

## A New Method of Insulation Wire for Power Transformers

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### ABSTRACT

This task go in order to developing a new way of enameled and polyester foil insulation of conductors used in building transformers thermal of class temperature about (150 C<sup>0</sup>), the production technology for two types of enameled and polyester foil-insulation conduction are presented. As will as the physical, mechanical and electrical characteristics of conductors in a normal climate N<sub>2</sub>, in a tropical climate T<sub>2</sub> and after 28 cycle at ( 200 C<sup>0</sup> ) are presented.

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## 1. INTRODUCTION

The enamel and fiber glass insulated conductors are produce widely in many countries for thermal insulation (class F). As polymer binder in stuck fiber glass alkyd or polyurethane resin based varnishes may used also. These conductors do not meet in this time requirements of machine buildings and electro technical manufactories since their insulation thickness is too high (0.25–0.50 mm). Fiber glass–insulation conductors comply with thermal insulation class (180 C<sup>0</sup>). In conformity with polyester foil-insulation conductors are resistant to hydrolytic oxidations if finally, after being insulated with polyester foil, they are coil like impregnated with an alkyd, izoftalic, epoxy, silicone or other based varnish. The some paper shows that by impregnation the conductor the temperature index at the impregnated winding increases. Thus, by impregnating a polyester foil-insulated conductor winding with a silicone varnish a temperature varnish of about 180C<sup>0</sup> i.e. a thermal insulation class of 180C<sup>0</sup> class is obtained [1-5].

## 2. EXPERIMENTAL INDUSTRIAL WORKS

The ultimate goal of the experimental work developed by the author was the production of enameled and polyester foil-insulted conductors class F with an insulation thickness (enamel film included) smaller than that of the enameled and fiber glass-insulated copper conductor, and also good mechanical and electrical properties in both a normal climate N<sub>2</sub>, at 40 C, and a tropical climate T<sub>2</sub> which properties are not offered by the fiber glass-insulated conductor, after a series of industrial tests the production technology was obtained for the enameled and polyester foil-insulated copper conductor. With a circular and rectangular section. In what follows a short review of the production technology of conductor's class f is given [6-9].

Enameled and polyester foil-insulated copper conductors with circular section type ET 1-55/1. The production of enameled and polyester foil-insulated conductors comprises the following technological operations [10-16].

- a. Conductor enameling is producing enameled conductors with a temperature index of min. 180 C named, in agreement with STAS 1.1444/3-80, "enameled conductors with a temperature index of min180 C. ". There is no industrial production of enameled conductors with a diameter higher than 3 mm.
- b. Polyester foil-insulation of the enameled conductor.

For insulation a polyester film (produced today) was use. The 36 thick winding of the enameled conductor was done on a classical winding machine for band conductors which was provided with an adhesive bath without drying oven. The band adhesive was ADEMAR, which the author produced the previous years. The drying and the polyaddition reaction were developed in a vent oven at 135 .... 140 C for 35 ... 45 minutes. The result was enameled and polyester foil-insulated conductors whose characteristics are shown in Table 1.

Table 1. Properties of Enameled and Polyester Foil-insulated Conductor's Type CuET 1-155/T

No.Characteristic	Conductors type	ET 1-155/I 2,5 mm	PE 225 3mm
1-total insulation thickness, mm	0.195	0.196	0.199
2-Degree of superposition	1/2	1/3	1/3
3- Eloganation at break	32	34	36
4-Breakdown voltage, kv			
- Winding state			
- At room temperature 8.45	8.6	8.75	1...1.3
- after 48 hours at 80% 8.35	8.5	8.65	-
After 28 cycles in tropical climate T2 5	5	5	-
- after elongation 30% 8.4	8.55	8.7	-
- after 2 hours at -40%C 8.25	8.3	8.35	-
- four windings, kv +++	++++	+++++	-
- at room temperatures 6.5	6.6	6.7	-
- after 28 cycles at 220 C 1.65	1.75	1.8	-
5- temperature index, C++++++ 156.1	156.1	156.1	155

+ Enamelled and fiber glass-insulated copper conductor

++ mean value for 10 tests

+++ mean value for 5 tests

++++ 0.10 mm cylinder

+++++ 0.15 mm cylinder

HR – relative humidity

I – rapped in polyester foil

O - Blank conductor diameter (unenamelled) – ET polyesterimide

- Enameled and ET 1-155/I insulated conductor characteristics analyzing the results presented in table 1, we conclude with the followings:

- Enameled and ET 1-155/I insulated conductor characteristics

Analyzing the results presented in table 1, we conclude with the following:

- Enameled and ET 1-155/I insulated conductors have excellent electrical and mechanical properties in normal climate as well as after tropical climate tests, T2, this being the reason for their recommendation in dry transformers building, resistant in tropical climate, T2.

- The unchanged electrical and mechanical properties after their testing at a temperature of 220 C and -40 C demonstrate the excellent characteristics of the insulating system. Therefore, the breakdown voltage reaches the value of 1.5 KV after 28 cycles at 200 C temperature.

