

# Occupational Exposure To Polychlorinated Dioxins, Polychlorinated Furans, Polychlorinated Biphenyls, and Biphenylenes after an Electrical Panel and Transformer Accident in an Office Building in Binghamton, NY

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A polychlorinated biphenyl (PCB) and tri- and tetrachlorinated benzene-containing electrical transformer was involved in an explosion and fire in a modern office building in Binghamton, New York, on February 5, 1981. Because of an unusual system of air shafts the entire building and adjacent garage became contaminated with toxic chemicals. Polychlorinated dioxins, furans, and biphenylenes were formed as pyrolytic by-products. Before the extent of the chemical contamination was appreciated workers were exposed to these chemicals. Four years after the explosion and after the expenditure of over \$22 million for cleaning and other expenses, the building remains closed.

## Introduction

On February 5, 1981, at approximately 5:30 AM, a surge of electricity caused an electrical panel in the basement of the Binghamton State (of New York) Office Building (Fig. 1), located in Binghamton, NY, 200 miles northwest of New York City, to fail. Circuit breakers failed, and multiple electrical arcing and explosions caused overheating and leakage of one of two large electrical transformers. Between 180 and 200 gal of transformer fluid or Pyranol leaked from the transformer which originally contained approximately 1060 gallons of fluid. The Pyranol, supplied by the General Electric Company, originally contained 65% polychlorinated biphenyls (Aroclor 1254) and 35% tri- and tetrachlorinated benzenes (1,2). Although PCBs can no longer legally be manufactured in the United States, an estimated 40,000 transformers and 2,800,000 capacitors containing 34,000 and 40,000 tons, respectively, of PCBs are thought to exist in the U.S. Buser and Rappe (3-5) had previously described the formation under laboratory conditions of polychlorinated dibenzofurans (PCDFs) from PCBs and

the formation of polychlorinated dioxins (PCDDs) as well as PCDFs from the pyrolysis of chlorobenzenes. The Binghamton incident appears to be the first documentation of this potential hazard outside of a laboratory setting.

Initial findings within the Binghamton State Office Building (BSOB) were as follows: PCB air level, upper floors (1st week), 80  $\mu\text{g}/\text{m}^3$ ; PCB in soot in BSOB stairwell, 10% by weight; polychlorinated furans in soot, 2,100,000 ppb; polychlorinated dibenzodioxins in soot, 20,000 ppb; polychlorinated biphenylenes in soot, 50,000 ppb; PCBs in soot on floor of Governmental Complex Parking Garage, 2000-4700  $\mu\text{g}/\text{m}^2$  (PCB air sample, upper floors, one month after the incident, 2-3  $\mu\text{g}/\text{m}^3$ ; PCBs in air near City Hall capacitor incident, April 1983, 800  $\mu\text{g}/\text{m}^3$ ; 12 hr after incident, 1 yd from capacitor.

The laboratories involved in the analyses performed on the Binghamton soot or air include those of Thomas Tiernan at Wright State University, Hans Rudolph Buser and Christopher Rappe in Switzerland and Sweden, respectively, David Stalling of the U. S. Fish and Wildlife Bureau, O'Keefe and Smith, New York State Health Department, and James Carnahan of General Electric Company (Schenectady, New York), Galson Laboratory of Syracuse, New York, and later the Versar and Battelle Companies.)

The affected transformer (Fig. 2) was located in the

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FIGURE 1. The Binghamton State Office Building is shown in the background. Surrounding it are the Broome County Office Building and Binghamton City Hall. The common Governmental Parking Garage is in the basement and subbasement level below the complex. The buildings were constructed during the past 20 years.

basement of the Binghamton State Office Building, which is one of four government buildings, including the Broome County Building, Binghamton City Hall and the Binghamton City Council Building, sharing a common basement and subbasement level parking garage. Air

shafts in the ceiling of the transformer room extended to the top of the 18 story Binghamton State Office Building. These shafts ventilated the two bathrooms on each floor of the building and opened to these rooms by a small opening covered by a metal grating. During the

