

## PCB RESIDUES IN TRANSFORMER CARCASSES

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### Abstract

There are restrictions on continued use and final disposal of transformers containing PCBs in the US. The results of studies of the distribution of PCBs in the major components of askarel-filled and in PCB containing oil-filled transformers are reported here. These results are used to consider some of the consequences of the requirements for reclassification and disposal of transformers.

### Introduction

The production of PCBs and the manufacture of electrical equipment insulated with askarels containing PCBs stopped in the US in 1978. Continued service of askarel-filled equipment has been allowed by the US Environmental Protection Agency (EPA), under limitations set by regulation of use and disposal of PCBs. The great majority of the 32 million load bearing transformers in use in the US today are filled with mineral oil. There was inadvertent mixing of minor quantities of askarels in a fraction of these oil-filled transformers. Continued use of these oil-filled transformers containing PCBs also has been allowed, subject to somewhat less stringent EPA regulation.

Since the initial EPA regulations were issued, a substantial number of transformers containing PCBs have been removed from service, either through normal attrition or in response to regulation. It is estimated that the number of oil-filled transformers with PCB concentrations greater than 50 µg/g oil declined from 3.3 million (containing 364,000 lb PCBs) in 1982 to 2.85 million units (containing 314,000 lb PCBs) in 1989. The number of askarel-filled transformers is estimated to have declined from 132,000 units containing 249,000,000 lb of PCBs in 1982 to 74,300 units containing 126,100,000 lb of PCBs in 1988. (As a matter of interest, it also is estimated that the number of large PCB capacitors in service declined from 3,290,000 containing 103,000,000 lb of PCB to 1,460,000 containing 45,500,000 lb in the same time period.) Substantial removal of PCBs has occurred; substantial amounts remain.

### Reclassification of Oil-filled Transformers Containing PCBs

Transformers are classified, under EPA regulations, as: "PCB" transformers - those filled with liquid containing >500 ppm PCBs (askarel-filled units are obviously "PCB" units); "PCB-contaminated" transformers - those filled with liquid containing between 50 and 500 ppm PCBs; and "non-PCB" transformers - those filled with liquid containing <50 ppm PCBs. The severity of regulation of use and disposal is greatest for "PCB" units and least for "non-PCB" units. The bulk of the PCBs in an operable oil-filled transformer can be removed by draining the liquid and the transformer will remain functional if carefully refilled with PCB-free oil. EPA rules allow reclassification of a functional transformer as "PCB-contaminated" or "non-PCB", if it can be demonstrated that the PCB concentration has been reduced to below 500 or 50 ug/g, respectively, in the replacement liquid. The transformer then becomes subject to the less stringent regulations of the new classification. The procedure for demonstration at present requires a PCB analysis of the fresh liquid after 90 days in service during which a temperature of 50°C is reached. Many transformers do not reach temperatures of 50°C in normal service and, in many cases, it is not practical to sample an installed transformer. Simplification of these reclassification requirements would encourage the replacement of PCB containing insulating liquid in transformers and the concurrent elimination of PCBs from the electrical network.

One part of the work reported here was to determine the level to which PCBs could be reduced with assurance by careful draining and refilling oil-filled transformers with PCB-free oil. (Askarel-filled transformers present a separate problem because of the much higher level of PCBs present and were not considered here.) Small transformers were disassembled and the amounts of PCBs associated with each of the major components was determined. Draining the oil with reasonable care was found to routinely remove 95% or more of the PCBs originally contained in these transformers. No preferential retention of PCBs in the insulation system or structural parts of the transformer was found. These results together with an examination of design data for oil-filled transformers rated to 160 MVA indicates that the PCB levels of "PCB-contaminated" oil-filled transformers of all ratings can be reduced to below 50 ug/g oil routinely by draining and refilling with PCB-free oil. A simplified reclassification procedure based on this approach is now being permitted for small "PCB-contaminated" distribution transformers.

