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ATTORNEYS FOR PLAINTIFF

UNITED STATES DISTRICT COURT

DISTRICT OF NEVADA

NEVADA POWER COMPANY, a Nevada
corporation,

Plaintiff,

vs.

MONSANTO COMPANY, a foreign
corporation; GENERAL ELECTRIC
COMPANY, a foreign corporation;
WESTINGHOUSE ELECTRIC
CORPORATION, a foreign
corporation; and DOES I through
XXV, inclusive,

Defendants.

CV-S-89-555-LDG-LRL

OPPOSITION TO DEFENDANT'S JOINT
MOTION FOR SUMMARY JUDGMENT AND
JUDGMENT ON THE PLEADINGS AND
REQUEST FOR ORAL ARGUMENT

EXHIBIT 11

MATERIAL SAFETY DATA SHEET

Required under OSHA Safety and Health Regulations for Ship Repairing,
Shipbuilding, and Shipbreaking (29 CFR 1915, 1916, 1917)

SECTION I

MANUFACTURER'S NAME General Electric Company	EMERGENCY TELEPHONE NO. Rome, Ga. 404-234-0211 Pittsfield, Mass. 413-494-1
ADDRESS (Number, Street, City, State, and ZIP Code) Bedford Circle, Rome, Ga. 30161 or 100 Woodlawn Ave., Pittsfield, Mass. 01201	
CHEMICAL NAME AND SYNONYMS Chlorinated Biphenyl/Chlorinated Benzene Blend	TRADE NAME AND SYNONYMS Pyranol, Aroclor
CHEMICAL FAMILY Askarel/Chlorinated Aromatics	FORMULA

SECTION II - HAZARDOUS INGREDIENTS

PAINTS, PRESERVATIVES, & SOLVENTS	%	TLV (Unit)	ALLOYS AND METALLIC COATINGS	%	TL (Unit)
PIGMENTS			BASE METAL		
CATALYST			ALLOYS		
VEHICLE			METALLIC COATINGS		
SOLVENTS			FILLER METAL PLUS COATING OR CORE FILLER		
ADDITIVES			OTHERS		
OTHERS					

HAZARDOUS MIXTURES OF OTHER LIQUIDS, SOLIDS, OR GASES

SECTION III - PHYSICAL DATA

BOILING POINT (°F.)	410-780°F	SPECIFIC GRAVITY (H ₂ O=1)	
VAPOR PRESSURE (mm Hg)	Approx. 1 mm @ 104°F	PERCENT VOLATILE BY VOLUME (%)	Rome, Ga. Pittsfield
VAPOR DENSITY (AIR=1)	Approximately 6.5	EVAPORATION RATE (—=1)	6 Hrs. @ 2
SOLUBILITY IN WATER	Nil		
APPEARANCE AND ODOR	Clear Liquid with Yellow Tint, Slight acrid odor		

SECTION IV - FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (METHOD USED)	Cleveland Open Cup None to Boiling Point	FLAMMABLE LIMITS	None	LM
EXTINGUISHING MEDIA	None Required			
SPECIAL FIRE FIGHTING PROCEDURES	Material is nonflammable			

ADM 002157 -

UNUSUAL FIRE AND EXPLOSION HAZARDS
Gases produced by electric arcing contain high percentage of HCl; the unpleasantness and irritation caused by HCl give ample warning of its presence.

SECTION V - HEALTH HAZARD DATA

PEL LIMIT VALUE Vapor 0.5 - 1.0 mgm/cu. meter/8 Hr. Day

EFFECT OF EXPOSURE Dermatitis; Possible Chloracne - Eye Irritation

See ANSI C107.1 - 1974

EMERGENCY AND FIRST AID PROCEDURES

1. Remove from exposure.
2. Wash skin; irrigate eyes.
3. Consult physician.

SECTION VI - REACTIVITY DATA

STABILITY	UNSTABLE		CONDITIONS TO AVOID
	STABLE	X	
INCOMPATIBILITY (Materials to avoid)			
HAZARDOUS DECOMPOSITION PRODUCTS HCl when arced electrically			
HAZARDOUS POLYMERIZATION	MAY OCCUR		CONDITIONS TO AVOID
	WILL NOT OCCUR	X	

SECTION VII - SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED

Use Fuller's earth to avoid spread of liquid. Immediate sweeping of the required with disposal into drum container designated for Pyranol contain

Fuller's earth - see ANSI C-107.1-1974.

WASTE DISPOSAL METHOD

Incineration

See ANSI C107.1-1974 "Guidelines for handling and disposal of capacitor transformer-grade askarels containing polychlorinated biphenyls".

SECTION VIII - SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION (Specify type) Gas mask of organic cannister type or self breathing apparatus to be used in emergency if exposed to high concentration

VENTILATION	LOCAL EXHAUST	SPECIAL BY ITS
	MECHANICAL (General)	OTHER

PROTECTIVE GLOVES Use gloves of neoprene, polyethylene or Viton

EYE PROTECTION Safety glasses or eye shield

OTHER PROTECTIVE EQUIPMENT

Use aprons of neoprene, polyethylene or Viton.

SECTION IX - SPECIAL PRECAUTIONS

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORING

Avoid open exposure of hot askarels ($> 130^{\circ}\text{F}$). Be alert for possible allergic actions. Normally shipped in metal containers. After handling, wash hands with soap and water and soap before eating, drinking, smoking or use of toilet facilities.

July 30, 1972

U.S. DEPARTMENT OF LABOR

WORKPLACE STANDARDS ADMINISTRATION

Bureau of Labor Standards

Form
May, 1972

MATERIAL SAFETY DATA SHEET

SECTION I

MANUFACTURER'S NAME MONSANTO COMPANY		EMERGENCY TELEPHONE NO. (314) 594-1000
ADDRESS (Number, street, City, state, and ZIP Code) 800 North Lindbergh Boulevard, St. Louis, Missouri 63166		
CHEMICAL NAME AND SYNONYMS Mixture		TRADE NAME AND SYNONYMS Pyranol A13B3B-2
CHEMICAL FAMILY Chlorinated aromatic	FORMULA Mixture	

SECTION II HAZARDOUS INGREDIENTS

PAINTS, PRESERVATIVES, & SOLVENTS	TLV (U.S.A.)	ALLOYS AND METALLIC COATINGS	TLV (U.S.A.)
PIGMENTS		BASE METAL	
CATALYST		ALLOYS	
VEHICLE		METALLIC COATINGS	
SOLVENTS		FILLER METAL PLUS COATING OR CORE FLUX	
ADDITIVES		OTHERS	
OTHERS			
HAZARDOUS MIXTURES OF OTHER LIQUIDS, SOLIDS, OR GASES			

SECTION III PHYSICAL DATA

BOILING POINT (mm Hg.)	760 mm	210 - 400°C	SPECIFIC GRAVITY IN H_2O @ 25/15°C
VAPOR PRESSURE (mm Hg.)		Not Avail	PERCENT VOLATILE BY VOLUME (%)
VAPOR DENSITY (AIR=1)		Not Avail	EVAPORATION RATE (g/m ² /hr @ 25°C)
SOLUBILITY IN WATER	20°C negligible		
APPEARANCE AND ODOR	Colorless oil	aromatic odor	

SECTION IV FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (Method used)	Burn	None to Boiling	FLAMMABLE LIMITS	LOI
EXTINGUISHING MEDIA	Self			N.A.
SPECIAL FIRE FIGHTING PROCEDURES Respiratory protection when fighting fires where exposure to vapors or gases is possible.				
UNUSUAL FIRE AND EXPLOSION HAZARDS Highly toxic gases (hydrogen chloride) can be evolved.				

SECTION V HEALTH HAZARD DATA

THRESHOLD LIMIT VALUE

Not available

EFFECTS OF OVEREXPOSURE

Skin irritation in the form of chloracne, systematic intoxication leads to nausea, vomiting, loss of weight, edema and a

EMERGENCY AND FIRST AID PROCEDURES

Remove from exposure. Remove contaminated clothing. dominal pain

Wash contacted area with large amounts of water and soap.

Refer to physician

SECTION VI REACTIVITY DATA

STABILITY

UNSTABLE

CONDITIONS TO AVOID

STABLE

X

INCOMPATIBILITY (Materials to avoid)

HAZARDOUS DECOMPOSITION PRODUCTS

CO, CO₂, smoke, soot, hydrogen chloride

HAZARDOUS
POLYMERIZATION

MAY OCCUR

CONDITIONS TO AVOID

WILL NOT OCCUR

X

SECTION VII SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED

Absorb on clay, sawdust or other absorbant material. Place in drums. Bury in approved chemical landfill in accordance with local and state regulations.

WASTE DISPOSAL METHOD

Burn in approved incinerator in accordance with local and state regulations.

SECTION VIII SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION (Specify type)

Bureau of Mines approved respirator for

VENTILATION

LOCAL EXHAUST

Yes - for vapors.

SPECIAL

MECHANICAL (General)

OTHER

PROTECTIVE GLOVES

rubber

EYE PROTECTION

chemical goggles

OTHER PROTECTIVE EQUIPMENT

SECTION IX SPECIAL PRECAUTIONS

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORING

Avoid skin and eye contact, avoid inhalation of vapors.

OTHER PRECAUTIONS

While the information and recommendations set forth herein are believed to be accurate as of the date hereof, MONSANTO COMPANY MAKES NO WARRANTY WITH RESPECT THERETO AND DISCLAIMS ALL LIABILITY FROM RELIANCE THEREON.

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U.S. DEPARTMENT OF LABOR

Form No. O
May, 1971

MATERIAL SAFETY DATA SHEET

SECTION I

MANUFACTURER'S NAME MONSANTO COMPANY		EMERGENCY TELEPHONE NO. (314) 604-1000
ADDRESS, Street, City, State, and ZIP Code 500 North Lindbergh Boulevard, St. Louis, Missouri 63166		
COMMON NAME AND SYNONYMS Mixture		TRADE NAME AND SYNONYMS Pyranol A1223R
CLASSIFICATION Chlorinated aromatic	FORMULA Mixture	

SECTION II HAZARDOUS INGREDIENTS

PAINTS, PRESERVATIVES, & SOLVENTS	TLV (mg/m ³)	ALLOYS AND METALLIC COATINGS	TLV (mg/m ³)
PIGMENTS		BASE METAL	
CATALYST		ALLOYS	
VEHICLE		METALLIC COATINGS	
SOLVENTS		FILLER METAL PLUS COATING OR CORE FLUX	
ADDITIVES		OTHERS	
OTHERS			

HAZARDOUS MIXTURES OF OTHER LIQUIDS, SOLIDS, OR GASES

SECTION III PHYSICAL DATA

BOILING POINT (°F)	760 mm	215-400°C	SPECIFIC GRAVITY IN 20° (15.5/15)
VAPOR PRESSURE (mm Hg)	Not Avail		PERCENT VOLATILE BY VOLUME (%)
VAPOR DENSITY (AIR=1)	Not Avail		EVAPORATION RATE (GALLON/GAL)
SOLUBILITY IN WATER	20°C negligible		
APPEARANCE AND ODOR	colorless oil		aromatic odor

SECTION IV FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (°F)	None	FLAMMABLE LIMITS	
EXTINGUISHING MEDIA			
SPECIAL FIRE FIGHTING PROCEDURES Respiratory protection when fighting fires where exposure to vapors or gases is possible.			
Hazardous decomposition products (chlorides and chlorine) can be evolved in fires of this product.			

HEALTH HAZARD DATA	Not available.
EFFECTS OF OVEREXPOSURE Skin irritation in the form of chloracne, systematic intoxication leads to nausea, vomiting, loss of weight, edema and abdominal pain	
FIRST AID AND FIRST AID PROCEDURES Remove from exposure. Remove contaminated clothing. Wash contacted area with large amounts of water and soap. Refer to physician.	

SECTION VI REACTIVITY DATA

STABILITY	UNSTABLE		CONDITIONS TO AVOID
	STABLE	X	
HAZARDOUS DECOMPOSITION PRODUCTS CO, CO ₂ , smoke, soot, chlorides and chlorine			
HAZARDOUS POLYMERIZATION	MAY OCCUR		CONDITIONS TO AVOID
	WILL NOT OCCUR	X	

SECTION VII SPILL OR LEAK PROCEDURES

EFFECTS OF SPILL OR LEAK Absorb on clay, sawdust or other absorbent material. Place in drums. Bury in approved chemical landfill in accordance with local and state regulations.	
WASTE DISPOSAL METHOD Burn in approved incinerator in accordance with local and state regulations.	

SECTION VIII SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION (Specify type) Bureau of Mines approved respirator for organic vapors			
VENTILATION	LOCAL EXHAUST	Yes - for vapors.	SPECIAL
	MECHANICAL (General)		OTHER
PROTECTIVE GLOVES rubber		EYE PROTECTION chemical goggles	
OTHER PROTECTIVE EQUIPMENT			

SECTION IX SPECIAL PRECAUTIONS

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE Avoid skin and eye contact, avoid inhalation of vapors.	
OTHER PRECAUTIONS	

ADM 002150

While the information and recommendations set forth herein are believed to be accurate as of the date hereof, MONSANTO COMPANY MAKES NO WARRANTY WITH RESPECT THERETO AND DISCLAIMS ALL LIABILITY FROM ANY AND ALL DAMAGES THEREON.

JAG:HOH:JTG:WBP

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May, 1971

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MATERIAL SAFETY DATA SHEET

SECTION I			
MANUFACTURER'S NAME MONSANTO COMPANY		EMERGENCY TELEPHONE NO. (314) 604-1000	
ADDRESS (Number, Street, City, State, and ZIP Code) 800 North Lindbergh Boulevard, St. Louis, Missouri 63166			
CHEMICAL NAME AND SYNONYMS Mixture		TRADE NAME AND SYNONYMS Aroclor 1260	
CHEMICAL FAMILY Chlorinated aromatic		FORMULA Mixture	
SECTION II HAZARDOUS INGREDIENTS			
PAINTS, PRESERVATIVES, & SOLVENTS	%	TLV (Units)	ALLOYS AND METALLIC COAT
PIGMENTS			BASE METAL
CATALYST			ALLOYS
VEHICLE			METALLIC COATINGS
SOLVENTS			FILLER METAL PLUS COATING OR CORE FLUX
ADDITIVES			OTHERS
OTHERS			
HAZARDOUS MIXTURES OF OTHER LIQUIDS, SOLIDS, OR GASES			%
SECTION III PHYSICAL DATA			
BOILING POINT (P.S.A. 760 mm)		385-420°C	SPECIFIC GRAVITY (H ₂ O = 1) (25/25°C)
VAPOR PRESSURE (mm Hg.)		195-245°C	PERCENT VOLATILE BY VOLUME (%)
VAPOR DENSITY (AIR = 1)		Not Avail	EVAPORATION RATE (1. Butyl = 1)
SOLUBILITY IN WATER		20°C negligible <0.01%	
APPEARANCE AND ODOR yellow soft resin slight aromatic odor			
SECTION IV FIRE AND EXPLOSION HAZARD DATA			
FLASH POINT (Inches used)		None	FLAMMABLE LIMITS
EXTINGUISHING MEDIA			
SPECIAL FIRE FIGHTING PROCEDURES Respiratory protection when fighting fires where exposure to vapors or gases is possible.			
UNUSUAL FIRE AND EXPLOSION HAZARDS Highly toxic gases (chlorides and chlorine) can be evolved in fires of this product.			

THRESHOLD LIMIT VALUE

Not avail.

EFFECTS OF OVEREXPOSURE

Skin irritation in the form of chloracne, systematic intoxication leads to nausea, vomiting, loss of weight, edema and abdominal pain.

EMERGENCY AND FIRST AID PROCEDURES

Remove from exposure. Remove contaminated clothing. Wash contacted area with large amounts of water and soap. Refer to physician.

SECTION VI

REACTIVITY DATA

STABILITY

UNSTABLE

CONDITIONS TO AVOID

STABLE

X

INCOMPATIBILITY (Materials to avoid)

HAZARDOUS DECOMPOSITION PRODUCTS

CO, CO₂, smoke, soot chlorides & chlorine.HAZARDOUS
POLYMERIZATION

MAY OCCUR

CONDITIONS TO AVOID

WILL NOT OCCUR

X

SECTION VII

SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED

Absorb on clay, sawdust or other absorbant material. Place in drums. Bury in approved chemical landfill in accordance with local and state regulations.

WASTE DISPOSAL METHOD

Burn in approved incinerator in accordance with local and state regulations.

SECTION VIII

SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION (Specify type)

Bureau of Mines approved respirator for organic vapors.

VENTILATION

LOCAL EXHAUST

Yes - for vapors

SPECIAL

vapors.

MECHANICAL (General)

OTHER

PROTECTIVE GLOVES

rubber

EYE PROTECTION

chemical goggles

OTHER PROTECTIVE EQUIPMENT

SECTION IX

SPECIAL PRECAUTIONS

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORING

Avoid skin contact and eye contact.
Avoid inhalation of vapors.

OTHER PRECAUTIONS

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MATERIAL SAFETY DATA SHEET

SECTION I

MANUFACTURER'S NAME MONSANTO COMPANY		EMERGENCY TELEPHONE NO. (314) 601-1000
ADDRESS, STREET, CITY, STATE, AND ZIP CODE 500 North Lindbergh Boulevard, St. Louis, Missouri 63166		
COMMON NAME AND SYNONYMS Mixture	TRADE NAME AND SYNONYMS Arcochlor 1254	
Chlorinated aromatic	Mixture	

SECTION II HAZARDOUS INGREDIENTS

PAINTS, PRESERVATIVES & SOLVENTS	TLV (ppm)	ALLOYS AND METALLIC COATINGS	
PIGMENTS		BASE METAL	
CATALYST		ALLOYS	
VEHICLE		METALLIC COATINGS	
SOLVENTS		FILLER METAL PLUS COATING OR COAT FLUX	
ADDITIVES		OTHERS	
OTHERS			

HAZARDOUS MIXTURES OF OTHER LIQUIDS, SOLIDS, OR GASES

ADM 002155

SECTION III PHYSICAL DATA

BOILING POINT (mm Hg)	760 mm	365-400°C	SPECIFIC GRAVITY (25/25°C)	
VAPOR PRESSURE (mm Hg)	180-220°C	3 mm	PERCENT VOLATILE BY VOLUME (25°C)	N
VAPOR DENSITY (AIR=1)			EVAPORATION RATE (25°C)	
SOLUBILITY IN WATER	2000	negligible	<0.01%	
APPEARANCE AND ODOR	Yellow viscous oil		aromatic odor	

SECTION IV FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (NEAREST METHOD)	None	FLAMMABLE LIMITS	
EXTINGUISHING MEDIA			
SPECIAL FIRE FIGHTING PRECAUTIONS Respiratory protection when fighting fires where exposure to vapors or gases is possible.			
Hydrogen chloride (chlorides and chlorine) can be evolved in fires of this product.			

0.5 mg/m³ of air

EFFECTS OF OVEREXPOSURE

Skin irritant. n in the form of chloracne, systematic intoxication leads to nausea, vomiting, loss of weight, edema and abdominal

EMERGENCY AND FIRST AID PROCEDURES

Remove from exposure. Remove contaminated clothing. Wash contacted area with large amounts of water-and soap. Refer to physician.

SECTION VI REACTIVITY DATA

STABILITY	UNSTABLE		CONDITIONS TO AVOID
	STABLE	X	

INCOMPATIBILITY (Materials to avoid)

HAZARDOUS DECOMPOSITION PRODUCTS

CO, CO₂, smoke, soot, chlorides and chlorine

HAZARDOUS POLYMERIZATION	MAY OCCUR		CONDITIONS TO AVOID
	WILL NOT OCCUR	X	

SECTION VII SPILL OR LEAK PROCEDURES

Steps to be taken in case material is released or spilled

Absorb on clay, sawdust or other absorbant material. Place in drums. Bury in approved chemical landfill in accordance with local and state regulations.

WASTE DISPOSAL METHOD

Burn in an approved incinerator in accordance with local and state regulations.

SECTION VIII SPECIAL PROTECTION INFORMATION

Respiratory Protection Approved For

Bureau of Mines approved respirator for organic

VENTILATION	LOCAL EXHAUST	Yes - for vapors	SPECIAL	vapors
	MECHANICAL EXHAUST		OTHER	

PROTECTIVE GLOVES	Rubber	EYE PROTECTION	Chemical goggles
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OTHER PROTECTIVE EQUIPMENT

SECTION IX SPECIAL PRECAUTIONS

Additional Precautions for Handling and Storage

Avoid skin and eye contact, avoid inhalation of vapors

OTHER PRECAUTIONS

ACM 002156.

