UNCLASSIFIED

PCBs: WHAT THE FUSS IS ABOUT

Polychlorinated biphenyls (PCBs) were first introduced for commercial use in 1929. Initially they were used for transformer and capacitor dielectric fluids, but since then their use has been expanded to include varnishes, waxes, sealants, glues, carbonless reproducing paper, flame retardants and pesticide extenders.

PCBs are widely used because of their special properties. They are clear liquids possessing both thermal stability and resistance to biodegradation. They are nonflammable, have a low vapor pressure, low water solubility, high organic solubility and high dielectric constants. Many of the same properties which make PCBs ideal in a commercial way make them undesirable from an environmental standpoint.

When PCBs were first tested in the 40's, they demonstrated low acute toxicity; however, when they were further tested in the 70's, it was determined that they are potent chronic toxicants. It is not known if there will be any long-range sublethal affects in generations to come when ingested by humans or animals, but it is known that they are stored in the fatty tissues. This could be a serious problem if the studies linking PCBs to liver, pancreatic and melanoma skin cancer prove to be true.

In laboratory testing, low levels of PCBs have been shown to inhibit photosynthesis in algae and cause reproductive failures in many species. PCBs may be twice as damaging as DDT in causing thinning of bird egg shells. Their highly persistent nature and tendency to bioaccumulate in the food chain add to their environmental impact.

It has been estimated that 1.25 billion pounds of PCBs have been used in the United States since 1930. Of this amount, about 750 million pounds are still in use, 290 million pounds are in landfills or dumps, 150 million pounds are free in the environment, and only about 55 million pounds have been destroyed.

The Toxic Substances Control Act gives EPA the authority to regulate manufacturing, processing, distribution and use of PCBs. It also requires that the agency prescribe methods of disposal and marking for PCBs and articles containing PCBs. The law mandates that all manufacturing and processing be stopped by January 1, 1979. Regulations prescribing marking and disposal requirements promulgated February 17, 1978. Rules banning the manufacture of new PCBs and regulation of existing stocks were finalized May 31, 1979.

PCB TRADE NAMES

(Can be found on transformer or equipment nameplates.)

NAME	MANUFACTURER
Aroclor	Monsanto
Asbestol	American Corporation
Askarel	Monsanto *
Chorextol	Allis Chalmers
Diaclor	Sangamo Electric
Dykanol	Cornell Dubilier
Elemex	McGraw Edison
Hyvol	Aerovox
Inerteen	Westinghouse
No-Flamol	Wagner
Pyranol	General Electric
Saf-T-Juhl	Kuhlman
Clophen	Bayer (Germany)
DK	Caffaro (Italy)
Fenclor	Caffaro (Italy)
Kannechlor	Mitsubishi (Japan)
Phenoclor	Prodelac (France)
Pyrelene	Prodalec (France)
Santotherm	Mitsubishi (Japan)

* PCBs are commonly called Askarel as Monsanto was the principal manufacturer of this product.

Explanation of Transformer Categories

In its final PCB ban ruling*, the United States Environmental Protection Agency (EPA) divided all liquid-filled transformers into three categories with respect to its PCB content. Below is a listing and brief explanation of these three categories.

Non-PCB Transformer

Defined as any transformer in which the PCB Level in the fluid is less than 50 parts per million (ppm)

Disposal Requirements - There are no specific requirements concerning the transformer; however, the fluid may not be used for road oiling or dust control if there is any detectable PCB.

No liquid-filled transformer may be considered Non-PCB unless a sample of fluid from the transformer has been analyzed.

PCB-Contaminated Transformer

Defined as any transformer in which its fluid is between 50 and 500 ppm of PCB

Disposal Requirements - There are no specific requirements concerning the transformer; however, the oil must be disposed of in accordance with 40 CFR 761.10.*

Any transformer on which the nameplate indicates "mineral oil" may be considered to be in this category without analysis. Regular inspection is required.**

PCB Transformer

Defined as a transformer in which the PCB Level in the fluid is over 500 ppm

Disposal Requirements - Both transformer and fluid must be disposed of in accordance with 40 CFR 761.10.*

Labelling Requirements - The transformer must be labelled in accordance with 40 CFR 761.44.*

Regular inspection is required.**

*May 31, 1979 Federal Register
**March 10, 1981 Federal Register

PROCEDURES

DEVELOPMENT OF METHODS TO RETROFILL TRANSFORMERS WITH SILICONE TRANSFORMER LIQUID

William C. Page, Terry Michaud
Dow Corning Corporation
Midland, Michigan 48640 U.S.A.

Summary-Because of new environmental and safety requirements for electrical equipment, silicone dielectric liquids are presently being used and evaluated as a transformer coolant. In the transformer maintenance and repair industry there is an interest and need to develop procedures to remove the existing liquid in a transformer, clean the transformer and refill it with silicone transformer liquid.

This paper describes retrofilling experiences and related experimentation carried out over the past 5(+) years. Pressure, solubility, processing, water, and other topics including specific case histories are covered.

The data and information collected on retrofill of transformers with silicone transformer liquid confirm that such a practice can technically be accomplished.

Introduction

In the late 1960's the unfortunate PCB poisoning of people in Japan and the toxicity/environmental studies that followed predicted the eventual elimination of all PCB-containing products. Silicone fluids became the prime candidates to replace PCB's in some applications because of good stability, extreme inertness, low vapor pressure, a wide range of viscosities, excellent fire safety and other properties. Early identification of the good dielectric properties of polydimethylsiloxane (PDMS) fluids had already led to over ten years of successful use in a number of electrical applications. Evaluations of PDMS fluids as PCB replacements have resulted in the commercialization of a PDMS vapor booster fluid for use in vacuum systems, the replacement of PCB's in some specialty heat transfer applications and the current widespread acceptance as a replacement for PCB-containing askarels in small power transformers.

After the Japanese incident, Dow Corning's long-running dielectric liquid evaluation program was expanded to design a product and substantiate its safety and efficacy for use in small power transformers. Portions of this program have been characterized in the literature.[2,3,4,5,6,7,8] By 1972 the polymer screening and characterizing studies were completed. The data generated identified the standard dielectric grade of PDMS fluid as the ideal choice for this application. It had a proven application history, having been used in electrical/electronic applications for a number of years; its production capability was well established, and a substantial amount of toxicity/environmental/fire/safety data were already collected.[9] Our data indicated this material would perform very well in power transformers. Since it was not possible at that time to purchase such a unit, a plan was developed to drain in-service askarel transformers, solvent clean them and refill them with silicone transformer liquid. This basic procedure has since become known as a retrofill. To assure reluctant plant people that the retrofill route was a technically sound approach to in-service evaluation, we conducted many specific studies, which will be discussed in the following text.

Pressure in a Transformer

Temperature-induced fluid expansion causes the liquid in a transformer to expand into the gas head space. This compression of the gas causes the pressure to increase. Temperature drops are accompanied by decreases in pressure. Silicone transformer liquid changes more in volume as the temperature changes than does transformer oil or askarel.

TABLE I
Coefficient of Expansion of Insulating Liquids

Liquid	Coefficient of Expansion
Silicone	.00104 cc/cc/°C
Transformer Oil	.00073 cc/cc/°C
Askarel	.0007 cc/cc/°C

Classical gas compression versus pressure equations indicated that many of the transformer oil and askarel transformers in our plant could be seeing pressure extremes in excess of their label ratings. This, in fact, does not happen which means that there are other factors involved. It appears that the liquid absorbs the gas as the pressure increases. Although silicone transformer liquid expands more than transformer oil or askarel, its ability to absorb gas is greater.

TABLE II
Air Solubility in Insulating Liquids

Liquid	Air Solubility 25°C 1 Atm.
Silicone Transformer Liquid	16.5%
Askarel	5.7%
Transformer Oil	10.0%

To determine what the real pressure difference would be when we replaced askarel with silicone transformer liquid we ran pressure versus temperature tests in the pressure vessel shown in Figure 1. Data are in Table III.

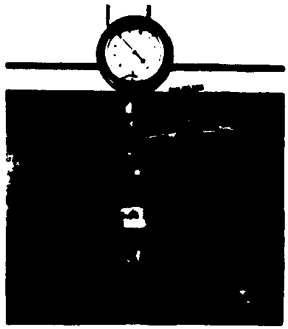

Fig. 1. Pressure Vessel.

TABLE III
Pressure vs. Temperature in a Pressure Vessel

	Silicone	Askarel
Initial pressure after fill and sealing at 23°C	0 psi	0 psi
Equilibrium pressure at 100°C	4.8 psi	4.2 psi

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TABLE III (con't.)

Calculated pressure at 100°C	23.2 psi	10.3 psi
Equilibrium pressure at 0°C	-3.6 psi	-4.2 psi

In our tests, the air-to-silicone liquid ratio was .176. When the pressure vessels were heated to 100°C, the pressure of those filled with silicone reached 7.25 psi and equilibrated to 4.8 psi, while those filled with askarel reached 7.3 psi and equilibrated to the lower pressure in about 23 hours. Our rate data are sketchy, but it appears the silicone did equilibrate faster, probably as a result of gas absorption.

These data indicate that neither the silicone transformer liquid nor the askarel generate the pressure predicted. They also show the pressure increase caused by silicone over that of askarel is not great enough to cause problems in transformers. This is confirmed by pressure data in Table VI, which were generated in a retrofilled 1000 KVA transformer.

Heat Rise in a Retrofilled Transformer

The effectiveness of a heat transfer fluid is dependent not only on viscosity but also on density, thermal conductivity, heat capacity and coefficient of thermal expansion.[11]

Although the higher viscosity of the silicone transformer liquid (see Table IV) will tend to reduce the liquid flow, the density difference between cool and warm silicone transformer liquid is greater than that of askarel or transformer oil (see Table I) thus improving the thermal syphon convection flow of silicone transformer liquid.

TABLE IV
Viscosity of Insulating Liquids

Liquid	Viscosity at 68°F, 20°C
Silicone Transformer Liquid	55 cs.
Typical Transformer Oil	16.5 cs.
Inertene70-30	16.5 cs.
Pyranol 1383B-3	13 cs.
Inertene100-42	18 cs.

It is evident that silicone transformer liquid has heat transfer advantages as well as disadvantages. In the beginning, we did not know just how these factors would balance out. With this in mind, transformers that were not heavily loaded were purposely picked to do our first retrofilling. One of these units was a 1000 KVA General Electric Power Center transformer which was loaded to about 60%. Temperature rise and ambient temperature were monitored and compared to data collected before the retrofill. No differences were found. This was a 22-year-old unit which had roughly 0.5 gallons of dielectric coolant per KVA. Many newer units are designed in the .14 to .2 gallons per KVA range and the equivalent cooling we saw in this test may not carry through into the new tighter designs.

At this point in our program two new units were evaluated; one containing Inertene®, a Westinghouse askarel, and an identical unit containing Dow Corning® 561 silicone transformer liquid. Load versus temperature data are shown in Table V. These units contained .236 gallons per KVA. Top oil temperature values indicated that the silicone transformer liquid unit ran warmer than the askarel unit but was still within acceptable heat rise values.

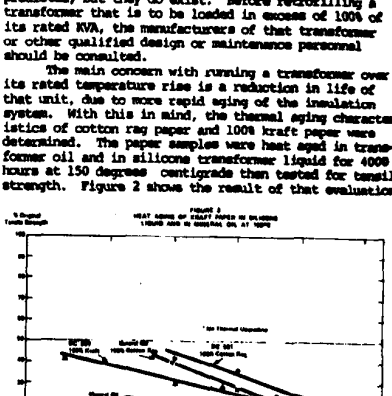
Other load versus temperature data on two askarel units and two transformer oil units retrofilled with silicone transformer liquid are in Table VI.

TABLE VI
Load vs. Temperature in Retrofilled Transformers

	Askarel	Silicone Transformer Liquid
2240 KVA, 3/60 13800 - 480Y		
Primary Rise, °C	61.5	62.7
Secondary Rise, °C	61.7	65.9
Top Oil Rise, °C	60.0	67.2
2200 KVA, 3/60 13800 - 480Y		
	Askarel	
Primary Rise, °C	57.3	54.0
Secondary Rise, °C	53.8	57.5
Top Oil Rise, °C	51.8	58.3
1000 KVA 34.5 KV WYE - 480 WYE		
	Transformer Oil	
Primary Rise, °C	63.5	71.0
Secondary Rise, °C	62.5	68.0
Top Oil Rise, °C	50.0	59.0
1000 KVA 4.16 KV Delta - 480 WYE		
	Transformer Oil	
Primary Rise, °C	47.2	50
Secondary Rise, °C	48.2	55
Top Oil Rise, °C	43	49
Pressure (psi)	2.4	2.5

These data show that heat transfer effectiveness of silicone is dependent on transformer design. Some units ran within specifications when cooled with silicone transformer liquid, while others exceeded the design specification by a few degrees. The differences found have been less than calculations on model systems predicted, but they do exist. Before retrofilling a transformer that is to be loaded in excess of 100% of its rated KVA, the manufacturers of that transformer or other qualified design or maintenance personnel should be consulted.

The main concern with running a transformer over its rated temperature rise is a reduction in life of that unit, due to more rapid aging of the insulation system. With this in mind, the thermal aging characteristics of cotton rag paper and 100% kraft paper were determined. The paper samples were heat aged in transformer oil and in silicone transformer liquid for 4000 hours at 150 degrees centigrade then tested for tensile strength. Figure 2 shows the result of that evaluation.



The data indicate that the test specimens retained more of their original tensile strength in the silicone transformer liquid than in the transformer oil.

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TABLE V
Transformer Temperature Rise Measured in °C

2500 KVA 14.8 KV DV DELTA - 450 LV WYE

Temperature Rating	Fluid	Load	Load Losses	Rise of Windings By Resistance Measurements		Top Fluid Rise
			Watts	H.V.	L.V.	°C
55°	Insulation	100%	27900	50.9	50.1	49.9
65°	Insulation	100%	-----	60.0	60.0	56.0
55°	DC 561	100%	28000	46.88	46.03	53.00
65°	DC 561	100%	-----	57.52	57.28	61.00

This may be an indication that although a retrofilled silicone transformer runs warmer, it has the same total life due to a reduction in the thermal aging of the insulation.

Solubility Studies

Solubility studies on a variety of askarel formulations indicated all were completely soluble in silicone transformer liquid in the 0 to 8% level. Therefore, if we reduce the askarel level below 8% in a retrofill, we will have a clear silicone liquid in the unit. A problem arises when we look at the reverse of this situation. While you can put up to 8% askarel in silicone, the solubility of silicone into askarel is less than 1%. This can create a two-phase situation because as the silicone transformer liquid is soaking into the askarel impregnated paper, wood, and pressboard, there may be spots in the transformer where the two liquids are not totally soluble. To see if this two-phase situation would result in insulation weak spots, we performed the following experiment:

A ball-to-plane test cell[11] developed in our laboratory was used in the study (see Figure 3). It is unique in that it allows multiple breakdown collection on one impregnation sample.

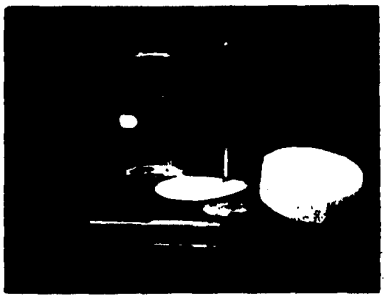

Fig. 3. Ball-to-Plane Test Cell

In this study, sheets of stabilized kraft paper were impregnated with Dow Corning® 561 silicone transformer liquid, transformer oil, and transformer askarel. These were then broken down in the cell using (+) and (-) impulse.

Next kraft paper which had been impregnated with askarel was rinsed lightly twice with trichlorobenzene, (TCB) covered with silicone transformer liquid and tested in a similar manner. Data are in Table VII.

This initial study did not indicate a problem.

A recent paper[12] again predicted that this two-phase situation would cause insulation system weak spots. Since there were limited data in that publication, two additional series of tests were conducted.

In the first series, paper samples were impregnated with askarels, removed, allowed to drip off, and placed in the test cell. Degassed silicone transformer liquid was poured slowly over the paper. Twenty data points were used to obtain the electric strength of the fluid/paper combination. As the silicone transformer liquid soaked into the askarel impregnated paper, insoluble two-phase mixtures of the two liquids probably formed. Data points were taken for the time period of 0 to 60 minutes with no significant change in the electric strength. Data were also taken over a time period of 300 hours with no deviation from the expected electric strength of silicone impregnated paper. The results are shown in Figure 4.

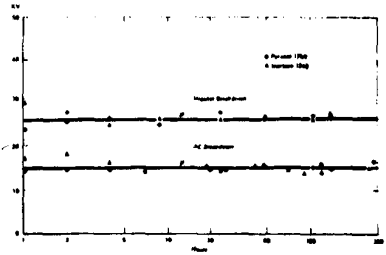

Fig. 4. Impulse vs. time on askarel impregnated kraft paper immersed in silicone transformer liquid.

Another series of tests was also conducted on two-phase systems. This was accomplished by combining papers impregnated with different liquids and testing in silicone liquid using the same test cell as above. Several combinations of impregnated papers and liquids were tested in order to determine the effect of the two phases on electric breakdown. Table VIII summarizes the results of these tests.

Comparison with the control data demonstrates that there is no significant reduction in electric strength. In fact, in the case where a TCB wash was used on the upper layer of paper, an increase in the impulse strength over that of silicone alone was observed. The conclusions reached from the test's results were that no significant problem existed. More than 16 transformers have been retrofilled with silicone fluid with not one failure. This supports our data and conclusion that the transformer reliability and capability are not reduced in the event of the formation of a two-phase interface within the dielectric.

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TABLE VII
Impulse Values of Kraft Paper Impregnated With Various Liquids

Impregnation Liquid	Liquid in Cell During Testing	(+) Impulse			(-) Impulse		
		Volts	S	# of Shots	Volts	S	# of Shots
Silicone Transformer Liquid	Same	28,030	2021	10	37,320	1786	10
Transformer Oil	Same	33,740	1228	10	37,910	1620	10
Askarel	Same	27,733	2532	10	36,887	6371	8
Askarel	Silicone Transformer Liquid	25,170	1355	10	30,820	1840	10

TABLE VIII
Electric Breakdown of a Two-Layer Impregnated Kraft Paper System

	AC	S	Impulse	S
DC* 561:Control	20.3	1.6	36	2.7
Pyranol 1260: Control	29	2.7	52	5.8
Inerteen 1242: Control	29	2.5	45	2.4
DC* 561 Inerteen 1242	19	1.5	28	3.7
DC* 561 Pyranol 1260	20	1	35	2.6
Inerteen 1242 TCB washed Inerteen 1242	21	4	46.5	7.9
Inerteen 1242 Inerteen 1242	23	2	38.5	3.0

Silicone Processing

A necessary consideration was processing silicone transformer liquid in the field. To minimize water contamination and reduce the dissolved gases it is desirable to degas the liquid or vacuum fill the transformer. The higher viscosity (Table IV) of silicone transformer liquid may cause the trapping of some air bubbles. Vacuum processed liquid will have the ability to absorb these bubbles. In our own laboratory studies silicone transformer liquid was found to impregnate cellulosic insulation material as easily as transformer oil and askarel. Transformers have been filled by simply pouring silicone liquid from the drum into the transformer with no additional processing. This might indicate the vacuum processing is an unnecessary step, but it is felt that it is a step that must be included until further data are available.

Many transformer tanks are only capable of withstanding pressures of -5 to -7 psi and are not properly piped to make vacuum filling practical. This made the use of a portable vacuum degasifier desirable. Such a device designed specifically for retrofilling is shown in Figure 5.

Production experience has shown thatdirt removal can easily be achieved by a variety of filter techniques including filter press, filter paper, and cartridge-type filters.

Standard paper-type filters and fullers earth which have been well dried can be used to remove water from silicone transformer liquid. Most drying techniques commonly used by field service people on transformer oil and askarel will work. However, it should be noted that silicone transformer liquid will pass through a filter at a slower rate because of its higher viscosity. The filter must also be properly dried, since silicone has the ability to pick up water from filter paper and fullers earth. Additional comments will be found under the heading Water. The best method of drying the silicone transformer liquid is vacuum degasification, which dries it and also removes the dissolved gases.



Fig. 5. Vacuum Degasifier

In one test two samples of silicone transformer liquid containing 35 and 90 ppm water were mixed and passed through a Keene Bowser vacuum degasifier at approximately 10 GPM with a sustained vacuum of 1 mm Hg. The temperature of the liquid was 100°F for this processing. Water contents dropped to 11-15 ppm.

In a second test a Keene of Canada vacuum degasifier was used for processing silicone transformer liquids ranging in water levels from 40 to 70 ppm. Passage through the unit at 5 GPM at 90°F with a sustained vacuum of 2 mm Hg. gave water contents below 20 ppm, with most samples approaching 10 ppm.

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Repeat Breakdown

Silicone transformer liquid has poor repeat breakdown strength when tested in the standard ASTM test cells with bare electrodes.[1*] When tested in an ASTM D-877 test cup, silicone transformer liquid will generally have half or less of the initial test value on all repeat breakdowns. Mineral oil or askarels do not show this degradation in performance when tested as a liquid alone. The reason for this poor repeat strength of silicone liquid is that solid particles ---silica, carbon, and silicon carbide do not escape from the electrode area. These degradation products are retained in the immediate vicinity of the electrodes by a polymer sheath formed by the gelation of the liquid by the arc. This poor self-healing characteristic was evaluated in configurations similar to those found in a transformer which has conductors separated with kraft paper.

The repeat breakdown strength of these three fluids can be considerably different when impregnated into kraft paper. To test the repeat strength, the ball-to-plane test cell shown in Figure 3 was used. The paper was initially penetrated with a 40 KV discharge from an impulse generator. This was well above the breakdown strength of the kraft paper impregnated with any of the three fluids. The repeat strength was then tested by stressing the cell with 60 Hz potential raised at the rate of 3 KV/second. The average of eighteen shots with silicone fluid was 942 volts per mil. For three of the tests the repeat strength was zero. Mineral oil had an average repeat strength of 277 volts per mil for twenty tests. For ten of the twenty tests the repeat strength was zero. When the same test was run with askarel, the result was nineteen "zero's".

Solvent Flushing

As part of a retrofill a solvent flush is used to further reduce the amount of PCB left in the transformer. It is not unreasonable to expect a retrofilled transformer to last 20(+) years. As such it is important that residual solvent left in the unit not cause any long-term compatibility problems. Trichlorobenzene was chosen because it is a component of many of the askarel formulations that have been used. This means the insulation systems have been specifically designed to be compatible with this solvent. Both industrial and dielectric grades of trichlorobenzene have been used for retrofilling. The electrical grade has the advantage of being supplied to a low water level and dielectric strength specification. In addition, it is usually an isomer mix (25% 1,2,3) (75% 1,2,4) with a low (0-5°C) freeze point. The industrial grades (usually 100% 1,2,4) can be cleaned easily to meet water and dielectric specifications of the electrical grade. They freeze at a higher temperature (17°C) thus creating handling problems. Another advantage of using trichlorobenzene is its flammability characteristics do not adversely affect fire point when mixed with silicone. The flash point is reduced to the level of a typical askarel.

TABLE IX
Fire Properties of Silicone Transformer Liquid with Trichlorobenzene in it

Liquid	Flash Point,°F	Fire Point,°F
silicone transformer liquid	550	650
silicone transformer liquid + 2% TCB	390	665

Trichlorobenzene is currently under some environmental pressure. If it becomes difficult to purchase, distillation can be used to clean up the flush solvent. TCB can also be distilled from TCB-containing askarels removed from transformers. This approach would reduce the total amount of askarel to be disposed of, and it would furnish a ready source of TCB for further retrofill use. This double economic incentive can be a strong consideration.

Successful retrofilling using flush solvents other than TCB have been done and can be considered if alternatives are needed or desired.

Data on units retrofilled to date indicate flush techniques are very important. Flushing for extended time periods (e.g., 1 hour), using multiple flushes of clean solvent, flushing radiators as well as the tanks, and making every effort to remove all askarel and flush solvent from low spots (e.g., areas below the drain port) all help to reduce the PCB level. Flushes using these techniques usually result in a transformer with less than 1% PCB in the silicone immediately after the retrofill. The PCB level will then increase for a period of time. This increase is probably due to PCB leaching out of the wood, paper, etc. in the insulation system. Data from a typical retrofill illustrates this leaching.

TABLE X
PCB in a Field-Retrofilled Transformer

Time	% PCB in the Silicone Transformer Liquid
Day of Retrofill	.34
5 days	.63
11 days	.65
6.5 months	1.02
1 year	.92

It appears to have leveled off after a year of operation.

In shop jobs where the core and coil are removed and thoroughly cleaned, lower PCB levels are seen. PCB levels increase with time, as shown in Table XI.

TABLE XI
PCB in a Shop-Retrofilled Transformer

Time	% PCB
Day of Retrofill	No data
3 months*	.13%
1 year	.31%

*This unit was not put in service till 3 months after retrofill.

Sufficient data do not yet exist to allow exact predictions of the PCB level in a retrofilled transformer, but experience to date indicates that less than 2% is realistic.

Water

Water saturation levels and data on dielectric strength versus ppm water indicated that silicone transformer liquid can contain far more water than askarel or transformer oil and still pass dielectric strength breakdown tests commonly used in periodic maintenance sampling and testing of transformers (see Figure 6).

This can be considered an advantage of silicone, but it has raised a concern that water will end up in the cellulose and cause a reduction in its dielectric strength. Silicone transformer liquid/water/paper equilibrium data are not yet available, but a number of experiences indicate that silicone transformer liquid will actually draw water out of cellulose and hold that water in solution.

In a particular study silicone transformer liquid went from 22 ppm water to 74 ppm water after passing through a paper filter cartridge which was brand new

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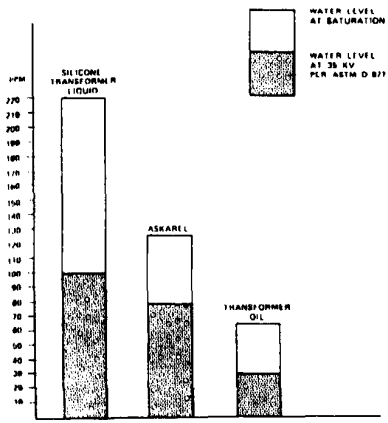

Fig. 6. Water in Dielectric Liquids

but had not been properly oven dried. This ability to draw water out of cellulose material is often seen when transformers are initially filled. In the manufacture of four new transformers, silicone transformer liquid which was processed down to 12 ppm was up to 30 ppm a short time after the units were filled, indicating that water in the core and coil were being drawn out by the silicone. We understand this technique of drying the core and coil was used by one Japanese transformer manufacturer to dry units before filling with transformer oil or askarel. This rapid water level increase has often been mistakenly thought to be pickup of water from the air by the silicone liquid.

To determine how much moisture silicone transformer liquid picks up from the air, data on relative humidity versus water in dielectric liquid at equilibrium was collected. These data are summarized in Table XII. The data were gathered at 25°C from 200 ml of liquid in a 250 ml beaker under static conditions. The starting level was 10 ppm.

TABLE XII
Water Pickup from the Air
For Silicone Transformer Liquid

Relative Humidity	Equilibrium Water Level in Silicone Transformer Liquid	Time to Reach Equilibrium
20	50 ppm	20 hours
54	100 ppm	30 hours
75	170 ppm	50 hours

The data show that the water pickup was not rapid and also indicated that at relative humidities as high as 54%, exposed silicone transformer liquid will retain acceptable dielectric strength values (54% = 100 ppm = 35 KV on ASTM D-877 from Table XII and Fig. 6). These data are corroborated by the fact a "topless" transformer tank has been exposed to relative humidity in the 40-55% range for 5(+) years with a water pickup below what would be predicted by Table XII.

Techniques for determining water content in silicone transformer liquids are in the literature.[15]

The First Retrofill

After reviewing these and other data the first retrofill was done on a 500 KVA Westinghouse Power Center transformer in July of 1972. The unit was drained, flushed once with industrial grade trichlorobenzene, and filled with Dow Corning® 200 dielectric grade fluid, 50 centistokes. This unit is on a double-ended substation. It is constantly energized and loaded to approximately 80% load 50% of the time. This transformer will complete five years of normal performance in July of 1977. The only unanticipated problem was that the float on the level guage was too dense to float in silicone. This was remedied by replacing it with one made of cork. Data collected on that unit are shown in Table XIII.

TABLE XIII
Data From the First Retrofilled Transformer

Sample Date: Service Time:	1972 Orig.	1973 1 year 5 mos.	1974 2 years 1 month	1975 3 years 1 month	1976 4 years
Type of Test					
Visual	Clear	Clear	Clear	Clear	Clear
Dielectric Strength, v/mil	375	371		427	353
PPM/H_2O				23	79
Viscosity, Cs.	50	40	42	42	38.5
% PCB		3.32	3.09	3.27	3.58
% Solvent				~3	3.0
Others					
Dielectric Constant @ 23°C	2.70	2.81	2.82	2.82	
Dissipation Factor @ 23°C	.00004	.00003	.000018	.000018	
Vol. Resistivity, ohm/cm @ 23°C	$4.1x10^{15}$	$2.5x10^{15}$	$1x10^{15}$	$2.9x10^{15}$	

Mineral Oil-to-Silicone Transformer Liquid Retrofilling

The idea of upgrading the fire safety of transformer oil transformers by retrofilling with a less flammable liquid is not new. A Westinghouse data sheet dating back to 1956 describes this procedure.[16] Residual transformer oil reduces the fire safety characteristics of the replacement liquid. This is shown in Table XIV.

