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TRANSFORMER REPORT

ON

EVENTS AT NORTH ANNA POWER STATION

June 16, 1983

POWER TRANSFORMER DIVISION

WESTINGHOUSE ELECTRIC CORPORATION

GREENTREE, PA 15220

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I. SCOPE

This report covers the investigation of the transformer events at VEPCO's North Anna power station from November of 1980 through March of 1983. The report is applicable to shop order HAM707 on which 7 units were manufactured.

Included are dielectric, fluid flow, gas evolution and processing considerations relating to the transformer. Also included is a system analysis relating to the event occurring on December 5, 1982.

II. EXECUTIVE SUMMARY

Seven transformer failures occurred at VEPCO's North Anna power station from November of 1980 to December of 1982. This report covers the investigation of these failures.

None of the failures could be reproduced in the laboratory, thus no definitive conclusions can be reached as to the exact cause of any of the failures.

The following statements can be made on each failure:

FAILURE #1: NORTH ANNA #2 - HV LEAD TO LV COIL
(2099)

Rebuilt ship: 1/77
Processed last: 2/79
Failed at N.A.: 11/80
Phase 'A'

- Additional transportation involved prior to rebuild.
- Unit involved in failure at Bowen and rebuilt at Muncie.
- No factory test difficulties on original or rebuilt unit.
- Unit did have overexcitation.
- Processing of main unit was done for a considerable length of time before the failure.
- Mis-operation of inertaire system did occur.
- Gas bubbles do occur in the oil under this condition.
- Dielectric strength degradation of lead configuration due to gas bubbles in the oil does occur.
- Simulated lead configuration withstood 400 kV for 48 hours with and without bubbles present -- corona was observed for large bubbles.
- No other source of bubbles found.

FAILURE #2: NORTH ANNA #2 - HV BUSHING
(2100)

Original ship: 2/74
Processed last: 2/79
Failed at N.A.: 6/81
Phase 'C'

- No factory test problems.
- Additional transportation was involved.
- In bank at Georgia Power when 2099 failure occurred.
- Unit overexcited.
- In bank when 2099 failure occurred at N.A.
- Failure involved bushing only.
- Processing was done a considerable length of time before failure.
- HV bushing was not stored properly.

FAILURE #3: <u>NORTH ANNA #2 - HV BUSHING, LV COIL AND TANK</u>
(2098)

Original ship:	2/74
Processed last: (Energized)	6/81
Failed at N.A.:	7/81
Phase 'B'	

- No factory test difficulties
- In bank at Georgia Power when 2099 failure occurred.
- Additional transportation was involved.
- Unit processed one month prior to failure.
- In bank when 2100 and 2099 failures occurred.
- Lead configuration changed 6/81.
- HV bushing was not stored properly.

FAILURE #4: <u>NORTH ANNA #2 - G.P. UNIT - HV LINE COIL, LV COIL, TANK</u>
(1527)

Original ship:	5/70
Processed last:	6/81
Energized:	7/81
Failed at N.A.:	7/81
Phase 'C'	

- No factory test difficulties.
- In bank when two other transformer failures occurred at G.P.
- Dielectrically tested above rated design level at Muncie plant.
- In bank when 2098 difficulty occurred.
- Failed immediately after energizing subsequent to 2098 failure at N.A.
- Large quantities of carbon observed during failure observations.

FAILURE #5: NORTH ANNA #2 - HV BUSHING, CORONA SHIELD AND LV WINDING AND TANK
(2100 Repaired at Muncie)

Rebuilt ship:	10/81
Processed last:	3/82
Energized:	3/82
Failed at N.A.:	8/82
Phase 'B'	

- Bushing transportation.
- At Muncie, lead configuration changed to present practice during rebuild.
- No factory test difficulties.
- Processed five months prior to failure -- factory tested bushing installed 1/82 -- unit was final processed 3/82 -- energized at intervals for five months.
- Mechanically fatigued bolt in bushing assembly found -- failure location in bushing correlates with physical evidence of bolt and washers.
- Possible physical evidence of oil electrification in coil assembly.

FAILURE #6: <u>NORTH ANNA #1 - HV BUSHING SHIELD AND LV COIL</u>
(1995)

Original ship:	8/73
Processed last:	8/82
Energized:	11/82
Failed at N.A.:	11/82
Phase 'C'	

- No factory test difficulties.
- In service since 1978 without difficulty.
- System configuration changed with addition of generator breaker prior to problem.
- Pumps removed and refurbished.
- Processed prior to difficulty.
- Ambient temperature change of 30°C noted two days prior to energizing.
- Cooler initiation and operation in accordance with task force report (coolers not operated prior to energization.)
- To date, gas bubbles have not been produced from the lead or oil in laboratory experiments except under vacuum.
- Bushing/lead configuration simulation withstood 400 kV for 48 hours with and without bubbles -- corona observed for large bubbles.

FAILURE #7: <u>NORTH ANNA #1 - HV LEAD, LV COIL, TURN-TO-TURN FAILURE</u>
(1994)

Original ship:	7/73
Processed last:	12/82
Energized:	12/82
Failed at N.A.:	12/82
Phase 'B'	

- No factory test difficulties.
- In service since 1978 without difficulty.
- System configuration changed with addition of generator breaker prior to problem.
- Pumps removed and refurbished due to metallic contamination, unit flushed.
- In bank during 1995 failure.
- Retrofitted with COPS.
- Removed barrel barrier,
- Partial discharge field test with waveguides installed.
- Pumps run prior to energization per instructions.
- To date, gas bubbles have not been produced from lead experiment except under vacuum.
- Bushing/lead configuration simulation withstood 400 kV for 48 hours with and without bubbles -- corona observed for large bubbles.
- To date, lab tests have not produced high turn-to-turn stresses in area of turn-turn failure observed for a high-low failure mode.

III. INTRODUCTION

Seven single phase generator step up transformers were manufactured and delivered to Virginia Electric Power Company in 1973 and 1974 for operation at the North Anna station. These are identified as S.O. HAM707. The units are rated 330 MVA with a 55°C rise and 369.6 MVA with a 65°C rise. The high voltage winding is 1300 kV BIL on the line end and 150 kV BIL at the neutral. The low voltage is 150 kV BIL. The nominal voltage is 500000 grd. Y/288675 to 22000 volts. There are de-energized taps at 303110, 295890, 281460 and 274240 volts. The cooling system is "FOA" and the oil preservation system is "inertaire" designed to operate between 0.5 and 8.0 psi pressure.

In addition there was involved a spare transformer that Virginia Electric Power Company borrowed from the Georgia Power Company. It is identified as S.O. HAM390. It is a single phase 277 MVA, 500000 grd. Y/288675 to 23800 volts.

The history of each of these units is detailed as follows:

Serial 7001965 S.O. HAM707

1. Tested originally 7/20/73.

2. Operated commercially.

3. Installed waveguide and "COPS" system - 11/82.

4. Removed barrel barriers from H.V. bushing and made general internal inspection -- 11/22/82. See J. B. Templeton's trip report of 12/15/82. (1)

5. Field corona tests by VEPCO -- 11/30/82 to 12/3/82. See W. J. Carter's trip report of 12/16/82. (2)

   (1) Appendix A - Item 1
   (2) Appendix A - Item 2

Serial 7001993 S.O. HAM707

1. Tested originally 7/24/73.

2. Originally the spare for the North Anna Station.

3. Put in place of serial 7002099 which failed on 11/29/80.

4. 500 kV lead changed from wire of coil and brush copper section to cable -- June, 1981. (Muncie Personnel)

5. 500 kV lead rechecked for quality -- July, 1981. (Muncie Personnel).

6. 500 kV bushing removed and replaced with bushing from serial 7002099. Bushing from serial 7002099 tested 7/11/81 in Muncie and returned to VEPCO.

7. Pumps replaced -- July, 1981. New pumps were sent from Muncie. The replaced pumps returned to Muncie were dismantled and two indicated signs of bearing wear.

8. Unit flushed to remove bearing particles -- July, 1981.

9. VEPCO accident -- water introduced inside unit.

10. Unit put on dry out process 7/19/81.

11. Waveguide installed 8/26/82.

Serial 7001994 S.O. HAM707

1. Tested originally 7/26/73.
2. Operated commercially.
3. Installed "COPS" system - 11/82.
4. Removed barrel barriers from H.V. bushing and made general internal inspection -- 11/22/82. See J. B. Templeton's trip report of 12/15/82. (3)
5. Field corona tests by VEPCO -- 11/30/82 to 12/3/82. See W. J. Carter's trip report of 12/16/82. (4)
6. Failed 12/5/82. See W. J. Carter's and D. White's teardown report of 1/10/83. (5)

Serial 7001995 S.O. HAM707

1. Originally tested 8/3/79.
2. Operated commercially starting in 1974 in North Anna #1.
3. De-energized May 1982.
4. Oil drained and refilled with new oil August 1982.
5. Failed 11/16/82 after three hours and six minute after energizing. See H. R. Moore's report of 12/3/82. (6)

(3) Appendix A - Item 1
(4) Appendix A - Item 2
(5) Appendix B - Item 1
(6) Appendix B - Item 2

Serial 7002098 S.O. HAM707

1. Tested originally 2/20/74.

2. Stored at VEPCO.

3. Loaned to Georgia Power Company for operation at Plant Bowen -- May, 1976.

4. Returned to Muncie on S.O. XDM1324 for retest -- tested 9/2/76.

5. Reshipped to VEPCO.

6. Overexcitation reported (140.9% for 42 seconds) -- 2/6/79.

7. 500 kV lead changed from wire of coil and brush copper section to cable -- June, 1982. (Muncie Personnel)

8. Failed while in service at North Anna Station -- 7/3/81.

9. Remains of 500 kV bushing returned to Muncie. See bushing report, serial 6, of 8/3/81 by L. B. Wagenaar. (7)

10. Pumps returned to Muncie.

11. Scrapped in the field - 9/81.

(7) Appendix B - Item 8

Serial 7002099 S.O. HAM707

1. Tested originally 2/22/74.
2. Stored at VEPCO.
3. Loaned to Georgia Power for operation at Plant Bowen -- May, 1976.
4. Failed while in service at Plant Bowen -- May, 1976. See Engineering Lab Report #41-5F by Puri/Hansen - 7/30/76. (8)
5. Returned to Muncie for repair on S.O. XDM1323.
6. XDM1323 tested on 1/31/77.
7. Reshipped to VEPCO.
8. Missing hardware problem. Conclusion it was never shipped. See I. L. Hansen's trip report of 3/24/77. (9)
9. Overexcitation reported (140.9% for 42 seconds) -- 2/6/79.
10. Failed while in service at North Anna Station -- 11/29/80. See trip report by B. W. Hugon of 12/17/80 (10) and disassembly report by L. E Luke of 6/5/81 (11).
11. Repaired on S.O. XDM1742.
12. Retested on 7/24/81 and reshipped to VEPCO.
13. Waveguide installed - 8/26/82.

(8) Appendix B - Item 3
(9) Appendix A - Item 3
(10) Appendix B - Item 4
(11) Appendix B - Item 5

Serial 7002100 S.O. HAM707

1. Tested originally on 3/4/74.

2. Stored at VEPCO.

3. Loaned to Georgia Power Company for operation at Plant Bowen -- May, 1976.

4. Returned to Muncie on S.O. XDM1324 for retest -- tested 9/23/76.

5. Reshipped to VEPCO.

6. Overexcitation reported (140.9% for 42 seconds) -- 2/6/79.

7. Failed while in service at North Anna Station -- 6/19/81. See disassembly report of 10/13/81 by B. W. Hugon. (12)

8. Remains of 500 kV bushing returned to Muncie. See bushing report, serial 7, of 8/3/81 by L. B. Wagenaar. (13)

9. Pumps returned to Muncie.

10. Repair order -- XDM1779. Rebuilt with new phase. Tested 10/21/81.

11. Failed while in service at North Anna Station - 8/22/82. See R&D report 82-7D7-MUNCI-R1, 10/6/82. (14)

12. Repair order - XDM1867. See teardown report of 2/23/83 by Dale White. (15)

(12) Appendix B - Item 6
(13) Appendix B - Item 9
(14) Appendix B - Item 10
(15) Appendix B - Item 7

Serial 7001527 S.O. HAM390

1. Tested originally 5/21/70.

2. Operated at Georgia Power Company, Bowen Plant.

3. Removed from service after failure of serials 7001526 and 7001528 -- March, 1976.

4. Returned to Muncie for tests on S.O. XDM1316.

5. Dielectric tests made at 1175, 1300, 1425, 1550 kV BIL.

6. Returned to Georgia Power Company, Bowen Plant, as a spare.

7. Shipped to VEPCO to replace Serial 7002100 -- June, 1981.

8. Failed at VEPCO North Anna Station -- 7/25/81.

9. Unit disassembled in the field and scrapped - 8/81.

A summary of the failure points for each of the incidents is as follows:

FAILURE POINTS

Serial	Shipped	Failed	HV Bushing	HV Corona Shield	HV Lead	HV Line Coils	HV Series Conn.	To LV Wdg.	LV Wdg.	Tank
7002099	1/77	11/80			X			X		
7002100	2/74	6/81	X							
7002098	2/74	7/81	X					X		X
7001527	5/70	7/81				X		X		X
7002100	10/81	8/82	X	X				X		X
7001995	8/73	11/82		X				X		
7001994	7/73	12/82			X			X	X	
7001993	7/73	---								
7001965	7/73	---								

IV. CONCLUSIONS

The investigation has not been able to simulate or duplicate the failure mechanism observed at the North Anna power station.

In general, the dielectric studies have indicated the following:

1. For large gas bubbles at high velocity oil flow rates, partial discharge was experienced but no flashovers occurred.

2. The high voltage line lead configuration was stressed at 400 kV to ground for a time equivalent to 5.7 years service at nominal operating voltage. This time equivalent is based on a volt-time probability function.

3. The effect of an improper taper joint in the taping of the high voltage line lead did not signficantly affect the partial discharge levels.

4. This combination of gas bubbles in the oil system and induced static electrification of the oil did increase the partial discharge levels but no flashovers occurred.

5. No evidence of problems with winding resonance effects could be determined.

6. No evidence of high transient voltage effects could be determined.

7. Gas trapped in taped insulated leads did not evolve into the oil as bubbles unless a negative pressure occurred above the oil.

8. No apparent system related problems have been determined.

A summary of each individual transformer is as follows:

FAILURE #1: <u>NORTH ANNA #2 - HV LEAD TO LV COIL</u>
(2099)

Rebuilt ship:	1/77
Processed last:	2/79
Failed at N.A.:	11/80
Phase 'A'	

- Additional transportation involved prior to rebuild.
- Unit involved in failure at Bowen and rebuilt at Muncie.
- No factory test difficulties on original or rebuilt unit.
- Unit did have overexcitation.
- Processing of main unit was done for a considerable length of time before the failure.
- Mis-operation of inertaire system did occur.
- Gas bubbles do occur in the oil under this condition.
- Dielectric strength degradation of lead configuration due to gas bubbles in the oil does occur.
- Simulated lead configuration withstood 400 kV for 48 hours with and without bubbles present -- corona was observed for large bubbles.
- No other source of bubbles found.

FAILURE #2: <u>NORTH ANNA #2 - HV BUSHING</u>
(2100)

Original ship: 2/74
Processed last: 2/79
Failed at N.A.: 6/81
Phase 'C'

- No factory test problems.
- Additional transportation was involved.
- In bank at Georgia Power when 2099 failure occurred.
- Unit overexcited.
- In bank when 2099 failure occurred at N.A.
- Failure involved bushing only.
- Processing was done a considerable length of time before failure.
- HV bushing was not stored properly.

FAILURE #3: NORTH ANNA #2 - HV BUSHING, LV COIL AND TANK
(2098)

Original ship: 2/74
Processed last: 6/81
(Energized)
Failed at N.A.: 7/81
Phase 'B'

- No factory test difficulties
- In bank at Georgia Power when 2099 failure occurred.
- Additional transportation was involved.
- Unit processed one month prior to failure.
- In bank when 2100 and 2099 failures occurred.
- Lead configuration changed 6/81.
- HV bushing was not stored properly.

FAILURE #4: <u>NORTH ANNA #2 - G.P. UNIT - HV LINE COIL, LV COIL, TANK</u>
(1527)

Original ship:	5/70
Processed last:	6/81
Energized:	7/81
Failed at N.A.:	7/81
Phase 'C'	

- No factory test difficulties.
- In bank when two other transformer failures occurred at G.P.
- Dielectrically tested above rated design level at Muncie plant.
- In bank when 2098 difficulty occurred.
- Failed immediately after energizing subsequent to 2098 failure at N.A.
- Large quantities of carbon observed during failure observations.

FAILURE #5: <u>NORTH ANNA #2 - HV BUSHING, CORONA SHIELD AND LV WINDING AND TANK</u>
(2100 Repaired at Muncie)

Rebuilt ship:	10/81
Processed last:	3/82
Energized:	3/82
Failed at N.A.:	8/82
Phase 'B'	

- Bushing transportation.
- At Muncie, lead configuration changed to present practice during rebuild.
- No factory test difficulties.
- Processed five months prior to failure -- factory tested bushing installed 1/82 -- unit was final processed 3/82 -- energized at intervals for five months.
- Mechanically fatigued bolt in bushing assembly found -- failure location in bushing correlates with physical evidence of bolt and washers.
- Possible physical evidence of oil electrification in coil assembly.

FAILURE #6: <u>NORTH ANNA #1 - HV BUSHING SHIELD AND LV COIL</u>
(1995)

Original ship:	8/73
Processed last:	8/82
Energized:	11/82
Failed at N.A.:	11/82
Phase 'C'	

- No factory test difficulties.
- In service since 1978 without difficulty.
- System configuration changed with addition of generator breaker prior to problem.
- Pumps removed and refurbished.
- Processed prior to difficulty.
- Ambient temperature change of 30°C noted two days prior to energizing.
- Cooler initiation and operation in accordance with task force report (coolers not operated prior to energization.)
- To date, gas bubbles have not been produced from the lead or oil in laboratory experiments except under vacuum.
- Bushing/lead configuration simulation withstood 400 kV for 48 hours with and without bubbles -- corona observed for large bubbles.

FAILURE #7: NORTH ANNA #1 - HV LEAD, LV COIL, TURN-TO-TURN FAILURE
(1994)

Original ship:	7/73
Processed last:	12/82
Energized:	12/82
Failed at N.A.:	12/82
Phase 'B'	

- No factory test difficulties.
- In service since 1978 without difficulty.
- System configuration changed with addition of generator breaker prior to problem.
- Pumps removed and refurbished due to metallic contamination, unit flushed.
- In bank during 1995 failure.
- Retrofitted with COPS.
- Removed barrel barrier,
- Partial discharge field test with waveguides installed.
- Pumps run prior to energization per instructions.
- To date, gas bubbles have not been produced from lead experiment except under vacuum.
- Bushing/lead configuration simulation withstood 400 kV for 48 hours with and without bubbles -- corona observed for large bubbles.
- To date, lab tests have not produced high turn-to-turn stresses in area of turn-turn failure observed for a high-low failure mode.

V. CORRELATION STUDIES

A multidimensional correlation study has been performed on all 500 kV generator step up transformers (GSU) manufactured by Westinghouse and subsequently put into service. The categories selected for the cross correlation are as follows:

1) Customer (VEPCO and Others)
2) Winding BIL (1300 kV, 1450 kV+)
3) Internal work (performed on site) (Yes, No)
4) Previous involvement (in a bank during failure) (Yes, No)
5) Bushing BIL (1300 kV, 1450 kV+)
6) High voltage lead (horizontal, vertical)

Each of the above six categories are subdivided into two classes as indicated, thus creating $2^6 = 64$ cells. One of the two classes in each category is perceived to have possible adverse effects on the failure rate.

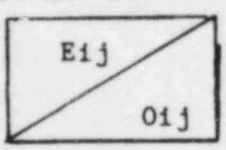
(Notes: Three phase transformers are counted as three transformers since each phase has had a chance to fail. Failure of a three phase transformer is counted as one failure. A rebuilt transformer is counted as a new transformer. Internal work is defined as the situation when a transformer is drained and actual physical work is performed inside before reprocessing and reenergization. Initial installation and filling of the transformer on site is not counted as Internal work. The remaining counting rules are self-explanatory).

160 transformers (500 kV GSU) have been manufactured and put into service and of these 16 have failed. The failure rate is therefore 0.1 or 10% of the population. Each of these 160 transformers was classified into one of the 64 cells. Table I shows the number of transformers in the upper left corner and the number of failed transformers in the lower right hand corner. As had been anticipated only a small portion of the cells, actually 11, contain any transformers. These 11 cells are listed in Table II in descending order of the number of transformers in each cell.

Data analysis was carried out on these 11 cells as shown in Table III. Each cell is divided into success and failure. Expected success (90%) and failure (10%) is calculated and the contribution to the X^2 value for each cell calculated.

$$X^2 = \sum_{i}^{k} \sum_{j}^{l} \frac{(O_{ij} - E_{ij})^2}{E_{ij}}$$

where Oij are observed and Eij are expected values. (i designates the column and j the row in Table III).



By definition the degrees of freedom is:

$$D = (i-1)(j-1)$$

which in this case is 11. X^2 is used as a measure of the deviation from a random distribution. If the failures were truly randomly distributed there would be only a 1% chance to obtain X^2 greater than 24.7. The actual calculated value is 83.3. Therefore the probability of the failures coming from a purely random distribution is extremely small. Cell 7 contributes 45 to the X^2 value, but even if cell 7 is disregarded, the value of X^2 is still higher than expected from a random distribution.

If next the elimination of any one of the chosen six categories is considered, cell 7 stays intact in all cases. This can easily be seen by noting that cell 7 in Table I has no non-empty cell in the vertical or horizontal direction. Cell 7 has the combination of all the perceived adverse effects on the failure rate from all the six categories.

Cells 8 to 11 contain only two or one transformers and are therefore statistically not very meaningful. They were therefore next combined into two cells based on whether the transformer has a horizontal or vertical high voltage lead. The first seven cells were kept intact. Table IV shows the result of a similar analysis to that in Table III. Cell 8^x in Table IV is the combination of the original cells 8 and 11, while cell 9^x is the combination of the original cells 8 and 11, while cell 9^x is the combination of the original cells 9 and 10 which also results in losing the category of Customer (VEPCO, Others) in cell 9^x. Cell 9^x now contributes 18 to the X^2 value while cell 8^x is relatively benign.

Similar results are obtained with two other approaches dealing with cells 8 to 11, if cells 8 to 11 are lumped into one new cell or lumped into two new cells based on whether the customer was VEPCO or not. In both these cases one new cell has a substantial contribution to X_2 indicating that cell 7 is not the only contributor to the lack of random behavior of the failure rate.

Eliminating any two of the original categories, similar results are obtained. That is, there remains at least two cells contributing significantly to X^2. Eliminating three of the categories, cell 7 stays intact with its 100% failure rate in most of the possible combinations of the remaining three perceived adverse effects on the failure rate. One particular case gives an interesting result and is described below:

Of the five non-empty cells, cells A and D contain only VEPCO transformers except on ein cell D. Only cell D has a failure rate which deviates significantly from the average failure rate. Cell A and D are comparable in size and both have a low winding BIL. Cell D contains nearly half the failed transformers. However, cell 7 stays intact with its 100% failure rate if the categories of Previous involvement, Customer and Internal work are the three categories retained. Those are the categories eliminated in cell D. Another example resulting in a cell with 100% failure rate, actually six failures out of six transformers, occurs when the categories of Customer, Bushing BIL and Winding BIL are retained, in which cells 7 and 10 combine. Conversely, if the categories Internal work, Previous involvement and H.V. lead are retained, cell 7 stays intact.

The eliminations of categories described above demonstrates the lack of data for comparison in the available data base. No particular combination of the perceived adverse effects appears to be significantly worse or better than any other combination because cell 7 has such a small amount of neighboring data (Table I).

Discussion

The results of this analysis indicate that there is a significant deviation from random behavior of the failure rate with a strong correlation to a combination of perceived adverse effects on the failure rate. Yet no single one of the perceived adverse effects is needed to show the strong deviation from a truly random failure rate.

It is speculated that a physical reason or reasons for many of the failures have occurred in correlation with many of the perceived adverse effects, but these physical reasons are not known or associated with any particular combination of the initially perceived adverse effects. The extreme deviation from random behavior of the combination of all the perceived adverse effects (cell 7) suggests that one or more unknown adverse physical conditions might have been associated with that group. However, such physical conditions may or may not be associated with any or all the perceived adverse effects on the failure rate.

TABLE I

a

TABLE II

C

TABLE III

Cell No.	1	2	3	4	5	6	7	8	9	10	11	
Success	80.1 / 88	29.7 / 30	8.1 / 8	7.2 / 6	5.4 / 6	4.5 / 4	4.5 / 0	1.8 / 2	0.9 / 0	0.9 / 0	0.9 / 0	144 / 144
Failure	8.9 / 1	3.3 / 3	0.9 / 1	0.8 / 2	0.6 / 0	0.5 / 1	0.5 / 5	0.2 / 0	0.1 / 1	0.1 / 1	0.1 / 1	16 / 16
No. of Transformers	89	33	9	8	6	5	5	2	1	1	1	160
$\Delta\chi^2$	7.8	0.03	.012	2.0	0.67	0.56	45	0.22	9	9	9	$\chi^2 \sim 83.3$

TABLE IV

Cell No.	1	2	3	4	5	6	7	Vert. 8*	Horiz. 9*	Total
Success	80.1 / 88	29.7 / 30	8.1 / 8	7.2 / 6	5.4 / 6	4.5 / 4	4.5 / 0	2.7 / 2	1.8 / 0	144
Failed	8.9 / 1	3.3 / 3	0.9 / 1	0.8 / 2	0.6 / 0	0.5 / 1	0.5 / 5	0.3 / 1	0.2 / 2	16
	89	33	9	8	6	5	5	3	2	160
χ^2 Value	7.8	.03	.012	2.0	0.67	0.56	45.0	1.8	18.0	$\chi^2 \sim 76.0$

VI. AREAS OF INVESTIGATION

Subsequent to the seventh failure of the Westinghouse transformers at the VEPCO North Anna power generating station a comprehensive program was initiated to study various aspects of the situation. The Westinghouse study included investigations into the transformers as well as the power system into which it was integrated.

The power system study was conducted by reviewing the data accumulated from the recording devices on the system and through analytical calculations. Calculations of voltages and currents for various scenarios of operation were completed and concentrated on the generator side of the transformer.

Along with the power system study, several investigations were made concurrently concentrating on the internal operation of the transformer. A study of the transformer hydraulic circuit consisted of a review of field processing records, a hydraulic flow analysis, analysis of gas and moisture content in oil samples, and a gas in oil equilibrium analysis. In support of the previous tests, various electrical tests were performed with a high voltage lead configuration as existed in the North Anna transformers. The purpose of the electrical tests was to determine if the insulation integrity degraded as the temperature and pressure changes of the oil produced an equilibrium change in the dissolved gases in the oil thus producing bubbles. Additionally, experiments were performed to determine any electrical effects from static electrification of the oil on the integrity of the high voltage lead insulation.

One of the failures identified in the seventh incident was a turn-to-turn fault in coil 1 of the low voltage winding. In order to determine the sequence as to when the fault occurred, a low voltage impulse distribution test was done to simulate a high voltage to low voltage arc with measurements to quantify the subsequent turn-to-turn stresses. Also, a review was made of the resonant frequency response of the transformer to determine if a low voltage bus duct flashover could result in transient voltages in the high voltage winding.

The transformer involved in the seventh incident had been equipped with an acoustical waveguide inside the transformer to detect incipient electrical problems during the operation of the transformer. A test was performed to determine if the waveguide would have had sufficient sensitivity to detect the turn-to-turn fault in the low voltage if the fault existed prior to the failure of the transformer.

In reviewing the seven incidents at North Anna relative to the field experience of other 500 kV units, the need was identified to conduct a statistical analysis of 500 kV transformers. Thus, a statistical correlation analysis involving multiple variables was completed.

The analysis of the North Anna incidents has entailed a comprehensive investigation. The details of the various studies are included in this report.

VII. SYSTEM INVESTIGATIONS FOR VEPCO NORTH ANNA TRANSFORMER - GENERATOR FAILURE OF DECEMBER 5, 1982

This report summarizes the results of the system investigations made by T&DSE to determine the possible causes of the VEPCO North Anna transformer and generator failures on December 5, 1983.

Analysis of Oscillograms and Events Records

The oscillograms for the December 5 failure as well as those from the previous August and November failures were examined. The only quantities measured were those from the 500 kV side of the step-up transformer with no generator or low-side quantities monitored. From this limited data nothing unusual could be determined. No external system disturbance was apparent that could have caused the failure.

The handwritten and typed notes on the sequence of events prior to and following the failure prepared by the VEPCO personnel was examined. Certain items from these noted led to the following investigations.

3 E_0 Bus Relay Operation

On Friday, December 3 it was noted that the $3E_0$ bus relay operated when the transformer was being backfed from the 500 kV system with the generator breaker open. This relay is connected across the broken delta of a set of potential transformers connected to the low voltage bus between the generator breaker and the low voltage winding of the transformer. A 48 ohm resistor is connected across the relay to stabilize the neutral of the low voltage system. The relay was set to trip at 19 volts which represents an E_0 on the system of 19/208 or approximately 10 percent.

It was originally thought that the relay tripping was due to the unbalanced reactances of the one McGraw single phase unit and the two Westinghouse units which make up the three-phase bank. The setting of the relay was raised and the bank reenergized.

The unbalanced reactances could not have caused the unbalance since there was essentially no load current flowing through the bank. This indicated that something else caused the unbalance, possibly indicative of a turn-to-turn fault existing in the low voltage winding of the transformer. Since these windings are connected in delta, it is impossible to calculate the resulting $3E_0$ without knowing the exact loading impedances on the system. Other possible causes were investigated.

A difference in taps on the McGraw unit compared to the Westinghouse units could be significant. It was determined, however, that the difference in tap settings were only .0007 percent, so this should not cause the relay trip.

Since the only ground source on the low voltage bus is this wye-broken delta potential transformer with only a 48 ohm resistor and relay across the broken delta, it is probable that unequal capacitances on the bus could cause the unbalance. While most of the capacitances (such as that of the iso-phase bus) are relatively equal for each phase, the capacitance of the McGraw unit is lower than the Westinghouse unit. The McGraw unit has a capacitance of 0.02 microfarads while the capacitance of the Westinghouse units is 0.03 microfarads. With this difference it was found that a $3E_o$ of greater than 10% would be obtained.

Figures 1 and 2 show the calculations for this condition. Figure 1 shows that the LV windings of the three single phase step-up units result in phase-to-ground capacitances of 0.025, 0.025 and 0.03 microfarads on phase "a", "b" and "c" respectively. Assuming 100 feet of isolated phase bus adds another 0.002 microfarads to each phase, and the three station service auxiliaries each have 0.005 microfarads per phase, the total would be 0.015 microfarads for each phase. Thus, the total capacitance on two of the phases is 0.042 microfarads with 0.047 microfarads on the third. the capacitances represent .06315 and .0562 megohms capacitive reactance respectively. This compares to the resistance of 0.2 megohms when the 48 ohm broken delta resistor is expressed as R_o on the primary side of the potential transformer.

Figure 2 shows the symmetrical component solution to this unbalanced capacitance condition. Solving the circuit of Figure 2(c) gives an E_o value of 0.0366 per unit or a $3E_o$ across the relay of 10.9 percent. This voltage is sufficient to cause the relay to operate.

It can be concluded from this study that it is possible that the $3E_o$ relay operation on December 3 could have indicated a turn-to-turn fault or some other abnormality in the transformer. If such were the case, however, one would have expected that the ultimate failure would have occurred before December 5. It is therefore more probable that the relay operation was caused by the unbalanced capacitance of the low voltage bus system.

$3E_o$ Potential Transformer Resonance

The above calculations clearly indicated that the 48 ohm resistor in the broken delta of the bus potential transformers was not sufficient to stabilize the neutral of the low voltage system with the generator breaker open. A logical question therefore arises, "could ferroresonance have occurred to cause the transformer failure?" A detailed ANACOM study of the North Anna installation would have to be run to determine the actual voltages involved, and whether ferroresonance could occur. As a substitute, the paper "Ferroresonance of Grounded Potential Transformers on Ungrounded Power Systems" by R. F. Karlicek and E. R. Taylor, Jr. (AIEE Power Apparatus & Systems, August 1959) was reviewed for general observations pertinent to the December 5 failure.

From this paper it could be concluded that the ohmic value of the resistor should be considerably less than 48 ohms to absolutely prevent ferroresonance, but the line-to-ground voltage resulting from any ferroresonance (should it occur) would probably not produce high enough voltages to breakdown the transformer insulation.

Distribution Transformer Grounding Bank

The lack of adequate grounding on the low voltage bus suggests another possible failure mode. Assume a line-to-ground fault in the bus between the generator breaker and the transformer. The system is well grounded through the generator neutral resistor and after a certain time delay the relay across this resistor will trip the generator. The ground fault now exists on a system only grounded through the 48 ohm resistor in the potential circuit. This results in a fault current on the order of 0.1 ampere which creates a very unstable arc. This arcing ground fault can cause high transient overvoltages and could cause a failure of the transformer.

This probably did not occur on December 5, since it requires the generator being isolated from the bus which would have protected the generator from damage. It is a real possibility for happening at some time, however, and most people using generator breakers provide a full scale grounding bank on the low voltage bus to protect against this and any other condition where an arcing fault could occur with the breaker open. In fact, the new ANSI standard C37.101-1983 "Generator Ground Protection Guide" contains a section on the relaying for such an installation.

The generally accepted rules for high resistance or distribution transformer grounding states that the grounding resistor size should be such that the resistor kilowatts should be equal to or greater than the capacitive charging kVA or that the ground fault current should be equal to or greater than 5 amperes; whichever gives the lowest resistor ohms. Since with the generator breaker open, the capacitive charging kVA of the bus is quite low, in this case the 5 ampere requirement would hold. Figure 3 shows that for the North Anna application a 1.08 ohm resistor should be used.

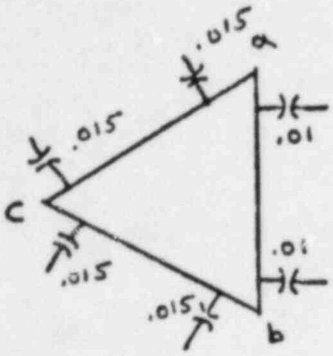
Note that when the generator breaker is closed, the generator neutral grounding system will be in parallel with the bus grounding system. Both ground relays should see the bus fault. C37.101 covers this condition with two suggested tripping modes:

1. Set the tripping time of the bus relay at a longer time than the generator relay. The generator will always be tripped and if the fault is in the generator, the integrity of the low voltage bus and thus the station auxiliary bus will be maintained. If the fault is on the bus side of the generator, then the high side transformer breakers will be tripped by the bus relay at some time after the generator breaker. Since in this case, the fault current is only 5 amperes (and no high transient overvoltages are produced) this additional time delay should not be objectionable.

2. An alternative tripping scheme suggested by C37.101 is to supervise the tripping of the bus relay with the auxiliary contacts of the generator breaker. Thus tripping by the bus relay cannot occur unless the generator breaker is open. Note that the operation of this scheme is the same as the one described above.

Generator Breaker

VEPCO has retained Power Technologies, Inc. to perform a detailed analysis of generator breaker performance. The results of that study are not included as part of this report.



C_a = .025 μf

C_b = .025 μf

C_c = .03 μf

Isophase Bus Capacitance = 20 pf/ft
Assume 100 ft of bus

C_{bus} = .002 μf

Station Service Xfmrs = .005 μf
3 transformers

C_{tr} = .015 μf

Total Capacitance:

ϕ_A = .025 + .002 + .015 = .042 μf

ϕ_B = .025 + .002 + .015 = .042 μf

ϕ_C = .03 + .002 + .015 = .047 μf

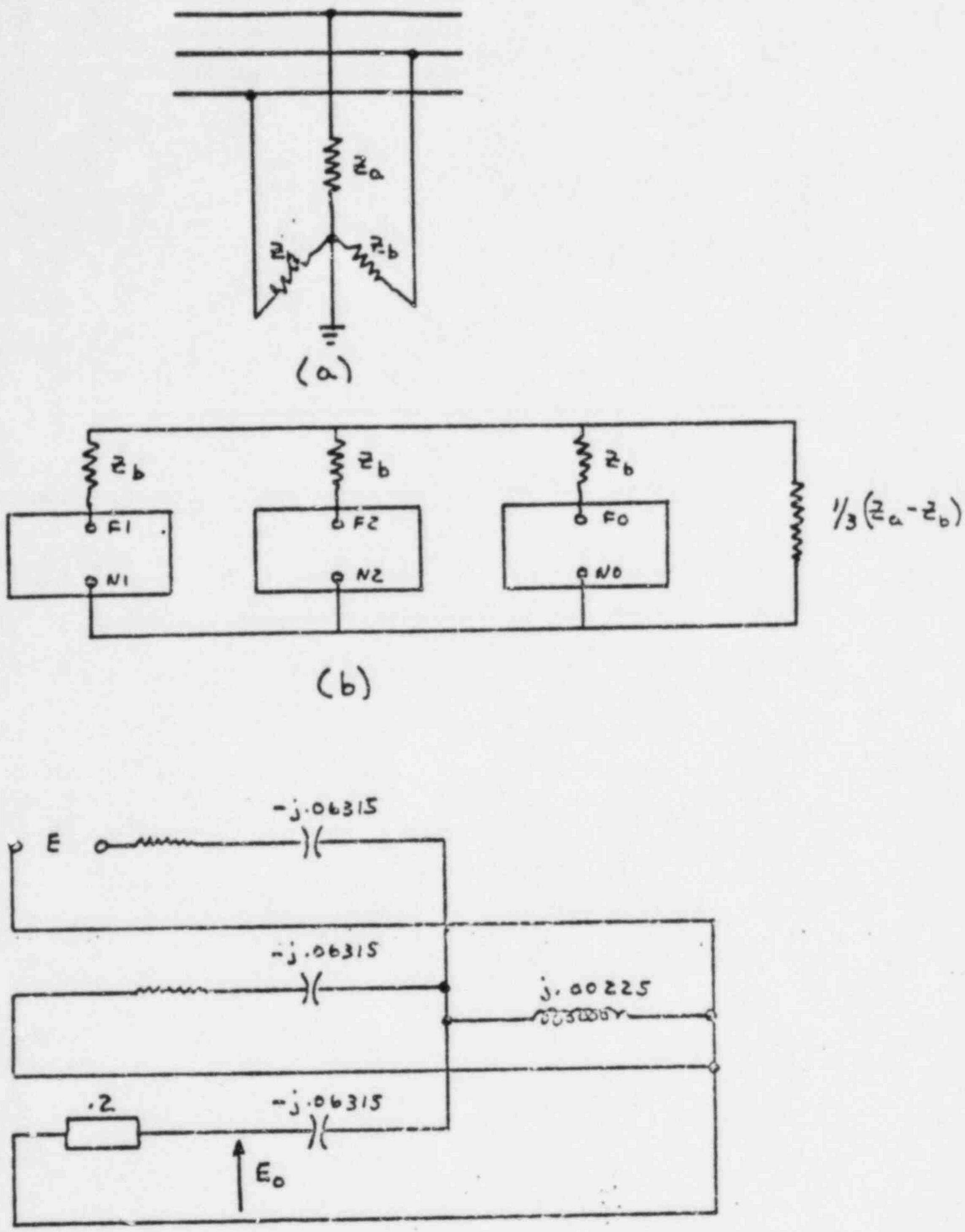
X_{ca} = .06315 x

X_{cb} = .06315 x

X_{cc} = .0564 x

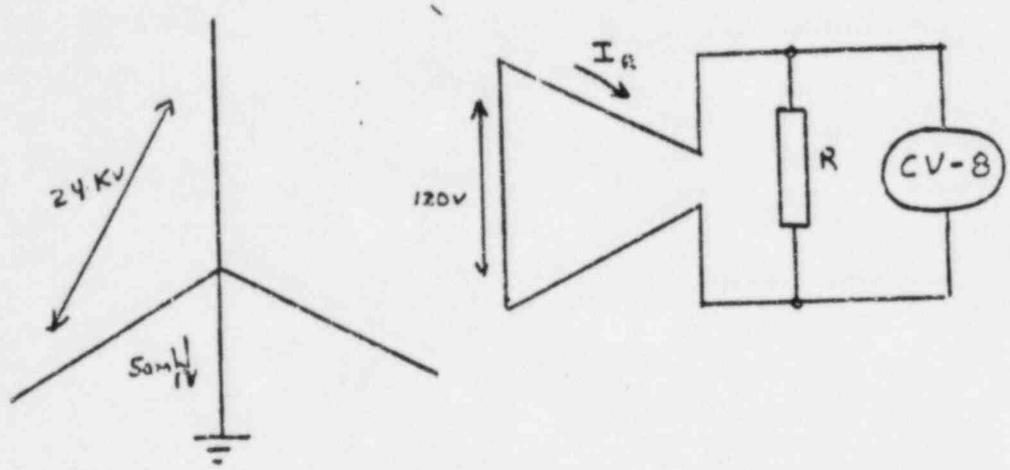
48 ohm PT Secondary Resistor = $\left(\frac{24,000}{\sqrt{3} \times 120}\right)^2 \times \frac{48}{3} \approx .2 \times 10^6$ ohms

Figure 1



Za
Zb
(a)
Zb
Zb
Zb
1/3(Za-Zb)
F1
N1
F2
N2
F0
N0
(b)
E
-j.06315
-j.06315
j.00225
.2
-j.06315
Eo
(c)

Figura 2.



$$I_R = \left(\frac{24,000}{\sqrt{3} \times 120}\right)\left(\frac{5}{3}\right) = 192 \text{ amp}$$

$$R = \frac{208}{192} = 1.08\ \Omega$$

$$E_R = 208\ V.$$

Figure 3

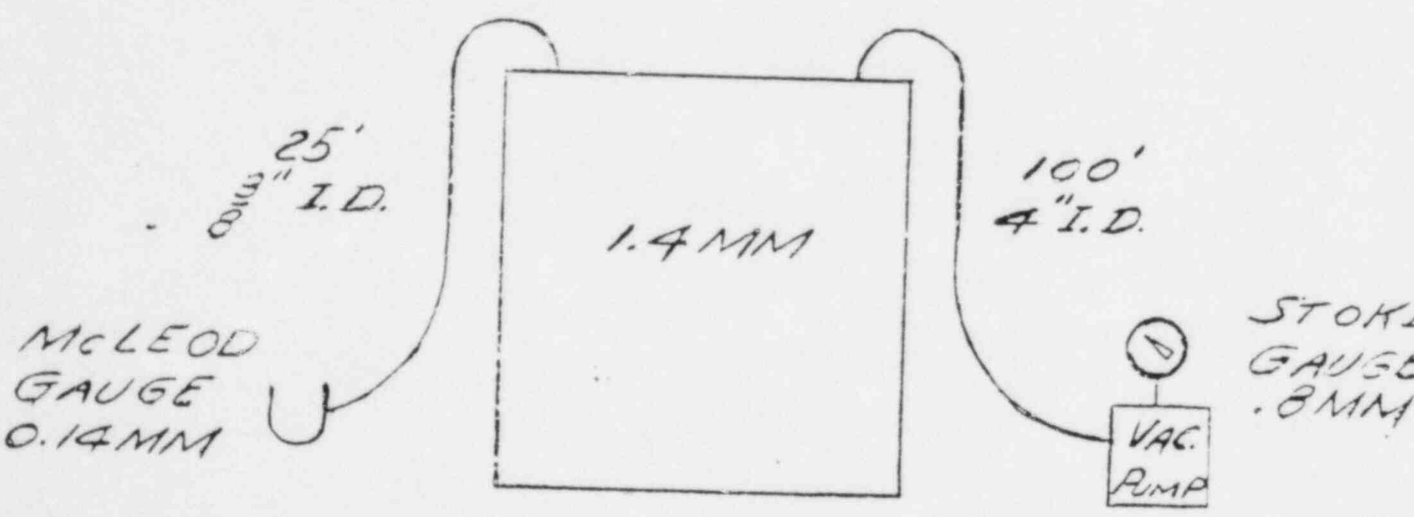
VIII. TRANSFORMERS PROCESSING RECORDS REVIEW

Processing Procedures

The field processing procedures on Westinghouse transformer units at North Anna in general and on the last failure, 7001994, in particular were reviewed to determine any possible processing-related contributant to failure. The following information was utilized: (1) VEPCO records and verbal information from VEPCO personnel as to the reprocessing of 7001994 in November, 1982, (2) test results of oil samples taken from 7001965, an unfailed unit processed similarly and at the same time as 7001994, and (3) VEPCO records as to the reprocessing of other Westinghouse units at North Anna. Available information does not indicate that the failure of 7001994, or the Westinghouse failures in general, are related to processing conditions or procedures.

Unit 7001994 was retrofitted with a COPS tank, reprocessed with new oil in late November, 1982, and the transformer failed in December. Detailed "EHV Equipment Fill Record" data for all Westinghouse North Anna units were supplied by VEPCO and can be found in Appendix C. Units 7001994 and 7001965 were evacuated for vacuum filling with oil on November 26, 1982. During this process two pressure readings were monitored: (1) at the vacuum pump via a Stokes gauge and (2) by a McLeod gauge separated from the main tank cover by approximately 25 feet of 3/8" i.d. Tygon tubing. The following schematic illustrates the relative position of these gauges and the average pressure readings on both units.

Calculation of Tank Pressure - HAM707



Because of the configuration of the reprocessing system and the fact that a McLeod gauge measures only partial pressure of the non-condensables, the pressure within the tank is different than measured by either gauge. Tank pressure can be calculated based on the Stokes gauge reading and conductance of the 100 feet of 4" vacuum hose.

This calculation (Appendix D) shows that the internal tank pressure was 1.4 mm Hg which is greater than the specification limit of 1.0 mm maximum (per Westinghouse Instruction Leaflet 48-668) prior to oil filling; although the vacuum meets the specification for pressure during oil filling, 2 mm maximum. The 20 hours during which the vacuum pump was on prior to oil filling is sufficient time to evacuate the tank completely and reach equilibrium.

Although the 1.4 mm absolute pressure is greater than the specification requirement prior to oil filling, the insulation should have been effectively impregnated and dried because of circulating hot, de-gassed oil through the system prior to energizing. Moisture in the oil during processing and prior to energization was within specification, 10 ppm maximum. There was very little difference in processing characteristics between 7001994 and 7001965. Unit 7001994 failed in December, 1982, and unit 7001965 did not show any irregular tendency during operation.

After failure of 7001994, samples of oil were taken from 7001965 and a COPS-type McGraw-Edison transformer C-0-6459-5-1 which was processed similarly and run on the same bank (North Anna #1) as the failed unit. These results, shown in Appendix E, indicate that both units have very similar oil characteristics. All tests were performed by Westinghouse in Muncie. The results agreed well with those measured by VEPCO after the 7001994 failure. These oil characteristics are indicative of proper processing and do not show high nitrogen levels which would be expected if the Westinghouse COPS retrofit procedure were not followed accurately or if the units were not processed completely. All tested oil results are what would be expected from normally operating power transformers of this type.

Gas-In-Oil Analysis

Gas-in-oil analysis of the Westinghouse North Anna units were completed by VEPCO on approximately a monthly basis. Oil samples were analyzed by both Doble and VEPCO laboratories, but primarily by VEPCO. These data are included in Appendix F.

It can generally be stated that abnormal transformer conditions would be represented by: (1) total combustible gas content greater than 500 ppm, (2) rate of combustible gas generation greater than 100 ppm for a 24 hour period under relatively constant load or (3) acetylene in excess of 20 ppm. In all cases the North Anna units appear normal. Total combustible gas levels seldom exceeded 100 ppm and were never measured greater than 200 ppm. The following data represent maximum combustible gas levels measured for each transformer regardless of testing laboratory.

Gas-In-Oil Analysis North Anna

Serial	Maximum TCG, ppm	Test Data	Ultimate Failure Date
7002100	152	10/16/80	06/19/81
7002100*	28	06/11/82	08/22/82
7002098	49	11/08/79	07/03/81
7001965	172	09/18/80	--
7001995	147	06/12/81	11/16/82
7002099	133	11/20/80	11/29/80
7002099*	185	10/07/82	--
7001993	103	04/16/81	--
7001994	180	06/12/81	12/05/82

* Unit rebuilt after initial failure

From the recorded data there is no indication of abnormal gas pattern or gas generation rates. In all respects the data are typical of normally operating units.

IX. GAS EVOLUTION CAUSES

Gas Bubble Evolution

The possibility of gas bubble evolution within the transformers at North Anna and within gas-space power transformers in general were investigated as to reliability considerations. Past research has shown that under certain circumstances gas bubbles will lead to reduced electric strength of the insulation system. The extent of strength loss is dependent on the type insulation structure, the condition of oil itself, including its degree of contamination and other factors which may be unpredictable. The presence of gas bubbles is hazardous where the bubbles can collect beneath collars, inverted channels, and other insulation pieces. Gas bubbles in large power transformers can result from the following sources:

(1) Leak in a low pressure area allowing outside air into the unit

(2) Gaseous cavitation of supersaturated oil

(3) Improper processing

(4) Thermal degradation of oil or insulation resulting from incipient faults.

An analysis of calculated local oil pressures at various locations in the initial HAM707 design (Figure 1) show that gas space pressures less than 0.7 psig would result in negative pressures in the top cooler assembly. Under these conditions should there be a leak in the upper valve assembly or packing gland, air would be sucked into the unit rather than oil being forced out. The resulting air bubble would be circulated with the oil until it dissolved or entered the gas space. If the oil was saturated with nitrogen such as would be expected of a gas-space transformer, the introduced air bubble would not dissolve. However, the probability of air entering the unit is very small since the transformer is pressure tested at the factory and indirectly pressure tested during shipment and processing. Furthermore, with the COPS retrofit design (such as was on the December 1982 failure of 7001994), the oil head caused by the height of the COPS tank generates sufficient static pressure so that all locations within the transformer are under positive pressure, preventing air from leaking into the unit.

The possibility of reduced reliability in large power transformers due to supersaturated transformer oil and the release of nitrogen bubbles because of gaseous cavitation has been speculated on for many years. Laboratory test have shown that bubbles can form in gas-space transformers under special circumstances such as after an extraordinary rapid temperature drop, failure of periphery gas regulating equipment and improper maintenance procedures.

Gases dissolve in all transformer oils, but the amount of gas which is dissolved at equilibrium will depend on the gas, the chemical nature of the oil (both its source and condition) and on the temperature and applied gas pressure. Figure 2 illustrates the effect of temperature on the solubility of nitrogen in a new transformer oil prior to aging or conditioning. At higher temperatures the amount of nitrogen that the oil absorbs will increase. If the gas pressure on the space over the oil is increased above atmosphere, the equilibrium gas content rises in direct proportion to the absolute pressure (Henry's Law) as shown in Figure 3. Thus, to determine the gas concentration in oil at any temperature and pressure it is necessary to apply the nitrogen solubility curve and Henry's Law.

For example, if a unit is at stable load at 6.5 psig gas-space pressure and 80°C, the amount of gas dissolved in the oil is (9.7%) (14.7 + 6.5)/14.7 = 14.0%. This condition is the maximum theoretical gas content at an oil temperature of 80°C because the relief device will bleed out at pressures over 6.5 psig.

As long as equilibrium conditions are maintained, the gas content of the oil is not a problem since only free bubbles will affect the dielectric strength of the oil. However, when the oil temperature is reduced (e.g. decrease in load, loss of excitation, reduced ambient), the gas pressure is also reduced. If the temperature drop is substantial and it occurs over a fast rate (several hours or less), the gas dissolved in the oil cannot escape through the oil-gas space interface fast enough to maintain equilibrium. The result is a condition of supersaturation in the oil.

Using the previous example, suppose the unit is deenergized and that there is no oil circulation (FOA equipment) and rapid cooling to 25°C. The pressure in the gas space would likely be in the range of 0.5 to 3 psig (we will assume 2 psig). The maximum gas content that the oil can hold is (8.9%) (14.7 + 2.0)/14.7 = 10.1%. However, the oil has 14.0% gas because sufficient time was not allowed for orderly diffusion. The saturation level then at the new equilibrium is 14.0/10.1 = 139%, and oil can be said to be supersaturated by a factor of 39%.

Supersaturated oil is not a problem in itself. However, when the local oil pressure is reduced below the gas saturation pressure, gas bubbles will be found. Local pressures within a transformer can be calculated knowing the static and dynamic head of oil and pressure drop incurred by circulating the oil through the cooling equipment. Figure 1 illustrates local pressures, P_L, that may exist in the HAM707 design. The data are based on a gas-space pressure of one atmosphere, and the localized pressures can be adjusted for various gas-space pressures by moving up or down the X-ordinate. Low-pressure regions could also occur by transients such as the mechanical shock of short circuit, electrical shock of transient voltages, and vibration.
Gas-saturation pressure (pressure of the gas-in-oil) can be calculated using a derivation of Henry's Law:

Gas Saturation Pressure = P_G = $(^C/Cs)(14.7) - 14.7$

Where C = measured gas content in oil
Cs = gas content in oil at equilibrium (100% saturation)
and C/Cs X 100% = percent saturation

To determine the percent gas saturation necessary for the first theoretical indication of gas bubbling:

$$P_G = P_L$$
$$(C/Cs)(14.7) - 14.7 = P_L$$
$$(C/Cs) = (P_L + 14.7)/14.7$$

Table I shows the value of C/Cs to just begin forming bubbles at various gas-space pressures and locations within a typical transformer tank. Values of C/Cs greater than those presented in Table I will lead to spontaneous generation of gas bubbles.

Table I

For the first bubble to form $P_G = P_L$ Pressures and saturation levels where first bubble will format locations F, 1, m, n are indicated on Figure 1.

Gas Space Pressure psig	P_L	$^F C / C_S$	P_L	$^1 C / C_S$	P_L	$^m C / C_S$	P_L	$^n C / C_S$
0.0	-1.2	92	9.0	161	2.7	118	0.6	104
0.5	-0.7	95	9.5	165	3.2	122	1.1	107
1.4	0.2	101	10.4	171	4.1	128	2.0	114
6.5	5.3	136	15.5	204	9.2	162	7.1	148

Note that supersaturation is not needed to generate bubbles. Only the criteria P_G greater than P_L need be satisfied. However, bubbles forming in undersaturated oil will quickly redissolve in the oil. Bubbles forming in supersaturated oil cannot dissolve but will expand and rise. Should these bubbles migrate to a high-stress region of the transformer, the dielectric characteristics may be seriously impaired. Prior investigations have shown as much as a 40% reduction in dielectric strength of oil (measured with VDE electrodes, 80 mil gap) due to the presence of gas bubbles evolving from supersaturated oil.

Gas bubbles could be found anywhere in the transformer depending on the level of saturation and the local pressure. However, they are not likely to evolve in a large power transformer unless:

1. The pumps are on causing low-pressure regions.

2. The gas-saturation level is such that the gas pressure in the oil exceeds the local pressure.

3. Temperature and pressure changes are rapid (i.e. allowing no or very little diffusion through the interface).

Such conditions would most likely be possible if: (1) a gas-space, FOA transformer is deenergized after establishing equilibrium, and ambient conditions are such that temperature drop of the oil is rapid, and the unit is reenergized before a new equilibrium condition could be established or (2) the gas-space regulation system malfunctions or the nitrogen supply is exhausted in which case a negative pressure could develop in the gas space. The only method found to prevent the possibility of bubble formation due to supersaturated oil is by using a constant pressure oil preservation system (COPS) which essentially removes the gas space (insuring continued low gas content in the oil) and does not allow pressure variation.

Gases may also be trapped in the insulation structures after draining and refilling of the transformer with oil. Figure 4 represents a cross section of trapped gas in an insulation structure and between layers of insulation. Attention thus far has focused on spontaneous formation of free gas bubbles in the bulk oil. But potential also exists for reduction of dielectric strength of major insulation structures from bubbles which are trapped in a gas pocket (Figure 4a) or between paper wraps and conductors (Figure 4b). In these places they may be effectively prevented from escaping during draining and filling operations. To eliminate these pockets one must rely on good vacuum treatment, good vacuum-filling procedures, and the circulating of oil with very low gas content through the transformer to dissolve the bubble prior to energizing. It must also be realized that the rate of dissolution of the gas in the bubble to the oil is very temperature dependent.

A high-voltage transformer is generally vacuum filled with oil after draining. Then the oil is circulated through a degassing plant which removes gases and moisture from the oil. Manufacturer's suggested gas content has been 1% or less, and moisture content maximum has been 10 ppm, for EHV units. However, these parameters are measured from the average bulk oil. Insulation areas could have high gas or moisture values yet not be large enough to affect the bulk oil properties. Since the solution of gas and moisture into oil is time and temperature dependent, it is best to adjust processing (circulation) time for oil temperature. After a unit has been sitting deenergized for a long period of time, the temperature of the core and coils are affected by the ambient. Processing in winter months should as a result continue longer, or the temperature of the circulating oil should be increased. Hot oil is usually obtainable from standard degassing plants, and the processing time should take into consideration the temperature of the oil being circulated. Figure 5 describes suggested temperature-dependent processing conditions for filling transformers. These new procedures have been developed primarily as a guide for draining and filling in cold weather months, but they are generally useful independent of the season.

VEPCO claims to have followed these procedures during reprocessing of the COPS retrofit units in November, 1982. To determine whether the processing procedures were adequate to impregnate the insulation around the HV lead in 7001994, a full size model lead was taped, processed and visually observed in a 350 gallon test tank equipped with an observation window. The results of various processing condition with respect to bubble evolution are shown in the following table.