While the information and recommendations set forth herein are believed to be accurate as of the date hereof, MONSANTO COMPANY MAKES NO WARRANTY WITH RESPECT THERETO AND DISCLAIMS ALL LIABILITY FROM RELIANCE THEREON

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U.S. DEPARTMENT OF LABOR

MATERIAL SAFETY DATA SHEET

SECTION I				
MANUFACTURER'S NAME MONSANTO COMPANY		EMERGENCY TELEPHONE NO. (314) 694-1000		
ADDRESS, STREET, CITY, STATE, AND ZIP CODE 500 North Lindbergh Boulevard, St. Louis, Missouri 63166				
COMMON NAME AND SYNONYMS Mixture		TRADE NAME AND SYNONYMS Proclor 1254 (A13B1)		
Chlorinated aromatic		Mixture		
SECTION II HAZARDOUS INGREDIENTS				
PAINTS, PRESERVATIVES, & SOLVENTS	%	TLV (U.S.)	ALLOYS AND METALLIC COATINGS	%
PIGMENTS			BASE METAL	
CATALYST			ALLOYS	
VEHICLE			METALLIC COATINGS	
SOLVENTS			FILLER METAL PLUS COATING OR CORE FILL	
ADDITIVES			OTHERS	
OTHERS				
HAZARDOUS MIXTURES OF OTHER LIQUIDS, SOLIDS, OR GASES				%
SECTION III PHYSICAL DATA				
BOILING POINT (°F)	760 mm	365-400°C	SPECIFIC GRAVITY (25/25°C)	
VAPOR PRESSURE (mm Hg)	180-220°C	3 mm	PERCENT VOLATILE BY VOLUME (%)	
VAPOR DENSITY (AIR=1)			EVAPORATION RATE (G/G)	
SOLUBILITY IN WATER	20°C negligible	<0.01%		
APPEARANCE AND ODOR	Yellow viscous oil		aromatic odor	
SECTION IV FIRE AND EXPLOSION HAZARD DATA				
FLASH POINT (MATERIAL)		None	FLAMMABLE LIMITS	
EXTINGUISHING MEDIA				
SPECIAL FIRE FIGHTING PROCEDURES				
Respiratory protection when fighting fires where exposure to vapors or gases is possible.				
Hazardous decomposition products (chlorides and chlorine) can be evolved in fires of this product.				

Aroclor 1254

SECTION V

HEALTH HAZARD DATA

0.5 mg/m³ of air

Effects of Overexposure:
Skin irritation in the form of chloracne, systematic intoxication leads to nausea, vomiting, loss of weight, edema and abdominal pain.

EMERGENCY AND FIRST AID PROCEDURES

Remove from exposure. Remove contaminated clothing. Wash contacted area with large amounts of water and soap. Refer to physician.

SECTION VI REACTIVITY DATA

STABILITY	UNSTABLE		CONDITIONS TO AVOID
	STABLE	X	

INCOMPATIBILITY (Materials to avoid)

HAZARDOUS DECOMPOSITION PRODUCTS

CO, CO₂, smoke, soot, chlorides and chlorine

HAZARDOUS POLYMERIZATION	MAY OCCUR		CONDITIONS TO AVOID
	WILL NOT OCCUR	X	

SECTION VII SPILL OR LEAK PROCEDURES

Absorb on clay, sawdust or other absorbant material. Place in drums. Bury in approved chemical landfill in accordance with local and state regulations.

HAZARDOUS WASTE METHOD

Burn in an approved incinerator in accordance with local and state regulations.

SECTION VIII SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION: Bureau of Mines approved respirator for organic vapors.

VENTILATION	LOCAL EXHAUST	Yes - for vapors	SPECIAL	vapors.
	MECHANICAL (General)		OTHER	

PROTECTIVE GLOVES Rubber EYE PROTECTION Chemical goggles

OTHER PROTECTIVE EQUIPMENT

SECTION IX SPECIAL PRECAUTIONS

Avoid skin and eye contact, avoid inhalation of vapors

OTHER PRECAUTIONS

ADM 002148

While the information and recommendations set forth herein are believed to be accurate as of the date hereof, MONSANTO COMPANY MAKES NO WARRANTY WITH RESPECT THERETO AND DISCLAIMS ALL LIABILITY FROM REFINANCE THEREON.

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MATERIAL SAFETY DATA SHEET

SECTION I

MANUFACTURER'S NAME MONSANTO COMPANY		EMERGENCY TELEPHONE NO. (314) 694-1000
ADDRESS (Number, Street, City, State, and ZIP Code) 800 North Lindbergh Boulevard, St. Louis, Missouri 63166		
CHEMICAL NAME AND SYNONYMS Mixture		TRADE NAME AND SYNONYMS Aroclor 1242
CHEMICAL FAMILY Chlorinated Aromatic	FORMULA Mixture	

SECTION II HAZARDOUS INGREDIENTS

PAINTS, PRESERVATIVES, & SOLVENTS	%	TLV (Units)	ALLOYS AND METALLIC COATINGS	%	TLV (Units)
PIGMENTS			BASE METAL		
CATALYST			ALLOYS		
VEHICLE			METALLIC COATINGS		
SOLVENTS			FILLER METAL PLUS COATING OR CORE FLUX		
ADDITIVES			OTHERS		
OTHERS					
HAZARDOUS MIXTURES OF OTHER LIQUIDS, SOLIDS, OR GASES				%	TLV (Units)

SECTION III PHYSICAL DATA

BOILING POINT (P.S.)	760 mm	325-360°C	SPECIFIC GRAVITY IN H_2O (25/25°C)	1.380
VAPOR PRESSURE (mm Hg.) (155-195°C)	3 mm		PERCENT VOLATILE BY VOLUME (%)	N.A.
VAPOR DENSITY (AIR=1)	Not Avail.		EVAPORATION RATE (BUAC 51)	<1
SOLUBILITY IN WATER	20°C negligible	<0.01%		
APPEARANCE AND ODOR	colorless oil slight aromatic odor			

SECTION IV FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (METHOD CODE)	C.O.C. 180°C	FLAMMABLE LIMITS	Loi	Uoi
			N.A.	N.A.
EXTINGUISHING MEDIA	Water, foam, CO ₂ or dry chemical			
SPECIAL FIRE FIGHTING PROCEDURES	Respiratory protection when fighting fires where exposure to vapors or gases is possible:			
UNUSUAL FIRE AND EXPLOSION HAZARDS	Highly toxic gases (chlorides and chlorine) can be evolved in fires of this product.			

THRESHOLD LIMIT VALUE	1.0 mg/m ³ of air.
EFFECTS OF OVEREXPOSURE Skin irritation in the form of chloracne, systematic intoxication leads to nausea, vomiting, loss of weight, edema and abdominal pain.	
EMERGENCY AND FIRST AID PROCEDURES Remove from exposure. Remove contaminated clothing. Wash contacted area with large amounts of water and soap. Refer to physician.	

SECTION VI REACTIVITY DATA

STABILITY	UNSTABLE		CONDITIONS TO AVOID
	STABLE	X	
INCOMPATIBILITY (Hazardous to combine)			
HAZARDOUS DECOMPOSITION PRODUCTS CO, CO ₂ , smoke, soot, chlorides and chlorine			
HAZARDOUS POLYMERIZATION	MAY OCCUR		CONDITIONS TO AVOID
	WILL NOT OCCUR	X	

SECTION VII SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED Absorb on clay, sand, or other absorbent. Place in drums and bury in approved chemical landfill in accordance with local and state regulations.
WASTE DISPOSAL METHOD Burn in an approved incinerator in accordance with local and state laws.

SECTION VIII SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION (Specify type)		
VENTILATION	LOCAL EXHAUST	Yes - for vapors
	MECHANICAL (General)	
PROTECTIVE CLOVES		Rubber
EYE PROTECTION		Chemical goggles
OTHER PROTECTIVE EQUIPMENT		

SECTION IX SPECIAL PRECAUTIONS

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE Avoid skin and eye contact, avoid inhalation of vapors.
OTHER PRECAUTIONS

ADM 002154

While the information and recommendations set forth herein are believed to be accurate as of the date hereof, MONSANTO COMPANY MAKES NO WARRANTY WITH RESPECT THERETO AND DISCLAIMS ALL LIABILITY FROM RELIANCE THEREON.

JAG:HOH:JTG:WBP

1/24/72

TABLE 2

COMPOSITION OF COMMONLY USED
GENERAL ELECTRIC PYRANOL TRANSFORMER DIELECTRIC FLUIDS*

<u>PYRANOL SPEC. NO.</u>	<u>COMPOSITION</u>
1467	60% PCB (Aroclor 1260) 40% trichlorobenzene 0.125% tin tetraphenyl
1470	45% PCB (Aroclor 1260) 40% trichlorobenzene 15% tetrachlorobenzene 0.125% tin tetraphenyl
1488	60% PCB (Aroclor 1260) 40% trichlorobenzene
1497 or A13B3B	45% PCB (Aroclor 1260) 40% trichlorobenzene 15% tetrachlorobenzene 0.125% diepoxide
A13B3B2	45% PCB (Aroclor 1254) 40% trichlorobenzene 15% tetrachlorobenzene 0.125% diepoxide
A13B3B3	60% PCB (Aroclor 1254) 40% trichlorobenzene 0.125% diepoxide
A50P524	80% PCB (Aroclor 1242) 13% trichlorobenzene 7% tetrachlorobenzene 0.125% diepoxide
A50P559	65% PCB (Aroclor 1254) 23% trichlorobenzene 12% tetrachlorobenzene 0.125% diepoxide
A50P570	40% PCB (Aroclor 1254) 60% trichlorobenzene 0.125% diepoxide

*NOTE: The use of Pyranol was discontinued in 1977.

PCB - AROCLOR-PYRANOL COMPOSITIONS

G.E. CAPACITOR PYRANOL DESIGN'N	PERCENT COMP'N	CHEMICAL ABBREV'N	MONSANTO AROCOR DESIGN'N	GE-MAT'L SPEC. NO.	GE-MAT'L CODE
1499	100	PCB	1242/1016	A13B1C	AAWH
1492	67 33	PCB ---	1260 5460	A13B1E ???	??? ??? ???
1481	75 25	PCB TCB	1254 ---	A13B29 A13B1 D5B76 OR D50PC36	AAWN AAWF DAFA/DAFC
1478	100	TCB	---	D5B76 OR D50PC36	DAFA/DAFC
1476	100	PCB	1254	A13B1	AAWF
1436	75 25 1	PCB TCB BCA	1254 --- ---	A13B2A A13B1 D5B76 OR D50PC36 D5J16	AAWM AAWF DAFA/DAFC DAHA
PC43 OR DC OIL	75 25 1	PCB PCB BCA	1242/1016 1221 ---	A50PC43 A13B1C A50PC42 D5J16	ACAV AAWH ACAU DAHA

PCB - AROCLOR-PYRANOL COMPOSITIONS					
G.E. CAPACITOR PYRANOL DESIGN'N	PERCENT COMP'N	CHEMICAL ABBREV'N	MONSANTO AROCLOR DESIGN'N	GE-MAT'L SPEC. NO.	GE-MAT'L CODE
P-II OR PYRANOL II	100 0.35	PCB 4206	1242/1016 ---	A50PC8A A13B1C D5D71A	ADAA AAWH DAGS
P-II OR PYRANOL II	99 0.7	PCB 4221	1242/1016 ---	A50PC8A A13B1C D5D70A	ADAA AAWH DAGW
P-II OR PYRANOL II	99 1.0	PCB 330	1242/1016 ---	A50PC8D A13B1C D50PC26(A)	ADAD AAWH DESL
P-I OR PYRANOL I	100	PCB	1242/1016	A13B1C	AAWH

MONSANTO AROCLOR 1254 - PENTACHLOROBIPHENYL MIXTURE

MONSANTO AROCLOR 1242 - TRICHLOROBIPHENYL MIXTURE

MONSANTO AROCLOR 1016 - TRICHLOROBIPHENYL MIXTURE REDISTILLED TO
REDUCE PENTA- AND HIGHER CHLOROBIPHENYLS

MONSANTO AROCLOR 1221 - MAINLY MONOCHLOROBIPHENYL MIXTURE

MONSANTO AROCLOR 5460 - CHLORINATED TERPHENYL MIXTURE

TCB - TRICHLOROBENZENE

BCA - BETA-CHLOROANTHRAQUINONE

UNION CARBIDE 4206 EPOXIDE - 4-VINYLCYCLOHEXENE DIEPOXIDE

UNION CARBIDE 4221 EPOXIDE - 3,4-EPOXYCYCLOHEXYLMETHYL-
3,4-EPOXYCYCLOHEXANE CARBOXYLATE
OR DICYCLO-DIEPOXY CARBOXYLATE

DOW'S DER 330 - DIGLYCIDYL ETHER OF BISPHENOL-A

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TABLE 2-2. Available Data on Usage of PCB-Based Dielectric Fluids in Hudson Falls (HF) and Ft. Edward (FE) Plants and Temperatures of Exposure to Plant Environment.

Year	Plant	Pyranol Grade	% of Production	Composition (see Key)
1946	FE	1476	95	100% 1254
		1436	4	75% 1254, 25% TCB, 1% BCA
		1481	1	75% 1254, 25% TCB
1950	FE	1499	80	100% 1242
		1476	15	100% 1254
		1436	4	75% 1254, 25% TCB, 1% BCA
		1481	1	75% 1254, 25% TCB
1952	HF	1476	95	100% 1254
		1436	4	75% 1254, 25% TCB, 1% BCA
		1481	1	75% 1254, 25% TCB
1953	HF	1499	~25	100% 1242
		1476	~70	100% 1254
		1436	4	75% 1254, etc.
		1481	1	75% 1254, etc.
1955	HF, FE	1499	95	100% 1242
		1436	5	75% 1254, etc.
1956-59	- Unconfirmed report of switch back to 1254			
1964	HF, FE	PII	99	100% 1242, 0.35% 4206
		1436	1	75% 1254, etc.
1965	HF, FE	PII	99	99% 1242, 0.7% 4221
		1436	1	75% 1254, etc.
1971	HF, FE	PII	99	99% 1016
		1436	1	75% 1254, etc.
1975	- Report of reintroduction of 0.7% 4221			
1976	- Displacement of 1016 by DEHP commenced			
1977	HF, FE	PII	25%	99% 1016, 0.7% 4221
1977	- June 30 - All PCB usage discontinued			

Temperatures at Which Wet Units Exposed to Air

Aroclor 1254-based fluids, FE, 90-95°C
 " " " HF, 45-60°C
 Aroclor 1242 or 1016 fluids, FE, 65-70°C
 " " " HF, 45-60°C

Key: 1254, Monsanto Aroclor 1254, pentachlorobiphenyl mixture. 1242, Monsanto Aroclor 1242, trichlorobiphenyl mixture. 1016, Monsanto Aroclor 1016, trichlorobiphenyl mixture redistilled to remove penta- and higher chlorobiphenyls. TCB, trichlorobenzene mixture. BCA, betachloroanthraquinone. 4206, Union Carbide epoxide 4206, 4-vinylcyclohexene diepoxide. 4221, Union Carbide epoxide 4221, 3,4-epoxy-6-methylcyclohexylmethyl 3,4-epoxy-6-methylcyclohexane carboxylate. DEHP, di(2-ethylhexyl) phthalate.

Data courtesy of Earl Dunham, GE Capacitor Products Dept.

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INSTRUCTIONS GEH-1093B

**PYRANOL TRANSFORMERS
AND
PYRANOL IMMERSED
CURRENT-LIMITING REACTORS**

TRANSFORMER & ALLIED PRODUCT DIVISIONS
GENERAL  ELECTRIC
PITTSFIELD, MASS.

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These instructions do not purport to cover all details of operations in equipment nor to provide for every possible contingency to be met in connection with installation, operation or maintenance. Should further information be desired or should particular problems arise which are not covered sufficiently for particular purposes, the reader should be referred to the General Electric Company.

PYRANOL TRANSFORMERS AND PYRANOL IMMERSSED CURRENT-LIMITING REACTORS

INTRODUCTION

Pyranol* is a cooling and insulating liquid which is noninflammable, chemically stable, and nonsludging. Pyranol supplied for use in transformers is straw-yellow in color and has a Saybolt viscosity of about 54 seconds at 37.8 C (100 F).

Mineral oil is completely miscible in transformer Pyranol and affects its noninflammable characteristics. Since it is practically impossible to separate the two liquids after they have been mixed, it is important that contamination with any petroleum oils be avoided.

Materials which are not soluble in Pyranol have been selected for use in constructing Pyranol transformers. No materials should be used in contact with transformer Pyranol except those approved by the General Electric Company.

PYRANOL IMMERSSED CURRENT-LIMITING REACTORS

A Pyranol immersed current-limiting reactor differs from a Pyranol immersed transformer in that it usually has no core, generally consisting of one winding immersed in Pyranol in a standard transformer tank. The following instructions, given for transformers, apply to these reactors.

RECEIVING

Pyranol transformers are pressure-tight, and are normally shipped completely assembled in their tanks, ready to be installed.

Upon receipt of the transformer, examine the equipment for any damage that might have been sustained in transit. If injury or rough handling is evident, a damage claim should be filed immediately with the transportation company, and the nearest General Electric Apparatus Sales Office should be notified promptly.

HANDLING

Lugs or eye nuts are provided for lifting the complete transformer and, when necessary, additional lugs and eye nuts are supplied for lifting the various parts. When lifting the complete transformer, use proper spreaders to obtain a vertical lift. Securely fasten the cover of the transformer in place to prevent buckling of the tank wall.

When necessary, transformers are provided with means of lifting with jacks, either by means of special jack bosses welded to the transformer tank, or by an extension of the base of the transformer. In no case should the transformer be moved or lifted by placing a jack or tackle under the drain valves, radiator connections, or other attachments.

STORAGE

Before storing a transformer, check it to see that the Pyranol is at the proper level. Renewal coils and insulation should also be stored under Pyranol, in a container that can be sealed from the air. The storage room should be clean and dry, and, when possible, free of extreme temperature changes.

Before a transformer is placed in service from storage, make sure that the Pyranol and interior of the transformer are dry.

INSTALLATION

INSPECTION

Prior to installation, carefully inspect the external parts of the transformer for damage which might have been sustained in transit. Tighten any parts that may have become loose, such as nuts and leads. Inspect the lead seals which are used to seal the valves at the base of the tank. They should be unbroken when the transformer is received.

Pyranol used for filling transformers should have a dielectric strength of 30 kv or higher. When the dielectric strength of Pyranol in transformers in service reaches 25 kv or

*Registered trade-mark for G-E Askarel

lower, filter it in accordance with the section on DRYING AND FILTERING PYRANOL.

If the dielectric strength is low, or if there is other evidence of free water, dry the core and coils in accordance with instructions on DRYING PYRANOL TRANSFORMERS. Under certain temperature conditions the Pyranol may condense into drops on the underside of the pressure-relief diaphragm. These drops should not be mistaken for free water.

Methods of sampling and testing Pyranol are covered in the section entitled SAMPLING AND TESTING PYRANOL.

If the transformer is to operate at a high altitude (3000 feet or more above sea level), open a fitting above the liquid level, either the top sampling valve on the side of the tank or the filling plug in the cover, to equalize the internal and external pressures at approximately 25 C before the transformer is placed in operation. If this is not practicable, the transformer should be vented and resealed at a pressure according to the Table under PRESSURE TEST.

If a transformer must be opened for inspection outdoors, on a damp or stormy day, take proper precautions to prevent the entrance of moisture.

FOUNDATION

The only foundation necessary for the installation of a Pyranol transformer is a level floor strong enough to support the weight.

If the transformer is equipped with a diaphragm mounted in the side of the tank, place the transformer so that the diaphragm is not facing an aisle or passageway.

CONNECTIONS

Do not change connections on a transformer that is under excitation, or make any connections except those authorized by the diagram or nameplate accompanying the transformer.

Tap leads on some transformers are connected to a tap changer, the handle of which may extend through the cover of the transformer or through the side of the tank—or it may be under the cover. When the tap-changer handle is brought out through the main cover or the side of the tank, the exposed mechanism is protected by a cover. If this cover is removed to operate the tap changer, it must be replaced to avoid the entrance of moisture.

Leads not in use must be insulated from ground and from all other leads.

Regardless of the floor or foundation on which the transformer is placed, ground the tank permanently and effectively by connecting to the grounding lug at the bottom of the tank. A good, permanent, low-resistance ground is essential for adequate protection. A poor ground may be worse than no ground at all, since it gives a false feeling of safety to those working around the equipment, and may result in loss of life or damage to the apparatus.

When a transformer or autotransformer is specially designed for use on a system having a solidly grounded neutral, be sure that the neutral lead, as indicated on the nameplate, is permanently and solidly grounded without resistance. In transformers specially designed for this service, the neutral lead is usually brought out through a bushing of a lower voltage rating than the line bushings. If the neutral is not solidly grounded, sufficient voltage may appear from neutral to ground to cause arc-over of the neutral bushing.