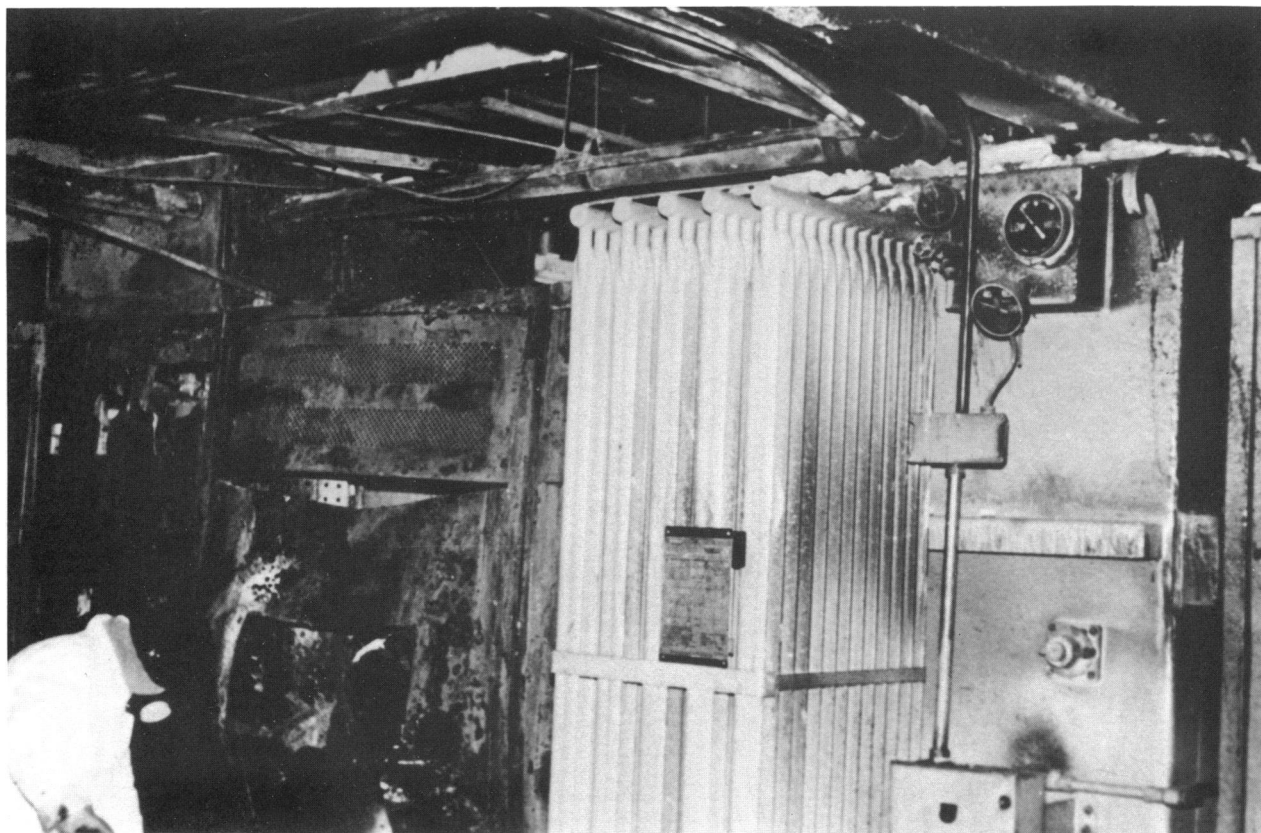


FIGURE 2. The damaged electrical panel is seen on the left behind a clean up worker. The damaged transformer is to the right of the panel. Soot is apparent on the panel and ceiling where burned wires and insulation are seen.

electrical arcing and fire, chemically contaminated smoke billowed up through the shafts, one more than the other, and contaminated the building with soot during the 10 to 30 min of the fire. In addition to these bathroom air shafts the fire was complicated by a smoke removal feature of the building: Two stairways extend up the building from the subbasement through the 18 floors of the building and end in a "penthouse" service area where fire doors, located on the roof, designed to open in the presence of heat or smoke, opened and created a thermal and pressure effect such that the chemically contaminated smoke and soot was sucked up in a vacuum cleaner-like effect from the bathroom air shafts, under and around the bathroom doors, through each floor to varying extents including the air venting systems, air plenums, inside of furnishings such as file cabinets, desks, and so forth, into the stairwells and, to a certain extent, out of the building at the roof level. During the month of February 1981 the nature of the contamination was appreciated (Figs. 3–10), and laboratory analysis confirmed the presence of PCBs, furans and dioxins. The building has been subjected to an extensive cleanup effort since that time.

