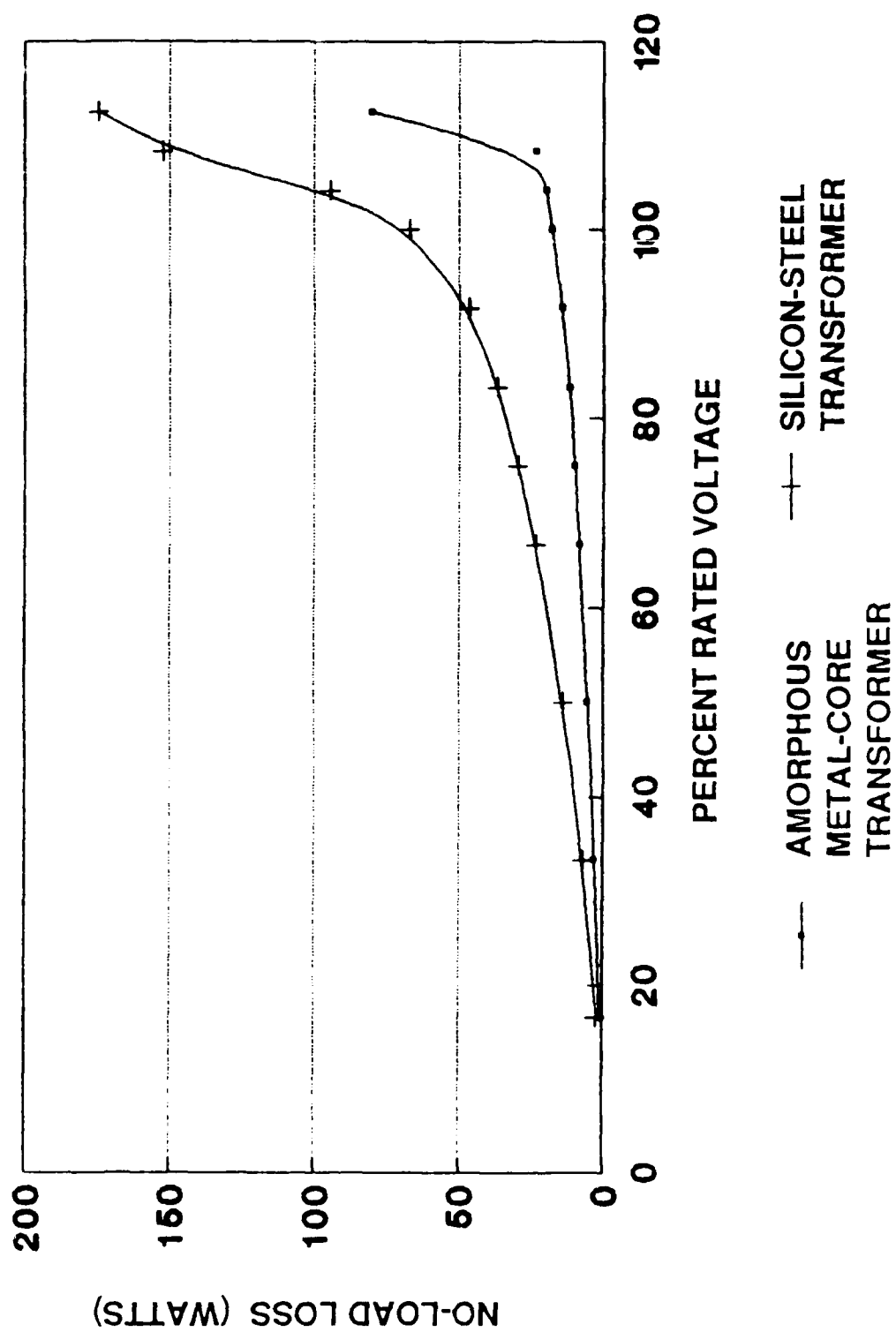


Figure 11. No-load loss versus % rated flux voltage at 150% load condition.

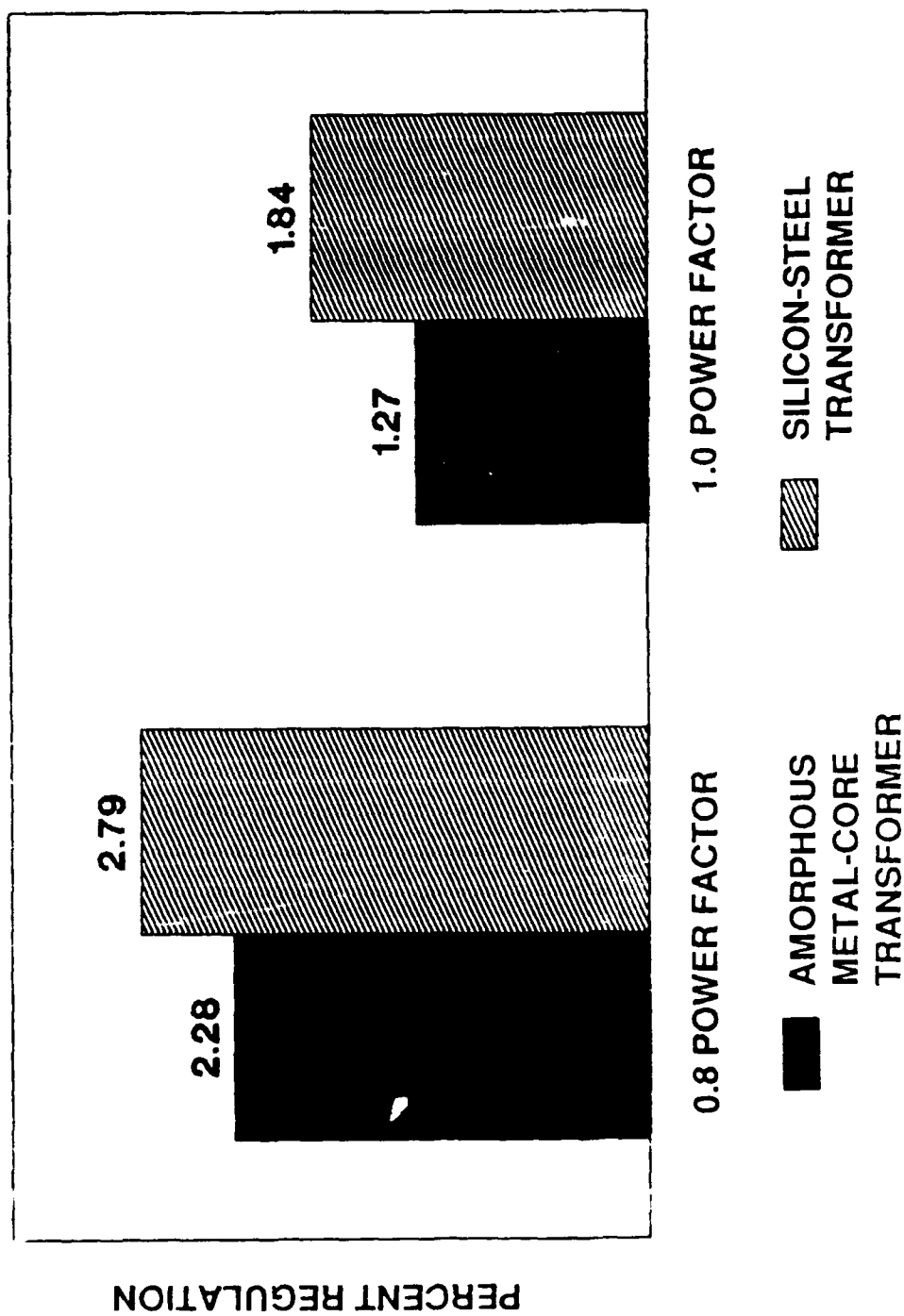


Figure 12. Percent regulation at 100% load.

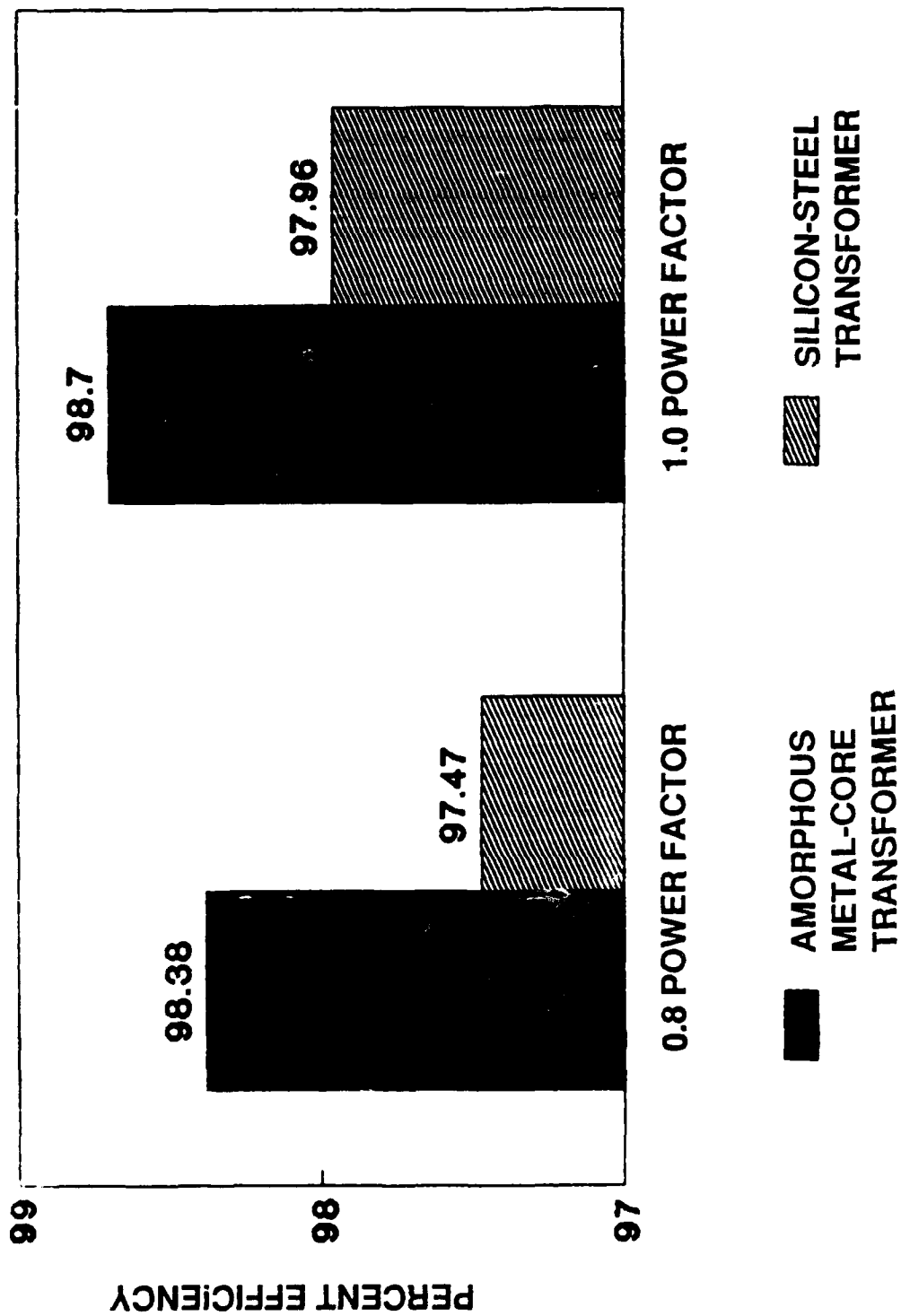


Figure 13. Percent efficiency at 100% load.

Appendix A

SUMMARY OF PHASE I TEST RESULTS FOR
25-kVA AMORPHOUS METAL-CORE TRANSFORMERS

[illegible]

MAXIMUM CHANGE IN
1960-1963
1963-1968
EFFICIENCY,
A REGULATION

Appendix B

WESTINGHOUSE ELECTRIC CORPORATION ENGINEERING REPORT NO. 87-11

Reliability Testing of
General Electric Amorphous Metal Distribution Transformers

PROPRIETARY CLASS III - Unlimited Distribution

DTD ENGINEERING REPORT #87-11

Reliability Testing of 25 kVA
General Electric Amorphous Metal Distribution Transformers

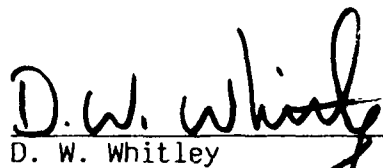
By



G. V. Jones

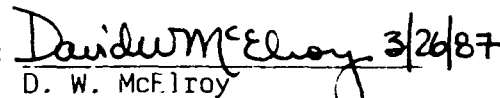
March 19, 1987

APPROVED:



D. W. Whitley
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D. W. McElroy
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APPROVED:



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WESTINGHOUSE ELECTRIC CORPORATION
DISTRIBUTION TRANSFORMER DIVISION
ATHENS, GEORGIA

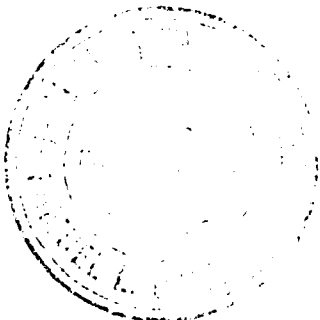
March 20, 1987

I certify that the attached Engineering Report #87-11 is an accurate summary of the testing done on three General Electric amorphous distribution transformers and two General Electric silicon steel transformers provided by N.C.E.I....

The tests which are specified by either ANSI or NEMA standards were done in accordance with those standards. The other tests were done in accordance with the N.C.E.I. statement of work. In the case of the drop test, the height was changed from 3 feet to 4 feet at the request of N.C.E.I. personnel witnessing the tests.

Samuel L. Carter, Jr.

Samuel L. Carter, Jr., P.E.
Engineering
Westinghouse Electric Corporation



I. INTRODUCTION

"The United States Naval Civil Engineering Laboratory (N.C.E.L.) engineers are evaluating amorphous metal transformers as emerging new technology to reduce electric baseload power consumption and as a PCB transformer replacement." As part of this evaluation, the N.C.E.L. contracted with the Westinghouse Distribution Transformer Division (DID) to test and evaluate three 25 kVA General Electric amorphous metal transformers (N.C.E.L. Requisition #N68305-6339-7731). Two 25 kVA General Electric silicon steel transformers were provided for comparison testing. All transformers were provided by N.C.E.L. and were returned to N.C.E.L. following test and evaluation. In January 1987, Westinghouse DID began a rigorous test program to determine the viability of amorphous metal transformers for Naval use. This report contains the results of that testing program.

II. CONCLUSIONS/RECOMMENDATIONS

The three amorphous metal transformers tested and evaluated by DID passed all tests. Amorphous metal transformers with wound cores are a viable product and functionally suitable for applications such as reducing electric baseload power consumption and replacing PCB transformers.

III. EXPERIMENTAL PROCEDURE/RESULTS

A list is given in Table 1 of the tests performed on the transformers with amorphous metal cores. Some tests were also performed on transformers with silicon steel cores for comparison purposes. These tests are also listed in Table 1. The test sequence for the transformers is given in Table 2. Finally, the test descriptions and results are given in Sections 1 through 11.

TABLE 1. TESTS PERFORMED

	25 kVA 75 kV BIL Amorphous Metal Test Status	25 kVA 75 kV BIL Silicon Steel Test Status	Test Results/ Description Section
ANSI "ROUTINE" TESTS			
Ratio	P	P	1
Polarity	P	P	1
HI IC	P	P	1
LIIC	P	P	1
400 HZ	P	P	1
No-Load Loss/Exciting Current	C	C	1
ANSI "DESIGN" TESTS			
Full Wave Impulse	P	P	1
Chopped Wave Impulse	*	X	6
Winding Resistance	C	C	1
Impedance/Load Loss	C	C	1
Temperature Rise	P	P	2
Sound Level	P	X	3
ANSI "OTHER" TESTS			
Radio Influence Voltage (RIV)	P	X	4
Short Circuit	P	X	5
ADDITIONAL TESTS **			
Front of Wave Impulse	*	X	6
Full Wave Impulse-Energized	P	X	7
Chopped Wave Impulse-Energized	P	X	7
Front of Wave Impulse-Energized	P	X	7
Safe Transit Test (Shake & Drop)	P	X	8
Infrared Scanning-Energized	C	C	9
Cold Load Pickup	P	X	10
Saturation Curves	C	C	11
Regulation & Efficiency	C	C	11

P = Passed Test

F = Failed Test

C = Testing Completed - No Pass/Fail Criteria Available

* = See Same Test With Unit Energized

Q = Qualified Pass

X = This test Not Part of Test Program for Silicon Steel Units

** = These tests are not defined or required by ANSI and/or NEMA Standards.

These tests were defined by mutual agreement with N.C.E.L. and specified in the Statement of Work (pages 3, 4 & 5 of Requisition #N68305-6339-7/31) provided by N.C.E.L.

TABLE 2. TRANSFORMER TEST SEQUENCES

Amorphous Metal Transformers		Silicon Steel Transformers	
Serial Numbers		Serial Numbers	
P217059-YZA	P217060-YZA	P239216-YOB	P239217-YOB
*Commercial Tests	RIV	Infrared Scan	100% Temp Rise
Short Circuit	Commercial Tests	100% Temp Rise	150% Temp Rise
Sound Level	100% Temp Rise	150% Temp Rise	Commercial Test
RIV	170% Temp Rise	Commercial Test	
Commercial Tests	Commercial tests	Regulation Tests	
Shake Test	Δ Impulse Energized	Efficiency Tests	
Commercial Tests	Infrared Scan	Saturation Curves	
Drop Test		Commercial Tests	
Commercial Tests			
Autopsy			

* Commercial Tests Include: Ratio, Polarity, Full Wave Impulse, Applied Potential (HV Winding (HLIC) & LV Winding (LHIC)), Induced Potential (400 Hz), NL Loss/Exciting Current, Winding Resistance, and Impedance/Load Loss.

Δ Impulse Energized Tests Include (in order): Reduced Full Wave, Chopped Wave, 400 Hz, Front of Wave, 400 Hz, Full Wave, 400 Hz, HLIC & LHIC.

9257R:8/bc/3

TEST DESCRIPTIONS AND RESULTS

1. Distribution Transformer Division (DTD) Standard Tests

Ratio per ANSI C57.12.90-1980 Sec. 7
Polarity per ANSI C57.12.90-1980 Sec. 6
Full Wave Impulse per ANSI C57.12.90-1980 Sec. 10.5
Applied Potential (HIC & LHIC) per ANSI C57.12.90-1980 Sec. 10.3
Induced Potential (400 Hz) per ANSI C57.12.90-1980 Sec. 10.4
NL Loss/Exciting Current per ANSI C57.12.90-1980 Sec. 8
Impedance/Load Loss per ANSI C57.12.90-1980 Sec. 9

These commercial tests are performed on each DTD transformer before it is shipped. In general the tests indicate the degree of consistency of manufacturing procedures and processes and serve as a check on the quality of the transformers. The amorphous metal transformers were commercially tested upon receipt and at other times during the test sequence when required. The amorphous metal transformers all passed the "as received" commercial tests (see Appendix A.1 for test reports).

2. Temperature Rise

Per ANSI C57.12.90-1980 Sec. 11

One coil of amorphous metal transformer P217059-YZA was sectioned to determine HV and LV conductor cross-sectional areas. These cross-sectional areas were used in the calculation of the LV and HV winding temperature rises for the amorphous metal transformers according to ANSI C57.12.90-1980 Sec. 11.3.1.1. For the silicon steel transformers at 100% load, the LV and HV winding temperature rises were calculated assuming winding load losses less than 14 watts/lb. and using a 1°C/minute after shutdown correction according to ANSI C57.12.90-1980 Sec. 11.3.1.1. For the silicon steel transformers at 150% load, the winding temperature rises were calculated using the cooling curve method according to ANSI C57.12.90-1980 Sec. 11.3.1.2.

Test results at 100% load were (test reports in Appendix A.2):

<u>Serial</u> <u>Number</u>	<u>Core</u> <u>Material</u>	<u>Top Oil</u> <u>Rise (°C)</u>	<u>HV Winding</u> <u>Rise (°C)</u>	<u>LV Winding</u> <u>Rise (°C)</u>
P217060-YZA	AM	39.1	48.9	47.5
P217061-YZA	AM	39.4	51.7	50.4
P239216-YOB	Silicon St.	53.7	60.2	58.8
P239217-YOB	Silicon St.	52.1	59.6	60.8

All of the above units operated under the ANSI 65°C temperature rise limit. The amorphous metal (AM) units operated at lower temperatures than the silicon steel units. The temperature rises are a function of the losses of the core/coil as well as the cooling surface of the tank. Amorphous metal core/coils tend to be physically larger than silicon steel core/coils with the same design value for losses. The amorphous metal units may be in larger diameter tanks, as was the case here, and therefore may tend to have lower temperature rises.

It was also planned to make temperature rise measurements on the above units at 170% load (not a required ANSI test). It was not possible to test the silicon steel units at 170% load because the oil temperature would have exceeded the flashpoint. Therefore, the silicon steel units were tested at 150% load. Test results were (test reports in Appendix A.2):

<u>Serial Number</u>	<u>Core Material</u>	<u>Load</u>	<u>Top Oil Rise (°C)</u>	<u>HV Winding Rise (°C)</u>	<u>LV Winding Rise (°C)</u>
P217060-YZA	AM	170%	101.7	127.5	122.4
P217061-YZA	AM	170%	101.7	129.2	123.4
P239216-YOB	Silicon St.	150%	102.1	120.6	112.5
P239217-YOB	Silicon St.	150%	99.8	118.8	110.2

The above units passed commercial tests following temperature rise testing (test reports in Appendix A.2).

3. Sound Level

Per ANSI C57.12.90-1980 Sec. 13
ANSI/IEEE Std. 141-1986
NEMA TR1-1980

Sound level tests were performed on an amorphous metal transformer after it was subjected to short circuit testing (see Section 5). The sound level measurements represented "worst case" conditions, since short circuit testing could increase sound level by loosening and/or fracturing core laminations if it were possible to do so.

Transformer P217059-YZA had a sound level of 32.4 dB(A) at 100% rated voltage (very low - only 0.1 dB(A) greater than semi-anechoic chamber) and 37.3 dB(A) at 110% rated voltage. The sound level measured at 100% voltage is well below the NEMA limit of 48 dB(A). There is no ANSI limit on the sound level at 110% voltage. The test report is included in Appendix A.3.

4. Radio Influence Voltage (RIV)

Per NEMA TR1-1980 Revision 2 Sec. 0.03 (Limits)
7.01 (Test Code)
107-1964 Reaffirmed 1981 (Test Methods)

Amorphous metal transformers P217059-YZA, P217060-YZA, and P217061-YZA produced no RIV at 100% or 110% rated voltage (test record in Appendix A.4).

5. Short Circuit

Per ANSI C57.12.90-1980 Sec. 12

The short circuit test results on amorphous metal transformer P21/059-YZA are:

SC Current X Rated	% Z Change/ Limit	% Io Change/ Limit	Inrush Current	
			X Normal 1st Peak	6th Peak
40	*5.3/11.1	*1.0/25	28.8	12.8

* As determined from before and after (W) standard commercial tests.

This transformer passed the short circuit test. Standard commercial tests following the short circuit test and an autopsy of the transformer revealed no damage attributable to short circuit testing. Short circuit and standard commercial test results are in Appendix A.5.

Magnetizing inrush current tests were also done on this unit (see above results). There are no industry standards on magnetizing inrush current tests. The magnetizing inrush current measurements were made under conditions which should have resulted in maximum peak inrush current.

6. Chopped Wave and Front of Wave Impulse

Per ANSI C57.12.90-1980 Sec. 10.5

Note that front of wave impulse is not a defined ANSI test for distribution transformers.

In order to increase the severity of these tests, they were performed with the transformer energized at rated voltage. See "Impulse Tests With Unit Energized", Section 7.

7. Impulse Tests with Unit Energized

Per ANSI C57.12.90-1980 Sec. 10.5 except with unit energized at rated voltage.

These experimental tests, which are neither required nor defined by ANSI, check the insulation strength of the transformer under simulated field operating conditions.

First, amorphous metal transformer P21/060-YZA received a reduced full wave impulse on each HV bushing to generate "baseline" waveforms for comparison with full wave impulse waveforms to be generated at the end of the test. Then the transformer passed 88 kV (1.6 μ sec to chop) chopped wave impulse and 135 kV (.5 μ sec to chop) front of wave impulse tests. To doublecheck the chopped wave and front of wave oscilloscope indications, the unit received and passed induced voltage (400 Hz) tests after the chopped wave and after the front of wave tests.

Next the transformer received the 75 kV full wave impulse test. The oscilloscope figures (see Appendix A.7) revealed two anomalies in the wave shapes produced by full wave impulse. First, the full wave tails rose above the reference line (Figures A.7.4A and A.7.4B) while the normal reduced wave tails rose to the reference line (Figures A.7.1A and A.7.1B). Second, the full wave in Figure 4A had a "kink" halfway between the peak and the reference line while the normal reduced wave had a "smooth" curve from the peak to the reference line. To determine if the anomalies signaled a failure in the insulation, the unit was given an induced voltage (400 Hz) test and applied voltage tests (HILIC and LHIC). The unit passed both of these auxiliary tests and was considered as having passed the full wave impulse test. To conclude, the unit passed chopped wave, front of wave, and full wave impulse tests with the unit energized at rated voltage. The test record is in Appendix A.7.

8. Safe Transit

Safe transit tests include a shake test (4 hours on the safe transit machine at 160 rpm) and a drop test (4 feet onto a hard surface). The drop test was changed from 3 feet as specified in the N.C.E.L. Statement of Work to 4 feet at the request of N.C.E.L. personnel witnessing the test. The shake test is designed to simulate a transformer traveling twice the distance from the east coast to the west coast in a transfer truck. The drop test is designed to simulate a transformer being improperly unloaded from the back of a utility truck. To pass the safe transit test, the transformer must complete the shake and drop tests with less than or equal to a 10% increase in no-load watts. The transformer also must pass DTD standard commercial tests after the shake test and after the drop test.

Amorphous metal transformer P217059-YZA was safe transit tested. The shake test resulted in no change in no load watts and the drop test resulted in a 3% decrease in no load watts. The transformer passed standard commercial tests after the shake and drop tests. The unit passed the safe transit test. Test records and reports are in Appendix A.8.

After the safe transit test, the unit was autopsied. During the autopsy, some mechanical damage was found such as a bent and distorted tank bottom, bowed core/coil top frame, and cracked core/coil pressure plates. This type of damage was not considered unusual in a 25 kVA transformer dropped from a height of four feet. Amorphous metal particles were discovered outside the core assembly. Specifically, they were found in the bottom of the tank, on the inside of the bottom frame (see Figure 1) and on the coils. Even though the unit passed the safe transit test and subsequent commercial tests, the presence of amorphous metal particles in the oil environment could lower the dielectric strength of the oil and/or reduce the insulation margin of the coil. This could be a greater concern in transformers operating at higher voltages than this one, and could be expected to play a more important role as the insulation system ages.



Figure 1. Amorphous Metal Particles Inside Bottom Frame

9. Infrared Scanning

An amorphous metal transformer P217060-YZA and a silicon steel transformer P239216-YOB were energized at various voltages and observed with infrared imaging equipment. The observations were recorded on a video cassette tape which was given to the N.C.E.L. This service was performed by Pedascan Inc. of Foristell, Missouri. Infrared imaging gives a visual indication of the relative amounts of energy required to magnetize the different cores

10. Cold Load Pickup

A cold load pickup test was conducted on an amorphous metal transformer P217061-YZA. This test was designed to simulate the following conditions:

1. Power outage in cold ($\approx -35^{\circ}\text{C}$) environment.
2. Replacement transformer brought from cold ($\approx -35^{\circ}\text{C}$) warehouse to restore service.
3. When service is restored, everyone turns on heat, appliances, etc. This puts a heavy load on a very cold transformer with oil viscosity much higher than normal.

The purpose of the test was to determine if the above conditions would have any injurious effect, such as thermal instability, on the transformer's operation.

For the test, the unit was placed in a cold chamber at -38°C . After the transformer oil reached -34°C , the unit was energized at 200% load (LV winding shorted). Watt loss was measured for the next 2 hours. The load was then reduced to 100% and watt losses were measured each hour for the next 6 hours (test report in Appendix A.10.).

There was no indication of thermal instability. Further, the unit passed all commercial tests (test report in Appendix A.10.) following the cold load pickup test. To conclude, the transformer performed satisfactorily during the cold load pickup test.

11. Saturation/Regulation/Efficiency

Temperature Rise Tests per ANSI C57.12.90 - 1980 Sec. 11

Saturation Curves per ANSI C57.12.90 - 1980 Sec. 8

Regulation Calculations per ANSI C57.12.90 - 1980 Sec. 14.4

Efficiency Calculations per ANSI C57.12.90 - 1980 Sec. 14.3

50%, 100%, and 150% load temperature rise tests were done on amorphous metal transformer P217061-YZA and silicon steel transformer P239216-YOB to obtain the data needed to plot percent regulation and percent efficiency versus percent load (see Appendix A.11 for temperature rise test records). Immediately after "shutdown" of each temperature rise test, no-load loss/excitation current measurements were made to obtain saturation curves for 50%, 100%, and 150% loading conditions.

Saturation, regulation, and efficiency are functions of transformer design parameters such as core design induction, core material, number of low voltage winding turns, low and high voltage conductor sizes and materials, etc. A comparison of the saturation, regulation, and efficiency of an amorphous metal versus a standard silicon steel transformer (based on units supplied by N.C.E.L.) yields the following conclusions:

1. From Tables A.11.1 through A.11.8 and Figures A.11.3 and A.11.4 (see Appendix A.11), the exciting current of the amorphous metal transformer is less than the exciting current of the silicon steel transformer for loads up to 150% and voltages up to 110% of rated nameplate voltage.
2. From Tables A.11.9 and A.11.10 and Figures A.11.5 and A.11.6 (see Appendix A.11), the percent regulation of the amorphous metal transformer is less than the percent regulation of the silicon steel transformer for loads up to 150% and voltages up to 110% of rated nameplate voltage at power factors of unity and 0.8 lagging.
3. From Tables A.11.11 and A.11.12 and Figures A.11.7 and A.11.8 (see Appendix A.11), the percent efficiency of the amorphous metal transformer is greater than the percent efficiency of the silicon steel transformer for loads up to 150% and voltages up to 110% of rated nameplate voltage at power factors of unity and 0.8 lagging.

Both transformers passed all commercial tests (see Appendix A.11 for test reports) following the saturation/regulation/efficiency tests.

