

Evaluation of Transformer Solid Insulation



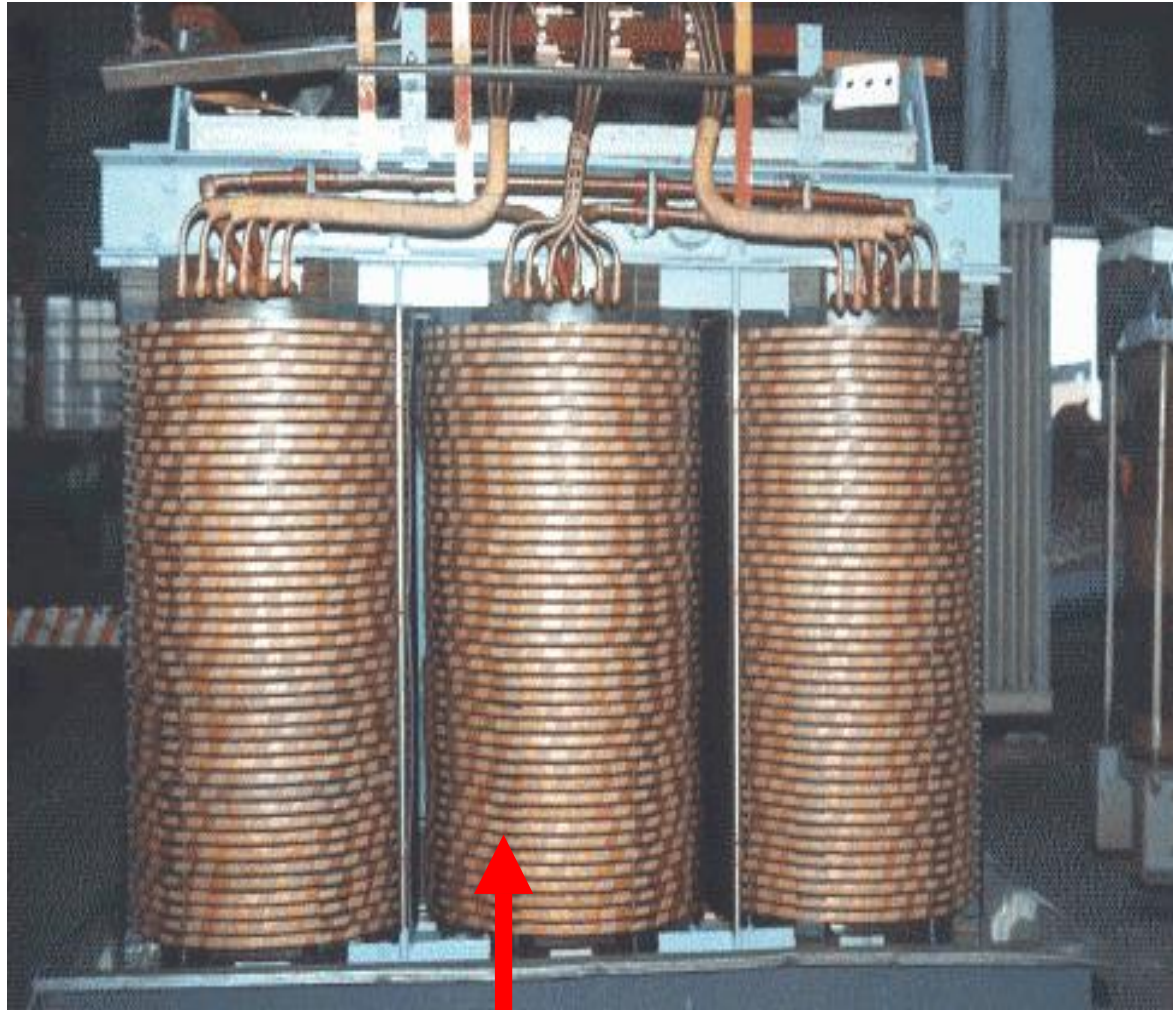
Dry Paper
Good Tensile Strength

End-of-Life

75% Tensile Strength Loss



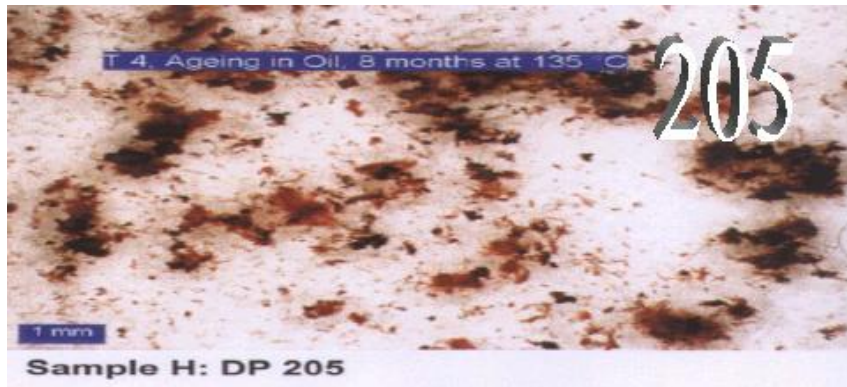
Wet Paper
Poor Tensile Strength



How can the insulation paper condition be accessed

Direct Evaluation

Analysis of paper insulation for its DP value requires removal of a few strips of paper -2grams



DP Value	Significance
1200-700	Healthy transformer
<250	End of life criteria



