

Distribution Transformers

Reference Information

R210-80-3

Copper vs. Aluminum Conductor

At Issue:

There is a common misconception that a distribution transformer with copper windings is in some way more efficient, more reliable, or has greater short circuit strength than a transformer with aluminum windings.

Recommendation:

Improvements in technology regarding the use of aluminum in transformers make aluminum-wound Cooper transformers an ideal choice for many of today's applications.

The Evidence:

It is obvious that, per square inch, copper can carry more amps than can aluminum. To overcome this, Cooper designs aluminum-wound transformers with windings of a larger cross-sectional area than would be used for a copper-wound unit. This larger cross-sectional area results in a lower current density at an equivalent operating temperature. Operating temperature is the key to controlling and predicting losses. **A copper-wound unit is not necessarily a low-loss unit.** By reducing the current density in the windings, a low-loss design may be achieved with either aluminum or copper windings.

Somewhat related to losses are operating temperature and transformer life. **A transformer's life is defined by the life of its insulation system.** Over the life of a transformer, insulation loses its tensile strength and becomes susceptible to breakdown under fault conditions. Insulation can deteriorate in high temperatures. Temperature is driven by current density. Because Cooper designs of aluminum-wound and copper-wound units run at equivalent operating temperatures, the insulation system for each design ages at the same rate.

Whether low losses are a goal or not, aluminum windings are typically less expensive than copper windings. Table 1 shows two equivalent-loss designs - one with aluminum windings and one with copper windings.

TABLE 1

		Design Aluminum	Design Copper
No-Load Losses	CW	2607	2599
Load Losses	WW	13261	13194
Total Losses	TW	15868	15793
Efficiency @ 100%load		99.40%	99.40%
Dimensions:			
Height		73	73
Width		71	69
Depth		42	38
Price		\$17,700	\$20,435

2500 kVA, 3-phase padmount transformer, 13800 Delta - 480Y/277

In this example, the losses are roughly equivalent, but the price of the aluminum-wound unit is over \$2700 (13%) lower.

Field experience with aluminum connections *outside* of transformer tanks contributes to the bias against aluminum windings. Aluminum conductor connections are more difficult to maintain in an environment where oxygen is present. Unless sealed correctly, these connections will gradually increase in resistance until the heat generated results in thermal runaway. The connections inside an oil-filled transformer are **sealed from oxygen at the factory** by the insulating fluid. Each connection thus maintains its quality in the field. Connection methods used by Cooper for aluminum conductors have been validated in laboratory tests as well as in over thirty years of experience in building aluminum-wound transformers.

The influence of power transformers on the specifications of distribution transformers also contributes to some misconceptions about aluminum windings. In a power transformer with round coils, the design parameter which dominates the design is the tensile strength of the conductor. Because windings are stretched across spacers, a great amount of tensile force is placed on the conductor during short-circuit testing (tension can reach 1000 psi.) The forces present are independent of conductor material; they are based on current level and coil geometry. The tensile strength of copper is higher than that of aluminum, making copper more suitable for a round coil transformer design.

Cooper's **rectangular coil design** makes a short-circuit test a test of core-clamp strength, rather than of conductor strength. The rectangular coil design greatly reduces the amount of tensile stress on the windings. Windings are stacked on top of each other rather than stretched across gaps between spacers. This stacking process allows each layer of windings to rest on the layer inside of it. No windings are bridged across gaps. The 1000 psi tensile force is simply a compressive force across an entire layer of windings. Aluminum or copper windings in a rectangular core design resist this pressure easily.

Conclusion:

Cooper Power Systems designs its aluminum-wound coils using the same thermal, dielectric, and mechanical rules as for its copper-wound coils. In pad-mounted and substation designs, Cooper aluminum-wound units and copper-wound units serve their loads equally well.



P. O. Box 1640
Waukesha, WI 53187
<http://www.cooperpower.com>