APPENDIX A.1

AS RECEIVED DTD STANDARD COMMERCIAL TEST REPORTS

WESTINGHOUSE DTD COMMERCIAL TEST REPORT

DATE: 01/05/87

CONDITION: AS RECEIVED

STYLE: S.E. 25KVA AMORPHOUS METAL POLE TYPE

LT: 129/240 HV: 41601 75KV BIL SERIAL #: P217059-YZA

RATIO	PASS	* HV RESISTANCE (OHMS)	3.7442
POLARITY	PASS	* LV RESISTANCE (OHMS)	0.017154
FULL WAVE IMPULSE	PASS	* I SQUARED R LOSS (WATTS)	705.91
APPLIED POTENTIAL - HLIC	PASS	* STRAYS	8.89
APPLIED POTENTIAL - LHIC	PASS	* LOAD LOSS (WATTS)	315.9
INDUCED POTENTIAL - 400 HZ	PASS	TOTAL LOSS (WATTS)	355.2
NL LOSS (WATTS)	19.4	* % RESISTANCE	1.26
% EXCITING CURRENT	0.097	* % REACTANCE	2.09
% EFFICIENCY @ PF=1	99.7	* % IMPEDANCE	2.44
% EFFICIENCY @ PF=.8	93.4	% REGULATION @ PF=1	1.29
		% REGULATION @ PF=.8	2.27

TEST ENGINEER:

GREGG V. JONES

* CORRECTED TO 95 DEGREES C

WESTINGHOUSE LTD COMMERCIAL TEST REPORT

DATE: 01/16/87

CONDITION: AS RECEIVED

STYLE: G.E. 25KVA AMORPHOUS METAL POLE TYPE

LV: 120/240 HV: 4160: 75KV BIL SERIAL #: P217050-Y2A

RATIO	PASS	* HV RESISTANCE (OHMS)	4.5835
POLARITY	PASS	* LV RESISTANCE (OHMS)	0.013161
FULL WAVE IMPULSE	PASS	* I SQUARED R LOSS (WATTS)	309.04
APPLIED POTENTIAL - HLIC	PASS	* STRAYS	10.03
APPLIED POTENTIAL - LHIC	PASS	* LOAD LOSS (WATTS)	318.3
INDUCED POTENTIAL - 400 HZ	PASS	TOTAL LOSS (WATTS)	335.4
NL LOSS (WATTS)	17.1	* % RESISTANCE	1.27
% EXCITING CURRENT	0.212	* % REACTANCE	2.1
% EFFICIENCY @ PF=1	98.7	* % IMPEDANCE	2.46
% EFFICIENCY @ PF=.8	98.4	% REGULATION @ PF=1	1.29
		% REGULATION @ PF=.8	2.29

TEST ENGINEER:

Gregg V. Jones
GREGG V. JONES

* CORRECTED TO 85 DEGREES C

KEITHLEY-8000 DTD COMMERCIAL TEST REPORT

DATE: 11-18-87

CONDITION: AS RECEIVED

STYLE: S.E. 05A4 AMORPHOUS METAL ROLE TYPE

LV: 00124- HV: 4100- 75KV 31L SERIAL #: R017061-104

RATIO	PASS	* HV RESISTANCE (OHMS)	4.6091
POLARITY	PASS	* LV RESISTANCE (OHMS)	0.012967
FULL WAVE INFLUENCE	PASS	* I REGULATED R LOSS (WATTS)	115.1
APPLIED POTENTIAL - RLIC	PASS	* STRAYS	10.13
APPLIED POTENTIAL - LRIC	PASS	* LOAD LOSS (WATTS)	115.9
INDUCED POTENTIAL - 400 HZ	PASS	TOTAL LOSS (WATTS)	115.7
% LOSS (WATTS)	10.13	* % RESISTANCE	1.17
% EXCITING CURRENT	1.17	* % REACTANCE	0.11
% EFFICIENCY @ PF=1	98.7	* % IMPEDANCE	0.46
% EFFICIENCY @ PF=0.8	98.3	% REGULATION @ PF=1	1.09
		% REGULATION @ PF=0.8	2.09

TEST ENGINEER:

Gregg V. Jones
GREGG V. JONES

* CORRECTED TO 95 DEC 1988

APPENDIX A.2

TEMPERATURE RISE TEST REPORTS

TRANSFORMER Pole TEMPERATURE TEST ON 25 K.V.A. TRANSFORMER STYLE Gen Electric
TYPE: _____
CONNECTED H.V. 4160 VOLTS L.V. 120/240 VOLTS
LOAD H.V. 100% 6.00 AMPS. L.V. 104 AMPS. 60 CYCLES
WATTS PER LB. H.V. 7.58 ? L.V. 5.78 MAGNETIZED _____ VOLTS _____ CYCLES ON _____
GALLONS OIL _____ CIRCUIT TEST METHOD Back NO. OF RADIATORS 0 NO. TUBES 0
REMARKS 1) Amorphous metal cores
2) Test for Navy SERIAL ACTP217060

TIME AFTER SHUTDOWN		TEMP. H.V. WINDING BY RESISTANCE							TIME AFTER SHUTDOWN		TEMP. L.V. WINDING BY RESISTANCE					
		AMB. TEMP.	BRIDGE READING	RATIO OR K	* OHMS	TEMP. BY RES.	CORREC- TION TO SHDN.	AVE. WIND. TEMP.			AMB. TEMP.	BRIDGE READING	RATIO OR K	OHMS	TEMP. BY RES.	CORREC- TION TO SHDN.
MIN.	SEC.								MIN.	SEC.						
		25.5	3740	.001	3.735						25.5	$(.01 + .00085) \times 1$		.01085		
1	25		4504	"	4.499	76.7	0.72	77.46	2	40		$(.01 + .0030) \times 1$		.01300	75.13	0.90

CALC. H.V. $77.46 - 67.7 = 9.76^\circ\text{C}$
 WINDING $77.46 - 28.6 = 48.86$
 RISE DIFF winding rise

CALC. L.V
WINDING 76.13 - 67.7 = 8.43°C / 76.13 - 28.6 = 47.53
RISE DIFF winding rise

TEMPERATURE READINGS					TEMPERATURE RISE					WATTMETER AND VOLTMETER	
HOURS	TIME	TOP OIL	BTTM. OIL	AMB. OIL	TOP OIL	BTTM. OIL					
Steady State		67.7		28.6	39.1						

LOAD TEST AT _____°C

AMPT

VOLTMETER

WATTMETER

NO LOAD TEST

(T.W.) WATTMETER

(A.W.) VOLTS _____ X AMPS _____

VA

TIME CONSTANT

63.3 x 39.1 °C OIL RISE - 24.75

TIME CONSTANT = 1.15

75X.139 $\frac{6 \text{ HRS.}}{15 \text{ MIN.}}$ round

TYPE CONDUCTOR H.V. namula

TYPE CONDUCTOR L.V. *nameplate*

18x9

CALCULATED COMPROMISE
CURRENT not used

OTHER REMARKS

car unit in back conf

.005 & bridge leads

LITS PER LG AT STeady STATE.

TEST REQUESTED BY Grey Jones DATE TESTED 2-4-87 BY Bill Belwan

7 8. BELUAN ATHENS 0036 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 100 PCT
 200 08:00:00 27.40 25.80 26.80 26.5 26.30 26.30 -0.3 26.40 -0.2 25KVA 41500
 08:15:00 27.80 25.80 26.80 26.8 26.40 26.40 -0.4 26.50 -0.2 07 60 TOP
 08:30:00 28.40 25.80 26.80 27.0 27.30 27.30 0.3 27.60 0.6 ← start 08 RISE
 08:45:00 28.20 25.80 26.90 26.9 28.60 28.60 1.7 28.90 2.0 09
 09:00:00 28.20 25.90 26.90 27.0 30.00 30.00 3.0 30.30 3.3 10
 09:15:00 28.50 25.90 26.90 27.1 31.40 31.40 4.3 31.70 4.6 11
 09:30:00 28.50 25.90 27.00 27.1 32.80 32.80 5.7 33.20 6.1 12
 09:45:00 28.60 26.00 27.10 27.2 34.20 34.20 7.0 34.60 7.4 13
 10:00:00 28.60 26.00 27.10 27.2 35.50 35.50 8.3 35.90 8.7 14
 10:15:00 28.50 26.10 27.20 27.2 36.80 36.80 9.6 37.10 9.9 15
 10:30:00 28.60 26.10 27.20 27.3 38.00 38.00 10.7 38.30 11.0
 10:45:00 28.70 26.20 27.30 27.4 39.10 39.10 11.7 39.40 12.0
 11:00:00 28.70 26.20 27.30 27.4 40.20 40.20 12.8 40.50 13.1
 11:15:00 28.70 26.30 27.40 27.4 41.30 41.30 13.9 41.60 14.2
 11:30:00 28.90 26.30 27.40 27.5 42.30 42.30 14.8 42.60 15.1
 11:45:00 28.70 26.40 27.50 27.5 43.30 43.30 15.8 43.60 16.0
 12:00:00 28.50 26.40 27.60 27.5 44.30 44.30 16.8 44.60 17.0
 12:15:00 28.80 26.50 27.70 27.6 45.20 45.20 17.6 45.40 17.8
 12:30:00 28.80 26.50 27.70 27.6 46.00 46.00 18.4 46.20 18.6
 12:45:00 28.80 26.60 27.80 27.7 46.90 46.90 19.2 47.20 19.5
 13:00:00 28.90 26.60 27.80 27.7 47.70 47.70 20.0 47.90 20.2
 13:15:00 29.10 26.70 27.90 27.9 48.50 48.50 20.6 48.60 20.7
 13:30:00 29.20 26.70 27.90 27.9 49.20 49.20 21.3 49.40 21.5
 13:45:00 28.90 26.80 28.00 27.9 49.90 49.90 22.0 50.10 22.2
 14:00:00 28.80 26.80 28.10 27.9 50.70 50.70 22.8 50.80 22.9
 14:15:00 28.90 26.90 28.10 27.9 51.40 51.40 23.5 51.50 23.6
 14:30:00 29.10 26.90 28.20 28.0 52.00 52.00 24.0 52.10 24.1
 14:45:00 28.80 26.90 28.20 27.9 52.70 52.70 24.8 52.80 24.9
 15:00:00 29.00 27.00 28.30 28.1 53.40 53.40 25.3 53.50 25.4
 15:15:00 29.20 27.10 28.40 28.2 54.00 54.00 25.8 54.10 25.9
 18:15:00 28.50 27.60 28.90 28.3 59.80 59.80 31.5 59.70 31.4
 21:15:00 28.50 27.90 29.30 28.5 63.20 63.20 34.7 62.90 34.4
 00:15:00 28.70 28.00 29.50 28.7 65.40 65.40 36.7 65.10 36.4
 03:15:00 28.70 28.30 29.70 28.9 67.60 67.60 38.7 67.30 38.4
 06:15:00 28.50 28.40 29.80 28.9 68.70 68.70 39.8 68.40 39.5
 07:23:05 28.00 28.40 29.90 28.7 68.90 68.90 40.2 68.60 39.9
 09:08:39 27.90 28.30 29.90 28.7 68.10 68.10 39.4 67.80 39.1
 09:14:15 27.70 28.30 29.90 28.6 66.00 66.00 39.4 67.80 39.2
 09:15:00 27.70 28.30 29.90 28.6 68.00 68.00 39.4 67.70 39.1
 09:53:08 25.70 27.90 29.50 27.7 65.40 65.40 37.7 65.30 37.6

← start

←

←

← Shut down

5/11/01 09:15

5-22

TRANSFORMER TYPE Poly TEMPERATURE TEST ON 25 K.V.A. TRANSFORMER STYLE Gen. Elect.
 CONNECTED H.V. 4160 VOLTS L.V. 120/240 VOLTS
 LOAD H.V. 100% L.V. 6.0 AMPS L.V. 104 AMPS 60 CY
 WATTS PER LB. H.V. _____ L.V. _____ MAGNETIZED _____ VOLTS _____ CYCLES ON _____
 GALLONS OIL _____ CIRCUIT TEST METHOD Back NO. OF RADIATORS _____ NO. TUBES _____
 REMARKS * 1°C per minute used for Correction back to shut down
 SERIAL # P239216-YOE

TIME AFTER SHUTDOWN		TEMP. H.V. WINDING BY RESISTANCE							TIME AFTER SHUTDOWN		TEMP. L.V. WINDING BY RESISTANCE						
		AMB. TEMP.	BRIDGE READING	RATIO OR K	OHMS	TEMP. BY RES.	CORREC- TION TO SHDN.	AVE. WIND. TEMP.			AMB. TEMP.	BRIDGE READING	RATIO OR K	OHMS	TEMP. BY RES.	CORREC- TION TO SHDN.	
MIN.	SEC.																
		25.0	5168	x.001	5,163		*				20.3	(.00520+.01)x1	.01520				
1	28		6428	"	6.423	86.01	1.5	87.51								*	
									2	56		(.00910+.01)x1	.01910	83.2	2.9		
CALC. H.V. WINDING RISE		$87.51 - 81 = 7.51^{\circ}\text{C}$							CALC. L.V. WINDING RISE		$86.13 - 81 = 6.13^{\circ}\text{C}$						
		DIFF $87.51 - 27.3 = 60.21^{\circ}\text{C}$									DIFF $86.13 - 27.3 = 58.83^{\circ}\text{C}$						
		H.V. winding rise									L.V. winding rise						

HOURS	TIME	TEMPERATURE READINGS					TEMPERATURE RISE					WATTMETER AND VOLTMETER	LOAD TEST AT _____ °C
		TOP OIL	BTM. OIL			AMB. OIL	TOP OIL	BTM. OIL					
	Steady State	81.0				27.3	53.7						AMPS _____
													VOLTMETER _____
													WATTMETER _____

TEST REQUESTED BY Greg Jones DATE TESTED 2-19-87 BY Bill Belvan L.SPEC. # _____

TRANSFORMER TYPE: Pole TEMPERATURE TEST ON 25 K.V.A. TRANSFORMER STYLE Gen. Electric
 CONNECTED H.V. 4160 VOLTS L.V. 120/240 VOLTS
 LOAD H.V. 100% 6.00 AMPS L.V. 104 AMPS 60 CYC
 WATTS PER LB. H.V. _____ L.V. _____ MAGNETIZED _____ VOLTS _____ CYCLES ON _____
 GALLONS OIL _____ CIRCUIT TEST METHOD Back NO. OF RADIATORS 0 NO. TUBES 0
 REMARKS * 1°C per minute used for correction back to shutdown
 SERIAL # P239217-YOB

TIME AFTER SHUTDOWN		TEMP. H.V. WINDING BY RESISTANCE							TIME AFTER SHUTDOWN		TEMP. L.V. WINDING BY RESISTANCE						
MIN.	SEC.	AMB. TEMP.	BRIDGE READING	RATIO OR K	OHMS	TEMP. BY RES.	CORREC- TION TO SHDN.	AVE. WIND. TEMP.	MIN.	SEC.	AMB. TEMP.	BRIDGE READING	RATIO OR K	OHMS	TEMP. BY RES.	CORREC- TION TO SHDN.	
		25.0	5168	.001	5.163		*				20.3	(.00529+.01) x 1				*	
1	59		6405	"	6.400	94.90	2.0	86.9	3	27		(.00530+.01) x 1		01930	84.63	3.5	

CALC. H.V. WINDING RISE $86.9 - 79.4 = 7.5^{\circ}\text{C}$ / $86.9 - 27.3 = 59.6^{\circ}\text{C}$ H.V. Winding Rise
 CALC. L.V. WINDING RISE $88.1 - 79.4 = 8.7^{\circ}\text{C}$ / $88.1 - 27.3^{\circ} = 60.8^{\circ}\text{C}$ L.V. Winding Rise

HOURS	TIME	TEMPERATURE READINGS				TEMPERATURE RISE				WATTMETER AND VOLTMETER	LOAD TEST AT _____ °C AMPS <u>6.00</u> VOLTMETER _____ WATTMETER _____
		TOP OIL	BTM. OIL	AMB. OIL	TOP OIL	BTM. OIL	AMB. OIL	TOP OIL	BTM. OIL		
											NO LOAD TEST (T.W.) WATTMETER _____ (A.W.) VOLTS _____ X AMPS _____ = _____ VA
											TIME CONSTANT $63.3 \times 52.1^{\circ}\text{C OIL RISE} = 33.0$ TIME CONSTANT = <u>4</u> HRS. <u>30</u> MIN.
											AL TYPE CONDUCTOR H.V. <u>Size - ?</u> AL TYPE CONDUCTOR L.V. <u>Size - ?</u>
											CALCULATED COMPROMISE CURRENT <u>Not used</u>
											OTHER REMARKS <u>Rear Unit</u>

TEST REQUESTED BY Greg Jones DATE TESTED 3-19-87 BY Bill Belvan L.SPEC. # _____

0050	01	02	03	04	05	06	17 TOP	RISE	07	08	09	10	11	12	13	14	15
700	AMB	AMB	AMB	AUER.	16 TOP	RISE	17 TOP	RISE	25.40	25.40	0.5	START UP					
14:00:00	25.30	24.20	25.30	24.9	25.50	0.6	25.40	0.5	25.40	25.40	0.5	START UP					
14:05:00	25.30	24.10	25.30	24.9	27.00	2.1	26.90	2.0	26.90	26.90	2.0						
14:10:00	25.30	24.20	25.30	24.9	29.60	4.7	29.50	4.6	29.50	29.50	4.6						
14:15:00	25.30	24.20	25.40	24.9	32.30	7.4	32.30	7.4	32.00	32.00	7.1						
15:00:00	25.30	24.20	25.40	24.9	34.60	9.7	34.30	9.4	34.30	34.30	9.4						
15:15:00	25.40	24.20	25.50	25.0	37.00	12.0	36.50	11.5	36.50	36.50	11.5						
15:30:00	25.40	24.30	25.50	25.0	39.20	14.2	38.70	13.7	38.70	38.70	13.7						
15:45:00	25.50	24.30	25.60	25.1	41.30	16.2	40.70	15.6	40.70	40.70	15.6						
16:00:00	25.50	24.40	25.60	25.1	43.30	18.2	42.60	17.5	42.60	42.60	17.5						
16:15:00	25.50	24.40	25.60	25.1	45.40	20.3	44.60	19.5	44.60	44.60	19.5						
16:30:00	25.60	24.50	25.70	25.2	47.50	22.3	46.60	21.4	46.60	46.60	21.4						
16:45:00	25.60	24.50	25.80	25.3	49.30	24.0	48.40	23.1	48.40	48.40	23.1						
17:00:00	25.70	24.60	25.80	25.3	51.10	25.8	50.10	24.8	50.10	50.10	24.8						
17:15:00	25.70	24.60	25.80	25.3	52.80	27.5	51.80	26.5	51.80	51.80	26.5						
17:30:00	25.70	24.70	25.90	25.4	54.40	29.0	53.30	27.9	53.30	53.30	27.9						
17:45:00	25.80	24.70	25.90	25.4	55.90	30.5	54.80	29.4	54.80	54.80	29.4						
18:00:00	25.80	24.80	26.00	25.5	57.40	31.9	56.10	30.6	56.10	56.10	30.6						
18:15:00	25.90	24.80	26.00	25.5	58.70	33.2	57.40	31.9	57.40	57.40	31.9						
18:30:00	25.90	24.90	26.10	25.6	60.00	34.4	58.60	33.0	58.60	58.60	33.0						
18:45:00	26.00	25.00	26.20	25.7	61.20	35.5	59.70	34.0	59.70	59.70	34.0						
19:00:00	26.00	25.00	26.20	25.7	62.20	36.5	60.70	35.0	60.70	60.70	35.0						
19:15:00	26.10	25.10	26.20	25.8	63.30	37.5	61.80	36.0	61.80	61.80	36.0						
19:30:00	26.10	25.10	26.30	25.8	64.30	38.5	62.80	37.0	62.80	62.80	37.0						
19:45:00	26.20	25.10	26.30	25.8	65.30	39.5	63.70	37.9	63.70	63.70	37.9						
20:00:00	26.20	25.20	26.40	25.9	66.20	40.3	64.60	38.7	64.60	64.60	38.7						
20:15:00	26.20	25.20	26.40	25.9	67.00	41.1	65.40	39.5	65.40	65.40	39.5						
20:30:00	26.30	25.30	26.50	26.0	67.80	41.8	66.30	40.1	66.30	66.30	40.1						
20:45:00	26.40	25.30	26.50	26.0	68.60	42.6	67.00	41.0	67.00	67.00	41.0						
21:00:00	26.40	25.40	26.60	26.1	69.30	43.2	67.80	41.5	67.80	67.80	41.5						
21:15:00	26.40	25.40	26.60	26.1	70.00	43.9	68.50	42.2	68.50	68.50	42.2						
21:30:00	26.50	25.40	26.70	26.2	70.60	44.4	68.50	42.7	68.50	68.50	42.7						
21:45:00	26.50	25.50	26.70	26.2	71.20	45.0	69.50	43.3	69.50	69.50	43.3						
22:00:00	26.50	25.50	26.70	26.2	71.90	45.7	70.10	43.9	70.10	70.10	43.9						
22:15:00	26.60	25.50	26.80	26.3	72.40	46.1	70.60	44.3	70.60	70.60	44.3						
22:30:00	26.60	25.60	26.80	26.3	72.80	46.5	71.10	44.8	71.10	71.10	44.8						
22:45:00	26.70	25.60	26.90	26.4	73.30	46.9	71.50	45.1	71.50	71.50	45.1						
23:00:00	26.70	25.60	26.90	26.4	73.70	47.3	71.90	45.5	71.90	71.90	45.5						
23:15:00	26.70	25.70	26.90	26.4	74.10	47.7	72.30	45.9	72.30	72.30	45.9						
23:30:00	26.70	25.70	27.00	26.4	74.50	48.1	72.70	46.3	72.70	72.70	46.3						
23:45:00	26.80	25.70	27.00	26.5	75.00	48.5	73.30	46.8	73.30	73.30	46.8						
00:00:00	26.80	25.70	27.00	26.5	75.50	49.0	73.70	47.2	73.70	73.70	47.2						
00:15:00	26.90	25.80	27.00	26.5	76.00	49.5	74.20	47.7	74.20	74.20	47.7						
00:30:00	26.90	25.80	27.10	26.6	76.40	49.8	74.70	48.1	74.70	74.70	48.1						
00:45:00	26.90	25.80	27.10	26.6	76.90	50.7	75.10	48.5	75.10	75.10	48.5						
01:00:00	27.00	25.90	27.20	26.7	77.30	50.7	75.60	48.9	75.60	75.60	48.9						

1830
1400
430

WESTINGHOUSE FORM 4857K

№ 00727

REMARKS

SERIAL # P217661 ACT

CALC. H.V. WINDING $155.2 - 127.7 = 27.5^\circ$ RISE DIFF $155.2 - 26 = 129.2^\circ$ winding rise	CALC. L.V. WINDING $149.4 - 127.7 = 21.67$ RISE DIFF $149.4 - 26 = 123.4^\circ$ winding rise
---	--

		TEMPERATURE READINGS			TEMPERATURE RISE			WATTMETER AND VOLTMETER
HOL	TIME	TOP OIL	BTTM. OIL	AMB. OIL	TOP OIL	BTTM. OIL		

TEST REQUESTED BY Greg Jones DATE TESTED 2-5-87 BY Bill Belvan

L.BPEC #

WESTINGHOUSE FORM 4857K

№ 00728

REMARKS

SERIAL # *ACT P217060*

CALC. H.V. WINDING $153.5 - 127.7 = 20.75^\circ / 153.5 - 26 = 127.5^\circ$ RISE DIFF H.V. Winding Rise	CALC. L.V. WINDING $148.4 - 127.7 = 20.7^\circ / 148.4 - 26 = 122.4^\circ$ RISE DIFF L.V. Winding Rise
---	--

LOAD TEST AT _____ °C

AMPS

VOLTMETER

WATTMETER

NO LOAD TEST

(T.W.) WATTMETER

(A.W.) VOLTS ____ X AMPS

VA

TIME CONSTANT *at 170°.*
$$63.3 \times 101.7^\circ \text{C OIL RISE} = 644$$

TIME CONSTANT 5 HRS. 15 MIN.

Metric (across 2 transformers)

Am meli

Watt meter

Voltmeter

du

TYPE CONDUCTOR H.V. *Same as*

De

TYPE CONDUCTOR L.V. *re-plat*

CALCULATED COMPROMISE
CURRENT *Not used*

OTHER REMARKS

TEST
REQUESTED BY *Meg Jones*

DATE TESTED 2-5-87

BY Bill Belvan

L. SPEC 2

0040 7 B. BELVAN ATHENS 02 01 03 04 05 06 07 08 09 10 11 12 13 14 15 16

240 GREG JONES 09 FEB 87 12

25KUA 41600 07 08

BACK/BACK ANDR. COPS 04 05 06 07 08 09 10 11 12 13 14 15 16

03 04 05 06 07 08 09 10 11 12 13 14 15 16

01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16

01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16

0040	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16
03:05:00	21.70	24.30	25.80	23.9	25.70	1.8	25.80	1.9								
09:20:00	21.70	24.40	25.90	24.0	27.30	3.3	27.60	3.6								
09:35:00	21.90	24.40	25.80	24.0	30.90	6.9	31.30	7.3								
09:50:00	22.10	24.40	25.90	24.1	35.20	11.1	35.80	11.7								
10:05:00	22.20	24.40	25.80	24.1	39.60	15.5	40.30	16.2								
10:20:00	22.50	24.40	25.90	24.2	43.90	19.7	44.50	20.3								
10:35:00	22.40	24.50	25.90	24.2	47.80	23.6	48.50	24.3								
10:50:00	22.60	24.50	25.90	24.3	51.60	27.3	52.20	27.9								
11:05:00	22.50	24.50	26.00	24.3	55.30	31.0	55.90	31.6								
11:20:00	22.60	24.50	26.00	24.3	58.80	34.5	59.40	35.1								
11:35:00	22.60	24.60	26.00	24.4	62.30	37.9	62.90	38.5								
11:50:00	22.40	24.60	26.10	24.3	65.60	41.3	66.20	41.9								
12:05:00	22.70	24.60	26.10	24.4	68.70	44.3	69.20	44.8								
12:20:00	22.50	24.70	26.10	24.4	71.50	47.1	72.00	47.6								
12:35:00	22.60	24.70	26.20	24.5	74.20	49.7	74.60	50.1								
12:50:00	22.80	24.80	26.30	24.6	76.70	52.1	77.10	52.5								
13:05:00	22.60	24.80	26.30	24.5	79.00	54.5	79.50	55.0								
13:20:00	22.20	24.90	26.40	24.5	81.20	56.7	81.80	57.3								
13:35:00	22.70	24.90	26.40	24.6	83.20	58.6	83.80	59.2								
13:50:00	22.80	25.00	26.40	24.7	85.20	60.5	85.60	60.9								
14:05:00	22.90	25.00	26.50	24.8	87.20	62.4	87.50	62.7								
14:20:00	23.30	25.10	26.50	24.9	88.90	64.0	89.20	64.3								
14:35:00	23.50	25.10	26.60	25.0	90.50	65.5	90.80	65.8								
14:50:00	23.60	25.20	26.70	25.1	91.80	66.7	92.10	67.0								
15:05:00	23.80	25.30	26.80	25.3	93.10	67.8	93.30	68.0								
15:20:00	24.10	25.30	26.80	25.4	94.20	68.8	94.50	69.1								
15:35:00	24.10	25.40	26.90	25.4	95.60	70.2	95.80	70.4								
15:50:00	24.30	25.40	27.00	25.5	97.20	71.7	97.40	71.9								
16:05:00	24.30	25.50	27.10	25.6	98.70	73.1	98.90	73.3								
17:05:00	25.30	25.80	27.50	26.2	104.00	77.8	104.30	78.1								
18:05:00	25.40	26.10	27.80	26.4	108.20	81.8	108.50	82.1								
19:05:00	25.40	26.30	28.10	26.6	111.40	84.8	111.70	85.1								
20:05:00	24.70	26.50	28.40	26.5	114.50	88.0	114.70	88.2								
21:05:00	24.70	26.70	28.60	26.6	116.50	89.9	116.50	89.9								
22:05:00	24.10	26.90	28.80	26.6	118.10	91.5	118.20	91.6								
23:05:00	24.00	27.00	28.90	26.6	119.30	92.7	119.40	92.8								
00:05:00	23.80	27.20	29.00	26.6	121.00	94.4	121.10	94.5								
01:05:00	23.50	27.30	29.10	26.6	122.80	96.2	122.90	96.3								
02:05:00	23.00	27.40	29.20	26.5	124.00	97.5	124.10	97.6								
03:05:00	22.80	27.40	29.30	26.5	125.10	98.6	125.20	98.7								
04:05:00	22.70	27.50	29.30	26.5	126.00	99.5	126.10	99.6								
05:05:00	22.20	27.50	29.30	26.3	126.60	100.3	126.70	100.4								
06:05:00	22.00	27.40	29.30	26.2	126.80	100.6	127.00	100.8								
07:05:00	21.60	27.40	29.30	26.1	127.10	101.0	127.30	101.2								
08:05:00	21.60	27.30	29.20	26.0	127.30	101.3	127.50	101.5								

14 33
14 06

1420
1405

←

0041 7 B. BELVAN ATHENS
 700 01 02
 AMB 21.30 27.30
 09:05:00 21.60 27.20
 10:05:00 21.20 27.30
 11:05:00 22.40 27.20
 12:05:00 21.80 27.40
 13:05:00 21.50 27.30
 13:19:28 21.70 27.20

03 03
 AMB 29.10 29.30
 29.20 29.40
 29.20 29.30
 29.30 29.40
 29.40 29.50
 29.30 29.40

BACK/BACK ANDR. CORES
 04 05
 AVER. 61 TDP 126.80 100.9
 25.9 26.0 25.9 26.3 26.2 26.0 26.0 26.0

06 06
 RISE 100.9 100.7 100.5 100.7 101.3 101.5 101.7 101.7

25KVA 41600 07 08
 60 TDP RISE 127.10 126.90 126.60 127.10 127.50 127.60 127.70 127.70

240 GREG JONES 09 10
 09 10 11 12

09 FEB 87 11 12

P217061 AND 60(PEAR) 13 14 15

170 18 19

shut down

TEST REQUESTED BY Greg Jones DATE 3-23-87 TESTED BY Bill Belvan L.SPEC. #

BACK-2-BACK

B. BELVAN ATHENS

0054	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16
700	AMB	AMB	AMB	AVER.	16 TOP	RISE	17 TOP	RISE								
03:05:00	26.00	24.80	26.00	25.6	26.00	0.4	25.90	0.3								
08:21:00	26.30	24.70	25.90	25.5	32.10	6.6	32.60	7.1								
03:36:00	25.90	24.70	25.90	25.5	39.70	14.2	39.70	14.2								
08:51:00	26.00	24.70	26.00	25.5	46.60	21.1	46.40	20.9								
09:06:00	26.00	24.70	26.00	25.5	53.00	27.5	52.40	26.9								
09:21:00	25.90	24.70	26.00	25.5	59.00	33.5	58.10	32.6								
09:36:00	26.00	24.70	26.00	25.5	64.40	38.9	63.50	38.0								
09:51:00	26.00	24.80	26.10	25.6	69.40	43.8	68.10	42.5								
10:06:00	26.00	24.80	26.10	25.6	74.30	48.7	72.60	47.0								
10:21:00	26.00	24.90	26.20	25.7	79.60	53.9	77.60	51.9								
10:36:00	26.10	24.90	26.20	25.7	84.30	58.6	82.20	56.5								
10:51:00	26.10	24.90	26.20	25.7	88.90	63.2	86.60	60.9								
11:06:00	26.10	25.00	26.30	25.8	93.20	67.4	90.80	65.0								
11:21:00	26.20	25.00	26.30	25.8	97.50	71.7	95.00	69.2								
11:36:00	26.20	25.10	26.40	25.9	101.70	75.8	99.10	73.2								
11:51:00	26.30	25.10	26.50	25.9	105.60	79.7	102.80	76.9								
12:06:00	26.30	25.20	26.50	26.0	108.90	82.9	106.00	80.0								
12:21:00	26.40	25.20	26.60	26.0	112.10	86.1	109.10	83.1								
12:36:00	26.40	25.30	26.70	26.1	114.90	88.8	111.80	85.7								
12:51:00	26.50	25.40	26.80	26.2	117.40	91.2	114.30	88.1								
13:06:00	26.60	25.40	26.80	26.2	119.70	93.5	116.50	90.3								
13:21:00	26.70	25.50	26.90	26.3	121.90	95.6	118.70	92.4								
13:36:00	26.70	25.60	27.00	26.4	122.70	96.3	119.30	92.9								
13:41:00	26.70	25.60	27.00	26.4	123.30	96.9	120.00	93.6								
13:56:00	26.80	25.70	27.10	26.5	123.50	97.0	120.30	93.8								
14:11:00	26.80	25.80	27.20	26.6	123.80	97.2	120.70	94.1								
14:26:00	26.90	25.90	27.20	26.6	124.10	97.5	121.00	94.4								
14:41:00	26.90	25.90	27.30	26.7	124.50	97.8	121.30	94.6								
14:56:00	27.00	26.00	27.40	26.8	124.90	98.1	121.80	95.0								
15:11:00	27.10	26.10	27.50	26.9	125.40	98.5	122.20	95.3								
15:26:00	27.20	26.10	27.50	26.9	125.80	98.9	122.70	95.8								
15:41:00	27.30	26.20	27.60	27.0	126.30	99.3	123.20	96.2								
15:56:00	27.30	26.30	27.70	27.1	126.70	99.6	123.60	96.5								
16:11:00	27.40	26.30	27.80	27.1	127.10	100.0	124.00	96.9								
16:26:00	27.40	26.40	27.90	27.2	127.40	100.2	124.30	97.1								
16:41:00	27.50	26.40	27.90	27.2	127.60	100.4	124.60	97.4								
16:56:00	27.50	26.50	28.00	27.3	127.80	100.5	124.80	97.5								
17:11:00	27.60	26.50	28.00	27.3	128.00	100.7	125.10	97.8								
17:26:00	27.70	26.50	28.10	27.4	128.20	100.8	125.30	97.9								
17:41:00	27.70	26.60	28.10	27.4	128.50	101.1	125.60	98.2								
17:56:00	27.70	26.60	28.20	27.5	128.70	101.2	125.80	98.3								
18:11:00	27.80	26.70	28.20	27.5	128.90	101.4	126.10	98.6								
18:26:00	27.80	26.70	28.30	27.6	129.00	101.4	126.20	98.6								
18:41:00	27.90	26.70	28.30	27.6	129.00	101.4	126.30	98.7								
18:56:00	27.90	26.80	28.30	27.6	129.00	101.4	126.30	98.7								

Notes: 2 + 150 ft.

