

# Capitalizing on a failure

## Background

July 17, 1996, East Watertown, NY—As part of regularly scheduled maintenance, a Niagara Mohawk Power Corporation (NIMO) service crew had just de-energized the East Watertown substation's transformer and temporarily removed the unit from service. In its place, the crew had connected one of the power company's fleet of 21 mobile back-ups—a 9-MVA unit with a 30-year history of dependable service.

The procedure was routine. As soon as the maintenance work on the main unit was complete, the crew would put it back into service, and the mobile would have done its job once again. But what happened next was far from routine. At 9:53 a.m., just minutes after being put into service, the mobile failed.

The resulting outage put more than 6,000 NIMO customers out of electrical service for 37 minutes, the amount of time it took the crew to get the main transformer back into service. The failed mobile unit served as backup to 58 substations, and it was critical to NIMO's ability to provide dependable service.

According to Jim Carpenter, of NIMO's System Electric Operations Department, "It was like an insurance policy for us—and it had worked very well in the past."

## Decision to up-rate

The situation had to be quickly addressed. NIMO faced three possible choices: repair in kind, repair with an up-rate or replace the unit with a new mobile. All three paths needed to be thoroughly analyzed and weighed against current and future needs.

NIMO was quite familiar with the up-rating strategy. Several of their transformers had been rewound and up-rated with DuPont NOMEX® brand paper and pressboard, and all of them continue to perform like new.

By up-rating from 9 MVA to 12 MVA, NIMO could increase not only the mobile's nameplate capacity but also its versatility. The mobile unit would be better able to cover a more complete array of emergency and scheduled maintenance situations. And with a vigilant eye always to holding down costs, NIMO could reap this benefit with a capital outlay of less than half the cost of a new unit. So NIMO decided to repair the unit and up-rate to 12 MVA, and the project was put out for bid.



Southwest  
Electric  
Company



CASE HISTORY

## The up-rate process

The failed unit had been built by GE at its Pittsfield, Massachusetts, facility in 1966. Records indicated that it had never been overloaded. Recent diagnostic tests, including power factor, dissolved gas and oil quality, gave no indication there was an impending problem.

An analysis of the failure, which included an internal inspection, proved the culprit to be the cumulative effect of through-faults that had weakened the unit over time. The actual breakdown was a turn-to-turn dielectric failure in the high-voltage winding, a common type of failure.

The bidding process was quickly concluded. NIMO awarded the contract to Southwest Electric Company of Oklahoma City, Oklahoma.

Southwest Electric Company has been a leader in the electrical service industry for more than 50 years. With additional repair and service divisions in Ohio and Tennessee, Southwest specializes in motor redesign/rewind, switchgear redesign, repair and rebuilding, medium and large power transformer redesign/rewind, and field service for switchgear and transformers. NIMO had previous experience with Southwest Electric Company transformer redesign/rewinds.

As part of their strategy, NIMO wanted a contractor who was familiar with DuPont NOMEX® brand paper and pressboards and their integral role in up-rating. Southwest had already redesigned several units with NOMEX® to provide cost-effective solutions to their customers' requirements. Southwest was well aware of the benefits of using NOMEX®, especially the increased versatility it provided and the added reliability at a lower cost.

The work was completed by Southwest and the unit was returned and ready for service in May of 1997. See the "up-rate at a glance" on this page for information concerning before-and-after performance characteristics.

The mobile transformer was completely overhauled and refurbished and brought up to the most demanding ANSI/IEEE standards of performance. For example,

## Niagara Mohawk up-rate at a glance

	Original	Up-rated transformer*	
<b>FOA rating</b>	9 MVA	at 9 MVA	at 12 MVA
<b>Load losses</b>	189.2	177.8	316.0
<b>No load losses</b>	11.7	15.2	15.2
<b>Total losses</b>	200.9	193.0	331.2
<b>Impedance</b>	15.54%	16.12%	21.49%
<b>Voltage—HV</b>	110 kV	115 kV	115 kV
<b>Voltage range—HV</b>	107–119 kV	109.25–120.75 kV	
<b>Voltages—LV</b>	2520/4360Y/2520 × 5040 × 7970/13800Y/7970 Volts		

\*Transformer is rated at 12 MVA, 95°C rise.