Note: Since it is usually not practical (and often dangerous to the transformer) to obtain a paper sample from a de-energised, in-service transformer an alternative method has been found.

Furan Analysis

When a cellulose molecule de-polymerises (breaks into smaller lengths or ring structures), a chemical compound known as a furan is formed.

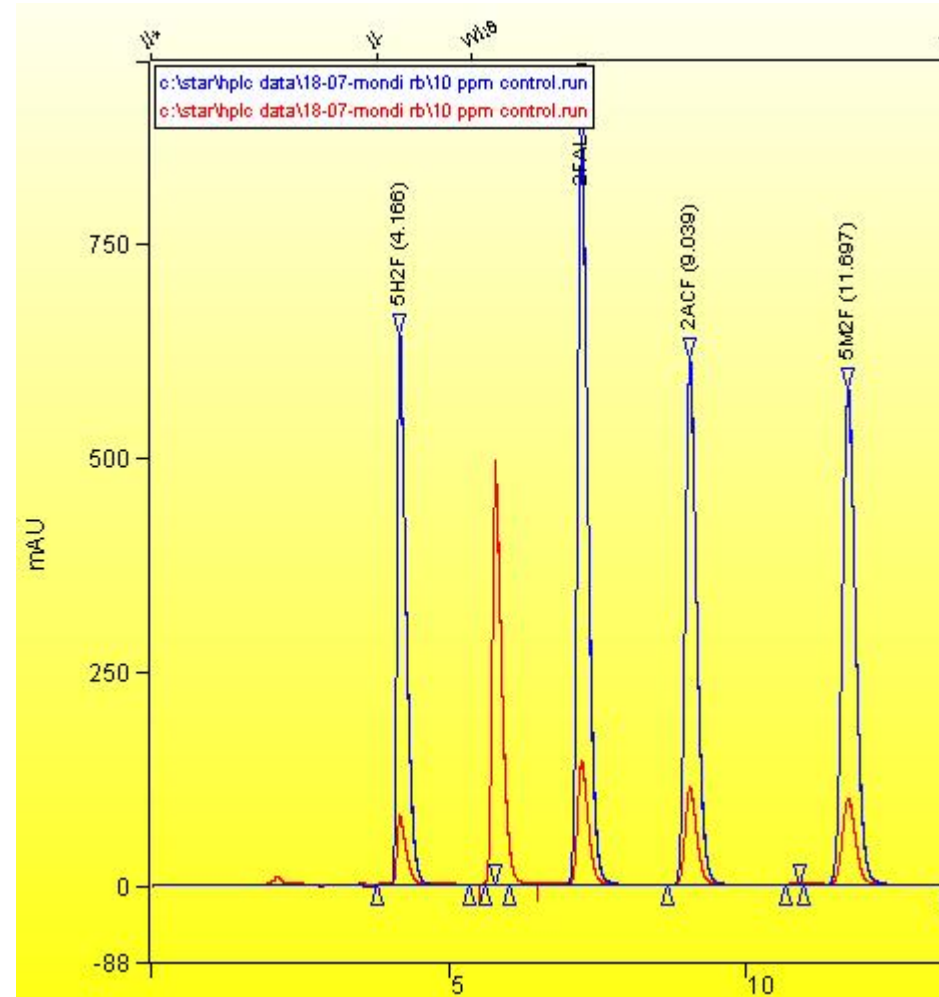
By measuring the quantity and types of furans present in a transformer oil sample, the paper insulation overall DP can be inferred with a high degree of confidence

