"OUT OF THE BOX" ENGINEERING WITH INSULATING MATERIALS

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Abstract: The emphasis of this paper is to illustrate the benefits of discussing proposed designs before finalization with manufacturers. This is best accomplished through alliance and cooperation which in the long-term provides a win-win.

I. INTRODUCTION

Quite often we believe certain electrical insulating materials are only available in a simple shape or form. Everyone knows broadly what is available. Many design engineers, based on the standard available forms, generate uses for these insulating materials.

Many times they are looking to do more with these materials, but are uncertain of just what can be done. By getting "out of the box", as the phrase goes, engineers can let their inventive genius and imagination flourish with new unique designs. True, many such designs are impractical, often difficult or impossible to produce. However, when those designs are reviewed with the individuals who are asked to produce them, usually the ideas start multiplying and feasibility become evident. As a result of "getting out of the box" and sharing the proposed design concept or task to be accomplished with the individuals who will try to make it happen, the inventive genius on both sides sets sparks flying.

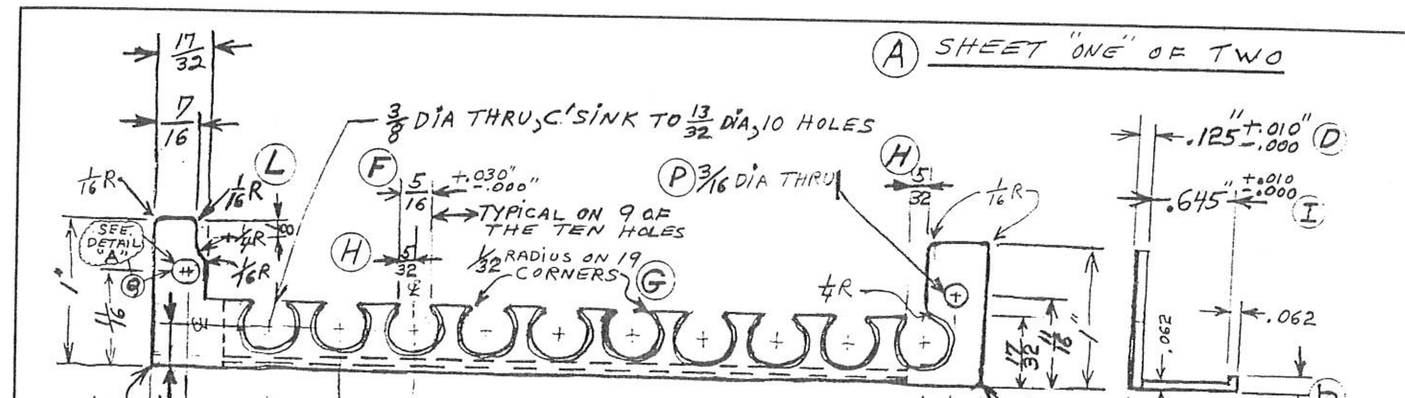

Figure 1: Hand sketch of "Fanning Block" Cover

ʼPLICATION & TESTING OF HIGH TEMPERATURE MATERIALS FOR SOLENOID COILS

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ABSTRACT: Sandia National Laboratories has designed and proven-in two new Solenoid coils for a highly-reliable electromechanical switch. Mil-Spec Magnetics, Inc., Walnut CA manufactured the coils. The new design utilizes two new materials: Liquid Crystal Polymer (Vectra C130) for the bobbin and Thermal Barrier Silicone (VI-SIL V-658) for the encapsulant. The use of these two new materials solved most of the manufacturing problems inherent in the old Sandia design. The coils are easier to precision wind and more robust for handling, testing, and storage. The coils have some unique weapon related safety requirements. The most severe of these requirements is the 400°C, 1600V test. The coils must not, and did not, produce any outgassing products to affect the voltage breakdown between contacts in the switch at these temperatures and voltages. Actual coils in switches were tested under these conditions. This paper covers the prove-in of this new coil design.

Key Words: Sandia National Laboratories, Solenoid Coils, Liquid Crystal Polymer, Thermal Barrier Silicone, VI-SIL V-658, High Temperature Encapsulant, Outgassing.