- The unchanged breakdown voltage after 30% elongation demonstrates the excellent flexibility of Adenmar adhesive with the polyester foil as well as polyesterimide polymeric film.

- The dry points on the conductor surface are resulted from the technologies of drying and firing which are statistically made on the roller which produces a bigger enough thickness of insulation.

Enameled and polyester foil insulated foil-insulated coil copper conductors with rectangular cross section, type TL 155/I, rectangular cross section conductors, class H because there is no industrial plant to produce the enameled conductors using the die method. Yet, there is a plant to manufacture enameled conductors using the method with cloth or felt. By using this method it cannot be obtained a uniform film on the whole length of the conductor, which results in a decrease of the breakdown voltage, in different points, up to 500 V. The same technologies are used as with enameled and polyester foil-insulated conductors having a circular cross section.

This technology will be briefly presented in the following:

- Conductor enameling. A varnish based on polyesterimide having min. 25% imidisation degree is used for enameling. Conductor enameling is made with a traditional enameled machine, type DR-6, through the cloth method [17-21]. Enameled conductors having the characteristics presented in Table 2 are obtained.

Table 2. Properties of Enameled Conductor, Type PET 1-180 CU

No. characteristics	Conductor type imposed value STR	CU PET 1-180
1. Insulation thickness mm	Max 0.035	0.030
2. Conductor elongation %	Min. 20	30
3. Enamel film adherence	Min 10	15
4. Breakdown voltage, v	Min.500	1400
-room temperature	Min.400	850
-180 C temperature		

x mean value after 10 tests

xx mean value after five tests

xxx with cuttings

p=profile

Cu=copper

180=value of temperature index, class H

Note: Enameling, according to this procedure, is applied to conductors having a cross section of min. 15 mm and max. 60 m.

Insulation of enameled and polyester foil insulated conductors.

These conductors are named PET 1155/I. conductor insulation was made on a traditional insulating machine with bands of paper o plastics. The working conditions were similar to those presented before for circular cross section conductors. The temperature test lasted 3 or 6 times more than that for insulated conductors type CU ET 1-155/I 2-3 because the latter ones had a 3-6 bigger cross section. Enameled and insulated conductors with the characteristics presented in Table 3 are obtained. Analyzing the results presented in Table 3 we can see that insulated conductors type CU ET 1-155/I.

Table 3. Properties of Enameled and Foil Insulated Conductors Type Cu PET 1-155/I

No. characteristic	Imposed value STR	Obtained value	Cu PET NTR 4475/2-84
1. Insulation thickness mm	Max 0.27	0.198-0.199	0.3.... 0.5
2. Overlap degree	1/2... 1/3	1/2	-
3. Elongation	Min 10%	15	Min 20
4. Breakdown voltage			
- At room temperatures	Min 2	4,7.....6.5	Min 1.5
- After 8 hours 80% UR	Min 1,5	4,7.....6.5	-
- After elongation 10%	Min 1	3.5....5.5	0
- After 2 hours at - 40 C	Min 1.5	4.5....6.5	-
5. Temperature index	Min 155	156.1	155

x mean value after ten tests

xx mean value after five tests

xxx tested on a=3.25

PET=polyesterimide enameled profile

155=temperature index for insulated conductor

PES=glass fiber insulated and enameled profile conductor

Enameled and glass fiber insulated conductors type CuPE2S are superior from the following points of view:

- Insulation thickness is much smaller with CuPET 1-155/I conductors than with CuPE2S conductors.
- Mechanical and electrical properties of enameled and polyester foil insulated conductors, type CuPET 1-155/I are completely superior to glass fiber insulated conductors, so the Cu PE 25 conductor after 10% elongation has a 0 breakdown voltage. The elongation over 20% causes the complete bare conductor which remains just as before insulation. Conductor properties type Cu PE 1-155/I are inferior to conductors type CuET 155 I because, during drying on rollers, it remains strained on its lower side and unstrained on its outer side and it has a rough surface due to the adhesive. In order to avoid these shortcomings we intend to design and manufacture a foil winding machine with drying oven.

### 3. CONCLUSIONS

From the facts presented we came to the following conclusions, Enamelled and polyester foil insulated conductors provide good mechanical and electrical properties in normal climate, N2 and in tropical climate T2, too. That is why are recommended in dry transformer building, for thermal insulation class F. By oil insulation of conductors, the mechanical and electrical properties rise 3-5time in contrast to those characterizing the glass fiber insulated conductors. Enameled copper conductors, type Cu PET1=180 obtained through the fault procedure have a similar character to insulated conductors, class F. The resulted insulating system system/enamel, foil, adhesive film has a temp index of 156,1 and corresponds to insulation class F. The excellent flexibility and adherence of polymer film after elongation as well as after bending on cylinders 0 10 and 15 mm show the very good quality of adenmar adhesive used for polyester foil gluing.

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