- Lead processed using processing information supplied -- 2.4 MM H_G
- Internal heater was implanted adjacent to copper
- Geometric configuration same as HAM707
- System brought to equilibrium to simulate inertaire
- Internal temperature raised in 10° steps to 136°C
- No bubbles were observed
- Drained oil and processed with poor vacuum -- 20 MM H_G
- Internal temperature raised in 10°C increments to 136°C - no bubbles observed
- Gas pressure over the oil system was reduced, but no bubbles observed until pressure went negative

- Lead processed poorly -- 20 MM H_G vacuum
- Heated to 70°C
- No bubbles observed
- Gas pressure over the oil system was reduced, but no bubbles until pressure went negative
- Number of bubbles was profuse when generated, and continued for a long period of time while under vacuum

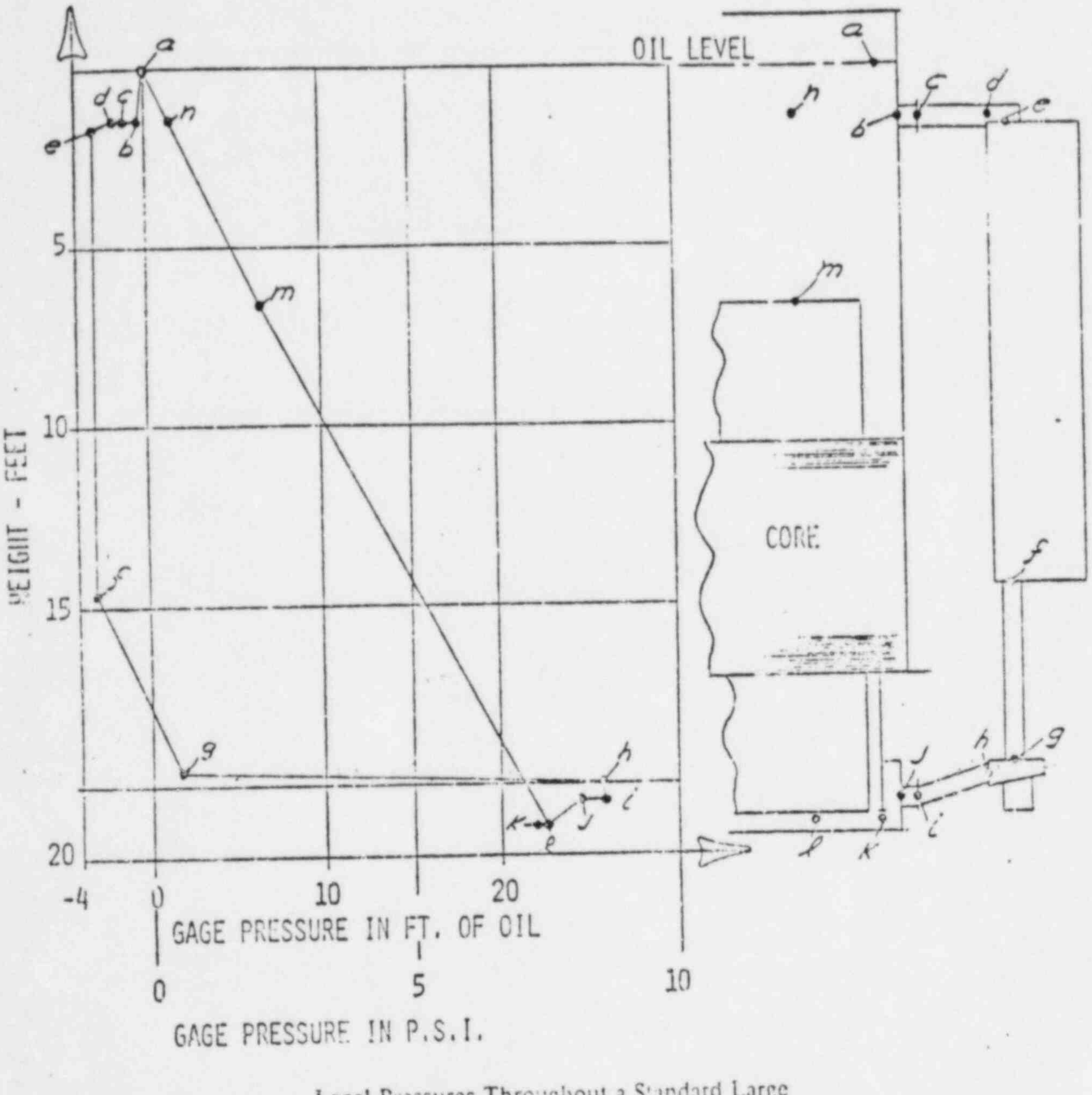
The only cases in which bubbles evolved from the lead insulation was when the gas space was under vacuum. Under positive or atmospheric pressure, bubbles were not noticed at the HV lead even when the insulation was grossly underprocessed.

Another possible source of gas bubbles is due to an incipient fault. In 7001994 a turn-turn fault was discovered in coil #1. An analysis was made to determine if gases generated from this fault could find there way to the HV lead to precipitate a breakdown to coil #21. Gas bubbles will dissolve in oil depending on their size, temperature and degree of oil saturation. It is likely that if gas bubbles were generated at coil #1 they would not dissolve for at least one period of circulation through the unit. Figure 5 shows the relative position of coil #1 and the HV lead. The pumps that were operating during the period immediately prior to failure are also noted. It would appear that due to the flow of oil a bubble found at the fault in coil #1 would move directly up through the windings and then transverse across the top of the coils toward the HV lead. However as shown in Figures 6 and 7, a bridge structure compartmentalizes the top of the unit so that the bubbles would have to creep under the bridge section supports and then come up inside the HV lead section of the bridge structure.

To determine the actual flow characteristics in the HAM707 design, field experiments were made on 7001965 which was not energized at the time. The Trip Report attached as Appendix G describes these tests and their results. The following was observed:

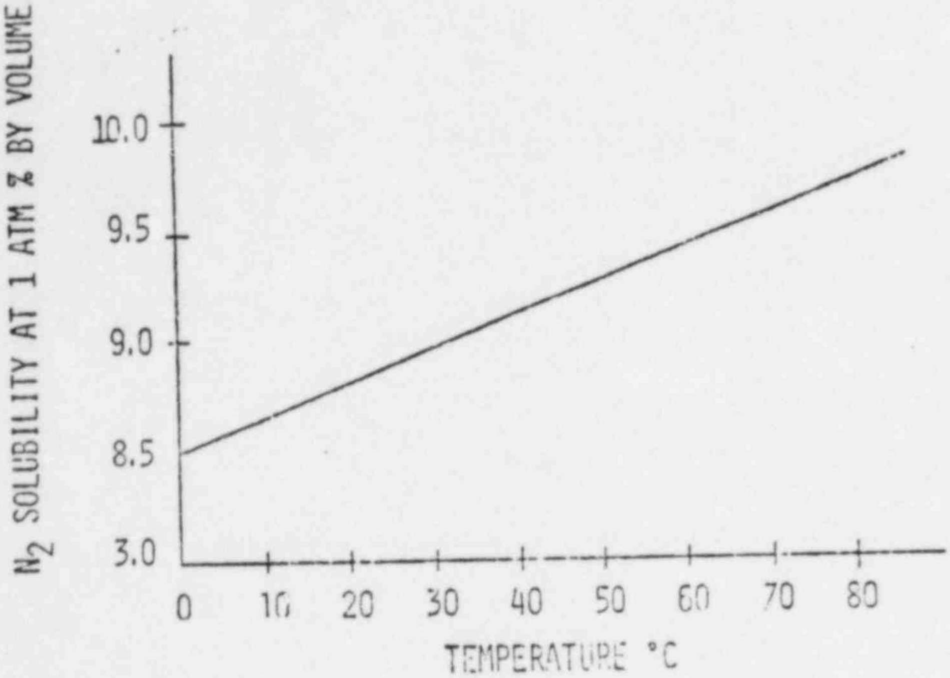
- On turning on the pumps no bubbles were noticed in the circulating oil.
- When bubbles were purposely injected through one of the pumps, they were found to progress straight up through the windings and then straight-up through the bridge structure.
- The quantity of injected bubbles were at least twice as great around the core and coils as opposed to through the coils.
- Calculations indicate that a given volume of gas, if present, will take seven minutes to complete one cycle through the main tank and cooling system.
- Reference data indicates that if the bubble size is greater than 1/4" in diameter, it would not dissolve in the oil before one cycle of circulation.

It was not likely that a bubble generated at coil #1 would approach the HV lead unless it was circulated through the cooling system and then come up through the HV lead bridge section.



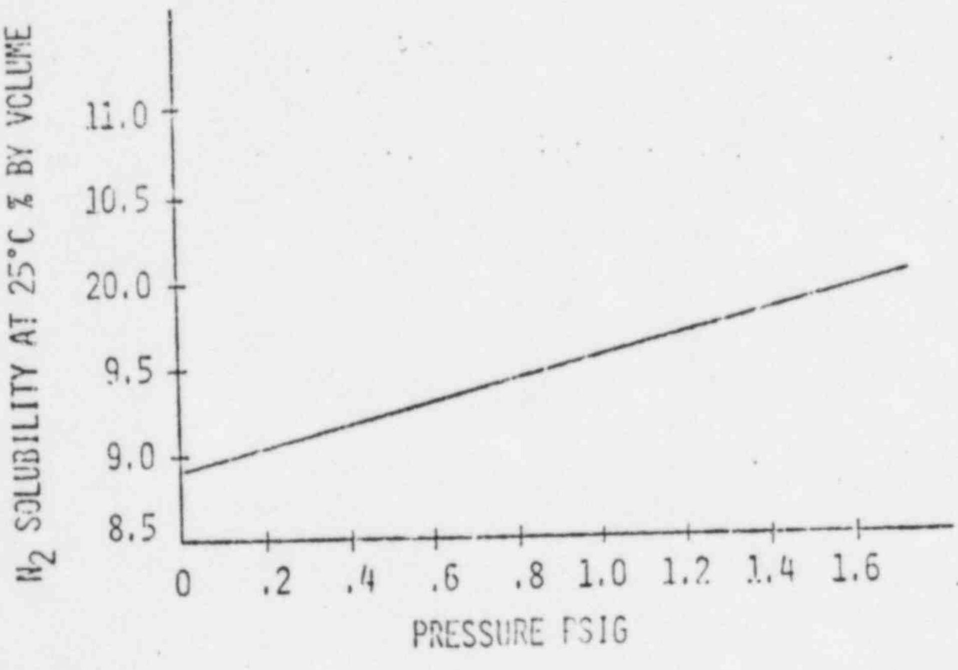
Local Pressures Throughout a Standard Large Power Transformer with Cooling Equipment On

FIGURE \



Nitrogen Solubility in Transformer Oil
As a Function of Oil Temperature

FIGURE 2



Nitrogen Solubility in Transformer Oil
As a Function of Gas-Space Pressure

FIGURE 3

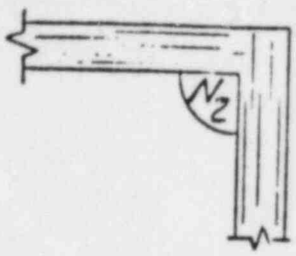
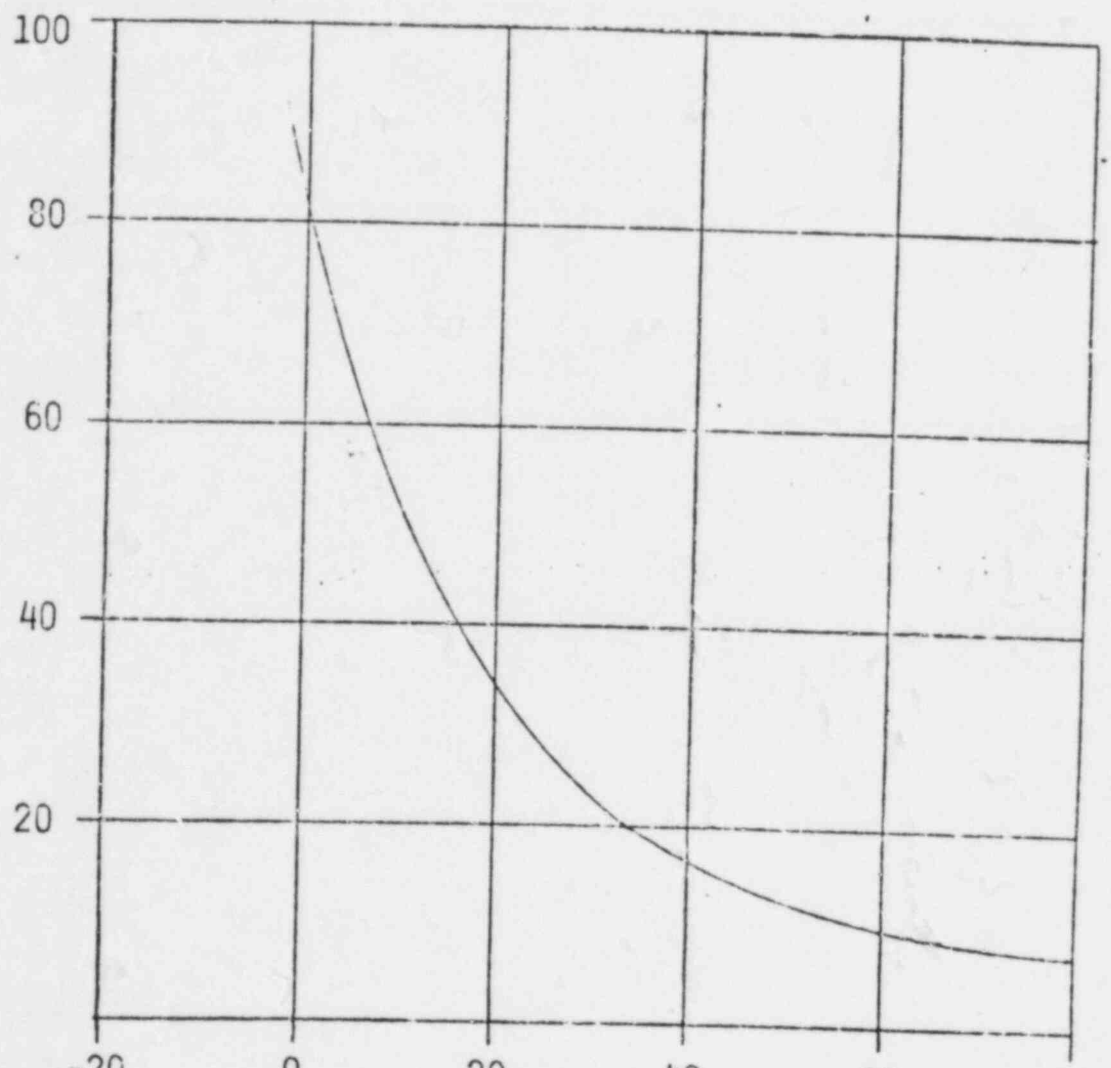


FIG. 4(A)

FIG. 4(B)

Various Methods of Gas Entrapment in Transformer Insulation Structures on Draining and Filling

FIGURE 4



Circulation Time Versus Oil Temperature Measured Either in Transformer Tank or at the Inlet to Degasser. Based on Westinghouse Large Power Transformer Insulation.

FIGURE 5

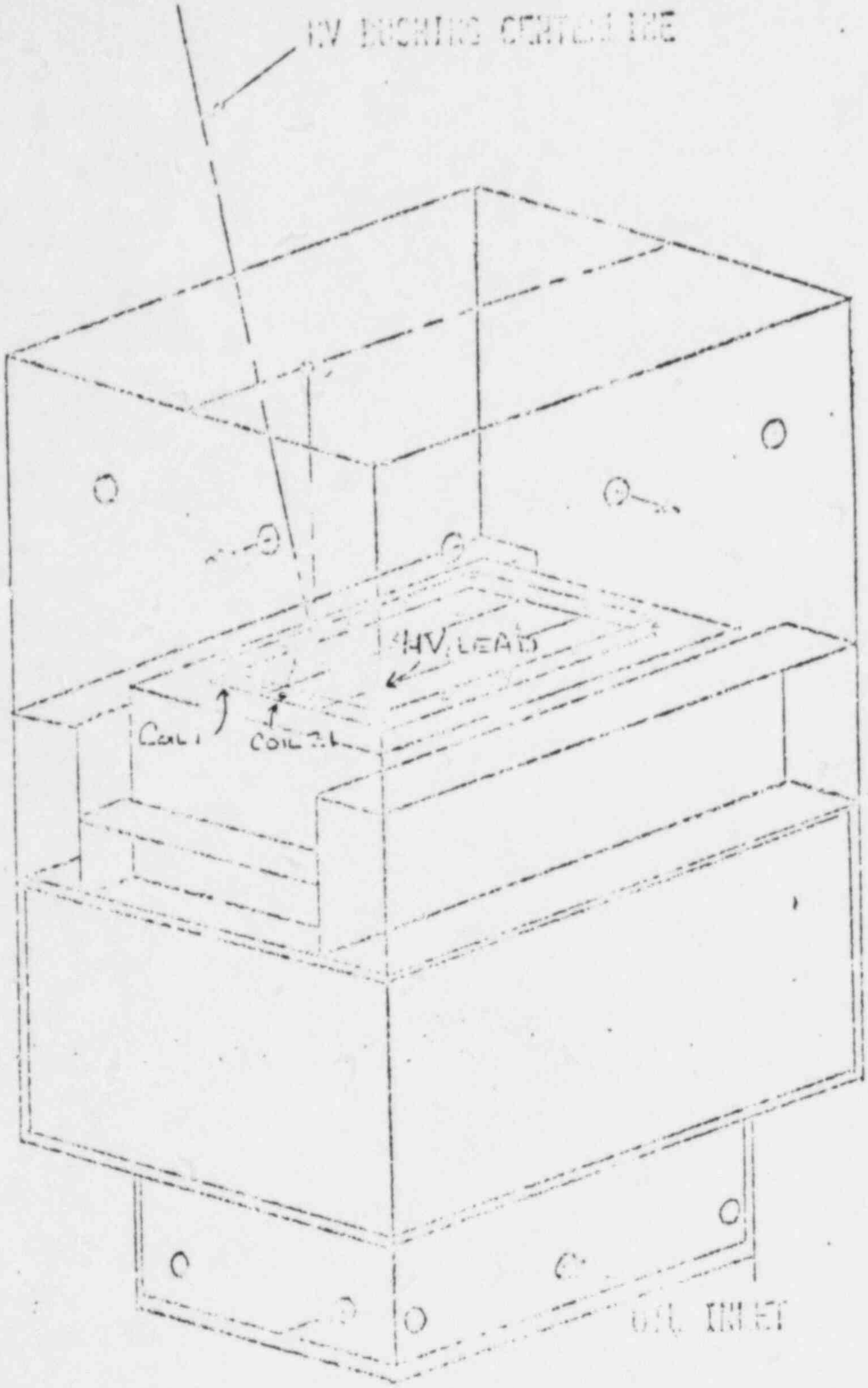


Figure 6 - Relative Position of Winding Coils and Lead

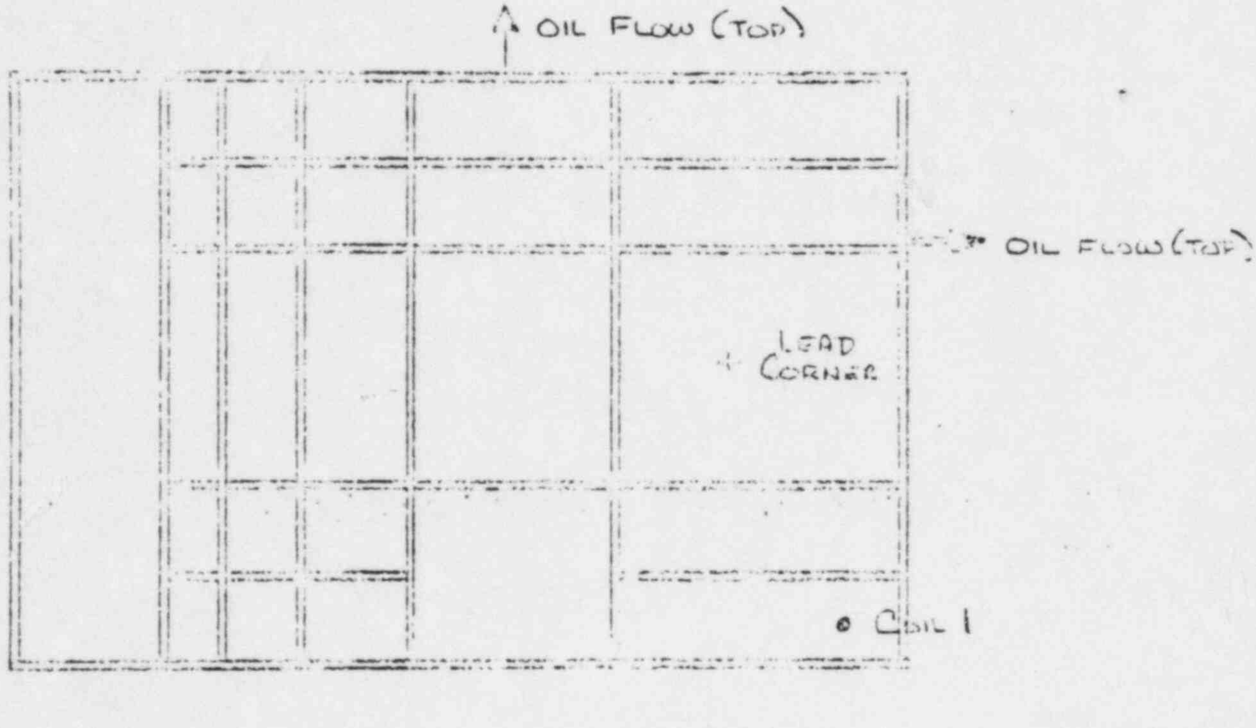


Figure 7 - Bridge Structure

X. OIL ELECTRIFICATION EFFECTS

Static Electrification

Static electrification phenomena in large power transformers has been studied (notably by Japanese researchers) with regard to reliability of high voltage, larger capacity units. The distribution of electrostatic charges in a transformer is fundamentally similar to that produced by oil flowing through a plain pipe. In a large power transformer, positive and negative charges in oil are separated by the flow of oil on the surface of paper insulation. The charges, positive or negative, are accumulated when the charges generated by oil flow exceed leakage charge to ground. The charges accumulated in the oil (generally positive) or on the solid insulation (generally negative) cause an electric field, and if it proceeds beyond a certain level may cause electrostatic discharge or creepage discharge in oil. Charging tendency in a power transformer is a complex interaction of a number of factors some of which follow.

Primary Factors Which Influence Flow Electrification

- Oil flow rate
- Bulk oil properties (temperature, conductivity, etc.)
- Surface conditions and structure of solid insulation
- Oil flow paths
- Moisture content of oil and paper
- Nature of ionic content of oil

We have examined the charging tendency of various commercial sources of transformer oil during various stages of oil processing and aging. The charging tendency is closely associated with the amount of substances such as ions or polar material that are in the oil. These substances can come from a number of sources such as: (1) products of thermal decomposition, (2) outside sources of contamination, or (3) the refining operation relative to a specific supplier. We had found that the concentration of these ions or polar substances need not be very great to significantly increase charging tendency. In fact the presence of such substances cannot be detected by standard analytical chemical methods, standard transformer oil specification tests, or any other known test other then by directly measuring charging tendency via a laboratory device specifically designed for the purpose (Exxon mini-static tester, Figure 8).

In experiments conducted at Muncie in 1982, various commercial sources of transformer oil where analyzed for charging tendency with the Exxon mini-static tester. The investigation was initially to determine if hydro-refined oil had greater charging tendency than acid refined oil. (Texaco the last and only domestic supplier of acid refined oil is a chief source of supply for the Muncie plant.) The results of the investigation did not show correlation between acid or hydro-refined oil and charging tendency, but it did show that one source of supply (Gulf Trancrest H) exhibited significantly greater charging tendency than any other source, Figure 9.

Further investigation has shown that the higher charging tendency of the Gulf oil is likely to be due to organic sulfur compounds in the oil. These contaminates can be removed from the oil and the charging tendency reduced to normal levels by clay filtering.

Figure 10 illustrates the trend of Gulf Trancrest H IFT (interfacial tension values) as measured by the semi-annual Doble oil survey. Although the degree of contamination required to provide significant charging tendency may not lower the IFT below the specification limit (40 dynes/cm), it would lower IFT somewhat. Figure 10 shows that the IFT values of Trancrest H dropped significantly after changing to the hydro-refining process, and an indication of a drop in IFT also occurs in mid-1980 through 1981. Oil produced in this time period was likely to have been used during factory testing or field filling some of the North Anna units.

The above data only indicate that Trancrest H has a relatively higher static charging tendency then most other oils. To determine whether this factor would have a significant bearing on the reliability of power transformers would require a great expenditure in resources. The complex interaction of parameters which effect charge generation is not fully understood and possibly could only be reliably reproduced in an actual transformer.

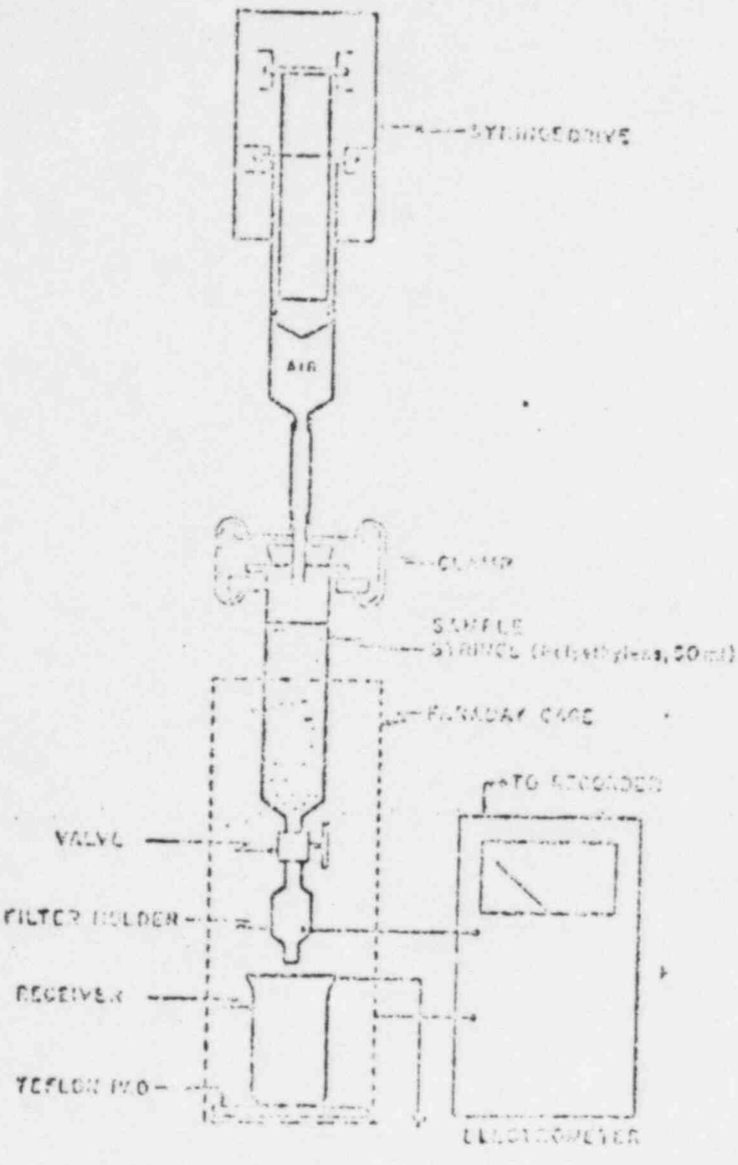


Figure 8 - Exxon Mini-Static Tester

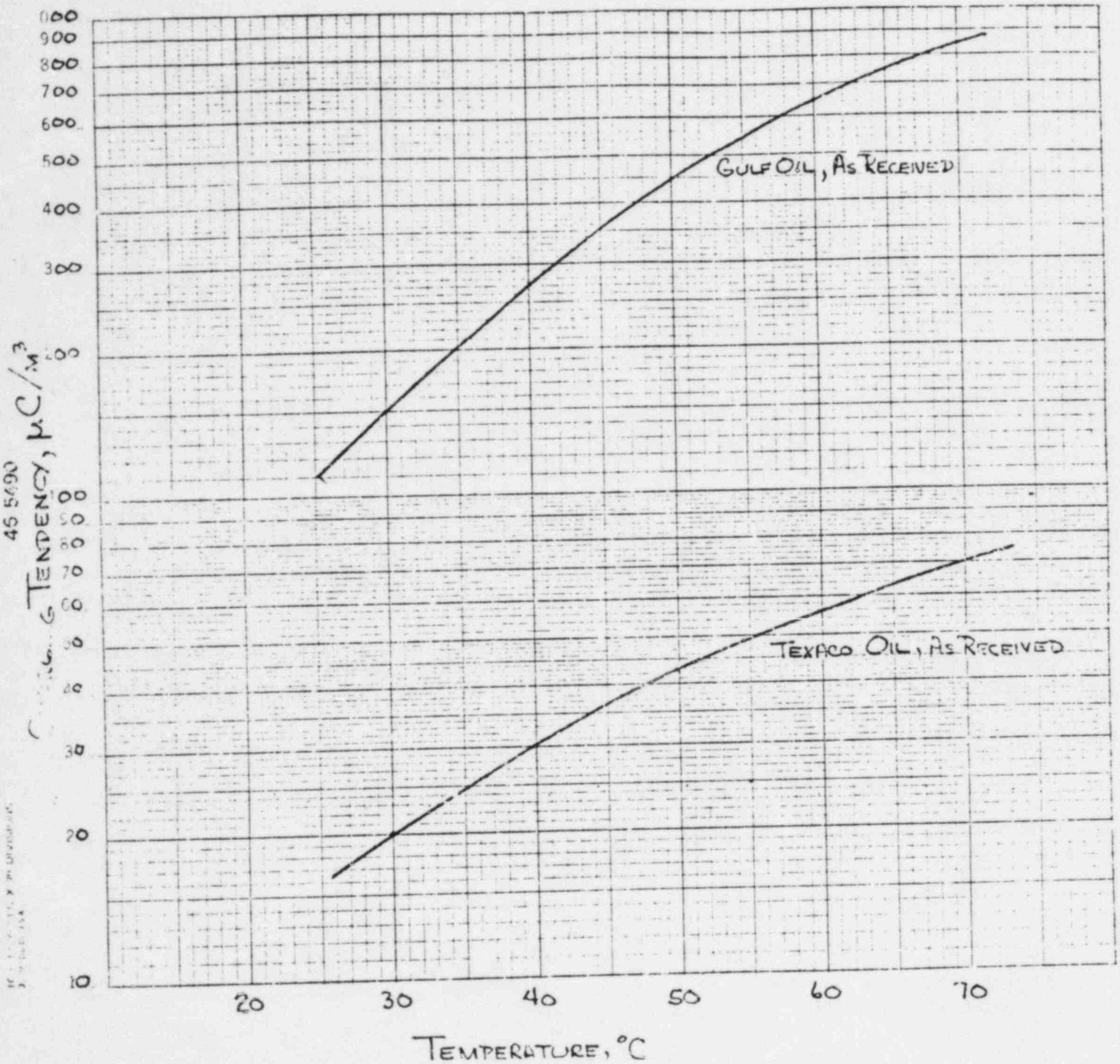


Figure 9 - Charging Tendency of Gulf and Texaco Transformer Oils

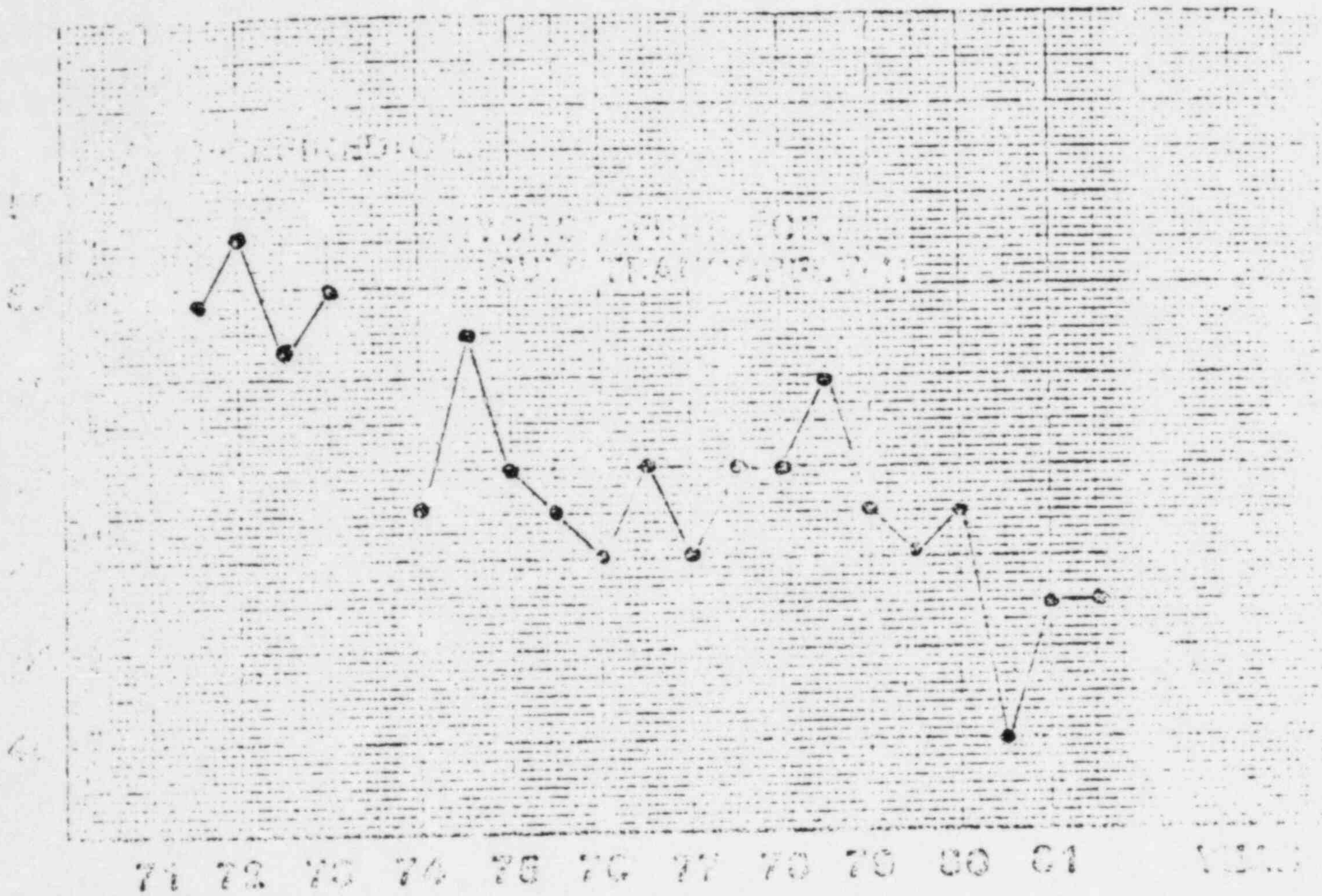


Figure 10 - IFT Values for Gulf Oil, 1971-81 taken from Doble Semi-Annual Oil Survey

XI. DIELECTRIC ANALYSIS OF LINE LEAD CONFIGURATION

Purpose

The project was undertaken to provide experimental data for the investigation of dielectric phenomenon around the HV line lead and bushing of the North Anna transformers. The effects of gas bubbles, lead taping, and electrification of oil were studied individually and in combination (gas bubbles/poor lead taping, gas bubbles/electrification of oil).

Experimental Assembly

To simulate the HV line lead assembly in the laboratory, a 500 kV bushing was mounted in a test tank. Attached to this bushing was a simulated lead consisting of two parts -- 1) the vertical section is composed of thin copper sheets that are soldered together at each end; this lead section is bolted to the bottom of the bushing; 2) the horizontal portion is made of solid copper bar; both items 1) and 2) were the same as existed in the North Anna units. Refer to Figure 1 for side and front elevation views of the experimental assembly. To simulate the LV coils and insulation, taped copper strap was placed inside pressboard angles; eight coils were simulated by this assembly. All dimensions were the same as the actual transformer. Gas bubbles were introduced into the experimental assembly using a tygon line positioned directly underneath the lead simulation.

Experimental Results (Standard Transformer Oil)

b,c

b,c

For correlation purposes, tests were performed before doping at 400 kV for the duration listed in Table 6. Three separate tests were performed -- 1) no oil flow/no bubbles; 2) oil flow/no bubbles; and 3) oil flow with bubbles. After doping, tests 2 and 3 were repeated. As shown in Table 7, the partial discharge increased when the oil was flowing with bubbles flowing past the lead. Although the extent of partial discharge increase with the combination of bubbles and electrification was not large, a qualitative trend does exist indicating an increase in partial discharge with the combination. No flashovers occurred during any of these tests.

b,c

HV LINE CONFIGURATION WITHOUT TAPE (BARE)

NO BUBBLES

b,c,e

TABLE 1

<u>HV LINE CONFIGURATION (INSULATED)</u>

b,c,e

[ ]

TABLE 2

HV LINE CONFIGURATION (TAPED)

EFFECT OF BUBBLES

b,c,e

TABLE 3

HV LINE CONFIGURATION TAPED WITH

OVERLAPPING JOINT HAVING LESS THAN NORMAL TAPER

WITHOUT BUBBLES

b,c,e

TABLE 4

HV LINE CONFIGURATION TAPED

VARYING BUBBLE SIZE

a,b,c,e

[ ]

TABLE 5

STATIC CHARGE TEST RESULTS

NO OIL FLOW/NO BUBBLES/NO AEROSOL OT

a,b,c,e

TABLE 6

STATIC CHARGE TEST RESULTS

TESTS WITH AEROSOL OT ADDITIVE IN THE OIL

OIL FLOW WITHOUT BUBBLES

b,c,e

TABLE 7

a, b, c, e

VEPCO FAILURE SIMULATION TEST IN HIGH VOLTAGE LAB

Figure 1

STATIC CHARGE TEST

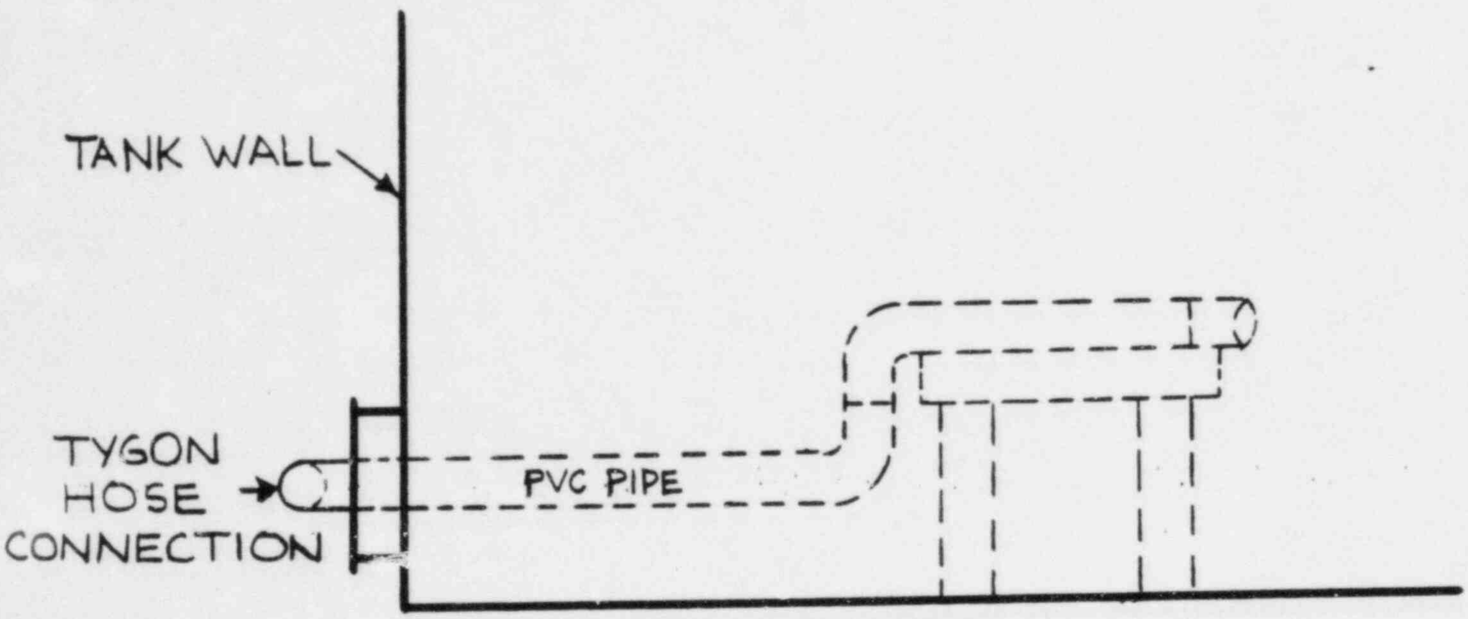


Figure 2

XII. IMPULSE DISTRIBUTION AND RESONANT FREQUENCY ANALYSIS

The seventh incident at the VEPCO North Anna station involving a Westinghouse generator step-up transformer exhibited a flashover from the high voltage line lead to low voltage coil 21. In addition, there were multiple flashovers in the isolated phase bus duct connecting the generator to the transformer. Similar flashovers in the isolated phase bus duct were also evident in the sixth incident. The seventh incident involved transformer serial number 7001994, which was also in the same three phase bank with transformer serial 7001995 which was involved in the sixth incident.

Serial 7001994 was completely disassembled and inspected at the Muncie Plant. The evidence from the disassembly included failure points on the HV line lead and low voltage coil 21 which were presumably the two endpoints to a flashover and a turn-to-turn fault in LV coil 1. Figure 1 shows a winding schematic of the coil arrangement with the arrow signifying a flashover to coil 21 and the "X" indicating the turn-to-turn failure in coil 1. The HV winding consists of the series combination of coils 5-14 and 23-34. All other coils are in the LV winding and are connected in four parallel paths. Coils 21 and 1 are in different parallel paths, however, both coils are approximately at the electrical midpoint of their respective parallel paths.

Upon finding the turn-to-turn fault in coil 1, the objective was to investigate as to whether the fault was a result of the high-low flashover or if the fault was incipient to the high-low flashover. Therefore, a test was devised to simulate the application of a transient voltage on the last turn of coil 21 and measure the subsequent turn-to-turn stresses in other parts of the low voltage winding. To accomplish this, transformer serial 7002100 was used. The transformer core and coil assembly was still intact and thus modelling of the windings was not required. A low voltage recurrent surge generator was used to inject a transient voltage into the LV winding with the last turn of coil 21 being the injection point. Measurements of the resulting turn-to-turn voltage were taken on coil 2 since the edge of coil 1 was inaccessible. However, the voltages in coil 2 should be approximately equivalent to the voltages in coil 1.

The waveshape of the voltage applied to coil 21 during the seventh incident is unknown, however, the recurrent surge generator was used to apply a full wave, a chopped wave, and a steep front wave in three separate tests. The results of the turn-to-turn voltages on coil 2 are as follows:

Full Wave	3.5% of applied voltage
Chopped Wave	7.5% of applied voltage
Steep Front Wave	5.5% of applied voltage

With these results and assuming the most pessimistic situation in which the chopped wave voltage is used and that no voltage drop exists in the high-low flashover arc, one would calculate the crest value of the voltage on coil 21 as 424 kV (2 X 300 kV line to ground for the 500 kV system). The resulting turn-to-turn voltage would be (.075)(424) = 32 kV.

The turn-to-turn insulation for the LV consists of paper tape on the conductor with an additional strip of pressboard located in the turn-to-turn space. One of the observations from the disassembly was that the pressboard between turns was shifted out of place thus leaving only the paper tape on the conductors for insulation. The design value for the electrical strength of the specified paper insulation on the conductors was 45 kV. Therefore, the 32 kV turn-to-turn was well below the design level of the paper alone which leads to the low probability of the turn-to-turn fault occurring as a result of the high-low flashover.

From this analysis the probability of the turn-to-turn fault being in existence prior to the high-low flashover is much greater than existing after the high-low flashover. A possible mechanism for producing the turn-to-turn fault involved the sixth incident with serial 7001995. As stated previously, the isolated phase bus ducts flashed over in the sixth incident. It is possible that when the C phase bus duct flashed over a negative impulse wave was applied to the terminal to which the parallel path containing coil 1 was connected. The magnitude of the wave would have been approximately equal to the crest flashover value of the bus duct. This situation was not modelled because it involves a complex interaction between two transformers and the associated isolated phase bus ducts. However, the point to be made is that serial 7001994 (seventh incident) was involved in another incident by being connected to another transformer which failed in a manner that transient voltages could have been applied to serial 7001994.

In summary, it is most probable that the turn-to-turn fault in coil 1 of serial 7001994 was the result of an event prior to the seventh incident.

Another aspect to the transfer of transient voltages involves the concept of producing voltage transients as the result of a resonant frequency condition. This may occur if a dynamic forcing function with a frequency component the same as the resonant frequency of the winding was applied to the winding. In the specific cases analyzed at North Anna in which the isolated phase bus ducts flashed over, the objective was to determine if a low side arc could produce potential differences between the HV and LV of sufficient magnitude to cause the high-low flashover.

One of the North Anna units was tested to determine the resonant frequency at which the HV line voltage is maximum when excited by a sinusoidal voltage on the low voltage terminals. This test produced results for determining as to whether a low side arc in the isolated phase bus duct could produce voltages in the HV in excess of the withstand high-low. Two resonant frequencies were identified for the HV line terminal; 9 kHz and 40 kHz. A flashover in the bus duct could produce a voltage approximated by a square wave with a period dependent on the reflection time from the fault location to the transformer terminal. Assuming an approximate 100 feet of bus duct length with a capacitance of 0.002 microfarads per phase, the voltage wave would be a square wave with a frequency of 2.5 MHz. The 2.5 MHz square wave would not contain any frequency components at or near the 9 kHz and 40 kHz resonant frequencies. Therefore, the conclusion is that the low side isolated phase bus duct flashovers did not produce the high-low flashovers in the transformer but rather the opposite occurred.

Figure 1

XIII. SENSITIVITY TESTS OF ACOUSTIC WAVEGUIDE SYSTEM

a,c

[ ]a,c

APPENDIX A - ITEM 1

TRANSFORMER REPORT ON EVENTS AT N. ANNA POWER STATION

APPENDIX A - ITEM 1

ENGINEER'S TRIP REPORT
WESTINGHOUSE FORM 3611 G

NOTE 1 - The Engineer reporting is responsible for the prompt delivery of his reports to all interested persons and for seeing that all points requiring action are cleared up without delay.

2 - For long reports give a summary of important points and recommendations.

For Westinghouse Representatives only. DATE 12/15/82

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☒	Muncie Plant	MR. H.R. Moore
☒	Muncie Plant	MR. R.J. Cossaart
☒	Muncie Plant	MR. M. Wood
☒	Muncie Plant	MR. J. Burgess
☒	File - HAM707-08	MR.
☐		MR.
☐		MR.
☐		MR.
☐		MR.
☐		MR.
☐		MR.
☐		MR.
☐		MR.
☐		MR.
☐		MR.
☐		MR.
☐		MR.
☐		MR.
☐		MR.

VISIT - NAME VEPCO NEG.

LOCATION North Anna #1 G.O. S.O. SER. O.

PURPOSE OF TRIP Remove barrel barriers from H.V. bushing and make general internal inspection.

CONFERENCE HELD AT North Anna Nuclear Plant DATE 11/22/82

THOSE PRESENT Mr. J. Markins and Mr. J. Templeton, Westinghouse; Mr. J. Macgregor, VEPCO.

SUMMARY:

See attached.

SIGNED (ENGINEER) [signature] 12/16/82 | APPROVED [signature] 12/17/82

DEPARTMENT | DIVISION | LOCATION | PAGE

TRIP REPORT TO VEPCO NORTH ANNA
POWER STATION ON 11/22/82

Mr. Joe Markins and Mr. Jim Templeton of the Muncie Westinghouse Plant and Mr. Joe Macgregor of VEPCO removed the barrel barriers from the HV bushing in serials 7001994 and 7001965 on 11/22/82. The two transformers were part of the transformer bank connected to the North Anna #1 generator. The third transformer in the bank was a McGraw Edison unit.

VEPCO had already prepared both transformers for inspection by draining all of the oil but they had not broken the seal of the manhole covers. With each unit, VEPCO placed a tent over the manhole which maintained a humidity level of about 20-30% above the open manhole.

The phase B unit, serial 7001994, was entered first. The only personnel to enter the transformer were J. Markins and J. Templeton of Westinghouse and J. Macgregor of VEPCO. The first operation completed was to remove the barrel barrier from the internal end of the HV bushing. This was accomplished rather simply by removing the permali nuts and bolts connecting the barrel barrier to the bridge walls. The pressboard barrier was then slipped from around the bushing without any cutting or tearing of the material required. However, as a precautionary measure the phase was packed with cloth material in the area where work was being performed.

After the barrel barriers were removed a general inspection of the transformer was made. The HV line lead and bushing shield were closely examined. The tape on the lead was firm with no soft spots. The bushing shield was in the proper orientation with no evidence of any abnormalities. The top end of all coils, both HV and LV, appeared acceptable.

In the HV line group four insulation items were pounded back into place. The items were the outermost angles for coils 23-28. The items were only raised about 1/2" and located approximately at the centerline of the phase. This condition was not identified as being critical.

In summary, the phase B transformer was in satisfactory condition. The total open time for the transformer was approximately two hours.

The phase A transformer, serial 7001965, was then worked upon in order to remove the barrel barrier and conduct a general inspection. The same procedures were followed with the second unit as used with the first. That is, the humidity was controlled, the phase was packed, the barrier removed without cutting any material, and the windings inspected. Here again, the barrier was removed with no difficulty. The HV line lead and bushing shield were examined and were satisfactory. One point to note about the configuration of the line lead is that the copper bar comprising the horizontal section of the lead was positioned flat in the serial 7001994 whereas it was on edge for the serial 7001965. Again, there was no evidence of any abnormalities with the HV line lead in either unit. The top end of all coils was satisfactory and minor corrections were made with the LV bus bar connections in that about 70% of the bolted connections were tightened. The connections were not excessively loose but were tightened in order to fully compress the lockwashers.

As with the phase B unit, the phase A transformer was open for approximately two hours. Nothing was found out of the ordinary and the VEPCO representative was satisfied with both units and subsequently instructed the crew on-site to pull vacuum on both units. At the time of leaving the power plant, both units were being processed under vacuum with the plan to refill the units per the instruction book vacuum filling procedure.

J. B. Templeton, Manager
Electrical & Programs Development

1302E

APPENDIX A - ITEM 2

TRANSFORMER REPORT ON EVENTS AT N. ANNA POWER STATION

ENGINEER'S TRIP REPORT
WESTINGHOUSE FORM 3611 G

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- ☐ MR. S. A. Barrett
- ☐ MR. H. R. Moore
- ☐ MR. T. D. Poyser
- ☐ MR. J. R. Templeton
- ☐ File L-Spec. HAM 707-08 — MR.

VISIT - NAME VEPCO NEG.

LOCATION Richmond, VA G.O. S.O. HAM 707 SER. O. 7001994 ~~7001065~~

PURPOSE OF TRIP To watch corona test on two transformers.

CONFERENCE HELD AT VEPCO - North Anna Station DATE 11/30 - 12/3

THOSE PRESENT Joe McGreggor, Ron Barker and Haden Keafauver of VEPCO; John Haubert of (W) Richmond; W. J. Carter of (W) Muncie

SUMMARY:

See attached.

SIGNED (ENGINEER) William J Carter APPROVED [signature]

DEPARTMENT DIVISION LOCATION PAGE

Trip Report Summary

The purpose of the trip was to observe the corona tests made on two units of shop order HAM707.

Vepco was having problems obtaining the required oil breakdown voltage and was not ready to make tests when I arrived. After reviewing their procedures, it was observed that:

1. Their test set was being operated on a low line voltage.

2. The oil samples were being tested at about 10-15°C temp. where a 20°C minimum temperature is required by the ASTM procedure.

3. The oil samples may have been taken using dirty fittings.

These problems were corrected and acceptable breakdown voltages were obtained. The moisture contents measure in serial 7001994 were 5.01 ppm in the bottom sample, 8.44 ppm in the top sample and 10.95 ppm in the COPS tank. The gas in oil was 1.05% in the top and .4% in the bottom. The measured moisture contents in serial 7001965 were 6 ppm top and bottom and 17 ppm in the COPS tank. The gas in oil results were .48% top and .6% bottom. Since the measurements in both COPS tanks were above the limit of 10 ppm, several gallons of oil was drained from the bottom of the COPS and new samples were were tested. These tests gave similar results. No free water was observed in the samples. Clearance was obtained from Muncie to accept these levels.

During the tests on unit 7001994 difficulties were encountered which resulted in high corona levels at about 50% voltage and higher. The corona levels were apparent on the RIV meters and on both acoustic detection systems. The acoustic signals were characteristic of conducted interference and not acoustically detected corona internal to the transformer. The corona would disappear with time and would then reappear at higher voltages. It was then determined that the source was corona observed and heard on the test set. The accustic meter on the waveguides measured approximately 45 during these events.

The weather during the entire test period was rainy and foggy. The moisture caused the problems encountered during the test. The final test results are tabulated on the attached page. These results were accepted by all parties. The corona levels were stable during these tests and no corona was detected by either acoustic system.

An attempt was made during the evening of 12/3 to back feed the unit. Before the unit was energized, the waveguide detected several switching events in the 500 kV yard. These events caused a response of about 2,000 to 20,000 on the meter. When the transformer was energized the meter jumped momentarily from 40 to about 45. After about five seconds, relaying on the low voltage bus caused the unit to trip off. The low voltage bus was meggered and a problem at the generator breaker was found and corrected. The transformer was re-energized from the high voltage side at 4:08 a.m. on 12/4/82. As the unit was energized the meter indicated a level of about 200 units on both waveguides. This signal remained steady for seven minutes and then suddently decreased to 40 on each waveguide. The 40 reading represented an ambient level present without voltage. The waveguide meters remained steady for over one hour after energization.

Interviews with people in the area of the transformer during the period of energization disclosed that in the interval corresponding with the 200 unit reading on the waveguide meter, severe external corona existed on the 500 kV bus. This external corona probably caused the 200 reading.

At this point, problems with the generator breakers were discovered, and it was decided that it would be several hours before the unit would start carrying load.

B. 7001994

%	Time	H1 V	H2 V	Acoustic Waveguide	GP
0	0	12-14	25-30	40	-
100	-	12-14	30-35		
125	-	12-14	35-40		
135	0	20-25	35-40	146% max. voltage	
135	5	20-25	35-40		
120	5	20-25	30-35		
	10	20-25	30-35	40	
	20	20-25	30-35	40	
	30	14-18	30-35	39	
	40	18-22	30-35	39	
	50	15-18	40-45	39	
	55	14-16	30-35	39	
135	55	14-16	40-45	39-42	
	56	18-20	35-40		
	57	16-18	30-35	38	
	58	18	30-35	38	
	59	16-18	30-35	38	
135	60	16-18	30-35	38	
120	60	20-25	30-35		

ALL CORONA READINGS ARE STABLE.

Weather conditions: Fog with light rain at end of test.

A. 7001965

%	Time	H1 V	H2 V	Acoustic Waveguide	GP
0	0	18-20	7-8	40	OK
100		30-32	8-10	40	
135	0	25-30	12-14	40	
	2	20-25	8-10	40	
	5	20-25	7-8	40	
120	5	25-30	6-8	40	
	10	20-25	6-8	40	
	15	20-25	12-14	40	
	20	22-27	14-16	40	
	25	30-35	14-16	40	
	30	20-25	16-18	40	
	35	20-25	14-16	40	
	40	20-25	20-25	40	
	45	20-25	16-18	40	
	50	20-25	14-16	40	OK
	55	25-30	20-25	40	
135	55	20-25	25-30	40	OK
	56	20-25	25-30	40	OK
	57	20-25	30-35	40	
	58	20-25	25-30	40	OK
	59	20-25	25-30	40	OK
	60	20-25	25-40	40	OK
120	-	20-25	16-18	40	OK
100	-	20-25	10-12	40	OK

STEADY

Weather Conditions: Heavy Fog

APPENDIX A - ITEM 3

TRANSFORMER REPORT ON EVENTS AT N. ANNA POWER STATION

APPENDIX A - ITEM 3

ENGINEER'S TRIP REPORT
WESTINGHOUSE FORM 3611 G

NOTE 1 - The Engineer reporting is responsible for the prompt delivery of his reports to all interested persons and for seeing that all points requiring action are cleared up without delay.

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For Westinghouse Representatives only.

DATE 3/24/77

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- ☐ MR.
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- ☐ MR.
- ☐ MR.
- ☐ MR.
- ☐ MR.
- ☐ MR.
- ☐ MR.
- ☐ MR.

V: NAME Virginia Electric Power Company NEG.

(Original S.O. HAM707)

LOCATION Fredericksburg, Virginia G.O. S.O. XDM1323 SER. O. 7002099

PURPOSE OF TRIP To search for missing hardware used in the shipping braces.

CONFERENCE HELD AT North Anna Power Station DATE 3/23/77

THOSE PRESENT Alfred Moore and "Smiley" Francis of VEPCO and C. F. Millis, V. A. Holford, and I. L. Hansen of Muncie.

SUMMARY:

A bolt in the shipping braces was minus a nut and washer upon arrival at the site. Several investigations by VEPCO and one by Muncie personnel failed to locate the missing hardware. It was the conclusion of the personnel from Muncie that the hardware was never on the bolt.

SIGNED (ENGINEER)		APPROVED	
I. L. Hansen	3/24/77	[signature]	
DEPARTMENT Engineering	DIVISION Large Power Transformer	LOCATION Muncie, Indiana	PAGE 1

TRIP REPORT

Virginia Electric & Power Company
S.O. XDM1323 (Originally HAM707)
Serial #7002099

When this unit was received at the North Anna Generating Station an internal inspection was performed with no discrepancies noted. After the unit was placed in an upright position and during the removal of the laydown shipping braces, a bolt was found with no nut or washer on it. Using the attached portion of Drawing HAM707-75 as reference, the location of the missing nut and washer is indicated. There are three bolts through this particular post and wall, and the one without a nut or washer was located near the bottom (or nearest the side member). The missing nut and washer were not discovered in the earlier inspection because of its inaccessibility.