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P239216 AND 17 (REAR)
15 14 15

240 GREG JONES 23 FEB 87
10 11 12

0054	7	B. BELVAN ATHENS	01	02	03	04	05	06	07	08	09	10	11	12	25KUA 4160W
000		AMB	AMB	AMB	AMB	AMB	AMB	AMB	17 TOP	RISE					
13:11:00		27.90	28.90	28.30	27.6	128.90	101.3	126.30	98.7						
14:26:00		27.90	28.80	28.30	27.6	128.90	101.3	126.30	98.7						
15:41:00		28.00	28.80	28.40	27.7	129.10	101.4	126.50	98.8						
16:56:00		28.00	28.90	28.40	27.7	129.20	101.5	126.60	98.9						
18:11:00		28.00	28.90	28.40	27.7	129.20	101.5	126.70	99.0						
19:26:00		28.10	28.90	28.50	27.8	129.10	101.3	126.70	98.8						
20:41:00		28.10	27.00	28.50	27.8	129.20	101.4	126.70	98.9						
21:56:00		28.20	27.00	28.60	27.9	129.20	101.3	126.70	98.8						
23:11:00		28.20	27.00	28.60	27.9	129.20	101.3	126.80	98.9						
24:26:00		28.30	27.10	28.70	28.0	129.30	101.3	126.90	98.9						
25:41:00		28.40	27.20	28.80	28.1	129.40	101.3	127.00	98.9						
26:56:00		28.40	27.20	28.80	28.1	129.50	101.4	127.20	99.1						
28:11:00		28.50	27.20	28.80	28.1	129.70	101.6	127.30	99.2						
29:26:00		28.50	27.30	28.90	28.2	129.80	101.6	127.50	99.3						
30:41:00		28.60	27.30	28.90	28.2	130.00	101.8	127.70	99.5						
31:56:00		28.60	27.30	28.90	28.2	130.20	102.0	128.00	99.6						
33:11:00		28.60	27.30	29.00	28.3	130.40	102.1	128.10	99.8						
34:26:00		28.70	27.40	29.00	28.3	130.60	102.3	128.30	100.0						
35:41:00		28.70	27.40	29.10	28.4	130.90	102.5	128.80	100.4						
36:56:00		28.70	27.40	29.10	28.4	131.40	103.0	129.20	100.8						
38:11:00		28.80	27.50	29.10	28.4	131.70	103.3	129.60	101.2						
39:26:00		28.80	27.50	29.20	28.5	132.10	103.6	130.00	101.5						
40:41:00		28.90	27.60	29.20	28.5	132.50	104.0	130.40	101.9						
41:56:00		28.90	27.70	29.30	28.6	132.90	104.3	130.70	102.1						
43:11:00		28.90	27.60	29.30	28.6	133.20	104.6	131.10	102.5						
44:26:00		28.90	27.70	29.30	28.6	133.50	104.9	131.50	102.9						
45:41:00		29.00	27.70	29.40	28.7	133.80	105.1	131.80	103.1						
46:56:00		29.00	27.70	29.40	28.7	134.10	105.4	132.10	103.4						
48:11:00		29.00	27.70	29.40	28.7	134.30	105.6	132.30	103.6						
49:26:00		29.00	27.80	29.40	28.7	134.60	105.9	132.60	103.9						
50:41:00		29.10	27.80	29.50	28.8	134.90	106.1	132.90	104.1						
51:56:00		29.10	27.80	29.50	28.8	135.10	106.3	133.20	104.4						
53:11:00		29.10	27.80	29.50	28.8	135.30	106.5	133.40	104.6						
54:26:00		29.20	27.90	29.60	28.9	135.50	106.6	133.60	104.7						
55:41:00		29.20	27.90	29.60	28.9	135.70	106.9	133.80	105.0						
56:56:00		29.20	27.90	29.60	28.9	135.90	107.0	134.00	105.1						
58:11:00		29.20	28.00	29.60	28.9	136.10	107.2	134.20	105.3						
59:26:00		29.20	28.00	29.60	28.9	136.10	107.2	134.30	105.4						
60:41:00		29.30	28.00	29.70	29.0	136.30	107.3	134.40	105.5						
61:56:00		29.30	28.00	29.70	29.0	136.40	107.4	134.50	105.5						
63:11:00		29.30	28.00	29.70	29.0	136.40	107.3	134.50	105.5						
64:26:00		29.30	28.00	29.70	29.0	136.40	107.3	134.50	105.5						
65:41:00		29.30	28.00	29.70	29.0	136.30	107.3	134.50	105.5						
66:56:00		29.30	28.00	29.80	29.0	136.30	107.3	134.40	105.4						
68:11:00		29.30	28.00	29.80	29.0	136.10	107.1	134.30	105.3						

EXPENSE. GOVERNMENT. CIV. (C) (U) (R) (F) (N)

$$\begin{array}{r} 91 \\ 133 \overline{) 1221} \\ \underline{1098} \\ 123 \\ \underline{118} \\ 51 \\ \underline{45} \\ 6 \end{array}$$

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60	91	11	28	17
240	GRE JONES	22 FEB 67		

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698-40	40	50	70
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THE
CITY

7-8-60

[illegible]

— adjust current from white hours

Shut down 15092

170⁹¹ 011

[illegible]