The types and concentration of furans in an oil sample can also indicate abnormal stress in a transformer, whether intense, short duration overheating or prolonged, general overheating.

5-Hydroxymethyl-2-furaldehyde	5H2F	Oxidation
Furfuryl alcohol	2FOL	High Moisture
2-Furaldehyde	2FAL	Overheating, old faults
2-Furyl methyl ketone	2ACF	Rare, lighting
5-Methyl-2-furaldehyde	5M2F	Local, severe overheating

HPLC

High Pressure Liquid Chromatography



CASE STUDY 1

Transformer Details

Client:	SAPPI SAICCOR	Region:	KZN	District:	UMKOMAAS
Substation:	SUB 17	Transformer No:	17001	Serial No:	5381/1
Sample Point:	MAIN TANK	Sample Date:	07-11-2001	Analysis Date:	16-11-2001
Primary Voltage:	6.6 KV	Secondary Voltage:	380V	VA Rating:	750 KVA
Vector Group:		Impedence:		Tap Changer:	Off Load
Make:	G.E.C.	Year Manufactured:	0	Report Number:	SAPPI-47961
Breather Size:	SA1	Oil Volume Litres:	900	Resample Date:	07-11-2002

Transformer Insulating Condition

Water Content:	34	Density @ 20C:	0.000
Dielectric Strength:	38	Kinematic Viscosity @ 40C:	0.00
Acidity:	0.10	Flash Point:	0
Interfacial Tension:	0.0	Pour Point:	0
Oil Quality Index:	0	Resistivity @ 90C:	0
Oil Colour:		Furan:	10.56
Dissipation Factor @ 90C:	0.000	P.C.B at CL:	
Transformer Oil Temp:	40	Water in paper: % Dry	1.92
Total P.C.B:	0	Water in paper: Total	2.45

RECOMMEND: Plan Internal Inspection of Paper insulation.