The crew that discovered the missing hardware searched for several hours, but failed to locate it. Mr. Alfred Moore of VEPCO also spent several hours on each of three different occasions searching for the hardware with no success. Mr. Moore and the crew also searched the tank bottom by inserting a magnet through the cooler valves. Since it is impossible to see into the tank bottom, there are undoubtedly large areas that were not covered.

On 3/22/77 V. A. Holford, C. F. Millis, and I. L. Hansen from Muncie inspected the shipping braces and hardware that were removed from the transformer. There was no indication of this bolt ever being tightened because neither the post nor wall had any indentations. All bolts were in one large bag so there was no way of locating and inspecting the bolt of interest to determine whether it had ever had a nut on it. Since it was raining the transformer was not examined internally until 3/23/77. This inspection revealed no loose hardware. Wedges between the shielding and phase were not removed, but gaps in the corners were examined with a boroscope.

In the final discussion with Mr. Moore, I. L. Hansen stated that he was satisfied that the nut and washer were never placed on the bolt at Muncie. Mr. Moore asked about the possibility of cutting into the tank bottom to determine whether anything had fallen into it. Mr. Hansen acknowledged the possibility of doing this, but attempted to discourage it. Mr. Moore said they would not cut into the tank without discussing it first with Muncie.

I L Hansen

I. L. Hansen
Design Engineer

3/24/77

APPENDIX B - ITEM 1

TRANSFORMER REPORT ON EVENTS AT N. ANNA POWER STATION

Teardown Report
VEPCO North Anna Unit
500/22 GSU S# 7001994
S.O. XDM1888 (HAM707)
1/10/83

Summary

This transformer failed on December 5, 1982 and was returned to Muncie for teardown and inspection. Visual examination of the phase indicated that the greatest damage occurred in the area of coil 21 located approximately below the HV bushing flexible connector. The edge of coil 21 was burned and the outermost layers of the coil displaced. The corners of washers 66, 67 and 68 were broken and missing. Arc burning was also found on the edge of the HV bushing flexible connector. Detailed inspection of the coils confirmed the assumption that an arc had occurred between the HV bushing flexible lead and the edge of coil 21.

The detailed inspection also uncovered an electrical failure between turns 7 and 8 of coil 1.

Detailed Inspection

Tank: The top section of the tank was distorted and ruptured in several places.

Bridge: Nearly all fiber studs in the bridge structure were broken and the bridge fell off the phase when the tank top section was removed.

Core Steel: The core steel stack was straight and undamaged.

Coil Support: The coil supports were undamaged.

Phase: Coil 1 - Had a turn-to-turn failure between turns 7 and 8 on the HV side 36 inches above the centerline. The turn-to-turn pressboard fill was displaced at the point of failure.

Coil 15 - A "S" shaped piece of copper wire was found near the start-start connection. No damage to this coil was found.

Coil 19 - The coil insulation directly adjacent to the damaged area of coil 21 was charred.

Coil 21 - The outer edge of the coil was burned and bare copper pitted on the A end, HV side. The outer layer of the coil was displaced.

Coil 22 - The insulation of the "A" end coil edge was skinned in 3 places.

Coil 38 - The insulation on the "A" end coil edge was skinned in 1 place.

Washers 66, 67, 68 - The "A" end HV side corners of the washers were broken off and missing.

HV Lead - There was electrical burning on the edge of this HV bushing flexible connection at about mid-length.

Conclusion

It is concluded that an electrical arc occurred between the HV bushing flexible lead and the edge of coil 21.

W. J. Carter
D. White
Engineering Operations

APPENDIX B - ITEM 2

TRANSFORMER REPORT ON EVENTS AT N. ANNA POWER STATION

APPENDIX B - ITEM 2

VEPCO TRANSFORMER
HAM 707, SERIAL 7001995, VEPCO PHASE C
FAILED NOVEMBER 16, 1982

BACKGROUND DATA

- Shipped 1973.
- Went into service 1974 (limited, full service 1975).
- Taken off line, May 1982.
- Drained, refilled with new oil, August 1982.
- Re-energized for first time on November 16, 1982.
- Failed 3 hours, 6 minutes after re-energizing.
- Weather reported to have been mild through the fall season until two nights before the failure.
- Failure occurred while unit was being back fed from the 500 kV system.
- Pump bearing wear had occurred in pumps on other two serials (7001965 and 7001994). These units cleaned, flushed and refilled with new oil. Harley Pump Co. report states that there was no bearing wear in pumps from serial 7001995.

DATA FROM VEPCO RECORDS AND OBSERVATIONS

- Fault Currents
  - Phase C - 16200 amperes
  - Phase A - 5250 amperes
  - Phase B - 5250 amperes

  Normal 120° Apart
- Breakers cleared fault in three cycles.
- No unusual occurrences or observations prior to failure.
- One stage of coolers initiated when unit was energized.
- Pipes to disconnected gas relay broken and distroted on Phase A and B tanks. Condition prior to Phase C failure thought to be normal.
- No failure on HV bushing.

FAILURE DAMAGE AND FAILURE PATH

- 1-1/2" diameter hole in lower edge of HV bushing shield. See Figure 1.
- Flashover from this hole across the surface of the cylindrical barrier down to the edge of L.V. coil #21 about 18" from the centerline of the phase. The damage on coil 21 was erosion of the strand surfaces for a depth of about 1/32". See Figure 1.
- Smoked area on insulation around failure on coil 21 was small.
- Insulation in good condition with exception of mechanical damage caused by broken porcelain and bridge walls.
- Both upper and lower porcelains on H.V. bushing broken. No evidence of a bushing failure.
- One small arc mark on tank wall opposite the corona shield which was felt to be a low energy secondary failure.
- Tank cover had some minor distortion and the welds at the ends of some cover braces were partially ruptured.

- No ruptures in tank so that there was no loss of oil.
- Turn ratio correct after failure.
- Meggar values in air 1000 megohms minimum indicating no failures to ground within the transformer insulation system.
- Flashovers reported in bus duct for phases A and C. See Figure 2. Found flashover in Phase A bus duct 8 feet from transformer. Did not find where Phase C flashed over as of 11/18/82.

HYPOTHESIS OF FAILURE CAUSE

The oil became saturated with nitrogen during the period between August and November. The saturation level would be the equilibrium values for ambient temperatures that existed. It appears that a maximum ambient of 30°C occurred during the period. Ambient temperatures dropped to -3° during two nights preceeding the re-energization. The temperature of the oil in coolers, piping and pumps would decrease rather rapidly resulting in super saturation of this oil and possibly formation of some small gas pockets.

When the pumps were started, nitrogen bubbles were evolved in the oil. Gas bubbles collected around the lower edge of the corona shield on the H.V. bushing. Corona was initiated by these gas bubbles which ultimately resulted in a flashover from the shield to the edge of L.V. coil #21.

The potential of the L.V. winding was elevated when the flashover from the H.V. bushing occurred. The potential became high enough to cause flashovers to ground in phases A and C bus duct. The bus duct was the weak link since it was insulated for 110 KV BIL while the transformer LV winding and bushings were insulated for 150 kV BIL. See Figures 1 and 2 for sketches of the failure paths.

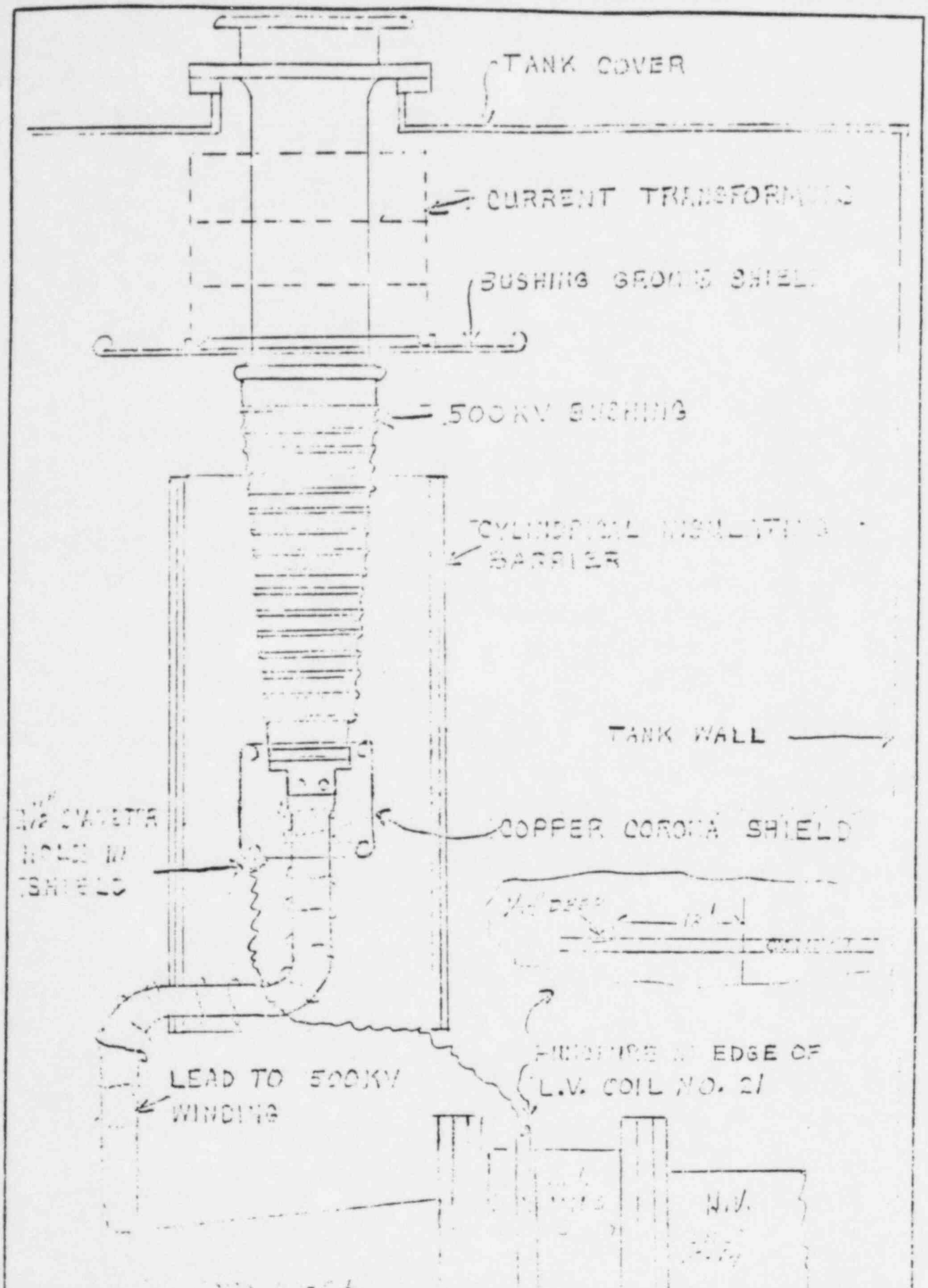
This failure sequence agrees with the magnitudes and phase angle relationships of the fault currents.

H R Moore

H. R. Moore
12/3/82

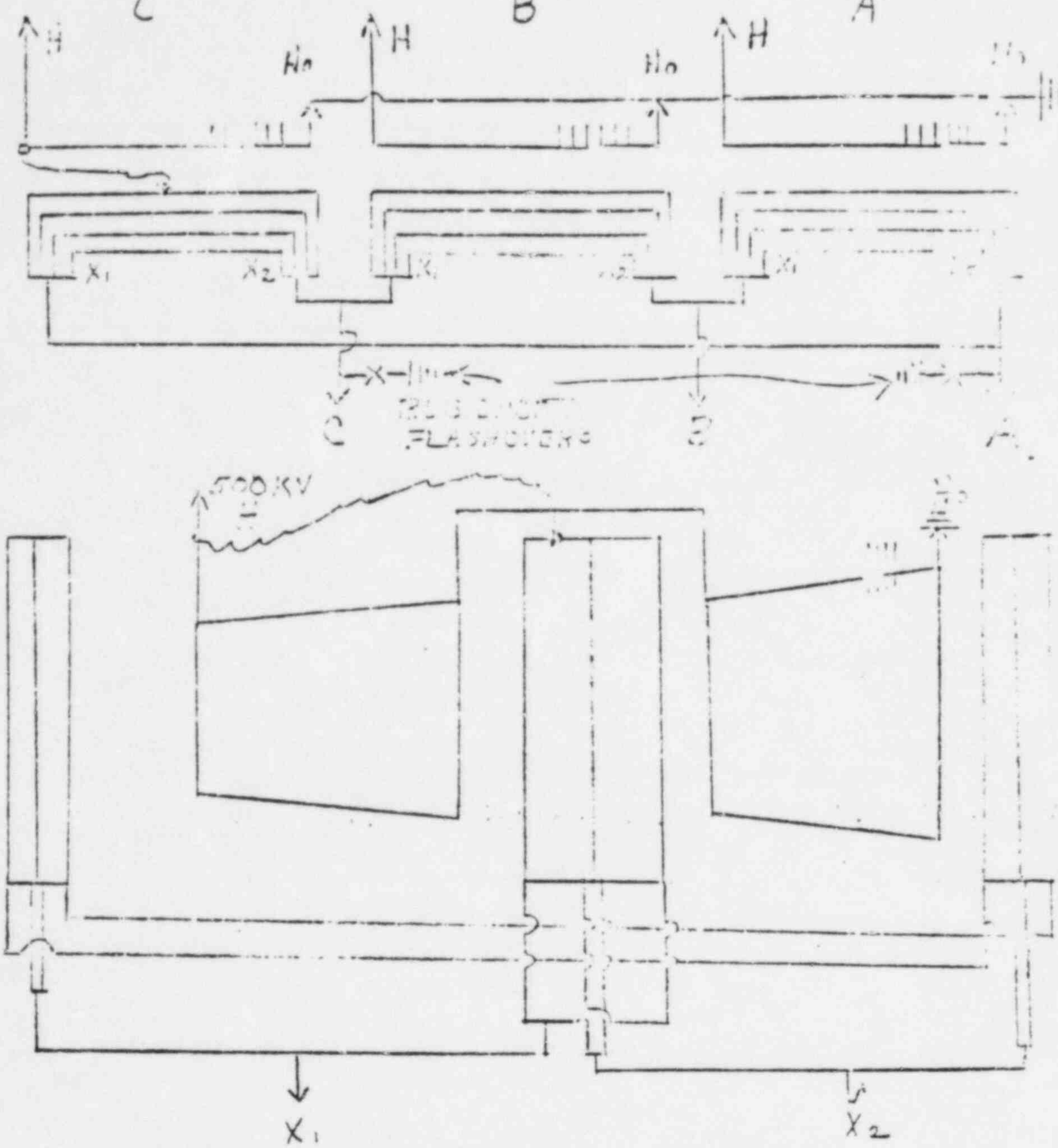
SKETCH SHEET
WESTINGHOUSE FORM 24443

WESTINGHOUSE ELECTRIC CORPORATION



VEPCO

WESTINGHOUSE ELECTRIC CORPORATION



SCHEMATIC OF EACH PHASE

APPENDIX B - ITEM 3

TRANSFORMER REPORT ON EVENTS AT N. ANNA POWER STATION

ENGINEERING LABORATORY REPORT #41-5F

DEVELOPMENT ENGINEERING

MUNCIE PLANT

TITLE: FIELD FAILURE IN S.O. HAM707

ABSTRACT: One of the single phase units (Ser. #7002099), built on S.O. HAM707 failed in the field as a result of flashovers across the ducts between H.V. coils #31, #32 and #33. Flashovers also occurred to the L.V. series connections. This report describes teardown of this unit and outlines a probable sequence of flashovers.

PREPARED BY:

J. L. Puri 7/30/76 (Date)
J. L. Puri
Development Engineer

I. L. Hansen 7/30/76 (Date)
I. L. Hansen
Design Engineer

APPROVED BY:

L. S. McCormick 7/30/76 (Date)
L. S. McCormick
Supervising Engineer
Electrical Development

H. R. Moore 7/30/76 (Date)
H. R. Moore, Manager
Electrical Development

DESCRIPTION OF UNIT

S.O.:	Ham707
Customer:	VEPCO
Type:	Shell Form, Single Phase, 60 Hertz, 4 H-L Generator
Rating:	330 MVA (FOA)
	H.V. - 288675 V (1300 kV BIL)
	L.V. - 22000 V (150 kV BIL)

FAILURE EVENTS

The tranasformer was brought up to full voltage level and it carried full load only for a few Hertz and failed. Heavy flow of ground currents was also recorded.

Various cases and events that resulted in the failure is still under investigation.

TEARDOWN OBSERVATIONS

The phase was removed from the tank bottom July 12, 1976. No evidence was found of a failure to the tank bottom, core, T-beam, or corona shields.

The bridge was removed; nothing unusual was noted except for the obvious failure which will be described later.

Customer representatives arrived at the Muncie Plant July 13, 1976. Dismantling of the phase began with coil 38. All items were inspected prior to being scrapped -- no evidence of corona was found anywhere.

Initial observations prior to dismantling were that the phase was very dirty with carbon deposits everywhere and copper shot in most of he A end. Channels were not intact in the A end of the phase over coils 30 through 33. A fault with apparently heavy currents had destroyed all but 1 strand of the outside turn on coil 33, burned through the edge strip on coil 32, and completely burned open the outside turn in 31 plus about 80% of the second turn. Burn marks were detected on the series connections between coils 35 - 1 and coils 38 - 4.

Coil 38

This coil had no burn marks on it; however, the series connection between coils 38 - 4 did. The crepe paper over the series connection had been burned through just above the washer line. The resulting cavity in the copper was approximately 1/4" in diameter and approximately 1/8" deep.

Coils 37 and 36

These coils were removed with no evidence of failure except for heavy carbon deposits resulting from the fault in the H.V.

il 35

This coil had burned spots all along the outside turn at the A end (see sketch). There were 14 cavities approximately 1/4" in diameter & 1/8" - 1/4" deep on Coil 36 side and 1 cavity at the 45° on Coil 34 side. In addition one of the outside strands were burned through just beyond the 45°. Most of the cavities were in the outside 4 layers of the turn, but two cavities were detected in the 5th and 6th layers. The series connection was burned in two places just above the washer level. The series connection split in three parts in the turn height direction (Fig. 22,5 layers each split); only two of the three parts had cavities in them corresponding to the layers that had cavities on the coil. The washers above & below Coil 35 were badly discolored but not "burned" through. The severe discoloration occurred wherever a cavity was formed.

The high-low insulation was dismantled with no evidence of any arcing or corona.

Coil 34

This HV line coil and it's associated static plate were free from unusual markings. The washers between Coils 34 & 33 were badly charred, but did not indicate any coil to coil punctures.

Coil 33

This coil had all but 1 strand of the outside turn burned out. This was located about 2 feet from the coil center line on the HV side of the coil. The failure also burned open seve al strands of the second turn on the Coil 32 side. This coil also had two cavities on Coil 32 side much like the cavities on Coil 35; they were located near the center line.

Coil 32

This coil had it's edge strip burned away in the area of the fault. In addition there were two cavities on the first layer & one cavity on the second layer; they were located at the 45° line at the A end on the LV side of the center line. Another cavity was noted on the 2nd layer at the tie. Washers between Coils 32 & 33 were burned open at the area of the fault.

L 31

This coil had it's outside turn burned open plus 3 strands in layers 1 and 2 and 1 strand in layers 3 of the second turn. The burned out area was in the A end on the HV side of the coil. There were four cavities on the outside turn also. One was under the tie on Coil 32 side; two were on Coil 30 side on the LV side 90° line; and one was on the coil center line on Coil 32 side.

The finish-finish connection between Coils 30 - 31 was burned nearly open. The burn was located approximately 1 foot toward the HV side of the braze; the burned out area was between and on the outside of the two figure 15 parts. The paper covering this area was not blackened as one might expect from a heating problem; rather, it appeared to have happened in a very short time.

The washers between Coils were burned through at the fault location.

Coil 30

This coil did not have portions of the turn burned open, but there e two cavities on the outside two layers about center line on the Coil 31 side. There was also one cavity on the third layer about center line on Coil 29 side.

Coil 29

This coil had one cavity on the third layer on Coil 30 side at the edge of the tie. Another cavity was located on the Coil 30 side 1-1/2" toward tie from center line. On Coil 30 side, third strand, 10" from edge of tie another cavity was detected. A cavity was noted between the first and second layer of the third turn at about the center line; this was the deepest penetration of cavities noted. There were no cavities noted on Coil 28 side; however, a cavity was located on Coil 28 side of the finish-finish connection.

The remaining coils did not have any unusual marks or distortions evident.

Conclusion

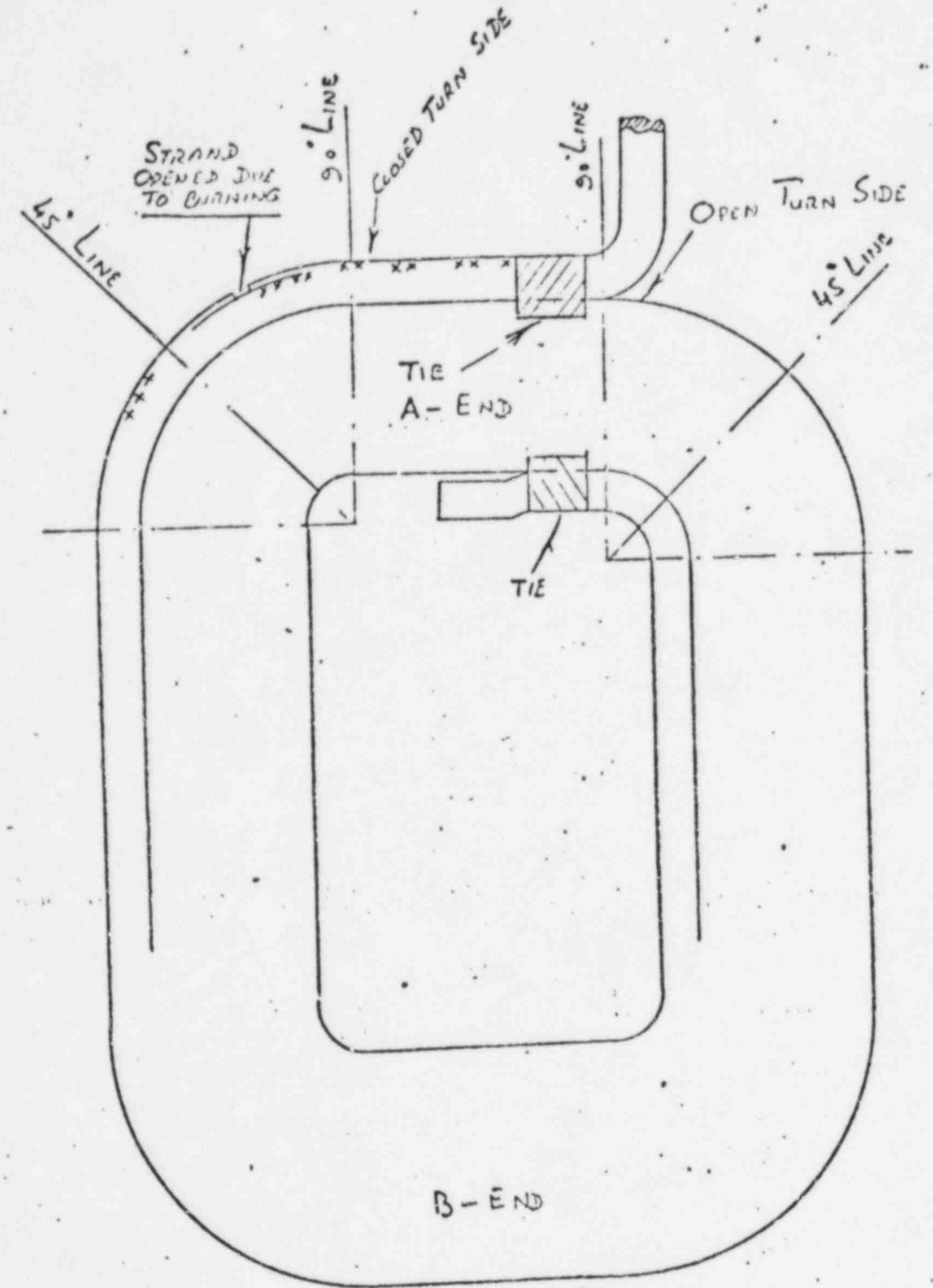
In the area of the failure across the second duct from the HV line, Coils 31 & 33 are "closed" and 32 is "open". Consequently the failure path from Coil 31 to 33 and over the top of 32 is essentially a straight line. The heavy currents that flowed during the coil-to-coil fault apparently generated a great deal of gas. The gas was distributed over most of the A end due to channels over the faulted coils and general gas expansion. The ionized gas then provided a low impedance path for multiple secondary failures from the HV, over the high-low washers, to the LV (Coil 35).

There were a total of 15 cavities on the LV Coil 35 plus one burned open strand. There were also three cavities in the LV series connections. An estimate of the current flowing between high and low would be marginal at best since it is difficult to estimate the current required to form the cavities and impossible to know how many paths were faulting simultaneously.

I. L. Hansen
I. L. Hansen
Design Engineer

J. L. Puri
J. L. Puri
Development Engineer

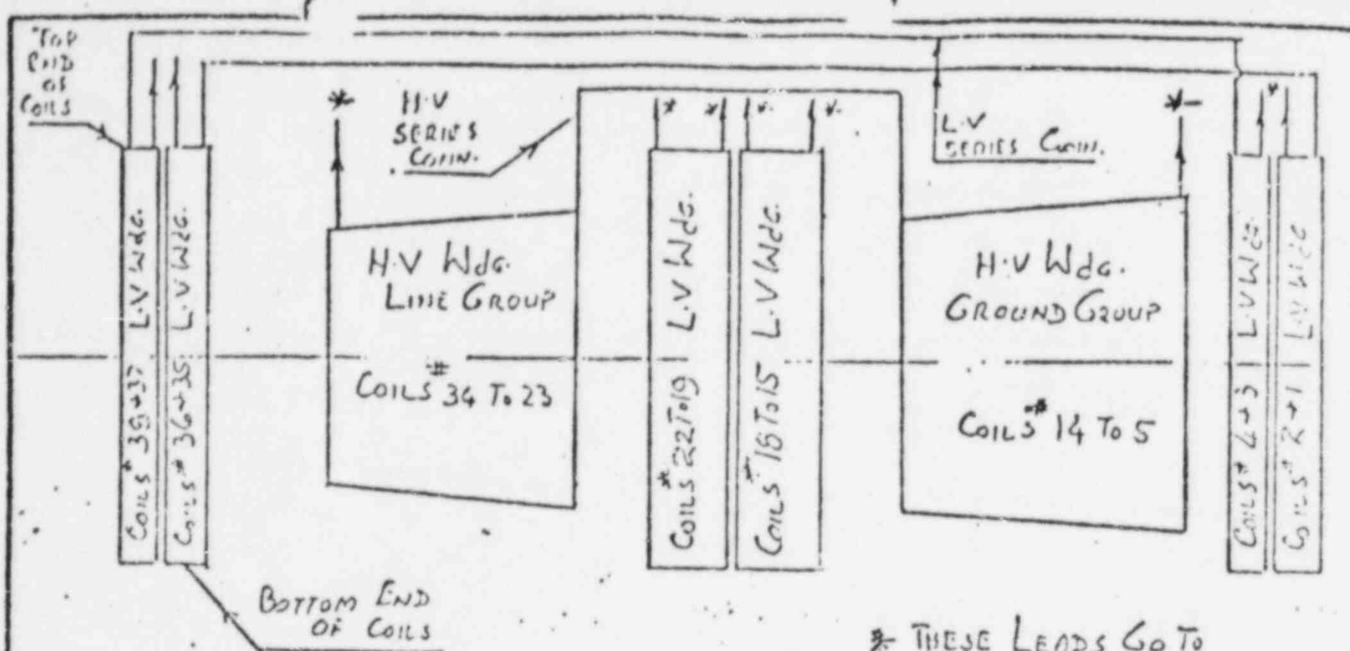
WESTINGHOUSE ELECTRIC CORP [illegible]TION



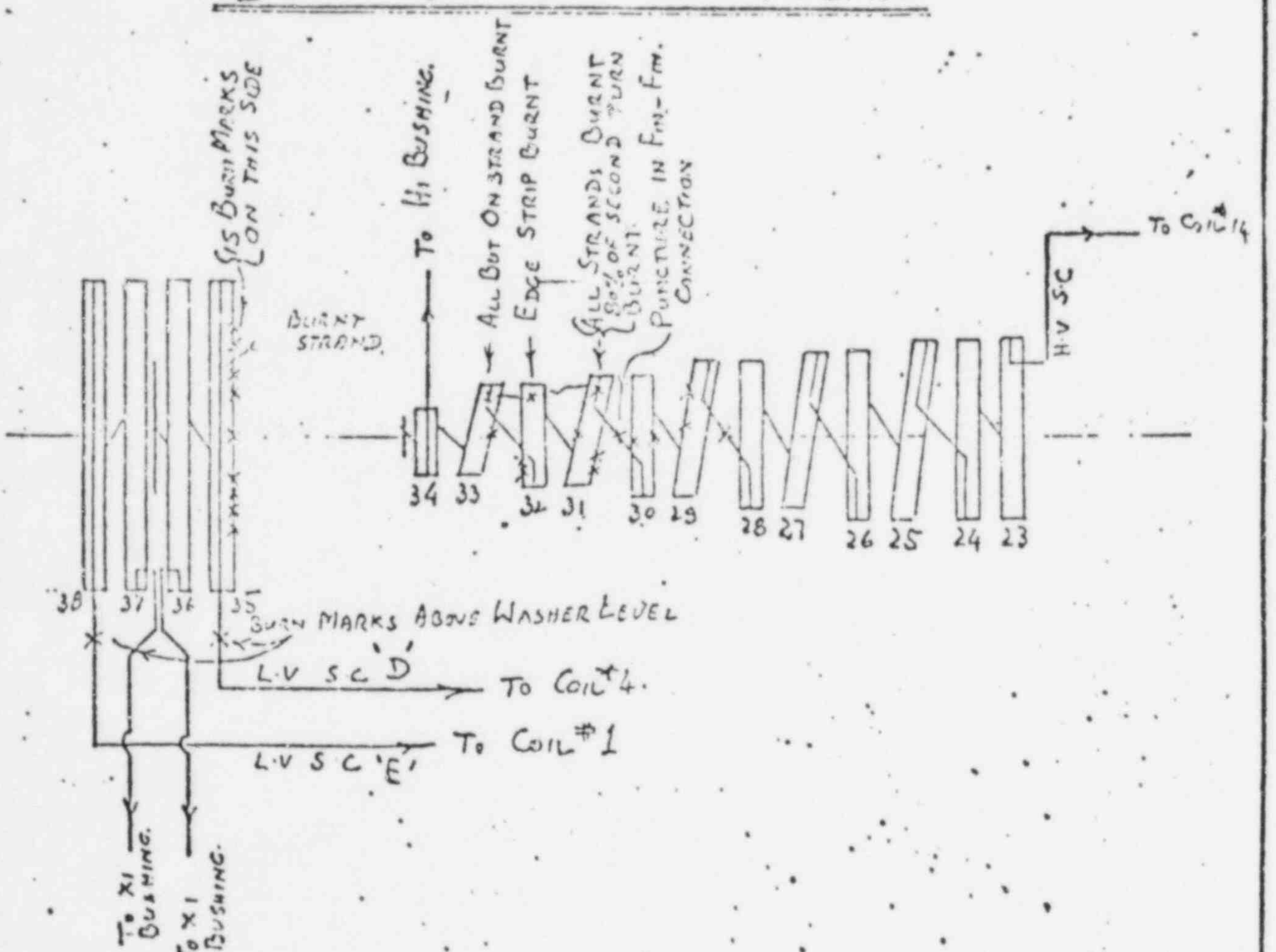
L.V COIL #35

"X" INDICATES CAVITIES

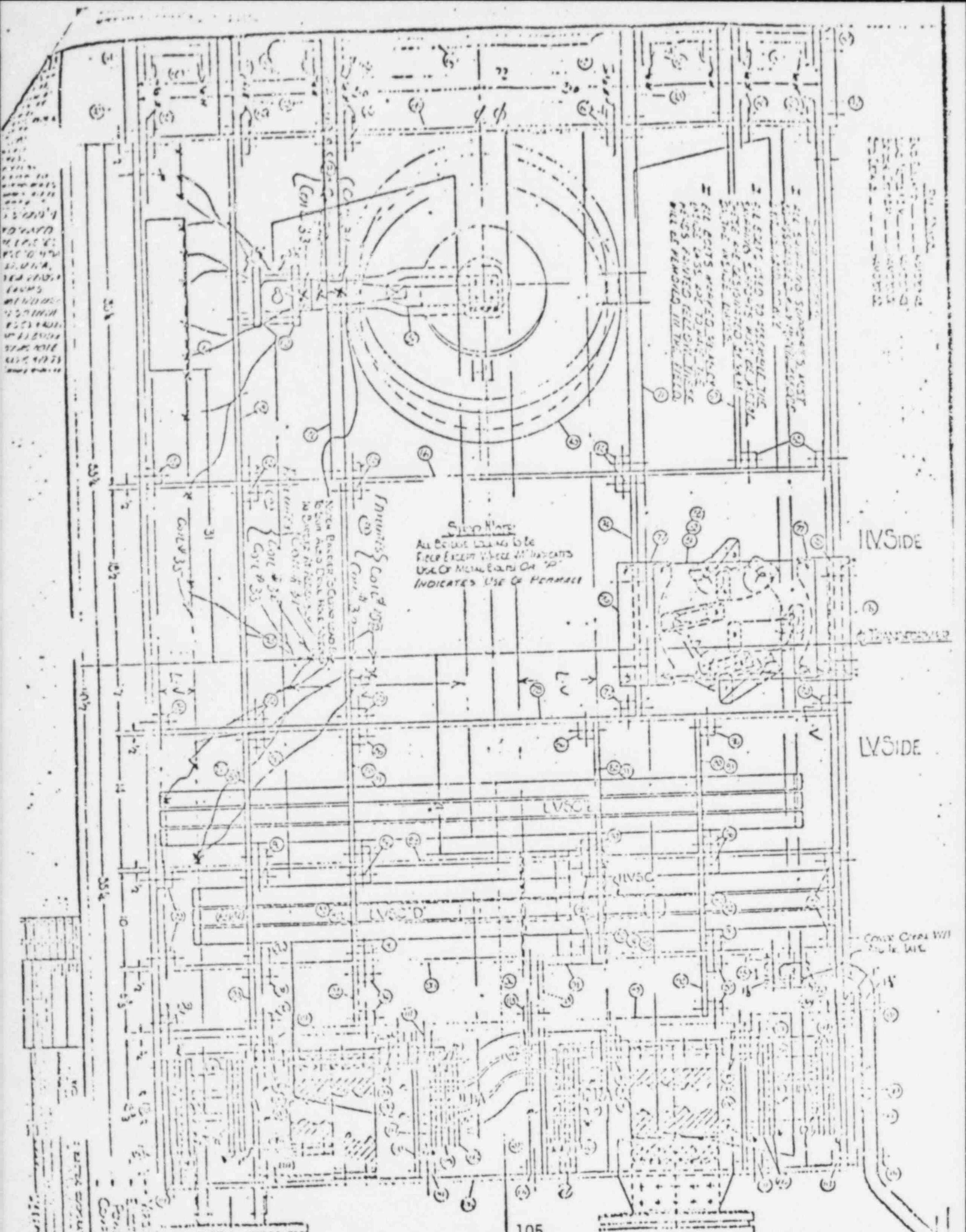
WESTINGHOUSE ELECTRIC CORPORATION



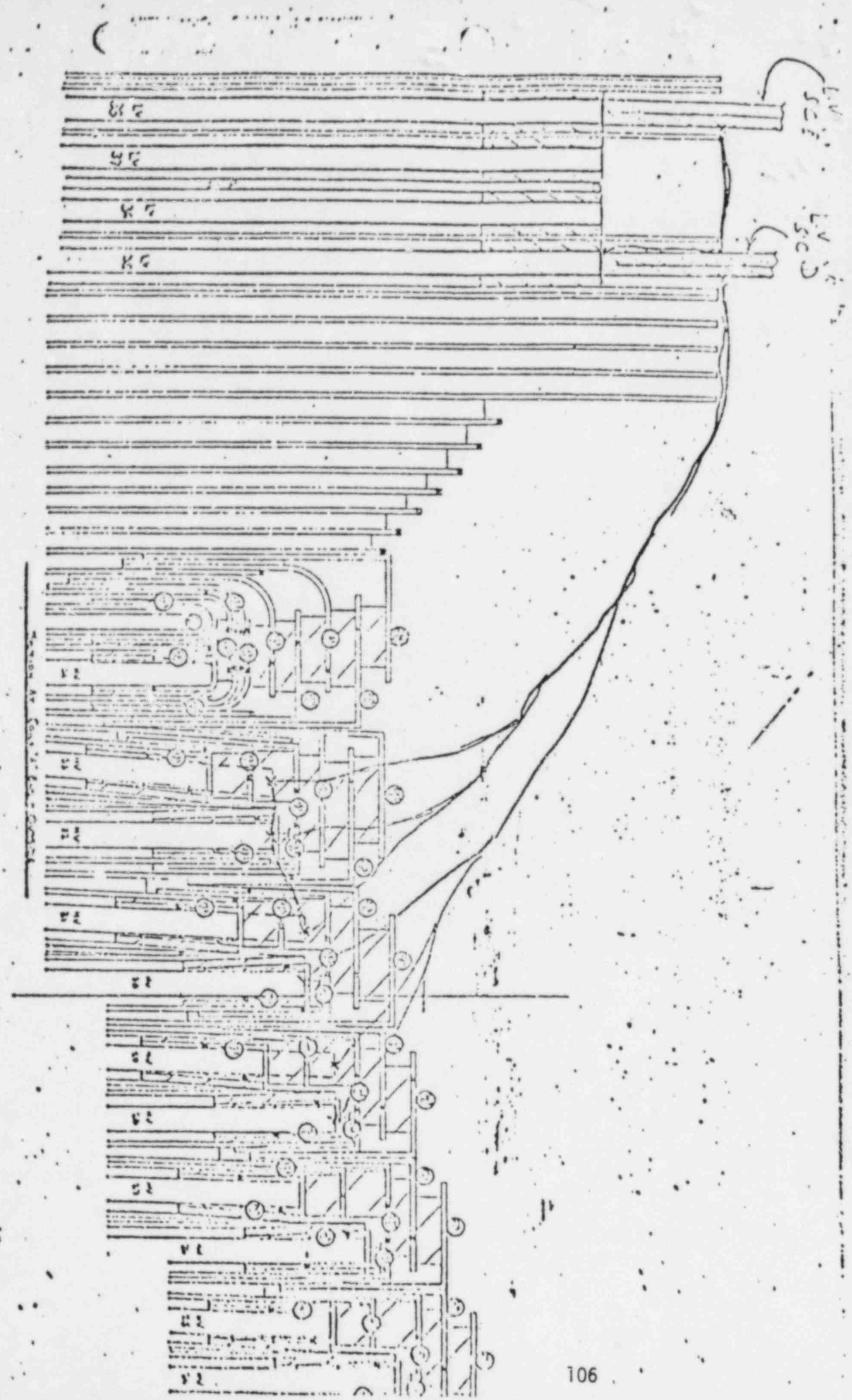
BLOCK DIAGRAM OF WINDINGS.



SKETCH OF CONNECTIONS AS VIEWED FROM TOP END OF WINDINGS.


Shop Note:
All Bolted Leads To Be
Fiber Except Where "M" Indicates
Use Of Metal Bolts Or "P"
Indicates Use Of Permali
HV Side
LV Side
LVSC
LVSC'D'
HVSC
Transformer

105



APPENDIX B - ITEM 4

TRANSFORMER REPORT ON EVENTS AT N. ANNA POWER STATION

APPENDIX B - ITEM 4

ENGINEER'S TRIP REPORT
WESTINGHOUSE FORM 3611 G

NOTE 1 - The Engineer reporting is responsible for the prompt delivery of his reports to all interested persons and for seeing that all points requiring action are cleared up without delay.

2 - For long reports give a summary of important points and recommendations.

For Westinghouse Representatives only.

DATE December 17, 1980

DATE OF ARRIVAL AT PROPERTY	DATE OF LEAVING PROPERTY

ORIGINAL TO ISSUING DEPARTMENT'S FILE NO.

COPY TO: (FOR REPORT DISTRIBUTION GUIDE - REFER TO REVERSE SIDE OF THIS SHEET)

☒	MUNCIE LPTD	MR. R. J. Cossaart
☒	MUNCIE LPTD	MR. H. R. Moore
☒	MUNCIE LPTD	MR. L. E. Luke
☒	MUNCIE LPTD	MR. G. B. Metzler
☒	MUNCIE LPTD	MR. M. P. Wood
☒	MUNCIE LPTD	MR. W. D. Jones
☒	RICHMOND, VA	MR. R. L. Bowman
☐		MR.
☒	File L - HAM 707-08	MR.

NAME Virginia Electric Power Company NEG.

(Original S.O. HAM707)

LOCATION Fredericksburg, Virginia S.O. XDM1323 SER. O. 7002099

PURPOSE OF TRIP To make internal inspection

CONFERENCE HELD AT North Anna Nuclear Generating Station DATE 12/15/80

THOSE PRESENT Messrs. W. Birckhead and R. Barker of VEPCO; R. L. Bowman of Westinghouse Richmond and B. W. Hugon of Westinghouse Muncie LPTD

SUMMARY:

There was a flashover from H.V. line lead to L.V. coil #16. We recommend the installation of complete new phase (coils, insulation and bridge).

SIGNED (ENGINEER)		APPROVED	
Bill Hugon	12/17/80	L. E. Luke	12/17/80

DEPARTMENT	DIVISION	LOCATION	PAGE
Eng.	LPTD	Muncie	1

TRIP REPORT

Virginia Electric and Power Company
S.O. XDM 1323 (originally HAM 707)
Serial 7002099

VEPCO reported that subject unit tripped off the line on November 29, 1980 during normal weather conditions. The SPR, mechanical relief device and differential relays had operated and the fault was cleared within 3-1/2 cycles. There was also a flashover to ground in the L.V. isolated phase bus duct and H.V. arrester damage which VEPCO feels was mechanical rather than electrical failure. VEPCO also reported that the unit will ratio correctly but the Doble readings are slightly low.

An internal inspection was made by Messrs. W. Birckhead and R. Barker of VEPCO and B. W. Hugon of Muncie LPTD on 12/15/80.

The H.V. line coil wire of coil comes up vertically through a clamp and then turns 90° and brazes to a horizontal run of copper bar. Brush copper bolts to the end of this bar and goes vertically upward to the H.V. line bushing which is located on the tank centerline.

There was a flashover from the bottom of the end of the horizontal run of the H.V. line lead to the radius of L.V. coil #16. This coil is 6" beyond rather than directly below the end of the horizontal run of the H.V. line lead. Bare copper was exposed for approximately one square inch on the H.V. line lead. The four conductors of the outside layer of coil #16 were severely pitted for about 12" and the strand adjacent to coil #15 was burned open. The free end of the open strand toward the coil centerline remained essentially in its normal position. The other free end projected upwards 4 or 5 inches and then turned downwards for about 2 inches.

No arc pits could be seen on L.V. coil #15, however, it appeared that the washer between coil #16 and #15 may have been ruptured, and there was considerable carbon on the coil #15 side of this washer. In this area the outside edge of coil #16 is approximately 5" higher than that of coil #15 since #16 is a "closed" coil while #15 is an "open" coil.

The round barriers around the H.V. line lead and the bridge walls supporting these barriers were broken.

The hanger straps for the lower half of the double do-nut corona shield on the H.V. bushing were distorted so that the side of the lower shield toward the L.V. side of the tank was lower than its normal position.

Many of the fiber studs in the bridge walls supporting the L.V. series connections were broken.

No arc to ground was observed during this inspection. It is, of course, possible that one or more L.V. coils may have flashed to the core in a location not visible at this time.

The amount of copper particles and carbon was fairly small for a field failure but still of sufficient magnitude that we would recommend the installation of complete new phase (coils, insulation and bridge). The tank, bushings, coolers and most core steel should be reusable.

BW Hugon 12/17/80

B. W. Hugon
Design Engineer

BWH:sjt:0154E

APPENDIX B - ITEM 5

TRANSFORMER REPORT ON EVENTS AT N. ANNA POWER STATION

APPENDIX B - ITEM 5

DISASSEMBLY REPORT

SUBJECT

Disassembly of transformer serial number 7002099, built originally on shop order HAM707. The transformer is a single phase, 330MVA, 500kV generator step-up transformer and was located at the North Anna Station of Virginia Electric and Power Company.

HISTORY

This unit failed in service on November 29, 1980. An internal inspection was performed on December 15, 1980 by Mr. W. Birckhead and R. Barker of Virginia Electric and Power Company and by Mr. B. Hugon of Westinghouse LPTD. This inspection indicated there had been an arc between the HV line lead and the center low voltage coil group. It was determined at that time, due to the contamination present, a new phase would be manufactured for re-assembly of this transformer.

REPORT OF DISASSEMBLY

The transformer was untanked and the core was removed. On May 17, 1981 the phase was dismantled by LPTD personnel in the presence of Mr. W. Birckhead and Mr. R. Barker of Virginia Electric and Power Company, Mr. J. Mechler of the Hartford Boiler Insurance Company, and Mr. E. Luke of Westinghouse. The phase assembly was split at the high-low space between coils 14 and 15. The entire group of coils, 1 through 14, was removed intact. Low voltage coil group 15 through 22 was then dismantled coil by coil. The only coil in this group that showed evidence of failure was coil 16. The other coils and their associated insulation were darkened as a result of the carbon and smoke from the arc.

The HV line lead was designed to come vertically up from coil number 34 and then make a 90° bend. Wire of coil was then brazed to a rectangular copper plate which had four holes for connection to a flexible lead which connected to the HV bushing. The failure was an arc from the corner of the copper plate to the edge of low voltage coil 16. The arc burned one strand of the outer layer of coil 16 conductor apart. The other three strands of this outside layer were pitted but had not burned open. There were also arc marks on the second layer of this turn on coil 16, but it is believed this occurred when the outer strand burned open. The arc had melted a small crater in the corner of the HV copper plate connector. Particles of copper from this arcing were observed on the phase. Coil washers in coil 15 to 22 group and some of the high-low washers between coils 22 and 23 were broken along the top edge by bridge items that collapsed as a result of the arc energy.

Attached is a portion of drawings HAM707-48 and HAM707-50 and Page 6 of L-HAM707-08. Drawing HAM707-50 shows that relative position of the HV lead with respect to the coil groupings.

This unit is being re-assembled utilizing a new phase which contains all new coils and insulation. The H.V. line lead has been redesigned such that the rectangular copper plate has been eliminated and the connection, from the coil wire to the H.V. bushing, will be made with insulated cable.

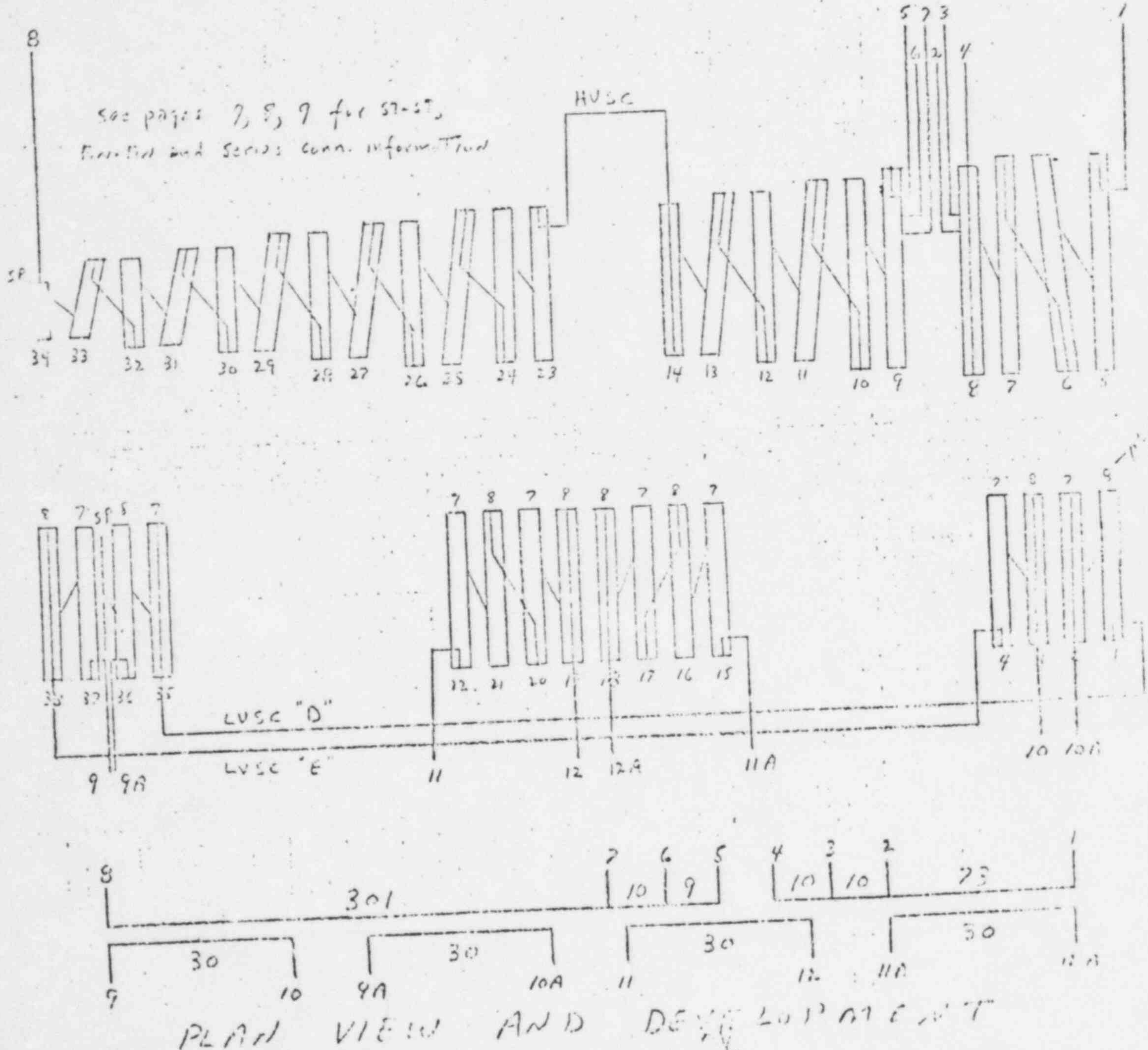
L. E. Luke, Manager
Design Applications

0406E 6/5/81

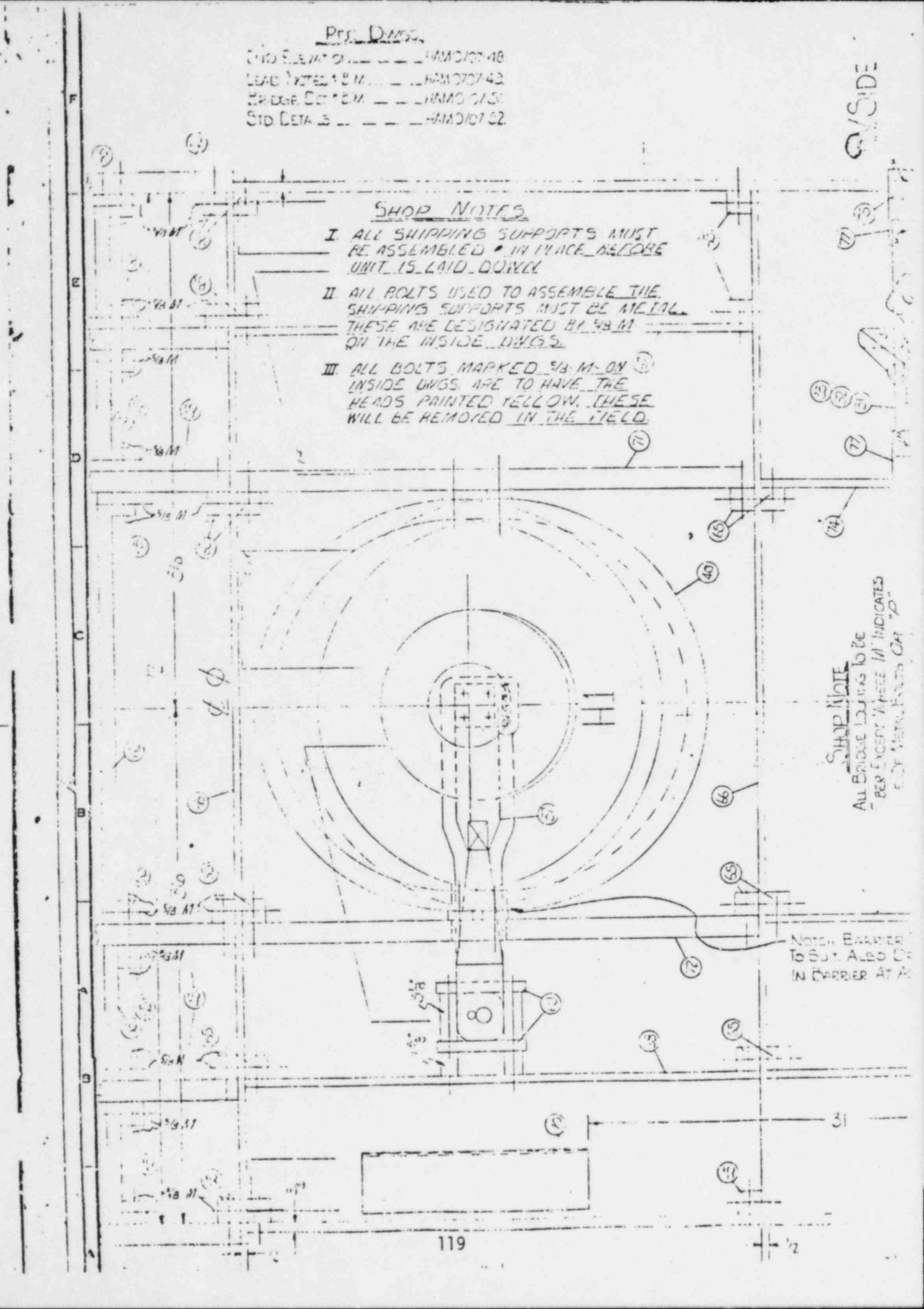
TABLE OF CONNECTIONS

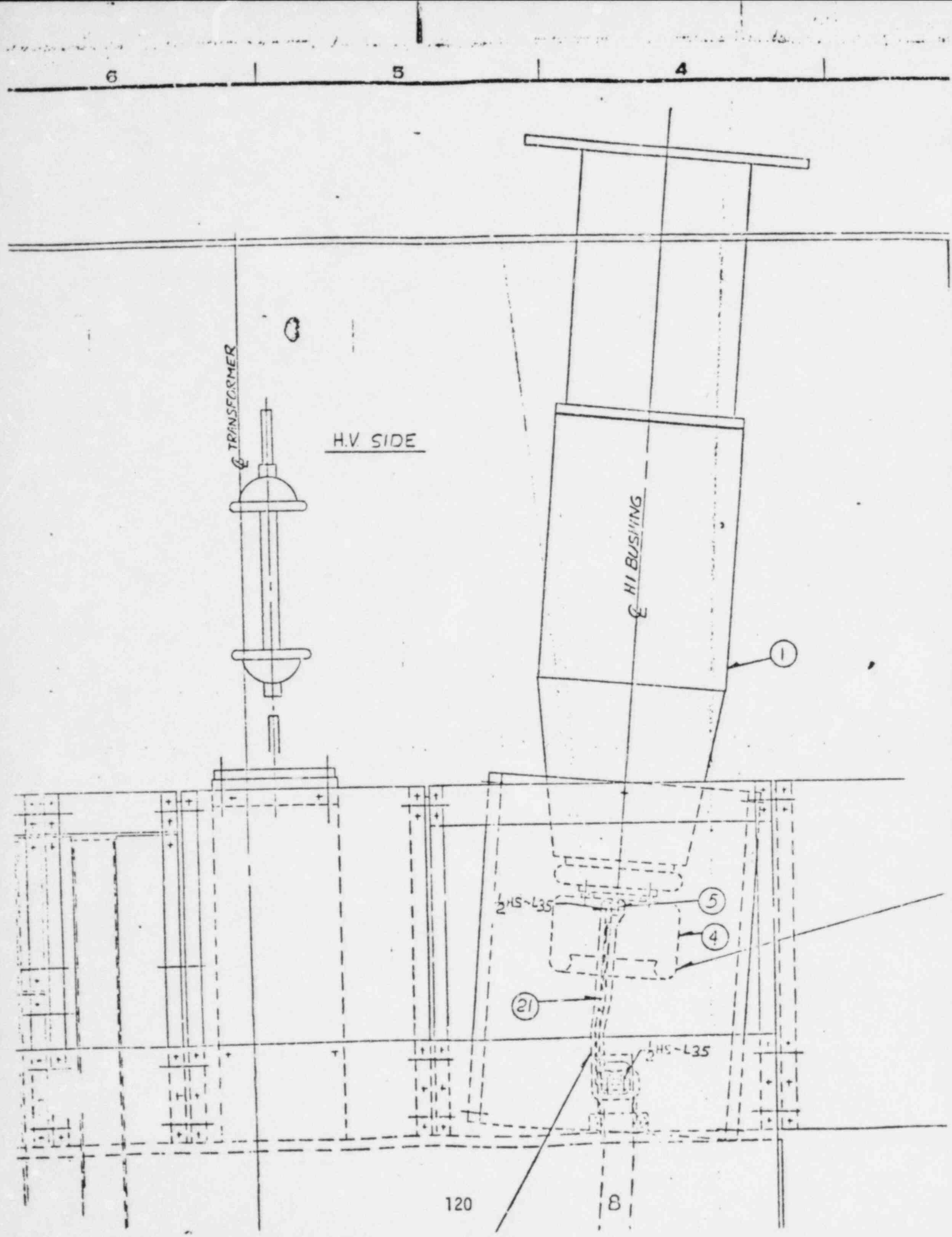
TAPS TO BE BROUGHT OUT AS FOLLOWS:

Coil No.	2	2	9	1								36	37		
To	2	3	6	1								[illegible]	[illegible]		
Sw	—	—	—	—								—	—		
Turn	1	11	11	1								8	12		
Distance from Centerline M	3½ T	24 T	16⅔ A	7 T								FIG 14	FIG 14		
Distance from Centerline N	3¾ T	20½ T	18⅔ A	6 T											
Side of Coil	R	R	R	R								R	R		
Lgth. of Tap	90	75	73	70											
S	32	23	17	33											
Fig. No.	25A	25A	25A	25A											



PLAN VIEW AND DEVELOPMENT


PRS. DWGS.
STD ELEVATION ...HAMO707-48
LEAD SYSTEM & B.M. ...HAMO707-43
BRIDGE DET. & B.M. ...HAMO...
STD DETAILS ...HAMO707-52
CV SIDE
SHOP NOTES
I. ALL SHIPPING SUPPORTS MUST BE ASSEMBLED IN PLACE BEFORE UNIT IS LAID DOWN.
II. ALL BOLTS USED TO ASSEMBLE THE SHIPPING SUPPORTS MUST BE METAL. THESE ARE DESIGNATED BY 5/8 M ON THE INSIDE DWGS.
III. ALL BOLTS MARKED 5/8 M ON INSIDE DWGS. ARE TO HAVE THE HEADS PAINTED YELLOW. THESE WILL BE REMOVED IN THE FIELD.
SHOP NOTE
ALL BRIDGE BOLTS TO BE ... EXCEPT WHERE 'M' INDICATES ... OF METAL BOLTS ON "D"
NOTCH BARRIER TO SUIT. ALSO ... IN BARRIER AT ...
H1
31



6
5
4
℄ TRANSFORMER
H.V SIDE
℄ H1 BUSHING
1
1/2 HS-L35
5
4
21
1/2 HS-L35
8

APPENDIX B - ITEM 6

TRANSFORMER REPORT ON EVENTS AT N. ANNA POWER STATION

→ F.I, L- ... 707-08

DISASSEMBLY REPORT

SUBJECT

Disassembly of transformer, serial number 7002100, built originally on shop order HAM707 and returned to Muncie for repair on shop order XDM1779. This transformer is a single phase, 330 MVA, 500kV generator step-up transformer and was located at the North Anna Station of Virginia Electric and Power Company.