These data indicate little effect on the fire point at the 2% level; however, it is not known how this mixture will perform when tested under the conditions of Underwriters Laboratory flammability classification program, the new FM test program to list acceptable askarel replacements, the proposed 1978 NEC article 450-23, or other fire safety classification schemes. Laboratory data and field experience indicate these

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TABLE XIV
The Effect of Transformer Oil on the Flash Point And Fire Point of Silicone Transformer Liquid

Weight % Transformer Oil	Flash Point °F	Fire Point °F
0	550	650
0.5	500	640
1.0	450	650
2.0	420	640
3.0	370	590
4.0	360	500

units are dielectrically sound, but more studies are needed to develop the retrofilling techniques and to better assess the true fire hazard situation. Data on two transformer oil-to-silicone retrofills are shown in Table XV.

TABLE XV
Transformer Oil-to-Silicone Transformer Liquid Retrofill

KVA	% Hydro-Carbon	Flash Point	Fire Point	Flush Liquid
750	1.3	515°F	600°F	Kerosene (Vapor Phase)
2000	1.3	470-500°F	645-650°F	80°C Silicone Transformer Liquid

Note: The hydrocarbon values given are immediately after the retrofill. It is not known to what extent this level will increase with operating time.

Why Retrofill?

Across the board retrofilling of all askarel-containing devices is not justified. However, there are many special cases where it would be practical and desirable.

Askarel transformers which require dielectric liquid replacement as a part of a repair job will have to be either discarded due to the unavailability of replacement askarel or refilled with silicone. This type of retrofill to silicone transformer liquid means the owner can continue to utilize existing equipment, avoid the costly expense of disposing of the old unit, and the cost of its replacement.

Some askarel transformers currently in service create special environmental hazards. Examples of these would be units setting on docks, over waterways and units installed close to drains, ditches or streams. In these situations an askarel-to- silicone retrofill will reduce the long-term environmental risk.

The similar idea of reducing environmental risk by going from askarel to transformer oil was recently described as follows in the General Electric magazine, POWER SYSTEMS.[11]

> "Substitution of oil for askarels, when the latter are no longer required, is simple, and reduces environmental risks. Units must retain their askarel nameplates because of PCB residue, but their dilution definitely lessens environmental risks. The disciplines involved in proper handling and disposal of askarels and askarel-contaminated materials are familiar to ASBD Shops."

(ASBD is G.E.'s Apparatus Service Business Division.)

Retrofill Procedures and Safe Handling

Another paper being presented at this meeting will cover these topics.[12]

Acknowledgment

The authors wish to recognize the contributions of Tor Orbeck, Gary Vincent, Dick Miller, Ray Price, Bill Brooks, Dick Burow, Dennis Klein, Tom Rice, Frank Robison, Janet Campbell, Jim Paxton, and Joan Beagle all of Dow Corning.

References

1. C. G. Currin, J. F. Dexter, "Dielectric Properties of Silicone Fluids," presented before the 1956 Insulation Conference of the National Research Council: New York, October 9, 1956.
2. R. F. Burow, G. A. Vincent, "Silicone Fluids vs. Hydrocarbon Oils: A Comparison of Thermal and Electrical Performance Capabilities," presented at 1974 Winter Meeting IEEE Power Engineering Society: Paper No. C 74 258-0.
3. R. F. Burow, T. Orbeck, "Performance Capabilities of Silicone Fluids as Insulating Liquids for High-Voltage Transformers," presented at the 1974 Doble Engineering Client Conference.
4. R. F. Burow, T. Orbeck, "Silicone Fluid Filled Transformers - An Alternative to Askarel and Dry-Type Transformers?", presented at the 1973 Doble Engineering Client Conference.
5. G. A. Vincent, F. W. G. Fearon, T. Orbeck, "The Behavior of Silicone Fluids and other Insulating Oils Under a Sustained Arc," presented at Conference on Electrical Insulation and Dielectric Phenomena, Montreal, Quebec, October 29-31, 1973.
6. G. Vincent, "The Effects of Water and Silanol on the Electrical Properties of Silicone Fluid," presented at Conference on Electrical Insulation and Dielectric Phenomena, Downington, Pennsylvania, October 21, 23, 1974.
7. G. A. Vincent, F. W. G. Fearon, T. Orbeck, "Structure Property Relationship in Silicone Fluid Dielectrics," 1972 Annual Report Conference on Electrical Insulation and Dielectric Phenomena, pp. 17-22.
8. R. F. Burow, G. A. Vincent, W. T. Brooks, "Methods for Evaluating New Dielectric Liquids For Use in High Voltage Electrical Equipment," presented at 11th Electrical/Electronics Insulation Conference, Palmer House, Chicago, Illinois, September 30 - October 4, 1973.
9. V. K. Rowe, H. C. Spencer, S. L. Bass, "Toxicological Studies on Certain Commercial Silicones," Journal of Industrial Hygiene and Toxicology, Volume 30, No. 6, pp. 332-352, November 1948.
10. "Retrofilling with Dow Corning® 561 Silicone Transformer Liquid," an information booklet from Dow Corning Corporation, January 17, 1977.
11. Leon A. Sigel, "Coolant Selection For Electronic Systems, Part 2," Electronic Packaging and Production, February, 1965, pp. 105-107.
12. W. T. Brooks, T. Orbeck, "Study of Dielectric Breakdown of Kraft and Aramid Papers Impregnated With Silicone Liquids," Paper E-8 presented at 1976 IEEE International Symposium on Electrical Insulation, Montreal, Canada.
13. L. A. Morgan, R. C. Osthoff, "Problems Associated with the Retrofilling of Askarel Transformers," IEEE Paper A 77120-9.
14. C. Hosticka, "Insulating Characteristics of Dimethyl Silicone in Bare and Insulated Uniform Field Gaps," presented at IEEE PES Winter Meeting, New York, New York, January 30 - February 4, 1977.
15. W. A. Fessler, C. Hosticka, T. O. Rouse, "Determination of Water in Dimethyl Silicone

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(Polydimethylsiloxane)," presented at IEEE PES Winter Meeting, New York, New York, January 30 - February 4, 1977.
16. W. W. Satterlee, "Preparation of Oil-Immersed Transformers To Use Inerteen and Preparation of Inerteen-Immersed Transformers To Use Wemco "C" Oil," Westinghouse Transformer Engineering Data Form No. 1501, June, 1969, supersedes E. D. L. #1236-C, dated August 1, 1956.
17. "Transformer Repair Keeps Pace With Technology," General Electric magazine, INDUSTRIAL POWER SYSTEMS, June, 1976, pp. 20, 21, 22, 23.
18. T. O'Neal, J. Kelley, "Silicone Retrofill of Askarel Transformers," Technical Paper 1977 EEI Conference.

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GUIDELINES FOR RETROFILLING ASKAREL TRANSFORMERS

Retrofilling askarel transformers has been studied by various organizations, including transformer manufacturers, service companies, and liquid suppliers. While some have met with apparent success, retrofilling is not universally recommended by everyone.

Before proceeding with a retrofill, it would be prudent to thoroughly discuss this subject with the manufacturer of the unit in question; with the service personnel that perform maintenance on the unit; and with representatives of the substitute liquid supplier.

ADVANCE PLANNING

1. Insurance company approval.

2. Electrical Inspector and OSHA approval.

3. Get name plate made up.

4. Check with the manufacturer of the transformer.

   Information that he may be able to give you that may be of value would include:

   - Types of seals (for compatibility purposes).

   - Pressure/vacuum capability of tank (often on label).

   - Heat transfer information (See Derating Section).

   - Other information the manufacturer feels may be relevant.

5. Check unit for other servicing to be done at the time of the retrofill. Check all areas including valves, bushings, gauges, welds, sample ports, manhole covers, pipe fittings, etc. for leaks. Check to see all gauges are working. Experienced service companies recommend that the unit be regasketed at the time of retrofill.

   Determine if you will need a pressure/vacuum regulator and dehydrating breather. Order all necessary materials.

6. Plan electricity rerouting so unit can be taken out of service. Also, you will need power at the retrofill site.

7. Purchase replacement liquid. Inspect to be sure it meets specifications.

8. Tour area and inspect for sewer drains in immediate area of the retrofill. Cover and plug drains and install other retention measures before the retrofill.

9. Arrange details on who is responsible for handling storage and disposal of askarel, askarel-contaminated flush, and askarel-contaminated rags, etc.

10. Coordinate activities with the safety, security, insurance, waste control, environmental and other involved departments in the company who owns the transformer.

11. Visit the work site before the date of the job to identify potential hazards or problems.

A TYPICAL STEP BY STEP PROCEDURE USED ON THE DAY OF A RETROFILL

1. A premeeting to coordinate the activities of the various work groups who will be involved in completing the retrofill. Safety and a detailed spill control and spill handling plan should be reviewed at this time.

2. Safety tour of facilities (eye wash-shower-emergency phone-fire equipment-waste receptacles, etc.).

3. Distribute safety and spill control equipment and check to see that all sewer drains are plugged and covered.

4. De-energize and ground out the transformer.

5. Position materials and equipment.

6. Electrically ground all liquid handling equipment.

7. Set barricades (to control people, road vehicles, etc.).

8. Position spill control devices (plastic sheets, pans, absorbing materials, rags, waste receptacles, etc.).

9. Sample and test askarel.

10. Run electric tests on transformer.

11. If testing is okay, proceed.

12. Install hoses (avoid creating a trip hazard, and secure with ropes. Check all connections).

13. Hook up dry air or nitrogen source (dehydrating breather or cylinders).

14. Drain transformer into approved containers; bleed dry air or nitrogen into the transformer as the askarel goes out.

15. Remove askarel from the bottom. In many transformers the drain port is not on the very bottom of the tank. Use a dip tube through the top or a flexible device through the drain port to remove that last 1"-2" of material.

16. Remove the top manhole cover. This will need to be done before completing 15 if you use a dip tube. Tie off all tools and empty your pockets before going on top of a unit with an open manhole cover.

17. Visually inspect inside of unit. Check for shifting, damage, loose or lost bolts, etc. Correct problems.

    NOTE: Do not leave cover open any longer than is necessary. This will minimize entrance of moist air and dirt. A see-through (glass or plastic) cover can be put over the hole to prevent contaminating the inside.

18. Repair leaks - Replace gasket materials, tighten compression seals, pressure test, and perform other maintenance items at this time.

19. Flush the tranformer.

    Breathing apparatus recommended:

    The objective of the flush is to remove as much askarel as possible and thus reduce the amount of PCB left in the transformer.

    Electrical grade trichlorobenzene is technically satisfactory. It is a component of many of the various askarels and compatible with the insulation systems used in askarel transformers. Because of a toxicity controversy on chlorinated solvents, availability problems, and because working with most solvents requires special precautions, you may want to use some other flushing liquid. However, if you choose another liquid or solvent, it must be compatible with the materials in the transformer. The transformer manufacturer, your service company or the substitute liquid supplier may have specific recommendations.

    Flushing can be accomplished by two methods; a complete fill with long-term circulation and soak; or by a series of small quantity flushes over a brief period of time.

In the small quantity flush, an amount of solvent equal to 20% of the capacity of the unit is set aside for flushing. After the transformer has been completely drained, including the residual at the bottom below the drain valve, one third of the flush is pumped in. The unit is then piped up to circulate the flush out the bottom drain port through a pump into the top manhole cover. A spray nozzle is used by a technician to direct the stream around the inside, washing down the core, coil, side walls and other askarel coated components. In most units it is possible to direct the stream of flush into the top radiator manifold holes and thus also flush out the inside of the radiators.

It is not advisable to direct a solid high pressure stream onto the paper and pressboard portions of the insulation system as you may physically degrade them. Use of an adjustable spray nozzle will allow the technician to change from a solid stream to a spray pattern.

The length of time for each flush should be left to the discretion of the technician, but it is generally carried out for a minimum of 15 minutes. The flush is drained, including the residual on the bottom, and the next flush is carried out.

The main keys to a low residual PCB level are adequate flushing with clean flush, doing a good job of washing down all parts of the unit, and removing the residual from the bottom each time.

20. Be sure to remove the flush liquid below the level of the drain port before proceeding. (As in 15 above).

If a large number of units are going to be retrofilled, additional savings on flushing may be realized by recovering the flush for future use. This would require removing the PCB contamination from the flush liquid.

NOTE: The next steps involve putting the replacement liquid into the transformer.

21. Hook up the processing equipment in a closed loop.

22. Sample liquid after processing and test dielectric strength, water content, and percent dissolved air to be certain the processing equipment is working.

23. Fill the transformer with processed liquid and close the unit up.

NOTE: If you vacuum fill*, fill from the top. The vacuum will do the best job of deairing the liquid if its surface area is maximized during the fill. Use a deflection plate or similar device to spread the liquid out. Bottom fill under vacuum is not

very effective because of the small surface area, plus the vacuum is working against the head of the liquid being formed as the unit fills.

*Know the vacuum capability of the transformer tank before drawing a vacuum on it. Exceeding it may cause physical damage to the tank. Do not draw vacuum on a transformer any longer than necessary as this may draw moisture into the tank through any leaks that may exist.

If you fill at standard pressure, fill from the bottom. This will reduce the creation of air bubbles and entrapped air. Bottom fill can be achieved by either filling from the drain port or by running your fill hose through the top cover to the bottom of the unit.

24. Let the transformer set for a period of time (e.g. 12 hours) to permit rising air bubbles and complete impregnation.

25. Sample the replacement liquid and test for dielectric strength and ppm water.

26. Retest the transformer, per item 10.

27. If results of 25 and 26 are acceptable, energize the transformer.

28. Let unit set energized a minimum of 4 hours before loading.

29. After the unit is back in service, take a sample for testing. A sample taken several days after energizing will be more meaningful than one drawn immediately after retrofill.

It is very important to keep good records of the activities during the process.

RESIDUAL PCB LEVEL

A retrofilling process will leave a residual PCB contamination level in your unit. If this level is not satisfactory, there are several methods of removing it under investigation by various service companies and liquid suppliers. Contact them directly for their recommendations.

DERATING

Load vs. temperature data on similar transformers indicate the unit may run warmer under heavy loading with a substitute liquid.

The design of some units is such that the heat rise at 100% load will exceed the specification limits when that unit is retrofilled. Information collected to date indicates the KVA ratings of retrofilled units will range from as specified to 10% less than specified. This should be considered if you are looking into retrofilling transformers that are run around 100% of their rated capacity. It is not known if this running warmer will reduce the life time of heavily loaded units. This question is being closely studied by various interests.

If a retrofilled transformer exceeds the specification defined, top oil temperature fans can be added for additional cooling. If heavy loading is anticipated, the manufacturer of the transformer should be consulted on this topic.

The guidelines presented represent the experience of a number of interested groups. They are based on the replacement of PCB-containing askarel with a substitute liquid. While some of the procedures might be of value in retrofilling from askarel to oil or from oil to a substitute liquid, little or no experience has been reported in this area.

Therefore, we do not recommend the use of these procedures for anything but their intended purpose.

Loss Prevention Data

October 1979

LESS FLAMMABLE TRANSFORMER FLUIDS

SCOPE

This supplement includes installation and protection guidelines for transformers containing insulating fluids which are less flammable than typical transformer oil. These new fluids have fire points of 300°C (572°F) or greater and other characteristics which permit different installation conditions from those outlined in Data Sheet 5-4/14-8 for Askarel and oil-filled transformers.

GENERAL DESCRIPTION

Askarel insulating fluids have been used in indoor transformer installations for many years without special fire protection requirements for the transformer. However, production of Askarel, which contains polychlorinated biphenyls (PCB's), has been discontinued in the United States for environmental reasons. As a result, several manufacturers have been working on the development of replacement fluids with suitable electrical and flammability characteristics. To date, none of the new fluids which have been developed match the performance of Askarel.

Several new fluids have higher fire points and lower heat release rates than ordinary transformer oil. Transformers containing fluid having a fire point of at least 300°C (572°F) for which the convective and radiative heat release rates are also known may be installed as outlined in this supplement.

When determining the ability of a building to withstand an interior fire, there are two factors that must be considered. The convective heat release rate of the fire is that which effects the exposure to the roof's structural members. The radiative heat release rate is that which effects the exposure to nearby exterior walls.

In some cases, the convective and radiative heat release rates of a less flammable transformer fluid fire are low enough to eliminate the possibility of structural damage.

Convective Heat Release (Exposure to Roof)

A steel-frame building roof should be able to withstand a maximum temperature of 750°F (399°C) without major structural damage. The maximum permissible convective heat release rates per unit curbed area shown in Figure 1 were thus obtained for various building heights and pool fire sizes which would limit the structural steel temperatures to this point. Likewise, the maximum permissible convective heat release rates per unit curbed area for exposure to reinforced concrete construction are shown in Figure 2. Convective heat release rates shown are for a minimum 2-hour fire resistance (proposed NFPA Type I Construction) using a temperature of 1000°F (538°C).

Figures 1 and 2 should be used to determine the maximum allowable convective heat release rates per unit curbed area for pool fires having the surface areas shown. In order to provide a factor of safety the entire curbed area, including the area occupied by the transformer, has been considered as burning surface in each case. Interpolation between the curves previously shown may be used for surface areas other than those included in the figures.

Radiative Heat Release (Exposure to Walls)

To determine the maximum permissible radiative heat release rate per unit curbed area for steel panel on steel-frame walls, Figure 3 should be used. Figure 3 applies to indoor installations as well as outdoor. Again, interpolation may be used where the areas do not correspond to those shown in the figure. Buildings constructed with wood walls should be protected in accordance with Table 1. Those constructed with masonry walls need not be evaluated if the exposure to the roof has been determined to be acceptable. In all cases, however, means should be provided to prevent direct flame impingement on the wall. This can be accomplished by allowing a minimum clearance of 5 ft (1.5 m) between the inside edge of the containment area and the building wall.

INDOOR TRANSFORMER INSTALLATIONS

Transformers that contain less flammable insulating fluids and are installed in buildings of combustible construction and/or buildings having a combustible occupancy should have physical protection provided in accordance with Table 1 and electrical protection provided in accordance with Table 2.

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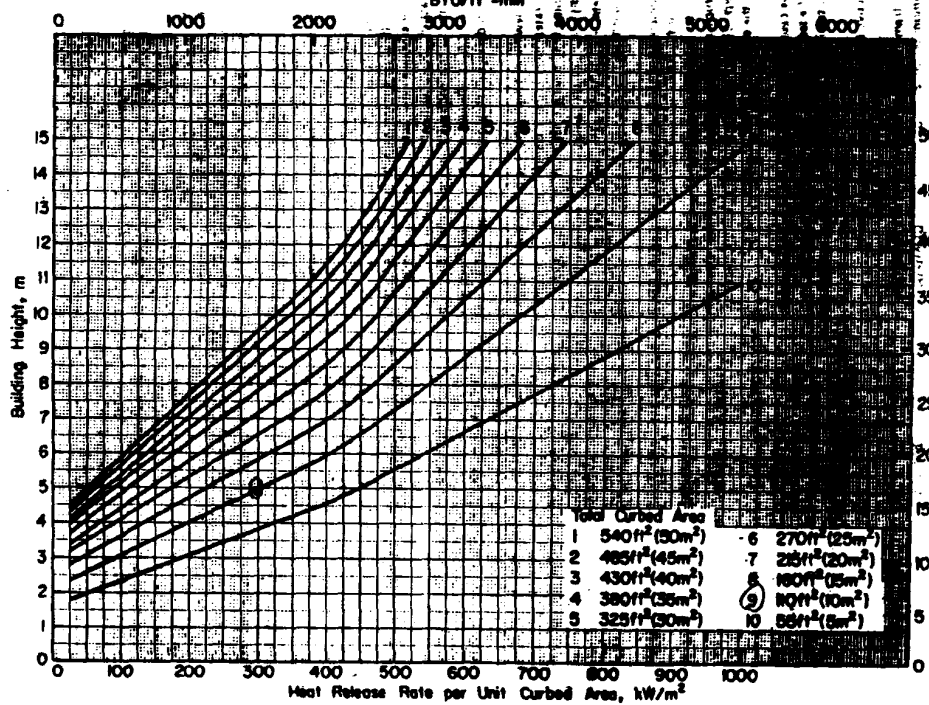
BTU/m²-min
0
1000
2000
3000
4000
5000
6000
Building Height, m
Building Height, ft
Heat Release Rate per Unit Curbed Area, kW/m²
0
100
200
300
400
500
600
700
800
900
1000
Total Curbed Area
1 540ft² (50m²)
2 485ft² (45m²)
3 430ft² (40m²)
4 380ft² (35m²)
5 325ft² (30m²)
6 270ft² (25m²)
7 215ft² (20m²)
8 160ft² (15m²)
9 110ft² (10m²)
10 55ft² (5m²)

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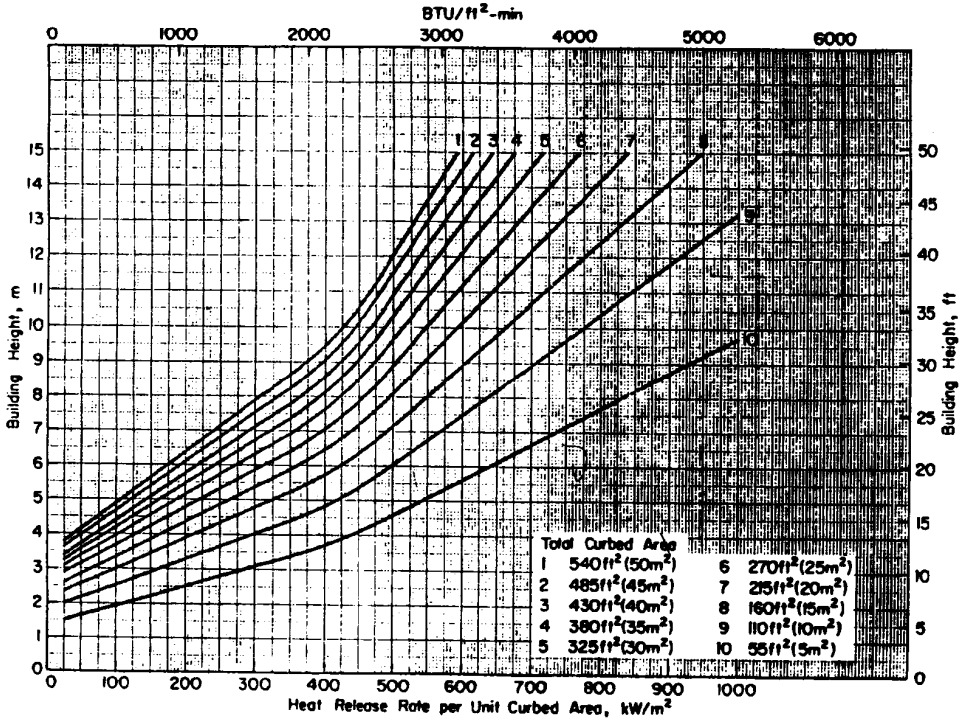
BTU/ft²-min
0
1000
2000
3000
4000
5000
6000
Building Height, m
Building Height, ft
Heat Release Rate per Unit Curbed Area, kW/m²
0
100
200
300
400
500
600
700
800
900
1000
1
2
3
4
5
6
7
8
9
10
Total Curbed Area
1 540ft²(50m²)
2 485ft²(45m²)
3 430ft²(40m²)
4 380ft²(35m²)
5 325ft²(30m²)
6 270ft²(25m²)
7 215ft²(20m²)
8 160ft²(15m²)
9 110ft²(10m²)
10 55ft²(5m²)

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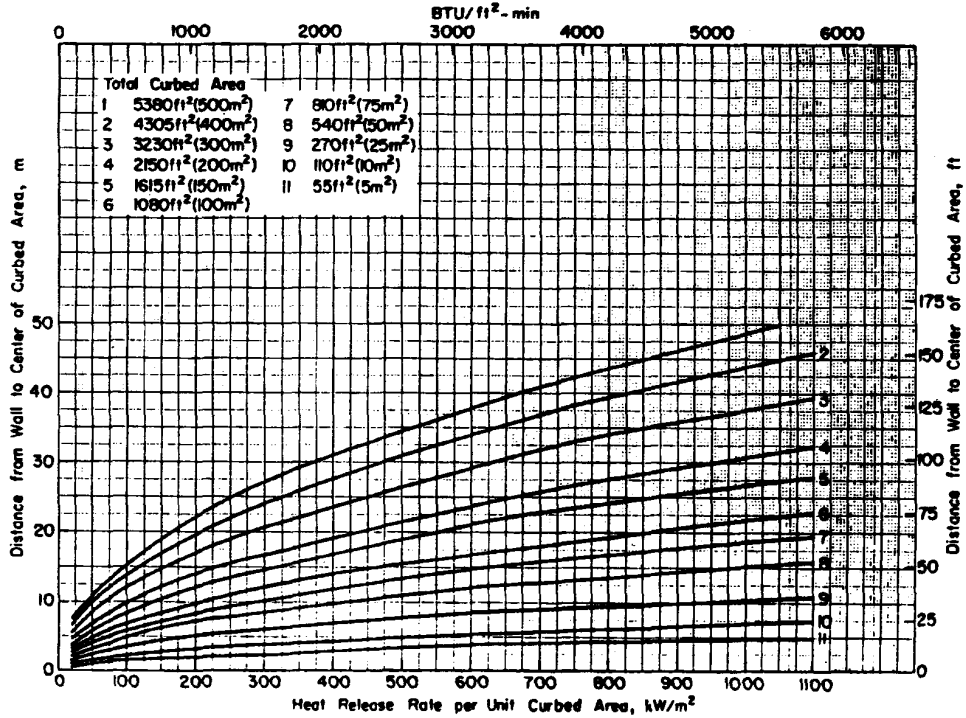

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Method to Calculate Convective and Radiative Heat Release

Transformers installed in noncombustible or fire resistive buildings having noncombustible occupancies should be evaluated as follows. Curbs should be provided around the transformer, with drains to a safe location whenever practical. The distance from the transformer tank to the inside of the curb should be at least one-half the transformer overall dimension, as shown in Figure 4. Curbs should be constructed of noncombustible materials and be of sufficient height to hold the entire fluid content of the tank.

In addition, use the convective heat release rate per unit curbed area for the fluid in the transformer and the following steps to determine whether more protection is needed. (See Example 1.)

1. Determine the minimum curbed area needed in accordance with Figure 4.

2. Using the curbed area computed and the building height and construction in question, find the maximum allowable convective heat release rate per unit curbed area (Btu/ft^2-min) (kW/m^2) in Figure 1 or 2.

3. If the convective heat release rate per unit curbed area (Btu/ft^2-min) (kW/m^2) of the fluid to be used does not exceed that shown in Figure 1 or 2, go on to steps 5, 6, and 7 to evaluate the radiative heat release rate (Example 2). Buildings with masonry walls and no exposed steel need not be evaluated for radiative heat release if the exposure to the roof is acceptable.

4. If the convective heat release rate per unit curbed area of the fluid to be used is greater than that permitted in Figure 1 or 2, provide protection in accordance with Table 1. In these cases the alternatives to curbing, shown in Table 1, may be used.

5. Using the curbed area computed to evaluate the convective heat release rate, the wall construction, and the distance from the center of the curbed area to the wall, find the maximum allowable radiative heat release rate per unit curbed area (Btu/ft^2-min) (kW/m^2) in Figure 3.

6. If the radiative heat release rate per unit curbed area (Btu/ft^2-min) (kW/m^2) of the fluid to be used is less than that shown in Figure 3, no further protection is needed.

7. If the radiative heat release rate per unit curbed area is greater than that permitted in Figure 3, provide protection in accordance with Table 1. In these cases the alternatives to curbing, shown in Table 1, may be used.

Example 1. Convective Heat Release Rate

A transformer to be filled with a less hazardous insulating fluid, having overall dimensions of 5½ ft by 5½ ft, is to be installed in a 20-ft high building. The building is constructed of a Class I insulated steel deck roof on steel frame with steel panel on steel frame walls. The occupancy is to be noncombustible. What is the maximum permissible convective heat release rate per unit curbed area of the transformer fluid that may be used?

Referring to Figure 4, we can compute the total curbed surface area which will be needed as 2A x 2B, or in this case 10½ ft by 10½ ft or 110 sq ft.

Referring to Figure 1, for steel-frame roofs, draw a horizontal line at the 20 ft point on the vertical scale labeled Building Height. Extend the line to intersect the 110 sq ft curve for Total Curbed Area. At the point of intersection, extend a vertical line to the horizontal scale labeled Heat Release Rate per Unit Curbed Area. In this case the maximum allowable convective heat release rate per unit curbed area which may be used is 2160 Btu/ft^2-min.

