

REINHOLD ENVIRONMENTAL Ltd.



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Diagnostic Evaluation of ESP Transformer/Rectifiers 2010 APC/PCUG Conference

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Concord, NC – July 20, 2010

WEIDMANN

ELECTRICAL TECHNOLOGY

WEIDMANN DIAGNOSTIC SOLUTIONS INC.
A Member of the **WICOR** Group

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Current ESP TR Maintenance

- Time-Based
- Reactive
- Replace at Failure



Maintenance

Management View

Tell me the day before the unit will fail if we do not perform maintenance.

Maintenance Goals

- Replace time and/or reactive maintenance with condition based maintenance
- Decrease unplanned outages
- Maximize Output

Why Oil Analysis was Rarely Used

- Reserved for High Value Station Equipment
- Perceived High Cost
- ESP TR Replacement Costs are Low



Why Use Oil Analysis for ESP T/Rs Today?

- Identify Current Condition
- Control Particulate Emissions
- Identify Problem units
- Minimize Failures



Development of Diagnostic Program

- Identify Fault Mechanisms
- Select Appropriate Analytical Tests to Identify Problem Units
- Develop Algorithms to classify ESP TR Condition
- Correlate test data with physical inspection

Transformer Fault/Failure Modes

Common causes of overheating of T/R components

- Over loading T/R by powering to many ESP discharge electrodes
 - Excessive hot spots in transformer windings and current limiting reactor windings

Transformer Fault/Failure Modes

Common causes of overheating of T/R components

- Dynamic Load of ESP
 - Winding overheating from short-circuits
 - Diode Failure – at solder joint or diode junction

Transformer Fault/Failure Modes

Partial Discharge within TR

- Air Core Reactors Insulation is highly stressed during ESP arcs to ground
- Improper Manufacturer or Inadequately Insulated Connections
- AVC not functioning correctly creating an overvoltage
 - Can affect transformer windings, CLR windings, Air Core Reactor, and Rectifier Diodes

Transformer Fault/Failure Modes

Common Causes of Arcing within T/R

- Failing / Failed Diodes
 - Melted Solder Connections
 - Diode Junction Failed to Open State
- Failed Diodes
 - Unequal Peak Inverse Voltage between Diodes
 - Only Common in Old T/Rs

Analytical Tests

- Dissolved Gas Analysis (DGA)
- Oil Quality Screen
 - Interfacial Tension
 - Acid
 - Color/Visual
 - Moisture
 - Dielectric Breakdown

Dissolved Gas Analysis

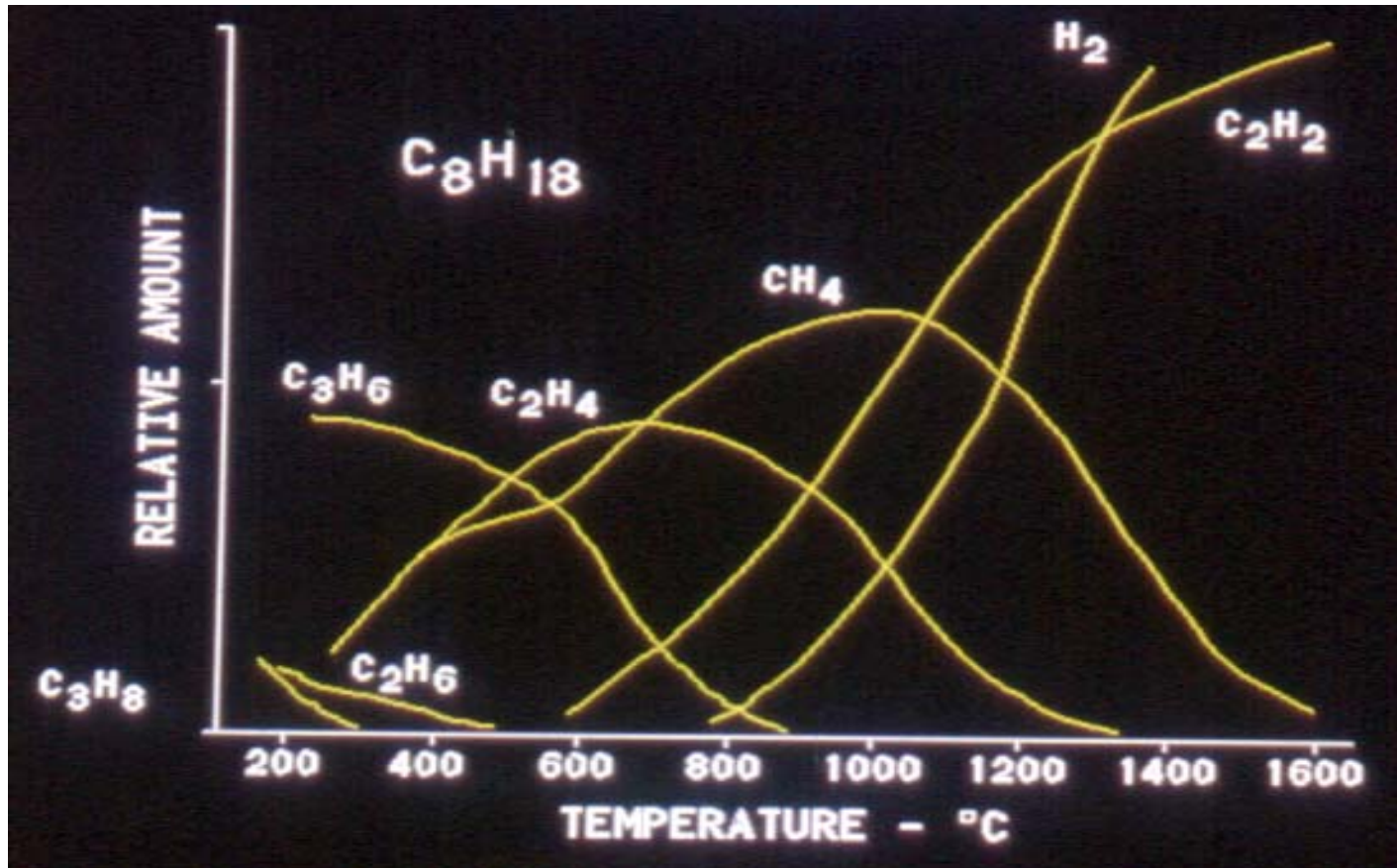
- Detects Thermal and/or Electrical Faults:
 - Partial Discharge
 - Pyrolysis (Thermal Decomposition)
 - Arcing

