

REINHOLD ENVIRONMENTAL Ltd.



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TR SET LIFE EXTENSION

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Special Thanks

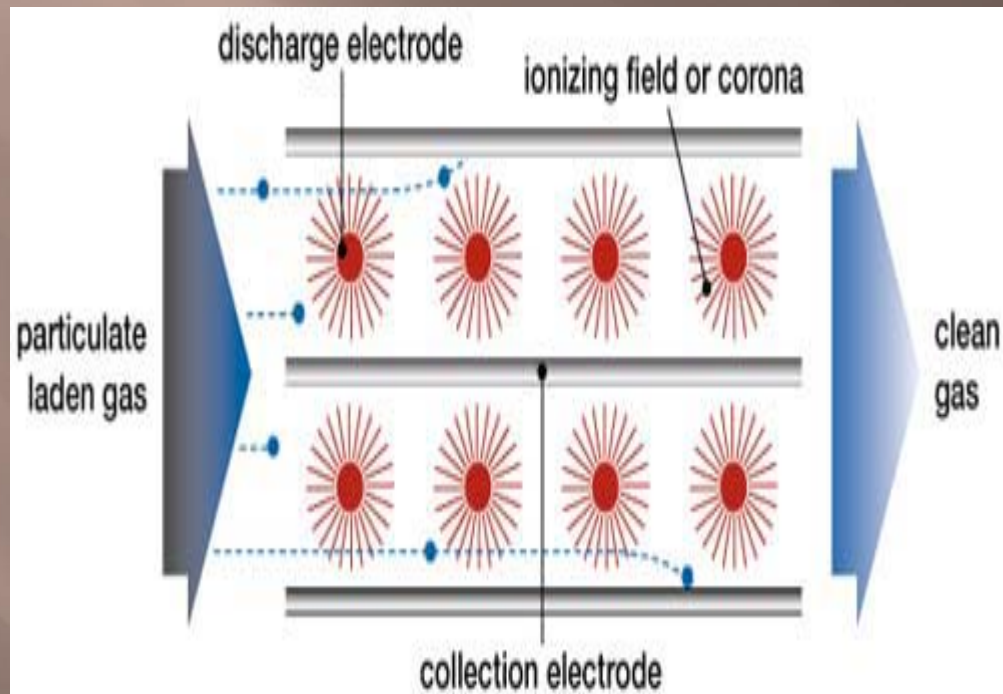
- ▣ Duke Energy
- ▣ AEP
- ▣ Progress Energy
- ▣ PacifiCorp
- ▣ Weidmann Diagnostics
- ▣ Stein Industries

Precipitator transformer understanding

- ▣ Precip summary
- ▣ TR Components
- ▣ Precip TR Testing & Maintenance
- ▣ Ageing factor of Paper and cellulose
- ▣ Precip TR Inspections
- ▣ Case studies/history
- ▣ Oil diagnostics
- ▣ Close