If the convective heat release rate per unit curbed area exceeds this level, then additional protection is needed in accordance with Table 1.

Example 2. Radiative Heat Release Rate

For the case described in Example 1, what is the maximum permissible radiative heat release rate per unit curbed area of the fluid that may be used if the center of the curbed area is to be located 15 ft from the building wall?

Referring to Figure 3, draw a horizontal line at the 15 ft point on the vertical scale labeled Distance from Wall to Center of Curbed Area. Extend the line to intersect the 110 sq ft curve for Total Curbed Area. At the point of intersection, extend a vertical line to the horizontal scale labeled Heat Release Rate per Unit Curbed Area. In this case, the maximum allowable radiative heat release rate per unit curbed area is 2500 Btu/ft^2-min. If the radiative heat release rate per unit curbed area exceeds this level, then additional protection is needed in accordance with Table 1.

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Physical

Protection Variables		Combustible Building Combustible Occupancy				Combustible Building Noncombustible Occupancy				Noncombustible Building Combustible Occupancy			
		Transformer Size, kVA[2]				Transformer Size, kVA[2]				Transformer Size, kVA[2]			
		≤10	>10 ≤10,000	>10,000 ≤50,000	>50,000	≤10	>10 ≤10,000	>10,000 ≤50,000	>50,000	≤75	>75 ≤250	>250 ≤10,000	>10,000 ≤50,000	>50,000
Separation	Distance (Transformers to Occupancy)	①	① ≥25 ft (7.6m)	① ≥25 ft (7.6m)	① ≥25 ft (7.6m)		① ≥10 ft (3m)	① ≥10 ft (3m)	① ≥10 ft (3m)		① ≥10 ft (3m)	① ≥25 ft (7.6m)	① ≥25 ft (7.6m)	① ≥25 ft (7.6m)
	Curbs and Drains		①	①	①		①	①	①		①	①	①	①
	1 Hour Vault		②	②	②		②	②	②					②
	Barriers		③	③	③			③	③		③	③	③	③
Fire Protection	Automatic Sprinklers or Water Spray	①	① ② ③	① ② ③	① ② ③	①	① ②	① ②	① ②	①	① ② ③	① ② ③	① ② ③	① ② ③
	Halon 1301 or CO_2				④				④					④

Table 1. Recommended Physical Protection For Transformers Filled With Less Flammable Fluids.[1]

[1] Different alternatives in each size column are designated by different circled numbers. The combination of all the same circled numbers in each transformer size column represent an alternative. The combination of all the different circled numbers represent another alternative, and so on.

[2] Transformer sizes are for single units or combined size of multiple units in same area. Units ≤ 50,000 kVA separated by less than 10 ft (3 m) or those > 50,000 kVA separated by less than 25 ft (7.6 m) are considered in the same area.

Electrical

Protection Variables	Combustible Building Combustible Occupancy				Combustible Building Noncombustible Occupancy				Noncombustible Building Combustible Occupancy			
	Transformer Size, kVA[2]				Transformer Size, kVA[2]				Transformer Size, kVA[2]			
	≤10	>10 ≤10,000	>10,000 ≤50,000	>50,000	≤10	>10 ≤10,000	>10,000 ≤50,000	>50,000	≤75	>75 ≤250	>250 ≤10,000	>10,000 ≤50,000	>50,000
Differential Relaying			① ② ③	① ② ③			① ② ③	① ② ③				① ② ③	① ② ③
Overcurrent	①	① ② ③	① ② ③	① ② ③	①	① ② ③	① ② ③	① ② ③	①	① ② ③	① ② ③	① ② ③	① ② ③
Gas Detection			① ② ③	① ② ③			① ② ③	① ② ③				① ② ③	① ② ③
Excess Temperature			① ② ③	① ② ③			① ② ③	① ② ③				① ② ③	① ② ③

Table 2. Recommended Electrical Protection For Transformers Filled With Less Flammable Fluids.[1]

[1] Different alternatives in each size column are designated by different circled numbers. The combination of all the same circled numbers in each transformer size column represent an alternative. The combination of all of a different circled numbers represent another alternative, and so on.

[2] Transformer sizes are for single units or combined size of multiple units in same area. Units ≤ 50,000 kVA separated by less than 10 ft (3 m) or those > 50,000 kVA separated by less than 25 ft (7.6 m) are considered in the same area.

Noncombustible Building Noncombustible Occupancy					Fire Resistive Building Combustible Occupancy					Fire Resistive Building Noncombustible Occupancy				
Transformer Size, kVA[2]					Transformer Size, kVA[2]					Transformer Size, kVA[2]				
≤75	>75 ≤250	>250 ≤10,000	>10,000 ≤30,000	>30,000	≤75	>75 ≤2500	>2500 ≤10,000	>10,000 ≤30,000	>30,000	≤75	>75 ≤2500	>2500 ≤10,000	>10,000 ≤30,000	>30,000
		① ≥10 ft (3m)	① ≥10 ft (3m)	① ≥10 ft (3m)		① ≥10 ft (3m)	① ≥25 ft (7.6m)	① ≥25 ft (7.6m)	① ≥25 ft (7.6m)			① ≥10 ft (3m)	① ≥10 ft (3m)	① ≥10 ft (3m)
		④	②	②		②	②	②	②			②	②	②
		④	④	④					④			④	④	④
		③	③	③		③	③	③	③			③	③	③
		⑤ ⑤ ⑤	⑤ ⑤ ⑤	⑤ ⑤ ⑤	①	⑤ ⑤ ⑤	⑤ ⑤ ⑤	⑤ ⑤ ⑤	⑤ ⑤ ⑤			⑤ ⑤ ⑤	⑤ ⑤ ⑤	⑤ ⑤ ⑤
				⑥					⑥					⑥

Noncombustible Building Noncombustible Occupancy					Fire Resistive Building Combustible Occupancy					Fire Resistive Building Noncombustible Occupancy				
Transformer Size, kVA[2]					Transformer Size, kVA[2]					Transformer Size, kVA[2]				
≤75	>75 ≤250	>250 ≤10000	>10,000 ≤30,000	>30,000	≤75	>75 ≤2500	>2500 ≤10,000	>10,000 ≤30,000	>30,000	≤75	>75 ≤2500	>2500 ≤10,000	>10,000 ≤30,000	>30,000
		①	①	①				①	①				①	①
①	①	⑤ ⑤ ⑤	⑤ ⑤ ⑤	⑤ ⑤ ⑤	①	⑤ ⑤ ⑤	⑤ ⑤ ⑤	⑤ ⑤ ⑤	⑤ ⑤ ⑤	①	①	⑤ ⑤ ⑤	⑤ ⑤ ⑤	⑤ ⑤ ⑤
			⑤	⑤				⑤	⑤				⑤	⑤
			⑤	⑤				⑤	⑤				⑤	⑤

Variations of the minimum curbed area are also permitted to reduce the burning surface area. Since the total convective and radiative heat release rates are proportional to the burning surface area, these variations may be used to reduce the total convective and radiative rates allowing the use of greater quantities of fluid in a given building. To qualify as an acceptable alternative, provisions must be made to confine the initial fluid discharge to an area equivalent to the minimum curbed area shown in Figure 4. This may be accomplished by the use of barriers, curbs, and pitched floors. In all cases it is best to drain the confinement area to a safe location whenever practical. Some of the possible alternatives are shown in Figure 5.

TRANSFORMER PHYSICAL PROTECTION (TABLE 1)

If it has been determined, using Figures 1, 2 or 3, that additional protection is needed, the recommendations in Table 1 should be followed. Table 1 covers physical fire protection recommendations for indoor transformers of all sizes that utilize less flammable insulating fluids.

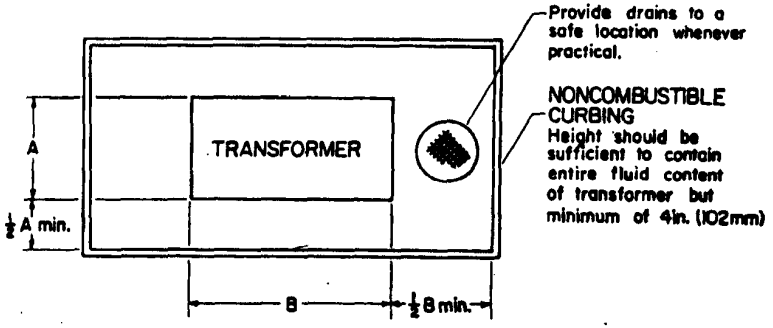

Fig. 4. Minimum curbed area (plan view).

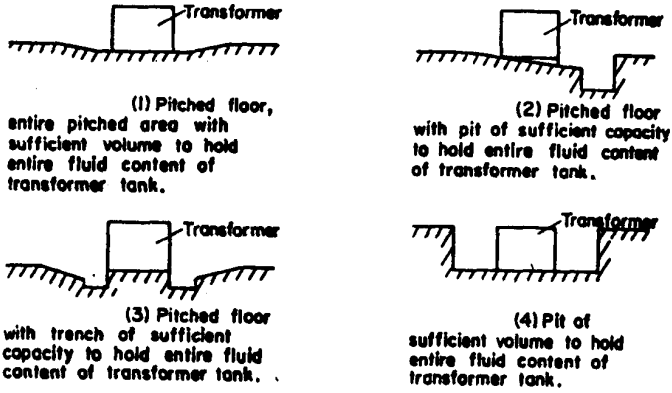

Fig. 5. Alternatives to curbing (sectional views).
Note: Pitched floors, pits, or trenches should be drained to a safe location whenever practical.

Transformer sizes are broken down into either four or five categories for each type of construction and occupancy. Sizes are given in kVA for single units or for the combined size of multiple units in one area. Transformers 50,000 kVA and less are considered to be in the same area if separated by less than 10 ft (3 m). Those larger than 50,000 kVA are in the same area if separated by less than 25 ft (7.6 m).

All protection aspects used are listed in the left hand column labeled Protection Variables. To choose the proper recommendations find the appropriate column for the building construction and occupancy desired. Then locate the transformer size column necessary. Reading down through the column pick all the variables with the same number. The combination will constitute one alternative. To choose another alternative, pick all the variables with the next number, and so on. In other words, all variables numbered 1 constitute one alternative, all those numbered 2 another, and so forth. (See Example 3.)

Separation

Distance refers to the physical separation that should be provided between the transformer and the combustible or high valued occupancy, such as automatic production machinery, rolling mills, and the like.

Curbs should be of sufficient height to hold the entire fluid content of the transformer tank but a minimum of 4 in. (102 mm) high, and constructed of noncombustible materials. Drains should be provided within the curbed area whenever possible.

Vaults should be constructed for a one-hour fire rating. Openings should be provided with automatic closing doors with fire resistance similar to that of the walls. Floor level openings should be provided with curbs or ramps arranged to prevent the spread of fluid outside the vault. Where gaseous extinguishing systems are provided within the vault, the openings should close tightly enough to maintain an adequate extinguishing concentration.

Barriers should be constructed of one-hour fire rated materials. They may be one, two, three, or four sided depending upon the arrangement of the transformer and occupancy.

Fire Protection

This category includes automatic sprinklers or water spray or automatically actuated total flooding Halon 1301 or carbon dioxide.

TRANSFORMER ELECTRICAL PROTECTION (TABLE 2)

This category includes all electrical protective devices that can be expected to minimize the intensity of an internal fault. Removing a faulted unit from service as quickly as possible will reduce the probability of a tank rupture and subsequent expulsion of fluid.

Differential relaying is extremely sensitive to all types of internal faults, acting as a supplement to other forms of overcurrent protection.

Overcurrent protection can be in the form of fuses or circuit breakers. When used in conjunction with differential relaying, it would most likely be time overcurrent relaying arranged to trip a circuit breaker.

A gas detector relay, either the cumulative gas or sudden pressure type, should be arranged to trip the unit and sound an alarm in a constantly attended location. Either type will sense an incipient fault before a tank rupture occurs.

Temperature detectors should be arranged to trip the unit when an excessively high temperature rise occurs.

Example 3.

A single 2500 kVA transformer filled with less flammable fluid is be installed in a noncombustible building housing a noncombustible occupancy. Using Figures 1, 2, or 3 it has been determined that the heat release rate of the insulating fluid exceeds that permissible in the building. What protection is needed?

Referring to Tables 1 and 2, locate the columns labeled noncombustible building, noncombustible occupancy. Then locate the appropriate size column for the 2500 kVA transformer (>250, ≤ 10,000 kVA). Looking down the column there are four alternatives, each designated by the same number adjacent to the pertinent protection variables shown in the left-hand column as follows:

Alternative 1. Automatic sprinklers or water spray, a minimum 10 ft (3 m) separation between the transformer and any occupancy which may be damaged by excessive heat, and overcurrent protection.

Alternative 2. Automatic sprinklers or water spray, curbs and drains, and overcurrent protection.

Alternative 3. Automatic sprinklers or water spray, barriers between the transformer and any occupancy which may be damaged by excessive heat, and overcurrent protection.

Alternative 4. Place the transformer in a 1-hour fire rated vault and provide overcurrent protection.

Any of these alternatives may be used for protection.

INSTALLATION OF MULTIPLE INDOOR TRANSFORMERS

Each transformer of a multiple unit installation should be provided with a separately curbed area having sufficient capacity to hold the entire fluid content of the individual unit. The curbed area should be drained to a safe location whenever practical. Transformers should be separated in accordance with the minimum clearances shown for distance between transformer and occupancy in Table 1; otherwise barriers or vaults should be provided. If the minimum clearances are provided, only the individual curbed areas for each transformer need be considered to calculate the total convective and radiative heat release rates.

When transformers are installed closer than shown in Table 1, and barriers or vaults are not provided, the combined curbed surface areas should be considered when computing total convective and radiative heat release rates in order to determine the need for additional protection. If it is determined that additional protection is needed, the alternatives to curbing, shown in Table 1, may be used.

MEZZANINE OR PLATFORM MOUNTED INDOOR TRANSFORMERS

Mezzanine or platform mounted indoor transformers should be treated similarly to units located directly on the floor. Welded steel pans should be provided beneath the transformers with minimum dimensions equal to the minimum curbed area recommended for floor mounted units. The sides of the pan should have sufficient height to hold the entire fluid content of the transformer. The pan should be drained to a safe location whenever practical. The maximum allowable convective and radiative heat release rates per unit curbed area are then based upon the distance from the pan to the roof.

ROOF-MOUNTED TRANSFORMERS

Roof-mounted transformers should be installed within welded steel pans or curbed concrete mats having dimensions equal to the minimum curbed area recommended for indoor installations. The sides of the pan or curbs should be of sufficient height to contain the entire fluid content of the transformer. Whenever practical the pan or curbed area should be drained to a safe location. Spacing of multiple roof-mounted transformers should be in accordance with recommendations for indoor transformers.

Transformers which expose taller buildings of combustible construction or of noncombustible construction with unprotected openings should be installed in accordance with distance separation recommendations shown in Table 1.

OUTDOOR TRANSFORMER INSTALLATIONS

Less flammable transformer fluids may be used for outdoor installations. In locations where transformers are isolated and present no exposure hazard to important structures, no fire protection is necessary with the exception of the usual hydrant and hose protection.

Transformers which expose important buildings or other structures should be provided with the curbing and crushed stone, or drained basin, normally recommended for outdoor oil-filled transformers. Figure 3 or 6 should be used to determine the need for additional exposure protection. These figures give the maximum allowable radiative heat release rates per unit curbed area for various size pool fires, depending upon the type of wall construction (wood or steel) and the distance between the center of the pool and the wall. Where curbed areas do not correspond to sizes shown in the figures, interpolation between curves may be used. However, means should be provided to prevent direct flame impingement on the wall. This can be accomplished by allowing a minimum clearance of 5 ft (1.5 m) between the inside edge of the containment area and the building wall.

Masonry walls require no exposure protection unless unprotected openings or windows are present. In these cases the openings should be protected in accordance with exposure protection recommendations for outdoor oil-filled transformers given in Data Sheet 5-4/14-8.

The following steps should be followed to determine if additional exposure protection is needed: (See Example 4.)

1. Determine the size of the curbed area or basin.

2. Using the surface area and the distance from the center of the pool to the building wall, find the maximum allowable radiative heat release rate per unit curbed area in Figure 3 or 6.

3. If the heat release rate per unit curbed area of the fluid to be used is less than that shown in Figure 3 or 6, no further protection is needed.

4. If the heat release rate per unit curbed area of the fluid to be used is greater than that permitted in Figure 3 or 6, provide protection in accordance with exposure protection recommendations given in Data Sheet 5-4/14-8.

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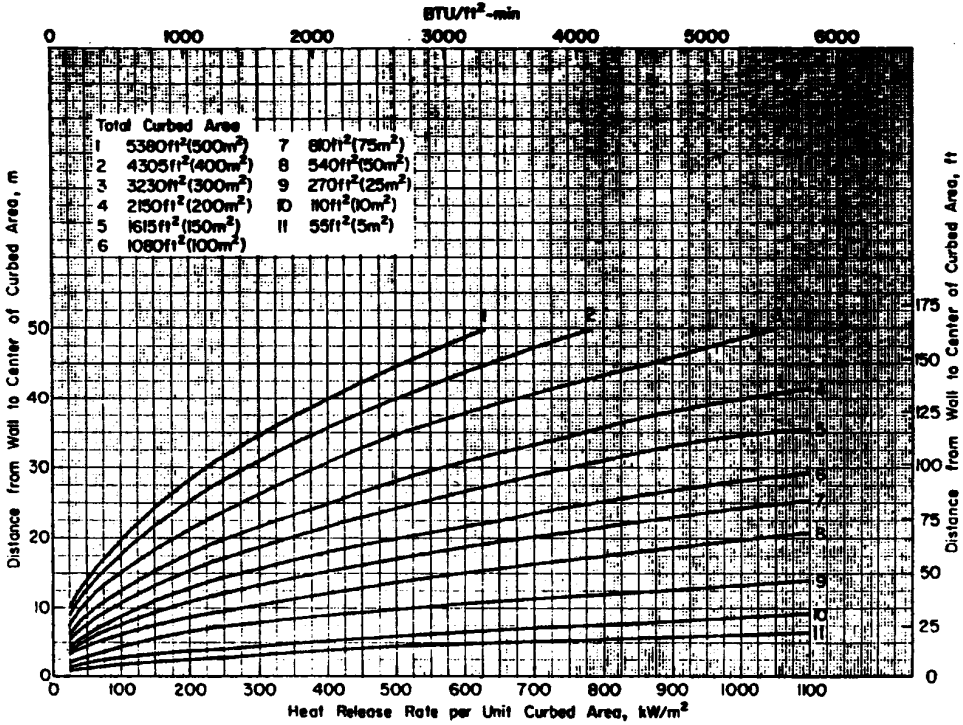
BTU/ft²-min
0
1000
2000
3000
4000
5000
6000
Total Curbed Area
1 5380ft²(500m²)
2 4305ft²(400m²)
3 3230ft²(300m²)
4 2150ft²(200m²)
5 1615ft²(150m²)
6 1080ft²(100m²)
7 810ft²(75m²)
8 540ft²(50m²)
9 270ft²(25m²)
10 110ft²(10m²)
11 55ft²(5m²)
Distance from Wall to Center of Curbed Area, m
Distance from Wall to Center of Curbed Area, ft
Heat Release Rate per Unit Curbed Area, kW/m²
0
100
200
300
400
500
600
700
800
900
1000
1100
10
20
30
40
50
25
75
125
150
175

Example 4.

A transformer containing a less flammable insulating fluid is to be installed outdoors adjacent to a blank steel panel on steel frame building wall. A curbed area of 540 sq ft is to be provided. The center of the curbed area is to be 30 ft from the building wall. If the fluid has a radiative heat release rate per unit curbed area of 3000 Btu/ft^2-min., is the 30 ft spacing adequate?

Referring to Figure 3 for steel walls, extend a horizontal line across from the 30 ft point on the vertical scale labeled Distance from Wall to Center of Curbed Area until it intersects the 540 sq ft curbed area curve. At that point draw a vertical line to the horizontal scale labeled Heat Release Rate per Unit Curbed Area. The maximum allowable radiative heat release rate per unit curbed area is found to be 1740 Btu/ft^2-min. The 30 ft spacing is, therefore, inadequate. The transformer and curbing should either be installed further from the wall or a fluid having a radiative heat release rate per unit curbed of 1740 Btu/ft^2-min. or less should be substituted for the original fluid.

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Factory Mutual System

TRANSFORMER FLUIDS

Less flammable transformer fluids are for use in the cooling and insulating of liquid-cooled transformers. They have a fire point greater than 572°F (300°C) (ASTM D-92-72).

Fluids approved and listed here have been tested to evaluate fire hazard only. In each case the fire hazard has been reduced to an acceptable degree, meeting the approval standards of Factory Mutual; other fluid properties are not investigated.

The convective and radiative heat release rates shown are assigned to these fluids from data of pool fire tests. These heat release rates are intended for use in conjunction with Factory Mutual Data Sheet 5-4S/14-8S, Less Flammable Transformer Fluids, to determine the protection recommended when these fluids are used in various occupancies.

	Heat Release Rate in BTU/ft^2-Min. (KW/m^2)	
	Convective	Radiative
Dow Corning, Midland, MI 48640 Dow Corning 561 Silicone Transformer Liquid	280 (53)	132 (25)
General Electric Co., Silicone Products Department Waterford, NY 12188 Silicone Dielectric Fluid SF97	349 (66)	137 (26)
General Electric Co., Large Transformer Div., 100 Woodlawn Avenue, Pittsfield, MA 01201 Iralec T-1	1957 (370)	1259 (238)
General Electric Co., Medium Transformer Dept., Redmond Circle, Rome, GA 30161 Transformer Fluid R-113	<264 (<50)	<132 (<25)
Gulf Oil Chemicals Co., P.O. Box 3766, Houston, TX 77001 Gulf FR Electrical Insulating Fluid	2983 (564)	2190 (414)
RTE Corporation, 1900 East North Street, Waukesha, WI 53186 RTEmp Fluid	2888 (546)	1909 (361)
Union Carbide Corp., P.O. Box 65 Tarrytown, NY 10591 Transformer Fluid L-305	349 (66)	137 (26)
Westinghouse Electric Corp. Transformer Div., 469 Sharpsville Avenue, Sharon, PA 16146 Insulating Oil Wemco FR	2845 (538)	2333 (441)

EVOLUTION OF HIGH FIRE POINT LIQUID-INSULATED TRANSFORMERS
IN THE NATIONAL ELECTRICAL CODE

1975 National Electrical Code

Not mentioned

1978 National Electrical Code

450-23. High Fire Point Liquid-Insulated Transformers. Transformers insulated with a nonpropagating liquid approved for the purpose, having a fire point not less than 300 C, shall be permitted to be installed indoors or outdoors. Such transformers installed indoors and rated over 35,000 volts shall be installed in a vault.

For the purposes of this article, a nonpropagating liquid shall be one which, when subjected to a source of ignition, may burn but the flame will not spread from the source of ignition.

1981 National Electrical Code

450-23. High Fire Point Liquid-Insulated Transformers. Transformers insulated with listed less-flammable liquids shall be permitted to be installed without a vault in noncombustible occupancy areas of noncombustible buildings, provided there is a liquid confinement area and the minimum clearances required by the heat release rates of the listed liquid are maintained.

Such indoor transformer installations not meeting the clearance requirements of the liquid listing, or installed in combustible buildings or combustible occupancy areas, shall be provided with an automatic fire extinguishing system or shall be installed in a vault complying with Part C of this article.

Transformers installed indoors and rated over 35,000 volts shall be installed in a vault.

Transformers installed outdoors shall comply with Section 450-27.

For purposes of this section, a less-flammable liquid is one with a fire point not less than 300 C.

FPN: For definition of "noncombustible" as used in this section, see Types of Building Construction, NFPA 220-1979.

FPN: See definition of "Listed", Article 100.

They have a fire point greater than 572°F (300°C). (ASTM D-92-72)

Fluids approved and listed have been tested to evaluate fire hazard only. In each case the fire hazard has been reduced to an acceptable degree, meeting the approval standards of Factory Mutual. Other fluid properties are not investigated.

The convective and radiative heat release rates shown are assigned to these fluids from data of pool fire tests. These heat release rates are intended to be used in conjunction with Factory Mutual Data Sheet 5-4S/14-8S, Less Flammable Transformer Fluids, to determine the protection recommended when these fluids are used in various occupancies.

Dow Corning Midland MI 48640

Product Designation	Heat Release Rate, Btu/ft²min (kW/m²) Convective	Radiative
Dow Corning 561 Silicone Transformer Liquid	280 (53)	132 (25)
General Electric Co Redmond Circle Rome GA 30161		
Transformer Fluid R-113*	<264* (<50)*	<132* (<25)*
General Electric Co 100 Woodlawn Av Pittsfield MA 01201		
Ireleo T-1	1957 (370)	1256 (238)
General Electric Co Waterford NY 12188		
Silicone Dielectric Fluid SF97	349 (66)	137 (26)
Gulf Oil Chemicals Co Box 3766 Houston TX 77001		
Gulf FR Electrical Insulating Fluid	2983 (564)	2189 (414)
RTE Corp 1900 E North St Waukesha WI 53186		
RTEmp Fluid	2856 (540)	1909 (361)
Union Carbide Corp Box 66 Tarrytown NY 10591		
Transformer Fluid L-306	348 (66)	137 (26)
Westinghouse Electric Corp 403 Sharpsville Av Sharon PA 16146		
Insulating Oil Wemco FR	2845 (538)	2339 (441)

*Heat release rate arbitrarily assigned per Factory Mutual test procedure. Did not burn.

TRANSFORMER FLUIDS P 278

McGraw-Edison Co (New Company) 1131 Adams Rd Franksville WI 53126
(New listing)

Product Designation	Heat Release Rate, Btu/ft²min (kW/m²) Convective	Radiative
HEPSOL Transformer Fluid	2867 (542)	2174 (411)
Union Carbide Corp (New listing)		
Y-7582 Silicone Transformer Fluid	364 (69)	353 (67)

TRANSFORMER FLUIDS

Less flammable transformer fluids are used in the cooling and insulating of liquid-cooled transformers.

SAMPLE PROBLEM

Existing Askarel transformer to be retrofilled. Transformer contains 330 gallons of liquid, is 6'4" long and 5'6" wide. The building and occupancy are noncombustible. Ceiling height is 12' and the ceiling is of reinforced concrete. The distance from the center of the curbed area to a wall composed of steel panel on steel frame is 15'.

QUESTION: Can the transformer be retrofilled with a high fire point liquid without additional protection?

SOLUTION: First, it will be necessary to have a curbed area around the transformer, constructed of noncombustible materials, of sufficient volume to contain all of the liquid in the transformer. Referring to Figure 4 of the Loss Prevention Data Sheet, the minimum dimensions of this curbed area will be twice the width (2 x 5'6") times twice the length (2 x 6'4"), or a total area of 139.37 square feet. The minimum curb height of four inches will provide a volume of 46.46 cubic feet, which is sufficient to contain the 330 gallons of liquid in the transformer (330 gallons equals 44.18 cubic feet).

Next, to determine the maximum allowable heat release rate of the liquid to be used, we refer first to Figure 2 to determine the convective heat release rate. Draw a line horizontally from the 12 foot point on the vertical scale (ceiling height) to a point between curves 8 and 9 which would correspond to the 140 square foot curbed area (curve 8 is for 160 square feet; curve 9 is for 110 square feet). From this point, extend a line vertically to either of the horizontal scales. Where this line intersects the horizontal scale, we can read the maximum allowable convective heat release rate of the retrofill liquid, 200 kW/square meter or approximately 1,050 BTU/square foot.

Then, we move to Figure 3 to determine the maximum radiative heat release rate. Using the same process as above, we determine that the maximum allowable radiative heat release rate of the liquid will be 385 kW/square meter, or approximately 2,025 BTU/square foot.

Referring next to the Approval Guide, we look for a material with a Convective Heat Release Rate less than 200 kW/square meter and a Radiative Heat Release Rate less than 385 kW/square meter. We find that there are several listed liquids which are suitable.

The transformer can be retrofilled, therefore, with a High Fire Point Liquid without additional protection.

APPLICATION
INFORMATION
DATA

ANALYSIS OF PCB'S IN
TRANSFORMER FLUIDS
AN 144

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ANALYTICAL CONDITIONS

STANDARDIZATION

TRANSFORMER FLUID ANALYSIS

TEST CHROMATOGRAMS AND CALCULATIONS

CONCLUSION

INTRODUCTION

Poly Chlorinated Biphenyls (PCB's) have been used for years as a dielectric cooling fluid in power transformers. The major reasons for the use of this particular fluid is its very high dielectric constant, its nonflammability, and its ability to remain effectively unchanged for years under a number of adverse conditions. With the toxicity of PCB's indicated, their use has been banned in the future for use in transformers. The fluid used to fill transformers was not 100% PCB's, but contained between 30 and 50% PCB depending upon the particular PCB mixture used. The remaining 50 to 70% contained trichloro benzene (TCB).