Fault Gasses

Gasses	Indication
Hydrogen	Partial Discharge, Heating, Arcing
Ethylene, Ethane, Methane	“Hot Metal” Gasses
Acetylene	Arcing
Carbon Oxides	Cellulose insulation degradation

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Thermal Decomposition of N-Octane



Oil Quality

- Dielectric Fluid Functions:
 - Heat Transfer
 - Insulation Between Components
 - Quenching of Arcs

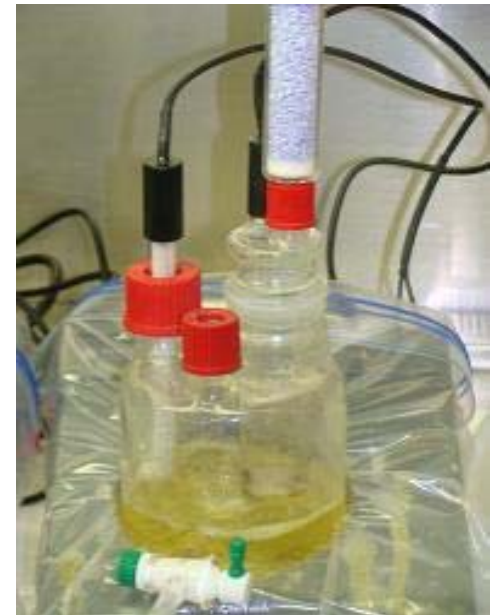
Why does Oil Deteriorate?

- Externally Derived Impurities
 - Oxygen
 - Water
- Internally Derived Impurities
 - Cellulose Fibers
 - Dissolved Insulation Materials
 - Carbon & Metal Particles

Moisture Content

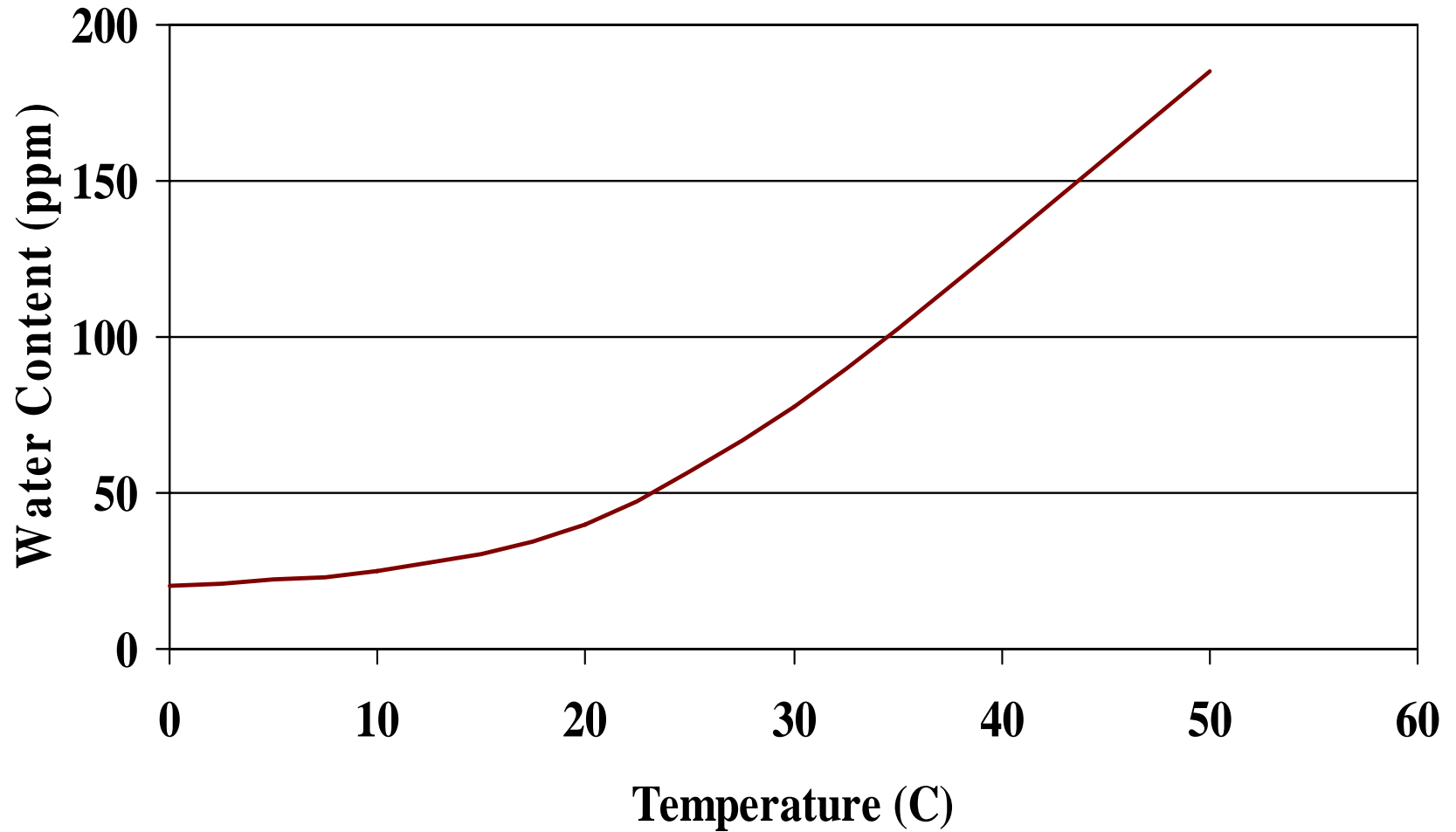
Procedure: Karl Fischer Titration with electrochemical generation of reagent according to ASTM method D-1533.