A transformer or an autotransformer is occasionally grounded through a low impedance or a tuned impedance of a higher value. In such instances, the neutral bushing is of sufficient insulation strength to meet the specific conditions. Special instructions accompany units designed for such applications.

A single-phase transformer suitable for Y operation on either the high- or the low-voltage side may be so connected on either side, but not simultaneously on both sides unless precautions are taken to suppress third-harmonic voltages.

Two transformers of identical voltage rating may be operated in multiple safely when they have the same polarity, ratio, phase rotation, and angular displacement, and approximately the same percent impedance.

When desiring to operate, in multiple, transformers that are not of identical design, communicate with the nearest Apparatus Sales Office of the General Electric Company for information. Be sure to state the serial numbers of the transformers that are to be operated in multiple.

Every transformer should be protected from lightning disturbances by some form of

stroke protection. An approved lightning arrester installed as near as possible to the transformer to be protected, is recommended. Provide the arrester with an efficient ground.

Whenever disconnecting switches, with or without arcing horns, are mounted on top of structures, erect grounded protective masts to give a 45 degree-angle shield over the top of the horns or open switch. A protecting screen is even more efficient than masts only.

PRESSURE TEST

Pressure test all Pyranol transformers before placing them in service. Subject the tanks to an internal pressure of five pounds per square inch when the installation is completed, using dry compressed air or dry nitrogen introduced through the filling hole in the cover. When this pressure has been attained, shut off the supply and allow the transformer to stand for 12 hours. Observe the pressure reading during this period, and examine the tank and fittings for leaks. If the pressure holds constant, the joints are satisfactory.

Leaks above the Pyranol level may be located by applying a solution of soap and water to all gasketed joints, pipe fittings, and cable connections.

Following the pressure test, and any time that it is necessary to break the transformer seal, reseal the transformer at the proper pressure, in accordance with Table I.

TABLE 1

Pyranol Temperature Degrees C	Approximate Pressure Lb Per Sq In.
25	0.0
30	0.5
35	1.0
40	1.5

Use dry air or nitrogen if the pressure must be increased to an amount greater than atmospheric pressure (zero lb per sq in. gage pressure).

If the seal is broken when the Pyranol temperature is lower than 25 C, reseal the transformer at atmospheric pressure; then vent the seal to atmospheric pressure when the Pyranol temperature reaches 25 C, to prevent excessive pressure when the Pyranol temperature exceeds 25 C.

COOLING COILS ON WATER-COOLED TRANSFORMERS

Cooling coils are thoroughly dried before shipment, and all traces of moisture are removed by means of a hot-air blast. Do not remove the caps from the terminals of a coil until ready to install or test the coil. Never circulate water through a coil unless the tank is filled with Pyranol, as moisture might condense on the coil and later be absorbed by the Pyranol.

After the tank is filled with Pyranol, make a final pressure test on the cooling coil at about 150 lb per sq in. The best method is to use dry air pressure so that any leaks may be located by observing bubbles in the Pyranol. If air is not available, fill the coil with Pyranol and apply pressure. After obtaining pressure, disconnect the supply, and after a half hour determine whether any fall in pressure is due to a leak in the coil or in the fittings at the ends of the coil.

GASKETS

The standard material for gaskets used in making liquid-tight joints on transformers and regulators is nitrile* rubber. However, some applications of composition-cork gaskets remain. These instructions explain the procedure for making a liquid-tight seal with both nitrile-rubber and composition-cork gaskets.

NITRILE-RUBBER GASKETS

Nitrile-rubber gaskets require no adhesive to make a liquid-tight seal, although adhesive A50P68 may be applied as a thin film in a few places, when required to hold the gaskets on a vertical surface. A small amount of adhesive is required to make scarfed joints in a gasket.

The resilience of nitrile rubber makes possible the reuse of these gaskets in forming a seal if the gasket has not been damaged.

Storage

Store spare nitrile-rubber gaskets in a dark room, away from places of high temperature, such as steam radiators.

Application of Gasket

Clean the gasket, and the surfaces to which it is to be applied, of all rust, water, grease, insulating liquid, loose paint, scale, or any

*A synthetic rubber compounded to G-E specifications

other foreign material except thoroughly dried oilproof paint. Denatured alcohol is recommended for use in cleaning the surfaces.

Place the gasket in the proper location. If this is a vertical surface, a thin film of adhesive A50P68 may be applied in a few places to secure it. As grooves or metal-to-metal stops are used on most gasketed joints, it is essential that gaskets of proper width and thickness be used so that correct bolt spacing and pressure can be maintained. (To be assured of obtaining gaskets with the correct dimensions and quality, order replacements from the General Electric Company.)

Tighten the bolts, drawing each down in small increments. Proceed around the bolt circle several times until the metal stops are reached, or, if no stops are provided, until the gasket is compressed to $2/3$ of the original thickness. Do not compress the gasket beyond this point. No subsequent tightening of the bolts is necessary.

Preparation of Scarfed Joints

Place the gasket in the scarfing fixture and cut to the proper angle. The correct lengths of scarf for various thicknesses of gasket are given in TABLE II.

TABLE 2

Thickness of Gasket (Inches)	Length of Scarf (Inches)
$3/8$	$1\ 1/2$
$1/4$	1
$3/16$	$3/4$

Sand the surface until it is perfectly flat, drawing the sanding block toward the thin edge only.

Wipe the scarfed area with a clean cloth dampened in acetone, alcohol, de-greaser solvent, or solvaton. Leave nothing on the scarf to interfere with the bond. Even a small amount of oil, such as might be left from rubbing with the fingers, will interfere with the quality of adhesion.

To the clean, scarfed surface, apply an even coat of A50P68 adhesive, and allow the surfaces to air-dry until a "tackiness" develops to the point that the adhesive will not transfer to the fingers (usually from 5 to 15 minutes). Then bring the scarfed surfaces together and press the joint firmly by hand with enough pressure to displace all air. Do

not distort the shape of the gasket excessively. Joints can be cured immediately, or at any time within a week.

To cure the joint, place the gasket in a heated press or vulcanizer and clamp together. Apply only enough pressure to insure a joint of uniform contact. Avoid excessive distortion of the gasket. Cure the joint in the press for 35 minutes at 130 C, or 20 minutes at 150 C. Do not heat over 160 C. Remove the gasket at the end of the curing cycle and dip in cold water until cool.

A properly prepared joint is sufficiently strong to withstand sharp bending, twisting, and elongation of 100 percent. There should be no gaps at either end of the scarf, and the adhesion should be uniformly good.

COMPOSITION-CORK GASKETS

Composition-cork gaskets will not hold liquid unless treated or coated; that is, the liquid will seep very slowly through the cork and will flow along the joint. For this reason, a suitable compound is essential with composition-cork gaskets. (Exceptions: Use no compound or sticker on the small gaskets in a bushing terminal cap, or on gaskets around a movable shaft.)

Application of Gasket

The following procedure applies particularly to the joint between the cover and tank, but it should be used as a general guide in the formation of other liquid-seal joints.

Clean the metal surfaces of black scale, oil, grease, water, rust, or any foreign material other than thoroughly dried oilproof paint, preferably with denatured alcohol.

Cut and scarf the gaskets to fit the tank flange. If the gaskets are to be mounted in a groove, place them in the center of the groove. Make sharp corners, such as in junction boxes, with angle pieces of cork.

Remove the gaskets from the flange and thoroughly coat them with G-E compound 880 of fairly heavy consistency; then suspend the gaskets in the air to drain until they are perfectly dry for handling. Such drying usually requires less than four hours. (If necessary, a small amount of talc may be sprinkled over the dried compound as an added precaution against sticking when handling.)

Apply one fairly heavy coat of compound to the flange and underside of the cover, and

allow to dry.

Before assembly, apply a light coat of compound 880 to the tank flange and underside of the gasket. After the compound has dried sufficiently so that it will not adhere to the fingers (about 15 minutes), assemble the gaskets on the tank flange. Place the gasket between the bolt holes and inner edge of the flange. When full width gaskets are used, make sure they are assembled with at least 3/4 in. of gasket width inside the bolt holes. Locate scarfed joints between bolt holes. Work each gasket section back and forth a few times over the compounded metal surface.

Make the scarfed joints as explained in a subsequent section.

Weight or clamp the gasket at frequent intervals to obtain the best possible adhesion to the metal surface. Use extra pressure at the scarfed joints and at curves. Leave the clamps or weights for at least 30 minutes. After this period, the compound should be quite "gummy" but not hard.

If full-width gaskets are used, ream openings through the gasket for the bolts, and cover all exposed gasket surface at the holes with compound 880. This should be done with the clamps in position.

Apply a light coat of compound to all exposed surfaces of the gasket and to the underside of the cover. When the compound is tacky, as previously explained, mount the cover.

Tighten the bolts, drawing down all bolts in small increments. Proceed around the bolt circle several times until the gasket is compressed to approximately one-half its original thickness. Allow several hours (2 to 6) to elapse, then retighten the bolts until the gasket is compressed to about one-third its original thickness. A third tightening, a few hours later, is also recommended. Keep the insulating liquid away from the joint until the final tightening.

Preparation of Scarfed Joints

Place the gasket in a suitable fixture and cut to the proper angle. The correct lengths of scarf for various thicknesses of gasket are given in TABLE III.

TABLE 3

Thickness of Gasket (Inches)	Length of Scarf (Inches)
3/8	2
1/4	1 1/4
3/16	1

Sand or file the surface until it is smooth, drawing the sanding block or file toward the thin edge only.

Apply a thin coat of G-E compound 880 to both scarfed surfaces and allow to dry until tacky.

If the gasket is not to be used for several hours, clamp the scarfed joint together firmly and allow the clamps to remain for at least 30 minutes.

Valve-stem Packings

Packings for radiator and conservator valve stems are made of rings of composition cork, 3/8 in. thick and 1/8 in. wide. They are inserted edgewise into the stuffing box, in which they fit snugly. Use no compound in applying these gaskets. The method of insertion is as follows:

Remove the handle and gland, and clean all surfaces. Place the cork rings around the stem and force them into the stuffing box with a piece of standard 3/8 in. pipe. Repeat until the stuffing box is full; then screw the gland down hard. Remove the gland and add more cork, pressing it down hard with the gland. Assemble the handle and adjust the gland until the valve stem turns quite hard.

PIPE FITTINGS

When assembling pipe fittings, clean the threads thoroughly to remove all oil, grease, Pyranol, old compound, and dirt. Apply a coating of G-E compound 880 to the threads and screw the mating parts tightly in place.

MAINTENANCE

In general, from the standpoint of maintenance, operation, overvoltage protection, and overcurrent protection, Pyranol transformers should be treated the same as oil-filled transformers. Specific instructions on items peculiar to Pyranol transformers are given in the sections which follow.

HANDLING PYRANOL

Transformer Pyranol may be handled in the

same manner as mineral oil. However, continued exposure to liquid Pyranol may produce local skin irritations. Cleanliness among workmen handling Pyranol constitutes an adequate safeguard against such effects. Ordinary medicinal washes will remove any irritation caused by Pyranol coming in contact with an open cut or skin abrasion. A drop of castor oil will neutralize any irritation caused by contact of liquid transformer Pyranol with the eyes. As with most volatile materials, exposure to concentrated Pyranol vapors in unventilated rooms should be avoided.

Pyranol must be handled in containers, pipes, all-metal hose, etc. which are free from oil, grease, pitch, or other foreign materials, since they contaminate the liquid and decrease its noninflammable properties. It is desirable that all such apparatus used in storing or transporting Pyranol be maintained for exclusive use with Pyranol, as it is extremely difficult to remove all traces of oil, or other Pyranol contaminants, from equipment of this type.

All-metal hose, instead of rubber-lined hose, must be used in handling Pyranol, since rubber is affected by Pyranol.

FILLING TRANSFORMERS

Although all Pyranol transformers are shipped filled with Pyranol, it may be necessary to refill a transformer. If so, proceed as follows: Before filling the transformer, make sure that the joints are tight and open all air vents. In order to prevent aeration of the Pyranol, it is preferable to fill the transformer through the drain valve, with a filter press. Fill to the 25 C mark on the gage, or up to the lower sampling valve if no gage is provided.

Baked-on Glyptal[®] paint is resistant to the action of Pyranol. Air-cured Glyptal paint used for touch-up work in the factory and for repainting in the field, however, requires a rather long curing period. Therefore, care should be taken to remove all traces of Pyranol that are spilled or dripped on the outside of the transformer.

PERIODIC INSPECTION

After the first few days of operation, test the top and bottom Pyranol for dielectric

strength. Refer to the section SAMPLING AND TESTING PYRANOL.

Pyranol samples may be drawn and tested semiannually or annually, except in water-cooled transformers, where tests every four months are recommended. Accurate records of these tests should be kept. If, at any time, the Pyranol tests below 25 kv at room temperature, a filter press may be used to restore the dielectric strength to 30 kv or more.

Maintain the level of the Pyranol in the transformer up to, or above, the mark on the Pyranol gage, or up to, or above, the lower sampling valve.

Note that with a low operating temperature one of the constituents of No. 1467 Pyranol has a tendency to separate and appear on the surface as a light deposit. When the operating temperature returns to normal, this compound recombines with the Pyranol.

Examine the condition of the external transformer surfaces at regular intervals. If it is found that weathering is taking place, clean the surfaces thoroughly and repaint with a good grade of durable paint recommended by the General Electric Company.

It is recommended that a pressure test be made once a year, or more often for severe operating conditions, to make sure that a complete seal is maintained. See instructions under heading PRESSURE TEST.

If the transformer is equipped with a pressure-vacuum gage, observe the gage reading periodically. If it continues to read approximately zero lb per sq in. with varying Pyranol temperatures, a leak in the seal is indicated, and a pressure test should be made.

WATER-COOLED TRANSFORMERS

The ingoing cooling water should have a temperature of approximately 25 C. Supply enough water so that the difference in temperatures between the ingoing and the outgoing is not more than 10 C. It is recommended that thermometers be permanently installed in the ingoing and outgoing water connections so that the difference in temperatures may be readily observed. Where multiple cooling coils are employed, see that the flow through each section is such as to produce the same temperature rise in each.

To prevent condensation, never allow water to pass through any portion of a cooling coil that has been exposed by lowering the Py-

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pyranol level of the transformer.

Nearly all cooling water will, in time, form scale or sediment in the cooling coil, which materially decreases the efficiency of the coil. This is indicated by a high Pyranol temperature and a decreased flow of water, load conditions and water pressure remaining the same.

Scale and sediment can be removed from a cooling coil without removing the coil from the tank. Disconnect both inlet and outlet pipes from the water system and temporarily pipe the coil to a point several feet away from the transformer, where the coil can be filled and emptied safely. Take special care to prevent any acid, dirt, or water from entering the transformer.

Blow or siphon all the water from the cooling coil, and pump it full of a solution of hydrochloric (muriatic) acid, specific gravity 1.10. (Equal parts of commercially pure, concentrated hydrochloric acid and water will give this specific gravity.) A petcock located on the elbow at the upper end of the coil must be used to vent a coil in a closed system when siphoning the water. The chemical action which takes place when the acid enters the coil may be very violent and often forces acid, sediment, etc. from both ends of the coil. Therefore, it is advisable to leave one end partially open to prevent abnormal pressure.

After the solution has stood in the coil about an hour, flush it thoroughly with clean water. If all the scale is not removed the first time, repeat the operation until the coil is clean, using a new solution each time. The number of times it is necessary to repeat the process will depend on the condition of the coil, although ordinarily one or two fillings will be sufficient.

If a water-cooled transformer is to be removed from service, it is recommended that the cooling coil be drained thoroughly, dried by hot air, filled with Pyranol, and sealed.

OPERATION WITHOUT COOLING MEDIUM

Do not run an artificially cooled transformer continuously, even at no load, without the cooling medium. If the circulation of the cooling medium is unavoidably stopped, immediately reduce the load as much as possible and keep a close watch on the winding temperature (if a winding-temperature indi-

cator is available) and on the Pyranol temperature.

SAMPLING AND TESTING PYRANOL

Follow the procedure outlined herewith to obtain consistent results from samples taken for either field or laboratory tests.

Sampling from Transformers

1. Take samples preferably when the temperature of the transformer is near 25 C. Take samples from outdoor apparatus on a clear day only and guard against contamination by wind-blown dust, etc.

2. Use glass bottles as sample containers. A one-quart bottle will hold sufficient Pyranol for complete tests.

3. To clean the bottles, rinse with non-leaded, oil-free gasoline; then wash with strong soapsuds, rinse thoroughly with water, and dry in an oven at 105 C to 110 C for at least eight hours. After drying the bottles, seal tightly with a glass stopper or a clean cork. Protect the cork by wrapping with clean metal foil.

4. Impurities tending to affect the dielectric strength of Pyranol will, in general, be at the top of the liquid. Therefore, take the sample from the top through the small valve or plug, and allow enough Pyranol to run out so that any moisture or foreign material which may have collected in the drain pipe, valve, or plug will be removed.

5. Draw a sample into the bottle, leaving sufficient air space to allow for possible expansion of the Pyranol. Carefully seal the container to prevent any exposure of the Pyranol to the atmosphere, using the stopper removed from the bottle.

6. After taking the sample, reseal the apparatus as described in **PRESSURE TEST**.

If the sample is taken when the temperature is lower than 25 C, reseal the apparatus at atmospheric pressure. However, when the temperature reaches 25 C, vent the apparatus to atmospheric pressure to avoid excessive internal pressure at higher temperatures.

Sampling from Drums

Take samples from drums after the Pyranol has remained undisturbed for at least eight hours, and when the Pyranol is at least as warm as the surrounding air. If the drums are outdoors, take samples on a clear day only and guard against wind-blown dust, etc. Take

a sample from the top of the drum by means of a chemically clean thief. Observe the sampling precautions outlined before.

Clean the glass thieves, used for taking the samples, in the same manner as the bottles, and dry, preferably at a temperature not less than 37.8 C (100 F).

Testing for Dielectric Strength

For testing the dielectric strength of Pyranol, the technique as specified by the American Society for Testing Materials in the test method entitled, "The Standard Method of Testing Electrical Insulating Oils" shall be followed. The following precautions and modifications should be observed:

1. Set the spacing of the two 1-inch disk electrodes at 0.100 inch.

2. Wipe the test cup and electrodes clean with dry, calendered tissues, or clean, dry chamois and rinse thoroughly with clean, non-leaded, oil-free gasoline.

3. Fill the cup with dry gasoline and make a breakdown test under standard conditions of voltage application (3 kv per second rise). If the dielectric strength is not less than 25 kv, the cup is considered suitable for testing purposes. The usual precautions in handling gasoline should be observed.

4. Immediately after the final rinsing with gasoline, rinse the test cup with the Pyranol under investigation and proceed with the test at once.

5. The temperature of the Pyranol, when tested, should be the same as that of the room, which should be between 20 C and 30 C (68 F and 86 F).

6. After filling the test cup, allow the Pyranol to stand for three minutes before testing, to allow entrained air bubbles to escape.

7. Test only once per filling. Fill at least five times and average the results.

Pyranol testing lower than 25 kv should be filtered or replaced.

PYRANOL TESTING SERVICE

For convenience in sampling and testing Pyranol, the General Electric Company will, upon receipt of order at an Apparatus Sales Office, furnish one-quart containers filled with clean, dry Pyranol. After emptying the container into the apparatus, immediately refill with the liquid to be tested. This obviates Step 3 under SAMPLING FROM APPARATUS, but the subsequent steps should

be followed to insure obtaining a sample representative of the original Pyranol.

Send the samples to the Field Engineer, Power Transformer Engineering Division, Pittsfield, Massachusetts, for testing. Recommendations for continued use or treatment will be furnished, in addition to a complete report covering the following tests:

- | | |
|------------------------|--------------|
| 1. Dielectric strength | 3. Acidity |
| 2. Color | 4. Condition |

To assist in furnishing the most useful comments on the results of the tests, request for this information should:

1. State why the tests are considered desirable.

2. Give the serial number and rating of the apparatus.

3. State whether or not the sample represents the Pyranol originally furnished with the apparatus. If not, when was the Pyranol replaced.

4. State the temperature and weather conditions at the time the sample was taken.

5. Give any other information that might have a bearing on the condition of the Pyranol.

6. State to whom the report should be sent.

FILTERING AND DRYING PYRANOL

Transformer Pyranol will seldom require filtration because the tank of a Pyranol transformer is sealed. Extensive filtering with fuller's earth will remove a portion of one of the constituents of Pyranol. Should much filtering be done it is recommended that a one-quart sample of the Pyranol be sent to the Field Engineer, General Electric Company, Pittsfield, Massachusetts, for test and recommendations for treatment of the Pyranol.