HISTORY

This unit failed in service on June 19, 1981. An investigation at that time indicated it was a high voltage line bushing failure and did not involve the windings.

REPORT OF DISASSEMBLY

The complete phase was disassembled coil by coil on October 7th and 8th, 1981 with Mr. Joe McGregor and Mr. Robby Bridges of VEPCO present. There was a very large amount of carbon deposited on both the coils and the insulation, but no failure was found. The termination of the tape, on the high voltage line lead from the coil to a point just below it's horizontal run, had essentially no taper rather than the specified 7" taper. There was, however, no evidence of tracking or any other electrical difficulty at this point. No other irregularities were found.

Prepared by:

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L E Luke 10/14/81

L. E. Luke (Date)
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APPENDIX B - ITEM 7

TRANSFORMER REPORT ON EVENTS AT N. ANNA POWER STATION

Teardown Report
VEPCO North Anna Unit
500/22 GSU S# 7002100
S.O. XDM1867 (HAM707)
2/22/83

Summary

This transformer failed August 22, 1982 and returned to Muncie for teardown and inspection. Visual inspection of the phase indicated greatest phase damage occurred in the LV coil 22 located approximately below the HV bushing and next to a H-L space. Several arc spots could be seen on the edge of coil 22 and the outer layers of the coil were displaced. Many arc spots were observed on the HV bushing shield and also on the HV ground plane located on the tank cover. Detailed inspection of the phase confirmed that arcing occurred between the HV bushing shield and the edge of the LV coil 22.

Detailed Inspection

Tank: The top section of the tank was distorted and ruptured in several locations (at brace ends). Several arc spots were observed on the HV bushing ground plane.

The bottom section was dirty but otherwise undamaged.

Bridge: The bridge structure was broken into several pieces. Nearly all fiber bolts connecting the bridge structure were broken.

Core Steel: The core was straight and undamaged.

Coil Supports: The coil supports were in place and undamaged.

Phase: Coil 22 - The coil outer edge was burned and the copper pitted at seven locations on the A end and spaced between the A end centerline and the tangent between the HV leg and the corner radius. The largest burned spot occurred at about the end of the corner radius (HV side) on the A end.

A large charred area (18" x 36") was located on the face of the coil at the tangent between the HV leg and the A end radius. The area included parts of the outer three turns. No turn-to-turn failures were found in the charred area. Three very small spots showing pitting of the copper were found on the outer turn: One between layers 3 and 4, and two between layers 8 and 9. One additional small area showed bare copper free of pitting.

Layers of the outer turn were distorted perpendicular to the plane of the coil. These distortions were located in the charred area. Spacer blocks on washer 69 (under coil 22) were found to be overlapping under the distorted area.

Coils 5, 6, 7, 9, 12, 23, 24, 26, 27, 29, 30, 31, 33 and 34 - Carbon deposits in the form of branching streamers were on the B end tight pressboard channels.

Coils 5, 9, 23 and 26 - Carbon deposits in the form of branching streamers were found on tight pressboard channels on the HV leg.

Coils 5, 23 and 26 - Carbon deposits in the form of branching streamers were on the tight, pressboard channels on the LV leg.

HV and LV side sheets - Carbon deposits in the form of branching streamers were found originating from the string ties and along the vertical pressboard strips. Streamers were also found along a crack in the HV side sheet.

Coil Washers - Several of the coil washers had carbon deposits in the form of branching streamers. They were especially noticeable on the following:

Washer 6 had streamers on the A end originating at the coil spacer blocks on the side facing coil 36. The opposite side of washer 6 (facing coil 35) was uniformly dark outside the coil perimeter.

Washer 7 had streamers along the A end edge originating at the edge. Also, a very long streamer at the B end HV corner.

Washer 56 had streamers between spacer blocks on coil 23 side on both HV and LV legs.

Washer 97 located between tap coils 9 and 8 had streamers on the bottom side (facing coil 8) instead of the top side.

Washer 99, between coils 7 and 8, had streamers on both sides.

Washer 109 had streamers between spacer blocks on both legs on the coil 4 side.

H-L Space Washers - Streamers between the spacer blocks and top and bottom edges were on all washers in the H-L space between coils 14 and 15, coils 22 and 23 and coils 34 and 35. The streamers occurred on one side with the other side uniformly dark.

HV Bushing - Chips of porcelain found on top of the phase show signs of arcing on the inside surface and inside the porcelain cross-section. These chips are from the upper half of the oil side porcelain.

Dale White

Dale White
Engineering Operations

1407E

APPENDIX B - ITEM 6

TRANSFORMER REPORT ON EVENTS AT N. ANNA POWER STATION

REPORT ON FAILED BUSHING

August 3, 1981

Bushing 255D500, Group 2
500 kV System Voltage, 1300 kV BIL
Built as HAM 707, Serial 6 in 1974

The remains of the bushing were received in Muncie on July 16, in a VEPCO shipping crate. Parts received were the condenser, flange, expansion cap assembly, lower porcelain assembly, lower shields, flexible cable to the transformer winding and broken pieces of the upper porcelain. Broken pieces of the lower porcelain were received in a separate shipping crate.

The bushing was disassembled on July 22 and the condenser was unwound on July 23. The lower 24 inches of the straight portion of the condenser; i.e., the paper area over approximately the lower half the ground foil layer (No. 55), was burned and torn for about one half the circumference. Both tapers had mechanical gouges due to broken proccelain and a few singled areas. The support sleeve had shifted upward about 2.88 inches relative to the condenser. The voltage top insulating board was firmly in its correct position.

After about five layers of paper, the burned and torn paper ended. Parts of the circumference of the condenser paper appeared to have spots which were impregnated but void of oil between layers of paper. Those regions were from about foil layer 52 to foil layer 53.

The entire condenser was unwound to the lead. No other damage or irregularties were found.

The 2 inch shield was still partially attached to the lower porcelain support. The lower shield was complete dislocated from the support, both of the support bolt heads having pulled through the copper material. Both shields had several arc marks on their sides, some of the holes burned completely through the material. The upper 2 inch shield also had five 0.5 to 1.5 inch semi-circles burned out on its top surface where it meets up with the top surface of the lower support. The lower support also had pock marks adjacent to the areas.

The bottom end of the expansion cap was domed inward. The spanner nut securing the spring assembly had some stripped threads and had cracked. Some of the matching threads on the lead tube had also stripped.

L. B. Wagenaar

0608E

APPENDIX B - ITEM 9

TRANSFORMER REPORT ON EVENTS AT N. ANNA POWER STATION

APPENDIX B - ITEM 9

REPORT ON FAILED BUSHING

August 3, 1981

Bushing 255D500, Group 2
500 kV System Voltage, 1300 kV BIL
Built as HAM707, Serial 7 in 1974

The remains of the bushing were received in Muncie on July 16 in a VEPCO shipping crate. Parts received were the condenser, flange, expansion cap assembly, lower support assembly, lower shield, have terminal and flexible cable to the transformer winding; neither of the porcelains was received.

The bushing was disassembled and the condenser was unwound on July 22. The exterior of the condenser was burned, wrinkled and fluffed up on the entire circumference on about the bottom 41 inches of the 56 inch long straight portion. About 16 inches of the ground layer foil (No. 55) between the top of the support sleeve and the ground layer groove was exposed. About 14 inches of the bottom of the foil was also exposed. About 0.144 and 0.308 inches of paper originally covered the ground and tap foil layer, respectively. The voltage tap insulation board was firmly in its correct position.

The lower taper of the condenser had a surface burn 4 to 24 inches wide running the full length of the taper, the burn getting wider as it progressed up the taper. The remainder of the taper surface was singed, but not badly burned. The top taper had a few singed areas, all of which were only on the surface.

The support sleeve has been shifted upward about 1.75 inches relative to the condenser. The outer 5.74 inches of the condenser had shifted about 0.31 inches upward relative to the lead.

The lead tube showed several burned marks from electrical arcing just below the bottom of the condenser for about one half of its circumference. Some of the burned marks formed a continuous 2 inch long crater. Some of the marks were just below the burned area on the condenser taper, but most were within a 90 degree arc to one side of the darkest area on the taper.

There was also evidence of arcing on the lower procelain support and the lock nut located on top of the former. These marks generally lined up with the burned area on the lower taper of the condenser. There were also arcing marks in both lower shields. Both shields had been dislocated from the lower support, the heads of the screws attaching them to the support having pulled either off or through the copper material.

The condenser was completely unwound. Burning was found through foil layer 53 (about 0.39 inches of paper thickness) and the amount of such decreased as this foil was approached. About 70% of the approximately 49 inch circumference of the lower ends of the last two foil layers (Nos. 54 and 55) had been burned away for 8 to 9 inches in length. The areas burned away from the foils were generally aligned and extended about 6.5 inches beneath the flange. The surface burn on the lower taper had progressed to within an inch of the bottom end of foil layer 53, but was only on the tapered surface below this point. No other damage or irregularities were found beyond foil layer 53.

L. B. Wagenaar

APPENDIX B - ITEM 10

TRANSFORMER REPORT ON EVENTS AT N. ANNA POWER STATION

R&D REPORT 82-7D7-MUNCI-R1

INVESTIGATION OF FRACTURE OF A POWER TRANSFORMER CAP SCREW FROM VEPCO'S NORTH ANNA NUCLEAR STATION

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October 6, 1982

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R&D REPORT 82-7D7-MUNCI-R1 October 6, 1982

INVESTIGATION OF FRACTURE OF A POWER TRANSFORMER CAP SCREW FROM VEPCO'S NORTH ANNA NUCLEAR STATION

A. Madeyski
Materials Engineering Department

ABSTRACT

A forced outage of the main generator stepup transformer at VEPCO's North Anna nuclear power station occurred on August 22, 1982. One hypothesis is that this was caused by the fracture of a cap screw supporting the insulator bushing. An investigation revealed that the final overload fracture of the screw started from a very deep crack produced by a low stress, high cycle bending fatigue. The fatigue cracking may have occurred earlier when the bushing was transported by truck several times. In transport to and from the factory, the bushing laid in a horizontal position in a crate, exerting a bending moment on the screw. Vibrations of the truck made the stress variable, resulting in the fatigue cracking of the screw.

1. INTRODUCTION

A recent forced outage of the main generator step-up transformer at the Virginia Electric and Power Company's North Anna nuclear station was found to have been caused by the fracture of a cap screw. The cap screw was part of the support structure of an insulator bushing, as shown schematically in Figures 1 and 2.* The 500 kV bushing assembly (Drawing No. 255D500) was manufactured in 1965 by the Westinghouse transformer plant in Sharon, Pennsylvania. The bushing was shipped to the customer when originally built. In 1976 the bushing was sent to the Westinghouse Power Transformer Division (PTD) plant in Muncie, Indiana, to correct an electrical connection, after which it was returned to the customer. In 1981 the bushing made another round trip to Muncie for electrical testing.

The broken cap screw was submitted by PTD to the Materials Engineering Department of the Westinghouse R&D Center for investigation. It was stipulated that the method used in the investigation should be non-destructive, if possible. Fortunately, we have succeeded in determining the causes of the cracking in the screw by non-destructive procedures, and the screw will be returned to PTD essentially as received.

The investigation consisted of macro-examination, optical and scanning electron microscope (SEM) fractography, energy-dispersive X-ray spectrometric (EDS) analysis of the material, and hardness testing.

Following is a report on the methods of investigation, the results obtained, and the conclusions reached.

---

*This design is not used anymore in presently built transformers.

2. EXPERIMENTAL PROCEDURES AND RESULTS

2.1 Optical Examination

The broken cap screw was carefully examined with unaided eye, and using a low power optical microscope. Figures 3 through 6 show the general appearance and details of the screw.

2.2 Fractography

The fracture of the screw was examined using an optical microscope and an SEM. The results are shown in Figures 7 through 10, and 13 through 21.

2.3 Energy-dispersive X-ray Spectrometry (EDS)

While inside the SEM chamber, the fracture face on the shorter piece of the cap screw was analyzed using the EDS attachment. The results are shown in Figures 11 and 12.

In interpreting these results it must be remembered that the EDS technique cannot detect any elements with the atomic number lower than 11. This includes hydrogen, helium, lithium, beryllium, boron, carbon, nitrogen, oxygen, fluorine, and neon. However, all the other elements, including important alloying additions such as chromium, nickel, molybdenum, vanadium, etc., can be detected and measured.

2.4 Hardness Tests

The side of the shank was used for hardness testing (Figure 4). Both Rockwell C and B scales were used. The results shown below were in agreement with each other:

RC 21-23;

RB 98-101;

The corresponding ultimate tensile strength is 112-120 ksi approximately.

3. DISCUSSION

Fractography has shown that the screw cracked very deeply in high cycle fatigue (Figure 9, areas 1 through 11), before it finally broke completely in shear overload (Figure 9, area 14). The fatigue crack started from multiple origins on the side of the screw marked 0° in Figure 9, and gradually moved across the screw to area 14. At this point the remaining cross-section carrying the load was very small, and eventually some relatively minor load produced the final catastrophic fracture. The overload fracture of this remaining ligament was of the "dimpled rupture" type (Figure 19), indicating that the screw material was fully ductile.

The "primary" origins of the fatigue fracture were all located at the same side of the screw (Figure 8), but it is interesting to note that there was also a very shallow "secondary" fatigue crack which started from the 180° location (Figure 9). This crack propagated only to the depth of about 0.01 in (Figure 20) before the screw finally broke completely.

The type of fatigue in which the fracture traverses the cross-section from one side to the other almost in a straight line is characteristic of bending in a single plane. In a normal operation of the transformer each cap screw acts only as a guide between the clamp ring and the cylindrical flange (Figures 1 and 2). Therefore, the cap screws are not expected to be subjected to any major bending moments. Furthermore, there is no obvious source of cyclic loading on the bushing support to produce fatigue cracking of the screws in normal service. However, when the bushing is shipped to and from the factory, it is crated in a horizontal position, and part of its weight rests on the center portion of a cap screw. Vibrations of the truck provide the variability of the load necessary for fatigue. A close examination of the broken s... provided additional evidence substantiating the hypothesis that the cracking occurred in transport. Figure 6 illustrates the wear areas in the middle of the screw. The wear area at the 0° location shows heavy peening and burnishing of the steel, indicating that a high transverse load acted at this point. This load provided the bending moment at the screw thread. A variable bending stress was thus superimposed on the constant tensile stress due to the tightening of the screw in the threaded hole. The resultant stress range apparently exceeded the fatigue threshold level and initiated the crack. The fact that this particular bushing was shipped 5 times prior to its forced outage, makes this explanation even more plausible.

A smaller amount of peening and burnishing in the middle of the screw at the 180° location (Figures 4 and 6) was presumably caused by an upward load due to bouncing of the truck on uneven roads. This load apparently started the secondary fatigue crack.

The hardness test indicated that the screw had a tensile strength in the vicinity of 115 ksi which is quite acceptable for a grade 2 screw (74 ksi min.). The EDS analysis has shown that the steel was of plain carbon grade, presumably middle carbon. There was also no fractographic evidence of any material or manufacturing defects which would have started fatigue cracking at an unusually low stress level. Thus, the quality of the screw does not seem to have been a contributive factor in the cracking.

The second cap screw did not break, but was severely bent, presumably after the first screw broke. The second screw was not submitted to the R&D Center for examination.

4. SUMMARY OF THE OBSERVATIONS AND CONCLUSIONS

1. The screw cracked deeply in high cycle, low stress fatigue before it eventually broke in shear overload at some minor load.

2. In normal operation of the transformer the bushing support cap screws are not expected to be subjected to any significant bending, or to cyclic stresses.

3. The evidence suggested that the screw cracked when the bushing was being shipped in the horizontal position, with its weight bending the screw. Bouncing of the truck on uneven roads provided the variable load necessary for fatigue cracking. The bushing was in transport 5 times before its forced outage.

4. The bushing was made in 1965. This design of the bushing suspension system is not used in transformers currently produced by Westinghouse.

5. ACKNOWLEDGEMENTS

The background information and the excellent cooperation provided by J. Templeton of the Power Transformer Division in Muncie, Indiana, is gratefully acknowledged. Thanks are also due to the following members of the Research and Development Center staff: R. C. Bates and J. W. Cunningham - general guidance and techical discussions; J. P. Yex - macrophotography; T. J. Mullen - SEM fractography and EDS analysis. J. Selchan - typing and assembling of the report before printing.

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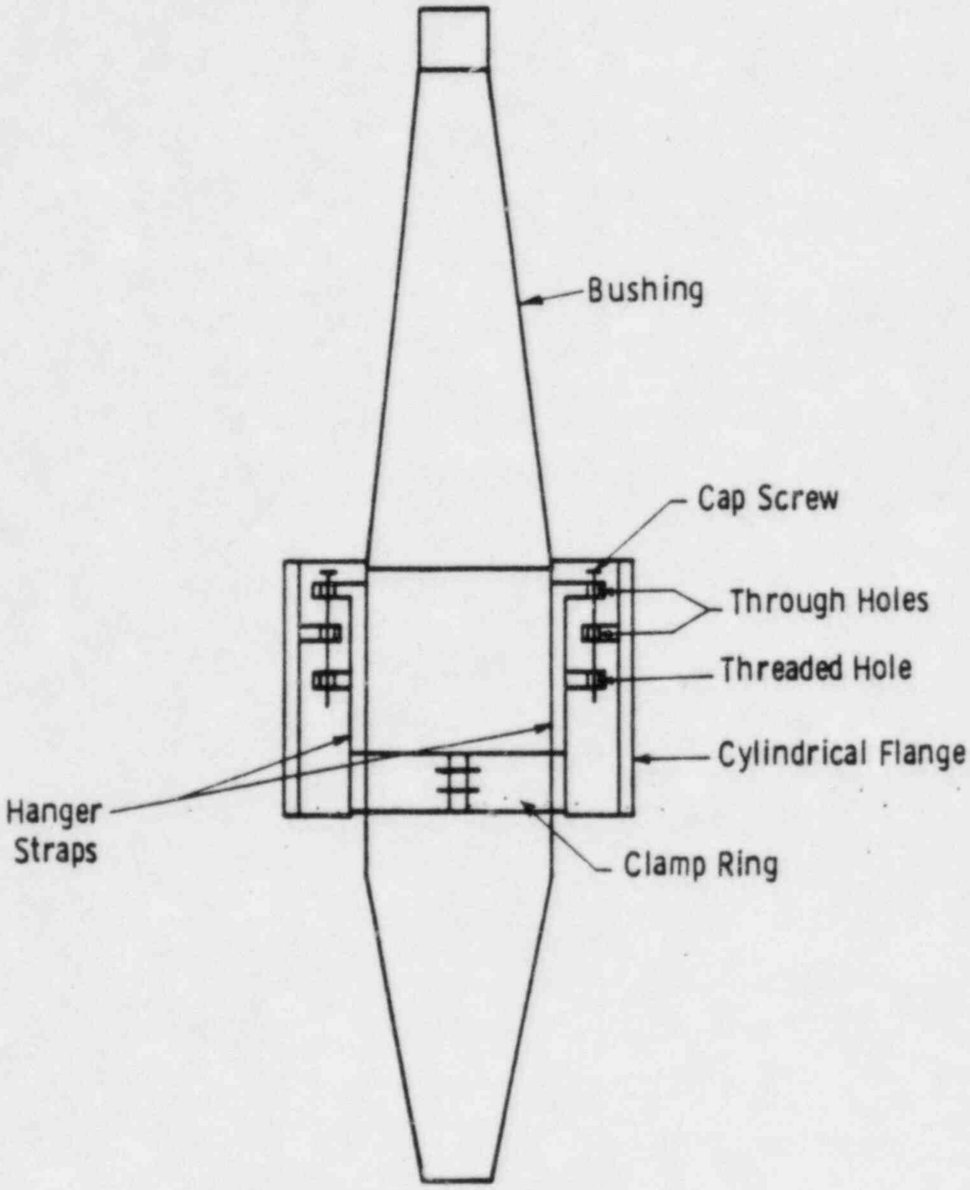


Fig. 1 — Schematic sketch showing the location of the two cap screws in the bushing support assembly. Not to scale.

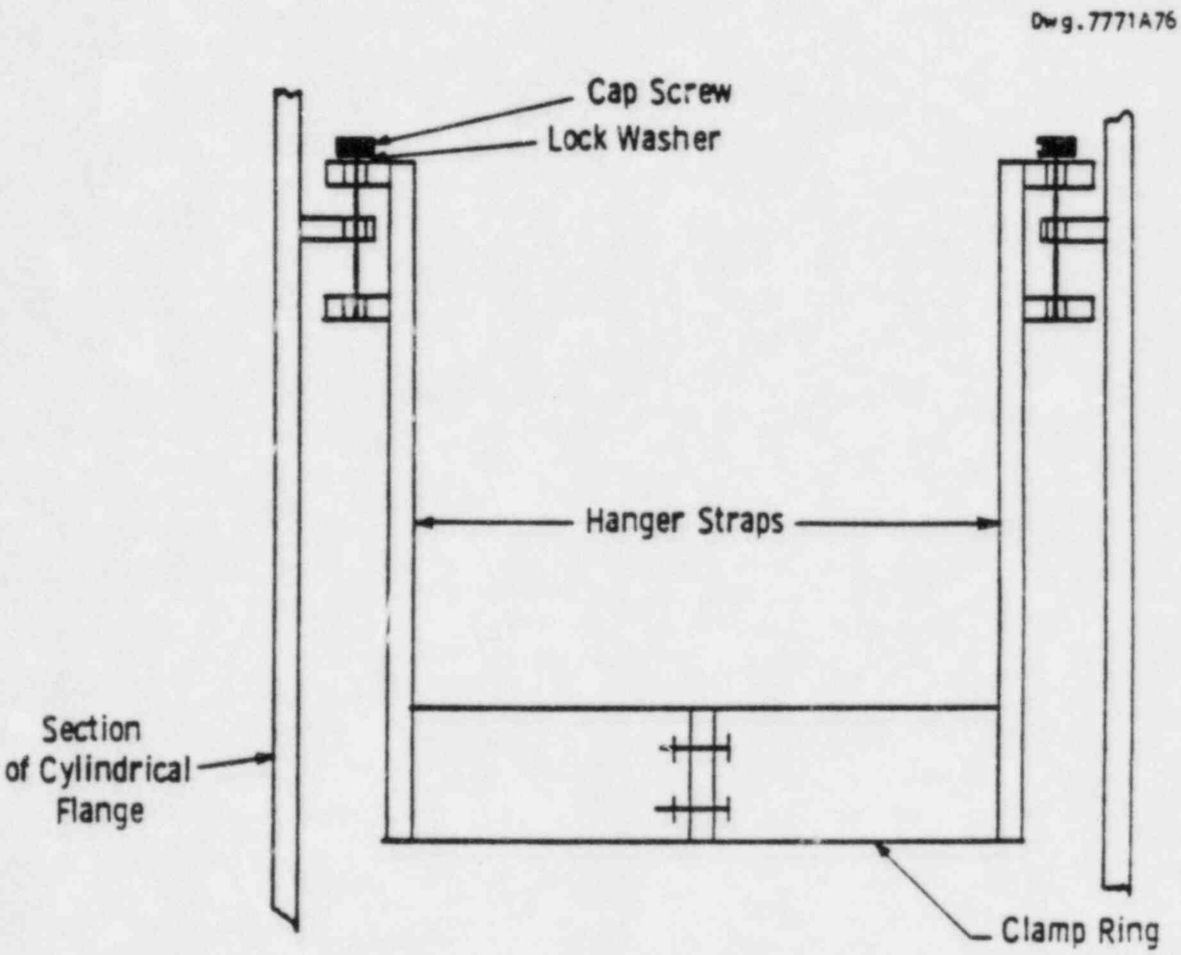
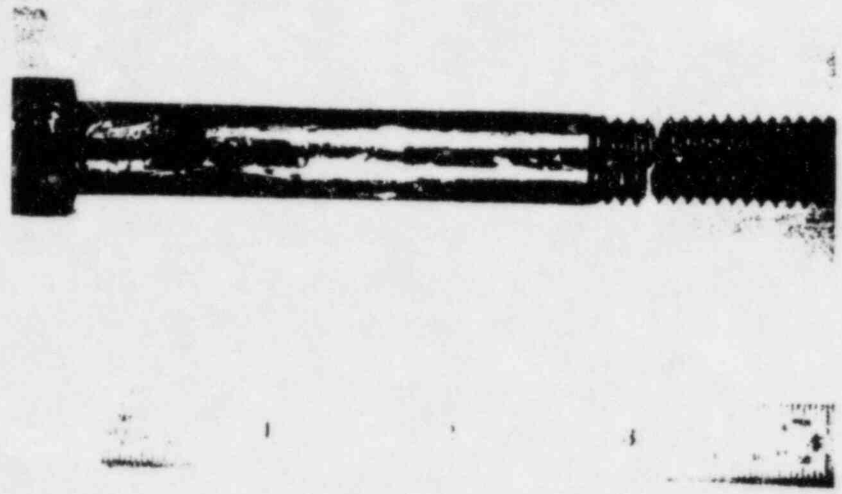
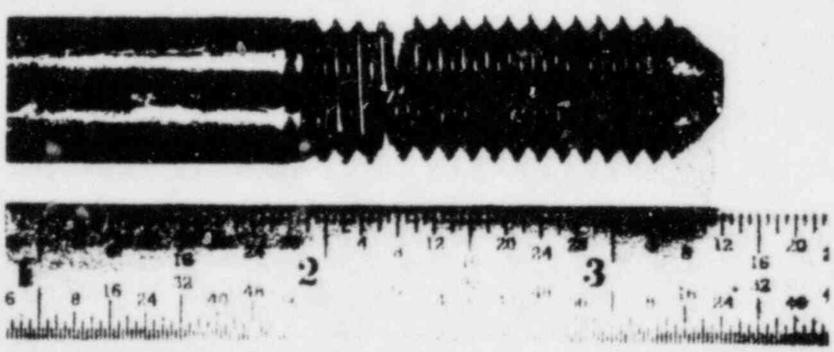


Fig. 2 — Schematic sketch showing the central detail from Fig. 1. Not to scale



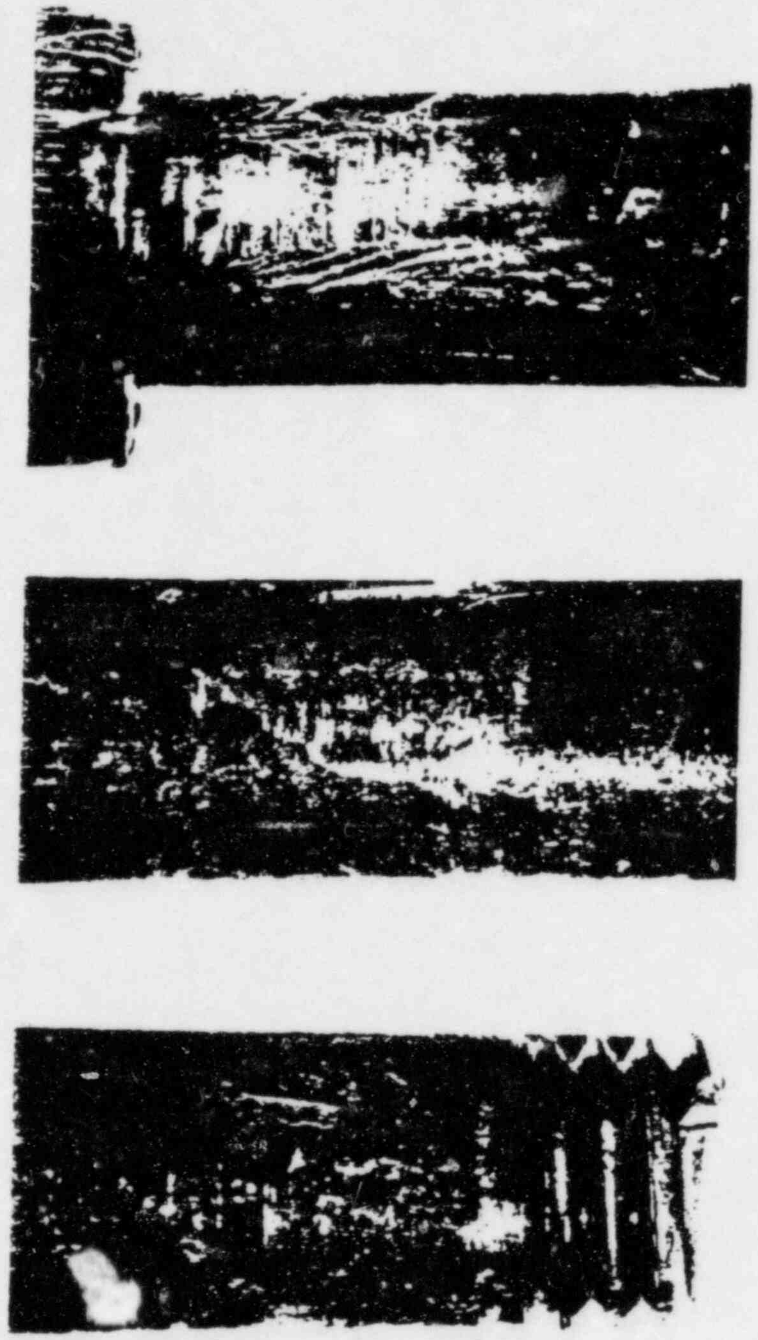
Mag. 0.95X



Mag. 1.5X

Figure 3. General view of the broken cap screw.

RM-97390



Mag. 3.5X

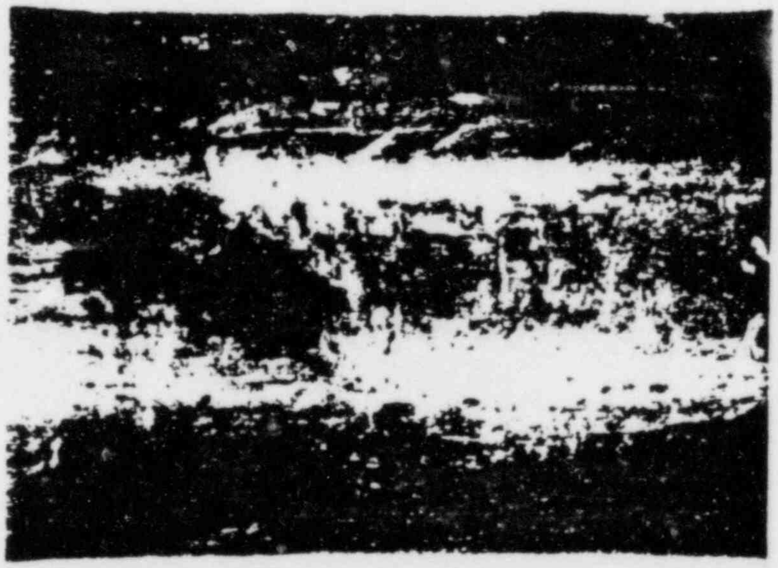
Figure 4. Details from Fig. 3. Note the wear marks under the head and in the middle of the screw. This side of the screw is located 180° from the main fracture origins (see Fig. 9). The indentations visible in the bottom photograph were produced in the hardness tests.

RM-97391

Mag. 6.3X

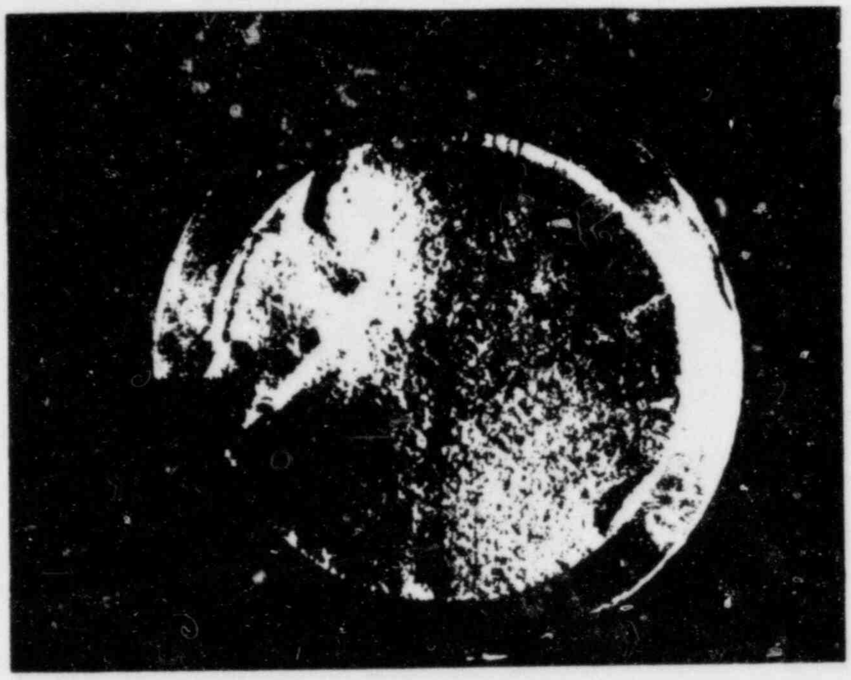
Figure 5. Wear area under the head of the screw at a higher magnification. Note that the wear was mainly in the form of scratches. Location at 180° from the main fracture origins.

Mag. 6.3X



Mag. 6.3X

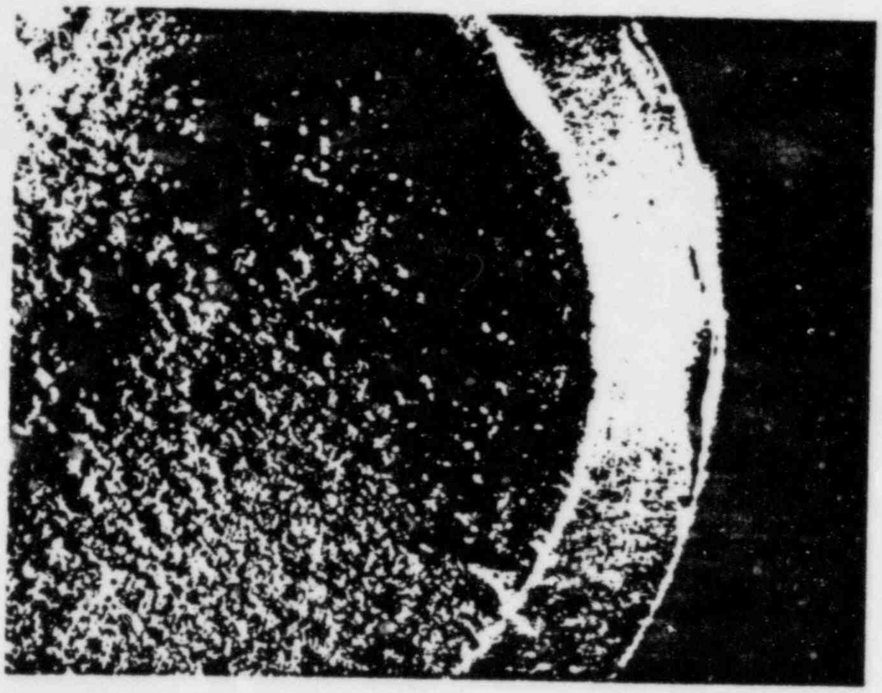
Figure 6. Details of the wear areas in the middle of the screw, 180° from the main fracture origin and 0° from the main fracture origins (see Fig. 9). The 180° photograph (upper) shows heavy peening and burnishing mostly in the central part of the wear area. The 0° wear area (lower photograph) is practically all heavily burnished.



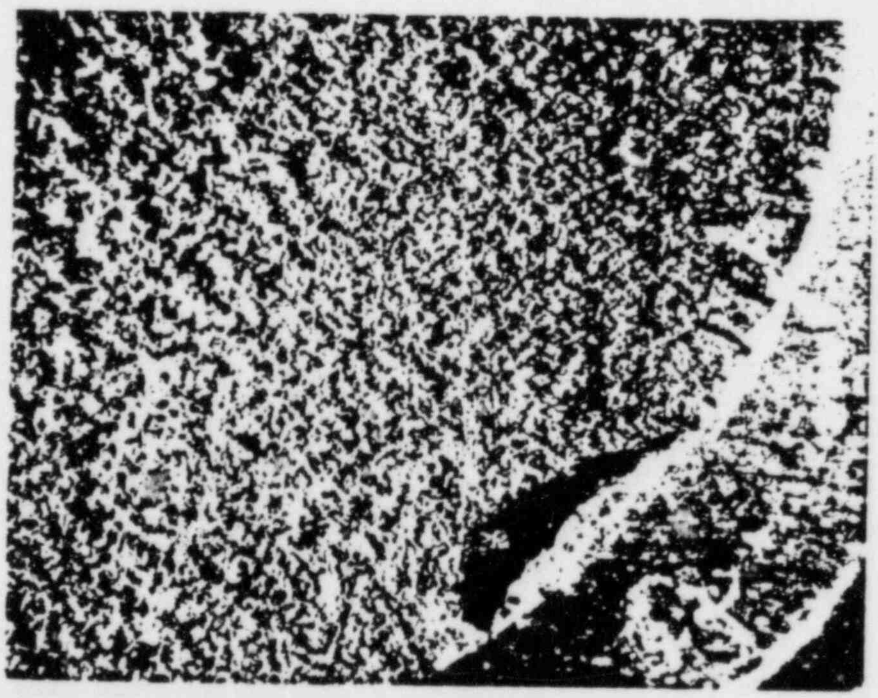
Mag. 6.3X

Mag. 6.3X

Figure 7. Fracture face on the head side (upper photograph) and on the thread side (lower photograph). Note the "beach marks" characteristic of fatigue.



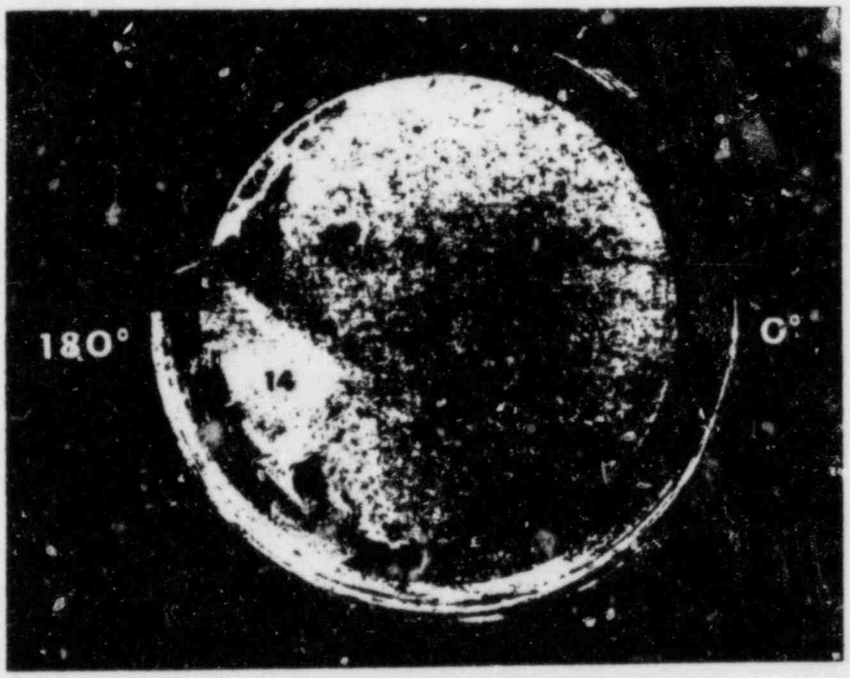
Mag. 12.5X



Mag. 20X

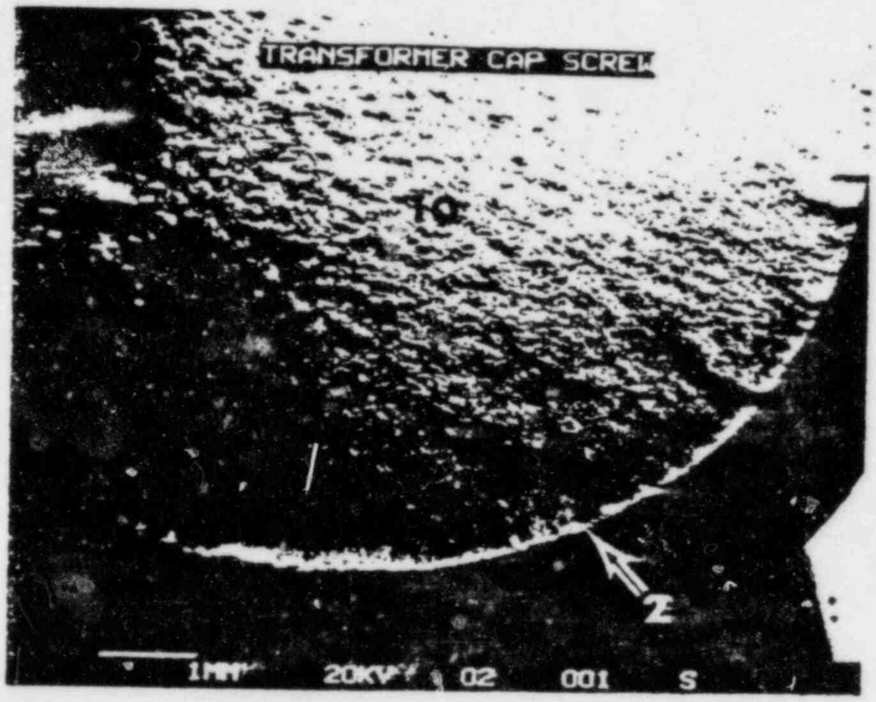
Figure 8. Details of the main origin areas of the fracture. The fracture had multiple origins located at the root of the thread visible on the right hand side of the photographs. Note also the beach marks.

RM-97395

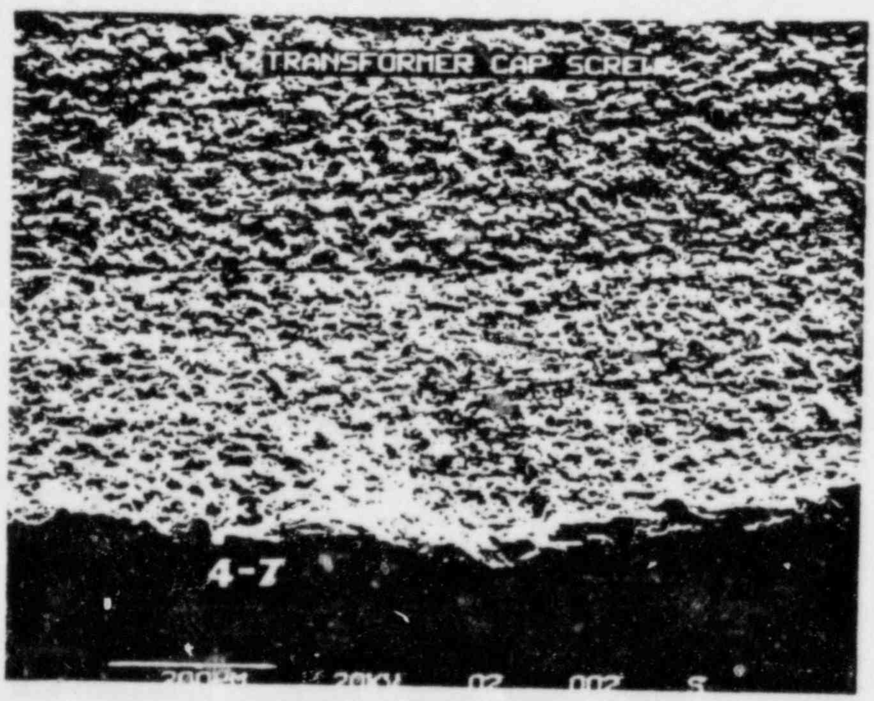


Mag. 6.3X

Figure 9. Fracture face on the thread side. The area numbers refer to the photograph numbers in the SEM fractography.



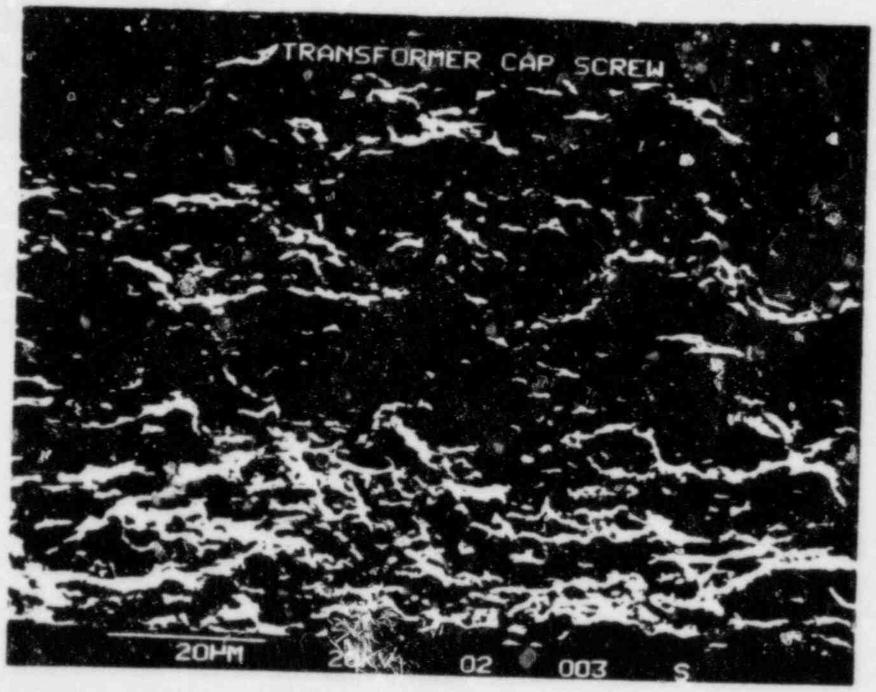
Mag. 12.5X



Mag. 100X

Figure 10. Area 1 from Fig. 9. Some of the primary fracture origins.

RM-97397



Mag. 1050X

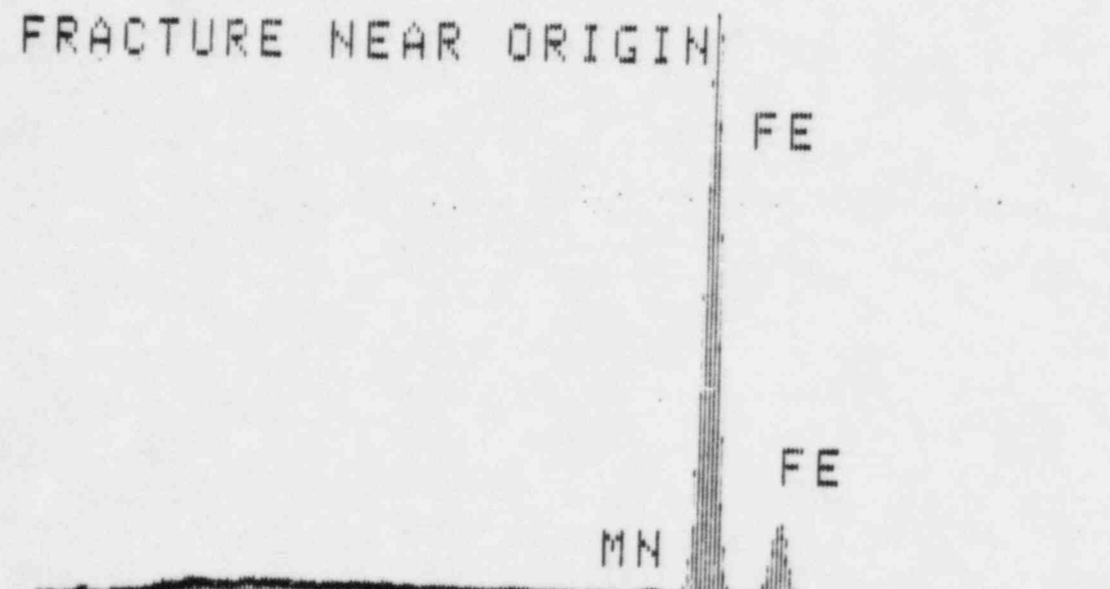


Figure 11. Energy-dispersive x-ray spectrum (EDS) of the fracture area 3 from Fig. 10, next to one of the origins. Numerical results of this analysis are shown in Fig. 12.

RM-97398

SPECTRUM TRANSFORMER SCREW SEP. 20. 1982

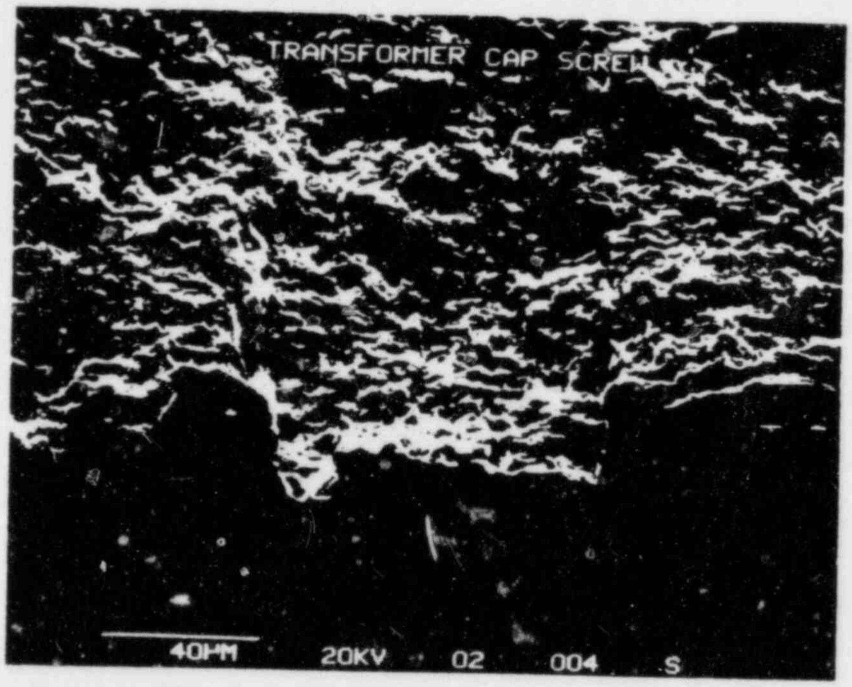
FRACTURE NEAR ORIGIN

STANDARDLESS EDS ANALYSIS
(Z4F CORRECTIONS VIA MAGIC V)

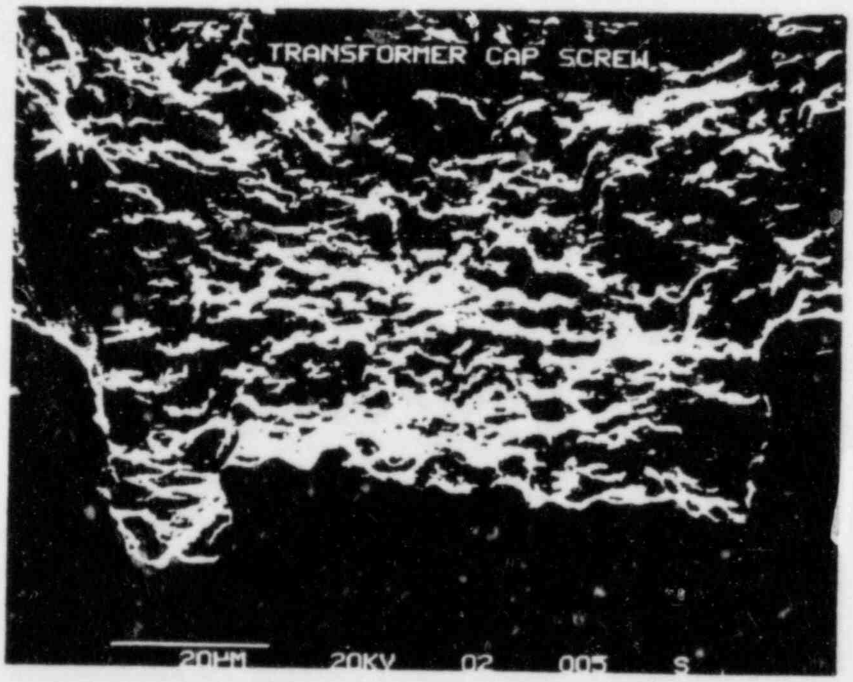
ELEMENT & LINE	WEIGHT PERCENT	ATOMIC PERCENT	PRECISION 2 SIGMA	K-RATIO	ITER
CR KA	0.24	0.26	0.06	0.0032	
MN KA	1.04	1.06	0.09	0.0107	
FE KA	98.38	98.37	0.39	0.9841	
NI KA	0.34	0.32	0.12	0.0031	2
TOTAL	100.00				

NORMALIZATION FACTOR: 1.001

Figure 12. Semi-quantitative EDS analysis of the fracture from Fig. 11. The analysis indicates that the cap screw was made of plain carbon steel.

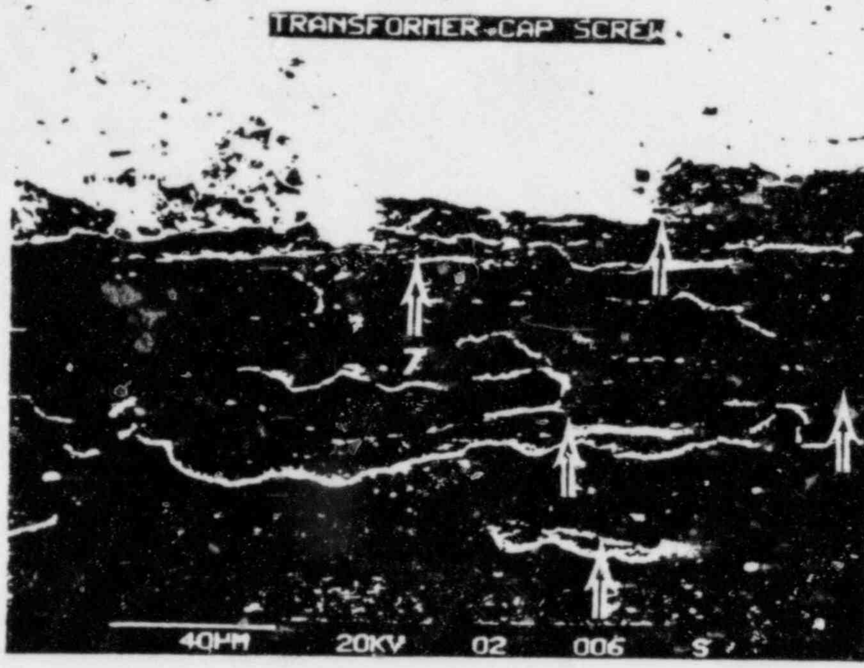


Mag. 525X

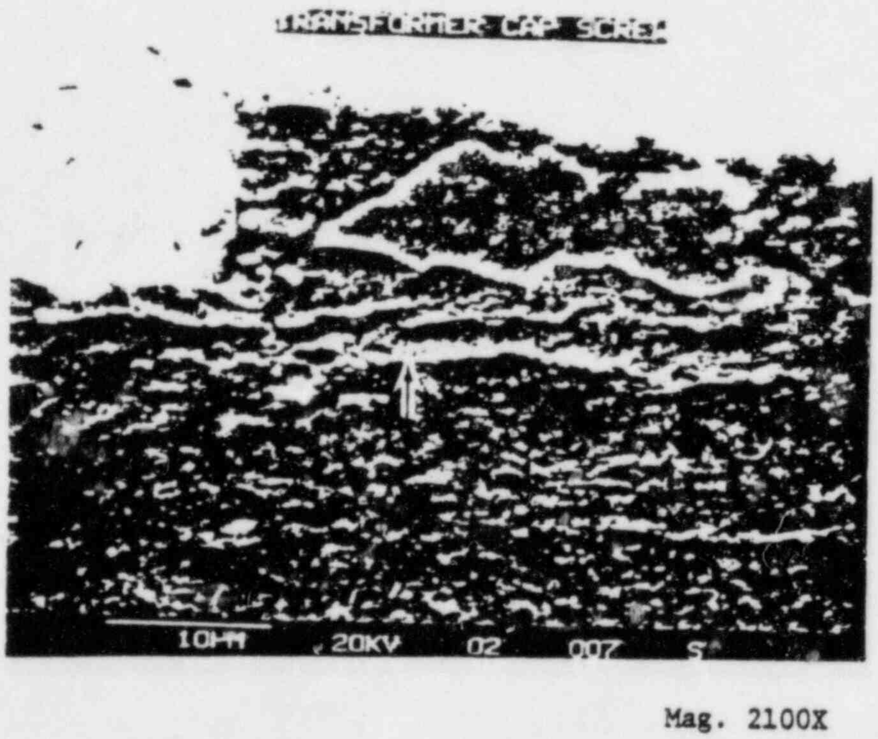


Mag. 1050X

Figure 13. One of the primary origins of the fracture, shown at two magnifications (area 4 from Fig. 10). Note the fracture topography characteristic of fatigue from the very beginning.