I. INTRODUCTION

Two coils are required for an electromechanical switch called the Strong Link Switch. The coils provide the energy to index a complicated mechanical switch which must operate in a highly reliable manner. This switch is a hermetically-sealed, electromechanical device with 6 electrical contacts that are closed by a dual coil solenoid rotary drive mechanism. The switch is used to control the arming of modern weapons. The original coil design was a development by Sandia National Laboratories (SNL) and Allied Signal, Kansas City Division (AS/KCD). A new material, Bendix Reinforced Plastic (BRP), was developed for the original coil design. The material was used for both the bobbin and for the encapsulation of this component design. The original design was difficult to manufacture, due to the fragility of the BRP material. The part had very low yields at the Department of Energy (DOE) Production Agencies; AS/KCD and Lockeed Martin Pinellas Plant.

The most important intrinsic property of the BRP material is that it does not exhibit any significant weight loss at elevated temperatures, i.e., does not outgass at temperatures up to 600^{0}C. SNL developed a new coil design and new materials to replace the BRP material. The BRP material needed replacement for several reasons: (1) The coil yields were often low ~ 10% due to the mechanical fragility of the material (cracking, etc.), (2) The production agency operated for DOE was closing, so a new supplier was needed, and (3) The cost of transferring the processes for the old coils was too high.

SNL did not do an exhaustive search for new materials, due to time and funding constraints. New materials were selected based on engineering judgment; Liquid Crystal Polymer (LCP) Vectra C130 for the bobbin, and Thermal Barrier Silicone (TBS) VI-SIL V-658 for the encapsulation. They met the requirements for manufacturability but were unproven for meeting the high temperature, shock and vibration, and other testing requirements. The high temperature requirements are needed to meet weapon safety disaster scenarios, i.e., the switch must fail safe. SNL and MIL-SPEC Magnetics Inc., (SNL supplier), performed extensive testing to prove-in the coil for weapons applications.

The critical operational design features are the inductance and resistance of the coil with the tight mechanical constants for part geometry. Our supplier developed a new encapsulation process to remove all surface voids from the encapsulation material. An additional constraint for molding of the parts was that

II. DISCUSSION

A few years ago an engineer with the New York telephone company brought us a problem where they needed a cover to protect lineman from wood splinters when servicing telephone lines. Thousands of hard wood "fanning blocks" were used to support and separate telephone wires (lines). Through many years of servicing, the edges of these wooden blocks became ragged and splintered.

They wanted to solve the problem without disturbing the existing wiring and terminal hookups. We suggested a mold laminated channel that was machined on two sides allowing it to slip over the existing wooden support block without disconnecting literally thousands of circuits. A hand sketch was made of the part. (See Figure 1) By using NEMA grade LE linen based Lamitex® mold laminated channel, the prototypes were machined, put into use, and tested for design and serviceability.

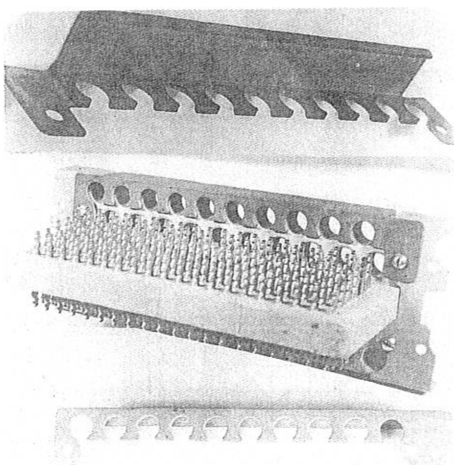

Figure 2: "Fanning Block" Cover - Top, Bottom , and In Use.

Once it was proven as a successful item, thousands of these "fanning strip adapters" were later molded in the exact same design from clear polycarbonate thermoplastic. (See Figure 2) By using the mold laminated thermoset plastic in this unique configuration for prototype and testing, the cost of solving the problem incorporating and improving that design was minimized. The same mold laminating process is in use today in the manufacture of dependable breaker arms and ignition cam rubbing blocks for automotive and off the road equipment. The telephone company engineer left his "design box" and presented his problem to a plastics engineer and ideas flowed into the practical design which economically solved the problem.