249 GREG JONES 23 FEB 87 12
09 10 11

80 20
00914 00952

BACK-04 05 06

ATHENS 02 03
CMB CMB

100-443887-100

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*** POWER OFF AT 0055:13:58:08. PC = 267E
HUB  HMB  HMB  HVER. 18

```

WESTINGHOUSE 000 COMMERCIAL TEST REPORT

DATE: 02/11/87

CONDITION: FOLLOWING 170% TEMPERATURE RISE

STYLE: G.E. 251VA AMORPHOUS METAL POLE TYPE

LV: 120/240 HV: 4150: 75KV BIL SERIAL 4:R217060-724

RATIO	PASS	* HV RESISTANCE (OHMS)	4.692
POLARITY	PASS	* LV RESISTANCE (OHMS)	0.01364
FULL WAVE IMPULSE	PASS	* I SQUARED R LOSS (WATTS)	107.5
APPLIED POTENTIAL - HUIO	PASS	* WATTS	9.5
APPLIED POTENTIAL - CHIO	PASS	* LOAD LOSS (WATTS)	107.5
INDUCED POTENTIAL - 40 HZ	PASS	TOTAL LOSS (WATTS)	145.7
W LOSS (WATTS)	13.7	* % RESISTANCE	1.71
% EXCITING CURRENT	1.04	* % REACTANCE	1.12
% EFFICIENCY @ PF=1	98.5	* % IMPEDANCE	2.49
% EFFICIENCY @ PF=0.8	98.7	% REGULATION @ PF=1	1.71
		% REGULATION @ PF=0.8	1.71

Bragg Jones

WESTINGHOUSE DTD COMMERCIAL TEST REPORT

DATE: 02-11-87

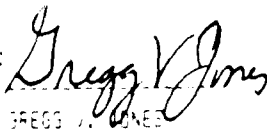
CONDITION: FOLLOWING 170% TEMPERATURE RISE

STYLE: S.E. 25KVA AMORPHOUS METAL POLE TYPE

LV: 120V/240 HV: 4150V 75KV BIL SERIAL #: P217061-17A

RATIO	PASS	* HV RESISTANCE (OHMS)	4.732
POLARITY	PASS	* LV RESISTANCE (OHMS)	0.01334
FULL WAVE IMPULSE	PASS	* I SQUARED P LOSS (WATTS)	715.7
APPLIED POTENTIAL - HLIC	PASS	* STRAYS	10.3
APPLIED POTENTIAL - LHIC	PASS	* LOAD LOSS (WATTS)	326.0
INDUCED POTENTIAL - 400 HZ	PASS	TOTAL LOSS (WATTS)	344.7
NL LOSS (WATTS)	18.3	* % RESISTANCE	1.36
% EXCITING CURRENT	1.2	* % REACTANCE	2.12
% EFFICIENCY @ PF=1	98.6	* % IMPEDANCE	2.49
% EFFICIENCY @ PF=0.8	99.3	% REGULATION @ PF=1	1.33
		% REGULATION @ PF=0.8	2.00

TEST ENGINEER:



 GREGG V. JONES

* CORRECTED TO BE DECREASED

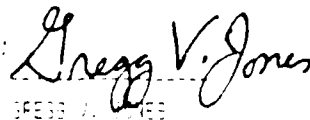
CONDITION: FOLLOWING 150% TEMPERATURE RISE

STYLE: G.E. 25KVA STANDARD SILICON STEEL POLE TYPE

LV: 120/240 HV: 4150V 25KV BIL SERIAL #: P207F015-108

RATIO	PASS	* HV RESISTANCE (OHMS)	6.5001
POLARITY	PASS	* LV RESISTANCE (OHMS)	0.019358
FULL WAVE IMPULSE	PASS	* I SQUARED R LOSS (WATTS)	444.6
APPLIED POTENTIAL - HLIC	PASS	* STRAYS	1.2
APPLIED POTENTIAL - LHIC	PASS	* LOAD LOSS (WATTS)	446.0
INDUCED POTENTIAL - 400 HZ	PASS	TOTAL LOSS (WATTS)	511.2
VL LOSS (WATTS)	65.7	* % RESISTANCE	1.78
% EXCITING CURRENT	0.9	* % REACTANCE	2.22
% EFFICIENCY @ PF=1	98.0	* % IMPEDANCE	2.85
% EFFICIENCY @ PF=0.8	97.5	% REGULATION @ PF=1	1.81
		% REGULATION @ PF=0.8	2.75

TEST ENGINEER:



GREGG V. JONES

* CORRECTED TO 65 DEGREES C

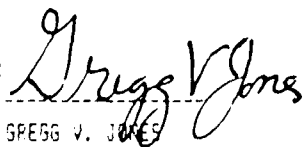
CONDITION: FOLLOWING 150% TEMPERATURE RISE

STYLE: 6.E. 15KVA STANDARD SILICON STEEL POLE TYPE

L.V. 120 VAC H.V. 4150V TEST: SIL SERIAL #: P202017-408

RATIO	PASS	* HV RESISTANCE (OHMS)	5.4984
POLARITY	PASS	* LV RESISTANCE (OHMS)	0.01927
FULL WAVE IMPULSE	PASS	* I SQUARED P LOSS (WATTS)	447.6
APPLIED POTENTIAL - HLIC	PASS	* STRAYS	5.7
APPLIED POTENTIAL - LHIC	PASS	* LOAD LOSS (WATTS)	449.5
INDUCED POTENTIAL - 400 HZ	PASS	TOTAL LOSS (WATTS)	519.4
HL LOSS (WATTS)	58.9	* % RESISTANCE	1.30
% EXCITING CURRENT	0.87	* % REACTANCE	2.04
% EFFICIENCY @ PF=1	98.0	* % IMPEDANCE	2.37
% EFFICIENCY @ PF=0.8	97.5	% REGULATION @ PF=1	1.80
		% REGULATION @ PF=0.8	2.78

TEST ENGINEER:



 GREGG V. JONES

* CORRECTED TO 35 DEGREES C

APPENDIX A.3

SOUND LEVEL TEST REPORTS

January 29, 1987

Roger Angelo Lucheta

Westinghouse Research Laboratory

1310 Beulah Road

Pittsburgh, PA 15235

Subject: Noise Test of Transformer

A report of the noise evaluation of a 25 kVA General Electric transformer, s/n P217059-YZA, is attached. The evaluation was performed by Dr. Francis McKendree at the Westinghouse Churchill Site during the period January 27, 1987 to January 29, 1987.

I have observed the performance of the tests and checked the calculations in the report. I certify that these noise measurements comply with the applicable provisions ANSI/IEEE Std. 141-1986, NEMA standard TR 1-1980, and ANSI/IEEE C57.12.90-1980.

Roger Angelo Lucheta

*Roger
Angelo
Lucheta*

SOUND MEASUREMENTS OF 25 kVA
GENERAL ELECTRIC TRANSFORMER
S/N P217059-YZA

Francis S. McKendree

Westinghouse R&D Center
1310 Beulah Road
Pittsburgh, PA 15235

DESCRIPTION OF TEST

Airborne sound pressure levels were measured in accordance with ANSI standard C57.12.90-1980 for sound measurement of transformers. The normal excitation was used, 120 V to each side of the secondary, and 10% above normal, 132 V to each side of the secondary. The room is a hemi-anechoic space located at the Westinghouse Churchill Site, Building 302, Room 102C. The measurements were made on 27 and 28 January 1987.

ANSI C57.12.90-1980 specifies that instrumentation for the sound level measurements shall meet the requirements of ANSI S1.4-1971 for Type 2 meters. The instrumentation used satisfies Type 1 requirements throughout. Type 1 compliance is inclusive of Type 2 compliance, since all requirements for Type 1 are more stringent than those for Type 2.

Airborne sound pressure levels were measured at one foot from the transformer case, beginning at the front center and spaced 90 degrees apart. The reported sound pressure levels are the averages over the test positions, for the indicated excitations. Narrow band sound pressure level spectra were also recorded at each test position and condition.

The transformer was serial number P217059-YZA of 25 kVA capacity. Because its noise levels were extraordinarily low, a second procedure in the standard ANSI C57.12.90-1980, regarding the use of narrow band spectral measurements, was also employed to give a better approximation of the actual sound pressure levels emitted by the transformer.

EQUIPMENT USED

The equipment used for these measurements is listed below:

<u>Manufacturer</u>	<u>Model</u>	<u>Serial</u>	<u>Description/Notes</u>
B&K	4220	1164904	pistonphone, 124.1 dB nominal, NBS traceable
B&K	4145	819114	microphone, 1 inch
B&K	2613	226513	mic preamp
B&K	2603	9A6253	measuring amplifier
Gen Rad	1925	181228	1/3 octave multifilter
DEC	11/24	AG02930	laboratory computer system with A/D

*Rogers
Angelo
Lucheta*

One-third octave band spectra were measured at each test position for no excitation, 120 V, and 132 V excitation. The spectra were summed on a true power basis in accordance with the applicable standard. The A-weighted levels reported for the transformers were derived from the spectra. The spectra and derived, arithmetically-averaged A-weighted levels, are listed in Table 1.

TABLE 1

One-third Octave Bands and A-weighted Levels Measured
on Transformer P217059-YZA Under Various Excitations

<u>BAND</u>	<u>AMBIENT</u>	<u>120 V</u>	<u>132 V</u>
50	36.8	36.6	36.0
63	41.2	40.9	40.7
80	34.7	34.5	34.1
100	31.4	33.4	33.6
125	29.7	35.6	39.4
160	26.6	27.2	27.2
200	24.2	24.8	25.0
250	22.4	27.8	28.3
315	20.8	24.2	26.2
400	19.9	25.4	29.2
500	19.0	23.2	33.8
630	18.7	22.4	34.4
800	19.2	20.6	26.8
1000	18.6	19.8	23.8
1250	18.4	18.9	22.6
1600	18.6	19.1	20.8
2000	19.3	19.6	20.2
2500	19.7	20.1	20.4
3150	20.4	20.6	20.9
4000	20.8	21.3	21.9
5000	21.0	21.2	21.6
dB(A)	32.4	34.0	38.6

*Roger
Angelo
Luchetta*

ANSI standard C57.12.90-1980 specifies procedures which are to be used if the ambient level measured in a given band, or with a given weighting, are within 10 dB of the combined ambient and transformer sound levels. For the ambient between 5 and 10 dB below the combined level, a correction is allowed to produce a reportable sound level for the transformer. If the ambient is within 5 dB of the combined level, the level must be reported as a level which the tested unit "does not exceed".

The A-weighted ambient level was 32.6 dB before the tests and 32.3 dB after the tests, for an average of 32.4 dB. The average A-weighted level was 34.0 dB with 120 V excitation, and 38.6 dB with 132 V excitation to each side of the transformer secondary.

Since the ambient level is within 5 dB of the combined level with 120 V excitation, the A-weighted average is reduced by 1.6 dB, and the net level is reported as the level which the transformer does not exceed:

"In accordance with ANSI C57.12.90-1980, the A-weighted sound level of transformer P217059-YZA, when excited with 120 V, does not exceed 32.4 dB(A)."

The average A-weighted sound pressure level when the transformer is driven with 132 V is between 5 and 10 dB above the ambient. Reference to the standard indicates a correction of 1.3 dB is appropriate, and the net level shall be reported as the sound level of the transformer:

"In accordance with ANSI C57.12.90-1980 except with regard to the excitation voltage,, transformer P217059-YZA, when excited with 132 V to each side of the secondary, produces an average A-weighted sound level of 37.3 dB(A)."

*Roger
Angelo
Luchetti*

ANSI C57.12.90-1980 permits measurements of narrow band tonal components. As the ambient noise is relatively broad band, a better signal-to-noise ratio can be obtained with narrow band measurements. When the tone levels of a transformer are to be measured, the even harmonics of the line frequency are to be measured up to and including the seventh. For the unit under test, these are 120, 240, 360, 480, 500, 720, and 840 Hz. The tone levels are to be averaged over the specified positions on a true power basis. The tones may be A, C, or linearly weighted, and may be summed on a true power basis to give the average sound level for the chosen weighting.

In ANSI S1.4-1971, a "sound pressure level" is defined as "20 times the logarithm to the base 10 of the ratio of the pressure of a sound to the reference pressure", and a "sound level" is defined as "Weighted sound pressure level measured by the use of a metering characteristic and weighting A, B, or C as specified in this standard". The A-weighting, originally developed as an approximation to the Fletcher-Munson 40 phon curve and specified as a set of time constants for an electrical filter network, is in ANSI S1.4-1971 defined at discrete frequencies corresponding to the center frequencies of the preferred 1/3 octave bands from 10 to 20,000 Hz.

The author uses a quadratic interpolation between the entries of this table to derive an A-weighting coefficient for a tonal noise at a frequency not equal to one of the preferred 1/3 octave band centers. The error which may be introduced by this procedure is far less than the tolerances which are permitted on a Class 1 implementation of the A-weighting network itself.

Narrow band spectra were measured on a 1 kHz frequency range with 400 lines of resolution, and the tone levels of the first seven harmonics of 120 Hz were measured. The tone levels are presented in Table 2.

TABLE 2

Tone Levels of Twice-line-frequency Harmonics

<u>FREQUENCY</u>	<u>AMBIENT</u>	<u>120 V</u>	<u>132 V</u>
120	23.6	35.7	39.9
240	12.4	27.7	29.2
360	6.4	24.8	31.0
480	2.6	21.3	34.3
600	2.0	17.6	31.0
720	1.7	13.9	25.4
840	2.2	6.3	20.6

*Roger
Angels
Lucheta*

All of the tone levels, which were measured with an effective bandwidth of 3.2 Hz, were more than 10 dB above the ambient, except for 840 Hz with 120 V excitation. This level was originally 7.6 dB, which is 5.2 dB above the ambient. In accordance with the ANSI standard procedure, the measured level has been reduced 1.3 dB and is reported as 6.3 dB.

Copies of 1 kHz and 2 kHz bandwidth spectral plots, for ambient and energized conditions at the front center of the transformer, are included with this report. It is evident that the tone levels can be reliably measured, since they are clearly above the ambient levels.

Table 3 shows the results of applying the A weighting to the first seven harmonics of the double line frequency. The A weighting values shown are derived from a quadratic interpolation from the tabulated A-weighting response curve in ANSI S1.4-1971.

TABLE 3

A-weighting and A-weighted Tone Levels

<u>Frequency</u>	<u>A-Weight</u>	<u>120 V</u>	<u>132 V</u>
120	-16.6	19.1	23.3
240	- 9.0	18.7	20.2
360	- 5.6	19.2	25.4
480	- 3.5	17.8	30.8
600	- 2.2	15.4	28.8
720	- 1.3	12.6	24.1
840	- 0.6	5.7	20.0
dB(A) sum		25.5	34.7

*Rgn
Angelo
Lucheta*

Examination of the 2 kHz spectral plots confirms that the first seven harmonics of twice the line frequency contain almost all of the sound energy, even after the A weighting is taken into account. The tone level and band levels may be compared as shown below in Table 4.

*Roger
Angelo
Lucheta*

TABLE 4

Comparison of Tone and Band Levels at Selected Frequencies

<u>Condition</u>	<u>120 Hz Tone</u>	<u>125 Hz Band</u>	<u>240 Hz Tone</u>	<u>250 Hz Band</u>
Ambient	23.6	29.7	12.4	22.4
120 Volt	35.7	35.6	27.7	27.8
132 Volt	39.9	39.4	29.2	28.3

The tone and band levels are quite comparable for the energized conditions, since in these bands the only significant component is the tone from the transformer. Under ambient conditions, the noise is relatively broad-band, so the tone level at a discrete frequency is considerably lower than the band level, which encompasses a range of frequencies.

The band levels above 840 Hz are dominated by the ambient noise, even with the transformer energized. The ANSI procedure for adjustment due to ambient noise is limited to 1.6 dB, which is inadequate to deal with noise levels as close to the ambient as those documented in this report. Section 13.5.4 reads:

"13.5.4 If ambient conditions necessitate, the sound level may be measured using discrete frequency components (see 13.6.4.)"

The sum of the levels of the first seven harmonics is 25.5 dB(A) for the 120 V excitation, and 34.7 dB(A) for the 132 V excitation. It will be recalled that the ANSI standard method applied to the

A-weighted measurements gave a result of "not exceeding 32.4 dB(A)" for 120 V and of 37.3 dB(A) with 132 V excitation. It is the opinion of the author that the A-weighted results, though they have been corrected in accordance with the ANSI standard, still have resulted in an overestimate of the actual transformer levels.

"In accordance with the Optional Frequency Analysis Procedure which described in section 13.6 of ANSI standard C57.12.90-1980, the sound level of transformer P217059-YZA on the A-weighting scale is 25.5 dB(A) at 120 Volts excitation to each side of the secondary, and 34.7 dB(A) with 132 Volts excitation to each side of the secondary."

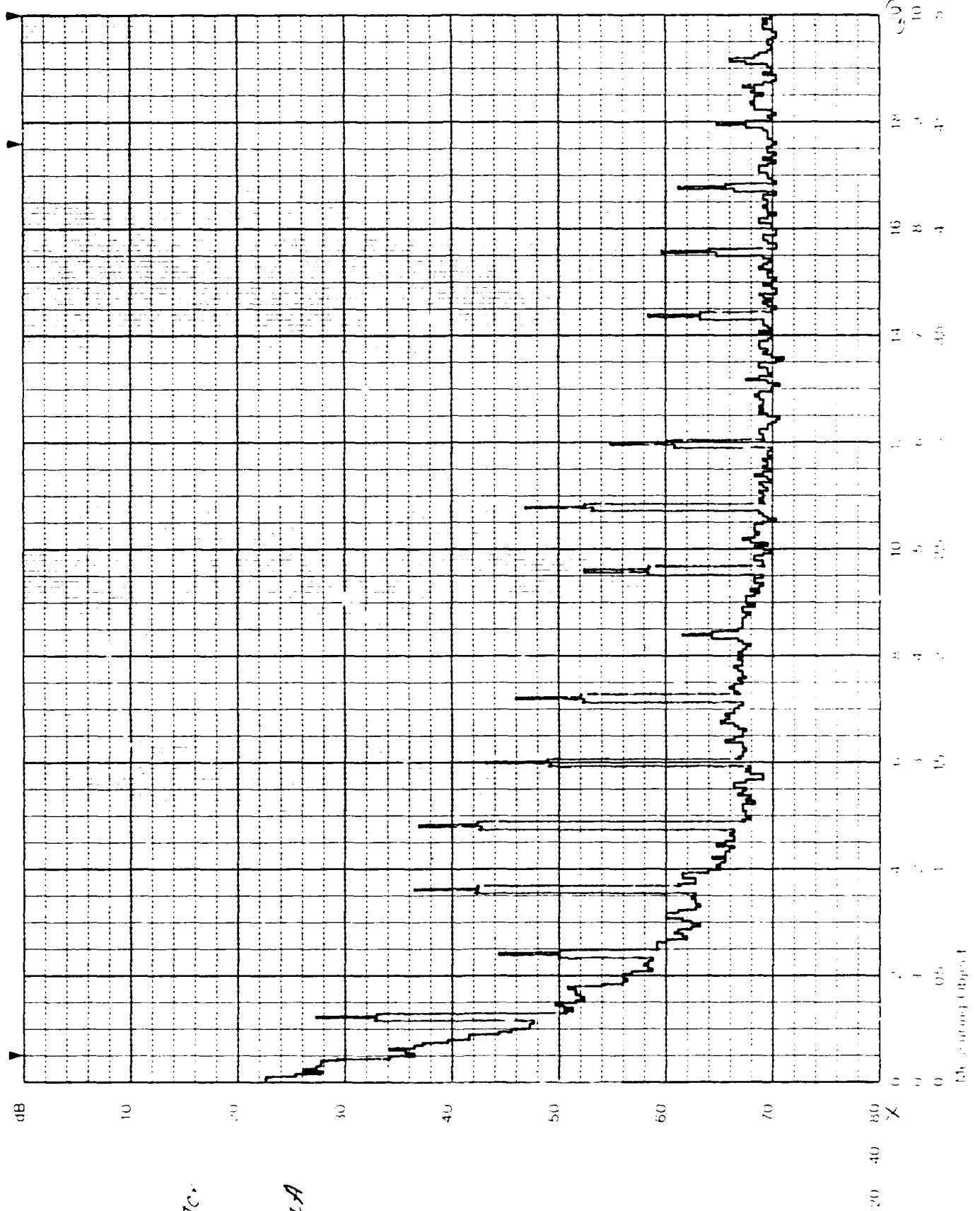
*Roger
Angelo
Lucheta*

Full Scale Level 20
 F. S. Frequency 20 Hz
 Weighting Hann
 Average Mode Lin
 No of Spectra 64
 Comments
 132V Left-Center
 Position 1
 254VA-6E
 SN P217059-VZA

B-53

Roger
 Angelo
 Schuketa

Record No
 Date 1-28-87
 Sign J. Allen



Bruel & Kjaer Time Function Start Seconds End Not Expanded Expanded

Full Scale Level 70
F S Frequency 2KHz
Weighting Flann
Average Mode Lin
No of Spectra 64

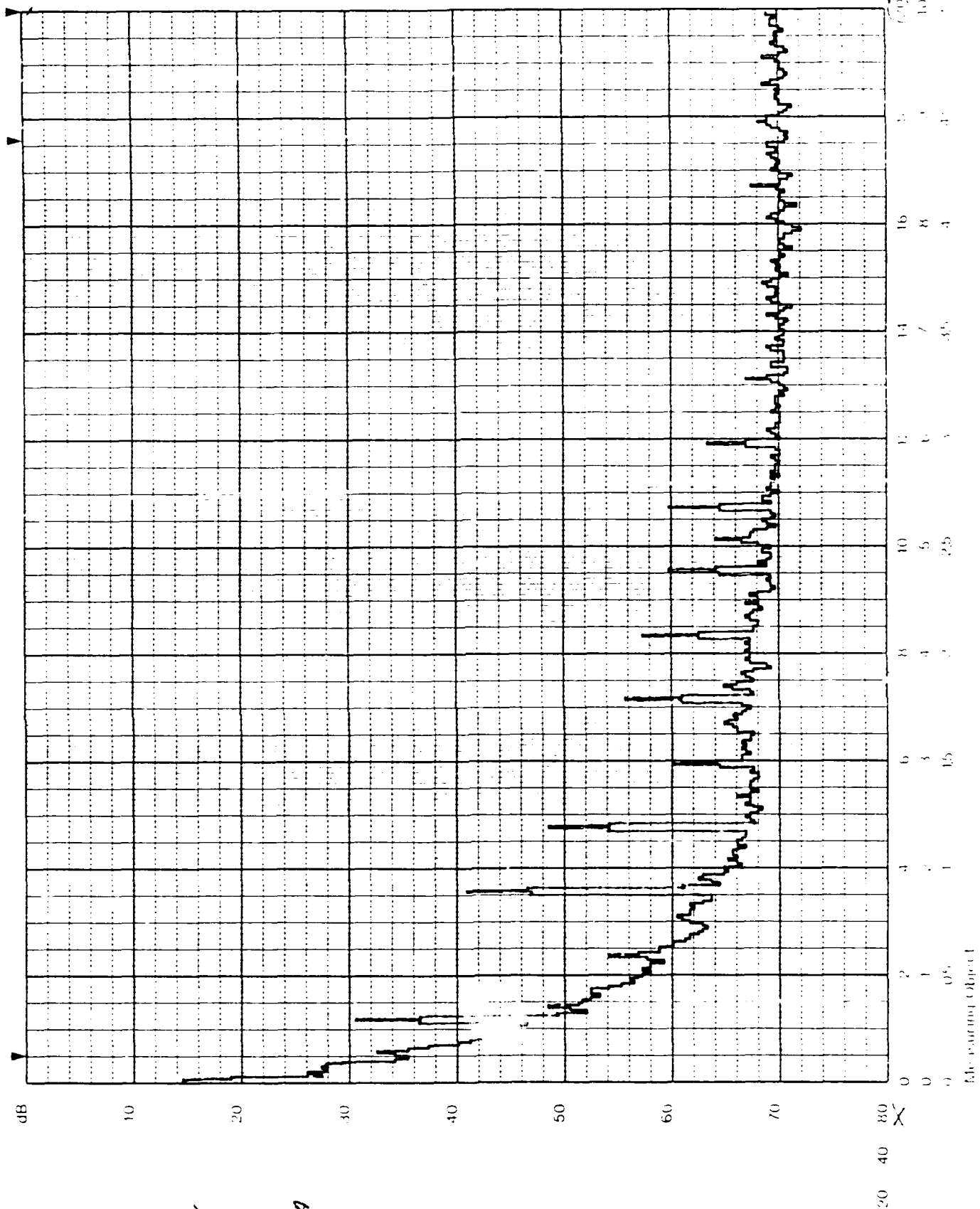
Comments
120V Left Center
Position 1

DSKVA - 6E
SN P017059 YIA

B-54

Copy
Angelo
Luchetti

Record No.
Date: 1-28-82
Sign: J. W. W.