This mixture is referred to Askarel. The various PCB mixtures have been marketed in this country under the trade name Aroclor. There are three mixes in general that have been used in transformer fluids. These are the Aroclor 1242, Aroclor 1254, and Aroclor 1260. The last two numbers in these number designations indicate the percent of chlorine in the particular fluid. The higher amount of chlorine in the fluid indicates a higher boiling composition of the mixture. In all cases, the various Aroclor mixtures were not pure materials, but a number of poly chlorinated biphenyls. It was simply a distillation-type cut.

By today's definitions, a PCB transformer is any transformer whose fluid contains more than 500 ppm PCB. If the PCB content is between 50 and 500 ppm, the transformer fluid is considered to be PCB

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RT. 41 & NEWARK RD., AVONDALE, PA. 19311 PHONE: (215)-268-3181

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contaminated. Below 50 ppm, it is considered to be a non-PCB fluid. PCB transformers can indeed remain in use, however, any leakage of the fluid must be disposed of by proper EPA procedures. A PCB transformer cannot be rebuilt. When the PCB transformer needs repair, it must be replaced.

On the other hand, a PCB contaminated transformer can indeed be rebuilt. The PCB contaminated fluid again must be disposed of by EPA regulations. A non-PCB transformer fluid (below 50 ppm PCB) currently does not come under any EPA regulations. Because of these regulations and the economies involved, it is feasible to retrofill transformers with fluids and to flush the transformers with sufficient fluid to at least get the PCB levels below 500 ppm. This would allow it to be rebuilt in the case of transformer failure. There is also an additional incentive to get below 50 ppm so that the transformer fluid does not come under EPA jurisdiction.

When transformers are being retrofilled on-site, it would be important to have analytical means available to ensure that the PCB level is below the desired amount. In addition, the EPA requires a sample to be taken after the retrofilled transformer has been in operation for three months. This ascertains the exact amounts of PCB remaining in the fluid which in turn defines the type of transformer.

This application note then details the instrumentation and procedures that can be used for on-site analysis of PCB's in transformer fluids.

ANALYTICAL CONDITIONS

The Analytical System chosen for the analysis of PCB's in transformer fluid is the AID Model 511 fully portable Gas Chromatographic System equipped with the Option 06 Electron Capture Detection System. This system was fitted with a 6 foot 3% SE 30 on 80 - 100 mesh Chromosorb W HP column, which was maintained at 220°C. The carrier gas was Argon with 5% methane (P-5 gas) and its flow was maintained at approximately 40 ml/min. The output of the gas chromatograph was presented on a 1 mv strip chart recorder. Using this analytical system, it is possible to identify and quantitate the Aroclor mixture used in a particular transformer as well as the amount of the particular Aroclor remaining in the transformer fluid after retrofilling.

STANDARDIZATION

The recommended solvent to be used throughout the analysis of PCB's in transformer fluid is isooctane. The isooctane can be obtained from any of the major laboratory supply houses. The particular grade of isooctane to be used is one that is labled Pesticide Grade Isooctane. This particular isooctane is checked by the

manufacturer for its lack of response on an Electron Capture Detector in the area where PCB's would emmerge. Thus, it will have no interfering peaks for the PCB analysis.

Standards are prepared in isooctane by a weight per unit volume. A known amount of the pure PCB mixture is weighed into a clean container. To this, a known volume of isooctane is added and the concentration of the PCB calculated as micrograms PCB per ml of solution. In general, the final concentration of the standard that will actually be injected into the chromatograph should be at about one microgram PCB per ml of solution. In practice, this will generally take a dilution of the sample following the initial solution preparation.

A practical approach for standard preparation is to weigh approximately 50 mg of the PCB mixture into a container and add 50 ml of isooctane. This gives a concentration of 1 mg/ml. This solution can then be diluted 1000 fold to provide a standard of 1 ug/ml.

Standards of PCB's in isooctane are available commercially at this level of concentration. (See Supelco Inc., Supelco Park, Bellfonte, PA 16823. Kit PCB-8-20, Part Number #4-4804. This kit contains 6 standards of 6 different Aroclor mixtures in isooctane at 1 ng/microliter. This is the same as 1 microgram per ml. One ml of each standard is supplied.) Standard chromatograms should be on hand for each of the Aroclor mixtures that one might encounter in transformer fluids. These would define the patterns of the peaks such that the particular Aroclor mixture could be identified immediately.

For quantitative analysis of the amount of PCB in a particular transformer fluid, standards should be ran of that particular mixture on the same day that the transformer fluid is being analyzed and it is that standard that is used for comparison.

TRANSFORMER FLUID ANALYSIS

Due to the viscosity of the transformer fluid, it is necessary to dilute the fluid with a solvent prior to its injection into the chromatograph. The following dilution scheme has been found to be quite satisfactory to cover a very broad range of PCB concentrations in transformer fluid and to provide a procedure that could be easily done in the field by simple equipment. The transformer fluid is first diluted to a 1% solution in isooctane by taking .1 ml of the fluid and 9.9 ml of isooctane solvent. This can be done in a small 12 ml vial with a foil lined cap.

After mixing of this diluted sample, it is further diluted to a .01% solution in isooctane by taking 10 microliters of the 1%

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solution and .99 ml of isooctane solvent. This can be done in a small 2 ml vial with foil lined cap. These volume dilutions are best done in the field using syringes. A 1 ml, or possibly even a .5 ml, syringe can be used to handle the transformer oil. A fairly large needle should be used, approximately 18 to 20 guage; this due to the viscosity of the fluid. The isooctane can be handled with a 10 ml syringe and a 1 ml syringe. The 1% solution that is being diluted to .01% is best handled by a 10 microliter syringe.

Gas chromatographic analysis is first performed on the diluted .01% solution. For this purpose, 3 microliters of .01% solution of the fluid is injected into the chromatograph that has been stabilized under conditions outlined in the Analytical Condition Section. These 3 microliters are best injected using a 10 microliter syringe with a solvent backup technique. Briefly this technique is as follows. The 10 microliter syringe is flushed thoroughly with pure isooctane solvent and approximately 1 microliter of pure solvent is drawn into the syringe. Following this, about 1 microliter of air is drawn into the syringe following the isooctane. Then the 3 microliters of diluted sample is drawn into the syringe followed again by a slug of air such that the entire amount of sample is pulled into the barrel of the syringe. At this point a typical 10 microlter syringe might look something like this. The plunger may be back at the 8 microliter mark. This is immediately followed by a slug of pure isooctane that may end at the 6.8 microliter mark (1.2 microliters isooctane). This would be followed by an air gap in the syringe barrel and perhaps the slug of isooctane would start at 5.4 microliters. That slug would end at 2.3 microliters and the remainder of the syringe barrel and needle would contain air. This would give a sample size of 3.1 microliters of sample.

When the syringe is injected into the chromatograph, the entire 3.1 microliters of the sample is indeed injected into the chromatograph and is flushed with the 1.2 microliters of the pure isooctane. The residual and the needle of the syringe contains only isooctane and no PCB's. If on the analysis of the .01 solution, no peaks are observed, even on a range of 1 and an attenuation of 64; then the injection is repeated using 3 microliters of the 1% solution. Again, if no detectable PCB's are observed on the 1-64 setting of sensitivity, one can say that the concentration of PCB's in the original transformer fluid was certainly less than 2 ppm PCB.

It is important in all cases when analyzing for PCB content in transformer fluid, to obtain some of the pure fluid that has no PCB's present. This fluid is analyzed by making a 1% solution in isooctane and running 3 microliters of this directly into the chromatograph. It must be determined that there are no components in the transformer fluid that would interfere with the particular peaks chosen for quantitation of the PCB analysis. In some cases,

transformer fluids will have peaks that occur in the PCB region. This will certainly eliminate these peaks as far as their use for quantitation is concerned.

TEST CHROMATOGRAMS AND CALCULATIONS

The first 3 chromatograms shown are standards prepared of Aroclor 1242, Aroclor 1254, and Aroclor 1260 in isooctane; at the concentrations, sample sizes and sensitivities shown under the chromatograms. All of these runs were made under the operating conditions described in the section on Analytical Conditions. These 3 chromatograms show the sensitivity of the recommended analytical procedure for various PCB's. They also show the patterns obtained for these 3 different Aroclor mixtures. Thus, it is not difficult to ascertain which Aroclor mixture is present and then to determine the amount of that Aroclor mixture by comparing to appropriate standards.

One can observe from these chromatograms that as the chlorine content of the Aroclor increases, so does the retention times of the major components that are present in the particular mixture. Thus, the Aroclor 1242 is completed in a relatively short period of time, while the Aroclor 1260 requires approximately 15 minutes for completion of the chromatogram.

The final chromatogram, shown in Figure 4, is an unknown transformer fluid (mineral oil) that has been diluted to 1% in isooctane. This diluted sample was then injected into the chromatograph. The pattern of the peaks shown in Figure 4 can be compared with the first 3 chromatograms that have known amounts of known PCB's. Certainly, the pattern conforms to Figure 3, which is the Aroclor 1242. To quantitate this, one would use selective peaks and compare peak heights of the known and the unknowns. For this purpose, the doublet peak marked "X" on Chromatogram 4 was used.

The following equation is the fundamental concentration equation used in quantitative analysis by GC. For manual measurement of the peaks, peak height is generally preferred and that is the term used in the equation to measure the size of the peak.

$$C_u = C_k \times \frac{SS_k}{SS_u} \times \frac{PH_u}{PH_k} \times \frac{Atten_u}{Atten_k}$$

Where C_u = Concentration of Unknown (ug/ml).

C_k = Concentration of Standard (ug/ml).

SS_k = Sample Size of Standard (ul).

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SS_u Sample Size of Unknown (ul).

PH_u = Peak Height of Unknown (cm).

PH_k = Peak Height of Standard (cm).

$Atten_u$ = Range x Attenuation of Unknown.

$Atten_k$ = Range x Attenuation of Standard.

The peak height of the unknown doublet in Figure 4 was measured and found to be 2.3 cm. The corresponding peak in Figure 3 for the standard was 1.6 cm. Fitting this data, sample size, and attenuation into the above equation we have:

$$C_u = 1.10 \times \frac{3.0}{2.2} \times \frac{2.3}{1.6} \times \frac{1 \times 1024}{1 \times 1024} = 2.15 \text{ ug/ml}$$

The concentration then that is determined, 2.15 micrograms/ml, is the concentration of the material actually injected into the chromatograph. Since this is a 1% dilution of the transformer oil, the concentration of the transformer oil was actually 215 micrograms/ml. Since the fluid here was mineral oil, which has a density of .85 grams/ml, the original fluid then would contain 215 micrograms PCB per .85 grams of the oil or 253 micrograms of PCB per gram of oil. Since both the PCBs now and the oil are on a weight-to-weight basis, this could be referred to directly as 253 ppm PCBs. This would classify this particular transformer fluid as being PCB contaminated (less than 500 ppm, but above 50 ppm).

CONCLUSION

The foregoing data certainly indicates that the Model 511 equipped with the 06 Option is a convenient way for the analysis of Poly Chlorinated Biphenyls in transformer fluids. Not only can the amount of PCB be determined well below 50 ppm, but the identification of the PCB can certainly be determined from the chromatogram. The complete portability of the Model 511 allows on-site analysis of the transformer at the time of retrofilling, thus ensuring that the PCB levels are as low as desired. The sample preparation is quite simple and straight forward and the complete analysis requires simply some standards and syringes, a Model 511 GC, and a portable recorder.

The results obtained on the Model 511 on various transformer fluids have corresponded well to analyses obtained later on various laboratory gas chromatographs equipped with Electron Capture Detector. However, the time and expense saved by performing this analysis at the transformer is considerable.

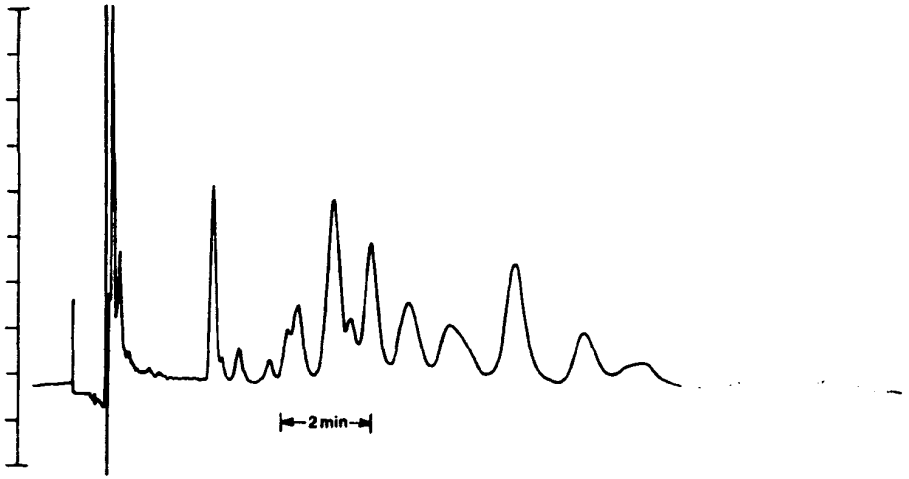

Figure 1

Aroclor 1260

2.4µl of 0.786 µg/ml injected at 1-1024.

MDNS 002856

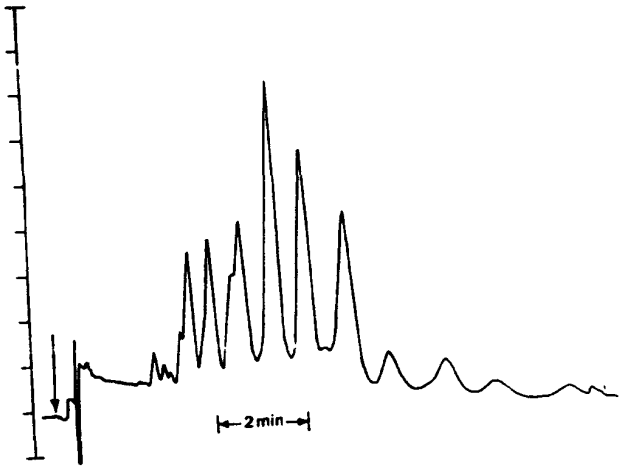

Figure 2

Aroclor 1254

3 µl of 0.767µg/ml injected at 1-1024.

MONS 002857

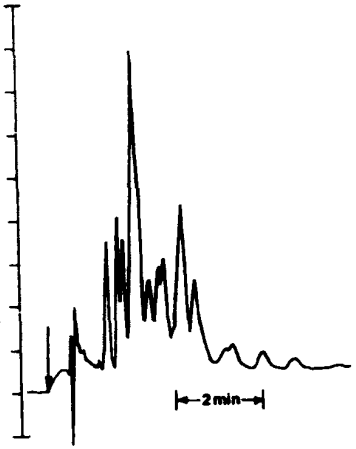

Figure 3

Aroclor 1242

3µl of 1.10 µg/ml injected at 1-1024.

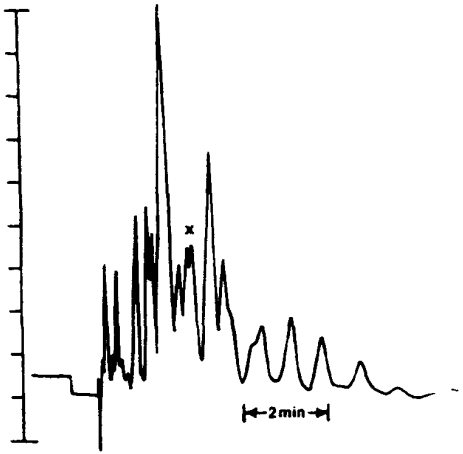

Figure 4

PCB in Mineral Oil

1% Dilution in Isooctane

2.2µl injected at 1-102[illegible].

MONS 002858

ADDENDUM to AN 144

FIELD PROCEDURE FOR PCB IN TRANSFORMER FLUID

1. Dilute 0.1 ml Transformer Fluid with 9.9 ml Isooctane - 1% Fluid in Solvent.

2. Dilute 10 ul 1% Solution with 0.99 ml Isooctane - 0.01% Fluid in Solvent.

3. Inject 3 ul of 0.01% Solution into 511-06.

4. If significant peaks observed, determine which Aroclor and quantitate.

5. If no peaks or very small peaks on 1-64, Inject 3 ul of 1% Solution into 511-06.

6. If significant peaks observed, determine which Aroclor and quantitate.

7. If no peaks or very small peaks on 1-64, then PCB content is less than 2 ppm.

FEDERAL REGISTER
EXCERPTS

TOXIC SUBSTANCES CONTROL ACT

MONS 002861

SUBPART A - GENERAL

761.1 Applicability

This part applies to all persons who manufacture, process, distribute in commerce, use, or dispose of PCBs or PCB Items. Unless it is otherwise specifically provided, the terms PCB and PCBs are used in this rule to refer to any chemical substances and combinations of substances that contain 50 ppm (on a dry weight basis) or greater.

Note:

The information contained in this booklet has been excerpted from the May 31, 1979 edition of the Federal Register. It represents our opinion on the principle features of the Toxic Substances Control Act as they relate to the electrical industry. The scope of this booklet is limited and is intended to be used only as quick reference.

MONS 002862

"Agency" means the United States Environmental Protection Agency.

"Capacitor" means a device for accumulating and holding a charge of electricity and consisting of conducting surfaces separated by a dielectric. Types of capacitors are as follows:

1. "Small Capacitor" means a capacitor which contains less than 1.36 kg (3 lbs.) of dielectric fluid.
2. "Large High Voltage Capacitor" means a capacitor which contains 1.36 kg (3 lbs.) or more of dielectric fluid and which operates at 2000 volts a.c. or above.
3. "Large Low Voltage Capacitor" means a capacitor which contains 1.36 kg (3 lbs.) or more of dielectric fluid and which operates below 2000 volts a.c.

"Commerce" means trade, traffic, transportation, or other commerce:

1. Between a place in a State and any place outside of such State, or
2. Which affects trade, traffic, transportation, or commerce described in subparagraph (1.) of this paragraph.

"Disposal" means to intentionally or accidentally discard, throw away, or otherwise complete or terminate the useful life of PCBs and PCB Items. Disposal includes actions related to containing, transporting, destroying, degrading, decontaminating, or confining PCBs and PCB Items.

"Distribute in Commerce" and "Distribution in Commerce" when used to describe an action taken with respect to a chemical substance, mixture, or article containing a substance or mixture means to sell, or the sale of, the substance, mixture, or article in commerce.

"Fluorescent Light Ballast" means a device that electrically controls fluorescent light fixtures and that includes a capacitor containing 0.1 kg or less of dielectric.

"Incinerator" means an engineered device using controlled flame combustion to thermally degrade PCBs and PCB Items. Examples of devices used for incineration include rotary kilns, liquid injection incinerators, cement kilns, and high temperature boilers.

"Leak" or "leaking" means any instance in which a PCB Article, PCB Container, or PCB Equipment has any PCBs on any portion of its external surface.

MONS 002863

"Mark" means the descriptive name, instructions, cautions, or other information applied to PCBs and PCB Items, or other objects subject to these regulations.

"PCB" and "PCBs" means any chemical substance that is limited to the biphenyl molecule that has been chlorinated to varying degrees or any combination of substances which contains such substance.

"PCB Article" means any manufactured article, other than a PCB Container that contains PCBs and whose surface(s) has been in direct contact with PCBs. "PCB Article" includes capacitors, transformers, electric motors, pumps, pipes and any other manufactured item.

"PCB Article Container" means any package, can, bottle, bag, barrel, drum, tank, or other device that contains PCBs or PCB Articles and whose surface(s) has been in direct contact with PCBs.

"PCB Container" means any package, can, bottle, bag, barrel, drum, tank, or other device that contains PCBs or PCB Articles and whose surface(s) has been in direct contact with PCBs.

"PCB Equipment" means any manufactured item, other than a PCB Container or a PCB Article Container, which contains a PCB Article or other PCB Equipment, and includes microwave ovens, electronic equipment, and fluorescent light ballasts and fixtures.

"PCB Item" is defined as any PCB Article, PCB Article Container, or PCB Equipment, that deliberately or unintentionally contains or has as a part of it any PCB or PCBs at a concentration of 50 ppm or greater.

"PCB Transformer" means any transformer that contains 500 ppm PCB or greater.
Non PCB Transformer - less than 50 ppm PCB
"PCB-Contaminated Transformer" means any transformer that contains 50 ppm or greater of PCB but less than 500 ppm PCB.

"Significant Exposure" means any exposure of human beings or the environment to PCBs as measured or detected by any scientifically acceptable analytical method.

"Small Quantities for Research and Development" means any quantity of PCBs (1) that is originally packaged in one or more hermetically sealed containers of a volume of no more than five (5.0) milliliters, and (2) that is used only for purposes of scientific experimentation or analysis of, PCBs, but not for research or analysis for the development of a PCB product.

"Storage for Disposal" means temporary storage of PCBs that have been designated for disposal.

"Totally Enclosed Manner" means any manner that will ensure that any exposure of human beings or the environment to any concentration of PCBs will be insignificant; that is, not measurable or detectable by any scientifically acceptable analytical method.

MONS 002864

SUBPART B - DISPOSAL OF PCBs AND PCB ITEMS

761.10 Disposal requirements

NOTE - This Subpart does not require removal of PCBs and PCB Items from service and disposal earlier than would normally be the case. However, when PCBs and PCB Items are removed from service and disposed of, disposal must be undertaken in accordance with these regulations.

PCBs: Except as provided in certain paragraphs of this section, PCBs must be disposed of in an incinerator which complies with Annex I.

Mineral oil dielectric fluid from PCB-Contaminated Transformers containing a PCB concentration of 50 ppm or greater, but less than 500 ppm, must be disposed of in one of the following:

1. In an incinerator that complies with Annex I, 761.40;
2. In a chemical waste landfill that complies with Annex II, 761.41 if information is provided to the owner or operator of the chemical waste landfill that shows that the mineral oil dielectric fluid does not exceed 500 ppm PCB and is not an ignitable waste as described in 761.41 of Annex II; — no longer after 11/19/87
3. In a high efficiency boiler.

Any non-liquid PCBs in the form of contaminated soil, rags, or other debris shall be disposed of:

1. In an incinerator which complies with Annex I; or
2. In a chemical waste landfill which complies with Annex II. still OK

PCB Transformers shall be disposed of in accordance with either of the following:

1. In an incinerator that complies with Annex I; or
2. In a chemical waste landfill which complies with Annex II; provided that the transformer is first drained of all free flowing liquid, filled with solvent, allowed to stand for at least 18 hours, and then drained thoroughly.

MONS 002865

Solvents may include kerosene, xylene, toluene and other solvents in which PCBs are readily soluble.

PCB-Contaminated Transformers shall be disposed of by draining all free flowing liquid from the transformer. The disposal of the drained transformer is not regulated by this rule.

PCB Capacitors: The disposal of any capacitor normally used in alternating current circuits shall comply with all requirements of this subpart unless it is known from label or nameplate information, manufacturer's literature, or chemical analysis that the capacitor does not contain PCBs.

Any person may dispose of PCB Small Capacitors as municipal solid waste, unless that person is subject to the requirements of a later subparagraph.

Any PCB Large High or Low Voltage Capacitor owned by any person shall be disposed of in accordance with either of the following:

A. Disposal in an incinerator that complies with Annex I; or

B. Until March 31, 1981, disposal in a chemical waste landfill that complies with Annex II.

Any PCB Small Capacitor owned by any person who manufactures or at any time manufactured PCB Capacitors or PCB Equipment and acquired the PCB Capacitors in the course of such manufacturing shall be disposed of in accordance with either of the following:

A. Disposal in an incinerator which complies with Annex I; or

B. Until March 31, 1981, disposal in a chemical waste landfill which complies with Annex II.

PCB Containers: Unless decontaminated in compliance with Annex IV or as provided below, a PCB Container shall be disposed of:

1. In an incinerator which complies with Annex I, or

2. In a chemical waste landfill that complies with Annex II; provided that if there are PCBs in a liquid state, the PCB Container shall first be drained.

Any PCB Container used to contain only PCBs at a concentration less than 500 ppm shall be disposed of as municipal solid wastes.

Prior to disposal, a PCB Container shall be stored in a facility which complies with Annex III.

Spills: Spills and other uncontrolled discharges of PCBs constitute the disposal of PCBs.

MONS 002866

Any person who is required to incinerate any PCBs and PCB Items under this subpart and who can demonstrate that an alternative method of destroying PCBs and PCB Items exists and that this alternative method can achieve a level of performance equivalent to Annex I incinerators or high efficiency boilers, may submit a written request to the Regional Administrator for an exemption from the incineration requirements of Annex I. The applicant must show that his method of destroying PCBs will not present an unreasonable risk of injury to health or the environment.

Testing Procedures.

Owners or users of mineral oil dielectric fluid transformers may use the following procedures to determine the concentration of PCBs in the dielectric fluid:

1. Dielectric fluid removed from mineral oil dielectric fluid transformers may be collected in a common container, provided that no other chemical substances or mixtures are added to the container.

2. For purposes of complying with the marking and disposal requirements, representative samples may be taken from either the common containers or the individual transformers to determine the PCB concentration, except that if any PCBs at a concentration of 500 ppm or greater have been added to the container then the total container contents must be considered as having a PCB concentration of 500 ppm or greater for purposes of complying with the disposal requirements of this subpart. For purposes of this subparagraph, representative samples of mineral oil dielectric fluid are either samples taken in accordance with American Society of Testing and Materials method D-923 or samples taken from a container that has been thoroughly mixed in a manner such that any PCBs in the container are uniformly distributed throughout the liquid in the container.

MONS 002867

SUBPART C - MARKING OF PCBs AND PCB ITEMS

761.20 Marking requirements

Each of the following items in existence on or after July 1, 1978 shall be marked as illustrated in Figure 1 in Annex V - 761.44: The mark illustrated in Figure 1 is referred to as M_L throughout this subpart.

1. PCB Containers;
2. PCB Transformers at the time of manufacture, at the time of distribution in commerce if not already marked, and at the time of removal from use if not already marked. (Marking of PCB-Contaminated Transformers is not required);
3. PCB Large High Voltage Capacitors at the time of manufacture, at the time of distribution in commerce if not already marked, and at the time of removal from use if not already marked;
4. Equipment containing a PCB Transformer or a PCB Large High Voltage Capacitor at the time of manufacture, at the time of distribution in commerce if not already marked, and at the time of removal of the equipment from use if not already marked;
5. PCB Large Low Voltage Capacitors at the time of removal from use;
6. Electric motors using PCB coolants;
7. Each storage area used to store PCBs and PCB Items for disposal.

As of October 1, 1978, each transport vehicle shall be marked on each end and side with M_L as described in Annex V - 761.44 if it is loaded with PCB Containers that contain more than 45 kg (99.4 lbs.) of PCBs in the liquid phase or with one or more PCB Transformers.

As of January 1, 1979, the following PCB Articles shall be marked with mark M_L as described in Annex V - 761.44:

1. All PCB Transformers not marked under the first paragraph of this section (Marking of PCB-Contaminated Transformers is not required);
2. All PCB Large High Voltage Capacitors not marked under the first paragraph of this section
   (a) Will be marked individually with mark M_L, or
   (b) If one or more PCB Large High Voltage Capacitors are installed in a protected location such as on a power pole, or structure, or behind a fence; the pole, structure, or fence shall be marked with mark M_L, and a record or procedure identifying the PCB Capacitors shall be maintained by the owner or operator at the protected location.

MONS 002868

As of January 1, 1979, all PCB Equipment containing a PCB Small Capacitor shall be marked at the time of manufacture with the statement, "This equipment contains PCB Capacitor(s)". The mark shall be of the same size as the mark M_L.

As of October 1, 1979, applicable PCB Items in the first paragraph, subparagraphs #1 and #6, containing PCBs in concentrations of 50 to 500 ppm and applicable transport vehicles in the second paragraph loaded with PCB Containers that contain more than 45 kg (99.4 lbs.) of liquid PCBs in concentrations of 50 ppm to 500 ppm shall be marked with mark M_L as described in Annex V - 761.44.

Where mark M_L is specified but the PCB Article or PCB Equipment is too small to accomodate the smallest permissable size of mark M_L, mark M_S as described in Annex V - 761.44, may be used instead of mark M_L.

Each large low voltage capacitor, each small capacitor normally used in alternating current circuits, and each fluorescent light ballast manufactured ("manufactured", for purposes of this sentence, means built) between July 1, 1978 and July 1, 1998 that do not contain PCBs shall be marked by the manufacturer at the time of manufacture with the statement, "No PCBs". The mark shall be of similar durability and readability as other marking that indicate electrical information, part numbers, or the manufacturer's name. For purposes of this subparagraph marking requirement only is applicable to items built domestically or abroad after June 30, 1978.

All marks required by this subpart must be placed in a position on the exterior of the PCB Items or transport vehicles so that the marks can be easily read by any persons inspecting or servicing the marked PCB Items or transport vehicles.

