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Porcelain Insulators
"<u>Hanging Tons on a Teacup</u>"

By Waymon P. Goch

"Hanging Tons on a Teacup" was the title of a commercial sound/slide presentation by the Ohio Brass Company about 50 years ago. It was made available to the utility industry and covered the design principles of porcelain cap and pin suspension insulators at that time and explained how porcelain, a relatively fragile, hard and brittle material could be made to support the high mechanical static and dynamic loading of overhead transmission and distribution lines.

Porcelain is not what one would normally consider to be a structural material and a modern porcelain cap and pin suspension insulator appears to be a pretty simple device, consisting of three components; metal cap, glazed porcelain disk and a metal pin rigidly held together with some type of cement (normally neat Portland). Not so. In fact, if an insulator was assembled as described it probably could not survive even moderate seasonal temperature and load variations in most outdoor service environments for more than a few years.

Although there are only four components or materials visible from the outside, additional critical materials are used in the interior and there are typically 13 material interfaces between the cap and pin. If one were to drill from the outside of the cap to the center of the pin the drill bit would typically pass through 13 interfaces and materials that differ in hardness, strength, elasticity, and thermal expansion characteristics. A typical cross section is shown in Figure 1.

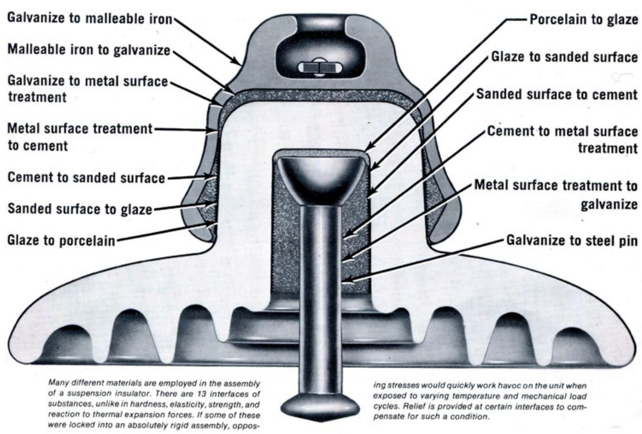
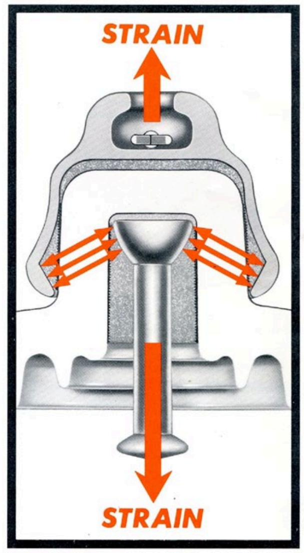


Figure 1

The porcelain in a suspension insulator is relatively weak in tension but very strong in compression. Thus, through very precise control of the porcelain head, cap and pin and their relationship to each other, axial loads applied to the cap and pin of a suspension insulator are translated to compression loads on the porcelain head and wall as shown in Figure 2. Equally important is the ability of the statically loaded suspension insulator cap and pin to move slightly in response to temporary mechanical and thermal overloads or excursions and return to their static loaded position following removal of the temporary condition. This is extremely important to prevent residual or trapped stress and this movement is made possible by the cap and pin geometry as well as permanent relief coatings on the bearing surfaces of cap and pin. Those coatings also provide chemical barriers between the hardware and cement.

The "sand" on both the outside and inside of the porcelain disk also contributes to the strength and loading of the porcelain. This sand is not really silica sand but rather small, sharp grains of unfired ceramic material that are applied to the bare, unfired porcelain with an adhesive glaze compound.



Opposing angular faces on the pin and inner lip of the cap convert axial strain on the insulator into compressive force on the porcelain head section. In such a system of mechanical loading, porcelain is exceedingly strong.