Many materials such as Nomex®, D/M/D, 100% Rag Paper, Vulcanized Fibre, Industrial Laminates, and many more can be fashioned to perform unique functions and tasks. Vulcanized Franklin Fibre is a material produced in sheet, rod, and tube form. When three dimensional parts are required from sheet material, often several machining operations are required to produce the final design. However, with special punching and impact type tooling, Vulcanized Fibre can be swedged or formed into three dimensional shapes. (See Figure 3)

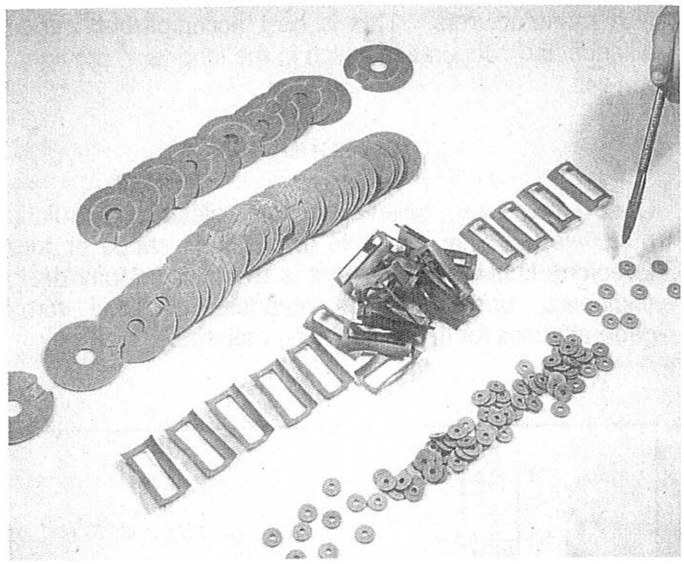

Figure 3: Examples of Franklin Fibre, Punched, Formed, and Swedged.

Two of the parts pictured are for electric motors. The upset fibre washers, because of their unique third dimension after swedging, have been used cost effectively for many years in various electrical stand-off or feed through insulating requirements.

An insulation engineer was designing a cover for the end of a stack of motor laminations. Because of its arc resistance, low cost, toughness, and light weight, Vulcanized Fibre was chosen. The part had a three dimensional design to it; and since Vulcanized Fibre was only available in sheet, rod, and tube form, an expensive molded thermoplastic design was being considered. By stepping back and leaning on other sources of information, we suggested a design in which the parts were punched and formed from flat sheet. By using some non-ferrous metal forming techniques, Franklin Fibre was able to tool up and produce the part as pictured on the top left of Figure 3.

While visiting a global transformer manufacturer, a young transformer engineer asked the author if we could supply a Vulcanized Fibre transformer insulation corrugated in a square pattern rather than the then available sinusoidal configuration. This was being used as a cooling duct separator. The engineer felt that the sinusoidal design did

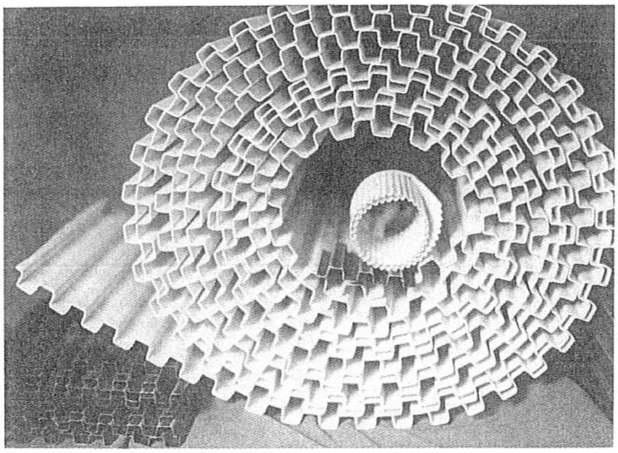

Figure 4: 3/8" Square Corrugated Fibre and Nomex® 410 Transformer Insulation.