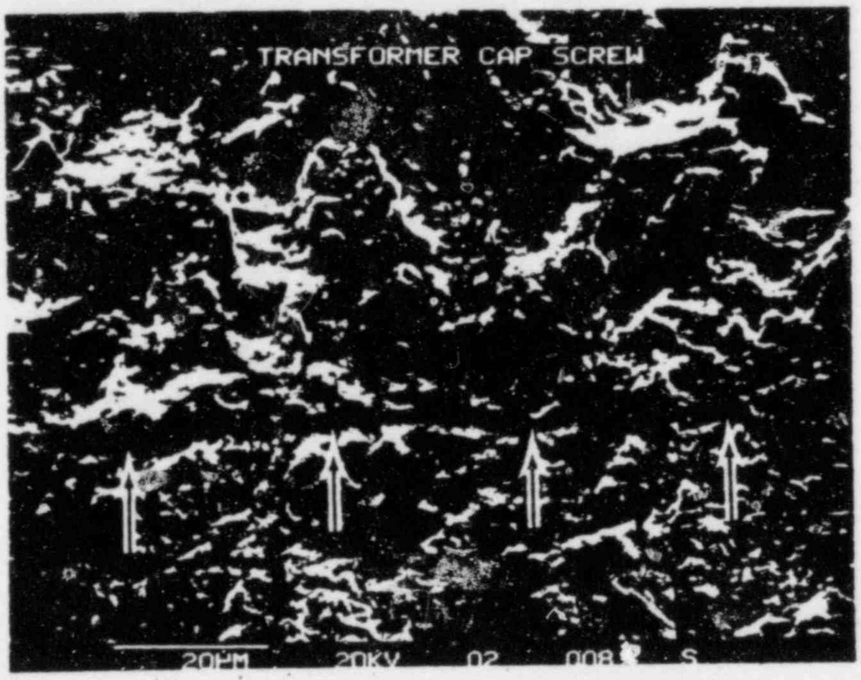


Mag. 525X



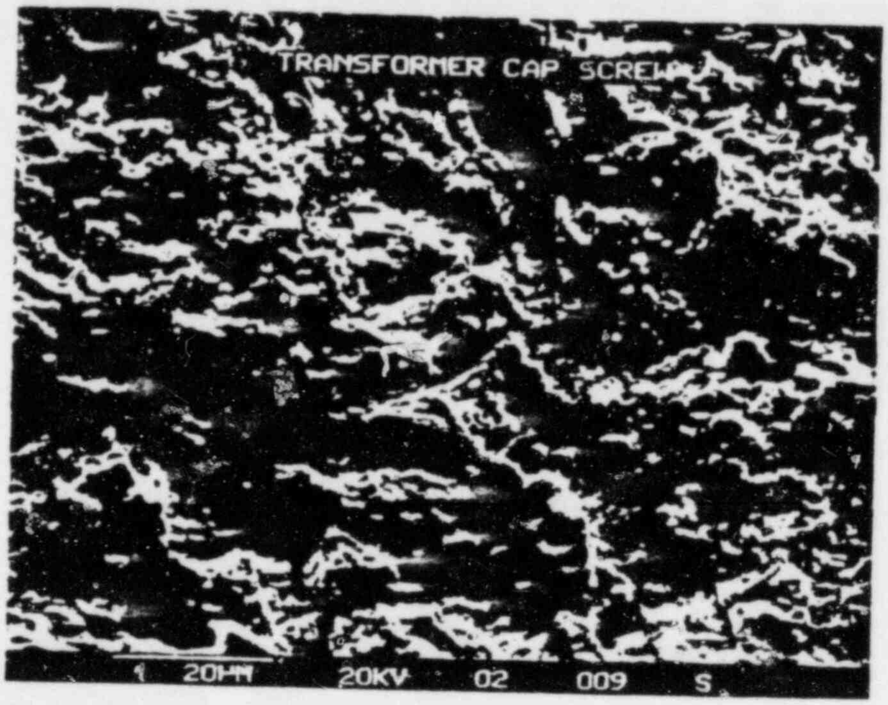
Mag. 2100X

Figure 14. Bottom of the thread groove at the primary crack origins. Note the spalling of the oxide due to metal strain, and a number of small cracks, marked with arrows. The lower photograph (No. 7) shows one of the cracks at a higher magnification.

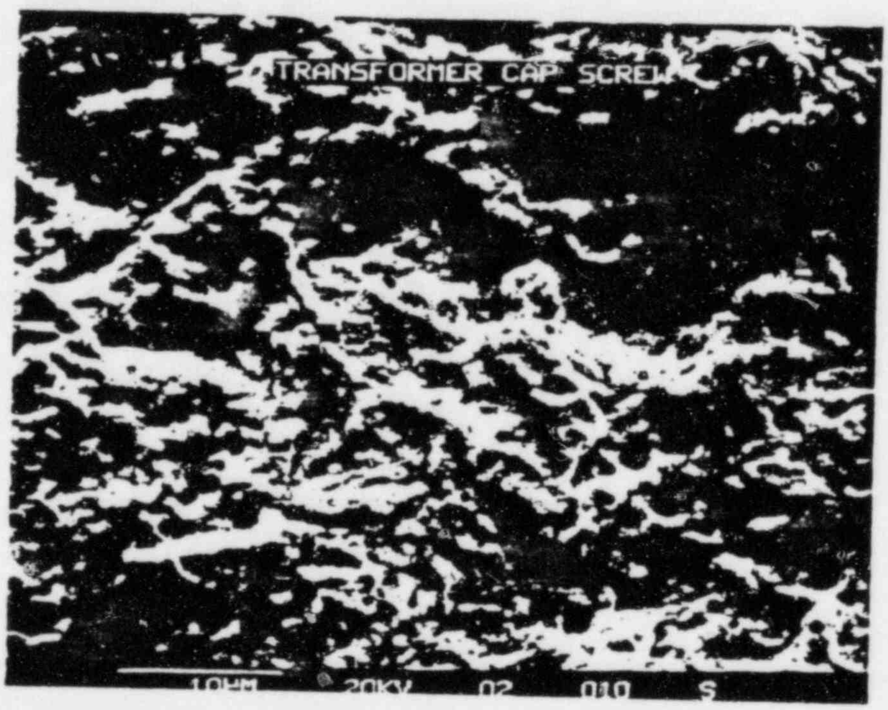


Mag. 1050X

Figure 15. The first major beach mark of the fracture (marked No. 8 in Fig. 10). The crack probably stopped here for some time, and then resumed the propagation.

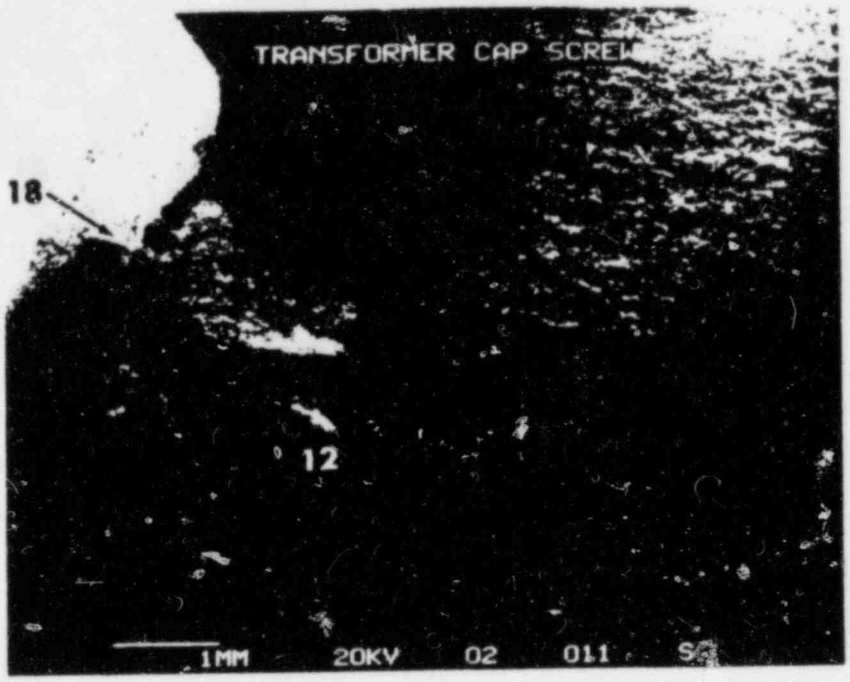


Mag. 1050X

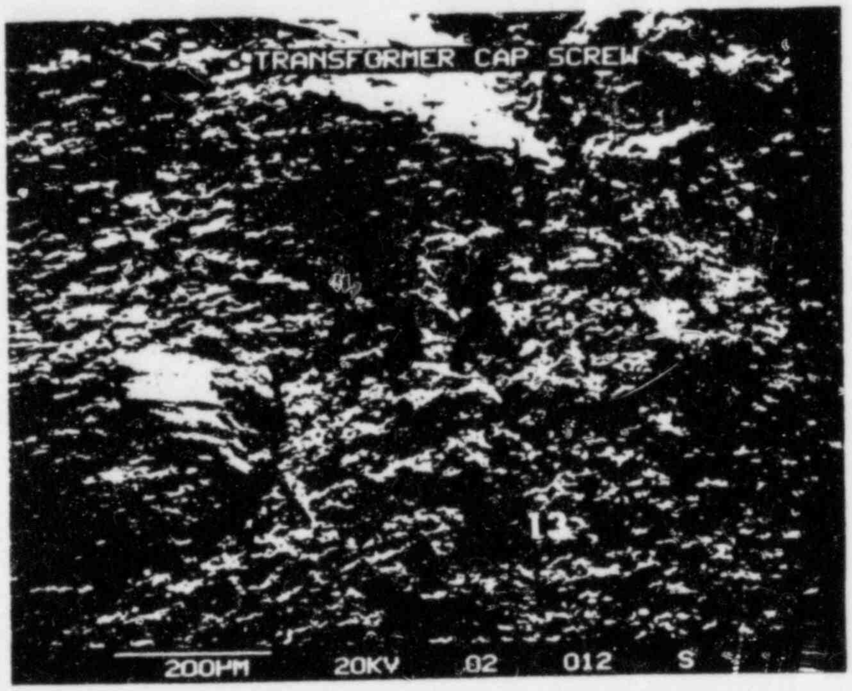


Mag. 2100X

Figure 16. Fracture areas 9 and 10 from Figs. 9 and 10. Note the topography characteristic of fatigue at a moderately high stress intensity range.

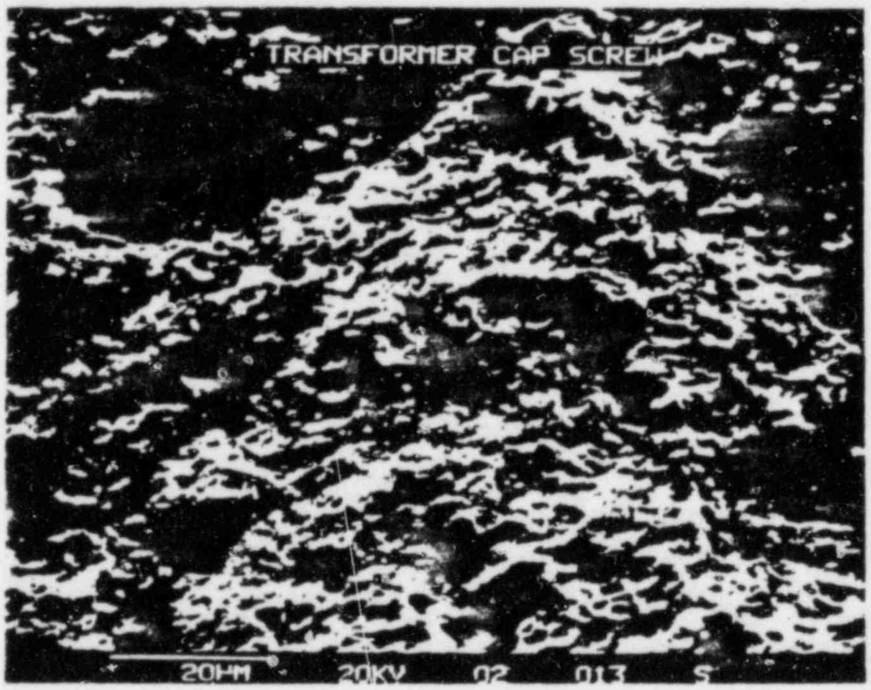


Mag. 15X



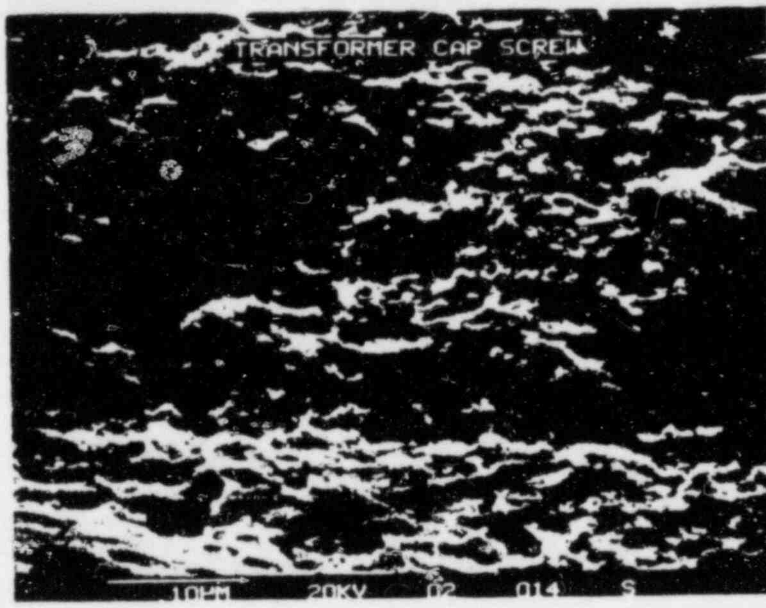
Mag. 105X

Figure 17. Fracture area 11 from Figs. 9 and 10. Note the side cracking characteristic of a high stress intensity fatigue fracture.

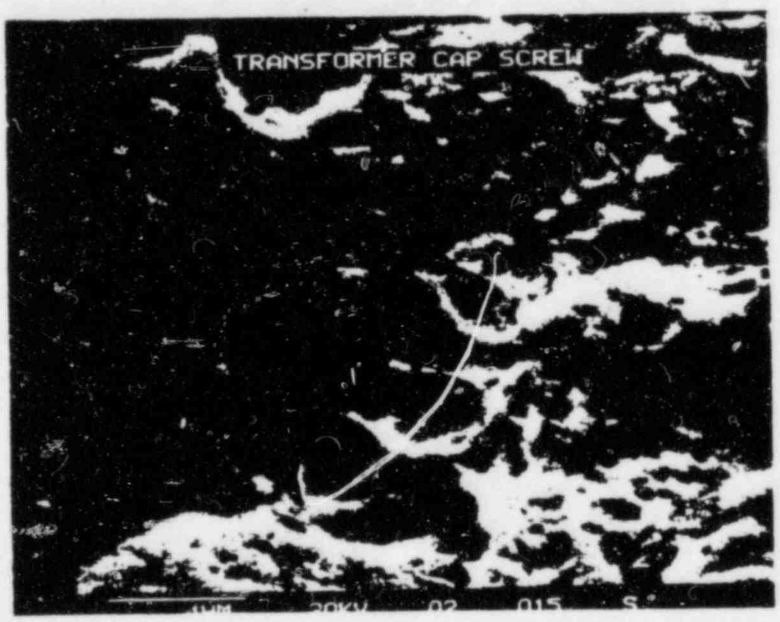


Mag. 1050X

Figure 18. Fracture area 13 from Fig. 17.

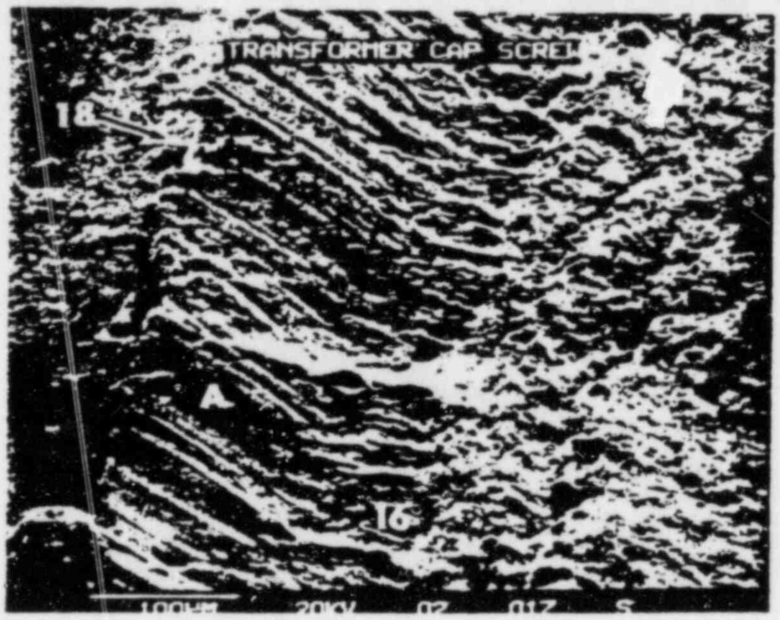


Mag. 2100X

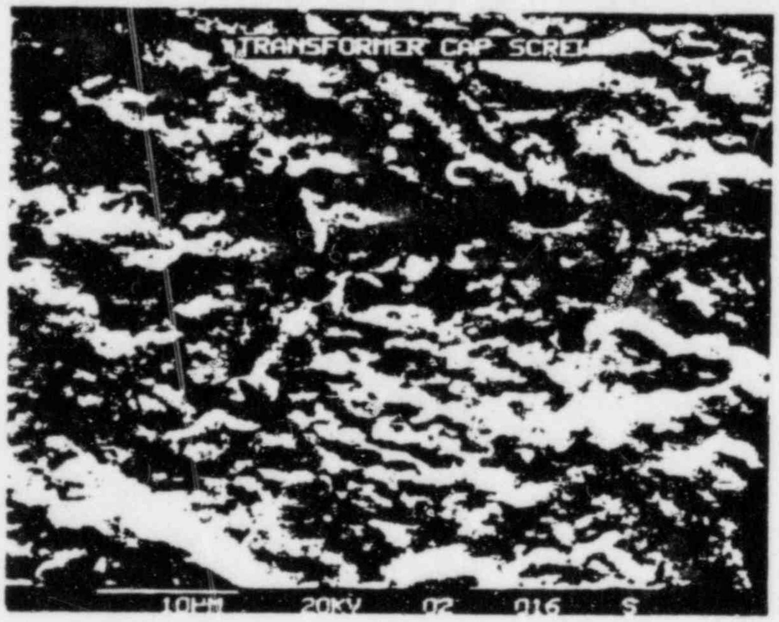


Mag. 5000X

Figure 19. Fracture area 14 from Figs. 9 and 17. Note the typical "dimpled rupture" topography, characteristic of an overload fracture in a ductile material. Since the dimples are all oriented in the same direction, there must have been a strong shear component in the final load.

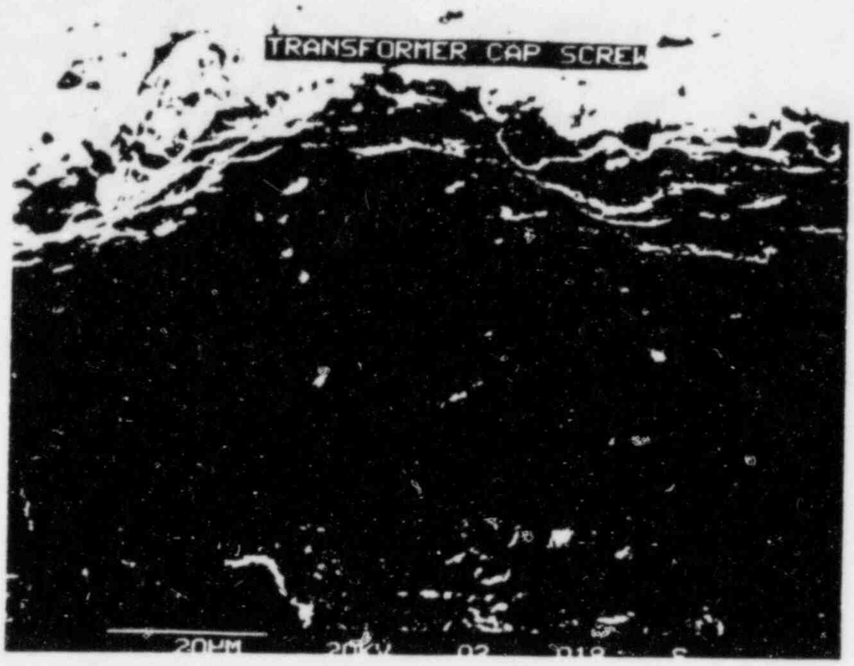


Mag. 210X

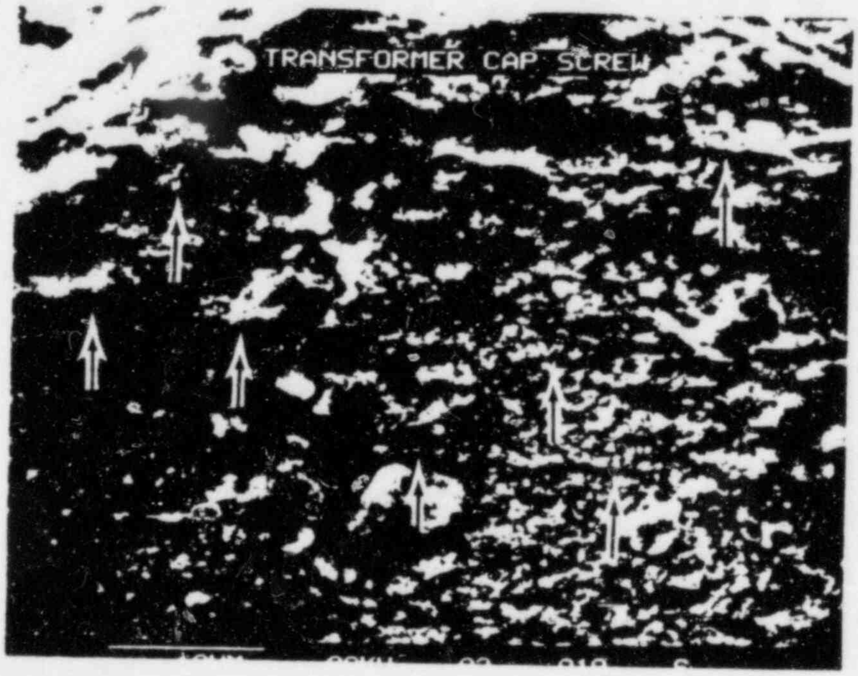


Mag. 2100X

Figure 20. Fracture area 16 from Fig. 9. When the cap screw broke in the final overload, the area marked "A" was rubbed and smeared. However, small portions of this area, such as "B" in the photograph 16, which were left undamaged, show that this was originally a fatigue crack that started from the "180°" side (Fig. 9), but did not propagate as far as the crack which started from the "0°" side. The rubbing of area "A" must have produced enough heat to create oxide "C".



Mag. 1100X



Mag. 2100X

Figure 21. Appearance of the bottom of the thread when viewed in the direction of the arrow 18 in Fig. 20. Note the spalling of the oxide, indicating strain, and some small original fatigue cracks marked with arrows.

APPENDIX C

TRANSFORMER REPORT ON EVENTS AT N. ANNA POWER STATION

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EHV EQUIPMENT FILL RECORD

Substation: M [illegible]
Equipment: #2 ST. UP. C.B
Manufacturer: WESTINGHOUSE
Serial Number: 7001527

6-30-81

Readings to be taken every half hour.

Probe # Oil In ______
Probe # Oil Out 2721 H

Date	Time	Trans. Vacuum mm hg	Streamline Vacuum mm hg	OIL OUT Temp. °C	OIL OUT KV	Flow Meter Reading	Remarks		Probe Temp. °C	Probe Reading	Dew Point	P	Ps	Cs	PPM
6-30	3:10					Initial Temp	START Vac	IN							
								OUT							
	4:00	1.5				82°	24 hrs Hold	IN							
								OUT							
	4:30	.5				82°		IN							
								OUT							
	5:00	.5				82°		IN							
								OUT							
	5:30	.5				81°		IN							
								OUT							
	6:00	.5				82°		IN							
								OUT							
	6:30	.5				81°		IN							
								OUT							
	7:00	.5				81°		IN							
								OUT							
	[illegible]	.55				81°		IN							
								OUT							
	[illegible]	.60				80°		IN							
								OUT							
	[illegible]	.70				79°		IN							
								OUT							
	[illegible]	.73				[illegible]		IN							
								OUT							
	[illegible]	.75				[illegible]		IN							
								OUT							
	[illegible]	.75				78°		IN							
								OUT							
	[illegible]	.70				75°		IN							
								OUT							

C = Moisture foncentration in sample in PPM.
C_s = 100% saturation of moisture in sample at temperature of measurement.
P = Water vapor pressure measured by prob
P_s = Saturated water vapor pressure a[illegible]

$$C = C_s \frac{(P)}{(P_s)}$$

APPENDIX C

EHV EQUIPMENT FILL RECORD

Substation [illegible]
Equipment [illegible] Tx.
Manufacturer [illegible]
Serial Number 7001527

Readings to be taken every half hour.

Probe # Oil In ______
Probe # Oil Out 2721 [illegible]

Date	Time	Trans. Vacuum mm hg	Streamline Vacuum mm hg	OIL OUT Temp. °C	OIL OUT KV	~~Flow Meter~~ Temp. °F Reading	Remarks		Probe Temp. °C	Probe Reading	Dew Point	P	Ps	Cs	PPM
	11:[illegible]	.75				75°		IN / OUT							
	[illegible]	.75				74°		IN / OUT							
	12:00	.75				[illegible]		IN / OUT							
7-1-81	[illegible]	.70				7[illegible]°		IN / OUT							
	1:[illegible]	.65				74°		IN / OUT							
	1:[illegible]	.60				73°		IN / OUT							
	[illegible]	.65				72°		IN / OUT							
	2 30	.60				71°		IN / OUT							
	3:00	.59				71°		IN / OUT							
	3:30	.58				71°		IN / OUT							
	[illegible]	.57				72°		IN / OUT							
	4 30	.56				71°	Rainy	IN / OUT							
	5:00	.56				71°		IN / OUT							
	5:30	.6[illegible]				70°		IN / OUT							
	6:[illegible]	.5[illegible]				64°		IN / OUT							

C = Moisture foncentration in sample in PPM.

C_s = 100% saturation of moisture in sample at temperature of measurement.

$$C = C_s \frac{(P)}{(P_s)}$$

P = Water vapor pressure measured by probe.

EHV EQUIPMENT FILL RECORD

Substation: NANNA Gen. Unit
Equipment: [illegible]
Manufacturer: WEST
Serial Number: 7001527

Readings to be taken every half hour.

Probe # Oil in ____
Probe # Oil Out 2721 H

Date	Time	Trans. Vacuum mm hg	Streamline Vacuum mm hg	OIL OUT Temp. °C	OIL OUT KV	Flow-Meter Reading	Remarks		Probe Temp. °C	Probe Reading	Dew Point	P	Ps	Cs	PPM
7-1-81	6:30	.55				70		IN							
								OUT							
	7:00	.55				69		IN							
								OUT							
	7:30	.55				69		IN							
								OUT							
	8:00	.55				69		IN							
								OUT							
	8:30	.45				69		IN							
								OUT							
	9:00	.45				[illegible]		IN							
								OUT							
	9:30	.45				[illegible]		IN							
								OUT							
	10:00	.44				69		IN							
								OUT							
	10:30	.43				69		IN							
								OUT							
	11:00	.43				71		IN							
								OUT							
	11:30	.40				72		IN							
								OUT							
	12:00	.40				74		IN							
								OUT							
	12:30	.40				76		IN							
								OUT							
	1:00	.40				77		IN							
								OUT							
	1:30	.45				78		IN							
								OUT							

C = Moisture concentration in sample in PPM.
C_s = 100% saturation of moisture in sample temperature of measurement.
P = Water vapor pressure measured by probe
P_s = Saturated water vapor pressure at temperature of measurement

$$C = C_s \frac{(P)}{(P_s)}$$

EHV EQUIPMENT FILL RECORD

Substation: N Anna
Equipment: [illegible]
Manufacturer: Westinghouse
Serial Number: 7??15?-7

Readings to be taken every half hour.

Probe # Oil In ______
Probe # Oil Out 2731 4

Date	Time	Trans. Vacuum mm hg	Streamline Vacuum mm hg	OIL OUT Temp. °C	OIL OUT KV	~~Flow Meter Reading~~ Temp. °F	Remarks		Probe Temp. °C	Probe Reading	Dew Point	P	Ps	Cs	PPM
1-1-81	7:00	.45				?0		IN / OUT							
	2:30	.48				80		IN / OUT							
	3:00	.70				[illegible]		IN / OUT							
	3:30							IN / OUT							
	4:00	.45	.8?	141			(Start oil)	IN / OUT	3?	.6?	-3?	.1?07	[illegible]	[illegible]	.34
	4:30	.45	.8?	140		?7??		IN / OUT	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	5:00	.46	.75	142		1461		IN / OUT	40°	.57	-39	.1081	55.324	114	.22
	5:30	.50	.80	148		2400		IN / OUT	38°	.51	-41	.0862	49.692	110	.19
	6:00	.50	.75	148		3300		IN / OUT	35°	.47	-46	.0481	42.175	99	.11
	6:30	.50	.80	148		4207		IN / OUT	36°	.46	-46	.0481	44.563	102	.11
	7:00	.50	.80	148		4711	Changed tanker	IN / OUT	36°	.46	-46	.0481	44.563	102	.11
	7:30	.55		143		5310		IN / OUT	3?	.43	-47	.04?6	4?.???	1??	.09
	8:00	.55	.80	143		1,5??		IN / OUT	[illegible]	.42	-48	.0??8	31.5??	8?	.10
	8:30	.57	[illegible]	14?		7735		IN / OUT	[illegible]	.41	-49	[illegible]	28.34?	82	.09
	9:00	.57	[illegible]	14?		8175		IN / OUT	2?	[illegible]	[illegible]	.07??	28.?	[illegible]	.05

C = Moisture foncentration in sample in PPM.
C_s = 100% saturation of moisture in sample at temperature of measurement.
P = Water vapor pressure measured by probe.
P_s = Saturated water vapor pressure at temperature of measurement.

$$C = C_s \frac{(P)}{(P_s)}$$

EHV EQUIPMENT FILL RECORD

Substation: N. [illegible]
Equipment: [illegible]
Manufacturer: WEST
Serial Number: 7001527

Readings to be taken every half hour.

Probe # Oil In:
Probe # Oil Out: [illegible]

Date	Time	Trans. Vacuum mm hg	Streamline Vacuum mm hg	OIL OUT Temp. °C	OIL OUT KV	Flow Meter Reading	Remarks		Probe Temp.	Probe Reading	Dew Point	P	Ps	Cs	PPM
1-1-[illegible]	[illegible]	.5				1370	ch TANKERS	IN							
								OUT	[illegible]	.39	-52	.0230	28.345	82	.05
	[illegible]	.5				4950		IN							
								OUT	28	35	-52	.0230	28.349	72	.05
	[illegible]					10530		IN							
								OUT							
	11:00							IN							
								OUT							
	11:30							IN							
								OUT							
								IN							
								OUT							
								IN							
								OUT							
								IN							
								OUT							
								IN							
								OUT							
								IN							
								OUT							
								IN							
								OUT							
								IN							
								OUT							
								IN							
								OUT							
								IN							
								OUT							
								IN							
								OUT							

C = Moisture concentration in sample in PPM.
C_s = 100% saturation of moisture in sample at temperature of measurement.
P = Water vapor pressure measured by probe.
P_s = Saturated vapor pressure at temperature of measurement.

$$C = C_s \frac{(P)}{(P_s)}$$

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Shaw

EHV EQUIPMENT FILL RECORD

SHEET 1 OF 3

Substation NAPS
Equipment #1 GSU R.P.
Manufacturer West
Serial Number 7001994

Readings to be taken every half hour.

Probe # Oil In ____________
Probe # Oil Out 41289- PR

11-26-82

Time	Trans. Vacuum mm hg	Streamline Vacuum mm hg	OIL OUT Temp. °C	OIL OUT KV	Flow Meter Reading	Remarks		Probe Temp. °C	Probe Reading	Dew Point	P	P_s	C_s	PPM
06:00						pull hose	IN / OUT							
06:15						pull TX	IN / OUT							
06:45	150						IN / OUT							
0700 07:10	30						IN / OUT							
0715	11						IN / OUT							
[illegible]	.65	.9					IN / OUT							
0800	.1	.8				HOLD 12 hrs	IN / OUT							
08:30	.14	.8	WINDING TEMP 10°C				IN / OUT							
09:00	.14	.8					IN / OUT							
09:30	.14	.75	WINDING TEMP 11°C				IN / OUT							
11:00	.14	.75	11°C				IN / OUT							
11:30	.15	.75	WINDING TEMP 11°C				IN / OUT							
11:30	.14	.75	11°C				IN / OUT							
11:30	.13	.75	11°C				IN / OUT							
12:00	.13	.75	11°C				IN / OUT							

SHEET 2 OF 3

EHV EQUIPMEN… …LL RECORD

Substation ____________
Equipment WESTINGHOUSE
Manufacturer #1 3Ø
Serial Number ____________

Readings to be taken every half hour.

Probe # Oil In ____________
Probe # Oil Out 41289-PR

Time	Trans. Vacuum mm hg	Streamline Vacuum mm hg	OIL OUT Temp. °C	OIL OUT KV	Flow Meter Reading	Remarks		Probe Temp. °C	Probe Reading	Dew Point	P	P_s	C_s	PPM
12:30	.13	.72			WINDING TEMP 12°C		IN / OUT							
13:00	.13	.72			Winding TEMP 12°C		IN / OUT							
13:30	.12	.72			Winding TEMP 14°C		IN / OUT							
[illegible]	.12	.70			WINDING TEMP 15°C		IN / OUT							
[illegible]	.14	.70			WINDING TEMP 16°C		IN / OUT							
[illegible]	.13	.70			WINDING TEMP. 16°C		IN / OUT							
[illegible]	.14	.70			WINDING TEMP 16°C		IN / OUT							
[illegible]	.15	.70			WINDING TEMP. 17°C		IN / OUT							
[illegible]	.14	.70			WINDING TEMP 17°C		IN / OUT							
[illegible]	.14	.70			WINDING TEMP 17°C		IN / OUT							
[illegible]	.14	.7			17°c		IN / OUT							
[illegible]	.18	.72			17°c		IN / OUT							
[illegible]	.14	.72			17°c		IN / OUT							
[illegible]	.13	.72			17°c		IN / OUT							
[illegible]	.09	0.3			17°	WARM UP OIL	IN / OUT							

SHEET 3 OF 3

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EHV EQUIPMENT FILL RECORD

Substation NAPS
Equipment WESTINGHOUSE
Manufacturer #GEN TX B Φ
Serial Number

Readings to be taken every half hour.

Probe # Oil In
Probe # Oil Out 41289PR

...e	Trans. Vacuum mm hg	Streamline Vacuum mm hg	OIL OUT Temp. °F	OIL OUT KV	Flow Meter Reading	Remarks		Probe Temp. °C	Probe Reading	Dew Point	P	P_g	C_s	Pf...
00	.07	.35				START OIL 2015	IN / OUT							
2050 30	0.1	.65	122°F		99 5010.0		IN / OUT	30	.36	-40	.09666	31.874	85	.2
2100 00	.09	.60	122		1450		IN / OUT	30	.36	-40	.09666	31.874	85	.2
2130 30	0.1	.60	122		2446		IN / OUT	36	.37	-38	.1209	44.563	102	.2
2200 00	0.1	.60	122		3400		IN / OUT	42	.39	-34	.1873	61.5	119	.3
2230 30	.09	.55	122		4300		IN / OUT	40	.38	-36	.1507	55.324	114	.3
2300 00	.08	.60	120		5080	WINDING TEMP 20°C	IN / OUT	40	.38	-36	.1507	55.324	114	.3
2330 30	0.1	.60	120		6200		IN / OUT	42	.38	-36	.1507	61.5	119	.2
12 M 08	1.08	.60	125		6912		IN / OUT	45	.38	-36	.1507	71.88	128	.2
782 0030 30	0.1	.60	125		7950	WINDING TEMP 25°C	IN / OUT	45	.38	-36	.1507	71.88	128	.2
0100 00	GAUGE Below 0.1	.60	126		8780	" " 35°c	IN / OUT	46	.38	-36	.1507	75.665	130	.2
0130 30		.60	126		9892	REMOVE VAC HOSE	IN / OUT							
25		.60			10380	MAIN TANK	IN / OUT							
					11547	+COPS	IN / OUT							

112787- SHEET 1 OF 3

TIME	OIL IN °F	OIL IN °C	OUT °F	OUT °C	FLOW METER	
0500	58 (~~14.4~~)	14.4	128	53		4hr @ 15-20°C
0530	59	15	128	53	1570	
0600	61	16.1	130	54.4	2600	
0630	61	16.1	130	54.4	3880	
0700	61	16.1	131	55	4800	
0730	61	16.1	131	55	5612	
0800	65	18	134	57	6900	
0830	67	19	134	57	7820	
0900	69	20.5	135	57.2	8875	
0930	70	21	135	57.2	9910	3hrs @ 20-25°C
1000	70	21	135	57.2	10940	
1030	72	22	136	58	12100	
1100	73	23	137	58.3	13000	
1130	75	24	138	59	14160	
1200	77	25	140	60	15250	
1230	78	25.6	142	61	16200	3.5hr @ 25-30°C
1300	80	26.7	143	62	17300	
1330	80	26.7	143	62	18400	
1400	82	27.8	146	63.3	19500	
1430	84	28.9	147	64	20600	

112782
SHEET 2 OF

C = 5/9 (F-32)

SHEET 2 OF

TIME 112782	OIL IN °F	OIL IN °C	OIL OUT °F	OIL OUT °C	FLOW METER
1500	85	29.4	148	64	21620
1530	86	30	150	65.5	22650
1600	88	31	150	65.5	23800
1630	89	31.6	151	66.1	25130
1700	90	32.2	151	66.1	26000
1730	90	32.2	151	66.1	26920
1800	91	32.7	152	66.6	27963
1830	93	33.8	153	67.2	29340
1900	94	34.4	154	67.7	30360
1930	95	35	154	67.7	31145
2000	95	35	156	68.8	32280
2030	96	35.5	156	68.8	33500
2100	97	36.1	157	69.4	34300
2130	98	36.6	158	70	35800
2200	98	36.6	154	67.7	36627
2230	98	36.6	150	65.5	37285
2300	100	37.7	161	71.6	38650
2330	100	37.7	162	72.2	39782
2400	100	37.7	163	72	4 254

4 hrs @ 30-35°

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SHEET 9 OF 3

11288 TIME	OIL IN °F	OIL IN °C	OIL OUT F°	OIL OUT C°	FLOW METER
0100	100	37.7	164	73.3	42655
0130	100	37.7	164	73.3	43840
0200	100	37.7	164	73.3	44380
0230	101	38.3	165	73.9	45475
0300	101	38.3	165	73.9	46520
0330	103	39	166	73.	47850
0400	104	39.6	166	73.9	48880
0430	104	39.6	166	73.9	49790
0500	105	40.1	168	74.8	50780
0530	105	40.1	168	74.8	51850
0600	106	40.7	168	74.8	53000

40.45°

180

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Begin 11-26-82

EHV EQUIPMENT FILL RECORD

Substation N/A Unit #1 A¢
Equipment nov. /82
Manufacturer WESTINGHOUSE
Serial Number 7001965

Readings to be taken every half hour.

Probe # Oil In ____________
Probe # Oil Out ____________

Date	Time	Trans. Vacuum (mm) hg	Streamline Vacuum mm hg	OIL OUT Temp. °C	OIL OUT KV	Flow Meter Reading	Remarks		Probe Temp. °C	Probe Reading	Dew Point	P	P_s	C_s
	16:30						START VAC.	IN / OUT						
	17:11	4.2mm					Leak CHECK	IN / OUT						
	19:45	1.5mm					Leak check	IN / OUT						
	20:10	.8mm ~~2.0~~					Leak check	IN / OUT						
	20:20	1.0mm					Leak check OK Finished	IN / OUT						
	20:30	.25mm	*	Begin VACuum			Winding Temp 21°C	IN / OUT						
	21:00	.22mm	.7mm				Winding [illegible] °C 21°C	IN / OUT						
	21:30	.24mm	.8mm					IN / OUT						
	22:00	.25mm	.7mm				21°C	IN / OUT						
	22:30	.23mm	.7mm				21°C	IN / OUT						
	23:00	.24mm	.7mm				20.25°C	IN / OUT						
	23:30	.23mm	.8mm				20.5°C	IN / OUT						
	24:00	.23mm	.8mm				20°C	IN / OUT						
	24:30	.22mm	.8mm				20°C	IN / OUT						
		.22	.9mm				20°C	IN						

10:00 Lost power
5 out
11:16 1.6 80%

EHV EQUIPMENT FILL RECORD

Substation N. ANNADANNA
Equipment #1 GSU
Manufacturer (W)
Serial Number 7001965 A Ø

Readings to be taken every half hour.

Probe # Oil In ______
Probe # Oil Out ______

11-29-82

Date	Time	Trans. Vacuum mm hg	Streamline Vacuum mm hg	OIL OUT Temp. °C	OIL OUT KV	Flow Meter Reading	Remarks		Probe Temp. °C	Probe Reading	Dew Point	P	P_s	C_s
	0:130	.22mm	.9mm				20°C	IN / OUT						
	02:00	.23mm	.8mm				20°C	IN / OUT						
	02:30	.23mm	.9mm				19°C	IN / OUT						
	03:00	.25mm	.9mm				18°C	IN / OUT						
	03:30	.25mm	.9mm				18°C	IN / OUT						
	04:00	.23mm	.9mm				18°C	IN / OUT						
	04:30	.24mm	.9mm				18°C	IN / OUT						
	05:00	.24mm	.9mm				17°C	IN / OUT						
	05:15 05:30	.22mm	SHUT VALVE TO VESSEL				17°C	IN / OUT						
	06:00	.23mm	—				17°C	IN / OUT						
	06:30	.24mm	—				16°C	IN / OUT						
	07:00	.23mm	—				16°C	IN / OUT						
	07:30	.25	—				16°C	IN / OUT						
	08:00	.25	—				16°C	IN / OUT						
		.22					16°C	IN						

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A Ø

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EHV EQUIPMENT FILL RECORD

Substation N. ANNA #1
Equipment #1 650 AΦ
Manufacturer WESTINGHOUSE
Serial Number 7001965

Readings to be taken every half hour.

Probe Ø Oil In ____________
Probe Ø Oil Out ____________

11-27-82

Time	Trans. Vacuum mm hg	Streamline Vacuum mm hg	OIL OUT Temp. °C	OIL OUT KV	Flow Meter Reading	Remarks		Probe Temp. °C	Probe Reading	Dew Point	P	P_s	C_s	PPM
10:00	Lost Power .5						IN / OUT							
11:16	1.6		80°c		(9999400)		IN / OUT							
12:00	.09	1.8	53°c		1890 (0000596)		IN / OUT	38.8	.39	-43	.0684	56.2	112	.18
12:30	.1	1.7	57.5°c		2574 0001283 0001918		IN / OUT	42.2	.425	-39	.1081	61.5	120	.2
13:00	.08	OC	58°c		3208		IN / OUT	42.7	.45	-37	.1351	63.1	120	.25
13:30	[illegible]	OC			3912	Loosing vac Stopped oil	IN / OUT	drawing down vac						
14:00	found small vac pump tripped off				investigated Thermal	and found ...	IN / OUT							
14:30	.13	1.8	65		4175	Started Pumping oil	IN / OUT	38.3	.66	-27	.389	55.8	110	.7
15:00	.1	1.7	59°c		4657		IN / OUT	37.7	.48	-34	.1873	49	109	.4
15:30	.09	1.7	60°		5400		IN / OUT	37.7	.46	-37	.1351	49	109	.3
16:00	.095	1.7	60°		6100		IN / OUT	37.7	.44	-38	.1209	49	109	.2
16:30	.1	1.7	60°		6700		IN / OUT	37.7	.43	-38	.1209	49	109	.2
17:00	.1	1.7	60°		7506		IN / OUT	37.7	.42	-39	.1081	49	109	.2
17:30	.1	1.6	59°		8156		IN / OUT	37.7	.42	-39	.1081	49	109	.2
18:00	1	1.5	59°		8850		IN / OUT	2	.41	-40	.0966	49	109	.2

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EHV EQUIPMENT FILL RECORD

SUNDAY

Substation: N. ANNA
Equipment: #1 GSU AP
Manufacturer: WESTINGHOUSE
Serial Number: 7001965

Readings to be taken every half hour.

Probe @ Oil In ______
Probe @ Oil Out ______

Appx. 20 HOURS = 6PM SUNDAY 11/28/82

11-27-82

Time	Trans. Vacuum mm hg	Streamline Vacuum mm hg	OIL OUT Temp. °C	Oil in Temp. °C	Flow. Meter Reading	Remarks		Probe Temp. °C	Probe Reading	Dew Point	P	P_s	C_s	PP
18:30	.10	1.7	58°C	—	9463	—	IN / OUT	105°F	.412	-40°C	.0966	—	—	—
19:00	.10 [illegible]	1.7 [illegible]	57°C [illegible]	—	[illegible]	Level of 980 oil	IN / OUT	100°F [illegible]	.335 [illegible]	[illegible]	[illegible]			
19:30	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	IN / OUT							
20:00	—	1.2mm	—	—	10608	MAIN TANK FULL	IN / OUT	—	—	—	—	—	—	
20:30	—	—			—		IN / OUT							
21:00							IN / OUT							
21:30	—	1.2 mm	65°C	—	11725	COPAS TANK FULL	IN / OUT	—	—	—	—	—	—	
22:00		1.0mm	74°C	11.5°C	000	*Begin* circulate	IN / OUT	105°F	.465					
22:30		1.0mm	58°C	12.5°C	980	—	IN / OUT	105°F	.461	—				
23:00		1.0mm	58°C	13°C	1734	—	IN / OUT	110°F	.490					
23:30		.08mm	60°C	13°C	2709	—	IN / OUT	110°F	.490					
24:00		.8mm	60C	14°C	3305	—	IN / OUT	111°F	.500					
24:30		.75mm	60.5°C	15C	4250	Midnight hour	IN / OUT	113°F	.505					
01:00		.8mm	61.0°C	15.5C	5042	11/28/82	IN / OUT	114°	.510					

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EHV EQUIPMENT FILL RECORD

Substation N. ANNA #1
Equipment GSU A Φ TRANSFORMER
Manufacturer WESTINGHOUSE
Serial Number 7001965

Readings to be taken every half hour.

Probe Φ Oil In ____________
Probe Φ Oil Out ____________

11-28-82

11/28/82 Time	Trans. Vacuum mm hg	Streamline Vacuum mm hg	OIL OUT Temp. °C	Oil In Temp. °C	Flow Meter Reading	Remarks		Probe Temp. °C	Probe Reading	Dew Point	P	P_s	C_s	PP
02:00		.80 mm	62°C	17°C	6784		IN / OUT	—	—					
02:30		.80 mm	62.5°C	17.5°C	7402		IN / OUT	105°F	.485					
03:00		.80 mm	63.0°C	18.0°C	8092		IN / OUT	104°F	.481					
03:30		.80 mm	64.0°C	18.5°C	8856		IN / OUT	101°F	.465					
04:00		.80 mm	64.5°C	19.5°C	9816		IN / OUT	100°F	.475					
04:30		.80 mm	65.0°C	20.8°C	10514		IN / OUT	100°F	.478					
05:00		.80 mm	65.5°C	21.0°C	11277		IN / OUT	100°F	.473					
05:30		.80 mm	66.5°C	21.5°C	12055		IN / OUT	100°F	.479					
06:00		.80 mm	67.0°C	22.0°C	12916		IN / OUT	100°F	.475					
06:30		.80 mm	68°C	23°C	14251		IN / OUT	100°F	.482					
07:00		.80 mm	69°C	24°C	15205		IN / OUT	100°F	.485					
07:30		.80 mm	69.5°C	24.5	15858		IN / OUT	101°F	.480					
08:00		.80 mm	70°C	25°C	16424		IN / OUT	100°F	.461					
08:30		.8	70	26	17150		IN / OUT	100	.461					
							IN							

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EHV EQUIPMENT FILL RECORD

Substation: NORTH ANNA #1
Equipment: EXU A Φ TRANSFORMER
Manufacturer: WESTINGHOUSE
Serial Number: 7001965

Readings to be taken every half hour.

Probe Ø Oil In ______________
Probe Ø Oil Out ______________

11-28 Time	Trans. Vacuum mm hg	Streamline Vacuum mm hg	OIL OUT Temp. °C	OIL IN Temp °C	Flow Meter Reading	Remarks		Probe Temp. °C	Probe Reading	Dew Point	P	P_s	C_s	PP
09:30		.8 mm	71	26.5	18750		IN / OUT	100	.463					
10:00		.8 mm	71	27	19500		IN / OUT	100	.470					
10:30		.8 mm	71.5	27.5	20278		IN / OUT	100	.470					
11:00		.8 mm	72	28	21108		IN / OUT	100	.465					
11:30		.8 mm	72.6	28.7	21916		IN / OUT	100	.468					
12:00		.8 mm	73	29	22656		IN / OUT	100	.470					
12:30		.8 mm	73.5	29.5	23450		IN / OUT	101	.470					
13:00		.8 mm	74	30	24207		IN / OUT	102	.431					
13:30		.8 mm	74.8	30.9	25240		IN / OUT	100	.420					
14:00		.8 mm	75	31	25818		IN / OUT	100	.435					
14:30		.8 mm	76	31.5	26762		IN / OUT	105	.460					
15:00		.8 mm	76	32.5	27533		IN / OUT	100	.407					
15:30		.8 mm	76	32.0	28309		IN / OUT	98	.405					
16:00		.8 mm	77	32.5	29075		IN / OUT	10	.470					
[illegible]		.8 [illegible]	71.5 [illegible]	3[illegible]	29870		IN	[illegible]	[illegible]					

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EHV EQUIPMENT FILL RECORD

Substation: N/A Unit #1 A∅
Equipment: GSU TRANSFORMER
Manufacturer: WESTINGHOUSE
Serial Number: 7001965

Readings to be taken every half hour.

Probe ∅ Oil In ______
Probe ∅ Oil Out ______

11-28-82 Time	Trans. Vacuum mm hg	Streamline Vacuum mm hg	OIL OUT Temp. °C	Oil IN Temp	Flow Meter Reading	Remarks		Probe Temp. °C	Probe Reading	Dew Point	P	P_s	C_s	P
17:00		.8 mm	76.5	33.0	30650	—	IN / OUT	100	.445					
17:30		.8 mm	77	33.5	31518	—	IN / OUT	100	.455					
18:00		.80 mm	77.0°C	34.0°C	32263	—	IN / OUT	105°F	.457					
18:30		.80 mm	77.5°C	34.0°C	32917	—	IN / OUT	100°F	.410					
19:00		.75 mm	78.0°C	34.0°C	33736	—	IN / OUT	100°F	.410					
19:30		.75 mm	78.0°C	34.5°C	34640		IN / OUT	100°F	.425					
20:00		.70 mm	78.5°C	34.8°C	35502	—	IN / OUT	100°F	.440					
20:30		.70 mm	78.5°C	35.0°C	36179	—	IN / OUT	100°F	.435					
21:00		.70 mm	78.7°C	35.3°C	37242	—	IN / OUT	100°F	.431					
21:30		.70 mm	78.9°C	35.5°C	37680	—	IN / OUT	100°F	.431					
22:00		.70 mm	79.5°C	36.0°C	38531	—	IN / OUT	100°F	.435					
22:30		.70 mm	79.8°C	36.0°C	39180	—	IN / OUT	100°F	.420					
23:00		.70 mm	80.2°C	36.2°C	40110	—	IN / OUT	100°F	.438					
23:30		.70 mm	80.5°C	36.5°C	40890	—	IN / OUT	105	.455					

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EHV EQUIPMENT FILL RECORD

Substation: N/A Unit I Aø
Equipment: GSU TRANSFORMER
Manufacturer: WESTINGHOUSE
Serial Number: 7001965

11-29-82
AM

Readings to be taken every half hour.

Probe Ø Oil In ____________________
Probe Ø Oil Out ____________________

Time	Trans. Vacuum mm hg	Streamline Vacuum mm hg	OIL OUT Temp. °C	Oil IN Temp. °C	Flow Meter Reading	Remarks		Probe Temp. °C	Probe Reading	Dew Point	P	P_s	C_s	PP
24:30		.70 mm	82.0°C	37.5°C	42491	—	IN / OUT	100°F	.432					
01:00	—	.70 mm	82.0°C	37.5°C	43212 [illegible]	—	IN / OUT	100°F	.431					
01:30	—	.70 mm	82.5°C	37.5°C	44088	—	IN / OUT	100°F	.432					
02:00	—	.70 mm	82.5°C	37.5°C	44778	Circulate Time Finished Total 24 hrs. Begin 24 hr. sit Period	IN / OUT	100°F	.415					
							IN / OUT							
							IN / OUT							
							IN / OUT							
							IN / OUT							
							IN / OUT							
							IN / OUT							
							IN / OUT							
							IN / OUT							
							IN / OUT							
							IN / OUT							
							IN							

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EHV EQUIPMENT FILL RECORD

Substation N. A. P. S.
Equipment #1 G.S.U. Tx C
Manufacturer WEST
Serial Number 7601595

Readings to be taken every half hour.

Probe # Oil In NA
Probe # Oil Out 41289-PR

SHEET 1 OF 4

Date	Time	Trans. Vacuum mm hg	Streamline Vacuum mm hg	OIL OUT Temp. °C	OIL OUT KV	Flow Meter Reading	Remarks		Probe Temp. °C	Probe Reading	Dew Point	P	P_s	C_s	PP:
8-10-92	10:45						WARM PUMP	IN / OUT							
	11:10						PULL HOSE	IN / OUT							
	11:15						PULL TX	IN / OUT							
	11:30	80						IN / OUT							
	12:00	20					12:15 .40	IN / OUT							
	12:30	.16						IN / OUT							
	13:00	.13						IN / OUT							
	1:30	1.3						IN / OUT							
	2:00	1.5						IN / OUT							
	2:30	.2						IN / OUT							
	3:00	.2						IN / OUT							
	3:30	.2						IN / OUT							
	4:00	.1						IN / OUT							
	4:30	.090						IN / OUT							
	5:00	.075						IN / OUT							

EHV EQUIPMENT FILL RECORD

Substation N.A.P.S
Equipment LG.S.U. TX Cϕ
Manufacturer WEST
Serial Number 700199C

Readings to be taken every half hour.

Probe # Oil In Nϕ
Probe # Oil Out 41289 PR

SHEET 2 OF 4

Date	Time	Trans. Vacuum mm hg	Streamline Vacuum mm hg	OIL OUT Temp. °C	OIL OUT KV	Flow Meter Reading	Remarks		Probe Temp. °C	Probe Reading	Dew Point	P	P_s	C_s	PP:
1092	5:30	.09						IN / OUT							
	6:00	.09						IN / OUT							
	6:30	.1						IN / OUT							
	7:00	.07						IN / OUT							
	7:30	.08						IN / OUT							
	8:00	.08						IN / OUT							
	8:30	.08						IN / OUT							
	9:00	.07						IN / OUT							
	9:30	.07						IN / OUT							
	10:00	.07						IN / OUT							
	10:30	.07						IN / OUT							
	11:00	.07						IN / OUT							
	11:30	.07						IN / OUT							
	12:00 MN	.08						IN / OUT							
	[illegible]	.08						IN							

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MHV EQUIPMENT FILL RECORD

Substation N.A.P.S.
Equipment G.S.U. TX CØ
Manufacturer WEST
Serial Number 7001995

Readings to be taken every half hour.