Any chemical substance or mixture that is manufactured after the effective date of this rule and that contains less than 500 ppm PCB (0.05% on a dry weight basis), including PCB that is a byproduct or impurity, must be marked in accordance with any requirements contained in the exemption granted by EPA to permit such manufacture and is not subject to any other requirement in this Subpart unless so specified in the exemption. This paragraph applies only to containers of chemical substances or mixtures. PCB articles and equipment into which the chemical substances or mixtures are processed, are subject to the marking requirements contained elsewhere in this Subpart.

MONS 002869

SUBPART D - MANUFACTURING, PROCESSING, DISTRIBUTION IN COMMERCE, AND USE OF PCBs AND PCB ITEMS

761.31 Authorizations.

The following non-totally enclosed PCB activities are authorized:

Servicing Transformers: PCBs may be processed, distributed in commerce, and used for the purposes of servicing including rebuilding transformers in a manner other than a totally enclosed manner until July 1, 1984, subject to the following conditions:

A. Regardless of its PCB concentration, dielectric fluids containing less than 500 ppm PCB that are mixed with fluids that contain 500 ppm or greater PCB must not be used as dielectric fluid in any transformer. Dielectric fluid from PCB-Contaminated Transformers may be assumed to have less than 500 ppm PCBs.

B. PCB-Contaminated Transformers (as defined in 761.2) may only be serviced (including rebuilding) with dielectric fluid containing less than 500 ppm PCB.

C. Any servicing (including rebuilding) of PCB Transformers that requires the removal of the transformer coil from the transformer casing is prohibited. PCB Transformers may be topped off with PCB dielectric fluid.

D. PCBs removed during servicing of a PCB Transformer or PCB-Contaminated Transformer or during rebuilding of a PCB-Contaminated Transformer must be captured and either reused as dielectric fluid or disposed of. PCBs from PCB Transformers must not be mixed with or added to dielectric fluid from PCB-Contaminated Transformers.

E. A PCB Transformer may be converted to a PCB-Contaminated Transformer by draining, refilling, and otherwise servicing the transformer with non-PCB dielectric fluid so that after a minimum of three months of in-service use subsequent to the last servicing conducted for the purpose of reducing the PCB concentration in the transformer, the transformer's dielectric fluid contains less than 500 ppm PCB (on a dry weight basis).

MONS 002870

F. After July 1, 1979, processing and distribution in commerce of PCBs for purposes of servicing transformers is permitted only for persons who are granted an exemption under TSCA section 6(e)(3)(B).

MONS 002871

SUBPART E - LIST OF ANNEXES

Annex III 761.42 Storage for disposal.

Any PCB Article or PCB Container stored for disposal before January 1, 1983, shall be removed from storage and disposed of as required by this Part before January 1, 1984. Any PCB Article or PCB Container stored for disposal after January 1, 1983, shall be removed from storage and disposed of as required by Subpart B within one year from the date when it was first placed into storage.

Except as provided in another paragraph of this section, after July 1, 1978, owners or operators of any facilities used for the storage of PCBs and PCB Items designated for disposal shall comply with the following requirements:

The facilities shall meet the following criteria:

1. Adequate roof and walls to prevent rain water from reaching the stored PCBs and PCB Items;

2. An adequate floor which has continuous curbing with a minimum six inch high curb. The floor and curbing must provide a contaminant volume equal to at least two times the internal volume of the largest PCB Article or PCB Container stored therein or 25 percent of the total internal volume of all PCB Articles or PCB Containers stored therein, whichever is greater;

3. No drain valves, floor drains, expansion joints, sewer lines, or other openings that would permit liquids to flow from the curbed area;

4. Floors and curbing constructed of continuous smooth and impervious materials, such as Portland cement concrete or steel, to prevent or minimize penetration of PCBs; and

5. Not located at a site that is below the 100-year flood water elevation.

Annex IV 761.43 Decontamination.

Any PCB Container to be decontaminated shall be decontaminated by flushing the internal surfaces of the container three times with a solvent containing less than 50 ppm PCB. The solubility of PCBs in the solvent must be five percent or more by weight. Each rinse shall use a volume of the normal diluent equal to approximately ten (10) percent of the PCB Container capacity. The solvent may be reused for decontamination until it contains 50 ppm PCB. The solvent shall then be disposed of as a PCB in accordance with 761.10. Non-liquid PCBs resulting from the decontamination procedures shall be disposed of in accordance with the provisions of 761.10.

Movable equipment used in storage areas shall be decontaminated by swabbing surfaces that have contacted PCBs with a solvent meeting the criteria of the first paragraph of this section.

MONS 002873

Annex V 761.44 Marking formats.

The following formats shall be used for marking:

Large PCB Mark - M_L: Mark M_L shall be as shown in Figure One [next page], letters and striping on a white or yellow background and shall be sufficiently durable to equal or exceed the life (including storage for disposal) of the PCB Article, PCB Equipment, or PCB Container. The size of the mark shall be at least 15.25 cm (6 inches) on each side. If the PCB Article of PCB Equipment is too small to accommodate this size, the mark may be reduced in size proportionately down to a minimum of 5 cm (2 inches) on each side.

Small PCB Mark - M_S: Mark M_S shall be as shown in Figure Two [next page], letters and striping on a white or yellow background, and shall be sufficiently durable to equal or exceed the life (including storage for disposal) of the PCB Article, PCB Equipment, or PCB Container. The mark shall be a rectangle 2.5 by 5 cm (1 inch by 2 inches). If the PCB Article or PCB Equipment is too small to accomodate this size, the mark may be reduced in size proportionately down to a minimum of 1 by 2 cm (.4 by .8 inches).

MONS 002874

CAUTION

CONTAINS

PCBs

(Polychlorinated Biphenyls)

A toxic environmental contaminant requiring special handling and disposal in accordance with U.S. Environmental Protection Agency Regulations 40 CFR 761—For Disposal Information contact the nearest U.S. E.P.A. Office.

In case of accident or spill, call toll free the U.S. Coast Guard National Response Center: 800:424-8802

Also Contact
Tel. No.

PC-6 LABELMASTER CHICAGO, IL 60660

Figure One



Figure Two

MONS 002875

Annex VI 761.45 Records and monitoring.

PCBs and PCB Items in service or projected for disposal.

Beginning July 2, 1978, each owner or operator of a facility using or storing at one time at least 45 kilograms (99.4 pounds) of PCBs contained in PCB Container(s) or one or more PCB Transformers, or 50 or more PCB Large High or Low Voltage Capacitors shall develop and maintain records on the disposition of PCBs and PCB Items. These records shall form the basis of an annual document prepared for each facility by July 1 covering the previous calendar year. Owners or operators with one or more facilities that use or store PCBs and PCB Items in the quantities described above may maintain the records and documents at one of the facilities that is normally occupied for 8 hours a day, provided the identity of this facility is available at each facility using or storing PCBs and PCB Items. The records and documents shall be maintained for at least five years after the facility ceases using or storing PCBs and PCB Items in the prescribed quantities. The following information for each facility shall be included in the annual document:

1. The dates when PCBs and PCB Items are removed from service, are placed into storage for disposal, and are placed into transport for disposal. The quantities of the PCBs and PCB Items shall be indicated using the following breakdown:

   A. Total weight in kilograms of any PCBs and PCB Items in PCB Containers including the identification of container contents such as liquids and capacitors;

   B. Total number of PCB Transformers and total weight in kilograms of any PCBs contained in the transformers; and

   C. Total number of PCB Large High or Low Voltage Capacitors.

2. For PCBs and PCB Items removed from service, the location of the initial disposal or storage facility and the name of the owner or operator of the facility.

3. Total quantities of PCBs and PCB Items remaining in service at the end of the calendar year using the following breakdown:

   A. Total weight in kilograms of any PCBs and PCB Items in PCB Containers, including the identification of container contents such as liquids and capacitors;

MONS 002876

B. Total number of PCB Transformers and total weight in kilograms of any PCBs contained in the transformers; and

C. Total number of PCB Large High or Low Voltage Capacitors.

NOTE - Any requirements for weights in kilograms of PCBs may be calculated values if the internal volume of containers and transformers is known and included in the reports, together with any assumptions on the density of the PCBs contained in the containers or transformers.

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PCB INTERIM SELF-INSPECTION PROGRAM

This document describes the interim measures required for all owner and users of PCB Transformers and certain owners and users of PCB-Contaminated Transformers who wish to continue to use, or store for reuse, transformers containing PCBs while EPA conducts further rulemaking with respect to PCB uses which the Agency previously had designated as 'totally enclosed.' To continue to use transformers containing PCBs during this interim period, owners and users of this equipment must comply with the requirements set forth in this document within sixty days after the publication by EPA of the Federal Register Notice announcing the Interim Measures Program or within ninety days after January 21, 1981 (the date of filing the Joint Motion for Further Stay of the Issuance of the Mandate), whichever is later.

I. Definitions: The following definitions apply to this document. The definitions which are part of EPA's PCB Ban Rule, 40 CFR Part 761, also apply to this document unless they are inconsistent with the definitions sat forth below.

A. "leak" means any instance in which a PCB Unit has any PCBs on any portion of its external surface.

B. "moderate leak" means any leak which results in any quantity of PCBs running off or about to run off the external surface of the PCB Unit.

C. "PCB Unit" means any PCB Transformer or PCB-Contaminated Transformer in use or stored for reuse.

D. "posing an exposure risk to food and feed products" means any potential exposure to food and feed products to PCBs as defined below. PCB Units used by federally inspected meat, poultry product, and egg product establishments, as well as facilities manufacturing, processing, packaging or holding human food or animal feed, but excluding retail establishments such as grocery stores and restaurants, are considered to pose an exposure risk to food and feed products, unless the PCB Unit is in a location such that a discharge of dielectric fluid cannot contaminate the food and feed products or processes.

E. "servicing" means repairing and cleaning or replacing the PCB Unit to eliminate the source of the leak. Cleaning of the PCB Unit means removing any unsolidified dielectric fluid on its external surface.

F. "visual inspection" means to investigate for any leak of dielectric fluid on or around the PCB Unit. A visual inspection should not require an electrical shutdown of the PCB Unit being inspected. The extent of the visual inspection will depend on the physical constraints of each PCB Unit installation.

II. The following procedures must be followed with respect to all PCB Units posing an exposure risk to food and feed products:

A user of a PCB Unit posing an exposure risk to food and feed products shall notify the owner of the PCB Unit that the Unit poses an exposure risk to food and feed products. If the user fails to notify the owner, the user is responsible for the inspection, recordkeeping, reporting and servicing of the PCB Unit as set forth below.

The owner of a PCB Unit posing an exposure risk to food and feed products shall perform the following activities:*

A. A visual inspection of each PCB Unit posing an exposure risk to food and feed products shall be performed at least once every week.

B. All leaks shall be recorded. All moderate leaks shall be reported to the appropriate EPA regional office within five business days from the date the leak is observed. If a PCB Unit is found to have a moderate leak, servicing is required and must commence within two business days from the date the leak is observed.

C. Records, containing inspection/servicing history, with respect to all PCB Units posing an exposure risk to food and feed products shall be maintained for a period of three years and shall be made available for inspection, upon request, by EPA. Such records shall contain the following information for each PCB Unit: 1) its location; 2) the date of each visual inspection made of the Unit, together with an identification of the person performing the inspection; 3) all leaks observed in the Unit, together with the date observed, and whether the leak was a moderate leak; and 4) a description of all servicing performed on the Unit commencing as of the date the Unit is first inspected pursuant to these Interim Measures, together with the date of such servicing.

D. Reports to EPA regional offices shall be in writing and shall contain the location of the PCB Unit, the date the moderate leak was observed, an estimate of the extent of the leak and a description of the servicing performed, including the date(s) of the servicing performed.

III. The following procedures must be followed with respect to all PCB Transformers in use or stored for reuse posing no exposure risk to food and feed products (all PCB Transformers not covered in section II):

A. A visual inspection of each PCB Transformer posing no exposure risk to food and feed products shall be performed at least once every three months.

B. All leaks shall be recorded. If a PCB Transformer is found to have a moderate leak, servicing is required and must commence within two business days from the date the leak is observed.

C. Records, containing inspection/servicing history, with respect to all PCB Transformers in use or stored for reuse shall be maintained for a period of three years and shall be made available for inspection, upon request, by EPA. Such records shall contain the following information for each PCB Transformer: 1) its location; 2) the date of each visual inspection made of the PCB Transformer, together with an identification of the person performing the inspection; 3) all leaks observed in the PCB Transformers, together with the date observed, and whether the leak is a moderate leak; and 4) a description of all servicing performed on the PCB Transformer commencing as of the date the PCB Transformer is first inspected pursuant to these Interim Measures, together with the date of such servicing.

*If the owner of the PCB Unit is not the owner of the food and feed establishment, the owner of the PCB Unit shall have no obligation to perform the inspections required in the section, until the owner is notified by the establishment that he is a food and feed facility or until the owner of the PCB Unit has other knowledge that the establishment is a food and feed facility. To inform food and feed establishments of the necessity of notifying owners of PCB Units used at their establishments, utilities undertake to mail to their commercial and industrial customers an announcement requesting food and feed establishments to contact the utility or other owner of the PCB Unit.

POLYCHLORINATED BIPHENYLS (PCBs);
Final Amendment to the Disposal Requirements
for PCB Capacitors in Chemical Waste Landfills

40 CFR Part 761
OPTS-62004A (PCB/RR-4); FRL 1450-2

COPIED FROM:
Federal Register/Vol. 45, No. 62/Friday, March 28, 1980/Rules and Regulations

Agency: Environmental Protection Agency (EPA).

Action: Final Rule.

Summary: On November 21, 1979, EPA requested comments on a proposed amendment modifying the disposal provisions of the PCB regulation (43 FR 7150, February 17, 1978; superseded by 44 FR 31514, May 31, 1979). The November amendment proposed to extend the deadline for allowing disposal of large PCB capacitors in chemical waste landfills from January 1, 1980, to thirty days after EPA announced that an Annex I incinerator was approved and operational for disposal of PCB capacitors. That amendment is being promulgated by this notice with certain modifications. First, EPA is treating small PCB capacitors owned by manufacturers of PCB capacitors or equipment the same as large PCB capacitors for purposes of disposal. Second, EPA will permit disposal of capacitors in chemical waste landfills until March 1, 1981. Third, the Assistant Administrator for Pesticides and Toxic Substances (hereinafter referred to as the Assistant Administrator) may authorize the reopening of chemical waste landfills after March 1, 1981, for disposal of PCB capacitors under specified conditions. Fourth, EPA will require all PCB capacitors to be containerized and packed with absorbent material prior to their disposal in a chemical waste landfill.

Effective Date: Effective March 28, 1980.

For Further Information Contact: John B. Ritch, Jr., Director, Industry Assistance Office TS-799, U.S. Environmental Protection Agency, 401 M St., S.W., Washington, D.C. 20460, Toll Free: 800-424-9065, Local to Washington, D.C.: 554-1404.

Supplementary Information: The PCB rule (43 FR 7150, February 17, 1978, superseded by 44 FR 31514, May 31, 1979) permits disposal, until January 1, 1980, of (1) large PCB capacitors and (2) small PCB capacitors that are in the possession of a manufacturer of small PCB capacitors or PCB equipment in Annex II chemical waste landfills. (See §761.10(b)(2) of the regulation at 44 FR 31547). After January 1, 1980, all capacitors in either of those categories must be disposed of in an incinerator that complies with Annex I of the PCB rule.

EPA proposed in the Federal Register of November 21, 1979 (44 FR 66851) to extend the date through which PCB large capacitors could be disposed of in chemical waste landfills until thirty days after EPA announces that one incinerator with the capability of destroying PCB large capacitors was approved and operational. EPA had anticipated at the times the PCB rule

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and its predecessor were promulgated that Annex I incinerators would be available by January of 1980. Since that time, unforeseen problems have delayed the approval of an incinerator capable of destroying PCB capacitors. Further, with the expiration of the date for landfill disposal of their PCB capacitors, industry is storing capacitors which might otherwise be disposed of, and thereby confronting the possibility that large amounts of additional suitable storage space will have to be built. Evidence was presented both at the hearing held on the proposed amendment on January 3, 1980, and in the written comments that many of the facilities would exhaust their existing storage space within 6 months if they were required to store the large capacitors. This confirmed EPA's understanding that many of the users of PCB capacitors had not anticipated that they would need to store their capacitors after January 1980 and therefore did not construct sufficient storage space. According to information in the comments, the cost to construct new storage facilities would range from $10,000 to $50,000 per storage facility depending upon the individual need. In light of the delays in approving incinerators, the limited amount of storage space, the cost to construct new storage space, and the relatively low risks associated with disposal of PCB capacitors in chemical waste landfills as compared to storage, EPA is adopting an extension of the deadline for such disposal.

This final amendment differs from the proposed amendment in several ways. First, this final amendment responds to evidence presented at the hearing and in the comments questioning the ability of the first approved incinerator to dispose of PCB capacitors at the rate they will be generated for disposal. Commentors also pointed out the difficulties of relying on a single incinerator for all disposal. The incinerator could experience technical difficulties which might lead to the need to temporarily shut down or operate at reduced capacity. Industry again would be faced with the prospect of having no available means of disposal. EPA was reminded that mechanical problems do occur and that this scenario is quite feasible. Other comments stressed that priority should be given to the incineration of liquid PCBs. Commentors suggested liquid PCBs pose a greater health and environmental hazard than non-liquids. These commentors argued that capacitors should not compete with PCB liquids for disposal in incinerators until there is no longer a shortage of incineration capacity.

EPA acknowledges the legitimacy of these concerns and has modified the rule in two ways to address them. Instead of permitting disposal of PCB capacitors in chemical waste landfills until thirty days after EPA announces that the first approved incinerator is available, EPA will allow landfilling until March 1, 1981. In addition, EPA is aware that it is possible that on or after March 1, 1981, adequate capacitor incineration capacity may not be available for a variety of reasons. EPA has concluded that it would be prudent to provide a mechanism for expeditiously reopening chemical waste landfills for PCB capacitor disposal subsequent to March 1, 1981, without the necessity of a further rulemaking. To allow such reopening, EPA has incorporated a second new provision into the rule which gives the Assistant Administrator the authority to reopen chemical waste landfills for PCB capacitors for whatever time period he deems appropriate.

In determining if it is appropriate to reopen landfills, the Assistant Administrator must consider the following factors which reflect concerns drawn from the comments. First, is there adequate incineration capability? Second, will

required incineration of capacitors significantly interfere with the disposal of liquids with PCB concentrations of greater that 500 parts per million (ppm)? Third, are there any other mitigating factors that would impact unreasonably upon the ability to incinerate PCB capacitors? As part of this evaluation, the Assistant Administrator will consider the impact of his decision on the incentives to construct or expand PCB incinerators. EPA is concerned about the small number of applications which have been received requesting approval of incinerators for disposal of PCBs and PCB capacitors and does not want to undercut or discourage through this rulemaking, or any other later action, the construction or expansion of incinerators to destroy PCB capacitors.

Part of this provision to the amendment provides the Assistant Administrator with the authority to reopen chemical waste landfills on a conditional basis. For example, he may restrict the reopening: (1) to large or small capacitors, (2) to certain segments of the country, and/or (3) for a specified period of time.

A third substantive change was included in the amendment to permit disposal of small capacitors, as well as large capacitors, in chemical waste landfills. EPA received a number of comments from persons requesting that the landfill option be extended to manufacturers of small capacitors and capacitor equipment. At the time of proposal, EPA had no information that small capacitor manufacturers or their users faced the same types of storage problems that large capacitor disposers faced. EPA was not aware that significant numbers of small PCB capacitors remained to be landfilled by manufacturers. In view of this information and for reasons of equity between owners of small and large capacitors, EPA has decided to permit landfilling of small PCB capacitors and PCB equipment. EPA considers an extension of the landfill option for small PCB capacitors in the possession of manufacturers to be within the scope of this rulemaking. Storage and disposal of both small and large PCB capacitors are closely related. Further, the number of comments received on the disposal of small capacitors also indicate that commentors assumed disposal of large and small capacitors to be within the scope of the rulemaking.

Fourth, EPA has decided to require (1) all large PCB capacitors and (2) all small PCB capacitors owned by manufacturers of small PCB capacitors and PCB equipment to be packed in Department of Transportation (DOT) drums with absorbent material prior to their disposal in chemical waste landfills. Capacitors larger than a DOT 55-gallon drum may be packed in a container with strength and durability comparable to that of the DOT specification containers. Considerable evidence was presented in comments that a significant number of capacitors were leaking by the time they were received for disposal at the landfill. In fact, two commentors acknowledged the added risk of leaking PCB capacitors and suggested that EPA consider requiring leaking PCB capacitors to be packed in containers with absorbent material. One person suggested that PCB capacitors, packed in drums with absorbent material, will be more secure than the original capacitor.

The requirement for containerization of PCB capacitors in drums with absorbent material is within the scope of this rulemaking. EPA announced in the preamble to the proposed amendment that the Agency would "consider in this rulemaking whether the amendment should permit continued disposal of leaking large PCB capacitors in chemical waste landfills" (44 FR 66851, May 31, 1979).

As earlier noted, information presented at the hearing indicated that a significant number of capacitors are leaking at time of disposal. Accordingly, to ensure adequate protection against leaking capacitors EPA has adopted a uniform procedure for all PCB capacitors subject to the rule which requires them to be placed in containers with absorbent material prior to disposal. This requirement will result in a maximum expenditure of $4,000,000 the first year.[1] The actual impact may be considerably less since some utilities and chemical waste landfills may have already undertaken this practice.

For small PCB capacitors, the total expenditure will be, at the most, $37,500.[2] This cost estimate also is likely to be higher than the actual cost since the estimate is based upon the assumption that all small capacitors are the same size. This, in fact, is not the case. Many small capacitors are extremely small. It would therefore take substantially more of these "smaller" capacitors to fill a 55-gallon drum.[3]

Under Executive Order 12044, EPA is required to judge whether a regulation is "significant" and therefore subject to the procedural requirements of the Order or whether it may follow other specialized development procedures. EPA labels these rules "specialized". This rule has been reviewed and it has been determined that it is a specialized regulation not subject to the procedural requirements of Executive Order 12044.

The public record for this rulemaking is located in Room 447, East Tower, EPA, 401 M Street, S.W., Washington, D.C., 20460. It is available for viewing from 9 a.m. to 4 p.m., Monday through Friday, excluding holidays.

EPA has prepared a support document responding to the major comments received in this rulemaking. This support document is available upon request from the Industry Assistance Office at the address previously given.

Pursuant to 5 U.S.C. §553(d), this amendment is made effective upon publication. The amendment extends PCB disposal provisions that have previously expired. Failure to make the rule immediately effective would prolong the PCB capacitor storage which this amendment is intended to avoid. Accordingly, it is in the public interest to make the rule immediately effective, and the Agency finds that there is good cause for doing so.

Dated: March 25, 1980.

Steven D. Jellinek,
Assistant Administrator for Pesticides and Toxic Substances

Authority: Section 6(e) of TSCA (15 U.S.C 2605). The preamble of the Manufacturing, Processing, Distribution in Commerce, and Use Prohibition Rule published in the Federal Register of May 31, 1979, 44 FR 31514, delegates authority to amend or modify this rule to the Assistant Administrator.

EPA is amending 40 CFR 761.10(b) by revising (b)(2)(iii) and (iv)(B) and by adding new paragraphs (v) and (vi) to read as follows:

§761.10 Disposal requirements.

* * * * *

(b) * * *

(2) PCB Capacitors.* * *

(iii) Any PCB Large High or Low Voltage Capacitor owned by any person shall be disposed of in accordance with either of the following:

* * * * *

(B) Until March 1, 1981, disposal in a chemical waste landfill that complies with Annex II.

(iv) Any PCB Small Capacitor owned by any person who manufactures or at any time manufactured PCB Capacitors or PCB Equipment and acquired the PCB Capacitors in the course of such manufacturing shall be disposed of in accordance with either of the following:

* * * * *

(B) Until March 1, 1981, disposal in a chemical waste landfill that complies with Annex II.

(v) Notwithstanding the restrictions imposed by §761.10(b)(2)(iii)(B) or (b)(2)(iv)(B). PCB capacitors may be disposed of in PCB chemical waste landfills that comply with Annex II subsequent to March 1, 1981, if the Assistant Administrator for Pesticides and Toxic Substances publishes a notice in the Federal Register declaring that those landfills are available for such disposal and explaining the reasons for the extension or reopening. An extension or reopening for disposal of PCB capacitors that is granted under this subsection shall be subject to such terms and conditions as the Assistant Administrator may prescribe and shall be in effect for such period as the Assistant Administrator may prescribe. The Assistant Administrator may permit disposal of PCB capacitors in EPA approved chemical waste landfills after March 1, 1981, if in his opinion,

(1) Adequate incineration capability for PCB capacitors is not available, or

(2) The incineration of PCB capacitors will significantly interfere with the incineration of liquid PCBs, or

(3) There is other good cause shown.

As part of this evaluation, the Assistant Administrator will consider the impact of his action on the incentives to construct or expand PCB incinerators.

(vi) Prior to disposal in an Annex II chemical waste landfill all large PCB capacitors and all small PCB capacitors described in §761.10(b)(2)(iv) shall be placed in one of the Department of Transportation specifications containers identified in §761.42(c)(6) or in containers that comply with 49 CFR 178.118 (specification 17H containers). Large PCB capacitors which are too big to fit inside one of three containers shall be placed in a

container with strength and durability equivalent to the DOT specification containers. In all cases, interstitial space in the container shall be filled will sufficient absorbent material (such as sawdust or soil) to absorb any liquid PCBs remaining in the capacitors.

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[1]Using the numbers provided in the comments provided by the Utility Solid Waste Activities Group (USWAG) that 26,000 large capacitors are removed for disposal per month and dividing by 2 (which is the average number of capacitors one can fit into a 55-gallon drum) and then multiplying by $25 (the approximate cost per drum) results in a total cost of $4,000,000. This assumes no cost for the absorbent material used to fill the drums.

[2]Using numbers provided in the testimony of the Ad Hoc Committee on Liquid Dielectrics (AHLCD) that between 50,000 and 150,000 small PCB capacitors are covered by the scope of this amendment and dividing by 100 (which is the fewest number of small capacitors that can fit in a 55-gallon drum) and them multiplying by the average cost per drum results in a total additional cost to containerize PCB small capacitors in drums of between $30,000 and $37,000.

[3]AHCLD found that it would take 5,000 of the "smaller" capacitors to fill a 55-gallon drum.