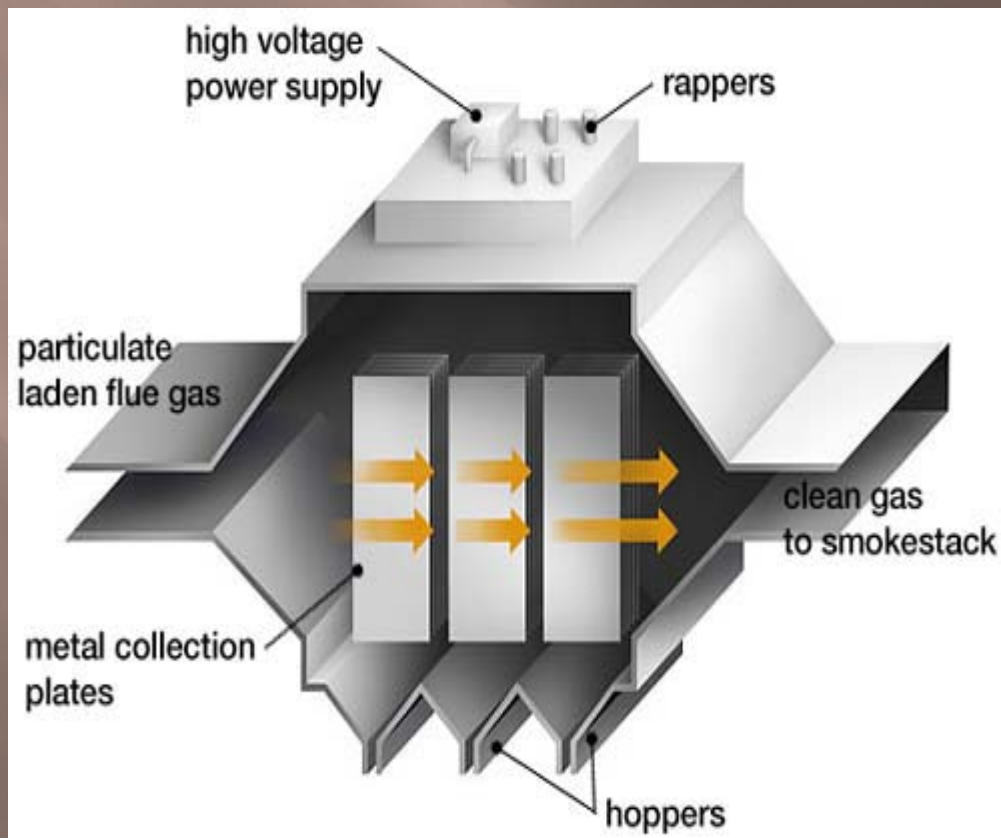


Precip gas flow

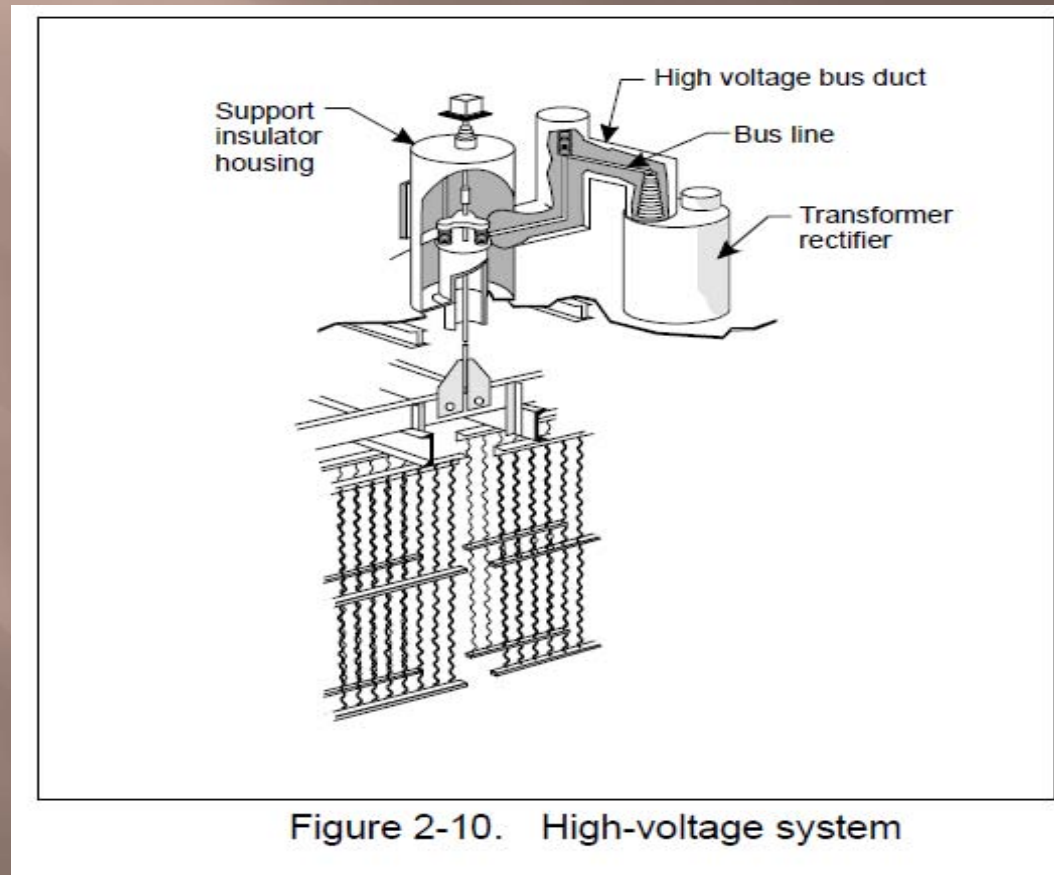


Power and control

TR is designed to provide voltage to the fields at the highest possible level. The voltage must be controlled to avoid causing sustained arcing or sparking between the electrodes and the collecting plates



Block Diagram



Internal support system

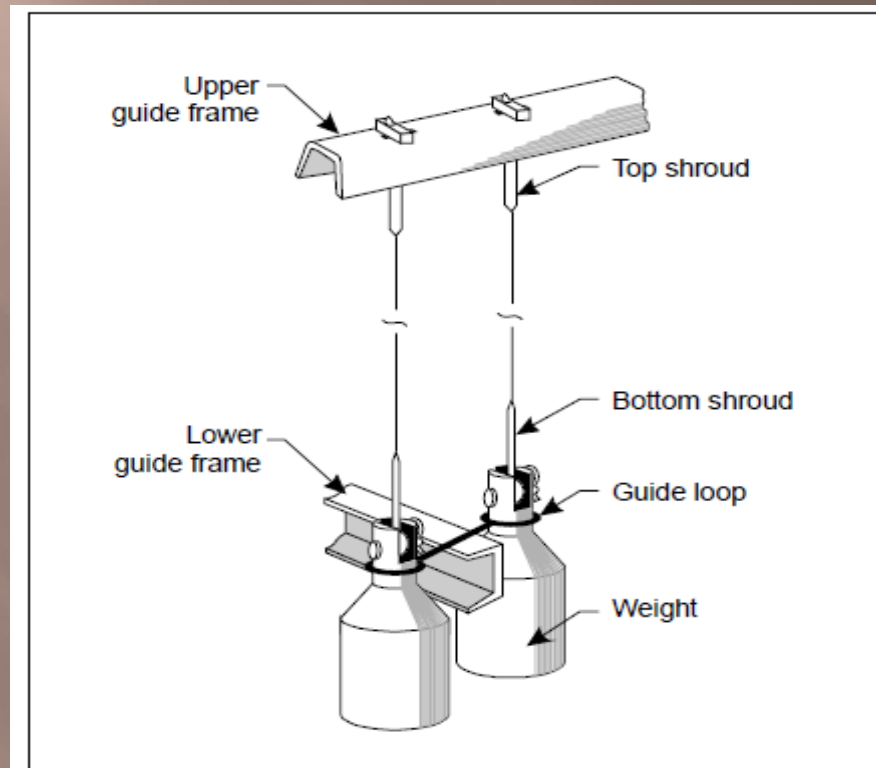


Figure 2-2. Guide frames and shrouds for discharge wires

Power and Control

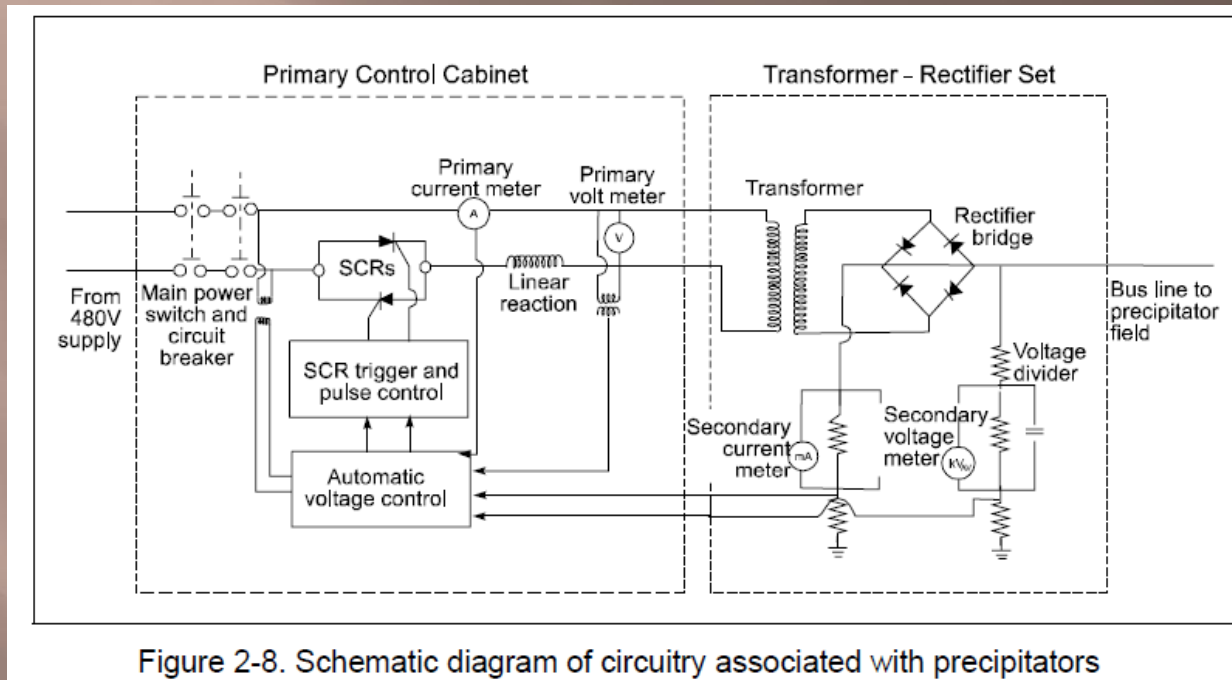


Figure 2-8. Schematic diagram of circuitry associated with precipitators

Voltage control

Automatic voltage control varies the power to the TR in response to signals received from sensors in the TR itself. It monitors the electrical conditions inside the precipitator, protects the internal components from arc-over damages, and protects the TR and other components in the primary circuit.

The ideal automatic voltage control would produce the maximum collecting efficiency by holding the operating voltage of the precipitator at a level just below the spark-over voltage. However, this level cannot be achieved given that conditions change from moment to moment. Instead, the automatic voltage control increases output from the transformer-rectifier until a spark occurs. Then the control resets to a lower power level, and the power increases again until the next spark occurs.



