Fail Proof Foil Wound Transformer

Rapid advancements and developments are taking place in the design, analysis, manufacturing and condition-monitoring technologies of transformers, currently world-over.

These advancements are due to various factors such as – continuous increase in ratings of distribution transformers and autotransformers, and specific needs for highest reliability, and lowest maintenance needs (such as in Ships) etc.

There are also vital design challenges – to address inherent problems in the contemperory deisgn & manufacturing,

- *stray losses,*
- *winding hot spots,*
- *short-circuit withstand capability*
- *insulation failure,*
- *bi-directional winding*

We offer a Fail-Proof Transformer that matches the advancements, design challenges above. Our strong design capability includes use of different form of basic materials, to fully draw their inherent characteristics, specific insulation materials, and customised CNC machine winding, are proof enough to demonstrate our acceptability in the market with 1,000's of Installations across India, already.

FeeFo
Electro Products Pvt Ltd

Providing :

- Transformer with double the life (atleast > 40 Years)
- getting rid problem - of insulation damage due to Oil
- higher efficiency - lowering eddy currents from bi-directional winding
- lower thermal problems - due to flatter winding material
- design with no-chance of hot-spots
- nullyfying the abnormal voltage variation between winding layers

Utilising :

- Choice of different basic design
- Choosing of Right Winding Material
- Choosing of Compatible Insulating Material
- Choice of Winding - Unidirectional

which helps in :

- higher Die-Electric Strength inherently
- Nil Humming / Vibration Noise
- Compact Size
- No Hot-Spot design & Winding
- Higher Heat Withstanding Capacity with no extra costing
- Low / Nil Maintenance
- Lower CAPEX

You can see in orderly manner, some of the aspects of FEEFO Fail-Proof Transformer basis, below :

- *Choice of Winding Material*
- *Form of Winding Material*
- *Insulation Material Choice*
- *Winding Method*
- *using inherent qualities of the above*

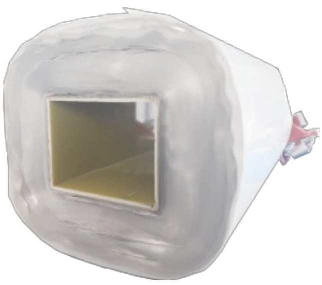
Further, the benefits of these, aiding in a real Fail-Proof Transformer.

- *a transformer designed for longer-lasting service life (than others)*
- *lower overall CAPEX costing*
- *lower overall OPEX costing*
- *lower TCO*
- *higher winding withstanding*
- *higher dielectric strength (in fact DOUBLE)*
- *very compact size*
- *less chance of vibration*
- *less chance of insulation failure*

and others on specific application.

This Fail-Proof Transformer is the basis for all the products of FEEFO.

- *Isolation Transformer*
- *Ultra-isolation Transformer*
- *Auto Transformer*
- *K-Rated Transformer*
- *Servo Stabiliser*
- *ABV Stabiliser*
- *LT Distribution Transformer*
- *HT Distribution Transformer*
- *Fire-Rated Transformer*



Choice of Winding Material : Aluminium - A++ factors

There are enough and more technical arguments with reference to the use of Aluminium as Winding Material as against Copper. Many of the arguments have become inconsequential and some are even considered as misinformation in the context of its usage. See the table in the next column.

Aluminium is the most abundant metal in the earths crust. It ranks second, next only to steel, in terms of volumes used due to its versatility, which stems from its excellent and diverse range of physical, chemical and mechanical properties. Aluminium, which is only one-third the weight of steel is highly resistant to most forms of corrosion, is non-magnetic, noncombustible, is non-toxic and impervious (hence used in the food and packaging industries) and is also a superb conductor of electricity. Other valuable properties include high reflectivity and rapid heat dissipation. The metal is malleable and easily worked by the common manufacturing and shaping processes.

India having the world's fifth bauxite reserves, an raw material for aluminium production.

In India the electrical sector is the largest consumer of aluminium. Bulk of the Aluminium usage is in overhead conductors and power cables used in generation, transmission and distribution of electricity. Aluminium is used in switchboards, coil windings, capacitors, and many other applications as well.

Key factors that favour the use of Aluminium.

Efficiency : While claims are made that aluminium has only 61% conductivity vis-a-vis copper, FEEFO Aluminium Transformers use aluminium conductors of larger cross-sectional area than copper. This covers the "equivalent conductivity losses" regardless of conductor material.

Tensile Strength : The use of larger-sized conductors results in aluminium winding strength which is nearly equivalent to copper windings. The ability of a transformer to withstand the long-term mechanical effects of “high impact” loads depends more on adequate coil balance and lead support than on conductor choice. Therefore, there is no significant difference in tensile strength, experienced between copper or aluminium transformers.

Thermal Conductivity : Use of proper hardware, ensures that Aluminium joints can be equal in quality to copper joints, which also addresses the expansion effects of aluminium under changing temperatures.

