

Transformer Insulation (Quality) Matters

by **Mark Suddarth**

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Today's electric utilities are driven by customers' needs and have a very low tolerance for failures, making "risk-costs" a very real consideration. The quality of the insulation system used inside a transformer is critical to the requirements that matter most to the asset owner: reliability, efficiency, and longevity.



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Since each transformer can feed a large number of customers, failure of a single transformer and the resulting loss of service means lost revenue, repair or replacement, and other collateral costs to the asset owner and operator. Sudden, catastrophic failures can be highly visible and negatively impact customer satisfaction and

bottom-line financial performance of the utility/asset owner.

When utility engineers and managers were asked in a recent survey to rank the importance of operation factors, they listed equipment reliability as the number one for the following reasons:

- Reduce unplanned outages
- Minimize the risk of major

incidents, especially with an aging fleet of transformers

- Reduce maintenance cost and cost of the overall operation
- Reduce insurance costs

In normal power transformer operation, the condition of the insulation system determines the life expectancy of the transformer. A simple risk analysis shows the different levels of risk for the transformer manufacturer and the owner/end user relating to insulation.

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	Transformer manufacturer	Transformer owner / End user
Insulation cost	2-8% of transformer selling price	Negligible percentage of cost of substation or generating plant where the transformer is located
Risk	Test floor or in-service failure within warranty	In service failure and resulting cost
Capital at risk	Cost of rework or replacement	Partial or total loss of substation or generation plant 7-10 times transformer cost
Duration at risk	Transformer production and warranty period (1-5 years)	Transformer operational life 20-30 years

Specifying high quality insulation materials will only negligibly impact the overall price, but significantly augment the efficiency, reliability, and longevity of the asset, lowering the end user's total cost of ownership.

Simply stated, while important to both the manufacturer and end user, the risk for the end user is much greater than that of the transformer manufacturer. Since the quality of materials used inside a transformer is critical to the requirements that matter most to the asset owner – reliability, efficiency and longevity, it stands to reason that the purchaser should have a greater say in the selection and design of the insulation system.

Have you ever wondered why there can be a significant difference in prices offered by different manufacturers for the same quote request? How is this possible? A major reason has to do with the priorities and strategy of the transformer manufacturer. The first priority is for the unit to pass the factory test so it can be shipped and sold. The second priority is to get the transformer through the warranty period, so they are no longer responsible. These priorities sometimes lead the manufacturer to use cheaper, lower quality insulation alternatives, but these types of materials will not deliver the long term reliability needs of the end users who rely on the transformer to operate efficiently and reliably for many years.

Many transformer purchasers' specifications contain very specific requirements for items such as copper conductors, core materials, fluids, cooling equipment, bushings gauges, instruments, paint and external components/hardware. However, many do not recognize the importance of specifying the insulation system and the vital role it plays in the attainment of the specification's objective. Given that the total insulation system cost makes up only 2-8% of the total transformer price, you would anticipate that all operators/end users would specify this in their tender documents, but this is not the case. Specifying only the highest quality insulation materials available to be used inside the transformer will negligibly impact the price whereas significantly augment the efficiency, reliability, and longevity of the asset and lower the end users, total cost of ownership.