Transformer/Rectifier

- ▣ Transformer-Rectifiers

The PS will perform best when the transformer-rectifiers operate at 70 - 80% of the rated capacity -without excessive sparking. This reduces the maximum continuous-load voltage and corona power inputs. Practical operating voltages for transformer-rectifiers depend on:

- ▣ Collecting plate spacing
- ▣ Gas and dust conditions
- ▣ Collecting plate and discharge electrode geometry

Resistivity/separation=Diode stress

- When separating dust of low or moderate resistivity, the degree of separation increases as the voltage between the electrodes increases. However, the possible voltage is not only restricted by the construction of the high-voltage rectifier, but also by the fact that at sufficiently high voltage, there will be flashover between the electrodes in the precipitator.
- This is effected by slowly increasing the current until flashover occurs. Subsequently, the current is reduced in a predetermined manner and then again slowly increased until the next flashover. The process is repeated periodically.

Transformer windings

- The step-up transformer is the major component of the PS. ESP transformer coils must be capable of withstanding repeated sparking and arcing of the load. Disruptions such as these, along with occasional shorted fields, cause current surges well above the system ratings. These surges cause the windings of the transformer to exert considerable physical force on the system insulation and support mechanism. If not properly accounted for, these forces will eventually cause premature destruction of the insulation and system failure.
- The transformer is typically the most reliable component in the system. Failures of transformers, however, do occur and can often be placed in two general categories. The first is degenerative failure that is caused by the long term breakdown of a component part. If the transformer is used within its rated parameters, then degenerative failure is most likely due to a defect of material or workmanship. The second failure category is overstress failure. Overstress failure is caused by subjecting the transformer to either excessive voltage or excessive current. Overstress failure is usually the case for transformers that fail between five and twenty years of operation.

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- Of the components and materials used on T/Rs, the layer insulation on the transformer winding determines the life expectancy of the system. Modern designs use Kraft insulation. The life expectancy of the insulation is a function of stress level (voltage across the insulation) and temperature of the insulation material. The operating temperature of the insulation is usually assumed to be 10° (C) higher than the overall temperature rise of the winding. The expected life of the insulation for modern designs is 34 years if the unit is continuously subjected to rated current and rated voltage (REF ANSI C57.91.1981). Degenerative insulation failure after less than 15 years, although possible is statistically very unlikely, unless there are other contributing factors. Degenerative insulation failure can be caused by abrasion caused by excessive vibration and physical movement of the transformer windings. Vibration is induced by the 60 cycle AC current while coil movement is induced by current surges. ESPs by nature present a harsh load for transformers due to the sparks and arcs that are expected.

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- The main problem that results from operating a precipitator at a level at which sparking occurs is that the automatic controller for the TR set must sense an arc and immediately reduce the voltage on the precipitator collector plate, because any spark can quickly create an arc between the plate and the electrode, with a resultant high current flow. The high current flow can cause severe damage to the precipitator grid or plate, or it can cause the transformer-rectifier set to fail. Any of those incidents will cause a section of the precipitator to be temporarily off-line, until the failures have been repaired. Repair can be a matter of minutes, or it can be weeks if the transformer-rectifier set has to be replaced.

Test and evaluation



Most Utility Engineers have not been concerned with TR integrity up to this point.

It could become a serious problem soon! 80 to 90% of the installed base has reached the end of the design life.

They never fail...why should I do anything different?

Everything fails sooner or later.

Implementing specific inspections, maintenance and diagnostics into an overall maintenance program will allow the following:

1. Gauge current condition
2. Guide scope and schedules of future maintenance practices
3. Determine the plan for the capitalization: upgrade/remanufacture - life extension

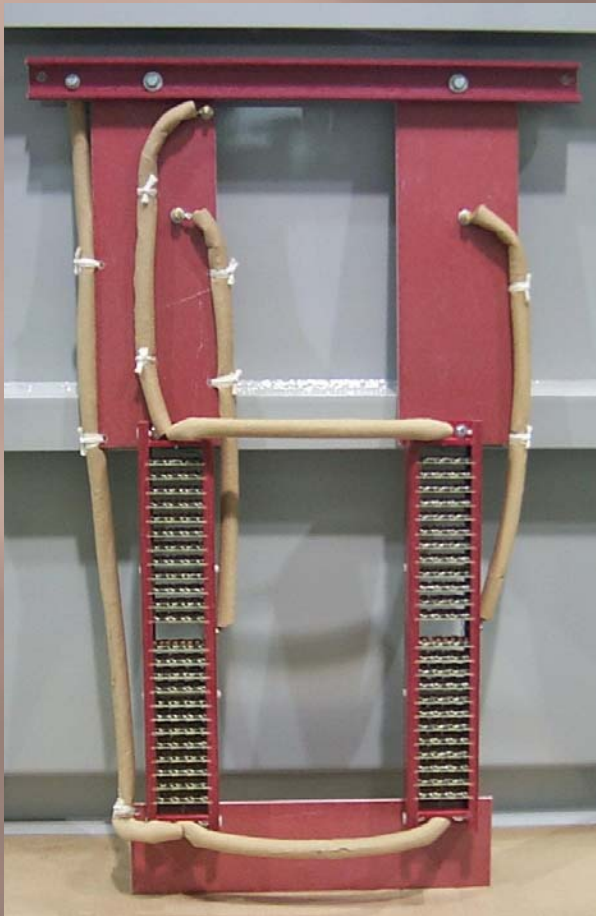
TR Set Components

- ▣ Transformer core/coil assembly
- ▣ Rectifier
- ▣ Choke Coil
- ▣ Gauges
- ▣ Arrestors
- ▣ Fluids
- ▣ Bushings LV/HV/Feedback
- ▣ Grounding switch assemblies

Transformer Windings



Rectifier & Reactor Choke Coils



Suggested test's

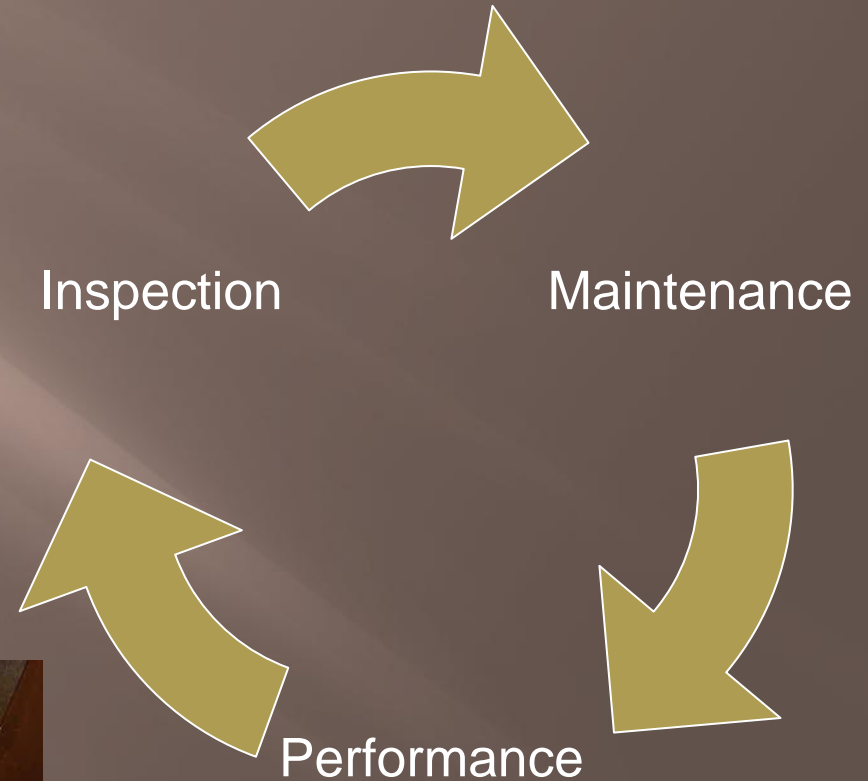
- ▣ Megger - Outage
- ▣ TTR - Outage
- ▣ Winding Resistance - Outage
- ▣ Power Factor - Outage
- ▣ Oil tests - Semi annual