The PCB levels of oil-filled "PCB" transformers containing as much as 1000 ug/g could be readily be reduced to less than 50 ug/g oil. Further, equilibration of the residual PCBs in the core and coil structures of drained transformers with fresh oil was found to occur rapidly, and with no important effect of temperature. PCB levels in "PCB" oil-filled units containing up to ~2500 ug/g can be reduced to <50 ug/g oil with a second refill with PCB-free oil. EPA

is considering the effect of these results on the requirements for reclassification.

#### Disposal of "PCB" Transformer Carcasses

To dispose of a "PCB-contaminated" transformer, EPA regulation requires that the liquid be drained and burned in a approved high efficiency boiler or high temperature incinerator. Disposal of the carcass is not limited by this regulation. Disposal of a "PCB" (>500 ug PCB/g oil) transformer requires that the unit be drained and refilled with a flushing liquid for a minimum of 18 hours. The PCBs in the insulating liquid must be destroyed with 99.9999% efficiency in an approved high temperature incinerator. The flushing liquid can be recovered for reuse if the PCB content is reduced to <2 ug/g and the separated PCBs are incinerated, or it also must be incinerated. The drained carcass must be buried in an approved chemical waste disposal site or itself incinerated. Both approved chemical landfill space and carcass incineration facilities are limited. Recognizing that this inhibits the elimination of PCBs in electric power apparatus, EPA has permitted an alternate procedure in which the liquid is drained and the combustible solid insulation and supports are separated from the metallic components of the transformer. The metal carcass, i.e., core steel, conductors, tank, can then be disposed of as a non-PCB item if the surfaces are cleaned to a level of <10 ug PCB/100 cm<sup>2</sup>. The combustible solids, the drained insulating liquid and any liquid used in cleaning must then be properly incinerated. (Cleaning liquid, like flushing liquid, can be reused if properly purified.)

The relationship between residues characterized by concentrations left on surfaces in transformers and residues characterized by concentrations in liquids in transformers had not been established. Another part of the work reported here was to establish this relationship. Small askarel-filled distribution transformers were disassembled, the amounts of PCBs remaining on the surfaces were measured, the metal surfaces were cleaned and the areas determined, and the ratio of the insulating liquid weight to metal surface area was calculated. Design data was used to calculate this ratio for askarel-filled transformers up to 3 MVA in load rating and oil-filled units up to 160 MVA. The minimum values found for this ratio was 12 g askarel/100 cm<sup>2</sup> surface area for askarel transformers and 8 g oil/100 cm<sup>2</sup> for oil-filled units. The values found for these ratios were often higher, but never lower. Design practices are much the same for both askarel and oil-filled units and the difference in the minimum values is due to the difference in density of the two fluids. The amount of PCBs in a residue of <10 ug PCB/100 cm<sup>2</sup> on the metal surfaces of an askarel-filled transformer carcass then is equivalent to that in a residue of <1 ug PCB/g left in the askarel initially contained in that transformer. A typical askarel in a such a transformer contains 600,000 ug PCB/g; 99.9998% of the PCBs initially present is eliminated in cleaning the carcass to a level of <10 ug/100 cm<sup>2</sup>. The destruction requirements of the regulation then are met, and disposal of

the cleaned carcasses of askarel transformers by simple burial or metal reclamation technology has been permitted. Substantially larger amounts of PCBs are allowed in the disposal of non-PCB transformers or "PCB-contaminated" transformer carcasses. The amount of PCBs in the residue left after draining 95% of the liquid from a "PCB-contaminated" transformer is the equivalent of up to 25 ug/g in the original transformer or up to 200 ug PCB/100 cm<sup>2</sup> left on the metal surfaces of its carcass after separation of the solid insulation. The entire amount of PCBs contained in a transformer at 49 ug/g oil is the equivalent of 392 ug/100 cm<sup>2</sup> of PCB residue remaining on the surface of the carcass.

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#### References

1. T.O. Rouse, W.A. Fessler and C.T. Raymond; "PCB Residues in Transformer Carcasses"; Electric Power Research Institute Report EL-6237; Palo Alto (Aug 1989). also, T.O. Rouse, W.A. Fessler, C.T. Raymond and G. Addis; Proceedings: 1989 EPRI PCB Seminar; papers 24 and 30; San Diego; and W.S. Trench; *op cite*; paper 37.