Advantages of Corrugated Transformer Insulation

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As new technologies and materials are discovered and become commercially available, it doesn't take long for the ingenuity of progressive engineers to find new and interesting applications. Corrugated Vulcanized FIBRE for cooling duct and tap out applications has been in use for many years. With adequate design, corrugated insulation can reduce heat -- the enemy of transformer efficiency. Through the improvement of manufacturing technologies and the arrival of higher temperature material, such as NOMEX innovations began and transformer insulation redesign was initiated, See Figure 1. Many engineers desire NOMEX aramid paper in place of Vulcanized FIBRE for the higher temperature ratings and improved dielectric strength which previously had not been available.

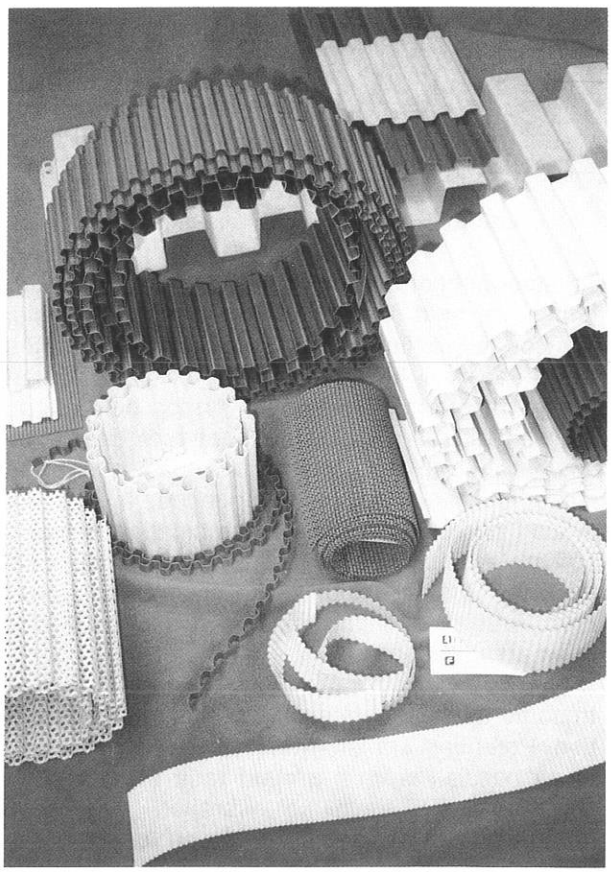

FIGURE 1 Corrugated Transformer Insulation

In the mid 70's, a young transformer engineer asked the author if he could supply, in a 3/8" square design, of a then sinusoidal corrugated Vulcanized Fibre insulation with approximately a 3/8" amplitude. Within a year, it was available. Few changes were made in that product until recently. Many transformer designs moved from 120°C to 150°C higher operating temperatures and high temperature insulating materials such as NOMEX, as it became more popular in transformer insulation. By the mid 80's, several NOMEX corrugations became a developed reality.

As the newer corrugated transformer insulation was initially promoted, many transformer engineers expressed a concern about the compressive strength of the corrugations, when the pressures from winding tension were applied. This is of special concern where the corrugated insulation is used as a cooling duct or barrier insulation, if the strand of wire is to be applied directly over the corrugated insulation. One of the significant advantages of using corrugated NOMEX or FIBRE is the fact that, in this corrugated configuration, they provide excellent energy absorption in compression with the ability to partially or almost fully spring back when compressive forces are removed. It also contributes approximately .030" of electrical insulation. With its corresponding dielectric strength, it can replace a layer of flat wrapped barrier insulation paper. Additionally, corrugated insulation provides improved cooling with consistent open and defined spacing while reducing overall weight.

Several wire manufacturers have recommended that winding tension not exceed 50% of the tensile strength of the copper wire. If tension is exceeded, then there is a chance of pulling the wire, or actually drawing the wire, which would cause "necking" at the point of yield. During such excessive winding, if the insulation doesn't yield, the wire could, especially at or after the rigid insulation point.

Such reduction in the wire size diameter, if not detected, results in a hot spot in the completed

winding. If wire "necking" has occurred, it would be better if the wire broke making this defect known and the coil rewound. The fact that the wire doesn't break after it may have been stretched or narrowed, creates a hidden future problem since the potential hot spot may go undetected until the coil is finished, wound, and tested. Corrugated duct or barrier insulation, because of its flexibility, tends to reduce the chance of wire "necking". There are no hard corners to concentrate wire stretching forces. When only solid sticks or "dog bones" are used for separation in cooling ducts or high/low barriers, excessive tension can more easily cause concentration locations of wire pulling or necking. Sticks generally are strong enough to handle very high winding tensions. However, high winding tensions can also cause sticks to move and, in some cases, even contact each other, and if undetected, thus block the through passage for cooling air or oil.

Another advantage of corrugated transformer insulation is that, once placed into position, it will maintain its open air or oil passages even if there is some slight compression of the corrugation at the point of wire contact. Duct cooling spaces will be constant, uniform, parallel, and standardized. A third and possibly the greatest advantage is the time and labor saving capability of corrugated insulation which makes it very cost effective. An additional advantage in corrugated transformer insulation exists when sticks must be used. It provides definite location, spacing, and automatic parallel alignment. A small amount of suitable adhesive, resin, or cement will hold them in the corrugated groove without taping. Such sticks can be pre-cemented in place conveniently prior to wrapping or placing the corrugation on to the winding.