When it is necessary to filter Pyranol to remove moisture or foreign material, the following is the recommended procedure: Use a Pyranol purifier consisting of a specially proportioned filter press, a positive-volume gear pump, driving motor, combined drip pan and mixing tank, and the necessary piping, valves, strainer, gages and drying ovens. Thoroughly clean the equipment to remove foreign material, including oil. Avoid oil contamination because oil is completely miscible in Pyranol and cannot be separated by any practical method. It is recommended that, wherever possible, separate equipment be reserved for the exclusive use of Pyranol.

TO REMOVE MOISTURE FROM PYRANOL OR ANY OTHER INSULATING LIQUID A THOROUGHLY DRY FILTERING MEDIUM IS ESSENTIAL. Filter paper and fuller's earth are used for this purpose on the Pyranol purifier, and the effectiveness of the filtering process is proportional to the care and thoroughness with which these materials are dried initially.

DRYING THE PAPER

The individual sheets of filter paper should be separated 1/8 inch or more when hung on the rods in the oven, to permit free circulation of air and to insure rapid drying. Dry the paper from six to twelve hours (depending upon the condition of the paper and the separation of the sheets) at a temperature of 95 C to 105 C. After drying the paper, take it from the oven directly to the filter, or, if this is not convenient, store it under moisture-free Pyranol (in a sealed container) for future use. When transferring the paper, take care to handle it as little as possible to avoid the absorption of moisture from the hands and to minimize the time that the paper is exposed to the air.

When the filter paper has been dried, do not permit it to cool to room temperature until actually clamped in the filter press or otherwise shielded from contact with the air, because a thoroughly dried sheet of paper will, when cooled, take up an appreciable amount of moisture from the air in a matter of seconds.

In many cases, it is considered preferable to provide special containers holding one or more complete charges of predried paper, the paper in this case being dried at a central point where it can be done effectively and economically. After drying, the paper is placed in the container while still hot, covered with moisture-free Pyranol, and the container sealed. Thus, a stock of moisture-free paper is always available for immediate use.

DRYING FULLER'S EARTH

Fuller's earth, a clay-like material with tiny pores having the ability to take up moisture and other impurities, should be thoroughly dried before being used in the filter, because pores already partially filled with moisture have only a limited capacity for taking up additional impurities.

Unlike filter paper and similar cellulose

material, fuller's earth can withstand temperatures far in excess of the boiling point of water. Therefore, by heating the earth to 200 C or 300 C (400 C is about the top limit), the moisture can be changed to steam and effectively driven from the microscopic pores. The length of time required to do this depends upon the depth of earth in the container and the temperature. For example, two hours at 250 C will be satisfactory if the earth is in shallow pans not more than two inches deep.

Dry fuller's earth, like dry filter paper, should not be permitted to cool to room temperature before it is actually mixed with the Pyranol. This avoids reabsorbing moisture from the air. The importance of this precaution can be most readily appreciated by considering the fact that Pyranol is dried during the few seconds it takes for the Pyranol to pass through a layer of properly prepared fuller's earth and filter paper.

When a high-temperature oven is not available at, or near, the filtering job, the earth can be dried simply and effectively by using the familiar plumber's furnace and a shallow, clean pan. A four-inch section cut from the bottom of a 14- or 16-inch distribution-transformer tank makes a satisfactory pan, or a pan may be fabricated with a heavy base section that will distribute the heat uniformly over the entire bottom surface. A single charge of earth (six pounds) for the Pyranol filter will be about 1-3/4 inches deep in a pan with a diameter of 16 inches.

Regulate the furnace to about the point where the bottom of the pan begins to take on a blue color (this value is not critical) and stir the earth slowly with a paddle to maintain a uniform temperature throughout. A charge of earth can be dried on the job just prior to being transferred into the filter, so that, being hot, it will not reabsorb moisture from the air during the charging operation.

CHARGING THE FILTER

The frames and plates should be placed alternately and so positioned that, when facing the pump or head end of the equipment, the small projections on their top edges are at the right-hand side.

Place three sheets of dry filter paper between each plate and adjacent frame, taking care that the holes in the paper coincide with

those in the plates. As soon as they are positioned, push the plates and frames together to prevent free circulation of air past the paper while the remaining sheets are being inserted. When all the sheets are in position, clamp the press securely by means of the compression screws at the back of the assembly.

The charge for the filter should consist of six pounds of 80/300 mesh fuller's earth (the equivalent in volume to a little more than one gallon in liquid measure). Mix about a third of this charge with five or six gallons of clean Pyranol in the mixing tank. When the charge is thoroughly mixed, open the valve leading from the mixing tank to the pump, and the valve between the press outlet and the drip pan, and make sure the other valves are closed. Then start the motor to circulate the Pyranol and fuller's earth mixture through the press so as to deposit a layer of fuller's earth on the surface of the filter paper. After the pump has been running about five minutes, the remainder of the six-pound charge of earth may be added gradually to the mixing tank. At the same time, stir the mixture thoroughly to prevent any dry lumps of earth being drawn into the pump. The addition of the remainder of the earth will take from 10 to 15 minutes. It is recommended that the purifier be run at least five minutes after the last of the earth is added to make sure that all earth is deposited in the press and that the cake is of proper depth. The purifier is then ready for use.

OPERATION

The most effective procedure for filtering is to pump the Pyranol through the filter and into a clean tank. When this is not practicable, the circulation method may be used, whereby the impure fluid is pumped directly from the transformer tank through the filter and back to the same tank. In such cases, it is recommended that the transformer be de-energized.

Since most of the free water and sediment are usually found near the top surface of the Pyranol, the inlet to the filter should be connected to the top of the transformer tank and the return fluid delivered into the bottom. During the filtering operation, any air which has been drawn into the filter press will be discharged into the bottom of the transformer

tank. Therefore, allow sufficient time (two hours or more) for this air to escape before the transformer is re-energized. If these instructions are followed, there should be no difficulty in obtaining a dielectric strength of 30 kv or higher, as measured with one-inch disks set 0.1 inch apart.

CLEANING THE FILTER

Compressed air passed through the press will release a considerable amount of Pyranol that would otherwise be retained in the earth and filter paper.

To do this, first close all valves except the one leading from the filter-press outlet to the drip pan. Then connect a supply of dry, oil-free compressed air to the connection at the press inlet and pass the air through the press until no further Pyranol is discharged into the drip pan. Air pressures as high as 100 pounds can be used; the higher the pressure, the more rapidly the Pyranol is forced out.

In addition to saving Pyranol, this operation simplifies the subsequent removal of the earth and filter paper. After blowing out the press, the individual frames, with the filter paper held in position on each side, can be lifted from the press intact, and the earth and paper discarded with minimum effort.

PUMP

The purifier is equipped with a constant-volume gear pump having a built-in relief valve adjusted to limit the output pressure to 100 pounds per square inch. The higher specific gravity of Pyranol does not permit long or high "suction" lifts; hence it is desirable to so locate the filtering apparatus that the inlet connections will be as short as possible. The Pyranol should preferably flow into the pump by gravity. Where long runs cannot be avoided, the use of large hose will give best results.

Where it is necessary to filter Pyranol in transformers located in subway manholes or street vaults, space limitations usually make it impractical to lower the purifier into the vault. To maintain full-capacity operation under these conditions, it is recommended that a portable auxiliary motor and pump unit be installed in the vault to pump the Pyranol up to the filter.

After the equivalent of several months of continuous service, the abrasive action of

the fuller's earth passing through the pump gears may cause considerable wear, particularly if the Pyranol and fuller's earth are not well mixed. The filter is designed for convenient pump replacement, and when this wear has advanced to the extent that the output of the apparatus is appreciably below normal, install a new pump. While individual repair parts can be obtained for these pumps, the wear will be found to be so generally distributed over the whole pump that a complete replacement is advisable.

MOTOR

The 1.5-horsepower motor is geared directly to the pump. Ordinarily, a single-phase, 110/220-volt, 60-cycle induction motor is supplied, but motors for other voltages and frequencies, or for direct current may be obtained.

STRAINER

The strainer is provided to prevent anything of appreciable size from entering and injuring the pump. It is easily accessible and should be thoroughly cleaned at regular intervals.

ELECTRIC DRYING OVEN

The oven for this purifier requires approximately 1400 watts and is designed to operate from either 100-volt or 220-volt, single-phase alternating current. The oven is provided with an automatic heat control to avoid overheating the paper and earth, and is divided into four compartments, each with rods for suspending the filter paper for drying.

DRYING PYRANOL TRANSFORMERS

Dry Pyranol transformers by the short-circuit method. Before applying voltage, blanket the transformer, beginning at the bottom of the corrugations, tubes, or radiators and wrapping the tank with heavy paper, cloth, or building felt until sufficient surface has been covered (judged by trial). To prevent condensation, thoroughly lag the cover. Ventilate the cover by raising the manhole covers, etc. and protect the openings if the transformer is out-of-doors. If the drying is carried on indoors, good ventilation or other means should be provided to exhaust the vapors from the room.

For two-winding transformers, short-circuit one winding and apply voltage to the other

winding to give the percent of full-load current for maximum allowable top-Pyranol temperatures in accordance with Table IV. Lower top-Pyranol temperatures may be used, but the length of the drying run will be increased.

Table IV gives the values which apply to the SELF-COOLED rating of type OA (self-cooled) as well as WC (water-cooled with internal cooling coil) transformers. The latter may not need blanketing of the tank, although the cover should be lagged.

Before drying three-winding transformers, or any of the forced-liquid-cooled types, obtain advice from the nearest Apparatus Sales Office of the General Electric Company.

TABLE 4

Maximum-allowable Short-Circuit Amperes in Percent of Full Load, Based on Self-Cooled Rating (see preceding paragraphs.)	Maximum-allowable Top-Pyranol Temperature
50	100°C
75	90°C

Do not allow the top-Pyranol temperature to exceed the specified value for the given percent load, because the windings are at a higher temperature than the Pyranol, and damage to the insulation may result.

Continue the drying until seven consecutive tests of samples of top Pyranol taken every four hours show a dielectric strength of 30 kv or higher. Allow the Pyranol samples to cool to room temperature (not higher than 40 C) before testing.

SPARE TRANSFORMERS

Time and expense will be saved if spare units are kept in readiness for instant use.

Inspect the following items during periods of idleness: Pyranol level, Pyranol dielectric strength, relief diaphragms, fan control and conduit, mercury seals, and load-ratio control. Also make periodic pressure tests.

LOCAL CONDITIONS AFFECTING THE OPERATION AND LIFE OF TRANSFORMERS

IMPURE AIR

Unless special care is taken, trouble may be experienced with transformers that are installed where abnormal conditions prevail.

Bushings must be kept clean, since the

formation of conducting deposits may cause bushing arc-overs.

Transformers near the seacoast should be kept well painted to prevent the corroding of any metal parts by the damp salt air.

Conduit piping leading from the station to the terminal box at the transformer should be sealed to prevent warm air flowing to the box and condensing.

ALTITUDE

If a transformer is moved to a location of a higher altitude, the effects due to the decreased air density are to increase its temperature rise (if self-cooled) and its pressure, and to lower the sparkover voltage of the bushings. These effects must be considered if a transformer is operated at a higher altitude than that for which it was designed. After moving the transformer, seal it at 25 C with zero lb per sq in. pressure.

Standard bushings may be used at any altitude up to 3300 feet. If transformers are to be moved to an elevation higher than 3300 feet, first communicate with the nearest Apparatus Sales Office of the General Electric Company relative to suitability of the bushings.

TRANSFORMER HOUSING

When large, self-cooled Pyranol transformers are installed in vaults or compartments, it is necessary to thoroughly ventilate the compartment. Provide cool-air inlets in, or near, the floor and outlets in, or near, the roof. Have the latter six feet or more above the top of the transformer. The number and size of the air outlets required will depend on their distance above the transformer, and on the efficiency and load cycle of the apparatus. In general, provide about 20 square feet each of inlet and outlet for each 1000 kva of transformer capacity. If the transformer will be required to operate for considerable periods at continuous full load, the areas of openings should be increased to about 40 square feet per 1000 kva of transformer capacity.

Arrange the air inlets and outlets so that they are permanently open. Do not use as ventilators, windows or doors which can be opened and closed by attendants, because of the danger of excessive heating. Doors which are inadvertently left closed during periods

of heavy load or high temperature.

If forced ventilation is used, supply about 5000 cubic feet of air per minute for each 1000 kva of transformer capacity, and conduct the incoming air directly to the transformers so that it will flow up through and around the radiating members of the tank. If this cannot be done, and the air is merely moved through the room, provide about 10,000 cubic feet per minute for each 1000 kva.

Do not let the temperature of the room in which the transformer is installed exceed the temperature of the air entering the room by more than 5 C. The entering air should come from a source not much warmer than the outside air.

LIQUID-TEMPERATURE INDICATOR TYPES P-2, M-13, A-10

The liquid-temperature indicator provides a means of reading the top-liquid temperature of a transformer. Such readings, if taken frequently, will indicate abnormal conditions affecting the transformer. However, the readings must not be relied upon as an indication of permissible load.

DESCRIPTION

General

The scale of the P-2 indicator reads 0 C-120 C; while the scales of the M-13 and A-10 indicators read 20 C-100 C. Each indicator has an indicating needle (white) and maximum-reading needle (red), a Bourdon tube, and a length of capillary tubing that extends from the Bourdon tube to a bulb. The capillary systems of the P-2 and M-13 indicators are of the liquid-filled type; whereas the system of the A-10 indicator is of the vapor-pressure type. In either system, a change in top-liquid temperature causes a change in pressure which actuates the Bourdon tube, thereby rotating the indicating needle.

The bulb of each type of indicator is mounted in a liquid-tight well in the top liquid of the transformer. Thus, an indicator can be removed without lowering the insulating liquid in the transformer.

A stop on the indicating needle moves the maximum-reading needle up scale so as to indicate the highest top-liquid temperature reached during a particular period. The maximum-reading needle can be reset by turning

the knurled knob on the front of the P-2 and M-13 indicators, or the reset lever extending below the case of the A-10 indicator.

Each indicator contains a small snap-action switch with normally open contacts that can be used in an alarm or signal circuit. These contacts are adjusted at the factory to close at 75 C on water-cooled and forced Pyranol cooled transformers, and at 80 C on other types.

Type P-2 Indicator

The P-2 indicator is furnished on transformers, regardless of rating, where the mounting height is 120 inches, or less, above the floor level. The bulb is mounted in a well located in the tank wall, or in a tube header.

To connect the alarm leads of this indicator into an alarm circuit, remove the cap shown in Fig. 1. Uncoil the leads in the housing and remove the threaded bushing and housing. To the threaded bushing, solder a 12-inch maximum length of flexible conduit; then reassemble the threaded bushing and conduit over the leads and into the indicator case.

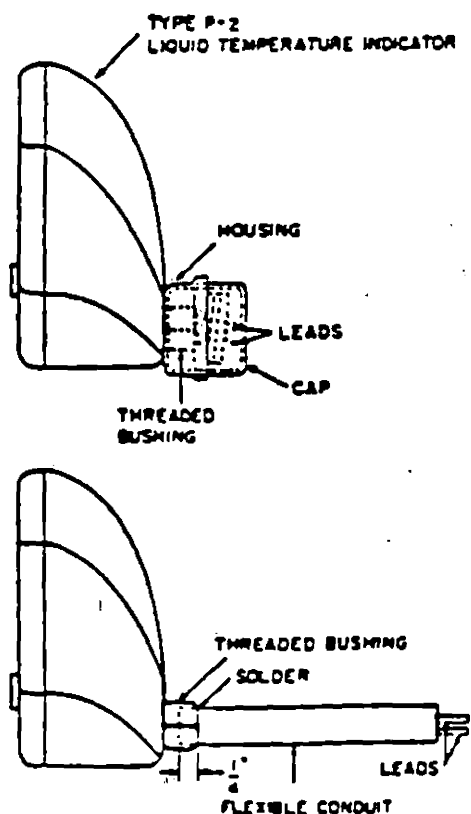


Fig. 1. Liquid-temperature indicator, Type P-2, lead protection and connection

Type M-13 Indicator

The type M-13 indicator is furnished on transformers 5001 kva to 7500 kva when a local-type winding-temperature indicator is not furnished. It is also furnished on transformers 501 kva to 7500 kva when the mounting height does not permit the use of the P-2 indicator (i.e. mounting heights over 120 inches).

The indicator dial is mounted at eye level above the base of the transformer.

The alarm leads of the M-13 indicator are brought out of the case through flexible lead-covered cable.

Type A-10 Indicator

This indicator is furnished on all transformers rated above 7500 kva and on transformers 5001 kva to 7500 kva when a local-type winding-temperature indicator is also furnished.

The indicator dial is mounted at eye level above the base of the transformer.

Connections to the alarm-switch leads are made in a similar manner to those on the P-2 indicator, as previously described.

PRESSURE-RELIEF DIAPHRAGMS

A pressure-relief diaphragm is standard equipment on all Pyranol transformers above 25 kva. This diaphragm is made of frangible material and is held in place by flanges.

A diaphragm breaker is normally used on transformers under 200 kva to rupture the diaphragm when the maximum safe pressure in the transformer tank is exceeded. The breaker consists of a spring-operated plunger which is set by hand and is released by a bellows that operates the release pin when the pressure in the tank exceeds the pressure setting of the device. (See Fig. 2.)

Older types of diaphragms do not have the breaker mechanism. In one type, the diaphragm is held between two flanges with cushioning gaskets, all assembled as a unit in a press so that uniform pressure is applied to the circumference of the diaphragm. The assembly is held together with flat-head screws, and the complete unit is bolted to a flange on the transformer. In bolting this assembly to the tank, a gasket is placed on the tank flange. The older-type gasket is cork composition. It requires a covering of G-E compound 880 on both sides; whereas the

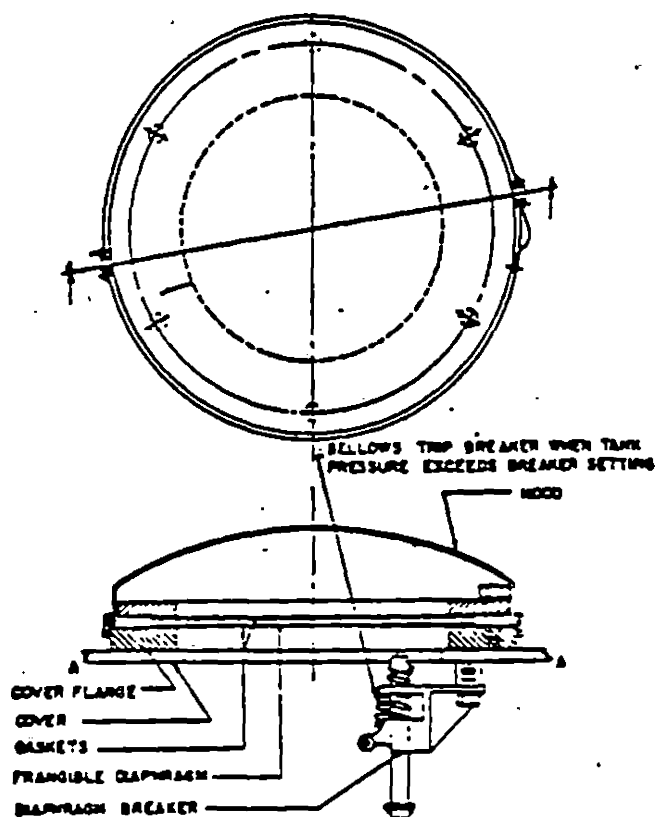


Fig. 2. Outline of pressure relief for transformers under 200 kva

nitrile-rubber gasket requires no compound to make a gas-and liquid-tight joint. The diaphragm assembly is bolted to the tank flange with cap screws fitted with lock washers, as just described.

In another type, the diaphragm is held between one flange welded to the transformer and a separate flange held by cap screws. The diaphragm is protected on both sides of the cushioning gaskets. The technique employed in bolting down this type of diaphragm and making the seal is of prime importance, since the rupture strength of the frangible material depends materially on the care with which this operation is performed.

When replacing diaphragms of the latter type, clean the gasket surface of the tank flange thoroughly. If the inner gasket is cork, coat both sides with G-E compound 880. Lay the gasket on the tank flange and place the diaphragm over the gasket, being careful to center it properly. Lay the cushion gasket over the diaphragm and assemble the clamping ring over the cushion, holding it in place with cap screws.

The diaphragms are usually protected by a spun-metal cover snapped in place over the diaphragm flange.

