Permashield™

An Extruded Stress Control Layer Using Non-Conductive Material

General

In December of 1961, the Kerite Company shipped its first length of cable containing an extruded non-conducting conductor shield. The use of this unique, specially designed material when applied over the conductor allowed a substantial reduction in insulation thickness without sacrificing the performance and reliability of the cable. When this same material was applied over the insulation, greatly simplified and more reliable terminations were also possible. Extruded shields are now common practice within the industry – but only Kerite provides the use of a non-conducting material for stress control in medium-voltage applications. We call this concept Permashield.

This is an introduction to our Permashield concept. To provide perspective with respect to industry developments and the technology of the period, the results of our program are summarized chronologically.

Discovery and Development (1957-1970)

Like many creative or innovative ideas, Permashield was the result of an unrelated product development program. In 1957, while working to develop reduced diameter splices to facilitate a long, single length submarine cable, Kerite engineers found that applying a thin layer of non-conducting compound over the splice connector improved the dielectric strength of the finished splices by at least thirty percent. As shown in Figure 1, these modified splices had a demonstrably higher dielectric breakdown strength than the cables they connected.

Mr. Andrew Hvizd, the Project Engineer, was convinced that this concept could be applied to cables. He applied for a patent and arranged for prototype tests. The results of the testing conducted on cables using this new, extruded strand shield are shown in Figure 2 compared with the previous conductor wrap (textile serving) design. The basis for the comparison was a three-hour, 60 Hz step test to dielectric failure.

On the basis of this and other data, in 1962 Kerite began commercial production of what was trademarked Permashield cable. The insulation walls were reduced, according to Table 1, on the basis of equivalent dielectric strength of previous designs. Factory test voltages for the reduced thickness designs remained the same as previous designs to assure comparable quality and system reliability. The table also shows current AEIC and ICEA insulation wall thickness and test levels. In 1985 Kerite increased wall thickness to provide dimensional compatibility with existing cable specifications and commercially available pre-molded cable accessories.