Table 1	True	False
Aluminum-wound transformer terminations are incompatible with copper line and load cables.		X
Properly terminating line and load connections is more difficult for aluminum-wound transformers.	X	
Line and load connections to copper-wound transformers are more reliable than those to aluminum-wound transformers.		X
Aluminum wound transformers are lighter in weight than copper wound equivalents.	X	
Copper-wound low voltage transformers are better for “high-impact” loads because copper has higher tensile strength than aluminum.		X
Aluminum-wound transformers have higher losses because copper is a better conductor.		X
Aluminum-wound transformers have higher hot-spot temperatures because copper is a better thermal conductor than aluminum.		X

Termination & Connection : The practice of using tin-plated aluminium lugs is universally accepted and has proven to be reliable throughout the more than 30 years aluminium -wound transformers have been in use.

Costing : Last but not the least, is the cost of Aluminium. It is considerably cheaper than copper and more importantly, the cost remains stable in comparison to the volatility of copper cost.

Availability : Aluminium is mined in India too, whereas copper world-wide is mined in very few countries, due to scarce avaialability. Also it is environmentally more taxing, for countries like India. And savings in precious foreign exchange.

in many countries, aluminium is the predominant choice of winding material for low-voltage, dry-type transformers, larger than 15 KVA.

The use of aluminum or copper foils results in a transformer with many advantages over conventional wire-wound versions :

- ***Increased reliability***
- ***Reduced size and weight***
- ***Higher ambient temperature operating capability***
- ***Improved electrical efficiency***
- ***Increased electrical stress resistance***
- ***Better overall regulation***

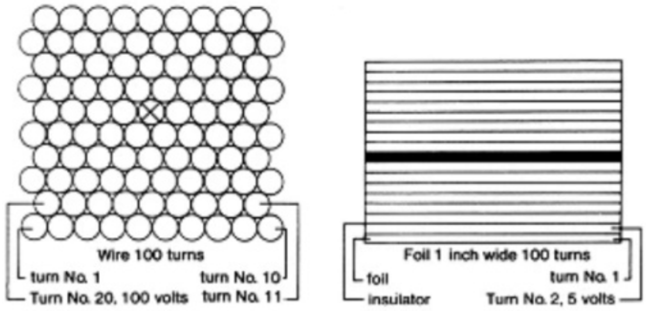
The basic transformer construction consists of electrical grade aluminum (or copper foil), temperature suitable interwinding insulation, fiberglass and nomex sheet insulation. The complete unit is vacuum impregnated with a specially formulated epoxy resin developed to assist in heat transfer and to bond the components into a stable, dense unit.

The use of strip foil conductors in large, high power transformers, to replace the conventional round or rectangular magnet wire, has been commonplace for many years.

The main advantage using aluminum foil rather than copper in transformers is the reduction in weight.

- The density of copper is 145 Grams per cubic inch while that of aluminum is 44 Grams per cubic inch.
- For a given winding volume, the aluminum winding would weigh one-third the weight of the copper.
- However, aluminum has only 60% the conductivity of copper.
- Even If the winding volume is increased by 40% to raise the aluminum conductivity to that of copper, it ***still leaves the aluminum coil weighing only 42% of the equivalent copper coil.***

Space Factor. The most efficient use of winding space is to layer wrap using magnet wire as shown in Figure 1A. Depending upon the size of the wire used, ***there is a percentage of the winding area which cannot be used for the conductors.***



(A) Wire Wound

(B) Foil Wound

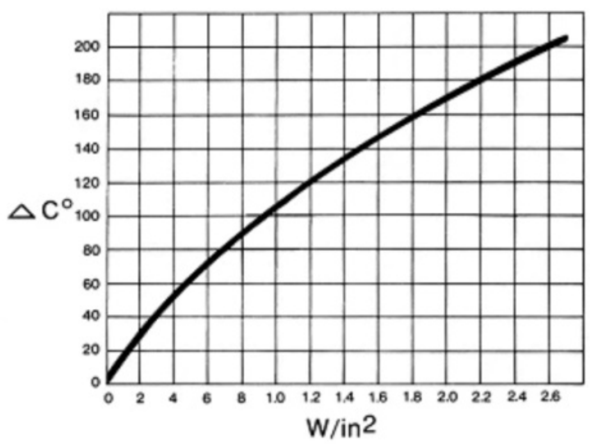
This lost area is ***made up of the space between the wires and the insulation with which each wire is coated***. As the voltage stress of the winding is increased, it is often necessary to add inter-layer insulation creating more lost space, thus decreasing the available conductor area.
The ***foil-wound coil*** illustrated in Figure 1B can be designed to make ***optimum use of the available winding area.***

Each turn of the ***foil extends edge-to-edge*** of the coil and is ***separated from the next turn*** by one thickness of insulation.

There is ***no lost winding space*** which means that foil with the same circular mil area as wire will fit into a smaller winding area, or conversely, more circular mils of foil may be wound into the same winding area.

Operating temperature of the transformer which affects its rating, efficiency and voltage regulation. The current flowing through the resistance of the coil wire results in heat generation, and, plus the losses in the magnetic material will increase the temperature. ***The temperature rise depends on how much, and, how fast the heat is generated and also how fast and efficiently this heat is wholly or partially removed.***

Figure 2 shows to what surface temperature a black body would rise above ambient as a function of watts power square inch of surface area of heat being dissipated into still air. The assumption is that



all internal losses appear at the surface to be radiated to the ambient air.