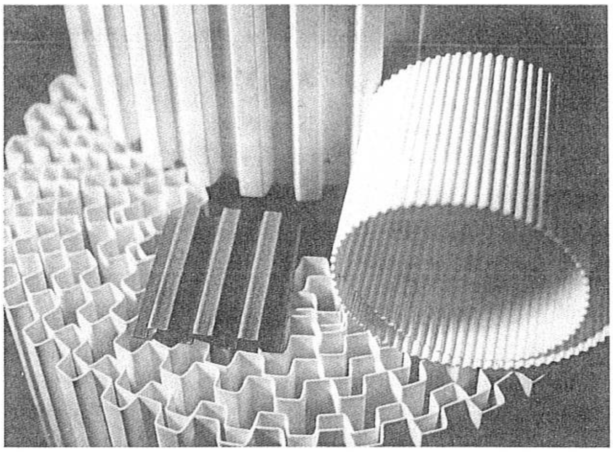

Figure 6: Sinusoidal and Square Corrugated Fibre and Nomex® 410.

not provide the compressive strength he felt necessary for his design.

He had never seen square corrugations, but felt that would be stronger and would provide for additional cooling and increased transformer efficiency. At that time, no one made 3/8" and larger square patterned corrugated transformer insulation. Because of this new "out of the box" thinking, we wanted to give this inventive concept a try. In less than a year large square corrugated Franklin Vulcanized Fibre transformer insulation was available. (See Figure 4) A few years later, the process was expanded to also provide square corrugated Nomex® transformer insulation. Subsequently, six (6) sizes of square and one (1) size of rectangular corrugations have been developed. Additionally, eight (8) sizes of sinusoidal corrugated insulation are now available, all in both Nomex® and Vulcanized Fibre. (See Figures 5 and 6)

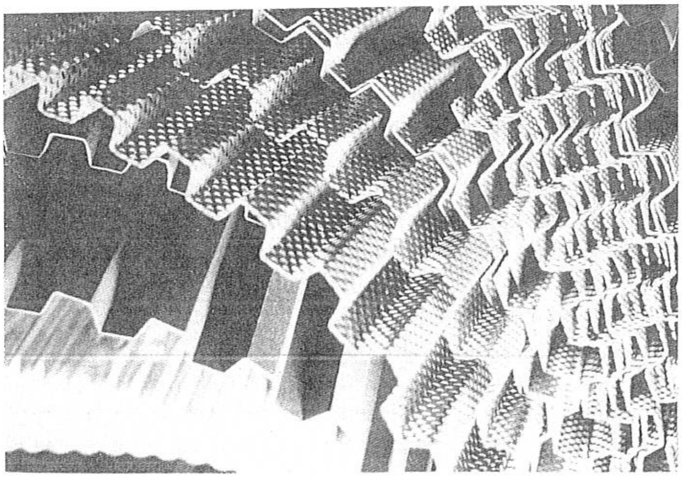

Figure 5: Many sizes of Corrugated Insulation.

A toroidal transformer design engineer was listening to the benefits of corrugated transformer insulation and interrupted the sales presentation with the comment, "That's an interesting application, but we don't use anything like that. My problem is insulating the corner of toroidal cores." After a brief explanation of what was needed and what was being used presently to insulate the corners, some proposed sketches were made.

The first samples functioned mechanically, but did not do the job electrically. After several attempts, and little success, in trying to put the insulation materials at the corner where it was needed, it was back to the drawing board. There had to be some way of providing satisfactory insulation. Finally, by considering a completely new design, T-COR(TM) corner insulation, a satisfactory product was developed. (See Figures 7 and 8)

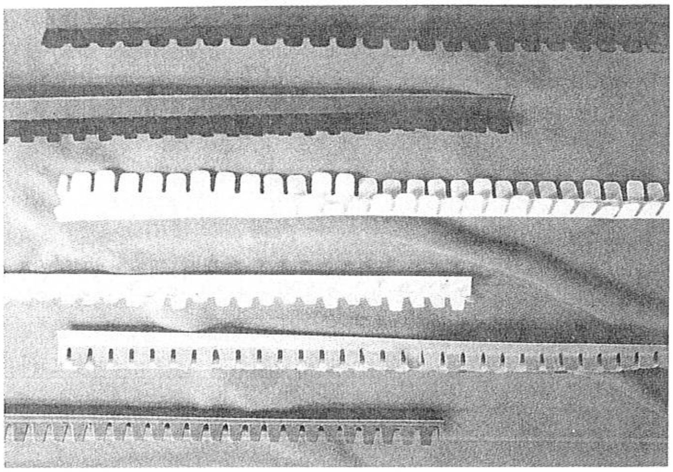

Figure 7: "T-Cor" Insulation, Inside and Outside Configurations.