← **Furan content: 10.56 PPM**

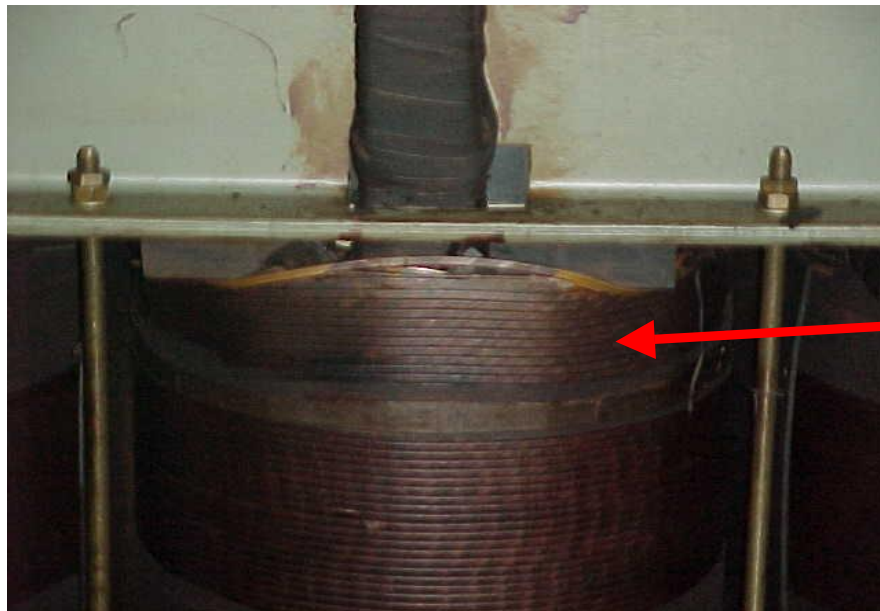
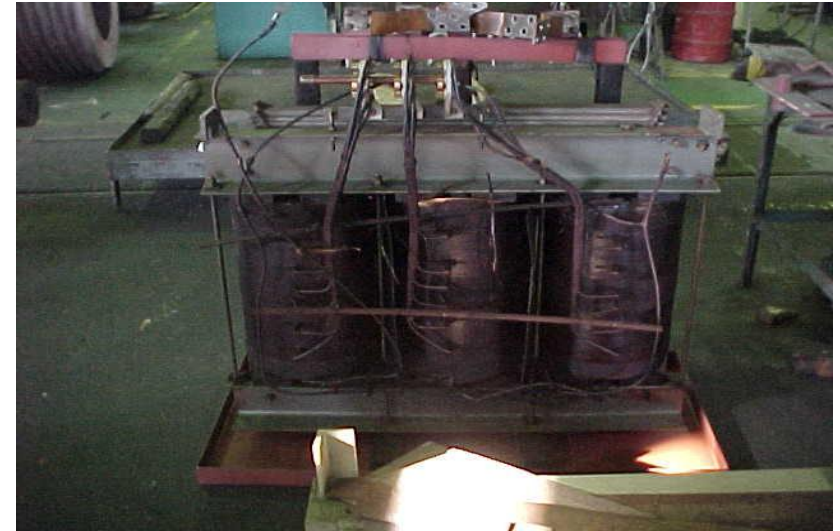
>10