Major events can be summarized as follows. The fire occurred 5:30 AM, Thursday, February 5, 1981. Cleanup and related costs to the State of New York (as of October 1984) were \$23,000,000. (\$5,600,000 more re-

quested in New York State Budget Year 1985–86 for a total, through 1985 of \$29,000,000). Contamination included: the Binghamton State Office Building, the underground parking garage, and part of Binghamton City Hall. Persons who believe they were exposed to toxic chemicals number over 500. Cleanup to date (10/83): walls, floors, ceilings, light fixtures were removed; the furniture was discarded; partly cleaned are air ducts and shafts, some wiring and plumbing, some hidden spaces including cinder blocks and areas behind some walls, some spaces under floors and above false ceilings, elevator shafts. Law suits filed or "intent to file" initiated at present amount to over one billion dollars. Toxicology studies using Binghamton State Office Building soot (New York State Department of Health) show that soot did not inactivate chemicals for guinea pig acute LD<sub>50</sub> 90-day toxicology studies; chick embryo teratogenicity and fetal lethality tests were positive and controls (charcoal and fireplace soot) were negative; liver ultrastructural changes were seen at all dose levels in a one oral dose study in guinea pigs 42 days after ingestion. Although 2,3,7,8 TCDD and 2,3,7,8 TCDF are present, much of the toxicity seems to be from penta- and other PCDFs, PCDDs and PCDBs and related chemical isomers, such as chlorinated naphthalenes and possibly also the biphenyl ethers.



FIGURE 3. This photograph shows the damaged, soot-covered, electrical panel and several workers wearing different sorts of protective clothing over their street clothing. Respirators with cartridges filtering air and particulates are apparently being worn by these workers but full facial protective masks or oxygen breathing apparatus are not being used. These photographs were taken in February 1981.

## Observations in Exposed Persons

Voluntary medical surveillance of 50 patients from the 500 who believed they were exposed in the original medical surveillance program showed chloracne (one case), transient skin rashes while in building, skin cancers (three known cases), liver pathology with no other causal etiology accompanied by ultrastructural alterations (three cases), one "successful" suicide attempt by a cleanup worker, nervousness, irritability, difficulty sleeping, and impotence, fatigue, elevated serum cholesterol and triglyceride levels, psychoneurotic illness leading to time off from work and psychiatric treatment, hypertension.

Because markers such as direct dioxin measurement along with isomer pattern characterization or liver ultrastructural alterations or other markers (e.g., urine porphyrin patterns, immune system alterations) to estimate extent of exposure are inadequately developed at this time, it is difficult to quantitate exposure. Thus we are forced to fall back on the tradition in occupational medicine of collecting medical information from those presumed exposed and also attempting to correlate this

with data with that from animal experiments. In addition the picture is complicated by the voluntary nature of the medical surveillance; no doubt exposed persons are not being followed and some who have been examined may not have been exposed to dioxins and related chemicals. Those exposed who may not have been followed would probably include users of the parking garage between the time of the incident and the discovery of the contamination of the garage. Another group would be City Hall workers or the users of City Hall especially during the time when portions of City Hall were used as staging areas for the clean up crew during February of 1981.

To illustrate the last point values found in the Binghamton City Hall from organic solvent-impregnated filter paper ("wet wipes") on March 3, 1982, 13 months after the incident, as determined by the New York State Health Department are as shown in Table 1 (illustrating residual contamination).

After finding the residual contamination noted above, the floors were repeatedly cleaned with detergent and water or the tiles removed if cleaning seemed not to be



FIGURE 4. A worker wearing full air pack, self-contained breathing apparatus (SCUBA) and full face and body protection is shown working in the transformer room.

Table 1.

Location	Aroclor 1254, <sup>2</sup> μg/m <sup>2</sup>
Mail room floor, basement	120
Maintenance room floor, basement	46
Signal room floor, basement	180
Floor of shower, men's locker area near signal room, basement	4100
Floor, radio and signal repair area, basement	210
Basement mailroom south floor behind door, basement	21
First floor, police conference room	700
Background levels from Binghamton Offices	<1.0

removing PCBs (and presumably dioxins and other contaminants).

The fate of the Building at this time is also not clear: Air sampling performed by the New York State Department of Health for selected isomers showed the values listed in Tables 2 and 3 (November 1982).