EIGHT-INCH PRESSURE RELIEF

Receiving

When the eight-inch pressure relief is shipped assembled in place on the transformer, one temporary wooden block under the free cap and another between the free cap and retained hood firmly support all parts. These temporary blocks are wired together at one end and marked with red paint. Remove the blocks before putting the transformer into operation.

For separate shipment of the pressure-relief device, a temporary cover is placed over the opening. The removable spider is left in place in the cover opening, and the diaphragm is packed separately. The top flange, free cap, and retained hood are shipped assembled.

Description

Fig. 3 shows the parts of this device with a plate which represents the tank cover. The

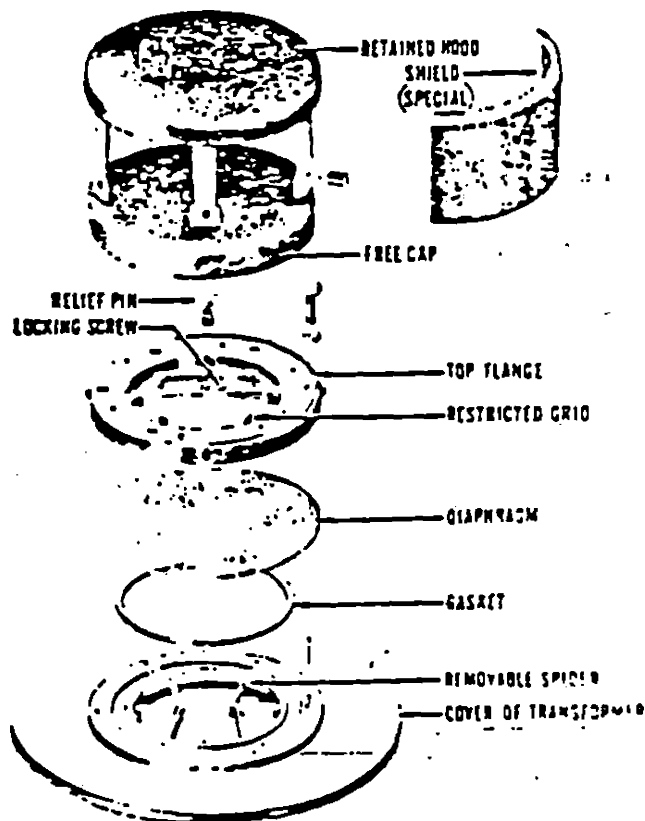


Fig. 3. Pressure relief with 8-inch di

relief diaphragm is a thin disk of molded material (G-E compound 2029B) firmly held between clamping rings with a gasketed joint. These clamping rings are the bottom flange on the main cover and the top flange. Located in the cover opening directly below the diaphragm is a removable spider which supports the diaphragm in case of vacuum in the tank. In the top flange is a crossbar rigidly held in place by a setscrew at each end. The lower side of the crossbar holds a blade with a knife edge a short distance above the diaphragm. A grid, which is restricted in its vertical movement by two screws, is fastened to the crossbar by a relief pin, so that the edges of the grid are located just above the diaphragm. A metal cap (free cap) fits down over the top flange and is held in place by two spring clips, thus providing weatherproof protection for the diaphragm. If the device is provided with an alarm switch, two supporting clips are mounted on the top flange to prevent the free cap from tilting. For a complete description of the alarm see the subsequent chapter on PRESSURE RELIEF ALARM. Assembled over the free cap is a retained hood with six feet bolted to the edge of the top flange. When required, a special shield is mounted on one side of the pressure-relief device to deflect any oil that may be ejected when the device operates. This shield is held in place by three long bolts and three spacers bolted to three of the holes in the edge of the top flange.

Should a sudden pressure occur within the transformer tank, the relief diaphragm will be forced up against the bottom edges of the grid, breaking the relief pin and allowing the grid to rise to the top of the screws. This permits the diaphragm to contact the knife edge, which immediately ruptures the diaphragm. The escaping gas raises the free cap and relieves the internal pressure, after which the free cap drops back in place to close the diaphragm opening, reducing the possibility of moisture entering the transformer tank.

The number "10" stamped on the head of the relief pin indicates a diaphragm rupturing pressure of 10 pounds per square inch; the number "15" signifies a diaphragm rupturing pressure of 15 pounds per square inch.

Installation

If the pressure-relief device was shipped on the transformer, it is only necessary to remove the temporary wooden blocks and make certain the diaphragm is intact to prepare the device for operation. To inspect the diaphragm, remove the retained hood and the free cap, then replace these parts.

If the pressure-relief device was shipped separately, remove the temporary shipping plate over the opening. Make certain the gasket is in place in the bottom flange, then place the diaphragm over the gasket. Assemble the top flange over the diaphragm, bolting it firmly in place. Fit the free cap firmly in place on top of the flange. If the device is equipped with an alarm switch, make sure the two supporting clips rest firmly against the free cap. Install the retained hood over the free cap by holding it to the edge of the top flange with six hex head screws.

If a shield is provided, assemble it in the desired location, using the long bolts and spacers.

On Sealed Transformers

Install the pressure-relief device on sealed transformers when the liquid temperature is between 25 C and 40 C. The pressure at which the transformer is sealed is dependent on the temperature of the liquid and should be in accordance with instructions under PRESSURE TEST.

When this pressure-relief device is used on a sealed transformer to be installed indoors, a gas absorber or a vent pipe to the outside atmosphere can be installed directly over the relief diaphragm, if required. If this installation is to be made, it is necessary to remove the retained hood and the free cap from over the relief diaphragm. Six tapped holes (1/2 inch-12) are provided in the top flange, to which the flange of the gas absorber or the vent pipe can be bolted. The outer end of a vent pipe should be protected from the weather.

Renewal of Diaphragm

To renew the relief diaphragm after it has been ruptured, it is necessary to remove the retained hood by taking out the six hex-head screws around the rim of the top flange. If a shield is provided on one side of the pressure-relief device, note its position.

it can be replaced in the same location. Remove the retained hood and lift off the free cap. Take out the six hex-head screws holding the top flange and remove the top flange together with the restricted grid. Remove the broken diaphragm. Note that a removable spider is located in the opening below the diaphragm. This spider must be left in place. However, it can be removed if it is necessary to use the opening as a handhole for any purpose. When replacing the spider, be sure the notched ends are down.

Make certain the gasket is in place in the groove in the top flange, then place a new diaphragm over the gasket. Remove the broken part of the relief pin from the crossbar in the top flange. (The bottom part of the relief pin is slotted to facilitate removal.) Remove the broken part of the relief pin from the top bar of the restricted grid by removing the small brass locking screw and washer. The new relief pin must have the same number (10 or 15) stamped on the head as the one being replaced. Install the new relief pin by inserting it through the central hole in the top bar of the restricted grid and carefully screwing it into place, using a very light twisting effort on the screw. For this reason, the relief pin is designed to be screwed in with the fingers. Replace the washer and small brass screw to lock the relief pin. Assemble the top flange over the diaphragm, bolting it firmly in place. Fit the free cap firmly in place on the top flange. On devices provided with an alarm switch, make sure the two supporting clips rest firmly against the free cap to prevent it from tilting. Install the retained hood over the free cap by bolting it to the edge of the top flange with the six hex-head screws. If a shield is provided on the pressure-relief device, assemble it in the proper place, using the long bolts and spacers.

Pressure-relief Alarm

A pressure-relief alarm switch can be mounted on the transformer cover adjacent to the pressure-relief device. The switch is assembled inside a weatherproof housing and has a shaft protruding and bent at a right angle. A coil spring on the shaft exerts considerable twisting effort, and a cam mounted near one end of the shaft acts as a stop, allowing the shaft about 90 degrees rotation. At one end of its travel the cam comes

against the actuating member of the small snap-action switch mounted inside the housing, closing the switch. The switch housing, fitted with a weatherproof cover, has provision for conduit connection.

The switch is rated 5 amperes at 250 volts a-c, or 10 amperes at 125 volts a-c. The d-c rating is approximately 0.05 ampere at 250 volts maximum.

There is also a visible alarm mounted on the shaft. This indicator (painted red) turns up to the vertical position when the shaft rotates.

To set the switch in the normal open position it is necessary to lift up the free cap on the pressure-relief device. Then use the reset pin to turn the shaft so as to bring the bent end to a vertical position. The free cap should then be pressed down in place with the vertical end of the shaft engaging in the hole in the angle bracket attached to the free cap. In this way, the switch is held in the open position.

TEN-INCH PRESSURE RELIEF

Receiving

For shipping purposes, the relief pin is removed and shipped separately with an extra relief pin, gasket, and diaphragm. Also, the relief cover is securely wired in place. When installing the transformer, remove the shipping wire from the cover and assemble the relief pin as described under INSTALLATION.

Description

Fig. 4 shows the outline of the 10-inch pressure relief and the internal construction in two sectional views. The diaphragm is a thin disk of G-E compound No. 2029B firmly held between a recessed gasket in the pipe flange and clamping flange. The grid in the pipe flange enables the diaphragm to withstand full vacuum in the tank, and a gasketed, metal cover, closed firmly over the diaphragm by spring tension, protects it from the weather and mechanical injury. The relief pin extends through the edge of the cover opposite the hinge, and is screwed into the diaphragm clamping ring to hold the cover closed. The treated aluminum composition of this pin precludes corrosion. One of two numbers will be found stamped on the head of the relief pin. The number "10" indicates

rupturing pressure of 10 pounds per square inch; the number "15" signifies a diaphragm rupturing pressure of 15 pounds per square inch.

A sudden pressure within the transformer tank will force the diaphragm out against the cover, exerting tension on the relief pin, which is designed to break when the tension reaches the predetermined value. As soon as the relief pin breaks, the diaphragm is released against a knife edge centrally located over the front of the diaphragm. The knife edge cuts through the diaphragm, which breaks open to relieve the pressure. Immediately after relief of the pressure, the cover is closed by spring action, shutting firmly against a gasket to reduce the possibility of moisture entering the transformer.

Installation

When installing the transformer, remove the shipping wire from the relief cover. Insert the aluminum relief pin through the steel pin in the edge of the cover, and screw it into the steel clamping ring. Use a nail in the hole just above the threads of the relief pin to screw it into place, and tighten the relief pin only until the head touches the steel pin in the cover without straining the relief pin. Do not turn the relief pin by its top end. After the relief pin is screwed into place, seal it to prevent tampering by using a piece of copper wire through the hole in the head of the pin and passing the wire around the steel pin as shown in section A-A of Fig. 4.

VENT PIPES AND GAS ABSORBERS

Pyranol transformers rated 15,000 volts or less can be installed in a building without a fireproof vault in accordance with the requirements of the 1947 National Electric Code*, since in sizes above 25 kva they are equipped with pressure-relief diaphragms or vents. This diaphragm meets the code requirements for transformers installed in well-ventilated areas. The upper steel clamping ring which fastens the diaphragm to the transformer is provided

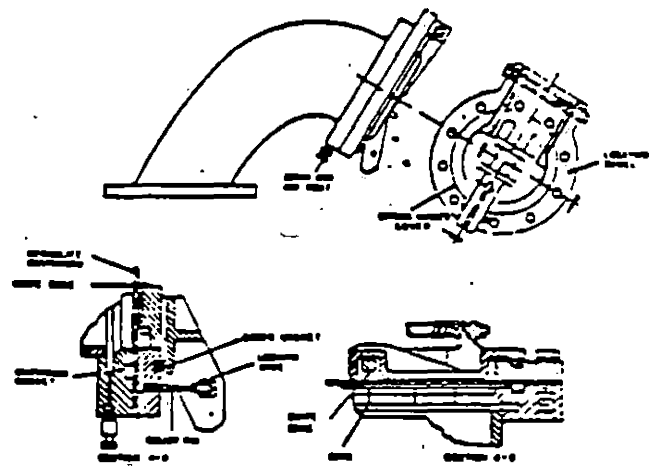


Fig. 4. Pressure relief with 10-inch diaphragm

with tapped holes, arranged to permit the easy attachment of a vent pipe that can be carried to the outside air, to a chimney, or to some other ventilating flue.

VENT PIPES

When a vent pipe is provided for carrying gases away from a poorly ventilated area, it

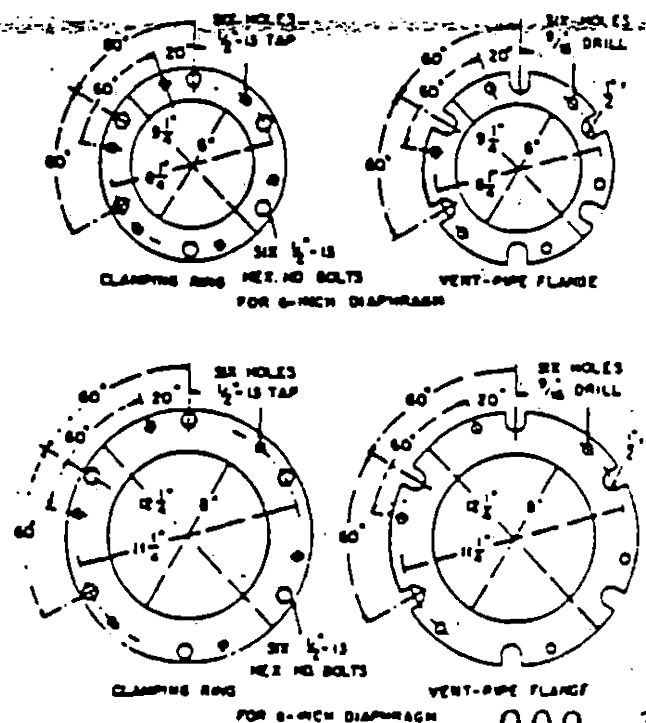


Fig. 5. Vent-pipe-flange outlines and dimensions

*4522. "Askarel-Insulated Transformers Installed Indoors. Askarel-Insulated transformers rated in excess of 25 kva shall be furnished with a pressure-relief vent. If installed in a poorly ventilated place they shall be furnished with a means for absorbing any gases generated by arcing inside the case, or the pressure-relief vent shall be connected to a chimney or flue which will carry such gases outside the building. Askarel-Insulated transformers rated more than 15,000 volts shall be installed in a vault".

is recommended that its diameter be no smaller than the clear diameter of the frangible diaphragm to which it is attached; that is, either six or eight inches, as shown in the outline (Fig. 5). It is also recommended that the metal of which the vent pipe is made shall not be lighter than No. 16 gage and that it shall be installed with the minimum of bends in order to provide a free passage of gas. It is further recommended that provision be made for inspecting the diaphragm and for removing any moisture that may accumulate on it. It is preferable that the pipe be so arranged that moisture cannot collect on the diaphragm.

GAS ABSORBERS

Where the installation of a vent pipe is not practicable, a gas absorber can be installed on the flange over the frangible diaphragm, as shown in Figs. 6 and 7. An absorber is designed to absorb the gases produced by arc disintegration of part of the Pyranol in the transformer,—two percent of the Pyranol in distribution and power transformers, and five percent for a-c network transformers.

This absorber has a steel tank with a mounting flange at the bottom for attachment to the relief vent of the transformer tank. At the top is a diaphragm with protecting cover.

Inside the absorber tank are several trays, one above the other, each of which has a perforated steel bottom. The trays are fastened together by a center bolt to facilitate assembly, and the entire group is secured to the absorber tank by two studs. The bottom tray is filled with chipped marble; the upper trays contain G-E Compound A50P9. For transformers rated over 500 kva, all trays contain the compound.

When an arc in the transformer generates gas and raises the pressure sufficient to break the diaphragm on the transformer, the gas passes into the absorber and is absorbed by the compound. Liquid carried along with the gas is stopped by the chipped marble and drains back into the transformer. If the gas exceeds the capacity of the absorber, the top diaphragm breaks.

APPLICATION

Under the provisions of the National Electric Code, it is the responsibility of the local code authority to determine whether vent pipes

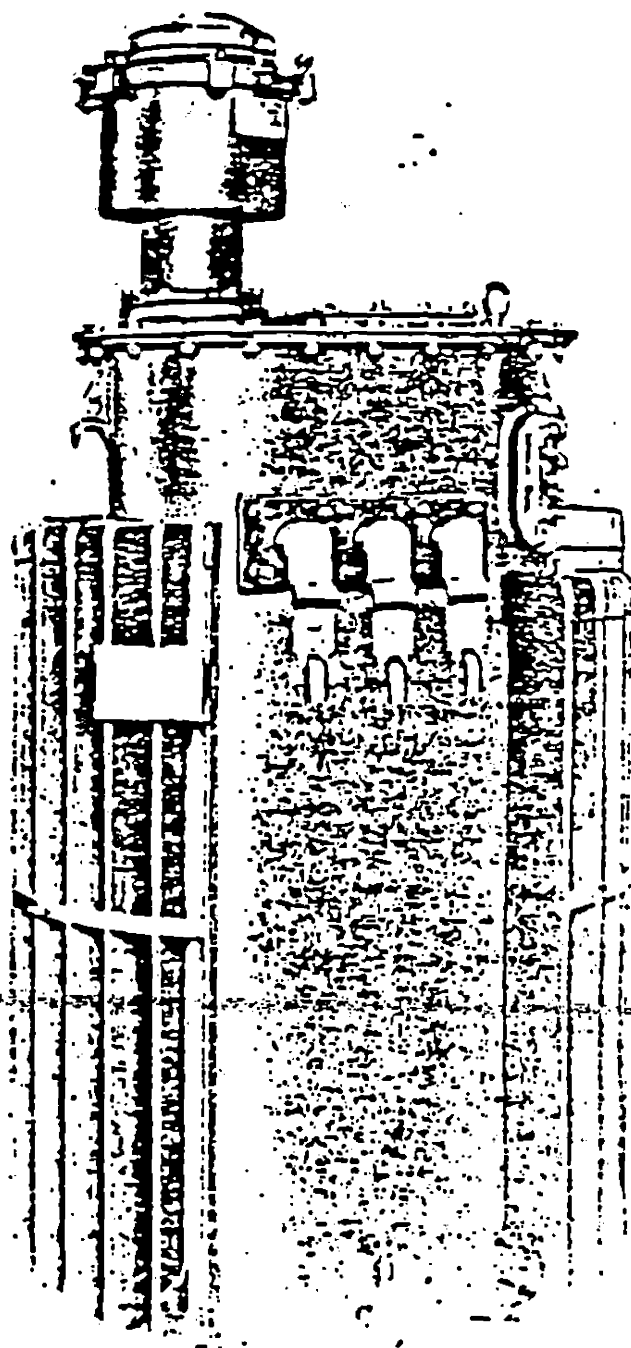


Fig. 6. Pyranol transformer with gas absorber

or absorbers are required for a given installation. Important factors to be considered are: the energy available in the circuit to which the transformers are connected, the type of protective equipment, the area and volume of the room in which the transformers are installed, the ventilation facilities in the room, the number of people employed in the

and the proximity of the employees to the transformers.

If absorbers are used, it is recommended that one absorber be used with each transformer. If one absorber is connected to two or more transformers by means of a header pipe, there is the possibility that if one transformer fails and sufficient gas is generated to break the glass diaphragm in that transformer, the pressure in the header pipe may also be sufficient to break the diaphragms in the other transformers. Furthermore, if more than one transformer were simultaneously involved in trouble, sufficient gas might be produced to exceed the capacity of one absorber.

The absorber should be inspected at intervals to make certain that the diaphragms are intact and that the compound in the absorber trays has not become damp or caked.

When a gas absorber is supplied, a separate instruction book, which describes the installation, operation and care of the device, accompanies the apparatus.

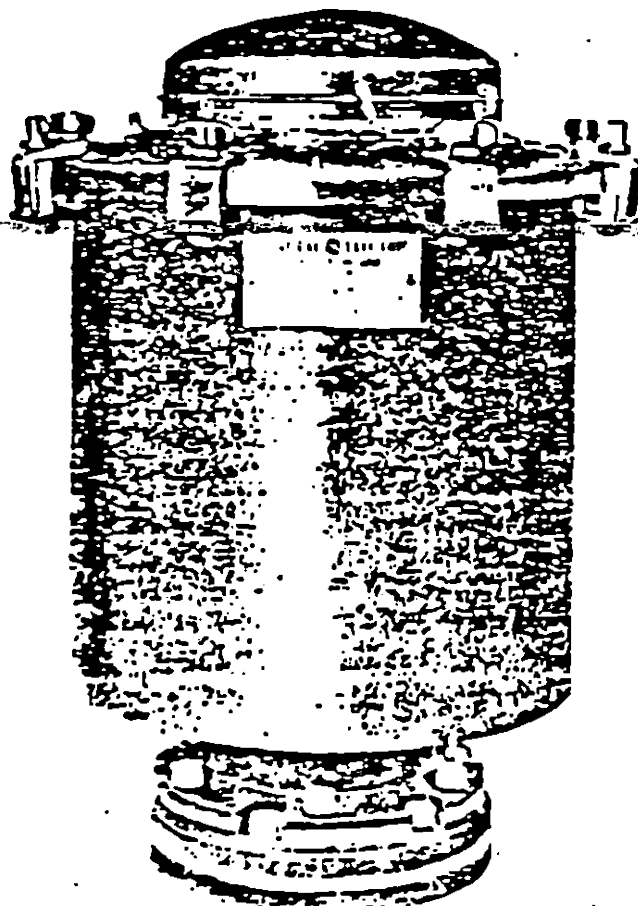


Fig. 7. Gas absorber

SAMPLING VALVE

Some transformers are provided with a sampling valve by means of which the height of the intake can be varied to coincide with the rise and fall of the Pyranol level, corresponding to temperature changes. This type of valve makes it possible to obtain a sample at the surface of the Pyranol at any time.

