

Solid-Cast Versus Resin-Encapsulated Transformers

Class 7300

Retain for future use.

OVERVIEW

The continuing development of dry-type transformers offers several construction techniques to choose from with primary voltages over 600 volts. Dry-type transformers can be categorized into good, better, and best classifications.

Transformer Type	Classification	Rationale
Conventional	Good	The standard reliable design for years
Resin-Encapsulated	Better	An improvement over older techniques
Solid-Cast	Best	Premium product and premium cost

The primary purpose of this data bulletin is to:

- provide definitions of common terms used to compare solid-cast and resin-encapsulated transformers.
- describe the vacuum-pressure impregnation (VPI) process for solid-cast and resin-encapsulated transformers.
- describe the advantages and disadvantages of both solid-cast and resin-encapsulated transformer construction.

DEFINITIONS

Dielectric Materials

Dielectric materials consist of the turn-to-turn and layer-to-layer insulating materials of the transformer winding (fiberglass, mica, aramid fiber paper, etc.)

Process Materials

Process materials can be varnish, epoxy resin, silicone resin, polyester resin, etc. The process materials are usually introduced into the processing tank or mold in a liquid state, and later cured to a solid state.

Pure Resin

Pure resin is a process material consisting of only the components of the resin. (For example, in the case of epoxy resin, the process material would consist of a base, hardener, flexibilizer, an accelerator, and perhaps a coloring agent). All components mixed together have a relatively low viscosity.

Filled Resin

Filled resin is a process material that combines a pure resin with suspended particles to increase the mechanical strength of the resin. Up to 60% of the resulting mixture may be sand, silica flour, quartz flour, glass particles, or some similar material.

Dielectric System

The dielectric system consists of the dielectric materials in combination with the process materials and air.

Impregnation

Impregnation of the windings by the process materials means the complete penetration of the windings' dielectric material.

Encapsulation

An encapsulated winding is one whose dielectric materials have been completely encased, but not necessarily impregnated, by the process materials.

Conventional

Dry-type transformers manufactured by the methods used for the past several decades are commonly referred to as “conventional”. It should be noted that a variety of construction techniques are lumped together under this umbrella term.

Resin-Encapsulated

Resin-encapsulated is a transformer winding that is encapsulated with a resin, with or without the aid of a vacuum, but without a mold to contain the resin during the cure cycle.

Solid-Cast

Solid-cast is a transformer winding that is impregnated and/or encapsulated in a mold, under vacuum, with a resin that will be allowed to cure before removing the mold.

Vacuum-Pressure Impregnation

Vacuum-pressure impregnation is the process of filling voids in a winding or insulation system by withdrawal of air and moisture, if any, from the contained voids by vacuum. This process also involves the admission of a resin or resin solution, followed by pressurization and cure, usually with the application of heat.

VACUUM-PRESSURE IMPREGNATION PROCESS

The VPI process can be used to produce either resin-encapsulated or solid-cast windings. The major difference between resin-encapsulated and solid-cast windings is that resin-encapsulated windings do not use molds during the curing cycle.

The VPI process consists of:

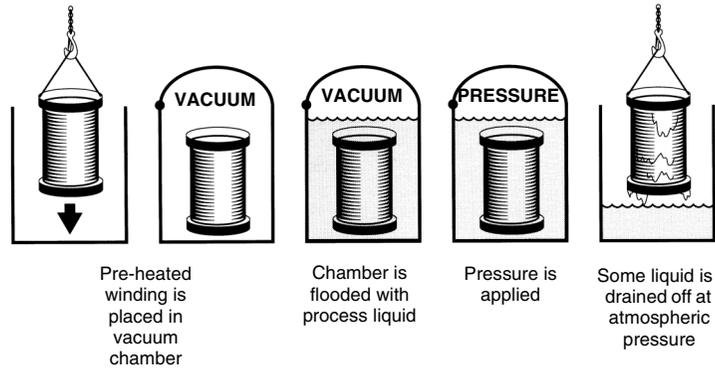
- A. **Pre-heat:** The windings are pre-heated in an oven or chamber to initiate the removal of moisture from the insulation and to aid in the subsequent impregnation of the resin. This is accomplished since the resin viscosity is lowered as the resin makes contact with the heated material.
- B. **Dry vacuum cycle:** During the dry vacuum cycle, gases and moisture are removed from the insulation materials and winding.
- C. **Vacuum immersion (resin-encapsulated) or vacuum fill (solid-cast):** While under vacuum, the resin is introduced as a liquid state into the processing tank (vacuum immersion) or mold (vacuum fill) containing the winding, until the winding is completely submerged.
- D. **Vacuum hold cycle:** The vacuum is maintained for a period of time to encourage the resin to impregnate the insulation and to remove air from the resin.
- E. **Pressure cycle:** Shortly following the vacuum hold cycle, the processing tank or mold is released, then pressurized on the free surface of the liquid bath to force the resin to impregnate the insulation voids.
- F. **Curing:** The winding or the tank is removed, and the winding is allowed to drip (dry) prior to being placed in an oven where the resin is cured to a solid.

Resin-Encapsulated

If further resin build is required on the windings of resin-encapsulated transformers, the VPI process can be repeated after the curing cycle. This "second dip" gives a more conformal coating and some improvement in the winding's isolation from the environment.