The chemical data of Tables 2 and 3, along with estimates of soot or air intake by employees over a 40-hr week for several decades, have served as the basis for risk assessments, which were prepared by Dr. Nancy Kim of the New York State Health Department. To summarize the risk assessments, an assumption was

Table 2. 2,3,7,8—Tetrachlorinated Dibenzofurans (TCDFs).

Location	TCDFs, pg/m <sup>3</sup>
Sixteenth floor-northeast	12, 16
Sixteenth floor-southeast	13
Sixteenth floor-northwest	9.2
Sixteenth floor-southwest	7.0
Mean	10.8 ± 2.8

Table 3. Selected air samples, 1983, Binghamton State Office Building.

Compound	Mean, pg/cm <sup>3</sup>
2,3,7,8-Tetrachlorinated dibenzofurans	14
Tetrachlorinated dibenzofurans	150
Pentachlorinated dibenzofurans	50
Hexachlorinated dibenzofurans	2-3
Biphenylenes	Trace
2,3,7,8-Tetrachlorinated dibenzodioxins	Trace

made that an "acceptable daily intake" (ADI) can be established for chlorinated dioxins, furans, biphenylenes, PCBs and probably chlorinated naphthalenes and biphenyl ethers which presumably exist in the Binghamton



FIGURE 5. An engineer wearing no protective clothing or respirator is shown in a contaminated area. Ingestion of chemical contaminated soot and air is probable through the respiratory, dermal or gastrointestinal routes as is the potential for movement of chemicals to the home via contaminated clothing.



FIGURE 6. A car in the electrical room area was contaminated with PCBs and presumably other chemicals. The PCB contamination which can be visualized on top of the car could not be removed by repeated scrubbing and detergent in steam cleaning. The car was eventually removed to a toxic waste dump.

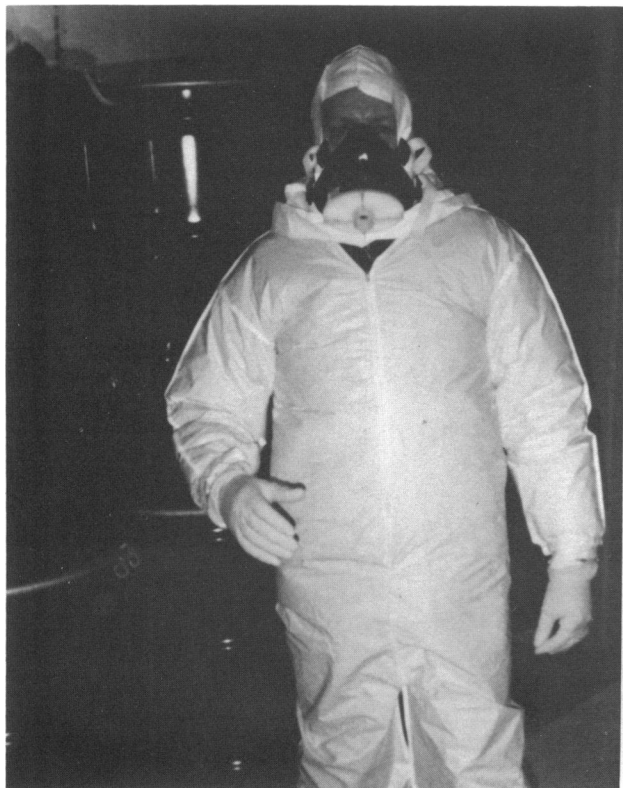


FIGURE 7. Various types of respirators and cartridges were used in the initial clean up during February 1981. Uncovered hair, face and eyes are seen, as is an apparently dust-type respirator as well as partially opened protective clothing over street clothes. Such irregularities document chemical exposure and pose a problem of patient evaluation and medical surveillance for the occupational medicine physician who may be involved afterwards. Direct measures of exposure such as sequential PCB blood or dioxin and furan adipose tissue determination may prove useful to better estimate exposure.