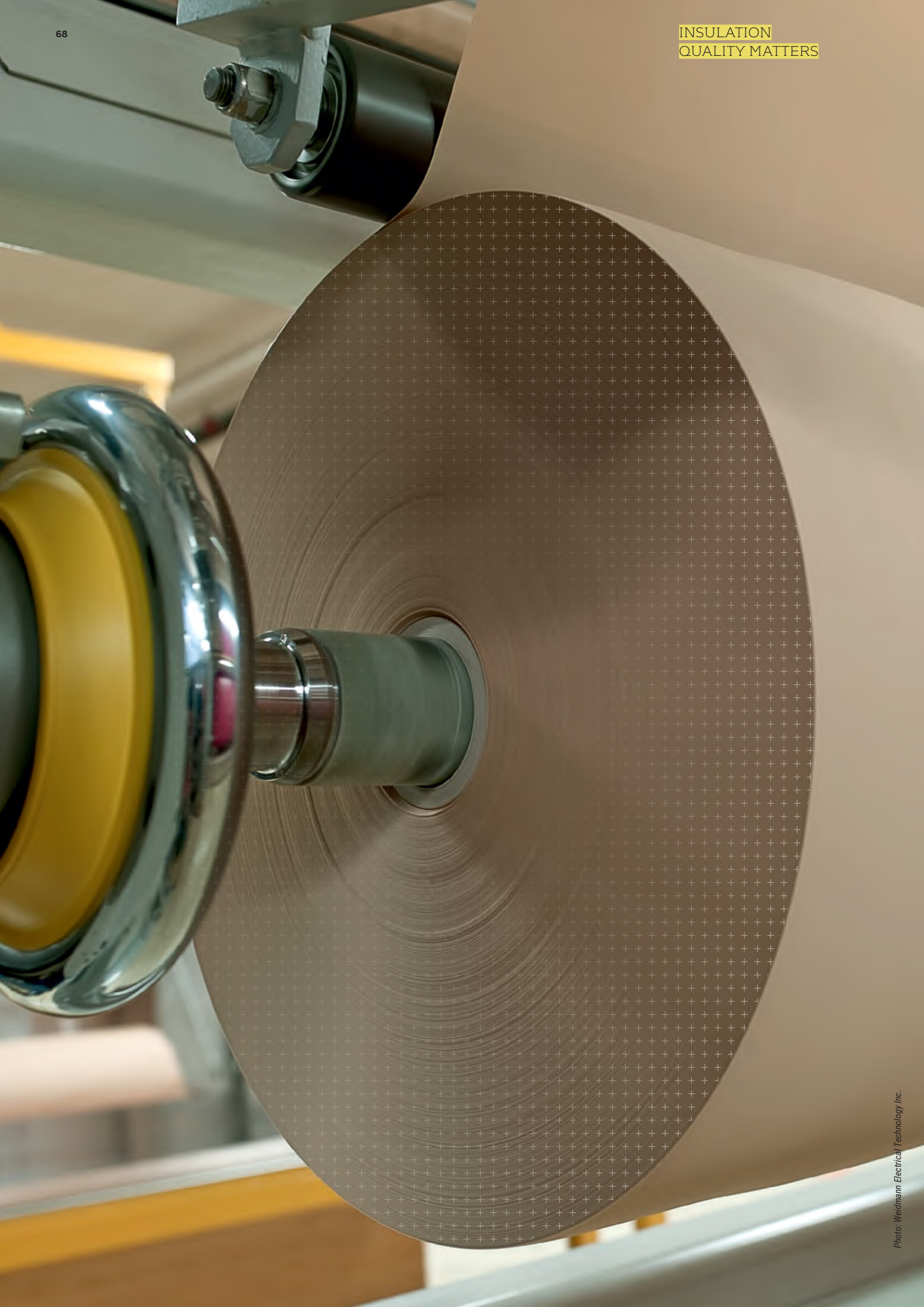
In the final analysis, it is the responsibility of the utility transformer specialist to specify the best transformer designs and materials for construction to maximize operational reliability, while minimizing risk, as a key part of their investment and



Photo: Weidmann Electrical Technology Inc.



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performance improvement strategies. With the insulation system of the power transformer making up only 5% of the total cost and a fraction of the total investment of a generation facility or substation, it makes sense to specify the best insulation materials, designs, and systems to reduce overall risks and total cost of ownership.

Another important reason end users should be sure to specify top-quality insulation materials are used inside their transformers has to do with transformer designs which have evolved from previous decades when transformers were over-engineered and over-built. Driven mainly by cost/economic pressures to do more with less, modern-day power transformer designs deliver the same or higher operating performance as their hefty predecessors, but today's power

transformers are often smaller in size and lighter in weight with capabilities more closely aligned with operating needs.

These modern-day "efficiencies" were not achieved by accident, but rather by optimization and pushing the edges of design parameters which have significantly decreased the size of oil/flow/cooling channels, resulting in increasing demands and stresses on the critical magnet wire insulation. Significant cost savings in steel, copper and oil have been achieved at the burden of the single most important component to reliability and longevity of a transformer – the magnet wire insulation.

Yet another important reason why end users should be sure to specify that only top-quality

insulation materials are used inside their transformers is that today's power transformers are expected to operate well beyond the 20-30 year life expectancy of their hefty predecessors, while utilities now expect 50-60 years of reliable service from their fleet. This is despite leaner designed transformers, increasingly severe weather events, increasing electrical demands, increasing grid/transmission voltages and grid-resilience requirements, all of which place operation stress on the most critical component to transformer reliability and life expectancy – the insulation material.

Such expansion in life expectancy of power transformers is only possible with a combination of:

- Solid/reliable design which manufacturers provide
- Top-quality insulation materials
- Operational excellence supported by state-of-the-art monitoring

Significant advances in power transformer fault/alarm monitoring devices and systems is another reason today's power transformers – new and old – are able to operate many years longer than previously thought possible. Technology today provides power transformer asset owners the ability to monitor their most valuable assets in real time 24/7/365, allowing operators to quickly and precisely adjust and balance loading, whereby protecting the critical insulation system from life-shortening damage when overloaded and run too hot. Additionally, combined with regular oil testing, such monitoring systems provide operators with actionable mitigation recommendations to faults/alarms, which enable them to much better manage transformer performance and mitigate issues before problems grow to the point where asset life is reduced or critical damage occurs. Although equipping power transformers with sophisticated fault/alarm monitoring systems obviously increases the initial cost of the asset, these one-time costs are easily outweighed by the benefit of significant reduction of the total cost of ownership over the 50-60 year life of the asset.