Application: Determination of Moisture Content in Dielectric fluids.



<i>IEEE</i>	Value for Voltage Class (kV) @ 60C		
	≤ 69	> 69 and ≤ 230	> 230
<i>C57.106-2006</i>			
Maximum Moisture Content (ppm)	35	25	20

Solubility of Water in Mineral Oil



Temperature Dependence of Water Distribution



Increase Temperature -

Water moves from Paper to Oil



Decrease Temperature -

Water moves from Oil to Paper

Acidity

(Neutralization Number)

Procedure:

The Acid is neutralized with a "strong" base (KOH) according to ASTM method D-974

Application:

Oxidation of oil results in the production of acid. Acid attacks Cellulose insulation and can lead to sludge formation.

<i>IEEE</i>	Value for Voltage Class (kV)		
	≤ 69	> 69 and ≤ 230	> 230
<i>C57.106-2006</i>			
Maximum	0.20	0.15	0.10
mg KOH /g			

Interfacial Tension

(Similar to Acid)

Procedure: Measurement of the force required to pull a Platinum ring through the fluid/water interface according to ASTM D-971.

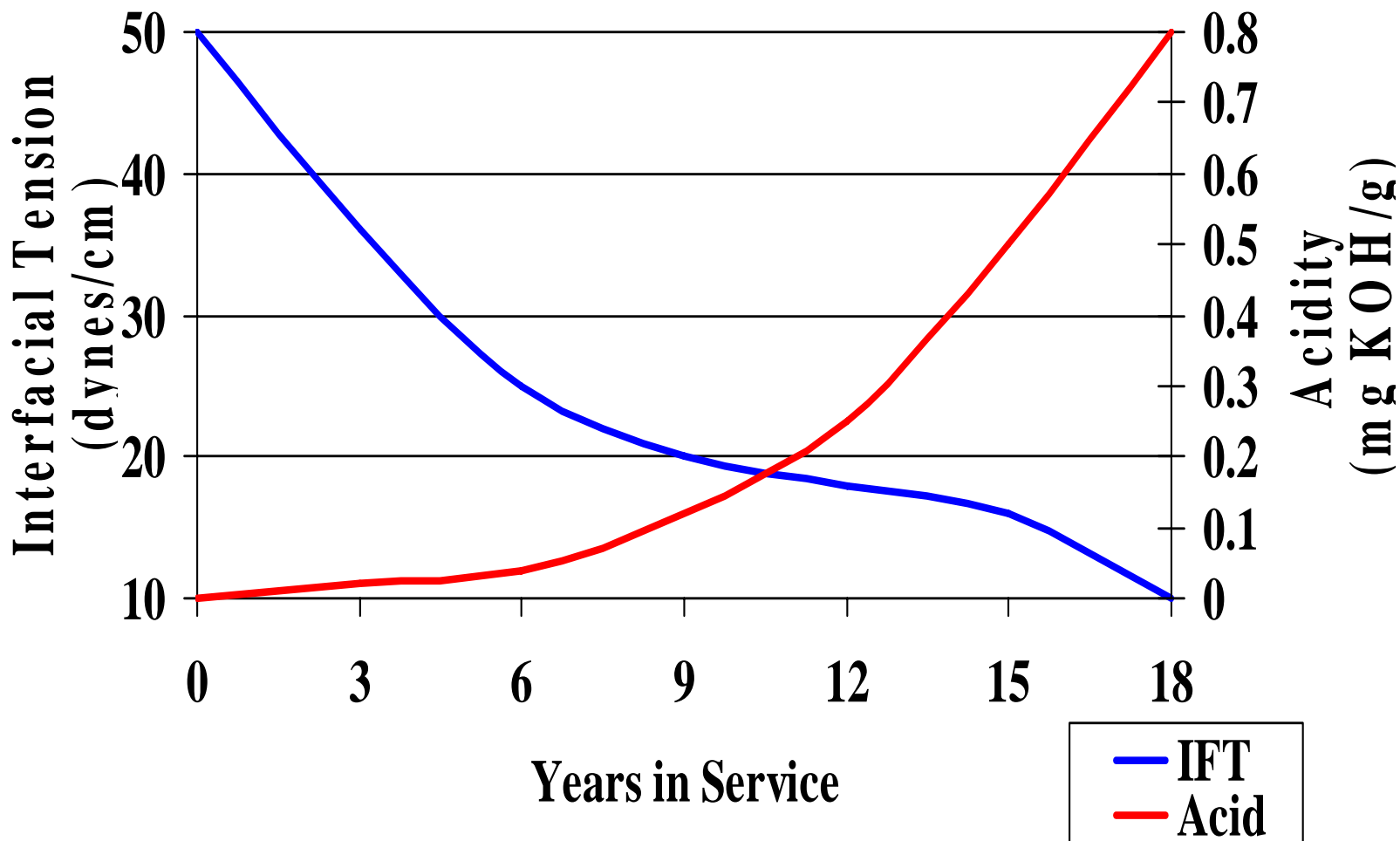
Application: The IFT is affected by the presence of polar contaminants.



