Risk Solutions

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The Locomotive

An Analysis of Transformer Failures, Part 1 – 1988 through 1997

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Introduction

Transformer failures are common and costly. In this article, the first of two parts, the author discusses the types of transformers most likely to break down, frequency and severity, and the issue of transformer age. The findings are based on a 10-year study of Hartford Steam Boiler transformer claims, one of a series of studies conducted over several decades.

An endless supply of electricity is taken for granted in today's world of commerce and business. Our dependence on a continuous supply of power is often overlooked until the lights suddenly go out, or the air conditioning or heating is lost, or production equipment comes to a halt. It is then that we become acutely aware of the importance of such things as circuit breakers, wiring, and transformers.

This awakening may come with a brilliant flash of light and an acrid burning odor, following a fault or short circuit in electrical equipment. Or the lights may just dim, and then go out. Sometimes, a serious fire follows, causing even more damage.

Transformers Losses Are Significant

As an object class, transformers have consistently been ranked in the top five objects for claims paid by Hartford Steam Boiler during the past several decades. Over the years, HSB has investigated thousands of transformer losses. Some were covered claims and some were not. Using the data collected, HSB has conducted a number of studies on transformer losses and published them in The Locomotive.

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In previous analyses, we examined Initial Parts to Fail, Age at Failure, and Cause of Failure. To improve our loss experience for transformers, the most recent study was conducted last year, and covers a 10-year period from 1988 through 1997. In 1999, we deleted the Initial Parts category and added two new categories: the Size and Frequency of Failures, and Where the Failures Were Occurring (by industry or occupancy).

10-Year Trend - Losses by Transformer Type

Over the past 10 years, HSB has paid hundreds of transformer claims that represent many millions of dollars. Chart No. 1, below, shows a breakdown of claims, according to the transformer type. The chart shows power transformers, askarel-filled (PCB), dry type, arc furnace, induction furnace, and rectifier transformers. Except for 1988, the power transformer dominates our loss history.

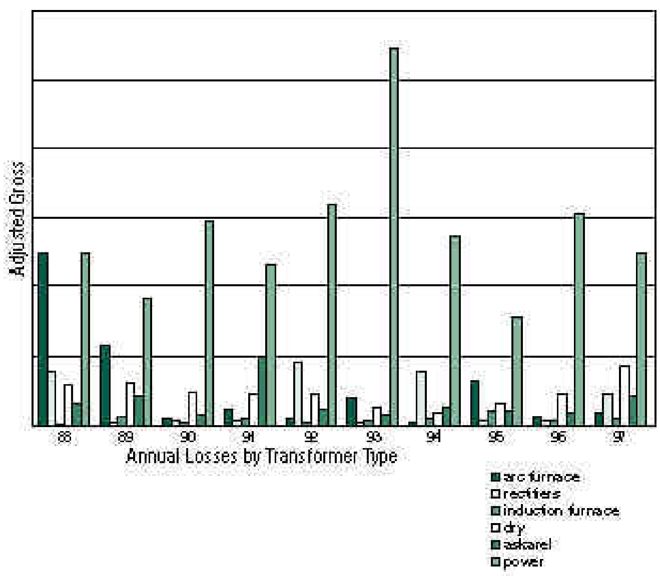

Chart No. 1

Occupancies Where Failures Occurred

HSB insures literally hundreds of different types of occupancies: shopping malls, bakeries, apparel manufacturers, electric utilities and steel mills. In order to analyze the transformer risk, we divided this long list of occupancies into 10 categories we call exposure groups. An exposure group is a set of occupancies with similar equipment, operations and loss profiles. Table 1, below, lists the 10 exposure groups, and identifies some specific examples within those groups.

Table 1: Exposure Group Description

Exposure Group	This group includes
Cement and Mining	
Chemical, Oil and Gas	Chemical Plants, Oil Refineries, Gas Transmission Lines, etc.
Electric Utilities	Investor Owned Utilities, Municipal Utilities, and Independent Power Producers
Food Processing	Breweries, Dairies, Meat Packing, Sugar Mills, Farms, Hatcheries, Candy Mfg., Cereal Mfg., Beverage Plants, Bakeries, Canning Plants etc.
Healthcare	
Manufacturing	Appliance, Automobile, Aircraft, Cosmetics, Electroplating /Galvanizing, Jewelry, Leather, Pharmaceuticals, Soaps, Semiconductors, Shipbuilding, Textiles, etc.
Primary Metals	Steel Mills, Aluminum Plants, Forge Shops, Special Alloy Foundries, Metal Reclamation Plants, etc.
Plastics	
Printing	
Commercial Buildings	Colleges, Hotels, Churches, Municipalities, Stadiums, Amusement Parks, City Steam Plants and Air Conditioning Plants, Office Buildings, Apartment Buildings, Shopping Malls, Television Stations etc.
Pulp and Paper Manufacturing	

Table No. 1

Frequency and Severity

In his book, Risk-Based Management: A Reliability-Centered Approach1, HSB's Dr. Rick Jones defines "risk" as the product of probability and consequence, or in insurance engineering terms, the frequency and severity of the losses. The severity can be defined as the average annual gross loss, and the frequency (or probability) can be defined as the average number of losses, divided by the population. Since we don't have a true transformer population, we needed to make a substitute. Because we are ranking the relative risk of exposure groups, we used the number of locations insured in each group for our "population." Thus, for any given exposure group:

Frequency equals the Number of Losses divided by the Number of Locations.