EPA REGIONAL OFFICES

Region I
John F. Kennedy Federal Building
Room 2203
Boston, Massachusetts 02203
PHONE: (617) 223-7223

Region II
26 Federal Plaza
Room 1005
New York, New York 10007
PHONE: (212) 264-2515

Region III
6th & Walnut Streets
Philadelphia, Pennsylvania 19106
PHONE: (215) 597-9826

Region IV
345 Courtland Street, N.E.
Atlanta, Georgia 30308
PHONE: (404) 881-3004

Region V
230 South Dearborn Street
Chicago, Illinois 60604
PHONE: (312) 353-2072

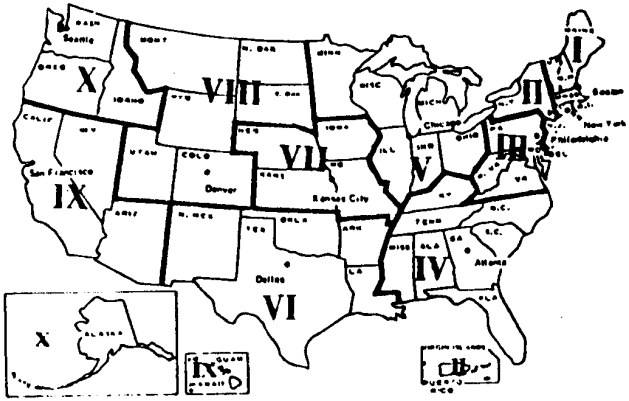
Region VI
1201 Elm Street
Dallas, Texas 75270
PHONE: (214) 749-1151

Region VII
1725 Baltimore Avenue
Room 249
Kansas City, Missouri 64108
PHONE: (816) 374-5894

Region VIII
1860 Lincoln Street
Denver, Colorado 80295
PHONE: (303) 837-4904

Region IX
215 Fremont Street
San Francisco, California 94105
PHONE: (415) 556-6694

Region X
1200 6th Avenue
Seattle, Washington, 98101
PHONE: (206) 442-1203



REGION NUMBER ONE

Maine:

Robert A. Demkowicz, Coord.
Hazardous Waste Management
Bureau of Land Quality Control
Dept. of Environmental Protect.
State House
Augusta, Maine 04333
(207) 289-2111

Vermont:

John Malter
Solid Waste Program
Agency of Envir. Conservation
State Office Building
Montpelier, VT 05602
(802) 828-3395

New Hampshire:

Dept. of HEW, Thomas Roy
Bureau of Solid Waste Mgt.
State Lab Building
Hazen Drive
Concord, NH 03301
(603) 271-4610

Massachusetts:

Stephen DeGabriele
Dept. of Envir. Quality Eng.
Division of Hazardous Waste
600 Washington Street
Room 320
Boston, Massachusetts 02111
(617) 727-0774

Rhode Island:

John Leo
Solid Waste Management Program
Dept. of Envir. Management
Cannon Building
Davis Street
Providence, RI 02908
(401) 277-2808

Connecticut:

Tom Turik
PCB Coordinator
Dept. of Environmental Protection
State Office Building
Hartford, Connecticut 06115
(203) 566-4856

REGION NUMBER TWO

New York:

Robert Collin
Chief, Toxic Substances Control Unit
New York State Department of Environmental Conservation
50 Wolf Road
Albany, New York 12233
(518) 567-1254

New Jersey:

David Lipsky
New Jersey State Department of Environmental Protection
Post Office Box 1390
Trenton, New Jersey 08625

REGION NUMBER THREE

Delaware:

Department of Natural Resources and Environmental Control
Delaware Solid Waste Authority
Post Office Box 981
Dover, Delaware 19901
(302) 678-5361

Maryland:

Department of Health & Mental Hygiene
Environmental Health Admin.
Bureau of Sanitary Engineering
201 W. Preston Street
Baltimore, Maryland 21201
(301) 383-2737

Pennsylvania:

Dept. of Environmental Resources
Division of Solid Waste Mgt.
Post Office Box 2063
Harrisburg, Pennsylvania 17120
(717) 787-7381

Virginia:

State Department of Health
Bureau of Solid Waste & Vector Control
401-A Colley Avenue
Norfolk, Virginia 23507
(804) 627-4511

West Virginia:

Department of Health
Solid Waste Program
1800 Washington Street, East
Charleston, West Virginia 25305
(304) 348-2970

REGION NUMBER FOUR

Mississippi:

Jack M. McMillan, Director
Div. of Solid Waste Mgt. & Vector Control
Bureau of Envir. Health
MS State Board of Health
Post Office Box 1700
Jackson, Mississippi 39205
(601) 982-6317/8
FTS OPR: 490-4211

North Carolina:

O. W. Strickland, Acting Head
Solid & Hazardous Waste Mgt. Programs
Division of Health Services
NC Dept. of Human Resources
Post Office Box 2091
Raleigh, North Carolina 27602
(919) 733-2178

South Carolina:

Hartsill W. Truesdale, Director
Solid Waste Management Division
SC Dept. of Health & Environmental Control
2600 Bull Street
Columbia, South Carolina 29201
(803) 758-5681
FTS OPR: 677-5011

Tennessee:

Tom Tiesler, Director
Div. of Solid Waste Management
TN Dept. of Public Health
320 Capitol Hill Building
Nashville, Tennessee 37219
(615) 741-3424
FTS OPR: 853-3424

Alabama:

Alfred S. Chipley, Director
Division of Solid Waste & Vector Control
State Dept. of Public Health
State Office Building
Montgomery, Alabama 36130
(205) 832-6728
FTS OPR: 229-1000

Florida:

William L. Buzick
Environmental Administrator
Solid Waste Mgmt. Program
FL Dept. of Environmental Regulation
Twin Towers Office Building
2600 Blair Stone Road
Tallahassee, Florida 32301
(904) 488-0300

Georgia:

Moses N. McCall, III, Chief
Land Protection Branch
Envir. Protection Division
GA Dept. of Natural Resources
270 Washington Street, SW
Room 822
Atlanta, Georgia 30334
(404) 656-2833

Kentucky:

Roger Blair
Div. of Hazardous Materials & Waste Management
KY Dept. for Natural Resources & Environmental Protection
Capital Plaza Towers - 5th Floor
Frankfort, Kentucky 40601
(502) 564-6716
FTS OPR: 351-6716

Tennessee:

D. Elmo Lunn, Director
Division of Water Quality Control
TN Dept. of Public Health
621 Cordell Hull Building
Nashville, Tennessee 37219
(615) 741-6610
FTS: 853-6610

REGION NUMBER FIVE

Minnesota:

Paul Deneka
Minnesota Pollution Control
1935 W. County Road B-2
Roseville, Minnesota 55113
(612) 296-7735

Wisconsin:

Mr. Perry Manor
Chief of Hazardous Waste Section
State of Wisconsin
Dept. of Natural Resources P.O. Box 7921
Madison, Wisconsin 53707
(608) 266-2857

Illinois:

John Renkes
Illinois Environmental Protection Agency
2200 Churchill Road
Springfield, Illinois 62706
(217) 782-3637

Indiana:

Guinn Doyle, Supr. of Hazardous Waste Program
Solid Waste Mgt. Section
Indiana State Board of Health
P. O. Box 1964 1330 W. Michigan Street
Indianapolis, Indiana 46206
(317) 633-0178

Michigan:

Mr. Richard A. Powers
Office of Toxic Materials Control
MI Dept. of Natural Resources, Envir. Services Div.
Stevens T. Mason Bldg. P.O. Box 30028
Lansing, Michigan 48909
(517) 373-6794

Ohio:

Dr. Edward Glod
Ohio Environmental Protection Agency
361 East Broad Street
Columbus, Ohio 43215
(614) 466-8934

REGION NUMBER SIX

Arkansas:

Buddy Parr
Arkansas Dept. of Pollution
Control and Ecology
Solid Waste Division
8405 Stanton Road
Little Rock, Arkansas
(501) 562-0700 72209

Louisiana:

Jerry Healy
Hazardous Waste Admin.
Dept. of Natural Resources
Post Office Box 44066
Baton Rouge, LA 70804
(504) 342-1227

New Mexico:

John Tompson, Chief
EID Community Support Services
Health and Environmental Dept.
Post Office Box 968
Crown Boulevard
Sante Fe, New Mexico 87503
(505) 827-5271

Oklahoma:

Don Hench
Director of Industrial Waste Div.
Oklahoma State Health Dept.
1000 N. E. 10th Street
Oklahoma City, Okla. 73152
(405) 271-5338

Texas:

Sam Pole
Texas Dept. of Water Resources
Post Office Box 13246
Austin, Texas 78711
(512) 475-2041

Washington, D.C.

Tom Allen
Hazardous Materials Office
Research/Special Programs Administration
Room 8102
400 Seventh Street, SW
Washington, DC 20590
(202) 426-2075

REGION NUMBER SEVEN

Missouri:

Missouri Department of Natural Resources
Division of Environmental Quality
Post Office Box 1368
Jefferson City, Missouri 65101

Kansas:

Kansas Department of Health and Environment
Division of Environment
Forbes Field
Topeka, Kansas 66620

Nebraska:

Nebraska Department of Environmental Control
Box 94877
State House Station
Lincoln, Nebraska 68509

Iowa:

Iowa Department of Environmental Quality
Henry A. Wallace Building
900 East Grand Avenue
Des Moines, Iowa 50319

REGION NUMBER EIGHT

Colorado:

A. J. Hazle, Director
Division of Radiation and
Hazardous Waste Disposal
Department of Health
4210 East 11th Avenue
Denver, Colorado 80220

Montana:

Duane L. Robertson, Chief
Solid Waste Management Bureau
Montana Dept. of Health and
Environmental Science
1400 11th Avenue
Suite A
Helena, MT 59601

North Dakota:

Jay Crawford, Director
Division of Environmental Waste
Management and Research
North Dakota State Health Dept.
1200 Missouri Avenue
Bismark, ND 58505

South Dakota:

Joel Smith
Air Quality and Solid Waste
Program
Dept. of Environmental Protection
Joe Foss Building
Pierre, SD 57501

Wyoming:

Charles Porter
Solid Waste Program Supervisor
Dept. of Envir. Quality
401 West 19th Street
Cheyenne, WY 82002

Utah:

Dale D. Parker, Chief
Bureau of Solid Waste Mgt.
Utah State Div. of Health
150 W. North Temple
Salt Lake City, UT 84113

REGION NUMBER NINE

California:

State Dept. of Health Services
Dr. David Stor
2151 Berkley Way
Berkley, California 94704
(415) 540-2043

Arizona:

Ty Canez
Bureau of Waste Control
AZ Department of Health Services
411 N. 24th Street
Phoenix, Arizona 85008
(602) 255-1160

Nevada:

Program Director
Waste Management
Division of Environmental Protection
Vern Rosse
201 S. Fall Street
Capitol Complex
Room 120
Carson City, Nevada 89710
(702) 885-4676

REGION NUMBER TEN

Alaska:

Richard Stokes
Solid Waste Management
Dept. of Environmental Conservation
Pouch O
Juneau, Alaska 99811
(907) 465-2635

Idaho:

Daryl Koch
Dept. of Health and Welfare
Division of Environment
Solid Waste Management
State House
Boise, Idaho 83720
(208) 334-4118

Washington:

Tom Cook
Department of Ecology
Land Disposal Program PV-11
Olympia, WA 98504
(206) 753-2849

Oregon:

Rich Reiter
Hazardous Waste Program
Dept. of Environmental Quality
Post Office Box 1760
Portland, OR 97207
(503) 229-6434

CITIZEN ENVIRONMENTAL ORGANIZATIONS

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NIOSH

A Recommended Standard for Occupational Exposure to. . . . .

Polychlorinated Biphenyls

A complete criteria document for occupational exposure to polychlorinated biphenyls (PCBs) has been prepared by the National Institute for Occupational Safety and Health (NIOSH). NIOSH recommends a new occupational environmental limit of 1.0 microgram total PCBs per cubic meter of air (μg/cu m).

The environmental limit of 1 μg/cu m is the lowest concentration of PCBs that can be reliably measured by the recommended sampling and analytical methods. This recommendation is based on data from animal studies which have shown PCBs to be carcinogenic and teratogenic, and hence potentially carcinogenic and teratogenic in man. NIOSH recommends that the standard apply to all commercial PCB preparations and that additional research be undertaken to determine whether all PCB isomers have carcinogenic and/or teratogenic potential.

The Toxic Substances Control Act of 1976 (Public Law 94-469) requires the United States Environmental Protection Agency (EPA) to promulgate marking and disposal regulations for PCBs within 6 months after the effective date of the Act. Further, the manufacture, processing, or distribution in commerce, or use of PCBs in any but a totally enclosed manner is banned, effective 1 year after October 11, 1976, the effective date of the Act. Two years after said effective date no person may manufacture PCBs, and their processing and distribution in commerce are to be banned two and one half years from that date. However, the Act allows the Administrator of EPA to rule otherwise if he finds that manufacture, processing, or distribution in commerce, or use in other than a totally enclosed manner will not present an unreasonable risk of injury to health or to the environment. The Toxic Substances Control Act does not affect use of equipment already containing PCBs in totally enclosed systems, so that a potential for occupational exposure to PCBs will continue to exist for many years as a consequence of their transportation, installation, use, and disposal. NIOSH estimates that 12,000 workers have potential occupational exposure as a result of current uses of PCBs in the working environment, i.e., in addition to their exposures from general environmental contamination.

PCBs are defined for the purposes of this recommended standard as commercial preparations of chlorinated biphenyl compounds, including those preparations which may be described as single isomers or classes of isomers, such as monochloro- or decachlorobiphenyls. Since biphenyl has many effects in common with its chlorinated derivatives, biphenyl occurring in commercial preparations of PCBs shall be measured, along with the chlorinated derivatives, and shall be treated in this standard as the chlorinated components of the preparations.

In addition to environmental limits, NIOSH also recommends adherence to work practices and engineering controls to minimize occupational exposure. PCBs are subject to transplacental movement and have been shown to cause liver damage and chloracne as a result of penetration through the skin. Thus, it is recommended that skin contact be prevented by the use of protective clothing and equipment as described in the subject document. NIOSH also recommends that preplacement or initial medical examinations of workers subject to PCB exposure include comprehensive medical and work histories with emphasis on hepatic function, condition of the skin, and reproductive history. Comprehensive physical examinations are called for, with particular attention to the skin and to hepatic function, including determinations of serum transaminase activities. Also, women in the work force who are of child-bearing age shall be advised of the potential adverse effects of PCBs on the unborn child. Women who bear children during employment that involves occupational exposure to PCBs shall be counseled concerning the advisability of nursing their babies.

These criteria for a recommended standard for PCBs are part of a continuing series of criteria documents developed by NIOSH in accordance with provisions of the Occupational Safety and Health Act of 1970. This document was transmitted

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Center for Disease Control
National Institute for Occupational Safety and Health

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to the Department of Labor for review and consideration in the standard setting process September 27, 1977. It was reviewed by 10 consultants, two professional societies, and government agencies having interest in and responsibility for occupational safety and health. The recommended standard is considered appropriate and no additional information that would affect it is available at this time.

The following is the first chapter of the criteria document. It contains the NIOSH recommendations for controlling worker exposure to Polychlorinated Biphenyls.

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I. RECOMMENDATIONS FOR A POLYCHLORINATED BIPHENYLS (PCBs) STANDARD

The National Institute for Occupational Safety and Health (NIOSH) recommends that employee exposure to polychlorinated biphenyls (PCBs) in the workplace be controlled by adherence to the following sections. The standard is designed to protect the health and provide for the safety of employees for up to a 10-hour workday, 40-hour workweek, over a normal working lifetime. The standard is measurable by techniques that are valid, reproducible, and available to industry and governmental agencies. Compliance with the standard should substantially reduce any risk of reproductive or tumorigenic effects of PCBs and prevent other adverse effects of exposure in the workplace. Employees should regard the recommended workplace environmental limit as the upper boundary for exposure and make every effort to keep exposure as low as possible.

Evidence indicates adverse reproductive and tumorigenic effects in experimental animals exposed to certain commercial PCB preparations. Currently available information is not adequate to demonstrate that other commercial PCB preparations do not have these effects. Should sufficient information become available to indicate that the standard offers greater or lesser protection from some chlorobiphenyl isomers or commercial preparation than is needed, it will be considered for revision.

The Toxic Substances Control Act of 1976 (Public Law 94-469) required the US Environmental Protection Agency (EPA) to prescribe marking and disposal regulations for PCBs by July 1, 1977 (**Federal Register** 42:26563-77, May 24, 1977). By this Act, the manufacture, processing, distribution in commerce, or use of PCBs in any but totally enclosed systems is to be banned, effective 1 year after the date of its enactment, October 11, 1976. Two years after the enactment date PCB manufacture is to be banned, and processing and distribution in commerce are to be banned 2.5 years from that date. However, the Act allows the Administrator of EPA to rule otherwise if he finds that manufacture, processing, distribution in commerce, or use in other than totally enclosed systems will not present an unreasonable risk of injury to health or to the environment. The Act does not affect use of equipment already containing PCBs in totally enclosed systems, so that a potential for occupational exposure to PCBs will continue to exist for many years as a consequence of their transportation, installation, use, and disposal. The part of the Act specific for PCBs is presented in Figure 1-1.

"PCBs" are defined for this recommended standard as commercial preparations of chlorinated biphenyl compounds, including those preparations which may be described as single isomers or classes of isomers, such as Decachlorodiphenyl. Biphenyl and its monochlorinated derivatives occuring in commercial preparations of PCBs shall be measured along with the polychlorinated derivatives, and shall be treated in this standard as the polychlorinated components of the preparations. "Occupational exposure to PCBs," is defined as working with PCBs or with equipment containing PCBs that can become airborne or that can spill or splash on the skin or into the eyes, or the handling of any solid products that may result in exposure to PCBs by skin contact or by inhalation. The term "PCB work area" is defined as an area where there is occupational exposure to PCBs. In areas where no occupational exposure to PCBs occurs, but where PCBs are present in equipment in the workplace, adherence is required only to Section 8(a).

Section 1 — Environmental (Workplace Air)

(a) Concentration

Occupational exposure to polychlorinated biphenyls (PCBs) shall be controlled so that no worker is exposed to PCBs at a concentration greater than 1.0 microgram total PCBs per cubic meter of air (1.0 μg/cu m), determined as a time-weighted average (TWA) concentration, for up to a 10-hour workday, 40-hour workweek.

(b) Sampling and Analysis

The recommended TWA occupational exposure limit for PCBs has been determined to be the lowest reliably detectable limit by the sampling and analytical methods recommended in this document. Environmental samples shall be collected and analyzed as described in Appendices I and II, or by any methods shown to be at least equivalent in accuracy, precision, and sensitivity to the methods specified.

Section 2 — Medical

Medical surveillance shall be made available to all employees subject to occupational exposure to PCBs.

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(a) Preplacement or initial medical examinations for workers shall include:

(1) Comprehensive medical and work histories with special emphasis on hepatic function, skin condition, and reproductive history.

(2) Comprehensive physical examination with particular attention to the skin and to hepatic function including determinations of serum glutamic-oxaloacetic transaminase (SGOT) and serum glutamic-pyruvic transaminase (SGPT) activities. The responsbile physician may also wish to obtain measurements of serum triglyceride concentrations or of other indices of fat metabolism.

(3) A judgment of the employee's ability to use positive pressure respirators.

(b) During examinations, applicants or employees having medical conditions that could be directly or indirectly aggravated by exposure to polychlorinated biphenyls or formulations containing polychlorinated biphenyls shall be counseled on the increased risk of impairment of their health that might result from working with these substances.

(c) Women in the work force who are of childbearing age shall be advised of the potential adverse effects of PCBs on the unborn child. Those who bear children while working with PCBs shall be counseled concerning the advisability of nursing their babies.

(d) Initial medical examinations shall be made available to all workers as soon as practicable after promulgation of a standard based on these recommendations.

(e) Periodic examinations shall be made available at least annually and include: (1) interim medical and work histories, and (2) physical examinations as outlined in paragraphs (a)(1) and (a)(2) of this section.

(f) If evidence of adverse effects of exposure to PCBs is suspected or confirmed, appropriate medical care shall be made available to the affected worker(s).

(g) Pertinent medical records shall be maintained for all employees exposed to PCBs in the workplace. Such medical records shall be maintained for the period of employment plus 30 years. These records shall be made available to the designated medical representatives of the Secretary of Health, Education, and Welfare, of the Secretary of Labor, of the employer, and of the employee or former employee.

Section 3 — Labeling and Posting

All labels and warning signs shall be printed both in English and in the predominant language of non-English-reading workers. Illiterate workers and workers reading languages other than those used on labels and posted signs shall be otherwise informed regarding hazardous areas and shall be informed of the instructions printed on labels and signs.

(a) Labeling

The following warning label shall be affixed in a readily visible location on PCB-processing or other equipment, and on PCB-storage tanks or containers:

POLYCHLORINATED BIPHENYLS
(PCBs)

DANGER! CONTAINS
POLYCHLORINATED BIPHENYLS
CANCER SUSPECT AGENT

Use only with adequate ventilation.
Do not get in eyes, or on skin or clothing.

First-Aid: In case of skin or eye contact, flush with running water.

(b) Posting

Warning placards shall be affixed in readily visible locations in or near PCB work areas. The information contained thereon shall be arranged as in the following example.

POLYCHLORINATED BIPHENYLS
(PCBs)

DANGER!

CANCER SUSPECT AGENT

AUTHORIZED PERSONNEL ONLY

Do not enter unless area is adequately ventilated.
Do not get in eyes, or on skin or clothing.

First-Aid: In case of skin or eye contact, flush with running water.

Section 4 — Personal Protective Equipment and Clothing

(a) Protective Clothing

In any operation where workers may come into direct contact with PCBs, protective clothing

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impervious to PCBs shall be worn. Gloves, boots, overshoes, and bib-type aprons that cover boot tops shall be provided when necessary. Protective apparel shall be made of materials which most effectively prevent skin contact with PCBs where it is most likely to occur. Employers shall ensure that all personal protective clothing is inspected regularly for defects and that it is in a clean and satisfactory condition.

(b) Eye Protection

Chemical safety goggles, face shields (8-inch minimum) with goggles, or safety glasses with side shields shall be provided by employers and shall be worn during any operation in which PCBs are present. If liquid or solid PCBs contact the eyes, the eyes shall be irrigated immediately with large quantities of water and then examined by a physician or other responsible medical personnel. (A drop of vegetable oil on the eye has been found to reduce the resultant irritation.) Eye protection shall be in accordance with 29 CFR 1910.133 and ANSI Z 87.1-1968.

(c) Respiratory Protection

(1) Engineering controls shall be used when needed to keep concentrations of airborne PCBs at or below the recommended TWA occupational exposure limit. The only conditions under which compliance with the permissible exposure limit may be achieved by the use of respirators are:

(A) During the time necessary to install or test the required engineering controls.

(B) For nonroutine maintenance or repair activities.

(C) During emergencies when concentrations of airborne PCBs may exceed the permissible limit.

(2) When the use of respirators is permitted by paragraph c(1) of this section, respirators shall be selected and used in accordance with the following requirements:

(A) The employer shall establish and enforce a respiratory protection program meeting the requirements of 29 CFR 1910.134.

(B) The employer shall provide respirators in accordance with Table 1-1 and shall ensure that employees properly use the respirators provided. The respirators shall be those approved by NIOSH or the Mining Enforcement and Safety Administration. The standard for approval is specified in 30 CFR 11. The employer shall ensure that respirators are properly cleaned, maintained, and stored when not in use.

TABLE 1-1

RESPIRATOR SELECTION GUIDE

Concentration of PCBs	Respirator Type Approved under Provisions of 30 CFR 11
Greater than 1.0 μg/cu m or Emergency (entry into area of unknown concentration)	(1) Self-contained breathing apparatus with full facepiece operated in pressure-demand or other positive pressure mode. (2) Combination Type C supplied-air respirator with full facepiece operated in presure-demand or other positive pressure mode and an auxiliary self-contained breathing apparatus operated in presure demand or other positive pressure mode.

Section 5 — Informing Employees of Hazards from PCBs

(a) All new and present employees in any area in which PCBs are used shall be informed of the hazards, relevant symptoms, and effects of overexposure to PCBs, and the precautions to be observed for safe use and handling of these materials.

(b) All employees involved with the manufacture, use, transport, or storage of PCBs shall be informed that PCBs have been found to induce tumors in experimental animals after repeated oral ingestion and that because of these findings it is concluded that PCBs are potential human carcinogens; employees shall also be informed that adverse reproductive effects may result from occupational exposure to PCBs.

(c) The employer shall institute a continuing education program, conducted by instructors qualified by experience or training, to ensure that all employees occupationally exposed to PCBs

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have current knowledge of job hazards, proper maintenance and cleanup methods, and proper use of protective clothing and equipment, including respirators. The instructions shall include a general description of the medical surveillance program and of the advantages to the employee of participation. Special attention shall be given to women in the workplace. They shall be made aware of the potential adverse effects of PCBs on the unborn child, and of the known transport of PCBs to breast milk. Elements of the program shall also include:

Emergency procedures and drills;
Instruction in handling spills and leaks;
Decontamination procedures;
Firefighting equipment location and use;
First-aid procedures, equipment location, and use;
Rescue procedures;
Confined space entry procedures;
Low warning (odor) properties of PCBs.

(d) The information explaining the hazards of working with PCBs shall be kept on file and be readily accessible to workers at all places of employment where PCBs are manufactured, used, stored, or transported. Required information shall be recorded on the "Material Safety Data Sheet" shown in Appendix III, or similar form approved by the Occupational Safety and Health Administration, US Department of Labor.

Section 6 — Work Practices and Engineering Controls

(a) Regulated Areas

Access to PCB work areas shall be regulated and limited to authorized persons. A daily roster shall be kept of persons entering such areas.

(b) Handling of PCBs and General Work Practices

(1) Operating instructions shall be formulated and posted where PCBs are handled or used.

(2) Transportation and use of PCBs shall comply with all applicable local, state, and federal regulations.

(3) PCBs shall be stored in tightly closed containers in well-ventilated areas.

(4) When PCB storage containers are being moved, or when they are not in use and are disconnected, valve protection covers shall be in place. Containers shall be moved only with the proper equipment and shall be secured to prevent dropping or loss of control during transport.

(5) Storage facilities shall be designed to contain spills completely within surrounding dikes and to prevent contamination of workroom air.

(6) Ventilation switches and emergency respiratory equipment shall be located outside storage areas in readily accessible locations which will remain minimally contaminated with PCBs in an emergency.

(7) Process valves and pumps shall be readily accessible and shall not be located in pits or congested areas.

(8) Containers and systems shall be handled and opened with care. Approved protective clothing as specified in Section 4 shall be worn by employees engaged in opening, connecting, and disconnecting PCB containers and systems. Adequate ventilation shall be provided to minimize exposures of such employees to airborne PCBs.

(9) PCB-operating and storage equipment and systems shall be inspected daily for signs of leaks. All equipment, including valves, fittings, and connections shall be checked for leaks immediately after PCBs are introduced therein.

(10) When a leak is found, it shall be repaired or otherwise corrected immediately. Work shall resume normally only after necessary repair or replacement has been completed, the area has been ventilated, and the concentration of PCBs has been determined by monitoring to be at or below the recommended TWA concentration limit.

(c) Control of Airborne PCBs

(1) Suitable engineering controls, designed to maintain exposure to airborne PCBs at or below the limit prescribed in Section 1(a), shall be used. Complete enclosure of processes is the recommended method for control of PCB exposure. Local exhaust ventilation may also be effective, used alone or in combination with process enclosure. When a local exhaust ventilation system is used, it shall be so designed and operated as to prevent accumulation or recirculation of airborne PCBs in the workplace environment and to effectively remove PCBs from the breathing zones of employees. Exhaust ventilation systems discharging to outside air must conform to applicable local, state, and federal regulations and must not constitute a hazard to employees or to the general population. Before maintenance work on control equipment begins, the generation of airborne PCBs shall be eliminated to the extent feasible.

Enclosures, exhaust hoods, and ductwork shall be kept in good repair so that designed airflows are maintained. Airflow at each hood shall be measured at least semiannually and preferably monthly. Continuous airflow indicators are recommended, such as water or oil manometers properly mounted at the juncture of fume hood and duct throat (marked to indicate acceptable airflow). A log shall

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be kept showing design airflow and the results of semiannual airflow measurements..

(2) Forced-draft ventilation systems shall be equipped with remote manual controls and shall be designed to shut off automatically in the event of a fire in the PCB work area.

(d) Special Work Areas

(1) PCB Hazard Areas

A hazard area shall be considered as any space having physical characteristics and containing sources of PCBs, such as transformers, that could result in PCB concentrations in excess of the recommended airborne PCB exposure limit. Exits shall be plainly marked, conveniently located, and open outwardly into areas which will remain minimally contaminated in an emergency.

(2) Confined or Enclosed Spaces

Entry into confined or enclosed spaces, such as tanks, pits, process vessels, and tank cars where there is limited egress, shall be controlled by a permit system. Permits shall be signed by an authorized representative of the employer and shall certify that appropriate measures have been taken to prevent adverse effects on the worker's health as a result of his or her entry into such space.

Confined or enclosed spaces which have contained PCBs shall be thoroughly ventilated to assure an adequate supply of oxygen, tested for PCBs and other contaminants, and inspected for compliance with these requirements prior to each entry. Adequate ventilation shall be maintained while workers are in such spaces. Leakage of PCBs into such confined or enclosed spaces while work is in progress shall be prevented by disconnecting and blanking the PCB supply lines. Each individual entering such confined or enclosed space shall be furnished with appropriate personal protective equipment and clothing and be connected by a lifeline harness to a standby worker stations outside of the space. The standby worker shall also be equipped for entry with approved personal protective equipment and clothing and have contact with a third person. The standby person shall maintain communication (visual, voice, signal line, telephone, radio, or other suitable means) with the employee inside the confined or enclosed space.

(e) Emergency Procedures

For all PCB work areas where there is a potential for the occurrence of emergencies, employers shall take all necessary steps to ensure that employees are instructed in, and follow, the procedures specified below as well as any others appropriate to the specific operation or process.

(1) If PCBs leak or are spilled, the following steps shall be taken:

(A) All nonessential personnel shall be evacuated from the leak or spill area.

(B) The area of the leak of spill shall be adequately ventilated to prevent the accumulation of vapors.

(C) If the PCBs are in liquid form, they shall be collected for reclamation or sorbed in vermiculite, dry sand, earth, or similar nonreactive material.

(2) Personnel entering the spill or leak area shall be furnished with appropriate personal protective equipment and clothing. All other personnel shall be prohibited from entering the area.

(3) Only personnel trained in the emergency procedures and protected against the attendant hazards shall shut off sources of PCBs, clean up spills, control and repair leaks, and fight fires, in areas where PCBs are used.

(4) All wastes and residues containing PCBs shall be collected in PCB-resistant containers and appropriately disposed of (**Federal Register** 42:26563-77, May 24, 1977).

(5) Safety showers, eyewash fountains, and washroom facilities shall be provided, maintained in working condition, and located so as to be readily accessible to workers in all areas where the occurrence of skin or eye contact with PCBs is likely. If liquid or solid PCBs are splashed or spilled on an employee, contaminated clothing shall be removed promptly and the skin washed thoroughly with soap and water for at least 15 minutes. Eyes shall be irrigated immediately with copious quantities of running water for at least 15 minutes if liquid or solid PCBs get into them. A drop of vegetable oil may be applied to the eye to relieve the irritating effect of PCBs.

Section 7 — Sanitation Practices

(a) Employees occupationally exposed to PCBs shall be provided with separate lockers or other storage facilities for street clothes and for work clothes.

(b) Employees occupationally exposed to PCBs shall not wear work clothing away from their place of employment.