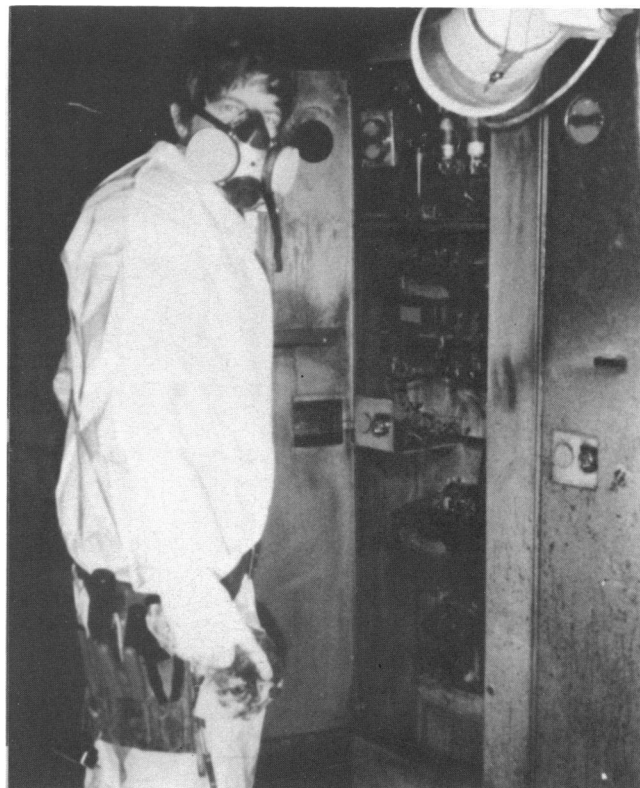


FIGURE 8. Contract electrician wearing street clothes, open protective clothing, a respirator without full face protection and apparently not a NIOSH-approved type of cartridge in his respirator. He later developed skin cancer on an exposed portion of his forehead.

amton State Office Building soot and air. This was done with the understanding that usually ADIs are not set for carcinogenic substances, but that because 2,3,7,8 TCDD and PCBs may be promoters rather than initiators of cancer, a given amount of dioxin exposure might constitute an acceptable assumption of additional risk for a worker or others using the building.

The Kociba three-generation no-observable-effect level for the 2,3,7,8-TCDD isomer in rats of 1 ng/kg of body weight or  $1 \times 10^{-9}$  g/kg/p day was used. Essentially, an assumption was made that the mixture of isomers would not have a synergistic effect and also that a 2,3,7,8-TCDD equivalent value could be extrapolated for the mixture from the animal toxicology data from guinea pigs fed Binghamton State Office Building soot and also from a partial knowledge of the chemical composition of the soot and the air within the building. The assumption was made that none of the compounds in the soot are genotoxic, an assumption that may have to be revised by the recent finding of Alistair Hay of a purported genotoxic effect of 2,3,7,8-TCDD in mammalian cell culture lines (6). Applying an uncertainty factor of

500 beyond the Kociba three-generation study (7) which included reproductive data as well as a 2-yr oncology study—but which was for the 2,3,7,8-TCDD isomer alone and in rats, not the more sensitive guinea pigs—an “acceptable daily intake” or ADI of 2 pg/kg/day or  $2 \times 10^{-12}$  g/kg/day for humans was arrived at for 2,3,7,8-TCDD equivalents.

In New York, calculation of “TCDD equivalents” weighs the various 2,3,7,8-Cl-containing PCDDs and PCDFs, giving lesser weight to furans and higher chlorinated compounds. The state of California, in sharp contrast, considers all 2,3,7,8-Cl-containing furans except octachlorofurans to be equipotent for purposes of risk assessment and reentry standards. Thus the California air standard of 10 pg/m<sup>3</sup> and the surface standard of 3 ng/m<sup>2</sup> for PCDD and PCDF in practice can be far more conservative than the seemingly identical New York reentry standards. Neither state’s risk assessment takes into consideration other chemical exposures and the possibility of dioxin, furan or PCB potentiation or synergism with other chemicals.

The lack of toxicological data on most of the isomers of dioxins or furans as well as our lack of knowledge concerning the effect of mixtures, especially relatively unique mixtures which occur after such environmental incidents, (8) presents still further complications. Further data from newer areas of toxicology such as neu-



FIGURE 9. Intense heat at the electrical panel produced this damage. Metal panels are destroyed or bent by the heat of the electrical arcing.

robehavioral toxicology may lead to even more complexity. Possibly levels considerably lower than 2 pg/kg/day for human ingestion may be considered a more appropriate additional health risk. The issue of assumption of even a small additional health risk from any toxic chemical also has to recognize the involuntary nature of the risk an employee, or other user of the building, may be asked to accept. Frequently individuals accept a significant voluntary risk, as from cigarette smoking, although they may not be willing to accept an additional involuntary risk.