(For example, if we have had an average of 10 losses per year, in a given exposure group and we insure 1,000 locations in that group, the probability of a failure is .01 each year, at any location in that group.) Therefore, we can rank our transformer risk by occupancy, using the product of frequency and severity. (Risk = Frequency x Severity).

The graph below, Chart No. 2, is a Frequency-Severity "scatter plot" for transformer risks in our 10 exposure groups, based on the last 10-year period. With each group plotted, frequency on the X axis and severity (or average gross loss) on the Y axis, the X-Y plot becomes a risk coordinate system. The diagonal lines are called equivalent lines of risk (for example, a probability of 0.1 for $1,000 and a probability of 0.01 for $10,000 can be considered an equal risk.) Coordinates in the upper right quadrant are the highest risk.

When frequency and severity of loss are taken into consideration, (as shown in Chart No. 2), the highest risk is electric utilities. Primary metals and manufacturing are second and third.

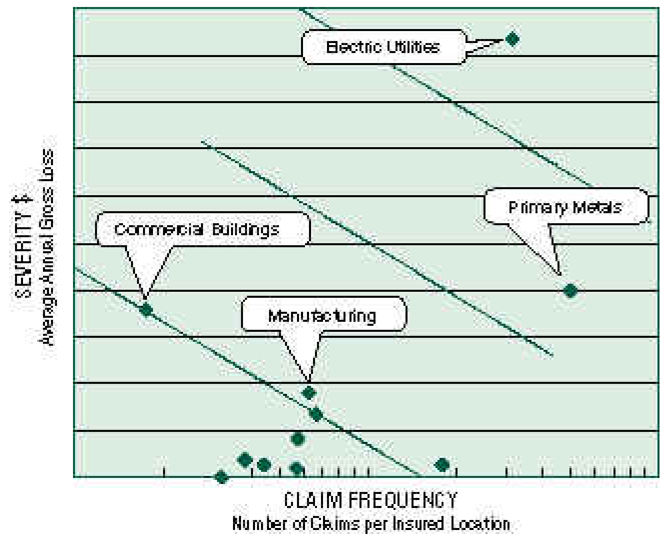

Chart No. 2

Transformer Age

Transformer design engineers tell us that a transformer can be expected to last 30 to 40 years under "ideal conditions." But, that is clearly not the case. In the 1975 study, it was found that the average age at the time of failure was 9.4 years. In our 1985 study, the average age was 11.4 years. In this study, the average age at failure was 14.9 years. One would expect to see a "bathtub curve" with infant mortality in the early years, and aging equipment at the far right. Instead, our claim statistics show that transformers do not have an indeterminate life. Chart No. 3, below, shows the age statistics for this study. These statistics should justify the time and expense to periodically check the condition of the transformer.

Chart No. 3

The age of transformers in the electric utility industry deserves special attention. The United States went through massive industrial growth in the post World War II era, causing a large growth in base infra-structure industries, especially the electric utilities. This equipment was installed from the 1950s through the early 1980s. The way it was designed and operated, most of this equipment is now in the aging part of its life cycle. According to U.S. Commerce Department data, the electric utility industry reached a peak in new installations in the United States around 1973-74. Today, that equipment is 25 years old. With today's capital spending on new and replacement transformers at its lowest level in decades, the average age of the installed U.S. transformer fleet continues to rise.

There are actually two problems here: our nation's transformer fleet is aging, and to compound this, the load on each transformer, (or its utilization), continues to grow. While installation of new transformers is declining, power consumption continues to grow at a rate of about 2 percent per year. Capital deferment has led to the increased overall utilization of transformers in the United States. Due to the steady growth in power consumption over the last 20 years, it is obvious that the utilization factor for transformers has increased significantly.

[In Part 2 of this article: The author discusses the causes of transformer failure, including lightning surges, line surges, poor workmanship, deterioration of insulation, overloading and other factors. He recommends a good maintenance program and concludes with several recommendations to help achieve maximum service life.]

Footnotes:
[1] R.B. Jones, Risk-Based Management: A Reliability-Centered Approach, Gulf Publishing Co., Houston, TX, 1995]

About the Author

William Bartley received a Bachelor of Science degree in electrical engineering from the University of Missouri at Rolla. Bill joined Hartford Steam Boiler as an electrical inspector in 1971 and is now a Principal Engineer in HSB's Engineering Department, specializing in the assessment and analysis of large electrical apparatus, primarily generators and transformers. He is responsible for developing standards, OEM relations, fleet problems, large failure investigations, repair procedure development, and new testing technologies.