Figure 2

The glaze coating of a suspension insulator is predominantly glass with a composition similar to that of the clay body with increased glass-forming and fluxing ingredients. The porcelain is fired in a temperature and atmospherically controlled kiln over a period of approximately 3 days. Vitrification, through which clay becomes porcelain, typically occurs over about 10 hours during the second day at a temperature of 2200°F (1205°C). The fired glaze surface is smooth and glassy to withstand service environments, resist contamination and facilitate natural and other cleaning if it becomes contaminated. The glaze is not required to prevent moisture penetration of the body because electrical grade porcelain is inherently free of porosity. In addition to these functions, the glaze also contributes to the mechanical strength of the porcelain – as much as 20% because it is also compressive. The glaze is compounded to have a lower coefficient of thermal expansion than the porcelain body, which places the glaze in compression after kiln firing and cooling to ambient.

Following are greatly exaggerated illustrations of the pin and cap movement during mechanical loading and recovery cycles.

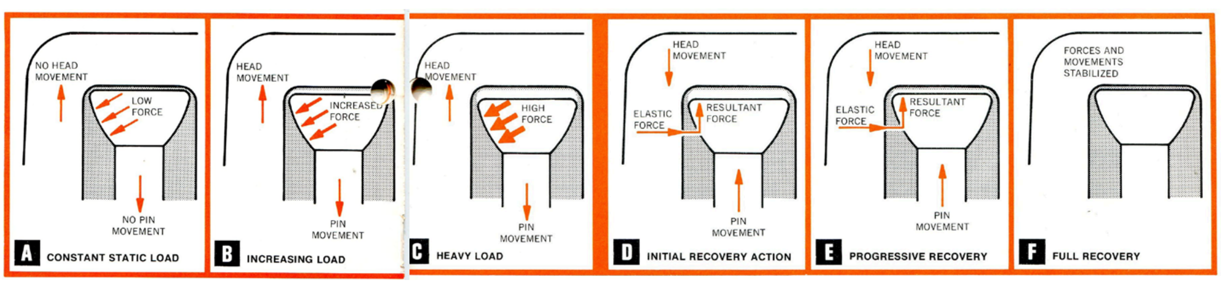


Figure 3. Pin loading and recovery

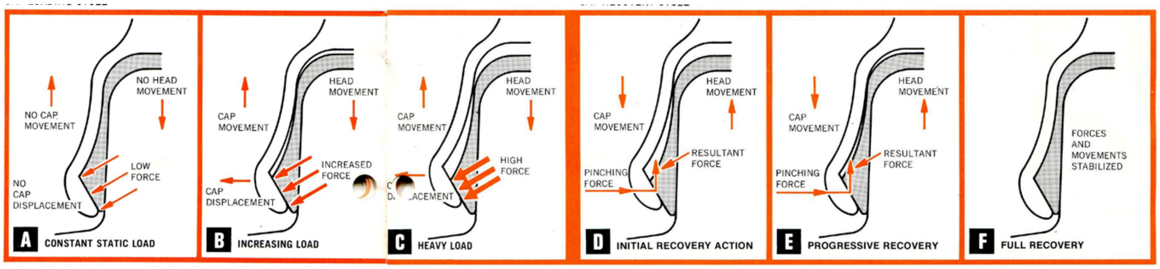


Figure 4. Cap loading and recovery

Probably the most succinct definition of a porcelain (or other) suspension or tension insulator is, "A mechanical support for an electrical conductor."

The primary role of suspension / tension insulators is to support the conductor mechanically, maintain sufficient electrical clearances and not reduce the dielectric strength of the primary air gaps under practically all operating conditions.

The integrity of the 13 interfaces discussed above is critical because insulators fail only at interfaces.

The primary constituents of a porcelain insulator are flint (quartz), alumina, ball clay, china clay (kaolin) and feldspar. Flint and alumina are used selectively, depending upon the desired strength of the porcelain body with flint being a primary constituent of standard strength electrical grade porcelain and alumina used for high strength body.

The porcelain insulator industry had its foundation in dinner ware, which is made from essentially the same basic materials, so it's not too much of a stretch to imply that we literally have been successfully hanging tons on a teacup for well over 100 years.

References: "How a Suspension Insulator Works", Ohio Brass Company Publication 2525-H.

"Birth of an Insulator", Ohio Brass Company Publication 2117-H.