Probe # Oil In N.A
Probe # Oil Out 41289 7R

SHEET 3 OF 4

Date	Time	Trans. Vacuum mm hg	Streamline Vacuum mm hg	OIL OUT Temp. °C	OIL OUT KV	Flow Meter Reading	Remarks		Probe Temp. °C	Probe Reading	Dew Point	P	P_s	C_s	PP:
8·11·82	1:00 AM	.08						IN / OUT							
	1:30	.08						IN / OUT							
	2:00	.08						IN / OUT							
	2:30	.06						IN / OUT							
	3:00	.25	.9	144	35	375	START OIL	IN / OUT	24	.64	-14	1.361	22.377	69	4.
	3:30	.15	.9	144		1315		IN / OUT	24	.54	-19	8,54	22.377	69	2.
	4:00	.15	.9	144		2220		IN / OUT	24	.52	-21	.705	22.377	69	2.
	4:30	.15	.9	146		3200		IN / OUT	24	.52	-21	.705	22.377	69	2.
	5:00	.15	.9	146		4200		IN / OUT	24	.50	-22	.64	22.377	69	1.
	5:30	.15	.9	146		5000		IN / OUT	24	.49	-23	.58	22.377	69	1.
	6:00	.15	.9	148		6100		IN / OUT	24	.48	-24	.526	22.377	69	1.
	6:30	.15	.9	148				IN / OUT	22	.46	-25	.476	19.827	65	1.
	7:00	.15	.9	146		7750		IN / OUT	22	.46	-25	.476	19.827	65	1.
	7:30	.15	.9	146		8640		IN / OUT	22	.46	-25	.476	19.827	65	1.
	8:00					7625		IN / OUT	22	.46	-25	.476	19.827	65	1.

EHV EQUIPMENT FILL RECORD

Substation N. A. P. S. #2
Equipment TX Bϕ G.S.U.
Manufacturer WEST
Serial Number 7001994

Readings to be taken every half hour.

Probe # Oil In ____________
Probe # Oil Out 41289 PR

START 8-5-82

SHEET 1 OF 4

Date	Time	Trans. Vacuum mm hg	Streamline Vacuum mm hg	OIL OUT Temp. °C	KV	Flow Meter Reading	Remarks		Probe Temp. °C	Probe Reading	Dew Point	P	P_s	C_s	P
5-82	19:00							IN OUT							
	19:30							IN OUT							
	20:00	.3						IN OUT							
	20:30	.15						IN OUT							
	21:00	.1						IN OUT							
	21:30	.35						IN OUT							
	22:00	.35						IN OUT							
	22:30	.35						IN OUT							
	23:00	.35						IN OUT							
	23:00	.35						IN OUT							
	23:00	.35						IN OUT							
	23:30	.35						IN OUT							
	24:00	.35						IN OUT							
	:30	.35						IN OUT							
	1:00	.4						IN O							

EHV EQUIPMENT FILL RECORD

Substation N.A.P.S
Equipment TX 1 G.S.U. BA
Manufacturer WEST
Serial Number 7001994

Readings to be taken every half hour.

Probe # Oil In
Probe # Oil Out 41289 PR

SHEET 2 OF 4

Date	Time	Trans. Vacuum mm hg	Streamline Vacuum mm hg	OIL OUT Temp. °C	OIL OUT KV	Flow Meter Reading	Remarks		Probe Temp. °C	Probe Reading	Dew Point	P	P_s	C_s	PPM
5-82	1:30	.4						IN							
								OUT							
	2:00	.35						IN							
								OUT							
	2:30	.35						IN							
								OUT							
	3:00	.35						IN							
								OUT							
	3:30	.35						IN							
								OUT							
	4:00	.35						IN							
								OUT							
	4:30	.35						IN							
								OUT							
	5:00	.35						IN							
								OUT							
	5:30	.35						IN							
								OUT							
	6:00	.35						IN							
								OUT							
	6:30	.40						IN							
								OUT							
	7:00	.25						IN							
								OUT							
	7:30	.3						IN							
								OUT							
	8:00	.3						IN							
								OUT							
	8:30	.3						IN							
								OUT							

EHV EQUIPMENT FILL RECORD

Substation N.M.P.S
Equipment TX 1 G.S.U. 3ϕ
Manufacturer WEST
Serial Number 7001994

Readings to be taken every half hour.

Probe # Oil In
Probe # Oil Out 41289 PR

SHEET 3 OF 4

Date	Time	Trans. Vacuum mm hg	Streamline Vacuum mm hg	OIL OUT Temp. °C	OIL OUT KV	Flow Meter Reading	Remarks		Probe Temp. °C	Probe Reading	Dew Point	P	P_s	C_s	P[illegible]
								IN / OUT							
8.5.82	9:00	.3						IN / OUT							
	9:30	.25						IN / OUT							
	10:00	.30	.7	140	35		START OIL	IN / OUT	24	.15	-19	.954	22.377	69	1.[illegible]
	10:30	.4	1.0	144		1066		IN / OUT	30	.56	-18	.935	31.827	85	2[illegible]
	11:00	.4	1.0			1965		IN / OUT	30	.52	-21	.705	31.827	85	1.[illegible]
	11:30	.4	1.0	144	35	3000		IN / OUT	30	.50	-22	.64	31.827	85	1.[illegible]
	12:00	.45	1.0	144	35	3902		IN / OUT	32	.48	-24	.526	35.663	91	1.[illegible]
	12:30	.37	1.0	146	35	5000		IN / OUT	32	.48	-24	.526	35.663	91	1.[illegible]
	13:00	.35	1.0	144		5670		IN / OUT	32	.47	-25	.476	35.663	91	[illegible]
	13:30	.35	1.0	145		6585		IN / OUT	36	.48	-24	.526	44.563	102	[illegible]
	14:00	.35	1.0	145		7500		IN / OUT	36	.48	-24	.526	44.563	102	[illegible]
	14:30	.35	1.0	145		8625		IN / OUT	36	.47	-25	.476	44.563	102	[illegible]
						9720	FIN.	IN / OUT							
	15:00							IN / OUT							
	15:30							IN / OUT							
	16:00														

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EHV EQUIPMENT FILL RECORD

Substation N. Anna
Equipment Tx 2 G.S.U
Manufacturer West
Serial Number 7002100

Readings to be taken every half hour.

Probe # Oil In 19656-PR
Probe # Oil Out 19652-PR

2-1-82

Date	Time	Trans. Vacuum mm hg	Streamline Vacuum mm hg	OIL OUT Temp. °C	OIL OUT KV	Flow Meter Reading	Remarks		Probe Temp. °C	Probe Reading	Dew Point	P	P_s	C_s	??
2-1-82	1300						START VAC	IN / OUT							
	1430	.45					2 mm 14[illegible]	IN / OUT							
	15:00	.16						IN / OUT							
	15:30	.25						IN / OUT							
	16:00	.3						IN / OUT							
	16:30	.25						IN / OUT							
	1700	.3						IN / OUT							
	1730	.35						IN / OUT							
	18:00	.35						IN / OUT							
	18:30	.35						IN / OUT							
	1900	.40						IN / OUT							
	19:30	.45						IN / OUT							
	2000	.45						IN / OUT							
	2030	.45						IN							

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EHV EQUIPMENT FILL RECORD

Substation N. ANNA
Equipment #2 G.S.U. SPARE
Manufacturer West
Serial Number 7002100

Readings to be taken every half hour.

Probe # Oil In 19156-PR
Probe # Oil Out 19652-PR

Date	Time	Trans. Vacuum mm hg	Streamline Vacuum mm hg	OIL OUT Temp. °C	OIL OUT KV	Flow Meter Reading	Remarks		Probe Temp. °C	Probe Reading	Dew Point	P	P_s	C_s	??
	2100	.46						IN / OUT							
	2130	.5						IN / OUT							
	2200	.5						IN / OUT							
	2230	.5						IN / OUT							
	2300	.1						IN / OUT							
	2330	.6						IN / OUT							
	2400		TROUBLE [illegible]					IN / OUT							
	2430		CONTROL					IN / OUT							
	100	.2						IN / OUT							
	130	.3						IN / OUT							
	200	.35						IN / OUT							
	230	.35						IN / OUT							
	300	.35						IN / OUT							
	330	.37						IN							

(,

$C_s = \frac{P}{P_s}$

9280

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EHV EQUIPMENT FILL RECORD

Substation N.ANNA
Equipment HZ-D G.S.U
Manufacturer WSAT
Serial Number 7CD2100

Readings to be taken every half hour.

Probe # Oil In 19656-PR
Probe # Oil Out 19652-PR

Date	Time	Trans. Vacuum mm hg	Streamline Vacuum mm hg	OIL OUT Temp. °C	OIL OUT KV	Flow Meter Reading	Remarks
2-2-82	4:00	1.6					START OIL
	4:30	.6	.62	128°F		600	
	5:00	.9	.75	105°F		1340	
	5:30	.6	.77	107°F		2220	
	6:00	2.6	.77	106°F		3040	
	6:30	1.7	.7	120°F		4000	
	7:00	.55	.75	118°F		4720	
	7:30	1.0	.75	118°F		5550	
	8:00	.94	.79	117°F		6380	
	8:30	1.1	.79	125°F		7350	
	9:00	.85	.79	125°F		8150	
	9:30	1.1	.79	125°F		8450	
	10:00					9671	FINISH

	Probe Temp. °C	Probe Reading	Dew Point	P	P_s	C_s
IN						
OUT						
IN	3°C	.61	-17	1.031	5.685	33
OUT	2°C	.35	-66	.00349	5.294	32
IN	3°C	.69	-13	1.490	5.685	33
OUT	30°C	.41	-46	.0481	31.824	85
IN	4°C	.71	-11	1.785	6.101	34
OUT	32°C	.40	-48	.0378	35.663	91
IN	4°C	.72	-10	1.950	6.101	34
OUT	34°C	.40	-48	.0378	39.898	97
IN	4°C	.71	-11	1.785	6.101	34
OUT	34°C	.40	-48	.0378	39.898	97
IN	4°C	.72	-10	1.950	6.101	34
OUT	36°C	.40	-48	.0378	44.563	102
IN	4°C	.72	-10	1.950	6.101	34
OUT	38°C	.40	-48	.0378	49.692	110
IN	4°C	.74	-9	2.131	6.101	34
OUT	36°C	.38	-54	.0178	44.563	102
IN						
OUT	36	.38	-54	.0178	44.563	102
IN						
OUT	36	.38	-54	.0178	44.563	102
IN						
OUT	39	.38	-54	.0178	52.442	112
IN						
OUT						
IN						
OUT						

198

#1

$C_s \frac{P}{P_s}$

EHV EQUIPMENT FILL RECORD

Substation: North Anna
Equipment: #2 G.S.U. TX
Manufacturer: West
Serial Number: 7002100

Readings to be taken every half hour.

Probe # Oil In ~~[illegible]~~
Probe # Oil Out ~~[illegible]~~

3-26-82 Sheet 1 of ___

Date	Time	Trans. Vacuum mm hg	Streamline Vacuum mm hg	OIL OUT Temp. °C	OIL OUT KV	Flow Meter Reading	Remarks		Probe Temp. °C	Probe Reading	Dew Point	P	P_s	C_s
							Start Vac	IN						
3-26-82	4:00 pm						[illegible] up	OUT / IN						
							[illegible] Vac Hose	OUT / IN						
3-26-82	5:00 am						Start Vac on TX	IN / OUT						
	5:30					[illegible] Rate .4 – 10 min	Leak [illegible] 10 min	IN / OUT						
	6:00	25 m				LK. Rate OK		IN / OUT						
	6:30	20						IN / OUT						
	7:00	10	10					IN / OUT						
	7:30	.1	.4					IN / OUT						
	8:00	.08	.4					IN / OUT						
	8:30	.07	.4		40		Start oil	IN / OUT						
	9:00	.04	.09				3.76 / 2.17	IN / OUT	8	.76 / .51	-20 / -23	.776 / .370	8.045 / 11.477	39 / 38
	9:30	.04	.09	136				IN / OUT						
	10:00	.09	.09	136		1500			7	.46	~~-20~~	.776	7.513	38
	10:30	[illegible]		[illegible]		[illegible]	3.91 / 1.7		7	.47	-28	.351	7.513	38

#2

199

EHV EQUIPMENT FILL RECORD

Substation N. ANNA
Equipment ~~#2 G.S.U. TX~~
Manufacturer W. [illegible]
Serial Number 7002100

Readings to be taken every half hour.

Probe # Oil In ~~8845 [illegible]~~
Probe # Oil Out ~~8450 [illegible]~~

Date	Time	Trans. Vacuum mm hg	Streamline Vacuum mm hg	OIL OUT Temp. °C	OIL OUT KV	Flow Meter Reading	Remarks		Probe Temp. °C	Probe Reading	Dew Point	P	P_s	C_s
	11:00	.08	.6	136		2670		IN / OUT	6 / 8	.46 / .46				
	11:30	.08	.6	136		3400		IN / OUT		.45 / .45				
	12:00 mid	.08	.6	136				IN / OUT						
3-27-92	12:30	.08	.6	136		4400		IN / OUT		.45 / .45				
	1:00	.08	.6	136				IN / OUT		.44 / .44				
	1:30	.08	.6	136		5700		IN / OUT						
	[illegible]	.08	.6	136		6700		IN / OUT		.43				
	[illegible]	.09	.6	141		7200		IN / OUT						
	3:00	.09 .09	.6 .6	136		8231 8019		IN / OUT						
	[illegible]	.09	.6	140		8494	Collapsed hose	IN / OUT						
	4:[illegible]	.09	.6	120		8800		IN / OUT						
	4:45			90			START CIRCULATION	IN / OUT						
	[illegible]			110				IN / OUT						
	[illegible]			120				IN / OUT						

C_s P / P_s

#3

200

EHV EQUIPMENT FILL RECORD

Substation N. ANNA
Equipment #2 G.S.U.
Manufacturer WEST
Serial Number 7002100

Readings to be taken every half hour.

Probe # Oil In ____________
Probe # Oil Out ____________

Date	Time	Trans. Vacuum mm hg	Streamline Vacuum mm hg	OIL OUT Temp. °C	OIL OUT KV	Flow Meter Reading	Remarks		Probe Temp. °C	Probe Reading	Dew Point	P	P_s	C_s
3/27	6:30			120				IN / OUT						
	7:00			120				IN / OUT						
	7:30			120				IN / OUT						
	8:00			120				IN / OUT						
	8:30			120				IN / OUT						
	9:00			120				IN / OUT						
	9:30			121				IN / OUT						
	10:00			121				IN / OUT						
	10:30			123				IN / OUT						
	11:00			125				IN / OUT						
	11:30			130				IN / OUT						
	12:[illegible]			130				IN / OUT						
	12:[illegible]			130				IN / OUT						
	1:[illegible]			135				IN						

201

#4

EHV EQUIPMENT FILL RECORD

Substation N. ANNA
Equipment ~~#2 GSU TX~~
Manufacturer ~~W 251~~
Serial Number 7002100
CIR. OIL

Readings to be taken every half hour.

Probe # Oil In NO PROBE
Probe # Oil Out ~~1456~~ 19652-PR
1000 SERIES

Date	Time	Trans. Vacuum mm hg	Streamline Vacuum mm hg	OIL OUT Temp. °C	OIL OUT KV	Flow Meter Reading	Remarks	Probe Temp. °C	Probe Reading	Dew Point	P	P_s	C_s
						OIL PPM OUT	IN OIL TEMP						
3/27	13:30			135									
	14:00			140			70						
	14:30			143			70						
	15:00			144			70						
	15:30			[illegible]			75						
	16:00			[illegible]			75						
	16:30			146			77						
	17:00			146		INSTALL 1000 PROBE	80	56					
	17:30			149		.53 ppm	81	48	.51	-29	.317	83.71	140
	18:00			149		.27 ppm	81	44	.46	-36	.1502	68.26	123
	18:30			148		.20 ppm	81	48	~~.45~~	-38	.1209	83.71	140
	19:00			148		.19	84	46	.44	-39	.1081	75.65	130
	19:30			160		.18	84	48	.44	-39	.1081	83.71	140
	20:00			164		.29	85	58	.48	-32	.2318	136.08	172

TCHELL / CORRIN

#5

202

EHV EQUIPMENT FILL RECORD

Substation North Anna
Equipment #2 GSU TX
Manufacturer West
Serial Number 7002100

Readings to be taken every half hour.

Probe # Oil In NO PROBE
Probe # Oil Out 19652 PR

CIR. OIL

Date	Time	Trans. Vacuum mm hg	MOPP 3 ~~Streamline~~ Vacuum mm hg	OIL OUT Temp. °F	OIL OUT KV	~~Flow Meter Reading~~ PPM	IN OIL TEMP Remarks		Probe Temp. °C	Probe Reading	Dew Point	P	P_s	C_s
3/27	20:30			OIL OUT 164		.14	85	OUT	55	[illegible]	-39	.1081	118.07	161
↓	21:00			166		.06	87	OUT	46	.40	-48	.0378	25.61	130
	21:30			166		.06	89	OUT	39	.39	-50	.0246	52.442	112
	22:00			166		.07	89	OUT	52	.41	-46	.0481	102.09	150
	22:30			162		.068	90	OUT	44	.40	-48	.0378	68.26	123
	23:00			168			90	OUT	44	.39				
	23:30			170			90	OUT		.41				
3/28	24:00			172			92	OUT	57	.43				
3/28	24:30			172			94	OUT	46	.38				
3/28	01:00			164			95	OUT	42	.39				
↓	01:30			164			95	OUT	42	.37				
	02:00			162			98	OUT	43	.38				
	02:30			162			98	OUT	52	.42				
	03:00			163			98	IN	53	.42				

M- CHELL
(3RIN

#6

AMBIENT 24°F
4° wind chill

203

EHV EQUIPMENT FILL RECORD

Substation N. ANNA
Equipment #2 GSU
Manufacturer WEST
Serial Number 2002100

Readings to be taken every half hour.

Probe # Oil In ____________
Probe # Oil Out ____________

Date	Time	Trans. Vacuum mm hg	Streamline Vacuum mm hg	OIL OUT Temp. °F	OIL OUT KV	Flow Meter Reading	IN OIL Temp. Remarks		Probe Temp. °C	Probe Reading	Dew Point	P	P_s	C_s	P
3-28	3:30			164			100	IN / OUT	53	.42					
	4:00			166			100	IN / OUT	54	.42					
	4:30			167			102	IN / OUT	57	.42					
	5:00			166			104	IN / OUT	52	.42					
	5:30			167			104	IN / OUT	57	.42					
	6:00			167			106	IN / OUT	54	.42					
	6:30			165			108	IN / OUT	57	.44	SEE REVERSE #1				
	7:00	BREAK VAC		(166)		4 lbs PRESS.	(110)	IN / OUT	52	.40					
	7:30	PUMP OIL OUT OF TX						IN / OUT							
	↓	DRAIN Oil						IN / OUT	PSI + N_2 PRESS						
	11:00	OPEN COOLER VALVES & START VACUUM						IN / OUT	WINDING TEMP GA = 40° C } w/no oil; LIQUID TEMP GA = 36° C						
								IN / OUT							
		SEE SHEET #7						IN / OUT							
								IN							

#7
MITCHELL/CORRIN

P.P. #7

204

EHV EQUIPMENT FILL RECORD

Readings to be taken every half hour.

Substation: N. ANNADANNA
Equipment: (W) #2 GSU TX
Manufacturer: (W)
Serial Number: 2002100

Probe Ø Oil In: N/A
Probe Ø Oil Out: 19652 PR

Date	Time	Trans. Vacuum mm hg	MOPP #2 ~~Streamline~~ Vacuum mm hg	OIL OUT Tank °C	KV	Flow Meter Reading	Remarks		Probe Temp. °C	Probe Reading	Dew Point	P	P_s	C_s
							See #ONE REVERSE	IN OUT						
3/28	11:00	START					SEE #TWO REVERSE	IN OUT						
	11:15	27.5"	19 mm/hg	N/A		N/A	SEE #3 REVERSE	IN OUT						
	11:30	12 TORR	15 mm/hg	N/A TANK TEMP °C		N/A		IN OUT						
	11:45	SEE NOTE #3	10 MM					IN OUT						
	12:00	6 MM	1.5 MM					IN OUT						
	12:15	6 mm	1.3 mm			MER GAUGE		IN OUT						
	12:30	5.9	1.1 mm	21.4c				IN OUT						
	12:45	5.5	1.05	20.8c				IN OUT						
	13:00	5.5	.95	20.1c			13:32 .85	IN OUT	START	HOLD	TIME			
	13:30	3.0	.92	20.1		1.25		IN OUT						
	14:00	3.0	.85	19.5		.9		IN OUT						
	14:30	2.5	.82	19.5		.95		IN OUT						
	15:00	2.3	.78	19		1.0		IN						
			[illegible]			1.05								

#8

MITCHELL / CORRIN   P.P. #8

EHV EQUIPMENT FILL RECORD

Readings to be taken eve[illegible] half hour.

Substation N. ANNADANNA
Equipment #2 G.S.U. TX
Manufacturer (GE)
Serial Number 7002100

Probe # Oil In N/A
Probe # Oil Out 19652 PR

Date	Time	Trans. Vacuum mm hg	MOPP #2 ~~Stream~~ Vacuum mm hg	TANK TEMP ~~Oil Out Temp.~~ °C	KV	MER GAUGE Flow ~~Meter Reading~~	Remarks (OUTSIDE AIR)		Probe Temp. °C	Probe Reading	Dew Point	P	P_s	C_s
3/28	16:00	2.3	.78	19.5		1.05		IN / OUT						
	16:30	2.3	.75	19.6		1.05		IN / OUT						
	17:00	2.3	.75	19.9		1.1		IN / OUT						
	17:30	2.2	.71	20.0		1.1		IN / OUT						
	18:00	2.2	.71	20.0		1.1		IN / OUT						
	18:30	2.2	.71	20.0		1.1		IN / OUT						
	19:00	2.2	.70	19.5		1.1		IN / OUT						
	19:30	2.2	.70	19.2		1.2		IN / OUT						
	20:00	2.2	.69	18.1		1.3		IN / OUT						
	20:30	2.2	.68	17.5		1.3		IN / OUT						
	21:00	2.2	.68	17.4		1.3		IN / OUT						
	21:30	2.2	.69	17.0		1.3		IN / OUT						
	22:00	2.2	.69	16.1		1.3	6°C	IN						
↓	[illegible]	2.2	.68	[illegible]		1.3	4°C							

205

MITCHELL/ORRIN

P.P. #9

206

EHV EQUIPMENT FILL RECORD

Substation N. ANNADANNA
Equipment #2 G.S.U. TX
Manufacturer (W)
Serial Number 7002180

Readings to be taken every half hour.

Probe # Oil In N/A
Probe # Oil Out 19692 PR

Date	Time	Trans. Vacuum mm hg	MOPP #3 TANK Vacuum mm hg	OIL OUT Temp. °C	KV	MER GAUGE Flow Meter Reading	OUTSIDE Remarks		Probe Temp. °C	Probe Reading	Dew Point	P	P_s	C_s
								IN						
3/28	23:00	2.2	.68	15.7		1.3	4°c	OUT						
								IN						
	23:30	2.2	.68	15.1		1.2	4°c	OUT						
								IN						
3/29	24:00	1.2	.68	14.9		1.2	4°c	OUT						
								IN						
	24:30	2.2	.68	14.8		1.3	4°c	OUT						
								IN						
	01:00	2.2	.68	14.5°		1.2	4°C	OUT						
								IN						
	01:30	2.2	.65	14.4°		1.2	3½°C	OUT						
								IN						
	02:00	2.2	.65	14.1°		1.2	3°c	OUT						
								IN						
	02:30	2.2	.62	13.7°		1.2	3°C	OUT						
								IN						
	03:00	2.0	.62	13.1°		1.2	2°C	OUT						
								IN						
	03:30	2.0	.62	13.1		1.2	2°C	OUT						
								IN						
	04:00	2.0	.62	13.0		1.2	2°C	OUT						
								IN						
	04:30	1.9	.65	12.1		1.2	1°C	OUT						
								IN						
	05:00	1.7	.65	12.0		1.2	1°C	OUT						
								IN						
	05:30	1.7	.65	11.8		1.2	1°c	OUT						
								IN						

#10.

$c = C_s \left(\frac{P}{P_s} \right)$

EHV EQUIPMENT FILL RECORD

Substation N. ANNA
Equipment #2 GEN TX
Manufacturer WEST
Serial Number 7002100

Readings to be taken every half hour.

Probe # Oil In N/A
Probe # Oil Out 19652 PR

Date	Time	Trans. Vacuum mm hg	Streamline Vacuum mm hg	OIL OUT Temp. °C	~~KV~~	Flow Meter Reading	TANK TEMP / ~~Remarks~~	IN / OUT	Probe Temp. °C	Probe Reading	Dew Point	P	P_s	C_s
3-29	6:00	2.0	.65		1.2		11.7 / 1°C							
	6:30	2.0	.61		1.2		11.7 / 1°C							
	7:00	2.0	.6		1.3		11.8 / 2°C							
	7:30	1.9	.61		1.3	START OIL	11.8 / 2°C	IN / OUT	7:45 START OIL - TRANS 18.3 hrs vac					
	8:00	1.9	.9	130	1.3	485	16.7 / 4°	OUT	32	.38	-52	.0230	35.363	91
	8:30	2.0	.78	130	1.3	1350	27.4 / 7	OUT	38	.39	-50	.0296	49.092	110
	9:00	2.0	.78	130	1.3	2300	31.4 / 8	OUT	38	.39	-50	.0296	49.692	110
	9:30	1.6	.60	130	1.3	3345	34.6 / 10	OUT	42	.41	-46	.0481	61.50	119
	10:00	1.6	.92	132	1.3	4385	36.1 / 11	OUT	40	.40	-48	.0378	55.324	114
	10:30	1.9	.95	134	1.25	5115	36.6 / 12	OUT	42	.42	-43	.0497?	61.50	119
	11:00	1.8	1.0	136	1.25	6180	35.6 / 12	OUT	48	.43	-42	.0768	83.71	140
	11:30	2.0	.85	134	1.25	7265	35.6 / 13	OUT	50	.45	-38	.1209	94.86	145
	12:00	2.0	.85	138	1.25	8115	33.4 / 14	OUT	51	.43	-40	.0966	97.20	147
	12:30	2.0	.94	176	1.15	9248	30.21 / 15	OUT	56	.47	-37	.1876	123.80	163
	13:00			138	[illegible]	9580								

28/MA 2 07:00

(INTO Tx)

#1.) A.) OIL OUT OF M.P.P. = 166°F.

b.) OIL IN (RETURNING TO M.O.P.P.) = 110°F.

c.) WINDING TEMP GAUGE INDICATING 78°C (OR 172.4°F)

d.) AMBIENT TEMP 24° F

e.) WIND CHILL FACTOR = APPROX 4°F

f.) DEW POINT RANGE ON N_2 = -47° TO -51°

g.) REQUIRED 5⅔ CYLINDERS OF N_2 TO FOLLOW OIL OUT AND PLACE 1 PSI + N_2 PRESS ON Tx

208

START VACUUM

#1.) a) COOLER VALVES OPENED

b.) 1 P.S.I. + N_2 PRESS. NO OIL IN TX

c.) WINDING TEMP. GAUGE INDICATING 40° C.

d.) LIQUID TEMP. GAUGE INDICATING 36° C.

e) OIL BEING CIRCULATED BETWEEN TANKERS WITH G.E. BLOTTER PRESS for duration of VACUUM TIME

#2.) a) TX VACUUM TAKEN w/ McLEOD GAUGE

b.) MOPP. VACUUM TAKEN w/ PENWALT/STOKES VACUUM TUBE GAUGE

#3.) A.) R/M McCLEOD GAUGE

b.) INSTALL STOKES RECORDING VACUUM TUBE GAUGE

C.) INSTALL THERMOMETER ON TX TANK

1340

EHV EQUIPMENT FILL RECORD

Substation N. Anna
Equipment A4
Manufacturer WEST
Serial Number 7001965

Readings to be taken every half hour.

Probe # Oil In
Probe # Oil Out

7-28-82

Date	Time	Trans. Vacuum mm hg	Streamline Vacuum mm hg	OIL OUT Temp. °C	OIL OUT KV	Flow Meter Reading	Remarks		Probe Temp. °C	Probe Reading	Dew Point	P	P_s	C_s	P
7-28	1135						START VAC	IN / OUT							
	1200	60	TEST	OK			LEAK TEST	IN / OUT							
	1230						HOLD	IN / OUT							
	1300	.2					16 hrs	IN / OUT							
	1330	.4						IN / OUT							
	1400	.45						IN / OUT							
	1430	.3						IN / OUT							
	1500	.35						IN / OUT							
	1530	.40						IN / OUT							
	1600	.40						IN / OUT							
	1630	.45						IN / OUT							
	1700	.45						IN / OUT							
	1730	.50						IN / OUT							
	1800	.55						IN / OUT							
	1830	.55						IN							

2 of 4

EHV EQUIPMENT FILL RECORD

211

Substation N.A.P.S.
Equipment A¢
Manufacturer WEST
Serial Number 7001965

Readings to be taken every half hour.

Probe # Oil In ______________
Probe # Oil Out ______________

Date	Time	Trans. Vacuum mm hg	Streamline Vacuum mm hg	OIL OUT Temp. °C	OIL OUT KV	Flow Meter Reading	Remarks		Probe Temp. °C	Probe Reading	Dew Point	P	P_s	C_s	P
7-28	1900	.70						IN / OUT							
	1930	.75						IN / OUT							
	2000	.75						IN / OUT							
	2030	.75						IN / OUT							
	2100	.85						IN / OUT							
	2130	.8[illegible]						IN / OUT							
	2200	.80						IN / OUT							
	2230	.80						IN / OUT							
	2300	.90						IN / OUT							
	2330	.85						IN / OUT							
	2400	.85						IN / OUT							
	0030	.9						IN / OUT							
	100	.8[illegible]						IN / OUT							
	130	[illegible]						IN / OUT							
	200	.9						IN							

212

EHV EQUIPMENT FILL RECORD

Substation N. Anna
Equipment A? G.S.U. TX
Manufacturer West
Serial Number 7001?

Readings to be taken every half hour.

Probe # Oil In
Probe # Oil Out 41289 - PR

Date	Time	Trans. Vacuum mm hg	Streamline Vacuum mm hg	OIL OUT Temp. °C	OIL OUT KV	Flow Meter Reading	Remarks		Probe Temp. °C	Probe Reading	Dew Point	P	P_s	C_s	PP?
	230	.9						IN / OUT							
	300	.9						IN / OUT							
	330	.72						IN / OUT							
	400	.75						IN / OUT							
	430	1.0				[illegible]	[illegible]	IN / OUT	22	.83	-5	3.013	22.377	69	2.2
	500	1.0	[illegible]			[illegible] 5:09	START OIL	IN / OUT							
	530	1.1	0.7	148	35	510		IN / OUT	22	.52	-21	.705	19.822	65	[illegible]
	600	1.1	0.75	154	35	1375		IN / OUT	20	.51	-21	.705	18[illegible]	[illegible]	[illegible]
	630	1.1	.07	149		2000		IN / OUT	22	.57	-18	.937	35.463	91	2.
	700	1.05	.07	156	35	2580		IN / OUT	20	.54	-19	.854	17.535	61	2.
	730	1.05	.07	141	35	3285		IN / OUT	20	.54	-19	.854	17.535	61	2.
	800	1.08	.07	142		4035		IN / OUT	20	.53	-20	.776	17.535	61	2.
	830	1.05	.07	144		4745		IN / OUT	20	.53	-20	.776	17.535	61	[illegible]
	900	1.1	.07	144		5700		IN / OUT	22	.53	-20	.705	17.535	65	2.
	930	1.08	.08	148		6000		IN / OUT	2[illegible]	.53	-20	.705	17.535	65	2.

25 - 16 3/8"
10 - 1"

16.375
3.5

EHV EQUIPMENT FILL RECORD

Sheet 4 of 4

Substation N.A.P. S
Equipment A Ø TX
Manufacturer WEST
Serial Number 7001405

Readings to be taken every half hour.

Probe # Oil In
Probe # Oil Out 41289 P2

TOTAL TIME 24.1 hrs

Date	Time	Trans. Vacuum mm hg	Streamline Vacuum mm hg	OIL OUT Temp. °C	OIL OUT KV	Flow Meter Reading	Remarks		Probe Temp. °C	Probe Reading	Dew Point	P	P_s	C_s	P
								IN							
	1000	1.0	.08	144		7100		OUT	21	.53	20	.776	17.535	61	2
								IN							
	1030	1.0	.85	144	35	8300		OUT	20	[illegible]	[illegible]	.776	17.535	61	
								IN							
	1100							OUT							
								IN							
	1133	1.0	.85	148		9420		OUT	28	.54					
								IN							
								OUT							
								IN							
								OUT							
								IN							
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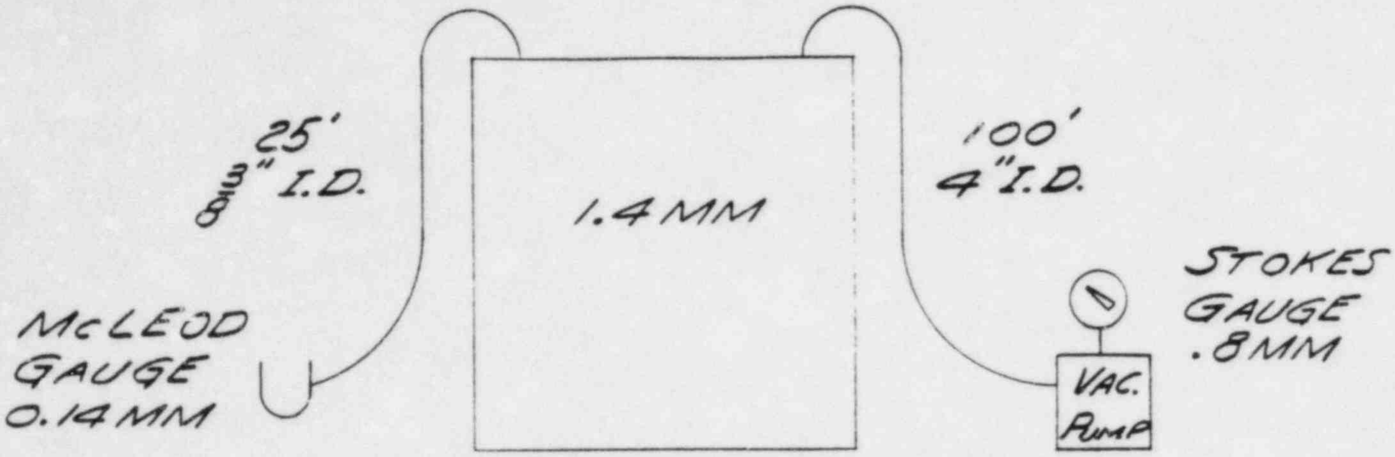
								OUT							
								IN							
								OUT							

APPENDIX D

TRANSFORMER REPORT ON EVENTS AT N. ANNA POWER STATION

Calculation of Tank Pressure - HAM707



The single phase transformer, HAM707, (retrofitted with a COPS unit) was evacuated to prepare for vacuum filling. During this process, two pressure readings were taken (1) at the vacuum pump and (2) by a McLeod gauge separated from the tank cover by approximately 25 ft. of 3/8 inch I.D. tubing. The question has been raised, what is the total pressure within the tank.

Conditions at the end of evacuation prior to oil filling were:

1. Pressure at pump, .8 mm. This is assumed to be a total pressure reading.
2. Pressure measured by McLeod gauge, .14 mm.
3. Ambient temperature assumed to be approximately 60°F.

Since the McLeod gauge records the partial pressure of the non condensables, the pressure within the tank can be calculated by the following equation.

$$P_1 = P_a + P_o + H_w$$

where

P_1 = Total pressure, mm

P_a = Partial pressure of air, mm

P_o = Partial pressure of oil, mm

P_w = Partial pressure of water, mm

At 60°F, the partial pressure of oil is negligible, therefore,

1382E

$$P_1 = P_a + P_w$$

The internal pressure within the tank is determined by applying standard formulas and graphs used in vacuum technology. (Copies of pertinent pages from the Stokes Bulletin 526 and 518-B are attached.)

From the Table on page 12, the conductance of a 100 ft. length of 4 inch diameter pipe is:

$$C = 9 \times 4 \times 800 / 26 = 1108 \text{ CFM}$$

Mass flow, Q, in mm - CFM is defined as

$$Q = \Delta P \times C = (P_1 - P_2) \times C, \text{ mm - CFM}$$

or

$$P_1 = \frac{Q}{C} + P_2, \text{ mm}$$

For a 1300 CFM blower, similar to the Stokes Model 1721, the pumping speed, S, is 840 CFM (see page 6 from Bulletin 518-B). The value of Q can be evaluated the pump itself.

$$Q = P_2 \times S$$

$$= 840 \times .8 = 672 \text{ mm - CFM}$$

Finally, the total pressure is

$$P_1 = \frac{672}{1108} + .8 = 1.4 \text{ mm}$$

and partial pressure of water

$$P_w = P_1 - P_a = 1.4 - .14 = 1.26 \text{ mm}$$

P. L. Thiel
Development Engineer

PENNWALT

Bulletin 518-B

STOKES® Vacuum Equipment

Stokes Vacuum Components Department, Pennwalt Corporation
5500 Tabor Road, Philadelphia, Pa. 19120 • 215-289-0100

The Complete Line of High-Performance Mechanical Booster Vacuum Pumps

multi-stage, high-speed mechanical booster pumps give more pumping performance per dollar

STOKES OFFERS A COMPLETE LINE OF MECHANICAL BOOSTER VACUUM PUMPS FOR YOUR SYSTEM REQUIREMENTS

The specifications detailed at the right, and the pumping performance curves on page 6 cover the eleven standard models which are most widely used. Stokes Advisory Service is available to help you select the correct model, or to determine the need for special models or modifications to match your requirements.

... 1722

Model 1..1

MODEL NUMBER	1718	1728	1730	1730 MB	1730 HC	1721	1721 MB
Displacement							
1st Stage Blower, cfm	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2nd Stage Blower, cfm	—	—	—	208	—	—	208
Microvac Forepump, cfm	50	80	150	150	300	150	150
Normal Cut-In Pressure, Torr	15	25	30	35	90	15	20
Pressure Limit for Continuous Operation, Torr	5	10	15	15	40	3	3
Drive							
1st Stage, hp	3	3	3	3	3	7½	7½
2nd Stage, hp	—	—	—	3	—	—	2
3rd Stage, hp	2	3	5	5	10	5	
Connections							
Suction Flange	4"	4"	4"	4"	4"	8"	8"
Discharge	1½" IPS	1½" IPS	2" IPS	2" IPS	3" IPS	2" IPS	2" IPS
Water Requirements							
1st Stage, gpm	½	½	½	½	½	½	½
2nd Stage, gpm	—	—	—	Air Cooled	—	—	Air Cooled
Forepump, gpm	Air Cooled	¾	1	1	2	1	1
Electrical Characteristics	Full Controls Su… 460V-3-60 Power With Transformer and 115V Co…						
Oil Requirements							
1st Stage	.8 Pt.	.8 Pt.	.8 Pt.	.8 Pt.	.8 Pt.	5 Pt.	5 Pt.
2nd Stage	—	—	—	.4 Pt.	—	—	.4 Pt.
Forepump	1 Gal.	1.5 Gal.	3 Gal.	3 Gal.	12 Gal.	3 Gal.	3 Gal.
Dimensions*							
Height, In.	43	45	49½	49½	58	51½	51½
Height to inlet, In.	36	36	36	36	36	41	41
Length, In.	48½	48½	48½	62	55	54	68
Width, In.	30	30	30	30	41½	38¾	38¾
Shipping Weight, Lb.	1230	1460	1855	2130	2700	3200	3475
Net Weight, Lb.	1080	1300	1685	1960	2485	2700	2975
Shipped in . . .	1 Pc.	1 Pc.	1 Pc.	1 Pc.	1 Pc.	1 Pc.	1 Pc.

*Dimensions are subject to minor changes. Confirm these prior to con…

Three new series of Mechanical Booster combinations. MB models provide for bla…

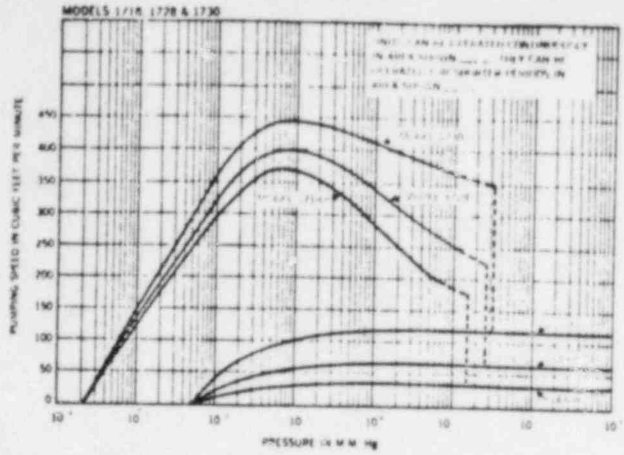
1722	1722 MB	1722 HC	1721-S	1722-S	1722 HCS	1724	1723	1725	1726	1719	1720	1727	1729
—	310	—	—	—	—	—		—	—	—	—	1300	1300
300	300	600	150	300	600	300	300	600	730	600	730	300	300
25	30	75	10	15	60	15	10	10	15	10	15	1st Stage 3.0 2nd Stage 25.0	1st Stag[illegible] 2.0 2nd Stag[illegible] 25.0
15	15	25	2	8	20	1.0	0.8	1.2	1.3	1.0	1.1	0.6	0.45
7½	7½	7½	10	10	10	20	25	30	30	40	40	40	50
—	2	—	—	—	—	—	—	—	—	—	—	7½	7½
10	10	2 @ 10	5	10	2 @ 10	10	10	2 @ 10	30	2 @ 10	30	10	10
8" 3" IPS	8" 3" IPS	8" 3" IPS (2)	8" 2" IPS	8" 3" IPS	8" 3" IPS (2)	8" 3" IPS	10" 3" IPS	12" 3" IPS (2)	12" 5" FLG.	14" 3" IPS (2)	14" 5" FLG.	18" 3" IPS	18" 3" IPS
½	½	½	½	½	½	2	2	2	2	2½	2½	3	3
—	Air Cooled	—	—	—	—	—	—	—	—	—	—	½	½
2	2	4	1	2	4	2	2	4	5	4	5	2	2

...Standard On All Models. Pressure Controls Only Are Optional. All NEMA 12.
...Circuit Is Standard. 230V-3-60 Power Is Optional for 10 HP Motors or Smaller. Special Arrangements Available.

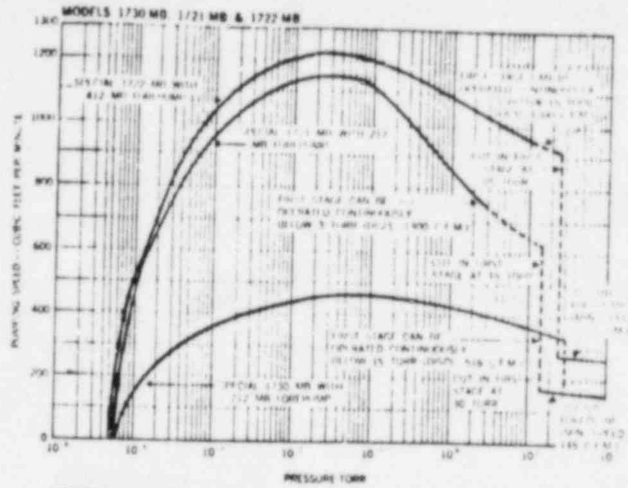
1722	1722 MB	1722 HC	1721-S	1722-S	1722 HCS	1724	1723	1725	1726	1719	1720	1727	1729
5 Pt.	5 Pt.	5 Pt.	5 Pt.	5 Pt.	5 Pt.	5¼ Gal.	5¼ Gal.	5¼ Gal.	5¼ Gal.	7¾ Gal.	7¾ Gal.	10¾ Gal.	15 Gal.
—	.4 Pt.	—	—	—	—	—	—	—			—	5 Pt	5 Pt.
12 Gal.	12 Gal.	24 Gal.	3 Gal.	12 Gal.	24 Gal.	12 Gal.	12 Gal.	24 Gal.	20 Gal.	24 Gal.	20 Gal.	12 Gal.	12 Gal.
58	58	56	51½	58	56	67	67	67	67	78	78	85	76
41	41	41	41	41	41	50	50	50	50	60	60	63	45
55	69	71	54	55	71	72	72	91	99	102	112	126	122
41½	41½	70	38¾	41½	70	46	50	70	57	70	60	71	118
4000	4275	6000	3300	4100	6100	5750	5900	8700	10,400	10,000	11,700	11,900	15,300
3500	3775	5300	2800	3600	5400	5250	5400	7900	9600	9200	10,900	10,900	13,300
1 Pc.	1 Pc.	2 Pcs.	1 Pc.	1 Pc.	2 Pcs.	1 Pc.	1 Pc.	2 Pcs.	2 Pcs.	2 Pcs.	2 Pcs.	2 Pcs.	2 Pcs.

...essures in the 10^{-3} range. HC and HCS series provide for faster and pumpdown capability as compared to standard models.

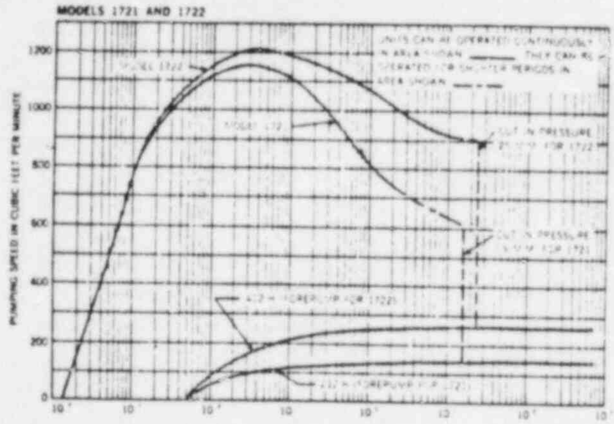
MODELS 1718, 1728 & 1730



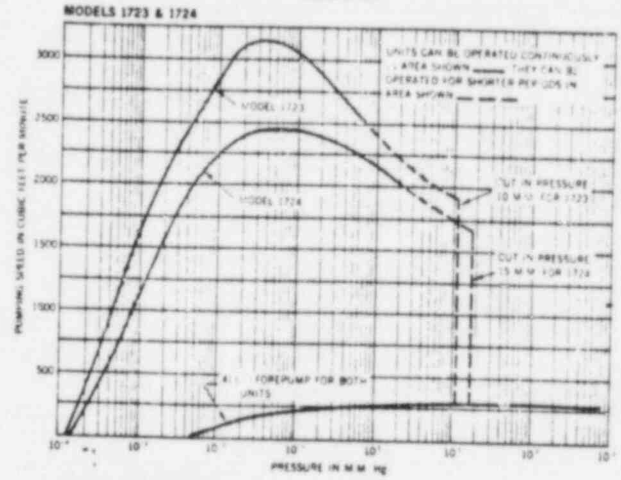
MODELS 1730 MB, 1721 MB & 1722 MB



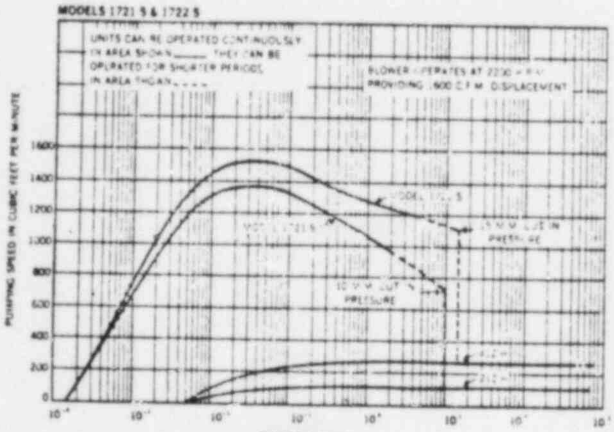
MODELS 1721 AND 1722



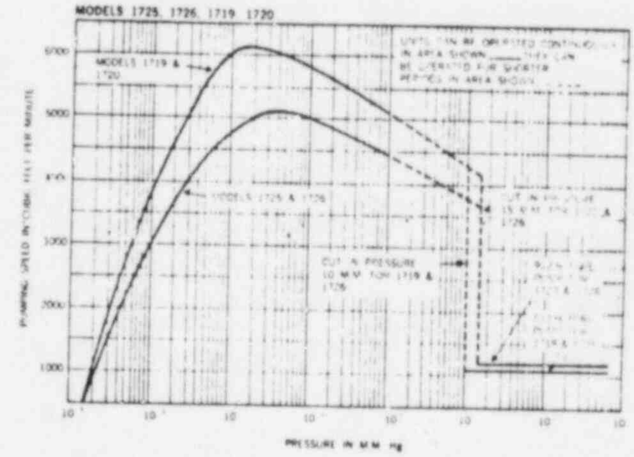
MODELS 1723 & 1724



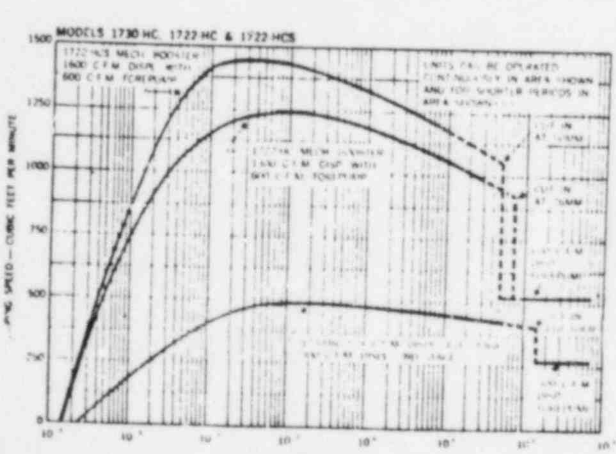
MODELS 1721 S & 1722 S



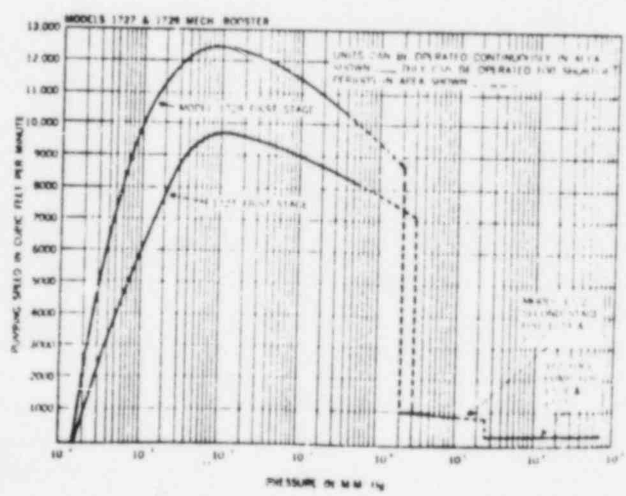
MODELS 1725, 1726, 1719, 1720



MODELS 1730 HC, 1722 HC & 1722 HCS



MODELS 1727 & 1729 MECH. BOOSTER

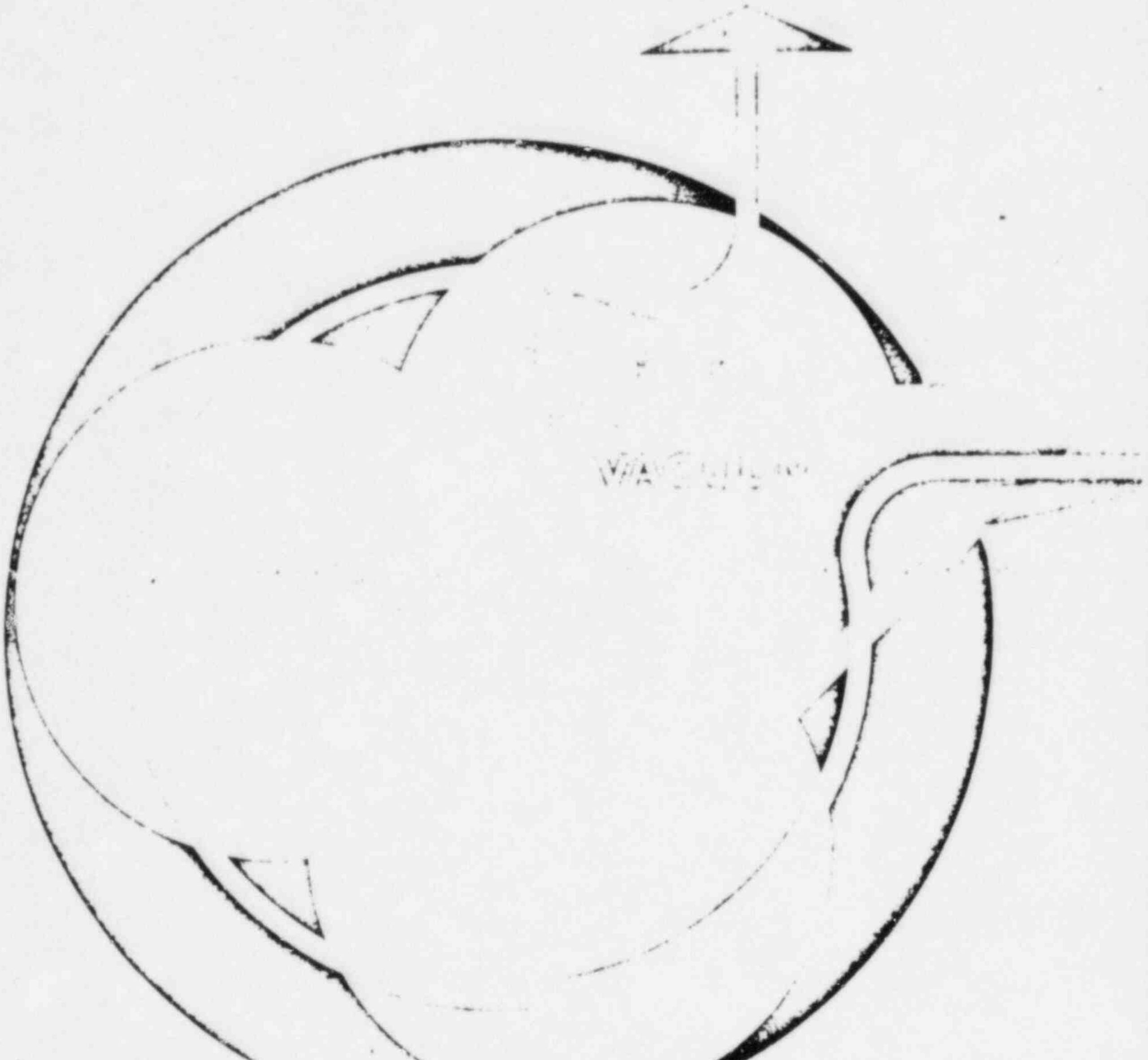


PENNWALT

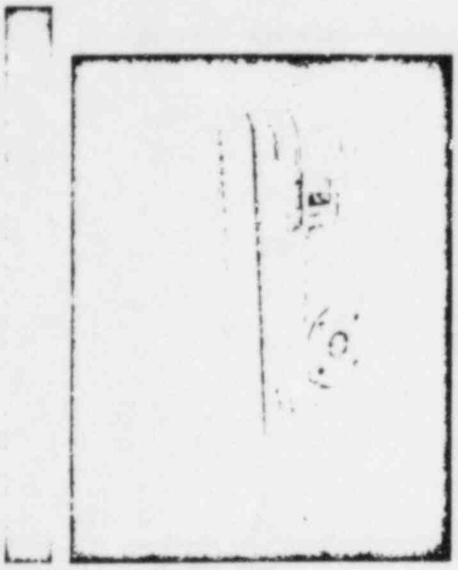
EXCLUSIVE
TWO-YEAR
WARRANTY

STOKES® MICROVAC® PUMPS

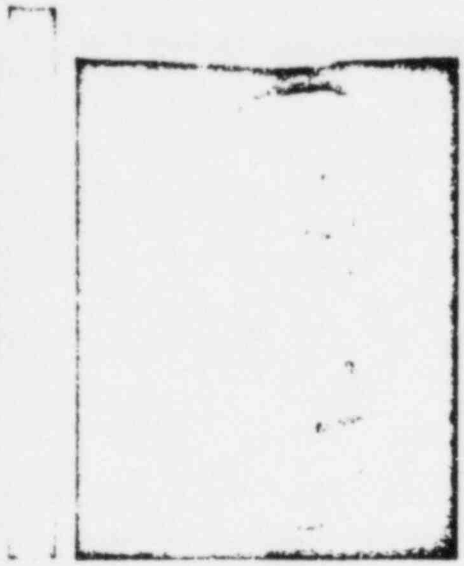
microvac®



WIDE [illegible] MODELS FOR



Model 146H
30 cfm displacement



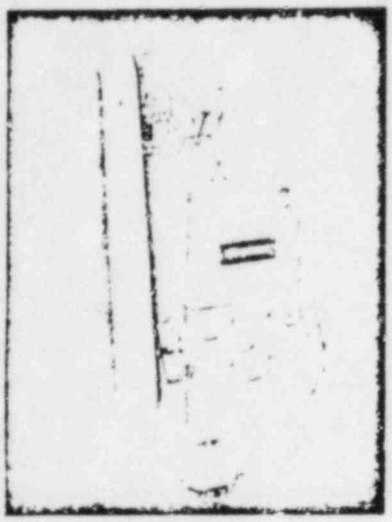
Model 148H
50 cfm displacement

Model 149H
80 cfm displacement

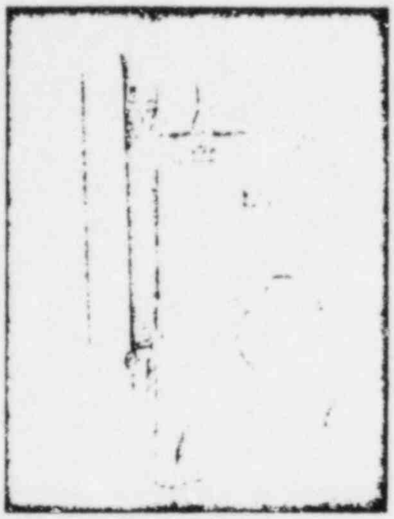
SPECIFICATIONS FOR STOKES MICROVAC PUMPS

	Model 146H	Model 148H	Model 149H	Model 212H	Model 412H	Model 612H	Model 912H
Displacement, Cubic Feet per Min.	30	50	80	150	300	600	728
Pump Speed (RPM)	800	610	[illegible]	490	490	490	438
Motor (HP)	1½	2	[illegible]	5	10	2-10 HP Motors	30
Motor Speed (RPM)	1800	1800	[illegible]	1800	1800	1800	1800
Pipe Connections: Suction	2" FLG.	1½" FLG.	[illegible]	3" FLG.	6" FLG.	6" FLG.	6" FLG.
Discharge	1¼" NPT	1½" NPT	[illegible]	[illegible]" NPT	3" NTP	3" NPT (2)	5" FLG.
Water Inlet	—	—	[illegible]	[illegible]" NPT	½" NPT	½" NPT (2)	1" NPT
Water Outlet	—	—	[illegible]	[illegible]" NPT	½" NPT	½" NPT (2)	1" NPT
Oil Capacity (Gal.)	½	1¼	[illegible]	3	12	24	20
Net Weight (Lbs.)	315	345	[illegible]	950	1750	3800	5500
Shipping Weight (Lbs.)	390	435	[illegible]	1075	1975	4500	6000
Height	30"	33"	[illegible]	43½"	51[illegible]/16"	55⅝/16"	66½"
Floor Space	14¼"x16¾"	17¼"x18⅞"	[illegible]	[illegible]"x30⅛"	22½"x40⅛"	44¾"x70"	42⅞"x50½"
Cooling System	Air	Air	Water	Water	Water	Water	Water
Water Consumption (Max.)	—	—	[illegible]	1½ GPM	2 GPM	4 GPM	5 GPM

ALL APPLICATIONS



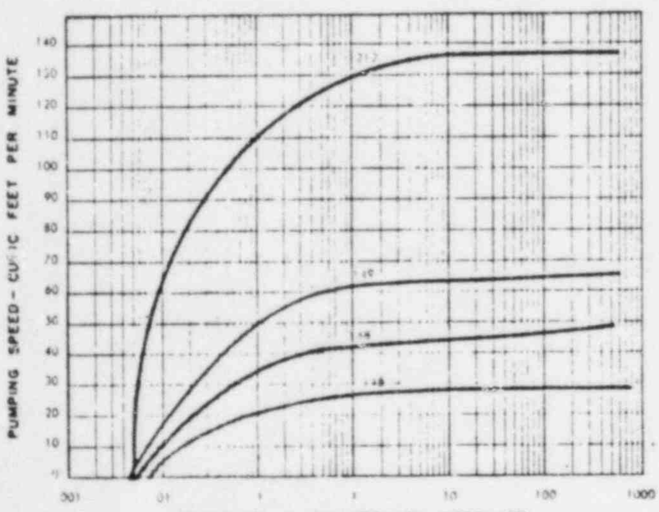
Model 212H
150 cfm displacement

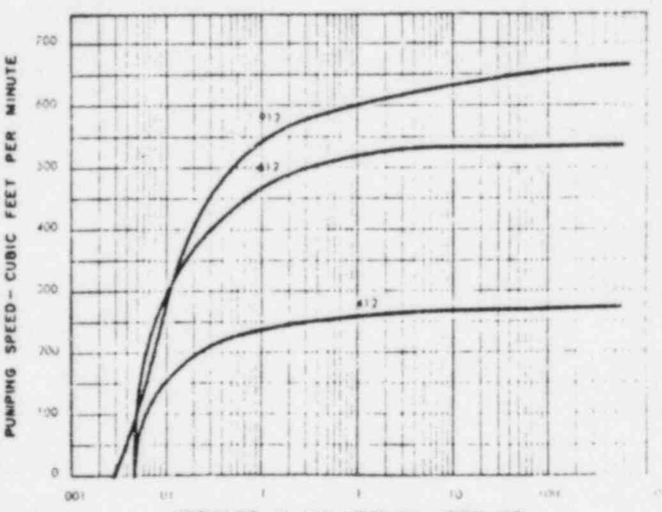


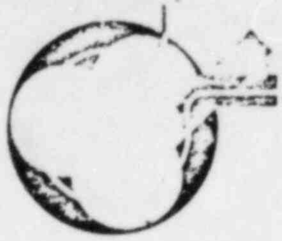
Model 412H
300 cfm displacement

Model 912H
728 cfm displacement

PERFORMANCE CURVES FOR MICROVAC PUMPS



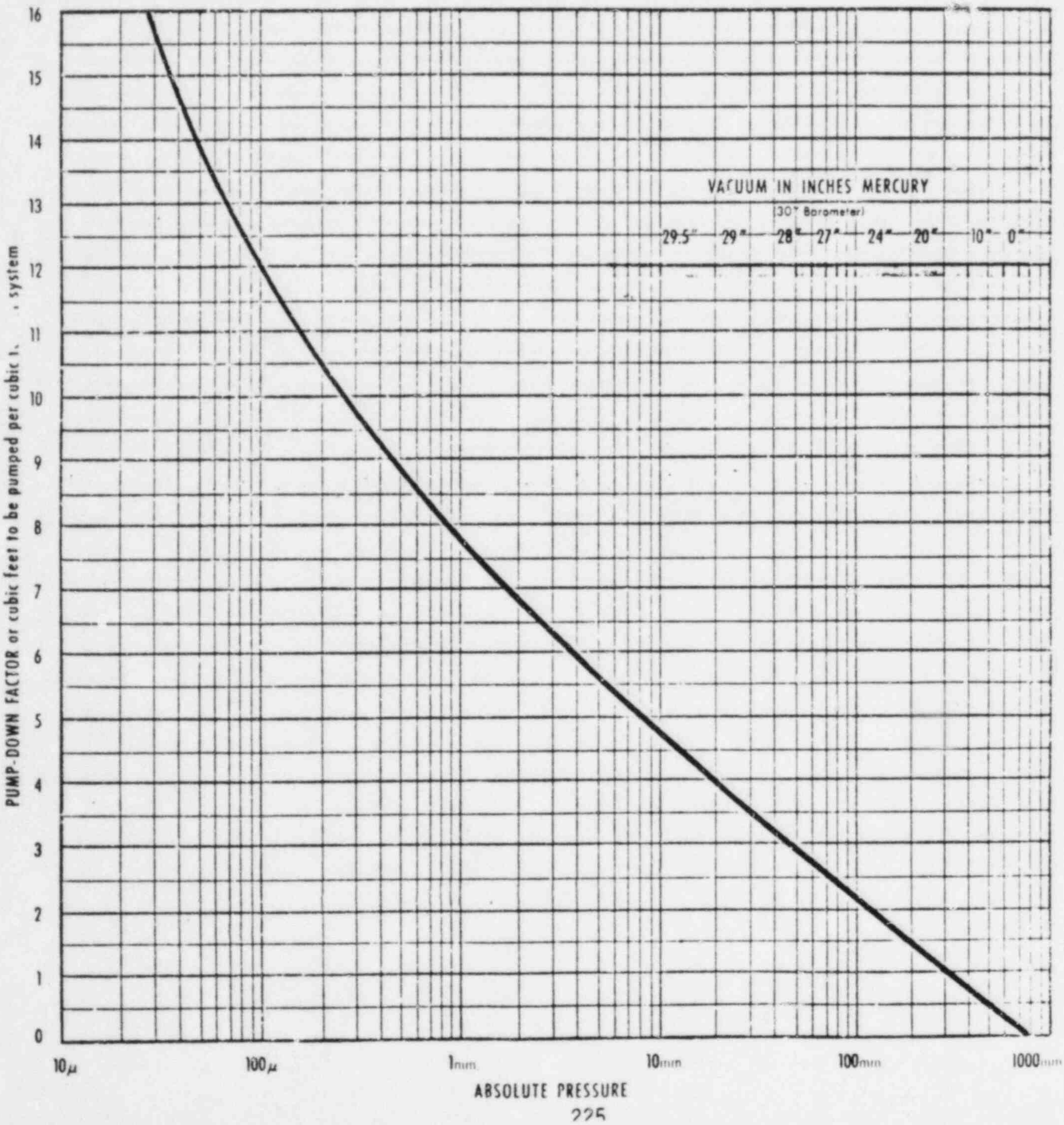




MICROVAC PUMP SELECTION...