<i>IEEE</i>	Value for Voltage Class (kV)		
	≤ 69	> 69 and ≤ 230	> 230
<i>C57.106-2006</i>			
Minimum IFT dynes/cm min.	25	30	32

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Interfacial Tension and Acidity vs. Service Life of Mineral Oil



Color & Visual/Sediment Examination

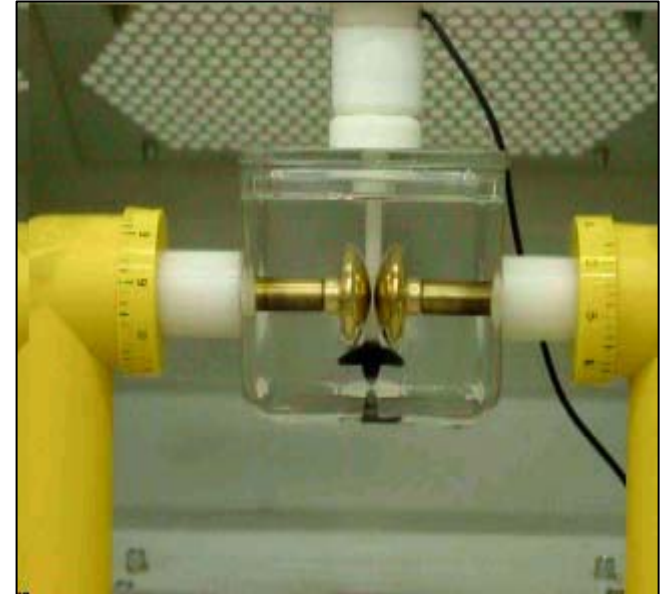
Procedure: Measures the darkening of oil due to oxidation, and detects any deviation from a “clear and sparkling” condition according to ASTM methods D-1500 and D-1524.

Application: Measures the extent of fluid deterioration and the intrusion of contaminants i.e. particles and sediment.

Dielectric Breakdown ASTM D-1816

Procedure: An a.c. ramp voltage (0.5 kV/sec) is applied between two hemispherical electrodes while the fluid is circulated and the voltage at which conduction is initiated is determined

Application: This test method is recommended for testing filtered, degassed oil and dehydrated oil prior to and during the filling of power system's apparatus. Recommended for In-Service testing of EHV equipment.



IEEE	Value for Voltage Class (kV)					
	≤ 69		> 69 and ≤ 230		> 230	
	23 (1mm)	40 (2mm)	28 (1mm)	47 (2mm)	30 (1mm)	50 (2mm)
C57.106-2006						
kV minimum						

Diagnostic Tools to Identify Failure Modes

Failure	Diagnostic Tools
Overloading	DGA
Moisture	moisture, dielectric, color/visual
Partial Discharge	DGA
Carbon	dielectric breakdown, color/visual
AVC (overvoltage)	DGA
Failing / Failed Diodes (Arcing)	DGA
Sludging	IFT, acid, color/visual
High Contact Resistance	DGA
Deteriorated paper insulation	DGA

T/R Condition Assessment using DGA

Diagnostic Development

The Procedure:

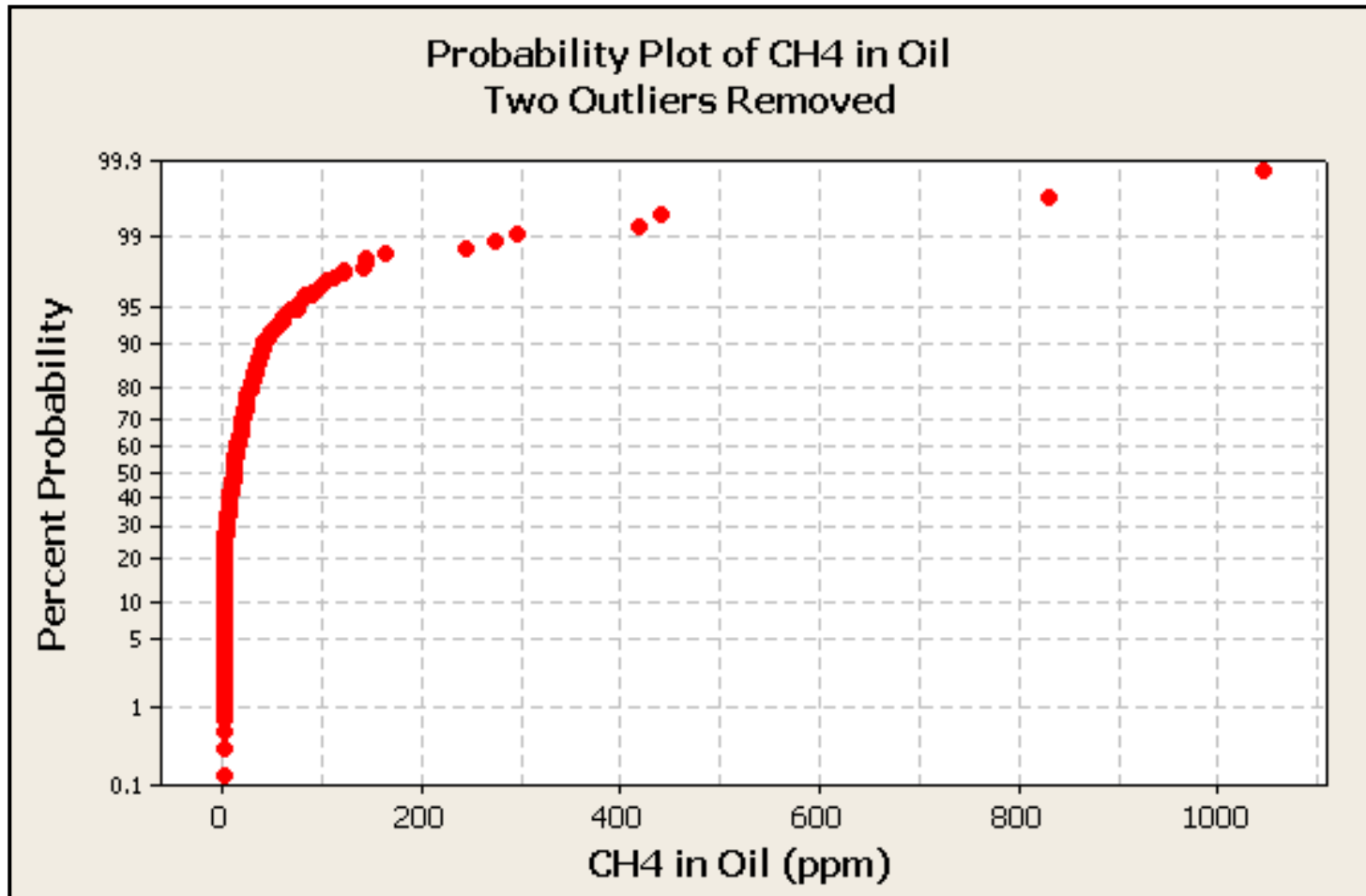
- Choose a database of T/R DGA results
- Apply statistical method to analyze the data
- Establish dissolved gas limits for “Good,” “Caution,” and “Warning” categories
- Establish gas ratio limits for “Good,” “Caution,” and “Warning” categories