<250

End of life
criteria

Transformer Failed One month later

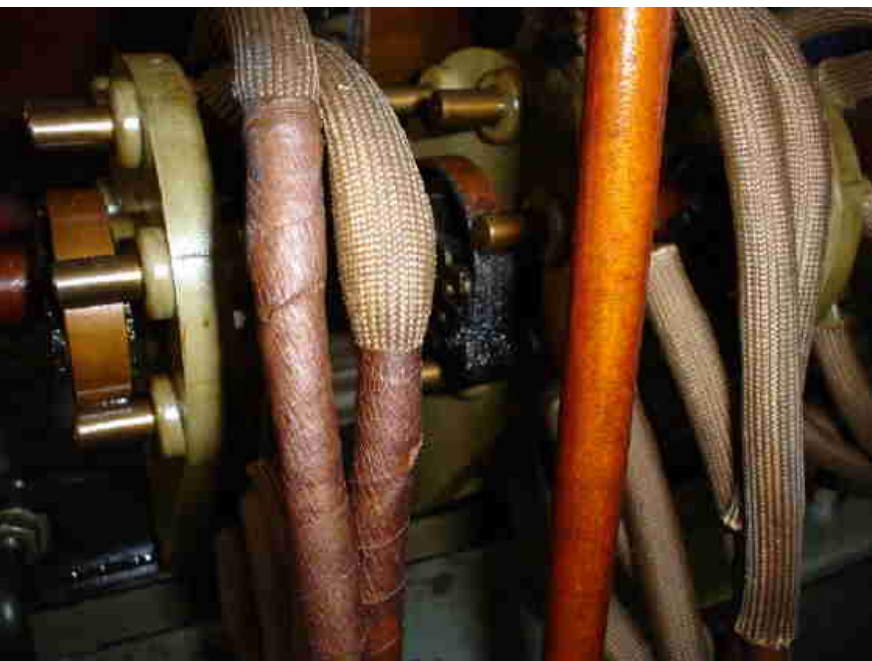
17001 Failure



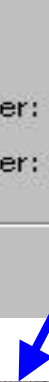
Primary Cause
Insulation Failure

Case Study Foskor

Transformer Internal Condition	
Hydrogen (H2):	128
Oxygen (O2):	2663
Nitrogen (N2):	34164
Methane (CH4):	72
Carbon Monoxide (CO):	424
Carbon Dioxide (CO2):	4589
Ethylene (C2H4):	178
Ethane (C2H6):	81
Acetylene (C2H2):	0
Total %Gas	7.52
Total Gas Combustibles:	883



Transformer Insulating Condition			
Water Content:	83	Density @ 20C:	0.000
Dielectric Strength:	27	Kinematic Viscosity @ 40C:	0.00
Acidity:	0.08	Flash Point:	0
Interfacial Tension:	0.0	Pour Point:	0
Oil Quality Index:	0	Resistivity @ 90C:	0
Oil Colour:	Amber	Furan:	13
Dissipation Factor @ 90C:	0.000	P.C.B at CL:	
Transformer Oil Temp:	34	Water in paper: % Dry	4.17
Total P.C.B:	6	Water in paper: Total	11.35





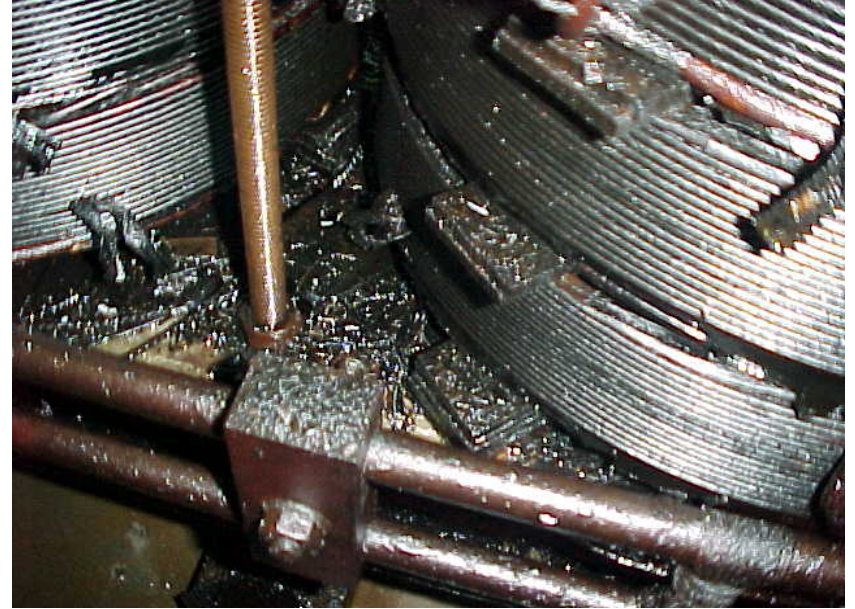
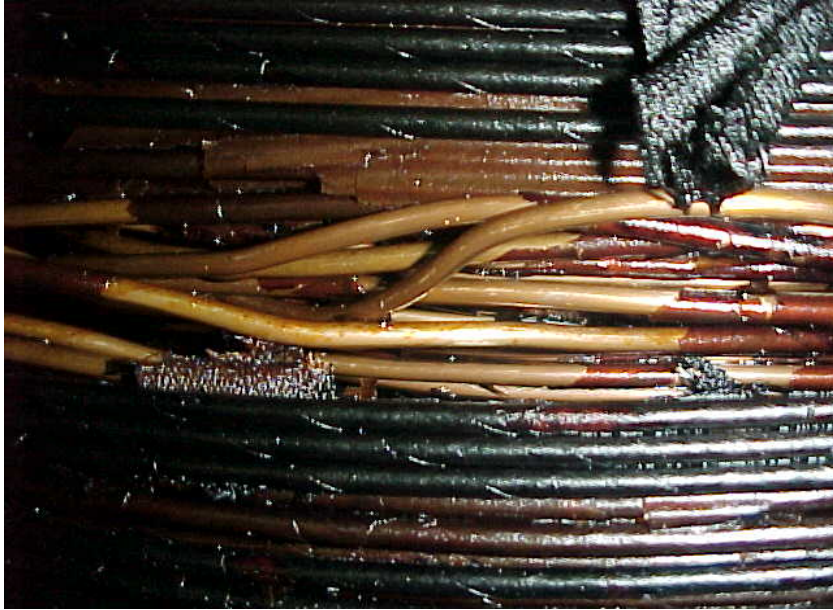
The “predicted” DP (degree of polymerisation) indicates an average paper condition over the whole transformer (subject to factors such as effective circulation).