Full Scale Level

F S. Frequency. 1 KHz

Weighting

Average Mode

No of Spectra

Comments:

132v - Left - Center
Position 1

25KVA-GE

ATZ-650C1Bd NS

B-55

Roger
Angelo
Lucchella

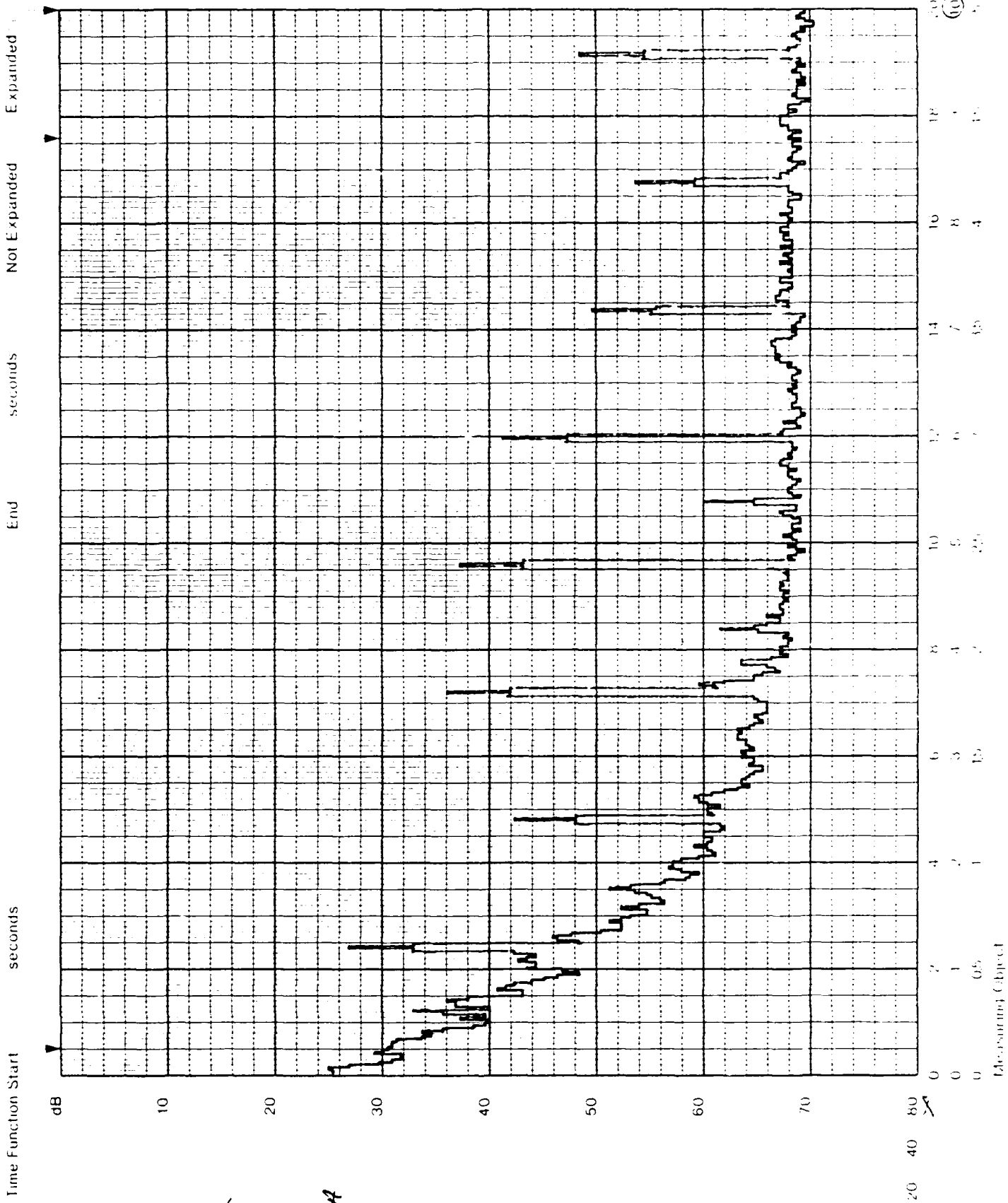
Record No.

Date: 1-25-87

Sign

J. Zeller

2001 45



Bruel & Kjaer

Full Scale Level 70
F S Frequency 1 KHz
Weighting Harn
Average Mode LA
No of Spectra 64

Comments

132V - Right-Center
Position 1

25KVA-GE
SN P017059-Y2A

B-56

*Copy
Analog
Structure*

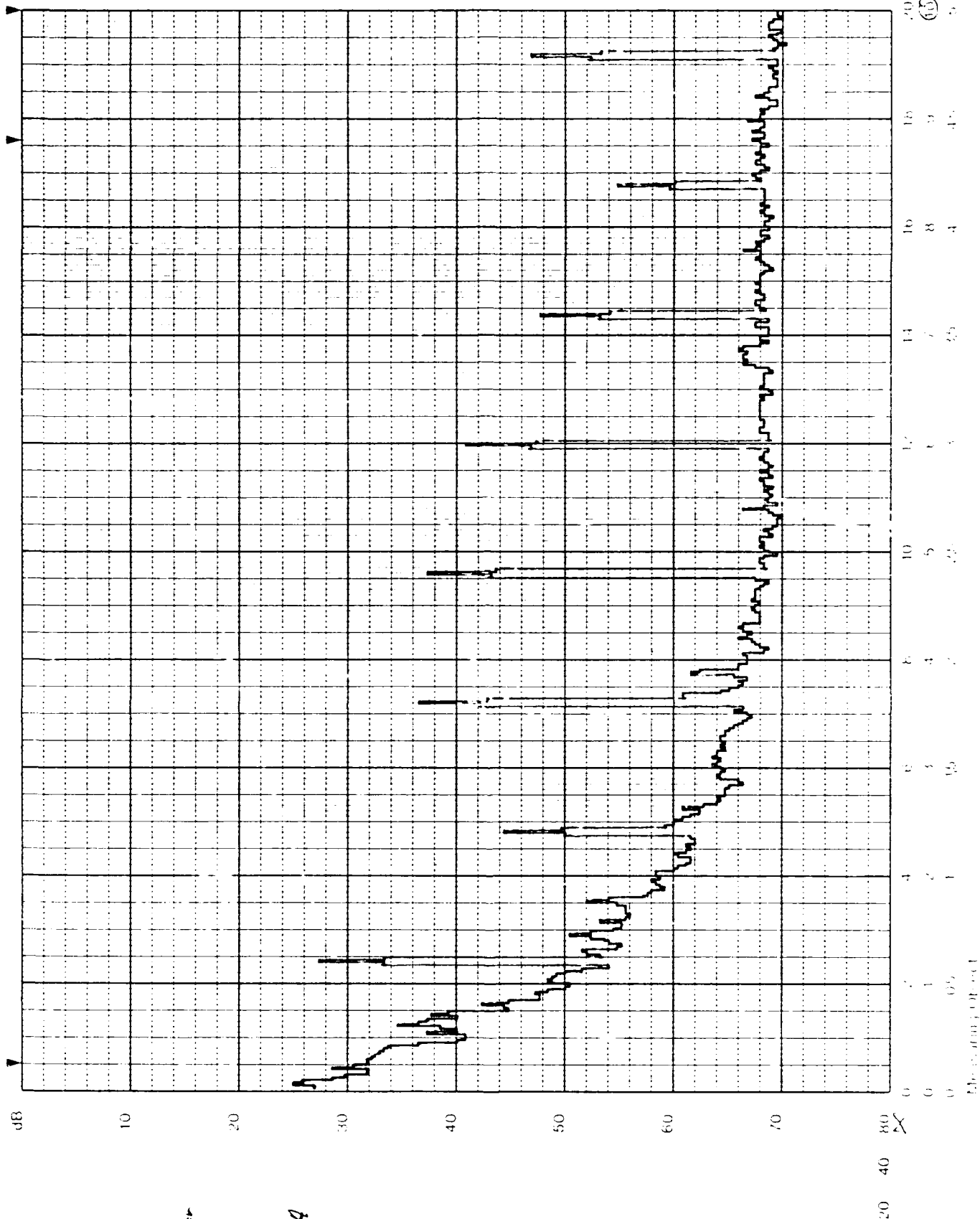
Record No

Date: 1-28-87

Sign: J. Elder

OP 1002

Time Function Start Seconds End Not Expanded Expanded



Brüel & Kjær Time Function Start Seconds End Seconds Not Expanded Expanded

Full Scale Level 70
 F S Frequency 1 KHz
 Weighting Hann
 Average Mode Lin
 No of Spectra 64

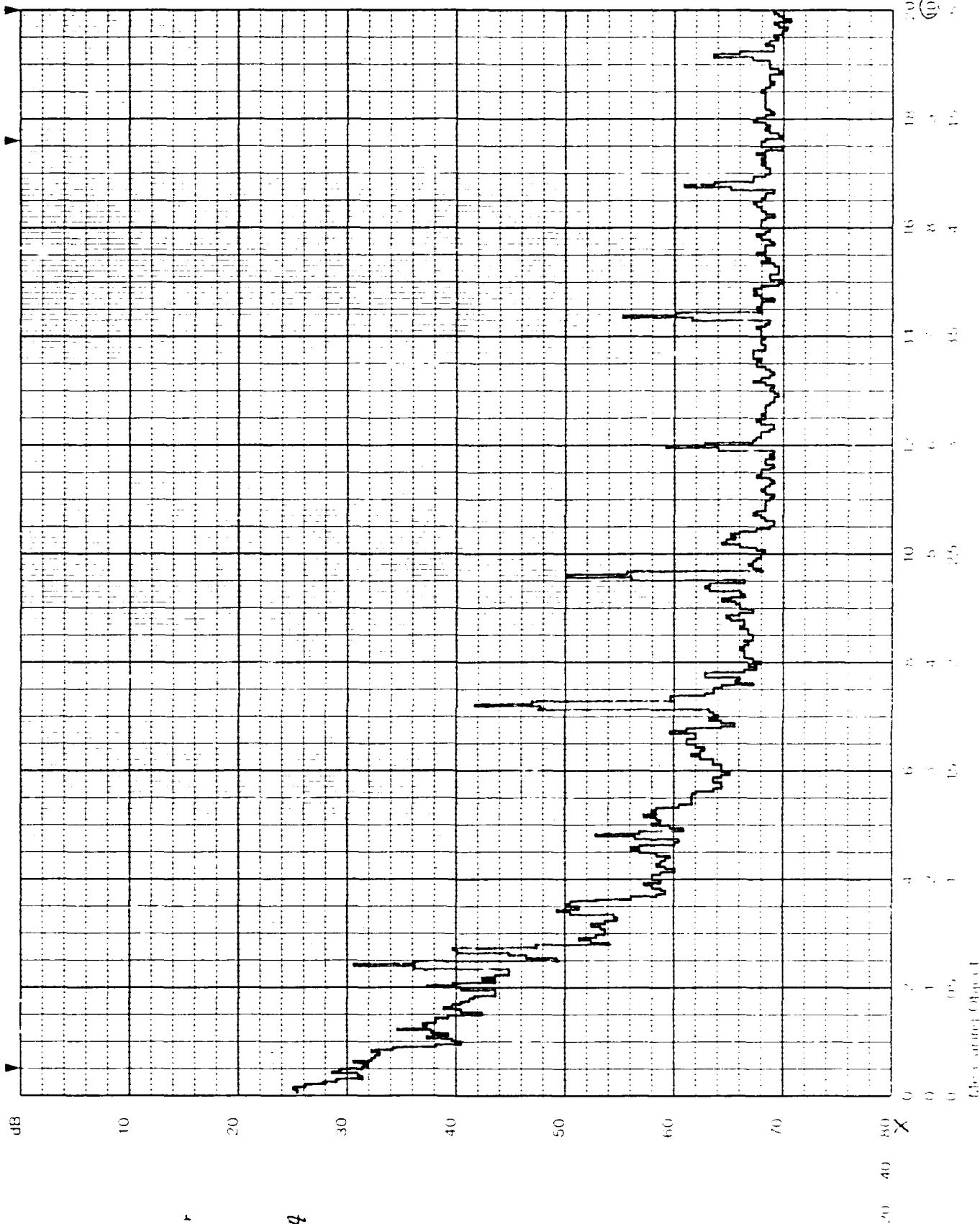
Comments
 120v Right-Center
 Position 1

25 KVA - GE
 SN P217059-42A

B-57

*Robert
 Angelo
 Schickel*

Record File
 Date 1-28-87
 Sign J. Miller



Expanded

Not Expanded

Seconds

End

Seconds

Time Function Start

Brüel & Kjær

Full Scale Level 70
 F S Frequency 1KHz
 Weighting Hann
 Average Mode Lin
 No of Spectra 04

Comments

120V Left-Center
 Position 1

25KVA - GE
 SN P212059-YZA

B-58

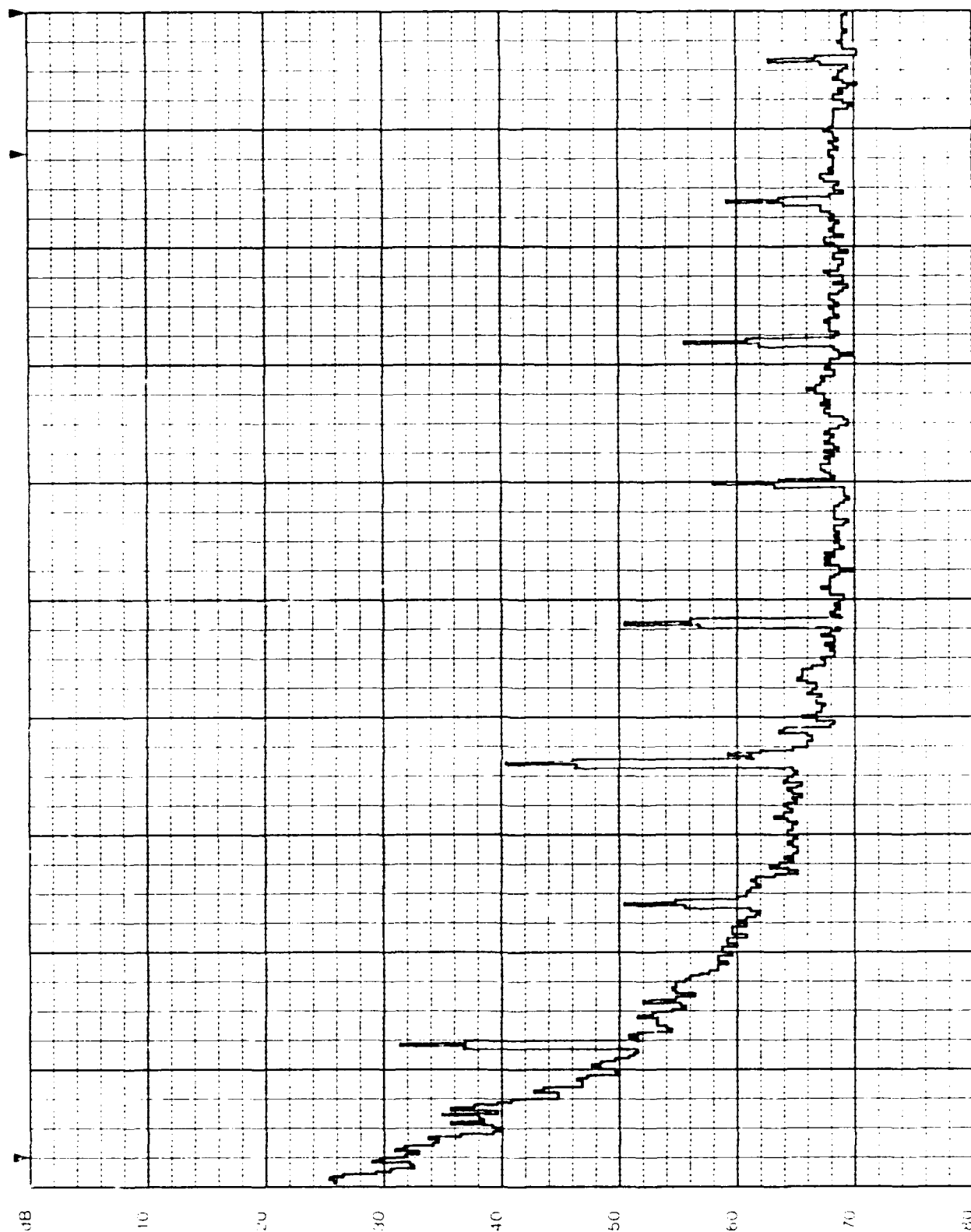
*Ray
 Angelo
 Luchetta*

Record File

Date 1-28-57

Sign g 2461

QP1002



0 20 40 60 80
 dB
 0 2 4 6 8 10 12 14 16
 kHz
 Decrement Output

Bruel & Kjaer

Full Scale Level 20

F S Frequency 1KHz

Weighting Hann

Average Mode Lin

No of Spectra 64

Comments Ambient

Position 1

J5HVA-GE

SNP217052-VZA

B-59

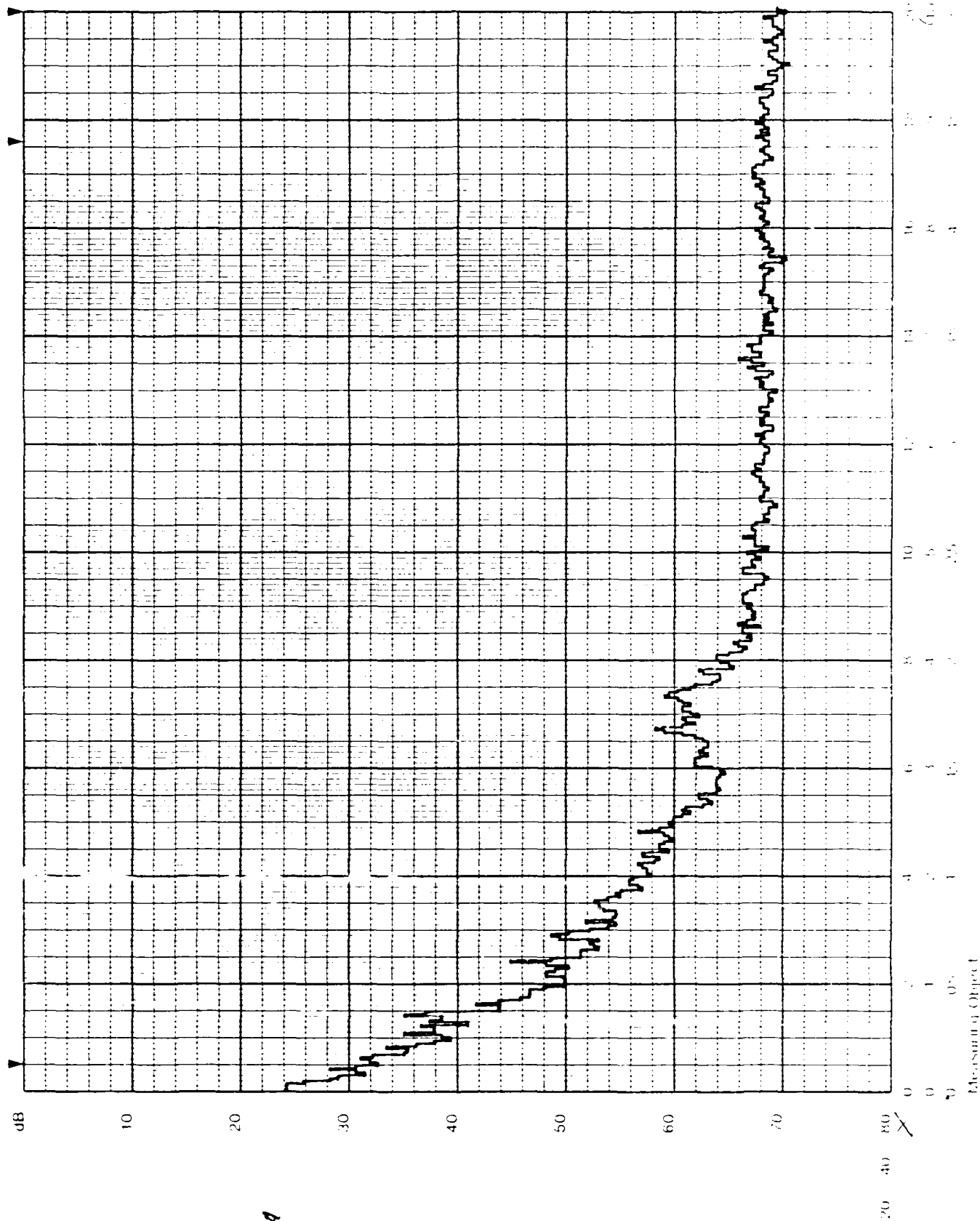
*Rogey
Angel
in cheta*

Record No.

Date 1-28-87

Sign J. Elder

Time Function S art Seconds End Not Expanded Expanded



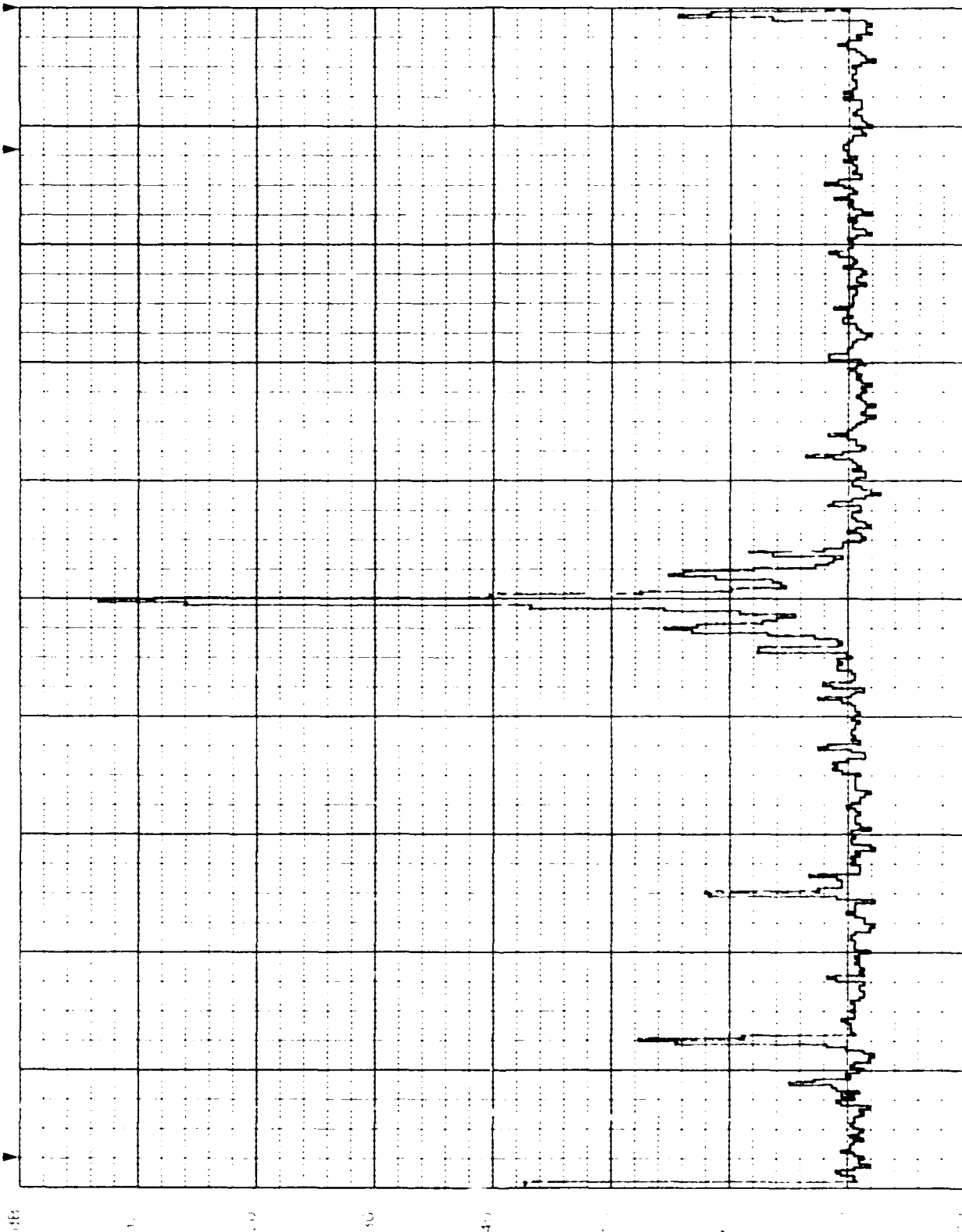
Brüel & Kjær Time from Test Start Span End Not Expanded Expanded

Full Scale Level 130
 F S Frequency 500
 Weighting Hann
 Average Mode Lin
 No of Spectra 64
 Comments
 Calibration
 250Hz-123.2dB
 25KVA GE
 SN P217059-Y2A

B-60

*Copy
 Angelo
 Lucchese*

Record No. 28-87
 Date
 Sign J. Keller



APPENDIX A.4

RIV TEST REPORT

APPENDIX A.5

SHORT CIRCUIT TEST REPORTS



McGRAW-EDISON
POWER SYSTEMS

Mr. Dorman Whitley
Westinghouse Electric Corporation
Newton Bridge Road
Athens, GA 30613

January 16, 1987

Subject: Distribution Transformer Test Report

Dear Dorman,

Enclosed is the test report covering the Short Circuit test on one General Electric™ Distribution Transformer. The tests were performed on January 16, 1987 at the McGraw-Edison Technical Center in Franksville, WI.

McGraw-Edisons' or Cooper Industries' company name may be used in promotional literature only if written permission is received for each complete copy of promotional material received.

It was a pleasure testing for you Dorman and we look forward to seeing you in the future.

Sincerely,

Ross Daharsh
Manager, Power Test Laboratories

1-(414)-835-1560
TECHNICAL CENTER

11131 Adams Road
PO Box 100
Franksville, WI 53126
414/835-2921

B-64



McGRAW-EDISON POWER SYSTEMS

WESTINGHOUSE ELECTRIC CORP.

SHORT CIRCUIT TESTS ON ONE GENERAL ELECTRIC™ DISTRIBUTION TRANSFORMER

Performed By:

**McGraw-Edison Power Testing Laboratories
McGraw-Edison Company
Division of Cooper Industries
11131 Adams Road
Franksville, WI 53126**

Test Date: January 16, 1987

TECHNICAL CENTER

11131 Adams Road
PO Box 100
Franksville, WI 53126
414/835-2921

B-65

Research Reports



McGRAW-EDISON
POWER SYSTEMS

INTRODUCTION:

The test program consisted of a standard ANSI C57.12.90-1980 Short Circuit Test Series on one General Electric™ 25 KVA Transformer, Serial Number P217059 YZA. This transformer had a Primary Voltage of 4160/7200 WYE and a Secondary Voltage of 120/240. The nameplate impedance was 2.51 % at 85° C. The test program was performed at the McGraw-Edison Technical Center in Franksville, WI under the direction of Mr. Dorman Whitley from the Westinghouse Electric Corporation. The test was performed on January 16, 1987.

PROCEDURE:

The transformer was impedance checked before, during and after the Short Circuit Tests using the classical E/I method. 5 Amperes of current was circulated in the secondary winding with the primary open circuited. The resulting secondary voltage was recorded. The current was metered with a Weston Ammeter, Model Number 370, Serial Number 6911. The voltage was monitored with a Fluke digital voltmeter Model 8000A, Serial Number 30437.

The test program was started with a magnetizing inrush current test shot followed by a reduced voltage check shot to verify impedances and metering. This was followed by the 6 ANSI test shots; 3 symmetric, 3 asymmetric; 15 cycles in length except for the long time shot required for heating. This shot was a minimum of 47 cycles in length. The impedance was checked after each test shot. The short circuit test data was recorded on a Honeywell Model 1912 Magnetic oscillograph. All recorded data has a laboratory accuracy of $\pm 3\%$.

RESULTS:

The original data sheets and oscillograms from the test program are included in the report Appendix.

The transformer passed the test program with a impedance change of 5.75%.

TECHNICAL CENTER

11131 Adams Road
PO Box 100
Franksville, WI 53126
414/835-2921



McGRAW-EDISON
POWER SYSTEMS

CERTIFICATION OF PERFORMANCE

BY

WESTINGHOUSE ELECTRIC CORPORATION

Short Circuit Tests on a 25 KYA
General Electric™ Distribution Transformer

Serial Number P217059 YZA

This is to certify that the above transformer was tested at the McGraw-Edison Thomas A. Edison Technical Center on January 16, 1987 in accordance with ANSI Standard C57.12.90-1980.

All data recorded and presented has a laboratory accuracy of $\pm 3\%$.

REFERENCE OSCILLOGRAMS

87C337 - 87C345

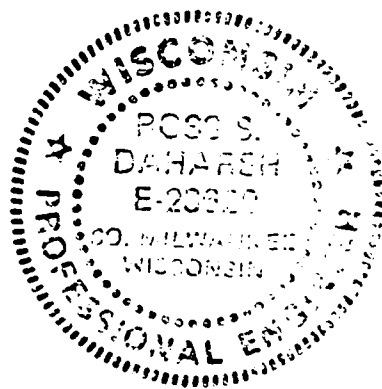
The total impedance change was 5.75% after the completion of the 6 test shots.

By the performance of these tests McGraw-Edison does not recommend or endorse the use or application of the products, devices or systems tested.

Ross S. Daharsh
Manager, Power Test Laboratories

TECHNICAL CENTER

11131 Adams Road
PO Box 100
Franksville, WI 53126
414/835-2921





McGRAW-EDISON
POWER SYSTEMS

APPENDIX

1. Original Film Data Sheet
2. Calibration Sheet
3. Original Oscillograms

TECHNICAL CENTER

11131 Adams Road
PO Box 100
Franksville, WI 53126
414/835-2921

B-68

THIS UNIT IS SERIAL NO. 0001
IT IS A 25 KVA RATED 4.16 KV AND 6.00962 AMPS
IT IS A CATEGORY 1 TRANSFORMER
SHORT CIRCUIT IMPEDANCE IS 15.728 OHMS
< 6.78217 +Jx 14.1906 >
%IZ= 2.2721 %IX= 2.05 %IR= .979765
40 TIMES RATED I IS 240.385 AMPS
LONG TIME TEST IS 46.25 CYCLES
MAXIMUM IMPEDANCE CHANGE IS 11.1395 PERCENT
'K' FACTOR<PK ASYM/RMS SYM> IS 1.76602

Job No. 66M87Y006C Test Date 1/16/87
Data Read & Recorded By, Date 1/12/87 J. Gengen

Test Date 1/16/97

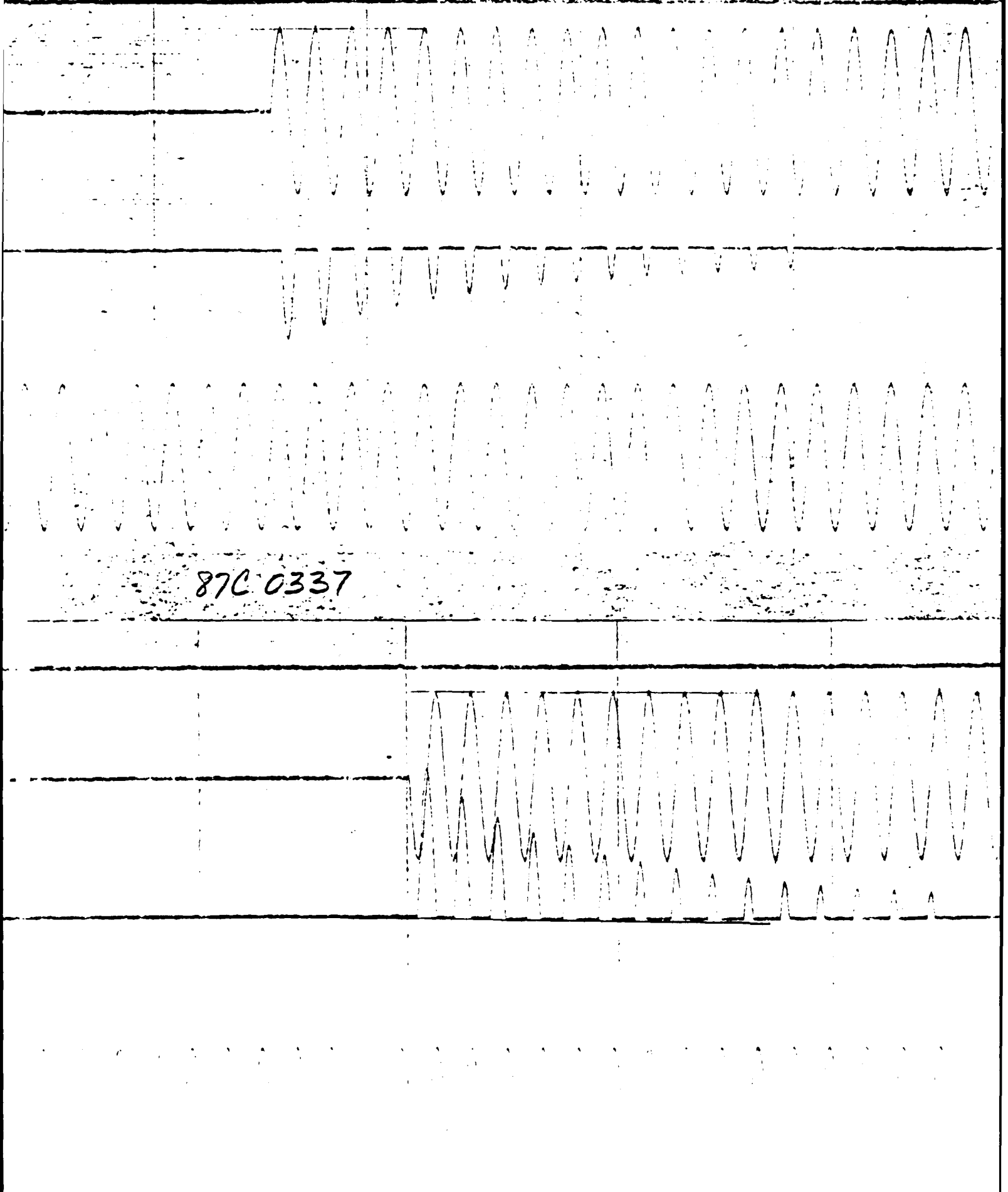
Request 14-66-01

[illegible]

POWER TEST LABS

COMPANY Westinghouse Elec TEST 25kVA TRANS
PROJECT NO. 66MELV006C REQUEST NO. 14-66-01
DATA BY 116187 DATE 11/16/87

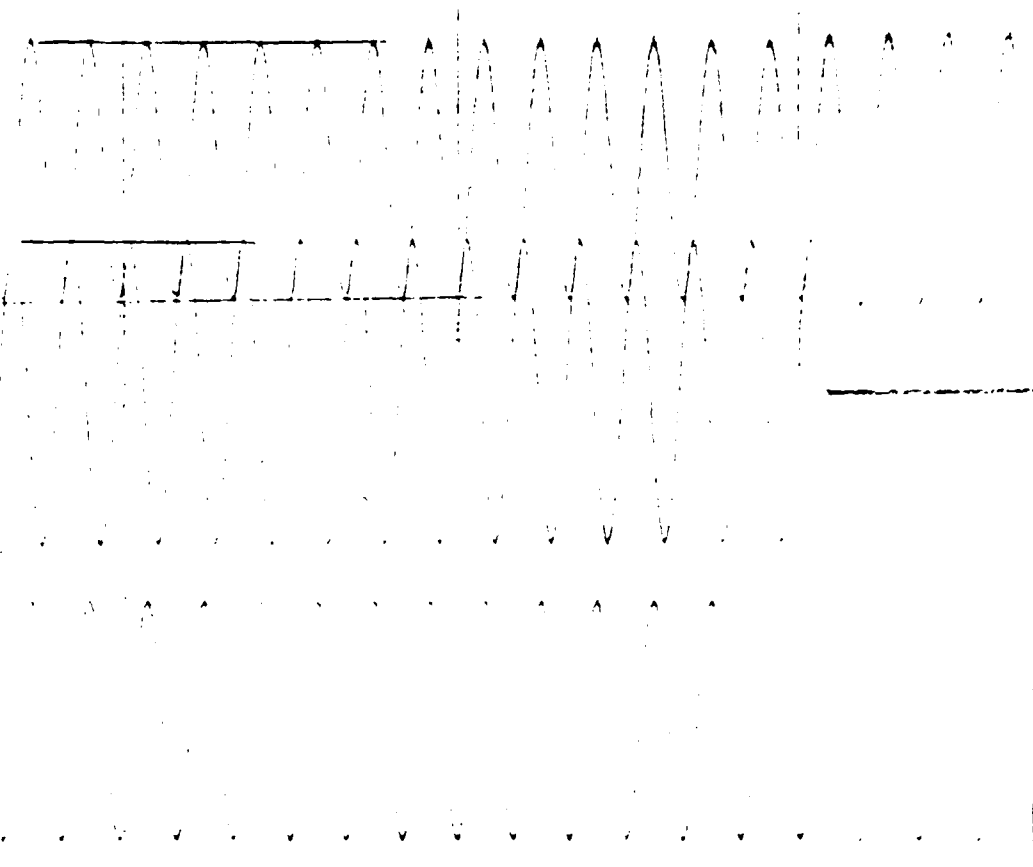
[illegible]



87C 0337

8700339

8700340



87C0341

87C 0343

87C 0344

CONDITION: FOLLOWING SHORT CIRCUIT, SOUND LEVEL, AND FIV

STYLE: G.E. 25KVA AMORPHOUS METAL POLE TYPE

LV: 120/240 HV: 41601 75KV SIL SERIAL #: F017059-12A

RATIO	PASS	* HV RESISTANCE (OHMS)	4.692
POLARITY	PASS	* LV RESISTANCE (OHMS)	0.01044
FULL WAVE IMPULSE	PASS	* I SQUARED R LOSS (WATTS)	110.9
APPLIED POTENTIAL - RLIC	PASS	* STRAYS	10.1
APPLIED POTENTIAL - LRIC	PASS	* LOAD LOSS (WATTS)	324.6
INDUCED POTENTIAL - 400 HZ	PASS	TOTAL LOSS (WATTS)	345.0
VL LOSS (WATTS)	19.0	* % RESISTANCE	1.00
% EXCITING CURRENT	0.998	* % REACTANCE	0.02
% EFFICIENCY @ PF=1	98.6	* % IMPEDANCE	0.97
% EFFICIENCY @ PF=0.9	98.0	% REGULATION @ PF=1	1.02
		% REGULATION @ PF=0.9	0.97

TEST ENGINEER:

Gregg V. Jones
GREGG V. JONES

* CORRECTED TO 35 DEGREES C

APPENDIX A.7

IMPULSE-ENERGIZED TEST REPORTS

TEST RECORD

LABORATORY

Everhead

SUBJECT: [REDACTED]

SUBJECT and hopped wave and deep front inputs are an energy good

TO DETERMINE

Handwritten: *Handwritten*

CUSTOMER

NAVY

ဝံ
ဟံ

L.SPEC.

TIMING CURVE

SERIAL P217060-Y2A

TEMPERATURE DRY BULB	WET BULB	BAROMETER	ABSOLUTE HUMIDITY	RELATIVE AIR DENSITY
I	6.0 deg. as continued and suggested in Q1251	(57.12 90-4940 Sec 105		
	specifies in 10511 that parameters given in Table 4			
	That was interpreted separately with a battery generator (done, pending)			
	from the L.V. side to the test transformer. The capacitor			
	discharged on the "out" side of the AC cycle since wave was to add together.			
	<u>Test equipment and results</u>			
I	Reduced full wave to each bushing H1 results: 46.4kV H2 46.8kV (emerged)			
II	2 chopped waves per bushing Lab results 4 shot to H2 bushing 70.4kV, 76kV, 81.1kV, 83.8kV (emerged)			
	(Barometer set up for future test gap 14mm = 50.475)			
	* 2 waves (2 per 4.5 arcmin)			
III	400 hertz 18 arcmin insulation at 2x rated voltage of transformer = Lab results - passed			
IV	2 steep front impulses per bushing Lab 135kV crest and slope at .5 microsecond			
	Lab results: H1: Q125, 126.6kV H2 Q1344kV (2) 136.1kV (emerged)			
	appeared to have passed			
V	400 hertz 18 arcmin insulation at 2x rated voltage of transformer - Lab results passed			
VI	1 shot per bushing at 75kV full wave (emerged)			
VII	400 hertz test and applied 265kV HV insulation test - passed			
	10kV L.V. insulation test passed			

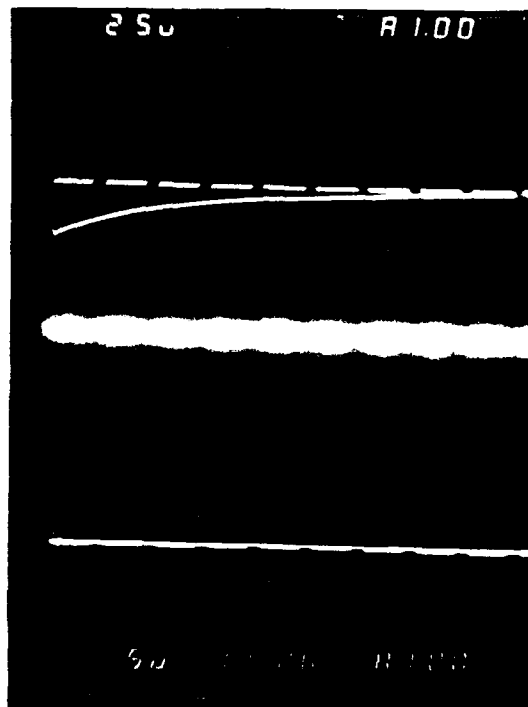


Figure A.7.1A. Reduced Full Wave - Bushing 1

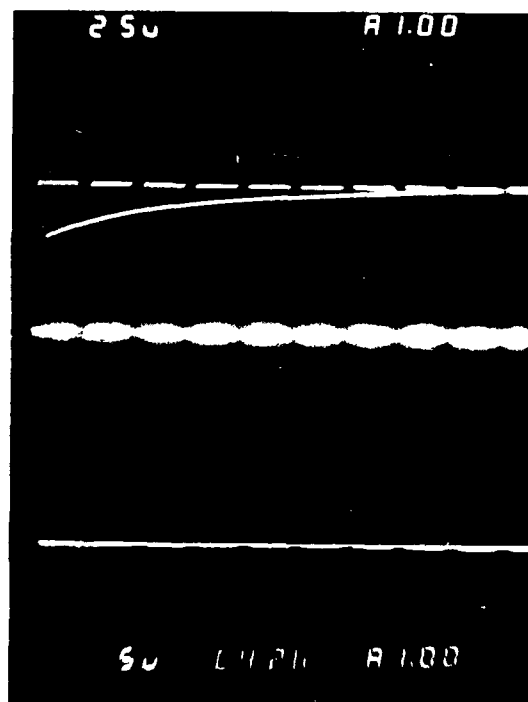


Figure A.7.1B. Reduced Full Wave - Bushing 2

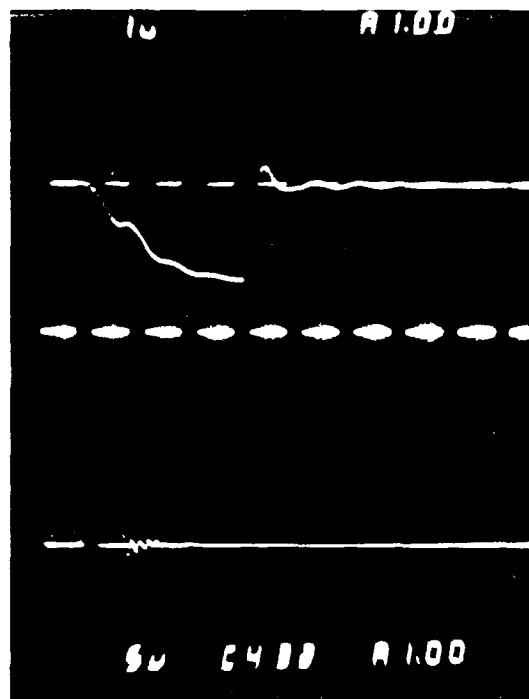
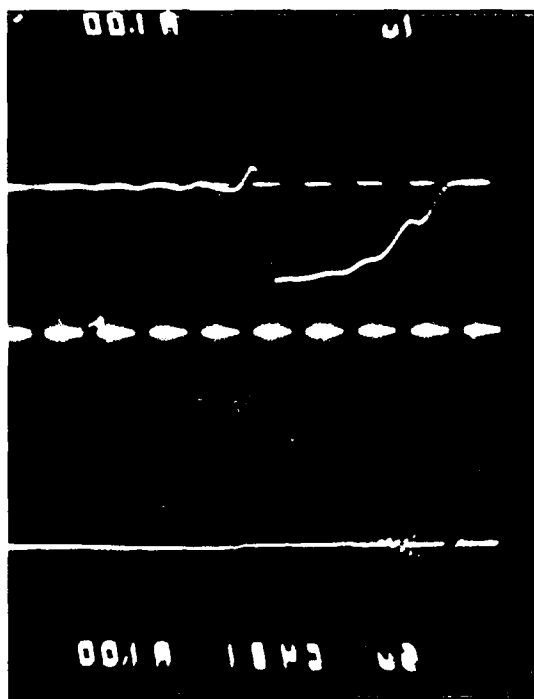


Figure A.7.2A. Chopped Wave - Bushing 1 Shot 1 Figure A.7.2B. Chopped Wave - Bushing 1 Shot 2

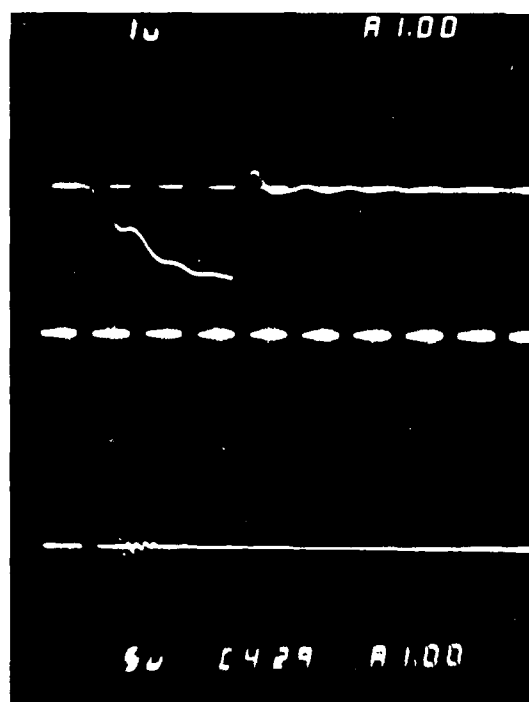
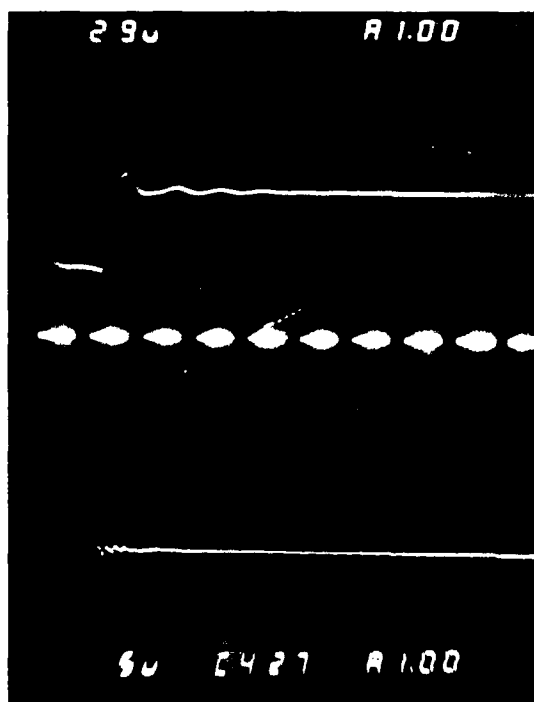


Figure A.7.2C. Chopped Wave - Bushing 2 Shot 1 Figure A.7.2D. Chopped Wave - Bushing 2 Shot 2

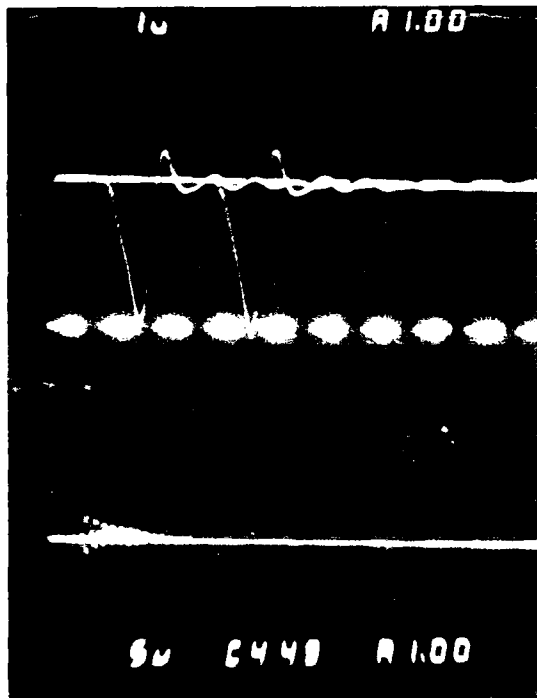


Figure A.7.3A. Front of Wave -
Bushings 1

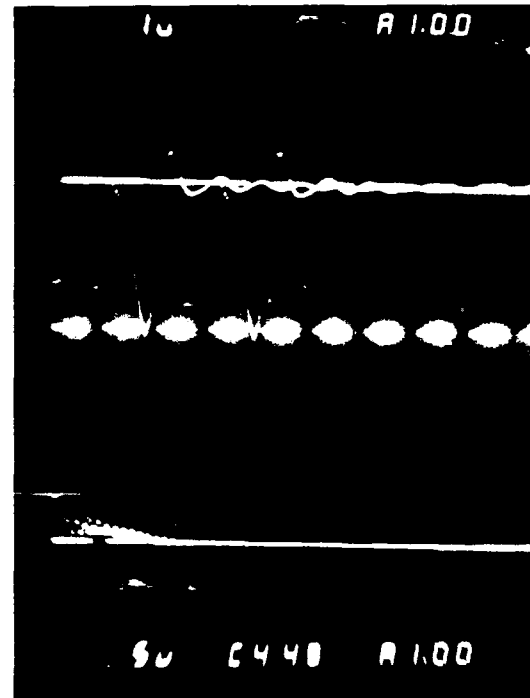


Figure A.7.3B. Front of Wave -
Bushings 2

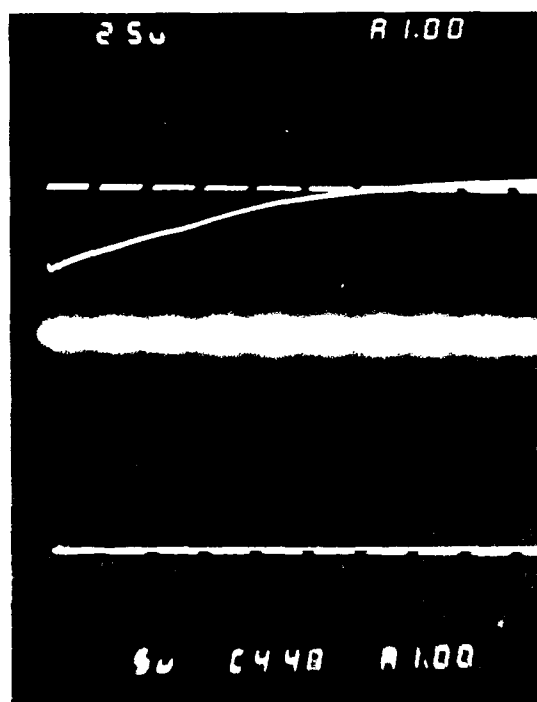


Figure A.7.4A. Full Wave -
Bushings 1

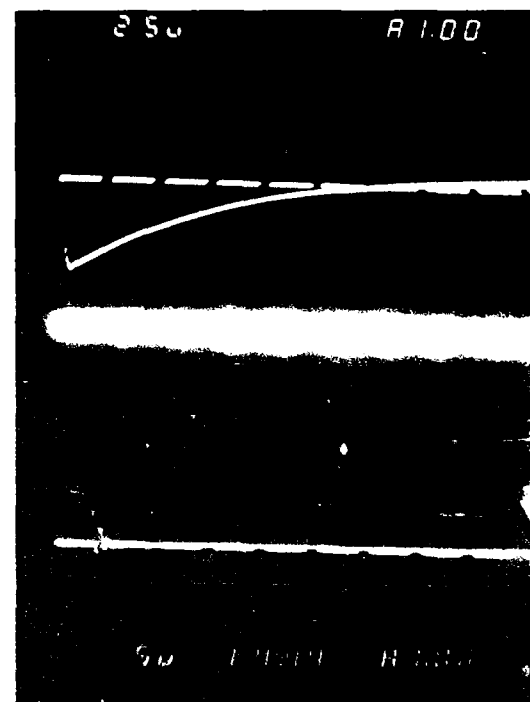


Figure A.7.4B. Full Wave -
Bushings 2

APPENDIX A.8

SAFE TRANSIT TEST REPORTS

TABLE A-1

FOR THE WIND TEST OF THE 1000 LBS. 1000 LBS. 1000 LBS.

START TIME 10:15 AM 10:15 AM 10:15 AM

TRANSFERRED FROM 1000 LBS. 1000 LBS. 1000 LBS.

0 HOURS

WIND	WIND	WIND	1 (GROSS)	21	22	23
100	100	100	0.177	0.07	15.9	15.9
120	100	120	0.213	0.10	19.7	19.7
132	110	132	0.353	0.19	27.9	27.9

1 HOURS

WIND	WIND	WIND	1 (GROSS)	21	22	23
100	90	100	0.177	0.07	15.9	15.9
120	100	120	0.213	0.10	19.7	19.7
132	110	132	0.353	0.19	27.9	27.9

2 HOURS

WIND	WIND	WIND	1 (GROSS)	21	22	23
100	90	100	0.177	0.07	15.9	15.9
120	100	120	0.213	0.10	19.7	19.7
132	110	132	0.353	0.19	27.9	27.9

3 HOURS

WIND	WIND	WIND	1 (GROSS)	21	22	23
100	90	100	0.177	0.07	15.9	15.9
120	100	120	0.213	0.10	19.7	19.7
132	110	132	0.353	0.19	27.9	27.9

END OF TEST

Gregg V Jones

1000 LBS. 1000 LBS. 1000 LBS.

WESTINGHOUSE STD COMMERCIAL TEST REPORT

DATE: 02/10/87

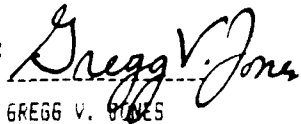
CONDITION: FOLLOWING FOUR HOUR SHAKE

STYLE: 6.E. 25kVA AMORPHOUS METAL POLE TYPE FOR

LV: 120/240 HV: 41601 75KV BIL SERIAL #: P217059-Y2A

RATIO	PASS	* HV RESISTANCE (OHMS)	4.632
POLARITY	PASS	* LV RESISTANCE (OHMS)	0.01344
FULL WAVE IMPULSE	PASS	* I SQUARED R LOSS (WATTS)	313.2
APPLIED POTENTIAL - HLIC	PASS	* STRAYS	3.8
APPLIED POTENTIAL - LHIC	PASS	* LOAD LOSS (WATTS)	317.0
INDUCED POTENTIAL - 400 HZ	PASS	TOTAL LOSS (WATTS)	335.2
NL LOSS (WATTS)	19.2	* % RESISTANCE	1.27
% EXCITING CURRENT	0.0968	* % REACTANCE	2.15
% EFFICIENCY @ PF=1	99.7	* % IMPEDANCE	2.50
% EFFICIENCY @ PF=.8	98.3	% REGULATION @ PF=1	1.29
		% REGULATION @ PF=.8	2.31

TEST ENGINEER:


GREGG V. JONES

* CORRECTED TO 35 DEGREES C

WESTINGHOUSE LTD COMMERCIAL TEST REPORT

DATE: 02.11.97

CONDITION: FOLLOWING FOUR FOOT DROP

STYLE: G.E. 25KVA AMORPHOUS METAL POLE TYPE

LV: 120/240 HV: 4160 75KV BIL SERIAL #: P217059-YZA

RATIO	PASS	* HV RESISTANCE (OHMS)	4.662
POLARITY	PASS	* LV RESISTANCE (OHMS)	0.01354
FULL WAVE IMPULSE	PASS	* I SQUARED R LOSS (WATTS)	315.0
APPLIED POTENTIAL - HLIC	PASS	* STRAYS	8.7
APPLIED POTENTIAL - LHIC	PASS	* LOAD LOSS (WATTS)	324.0
INDUCED POTENTIAL - 400 HZ	PASS	TOTAL LOSS (WATTS)	342.8
NL LOSS (WATTS)	18.8	* % RESISTANCE	1.30
% EXCITING CURRENT	0.11	* % REACTANCE	2.21
% EFFICIENCY @ PF=1	98.6	* % IMPEDANCE	2.56
% EFFICIENCY @ PF=.8	98.3	% REGULATION @ PF=1	1.32
		% REGULATION @ PF=.8	2.77

TEST ENGINEER:

Gregg V. Jones
GREGG V. JONES

* CORRECTED TO 35 DEGREES C

APPENDIX A.10

COLD LOAD PICKUP TEST REPORTS

TEST RECORD *Albany* LABORATORY *Overhead* No 01099 -1
 SUBJECT *Cold load pickup test on a 250VA GE transformer*
 TO DETERMINE *load handling capability at cold temperature*
 CUSTOMER *APT /NAVY*

S. O. L-SPEC. TIMING CURVE SERIAL *P217061-YZA*

TEMPERATURE DRY BULB	WET BULB	BAROMETER	ABSOLUTE HUMIDITY	RELATIVE AIR DENSITY		
oil change						
State here temp	temp	Load	A	V	W	hours
3/12 7:45 -34 -38		200	12.00	185	788	0 start up 200% loading
8:15 -33 -38		200	12.06	194	930	0.5
8:30 -30 -38		200	12.1	196	985	0.75
8:45 -25 -38		200	12.04	196	1000	1.0
9:30 -8 -38		200	12.03	198	1066	1.75
9:45 -3 -38		200	12.01	1985	1077	2.0 Complete 2 hour minimum 200% loading
BEGINS 6 HOURS AT 100% LOADING						
9:45 -3 -38		100	6.00	100.0	276	0
11:45 -3 -38		100	6.00	985	240	2
1:30 P -6 -38		100	6.00	978	244	3.75
2:15 -7 -38		100	6.00	968	2388	4.30
3:00 -7 -38		100	6.03	974	2411	5.25
3:45 -8 -38		100	6.02	972	2411	6.0
* thermocouple temperature only after some approx 1 hour warm up time at 100% to center of transformer						

PREVIOUS TEST PAGE TESTED BY *Will K. H. H.* REPORTED BY *Will K. H. H.* ENGINEER DATE *3/12/51*

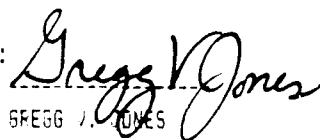
CONDITION: FOLLOWING COLD LOAD PICK UP

STYLE: S.E. 25KVA AMORPHOUS METAL POLE TYPE

LV: 120/240 HV: 41604 25KV BIL SERIAL #1P217051-12A

RATIO	PASS	* HV RESISTANCE (OHMS)	4.522
POLARITY	PASS	* LV RESISTANCE (OHMS)	0.01304
FULL WAVE IMPULSE	PASS	* I SQUARED R LOSS (WATTS)	308.4
APPLIED POTENTIAL - HLIC	PASS	* STRAY	19.5
APPLIED POTENTIAL - LHIC	PASS	* LOAD LOSS (WATTS)	319
INDUCED POTENTIAL - 400 HZ	PASS	TOTAL LOSS (WATTS)	337.5
VL LOSS (WATTS)	19.5	* % RESISTANCE	1.28
% EXCITING CURRENT	0.18	* % REACTANCE	2.12
% EFFICIENCY @ PF=1	99.7	* % IMPEDANCE	2.48
% EFFICIENCY @ PF=.8	98.3	% REGULATION @ PF=1	1.3
		% REGULATION @ PF=.8	2.3

TEST ENGINEER:



 GREGG V. JONES

* CORRECTED TO 95 DEGREES C

APPENDIX A.11

SATURATION/REGULATION/EFFICIENCY TEST REPORTS

TEMPERATURE TEST RECORD

W. B. THINGHOUSE FORM 4857K

DTD LAB PAGE No 00733

TRANSFORMER PC TYPE 25 K.V.A. TRANSFORMER STYLE Gene of Shetland
 CONNECTED H.V. 4140 VOLTS L.V. 120/240 VOLTS
 LOAD H.V. 100 AMPS L.V. 6.00 AMPS 60 CYCLES