Suggested Maintenance

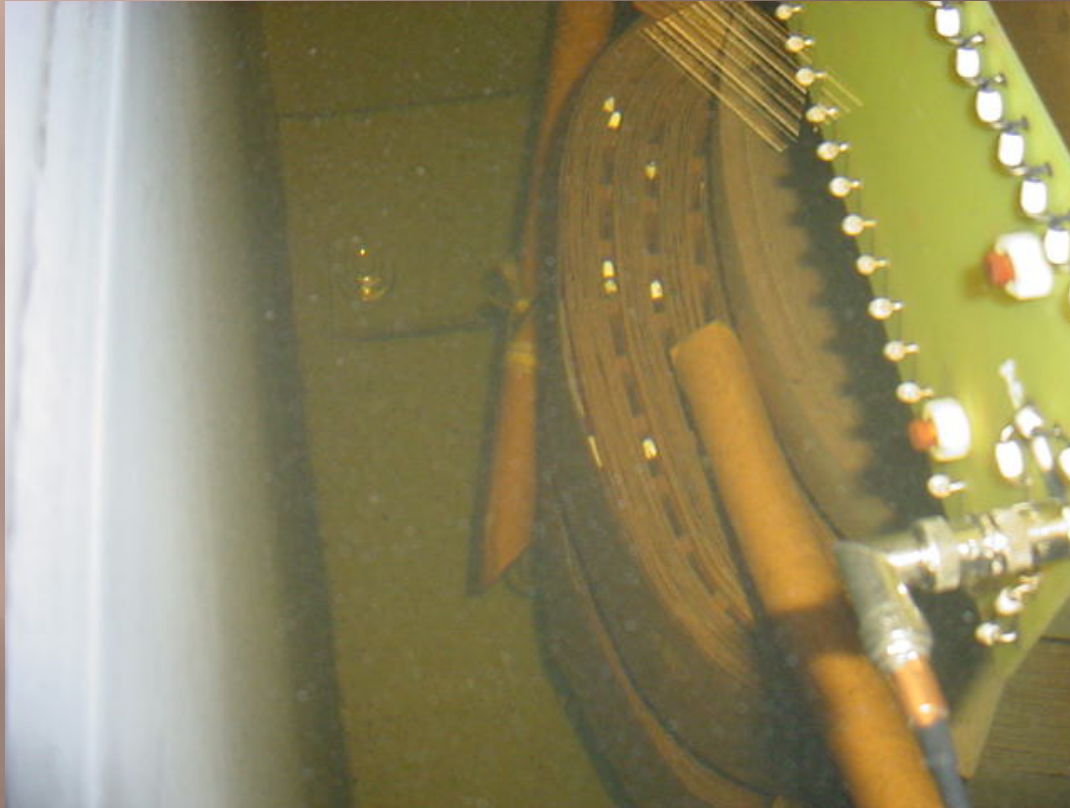
- ▣ Perform inspection & maintenance once per year as a minimum
- ▣ Monitor trends, DGA/OIL SCREEN
 - *RESULTS*
- ▣ Prevent future problems
- ▣ Reduce the probability of unplanned T/R outages and consequential non-compliances due to opacity excursions, generator capacity limits, lost revenue

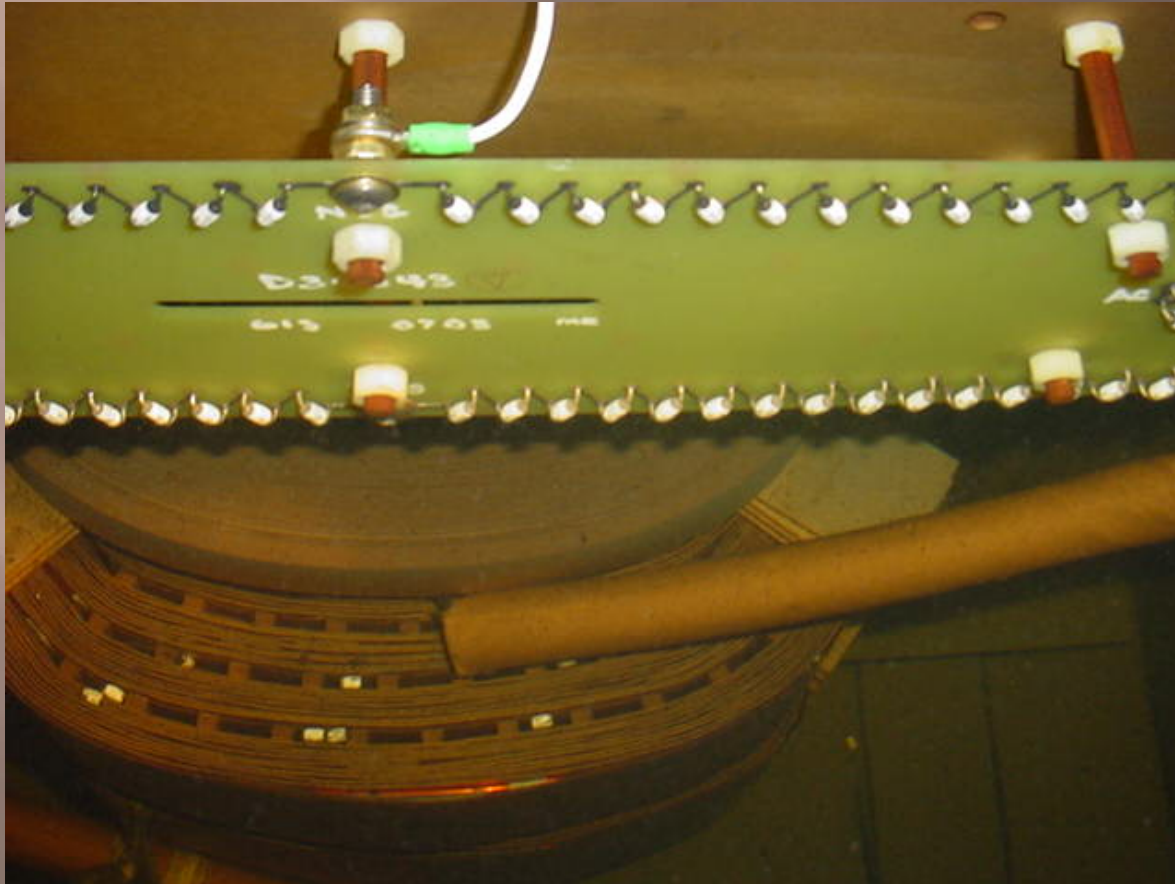
Why Do Inspection & Maintenance?