DP at these sites < 200

Case Study 2

OVERVIEW: The transformer failed in service while undergoing Power-On purification to remove moisture from the insulating oil.



After Failure Analysis:

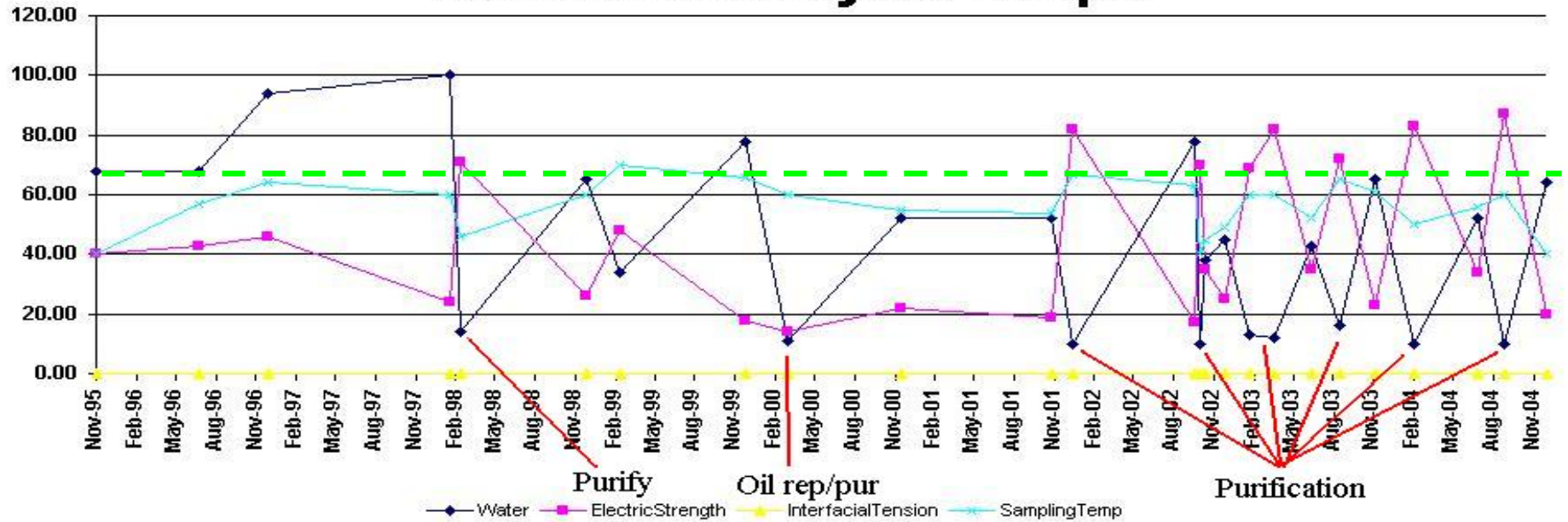
Furan analysis of 8.97 ppm indicated Extensive paper deterioration