The valve is placed in the tank wall at a point about one inch below the 25 C Pyranol level. The intake pipe is a tube inside the tank and located parallel to the tank wall, the end of which may be raised or lowered by rotating the outside part of the valve by moving the handle which extends below it. Note that when the handle points straight down, the intake pipe points straight up and is in position for maximum Pyranol level. The valve is fitted with a knurled nut which can be opened by hand, or by the use of a coin or screwdriver.

To take a sample, set the operating handle pointing down, open the valve, and rotate the operating handle slowly until the liquid begins to flow, at which point the rotation should be stopped to assure getting a sample of the surface liquid.

Some transformers do not use the rotating feature, in which case the sample is taken by merely opening the valve and allowing the liquid to flow out.

Pyranol transformers are sealed, and no breathing takes place with the rise and fall of the Pyranol level. Thus, when the Pyranol is at a temperature other than 25 C, there is either a pressure or a vacuum within the tank, depending upon whether the temperature is above or below 25 C. For this reason, it is advisable to take a sample only when the Pyranol level gage is resting on, or slightly above, the 25 C mark. If the valve has been opened at any other time, and the vacuum or the pressure has been relieved, the valve should again be opened when the Pyranol next reaches the 25 C level so that no abnormal pressure or vacuum will be developed during subsequent changes in temperature. If the transformer is resealed while the Pyranol is at a temperature that is above 25 C, the pressure in the air space can be restored to the proper value by dry compressed air or nitrogen. The proper sealing press

various temperatures are listed in a Table under Pressure Test.

TAP CHANGERS FOR DE-ENERGIZED OPERATION

There are several types of tap changers (ratio adjusters) known as "drum", "plunger", "crab", and "wedge".

All tap changers have indicating marks on stationary and rotating parts which must be in alignment when the tap changers are on position No. 1.

NOTE: DO NOT ATTEMPT TO CHANGE CONNECTIONS BY MEANS OF THE TAP CHANGER WHILE A TRANSFORMER IS EXCITED.

DRUM TYPE

A change in voltage ratio with a drum-type tap changer is made by a partial turn of the handle. Remove the two bolts that hold the handle in place, or the cover over the handle, and turn until the index line points directly to the desired figure on the dial. After the handle is in the proper position, lock securely by replacing the two bolts or the cover.

Before removing a power-transformer cover, take out the bolts that attach the tap changer to the cover flange, then lift the handle and shaft out of the cover. Do not replace a cover on a tank with the tap-changer operating rods in place. First, assemble the cover and lower the rods through their respective openings, noting that they engage properly with the tap changers, and finally add the cover operating mechanism.

When more than one operating rod is furnished, the rods are numbered in accordance with the nameplate, and are not interchangeable. Match marks on the operating rods and the internal core-and-coil structure indicate the proper assembly of the operating rods and tap changers. The slot and pin joining the rod to the operating cap are larger on one side of the rod than on the other to aid in making correct assembly. A vernier coupling is used between the rod and the operating cap to assure that the indicator points directly to the dial number when the mechanism is in a correct operating position. Sometimes, in re-assembling, it may be necessary to change the vernier coupling in order to obtain proper alignment of the shafts. Be sure that the

operating cap does not force the rod down on the mechanism. It should be possible to move the rod slightly up and down and rotate it an equal distance to either side after the assembly is completed; otherwise, the mechanism might be damaged. If this vertical play is not obtained, remove the metal sleeve from one end of the rod, cut a small amount from the rod, and replace the sleeve.

PLUNGER TYPE

The plunger-type tap changer provides solid insulation between the tap connections. This insulation must be lifted over the contact members each time the taps are changed.

To change taps, remove the two hex-head bolts in the cap and lift off the cap. Pull up the handle as far as it will come (about seven inches). Rotate the handle until the pointer end is over the desired tap position, and then push down into the original position. Tighten the gland and bolt down the cap.

The contactor is of the scraping type and is self-cleaning. If it is considered desirable to make an inspection, proceed as follows: Remove the cap, lift up the handle as in changing taps, and turn the contactor to a position between taps. It will stand in this position. Then remove the three studs and take off the clamping ring. Lift straight up on the handle. This will remove the small cover through which the shaft passes and also the operating shaft and contactor.

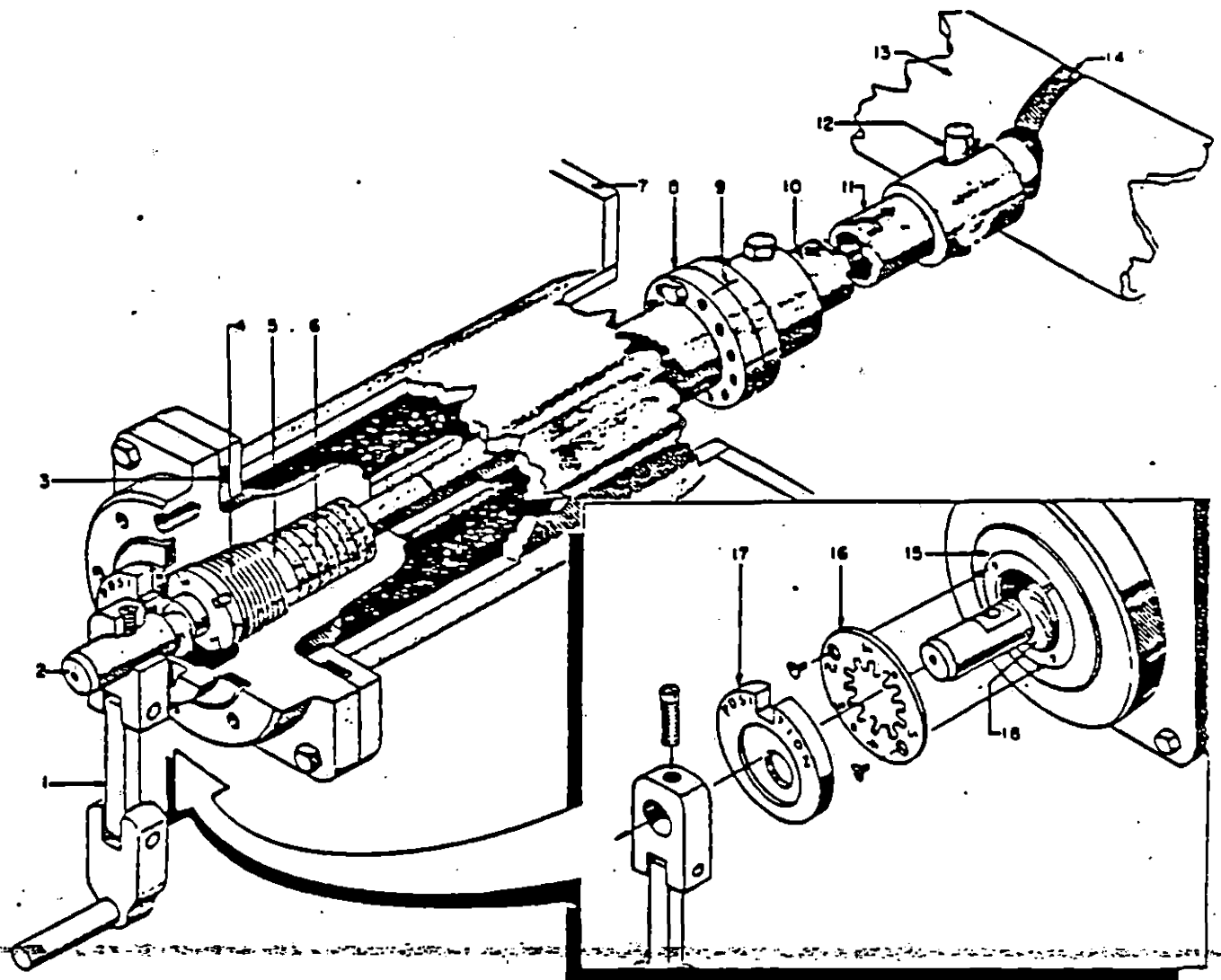
When it is desired to remove the transformer cover, the tap-changer contactor should first be removed from the transformer.

CRAB TYPE

This type of tap changer is so named because of the unique action by which the eccentric drive shaft and the contact arm, which it actuates, rotate in opposite directions.

The construction consists essentially of a number of round contact rods with studs, to which the tap leads are connected. These contact rods are mounted between insulating heads of molded compound with Herkolite[®] tube inserts. A centrally mounted crankshaft that actuates the movable contact arm is operated through a Herkolite insulating coupling. The contact arm has fingers which contact the individual contact rods at the outer end, and, at the inner end, a cylindrical copper collector which is placed over the

[®]Trade-mark Reg. U.S. Pat. Off.



- | | | |
|-------------------|--------------------------|----------------------|
| 1. Folding handle | 7. Tank of transformer | 13. Half cylinder |
| 2. Shaft | 8. Vernier coupling | 14. Index paint mark |
| 3. Gasket | 9. Index marks | 15. Gasket |
| 4. Nut | 10. Insulating shaft | 16. Numbered disk |
| 5. Follower | 11. Index line | 17. Disk |
| 6. Gaskets | 12. Tap-changer coupling | 18. Cam |

Fig. 8. Operating mechanism for wedge-type tap changer

drive shaft. Extending from this collector is a copper arm which connects to a separate stud similar to the contact rods. This stud forms a common terminal, completing the circuit through the tap changer from any of the contact rods.

WEDGE TYPE

Folding-handle Operating Mechanism

The operating mechanism for the wedge-type tap changer has a folding handle. (See Fig. 8.) To change taps, take out the two

bolts in the mechanism cover and remove the cap. This completely uncovers the folding crank, which can be unfolded by grasping the nearest section and lifting out. When the crank is unfolded, the position number is exposed. Turn the tap changer by means of the crank to the desired position, fold the crank to the "locked" position, and replace the cap. When the cap is bolted over the mechanism, a metal pointer will be in alignment with a number on the rim of the cap to indicate the tap position on which the tap changer stands. One

of the bolts in the cover has a hole into which a padlock can be inserted to lock the operating mechanism in position.

If the operating mechanism and insulating rod are shipped separate from the transformer, they must be carefully assembled to assure satisfactory operation. Operating mechanisms and rods are identified by the tap-changer number and the last three numbers of the serial number of the transformer, as shown on the nameplate.

Operating mechanisms with insulating rods attached must be assembled to the tap changers when both are on position 1. On this position the contact wedge of the tap changer is always between the two contact rods that are connected to the leads tagged A and B. Check to see that the tap changer is on position 1. On this position only, the large end of the driving pin lines up with the line on the cylinder or clamp. Next, check the connection of the vernier coupling at the top of the insulating rod. The marks on the two coupling halves should line up. Insert the insulating rod through the opening in the tank or cover onto the driving pin on the tap-changer shaft. If the tap changer and insulating rod are in the correct position, the mark on the insulating rod will be in an exact line with the mark on the top core clamp of the transformer. The operating rod should be entirely suspended from the operating mechanism; none of its weight should be carried by the tap changer.

The bolt holes in the mechanism gland should line up with those on the tank or cover flange. When bolting the mechanism to the flange on the cover, the pointer for the position indicator must be assembled under the flange bolt or bolts which are located next to the tank wall. Where the operating mechanism is mounted on the side of the tank, the position-indicator pointer should be assembled under the bolt or bolts on the lower side of the tank flange. Start one or two bolts by hand to prevent the gland from turning, then tighten the others.

After completing assembly, check to see that the wedges make the best contact in each position by observing the torque as the tap changer is operated in both directions into a tap position. Starting from an operating position, the contact pressure is reduced to zero during the first 30-degree movement of the shaft. To shift the wedge to a point entering

the next operating position requires about 2/3 of a revolution. As there is little or no friction to overcome, the torque will be noticeably small. A 30-degree movement is then required to drive the wedge home and to build up the contact pressure.

The degree of contact of the wedge can also be determined by using a 115-volt lamp in series with the winding containing the tap changer. (Short-circuit the opposite winding or the lamp will not light.) The best position is midway in the band in which the lamp shows light. The design is such that a few degrees either side of the dial marking is permissible.

If it is necessary to move the wedge contact slightly, this is done by means of the vernier coupling. After making the adjustment, put the bolts through the holes that line up and recheck positioning as described above. After setting the tap changer, lock in position by mounting the cap and bolts before energizing the transformer.

The cast-iron cap and folding crank are sometimes removed for shipment. When this is done, a temporary metal cover painted red is used over the end of the operating shaft. This cap locks the tap changer on position 1, and it should not be removed until the folding crank can be installed. Do not turn the shaft until the crank is installed. To assemble the crank, it is necessary only to remove the screw through the shaft and replace the screw through the crank hub and shaft. These parts can be assembled only one way. Fold over the crank and bolt on the permanent cast-iron cap. The temporary cap and three screws can be discarded.

When the tap changer is mounted in a vertical position, and the operating mechanism is mounted in a horizontal position, a position indicator is provided on the bracket for the bevel gears inside the transformer tank. When it is necessary to reconnect the drive shaft inside the tank to the operating mechanism, this internal position indicator must be observed and set on the same position number as the operating mechanism.

Cap-type Operating Mechanism

Older designs of the operating mechanism for a wedge-type tap changer have a cap instead of a folding handle. To operate the tap changer, remove the two bolts which

cap, remove the cap, and invert it. Fit the inverted cap to the end of the operating shaft and use it as a handwheel to set the tap changer. To lock the tap changer in position after setting, replace the cap and bolts.

Operation of Wedge-type Tap Changers from Floor Level

Floor-level operation is accomplished on large transformers by extending the shaft through a liquid seal on the tank wall to a pair of bevel gears, from which the shaft descends to a handwheel located at a convenient height above the floor.

This seal affords a continuously high degree of protection against leakage, with the minimum amount of attention and maintenance. A powerful spring exerts a continuous, heavy pressure upon the packing material so that no periodic tightening is required. The shafts are supported in the housing by self-lubricating bearings.

The handwheel is equipped with a position indicator and a locking pin which engages only on operating positions, and which can be padlocked. The handwheel can be provided with a key-interlock, if desired.

Installation of Floor-level Drive

The tap changer with operating mechanism at floor level is usually shipped in place on the transformer and set on position 1.

If the operating mechanism and insulating shaft are shipped separately, they must be assembled in the correct position to assure proper operation. Operating mechanisms and rods are identified by the tap-changer number and the last three figures of the transformer serial number as shown on the tap-changer nameplate. Some parts are not interchangeable between tap changers.

Before attempting to assemble the mechanism and rod, see that the dial indicator on top of the bevel-gear drive inside the tank, and the position indicator for the handwheel, are on position 1.

Refer to the Outline drawing furnished with the transformer, and bolt the liquid seal and long shaft to the flange on the outside of the tank. Insert the steel shaft of the handwheel drive mechanism into the lower end of the long coupling, and mount the mechanism in place on the tank.

Inside the tank, install the short-shaft coup-

ling between the stub shaft of the liquid seal and the transformer-shaft assembly. Two different-size slots in the metal coupling permit assembly in only one position. The shafts are also marked to indicate proper alignment.

After completing the assembly, check the contact of the wedges as described in WEDGE-TYPE TAP CHANGER.

TEST OF TAP CHANGERS

It is good policy to test each tap changer to make sure that the positions are correct and that the voltage steps are progressive. This can be done by applying a low voltage to one winding and measuring the voltage across the other winding for each position of the tap changer.

BUSHINGS

Replacement bushings for Pyranol transformers should be ordered especially for use in Pyranol. Since instruction books are shipped with bushings, only brief, general instructions are given here.

INSTALLATION

See that bushings are clean and dry when installed. To expose the insulating material other than the porcelain to dirt or moisture is to invite deterioration and possible failure in service.

Do not attempt to install a bushing in the transformer during damp or stormy weather without providing adequate means for excluding moisture.

A bushing not having a detachable conductor should be installed in the cover of a transformer by first mounting the bushing upon the cover and subsequently connecting the terminal at the lower end of the cable conductor to the proper lead from the transformer winding.

The gasket beneath the terminal cap should be in perfect condition and should be made absolutely tight. A defective gasket or leak from any source at this point will allow water to enter the central tube from where it can run down into the transformer.

LINE CONNECTIONS

When connecting bushings to the line or external circuit, inspect the terminals or couplings after the connections are made to make sure that they are tight. The line co

must not bring any strain on the terminals which will cause the joints or contacts to become loose. Sufficient flexibility in the connecting leads must be provided to avoid mechanical strains due to expansion or contraction which may break the porcelain. The bushings will support a reasonable weight of connecting conductor, but long spans of unsupported conductor, especially if out-of-doors, should be avoided.

Bushings should be inspected at regular intervals and kept reasonably free from dust and dirt. In locations where abnormal conditions prevail, such as salt deposits, cement dust, acid fumes, etc., it should be recognized that a special hazard exists, and the bushings should be cleaned regularly to avoid accumulations on the external surface which may result in flashover.

CONNECTORS

A standard line of terminal connectors for use with both solid and liquid-filled bushings has been developed and these parts may be ordered as accessories to the bushings. These connectors provide for attaching cables, rods, tubes, and bars to the various standard bushings.

BUSHING-TYPE CURRENT TRANSFORMERS

Bushing transformers are those in which the secondary coil and core surround a bushing, the conductor of which forms the primary. This secondary coil and core are located either in an adapter on the main transformer cover or in a cradle suspended from the inside of the cover. These current transformers may be used to actuate either relays or ammeters. See the nameplate on the secondary outlet for turn ratios.

INSTALLATION

Bushing current transformers are usually shipped completely assembled in the power transformer, or at least in place in the high-voltage bushing adapters. It is then only necessary to inspect them to see that they are dry. If evidence of moisture is found, the current transformers must be removed and dried by hot air, not exceeding a temperature of 90 C.

If the bushing current transformer is shipped separately, assemble it in place with insulation as shown in Fig. 9. Be sure that the

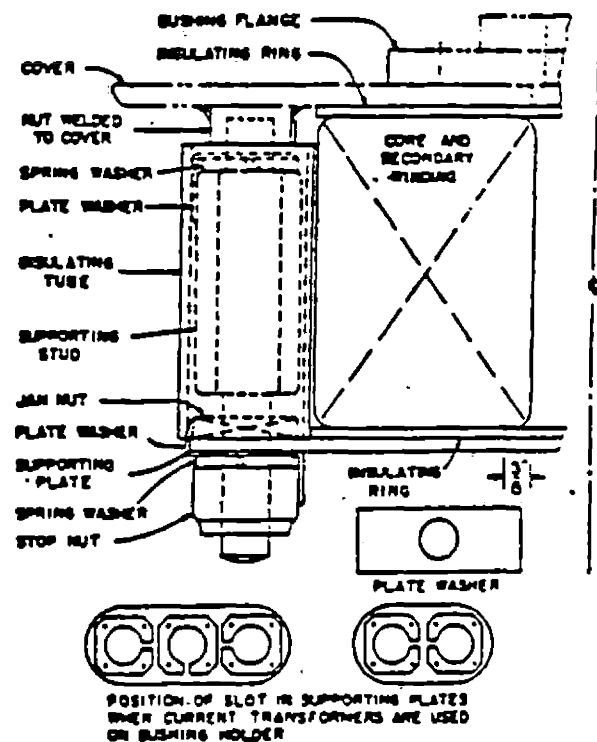


Fig. 9. Current-transformer support

coil is right-side up, as indicated by the word "TOP" or the letter "H₁" painted thereon. Handle the coil carefully so that the conductor insulation will not be injured.

Connect the leads to the inside terminals of the outer block, making sure that the letters on the inside and outside leads correspond.

To assemble the current transformer into the bushing adapter, remove the top of the adapter, fit the transformer into place, and replace the adapter top. Bolt the top down squarely to compress the gasket evenly.

On double-section tanks it is sometimes necessary to remove this type of current transformer from the underside of the cover for shipment. In such cases, reassemble with the end marked "TOP" or "H₁" uppermost in accordance with Fig. 9. The insulating tube can be pushed up while tightening the jam nut. New plate washers are furnished and should be bent to lock in place, as indicated. Maintain the 3/8-inch overhang of the current transformer inside the supporting plate opening.