(c) Employees occupationally exposed to PCBs shall be provided clean work clothing daily, and cleaning establishments shall be informed as to the hazards of handling PCBs and proper disposal procedures for PCB-contaminated waste water.

(d) Facilities for shower baths shall be provided for employees occupationally exposed to PCBs. Workers should shower before changing into street clothes.

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(e) Employees exposed to PCBs shall be advised to wash their hands and exposed skin before eating drinking, smoking or using toilet facilities during the work shift.

(f) Food, drink, or smoking materials shall not be permitted in areas where PCBs are handled, processed, or stored.

Section 8 — Monitoring and Recordkeeping Requirements

(a) Monitoring

(1) As soon as practicable after the promulgation of a standard based on these recommendations, each employer who manufactures, processes, handles, stores or otherwise uses PCBs shall determine by an industrial hygiene survey whether occupational exposure to PCBs may occur. Surveys shall be repeated at least once every year and within 30 days of any process change likely to result in occupational exposure to PCBs. Records of these surveys, including the basis for any conclusion that there may be no occupational exposure to PCBs, shall be retained until the next survey has been completed.

(2) If occupational exposure to PCBs is determined to be possible, a program of personal monitoring shall be instituted to measure or permit calculation of the exposures of all employees.

(A) In all personal monitoring, samples representative of the employees' breathing zones shall be collected.

(B) For each TWA concentration determination, a sufficient number of samples shall be taken to characterize each employee's exposure during each work shift. Variations in work and production schedules and in employees' locations and job functions shall be considered in choosing sampling times, locations, and frequencies.

(C) Each operation in each work area shall be sampled at least once every 3 months.

(3) If an employee is found to be exposed to PCBs in excess of the recommended TWA concentration limit, control measures shall be initiated, the employee shall be notified of the exposure and of the control measures being implemented to correct the situation, and the employee shall be monitored every 30 days. Such monitoring shall continue until two such consecutive determinations indicate that the employee's exposure no longer exceeds the recommended TWA concentration limit. Routine monitoring may then be resumed.

(b) Recordkeeping

Environmental monitoring records shall be maintained for at least 30 years after the employee's last occupational exposure to PCBs. These records shall include the dates and times of measurements, job function and location of employees within the worksite, methods of sampling and analysis used, types of respiratory protection in use at the time of sampling, TWA concentrations found, and identification of exposed employees. Each employee shall be able to obtain information on his or her own environmental exposures. Daily rosters of authorized persons who enter regulated areas shall be retained for 30 years. Environmental monitoring records and entry rosters shall be made available to designated representatives of the Secretary of Labor and of the Secretary of Health, Education, and Welfare.

Pertinent medical records for each employee shall be retained for 30 years after the employee's last occupational exposure to PCBs. Records of environmental exposures applicable to an employee should be included in that employee's medical records. These medical records shall be made available to the designated medical representatives of the Secretary of Labor, of the Secretary of Health, Education, and Welfare, of the employer, and of the employee or former employee.

Also see Reference DHEW Publication #77-225
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RECORDS

NETA CONFERENCE - FEBRUARY 1980

DALLAS, TEXAS

THE PHYSIOLOGICAL ASPECTS OF PCBs

REGARDING THE SERVICE COMPANY

BY

RICHARD R. LUSSIER, JR.
NORTHEAST ELECTRICAL TESTING
MERIDEN, CONNECTICUT

Introduction

The final PCB ban rule of May 31, 1979, published in the Federal Register 40 CFR Part 761 leaves little doubt that polychlorinated biphenyls may be hazardous to our health. Studies have shown that PCBs, after being released into the environment, do not biodegrade into new chemical configurations, but instead bioaccumulate in organisms within the environment. Also, a biomagnification process takes place. As PCBs are accumulated into the tissues of living organisms, they are passed along the food chain with accumulations mounting from everyday consumption of contaminated organisms by higher forms of life. At the end of this chain is man who receives the total accumulated dosage from the forms of life which may have consumed PCBs before him.

Identification

The primary manufacturer of PCBs was Monsanto Corporation who utilized the trade name Askarel. Other corporations who were in the transformer and capacitor manufacturing industry purchased the Askarel from Monsanto and assigned their own trade names to the product. Among these are Aroclor, Pydraul, Therminol, Pyroclor, Santotherm, Pyralene, Pyranol, Inerteen, Asbestol, Chlorextol, Diachlor, Dykanol, Elemex, Hyvol, No-Flamol, Saf-T-Kuhl, Aroclor B, Chlorinol, Clorphen and Eucarel. Askarel may also be identified by its unique odor which is similar to that of moth balls.

Contamination

The first plant to produce polychlorinated biphenyls opened in 1929 in Anniston, Alabama. From 1929 to 1977, one and one-half billion tons were manufactured. Of this, a substantial portion has been released into the environment through random dumping of wastes and accidental spills. Be advised that it was not common knowledge until the early 1970's that PCBs presented an environmental problem. The handling of wastes in the past reflected this ignorance.

Initially, the main use of PCBs was for heat transfer and as a dielectric in power transformers. Heat and fire properties of PCBs made them of special value in these devices. Later, PCBs were found useful in entirely new ways such as in making transformers for television sets and fluorescent fixtures. They were also used extensively in capacitors and other electrical devices. They have been used in paints, adhesives, caulking compounds, plasticizers, inks, lubricants, carbonless copy paper, sealants, coatings and dust control agents.

PCBs now have the distinction of being the most wide spread contaminant on this planet. Traces can be found in every ocean in the world. They can be found in the Arctic and can be measured in the snows of the Anarctic. PCBs can be found in the milk of nursing mothers, not only in industrialized areas but throughout the world. In studies of human milk, seven times the amount of PCBs permitted for cows' milk has been found.

In 1972, New York state scientists found alarmingly high levels of PCBs in Hudson River fish normally used for human consumption. The following is public record: "The PCB was coming from Hudson Falls in Ft. Edwards in upstate New York. General Electric plants there had discharged half a million pounds of PCB-contaminated wastes into the river over a period of years through leakage or spills."[1] General Electric was fined four million dollars. The current estimate for the removal is two hundred million dollars and it is questionable if this is technologically possible. It is this incident that finally led to congressional action resulting in the Toxic Substances Control Act of 1976.

Toxic Effect in Humans

If we were to perform a random sampling of PCB accumulation in humans, the average individual's blood level would show 5 to 20 parts per billion. As a comparison, a study performed on capacitor workers in New York, who were experiencing deleterious effects attributed to PCB exposure, were in the magnitude of 30 to 200 parts per billion and 10 to 15 parts per million in their fat samples. Fat levels of PCB generally run about 3 parts per million in the general population. The infinitely small quantities are what make research so difficult in PCB studies. It is impossible to put a radioactive tracer into a subject without introducing a quantity of PCBs that would have a harmful or fatal effect on the subject.

There is, however, enough information documented through studies showing definitely that PCB accumulation in humans causes chloracne, impotence, reproductive failures, extraordinary headaches, digestive disorders and jaundice. PCBs have, in laboratory animal tests, caused tumors and skin lesions in addition to the above. PCBs are suspected of altering the DNA molecular chain causing mutants and other birth defects. They also rate very high on researchers' lists of suspected carcinogens.

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[1]WGBH Transcripts - WGBH Educational Foundation - Nova, Plague on Our Children.

In a recent government supported study, 100% of human sperm tested showed PCB contamination. A definite correlation between the amount of PCB contamination and lower sperm count was found. Even more interesting is the fact that, since the introduction of PCBs into the environment, the average American male's sperm count has dropped up to 30%. To date, the link between this drop and PCBs has yet to be proved; however, the coincidence is alarming.

Service Companies

In early October of 1979, Northeast Electrical Testing consulted with Dr. Mark Cullen of the Yale Occupational Medicine Program in New Haven, Connecticut. Northeast Testing had been handling PCBs through sampling and servicing Askarel-filled transformers for eight years. In addition, several of the technicians had experienced exposure over many years prior to their employment with Northeast Testing.

Dr. Cullen was consulted to determine the extent of PCB accumulation in the technicians and as advisor for safety procedures and techniques in the performance of PCB work. Since no study had yet been performed on a service company, the results of the testing would be compared to those in a study performed in New York on capacitor workers in a manufacturing plant. In addition, he would use two "control" volunteers for comparison data. The following tests and evaluations were to be performed on each subject: differential blood count, urinalysis, complete chest X-rays, pulmonary function tests, serum PCB level, fat PCB level, and a complete physical examination including dermatology. The tests were to be performed at Yale-New Haven Hospital; the fat and serum samples to be sent to Mount Sinai Hospital in Manhattan for gas chromatography and electron capture detection. Each subject was extensively interviewed to determine work habits and history of PCB exposure. After initial consulation, Dr. Cullen advised that no one from the company who was exposed to PCBs should conceive children until the tests were complete and the results analyzed.

In the latter part of October the tests were performed, taking about four hours for each individual. No one experienced any pain, but a 3-inch contusion was left where fat sample was extracted which healed in several days.

The results were forwarded to Northeast Electrical Testing in five weeks. A meeting between personnel and Dr. Cullen took place shortly thereafter for an explanation of results. Dr. Cullen opened the meeting stating, "Bottom line, which I'll start with and work my way back, is that no one had an enormous accumulation of PCBs and, as a group, the numbers were to some extent almost surprisingly low. Everyone was pretty much normal by every criteria by which we evaluate." In addition, no one tested in this survey showed any physiological symptoms of PCB exposure.

As a group, the results were as follows:

Complaints		Varied or none dependent on the individual
Exposure History		
PCB Estimate	*	Days/Year Entry
	*	Days/Month Filtering
	*	Days/Month Lab Work
Last Contact	*	
Physical Exam		All normal with minor exceptions
Laboratory Data		
Blood count, differential		Normal
Urinalysis		Normal
Chest X-ray		Normal
Pulmonary Function Tests		Normal
Serum PCB Level		5 - 30 parts per billion
Fat PCB Level		3 - 5 parts per million
Interpretation		Minimal accumulation
Recommendation		None pertaining to required medical treatment

*Numbers varied per individual.

The test results on an individual basis were indicative of the amount of exposure one had received. Higher accumulations were found in those who had worked with PCBs over a longer period of time or in those who had a greater frequency of exposure. The two control subjects tested along with the exposed subjects had PCB levels of 5 and 7 parts per billion in the blood and 3 parts per million in the fat.

Dr. Cullen pointed out that as of this date no safe levels of accumulation have yet been determined and that it may be thirty years before enough studies have been performed to ascertain these levels. He also stated that "there has been some accumulation in some of you" (Northeast Testing personnel). "No one has a large accumulation, but I think that there is enough evidence to show that protective equipment is in order."

Recommendations

Northeast Electrical Testing, with the help and advise of Dr. Cullen and occupational safety experts, has concluded that the following equipment be

used until further testing or additional knowledge of PCB physiological effects prove that this equipment is unwarranted:

A. The use of positive pressure respirators including full face mask fed from a compressor in an area where no immediate PCB risk is imminent.

B. Disposable clothing (paper with a plastic coating) will be used. The clothing consists of full coveralls, shoe covers, hats and gloves.

C. The use of a "step off" area utilizing sheet plastic covered with commercially available blotter paper to absorb small spills and contain the area in which the PCB liquid is handled.

D. The waste clothing and step off pad will be placed into a separate 55-gallon drum for disposal or storage upon job completion.

Conclusion

By no means is this study and these recommendations to be considered complete. The study reflects the exposures, work habits and characteristics of one small company. The Yale Occupational Medicine Program welcomes inquiries and/or additional subjects on which to gather more data. They will be working with Northeast Electrical Testing in the future, gathering more information such as how much PCB in particulate form is the technician exposed to when a transformer is opened. It is hoped that in the near future it will be learned just how many precautions are required in sampling dielectric versus servicing or retrofilling.

The client must be advised as to the potential dangers of PCBs in regard to the environment, and must be made knowledgeable in order to act in a rational manner. Qualified personnel should be used for all work on units containing PCBs.

Let us all bear in mind the responsibility we have to our environment and our children.

(This paper is reprinted by permission from Mr. Richard R. Lussier, Jr., Northeast Electrical Testing, Meriden, Connecticutt.)

MONS 002907

PCB WASTE TRACKING FORM

I. GENERATOR OF WASTE (Must be filled in by Producer)

A. NAME _____ TELEPHONE NO. _____

STREET OR ROUTE _____

CITY, STATE, ZIP CODE _____

B. PRODUCER ORDER # _____ PLACED BY _____ DATE _____

II. DESCRIPTION OF WASTE (Must be filled in by Producer)

A. TYPE OF PCB WASTE (✓One Below)

- ☐ PCB Fluid (Dielectric, Hydraulic, etc.)
- ☐ PCB Contaminated Soil
- ☐ PCB Contaminated Cleanup Materials (Rags, etc.)
- ☐ PCB Contaminated Fluid
- ☐ [illegible]
- ☐ PCB Contaminated Machinery
- ☐ [illegible]
- ☐ PCB Contaminated Process Waste
- ☐ PCB Contaminated Solvents
- ☐ Other (Specify) _____
- ☐ PCB Contaminated Oil

B. REVERSE DESCRIPTION OF PCB WASTE

1. Total Quantity _____ (✓One Below)
   - ☐ Lbs.
   - ☐ Tons
   - ☐ Cu. Yards
   - ☐ Gal.
   - ☐ 55 Gal. Drums
   - ☐ Bulk Tanks
   - ☐ Other (Specify) _____
2. Number of Containers _____ (✓One Below)
   - ☐ 55 Gal. Drums
   - ☐ Bulk Tanks
   - ☐ Other (Specify) _____
3. Physical State _____ (✓One Below)
   - ☐ Solid
   - ☐ Liquid
   - ☐ Gas
   - ☐ Sludge
4. PCB Concentration _____ PPM
5. Hazardous Properties (✓Below All That Apply)
   - ☐ Volatile
   - ☐ Toxic
   - ☐ Corrosive
   - ☐ Flammable
   - ☐ Explosive

C. SPECIAL HANDLING INSTRUCTIONS AND TOXIC EFFECTS (If Any) _____

III. INTENDED DISPOSITION OF WASTE (Must be filled in by Producer)

A. NAME OF INTENDED HAULER _____

BUSINESS STREET OR ROUTE _____

BUSINESS CITY, STATE, ZIP CODE _____

B. NAME OF INTENDED DISPOSER OR SERVICE FACILITY _____

STREET OR ROUTE _____

CITY, STATE, ZIP CODE _____

IV. GENERATOR CERTIFICATION

I certify that the foregoing information is true and correct.

NAME AND TITLE (Typed or Printed) _____

SIGNATURE _____ DATE _____

Keep Generator Copy for your records. Give remaining copies to transporter.

V. TRANSPORTER OR FULL SERVICE CONTRACTOR (Must be filled in by Hauler)

A. NAME _____ TELEPHONE NO. _____

STREET OR ROUTE _____

CITY, STATE, ZIP CODE _____

B. STATE LIQUID OR SOLID WASTE HAULER LICENSE NUMBER _____

C. HAULER JOB NO. _____ PICKUP DATE _____

D. VEHICLE LICENSE NO. _____ STATE _____ NO. OF TRIPS _____

VI. TRANSPORTER OR FULL SERVICE CONTRACTOR

I certify as true and correct that the waste described in Part II of this manifest was hauled by me to the following named Service or Disposal Facility, and was accepted by that Service or Disposal Facility.

NAME AND TITLE (Typed or Printed) _____

SIGNATURE _____ DATE _____

Keep Transporter Copy for your records. Give remaining copies to Service or Disposal Facility

VII. SERVICE FACILITY (Must be filled in by Facility)

A. NAME _____ TELEPHONE NO. _____

STREET OR ROUTE _____

CITY, STATE, ZIP CODE _____

B. TOTAL QUANTITY OF PCB RECEIVED _____ (✓ONE)

- ☐ Lbs.
- ☐ Tons
- ☐ Gal.
- ☐ Cu. Yds.
- ☐ 55 Gal. Drums
- ☐ Bulk Tanks
- ☐ Other (Specify) _____

C. DESCRIPTION OF PCB WASTE PRODUCE RECEIVED _____

D. PCB WAS ☐ Disposed of ☐ Reclaimed

E. NAME OF INTENDED DISPOSER _____

VIII. SERVICE FACILITY CERTIFICATION

I certify as true and correct that the Transporter or Full Service Contractor named above delivered the waste described in Part II of this manifest to this Service Facility; that this waste was an acceptable material under the terms of federal, state and local regulations; and that it was processed at this facility.

NAME AND TITLED (Typed or Printed) _____

SIGNATURE _____ DATE _____

Keep Service Facility Copy for your records. Send Generator Copy to Generator if PCB waste was reclaimed. Give remaining copy(s) to Disposal Facility if waste is intended for disposal.

IX. DISPOSER OF WASTE (Must be filled in by Disposer)

A. NAME _____ TELEPHONE NO. _____

STREET OR ROUTE _____

CITY, STATE, ZIP CODE _____

B. ADDRESS OF DISPOSAL SITE IF DIFFERENT FROM ABOVE _____

C. STATE INCINERATOR PERMIT NO. OR LANDFILL LICENSE NO. _____

D. QUANTITY OF PCB WASTE RECEIVED AND DISPOSED

1. Total Quantity _____ (✓One Below)
   - ☐ Lbs.
   - ☐ Tons
   - ☐ Gals
   - ☐ Cu. Yards
2. Number of Containers _____ (✓One Below)
   - ☐ Landfill
   - ☐ Incineration
   - ☐ Other (Specify)

E. DISPOSAL METHOD (✓One Below)
- ☐ Landfill
- ☐ Incineration
- ☐ Other (Specify) _____

F. DISPOSAL DATE _____

X. DISPOSER CERTIFICATION

I certify as true and correct that the Transporter or Full Service Contractor named above delivered the waste described in Part II of this manifest to this Disposal Facility; that the waste was an acceptable material under the terms of federal, state and local regulations; and that it was disposed of at this site.

NAME AND TITLE (Typed or Printed) _____

SIGNATURE _____ DATE _____

Keep Disposer of Waste Copy for your records. Send a copy to Generator

SPILLS OF PCB MUST BE REPORTED

(CONTINUED NEXT COLUMN)

MONS 002908

PCB RECORD

Unit #	Material Description	Removed From	Quantity Gallons	Weight Kgms.	Volume FT3	Date Into Storage	Date Shipping to Disposal	Transport Company	Disposal Site	Disposal Manifest	

APPENDIX

DOT SPECIFICATION METAL SHIPPING CONTAINERS

The information on selected containers found in this booklet has been abstracted from the Code of Federal Regulations, Title 49, Parts 100-199 and is intended to serve as an aid for in-house use when reviewing your hazardous materials procedures. It does not include or refer to all applicable D.O.T. requirements.

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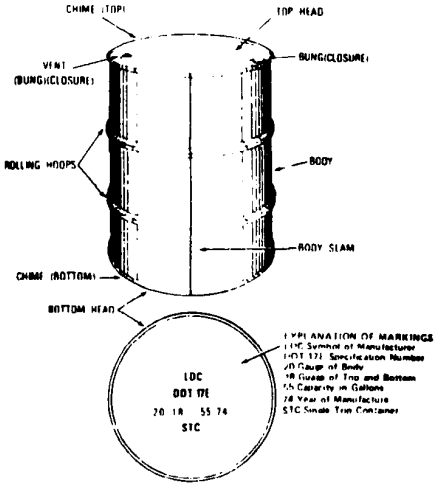
U. S. DEPARTMENT OF TRANSPORTATION
Materials Transportation Bureau
Office of Hazardous Materials Operations
2100 Second Street, S. W.
Washington, D. C. 20590

Revised September 1976
Reprinted March 1977

MONS 002911

TYPICAL LIGHT GAUGE CLOSED HEAD DRUM

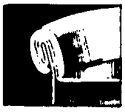
SPECIFICATION 17E, STEEL DRUM, SINGLE TRIP CONTAINER (STC) REMOVABLE HEAD CONTAINERS NOT AUTHORIZED



TYPICAL CHIME CONSTRUCTION STEEL DRUMS



DOUBLE SEAMED CHIME SECTION

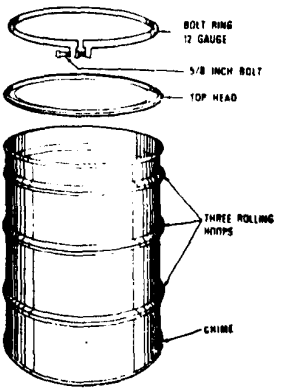


DOUBLE SEAMED CHIME SECTION WITH REINFORCING RING

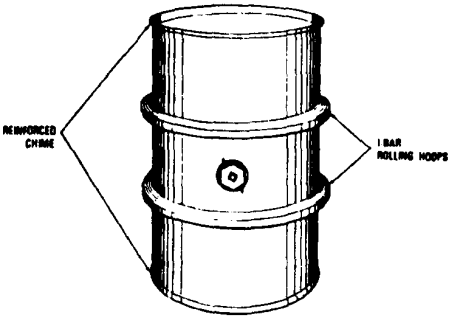


WELDED CHIME SECTION WITH REINFORCING RING

TYPICAL DOT OPEN HEAD DRUMS
DOT-17C OR DOT 17H



55 GALLON



DOT-6A DRUMS

TYPICAL HEAVY GAUGE OPEN HEAD DRUM

DOT METAL SHIPPING CONTAINERS

DOT-5 (178.80)

GENERAL REQUIREMENTS	CAP. (GAL)	AUTH. GROSS* WT.	REMOVABLE HEAD AUTHORIZED — MINIMUM GAUGE: BODY	B. HEAD	T. HEAD	CLOS. RING	REUSABLE CONTAINERS — CLOS. RING COLT SIZE	LEAKAGE TEST (PSI)	NO. OF ROLLING HOOPS
A. OPEN HEAD	5	*	22	22	22	N/A	(16 Luge)	15	None
1. Drop test required.	10		20	20	20	12	3/8	15	None
2. Hydrostatic pressure test required.	33		16	16	16	12	5/8	15	None
3. Leakage test is required for all containers produced.	55		18	18	18	12	5/8	15	2
4. Containers over 25 gal. capacity must have chime reinforcement.	55		16	16	16	12	5/8	15	3
	110		14	14	14	12	5/8	15	3
	33		18	18	18	12	5/8	15	2
	55		16	16	16	12	5/8	15	3
	100		14	14	14	12	5/8	15	3
	33		16	16	16	12	5/8	15	3
	55		13	16	16	12	5/8	15	3
	33 Bilge		16	16	16	12	5/8	15	None
	55 Bilge		13	13	16	12	5/8	15	None

DOT-5 (178.80)

			REMOVABLE HEAD AUTHORIZED			REUSABLE CONTAINERS			
B. CLOSED HEAD	5		22	22	22	**	**	15	None
	10		20	20	20			15	None
"Same as Listed Above"	33		16	16	16			15	None
	33		18	18	18			15	2
	55		16	16	16			15	2
	110		14	14	14			15	2
	33		18	18	18			15	2
	55		16	16	16			15	2
	100		14	14	14			15	2
	33		16	16	16			15	2
	55		16	16	16			15	2
	33B		14	14	16			15	None
	55B		13	16	16			15	None

* Requirements not cited in the regulations.

** Requirements not applicable to closed head containers.

DOT METAL SHIPPING CONTAINERS

DOT-5A (178.81)

REMOVABLE HEAD NOT AUTHORIZED — REUSABLE CONTAINERS

GENERAL REQUIREMENTS	CAP. (GAL)	AUTH GROSS WT.	MINIMUM GAUGE				CLOS. RING LOLT SIZE	LEAKAGE TEST (PSI)	NO. OF ROLLING HOOPS
			BODY	B. HEAD	T. HEAD	CLOS. RING			
CLOSED HEAD ONLY	10		16	16	16	**	**	15	None
1. Drop test required.	30		16	16	16			15	1
2. Hydrostatic pressure test required.	55		14	14	14			15	1
	110		12	12	12			15	2
3. Leakage test is required for all containers produced.	308		14	16	16			15	None
4. Openings over 2.3" diameter not authorized.	558		13	14	14			15	None
5. Containers over 25 gal. capacity must have chime reinforcement.									

DOT METAL SHIPPING CONTAINERS

DOT-5B (178.82)

REMOVABLE HEAD AUTHORIZED — REUSABLE CONTAINERS

GENERAL REQUIREMENTS	CAP. (GAL)	AUTH GROSS WT.	MINIMUM GAUGE				CLOS. RING LOLT SIZE	LEAKAGE TEST (PSI)	NO. OF ROLLING HOOPS
			BODY	B. HEAD	T. HEAD	CLOS. RING			
A. OPEN HEAD	5	*	24	24	24	N/A	(16 lugs) N/A	15	None
1. Drop test required.	10		22	22	22	12	3/8	15	None
2. Hydrostatic pressure test required.	15		20	20	20	12	3/8	15	2
3. Leakage test is required for all containers produced.	33		18	18	18	12	5/8	15	2
	55		16	16	16	12	5/8	15	3
4. Containers over 25 gal. capacity must have chime reinforcement.	110		13	14	14	12	5/8	15	3
	Bilge 33		16	16	16	12	5/8	15	None
	Bilge 55		14	14	14	12	5/8	15	None

DOT-5B (178.82)

REMOVABLE HEAD AUTHORIZED — REUSABLE CONTAINERS

B. CLOSED HEAD	5	*	24	24	24	**	**	15	None
(Same as listed above)	10		22	22	22			15	None
	15		20	20	20			15	2
	33		18	18	18			15	2
	55		16	16	16			15	2
	110		13	14	14			15	2
	Bilge 33		16	16	16			15	None
	Bilge 55		14	14	14			15	None

*Requirement not cited in the regulations.
**Requirements not applicable to closed head containers.

DOT-5C (178.83)

DOT METAL SHIPPING CONTAINERS
REMOVABLE HEAD NOT AUTHORIZED
REUSABLE CONTAINERS

GENERAL REQUIREMENTS	CAP. (GAL)	AUTH. GROSS WT.	MINIMUM GAUGE				CLOS. RING BOLT SIZE	LEAKAGE TEST (PSI)	NO. OF ROLLING HOOPS
			BODY	B. HEAD	T. HEAD	CLOS. RING			
CLOSED HEAD ONLY	15	*	20	20	20	**	**	15	None
	30		18	18	18			15	1
1. Drop test required	55		16	16	16			15	2
2. Hydrostatic pressure test required.	10		14	14	14			15	1
3. Leakage test is required for all containers produced.	Bilge 15		16	16	16			15	None
4. Containers over 10 gal. capacity must have chime reinforcement.	Bilge* 30		14	16	16			15	None
5. Openings over 2.3" in diameter not authorized.	Bilge 55		13	14	14			15	None

DOT-6B (178.98)

DOT METAL SHIPPING CONTAINERS
REMOVABLE HEAD AUTHORIZED
REUSABLE CONTAINERS

GENERAL REQUIREMENTS	CAP. (GAL)	AUTH. GROSS WT.	MINIMUM GAUGE				CLOS. RING BOLT SIZE	LEAKAGE TEST (PSI)	NO. OF ROLLING HOOPS
			BODY	B. HEAD	T. HEAD	CLOS. RING			
	5-10	160	18	18	18	*	*	15	None
A. OPEN HEAD	5-30	480	16	16	16			15	2
1. Drop test required.	5-55	880	14	14	14			15	2
2. Hydrostatic pressure test required.	5-30	480	16	16	16			15	2
3. Leakage test is required for all containers produced.	5-55	880	14	14	14			15	2
	5-110	1,760	12	12	12			15	2
	Bilge 5-33	480	13	16	16			15	None
	Bilge 5-55	880	13	14	14			15	None

DOT-6B (178.98)

REMOVABLE HEAD AUTHORIZED
REUSABLE CONTAINERS

B. CLOSED HEAD	5-10	160	18	18	18	**	**	15	None
(Same as listed above)	5-30	480	16	16	16			15	2
	5-55	880	14	14	14			15	2
	5-30	480	16	16	16			15	2
	5-55	880	14	14	14			15	2
	5-110	1,760	12	12	12			15	2
	Bilge 5-33	480	13	16	16			15	None
	Bilge	880	13	14	14			15	None

* Requirement not cited in the regulations.

** Requirements not applicable to closed head containers.

MONS 002916

DOT METAL SHIPPING CONTAINERS

DOT-17C (178.115) — REMOVABLE HEAD AUTHORIZED — SINGLE TRIP CONTAINERS

GENERAL REQUIREMENTS	CAP. (GAL)	AUTH GROSS WT.	MINIMUM GAUGE: BODY	B. HEAD	T. HEAD	CLOS. RING	CLOS. RING BOLT SIZE	LEAKAGE TEST (PSI)	NO. OF ROLLING HOOPS
A. OPEN HEAD	5	*	24	24	24	N/A (Lug)	N/A (Lug)	15	None
1. Drop test required.	10		20	20	20	12	3/8	15	None
2. Hydrostatic pressure test required.	30		18	18	18	12	3/8	15	2
3. Leakage test is required for all containers produced.	55		16	16	16	12	5/8	15	3
4. Convexity to be min. of 3/8" for drums over 25 gallons.									