 WATTS PER LB. H.V. 7.68 L.V. 5.88 MAGNETIZED VOLTS 0 CYCLES ON 0
 GALLONS OIL NAVD 1 AC 100 CIRCUIT TEST METHOD Compromise NO OF RADIATORS 0 NO TUBES 0
 REMARKS NAVD 1 AC 100 Compromise Amorphous core

SERIAL # P217061

TIME AFTER SHUTDOWN		TEMP. H.V. WINDING BY RESISTANCE					TIME AFTER SHUTDOWN		TEMP. L.V. WINDING BY RESISTANCE				
MIN.	SEC.	AMB. TEMP.	BRIDGE READING	RATIO OR K	OHMS	TEMP BY RES.	MIN.	SEC.	AMB. TEMP.	BRIDGE READING	RATIO OR K	OHMS	TEMP BY RES.
1	15	25.5			3.77				25.5			0.01062	
					4.535	76.00						0.01275	75.74
						0.65							0.76
						76.65							76

CALC. H.V. WINDING RISE $76.65 - 66.8 = 9.85$ $9.85 + 39.2 = 49.05^\circ\text{C}$
 DIFF Winding rise

CALC. L.V. WINDING RISE $76.5 - 66.8 = 9.7^\circ\text{C}$ $9.7 + 39.2 = 48.9^\circ\text{C}$
 DIFF Winding rise

TEMPERATURE READINGS				TEMPERATURE RISE				WATTMETER AND VOLTMETER
HOURS	TIME	TOP OIL	BTTM. OIL	AMB. OIL	TOP OIL	BTTM. OIL		
Steady State		67.3			28.1	39.25	Compromise - St Steady	
C		67.3			28.1	39.2	- Begin 2 hrs at rated I	
2		66.8			28.1	38.7	Shut down	

LOAD TEST AT 25.5 C

AMPS 6.00

VOLTMETER 986

WATTMETER 259.45

Lab - magnetron analyzer

NO LOAD TEST

(T.W.) WATTMETER 1832

(A.W.) VOLTS 240 X AMPS 1.99

47.76 VA

TIME CONSTANT

63.3 X 0 C OIL RISE

TIME CONSTANT 0 HRS. 0 MIN.

	<u>Begin Compromise</u>	<u>Compromise St Steady</u>	<u>Begin 2 hrs at rated I</u>	<u>Shut down</u>
Amperes	6.18	6.18	6.00	6.00
Volts	102	106	102.8	102.8
Watts	281.8	331.2	311.4	307.4

AL TYPE CONDUCTOR H.V.

AL TYPE CONDUCTOR L.V.

CALCULATED COMPROMISE CURRENT 6.18

OTHER REMARKS

This same unit was tested in back-back position as shown on P00726

TEST REQUESTED BY Greg Jones

DATE TESTED 3-11-57 BY Bill Behan

L.SPEC # N/A

TEMPERATURE TEST RECORD

W23TINGHOUSE FORM 4857K

DTD LAB PAGE No 00734

TRANSFORMER TYPE *File* TEMPERATURE TEST ON *25* K V A TRANSFORMER STYLE *an electric*
 CONNECTED H.V. *4160* VOLTS L.V. *120/240* VOLTS
 LOAD H.V. *50%* AMPS L.V. *3.00* AMPS *59 amp (104 ÷ 2)* AMPS *60* CYCLE
 WATTS PER LB. H.V. *50%* *4.32* L.V. *3.3* MAGNETIZED VOLTS CYCLES ON
 GALLONS OIL CIRCUIT TEST METHOD *Compromise* NO. OF RADIATORS NO TUBES
 REMARKS

SERIAL - *P217061*

TIME AFTER SHUTDOWN		TEMP. H.V. WINDING BY RESISTANCE										TIME AFTER SHUTDOWN		TEMP. L.V. WINDING BY RESISTANCE									
MIN	SEC	AMB TEMP	BRIDGE READING	RATIO OR K	OHMS	TEMP BY RES	CORRECTION TO SHDN	AVERAGE WINDING TEMP	MIN	SEC	AMB TEMP	BRIDGE READING	RATIO OR K	OHMS	TEMP BY RES	CORRECTION TO SHDN	AVERAGE WINDING TEMP	MIN	SEC	AMB TEMP	BRIDGE READING	RATIO OR K	OHMS
<i>1</i>	<i>05</i>	<i>25.5</i>			<i>3.77</i>	<i>4.055</i>	<i>44.44</i>	<i>0.31</i>	<i>44.75</i>	<i>1</i>	<i>45</i>	<i>25.5</i>			<i>0.1062</i>	<i>0.140</i>	<i>43.9</i>	<i>0.384</i>					

CALC. H.V. WINDING $44.75 - 41.2 = 3.55$ / $3.55 + 14.3 = 17.85^{\circ}\text{C}$ Winding rise
 RISE DIFF
 CALC. L.V. WINDING $44.28 - 41.2 = 3.08$ / $3.08 + 14.3 = 17.38^{\circ}\text{C}$ Winding rise
 RISE DIFF

TEMPERATURE READINGS				TEMPERATURE RISE				WATTMETER AND VOLTMETER		LOAD TEST AT	
HOURS	TIME	TOP OIL	BTM. OIL	AMB OIL	TOP OIL	BTM. OIL				AMPS	C
<i>1</i>	<i>05</i>	<i>42.1</i>		<i>27.8</i>	<i>14.3</i>	<i>50%</i>	<i>Compromise Current</i>				
<i>0</i>	<i>42.1</i>			<i>27.8</i>	<i>14.3</i>	<i>begin shen at rated</i>					
<i>2</i>	<i>4.2</i>			<i>27.7</i>	<i>2.5</i>	<i>Shutdown</i>					

Time rise		Winding shen		Shutdown	
Time	Rate	Time	Rate	Time	Rate
<i>3.33</i>		<i>3.00</i>		<i>3.1</i>	
<i>55.75</i>		<i>50.17</i>		<i>50.46</i>	
<i>86.1</i>		<i>69.5</i>		<i>71</i>	

NO LOAD TEST
 (T.W.) WATTMETER
 (A.W.) VOLTS X AMPS
 TIME CONSTANT
 63.3 X C OIL RISE
 TIME CONSTANT HRS MIN

AL TYPE CONDUCTOR H.V.
 AL TYPE CONDUCTOR L.V.

CALCULATED COMPROMISE CURRENT *3.33*

OTHER REMARKS

TEST REQUESTED BY *Leg Jones* DATE TESTED *3-12-57* BY *Bill Belvan* L SPEC *N/A*

WATSONHOUSE FORM 4857K

DTD LAB PAGE

№ 00735

TRANSFORMER Pre TEMPERATURE TEST ON 25 K.V.A. TRANSFORMER STYLE Gen. of Electric
TYPE: _____
CONNECTED H.V. 4160 VOLTS L.V. 120/240 VOLTS
LOAD H.V. 150% 9.0 AMPS. L.V. 156 AMPS. 60 CYCLES
WATTS PER LB. H.V. 17.3 L.V. 13.23 MAGNETIZED _____ VOLTS _____ CYCLES ON. _____ V
GALLONS OIL _____ CIRCUIT TEST METHOD Compressive NO. OF RADIATORS 0 NO. TUBES 0
REMARKS NAVY - ACP

SERIAL # P217061

TIME AFTER SHUTDOWN		TEMP. H.V. WINDING BY RESISTANCE							TIME AFTER SHUTDOWN		TEMP. L.V. WINDING BY RESISTANCE						
MIN.	SEC.	AMB. TEMP.	BRIDGE READING	RATIO OR K	OHMS	TEMP. BY RES.	CORREC- TION TO SHDN.	AVE. WIND. TEMP.	MIN.	SEC.	AMB. TEMP.	BRIDGE READING	RATIO OR K	OHMS	TEMP. BY RES.	CORREC- TION TO SHDN.	A
		25.5			3.77						25.5				.01062		
1	23				5.265	12483	1.6	126.43	2	15					.01470	12173	1.85

CALC. H.V.
WINDING $126.43 - 106.4 = 20.0^{\circ}/20 + 78.6 = 98.6^{\circ}\text{C}$
RISE DIFF Winding Rise 15.6%

CALC. L.V. WINDING RISE $1236 - 106.4 = 17.2^{\circ}\text{C}$ Diff $17.2 + 786 = 958^{\circ}\text{C}$ Winding rise 15

HOURS	TIME	TEMPERATURE READINGS			TEMPERATURE RISE		WATTMETER AND VOLTMETER	LOAD TEST AT _____ C
		TOP OIL	BTTM. OIL	AMB. OIL	TOP OIL	BTTM. OIL		
Steady								AMPS _____
Stab 153%	107			28.4	78.6	- 15% Compressor Current		VOLTMETER _____
0	107			28.4	78.6	- began 2 hours at rated I x 15%		WATTMETER _____
2	106.4			28.3	78.1	- shut down		

NO LOAD TEST

(T.W.) WATTMETER

(A.W.) VOLTS _____ X AMPS

VA

TIME CONSTANT

63.3 X _____ °C OIL RISE - _____

TIME CONSTANT =

HRS. MIN.

9c TYPE CONDUCTOR H.V.

Qc TYPE CONDUCTOR L.V.

CALCULATED COMPROMISE 7.13
CURRENT _____

OTHER REMARKS

TEST
REQUESTED by 1000
BY by 1000

DATE 3-13-87
TESTED

BY Cecil Beltran

L.SPEC. : NA

DR. BROWN	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16
LUMPRINISE																
HARR. LURE ZORVA 41809																
240 UREA JUNE 20																
NEW ELECTRIC																

TIME	AMB	AMB	AMB	RIVER	61 TOP	RISE
13:25:00	25.80	24.90	25.90	25.5	26.00	0.5
14:25:00	25.90	25.00	26.10	25.6	30.30	4.7
15:25:00	26.30	25.40	26.50	26.0	36.20	10.2
16:25:00	26.70	25.80	26.90	26.4	41.20	14.8
17:25:00	27.10	26.10	27.20	26.8	45.40	18.6
18:25:00	27.40	26.40	27.50	27.1	49.00	21.9
19:25:00	27.60	26.60	27.70	27.3	51.90	24.6
20:25:00	27.90	26.80	27.90	27.5	54.50	27.0
21:25:00	28.00	26.90	28.10	27.6	56.60	29.0
22:25:00	28.20	27.00	28.20	27.8	58.40	30.6
23:25:00	28.30	27.00	28.40	27.9	59.90	32.0
00:25:00	28.40	27.10	28.50	28.0	61.50	33.5
01:25:00	28.50	27.10	28.50	28.0	62.90	34.9
02:25:00	28.60	27.20	28.60	28.1	64.10	36.0
03:25:00	28.60	27.20	28.70	28.1	65.10	37.0
04:25:00	28.70	27.20	28.70	28.2	65.90	37.7
05:25:00	28.70	27.20	28.80	28.2	66.50	38.3
06:25:00	28.70	27.10	28.80	28.2	67.00	38.8
07:25:00	28.70	27.10	28.80	28.2	67.30	39.1
07:32:56	28.70	27.10	28.80	28.2	67.30	39.1
08:25:00	28.70	27.00	28.80	28.1	67.40	39.3
09:00:00	28.70	27.00	28.80	28.1	67.30	39.2
10:00:00	28.70	26.90	28.80	28.1	67.00	38.9
11:00:00	28.70	26.90	28.80	28.1	66.80	38.7

— Steady state — begin 2 hrs at rated $\pm$ (6.00 AMPs)
 — Shu + down

39.5
39.2 — steady state — begin 2 hrs at Rated I (6.00 AMPs)
38.9
38.7 — Shk + down

[illegible]

Steady State - begin 2 hrs. at rated I (7.00 amps)

0071 700	01 AMB	02 AMB	03 AMB	04 AVER.	05 61 TOP	06 RISE	07 08 09 10 11 12 13 14 15	16
12:16:00	27.80	26.20	27.80	27.2	38.60	11.4		
12:20:09	27.80	26.20	27.80	27.2	38.50	11.3		
12:21:00	27.80	26.20	27.80	27.2	38.50	11.3		
15:21:00	27.90	26.30	28.10	27.4	68.40	41.0		
16:21:00	28.40	26.80	28.50	27.9	86.60	58.7		
21:21:00	28.80	27.10	28.90	28.2	95.60	67.4		
00:21:00	28.80	27.10	29.10	28.3	101.10	72.8		
03:21:00	29.00	27.30	29.30	28.5	105.40	76.9		
06:21:00	29.20	27.40	29.40	28.6	107.30	78.7		
07:23:58	29.10	27.30	29.30	28.5	107.20	78.7		
07:27:00	29.10	27.30	29.40	28.6	107.20	78.6		
08:27:00	29.10	27.20	29.30	28.5	107.10	78.6		
09:09:00	29.00	27.10	29.20	28.4	107.00	78.6		
10:09:00	29.00	27.10	29.20	28.4	106.60	78.2		
11:03:49	28.90	27.00	29.20	28.3	106.40	78.1		
11:09:00	28.90	27.00	29.20	28.3	106.40	78.1		

— begin sho at 150% X noted
— shut down

TEMPERATURE TEST RECORD

WELSHINGHOUSE FORM 4857K

DTD LAB PAGE No 00736

TRANSFORMER Pol TYPE: 4160 TEMPERATURE TEST ON 25 K.V.A. TRANSFORMER STYLE General Electric
 CONNECTED H.V. 50% VOLTS L.V. 120/240 VOLTS
 LOAD H.V. 50% AMPS L.V. 52 AMPS 60 CYCLES
 WATTS PER LB. H.V. Cooling curve L.V. 52 MAGNETIZED VOLTS CYCLES ON 60
 GALLONS OIL 1 CIRCUIT TEST METHOD Compromise NO. OF RADIATORS 0 NO. TUBES 2
 REMARKS slow cooling curve

SERIAL # 239216

TIME AFTER SHUTDOWN		TEMP. H.V. WINDING BY RESISTANCE							TIME AFTER SHUTDOWN		TEMP. L.V. WINDING BY RESISTANCE						
MIN.	SEC.	AMB. TEMP.	BRIDGE READING	RATIO OR K	OHMS	TEMP. BY RES.	CORREC. TION TO SHDN.	AVE. WIND. TEMP.	MIN.	SEC.	AMB. TEMP.	BRIDGE READING	RATIO OR K	OHMS	TEMP. BY RES.	CORREC. TION TO SHDN.	A
1	01	55			5172				25		01555						
					5.650	48.4	0.63	49.03	1	39	01690				47.24	0.32	47
by cooling curve - 49.03									by cooling curve - 47.56								
CALC. H.V. WINDING RISE $49.03 - 48.0 = 1.03^{\circ}\text{C}$ DIFF $1.03 + 22.6 = 23.63^{\circ}\text{C}$ H.V. winding rise									CALC. L.V. WINDING RISE $47.56 - 48 = -0.56$ DIFF $-0.56 + 22.6 = 22.04^{\circ}\text{C}$ L.V. winding rise								

HOURS		TIME		TEMPERATURE READINGS		TEMPERATURE RISE		WATTMETER AND VOLT METER	
		TOP OIL	BTTM. OIL	AMB. OIL	TOP OIL	BTTM. OIL			
Steady		51.0	41.3	28.4	22.6		Compromise Curve		LOAD TEST AT <u>25</u> C
Stale									AMPS <u>6.00</u>
0		51.0	41.3	28.4	22.6		Begin 2 hours at rated I		VOLTMETER <u>111.6</u>
2		48.0	39.5	27.1	20.2		Shutdown		WATTMETER <u>366.21</u>

Lab instrument
 NO LOAD TEST
 (T.W.) WATTMETER 66.33
 (A.W.) VOLTS 209.1 X AMPS 3.79 VA

TIME CONSTANT
 63.3 X °C OIL RISE =
 TIME CONSTANT = HRS. MIN.

AL TYPE CONDUCTOR H.V.

AL TYPE CONDUCTOR L.V.

CALCULATED COMPROMISE CURRENT 50% = 3.79

OTHER REMARKS

	Compromise	Begin 2 hrs at rated I	Shutdown
Ammeter	3.801	3.00	3.00
Voltmeter	73.6	58.1	58.0
Wattmeter	163.7	102.0	101.5

TEST REQUESTED BY Key Jones DATE TESTED 3-16-87 BY Bill Beltran L.SPEC. # N/A

WEATINGHOUSE FORM 4857K

№ 00737

TEST REQUESTED BY W. Jones DATE TESTED 3-18-57 BY Bill Belvan L.SPEC. # —

TEMPERATURE TEST RECORD

WESTINGHOUSE FORM 4857K

DTD LAB PAGE No 00736

TRANSFORMER TYPE: Pole TEMPERATURE TEST ON 25 K.V.A. TRANSFORMER STYLE General Electric
 CONNECTED H.V. 4160 VOLTS L.V. 120/240 VOLTS
 LOAD H.V. 1507 AMPS L.V. 9.0 AMPS 60 CYCLES
 WATTS PER LB. H.V. Cooling Curve L.V. 9.0 MAGNETIZED 9.0 VOLTS 60 CYCLES ON 9.0
 GALLONS OIL 9.0 CIRCUIT TEST METHOD Compromise NO. OF RADIATORS 9.0 NO TUBES 9.0
 REMARKS 9.0

TEMP. H.V. WINDING BY RESISTANCE										TEMP. L.V. WINDING BY RESISTANCE									
TIME AFTER SHUTDOWN	MIN.	SEC.	AMB. TEMP.	BRIDGE READING	RATIO OR K	OHMS	TEMP. BY RES.	CORREC. TION TO SHDN.	AVE. WIND. TEMP.	TIME AFTER SHUTDOWN	MIN.	SEC.	AMB. TEMP.	BRIDGE READING	RATIO OR K	OHMS	TEMP. BY RES.	CORREC. TION TO SHDN.	AVE. WIND. TEMP.
1 11			25.5			5.172				1 54			25.5			0.1555			
						7.639	14498	-	14498							102264	1397	-	13.1

CALC. H.V. WINDING RISE $14498 - 128.3 = 16.68^{\circ}C$ DIFF $16.68 + 100.8 = 117.48^{\circ}$ winding rise
 CALC. L.V. WINDING RISE $139.7 - 128.3 = 11.4^{\circ}C$ DIFF $11.4 + 100.8 = 112.2^{\circ}C$ winding rise

TEMPERATURE READINGS					TEMPERATURE RISE					WATTMETER AND VOLTMMETER				
HOURS	TIME	TOP OIL	BTTM. OIL	AMB. OIL	TOP OIL	BTTM. OIL	AMB. OIL	TOP OIL	BTTM. OIL	WATTMETER	AND	VOLTMMETER	LOAD TEST AT	C
Steady													AMPS	
1	1297	95.3			289	100.8							VOLTMETER	
2	1283	94.8			289	100.8							WATTMETER	
					287	99.6							see Page 00737	

NO LOAD TEST
 (T.W.) WATTMETER
 (A.W.) VOLTS X AMPS = VA

TIME CONSTANT
 63.3 X 9.0 $^{\circ}C$ OIL RISE =
 TIME CONSTANT = HRS. MIN

OL TYPE CONDUCTOR H.V.
 OL TYPE CONDUCTOR L.V.

CALCULATED COMPROMISE CURRENT
 OTHER REMARKS

TEST REQUESTED BY Irey Jones DATE TESTED 3-18-87 BY Bill Belvan L.SPEC. #

7	B. BELVAN ATHENS	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16
0072					COMPROMISE	STEEL CORE	25KV	1160V	240	GREG JONES	16	MAR 87	GEN ELECTRIC	P239216	50 PCT		

7	B. BELVAN ATHENS	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16
0072					COMPROMISE	STEEL CORE	25KV	1160V	240	GREG JONES	16	MAR 87	GEN ELECTRIC	P239216	50 PCT		

7	B. BELVAN ATHENS	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16
0072					COMPROMISE		STEEL CORE	25KV	1160V	240	GREG JONES	16 MAR 87	GEN ELECTRIC	P239216	50 PCT		

st. state - begin 2 hrs of rated
50%

Shutdown

C076	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16
700	AMB	AMB	AMB	AMER.	16 TOP	RISE	BTM OIL									
15:15:00	26.60	25.50	26.70	26.2	48.40	22.2	39.30									
17:15:00	27.20	26.20	27.40	26.9	82.10	55.2	54.50									
19:15:00	28.00	27.00	28.20	27.7	101.60	73.8	70.80									
21:15:00	28.50	27.40	28.80	28.2	112.10	83.9	80.50									
23:15:00	28.90	27.70	29.20	28.6	117.60	89.0	85.70									
01:15:00	29.20	28.00	29.60	28.9	122.40	93.5	89.50									
03:15:00	29.60	28.20	29.90	29.2	125.20	96.0	92.00									
05:15:00	29.90	28.40	30.20	29.5	126.60	97.1	93.40									
07:15:00	30.10	28.60	30.40	29.7	126.70	97.0	93.70									
07:22:56	30.10	28.60	30.40	29.7	126.70	97.0	93.70									
08:11:00	29.90	28.50	30.10	29.5	128.90*	99.4	94.20									
09:11:00	29.50	28.20	29.70	29.1	129.30*	100.2	94.50									
10:11:00	29.30	28.10	29.50	28.9	129.60*	100.7	95.10									
10:52:00	29.20	28.00	29.50	28.9	129.70*	100.8	95.30									
11:52:00	29.10	27.90	29.40	28.7	129.10*	100.4	95.30									
12:52:00	29.10	27.90	29.30	28.7	128.30*	99.6	94.80									
12:53:00	29.10	27.90	29.30	28.7	128.30*	99.6	94.80									
12:54:00	29.10	27.80	29.30	28.7	128.30*	99.6	94.80									
12:55:00	29.10	27.90	29.30	28.7	128.20*	99.5	94.70									
12:56:00	29.10	27.90	29.30	28.7	128.10*	99.4	94.60									
12:57:00	29.10	27.90	29.30	28.7	128.00*	99.3	94.60									
12:58:00	29.10	27.90	29.30	28.7	127.90*	99.2	94.50									
12:59:00	29.10	27.90	29.30	28.7	127.70*	99.0	94.50									

150°
 ← State - began - has at 1700

← Shut down } 111.55 min

← ~~Shut down~~ 111.2

0076	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16
700	RMB	RMB	RMB	RMB	16 TOP	RISE	BIM OIL									
07:46:00	27.40	26.60	27.60	27.2	80.40	53.2	60.80									
08:35:00	27.40	26.60	27.60	27.2	80.40	53.2	60.80									
09:35:00	27.40	26.50	27.50	27.1	79.30	52.2	60.20									
10:35:00	27.50	26.40	27.50	27.1	78.50	51.4	59.60									
10:38:00	27.40	26.40	27.50	27.1	78.40	51.3	59.50									
10:39:00	27.40	26.40	27.40	27.0	78.40	51.4	59.40									
10:40:00	27.40	26.40	27.50	27.1	78.30	51.2	59.40									
10:41:00	27.40	26.40	27.50	27.1	78.30	51.2	59.40									
10:42:00	27.40	26.40	27.50	27.1	78.20	51.1	59.30									
10:43:00	27.40	26.40	27.50	27.1	78.10	51.0	59.30									
10:44:00	27.40	26.40	27.50	27.1	78.10	51.0	59.30									
10:45:00	27.40	26.40	27.50	27.1	78.00	50.9	59.20									

-begin this at Rated

TABLE A.11.1 NO-LOAD LOSS SATURATION DATA.

FOR TOP OIL TEMPERATURE STABILIZED AT 31.7°C WITH NO LOAD.
AMORPHOUS METAL TRANSFORMER P217061-YZA.