## Discussion

Emotional considerations must also be taken into effect. Whether direct toxic central nervous system effect or a nonphysical or purely psychological mechanism contributed to the one suicide of a janitorial worker involved in the cleanup of the Binghamton State Office Building must be considered when assessing whether emotionally unstable workers or persons with the potential for psychiatric illness can successfully work in a building with small amounts of dioxins remaining. The patient who committed suicide was a janitor with pre-existing emotional and alcoholism problems who was asked to continue his janitorial duties in the building during the initial toxic chemical cleanup. Such workers



FIGURE 10. The intense heat burned the insulation from these wire cables. This implies other chemicals such as vinyl chloride may have been involved in the initial worker exposure, especially that of firefighters, police and supervisory workers, as well as photographers and other representatives of the press.

would normally be screened out and not accepted as toxic chemical cleanup workers. He later became obsessed by the possible adverse outcome on reproduction dioxins might have and hanged himself; after lingering in a coma for over a year he finally died. Higher initial blood PCB levels followed by lower levels months later lead to the hypothesis that ingestion of some dioxins and related chemicals may well have occurred, but it is not clear whether a direct toxic effect on his central nervous system occurred. As a rule of thumb it has been customary, in the U.S., to assume that approximately 10% of the working population will be subject to sufficient mental illness to require psychiatric or psychological treatment. The same percentage may exist in the general public who might be required to use the Binghamton State Office Building, should it ever open, which poses questions of some difficulty. With dioxins having become well known in the United States because of their presence in Agent Orange and their finding in certain areas of the United States such as Times Beach, MO, many persons react quite strongly and adversely when dioxins are found in their environment. Also, the extreme toxicity of dioxins in multiple animal species is now well known to the general public.

In the U.S., the frequency of lawsuits over injuries



suffered after toxic chemical exposure is increasing, as are large awards. Multimillion dollar out-of-court settlements as well as verdicts for injuries sustained after and purportedly because of dioxin exposure have begun to occur during the past few years. The cost of litigation as well as of awards resulting from successful litigation must be considered before deciding whether buildings such as the Binghamton State Office Building should be reopened or dismantled and buried in a toxic waste site, as happened to the Givaudan Company's ICMESA plant in Seveso, Italy, years after the incident. It should be noted that some of the contaminated homes are now being used.

Standards which may seem acceptable in one country may not be acceptable for another. Certainly, within the U.S. the difference between two governmental agencies with respect to acceptable levels of airborne PCBs in the workplace is striking. The Occupational Safety and Health Administration (OSHA) permits up to 1000  $\mu\text{g}/\text{m}^3$  of PCBs in the workplace for a 40-hr week. However, the National Institute on Occupational Safety and Health (NIOSH) in a "Criteria Document" recommended that no more than 1  $\mu\text{g}/\text{m}^3$ , at that time (1977) the detection limit, be considered permissible, evidently feeling that there was no safe or acceptable level, and that using the level of detection at that time was an appropriate way of so stating concern (9).

The Binghamton State Office Building seems to be unique only in that it was the first such incident to have been recognized. The analysis of the soot by a number of skilled chemists made it possible to recognize the chemical cocktail that is now being seen with increasing frequency in Finland, as described by Rantanen, for the 30 PCB-containing transformer or capacitor incidents described at this meeting which occurred during 1982-1983 in Finland, or Rappe who described nine incidents at the 1983 Dioxin Session of the American Chemical Society meeting. The recent San Francisco PCB transformer fire contaminated part of an office building with PCDFs as well as PCBs.

Prevention of similar incidents will be of increasing importance in future years. Chemical containment (including no air shafts running from electrical system

rooms) better fuses and circuit breakers, prevention of surges in electricity reaching electrical panels and transformers, rapid methods for extinguishing fires, such as by noncombustible gases now used in some industries, or substitution of non-PCB and nonchlorinated benzene-containing equipment should be considered. The substituted material must also be evaluated for toxicity before replacement of PCB. Last, the health effect of most of these isomers in man is an unknown area, certainly one in which extensive medical research is urgently needed.

A portion of this work was made possible by a fellowship from the Sandoz Foundation which is gratefully acknowledged.

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