That product is now available in 100% rag paper, Vulcanized Fibre, D/M/D, and Nomex® depending on the temperature requirement of the toroidal coil.

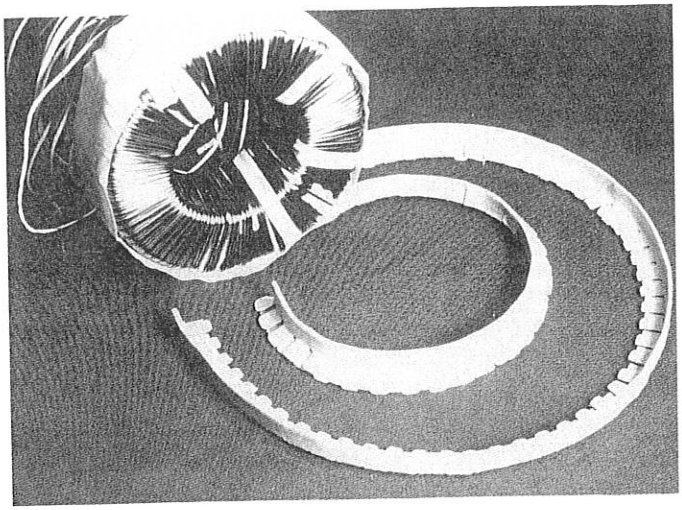

Figure 8: Toroidal Coil with Inside and Outside "T-Cor" Insulation.

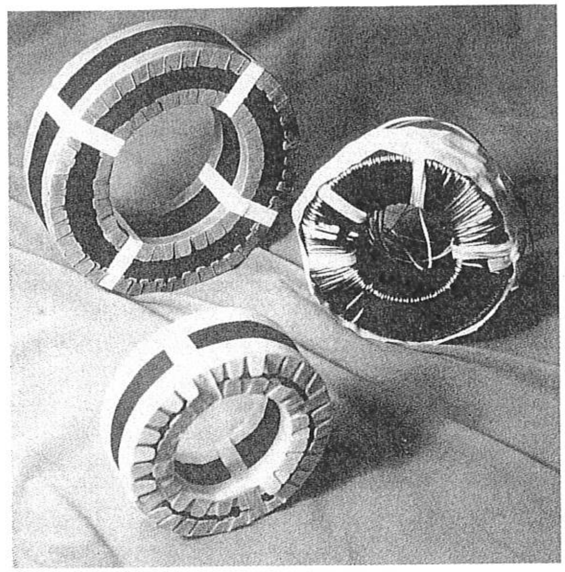

Figure 9: "T-Cor" Corner Insulation on Cores and in Finished Toroid.

By knowing the need and what can be done with the materials, a successful marriage was made between the engineering designer and a supplier. Today, five (5) sizes of that standard product are available. (See Figure 9) All insulating the corner of toroidal cores. By getting "further out of the box", this insulation is now used within toroidal coil windings, as well as on core corners.

III. CONCLUSION

Unfortunately, many designers limit themselves to computer assisted designs (CAD). This can result in a beautiful design of an item that may be impractical to produce.

Only by close liaison and alliances with the manufacturer / supplier, can a design engineer maximize his or her design. "I didn't know you could do that," or "We didn't think that was possible," are often comments when full manufacturing potential is discussed and made available. Often another benefit is reduced total cost.

By getting "out of the box" and working closely through designer/manufacturer alliances, with genuinely interested suppliers, insulation applications will be improved and many problems can be solved.

Nomex: Registered Trade Mark, E.I. duPont de Nemours & Co., Inc.
Lamitex: Registered Trade Mark, Franklin Fibre-Lamitex Corp.
Franklin Fibre & **T-COR**: Trade Names, Franklin Fibre-Lamitex Corp.

James E. Vachris received his B.S. degree in Mechanical Engineering in 1955 from the University of Notre Dame. After serving as a Pilot in the U.S. Air Force he began his career in thermoset insulation materials at Franklin Fibre-Lamitex Corp. After serving in many Engineering, Sales and Management positions, he became President in 1988. He has been active in the Society of Plastics Engineers, NEMA, and is a Past President of the International Association of Plastic Distributors.