

**FACILITIES INSTRUCTIONS, STANDARDS,  
AND TECHNIQUES**

**Volume 3-7**

**PAINTING OF TRANSFORMERS AND  
CIRCUIT BREAKERS**

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## SECTION 1 - COOLING EFFECT WITH VARIOUS PAINTS

Considerable misunderstanding exists regarding the cooling effect that can be obtained by painting transformers with different types and colors of paint. It is thought by some that, as aluminum paint is a good reflector, that transformers painted with aluminum will operate considerably cooler than those painted with gray or black paint. This is true only for sources of heat outside the transformer and overlooks the fact that heat inside the transformer must be dissipated. Heat is dissipated from the transformer by conduction, radiation, and convection.

## SECTION 2 - HEAT LOSS BY CONDUCTION

Heat loss by conduction depends on the formula

$$W_{cd} = \frac{\Theta}{L \times R}$$

where

Wcd = watts loss per square meter by conduction

T = difference in temperature between the two ends of the material in degrees C

L = Length the heat must travel in meters

R = thermal resistivity of the material through which the heat must pass.

In a transformer the heat must pass from the conductors-and core iron through the insulation, oil, the steel case, and the paint coating. The thickness of the paint will add only an infinitesimal amount to either the length of the path or the combined thermal resistivity of the material through which the heat must pass. Any type or color of paint will therefore have a negligible effect on heat loss by conduction.

## SECTION 3 - HEAT LOSS BY RADIATION

Heat loss by radiation depends on the formula

$$Wr = KE (T_2^4 - T_1^4)$$

Where

Wr = watts loss per square meter by radiation

K =  $2.37 \times 10^{-14}$  T<sub>2</sub> = hot body temperature in absolute degrees

T<sub>1</sub> = ambient temperature in absolute degrees

E = emissivity factor

The value of E for aluminum paint is 0.55; for mat black paint 0.95; and for practically any other paint 0.90 to 0.95. An aluminum painted transformer will therefore dissipate by radiation approximately 1/3 less heat than a transformer painted some other color.

## SECTION 4 - HEAT LOSS BY CONVECTION

Heat loss by convection depends on the shape and size of the transformer and the temperature and rate of movement of the cooling medium. The type and color of paint have no effect on convection.

## SECTION 5 - INDOOR TRANSFORMERS

As there is no reflection of the sun's rays to be considered with transformers located indoors, the type and color of paint will effect only the heat loss by radiation. An aluminum painted transformer would be expected to operate at a higher temperature than one painted black or any other color due to the low emissivity factor of aluminum paint. Tests were made indoors on two standard 25-kVA transformers by General Electric Company. These transformers were tested with black painted tanks. Then the tanks were painted aluminum, and the tests were re-

peated at the same currents and voltage. The tabulated results are given in Section 6-85 of the Standard Handbook for Electrical Engineers as follows:

Comparison of temperature rise of 25-kVA transformers located indoors

(smooth tanks painted black and aluminum, room temperature 26 EC)

Transf No.	Top oil rise (EC)		Max. tank surface rise (EC)	
	Black	Aluminum	Black	Aluminum
	1	37.2	46.3	32.5
2	36.7	47.6	32.0	41.6
Average	37.0	47.0	32.3	41.3
Relative %	78.5	100	78.5	100

From the design of the transformers, it was estimated that 55 percent of the heat dissipated was by radiation and 45 percent by convection and conduction. If the emissivity factor of the aluminum paint is taken as 0.55 and the black paint as 1.0, the theoretical relative temperature rise for a tank painted black compared to a tank painted aluminum would be

$$55\% \times \frac{0.55}{1.0} + 45\% = 75.2\%$$

and the average top oil rise of the black tank would be 47.0 x 75.2 = 35.5 EC. This agrees reasonably close with the results obtained by the tests. For colors having an emissivity factor of 0.95 the relative temperature rise would be

$$55\% \times \frac{0.55}{0.95} + 45\% = 76.8\%$$

and the average top oil rise would be 31.6 EC. Considering temperature alone, the best color for indoor self-cooled transformers is dull black. However, gray, green, or almost any other color will increase the temperature such a small amount that the paint can be selected on the basis of appearance or the existing color scheme.

## SECTION 6-OUTDOOR TRANSFORMERS

When transformers are located in the sun, both the absorption of solar heat and radiation of the transformer heat must be considered. Unfortunately, the colors that give the best radiation of transformer heat will permit the highest absorption of heat from the direct rays of the sun. The coefficients of absorption of solar radiation are as follows:

White lead paint coating <sup>1</sup>	0.25
Light cream paint coating	0.35
Aluminum paint coating	0.55
Gray paint coating	0.75
Mat black paint coating	0.97

The amount of heat absorbed by the transformers will depend not only on these coefficients which change somewhat as the paint weathers, but will also depend on other conditions such as shape, size, the area exposed to the direct rays of sun, and the time of such exposure. As these conditions vary widely, the best indication of the effects of paint on the transformers located in the sun can be obtained from field tests.