CONNECTIONS AND POLARITY

Insulate all leads not in use from all other leads and ground. Do not allow the secondary

circuit of a current transformer to remain open. It must be closed through a burden or by the short-circuiting links provided for the purpose.

The relative instantaneous directions of primary and secondary currents are shown in Fig. 10.

PYRANOL IMMERSED, AIR-PRESSURE-COOLED TRANSFORMERS

These Pyranol immersed transformers are cooled by a free-air discharge applied to the cooling surface. Air for cooling the transformer is supplied by a unit blower and motor or by small, weatherproof, outdoor fans which may be provided with hand or automatic control.

All equipment is designed for outdoor service.

The fan motors require the care usually given such apparatus.

If thermal devices are furnished for fan control, they are adjusted at the factory and should not be disturbed. If changes need to be made, recommendations should be obtained from the nearest Apparatus Sales Office of the General Electric Company.

When fans are not in use, they should be operated periodically to make sure they are in satisfactory condition.

FORCED PYRANOL COOLED TRANSFORMERS

In forced Pyranol cooled transformers, the Pyranol is cooled by forced circulation through an external cooler.

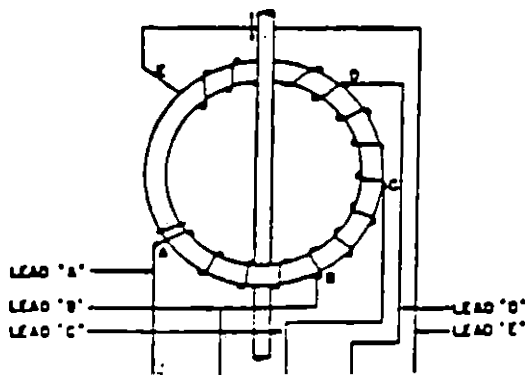


Fig. 10. Schematic diagram of bushing transformer, showing method of marking leads and tapping secondary winding

NOTE:- The Pyranol must be circulated and cooled at all times on an excited transformer regardless of whether or not the transformer is carrying load.

A special Pyranol cooler is generally furnished as well as a pump and motor. The cooler is designed for outdoor installation, and can be installed in either the vertical or horizontal position.

The piping connection should be such that the water passes through the tubes in the opposite direction to the Pyranol flow. This is essential in order to obtain maximum efficiency of heat transfer. It is also essential that the water pressure be kept below the Pyranol pressure to prevent any water entering the Pyranol should a leak develop in the cooler. The coolers in most cases are designed so that this difference will always exist when rated Pyranol flow and water flow are maintained.

One end of the cooler is provided with a floating head, and sufficient space should be allowed in the piping for the removal of this head.

When forced-air coolers are used instead of water coolers, special instructions will be furnished.

The quantity of Pyranol circulated has a direct bearing upon the heating and temperature rise of the transformer. It is very desirable, therefore, that the inlet and outlet temperatures of the Pyranol be measured and recorded to check the quantity of Pyranol flowing.

The top Pyranol is cooled about 15 C during passage through the cooler and the water temperature increased about 5 C. Usually the water flow is 50 percent greater than the Pyranol flow.

The tubes in the cooler should be kept clean. To clean them, remove the cover plates from each end of the cooler and clean the inside surface with a wire brush.

The external surface of the tube bundle may be cleaned by flushing out with a volatile cleansing fluid. The tubes must then be dried by passage of hot air through this section of the cooler.

Coolers may be tested at a pressure of 100 lb per square inch to determine whether there is any leakage.

It is possible to cool the Pyranol from a bank of transformers by using one

one Pyranol pump, but this practice is not favored. In such installations, equalizers must be used to obtain proper Pyranol distribution, which is difficult to obtain and uncertain. Also, in case of trouble in one unit, damaged Pyranol would be pumped directly into the good transformers. A separate cooler and Pyranol pump for each transformer are recommended.

IF TRANSFORMER DOES NOT OPERATE

The procedure to be followed if a transformer fails to operate depends on which of two Pyranols, No. 1488 or No. 1467, is used in the transformer. Transformers shipped prior to November 20, 1944 were filled with No. 1488 Pyranol. Transformers shipped after this date were filled with No. 1467 Pyranol. Transformers containing No. 1488 Pyranol require different handling from those containing No. 1467 Pyranol.

To determine which Pyranol the transformer contains, refer to the transformer nameplate. Nameplates of transformers containing No. 1467 Pyranol bear this number preceding the quantity of Pyranol shown in the tabulation of weights. No Pyranol number is given on the nameplates of the transformers containing No. 1488 Pyranol. Should there be any doubt as to the Pyranol contained in the transformer, handle it as if it were No. 1488.

TRANSFORMERS IMMERSSED IN NO. 1488 PYRANOL

If a transformer filled with No. 1488 Pyranol fails to operate, it is recommended that the unit be sealed immediately from the atmosphere and the nearest General Electric Apparatus Sales Office notified.

Take a sample of Pyranol from the top of the transformer and inspect it for discoloration and the presence of water.

Keep the transformer sealed; do not remove the interior for examination until recommendations are received from the General Electric Company.

TRANSFORMERS IMMERSSED IN NO. 1467 PYRANOL

If the transformer contains No. 1467 Pyranol, it may be handled in the same manner as a transformer containing 10-C oil with exceptions as noted below.

GENERAL PROCEDURE (With either No. 1467 or No. 1488 Pyranol)

The following instructions concerning repairs presuppose that a transformer containing No. 1488 Pyranol has been prepared for unranking in accordance with recommendations obtained from the General Electric Company.

1. Filter the Pyranol and store in thoroughly dry, clean, and oil-free containers. All pumps, filters, and piping used in this process must also be thoroughly clean, dry, and oil-free. See previous instructions covering filtering.

2. As soon after the filtering as possible, send a one-quart sample of the purified Pyranol, together with the serial number and rating of the transformer, and the results from the examination of the original Pyranol sample (if Pyranol is No. 1488) to the Field Engineer, General Electric Company, 100 Woodlawn Ave., Pittsfield, Mass., so that analysis and recommendation for repairs can be made.

3. Thoroughly clean the top yoke and top core laminations to prevent tackiness which would hinder reassembly. No. 1478 Pyranol is the most satisfactory cleaning agent. Naphtha may be used, but presents a fire hazard.

4. Until repair materials are available, store the core and coils in a clean, dry room. Pyranol film becomes tacky, making dust or dirt difficult to remove. If the core and coils have not been disassembled, resubmersion in the filtered Pyranol is recommended, provided an adequate container is available.

5. When reassembled, Pyranol transformers can be dried by the short-circuit method. (See DRYING PYRANOL TRANSFORMERS.) During drying, the top Pyranol temperature should be from 90 C to 100 C.

JUNCTION BOXES

A transformer is sometimes equipped with a junction box, a metal housing that completely encloses the connection between the transformer bushing and the cable. A junction box should be kept filled to the proper level with the insulating medium specified: Pyranol, oil, or petrolatum. For the lower voltages, air is sometimes used.

The junction box can usually be removed from those transformers so equipped, to facilitate lowering the transformer tank into the vault.

Before making the connections, refer to the special instructions furnished with the cable end or cable terminal.

TRUCKS

Bearings, whether bushed or of the roller-bearing type, have a 1/8-inch pipe plug provided in the end of the journal. To lubricate the bearing, remove the plug and insert an Alemite fitting. Trucks are shipped with the bearings filled with grease, but the bearings should be inspected and refilled from time-to-time to prevent corrosion.

LOAD-RATIO CONTROL

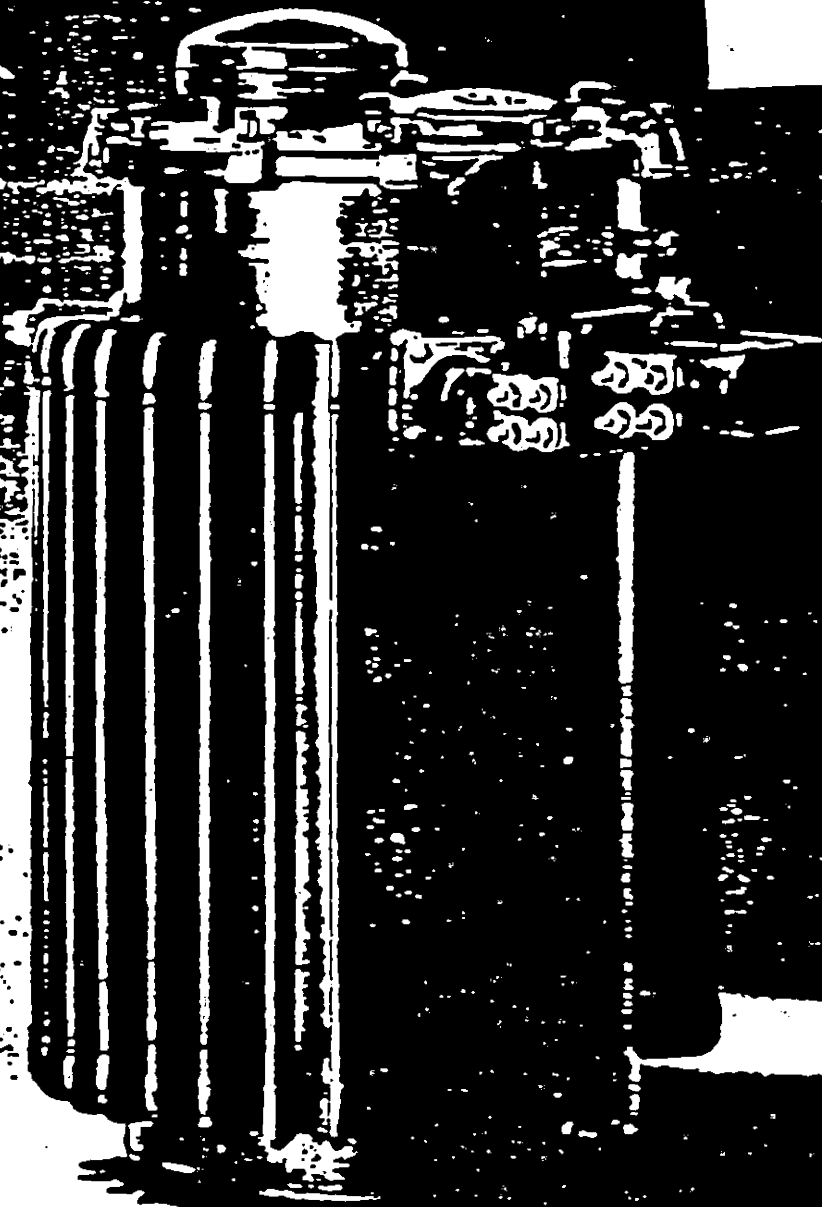
Transformers which are equipped with load-ratio control, that is, those arranged to permit a change of taps without disconnecting the load, require the addition of a number of mechanical parts, and call for special electrical connections. Their installation, therefore, needs special attention. For this reason, all such transformers are covered by a special instruction book which should be thoroughly

read before any attempt is made to assemble or operate such transformers.

RENEWAL PARTS

When ordering renewal parts or Pyranol, or when requesting information regarding a particular transformer, always state the serial number of the transformer. This number will be found on the nameplate of the transformer. On large transformers, it will also be found stamped on the top core frame, the top band of the tank, and on the cover directly above the number on the tank band. A sketch showing the exact location of coils, insulation or other parts required will greatly facilitate the filling of the order. This sketch must always state which side of the transformer is shown.

Any additional information as to the electrical or mechanical construction, operation, or installation of a particular transformer may be obtained by application to the nearest sales office of the General Electric Company, mentioning the serial number and the rating.



Dynamo-L Transformers

GENERAL  ELECTRIC

GENERAL ELECTRIC

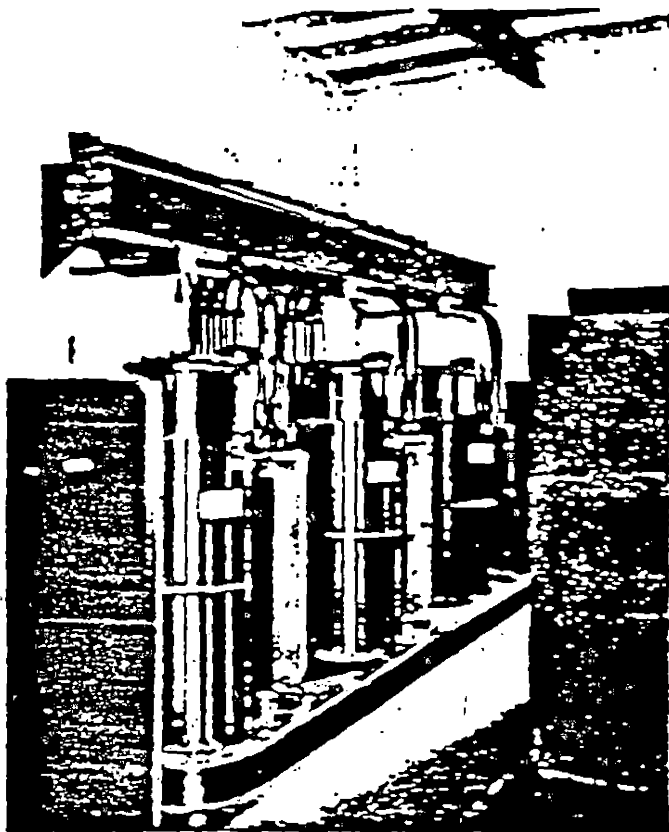
Pyranol^{*}, the cooling and insulating liquid of General Electric Pyranol transformers, is noninflammable

From this one fact spring many benefits to users of these transformers—direct benefits, including substantial savings realized not only during installation but, in most cases, throughout subsequent operation as well.

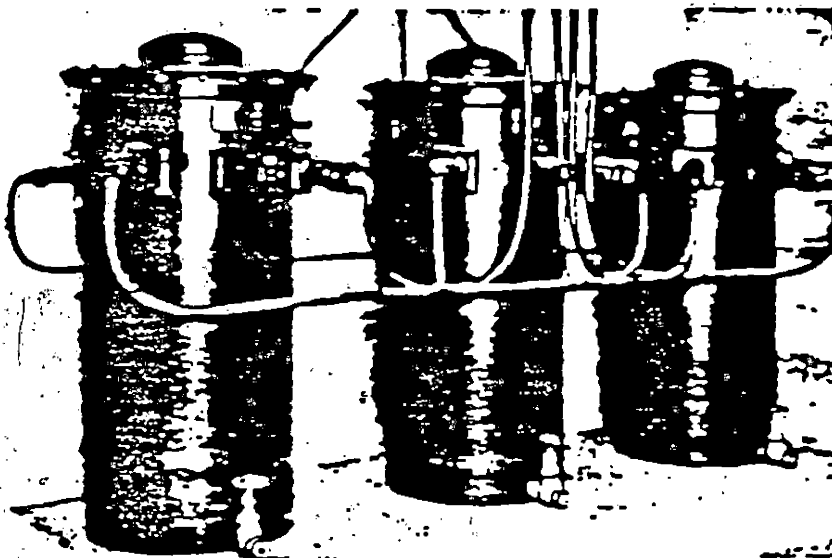
On these benefits is based the industry's wide acceptance of G-E Pyranol transformers, an acceptance which is best indicated by the fact that more than 7500 units, ranging in size from $1\frac{1}{2}$ to 12,000 kva, and totalling more than 2,000,000 kva, have been installed.

This bulletin outlines the principal advantages of General Electric Pyranol transformers and shows typical installations, selected from the wide range of service to which these transformers are applied.

**Registered trademark for G-E askarel.*

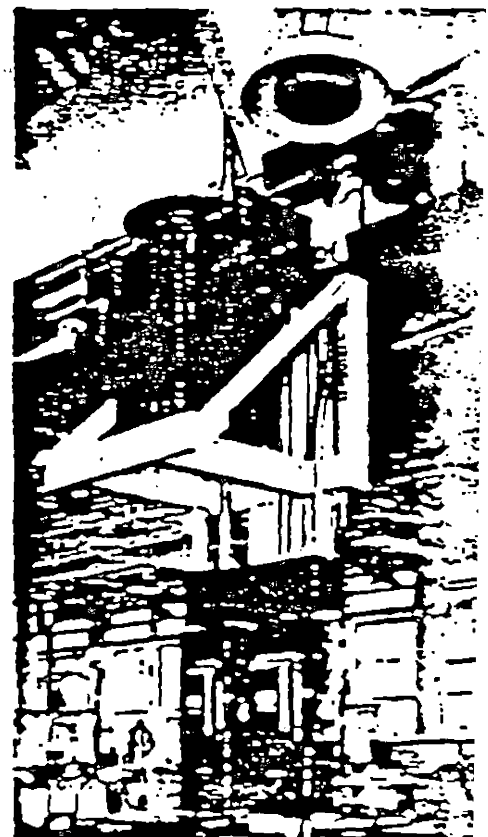


ON THE FLOOR in a motor room, Pyranol transformers bring primary power right to the load.



UNDERGROUND—with no costly enclosing vault required—Pyranol transformers eliminate long runs of secondary copper.

OVERHEAD and out of the way, at the center of the lighting load—in a modern industrial plant.



PYRANOL TRANSFORMERS

For Convenient, Economical Installations

Indoors or Outdoors

Pyranol transformers are ideally adapted for indoor installations in apartment, office, hospital, hotel, school, and theater buildings, where the noninflammable characteristics of Pyranol contribute to increased safety for occupants.

In addition, contractors and builders find that Pyranol transformers make possible many direct savings in time, materials, and expense in such installations. Contractors can install Pyranol transformers with only a simple protective metal fence or grille, and yet meet the full requirements of the National Electrical Code, whereas the use of oil-immersed equipment usually requires the construction of fireproof enclosing vaults, together with sills for these vaults sufficient to confine all of the liquid contained in the largest transformer in the vault. In addition, doors or ventilating ducts leading from the vault into the building may require special safety construction. Obviously, Pyranol transformers make possible a great saving in initial installation cost in such cases.

Because of this freedom from installation restrictions, Pyranol transformers can often be installed in out-of-the-way locations, usually close to the center of the electrical load. By eliminating long—and expensive—runs of secondary copper, they not only effect important savings in this critical material, but also pay daily dividends in the form of improved voltage conditions for lighting, appliances, and similar equipment.

These same factors also make Pyranol transformers a money-saving selection for many out-of-door installations. The degree of safety these units provide makes it possible to save valuable outdoor space by placing them in spaces formerly unused because they are not suitable for oil-immersed units—on roofs, for example. In like manner, pole-type substations can frequently be eliminated from urban areas by installing Pyranol units in out-of-sight locations suitable for only these noninflammable units.

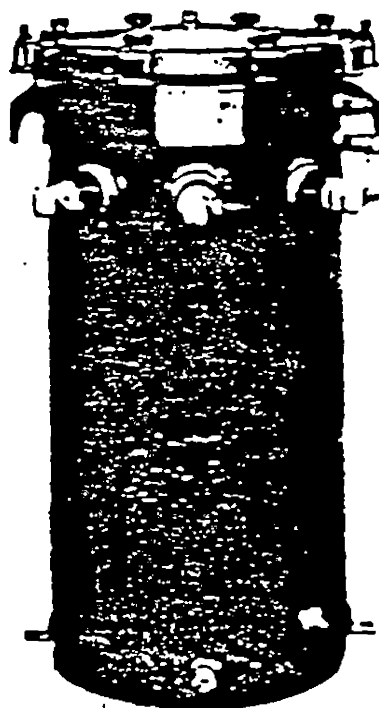


Fig. 1. Single-phase Pyranol transformer showing low-voltage tank-wall bushings. Rating 25 kva, 2400 4160 Y to 120 240 volts

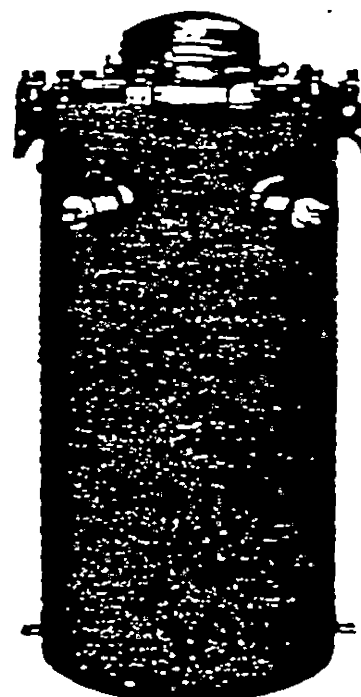
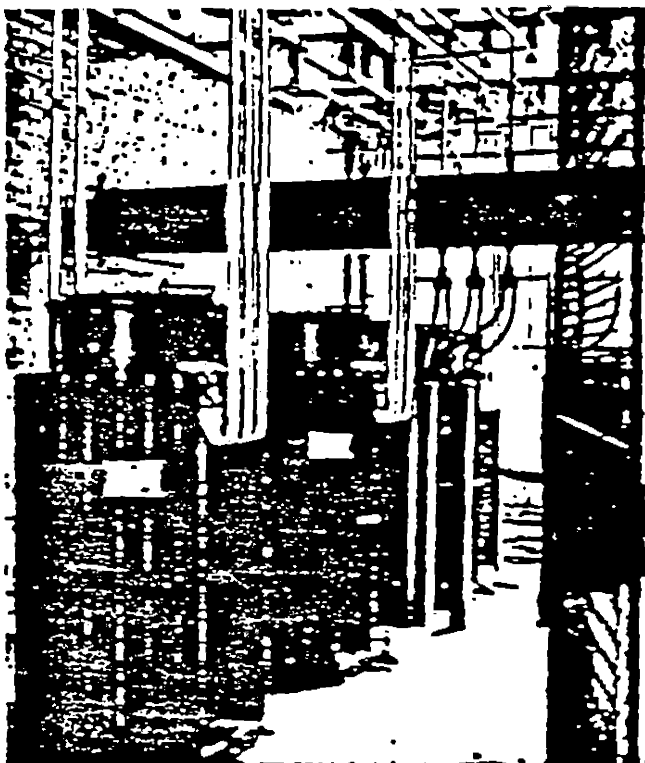


Fig. 2. Single-phase Pyranol transformer with relief diaphragm on cover showing high-voltage tank-wall bushings. Rating 50 kva, 2400 4160 Y to 120 240 volts

INDUSTRIAL PLANTS SAY



PYRANOL TRANSFORMERS were selected by a California industrial plant because the use of oil-filled units would have required the digging and lining of an underground vault in the production area of the plant. Furthermore, there were savings in installation time and costs.