The VPI steps are shown in Figure 1:

Figure 1: Resin-Encapsulated Transformer Winding



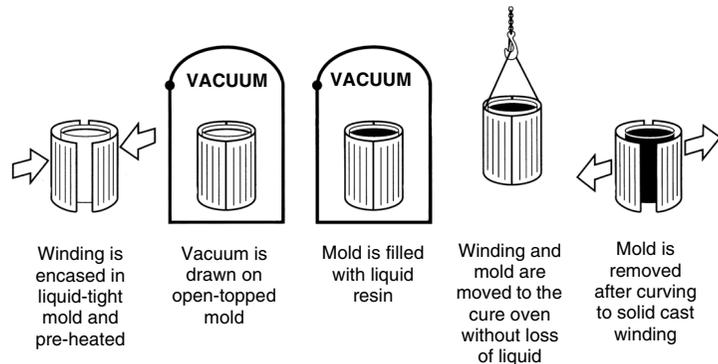
Because this method does not ensure complete impregnation of the windings, turn-to-turn insulation and layer insulation must be sufficient for the anticipated voltage stress without relying on help from the process material (liquid resin encapsulant).

Solid-Cast

Solid-cast transformers take their shape from the mold in which they are cast. The difference between resin-encapsulated windings and solid-cast windings is that the resin, once introduced into the solid-cast winding, is never allowed to run out of the winding. The process material is contained in the winding by the mold in which the casting takes place. The mold is not removed until after the curing cycle has converted the process material to a solid dielectric casting.

This process is shown in Figure 2 (details generally follow Power-Cast™ II construction techniques).

Figure 2: Solid-Cast Transformer Winding



Construction Advantages and Disadvantages

The principal advantage of solid-cast construction over resin-encapsulated construction stems from solid-cast construction having been cast in a mold that retains all the process material (resin) in place during the curing cycle. This can provide greater assurance of total impregnation of the windings. The solid cast transformer maintains whatever degree of impregnation was achieved during processing because the mold is not removed until after curing of the resin. By contrast, resin-encapsulated techniques can lead to the re-entry of air into the winding as the fluid process resin drains away after vacuum/pressure processing, but before curing.

Secondly, the resin coating on solid-cast windings is thicker than that of resin-encapsulated windings. The additional thickness adds mechanical strength to the resin system. If fiberglass reinforcement is also present in the resin coating, the resin encapsulation can, without undue thickness, become the principal means of providing short-circuit strength to the winding. Conductors are braced over their entire circumference by virtue of being embedded in a rigid, highly reinforced medium which contains short-circuit forces internally rather than relying on external bracing. Resin-encapsulated units, on the other hand, like the conventional varnished dry units they replaced, depend primarily on external bracing, the use of foil-wound secondaries, and skillful use of geometry to overcome short-circuit stresses.

It is important to recognize that neither solid-cast construction nor VPI processing is, without careful consideration of other factors, a guarantee that the windings actually will be impregnated by process resins according to the definition of impregnation set forth in this bulletin. (This is true in spite of the implication of the term VPI—that process alone ensures winding impregnation. Other factors, principally including the absorbency of the dielectric materials and the viscosity of the process materials will determine the degree of impregnation actually achieved.)

The main advantages of resin-encapsulated construction over solid-cast construction lie in the simpler manufacturing processes involved, the smaller amounts of resin contained in the finished winding, and hence a lighter weight and lower cost of the finished product. Additionally, because solid-cast windings are invariably made with epoxy resin, and resin-encapsulated windings can be satisfactorily produced with other resin types, resin-encapsulated units can surpass the present 185° C limitation of solid-cast units.

Polyester resin-encapsulated transformers are manufactured with ratings as high as 150° C rise (220° C insulation system ratings).

SUMMARY

The ideal dry resin transformer would:

- Include total impregnation and saturation of the process materials into the dielectric materials, so that the conductors are embedded in a solid matrix which capitalizes on the superior dielectric properties of the resin process materials, as well as the dielectric properties of the dry dielectric materials used.
- Contain the short-circuit forces within the windings rather than relying on external bracing. This takes advantage of the resin's ability, properly reinforced, to embed the conductors in a solid mass and prevent any conductor movement. (This is equally important in secondary windings because of the higher short-circuit forces.)
- Encapsulate the windings in an impervious shell that would protect them from hostile environments and moisture.
- Achieve sufficient mechanical strength with minimum wall thickness of resin so that heat would not be trapped within the winding. This would also provide sufficient wall thickness and reinforcement to ensure that the outer surfaces of the winding would not crack with age and thermal cycling.

Solid-cast transformers achieve the above aims to the optimum degree. The resin-encapsulated transformer, utilizing an improved resin when compared to the conventional varnish, is a greatly improved conventional dry-type transformer. However, it is by no means equals to the solid-cast transformer for environmental protection, dielectric strength, or short-circuit performance.

Schneider Electric USA
1809 Airport Road
Monroe, NC 28111
1-888-SquareD (1-888-778-2733)
www.us.SquareD.com

Electrical equipment should be installed, operated, serviced, and maintained only by qualified personnel. No responsibility is assumed by Schneider Electric for any consequences arising out of the use of this material.

© 1992–2004 Schneider Electric All Rights Reserved