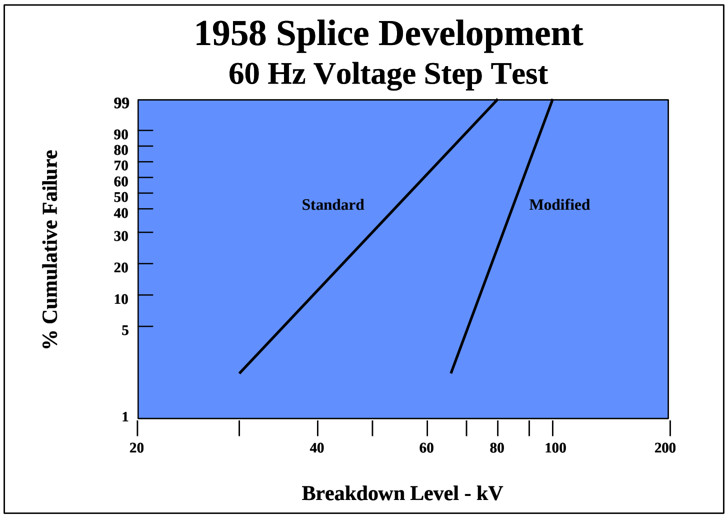

Figure 1

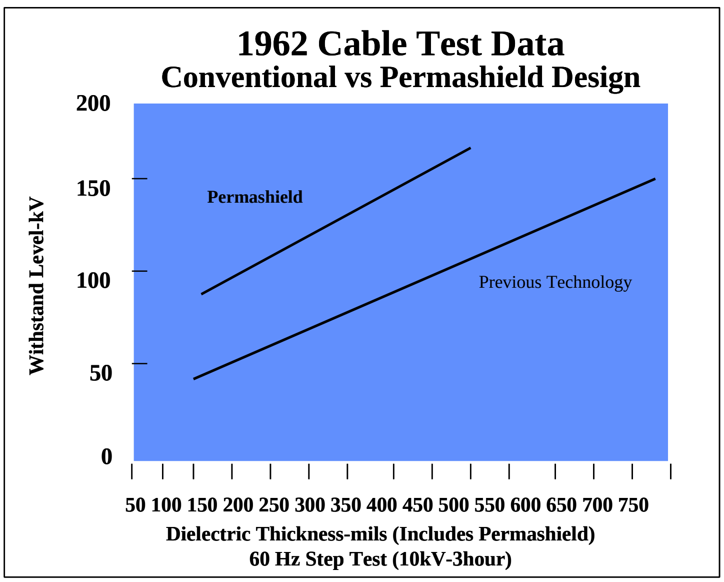

Figure 2

Table 1
Comparison of Insulation Thickness and Test Voltage

		Kerite			ICEA S68-516	AEIC CS6	
		1961	1962	1985	1988	1982	1987
	Conductor Shield (mils)	CW*	18	18	2.5	15	15
15kV	Insulation (mils)	295	170	175	175	175	175
	Test Voltage 60 Hz - kV	35	35	36	27	27	35

25kV	Insulation (mils)	455	240	260	260	260	260
	Test Voltage 60 Hz - kV	50	50	53	38	38	52
35kV	Insulation (mils)	640	310	345	345	345	345
	Test Voltage 60 Hz - kV	60	60	69	49	49	49

*CW =Conductor Wrap

<u>Comparison to Semi-Conducting Shields (1970 – Present)</u>

About the time Kerite was pioneering with the Permashield concept, the cable industry was involved in the development of extrudable semi-conducting compounds for use as conductor shields. In fact, Mr. Hvizd’s patent application was met with some initial objections by patent examiners since the differences between semi-conducting and non-conducting materials were not clear to them.

The electrical properties of Permashield are shown, scaled with other known materials, in Figure 3. Compared to semi-conducting compounds used in wire and cable, Permashield is considered and insulating compound.

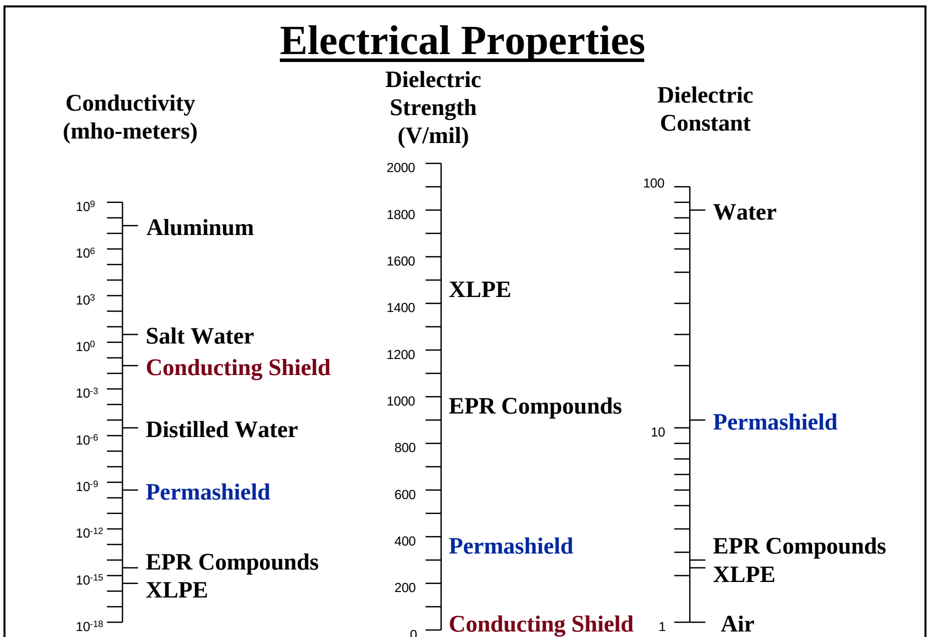

Figure 3

More specifically, the electrical conductivity of Permashield is one million times less than semi-conducting materials and will support voltage stress levels up to 300 volts/mil without electrical failure. The semi-conducting compounds used in wire and cable have virtually no dielectric strength. These two unique properties of Permashield provide very functional benefits not achievable with conducting compounds.