If the heat transfer from the center of the transformer is restricted, then the internal temperature will be hotter than the exterior and will seriously affect the efficiency, regulation and power rating.

So, ***the transformer design that reduces the rate of heat generation and / or increases the rate of heat transfer can result in:***

- A unit that is ***smaller and lighter*** with the same ratings.
- A unit that has the same size and rating but a ***lower operating temperature***.
- A unit that is the same size, operates at the same temperature, but can have a higher rating.
- A combination of any of the above.

Referring to above Figure 2,
- consider the same initial current flowing in each turn of the coil, and each turn starting with the same resistance, and that an equal amount of heat will be initially generated by each turn.
- Since all of the heat generated must make its way to the outer surface of the coil before it can be dissipated, a temperature gradient starting from the outside turn (the coolest) to the center turn (the hottest) is immediately established.
- Further, the temperature of this central inside turn will be very high since the path the heat must travel to get to the coil surface is through many layers of wire insulation which in themselves are very poor thermal conductors.
- To further complicate the situation, the resistance of each turn of wire will now increase slightly due to its increased temperature.
- This in turn will increase the heat generated and this cycle will repeat until a temperature stabilization level for each turn is reached.

Analysis of Figure 1B shows
- the ***unique advantage that a foil-wound unit has relative to the problem of dissipating the generated heat***.
- Each turn extending the full width of the coil has two edges in contact with the surrounding air.
- The ***tremendous advantage of the solid metal conducting path that each turn has for getting the heat directly to the outer surface of the coil***
- The ***net result for an aluminum foil design, even with its higher resistivity figure (and consequently more heat generated per unit increment), is a sharply reduced temperature gradient from the outside to the center of the coil.***

Thus, in the example described, the use of the aluminum foil winding is such that ***there is a smaller percentage of increase in the resistance from no-load to full-load (high I2R) than with a wire wound coil. This then reduces the need for the aluminum foil to have the same conductivity of the copper wire to produce the same results.***

A third ***advantage of the foil wound transformer is the voltage stress between adjacent turns***.
- In the wire wound unit, the insulation on the wire must withstand a higher voltage gradient than the foil insulation.
- For instance, assume both coils in Figure 1 to be made of 100 turns with 500 volts on the coil.
- Then, each coil will have a 5-volt drop per turn.
- In the continuous wound wire coil, turn number 20 is in direct contact with turn number 1 and therefore, the insulation must be capable of withstanding 100 volts.
- If the coil was random wound, the actual voltage difference between adjacent turns can be in the order of several hundreds of volts.
- This could not only cause dielectric breakdown but also corona degradation.
- In the foil wound unit (Figure 1B), each turn is only 5-volt different from its next turn and can never be more than 5 volts between any two turns.

One ***further advantage occurs in the mechanical strength of the foil unit.***
- Abrupt electrical stresses or mechanical vibrations and shock can cause the wire wound coils to fail because of the friction and abrasion between turns unless solidly cast in an epoxy resin.
- The expansion and contraction of the foil wound unit, because of mechanical or electrical extremes, causes no movement between the turns, thus eliminating any degradation.

The judicious use of foil can produce a lightweight transformer without compromise of the other characteristics.

Foil Wound Vs. Wire Wound Transformer

Parameter	Wire-Wound	Foil Wound	Remarks
Heating in the Winding	Higher	Very Low	Due to more surface area the total heat gets distributed, so low chance of disruption
Heat Radiation from Winding	Quite High & gets blocked in the lower winding – creating heat related issues	Very Even, the heats does not get trapped and been radiated without getting blocked.	Higher Safety for Foil Wound Transformer, inherently
Insulation Material	Paper Based	Polyester Film based	Higher Dielectric Strength – since Polyester Film can withstand more voltage / current for Insulation Disruption
Oil absorption by Insulation Material	Quite High	Nil	Since the Polyester does not absorb oil, it never gets
Insulation Material Damage	Quite High	Nil	Since there is no protruding of the wire surface (for Foil) it does not prick the Polyester film and damage it when it if fully loaded and have served good years.
Size of the Transformer	20 to 25 % bigger	Very Compact	Foil-Wound TX saves space in the inner winding, and insulation material of compact thickness
Bi-Directional Winding	From the beginning till end – the wiring direction changes left to right, vice versa. Long term effects of vibration, lower efficiency, higher heating of winding	Uni-Directional Winding	Dilutes and Prevent many of the problems due to winding variation – giving higher overall efficiency, higher reliability, low noise and vibration, over time
Built-in Heat Sink – for heat radiation of the winding	Nil	Yes	Makes Foil-Wound TX to be more reliable, and longer service life
Compatible for IT / Fire Hazard Zone Sites	Need Oil Cooled – above 150 KVA	Can do upto 500 KVA without Oil Cool Design	Complete range of compatibility