- ▣ Prevention of Failure
- ▣ Monitor Performance
- ▣ Ensure Opacity Compliance



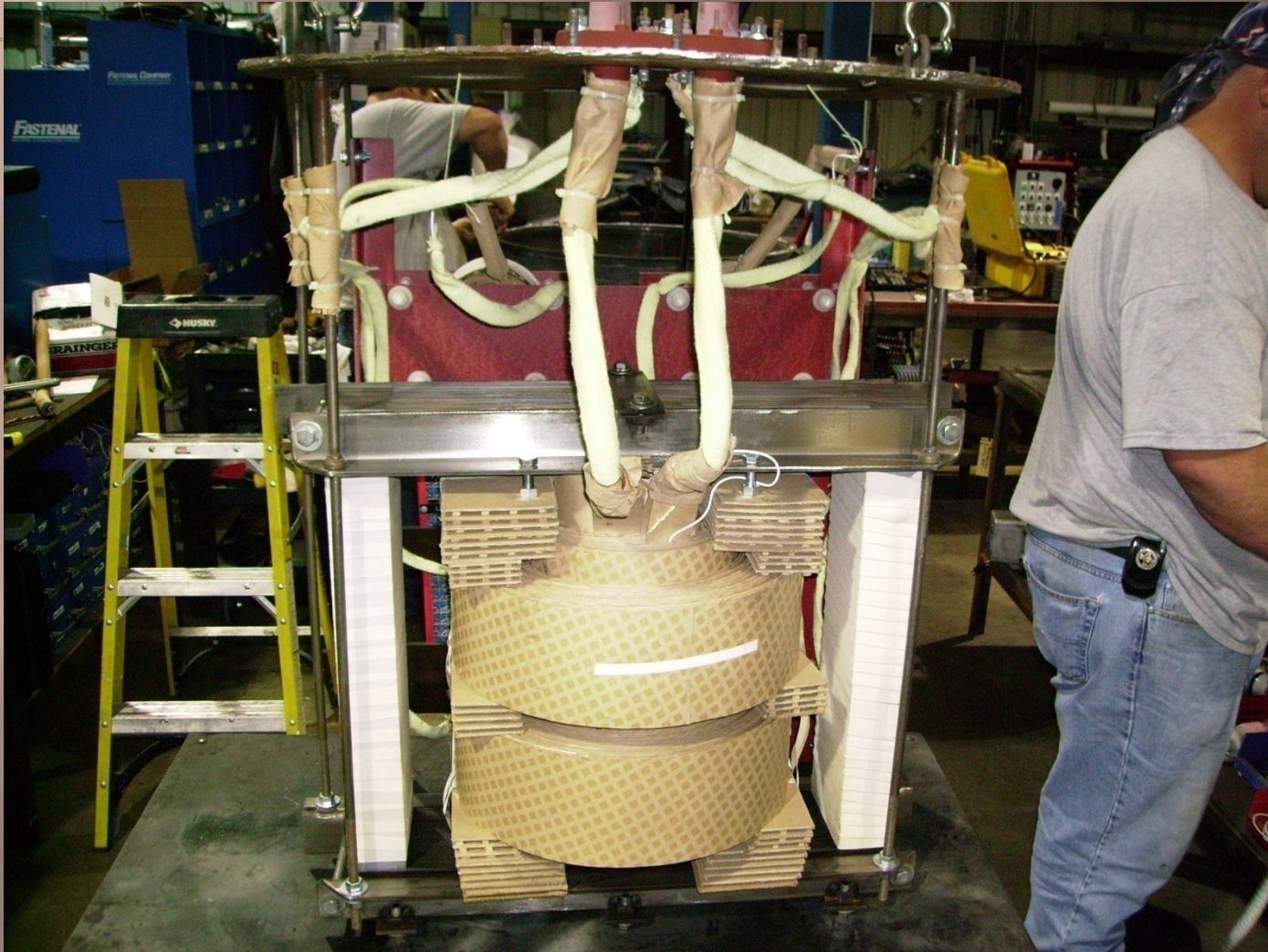
Examples of failures





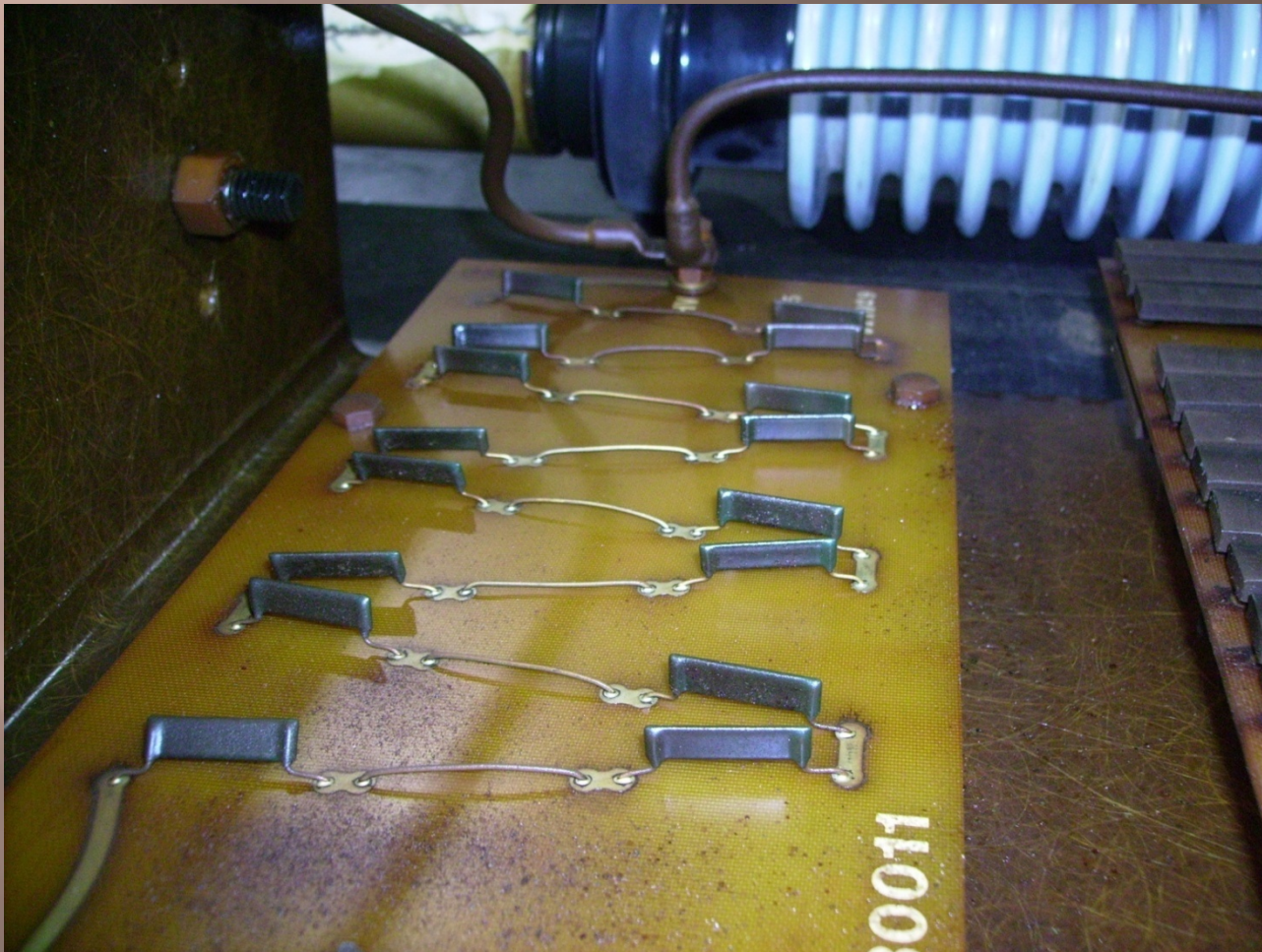




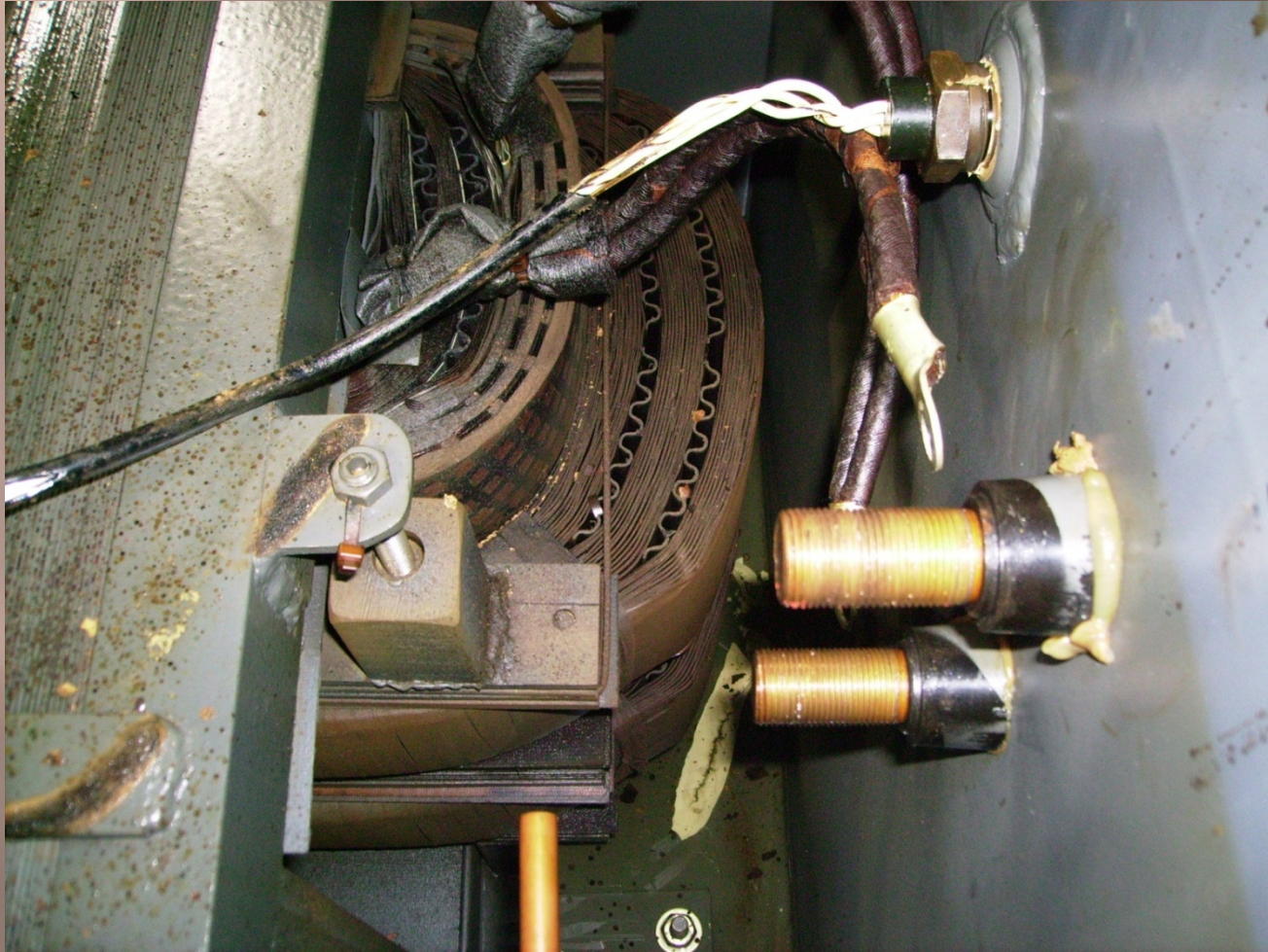




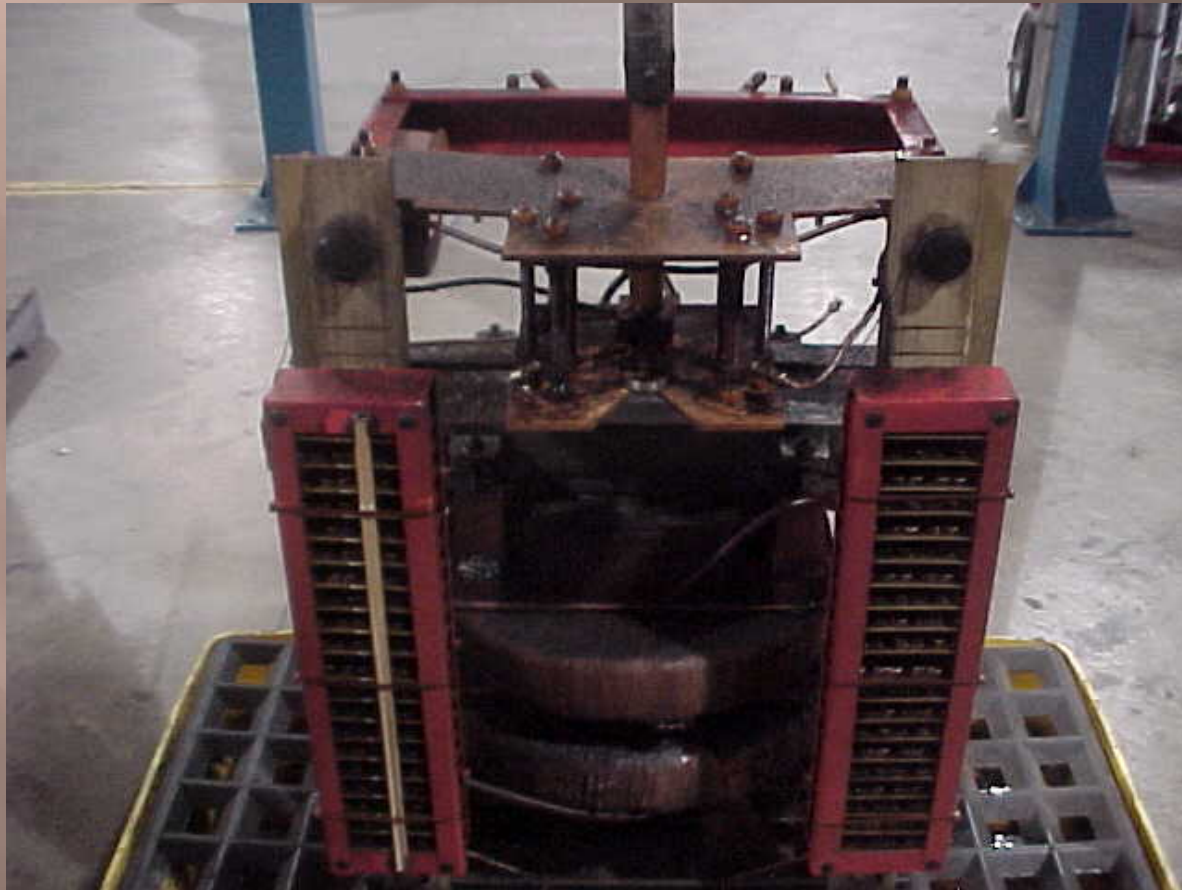












Techniques to Mitigate the Ageing Process

It is not possible (today) to reverse the ageing of the cellulose insulation

Control (slow down) the ageing process

Remove the catalysts

Moisture

Acids

Oxygen

Process the oil

Removes moisture, acids, particles, gasses

Resets the Furan levels

Dry the transformer

Removes moisture from solid insulation

Reduces the clamping pressure on windings

Effects of moisture

- Accelerated Aging of the Cellulose
- Significant Reduction in Dielectric Strength
- Bubble Formation and Dielectric Failure
- Partial discharges in the Insulation