First, a 100 percent factory quality assurance test during extrusion over the conductor is possible simply by applying a moderate test voltage to the Permashield layer immediately after its extrusion and prior to extrusion of the insulation. This is shown in the photograph of Figure 4.

On Line Production Test

2KV - DC Test - Permashield

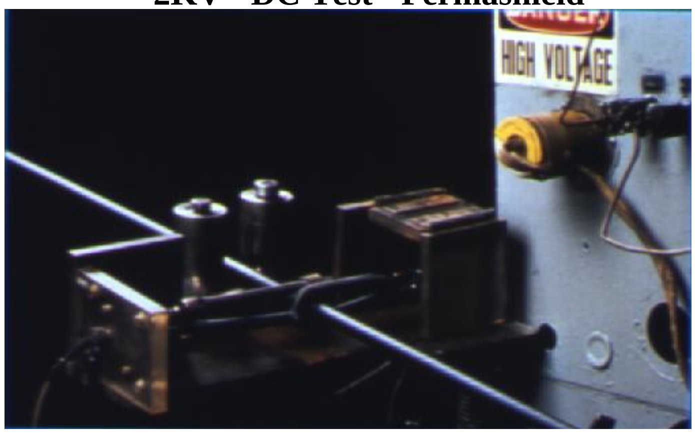

Figure 4

Secondly, when applied over the insulation (a construction referred to as double Permashield, or DPS) and left on in the termination area, the reliability of the termination is greatly increased. The layer serves to protect the insulation from workmanship errors as accidental cuts into the outer Permashield layer can be tolerated. With improved workmanship and availability of pre-molded, shrinkable and other prefabricated terminations and splice devices, the advantages of outer Permashield have become less critical, and most Kerite cable shipped is of the single Permashield type (SPS – only the conductor shield is Permashield). It is interesting to note that the principle for stress relief in many of the termination devices available today is the same as that which has long been provided by the outer Permashield in Kerite DPS cable.

Semi-conducting materials provide stress control due to their high conductivity. Permashield provides stress control by virtue of its high dielectric constant. Like capacitors in series, the voltage within a power cable will divide in proportion to the capacitance of the extruded layers. The capacitance of each layer would be determined by the geometry (inner and outer diameter) and the dielectric constant of the materials. However, subsequent testing proved this simple analysis and explanation to be incomplete.

Dielectric Test on Cables (1970 – Present)

Based on a simple electrostatic voltage division model, a comparative stress analysis between cable constructed with a conductor shield consisting of semi-conducting compound and a cable using Permashield is shown graphically in Figure 5. The figure shows the stress levels resulting from protrusions of the types permitted by industry standards.