Data at 9 MVA is provided for comparison with original unit.

Core losses are higher on the same basis due to voltage changes in the HV winding.

the control power was originally supplied from a few independent turns wound on the main transformer. With the redesign by the engineers at Southwest, control power is now supplied by a separate control power transformer (CPT) mounted and connected externally to the main tank. Now if it were to fail, damage would be minimal and far less costly to repair.

Additionally, the aluminum tank itself, which had been damaged by the force of the failure, was repaired and strengthened. All controls were tested and verified. The unit was refitted with new gaskets, and the high-voltage bushings were replaced. Southwest Electric also improved the short circuit withstand rating of the transformer.

As part of its long-standing policy toward mobiles, Southwest specified the use of copper conductors wrapped with NOMEX® insulation. The repair company does this whenever possible, even when the customer doesn't require it. NOMEX® has a much higher tensile strength than cellulose insulation; thus it offers exceptional resistance to tearing and is far less prone to becoming brittle with use. By habitually going beyond what's expected, Southwest demonstrates a genuine commitment to providing clients with the highest quality and value.

In situations where the customer expresses a need for increased capacity, Southwest Electric recommends the use of NOMEX® insulation as a cost-effective solution.



In cases where a significant up-rate is required, Southwest offers a hybrid insulation system. In this option, the cooler areas in the transformer are insulated with traditional cellulose material, while NOMEX® brand insulation is applied to the hotter areas.

In a typical hybrid insulated core-form transformer repair, the hot areas requiring NOMEX® brand insulation are limited to conductor wrap, radial spacers and axial sticks, as is shown in the picture of the NIMO unit above. This usage results in a unit with a 95°C average winding rise. In another option, Southwest also has rebuilt transformers using NOMEX® as a conductor wrap only. This results in a 75°C rise unit with a smaller capacity increase (see "Another repair option" on the next page).

## Benefits of an up-rate

With either of these approaches, failed transformers can be redesigned to current standards and up-rated to meet a variety of capacity needs. These options provide sound, economical alternatives that can be implemented in a much shorter turn-around time than the purchase of a new and larger transformer.

If the “Re-engineered with NOMEX®”™ option had not been available to NIMO, the unit could still have been repaired.

However, the original capacity rating would have remained. With load growth over the past 30 years having already rendered the mobile unit too small for certain situations, its future performance and versatility would have been more limited.

It was NIMO’s awareness and confidence in the up-rate with NOMEX® option that turned this story of failure into a startling success. That and Southwest’s know-how and expertise in satisfying their customers’ needs. The up-rate strategy has proved to be a wise investment and continues to provide dividends to NIMO and its customers.



### Southwest Electric Company Power Transformer—redesign and remanufacture

The Power Transformer Division of Southwest Electric redesigns and remanufactures failed or obsolete power transformers to current ANSI/IEEE standards, utilizing copper conductors and modern insulating materials.

A resident engineering staff performs computer-based short circuit analysis and redesigns the transformer, incorporating Southwest’s coil-clamping system plus any needed reinforcements to structural members, to ensure compliance with ANSI/IEEE short circuit withstand requirements. Skilled, experienced craftsmen then remanufacture the transformers in accordance with documented procedures and under the controls of a comprehensive quality program to ensure compliance with customer requirements and Southwest Electric standards.

## Traditional cellulose vs. NOMEX® brand insulation

The major problem associated with cellulose as an insulation material is its thermal aging factor, which rapidly accelerates at temperatures not far above the accepted normal operating range for transformer conductors. As it ages, cellulose releases carbon monoxide, carbon dioxide and water. The water reduces oil quality and dielectric strength, which in turn leads to transformer failure.