The maintenance history of the transformer revealed that oil replacement and purification took place on 12-03-2000. The Furan production rate was 160 ppb (parts per billion) per month (ppb/month)

The Morgan Schafer Company reports that a furan production rate of 25 ppb/month is cause for concern

Review of Maintenance History.

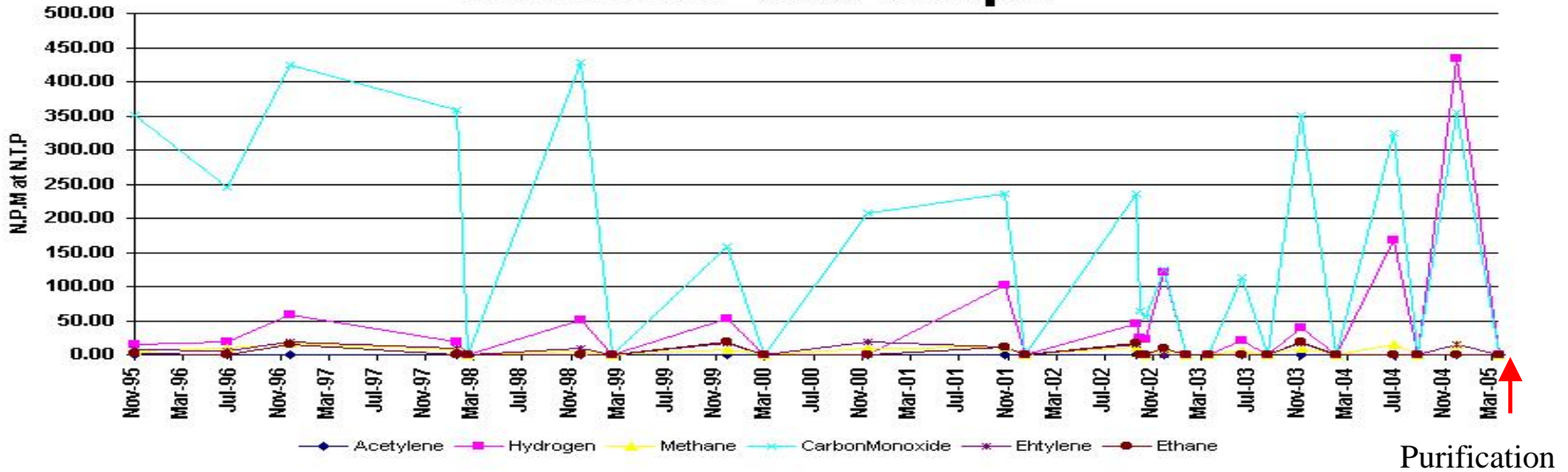
Chemical Analysis Graph



The transformer had undergone oil purification on ten occasions since 1995 in an attempt to remove moisture and improve the dielectric. With oil replacement on 12-03-2000. The oil purification had no effect in improving the oil condition

Review of Maintenance History.