FLUX VOLTS	% RATED FLUX VOLTS	RMS VOLTS	CURRENT	% CURRENT	WATTS
20.0	16.7	20.4	0.060	0.005	1.1
40.0	33.3	40.2	0.072	0.01	1.1
60.0	50.0	60.1	0.096	0.02	5.1
80.0	66.7	80.0	0.113	0.04	9.4
90.0	75.0	90.0	0.127	0.05	10.7
100.0	83.3	100.1	0.153	0.06	10.5
110.0	91.7	110.0	0.210	0.09	15.7
120.0	100.0	120.0	0.378	0.12	13.7
125.0	104.2	125.1	0.571	0.29	20.7
130.0	108.3	130.1	0.957	0.50	23.9
135.0	112.5	133.0	1.848	1.00	25.4

TABLE A.11.2 NO-LOAD LOSS SATURATION DATA.

FOR TOP OIL TEMPERATURE STABILIZED AT 41°C AFTER LOADING
AT 50% OF NAMEPLATE RATING.
AMORPHOUS METAL TRANSFORMER P217061-YZA.

FLUX VOLTS	% RATED FLUX VOLTS	RMS VOLTS	CURRENT	% CURRENT	WATTS
20.0	16.7	20.5	0.068	0.006	1.2
40.0	33.3	40.2	0.080	0.01	1.1
60.0	50.0	60.2	0.094	0.02	5.7
80.0	66.7	80.0	0.110	0.04	9.0
90.0	75.0	90.1	0.126	0.05	10.0
100.0	83.3	100.0	0.152	0.06	11.7
110.0	91.7	110.0	0.217	0.10	14.9
120.0	100.0	120.1	0.404	0.19	19.4
125.0	104.2	125.0	0.636	0.32	20.7
130.0	108.3	129.9	1.111	0.58	22.5
135.0	112.5	135.1	2.418	1.31	25.7

TABLE A.11.3 NO-LOAD LOSS SATURATION DATA.

FOR TOP OIL TEMPERATURE STABILIZED AT 51.90 AFTER LOADING
AT 100% OF NAMEPLATE RATING.
AMORPHOUS METAL TRANSFORMER P217061-YZA.

FLUX VOLTS	% RATED FLUX VOLTS	RMS VOLTS	CURRENT	% CURRENT	WATTS
20.0	16.7	20.4	0.063	0.005	1.7
40.0	33.3	40.1	0.075	0.01	2.9
60.0	50.0	60.2	0.089	0.02	5.1
80.0	66.7	80.1	0.107	0.03	7.7
90.0	75.0	90.1	0.123	0.04	9.7
100.0	83.3	100.0	0.152	0.06	11.9
110.0	91.7	110.1	0.228	0.10	14.6
120.0	100.0	119.9	0.468	0.22	18.0
125.0	104.2	125.1	0.773	0.39	19.9
130.0	108.3	130.1	1.459	0.76	22.1
135.0	112.5	135.6	4.785	2.60	26.7

TABLE A.11.4 NO-LOAD LOSS SATURATION DATA.

FOR TOP OIL TEMPERATURE STABILIZED AT 106C AFTER LOADING
AT 150% OF NAMEPLATE RATING.
AMORPHOUS METAL TRANSFORMER P217061-YZA

FLUX VOLTS	% RATED FLUX VOLTS	RMS VOLTS	CURRENT	% CURRENT	WATTS
20.0	16.7	20.3	0.061	0.005	1.1
40.0	33.3	40.2	0.074	0.01	0.9
60.0	50.0	60.0	0.086	0.02	4.9
80.0	66.7	80.1	0.104	0.03	7.7
90.0	75.0	90.0	0.124	0.04	9.5
100.0	83.3	100.1	0.160	0.06	11.7
110.0	91.7	109.8	0.268	0.12	14.4
120.0	100.0	120.0	0.654	0.31	17.7
125.0	104.2	125.0	1.218	0.61	19.7
130.0	108.3	130.2	3.537	1.84	23.1
135.0	112.5	139.6	8.956	5.00	70.9

* CORRECTED ACCORDING TO ANSI C57.12.90 - 1990 SEC. 5.1.2

TABLE A.11.5 NO-LOAD LOSS SATURATION DATA.

FOR TOP OIL TEMPERATURE STABILIZED AT 22.7C WITH NO-LOAD.
STANDARD SILICON STEEL TRANSFORMER P239216-Y08.

FLUX VOLTS	% RATED FLUX VOLTS	RMS VOLTS	CURRENT	% CURRENT	WATTS
20.0	16.7	20.4	0.197	0.016	2.9
40.0	33.3	40.1	0.242	0.04	7.1
60.0	50.0	60.0	0.299	0.07	15.3
80.0	66.7	80.0	0.361	0.12	25.5
90.0	75.0	90.1	0.402	0.14	31.9
100.0	83.3	99.9	0.463	0.19	39.5
110.0	91.7	109.9	0.618	0.27	49.7
120.0	100.0	120.0	1.829	0.88	68.9
125.0	104.2	125.2	4.447	2.23	92.6
130.0	108.3	131.0	7.611	3.99	138.6
132.0	110.0	133.9	8.537	4.57	163.2 *

TABLE A.11.6 NO-LOAD LOSS SATURATION DATA.

FOR TOP OIL TEMPERATURE STABILIZED AT 47.8C AFTER LOADING
AT 50% OF NAMEPLATE RATING.
STANDARD SILICON STEEL TRANSFORMER P239216-Y08.

FLUX VOLTS	% RATED FLUX VOLTS	RMS VOLTS	CURRENT	% CURRENT	WATTS
20.0	16.7	20.3	0.179	0.015	2.6
40.0	33.3	40.3	0.243	0.04	7.8
60.0	50.0	60.2	0.300	0.07	15.2
80.0	66.7	80.0	0.358	0.11	24.9
90.0	75.0	90.1	0.399	0.14	31.0
100.0	83.3	100.0	0.458	0.18	38.4
110.0	91.7	110.1	0.623	0.27	48.9
120.0	100.0	120.1	1.979	0.95	68.5
125.0	104.2	125.3	4.850	2.43	93.2
130.0	108.3	131.1	7.785	4.08	139.1
132.0	110.0	134.7	8.892	4.79	166.6 *

* CORRECTED ACCORDING TO ANSI C57.12.90 - 1980 SEC. 8.2.1

TABLE A.11.7 NO-LOAD LOSS SATURATION DATA.

FOR TOP OIL TEMPERATURE STABILIZED AT 78C AFTER LOADING
AT 100% OF NAMEPLATE RATING.
STANDARD SILICON STEEL TRANSFORMER P239216-YCB.

FLUX VOLTS	% RATED FLUX VOLTS	RMS VOLTS	CURRENT	% CURRENT	WATTS
20.0	16.7	20.4	0.172	0.014	2.5
40.0	33.3	40.2	0.230	0.04	7.4
60.0	50.0	60.2	0.289	0.07	14.6
80.0	66.7	80.2	0.350	0.11	24.2
90.0	75.0	89.9	0.392	0.14	30.3
100.0	83.3	100.0	0.453	0.19	37.7
110.0	91.7	110.1	0.629	0.28	47.7
120.0	100.0	120.1	2.096	1.01	67.3
125.0	104.2	125.1	5.280	2.64	93.4
130.0	108.3	130.8	7.900	4.13	143.0
132.0	110.0	134.3	9.028	4.65	176.6 *

TABLE A.11.8 NO-LOAD LOSS SATURATION DATA.

FOR TOP OIL TEMPERATURE STABILIZED AT 128C AFTER LOADING
AT 150% OF NAMEPLATE RATING.
STANDARD SILICON STEEL TRANSFORMER P239216-YOB

FLUX VOLTS	% RATED FLUX VOLTS	RMS VOLTS	CURRENT	% CURRENT	WATTS
20.0	16.7	20.3	0.156	0.013	2.2
40.0	33.3	40.1	0.218	0.03	6.9
60.0	50.0	60.1	0.277	0.07	13.9
80.0	66.7	80.1	0.340	0.11	23.5
90.0	75.0	90.1	0.382	0.14	29.5
100.0	83.3	100.0	0.450	0.19	36.7
110.0	91.7	110.0	0.649	0.29	46.5
120.0	100.0	120.1	2.494	1.20	63.8
125.0	104.2	125.2	6.325	3.17	94.5
130.0	108.3	131.3	8.514	4.47	150.2
131.2	109.3	134.7	9.478	5.11	174.5 *

* CORRECTED ACCORDING TO ANSI C57.12.90 - 1980 SEC. 8.2.

FIGURE A.11.1

SATURATION CURVES --- WATTS

AMORPHOUS METAL UNIT P217061-YZA

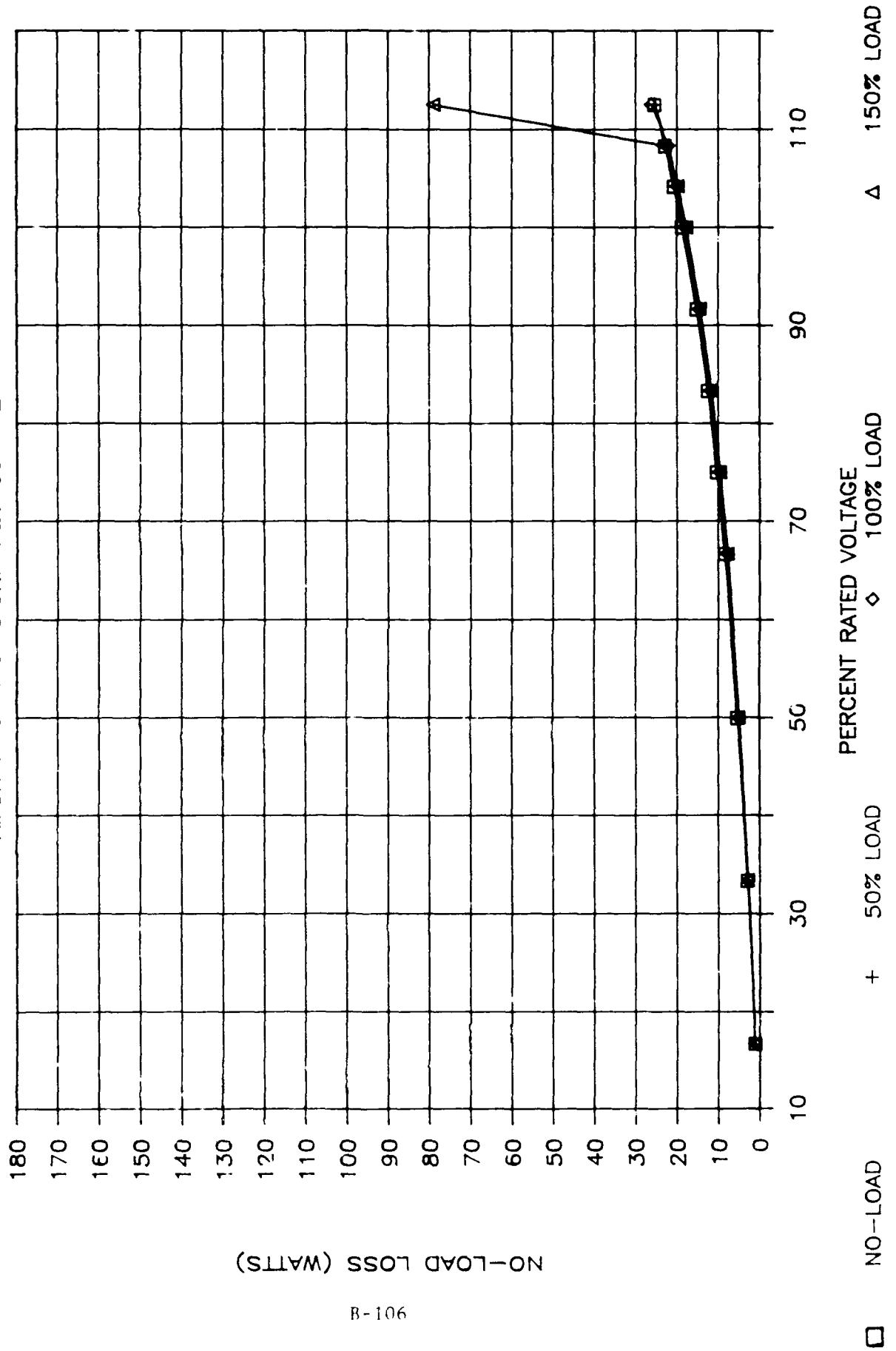


FIGURE A.11.2

SATURATION CURVES --- WATTS

STD SILICON STEEL UNIT P239216-YOB

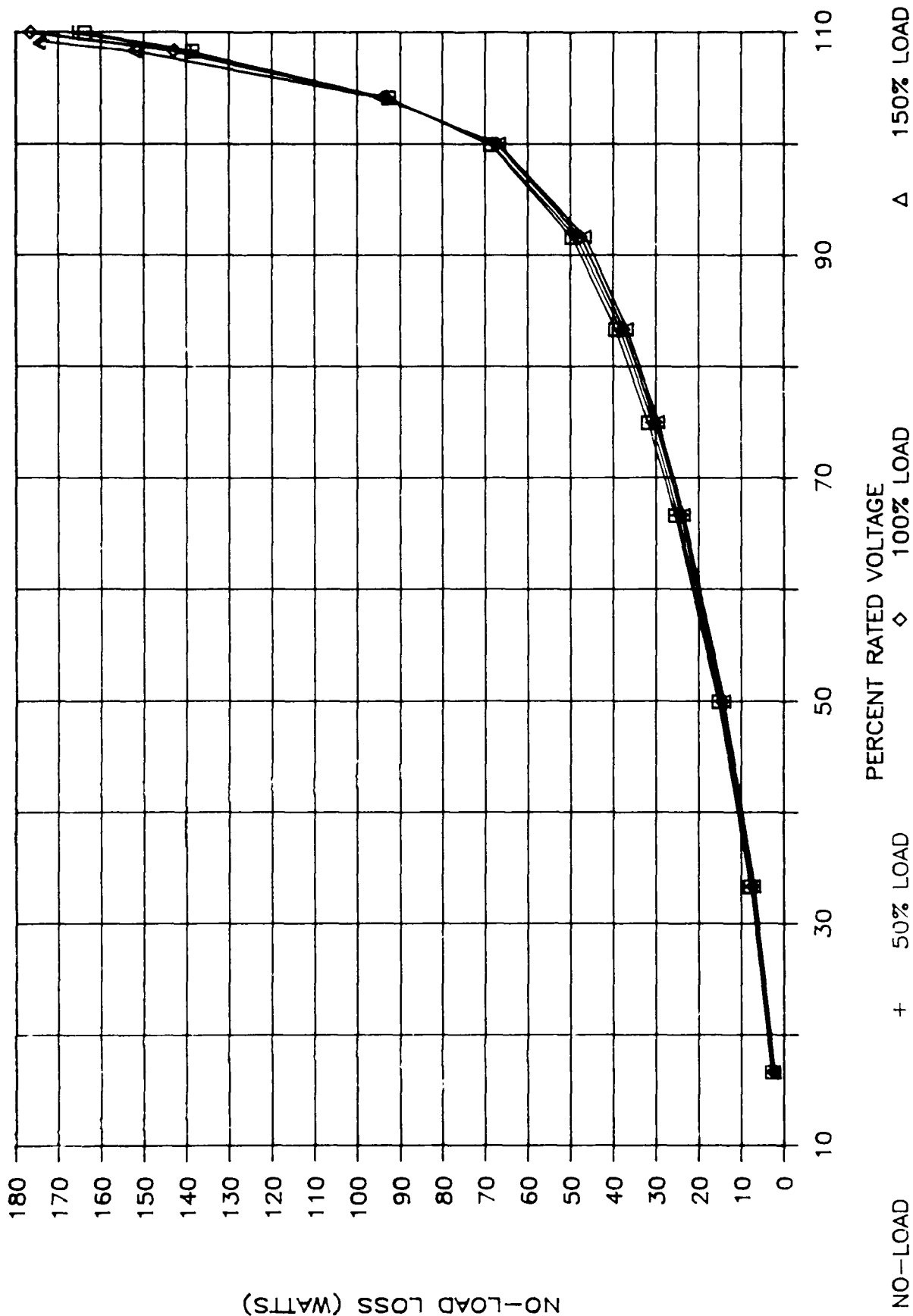
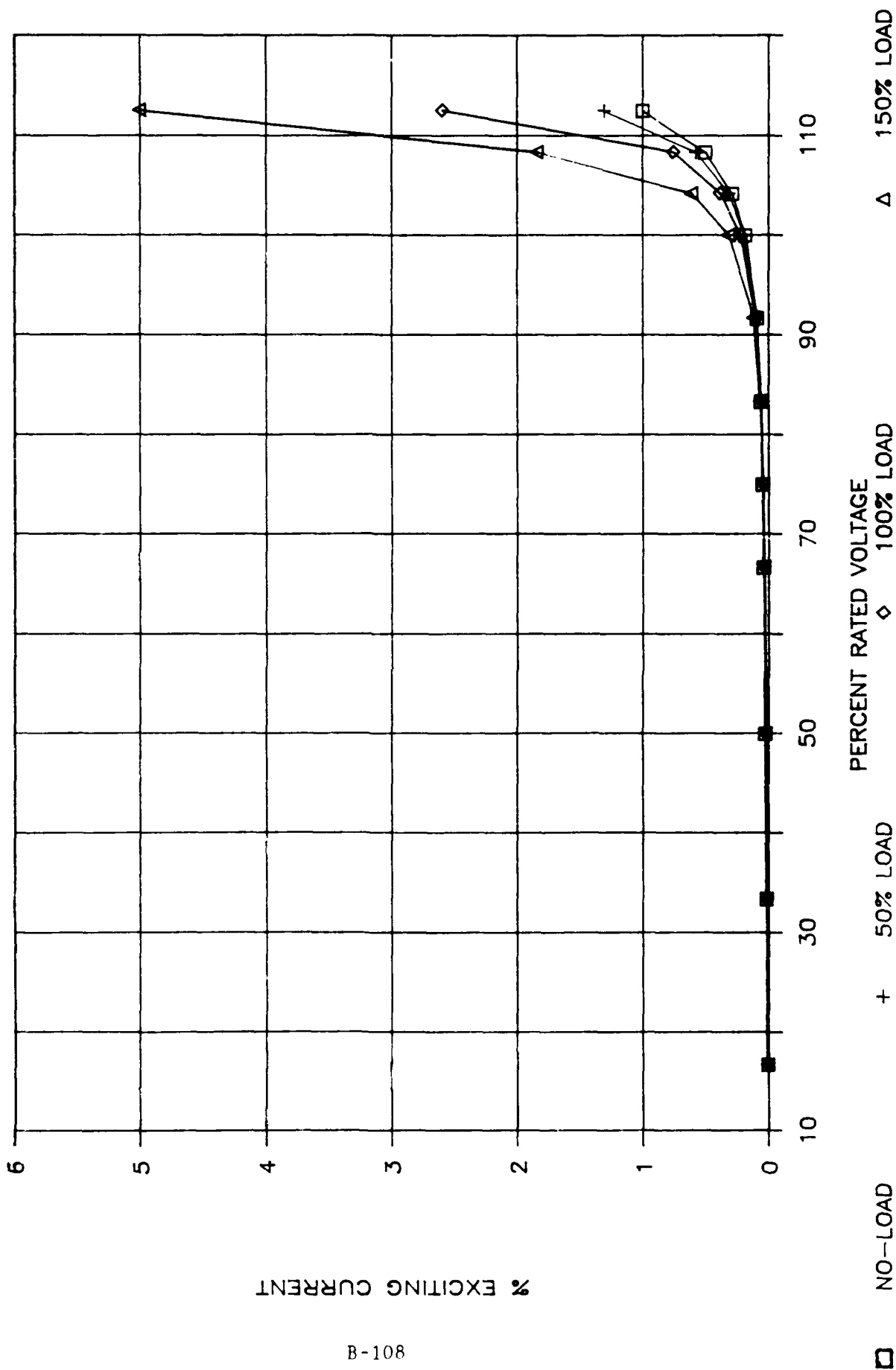


FIGURE A.11.3

SATURATION CURVES -- % EXCITING CURRENT

AMORPHOUS METAL UNIT P217061-YZA



SATURATION CURVES — — % EXCITING CURRENT

STD SILICON STEEL UNIT P239216--Y0B

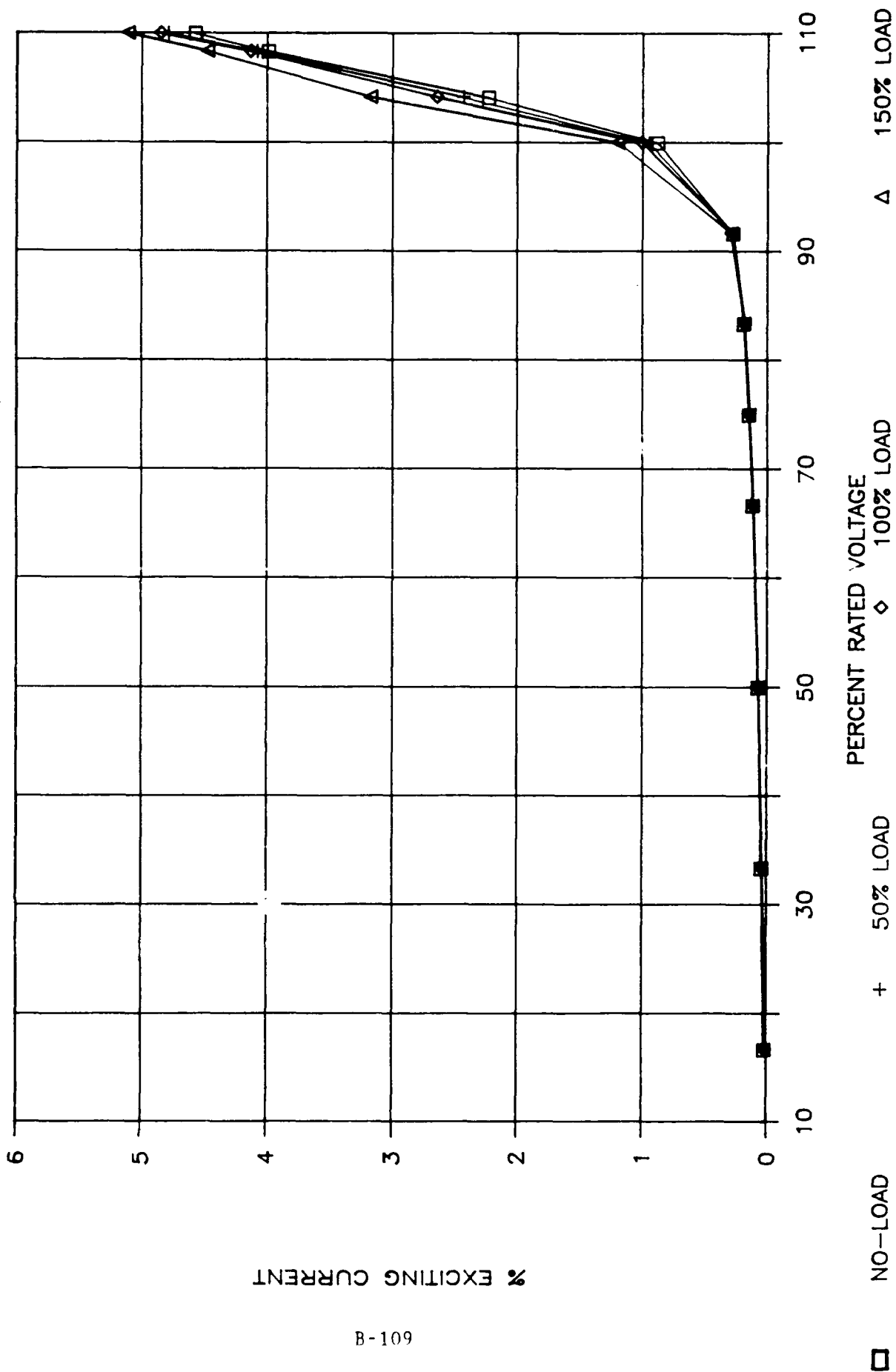


TABLE A.11.9 PERCENT REGULATION - MEASURED & CALCULATED VALUES
FOR AIRCORED METAL TRANSFORMER POZTUS-104

% LOAD	LOAD LOSS (WATTS)	% RESISTANCE	% REACTANCE	MEASURED VALUES - (SEE NOTE)		CALCULATED FROM COMMERCIAL TEST REPORT (APPENDIX A.11)	
				*****		*****	
				% REGULATION PF = 1	% REGULATION PF = .8 LAG	% REGULATION PF = 1	% REGULATION PF = .8 LAG
50	69.5	0.06	0.17	0.70	1.51		
100	110.4	0.15	0.17	1.07	2.08	1.71	2.72
150	175.0	0.22	0.17	1.64	2.65		

TABLE A.11.10 PERCENT REGULATION - MEASURED & CALCULATED VALUES
FOR STANDARD SILICON STEEL TRANSFORMER POZTUS-105

% LOAD	LOAD LOSS (WATTS)	% RESISTANCE	% REACTANCE	MEASURED VALUES - (SEE NOTE)		CALCULATED FROM COMMERCIAL TEST REPORT (APPENDIX A.11)	
				*****		*****	
				% REGULATION PF = 1	% REGULATION PF = .8 LAG	% REGULATION PF = 1	% REGULATION PF = .8 LAG
50	100.7	0.41	0.27	0.47	1.66		
100	450.8	1.31	0.27	1.84	2.79	1.87	2.78
150	1010.7	4.81	0.27	4.87	5.19		

NOTE: % REGULATION IS CALCULATED PER ANSI C57.12.90 SEC 4.4.4.1.

MEASURED VALUES OF % REGULATION ARE CALCULATED USING THE FIRST FOUR COLUMNS OF DATA: % LOAD, LOAD LOSS, & % RESISTANCE VALUES ARE FROM TEMPERATURE RISE TESTS (SEE THIS APPENDIX). % REACTANCE VALUES ARE FROM THE COMMERCIAL TEST REPORT (SEE THIS APPENDIX). REACTANCE IS ASSUMED CONSTANT WITH CHANGING LOAD TEMPERATURE.

% REGULATION (MEASURED & CALCULATED)

AMORPHOUS METAL UNIT P217061-YZA

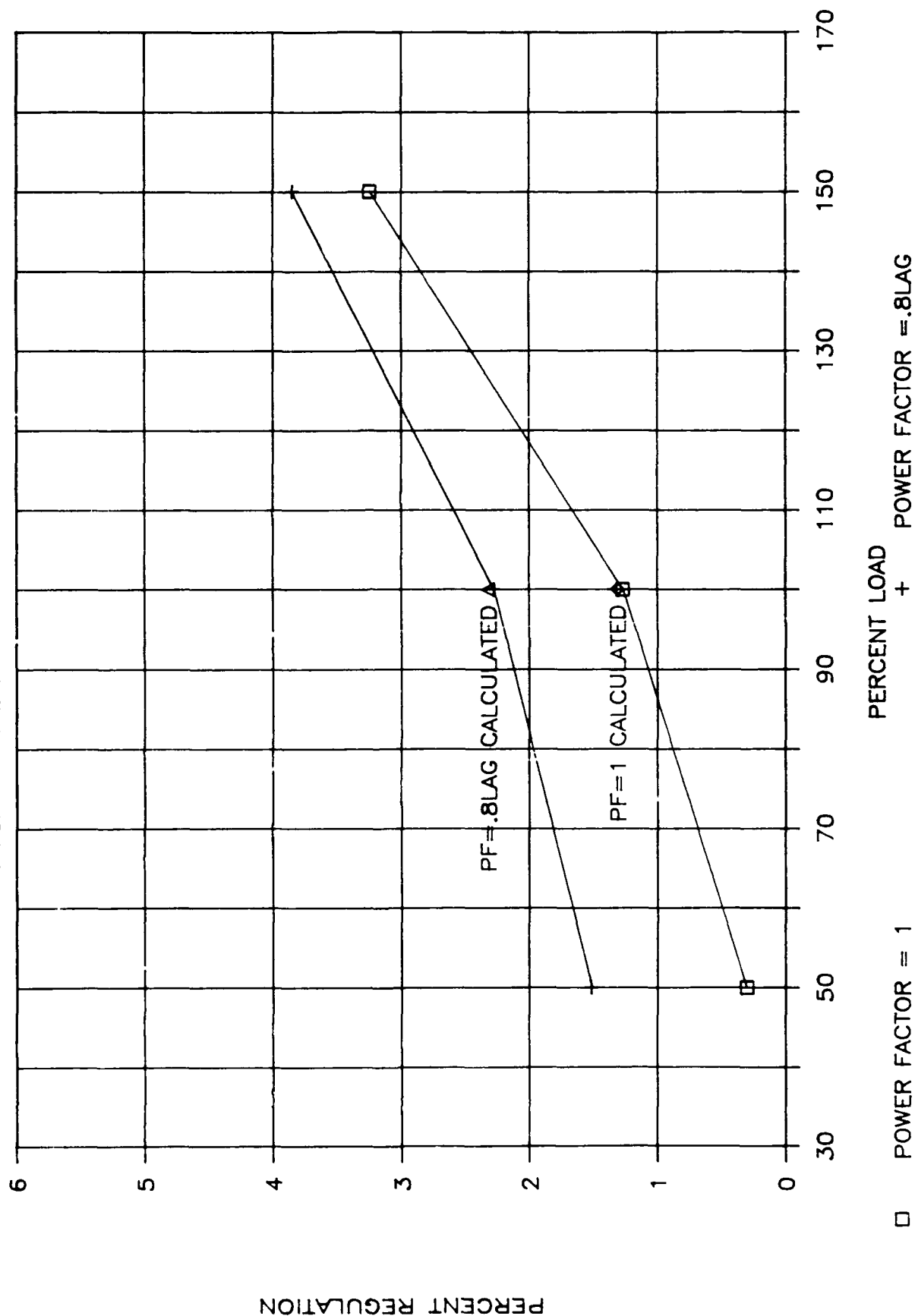


FIGURE A.11.6

% REGULATION (MEASURED & CALCULATED)

STD SILICON STEEL UNIT P239216--YOB

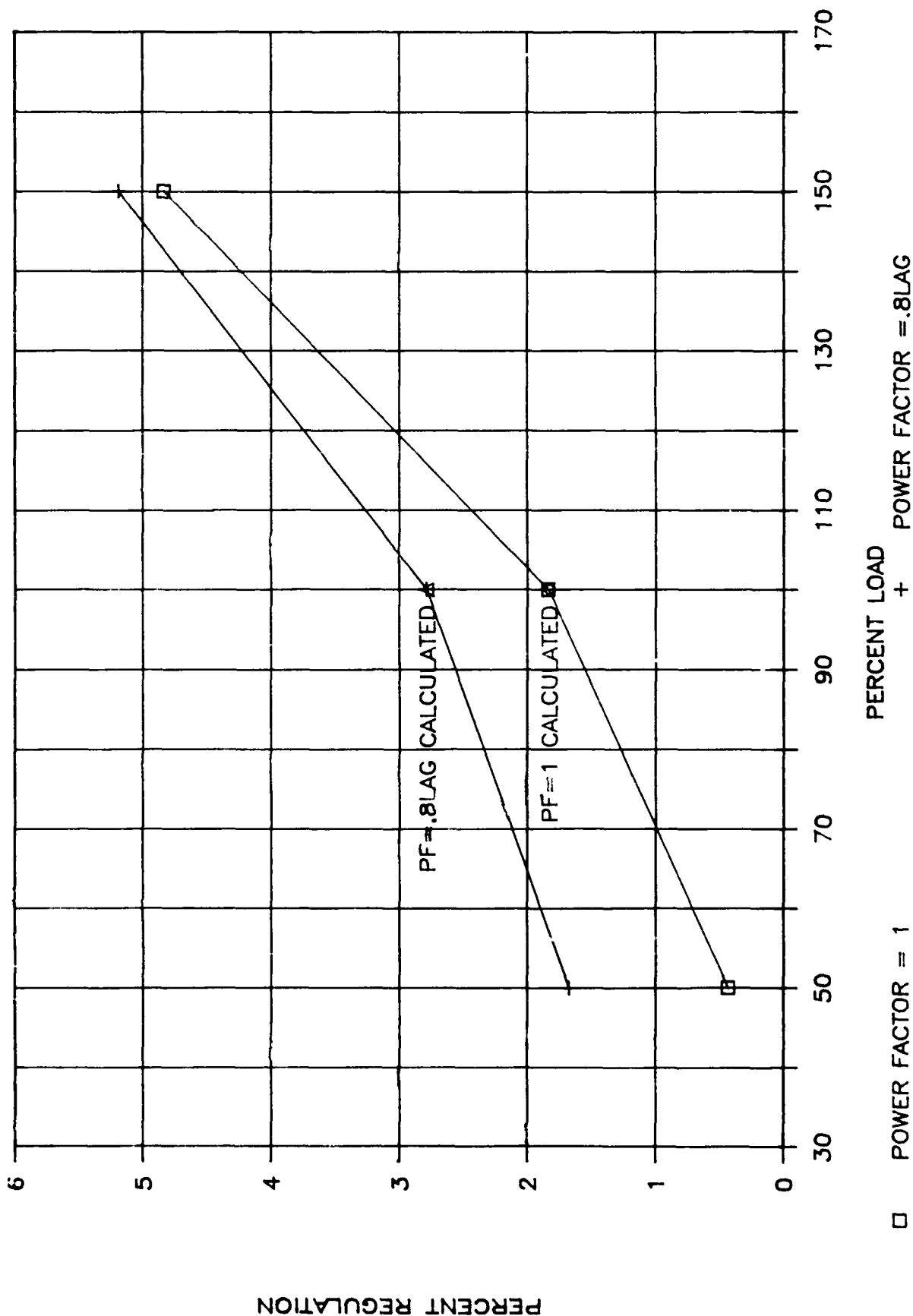


TABLE A.11.11 PERCENT EFFICIENCY - MEASURED & CALCULATED VALUES
FOR AMORPHOUS METAL TRANSFORMER P217061-Y2A

% LOAD	LOAD LOSS (WATTS)	% NO-LOAD LOSS (WATTS)	" MEASURED VALUES " (SEE NOTE)		CALCULATED FROM COMMERCIAL TEST REPORT (APPENDIX A.11)	
			*****		*****	
			% EFFICIENCY PF = 1	% EFFICIENCY PF = .8 LAG	% EFFICIENCY PF = 1	% EFFICIENCY PF = .8 LAG
50	69.5	18.4	99.65	99.56		
100	311.4	18.0	98.70	98.38	98.7	98.3
150	805.0	17.7	96.88	96.13		

TABLE A.11.12 PERCENT EFFICIENCY - MEASURED & CALCULATED VALUES
FOR STANDARD SILICON STEEL TRANSFORMER P239216-Y08

% LOAD	LOAD LOSS (WATTS)	% NO-LOAD LOSS (WATTS)	" MEASURED VALUES " (SEE NOTE)		CALCULATED FROM COMMERCIAL TEST REPORT (APPENDIX A.11)	
			*****		*****	
			% EFFICIENCY PF = 1	% EFFICIENCY PF = .8 LAG	% EFFICIENCY PF = 1	% EFFICIENCY PF = .8 LAG
50	102.0	68.5	99.32	99.15		
100	452.8	67.3	97.96	97.47	98.00	97.50
150	1202.0	66.8	95.17	94.03		

NOTE: % EFFICIENCY IS CALCULATED PER ANSI C57.12.90 SEC 14.3.

* MEASURED VALUES * OF % EFFICIENCY ARE CALCULATED USING THE FIRST THREE COLUMNS OF DATA. % LOAD AND LOAD LOSS VALUES ARE FROM TEMPERATURE RISE TESTS (SEE THIS APPENDIX). NO-LOAD LOSS VALUES ARE FROM THE SATURATION CURVES (SEE TABLES A.11.1 THRU A.11.8).

FIGURE A.11.7

% EFFICIENCY (MEASURED & CALCULATED)

AMORPHOUS METAL UNIT P217061-YZA

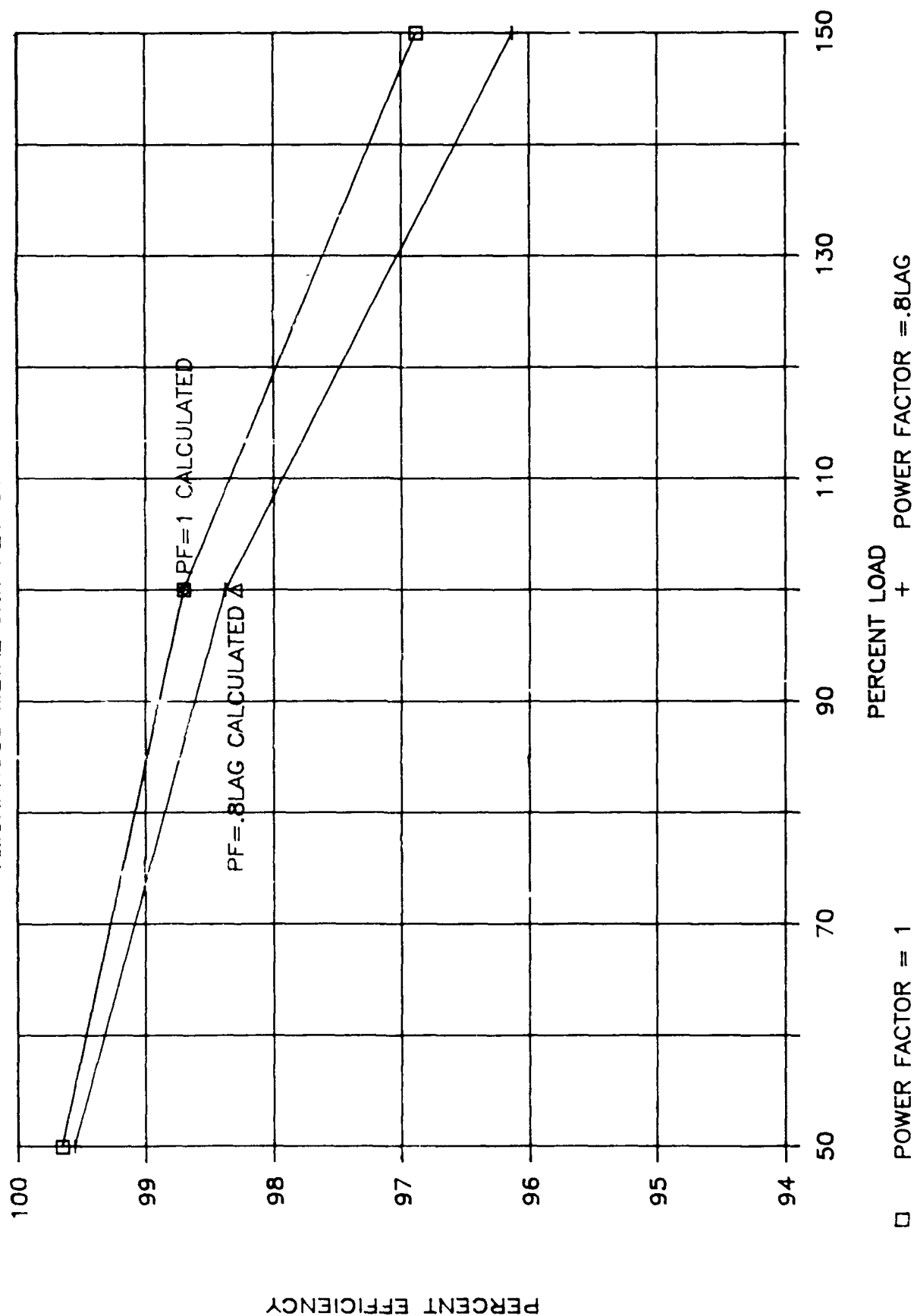
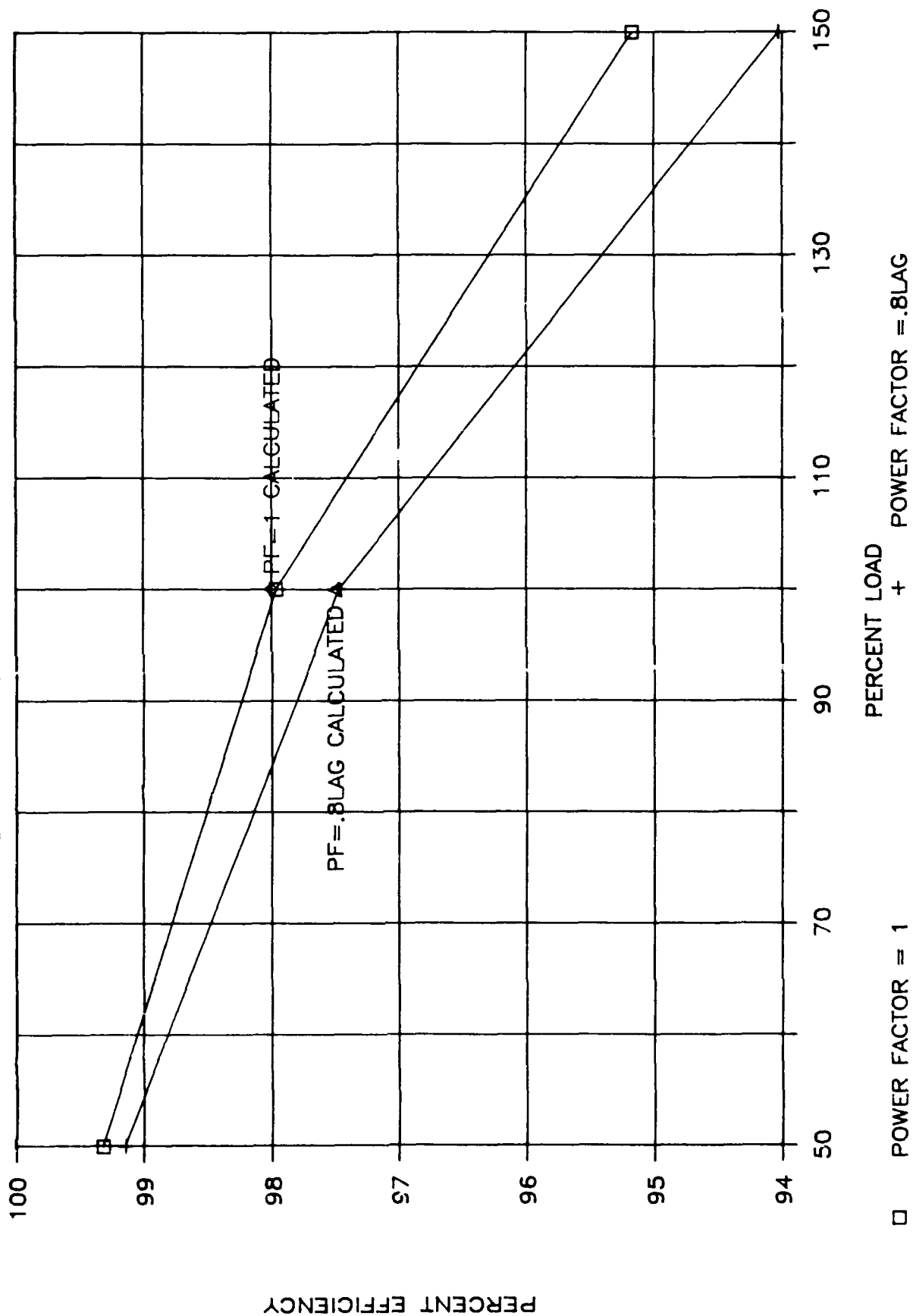


FIGURE A.11.8

% EFFICIENCY (MEASURED & CALCULATED)

STD SILICON STEEL UNIT P239216-YOB



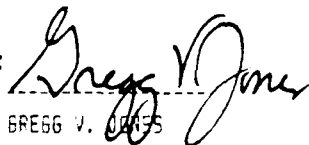
CONDITION: FOLLOWING SATURATION CURVES

STYLE: G.E. 25kVA STANDARD SILICON STEEL POLE TYPE

LV: 120/240 HV: 4160: 75KV BIL SERIAL #: P239216-Y08

RATIO	PASS	* HV RESISTANCE (OHMS)	6.342
POLARITY	PASS	* LV RESISTANCE (OHMS)	0.01924
FULL WAVE IMPULSE	PASS	* I SQUARED R LOSS (WATTS)	437.9
APPLIED POTENTIAL - HLIC	PASS	* STRAYS	13.1
APPLIED POTENTIAL - LHIC	PASS	* LOAD LOSS (WATTS)	451.0
INDUCED POTENTIAL - 400 HZ	PASS	TOTAL LOSS (WATTS)	519.0
NL LOSS (WATTS)	67	* % RESISTANCE	1.80
% EXCITING CURRENT	0.92	* % REACTANCE	2.23
% EFFICIENCY @ PF=1	98.0	* % IMPEDANCE	2.97
% EFFICIENCY @ PF=.8	97.5	% REGULATION @ PF=1	1.93
		% REGULATION @ PF=.8	2.78

TEST ENGINEER:



 GREGG V. JONES

* CORRECTED TO 85 DEGREES C

CONDITION: FOLLOWING SATURATION CURVES

STYLE: G.E. 25KVA AMORPHOUS METAL POLE TYPE

LV: 120/240

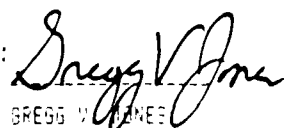
HV: 4160V

75/0 BIL

SERIAL #: FC17081-Y02

RATIO	PASS	* HV RESISTANCE (OHMS)	4.882
POLARITY	PASS	* LV RESISTANCE (OHMS)	0.01324
FULL WAVE IMPULSE	PASS	* I SQUARED R LOSS (WATTS)	312.6
APPLIED POTENTIAL - HLIC	PASS	* STRAYS	10.2
APPLIED POTENTIAL - LHIC	PASS	* LOAD LOSS (WATTS)	323.0
INDUCED POTENTIAL - 400 HZ	PASS	TOTAL LOSS (WATTS)	340.1
NO LOSS (WATTS)	17.1	* % RESISTANCE	1.29
% EXCITING CURRENT	0.17	* % REACTANCE	0.10
% EFFICIENCY @ PF=1	98.7	* % IMPEDANCE	0.49
% EFFICIENCY @ PF=0.8	98.7	% REGULATION @ PF=1	1.71
		% REGULATION @ PF=0.8	2.70

TEST ENGINEER:



 GREGG V. JONES

* CORRECTED TO 85 DEGREES C

Appendix C

PHOTOGRAPHS OF AMORPHOUS METAL-CORE TRANSFORMER TESTING



Figure C-1. 25-kVA amorphous metal-core transformer windings and core.



Figure C-2. A 25-kVA amorphous metal-core transformer on the left. A 25-kVA silicon-steel transformer on the right. Note that the amorphous metal-core transformer is larger.

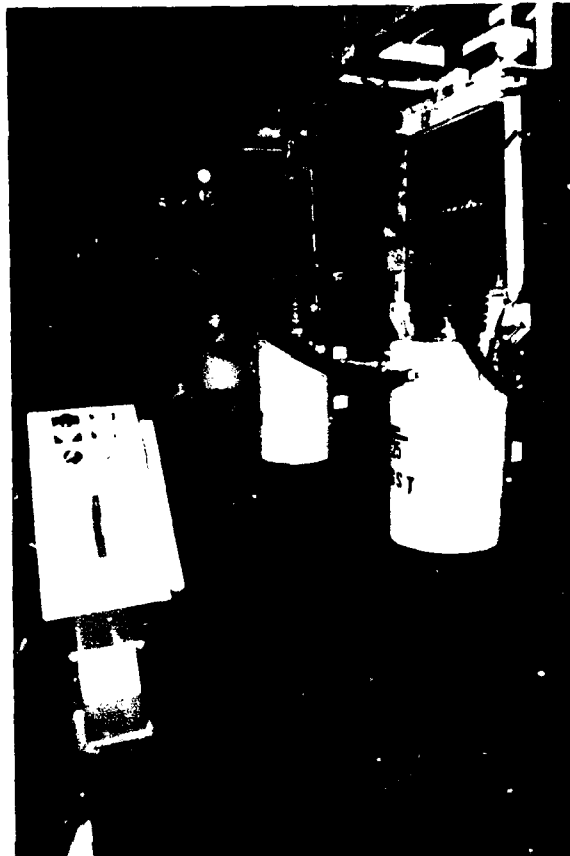


Figure C-3. 25-kVA amorphous metal-core transformers undergoing commercial tests at transformer plant.

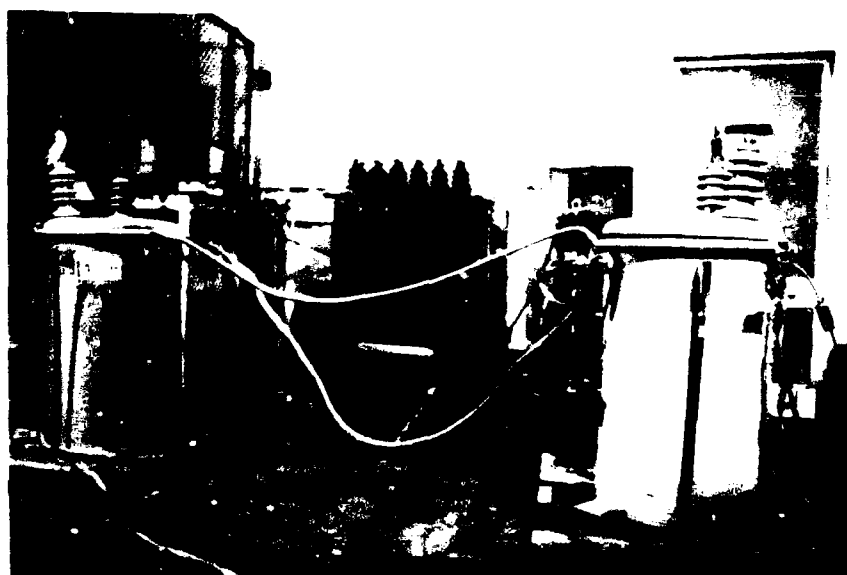


Figure C-4. 24-kVA amorphous metal-core transformers undergoing design tests at transformer plant.



Figure C-5. Infrared scanning test of 25-kVA amorphous metal-core transformer (left) and a 25-kVA silicon-steel transformer (right).



Figure C-6. General Electric engineers inspecting the bottom frame and containment box of a 25-kVA amorphous metal-core transformer for amorphous metal particles.

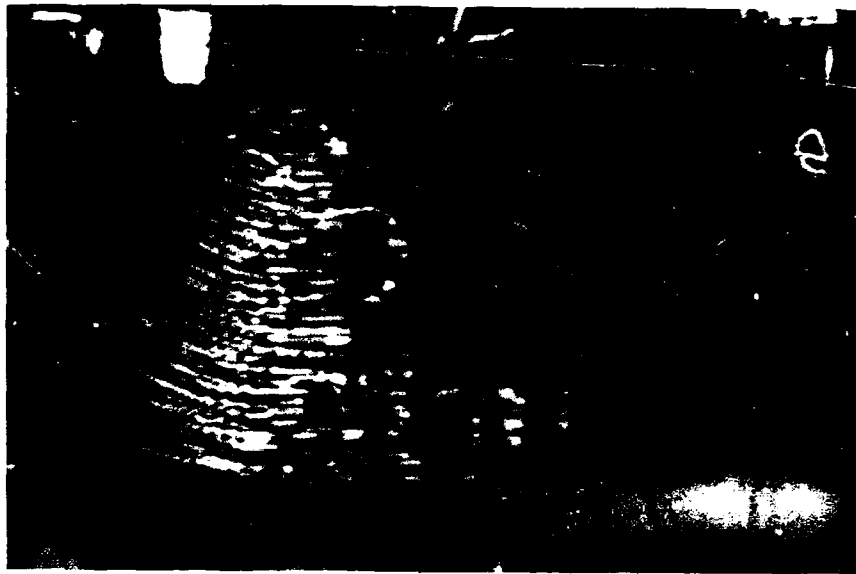


Figure C-7. Several amorphous metal particles found on the core of a 25-kVA amorphous metal-core transformer.

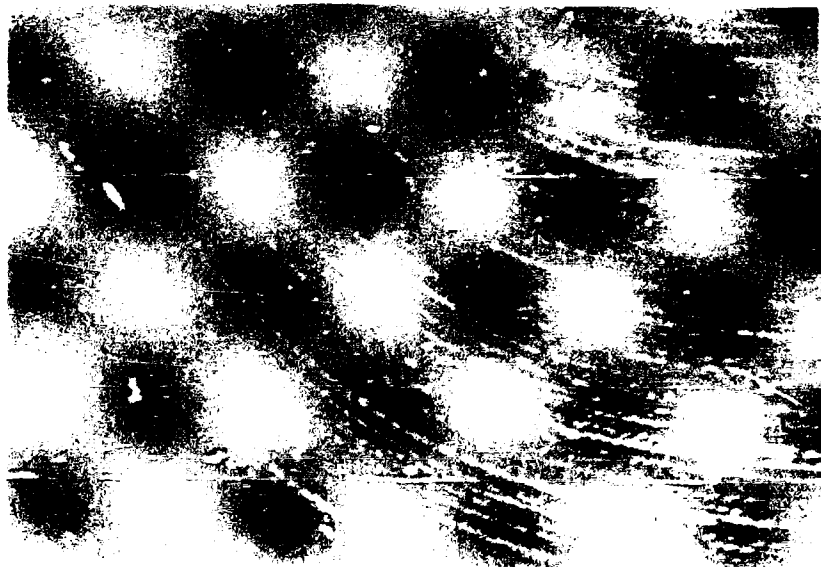


Figure C-8. Amorphous metal chip on the core of a 25-kVA amorphous metal-core transformer discovered during Phase I testing.

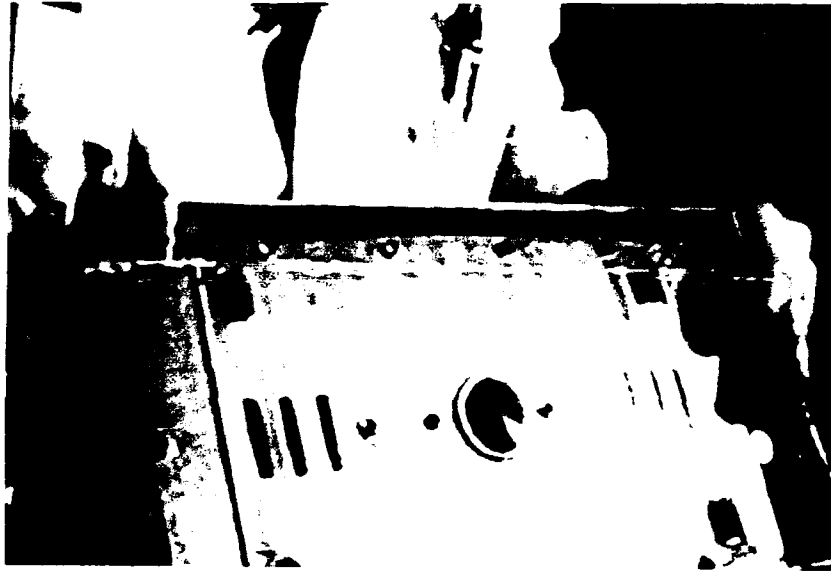


Figure C-9. Several amorphous metal particles found in the bottom frame of a 25-kVA amorphous metal-core transformer during Phase I testing.



Figure C-10. An amorphous metal particle found in the bottom frame of a 25-kVA amorphous metal-core transformer.



Figure C-11. A 25-kVA amorphous metal-core transformer undergoing a 4-foot drop test.

Figure C-12. A 25-kVA amorphous metal-core transformer after a 4-foot drop test.



Appendix D

REVISED PHASE I SATURATION TEST DATA

TABLE A.1.11.1 NO-LOAD LOSS SATURATION DATA
 FOR TOP OIL TEMPERATURE STABILIZED AT 21.7 DEG C WITH NO LOAD
 AMORPHOUS METAL TRANSFORMER P217061-Y2A

FLUX	%RATED			% RATED	
VOLTS	FLUX	RMS VOLTS	CURRENT	EXCITING	WATTS
20.000	16.700	20.400	0.060	0.029	1.100
40.000	33.300	40.200	0.079	0.038	3.000
60.000	50.000	60.100	0.096	0.046	5.400
80.000	66.700	80.000	0.113	0.054	8.400
90.000	75.000	90.000	0.127	0.061	10.300
100.000	83.300	100.100	0.153	0.073	12.500
110.000	91.700	110.000	0.210	0.101	15.200
120.000	100.000	120.000	0.378	0.181	18.700
125.000	104.200	125.100	0.571	0.274	20.700
130.000	108.300	130.100	0.857	0.459	22.800
135.000	112.500	135.000	1.210	0.737	26.400

TABLE A.1.11.2 NO-LOAD LOSS SATURATION DATA
 FOR THE 1000 TEMPERATURE STABILIZED 4F 41 CH 3 C WELDER 1400-1
 AT 50% OF NAMEPLATE RATING
 AMORPHOUS METAL TRANSFORMER P017061-70A

FLUX	%RATED FLUX			% RATED EXCITING	
VOLTS	VOLTS	RMS VOLTS	CURRENT	CURRENT	WATTS
20,000	15,700	20,000	0.068	0.032	1.200
40,000	31,400	40,000	0.086	0.078	2.100
60,000	47,100	60,000	0.094	0.040	3.000
80,000	62,800	80,000	0.110	0.053	4.200
100,000	78,500	100,000	0.120	0.060	5.000
120,000	94,200	120,000	0.132	0.070	6.200
140,000	109,900	140,000	0.217	0.104	14.500
160,000	125,600	160,000	0.404	0.194	18.400
175,000	141,300	175,000	0.674	0.305	29.700

TABLE A.1.11.3 NO-LOAD LOSS SATURATION DATA
 FOR 100% OIL TEMPERATURE STARTED AT 15 °C BEG. W. OF 100% RATING
 AT 100% OF NAMEPLATE RATING
 AMORPHOUS METAL TRANSFORMER P217061-Y2A

FLUX	%RATED FLUX			% RATED EXCITING	
VOLTS	VOLTS	RMS VOLTS	CURRENT	CURRENT	WATTS
20,000	15.700	20.400	0.080	0.030	1.300
40,000	31.300	40.800	0.075	0.032	1.300
60,000	46.900	60.100	0.068	0.041	2.500
80,000	62.700	80.100	0.107	0.051	3.500
100,000	78.500	100.100	0.100	0.059	4.500
120,000	94.300	120.100	0.132	0.060	11.500
140,000	110.100	140.100	0.209	0.109	14.500
160,000	125.900	160.000	0.452	0.205	18.500
175,000	138.100	175.100	0.770	0.331	19.500

TABLE A.1.11.4 NO-LOAD LOSS SATURATION DATA
 FOR TOP OIL TEMPERATURE STABILIZED AT 45°C AFTER 10% THD
 AT 150% OF NAMEPLATE RATING
 AMORPHOUS METAL TRANSFORMER PD17061-HYJA

FLUX	%RATED FLUX			% RATED EXCITING	
VOLTS	VOLTS	RMS VOLTS	CURRENT	CURRENT	WATTS
20,000	18.700	20.700	0.061	0.029	1.100
40,000	37.300	40.200	0.074	0.036	3.000
60,000	56.000	60.000	0.085	0.041	5.400
80,000	66.700	80.100	0.106	0.051	8.300
90,000	75.000	90.000	0.101	0.050	9.900
100,000	83.300	100.000	0.100	0.050	11.500
110,000	91.700	109.800	0.262	0.126	14.400
120,000	100.000	120.000	0.654	0.314	17.700
125,000	104.200	125.000	1.712	0.585	19.500

TABLE A.1.11.5 NO-LOAD LOSS SATURATION DATA
FOR TOP OIL TEMPERATURE STABILIZED AT 22.7 DEG C WITH NO LOAD

STANDARD SILICON STEEL TRANSFORMER P 239216-Y03

FLUX	%RATED FLUX			% RATED EXCITING	
VOLTS	VOLTS	RMS VOLTS	CURRENT	CURRENT	WATTS
20.000	16.700	20.400	0.197	0.093	2.900
40.000	33.300	40.100	0.242	0.116	7.900
60.000	50.000	60.000	0.299	0.144	15.300
80.000	66.700	80.000	0.361	0.173	25.500
90.000	75.000	90.100	0.402	0.193	31.900
100.000	83.300	99.900	0.463	0.222	38.500
110.000	91.700	109.900	0.618	0.297	45.700
120.000	100.000	120.000	1.829	0.878	68.800
125.000	104.200	125.200	4.447	2.135	72.600
130.000	108.300	131.000	7.611	3.653	103.600
132.000	110.000	133.900	8.537	4.052	103.800

TABLE A.1.11.5 NO-LOAD LOSS SATURATION DATA
FOR TOP OIL TEMPERATURE STABILIZED AT 47.5 DEG C AFTER LOADING AT