Cellulose insulation poses two additional problems for transformers: moisture absorption and shrinkage. Over time, cellulose becomes spongy and compresses when mechanical forces are applied through normal and extreme use, allowing the winding conductors to move. This movement can often lead to failure. With mobile units that are normally hauled and jostled over all types of terrain, the situation is even more problematic.

In contrast, NOMEX® brand insulation maintains its integrity under the toughest conditions. Below 200°C, it has an infinitesimal thermal degradation factor that is far superior to cellulose. In addition, because of its remarkable tensile strength, NOMEX® brand insulation is exceptionally resistant to tearing. Also, it has compression characteristics that are far superior to cellulose. Consequently, transformer windings remain tight and far more resistant to ordinary and extraordinary stresses.

At the typical operating temperatures of electrical transformers, NOMEX® will not turn brittle. It outperforms cellulose at elevated temperatures and has a much longer lifespan. The superior mechanical toughness of NOMEX® paper and pressboard enables windings to withstand the most severe mechanical shocks.

Simply stated, NOMEX® brand insulation is the ideal material for high-performance electrical transformers of today and tomorrow.

## Another repair option with NOMEX® brand insulation

When a significant up-rate is not required, there’s another, often over-looked, repair option available to operators that can provide a respectable 10–12% capacity increase at a very minimal cost.

### Two illustrations

In 1995 Southwest Electric redesigned a Federal Pacific Electric transformer for Union Electric Company of St. Louis, Missouri. The unit was originally rated 60/80/100/112 MVA, OA/FOA/FOA, 55°/65°C rise, 139.2 kV delta to 34.5 kV wye with LTC.

In this case, Union Electric did not require an increase in capacity. Instead, they requested that the BIL on the HV windings be raised from 450 kV to 550 kV, thus creating a unique problem for Southwest engineers: how to meet this requirement within the existing dimensions of the unit and still provide the required capacity. The problem was solved by using NOMEX® as the new insulation material on the conductor. This enabled the designer to increase dielectric clearances while obtaining a higher MVA rating due to the allowable temperature rise of 75°C.

In 1997 Southwest Electric received an order from another Midwest utility to up-rate an autotransformer. The unit had an original rating of 45/60/75/84 MVA, OA/FA/FA, 55°/65°C rise, 161 kV to 69 kV with a 13.8 kV tertiary. By insulating the conductors with NOMEX® brand insulation, Southwest was able to rebuild the transformer to a 75°C temperature rise with a top rating of 94 MVA.



For more information about retrofitting transformers, contact:

Southwest Electric Company  
Power Transformer Division  
6501 SE 74th St.  
Oklahoma City, OK 73135  
(800) 364-5691/Toll-Free  
(405) 737-5691/Direct  
(405) 733-9551/Fax

## NOMEX® brand insulation

*Providing future solutions today*

NOMEX® brand insulation is used in many applications in addition to transformer repair, such as traction and industrial transformers and dry-type transformers (including resin-cast), as well as in new mobile transformers. Applications in motors and generators and other types of electrical apparatus are also widespread. Case histories are available describing the many applications. For more information about NOMEX® brand insulation, contact your local DuPont representative or one of these regional contacts:

### Americas

DuPont  
Advanced Fibers Systems  
Customer Inquiry Center  
5401 Jefferson Davis Highway  
Richmond, VA 23234  
Tel. (800) 453-8527  
(804) 383-4400  
Fax (800) 787-7086  
(804) 383-3963

### Europe

DuPont  
Engineering Fibres  
P.O. Box 50  
CH-1218 Le Grand-Saconnex  
Geneva, Switzerland  
Tel. ++41-22-717 55 54  
Fax ++41-22-717 62 18

### Asia Pacific

DuPont Korea Inc.  
4/5th Floor, Asia Tower  
#726, Yeoksam-Dong  
Kangnam-ku, Seoul  
135-082, Korea  
Tel. (822) 222-5255  
Fax (822) 222-5240

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Printed in U.S.A.  
H-52736 10/98



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