T/R Condition Assessment using DGA

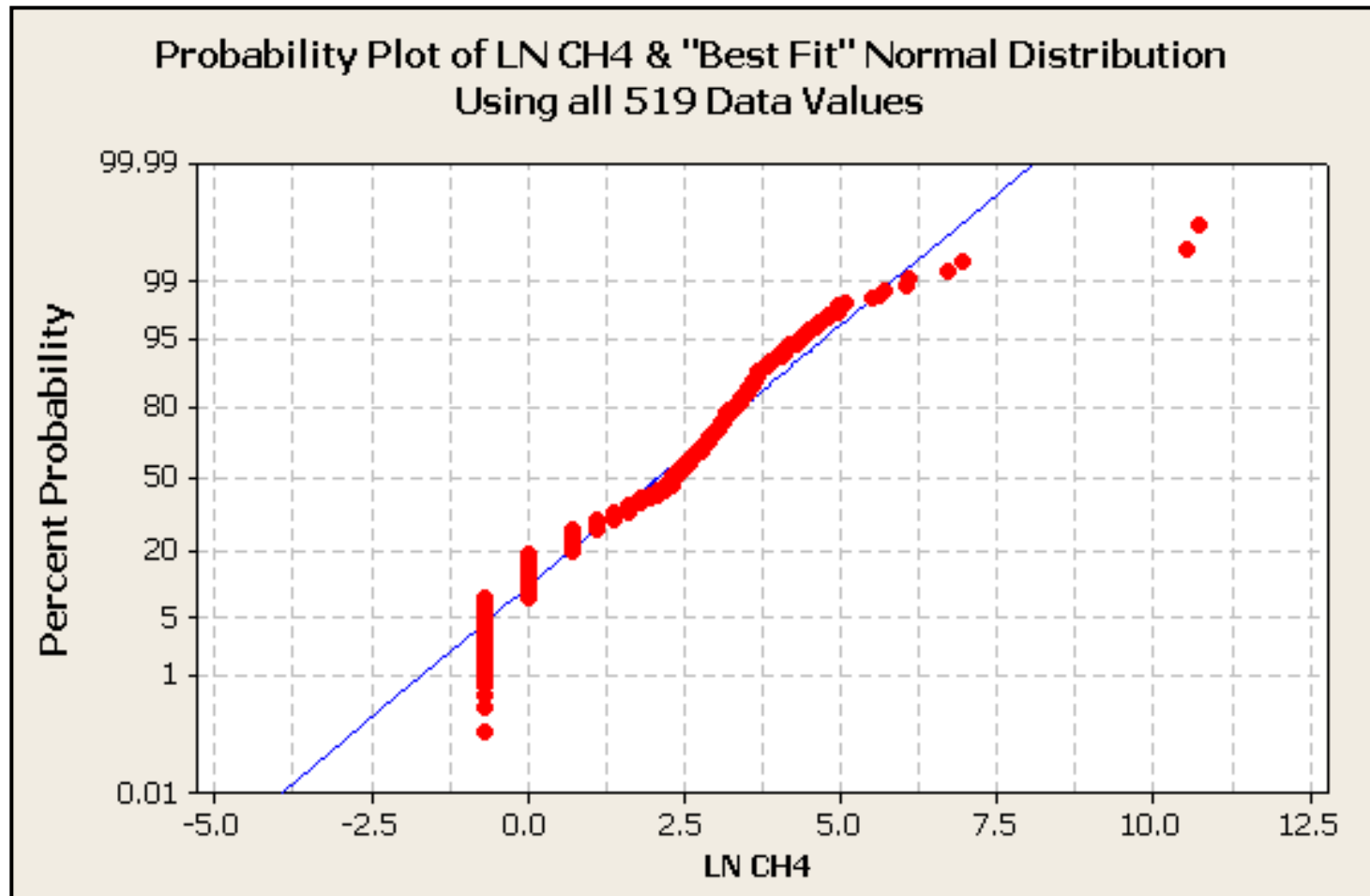
Database chosen from WEIDMANN T/R customers

- Data spanned 9 years, from 1998 to 2007
- Mineral oil: 519 samples, 398 T/Rs
- Silicone fluid: 340 samples, 287 T/Rs
- T/Rs from 24 kVA to 115 kVA

