

# Interfacial Tension (IFT): Why It Matters

Interfacial Tension (IFT) is a small test with big implications. It reflects the chemical health of transformer oil and helps utilities understand the hidden impact of moisture on insulation aging and reliability.



## What is IFT?

Interfacial Tension (IFT) is the force that exists at the interface between transformer oil and water.

It is measured in mN/m (milli-Newton per meter) according to:

ASTM D971 | IEC 62961



## IFT Indicates the Chemical Condition of Oil

IFT does not measure water directly.

Instead, it indicates the presence of:



Polar contaminants



Oxidation products



Acids



Sludge precursors



Aging by-products

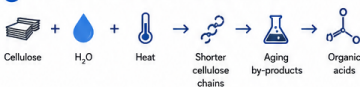
These compounds accumulate over time and reduce the natural interfacial tension of oil.

## Why Does IFT Decrease?

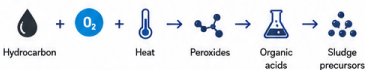
Fresh transformer oil contains very few polar compounds. As a transformer ages, moisture accelerates two major processes that create polar contaminants.



### 1. Moisture accelerates cellulose hydrolysis



### O<sub>2</sub> 2. Moisture accelerates oil oxidation



These oxidation products are polar molecules. They accumulate at the oil-water interface and reduce the surface tension.

More contaminants → Lower IFT



## Why Moisture Is Important

Moisture itself does not directly reduce IFT significantly. However, moisture acts as a catalyst for:

- Cellulose degradation
- Oil oxidation
- Acid formation
- Sludge formation

Therefore, moisture drives the chemistry that eventually lowers IFT.



Utilities often observe the following pattern in aging transformers:

Increasing moisture → Increasing acidity → Decreasing IFT → Accelerated aging

## Typical Interpretation

IFT (mN/m)	Condition
> 40	Excellent
30 – 40	Good
22 – 30	Aging evident
17 – 22	Significant deterioration
< 17	Severe contamination / sludge risk

Reference: IEC 60422 and industry practices



**Key Message:** IFT is not a moisture measurement. It is a chemical aging indicator that often reflects the long-term consequences of moisture inside the insulation system.



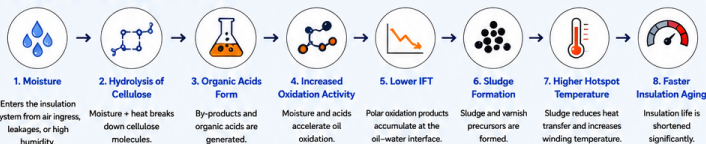


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### How IFT Connects Moisture, Aging and Reliability

IFT is the outcome of a chain of chemical and physical processes in the insulation system—where moisture plays the central role.

#### The Moisture–Oxidation–IFT Chain



#### IFT in Context: Correlation with Other Tests

IFT should always be analyzed with other key diagnostics to understand the true condition of the insulation system.

Test / Parameter	How it Relates to IFT
Moisture (IEC 60814)	Root cause indicator. Higher moisture accelerates chemical reactions that lower IFT.
Relative Saturation (%RS)	Indicates moisture risk. High %RS often leads to faster IFT decline.
TAN (Acidity)	Acidity usually increases as IFT decreases due to oxidation and hydrolysis.
Furans (2-FAL)	Indicates cellulose degradation. Higher furans are often associated with lower IFT.
Methanol	Early indicator of cellulose degradation and moisture activity.
Dissipation Factor (tan δ)	May increase as contamination and aging by-products accumulate.
Resistivity	Usually decreases as polar contaminants and acids increase.
DGA (CO / CO <sub>2</sub> )	Supports assessment of paper degradation and thermal stress.

#### DryTrans Perspective



Moisture does not significantly reduce IFT by itself; however, it accelerates hydrolysis and oxidation processes that generate polar contaminants responsible for lowering IFT.

Continuous moisture management helps slow the mechanisms that degrade oil quality and reduce IFT:



This helps preserve oil quality and slows the long-term decline of IFT.

#### Typical Trend Observed in Aging Transformers

Parameter	Trend	Impact
Moisture	↑	Increases hydrolysis and oxidation
Acidity (TAN)	↑	More acid formation
Furans	↑	Advanced paper degradation
Methanol	↑	Early cellulose aging
IFT	↓	Loss of oil quality and higher sludge risk
Resistivity	↓	Reduced dielectric performance
Sludge Risk	↑	Poor cooling and higher hotspot temperature



A declining IFT is often one of the earliest warnings that the oil is losing its ability to resist contamination and maintain insulation integrity.

#### Why Utilities Monitor IFT

- Detect oxidation before sludge becomes visible
- Assess insulation aging progression
- Support oil replacement decisions
- Support reclamation decisions
- Track effectiveness of moisture control programs
- Evaluate long-term transformer reliability



#### Final Takeaway

IFT is one of the most powerful indicators of transformer oil aging because it reflects the combined effects of moisture, oxidation, acid formation, and contamination.

Managing moisture is one of the most effective ways to slow the mechanisms that reduce IFT and shorten transformer insulation life.



#### References

- IEC 60422: Mineral insulating oils in electrical equipment – Supervision and maintenance guide.
- ASTM D971: Standard Test Method for Interfacial Tension of Oil Against Water by the Ring Method.
- IEEE C57.106: Guide for Acceptance and Maintenance of Insulating Mineral Oil in Electrical Equipment.
- T. V. Oommen, *Transformer Engineering: Design, Technology, and Diagnostics*, CRC Press.