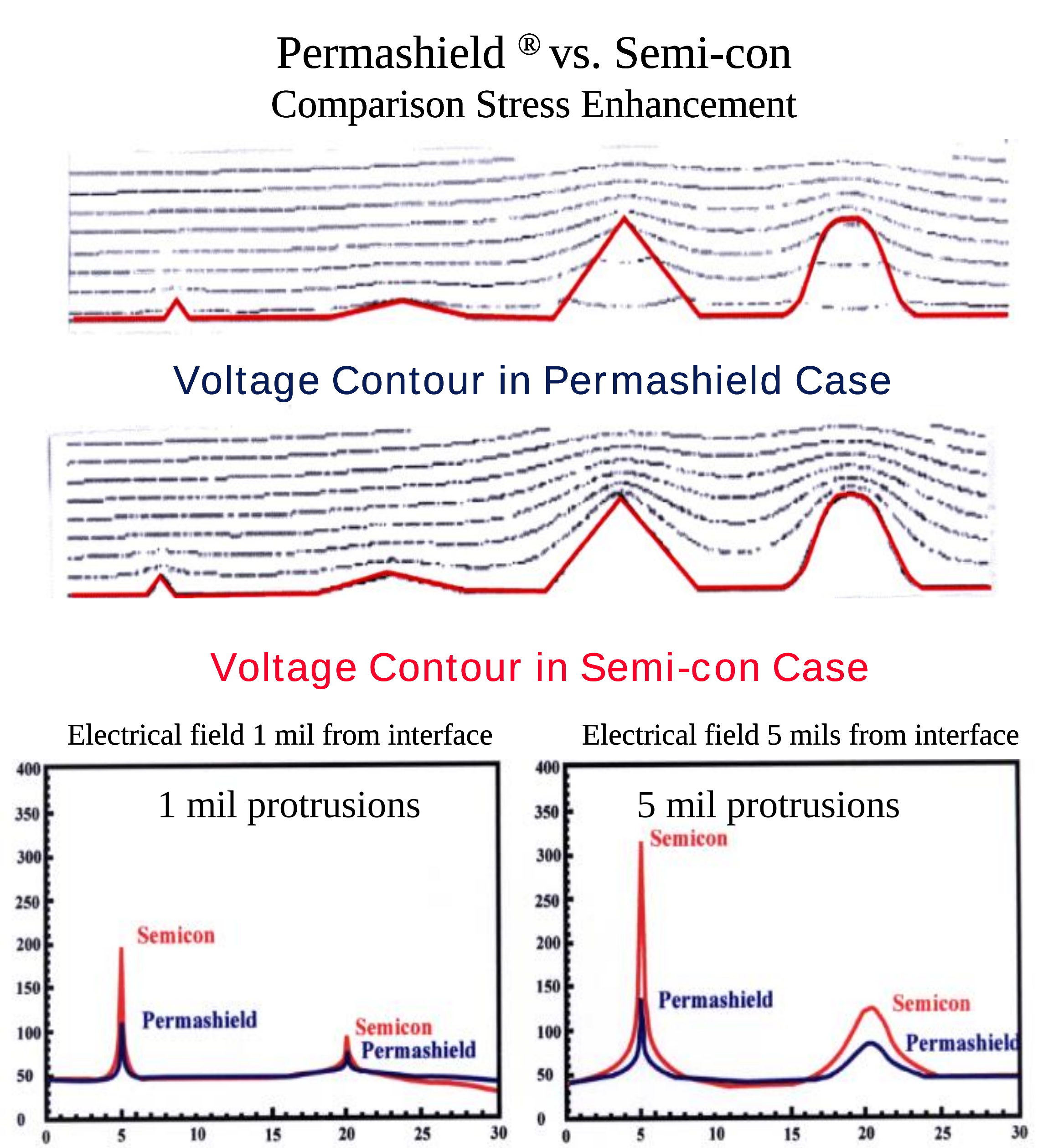

Figure 5

Figure 5 shows the stress levels attained when the respective shields have protrusions of the magnitude permitted by standards. Because of the fact that the Permashield shares the voltage in the cable, on a typical URD cable the average voltage stress is six percent lower in the main insulation of the Permashield cable than the cable employing semi-conducting material for conductor stress control.

60 Hz step breakdown tests conducted on model cables manufactured with both types of conductor shields appear to support the simple voltage division model. The results of the test are shown in Figure 6.