DOT-17C (178.115) — REMOVABLE HEAD AUTHORIZED — REUSABLE CONTAINERS

B. CLOSED HEAD	5		24	24	24	**	**	15	None
	10		20	20	20			15	None
"Same as Listed Above"	30		18	18	18			15	2
	55		16	16	16			15	2
								15	

DOT-17E (178.116) — REMOVABLE HEAD NOT AUTHORIZED — SINGLE TRIP CONTAINERS

GENERAL REQUIREMENTS	CAP. (GAL)	AUTH GROSS WT.	MINIMUM GAUGE: BODY	B. HEAD	T. HEAD	CLOS. RING	CLOS. RING BOLT SIZE	LEAKAGE TEST (PSI)	NO. OF ROLLING HOOPS
CLOSED HEAD ONLY	5		24	24	24	**	**	5	None
1. Drop test required.	10		22	22	22			5	None
2. Hydrostatic pressure test required.	25		19 (20A)	19 (10A)	19 (20A)			5	2
3. Leakage test is required for all containers produced	30		19 (20A)	19 (10A)	19 (20A)			7	2
4. Drop test, hydrostatic and leakage tests are required.	55		18	18	18			7	2
5. Convexity to be min. of 3/8"	55		20 (auth)	18	18			7	2

*Requirement not cited in the regulations.

**Requirements not applicable to closed head containers.

DOT METAL SHIPPING CONTAINERS

DOT-17H (178.118) — REMOVABLE HEAD REQUIRED — SINGLE TRIP CONTAINERS

GENERAL REQUIREMENTS	CAP. (GAL)	AUTH. GROSS WT.	MINIMUM GAUGE: BODY	B. HEAD	T. HEAD	CLOS. RING	CLOS. RING DOLT SIZE	LEAKAGE TEST (PSI)	NO. OF ROLLING HOOPS
OPEN HEAD ONLY	5	*	24	24	20	N/A	N/A	5	None
	30		18	18	16	12	3/8	7	2
1. Drop test required.	55		18	18	14 (10A)	12	5/8	7	3
2. Hydrostatic pressure test required.									
3. Leakage test is required for all containers produced.									
4. Convexity (R/12 max. for 55-gallon drums.									
5. 16 gauge auth. provided there are one or more corrugations in the cover near the periphery.									

DOT-37A (178.131) — REMOVABLE HEAD REQUIRED — SINGLE TRIP CONTAINERS

GENERAL REQUIREMENTS	CAP. (GAL)	AUTH GROSS WT.	MINIMUM GAUGE: BODY	B. HEAD	T. HEAD	CLOS. RING	CLOS. RING DOLT SIZE	LEAKAGE TEST (PSI)	NO. OF ROLLING HOOPS
OPEN HEAD ONLY	1	60	26	26	26	N/A	N/A	*	None
1. Drop test required.	5	60	26	26	26	N/A	N/A		None
2. Hydrostatic Pressure test not required.	5	80	24	24	24	N/A	N/A		None
3. Leakage test not required.	5	80 (173.120)	26	26	26	N/A	N/A		None
4. Closing ring clearance 1/16 min. and 3/32 max. recommended.	10	160	24	24	26	N/A	N/A		None
	55	150	26	26	26	18	*		1
	55	275	24	24	26	18	*		2
	55	350	24	24	24	16	*		3
		480	22	22	22	16	*		2
		490 (173.194)	22	22	22	16	*		2

DOT METAL SHIPPING CONTAINERS

DOT-37B (178.132) — REMOVABLE HEAD NOT AUTHORIZED — SINGLE TRIP CONTAINERS

GENERAL REQUIREMENTS	CAP. (GAL)	AUTH GROSS WT.	MINIMUM GAUGE: BODY	B. HEAD	T. HEAD	CLOS. RING	CLOS. RING DOLT SIZE	LEAKAGE TEST (PSI)	NO. OF ROLLING HOOPS
CLOSED HEAD ONLY	5	60	28	28	28	**	**	*	None
	55	275	26	26	26				2
1. Drop test required.	55	450	24	24	24				3
2. Hydrostatic pressure test not required.	55	650	22	22	22				2
3. Leakage test not required.	55	650	22	22	24				3

DOT-37C (173.135) — REMOVABLE HEAD REQUIRED — NON REUSABLE CONTAINERS

OPEN HEAD ONLY	5	80	28	28	26	N/A	N/A	*	
1. Drop test required.									
2. Hydrostatic pressure test not required.									
3. Leakage test not required.									
4. Bottom head must have 3 inwardly-embossed circumferential beads.									
5. Must have two inwardly embossed circumferential heads and at least 16 lugs spaced not more than 1/4 inch apart.									

*Requirement not cited in the regulations.

**Requirements not applicable to closed head containers.

PCB REMOVAL FROM TRANSFORMER INSULATING FLUIDS

Copyright Material IEEE
Paper No. PCI-81-4

M. A. Thompson, Member IEEE
RTE Corporation
Waukesha, Wisconsin

ABSTRACT

PCB removal techniques differ from PCB destruction techniques in that they seek the reclamation of the electrical insulating fluid as well as the destruction of the PCB contaminants. There are two different approaches to PCB removal; these are chemical decomposition and physical separation. A schematic of the various processes for PCB removal is presented, along with a discussion of each technique.

INTRODUCTION

Polychlorinated biphenyls were first introduced in large quantities in 1929. Their excellent dielectric properties, low flammability, high heat capacity, chemical and thermal stability were recognized almost immediately as having the potential to provide low fire risk indoor type transformers with the inherent advantages of liquid cooled efficiency and reliability. General Electric Company patented the electrical application of these fluids, and they were subsequently marketed as transformer askarels under such trade names as Pyranol (General Electric), Inerteen (Westinghouse), and Chlorextol (Allis-Chalmers).

In the late 1960's, it became apparent that PCB's had entered and contaminated the environment (primarily from non-electrical applications). Investigation into the long range effect of this contamination demonstrated that although the acute toxicity of PCB's was low its resistance to biodegradation and its tendency to bioaccumulate and biomagnify could create situations where PCB levels would be harmful to man and his environment. As a result, manufacturers instituted voluntary restrictions on the sale and use of PCB's except in closed electrical equipment, federal and state agencies took steps to minimize or eliminate the release of additional PCB's into the environment, and users also instituted controls to prevent the further spread of PCB contamination.

Unfortunately, during the first forty years of use the environmental problem with PCB's was not recognized, and a number of activities took place which caused the widespread PCB contamination of conventional oil-filled equipment. Transformer manufacturers used common filling hoses for both PCB's and regular transformer oil, common oil processing equipment, common impregnation equipment, and in some cases actually impregnated transformers with PCB's for electrical testing safety and then subsequently drained and refilled them with conventional transformer oil. Owners of transformers (and contractors servicing them) used common hoses, pumps and filters on both PCB transformers and conventional oil-filled transformers. Oil storage tanks in service shops were sometimes used interchangeably for conventional transformer oil or for PCB's.

As a result of these manufacturing and maintenance practices, there are now millions of gallons of conventional napthenic transformer oil, both in operating transformers and in bulk storage tanks, that are contaminated with relatively low, less than 500 PPM (< .05%), PCB levels. There is a much smaller volume of "high fire point" liquids used as transformer insulating fluid in place of the askarel in retrofilled PCB transformers. Due to leaching of the impregnated PCB's out of the cellulose in these transformers, the retrofilled fluids typically become contaminated at relatively high, 5 to 20% (50,000 to 200,000 PPM), PCB levels.

Since there is only one commonly used transformer insulating fluid, this paper will deal primarily with removal of PCB's from conventional napthenic transformer oil; the special case of PCB removal from high fire point liquids will be treated as a separate section.

REVIEW OF BASIC APPROACHES TO PCB REMOVAL

Since the early 1970's when the environmental problems of PCB's were first recognized, two different approaches to PCB removal have received ever increasing attention: CHEMICAL DECOMPOSITION and PHYSICAL SEPARATION. In the first approach, the methods seek the destruction of the PCB molecule itself; since these methods offer a final resolution to PCB contamination, they are being very thoroughly studied by a wide variety of public and private institutions. In the second approach, the methods seek removal and concentration of the PCB contaminants for subsequent disposal; although in many cases this two-step process of isolation and disposal could be economically attractive, these methods have not yet received widespread attention. This may largely be attributed to the fact that until the recent EPA approval of two PCB incinerators, there was no way to dispose of the PCB's; once removed, they could only be stored.

In the paper, "PCB Problems: From Basics to New Innovations for Disposal,"[1] the author differentiates between methods designed for reclamation of contaminated fluids and methods designed primarily for the destruction of PCB liquids. The schematics outlining the various processes are reproduced in Figures 1 and 2. The bottom half of Figure 1 provides a breakdown of the chemical and physical approaches to PCB removal; the remainder of the schematics serves to put these processes into perspective with the many other techniques being developed today.

Regardless of the ultimate dispostion of the PCB's themselves, certain performance criteria apply to all potential methods for removing PCB's from transformer insulating fluids:

1. THE SYSTEM MUST BE EFFECTIVE
Final PCB levels must be well below the EPA defined maximum (currently 50 PPM).
Recovery rate of the insulating fluid should be high.

2. THE SYSTEM MUST MAINTAIN THE INTEGRITY OF THE INSULATING FLUID
The fundamental composition of the fluid should not be altered, the process should not preferentially remove any significant components of the fluid, and no new chemicals should be added as a result of the process. The electrical, chemical, physical, and aging characteristics of the processed fluid should be as close to new fluid as possible.

3. THE SYSTEM MUST BE COMMERCIALLY VIABLE
It must be economical, non-polluting, easy to use, and must use readily available chemicals and equipment. The system should be applicable to bulk storage tanks and to in-service transformers.

CHEMICAL DECOMPOSITION

In the book, "The Chemistry of PCB's,"[2] the authors state "one of the main reasons for the usefulness of PCB as industrial compounds is their low reactivity. For instance, PCB's are stable to conditions of hydrolysis and oxidation encountered in industrial use." "The most important reactions known to occur with chlorobiphenyls" are discussed in the chapter "Chemical Reactions of Chlorobiphenyls." Those reactions pertinent to PCB removal are: oxidation, reduction (reductive dechlorination), reaction with alkoxide, and reaction with amines. All of the current systems for the chemical decomposition of PCB's employ one of these methods.

The chemical decomposition of PCB's while they are dissolved in a potentially recoverable fluid is a difficult process. Any method that seeks the destruction of the PCB molecule must necessarily involve very strong reactions, very harsh processing conditions, or both. The problem, therefore, is to find a chemical process that specifically attacks the carbon-chlorine bond of the PCB molecule and yet does not damage the remaining fluid. A variety of chemical, biological, and radiation-induced PCB decomposition methods are referenced in the annotated bibliography. "Degradation of Chemical Carcinogens,"[3] Most of these, however, have not been tested for use with conventional transformer oil.

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The chemistry of "petroleum mineral oils" is covered very well in Wilson's book "Insulating Liquids: Their Uses, Manufacture, and Properties."[4] Conventional napthenic transformer oils contain a large percentage of cycloparaffins (napthenes), often with alkyl substitutions. There is a moderate percentage of regular (straight and branched chain) paraffins, and a small percentage of aromatics. Extensive refining processes are used for the production of transformer oil: "Severe hydrogenation, also called 'hydrofining,' is used to reduce the total unsaturated ring compounds; for example, aromatic to napthene and paraffin hydrocarbons." "In producing electrical oils particular attention is paid to producing an oil with good electrical properties, oxidation stability and, where required, gas-absorbing properties. This calls for a low sulphur and nitrogen content, but an optimum aromatic content."[4]

Whereas new transformer oil essentially contains only paraffins, napthenes, and aromatics, aged transformer oil is a very complex mixture that also contains water (primarily from the thermal and chemical degradation of the cellulose in the transformer), esters, ketones, organic acids, alcohols, and sludge products (from condensation and polymerization reactions). Due to arcing, partial discharges, and thermal degradation there will also be dissolved gases such as hydrogen, methane, ethane, ethylene, and acetylene. Other contaminants include metallic salts (of iron, copper, aluminum) and various other ionic and polar compounds depending upon the method of refining, the composition of the initial crude petroleum, and the materials used in the construction of the transformer (wire insulation, etc.).

Since many of the contaminants in aged oil either will participate in any reaction involving PCB's or will inhibit or catalyze the reaction, the development of a particular chemical decomposition method becomes very difficult indeed. Several methods are, however, being commercially developed, such as the Acurex, PCBX (SunOhio), and NaPEG (Franklin Institute) systems.

Chemically Induced Decomposition

"Alkali metals such as sodium (and potassium and lithium) happen to be both very aggressive chemically and very specific (within the range of compounds found in most PCB contaminated liquids) toward the carbon-chlorine bond. Therefore, most of the chemical destruction processes for PCB's employ sodium as the active compound. Since sodium metal is quite dangerous to work with, virtually all of these techniques first react sodium to some organic compound to create a new organo-metallic compound that is then used as the reagent to decompose the PCB's. This intermediate step allows the sodium to be processed at a central plant, producing a reagent that is easier to transport and safer to use."[1]

In the Goodyear process,[5] for example, napthalene is dissolved in tetrahydrofuran and then reacted with sodium shot to form sodium napthalide. The sodium napthalide mixture is then used as a reagent to strip the chlorines off of the PCB molecules. The end products are a polymerized mass of biphenyl units, salt, and any secondary reaction products. The sodium napthalide must be used in a 100:1 stoichiometric excess as low PCB levels to ensure complete reaction, and the excess reagent is destroyed with a water quench. The resulting napthalene (and tetrahydrofuran) remain in the fluid, also. Acurex Corporation has modified the Goodyear process to use a new intermediate compound rather than napthalene, since napthalene is presently a Priority 1 pollutant.[6]

Other techniques such as reductive dechlorination using hydrogen over a nickel catalyst[2] and voltammetric reduction[3] are being explored, but it is not known at this time whether or not these techniques will be applicable to the reclamation of oil as well as the destruction of the PCB's. Researchers at the British Columbia Hydroelectric Utility in Vancouver, have developed a process that can use lithium or potassium as well as sodium; the chemistry of the process has not been specified, however.

The most widely publicized chemical destruction process for PCB's is undoubtedly the PCBX process developed by Sun-Ohio Corporation. While the operation of the prototype mobile unit was presented recently,[7] the actual chemistry of the process has never been revealed to the general public. It appears, however, that this process uses sodium metal, reacted with an amine, to accomplish the dechlorination of PCB's. It is known, for example, that sodamide (formed from sodium plus ammonia) will, if dissolved in liquid ammonia, rapidly dechlorinate PCB's. When the information finally is released, it will be interesting to learn the chemistry of the actual process employed by PCBX. The by-products of the PCB destruction are a polymerized chain of biphenyl molecules and "naturally occurring chlorides."[7]

Another sodium based process has been developed by the Franklin Institute. Unlike the other processes, however, the NaPEG (Sodium, Na + Polyethylene Glycol, PEG) reagent employed in this process is an alkoxide rather than a simple metal-organic compound. "Chemically, it is insensitive to moisture or air and precautions to exclude these simple substances are therefore unnecessary."[8] When the NaPEG is reacted with PCB's, the PCB molecules are oxidized rather than reduced, and the PCB decomposition products are water-soluble oxygenated compounds. "The reaction products are: purified oil, non-toxic oxygenated organics and sodium chloride — ordinary table salt. The treated oil is easily cleaned up by water washing, drying and returning to service, if desired. The washings and other reaction products are treated simply and discharged to municipal sewage systems, biodegraded, or drummed for disposal in an ordinary landfill."[8]

Radiation Induced Decomposition

In the book, "Degradation of Chemical Carcinogens,"[1] both photodecomposition and ionizing radiation methods are referenced; these include the use of Cobalt-60, ultraviolet light, and sunlight. The only system being explored commercially, however, seems to be that of Atlantic Research Corporation,[9] which uses hydrogen gas as a reducing agent, and employs ultraviolet light to excite the PCB molecules and make them more reactive.

Biologically Induced Decomposition

Although many studies have been carried out using various microbes[2,3], the success of these attempts has been limited, and there are as yet no commercial ventures using this technique. The great specificity of the biological systems is a drawback in this case; heavily chlorinated biphenyls are either not attacked at all, or only very slowly. Furthermore, the position of the chlorine atoms on the two rings is critical to the stereochemistry of the enzymes.

PHYSICAL SEPARATION OF PCB'S

Physical processing techniques provide a promising means for reduction of PCB's in transformer oils. Physical processing can reduce PCB's from 500 PPM (or more) to less than 50 PPM and provide a greatly reduced volume of material which must be disposed of. Although physical methods do not destroy PCB's, the much smaller volume of material which contains the PCB's can be easily stored and can be easily shipped to PCB incineration facilities. Furthermore, physical processing methods are less likely to result in detrimental changes to the properties of transformer oils than are chemical destruction methods.

The greatest problem in the physical separation of PCB's from transformer oil is the fact that neither fluid is a single, simple compound; both fluids are complex mixtures of various molecular weight compounds having similar properties. As a result, both PCB's and transformer oil have very broad distillation ranges. Even a gas chromatograph column used for PCB detection cannot normally separate the PCB's from the oil; because the peaks overlap so much, special chlorine sensitive detectors are used so that the interference from the oil will be minimized. Despite the problems associated with physical separation, however, some successful methods have been developed, such as a proprietary azeotropic distillation process for hydraulic fluid (Battelle-Columbus Laboratories), and a chemisorption process for transformer oils (EPAC System, RTE Corporation).

Distillation

Distillation is used to separate solutions into higher and lower boiling constituents. Vacuum distillation refers to distillation at pressures below atmospheric. Vacuum is used to reduce the vapor pressure requirements, and thus the temperature of the system, distilling at atmospheric pressure would result in temperatures which would probably decompose the transformer oils. Since vapor pressure is not a constant function of temperature for all materials, it is often possible to find an optimum pressure range for the separation of two materials.

In theory, any two components can be separated by distillation as long as their boiling points are not identical. In practice, as the boiling points approach each other, the separation becomes more and more difficult and more and more costly. If PCB's were lower boiling than the oil they were to be separated from, the PCB's could be easily and economically removed as an overhead product. However, the PCB's are higher boiling than most of the oil they are to be separated from, the PCB's could therefore be removed as the "bottoms" but the process would be less energy effective since the bulk (over 95 percent) of the material would have to be taken off overhead. Since a portion of the PCB's and the oil that they are to be separated from boil at about the same temperature, separation is difficult and other means, such as azeotropic separation, would be more effective.

An alternative to vacuum distillation would be steam stripping. The presence of steam reduces the vapor pressure (and thus temperature) required for a material undergoing distillation. Separations can thus be achieved at atmospheric pressure without thermally damaging the materials being separated. Steam stripping may also be carried out at pressures above or below atmospheric. This technique, however, is still subject to the problems of overlapping boiling ranges.

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In azeotropic separation, a substance not normally present in the mixture is added to effect separation by changing the relative volatility of the most difficultly separable component. The added substance (azeotrope former or entrainer) forms a weak chemical bond with the component and the combination is referred to as an azeotrope. Usually, when the azeotrope appears in the overhead during distillation, the process is referred to as azeotropic distillation. When the azeotrope leaves the column with the bottoms products, the process is referred to as extractive distillation.

It would be desirable for the entrainer to form a low boiling azeotrope with PCB since the separation could then be accomplished by distilling over the small quantity of the azeotrope rather than the large quantity of transformer oil. In addition to forming a low-boiling azeotrope, the entrainer should be soluble in the transformer oil, and it should be easily separable from both the PCB mixture and the transformer oil. (The easiest separation would occur if the entrainer and the PCB's were immiscible.)

These various distillation (or "stripping") techniques are being investigated, and appear to work very well, for the removal of PCB's from simple compounds such as solvents or synthetic hydraulic and heat transfer fluids. It is unlikely that the problem of the broad boiling ranges of transformer oils and PCB's can be overcome, so these techniques probably will not become commercially viable for insulating fluids.

Extraction

Liquid-liquid extraction of PCB's from transformer oil materials can in theory be a very simple method of PCB removal. To successfully extract PCB's a solvent system must be found in which the PCB's are more soluble than the other transformer oil components. The alternative situation in which the PCB's are not as soluble as the other transformer oil components is probably not practical because of the small amounts of PCB's present and the almost universal solubility of PCB's in nonaqueous solvents. In practice, PCB's are soluble in almost every nonaqueous solvent and even to some extent in alcohol-water systems. The solubilities of the other transformer oil components will vary somewhat with the type of transformer oil. In general, however, the solubility of PCB's in hydrocarbons is greater than in virtually all other common solvents.[2]

Although several companies are now experimenting with extraction techniques, the strong affinity of the hydrocarbons for the PCB's and the fact that the oil is a mixture of aromatics and aliphatics will make commercialization of this technique very difficult.

Adsorption

In adsorption processes, one or more constituents of a complex mixture are preferentially adsorbed onto a solid phase thereby bringing about a separation between the constituents of the mixture. The primary objective in the development of a process for adsorbing PCB's from transformer oil would be to find an adsorbent which preferentially removes PCB from the oil. Depending on how tightly the PCB's are bonded to the solid phase, adsorption processes could be developed that are batch-oriented, semi-batch, or continuous in operation.

There are two filtration systems in use today for removal of PCB's from contaminated fluids: the EPAC system for hydrocarbons, and activated charcoal for silicones. The EPAC filtration system developed by RTE Corporation employs a chemisorption process, and was originally intended to remove high level (up to 10 percent or 100,000 ppm) PCB contamination from RTEmp fluid in retrofilled askarel transformers. (RTEmp fluid is a high fire-point liquid dielectric coolant that is produced from paraffinic hydrocarbons, and many of its characteristics are quite similar to conventional napthenic transformer oil.) The predominant use today for EPAC systems is to remove relatively low level (below 2,000 PPM or .2 percent) PCB contamination from conventional transformer oil, either in bulk storage tanks or in operating transformers.[10]

HIGH FIRE POINT LIQUIDS

High fire point dielectric fluids are required by NEC 450-23 to have a fire point in excess of 300° C.[11] Although their primary use is to provide extra safety in critical applications of new transformers, they are also being used as replacement fluids in existing askarel filled transformers ("retrofilling" of transformers). Although there are several high fire point fluids being marketed, including synthetic esters and chlorinated benzenes, there are only two fluids that are being used in significant volumes: high molecular weight hydrocarbons and polydimethylsiloxanes (silicones).

When a "retrofilled" transformer is placed back into service, the new, clean fluid gradually becomes contaminated as the residual PCB's leach out of the cellulose. "If the transformer has been properly drained and flushed, with removal of the bottom residual fluid at each step, the initial concentration in the new dielectric fluid should be less than 1 percent PCB. However, due to the large quantity of cellulose in a typical transformer, between 4 and 6 percent of the total original volume of askarel will still be contained in the windings of the transformer. This impregnated askarel cannot be removed by a simple flushing process. Once the transformer is energized, the internal heat generated in the coils will promote diffusion of the PCB's from the paper out into the oil."[12]

In order to remove the PCB's that diffuse out into the new dielectric fluid, RTE Corporation has developed the EPAC Filtration System for RTEmp fluid[10], and silicone fluid retrofill contractors have developed an activated charcoal filter. The EPAC system is designed to be attached to the transformer and performs a continuous filtration of the RTEmp fluid, the activated charcoal filter for silicone units is hooked up to the transformer for a few hours about every six months. In either case, the limiting factor in achieving a permanently low level of PCB contamination is the availability of the PCB's in the fluid; neither filter can remove PCB's any faster than the leaching rate makes them available. For this reason, both systems will necessarily be equivalent in terms of overall length of time required.

So far, only physical separation techniques have been developed for removal of PCBs from the high fire point fluids. Since the volume of contaminated conventional oil is so much greater, virtually all of the work on chemical decomposition methods have concentrated specifically on that fluid.

CONCLUSIONS

Many new techniques for the removal of PCB's from transformer insulating fluids are currently being developed. The most promising approaches are chemical decomposition (PCBX, NaPEG, Acurex) and adsorption (EPAC).

Chemical decomposition techniques must be very agressive to and PCB's and yet very gentle toward the insulating fluid; furthermore, they must contend with a wide variety of additional types of contamination in aged oils.

Physical separation techniques are hampered by the broad, overlapping boiling ranges of PCB's and of conventional transformer oil, and by the fact that both fluids are complex mixtures of many compounds.

REFERENCES

1. M. A. Thompson. *PCB Problems: From Basics to New Innovations for Disposal*. IEEE Power Engineering Society, Phoenix Section. 1981 Arizona Technical Symposium. April 24, 1981.
2. O. Hutzinger, S. Safe, V. Zitko. *The Chemistry of PCBs*. CRC Press. 1974.
3. M. W. Stein and E. B. Sansone. *Degradation of Chemical Carcinogens. An Annotated Bibliography*. Van Nostrand Reinhold Company. 1980.
4. A.C.M. Wilson. *Insulating Liquids: Their Uses, Manufacture, and Properties*. Institute of Electrical Engineers, London and New York. 1980.
5. D. K. Parker and W. L. Cox. *Detoxifying PCB-Contaminated Transformer and Heat Transfer Fluids*. Plant Engineering. August 21, 1980.
6. *Disposing Safely of PCBs: What's Available, What's On the Way*. Power. February, 1981.
7. T. F. Savastano. *PCBX: A Chemical Process for Destroying PCBs*. Doble Client Conference. April 9, 1981.
8. L. A. Lee. *Removal of PCBs From Contaminated Oils with NaPEG™ Reagents*. 1981 Spring Convention of Southeastern Electric Exchange. April 23, 1981.
9. *Assessment: At Least Nine PCB Destruction Processes Under Development or EPA Review*. Electrical Week. October 6, 1980.
10. M. A. Thompson. *Field Performance of the EPAC Filtration System*. Doble Client Conference. April 9, 1981.
11. *The Amended Section 450-23 of the 1981 National Electric Code Eliminates Heat Release Concept*. Pipeline #21. RTE Corporation Fluids Division. February 9, 1981.
12. M. A. Thompson. *Retrofilling of PCB Transformers*. Missouri Valley Electric Association - Engineering Conference. April 24, 1981.

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DISPOSAL OF PCB CONTAMINATED LIQUID

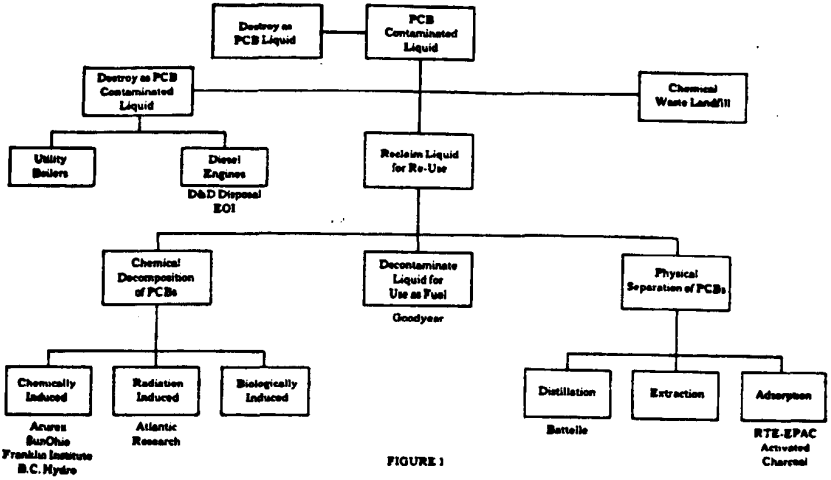

FIGURE 1

DISPOSAL OF PCB LIQUID

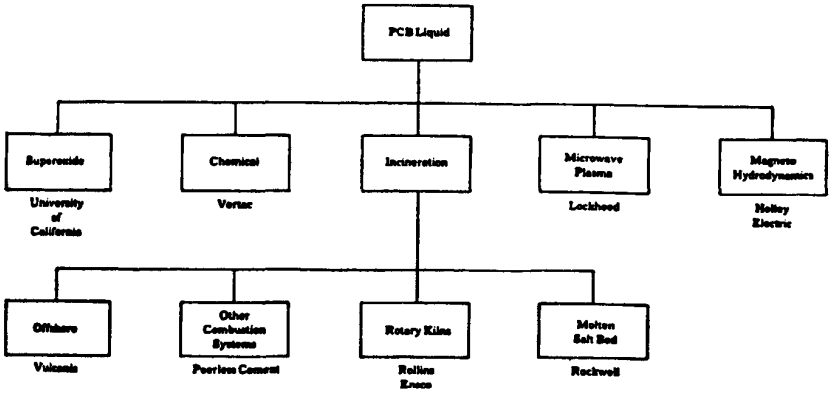

FIGURE 2

The following safety supply companies
carry Viton Material Gloves

SHERIDAN SAFETY SUPPLY
3341 N. Dixie Drive
Dayton, Ohio 45414
(513) 278-4845

MILLER PRODUCTS, INC.
29 Warren Street
New York, New York 10007

NORTON SAFETY PRODUCTS COMPANY
2000 Plainfield Pike
Cranson, R.I. 02920