The basic functions of a vacuum pump are, first, to remove air from the system until the desired low pressure has been obtained; and second, to maintain this low pressure . . . i.e., to pump out non-condensable vapors or gases resulting from decomposition, vaporization, air inleakage and other sources. The size of the vacuum pump that is most efficient and economical for a given application depends primarily on five factors:

1. Degree of vacuum required.
2. Size of the system.
3. Nature and quantity of vapors and gases to be handled.
4. Pump-down time.
5. Frequency with which the system is pumped down to operating vacuum.



Typical Problems and Their Solutions

When these factors are properly evaluated, it is relatively simple to select the correct Microvac pump and to obtain a system that operates with minimum attention and maintenance. The pump-down graph given here makes it possible to determine rapidly (1) the size of pump required to exhaust a given volume to a specified vacuum in a given time; or (2) the time required to exhaust a given volume to a specified vacuum, when the pump to be used is already available or installed. The problems that can be solved with the aid of this graph vary widely in nature. However, these typical cases illustrate its basic uses.

Determine the Microvac pump that will evacuate a 350 cubic foot vacuum dryer to a pressure of 5 mm in 10 minutes.

From the pump-down graph, we find that to reach 5 mm, there are 5.6 cubic feet to be pumped for every cubic foot of system. Multiplying this factor (5.6) by the number of cubic feet in the system (350), gives the total cubic feet to be pumped (1960). Dividing this by the time (10 minutes) determines the cubic feet per minute to be pumped (196). Microvac pump Model 412, having a displacement of 300 cubic feet per minute, has ample capacity to perform the job.

$$\frac{5.6 \times 350}{10} = 196 \text{ cfm}$$

How long will it take a Model 149 Microvac pump (displacement 80 cfm) to evacuate a 225 cubic foot impregnating tank to a pressure of 450 microns?

From the pump-down graph, we find that at 450 microns, 9.0 cubic feet must be pumped for every cubic foot of system. Dividing the product of the pump-down factor (9.0) and the volume of the system (225 cubic feet) by the displacement of the Microvac pump (80 cfm) gives the time required, 25.3 minutes.

$$\frac{9.0 \times 225}{80} = 25.3 \text{ min.}$$

Determine the Microvac pump that will evacuate refrigeration units having a total volume of 9 cubic feet to a pressure of 100μ in 2 minutes.

From the pump-down graph, we find that at 100μ there are 12.0 cubic feet to be pumped for every cubic foot of system. Multiplying this factor (12.0) by the number of cubic feet in the system (9) gives the total cubic feet to be pumped (108). Dividing this by the time (2) determines the cubic feet per minute to be pumped (54). Microvac pump Model 149, having a displacement of 80 cubic feet per minute, has ample capacity to perform the job.

$$\frac{12.0 \times 9}{2} = 54 \text{ cfm}$$

A vacuum pump must be selected for an altitude test chamber application. The test chamber has a volume of 15 cubic feet and is to be evacuated to 1 mm, raised to 100 mm, and then re-evacuated to 1 mm. The cycling from 100 mm to 1 mm must take place 10 times per hour.

On the assumption that 2 minutes will be required to increase the pressure from 1 mm to 100 mm by controlled air admission, 20 minutes of each hour are used to increase the pressure. This leaves 40 minutes per hour, or 4 minutes per cycle for re-evacuation. From the pump-down graph, we find that 2.12 cubic feet per cubic foot of volume must be pumped to reach 100 mm; and a total of 7.75 cubic feet per foot of volume to reach 1 mm. Subtracting the former from the latter gives the cubic feet to be pumped per cubic foot of system (5.63) to reduce the pressure from 100 mm to 1 mm. Multiplying this by the volume of the tank gives the total cubic feet to be pumped (84.5). Dividing this by the number of minutes in the re-evacuation cycle (4) gives the cubic feet per minute to be pumped as 21.1. Microvac Model 148, having a displacement of 38 cfm, will do the job.

$$7.75 - 2.12 = 5.63$$

$$\frac{5.63 \times 15}{4} = 21.1 \text{ cfm}$$

VACUUM PROBLEMS AND THEIR SOLUTIONS

The formulas, graphs, constants, conversion factors and other data provided on the following pages can be used to solve a wide variety of vacuum problems. These examples illustrate the solutions of some typical ones. In each case, it is assumed that the chamber is clean, dry, empty and leak-free.

Calculate the net pumping speed of a vacuum system consisting of a Model 212 Microvac pump (displacement 140 cfm) connected to a tank through 30 feet of 3-inch pipe. The system is operating at a pressure of 250 microns.

From the Conductance Chart on page 12, the conductance of the pipe can be calculated using the method described above the chart. This is found to be 334.6 cubic feet per minute.

$$C_{chart} = 11.6 \text{ cfm}$$

$$C = \frac{11.6 \times 3 \times 250}{26} = 334.6 \text{ cfm}$$

The pumping speed of the Model 212 Microvac pump at 250 microns can be determined from the performance curve on page 7. At this pressure, the pumping speed is 115 cfm. Using the formula on page 11 for the conductance of the vacuum system, the net conductance is determined as follows:

$$\frac{1}{S} = \frac{1}{115} + \frac{1}{334.6}$$

$$S = 86 \text{ cfm}$$

How long will it take to remove 1.5 pounds of water from a product at an average pressure of 5 mm. using a Stokes 412-H Microvac pump (displacement 300 cfm), assuming that heat input to the drying product is sufficient to maintain the vapor pressure at 5 mm.?

In this case, water is being removed in the form of vapor which will condense in the pump oil and affect the vacuum attainable unless the water is removed. All Microvac pumps have gas ballast to remove water vapor. Assuming that this will prevent oil contamination, proceed with solution.

From chart on page 13 showing the volume of 1 pound of water at various pressures, the volume of 1 pound of water at 5 mm. is 3250 cu. ft. Therefore, 1.5 pounds will have a volume of 4875 cu. ft. at 5 mm. Dividing this by the net speed of the 412-H pump (per performance curve page 7), 265 cfm, time required = 18.3 minutes, assuming piping is adequately sized and disregarding time required to pump down to 5 mm. initially.

$$t = \frac{4875}{265} = 18.3 \text{ min.}$$

At 5 mm., the use of full gas ballast does not affect pumping speed of the 412-H Microvac pump appreciably, and permits handling up to 7 pounds of water per hour. Only 1.5 pounds of water is handled in 18.3 minutes, so the 412-H operating with full gas ballast is satisfactory.

A vacuum system is found by test to have a leak rate resulting in a pressure rise of 1 mm. Hg per hour. The volume of the vacuum system is known to be 200 cubic feet. How large a pump will be required to maintain a pressure of 100 microns within the system with this leak rate?

The tank volume is 200 cu. ft. and the observed pressure rise is 1000μ (1 mm.) per hour. This is a mass of 200,000μ cu. ft. per hour, or 3300μ cu. ft./min. To handle this at a pressure of 100μ requires a pump having a net speed at this pressure of 33 cu. ft. per minute.

$$s = \frac{3300\mu \text{ cu. ft./min.}}{100\mu} = 33 \text{ cu. ft./min.}$$

The speed of a 149-H Stokes Microvac pump (displacement 89 cfm) at 100μ is 51 cfm. Thus, a 149-H pump is entirely adequate.

In a low-temperature drying system the condenser has a minimum temperature of −45° F. Assuming that a minimum of 10° temperature differential between the product and the condenser surface is required (product temp. ≈ −35° F.), what is the minimum pressure at which the product can be dried efficiently?

It will be seen from the vapor pressure and temperature chart on page 13 that at −35° F. the vapor pressure of water is 140 microns. Operating at this pressure will be satisfactory to maintain efficient drying.

In a vacuum impregnation system it is found necessary to determine whether or not the piping system will seriously affect the pump-down time. The tank has a capacity of 250 cubic feet and is connected to a Stokes 412-H Microvac pump (displacement 300 cfm) by 25 feet of 3″ pipe. The final operating pressure is 1 mm.

As can be seen from the formula for the conductance of a vacuum system on page 11, it is obvious that if the conductance of the piping is sufficiently greater than the pumping speed of the pump, it will have no appreciable effect on the net pumping speed of the system. From the conductance chart on page 12, using the conversion factors in the mechanical pump range, the conductance of the piping system can be determined.

$$C_{chart} = 14 \text{ cfm}$$

$$C = \frac{14 \times 3 \times 1000}{26} = 1615 \text{ cfm}$$

This figure is sufficiently greater than the speed of the pump (260 cfm at 1 mm. from performance curve on page 7) so that it will have only a slight effect on the net pumping speed of the system, as can be seen from the calculation of the net pumping speed.

$$\frac{1}{S} = \frac{1}{260} + \frac{1}{1615}$$

$$S = 223 \text{ cfm}$$

At higher pressures the conductance of the piping would be greatly increased and thus have correspondingly less effect; or if pipe size is increased, the effect also will be less.

A manufacturer wishes to remove and recover benzene solvent from his final product. Tests show that the final product will discolor if heated above 123° F. The solvent cannot be extracted at atmospheric pressure, for at this pressure a temperature of 176° F. is required. The plant has cooling water available at a maximum summer temperature of 80° F. Under what vacuum conditions should he operate?

The solvent vapors must be condensed with 80° F. cooling water; therefore, it is easily seen from the graph of Boiling Points of Solvents Under Vacuum (page 13) that the vacuum cannot be higher than 26.25 in. Hg. If a vacuum of 22 in. Hg is used, the benzene will boil at 110° F. This is sufficiently below the 123° F. limiting temperature for satisfactory operation and yet high enough to produce a sufficient temperature differential in the condenser; thus the solvent vapors will readily condense.

VACUUM FORMULAS, CONSTANTS AND CONVERSION FACTORS

Rate of flow of air through an orifice.

For air at 20°C in diffusion pump range

$S = 158A$

For air at 20°C in mechanical pump range

$$W = \frac{.533 \times C_v \times A \times P_1 \times 60}{\sqrt{R}} = 1.39\ A\ P_1 \text{ pounds per min.}$$

$$S = W \times 13.3 \frac{Pa}{P_1}$$

.533 = Critical P_R Ratio
A = Sq. in. of orifice
Pa = Atmospheric Pressure—psia
P_1 = P_1 Upstream Pressure—psia
C_v = Orifice Coefficient (Assumed as 1)

$$\sqrt{R} = \sqrt{\text{Degrees Rankine}} = \sqrt{°F + 460} = 23$$

S = Speed = cu. ft./min @ P_1

Rate of flow of gases through a tube.

$$Q = \frac{4}{3}\sqrt{2\pi}\ \sqrt{\frac{RT}{M}}\ \frac{r^3}{L}\ (P_1 - P_2)$$

Q = Mass flow in micron-liters per second
R = gas constant = 83.1
T = absolute temperature
M = molecular weight
r = inside radius of tube in cm.
L = length of tube in cm.
P_1 = initial pressure microns
P_2 = final pressure microns

From Knudsen's Equation above the following rule-of-thumb equations have been derived for calculating conductance in various pressure ranges of air at 20°C.

(a) Diffusion pump range, where there is molecular flow and when pressure in microns multiplied by diameter in inches is less than 7.

$$C = 13 \frac{D^3 \text{ inches}}{L \text{ (feet)}}$$

(b) Intermediate range, where pressure in microns multiplied by diameter is greater than 7 and less than 220.

$$C = 0.5 \frac{D^4}{L} \bar{P} + 11 \frac{D^3}{L}$$

(c) Mechanical pump range, where pressure times diameter is greater than 220.

$$C = .5 \frac{D^4}{L} \bar{P}$$

C = conductance in c.f.m.
D = diameter in inches
L = length in feet

$$\bar{P} = \text{Mean pressure in microns} = \frac{P_1 + P_2}{2}$$

P_1 = Upstream pressure in microns
P_2 = Downstream pressure in microns

Conductance of vacuum system

$$\frac{1}{S} = \frac{1}{S_p} + \frac{1}{C}$$

S = Net pumping speed in cfm
S_p = Speed of pump in cfm
C = Conductance of piping in cfm

Calculating "pump-down" time

(Chart on page 8 is derived from this and includes system factors*)

$$T = \frac{V}{S}$$

T = Time in minutes
V = Cubic feet to be pumped to reach final pressure
S = Speed of pump in cfm

$$V = V_o \log_e \frac{P_o}{P}$$

V = Cubic feet to be pumped to reach final pressure P
V_o = Volume of system
P_o = Initial pressure in mm.
P = Final pressure in system in mm.

*Adequate system factors should be included.

Calculation of velocity of molecules

Average velocity

$$\Omega = \sqrt{\frac{8RT}{\pi M}} = 14{,}551 \sqrt{\frac{T}{M}} \text{ Cm. per sec.}$$

Most probable velocity

$$W = \sqrt{\frac{2RT}{M}} = 12{,}900 \sqrt{\frac{T}{M}} \text{ Cm. per sec.}$$

Where
R = Gas Constant = 8.315 x 10^7 ergs per Mole °K
T = Absolute Temperature, °K
M = Molecular weight

Calculation of mean free path

$$L = 8.524\ \frac{\eta}{P} \sqrt{\frac{T}{M}} \text{ Cm.}$$

P = Pressure in mm.
η = Viscosity in c.g.s. units
T = Absolute Temperature
M = Molecular weight
Ω = Average velocity

Mass of gas striking unit area per unit time

$$m = 58.32 \times 10^{-3}\ P \sqrt{\frac{M}{T}} \text{ gm per Cm.}^2 \text{ per sec.}$$

M = Molecular weight
P = Pressure in mm.
T = Absolute Temperature

Conversion factors for "pumping speed" in various units

To convert from	*To*	*Multiply by*
Cubic cm/sec.	Cubic ft./min.	0.0021
Liters/sec.	Cubic ft./min.	2.12
Cubic meter/hr.	Cubic ft./min.	0.589
Cubic ft./min.	Liters/sec.	0.4719
Cubic ft./min.	Cubic meter/hr.	1.699

Calculation of velocity of molecules.

1 micron (μ) Hg	= 1 millitorr
1 micron (μ) Hg	= 0.001 mm Hg = 10^{-3} mm Hg
1 micron (μ) Hg	= 1.33 dynes per sq. cm.
1 μ μ mercury	= 0.000001 mm Hg = 10^{-6} mm Hg
1 μ μ mercury	= 1.33 X 10^{-3} dynes per sq. cm.
1 millibar (International)	= 0.75 mm Hg
1 bar (International)	= 750 mm Hg = 29.53 in. Hg
1 millitorr	= 1 micron (μ) Hg
1 millimeter Hg	= 1 Torr
1 millimeter Hg	= 1000 microns = 10^3 microns
1 millimeter Hg	= 1333 dynes per sq. cm.
1 millimeter Hg	= 1.33 millibar
1 millimeter Hg	= 0.0013 bar
1 millimeter Hg	= 0.03937 in. Hg
1 millimeter Hg	= 0.01934 lbs. per sq. inch
750 millimeters Hg	= 10^6 dynes per sq. cm. = 1 megabar

(All at 0°C., and g = 980.6)

1 inch Hg @ 32°F.	= 0.4912 lbs. per sq. inch
1 inch Hg @ 58.4°F.	= 0.4898 lbs. per sq. inch
29.921 inches Hg @ 32°F.	= 14.696 lbs. per sq. inch = 760 mm Hg
30.000 inches Hg @ 58.4°F.	= 14.696 lbs. per sq. inch = 762 mm Hg
1 atmosphere	= 760 mm Hg = 14.7 lbs. per sq. inch
1 lb. per sq. inch	= 2.036 in. Hg @ 32°F. = 51.72 mm Hg
1 lb. per sq. inch	= 2.041 in. Hg @ 58.4°F. = 51.85 mm Hg
1 bar (England)	= 10^6 dynes per sq. cm. = 750 mm Hg
1 microbar (England)	= 1 dyne per sq. cm.
1 microbar (England)	= 0.00075 mm = .75 X 10^{-3} mm Hg
1 bar or barye	= 0.00075 mm = .75 X 10^{-3} mm Hg
1 Torr	= 1 millimeter Hg

CONDUCTANCE OF PIPES FOR AIR FLOW

This graph can be used to determine the conductance of a pipe in the diffusion pump range. In the intermediate range, use formula (b) on page 11. In the mechanical pump range, the conductance can be calculated by determining the conductance from the graph and multiplying it by the diameter of the pipe in inches and the pressure in microns divided by 26.

$$C = \frac{C_{chart} \times d \times p}{26}$$

EXAMPLE

Calculate the conductance of a 1" pipe 25 feet long at 1 mm. The conductance from the graph is .52 cfm. Multiplying this by the diameter (1") and the pressure in microns (1000) and dividing by 26 gives a conductance of approximately 20 cubic feet per minute.

$$C_{chart} = 0.52 \text{ cfm}$$

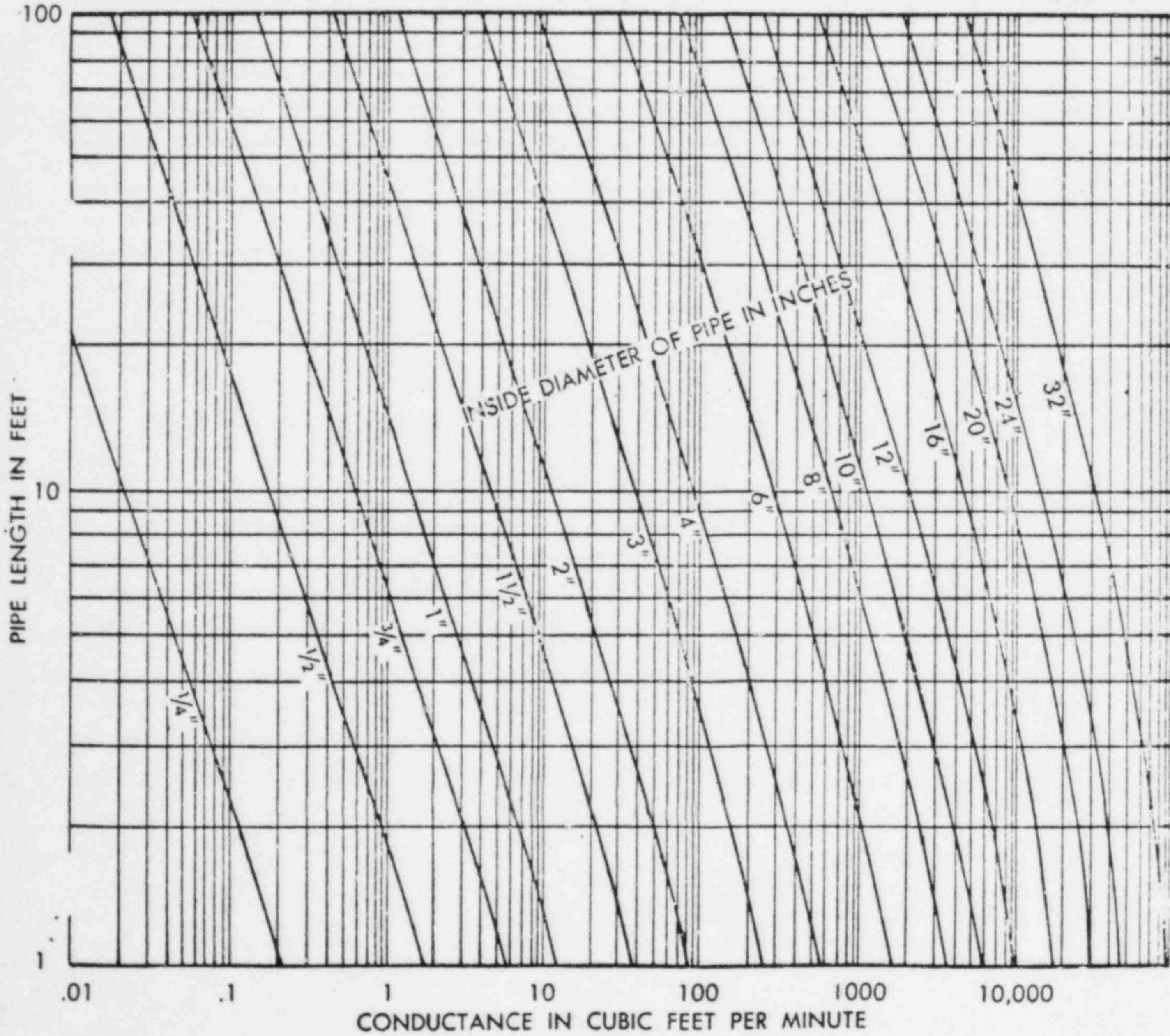
$$C = \frac{0.52 \times 1 \times 1000}{26} = 20 \text{ cfm}$$

Calculate the conductance of a 3" pipe 40 feet long at 160μ. The conductance from the graph is 9 cfm. Multiplying this by the diameter (3") and the pressure in microns (160) and dividing by 26 gives a conductance of approx. 166 cfm.

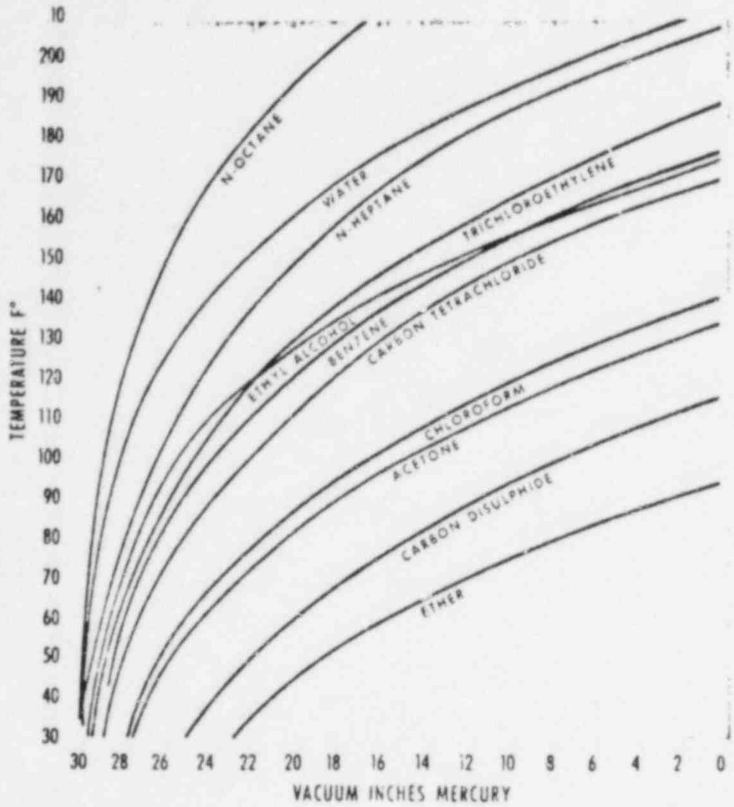
$$C_{chart} = 9.0 \text{ cfm}$$

$$C = \frac{9.0 \times 3 \times 160}{26} = 166 \text{ cfm}$$

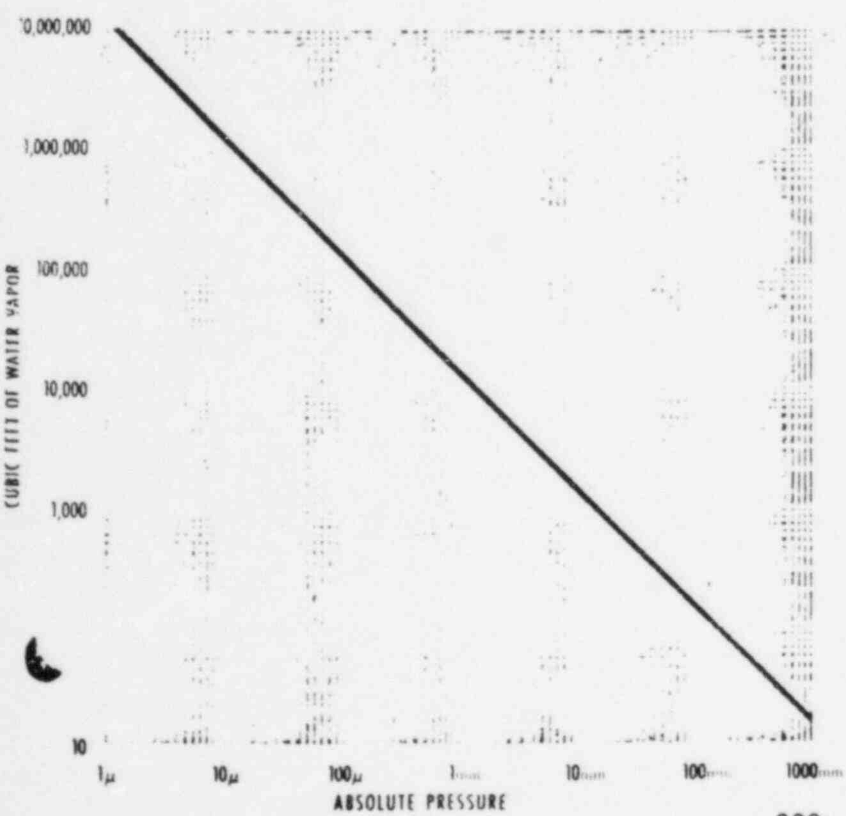
For other examples using the conductance chart, see page 10.



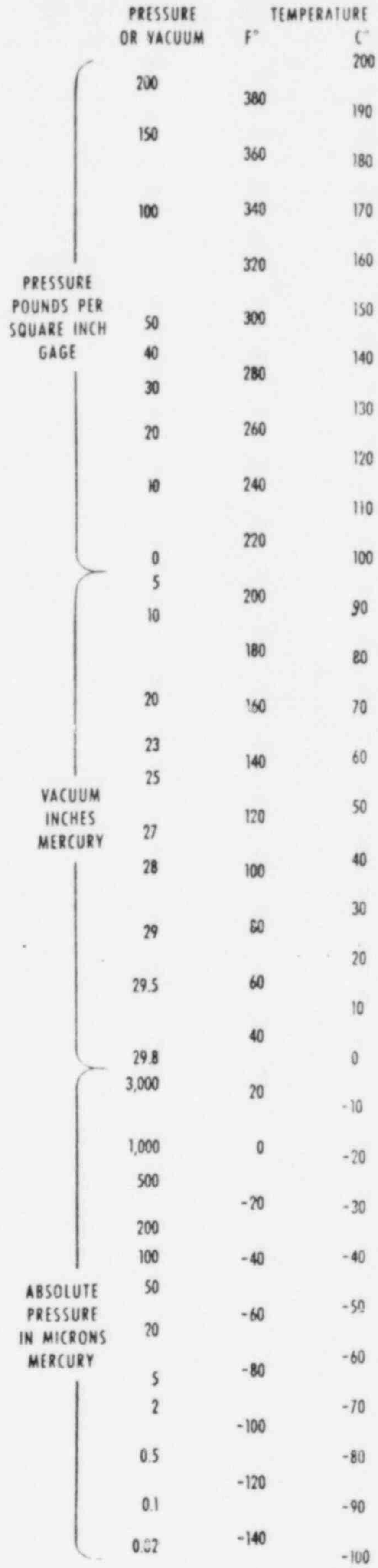
BOILING POINTS OF SOLVENTS UNDER VACUUM



VOLUME OF POUND OF WATER VAPOR UNDER VACUUM at 20° C.



VAPOR PRESSURE OF WATER AT VARIOUS TEMPERATURES



APPENDIX E

TRANSFORMER REPORT ON EVENTS AT N. ANNA POWER STATION

WESTINGHOUSE ELECTRIC CORPORATION
LARGE POWER TRANSFORMER DIVISION

TRANSFORMER OIL TEST REPORT

Customer: VEPCO
Location: North Anna #1
Sample I.D.: McGraw #1 GSU Lab No.: 146, 147

G.O.:
Transformer Shop Order:
Transformer Serial No.: C-0-6459-5-1

	TOP	BOTTOM
Dielectric Strength, KV		
DISC Electrode:		
VDE Electrode:		
Power Factor, % 60 Hz @ 25°C:	0.0112	0.0086
Interfacial Tension Dynes Per CM:	39.0	39.8
Neutralization Number, KOH Per Gram:		
Color:		
Moisture Content, PPM:	5.5	6.1

I hereby certify the above report is a time record taken from laboratory tests in accordance with current Westinghouse and/or ASTM methods.

T. V. Oommen 1-14-83
Engineer Date

E. M. Polin 1-17-83
Manager Date

0026S

WESTINGHOUSE ELECTRIC CORPORATION
LARGE POWER TRANSFORMER DIVISION

TRANSFORMER GAS-IN-OIL ANALYSIS REPORT

Customer: VEPCO
Location: North Anna #1
Sample I.D.: McGraw #1 GSU Lab No.:

G.O.:
Transformer Shop Order:
Transformer Serial No.: C-0-6459-5-1

Date Sampled:

Gas	TOP PPM GAS IN OIL	BOTTOM PPM GAS IN OIL	PPM GAS IN OIL
Nitrogen, N_2	21657 (91%)	11363 (98%)	
Oxygen, O_2	2112 (9%)	275 (2%)	
Carbon Dioxide, CO_2	75	67	
*Carbon Monoxide, CO	16	15	
*Hydrogen, H_2	1	1	
*Methane, CH_4	2	2	
*Ethane, C_2H_6	1	1	
*Ethylene, C_2H_4	0	0	
*Acetylene	0	0	
Other:			
*Total Combustibles	20	19	
Total Gas In Oil (Note: 1% = 10,000 PPM)	2.39 %	1.17 %	%

Remarks:

I hereby certify the above report is a true record taken from laboratory tests in accordance with current Westinghouse and/or ASTM methods.

T. V. Oommen 1-14-83
Engineer Date

[illegible] 1-17-[illegible]
Manager Date

0025S

WESTINGHOUSE ELECTRIC CORPORATION
LARGE POWER TRANSFORMER DIVISION

TRANSFORMER OIL TEST REPORT

Customer: VEPCO
Location: North Anna #1
Sample I.D.: WH #1 GSU   Lab No.: CS-148 / 149

G.O.:
Transformer Shop Order: HAM707
Transformer Serial No.: 7001965

	TOP	BOTTOM
Dielectric Strength, KV		
DISC Electrode:		
VDE Electrode:		
Power Factor, % 60 Hz @ 25°C:	0.0090	0.0075
Interfacial Tension Dynes Per CM:	39.0	40.1
Neutralization Number, KOH Per Gram:		
Color:		
Moisture Content, PPM:	5.1	6.8

I hereby certify the above report is a time record taken from laboratory tests in accordance with current Westinghouse and/or ASTM methods.

T. V. Oommen 1-14-83
Engineer   Date

E. W. Patton 1-17-83
Manager   Date

0026S

TRANSFORMER GAS ANALYSIS REPORT

TRANSFORMER I.D.: S.O. [illegible] / S/N [illegible] LAB #: 3-195

SAMPLE SUPPLIER: VEPCO [illegible] ANNA, UNIT #2 DATE SAMPLED: 1-20-[illegible]

SAMPLE I.D.: BOTTOM DATE ANALYZED 1-20-[illegible]

BEFORE/AFTER TEMP RUN

OTHER________

	GAS		PPM GAS IN OIL
H_2	HYDROGEN	*	2.0
O_2	OXYGEN		620.0
N_2	NITROGEN		9520.0
CH_4	METHANE	*	2.0
CO	CARBON MONOXIDE	*	14.0
CO_2	CARBON DIOXIDE		150.0
C_2H_4	ETHYLENE	*	2.0
C_2H_6	ETHANE	*	1.0
C_2H_2	ACETYLENE	*	
C_3	PROPANE/PROPYLENE	*	2.0
OTHER			
	TOTAL		10100.0

* COMBUSTIBLE GAS

[illegible]

TOTAL [illegible] % [illegible] .01

[illegible] 23.0

APPENDIX F

TRANSFORMER REPORT ON EVENTS AT N. ANNA POWER STATION

Page 4

GALLONS OF OIL ATMOSEAL YES NO	HYDROGEN H_2	OXYGEN O_2	NITROGEN N_2	METHANE CH_4	CARBON MONOXIDE CO	ETHANE C_2H_6	CARBON DIOXIDE CO_2	ETHYLENE C_2H_4	ACETYLENE C_2H_2	COMBUSTIBLE GAS CONTENT PPM	ESTIMATED T.C.G. %	X REF: 3204 MFGR: WH S/N: 700.2899 LOCATION: N.G. GSU 2C REPORT No.-REMARKS
Doble — SAMPLE DATE 8-23-82, SYRINGE No. N-0769, OIL TEMP, TEST DATE 8-23-82 — Bottom	0	1000	100,108	9	13	12	630	3	0	101,667 / 37	.01	595-A
Vipco — SAMPLE DATE 8-23-82, SYRINGE No. 24057, OIL TEMP, TEST DATE 8-25-82 — Top	61	2344	87,292	N/D	26	N/D	579	N/D	N/D	90356 / 87		G128
Contains air bubble the size of a marble.												
Vipco — SAMPLE DATE 8-23-82, SYRINGE No. T9727, OIL TEMP, TEST DATE 8-25-82 — Bottom	11	4895	101,813	N/D	38	N/D	518	N/D	N/D	107275 / 49		G125
SAMPLE DATE 8-27-82, SYRINGE No. T3700, OIL TEMP, TEST DATE 8-27-82 — Top	10	4071	116,116	7	26	0	432	0	0	130662 / 43		G137
SAMPLE DATE 8-27-82, SYRINGE No. D2448, OIL TEMP, TEST DATE 8-27-82 — Bottom	19	7145	110,045	8	28	0	435	0	0	117,680 / 55		G136
SAMPLE DATE 10-7-82, SYRINGE No. D306, OIL TEMP 57°C, TEST DATE 10-18-82	150	2300	100,100	10	8	13	760	4	0	103,245 / 185	.26	604A
Doble — SAMPLE DATE 12-27-82, SYRINGE No. S-3886, OIL TEMP 25°C, TEST DATE 1-7-83 — (Decrease in H_2)	4	1800	110,000	11	31	9	880	3	0	112,738 / 58	0.03	621 Resample 1 year
SAMPLE DATE, SYRINGE No., OIL TEMP, TEST DATE												

COLOR					
DATE					
DIELECTRIC	/	/	/	/	/
DATE					
I.F.T.					
DATE					
NEUT. No.					

PCB (PPM)	
DATE	
WATER CONTENT (PPM)	37
DATE	8/23/82
METALLIC ANALYSIS	
DATE	
POWER FACTOR %	
DATE	

Page [illegible]

X REF: 3204
MFGR: WH
S/N- 700 2099
LOCATION: [illegible]

	HYDROGEN H_2	METHANE CH_4	CARBON MONOXIDE CO	ETHANE C_2H_6	CARBON DIOXIDE CO_2	ETHYLENE C_2H_4	ACETYLENE C_2H_2	TOTAL GAS CONTENT PPM	COMBUSTIBLE GAS CONTENT PPM	ESTIMATED T.C.G. %	REPORT No. - REMARKS
SAMPLE DATE: [illegible] SYRINGE No. C 7C44 TEST DATE 10-15-81	0	6	2	10	560	1	0	82,579	19	0.00	505A Resample 1 year
SAMPLE DATE 11-6-81 SYRINGE No. Y9135 TEST DATE 11-16-81	3	4	29	14	610	2	0	93,412	62	0.03	512 C Resample 1 year.
SAMPLE DATE [illegible] SYRINGE No. [illegible] 4 TEST DATE 12-21-81	0	9	23	11	690	2	0	95935	45	0.02	527A Resample 1 year
SAMPLE DATE 1-25-82 SYRINGE No. B-6834 TEST DATE 2-1-82	14	11	30	12	570	4	0	95,041	71	0.05	533 B Resample 1 year
SAMPLE DATE 2-22-82 SYRINGE No. S 3359 TEST DATE 3-9-82	0	8	16	95	520	3	0	92,542	122	.02	544B Resample 1 year
SAMPLE DATE 4-7-82 SYRINGE No. S-3456 TEST DATE 4-2-82	0	7	23	9	380	4	0	82,923	43	0.02	557E Resample 1 yr.
SAMPLE DATE 6-11-82 SYRINGE No. B-3079 TEST DATE 6-28-82	0	5	10	5	210	2	0	50,232	22	.02	580B Resample 1 year.
SAMPLE DATE 8-23-82 SYRINGE No. D902 TEST DATE 8-23-82	TOP- 1	8	29	12	580	4	0	102,334	54	0.3	595

COLOR						
DATE						
DIE-kv 877/1816	/	/	/	/	/	
DATE						
I.F.T.						
DATE						
NEUT. No						
DATE						

PCB (PPM)					
DATE					
WATER CONTENT (PPM)	19	2.56			
DATE	12/11/81	3/9/82			
METALLIC ANALYSIS					
DATE					
POWER FACTOR %					
DATE					

Page 2

North Anna GS2A	HYDROGEN H_2	METHANE CH_4	CARBON MONOXIDE CO	ETHANE C_2H_6	CARBON DIOXIDE CO_2	ETHYLENE C_2H_4	ACETYLENE C_2H_2	TOTAL GAS CONTENT PPM	COMBUSTIBLE GAS CONTENT PPM	ESTIMATED TCG %	X REF 3264; MFGR: WH; S/N- 700 2099; LOCATION North Anna G... REPORT No. - REMARKS
SAMPLE DATE 12-1-80; SYRINGE No. N 8670; TEST DATE 12-2-80	3200	980	150	50	2200	720	860	108,860	5960	5.44	(393G) Resample 1 year 12-2-81
	Post Mortem To be repaired HAW.										
SAMPLE DATE; SYRINGE No.; TEST DATE	Returned from Factory to North Anna - Replacing failure on GS2 "C"										
SAMPLE DATE [illegible]; SYRINGE No. [illegible]; TEST DATE 8-12-81	0	0	7	0	81	0	0	8-12-81 By Phone. 18,088	7	.03	TOP 484 Resample 3 mo.
SAMPLE DATE [illegible]; SYRINGE No. Y9423; TEST DATE 8-12-81	0	0	2	0	49	0	0	8-12-81 By Phone 8151	2	.02%	BOTTOM 484A - Resample 3 months.
SAMPLE DATE 8-10-81; SYRINGE No. 17164; TEST DATE [illegible]	—	—	7	—	90	—	—	2.0%	7		Vepco lab.
SAMPLE DATE [illegible]; SYRINGE No. [illegible]; TEST DATE 8-12-81	—	—	—	—	—	—	—	0.4%	—	—	Vepco lab.
SAMPLE DATE [illegible]; SYRINGE No.; TEST DATE 8-10-81	0	7	48	34	413	6	0	82,942	95	.01%	Vepco lab.
SAMPLE DATE 9-10-81; SYRINGE No. 13771; TEST DATE 9-21-81	0	9	55	12	690	1	0	111,867	77	0.04	497 Resample 6 mo.

Margin notes: Vepco lab.; Vepco lab.; Vepco lab.; "C" Φ

COLOR						PCB (PPM)				
DATE						DATE				
DIE-ST STR. (KV)	43	/	/	/	/	WATER CONTENT (PPM)	11	21		
DATE	9/18/81					DATE	12/2/80	9/12/81		
I.F.T.	46.0					METALLIC ANALYSIS				
DATE	9/18/81					DATE				
NEUT No.	.028					POWER FACTOR %				
DATE	9/18/81					DATE				

Phase 2

G52A

X REF: 3204

MFGR: [illegible]

S/N- 7002099

LOCATION: [illegible]

	HYDROGEN H_2	METHANE CH_4	CARBON MONOXIDE CO	ETHANE C_2H_6	CARBON DIOXIDE CO_2	ETHYLENE C_2H_4	ACETYLENE C_2H_2	TOTAL GAS CONTENT PPM	COMBUSTIBLE GAS CONTENT PPM	ESTIMATED T.C.G. %	REPORT No. - REMARKS
SAMPLE DATE 10-18-78 SYRINGE No. TEST DATE	0	6	16	7	280	2	0	89,511	31	.01	(286C)
SAMPLE DATE 2-2-79 SYRINGE No. TEST DATE	0	5	0	6	190	2	0	92,103	13	.002	(291A)
SAMPLE DATE 11-8-79 SYRINGE No. TEST DATE	13	9	18	9	710	4	0	88,463	53	0.04	(314B) Resample 1 yr. 11-80
SAMPLE DATE 5-31-80 SYRINGE No. TEST DATE	0	16	32	21	630	4	0	95,683	73	0.03	(348Q) Resample 1 yr. 5-81 [illegible]
SAMPLE DATE 9-19-80 SYRINGE No. TEST DATE	0	11	88	6	840	3	0	112,148	108	.06	(371C) Resample 1 yr. 9-19-81 38th wk
SAMPLE DATE [illegible] X 0536 SYRINGE No. 10-23-80 TEST DATE	14	16	93	5	1300	3	1	123,026	126	0.09	381E - Resample 1 year - 10-16-81 (42wk)
Vepco Lab SAMPLE DATE 11-20-80 Y5707 SYRINGE No. TEST DATE	Vepco lab Closed - Same test sent to Doble										
Doble SAMPLE DATE 11-20-80 Y5707 SYRINGE No. TEST DATE	13	11	100	9	2000	2	0	114,533	133	.09	(392B)

Failed 11-29-80.

COLOR		1				
DATE		[illegible]				
DIE.-kv 877/1816	47/31	40/	/	/	/	
DATE	10/20/80	[illegible]				
I.F.T.		[illegible]				
DATE		[illegible]				
NEUT. No.		.028				
DATE		6/30/81				

PCB (PPM)	<5				
DATE	[illegible]				
WATER CONTENT (PPM)	<1				
DATE	11/20/80				
METALLIC ANALYSIS	371H				
DATE	9/19/80				
POWER FACTOR %	.10	.05			
DATE	10/20/80	6/30/81			

Continued [illegible] 2

	HYDROGEN H_2	METHANE CH_4	CARBON MONOXIDE CO	ETHANE C_2H_6	CARBON DIOXIDE CO_2	ETHYLENE C_2H_4	ACETYLENE C_2H_2	TOTAL GAS CONTENT PPM	COMBUSTIBLE GAS CONTENT PPM	ESTIMATED TCG %	X REF. 3174 / MFGR. WH / S/N 7001994 / LOCATION N.A #1 BGSU / REPORT No. - REMARKS
SAMPLE DATE 12.3.82 / SYRINGE No. A-9745 / TEST DATE 12/6/82	Top - After Corona Test										
	2	ND	ND	ND	ND	ND.	ND	N/D	8905	2	G245.
SAMPLE DATE 12-3-82 / SYRINGE No. D 7814 / TEST DATE 12.6.82	Bottom - After Corona Test										
	2	2	7	N/D	81	ND	ND	23065	11		G246
SAMPLE DATE / SYRINGE No. / TEST DATE	→ Failed 12/15/82 ←										
SAMPLE DATE / SYRINGE No. / TEST DATE											
SAMPLE DATE / SYRINGE No. / TEST DATE											
SAMPLE DATE / SYRINGE No. / TEST DATE											
SAMPLE DATE / SYRINGE No. / TEST DATE											
SAMPLE DATE / SYRINGE No. / TEST DATE											

By phone ↓

							PCB (PPM)						
COLOR							PCB (PPM)						
DATE							DATE						
DIE.-kv 877	/	/	/	/	/		WATER CONTENT (PPM)						
DATE							DATE						
I.F.T.							METALLIC ANALYSIS						
DATE							DATE						
NEUT. No.							POWER FACTOR %						
DATE							DATE						

X-REF: 3174
MFGR: WH
S/N-7001994
LOCATION NA #1BGSU

GALLONS OF OIL / ATMOSEAL YES NO	HYDROGEN H_2	OXYGEN O_2	NITROGEN N_2	METHANE CH_4	CARBON MONOXIDE CO	ETHANE C_2H_6	CARBON DIOXIDE CO_2	ETHYLENE C_2H_4	ACETYLENE C_2H_2	COMBUSTIBLE GAS CONTENT PPM	ESTIMATED T.C.G. %	REPORT No.-REMARKS
SAMPLE DATE 10-7-82 / SYRINGE No. A-0553 / OIL TEMP 25°C / TEST DATE 10/28/82	0	2500	65000	2	35	3	700	2	0	66242 / 42	0.04	604E Resample 1 year.
SAMPLE DATE 11-16-82 / SYRINGE No. Y9230 / OIL TEMP / TEST DATE 11/17/82	17	4765	70650	N/D	32	N/D	552	N/D	N/D	76016 / 49		G218
SAMPLE DATE 11-17-82 / SYRINGE No. 0-137 / OIL TEMP / TEST DATE 11-18-82	6	1541	48579	N/D	24	N/D	372	N/D	N/D	50522 / 30		G223.
SAMPLE DATE 11-17-82 / SYRINGE No. / OIL TEMP / TEST DATE 11/18/82	Bomb 3881 → 175	73895	925169	N/D	49	N/D	N/D	N/D	N/D	999278 / 224		G225
SAMPLE DATE 11-29-82 / SYRINGE No. Z 5344 / OIL TEMP 34°C / TEST DATE 11-30-82	BEFORE CORONA TEST - BOTTOM 3	2368	8110	N/D	N/D	8	8	N/D	N/D	10494 / 11		G232
SAMPLE DATE 11-29-82 / SYRINGE No. X 9995 / OIL TEMP 35°C / TEST DATE 11-30-82	BEFORE CORONA TEST - TOP N/D	866	3178	N/D	2	N/D	N/D	N/D	N/D	4046 / 2		G236
SAMPLE DATE 11-30-82 / SYRINGE No. 0-397 / OIL TEMP 20°C / TEST DATE	BEFORE CORONA TEST - TOP											
SAMPLE DATE 11-30-82 / SYRINGE No. A-0422 / OIL TEMP 20°C / TEST DATE	BEFORE CORONA TEST BOTTOM											

COLOR	0.5				
DATE	10/6/82				
DIELECTRIC	47/34	/	/	/	/
DATE	10/6/82				
I.F.T.	41				
DATE	10/6/82				
NEUT. No.	<0.01				
DATE	10/6/82				

PCB (PPM)						
DATE						
WATER CONTENT (PPM)	15					
DATE	10/8/82					
METALLIC ANALYSIS	3942					
DATE	10/11/82					
POWER FACTOR %/100°	0.54					
DATE	10/6/82					

-18-82 By Done 11:40 AM
G
F.5PM.

242

X REF. 3174
MFGR. [illegible]
S/N- 78C1994
LOCATION [illegible]

		HYDROGEN H_2	METHANE CH_4	CARBON MONOXIDE CO	ETHANE C_2H_6	CARBON DIOXIDE CO_2	ETHYLENE C_2H_4	ACETYLENE C_2H_2	TOTAL GAS CONTENT PPM	COMBUSTIBLE GAS CONTENT PPM	ESTIMATED T.C.G. %	REPORT No. - REMARKS
TOP	SAMPLE DATE: 10-8-81; SYRINGE No. T3771; TEST DATE 10-19-81	22	13	11	9	5000	30	0	102,585	85	0.05	506B. Resample 1 year
BOTTOM	SAMPLE DATE: 10-8-81; SYRINGE No. K9714; TEST DATE 10-15-81	12	15	0	10	5100	35	0	106,132	72	0.03	505C Resample 1 year
	SAMPLE DATE: 11-6-81; SYRINGE No. R4949; TEST DATE 11-16-81	11	12	1	7	3900	26	0	105,357	57	0.02	512 Resample 1 year.
	SAMPLE DATE: [illegible]; SYRINGE No. Z8578; TEST DATE 12-21-81	0	16	0	9	4400	35	0	105060	60	0.01	527B Resample 1 year.
	SAMPLE DATE: 1-25-82; SYRINGE No. X-9975; TEST DATE 2-1-82	6	11	1	7	2900	25	0	79,050	50	0.02	533D Resample 1 year
	SAMPLE DATE: [illegible]-22-82; SYRINGE No. T9337; TEST DATE 3-9-82	0	11	0	6	3000	24	0	88041	41	.00	544A - Resample 1 year
	SAMPLE DATE: 4-7-82; SYRINGE No. V-0126; TEST DATE 4-2-82	0	13	0	8	3700	28	0	100,249	49	0.00	557-C Resample 1 year
	SAMPLE DATE: 6-11-82; SYRINGE No. X2942; TEST DATE 6-28-82	0	8	1	5	1900	18	0	60,432	32	.01	580C Resample 1 year.