Dissolved Gas Graph



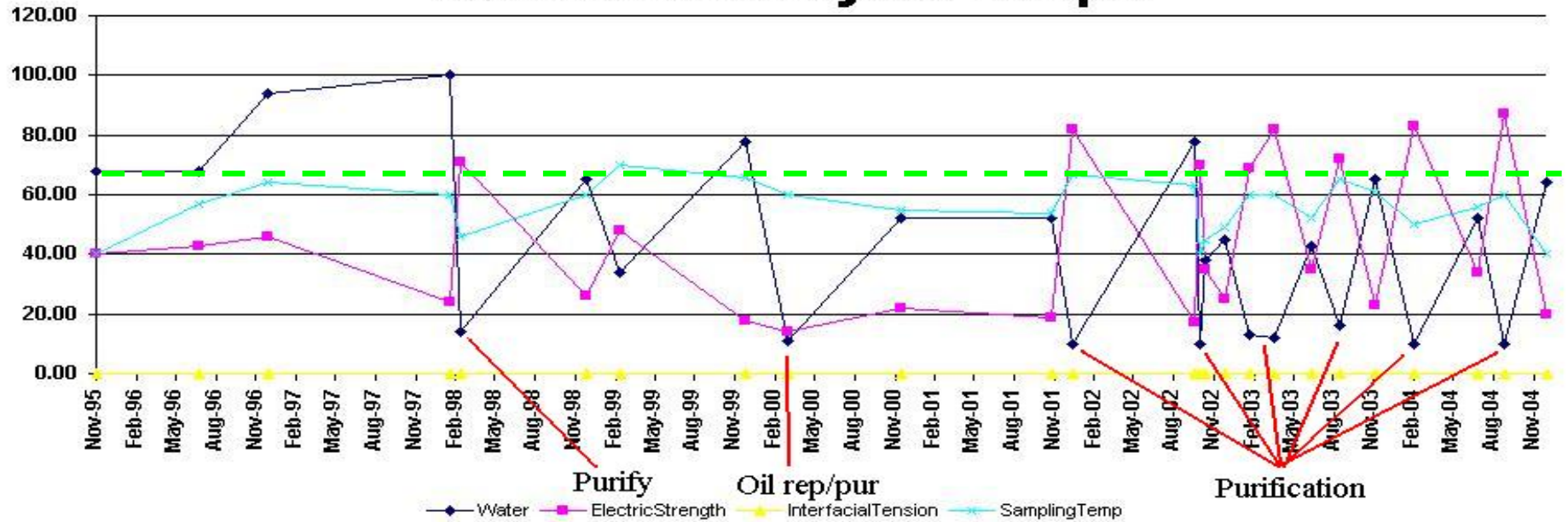
The Dissolved Gas analysis indicated a Partial discharge of low energy density (IEC 599) with the C02/C0 Ratio of 16.5 indicating insulation paper degradation. (>3 and <11) Normal Ratio.

Transformer Internal Condition

Hydrogen (H ₂):	434
Oxygen (O ₂):	2340
Nitrogen (N ₂):	64873
Methane (CH ₄):	16
Carbon Monoxide (CO):	355
Carbon Dioxide (CO ₂):	5863
Ethylene (C ₂ H ₄):	15
Ethane (C ₂ H ₆):	0
Acetylene (C ₂ H ₂):	0
Total %Gas	8.63
Total Gas Combustibles:	820

Review of Maintenance History.

Chemical Analysis Graph



The transformer had undergone oil purification on ten occasions since 1995 in an attempt to remove moisture and improve the dielectric. With oil replacement on 12-03-2000. The oil purification had no effect in improving the oil condition

Economic Consideration



The assumed average maintenance cost for this transformer was R 25 000 since 1995 with no benefits i.e. there had been no improvement in fluid insulation condition with a deterioration in solid (paper) condition.



The end result being in service failure amounting to significant losses.

In this case a more cost effective maintenance plan would be to remove the transformer to a works facility for Refurbishment.



Conclusion.

The use of furan in oil analysis has a significant cost benefit in planning a maintenance program

This data needs to be viewed in conjunction with Dissolved Gas Analysis, fluid insulation tests and the maintenance history.



When the transformer reaches the end of its reliable, cost effective life. One of the things that can be done with the transformer as it is taken out of service is to rewind or remanufacture it.



END

A furan test should be included with yearly maintenance and trends developed to monitor the condition of the paper.