90% OF NAMEPLATE RATING

STANDARD SILICON STEEL TRANSFORMER P 239216-Y08

FLUX	%RATED FLUX			% RATED EXCITING	
VOLTS	VOLTS	RMS VOLTS	CURRENT	CURRENT	WATTS
20.000	15.700	20.300	0.179	0.086	2.600
40.000	31.300	40.300	0.243	0.117	7.800
60.000	50.000	60.200	0.300	0.144	15.200
80.000	66.700	80.000	0.353	0.169	24.200
90.000	75.000	90.100	0.399	0.191	31.000
100.000	83.300	100.000	0.438	0.210	38.400
110.000	91.700	110.100	0.623	0.299	48.800
120.000	100.000	120.100	1.979	0.950	68.500
130.000	101.100	130.100	3.050	2.008	81.000
140.000	102.200	140.100	4.075	2.700	91.000
150.000	103.300	154.100	5.641	4.120	100.000

TABLE A.1.11.7 NO-LOAD LOSS SATURATION DATA
FOR TOP OIL TEMPERATURE STABILIZED AT 78 DEGS C AFTER WARMING UP
100% OF NAMEPLATE RATING

STANDARD SILICON STEEL TRANSFORMER R 209218-K08

FLUX	%RATED FLUX	RMS VOLTS	CURRENT	% RATED EXCITING CURRENT	WATTS
VOLTS	VOLTS				
20.000	18.700	20.100	0.172	0.083	2.000
40.000	37.400	40.200	0.200	0.110	7.800
60.000	56.100	60.200	0.289	0.139	14.600
80.000	74.800	80.200	0.350	0.168	24.200
100.000	93.500	99.900	0.392	0.188	36.200
120.000	112.200	100.000	0.453	0.217	47.300
140.000	130.900	110.100	0.629	0.302	67.700
160.000	149.600	120.100	2.095	1.005	87.700
180.000	168.300	130.100	2.200	1.110	97.700
200.000	187.000	140.100	2.200	1.110	107.700
220.000	205.700	150.100	2.200	1.110	117.700

TABLE A.1.11.8 NO-LOAD LOSS SATURATION DATA
FOR TOP OIL TEMPERATURE STABILIZED AT 128 DEG C AFTER LOADING AT
150% OF NAMEPLATE RATING

STANDARD SILICON STEEL TRANSFORMER P 279216-YOB

FLUX	%RATED FLUX			% RATED EXCITING	
VOLTS	VOLTS	RMS VOLTS	CURRENT	CURRENT	WATTS
20.000	15.700	20.300	0.156	0.075	2.200
40.000	31.300	40.100	0.218	0.105	6.900
60.000	50.000	60.100	0.277	0.133	13.900
80.000	65.700	80.100	0.340	0.163	23.500
90.000	75.000	90.100	0.382	0.183	29.500
100.000	83.300	100.000	0.450	0.216	36.700
110.000	91.700	110.000	0.648	0.312	48.500
120.000	100.000	120.100	2.484	1.127	66.800
125.000	104.200	125.100	4.735	2.202	81.500
130.000	108.300	130.100	6.984	3.297	102.100
134.000	110.000	134.700	8.148	4.549	124.500

AMORPH EXCITE CURRENT NO LOAD	SILICON EXCITE CURRENT NO LOAD	SI/AM EXCITE CURRENT NO LOAD	AMORPH NO-LOAD LOSS WATTS	SILICON NO-LOAD LOSS WATTS	AM/SI NO-LOAD LOSS WATTS	TREATED FLUX VOLTS
0.060	0.197	3.283	1.100	2.900	0.379	18.700
0.079	0.242	3.063	3.000	7.900	0.380	33.300
0.096	0.299	3.115	5.400	15.300	0.353	50.000
0.113	0.361	3.195	8.400	25.500	0.329	66.700
0.127	0.402	3.165	10.300	31.900	0.323	75.000
0.153	0.463	3.026	12.500	38.500	0.326	83.300
0.210	0.618	2.943	15.200	45.700	0.333	91.700
0.378	1.829	4.839	18.700	68.800	0.272	100.000
0.571	4.447	7.788	20.700	72.600	0.285	104.200
0.957	7.611	7.953	22.800	138.600	0.165	108.300
1.848	8.537	4.620	25.400	163.800	0.155	112.500

AMORPH SILITE CURRENT 50% LOAD	SILICON SILITE CURRENT 50% LOAD	SI-4N SILITE CURRENT 50% LOAD	AMORPH SILITE LOSS WATTS	SILICON SILITE LOSS WATTS	AM-51 SILITE LOSS WATTS	AM-51 SILITE VOLTAGE
0.088	0.179	2.532	1.220	2.600	0.401	10.700
0.090	0.243	3.075	3.100	3.900	0.577	13.100
0.094	0.300	3.191	5.300	15.200	0.743	15.000
0.110	0.787	3.219	8.200	24.300	0.829	16.700
0.120	0.999	3.187	10.000	31.900	0.927	18.000
0.137	0.440	2.900	11.000	30.000	0.917	18.700
0.217	0.821	3.971	14.700	43.800	0.945	19.700
0.124	1.878	4.999	18.800	58.000	0.943	19.800
0.120	0.000	0.000	0.000	0.000	0.000	0.000
0.111	1.733	3.007	12.000	109.100	0.924	19.300
0.112	3.800	3.807	25.700	100.000	0.931	19.500

AMORPH EXCITS	SILICON EXCITS	SI-AM EXCITS	AMORPH NO-LOAD	SILICON NO-LOAD	AM-AM NO-LOAD	TEMPERATURE
CURRENT	CURRENT	CURRENT	LOSS	LOSS	LOSS	FLUX
100%LOAD	100%LOAD	100%LOAD	WATTS	WATTS	WATTS	VOLTS
0.067	0.172	2.730	1.200	2.300	0.027	16.000
0.075	0.230	3.067	2.800	7.400	0.178	33.300
0.089	0.289	3.247	5.100	14.800	0.249	50.000
0.107	0.350	3.271	7.900	24.200	0.306	66.700
0.123	0.392	3.187	9.700	30.300	0.320	73.300
0.152	0.457	2.700	11.900	37.700	0.337	80.000
0.228	0.629	2.759	14.600	47.700	0.306	91.700
0.466	0.096	4.479	18.000	67.300	0.367	100.000
0.707	0.200	6.700	18.000	87.400	0.300	100.000
1.459	7.800	5.346	22.100	143.000	0.100	100.000
4.765	9.028	1.887	26.700	176.800	0.149	112.500

AMORPH EXCITG CURRENT 150%LOAD	SILICON EXCITG CURRENT 150%LOAD	SI/AM EXCITG CURRENT 150%LOAD	AMORPH NO-LOAD LOSS WATTS	SILICON NO-LOAD LOSS WATTS	AM/SI NO-LOAD LOSS WATTS	CRATED FLUX VOLTS
0.061	0.156	2.557	1.100	2.200	0.500	16.700
0.074	0.218	2.946	3.000	4.900	0.435	33.300
0.086	0.277	3.221	5.400	13.900	0.388	50.000
0.106	0.340	3.208	8.300	23.500	0.353	66.700
0.124	0.382	3.081	9.900	29.500	0.336	75.000
0.160	0.450	2.813	11.700	36.700	0.319	83.300
0.262	0.649	2.477	14.400	46.500	0.310	91.700
0.654	2.494	3.813	17.700	66.800	0.265	100.000
1.218	6.325	5.193	19.700	94.500	0.208	104.200
3.537	8.514	2.407	23.100	152.200	0.152	108.300
8.956	9.478	1.058	79.900	174.500	0.458	112.500

Appendix E

GENERAL ELECTRIC COMPANY TEST REPORT NO. 88-AMT-001

Amorphous Metal Distribution Transformer 3-Foot Drop Test

(Printed by permission of General Electric
Company, July 1989, distribution unlimited)



GE Transformer
Business

Systematic Approach
to Improving Quality
of Service
and Productivity

February 10, 1988

Mr. Guy V. Urata
Naval Civil Engineering Lab
Code L72
Port Hueneme, CA 93043-5003

Subject: Amorphous Metal Distribution Transformer,
3-Ft. Drop Test Report 88-AMT-001

Dear Mr. Urata:

Per Mr. Westhaus' request, I've prepared the subject test report 88-AMT-001, which documents the 3-ft. drop test on three GE Amorphous Metal Cored Distribution Transformers. This test was performed at the GE Distribution Transformer Plant, Hickory, N. C. on April 22, 1987. Mr. John Franchi, of NCEL witnessed all test operations, as well as post drop test examination of the interior assemblies. In addition, Mr. Robert Wright of NCEL took both still photos and video tapes of these operations.

We are very pleased on the outcome of this 3-ft. drop test. It verified once and for all the structural integrity of GE's amorphous metal cored distribution transformers. Please call me if you have any questions.

Sincerely yours,

Albert C. Lee
Senior Development Engineer

1/021088-1

p.s.: Computer tabulation of initial factory test results on the three transformers is also attached.

cc: Randy Westhaus
Advance Technology, Inc.
751 Daily Drive, Suite 220
Camarillo, CA 93010

John Franchi
Naval Civil Engineering Lab
Code L72
Port Hueneme, CA 93043-5003

R. M. Carr-GE Company
9350 Flair Drive
El Monte, CA 91731

01/11/87

LOSSES FILE LISTING BY CUSTOMER ---

PAGE

TS NUMBER	SER NUMBER	ACTUAL NOLOAD	ACTUAL LOAD	ACTUAL TOTAL	IZ	EXC CURR	TEST TEMP	TEST DATE	SHIP DATE	TALLY
3601A00A25LA0	P217059	17.90	319.20	337.10	2.46	.11	0024	1210	121786	
3601A00A25LA0	P217060	17.21	317.40	333.61	2.46	.31	0026	1217	121786	
3601A00A25LA0	P217061	17.20	312.10	329.30	2.46	.30	0026	1216	121786	
TSNO TOTAL		17.10	316.23	333.33	2.46	.24				3

3/11/87

LOSSES FILE LISTING BY CUSTOMER ---

PAGE

TS NUMBER	SER NUMBER	ACTUAL NOLOAD	ACTUAL LOAD	ACTUAL TOTAL	IZ	EXC CURR	TEST TEMP	TEST DATE	SHIP DATE	TALLY
3601A00A25LA0	P265882	13.60	315.80	329.40	2.49	.15	0022	0323	COMPLT	
3601A00A25LA0	P265884	13.70	316.10	329.80	2.50	.18	0023	0323	COMPLT	
3601A00A25LA0	P265885	13.60	319.50	333.10	2.49	.17	0022	0323	COMPLT	
3601A00A25LA0	P217059	17.90	319.20	337.10	2.46	.11	0024	1210	121786	
3601A00A25LA0	P217060	16.20	317.40	333.60	2.46	.31	0026	1217	121786	
3601A00A25LA0	P217061	17.20	312.10	329.30	2.46	.30	0026	1216	121786	
TSNO TOTAL		15.36	316.68	332.05	2.47	.20				6

9/12/87

LOSSES FILE LISTING BY TS NUMBER (EASYLOSS BYTSNUM)

PAGE

1

TS NUMBER	SERIAL NUMBER	NO-LOAD LOSS-TST	LOAD-LOSS TEST	TOT-LOSS TEST	ΣIMP TEST	XEXC TEST	TEST TEMP	TEST DATE	FINISH DATE	SHIP DATE	TALLY
3601A00A25LA0	P217059	17.90	319.20	337.10	2.46	.11	24	861210	861212	861217	
	P217060	17.20	317.40	333.60	2.46	.31	26	161217	861217	861217	
	P217061	17.60	312.10	329.70	2.47	.28	27	170422	861217	861217	
	P265882	13.90	314.80	328.70	2.49	.25	27	870422	870324		
	P265883	13.60	316.50	330.10	2.47	.21	22	870421	870402		
	P265884	14.10	311.20	325.30	2.49	.24	22	870421	870324		
	P265885	13.60	312.90	326.50	2.48	.23	28	870422	870324		
3601A00A25LA0		15.27	314.90	330.17	2.47	.23	25				7

Post 3-ft.
Drop Test

GENERAL ELECTRIC

DISTRIBUTION TRANSFORMER BUSINESS DEPARTMENT



Test Record

Subject	Amorphous Metal Cored Distribution Transformers	Report Number	88-AMT-001
Title	Static Drop Test, 25 kVA	Date	2/8/88

Object To confirm the structural integrity of amorphous metal cores used in distribution transformers by dropping them vertically from a height of three ft. onto a concrete pavement. This DROP TEST is considered as a DESTRUCTIVE TEST.

Test Equipment Pole-type distribution transformers, per GE TS3601A00A25LA0 with voltage ratings of 150/7200Y-120/240. S/N P217061 (1), P265882 (2) and P265885 (2). All three transformers completed a trucking round trip between Hickory, N. C. and Naval Civil Engineering Lab (NCEL) in Port Hueneme, CA (A total shipping distance of ~5000 miles). Notes: 1) core has no encapsulant at joint area; 2) core has encapsulant at joint area.

Test Method DROP TEST was conducted at Hickory, N. C. on April 22, 1987. It consists of lifting the transformer to a three foot height and hanging in air by means of a steel wire. The wire was then cut and allowed the transformer to drop squarely onto the concrete pavement. See photos 1 & 2.

After completion of the 5000-mile shipping distance and after the DROP TEST, each transformer was untanked, and the interior assembly was examined for any sign of damage and any presence of amorphous metal particles and chips.

Each transformer was given a commercial electrical test in the factory before and after the DROP TEST. Tests were also performed in the Dev. Lab.

Results	S/N P217061				S/N P265882				S/N P265885			
	Factory Test		Lab Test		Factory Test		Lab Test		Factory Test		Lab Test	
1. Elect.*	Watts	Amps	Watts	Amps	Watts	Amps	Watts	Amps	Watts	Amps	Watts	Amps
Before:	18.7	.29	18.2	.37	13.0	.25	14.5	.27	14.3	.27	14.5	.34
After:	17.6	.29	18.1	.41	13.9	.26	14.2	.28	13.6	.24	14.1	.32
Change%	-5.6	-0-	+0.55	+11.1	+6.9	+4.0	-2.1	+3.0	-4.9	+11.1	-2.8	-5.9

2. Mech.**

a. Tank bottom "bulged"	Tank bottom "bulged"	Tank bottom "bulged"
b. Top clamp bent	Top clamp bent	Top clamp bent
c. ---	H1 HV bushing broken	---

3. AM Metal - Particles & Chips

a. None in oil	None in oil	None in oil
b. 7 small chips inside bottom chip containment box.	4 small chips inside bottom chip containment box.	1 small chip inside bottom chip containment box

* (See computer printouts) ** (See Photos 3, 4 & 5)

Conclusions (1) Amorphous metal core, with & w/o encapsulant over the cut joint area, remains structurally sound after a 3-ft. drop; (2) Electrical performance remains essentially unchanged after a 3-ft. destructive DROP TEST; (3) The effectiveness of chip containment box was demonstrated; and (4) in spite of tank deformation and clamp damage, all 3 transformers remain functionally good (except broken HV bushing must be replaced).

GENERAL ELECTRIC CO
P. O. BOX 2188 *
HICKORY, NC 28601

ENGINEER

Albert C. Lee

TITLE Sr. Dev. Eng.

PAGE 1 OF 10

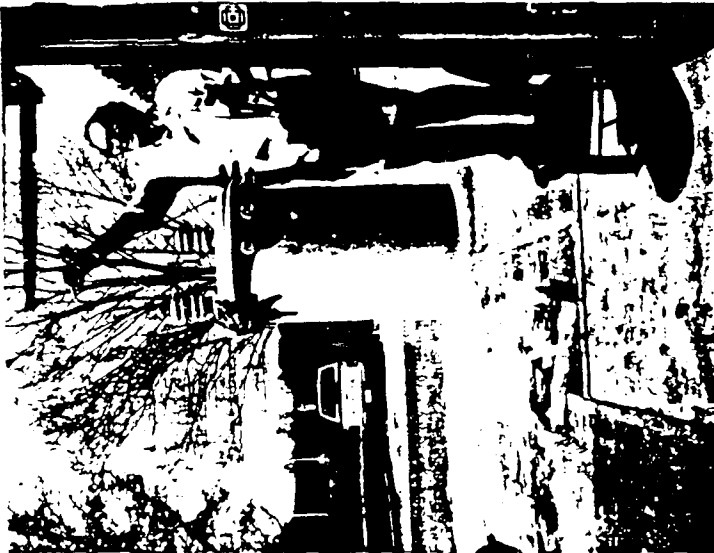


Photo #1 GENERAL ELECTRIC
AM Distribution Transformer
Ready for a 3-ft. Drop Test

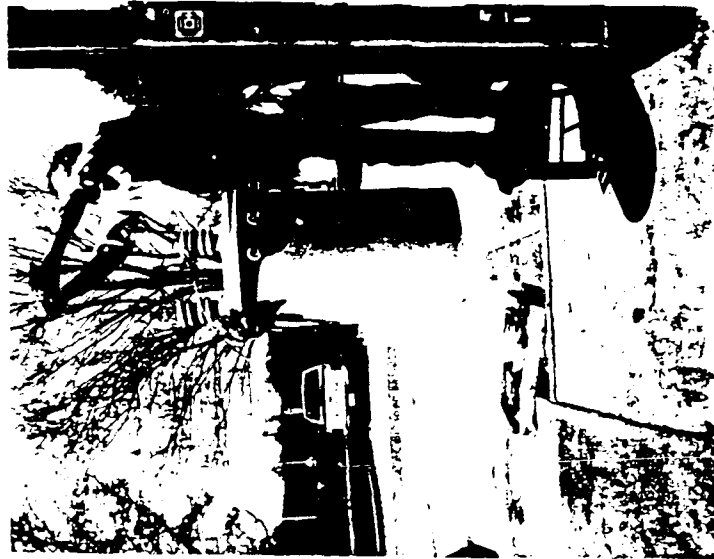


Photo #2 GENERAL ELECTRIC
AM Distribution Transformer
Being Dropped from a 3-ft. Height

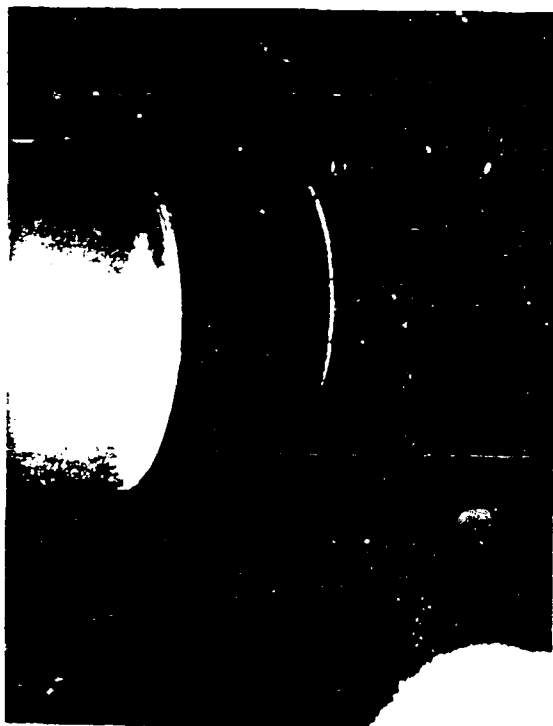


Photo #3 Bottom of Tank "Bulged" After a 3-Ft. Drop. Note imprint by tank on concrete pavement.

Photo #4 One of the High Voltage bushings (H1) broke after impact.

Photo #5 Interior assembly untanked for examination. Note bent top clamp



Photo #5

Photo #4



Photo #4

A. After 5000-mile Shipping Distance & Before 3-Ft. Drop Test

SER.NO. P217061-YZA T.S.NO. 3601AD0A2SLAOL KVA 25 RATING 240. 4147
BLUE QUAD DATE 11-APR-87 TIME 10:22:30

	FLUXV	RMSV	AMPS	WATTS		
EXCITATION	240.3	243.5	0.29	17.6	RATIO =	17.75
INDUCE		480.1	0.88	25.7		
IMPERANCE		5.61	103.97	250.1	TEMP =	0.0
TOTAL WATTS @ 85C				329.0	TEMP =	0.0
LV HIPOT KV		10.0				PASS
HV HIPOT KV		25.0				PASS
IMPULSE KV H1 =	93.3	X3 =	0.0	X1 =	0.0	H1 PAR =
CB LEFT	AMPS =	0.0	MAIN =	0.0	TEMP =	0.0
FAILURE MODE					LIGHT =	NONE
						PASSED UNIT

B. After 3-Ft. Drop Test

SER.NO. P217061-YZA T.S.NO. 3601AD0A2SLAOL KVA 25 RATING 240. 4147
WHITE QUAD DATE 12-APR-87 TIME 16:23:41

	FLUXV	RMSV	AMPS	WATTS		
EXCITATION	240.3	243.5	0.29	17.6	RATIO =	17.75
INDUCE		480.3	0.88	25.7		
IMPERANCE		5.66	103.97	250.1	TEMP =	0.0
TOTAL WATTS @ 85C				329.0	TEMP =	0.0
LV HIPOT KV		10.0				PASS
HV HIPOT KV		25.0				PASS
IMPULSE KV H1 =	93.3	X3 =	0.0	X1 =	0.0	H1 PAR =
CB LEFT	AMPS =	0.0	MAIN =	0.0	TEMP =	0.0
FAILURE MODE					LIGHT =	NONE
						PASSED UNIT

A. After 5000-Mile Shipping Distance & Before 3-Ft. Drop Test

SER.NO. P265882-YRB T.S.NO. 3601AD0A2SLAOL KVA 25 RATING 240V 415
WHITE GUAD DATE 21-APR-87 TIME 11:30:13

	FLUXV	RMSV	AMPS	WATTS		
EXCITATION	241.0	244.1	0.25	13.0	RATIO =	17.31
INDUCE		482.2	0.89	16.7		1084
IMPEDANCE		5.72	104.35	251.0	TEMP =	23.0
TOTAL WATTS @ 55C				328.7	1 IMP =	1.34
LV HIPOT KV		10.0				1084
HV HIPOT KV		26.0				1084
IMPULSE KV H1 =	92.8	X3 =	0.0	X1 =	0.0	H1 PAR =
CR LEFT AMPS =	0.0	MAIN =	0.0	TEMP =	0.0	LIGHT =
FAILURE MODE		PASSED UNIT				

B. After 3-Ft. Drop Test

SER.NO. P265882-YRB T.S.NO. 3601AD0A2SLAOL KVA 25 RATING 240V 415
WHITE GUAD DATE 22-APR-87 TIME 15:43:40

	FLUXV	RMSV	AMPS	WATTS		
EXCITATION	240.6	243.5	0.26	13.9	RATIO =	17.35
INDUCE		479.6	0.89	19.6		1084
IMPEDANCE		5.73	103.97	251.0	TEMP =	23.0
TOTAL WATTS @ 55C				328.7	1 IMP =	1.34
LV HIPOT KV		10.0				1084
HV HIPOT KV		25.9				1084
IMPULSE KV H1 =	92.8	X3 =	0.0	X1 =	0.0	H1 PAR =
CR LEFT AMPS =	0.0	MAIN =	0.0	TEMP =	0.0	LIGHT =
FAILURE MODE		PASSED UNIT				

A. After 5000-Mile Shipping Distance & Before 3-Ft. Drop Test

SER.NO. P265885-YRB T.S.NO. 3601AD0A25LA0L KVA 25 RATING 240V 4160

RED QUAD DATE 21-APR-87 TIME 12:31:31

	FLUXV	RMSV	AMPS	WATTS		
EXCITATION	241.0	244.0	0.27	14.3	RATIO =	17.36 PASS
INDUCE		480.1	0.88	22.5		PASS
IMPEDANCE		5.71	103.69	254.0	TEMP =	22.0 PASS
TOTAL WATTS @ 85C				326.9	% IMP =	1.50
LV HIPOT KV		10.0				PASS
HV HIPOT KV		25.9				PASS
IMPULSE KV H1 =	92.7	X3 =	0.0	X1 =	0.0	H1 FAR = 0.0 PASS
CB RIGHT AMPS =	0.0	MAIN =	0.0	TEMP =	0.0	LIGHT = 0.0 NONE
FAILURE MODE		PASSED UNIT				

B. After 3-Ft. Drop Test

SER.NO. P265885-YRB T.S.NO. 3601AD0A25LA0L KVA 25 RATING 240V 4160

GREEN QUAD DATE 22-APR-87 TIME 15:31:20

	FLUXV	RMSV	AMPS	WATTS		
EXCITATION	240.6	243.5	0.24	13.6	RATIO =	17.35 PASS
INDUCE		480.2	0.85	19.7		PASS
IMPEDANCE		5.71	104.00	259.9	TEMP =	28.0 PASS
TOTAL WATTS @ 85C				326.5	% IMP =	1.46
LV HIPOT KV		10.0				PASS
HV HIPOT KV		25.9				PASS
IMPULSE KV H1 =	92.8	X3 =	0.0	X1 =	0.0	H1 FAR = 0.0 PASS
CB RIGHT AMPS =	0.0	MAIN =	0.0	TEMP =	0.0	LIGHT = 0.0 NONE
FAILURE MODE		PASSED UNIT				

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