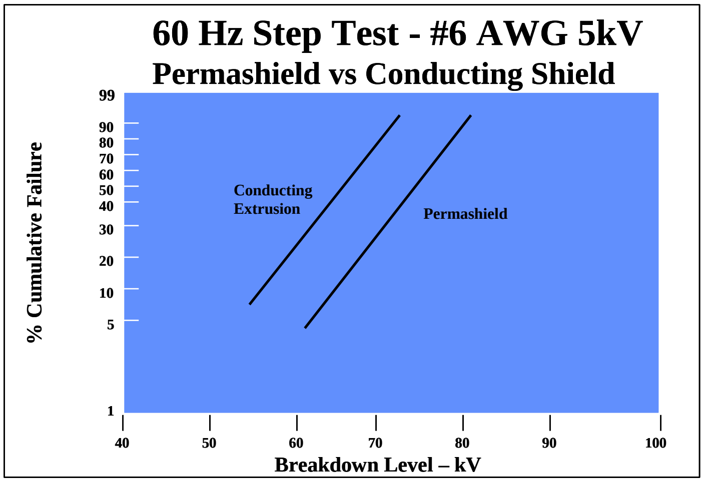

Figure 6

However, in impulse tests the resulting cable breakdown levels of the Permashield constructions were higher than the simple model has predicted, particularly in the low breakdown region. These results are shown in Figures 7a and 7b for two different cable constructions.

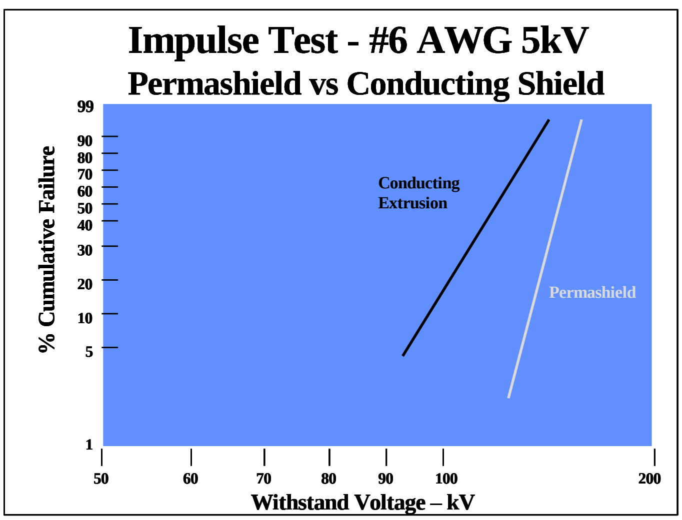

Figure 7a

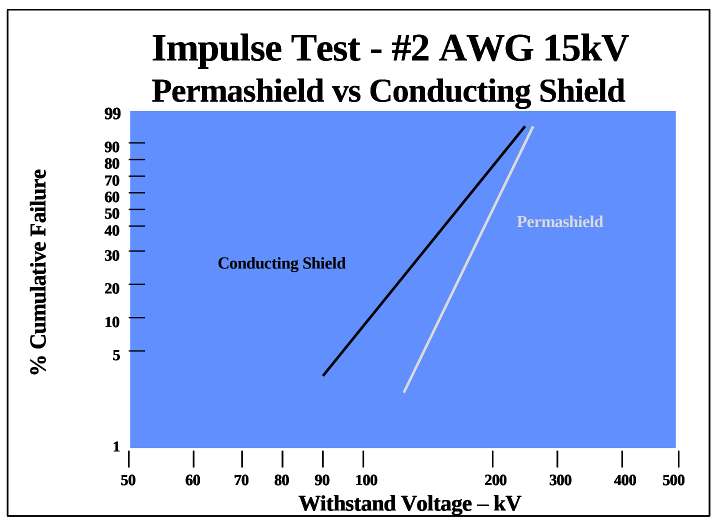

Figure 7b

The results of our cable tests comparing the different stress control designs suggested that the interface between the extruded shield and the insulation is a contributing, if not a controlling factor in the dielectric strength of the cable. In 1974, in a subsequent patent for high voltage cables, Mr. Hvizd theorized that “electron trapping” or “energy absorption” occurs at the interface when high dielectric constant material is used as shields.