COLOR						PCB (PPM)				
DATE						DATE				
DIE.-kv 877/1816	/	/	/	/	/	WATER CONTENT (PPM)	9	18		8
DATE						DATE	10/8/81	10/8/81		12/11/81
I.F.T.						METALLIC ANALYSIS	[illegible]		514	
DATE						DATE	[illegible]		10/22/81	
NEUT. No						POWER FACTOR %				
DATE						DATE				

	HYDROGEN	METHANE	CARBON MONOXIDE	ETHANE	CARBON DIOXIDE	ETHYLENE	ACETYLENE	TOTAL GAS CONTENT	COMBUSTIBLE GAS CONTENT	ESTIMATED T.C.G.	X REF: 3174 / MFGR: [illegible] / S/N- 7001974 / LOCATION N.A GS1B
	H_2	CH_4	CO	C_2H_6	CO_2	C_2H_4	C_2H_2	PPM	PPM	%	REPORT No. - REMARKS
SAMPLE DATE: [illegible]-8-78 / SYRINGE No. / TEST DATE	28	16	0	8	2500	33	0	100,285	85	.05	(286 B)
SAMPLE DATE: 11-8-79 / SYRINGE No. / TEST DATE	26	14	2	9	1600	27	0	103,978	78	0.05	314A Resample 1 yr.
SAMPLE DATE: 5-30-80 / SYRINGE No. / TEST DATE	0	16	0	9	1200	21	0	87,446	46	.01	349E Resample 1 yr. 5-81 (22 wk)
SAMPLE DATE: 9-18-80 / SYRINGE No. B7064 / TEST DATE	15	10	11	8	5200	25	0	118,769	69	0.03	371D - Resample 1 yr.
SAMPLE DATE: 10-16-80 / SYRINGE No. Z5318 / TEST DATE 10-23-80	13	11	11	8	3900	24	0	100,367	67	0.03	(381F) Resample 1 year 10-16-81 (42nd wk)
SAMPLE DATE: 11-20-80 / SYRINGE No. W8185 / TEST DATE	Vapco Tank Closed - [illegible] sent to Doble										
SAMPLE DATE: 11-20-80 / SYRINGE No. W 8185 / TEST DATE	33	14	16	12	4000	29	1	94,705	105	0.08	392A Resample 1 yr. 11-20-81
SAMPLE DATE: 12-16-80 / SYRINGE No. W 8439 / TEST DATE 12-23-80	13	12	0	10	3500	26	0	95,861	61	0.03	(399D) Resample 1 yr. 12-16-81 - 51st wk

Vapco Test

Doble

COLOR						PCB (PPM)	<5
DATE						DATE	11/8/79
DIE.-kv 877/1816	48/33	/	/	/	/	WATER CONTENT (PPM)	0
DATE	10/20/80					DATE	11/20/80
I.F.T.						METALLIC ANALYSIS	371H
DATE						DATE	9.18.80
NEUT. No						POWER FACTOR %	
DATE						DATE	

[illegible]

	HYDROGEN	METHANE	CARBON MONOXIDE	ETHANE	CARBON DIOXIDE	ETHYLENE	ACETYLENE	TOTAL GAS CONTENT	COMBUSTIBLE GAS CONTENT	ESTIMATED T.C.G.	X REF: 3174 / MFGR: WH / S/N: [illegible] / LOCATION: [illegible]
	H_2	CH_4	CO	C_2H_6	CO_2	C_2H_4	C_2H_2	PPM	PPM	%	REPORT No - REMARKS
SAMPLE DATE: — / SYRINGE No: V 4195 / TEST DATE: 1-30-81	2	10	0	8	2300	22	0	95,542	42	.01	(408C) Resample 1 year 1-22-82
SAMPLE DATE: 2-18-81 / SYRINGE No: A-9997 / TEST DATE: 3-10-81	0	9	8	7	1700	21	0	75,145	45	0.01	(425F) Resample 1 year - 2-18-82 8th WK 82
SAMPLE DATE: 3-19-81 / SYRINGE No: A 9094 / TEST DATE: 4-1-81	17	0	4	7	1500	18	0	75,155	55	0.05	(435F) Resample 1 year
SAMPLE DATE: [illegible] / SYRINGE No: S 3984 / TEST DATE:											
SAMPLE DATE: 3-30-81 / SYRINGE No: P 2449 / TEST DATE: 3-21-81	By Receive 4-1-81 0	12	0	9	4000	28	0	106,649	49	0.00	(434B) Resample 1 year
SAMPLE DATE: 6-12-81 / SYRINGE No: E 5830 / TEST DATE: 6-30-81	60	26	21	38	5700	50	1	117,596	196	0.111	465C Resample 1 year -
SAMPLE DATE: 6-12-81 / SYRINGE No: Y 6006 / TEST DATE: 7-9-81	27	27	38	47	9310	41	N/D	8.8%	180		
SAMPLE DATE: 9-10-81 / SYRINGE No: Y 9910 / TEST DATE: 9-2-81	19	17	15	11	5300	36	1	106,799	99	0.05	497A Resample 1 year
	(0	12.5	6.5	14.4	5780	38.7	0	WEST)			

COLOR	1					
DATE	6/30/81					
DIE - KV	87 / 46	46	/	/	/	
DATE	6/30/81	9/18/81				
I.F.T.	45.2	42.5				
DATE	6/30/81	9/18/81				
NEUT No	.038	.056				
DATE	6/30/81	9/18/81				

PCB (PPM)		
DATE		— —
WATER CONTENT (PPM)		16
DATE		9/10/81
METALLIC ANALYSIS		
DATE		
POWER FACTOR %	.08	
DATE	6/30/81	

X REF: 3172
MFGR: WH
S/N-7001993
LOCATION: NA-GS2A

GALLONS OF OIL
ATMOSEAL YES NO

	HYDROGEN H_2	OXYGEN O_2	NITROGEN N_2	METHANE CH_4	CARBON MONOXIDE CO	ETHANE C_2H_6	CARBON DIOXIDE CO_2	ETHYLENE C_2H_4	ACETYLENE C_2H_2	COMBUSTIBLE GAS CONTENT PPM	ESTIMATED T.C.G. %	REPORT No.-REMARKS
SAMPLE DATE 8-27-82 / SYRINGE No. V5697 / OIL TEMP / TEST DATE 8-27-82	BOTTOM N/D	2553	88807	0	5	0	400	0	0	91765 / 5		G139
SAMPLE DATE 8-25-82 / SYRINGE No. V5354 / OIL TEMP / TEST DATE 8-27	TOP N/D	1934	5498	N/D	N/D	N/D	299	N/D	N/D	59022	0	G127
Small air bubble size of pea in bottle.												
SAMPLE DATE 10-7-82 / SYRINGE No. T-5746 / OIL TEMP 60°C / TEST DATE 10/28/82	0	2100	97000	7	15	9	1300	1	0	100,432 / 32	0.01	604F Resample 1 year
SAMPLE DATE 12-27-82 / SYRINGE No. M-0769 / OIL TEMP 45°C / TEST DATE 1-7-83	0	650	110,000	3	0	6	1100	0	0	111,759 / 9	0.00	621 Resample 1 year
SAMPLE DATE / SYRINGE No. / OIL TEMP / TEST DATE												
SAMPLE DATE / SYRINGE No. / OIL TEMP / TEST DATE												
SAMPLE DATE / SYRINGE No. / OIL TEMP / TEST DATE												
SAMPLE DATE / SYRINGE No. / OIL TEMP / TEST DATE												

Doble "

COLOR					
DATE					
DIEL. kV	/	/	/	/	/
DATE					
I.F.T.					
DATE					
NEUT. No.					

PCB (PPM)					
DATE					
WATER CONTENT (PPM)					
DATE					
METALLIC ANALYSIS					
DATE					
POWER FACTOR %					
DATE					

GALLONS OF OIL / ATMOSEAL YES NO	HYDROGEN H_2	OXYGEN O_2	NITROGEN N_2	METHANE CH_4	CARBON MONOXIDE CO	ETHANE C_2H_6	CARBON DIOXIDE CO_2	ETHYLENE C_2H_4	ACETYLENE C_2H_2	COMBUSTIBLE GAS CONTENT PPM	ESTIMATED T.C.G. %	X REF: 3172 / MFGR: TI) H / S/N: 7001993 / LOCATION: NA GS2A / REPORT No.—REMARKS
SAMPLE DATE 2-22-82 / SYRINGE No. T9291 / OIL TEMP 28°C / TEST DATE 3-9-82	0	1200	85000	1	0	3	630	0	0	86,834 / 4	0.00	544E Resample 1 year
SAMPLE DATE 4-7-82 / SYRINGE No. S0296 / OIL TEMP 40°C / TEST DATE 4-?-82	0	2000	80000	1	0	2	410	0	0	82413 / 3	0.00	557B Resample 1 year
SAMPLE DATE 6-11-82 / SYRINGE No. J385 / OIL TEMP 37°C / TEST DATE 6-28-82	0	2100	98000	0	0	2	360	0	0	100,462 / 2	.00	580F Resample 1 year.
Dable — SAMPLE DATE 8-23-82 / SYRINGE No. N1073 / OIL TEMP / TEST DATE 8-23-82 — Bottom ... By Phone	0	1000	95000	1	0	2	580	0	0	96,583 / 3	0	595C
Doble — SAMPLE DATE 8-23-82 / SYRINGE No. D606 / OIL TEMP / TEST DATE 8-23-82 — Top By phone	0	1200	94000	2	0	2	590	0	0	95,794 / 4	0	595B.
Vepco — SAMPLE DATE 8-23-82 / SYRINGE No. 400010 / OIL TEMP / TEST DATE 8-23-82 — Top By Phone	N/D	1934	56,___	N/D	N/D	N/D	299	N/D	N/D	59022		
Vepco — SAMPLE DATE 8-23-82 / SYRINGE No. W8177 / OIL TEMP / TEST DATE 8-23-82 — Bottom	N/D	1325	69866	N/D	N/D	N/D	371	N/D	N/D	71622 / 0		
Vepco — SAMPLE DATE 8-27-82 / SYRINGE No. A0553 / OIL TEMP / TEST DATE 8-27-82 — TOP.	34	11553	78354	0	8	0	280	0	0	90229 / 42		G138

COLOR						PCB (PPM)				
DATE						DATE				
DIEL. ___	/	/	/	/	/	WATER CONTENT (PPM)	5.56	11		
DATE						DATE	3/9/82	8/23/82		
I.F.T.						METALLIC ANALYSIS				
DATE						DATE				
NEUT. No.						POWER FACTOR %				
DATE						DATE				

(Page 3)

	HYDROGEN H_2	METHANE CH_4	CARBON MONOXIDE CO	ETHANE C_2H_6	CARBON DIOXIDE CO_2	ETHYLENE C_2H_4	ACETYLENE C_2H_2	TOTAL GAS CONTENT PPM	COMBUSTIBLE GAS CONTENT PPM	ESTIMATED T.C.G. %	X REF. 3172 / MFGR: WH / S/N-7001993 / LOCATION: N.A. - GS2A / REPORT No. - REMARKS
8-6-81 SAMPLE DATE; U 7309 SYRINGE No.; TEST DATE	0 (Rush)	2	1	3 (By phone)	65	0	0	23,961 (8/11/81)	6	.01	483C Resample 1 month
6-1?-81 SAMPLE DATE; W8694 SYRINGE No.; 7-29-81 TEST DATE	17	20	50	N/D	3948	10	N/D	7.2%	97		[illegible]
8-19-81 SAMPLE DATE; SYRINGE No.; 8-?-81 TEST DATE	16	6 (Trash)	15	34	381	13	0	82,779	78	.01%	[illegible]
9-16-81 SAMPLE DATE; N, 715 SYRINGE No.; 9.21.81 TEST DATE	0	4	8	5	860	0	0	100,857	17	0.01	497C Resample 1 mo.
10-8-81 SAMPLE DATE; F 1584 SYRINGE No.; 10-16-81 TEST DATE	0	3	0	4	920	0	0	96,027	7	0.00	505B Resample 1 year
11-6-81 SAMPLE DATE; N, 312 SYRINGE No.; 11-16-81 TEST DATE	0	2	0	3	730	0	0	85,135	5	0.00	512A Resample 1 year.
?-?-81 SAMPLE DATE; Y 7546 SYRINGE No.; 12-19-81 TEST DATE	0	3	0	4	840	7	0	102,354	14	0.00	527C Resample 1 year.
1-25-82 SAMPLE DATE; W 8196 SYRINGE No.; 2-1-82 TEST DATE	0	2	0	2	640	0	0	91044	4	0.00	533C Resample 1 year

Margin notes: Taken before & after E ??? (?) ???; [illegible]

COLOR	<1.0					
DATE	7/30/81					
DIE.-kv 877/1816	51/41	/	/	/	/	
DATE	7/30/81					
I.F.T.	37					
DATE	7/30/81					
NEUT. No.	<0.01					
DATE	7/30/81					

PCB (PPM)					
DATE					
WATER CONTENT (PPM)	35	16	5		
DATE	7/30/81	9/2?/81	10/?/81		
METALLIC ANALYSIS					
DATE					
POWER FACTOR % 25C	0.019				
DATE	7/30/81				

X REF. 3172
MFGR. W H
S/N- 7CC 1993
LOCATION [illegible]

	HYDROGEN H_2	METHANE CH_4	CARBON MONOXIDE CO	ETHANE C_2H_6	CARBON DIOXIDE CO_2	ETHYLENE C_2H_4	ACETYLENE C_2H_2	TOTAL GAS CONTENT PPM	COMBUSTIBLE GAS CONTENT PPM	ESTIMATED T.C.G. %	REPORT No. - REMARKS
SAMPLE DATE 7-?-81	By phone 7-14-81										
SYRINGE No. T9341	0	3	14	0	150	2	0	17509	19	.06	466A Resample 1 year
TEST DATE	pcb - <5 ppm - Kahle Lab.										
SAMPLE DATE 7-27-81	Add moisture content										
SYRINGE No. [illegible]	0	1	0	1	81	0	0	10483	2	.000	474A Resample 1 mo.
TEST DATE 7-30-81											
SAMPLE DATE	Add moisture content										
SYRINGE No.	0	2	2	1	57	0	0	18762	5	.001	474B Resample 1 month
TEST DATE 7-30-81											
SAMPLE DATE	W/H										
SYRINGE No. [illegible]											
TEST DATE											
SAMPLE DATE	W/H										
SYRINGE No. [illegible]											
TEST DATE											
SAMPLE DATE 8-6-81	Rush By Phone 8/11/81										TOP
SYRINGE No. S 9964	0	2	6	2	110	2	0	28,422	12	.02	483A Resample 1 month
TEST DATE 8-11-81											
SAMPLE DATE 8-6-81	Rush By Phone 8/11/81										"TOP"
SYRINGE No. V4528	0	2	5	2	160	2	0	29,971	11	.01%	483 Resample 1 mo.
TEST DATE 8-11-81											
SAMPLE DATE 8-6-81	Rush By Phone - 8/11/81										"BOTTOM"
SYRINGE No. X9945	0	2	6	3	68	0	0	26,174	6	.01%	483B Resample 1 month
TEST DATE 8-11-81											

TAKEN Before AND AFTER GE over voltage Test

COLOR						PCB (PPM)	<5			
DATE						DATE	7-?-81			
DIE.-kv 877/1816	41	/	/	/	/	WATER CONTENT (PPM)	9	15	5	
DATE	9/8/81					DATE	7/7/81	7/27/81	7/27/81	
I.F.T.	46.0					METALLIC ANALYSIS				
DATE	9/8/81					DATE				
NEUT. No	.028					POWER FACTOR %				
DATE	9/8/81					DATE				

North Anna Main Spare

X REF: 3172
MFGR: W
S/N- 7001993
LOCATION: N. A GS2A

Sample	HYDROGEN H_2	METHANE CH_4	CARBON MONOXIDE CO	ETHANE C_2H_6	CARBON DIOXIDE CO_2	ETHYLENE C_2H_4	ACETYLENE C_2H_2	TOTAL GAS CONTENT PPM	COMBUSTIBLE GAS CONTENT PPM	ESTIMATED T.C.G. %	REPORT No. - REMARKS
SAMPLE DATE 9-18-80; SYRINGE No. K 2729; TEST DATE	14	9	150	11	770	6	0	75,160	140	0.18	(371E) Resample 1 yr 9-18-81. (38th wk) PCB - Vyes Lab.
Moved to Pos. GS2A following failure of #7002099. Oil from 7002099 used (streamlined)											
SAMPLE DATE 12-16-80; SYRINGE No. S 9603; TEST DATE 12-22-80	5	4	49	3	800	5	0	80,866	66	0.06	(399F) Resample 1 yr. 12-16-81 (51st wk)
SAMPLE DATE 1-22-81; SYRINGE No. A 9997; TEST DATE 1-30-81	0	10	42	4	1000	6	0	98,968	62	.03	(408B) Resample 1 year - 1/22/82
SAMPLE DATE 2-18-81; SYRINGE No. W 8939; TEST DATE 3-10-81	7	9	55	5	1200	5	0	89,781	81	0.06	(425E) Resample 1 year 2/18/82 8th wk 82
SAMPLE DATE 3-19-81; SYRINGE No. A 9293; TEST DATE 4-1-81	20	10	58	6	1400	7	0	99,301	101	0.08	(439A) Resample 1 year
SAMPLE DATE [illegible]; SYRINGE No. [illegible]; TEST DATE [illegible]	[illegible]	11	[illegible]	7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] 4316 [illegible]
SAMPLE DATE 5-19-81; SYRINGE No. Z 1902; TEST DATE 6-4-81	0	6	41	4	1400	4	0	69,655	55	.05	459A - Resample 1 year. 5-19-82
SAMPLE DATE 6-13-81; SYRINGE No. R 6853; TEST DATE 6-30-81	17	10	43	6	3000	5	0	99181	81	0.06	465I Resample 1 year

COLOR							PCB (PPM)	[illegible]	[illegible]			
DATE							DATE	[illegible]	[illegible]			
DIE.-kv 877/816	[illegible]	/	/	/	/	/	WATER CONTENT (PPM)	15				
DATE	[illegible]						DATE	4/16/81				
I.F.T.							METALLIC ANALYSIS	371H	[illegible]			
DATE							DATE	9/18/80				
NEUT. No							POWER FACTOR %	[illegible]				
DATE							DATE	[illegible]				

[illegible] 2

X REF: 3175
MPSR: YWH
S/N- NA #1CGS1
LOCATION 7001995

GALLONS OF OIL / ATMOSEAL YES NO	HYDROGEN H_2	OXYGEN O_2	NITROGEN N_2	METHANE CH_4	CARBON MONOXIDE CO	ETHANE C_2H_6	CARBON DIOXIDE CO_2	ETHYLENE C_2H_4	ACETYLENE C_2H_2	COMBUSTIBLE GAS CONTENT PPM	ESTIMATED T.C.G. %	REPORT No.-REMARKS
SAMPLE DATE 10-7-82 SYRINGE No. W820C OIL TEMP 35°C TEST DATE 10-28-82	0	1800	54000	3	20	3	520	0	0	61,346 / 26	.03	604C Resample 1 year.
SAMPLE DATE 11-16-82 SYRINGE No. A-0361 OIL TEMP TEST DATE 11/17/82	1844	4845	67358	497	34	26	466	421	497	75988 / 3319		G219
SAMPLE DATE SYRINGE No. OIL TEMP TEST DATE	Failed 11/16/82 -											
SAMPLE DATE SYRINGE No. OIL TEMP TEST DATE												
SAMPLE DATE SYRINGE No. OIL TEMP TEST DATE												
SAMPLE DATE SYRINGE No. OIL TEMP TEST DATE												
SAMPLE DATE SYRINGE No. OIL TEMP TEST DATE												
SAMPLE DATE SYRINGE No. OIL TEMP TEST DATE												

COLOR	0.5				
DATE	10/5/82				
DIEL. STR. KV	46/30	/	/	/	/
DATE	10/15/82				
I.F.T.	41				
DATE	10/5/82				
NEUT. No.	<0.01				
DATE	10/5/82				

PCB (PPM)					
DATE					
WATER CONTENT (PPM)	26				
DATE	10/5/82				
METALLIC ANALYSIS	3943				
DATE	10/11/82				
POWER FACTOR %/100 °C	0.72				
DATE	10/5/82				

X REF. 3175
MFGR: W/H
S/N- 7001995
LOCATION: N/H GS1C

	HYDROGEN H_2	METHANE CH_4	CARBON MONOXIDE CO	ETHANE C_2H_6	CARBON DIOXIDE CO_2	ETHYLENE C_2H_4	ACETYLENE C_2H_2	TOTAL GAS CONTENT PPM	COMBUSTIBLE GAS CONTENT PPM	ESTIMATED TCG %	REPORT No. - REMARKS
TOP SAMPLE DATE: 10-[illegible] SYRINGE No. Y-7742 TEST DATE 10-19-81	42	17	20	7	4400	22	0	103,808	108	0.09	506C. Resample 1 year
Bottom SAMPLE DATE: 10-8-81 SYRINGE No. A-7140 TEST DATE 10-19-81	31	16	2	8	3900	19	0	99,576	76	0.06	506A Resample 1 year
SAMPLE DATE: 11-6-81 SYRINGE No. N 8233 TEST DATE 11-16-81	19	19	0	7	3700	24	0	106,669	69	0.04	512E Resample 1 year.
SAMPLE DATE: [illegible] SYRINGE No. T 9193 TEST DATE 12-21-81	15	16	1	6	3200	21	0	96,459	59	0.03	527D Resample 1 year.
SAMPLE DATE: 1-25-82 SYRINGE No. W 8623 TEST DATE 2-1-82	18	20	11	8	3300	27	0	98184	84	0.05	533A Resample 1 year.
SAMPLE DATE: 2-22-82 SYRINGE No. C-0919 TEST DATE 3-9-82	12	19	1	7	3200	23	0	104,962	62	0.03	544D Resample 1 year
SAMPLE DATE: 4-7-82 SYRINGE No. S-0450 TEST DATE 4-2-82	17	17	11	7	3300	19	0	86,371	71	0.05	557D. Resample 1 year.
SAMPLE DATE: 6-11-82 SYRINGE No. D-095 TEST DATE 6-28-72	15	20	2	8	2800	25	0	95,470	70	0.04	580D Resample 1 year.

COLOR					
DATE					
DIE.-kv 877/1816	/	/	/	/	/
DATE					
I.F.T.					
DATE					
NEUT. No					
DATE					

PCB (PPM)					
DATE					
WATER CONTENT (PPM)	(T) 59	(B) 19		7	
DATE	10/8/81	10/8/81		12/11/81	
METALLIC ANALYSIS	H/1680		514		
DATE	11/30/81		9/22/81		
POWER FACTOR %					
DATE					

Page 2 [redacted]

X REF. 3175
MFGR. WH
S/N 700 1995
LOCATION N. A. -GSIC

Sample date / Syringe No. / Test date	HYDROGEN H_2	METHANE CH_4	CARBON MONOXIDE CO	ETHANE C_2H_6	CARBON DIOXIDE CO_2	ETHYLENE C_2H_4	ACETYLENE C_2H_2	TOTAL GAS CONTENT PPM	COMBUSTIBLE GAS CONTENT PPM	ESTIMATED T.C.G. %	REPORT No. - REMARKS
1-22-81 SAMPLE DATE; B7289 SYRINGE No.; 1-30-81 TEST DATE	12	8	12	4	1200	7	0	97,043	43	.03	(408E) Resample 1 year 1-22-82
2-18-81 SAMPLE DATE; M 4676 SYRINGE No.; 3-10-81 TEST DATE	19	8	8	3	940	6	0	73,784	44	0.05	(425D) Resample 1 year - 2-18-82 8th WK
3-19-81 SAMPLE DATE; W 8879 SYRINGE No.; [illegible] TEST DATE	0	8	7	4	850	7	0	66,776	26	0.01	(436E) Resample 1 year
3-30-[illegible] SAMPLE DATE; M4028 SYRINGE No.; TEST DATE											
3-[illegible]-81 SAMPLE DATE; Y9291 SYRINGE No.; 3-31-81 TEST DATE	By phone 4-1-81 9	12	18	7	3000	16	0	104,162	62	0.03	(434) Resample 1 yr 3-30-82
6-12-81 SAMPLE DATE; X-9911 SYRINGE No.; 6-30-81 TEST DATE	72	16	30	9	4400	.19	1	106,147	147	0.14	465-A Resample 1 year. 6-12-82
6-12-81 SAMPLE DATE; T7167 SYRINGE No.; 7-29-81 TEST DATE	34	27	36	9	5656	17	N/D	8.8%	123		
9-10-81 SAMPLE DATE; K7190 SYRINGE No.; 9-21-81 TEST DATE	39	14	22	8	4500	21	0	115,909	109	0.08	4?7D Resample 1 year
	(0	15.5	6.7	5.5	4567	25	0	west)			

Left margin notes: Repeat [illegible] (beside 3-30 row); [illegible] (beside 3-[illegible]-81 row); Repeat [illegible] (beside 6-12-81 T7167 row)

COLOR						PCB (PPM)		
DATE						DATE		
DIE-ev. [illegible]	43	/	/	/	/	WATER CONTENT (PPM)	16	
DATE	9/18/81					DATE	9/18/81	
I.F.T.	46.0					METALLIC ANALYSIS		
DATE	9/18/81					DATE		
NEUT No.	.028					POWER FACTOR %		
DATE	9/18/81					DATE		

North Anna

X REF: 3175
MFGR: WH
S/N- 7001995
LOCATION: N. A. GSIC

	HYDROGEN H_2	METHANE CH_4	CARBON MONOXIDE CO	ETHANE C_2H_6	CARBON DIOXIDE CO_2	ETHYLENE C_2H_4	ACETYLENE C_2H_2	TOTAL GAS CONTENT PPM	COMBUSTIBLE GAS CONTENT PPM	ESTIMATED T.C.G. %	REPORT No. - REMARKS
SAMPLE DATE: 10-18-79; SYRINGE No.; TEST DATE	19	5	0	3	1300	2	0	112,929	29	.02	(286J)
SAMPLE DATE: 11-8-79; SYRINGE No.; TEST DATE	22	21	11	15	1300	6	0	113,875	75	0.04	(314D) Resample 1 yr. 11/80
SAMPLE DATE: 5-30-80; SYRINGE No.; TEST DATE	23	9	0	8	1500	10	0	89,050	50	0.05	(348E) Resample 1 yr 5-81 (22 wk)
SAMPLE DATE: [illegible]; SYRINGE No. 9656; TEST DATE	25	10	22	5	2200	9	0	106,471	71	.06	(371A) Resample 1 yr 9-19-81 (38th wk)
SAMPLE DATE: 10-16-80; SYRINGE No. E7740; TEST DATE 10-23-80	23	10	15	4	2300	8	0	95,860	60	0.06	(381A) Resample 1 yr 10-16-81 (42nd wk)
SAMPLE DATE: 11-20-80; SYRINGE No. Y5480; TEST DATE	Vipco Lab closed - some test sent to Doble										
SAMPLE DATE: 11-20-80; SYRINGE No. Y5480; TEST DATE	12	12	21	6	2100	9	0	129,960	60	0.03	(392C) Resample 1 year 11-20-81
SAMPLE DATE: 12-16-80; SYRINGE No. M4175; TEST DATE 12-23-80	40	11	11	5	2000	10	0	92,777	77	0.08	(399A) Resample 1 yr 12-16-80 - 51st wk.

Vipco Lab.

Doble

						PCB / tests					
COLOR		1				PCB (PPM)	<5				
DATE		6/20/81				DATE	11/20/80				
DIE.-kv 877/1816	47/32	41/	/	/	/	WATER CONTENT (PPM)	8				
DATE	10/20/80	6/20/81				DATE	10/20/80				
I.F.T.		452				METALLIC ANALYSIS	371H				
DATE		6/30/81				DATE	9-18-80				
NEUT. No		.028				POWER FACTOR %	.065	.08			
DATE		6/30/81				DATE	10/20/80	6/30/81			

[illegible]

GALLONS OF OIL / ATMOSEAL YES NO	HYDROGEN H_2	OXYGEN O_2	NITROGEN N_2	METHANE CH_4	CARBON MONOXIDE CO	ETHANE C_2H_6	CARBON DIOXIDE CO_2	ETHYLENE C_2H_4	ACETYLENE C_2H_2	COMBUSTIBLE GAS CONTENT PPM	ESTIMATED T.C.G. %	X REF: 3173 / MFGR: WH / S/N: 7001965 / LOCATION: N/A GSU 1A / REPORT No.-REMARKS
SAMPLE DATE	Bomb B				Phoned in to R. Proffitt							
SYRINGE No.												G301
OIL TEMP	10	3345	128,92	N/D	4	N/D	59	N/D	N/D	16610		
TEST DATE					Water content =					14		
SAMPLE DATE												
SYRINGE No.												
OIL TEMP												
TEST DATE												
SAMPLE DATE												
SYRINGE No.												
OIL TEMP												
TEST DATE												
SAMPLE DATE												
SYRINGE No.												
OIL TEMP												
TEST DATE												
SAMPLE DATE												
SYRINGE No.												
OIL TEMP												
TEST DATE												
SAMPLE DATE												
SYRINGE No.												
OIL TEMP												
TEST DATE												
SAMPLE DATE												
SYRINGE No.												
OIL TEMP												
TEST DATE												

COLOR					
DATE					
DIEL-kv STD/	/	/	/	/	/
DATE					
I.F.T.					
DATE					
NEUT. No.					
DATE					

PCB (PPM)					
DATE					
WATER CONTENT (PPM)	545				
DATE	1/20/83				
METALLIC ANALYSIS					
DATE					
POWER FACTOR %					
DATE					

Vecco Lab.

255

GALLONS OIL AMNOSEAL YES NO	HYDROGEN H_2	OXYGEN O_2	NITROGEN N_2	METHANE CH_4	CARBON MONOXIDE CO	ETHANE C_2H_6	CARBON DIOXIDE CO_2	ETHYLENE C_2H_4	ACETYLENE C_2H_2	COMBUSTIBLE GAS CONTENT PPM	ESTIMATED T.C.G. %	X REF: 3173 MFGR: WH S/N- 7001965 LOCATION N.A. GSU1A REPORT No.-REMARKS
SAMPLE DATE 12-3-82 SYRINGE No. D-258 OIL TEMP 20°C TEST DATE 12/6/82	Top - After Test ND	2726	11336	ND	4	3	ND	ND	ND	13969 / 7		G250
SAMPLE DATE 12-3-82 SYRINGE No. B5565 OIL TEMP 20°C TEST DATE	Bottom - After Corona Test ND	1585	6478	1	2	ND	3	ND	ND	8069 / 3		G249
SAMPLE DATE 12-5-82 SYRINGE No. D-087 OIL TEMP TEST DATE 12-6-82	Bottom - After 1"B" failure ND	3426	9867	2	12	N/D	21	N/D	N/D	13328 / 14		G243
SAMPLE DATE 12-6-82 SYRINGE No. L 0074 OIL TEMP [illegible]°C TEST DATE [illegible]-7-82	TOP - AFTER 1"B" failure ND	1961	6509	ND	3	ND	21	ND	ND	8494 / 3		G253
SAMPLE DATE 1-20-83 SYRINGE No. X-9921 OIL TEMP 7°C TEST DATE 1- -83	Top - Doble - Rush - 1	1500	6500	2	8	1	140	1	0	8153 / 13		Phone to R. White.
SAMPLE DATE 1-20-83 SYRINGE No. T 9227 OIL TEMP 7°C TEST DATE	Bottom - Doble - Rush. 1	1900	8100	2	8	1	170	2	0	10184 / 14		Phone to R. White
SAMPLE DATE 1-20-83 SYRINGE No. B2596 OIL TEMP 7°C TEST DATE	TOP - Vepco - LAB - N/D	230	8486	1	4	N/D	55	N/D	N/D	10935 / 5		Phone to R. Proffitt G299
SAMPLE DATE 1-20-83 SYRINGE No. B1812 OIL TEMP 7°C TEST DATE	Bottom - Vepco - LAB. 22	11635	46047	N/D	11	N/D	114	N/D	N/D	57829 / 33		G300

By [illegible] —

COLOR							PCB (PPM)					
[illegible]							DATE					
[illegible] 877 / 1816	/	/	/	/	/		WATER CONTENT (PPM)					
DATE							DATE					
I.F.T.							METALLIC ANALYSIS					
DATE							DATE					
NEUT. No.							POWER FACTOR %					
DATE							DATE					

X REF: 3173

MFGR: (WH)

S/N- 7001965

LOCATION: N.A GSU#1A

GALLONS OF OIL / ATMOSEAL YES NO	HYDROGEN H_2	OXYGEN O_2	NITROGEN N_2	METHANE CH_4	CARBON MONOXIDE CO	ETHANE C_2H_6	CARBON DIOXIDE CO_2	ETHYLENE C_2H_4	ACETYLENE C_2H_2	COMBUSTIBLE GAS CONTENT PPM	ESTIMATED T.C.G. %	REPORT No.-REMARKS
SAMPLE DATE 4-7-82; SYRINGE No. O-391; OIL TEMP 40°C; TEST DATE 4-21-82	0	5000	83000	6	0	13	1800	56	0	89875 / 75	0.01	577-A Resample 1 year.
SAMPLE DATE 6-11-82; SYRINGE No. K-119; OIL TEMP 30°C; TEST DATE 6-28-82	0	2300	88000	14	0	14	1600	62	1	91,991 / 91	0.00	580A Resample 3 mo.
SAMPLE DATE 10-7-82; SYRINGE No. T 9614; OIL TEMP 75°C; TEST DATE 10-28-82	0	1800	67000	3	22	4	360	3	0	69,192 / 32	.03	604 B Resample 1 year.
SAMPLE DATE 11-16-82; SYRINGE No. Z-0067; OIL TEMP; TEST DATE 11-17-82	5	2677	56869	2	28	N/D	223	N/D	N/D	59804 / 35	.35	G217
SAMPLE DATE 11-17-82; SYRINGE No. K7537; OIL TEMP; TEST DATE 11-18-82	3	5075	60846	2	26	N/D	330	N/D	N/D	66282 / 31		G224
SAMPLE DATE 11-18-82; SYRINGE No. Bomb 4033; OIL TEMP; TEST DATE 11-18-82	153	61462	937376	N/D	183	N/D	N/D	N/D	N/D	999174 / 336		G226
BEFORE CORONA TEST — BOTTOM. SAMPLE DATE 11-29-82; SYRINGE No. A-507; OIL TEMP 25°C; TEST DATE 11-30-82	NO Sample	964	3879	N/D	2	N/D	5	N/D	N/D	4850 / 2		G234
BEFORE CORONA TEST — TOP. SAMPLE DATE 11-29-82; SYRINGE No. A-3?7; OIL TEMP 25°C; TEST DATE 11-30-82	N/D	1108	4937	N/D	5	N/D	5	N/D	N/D	6055 / 5		G235

COLOR	0.5				
DATE	10/15/82				
DIEL.	47/36	/	/	/	/
DATE	10/15/82				
I.F.T.	40				
DATE	10/15/82				
NEUT. No.	<.01				
DATE	10/15/82				

PCB (PPM)	
DATE	
WATER CONTENT (PPM)	24
DATE	10/15/82
METALLIC ANALYSIS	3941
DATE	10/18/82
POWER FACTOR % 25°C	1.21
DATE	10/15/82

Called WA 11/18/82 10:50 AM

11:51 PM By Phone

257

[redacted]

MAIN GSI

X REF. 3173
MFGR. WH
S/N-7001965
LOCATION N.A. GS1A

	HYDROGEN H_2	METHANE CH_4	CARBON MONOXIDE CO	ETHANE C_2H_6	CARBON DIOXIDE CO_2	ETHYLENE C_2H_4	ACETYLENE C_2H_2	TOTAL GAS CONTENT PPM	COMBUSTIBLE GAS CONTENT PPM	ESTIMATED T.C.G. %	REPORT No. - REMARKS
SAMPLE DATE 10-18-78 SYRINGE No. TEST DATE	0	8	0	8	1200	27	0	113,743	43	.003	(286R)
SAMPLE DATE 11-8-79 SYRINGE No. TEST DATE	6	19	1	13	790	60	1	86,990	100	0.02	(314) Resample 1 year
SAMPLE DATE 5-30-80 SYRINGE No. TEST DATE	0	21	0	13	1000	64	1	83,499	99	.01	(348B) Resample 1 yr 5/81
SAMPLE DATE 9-18-80 SYRINGE No. Y9374 TEST DATE	0	30	7	21	2100	110	4	123,272	172	0.02	371F Resample 3 mo 12-18-80 (50th wk)
SAMPLE DATE 10-16-80 SYRINGE No. X9414 TEST DATE 10-23-80	0	28	6	16	1500	90	4	86,944	144	0.02	381C - Resample 1 year 10-16-81 (42 wk)
SAMPLE DATE 11-20-80 SYRINGE No. W8267 TEST DATE	Pipe Tank - Closed - Some test sent to Doble										
SAMPLE DATE 11-20-80 SYRINGE No. W8267 TEST DATE	4	21	14	20	1400	98	3	79,560	160	0.04	392B - Resample 1 year 11/20/81
SAMPLE DATE 12-16-80 SYRINGE No. W8878 TEST DATE 12-22-80	0	27	0	23	1300	110	2	88,262	162	0.02	(399B) Resample 1 yr 12-16-81 - 51st WK

see Tank

Doble

COLOR		1				PCB (PPM)	<5				
DATE		[illegible]				DATE	11/8/79				
DIE.-kv 877/1816	45/31	43/	/	/	/	WATER CONTENT (PPM)	-26	13			
DATE	10/20/82	[illegible]				DATE	11/20/80	4/16/81			
I.F.T.		[illegible]				METALLIC ANALYSIS	371H		394I		
DATE		[illegible]				DATE	9/18/80		10/11/82		
NEUT No		.028				POWER FACTOR %		.03			
DATE		[illegible]				DATE		[illegible]			

[redacted]

X REF 3173
MFGR: WH
S/N: [illegible]
LOCATION: [illegible]

	HYDROGEN H_2	METHANE CH_4	CARBON MONOXIDE CO	ETHANE C_2H_6	CARBON DIOXIDE CO_2	ETHYLENE C_2H_4	ACETYLENE C_2H_2	TOTAL GAS CONTENT PPM	COMBUSTIBLE GAS CONTENT PPM	ESTIMATED T.C.G. %	REPORT No. - REMARKS
SAMPLE DATE [illegible] / SYRINGE No. / 1-30-81 TEST DATE	0	24	0	21	770	100	2	80,417	147	.01	(408A) Resample 1 yr 1-22-82
2-18-81 SAMPLE DATE / Y9070 SYRINGE No. / 3-10-81 TEST DATE	0	18	0	17	570	81	1	71,987	117	.001	(425C) Resample 1 yr. 2-18-82 8th wk
3-19-81 SAMPLE DATE / T9444 SYRINGE No. / 4-1-81 TEST DATE	0	20	0	22	620	100	1	8[illegible]	[illegible]43	.01	438 - Resample 1 year
[illegible] SAMPLE DATE / N 8070 SYRINGE No. / TEST DATE											
3-[illegible]-81 SAMPLE DATE / K7549 SYRINGE No. / 3-31-81 TEST DATE	By Plt. We 4-1-81 6	22	0	29	1400	110	2	100,669	169	.002	(434H) Resample 1 year.
[illegible] SAMPLE DATE / [illegible] SYRINGE No. / 5-[illegible] TEST DATE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	81	2	[illegible]	[illegible]	[illegible]	[illegible] 4-16-82
5-19-81 SAMPLE DATE / [illegible] SYRINGE No. / 6-4-81 TEST DATE	0	13	5	14	1600	73	2	79,607	107	.01	459B - Resample 1 year.
6-12-81 SAMPLE DATE / V9896 SYRINGE No. / 6-30-81 TEST DATE	5	15	0	18	2500	88	3	102,129	129		465J Resample 1 year

COLOR						PCB (PPM)						
DATE						DATE						
DIE - No [illegible]	/	/	/	/	/	WATER CONTENT (PPM)						
DATE						DATE						
I.F.T.						METALLIC ANALYSIS	[illegible]					
DATE						DATE	[illegible]					
NEUT No						POWER FACTOR %						
DATE						DATE						

Pg. 3

X REF 3173
MFGR: WH
S/N: 7CC1965
LOCATION: NGGS1A

	HYDROGEN H_2	METHANE CH_4	CARBON MONOXIDE CO	ETHANE C_2H_6	CARBON DIOXIDE CO_2	ETHYLENE C_2H_4	ACETYLENE C_2H_2	TOTAL GAS CONTENT PPM	COMBUSTIBLE GAS CONTENT PPM	ESTIMATED T.C.G. %	REPORT No. - REMARKS
SAMPLE DATE 6-12-81?; SYRINGE No. B-3466; TEST DATE	32	19	13	N/D	2342	90	N/D	6.8%	154		
SAMPLE DATE 9-16-81; SYRINGE No. M4201; TEST DATE 9-21-81	0	11	4	18	3000	81	2	99,516	116	0.01	497B Resample 1 year
SAMPLE DATE 10-5-81; SYRINGE No. B 6233; TEST DATE 10-15-81	0	10	0	19	3000	80	1	98,610	110	0.01	505E Resample 1 year
SAMPLE DATE [illegible]-81; SYRINGE No. S3242; TEST DATE 10-15-81	0	9	0	15	2700	68	1	92,993	93	0.01	505F Resample 1 year
SAMPLE DATE 11-6-81; SYRINGE No. K9703; TEST DATE 11-16-81	0	8	0	13	2100	58	1	87380	80	0.01	512D Resample 1 year.
SAMPLE DATE; SYRINGE No. D-156; TEST DATE 12-21-81	0	7	0	15	2000	63	1	97,386	86	0.01	527F Resample 1 year
SAMPLE DATE 1-25-82; SYRINGE No. D-628; TEST DATE 2-1-82	0	7	0	15	1800	61	1	95684	84	0.01	533E Resample 1 year
SAMPLE DATE 2-23-82; SYRINGE No. Y9549; TEST DATE 3-4-82	0	6	0	11	1600	50	0	85,867	67	0.01	544F Resample 1 year.

Margin notes: 1-200 [illegible] (row 1); TOP (row 3); Bottom (row 4)

COLOR						
DATE						
DIE.-kv 877/1816	41	/	/	/	/	/
DATE	9/18/81					
I.F.T.	46.2					
DATE	9/18/81					
NEUT. No	.038					
DATE	9/18/81					

		Top	Bottom	
PCB (PPM)				
DATE				
WATER CONTENT (PPM)	12	7	3	14
DATE	9/10/81	10/15/81	10/15/81	12/11/81
METALLIC ANALYSIS			514	
DATE			10/22/81	
POWER FACTOR %				
DATE				

Pg. 3

North Anna G Ø 2 B

X REF 3203
MFGR: WH
S/N- 7002098
LOCATION N.A. GØ2B

	HYDROGEN	METHANE	CARBON MONOXIDE	ETHANE	CARBON DIOXIDE	ETHYLENE	ACETYLENE	TOTAL GAS CONTENT	COMBUSTIBLE GAS CONTENT	ESTIMATED T.C.G.	
	H_2	CH_4	CO	C_2H_6	CO_2	C_2H_4	C_2H_2	PPM	PPM	%	REPORT No - REMARKS
SAMPLE DATE 12-1-80 / SYRINGE No B1502 / TEST DATE 12/5/80	0	9	0	7	430	7	0	94,753	23	0	(393F) Resample 1 yr. 12-2-81
SAMPLE DATE 12-16-80 / SYRINGE No B2343 / TEST DATE 12-16-80	0	9	10	12	660	9	0	106,100	40	0.01	(399E) Resample 1 year 12-16-81 (51st WK)
SAMPLE DATE 1-22-81 / SYRINGE No Z8044 / TEST DATE 3-?-81	0	9	0	9	540	8	0	102,466	26	.00	(408) Resample 1 year 1-22-82.
SAMPLE DATE 2-18-81 / SYRINGE No Y9094 / TEST DATE 3.9.81	0	10	0	10	680	8	0	45238	28	0.01	(425B) Resample 1 year - 2.18.82 8th wk.
SAMPLE DATE 3-19-81 / SYRINGE No T3700 / TEST DATE 4-1-81	0	10	0	10	740	10	0	113,170	30	.00	(438?) Resample 1 year 3.19.82
SAMPLE DATE 6-12-81 / SYRINGE No K9101 / TEST DATE 6-30-81	0	10	10	11	1500	9	0	112,740	40	0.009	465F Resample 1 year.
			Failed			7/3/81			B Ø		NORTH ANNA
SAMPLE DATE 6-12-81 / SYRINGE No S-3159 / TEST DATE 7.29.81	N/D	12	11	N/D	2340	N/D	N/D	9.2%	23		
SAMPLE DATE / SYRINGE No / TEST DATE											

Spare [illegible]

Sold for Junk

COLOR						PCB (PPM)					
DATE						DATE					
DIC-kv 87/D.C.?	/	/	/	/	/	WATER CONTENT (PPM)	4				
DATE						DATE	12/2/80				
I.F.T.						METALLIC ANALYSIS					
DATE						DATE					
NEUT No						POWER FACTOR %					
DATE						DATE					

[redacted]

Watt Area - GS 25	HYDROGEN	METHANE	CARBON MONOXIDE	ETHANE	CARBON DIOXIDE	ETHYLENE	ACETYLENE	TOTAL GAS CONTENT	COMBUSTIBLE GAS CONTENT	ESTIMATED T.C.G.	X REF: 3203 MFGR: WH S/N- 7002098 LOCATION: N.A. - GS25
	H_2	CH_4	CO	C_2H_6	CO_2	C_2H_4	C_2H_2	PPM	PPM	%	REPORT No. - REMARKS
10-18-78 SAMPLE DATE SYRINGE No. TEST DATE	0	9	14	10	180	0	0	93,413	33	.01	(286M)
2-2-79 SAMPLE DATE SYRINGE No. TEST DATE	0	9	18	9	150	3	0	83,989	39	.02	(291E)
11-8-79 SAMPLE DATE SYRINGE No. TEST DATE	9	13	5	15	290	7	0	90,339	49	0.02	(314) Resample 1 yr 11-80
5-[illegible] SAMPLE DATE SYRINGE No. TEST DATE	0	9	0	2	240	5	0	105,361	21	.00	(348H) Resample 1 yr 5-81 (20wk)
9-18-80 SAMPLE DATE Y9127 SYRINGE No. TEST DATE	0	10	9	9	480	8	0	129,316	36	0.01	(371G) Resample 1 yr 9-18-81 (38 wk)
[illegible] SAMPLE DATE Y [illegible] SYRINGE No. 10-23-80 TEST DATE	0	10	15	7	660	7	1	102,800	40	0.01	381-D. Resample 1 yr 10-16-81 (42 wk 81)
11-20-80 SAMPLE DATE Y9059 SYRINGE No. / TEST DATE	Tepco Lab closed - Same test sent to Doble										
11-20-80 SAMPLE DATE Y9059 SYRINGE No. 12-2-80 TEST DATE	0	10	0	7	380	7	0	79,904	24	0	(392A) Resample 1 yr 11-20-81.

Margin notes: Tepco Lab; Doble

COLOR						PCB (PPM)	<5				
DATE						DATE	11/10/80				
DIE.-kv 877/1816	44/34	/	/	/	/	WATER CONTENT (PPM)	5				
DATE	10/20/80					DATE	11/20/80				
I.F.T.						METALLIC ANALYSIS	371H				
DATE						DATE	9/18/80				
NEUT No.						POWER FACTOR %	.11				
DATE						DATE	10/20/80				

Continued - Page 2

GALLONS OF OIL / ATMOSEAL YES NO	HYDROGEN H_2	OXYGEN O_2	NITROGEN N_2	METHANE CH_4	CARBON MONOXIDE CO	ETHANE C_2H_6	CARBON DIOXIDE CO_2	ETHYLENE C_2H_4	ACETYLENE C_2H_2	COMBUSTIBLE GAS CONTENT PPM	ESTIMATED T.C.G. %	X REF: 3205 / MFGR: WH / S/N- 7002100 / LOCATION: NA GS2B / REPORT No.-REMARKS
SAMPLE DATE / SYRINGE No. / OIL TEMP / TEST DATE	Repaired - Rebuilt from factory - Installed and will be energized OSU 2 "B"											
SAMPLE DATE 4-2-87 / SYRINGE No. M-2766 / OIL TEMP 0°C / TEST DATE 4-27-87	0	1300	8500	1	6	1	41	0	0	9849 / 8	0.05	557 Resample 1 year.
SAMPLE DATE 6-11-87 / SYRINGE No. T9128 / OIL TEMP / TEST DATE 10-28-87	0	2200	6200	3	22	3	110	0	0	64,338 / 28	0.03	588E Resample 1 year.
SAMPLE DATE / SYRINGE No. / OIL TEMP / TEST DATE	Failed 8/22/87.											
SAMPLE DATE / SYRINGE No. / OIL TEMP / TEST DATE												
SAMPLE DATE / SYRINGE No. / OIL TEMP / TEST DATE												
SAMPLE DATE / SYRINGE No. / OIL TEMP / TEST DATE												
SAMPLE DATE / SYRINGE No. / OIL TEMP / TEST DATE												

COLOR					
DATE					
DIEL. by 877/1816	/	/	/	/	/
DATE					
I.F.T.					
DATE					
NEUT. No.					
DATE					

PCB (PPM)					
DATE					
WATER CONTENT (PPM)					
DATE					
METALLIC ANALYSIS					
DATE					
POWER FACTOR %					
DATE					

[redacted]

X REF: 3205
MFGR: WH
S/N-7002100
LOCATION: NA G 52C

	HYDROGEN H_2	METHANE CH_4	CARBON MONOXIDE CO	ETHANE C_2H_6	CARBON DIOXIDE CO_2	ETHYLENE C_2H_4	ACETYLENE C_2H_2	TOTAL GAS CONTENT PPM	COMBUSTIBLE GAS CONTENT PPM	ESTIMATED T.C.G. %	REPORT No. - REMARKS
12-16-80 SAMPLE DATE W8510 SYRINGE No. 12-22-80 TEST DATE	2	29	2	14	780	39	1	103,467	87	0.01	(399C) Resample 1 year 12/16/80 – 51st wk
1-22-81 SAMPLE DATE V9866 SYRINGE No. 1-30-81 TEST DATE	9	26	2	13	600	37	1	98,988	88		(408D) Resample 1 year 1-22-82
2-18-81 SAMPLE DATE A-9142 SYRINGE No. 3-9-81 TEST DATE	0	27	2	15	740	40	1	41,415	85	0.02	(425A) Resample 1 year 2/18/82 8th wk.
3-19-81 SAMPLE DATE Y9546 SYRINGE No. 4-1-81 TEST DATE	17	26	11	15	720	40	0	97,427	109	0.05	(438E) Resample 1 year.
5-19-81 SAMPLE DATE V4691 SYRINGE No. 6-3-81 TEST DATE	0	20	15	14	670	33	0	72722	82	0.02	459 - Resample 1 year -
~~6-12-81~~ SAMPLE DATE B-7796 SYRINGE No. TEST DATE	20	26	16	16	1500	40	2	99020	120	.055	(465G)
Failed 6/19/81 C φ at North Anna											
6-22-81 SAMPLE DATE C1886 SYRINGE No. TEST DATE	By phone 5100	1600	34	120	1200	1700	2400	96,554	10,954	9.8	464 Severe
6-12-81 SAMPLE DATE S34156 SYRINGE No. 7-24-81 TEST DATE	7	40	40	25	2425	38	N/D	9.2%	150		

COLOR							PCB (PPM)					
DATE							DATE					
DIE-... 3/?/81	/	/	/	/	/		WATER CONTENT (PPM)	21	7.48			
DATE							DATE	6/22/81	3/9/81			
I.F.T.							METALLIC ANALYSIS					
DATE							DATE					
NEUT No							POWER FACTOR %					
DATE							DATE					

North Anna GS 3 C

X REF: 3205

MFGR: WH

S/N: 7002100

LOCATION: N.A. GS3C

	HYDROGEN H_2	METHANE CH_4	CARBON MONOXIDE CO	ETHANE C_2H_6	CARBON DIOXIDE CO_2	ETHYLENE C_2H_4	ACETYLENE C_2H_2	TOTAL GAS CONTENT PPM	COMBUSTIBLE GAS CONTENT PPM	ESTIMATED T.C.G. %	REPORT No. - REMARKS
SAMPLE DATE 12-18-78 SYRINGE No. TEST DATE	0	11	28	9	200	5	0	92,555	53	.02	(286 I)
SAMPLE DATE 2-2-79 SYRINGE No. TEST DATE	7	16	37	18	140	11	0	88,029	89	.05	(291D)
SAMPLE DATE 11-8-79 SYRINGE No. TEST DATE	9	28	31	29	94	13	0	77,604	110	0.06	(314E) Resample 1 yr. 11-80
SAMPLE DATE 5-2-80 SYRINGE No. TEST DATE	0	29	17	16	200	22	0	93,684	84	0.022	(348R) Resample 1 yr. 5-81 (22 wks)
SAMPLE DATE 10-16-80 SYRINGE No. Z1612 TEST DATE [illegible]	31	31	46	10	770	32	2	103,422	152	0.09	(381B) Resample 1 year 10-16-81 (42nd wk)
SAMPLE DATE 11-20-80 SYRINGE No. D9723 TEST DATE	Tipco Lab Closed - Some test sent to Doble										
SAMPLE DATE 11-20-80 SYRINGE No. D9713 TEST DATE 12-2-80	20	27	28	11	560	32	1	58,879	119	.11	(392) Resample 1 yr
SAMPLE DATE 12-1-80 SYRINGE No. S4112 TEST DATE 12-5-80	11	32	31	22	670	54	1	96,421	151	.05	(393 H) Resample 1 yr 12-2-81

Tipco Lab

Doble

COLOR						PCB (PPM)	<5				
DATE						DATE	1/7/80				
DIE.-kv 877/1816	47/37	/	/	/	/	WATER CONTENT (PPM)	30	6			
DATE	10/20/80					DATE	11/20/80	12/1/80			
I.F.T.						METALLIC ANALYSIS	371H				
DATE						DATE	9.18.80				
NEUT. No.						POWER FACTOR %	.07				
DATE						DATE	10/20/80				

APPENDIX G

TRANSFORMER REPORT ON EVENTS AT N. ANNA POWER STATION

APPENDIX G

ENGINEER'S TRIP REPORT
WESTINGHOUSE FORM 3611 C

NOTE 1 - The Engineer reporting is responsible for the prompt delivery of his reports to all interested persons and for seeing that all points requiring action are cleared up without delay.

2 - For long reports give a summary of important points and recommendations.

For Westinghouse Representatives only.

DATE 1/25/83

ORIGINAL TO ISSUING DEPARTMENT'S FILE NO.	DATE OF ARRIVAL AT PROPERTY	DATE OF LEAVING PROPERTY
	1/21/83	1/21/83

COPY TO: (FOR REPORT DISTRIBUTION GUIDE - REFER TO REVERSE SIDE OF THIS SHEET)

☐	Muncie PTD	MR. D. A. Yannucci
☐	Muncie PTD	MR. H. R. Moore
☐	Muncie PTD	MR. E. M. Petrie
☐	Muncie PTD	MR. B. W. Hugon
☐	Muncie PTD	MR. M. P. Wood
☐	FILE L-SPEC. HAM707-08	MR.
☐		MR.
☐		MR.
☐		MR.
☐		MR.
☐		MR.
☐		MR.
☐		MR.
☐		MR.
☐		MR.
☐		MR.
☐		MR.
☐		MR.
☐		MR.
☐		MR.

NAME North Anna Nuclear Station NEG.

LOCATION G.O. S.O. SER. O.

PURPOSE OF TRIP Perform hydraulic experiments on HAM707.

CONFERENCE HELD AT DATE

THOSE PRESENT Messrs. Robert Bowman, (W) Field Salesman; John Haubert, District Engineer; Joe McGregor, VEPCO.

SUMMARY:

See attached.

SIGNED (ENGINEER) P. L. Thiel *P. L. Thiel*

APPROVED E. M. Petrie *E. M. Petrie 1-31-83*

DEPARTMENT Engineering | DIVISION PTD | LOCATION Muncie, IN | PAGE 1

TRIP REPORT - NORTH ANNA

I traveled to the North Anna Nuclear Station to perform several experiments on their HAM707 unit which was retrofitted with COPS unit in December of 1982.

A summary of these tests and my conclusions follows:

1. Ran pumps #1, 2, 3 together and observed if any bubbles were circulated through the phase. Only pumps #1, 2, and 3 were run because the temporary circuit supplying power to the pumps would trip when all five pumps were operated. No bubbles were observed. The oil was highly illuminated by a special 150 watt light source immersed in the oil.

2. Introduced dry air through a fitting mounted on pump #2 while pumps #1, 2, and 3 were operated. A generous quantity of bubbles passed upward from around the phase and through the phase. The highest velocity area was found to be between the phase and the core directly above the edge of the T-beam. The bubbles traveled with a higher velocity at the perimeter of the phase than within the phase but the interior flow (above the coils) was greater than I expected. All bubbles regardless of the exit location traveled vertically with no sideways movement.

3. The oil was drained from the unit down to the top of the end frames exposing the bridgework. The outside edge of the bridge lined up with the outside of the padding washers on three sides of the phase. On the side adjacent to the HV bushing, the bridge was set back from the outside padding washer approximately 2.5 inches.

   The welds joining the side members to the end frames had good appearance. Wedging on all four sides of the phase was tight which reduced the leakage from around the phase more than expected.

I discussed with Mr. J. McGregor about the processing of this unit when it was being retrofitted with the COPS unit. Nitrogen was introduced into the unit as the unit was drained and maintained on the unit prior to opening the unit at the manhole cover. When the manhole cover was removed, the unit was purged with dry air and a tent positioned over the manhole where the relative humidity of the air was measured at under 40 percent. The mechanical relief device was modified to provide a fitting through which vacuum could be drawn for the filling process since the unit was being retrofitted with a COPS tank. The unit was then vacuum filled to within several inches of the cover and vacuum broken by admitting nitrogen into the tank. The COPS was then filled. They used the Vokes #2 streamliner to process the oil down to 5 ppm H_2O.

1339E

APPENDIX H

TRANSFORMER REPORT ON EVENTS AT N. ANNA POWER STATION

APPENDIX H

BLUE RIBBON COMMITTEE ORGANIZATION

George Mechlin - Chairman
Vice President of R&D Westinghouse

Members:

D. Berg	-	Consultant, (______-Mellow University
W. Emmerich	-	Technical Director, R&D Westinghouse
R. Ratica	-	Westinghouse Power System Customer Service Representative
S. Quick	-	General Manager, Westinghouse Steam Turbine Generator Div.
J. Ka:nash	-	Westinghouse Law Department

APPENDIX I

TRANSFORMER REPORT ON EVENTS AT N. ANNA POWER STATION

TRANSFORMER EVALUATION COMMITTEE

J. Skooglund - Chairman
Engineering Manager - Power Transformer Div.

Systems:

J. Bonk	Westinghouse T&D Systems Engr.
C. Wagner	Westinghouse T&D Systems Engr.
E. Taylor	Westinghouse T&D Systems Engr.
D. Shankle	Westinghouse AST
S. Baldwin	Westinghouse Steam Turbine Generator Division (Liaison to Power Generation)

Transformer

Insulation and Field Analysis - A. Sletten
Westinghouse R&D

Hydraulics - R. Rothmann - Westinghouse R&D
- E. Petrie - Westinghouse PTD

Design - J. Cossaart - Westinghouse PTD
- H. Moore - Westinghouse PTD
- J. Templeton - Westinghouse PTD
- D. Yannucci - Westinghouse PTD

Consultants:

S. Bennon