Dry = Cellulose < 0.5% by weight
& Oil < 10 ppm H₂O

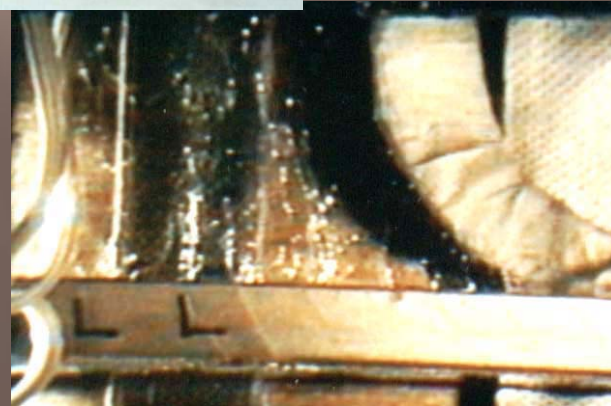
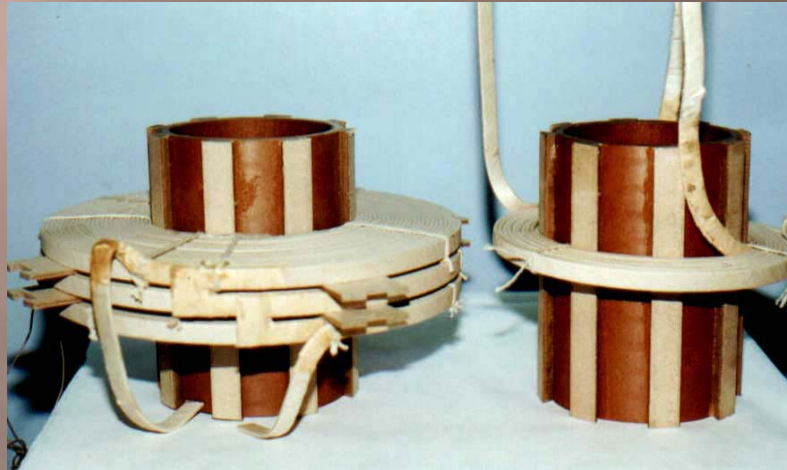
Moisture causing gas

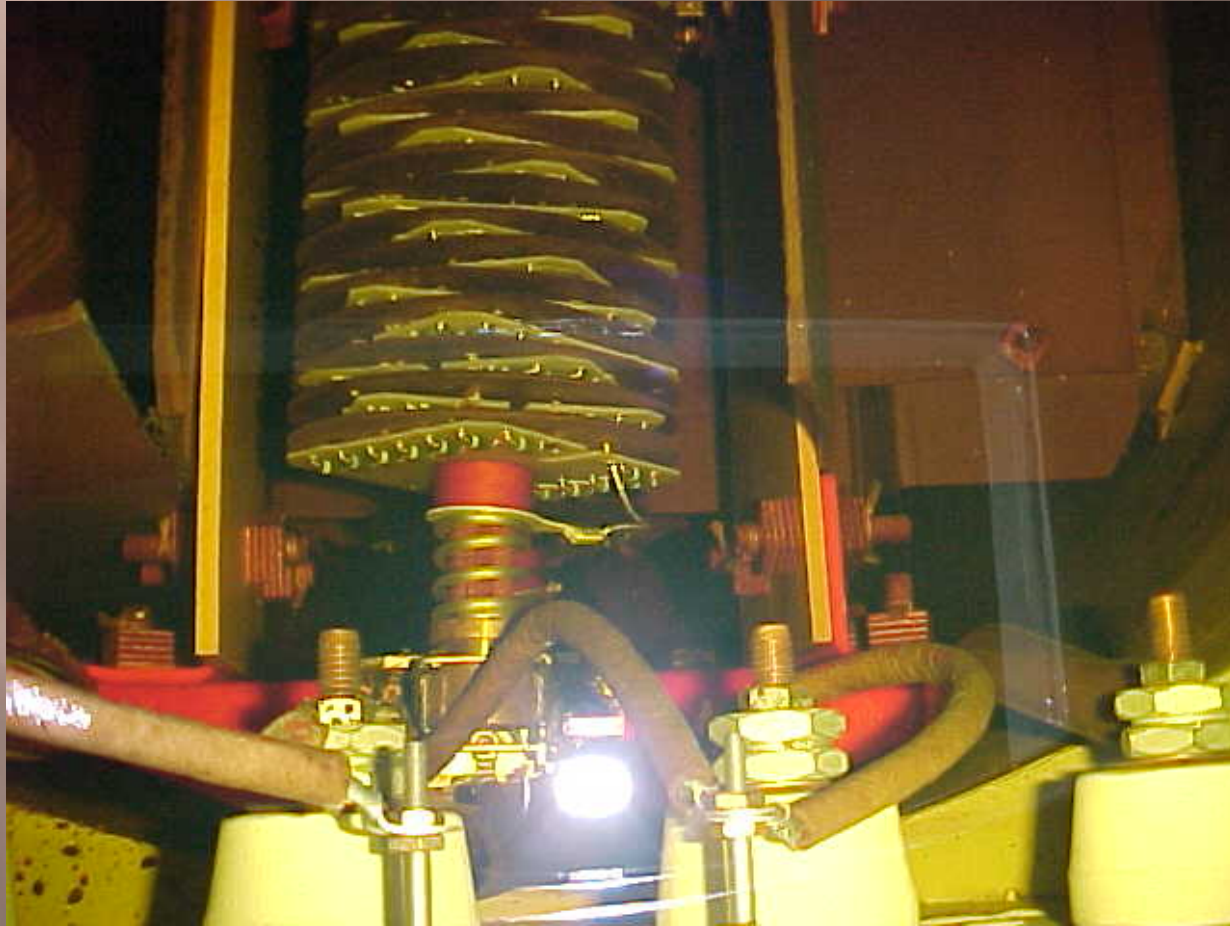
▣ Excessive moisture results

Residual moisture in winding insulation can lead to generation of gas bubbles at high temperature
This is the dominant concern in the selection of a limiting hot spot temperature for safe operation
Determinant factors for bubble generation have been identified :

- Moisture content in insulation
- Hydrostatic pressure
- Duration of the high temperature