Tests made by the Texas Light and Power Company at Dallas on identical transformers with equal loads and located in the sun showed a maximum oil temperature of 40 EC for black painted transformers and 39 EC for the aluminum painted ones. Similar tests by the San Joaquin Light and Power Company showed a maximum oil temperature of 29.5 EC for black, 29.0 EC for medium gray, and 27.0 EC for light gray. At Pittsfield, Massachusetts, similar tests were run over a 24-hour period. During the day the maximum oil temperature were 52 EC for black, 49 EC for aluminum, and 48 EC for white. At night the maximum temperatures were 41 EC for aluminum and 39 EC for black and white. In all the test reports available, the aluminum painted transformers ran cooler than black painted transformers when exposed to the sun. The difference in temperature was small, averaging

<sup>1</sup>For comparison purposes only, White lead paint is no longer used because of its toxicity.

between 1 and 2°. In cases where transformers are operating near the limit of their safe temperature might be important. This decrease in temperature would be, to a certain extent, counteracted by an Increase in temperature at night. In general, the total effect of the type and color of paint is too small to justify any repainting for its effect on temperature alone. When painting is necessary, it should be done on the basis of appearance and durability. While aluminum paint has unusually good lasting qualities for metal exposed to the sun, paints conforming to existing color schemes have adequate durability and should be selected.

### **SECTION 7 - WATER OR FORCED-OIL-COOLED TRANSFORMERS**

On water-or forced-oil-cooled transformers the majority of the heat is dissipated by convection which does not depend on the kind of paint used. The paint for these transformers should be selected on a basis of appearance as well as the lasting quality of the paint, and should be harmonious with the color scheme.

### **SECTION 8 - CIRCUIT BREAKERS**

The heat dissipated in a circuit breaker is generally small and the kind of paint used is not important from a heating standpoint. Therefore, the circuit breakers, and any other auxiliary equipment should be painted to present a good appearance.

### **SECTION 9 - SUMMARY**

- a. Indoor transformers should not be painted aluminum, since other paints will have satisfactory lasting qualities where protected from the weather and will result in a cooler transformer. Any color that fits the color scheme can be used.
- b. Self-cooled transformers exposed to the sun should be painted aluminum only where operating temperatures are critical. Other colors are preferable from an

appearance standpoint and should fit into an established color scheme.

- c. Water-cooled or forced-oil-cooled transformers can be painted any color that fits the color scheme or general surroundings.
- d. Environmentally such color schemes should be chosen for exterior items which are visible to the public.

The use of aluminum topcoats should be avoided on the painted metal surfaces of outdoor equipment. Help in arriving at suitable color schemes should be obtained by furnishing lists of items to be coated and photographs to the Assistant Commissioner - Engineering and Research, Attention: Code D-3130, with your request for a color design schedule.

### **SECTION 10 - TOUCHUP PAINTING**

If touchup or maintenance of an existing coating is indicated, the surface should be prepared by removing rust, loose paint, dirt, scum, or foreign matter by sanding, grinding, scraping, or other effective means. Bare metal should be given one prime coat plus one coat of paint as Indicated in the following paragraph, followed with a complete top coat of enamel or aluminum paint for all surfaces.

### **SECTION 11 - PAINT SPECIFICATIONS**

Where large areas of bare metal are to be painted, the specifications written for cleaning and painting new transformers and circuit breakers should address the following:

- a. All exterior exposed surfaces of ferrous metalwork for the transformers shall be cleaned to base metal by sandblasting or steel gritblating. After cleaning, the surfaces shall be given one coat of priming paint followed by two coats of semigloss enamel? The exterior surfaces of alumi-

<sup>2</sup>As an alternate for circuit breakers, these areas may be glavanized in accordance with ASTM Designation: A-123 and A-153.

num metal shall be cleaned by using clean rags and a solvent (xylol). After cleaning, apply metal conditioner followed by one coat of zinc dust-zinc oxide primer and two coats of semigloss enamel. All paint shall be applied in a workmanlike manner. Surfaces to be painted shall be thoroughly clean and dry before application of the paint.

b. Coating materials shall conform to the specifications which govern the specific project or solicitation for which they are to be used.

c. The contractor shall furnish the Government with a certification by the manufacturer, stating that these materials conform to the requirements of the designated specifications. The contractor shall be responsible for the accuracy of the certificates. The certificates must contain in addition, the type, batch, color, quantity, and Bureau of Reclamation solicitation/specifications numbers under which the material is to be used. A copy of the purchase order for the materials should be included as well. In the absence of a written purchase order, a statement that it was a verbal one will suffice. The Government reserves the right to test materials accepted on certification.