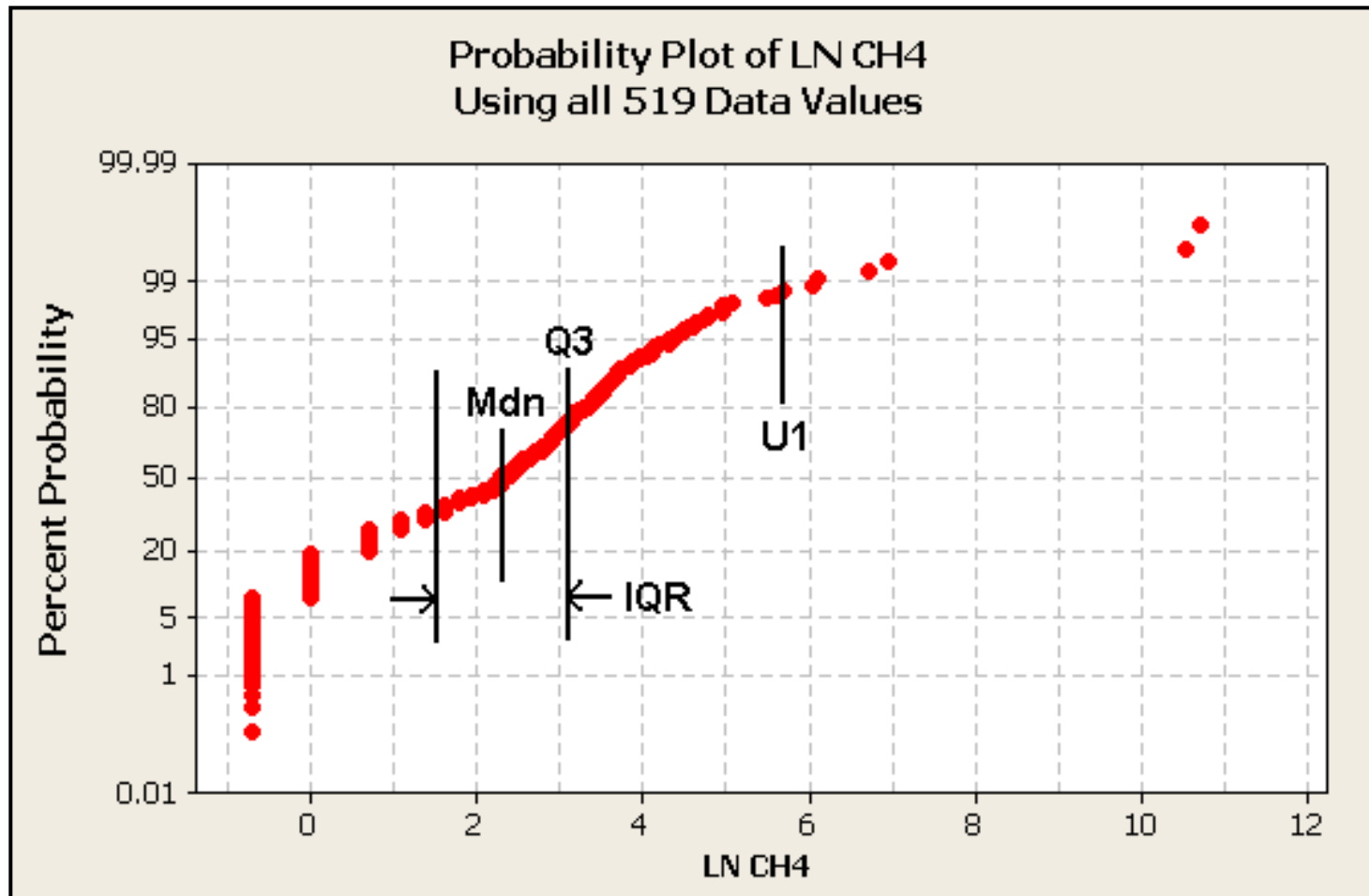
T/R Condition Assessment using DGA



T/R Condition Assessment using DGA

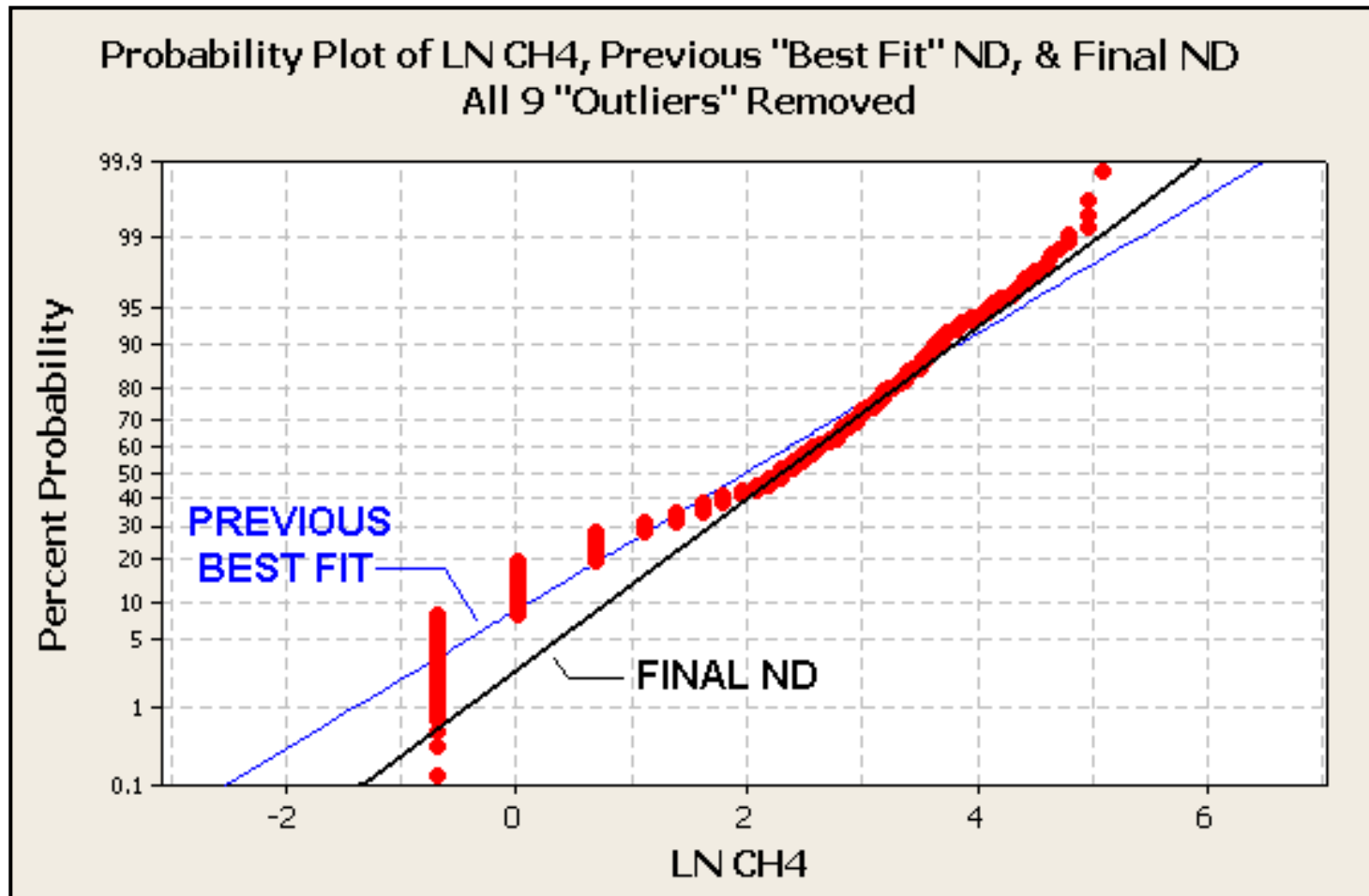


T/R Condition Assessment using DGA



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T/R Condition Assessment using DGA



T/R Condition Assessment using DGA

Using the final Log-Normal Distribution we find:

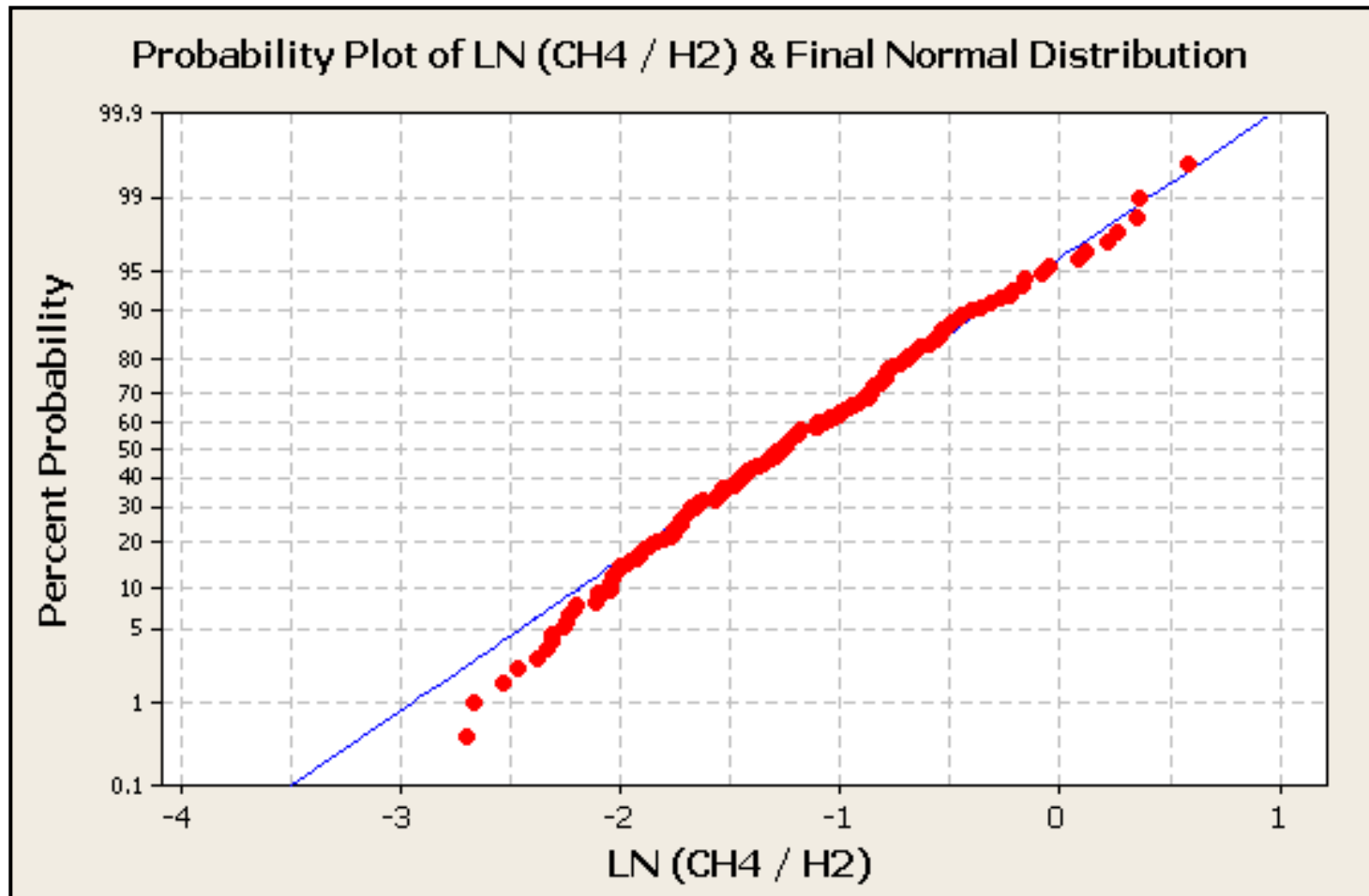
- The 90th Percentile Point, $C_{0.90} = \exp(3.80) = 45$ ppm of CH₄
- The 98th Percentile Point, $C_{0.90} = \exp(4.70) = 110$ ppm of CH₄

T/R Condition Assessment using DGA

Limits for Rogers Ratios were developed in the same manner.

Calculate ratio values only when both gasses are at least 10x their respective detection limit.

T/R Condition Assessment using DGA



T/R Condition Assessment using DGA

Again, using the final Log-Normal Distribution we find for CH₄/H₂:

- The 90th Percentile Point, $C_{0.90} = 0.7$
- The 98th Percentile Point, $C_{0.90} = 1.2$

These ratio values can be used as a guide for providing diagnostic messages.

T/R Condition Assessment using DGA

When $\text{CH}_4/\text{H}_2 > 1.2$

“Strong indication of excessive internal heating.”

When $0.7 < \text{CH}_4/\text{H}_2 < 1.2$

“Indication of excessive internal heating.”

Similar diagnostic messages were created for the other ratios.

Summary

- Maintenance costs can be significantly reduced
- ESP T/R failures can be reduced
- Unscheduled outages can be reduced
- ESP can run at maximum output

Benefits of the ESP T/R Diagnostic Evaluation Program

- Current condition assessment
- Recommended action
- ESP T/R condition codes
 - Normal
 - Caution
 - Warning