Moisture/Gas







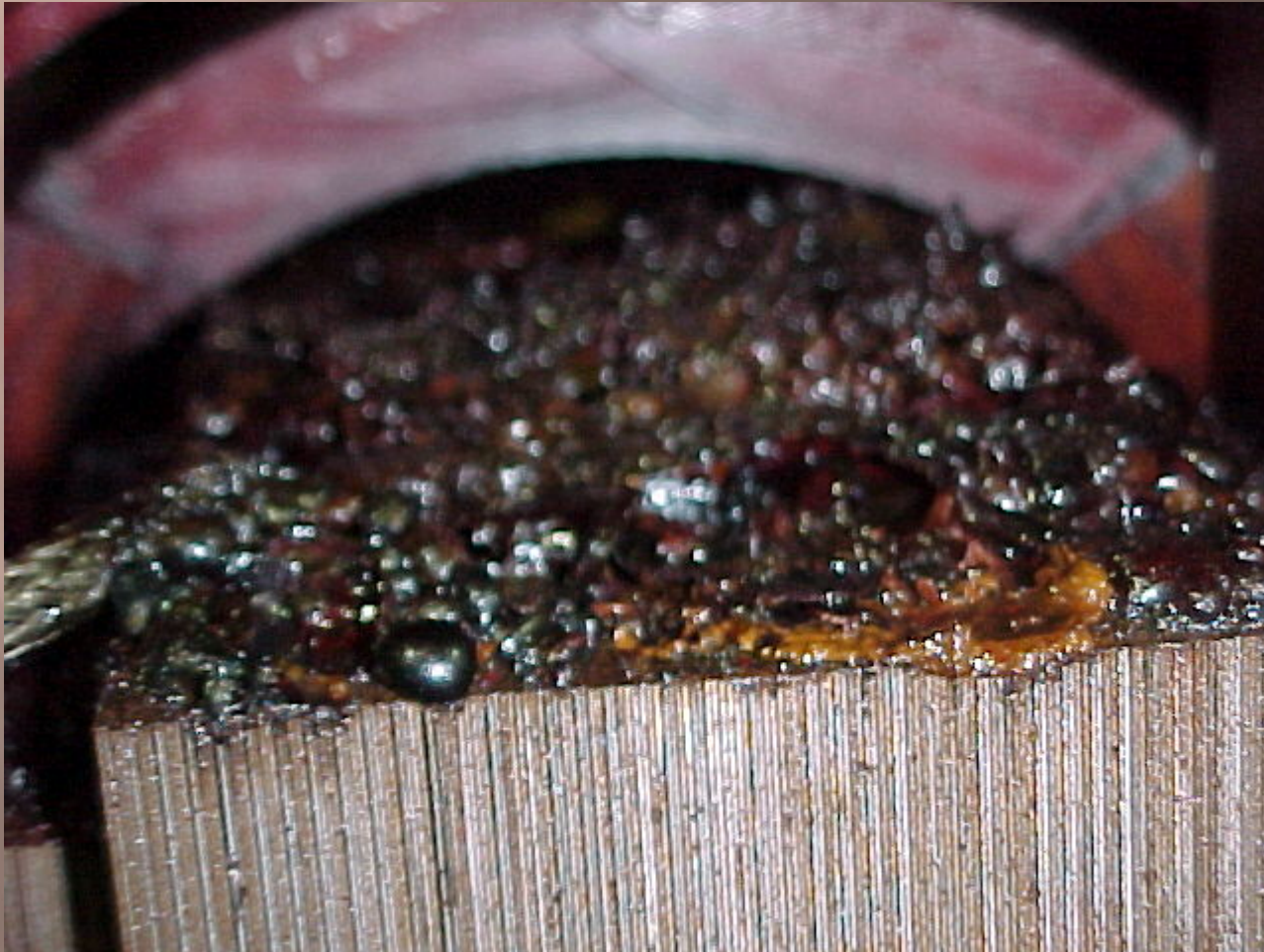


Inspection

- ▣ Internal inspection, does the oil smell burnt? Take the unit out of service as soon as possible. After repair is made, DE GAS IS A MUST!
- ▣ Send oil out for DGA test after repair and processing



Examples of poor DGA/oil quality

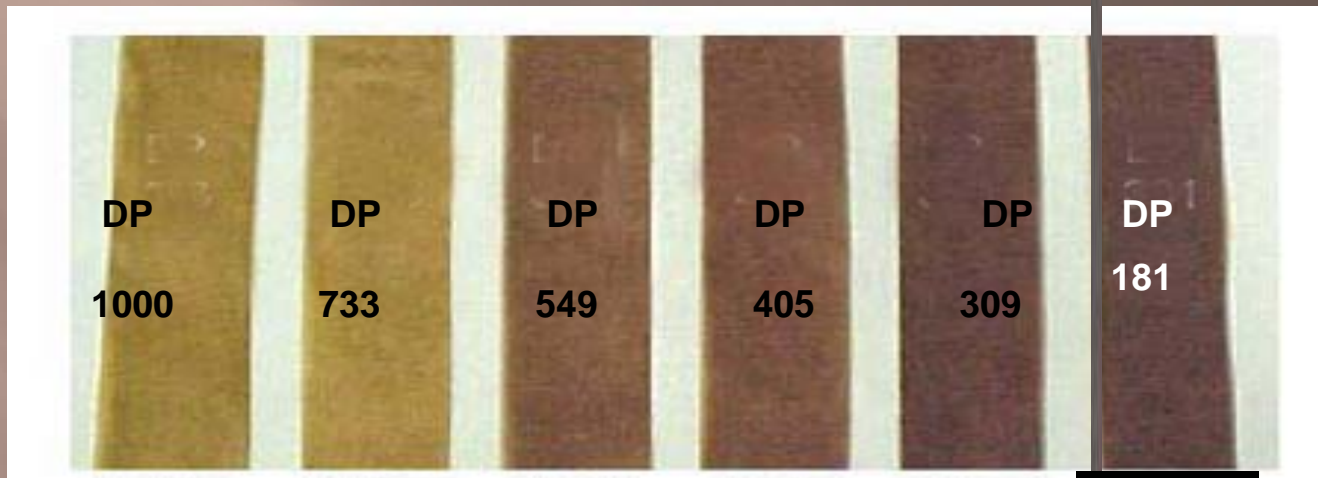








Aged paper in oil



Progressive aging with time

End of
mech str.

Brittle & dark

Ageing

Effects of aging:

- darkening of color
- loss of electrical and mechanical strength; trans. failure
- shortening of cellulose chains – DP lowered
- paper becomes wetter, and acidic
- by-products contaminate the o



Formal Inspection & Maintenance

“ EXPERIENCED PERSONEL ONLY”

BEFORE REMOVING TR FROM SERVICE

- ▣ Check the insulating fluid
- ▣ Dielectric strength
- ▣ Water content
- ▣ Dissipation factor
- ▣ Dissolved gas analysis



Oil Analysis

DGA (Dissolved Gas Analysis)

- Most sensitive indicator
- Easily obtained

Measured gasses for sample diagnosis:

- Hydrogen (H_2)
- Methane (CH_4)
- Ethane (C_2H_6)
- Ethylene (C_2H_4)
- Acetylene (C_2H_2)
- Carbon Monoxide (CO)
- Carbon Dioxide (CO_2)

DGA Evaluation

- ▣ High hydrogen and acetylene can indicate arcing and insulation break down
- ▣ High methane / ethane / ethylene can indicate elevated temperatures, low temp. arcing in a confined space
- ▣ Carbon Monoxide/Carbon dioxide can indicate overheating of cellulose

Oil Quality Interpretation

- ▣ Dielectric breakdown
 - ▣ when insulating fluid begins to conduct
- ▣ Acid number
 - ▣ oxidation of insulating fluids will result in the production of acidic compounds. The build up of acidic compounds will increase the formation of sludge.
- ▣ Interfacial Tension
 - ▣ the IFT of insulating oil is sensitive to the presence of oxidation byproducts and can be used together with acidity measurements as an indicator to monitor sludge development

- ▣ Color number and visual

- ▣ The color number will increase as oil darkens due to oxidation or the presence of contamination.

- ▣ Power Factor

- ▣ Measure of dielectric losses in an insulating fluid due to heat dissipation when the fluid is placed in an AC electrical field.

TR Options

- ▣ New/Remanufacturing / Repair options for all OEM types of equipment
- ▣ Individual components are now available in the after market
- ▣ Fast turn around times are available
- ▣ Warranties still apply