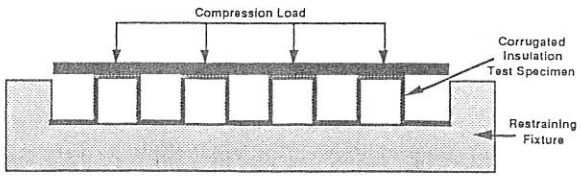

FIGURE 2 Schematic of Flat Crush Test Configuration

From the compression tests illustrated in Figure 2 and shown in Figure 3, it is obvious that corrugated insulation of both Vulcanized FIBRE and NOMEX absorbs considerable amounts of energy in compression as seen by its ability to flex and recover fairly close to its original shape. High speed motion pictures of transformer short tests have shown a high level of movement in expansion and contraction. We believe corrugated products cannot only continue to serve as intended, but also upgrade transformers to more effectively withstand such surge faults or short circuit forces.

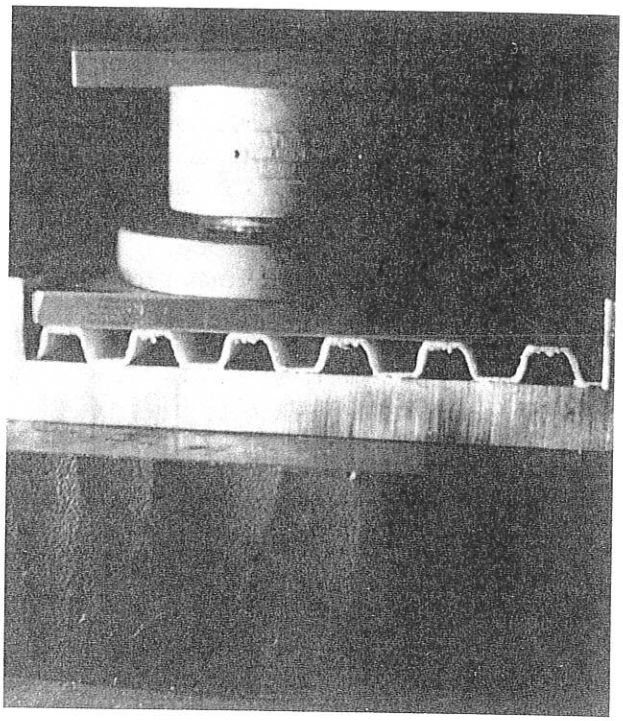

FIGURE 3 Compression Testing Of Corrugated

Transformers of more rigid design with sticks, "dog bones", or rigid spacers may not exhibit sufficient give or flex which could cause accelerated total failure after a lightening strike or power surge. Many transformer engineers firmly believe that only a rigid barrier and cooling duct design can survive the various types of overload, shorts, and surge faults commonly experienced. In such operating cases we believe a combination design of corrugated insulation with supplemental sticks be utilized. Such a design would use fewer sticks in more precise definite locations and provide more open area for cooling.

In some transformers such as PT's, ground detection Potential Transformers, ferroresonance can occur possibly from a ground fault or some other condition. The resulting vibration can cause humming and other noise, and can loosen insulation. Corrugated barrier or cooling duct insulation tends to absorb that energy with the advantage of reducing noise levels and insulation fatigue.

Vulcanized FRANKLIN FIBRE, rated at 120°C under UL File #E48013, has been used in corrugated transformer cooling duct and tap-out applications for over 50 years. The concept is not new, but many of the configurations and materials available for corrugation are new and have increased the utility of corrugated products. For many years rectangular 3/16" high x 1/4" wide and square 1/4" were commercially available. Corrugated insulation tends to remain fixed in location insulating one circuit from the other and from ground. In the mid 70's, the author designed some new shapes in corrugated insulation. Sizes such as 3/8" and 1/2" square were developed and manufactured. Currently, 3/4", 1", and 1-1/2" are experimentally available. The development of some new shapes for corrugated insulation, like many new products and concepts, require testing and evaluation for further product consideration of transformer insulation and design engineers. NOMEX and Vulcanized FIBRE corrugated products are meeting the re-design requirement of such engineers for improved transformer efficiency. Some core losses, through overall size reduction, and many coil losses can and have been reduced. Higher operating temperatures are obtainable. NOMEX is rated 220°C under UL File #E34739A. More compact and lighter designs are possible because of increased electrical insulation and thermal properties, as well as improved designed cooling capabilities.

New materials continue to be developed and tested for various temperature ranges and operating conditions. Several sinusoidal corrugated sizes are now also available, as well as many special combinations to satisfy specific transformer insulation and strength design requirements. Small sizes of square and rectangular NOMEX are available to keep primary and secondary winding closely interlaced while providing higher temperature dielectrics for both air and oil cooled transformers. The variations are endless, limited only by the imagination and ingenuity of transformer engineers.

REFERENCES

ASTM D 1225 American Society Of Testing Materials.

Nomex - Registered Trade Mark, E.I. du Pont de Nemours & Co., Inc.
Franklin Fibre - Trade Name, Franklin Fibre-Lamitex Corp.