Towards a Better Understanding (1980 – Present)

To further our understanding of interface contribution, Kerite commissioned A. D. Little to conduct a study to explore the physics of interface behavior. The study was based on the dielectric breakdown of 20 mil thick composite slabs consisting of two different materials, and the interface between them (Figure 8). To prevent breakdowns initiated by the metal electrode interfaces, mirror finishes were applied.

Physics of Permashield - A.D. Little

A Schematic Representation of The Composite Sample

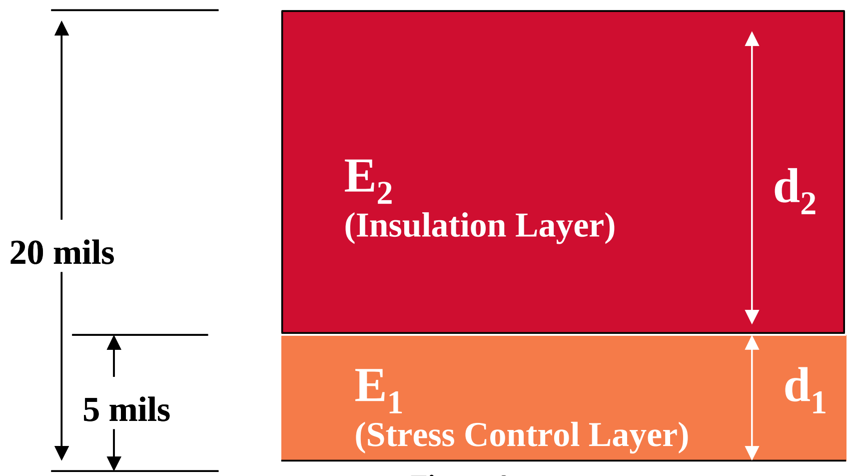

Figure 8

In addition to the primary goal of the program, comparisons between conducting materials and Permashield were also obtained.

Dielectric strength tests were first conducted on 20 mil thick insulation specimens, which did not contain an interface other than at the metallic electrodes. An average breakdown strength of 45kV (2,250 volts/mil) was obtained. It is important to note that this level is approximately three times higher than normally achieved in insulated wire and cable using this insulation.

When the test specimens incorporated a 5 mil layer of semi-conducting material (15 mils insulation), the breakdown level dropped to 20.4kV, well below the expected 33kV breakdown estimated for the 15 mil insulation thickness based on the 20 mil slab data. The difference can only be attributed to an interface initiated breakdown mechanism.

When the semi-conducting layer was replaced with Permashield, the average breakdown strength increased to 34kV. The performance of the Permashield interface was clearly superior to that of semi-conducting materials.

After normalizing to adjust for overall wall thickness and composite ratio, the comparative results are shown in Table 2.

Table 2
1983 Physics of Permashield – A. D. Little
Summary of Results

Material Type	Average Breakdown* (kV)	Insulation Stress at Breakdown (v/mil)
Semi-conducting/Insulation	20.4	1194
Permashield/Insulation	34.0	1704
Improvement	66%	42%

*Adjusted to common wall thickness and ratio of individual material thickness

Summary

Kerite continues to actively pursue improvements in power cable design concepts. Our products are a result of many years of experience and knowledge, and they consistently reflect a conservative approach to market introduction of design changes.

Permashield cables have been installed since 1961 and are operating using wall thickness at or below those specifed in AEIC CS 6-87

Permashield is recognized in both ICEA and AEIC as nonconductive stress control layer. Its electrical properties are distinct from semi-conducting layers and its benefits include, on-line fatory testing, reduced insulation stress, and improved electrical performance at the interface with the insulation.

We continue to believe that there is merit in the use of a nonconducting type strand shield and employ this technology starting at 5kV. The advantages of Permashield are not available from other manufacturers.