An increasing number of industrial-plant managers and electrical superintendents are taking advantage of these distinctive economic benefits that Pyranol transformers offer for many types of duty:

INSTALLED QUICKLY AND INEXPENSIVELY

Because Pyranol transformers can be quickly and safely installed indoors without a fireproof enclosing vault, an open pipe railing often constitutes the only protection required. The trans-

formers can be installed close to the load, eliminating the cost of long heavy-copper secondary runs.

These transformers require a relatively small floor space. In many cases, they can be located in convenient out-of-the-way places which do not provide adequate space for installing oil-immersed units in vaults. Many users place them on overhead beams when floor space is at a premium.

These combined savings in installation cost alone often make them a money-saving choice for indoor installations.

POWER WHERE IT IS NEEDED

Because Pyranol transformers can be installed where they are most needed—at load-center points—they make possible the most economical distribution of power to lamps, motors, and other factory loads. Plant engineers call this "load-center distribution"; they know that by bringing primary power to the center of the electric load they gain savings in reduced secondary losses. They also gain by improved voltage conditions, which enable electric equipment to operate at higher efficiency.

IDEAL FOR PLANT-EXPANSION PROGRAMS

The distinct advantages of Pyranol transformers make these units valuable to plant superintendents who are faced with a pressing need for increased power capacity. New installations can be made quickly at plant load centers. Their flexibility of application also permits locating them where they will facilitate the flow of materials.

In addition, the load on existing circuits can sometimes be greatly increased by installing Pyranol transformers at load-center points that are not suited for oil-immersed equipment. In some cases the capacity of factory lighting and power circuits has been doubled, and even trebled by dividing them into sections and supplying each section from its load center with a Pyranol transformer.

WITH PYRANOL TRANSFORMERS

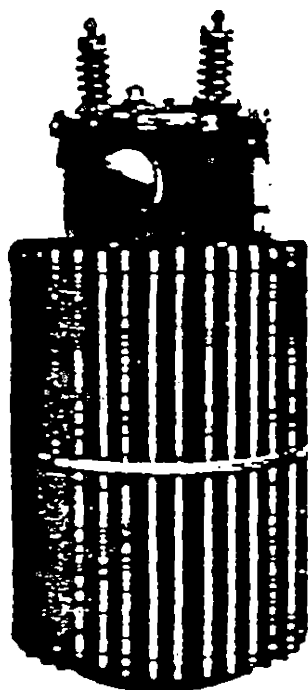


Fig. 3. Single-phase, 150-kva Pyranol transformer with cover-type high-voltage bushings and diaphragm on tank wall

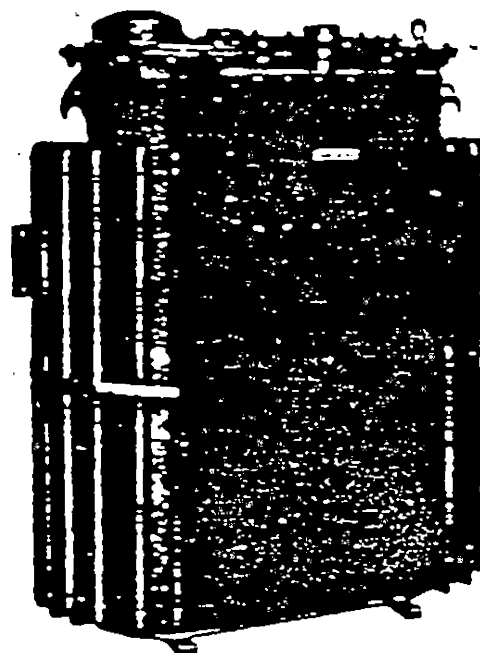


Fig. 5. Three-phase, 150-kva Pyranol transformer, with high-voltage terminal compartment arranged for conduit connection

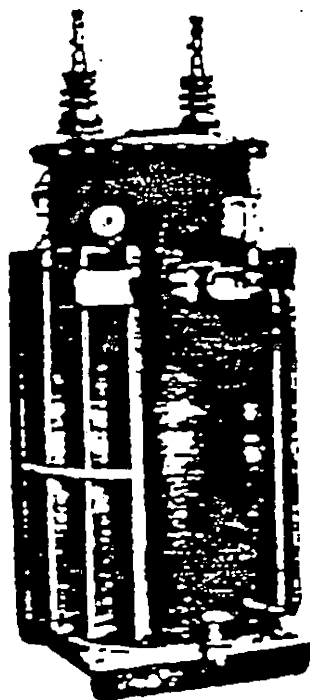


Fig. 4. Single-phase 250-kva Pyranol transformer, showing low-voltage concentric bushing



Fig. 6. Single-phase, 333-kva Pyranol transformer

FOR CONFINED LOCATIONS THE EXTRA DEGREE OF SAFETY PROVIDED BY PYRANOL TRANSFORMERS IS ESPECIALLY VALUABLE

NETWORK VAULTS—SIDEWALK AND STREET

The duty imposed upon a network transformer may be severe, because the inherent operating characteristics of low-voltage a-c network systems usually require secondary short circuits to burn themselves clear. Furthermore, because there is no means of automatically removing an individual network transformer from the power supply, the unit may be subject to high overloads and high temperatures. Because of these conditions, and because underground installation reduces the accessibility of these units, the extra safety offered by the noninflammable characteristics of Pyranol transformers is especially desirable for this type of service.

MINES AND TUNNELS

For meeting the strict safety requirements for mines and tunnels, Pyranol transformers are often a wise choice, because neither Pyranol nor its gases can be ignited by an internal arc or an external fire.

Although these safety features alone often result in the choice of Pyranol transformers, users also find that the savings which attend installing

them in above-ground substations can also be obtained by using them for underground service. Placed at the load center in underground areas, they save costly vault construction and shorten runs of secondary copper. This means reduced copper losses and better voltage regulation.

Because the Pyranol transformer is completely sealed against the entrance of dust and moisture, it is ideal for underground service.

The ease with which Pyranol transformers can be installed and removed makes them especially valuable to mine operators when changing loads make it necessary to move transformers to new locations.

RAILWAY CARS, LOCOMOTIVES, DOCKS, SHIPS

The same considerations that affect the installation of transformers in mines, tunnels, and subways naturally apply to installations on railroad cars, locomotives, docks, and ships, where the advantages of Pyranol transformers are similarly important.

Since 1933, Pyranol transformers have been used, with a remarkable service record, for heating and lighting railway cars.

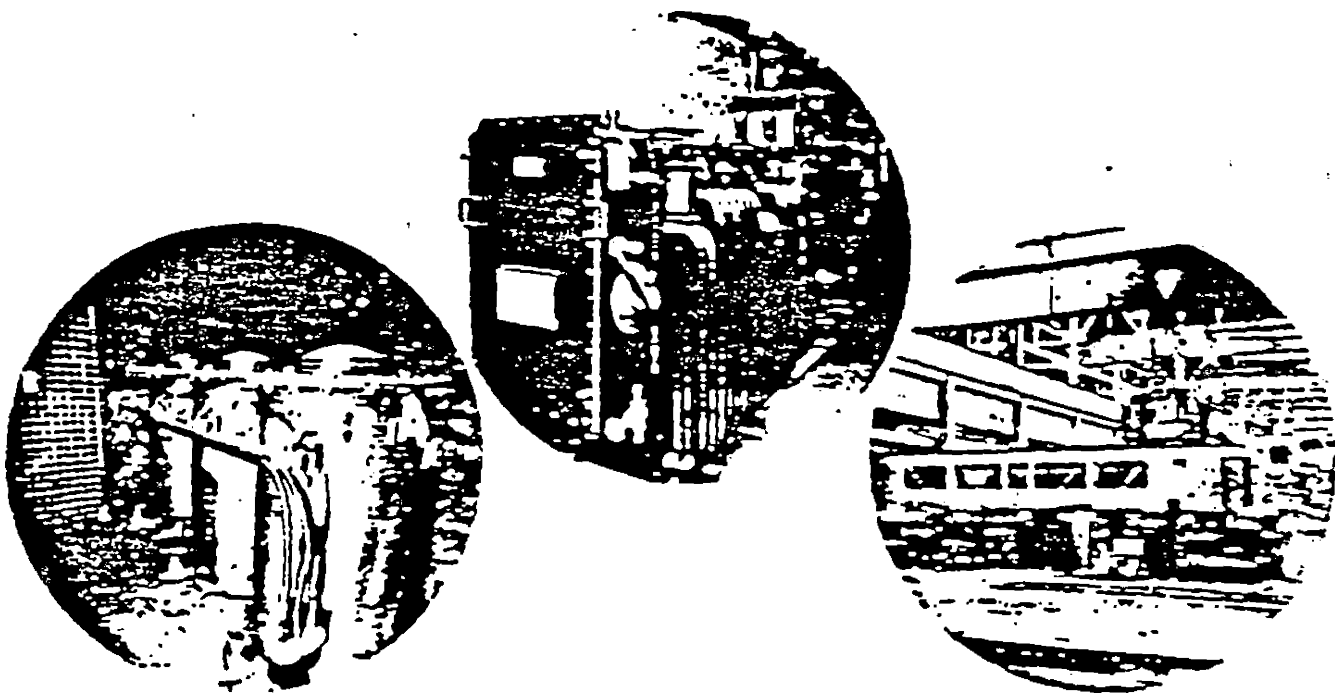


Fig. 7 Pyranol transformers (left) in underground mine vault (center) in a-c network vault (right) being installed in railway locomotive

EXTERIOR CONSTRUCTION IS BASED ON PROVED GENERAL ELECTRIC DESIGN FEATURES

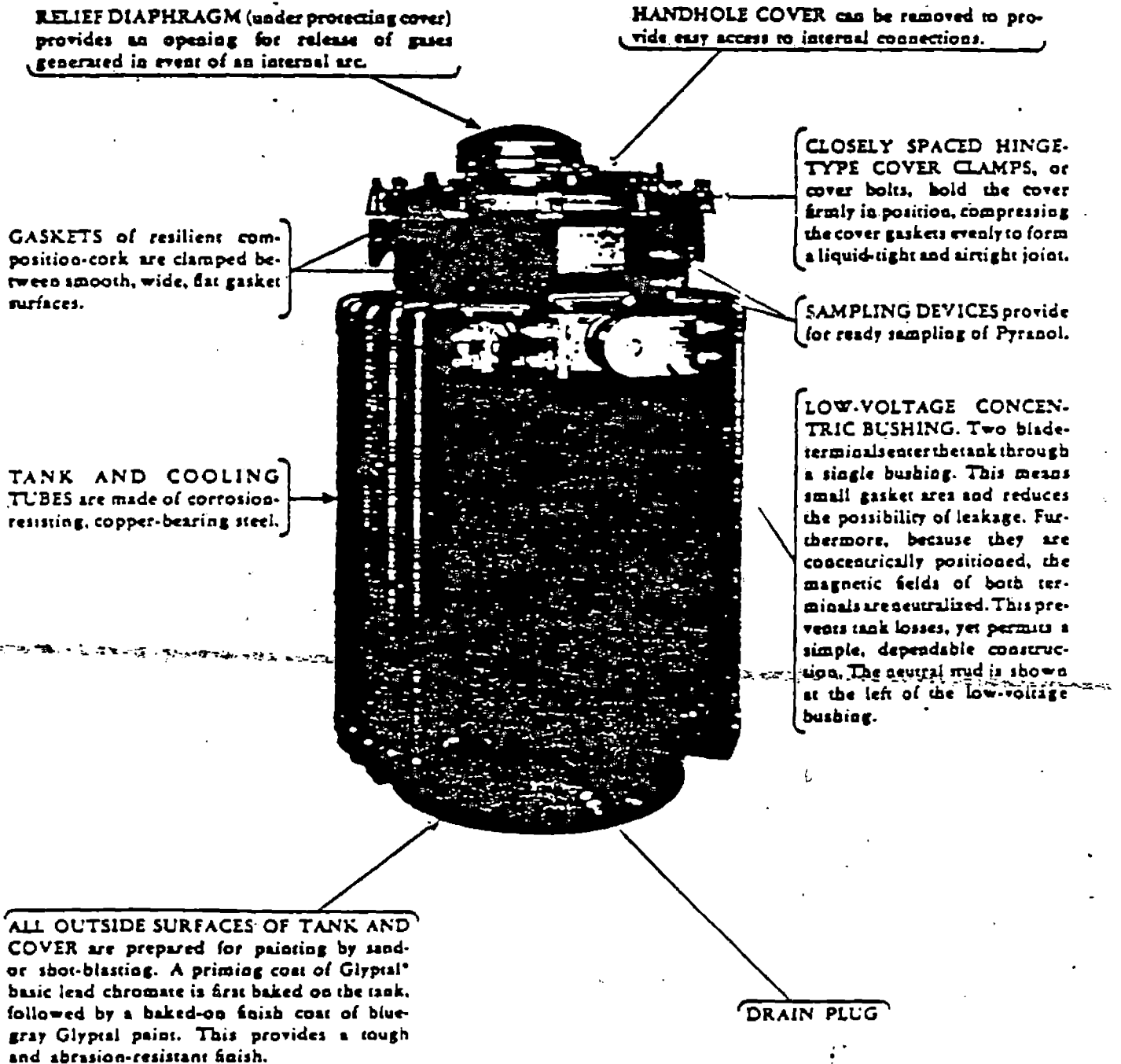


Fig. 1. Single-phase 75-kva Pyranol transformer

* G-E registered trademark.

DESIGN FEATURES

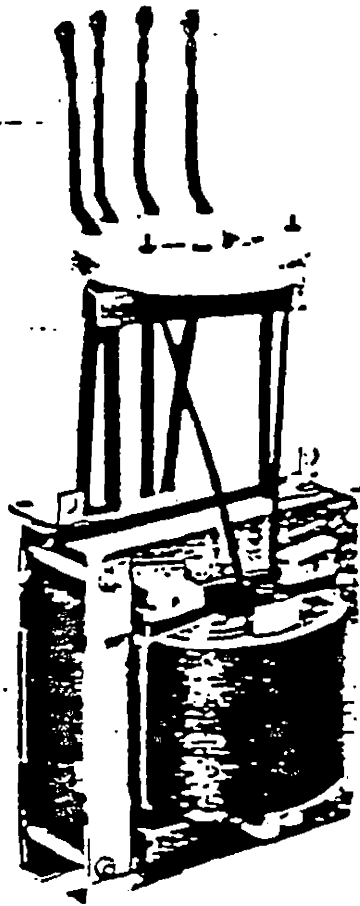


Fig. 9. Complete interior of 15-kva, 2400-volt transformer having Spirakore construction.



Fig. 10. Assembled core-and-coils of single-phase, 333-kva Pyranol transformer, showing Spirakore construction for larger sizes.

Operating experience since 1932 has proved the dependability of Pyranol transformers under widely varying conditions of service. They have all the features that have made liquid-filled transformers the most nearly trouble-free electric apparatus in service today. For example:

A. They have high dielectric strength at both normal and impulse frequencies—important as a safeguard against damage to transformer from voltage surges caused by switching operations or by lightning.

B. The heat-storage capacity inherent in liquid-filled transformers makes Pyranol units ideal for sustained emergency overloads.

C. Their pressure-tight tanks protect vital parts of the transformer against moisture, dust, dirt, and sabotage.

D. Immersion of the transformer interior in the liquid Pyranol prevents drying and cracking of the winding insulation, and retains the high dielectric strength originally built into the transformer.

CORE AND COILS

The internal construction follows closely that of corresponding oil-immersed G-E transformers described in Bulletin GEA-2600.

This means that the benefits of Spirakore construction, using cold-rolled high-permeability silicon steel cores, are likewise being made available for single phase Pyranol transformers as large as 500-kva. Figures 9 and 10 illustrate typical constructions for small and large kva ratings, respectively.

*G-E registered trademark

TANK

All Pyranol transformers are completely sealed to prevent evaporation of the Pyranol. A frangible diaphragm, described on the succeeding page, protects the transformer by relieving overpressure in event of an internal arc.

Sampling valves permit ready sampling of the Pyranol. Because the high specific gravity of Pyranol causes most contaminants to float, the sampling valves are located near the top level.

PYRANOL TRANSFORMERS

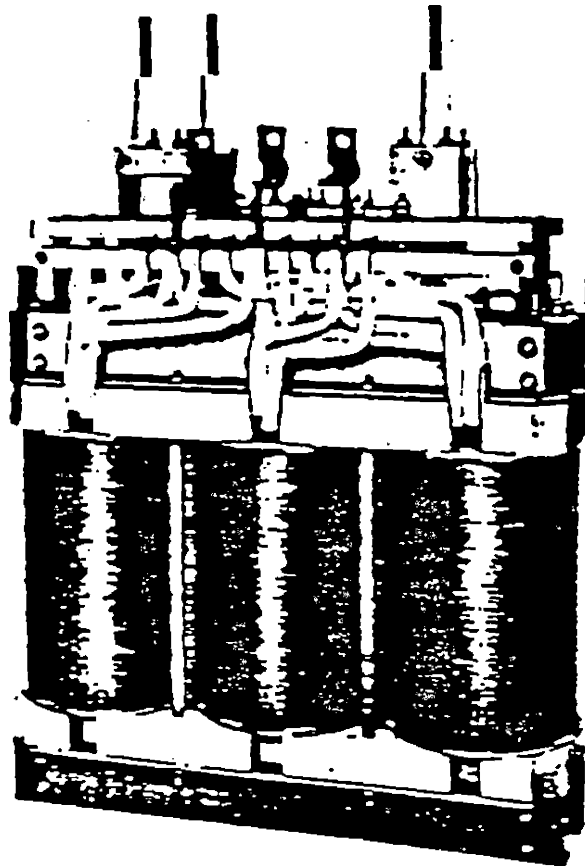


Fig. 11. Core-and-coil assembly for three-phase Pyranol transformer rated 300 kva

PYRANOL

Pyranol is nonflammable, chemically stable, and inert. Tests and field experience prove that it shows no development of corrosive acidity or sludge even after long periods at high temperatures.

Pyranol and its vapors have no effect on the metals and other materials used in Pyranol equipment. The life of these materials, when immersed in Pyranol, is approximately the same as that when they are immersed in oil.

The dielectric strength of Pyranol is of a high order. Standard commercial-test values higher than 30 kv are customarily obtained. Like insulating oil, however, Pyranol follows the usual gas-solubility laws. Exposed to wet air, it will absorb some water and, for this reason, every care is taken to assure the airtightness of the tank.

Liquid Pyranol can be handled at room temperature without fear of toxic effects. During the

twelve years' experience of the General Electric Company in manufacturing Pyranol, there is no record of any workman's requiring first aid or medical assistance because of Pyranol vapors.

Because of the nonoxidizing characteristics of Pyranol, filtration of the liquid will in general be required less often than is required with insulating oil. If it should become necessary to filter the Pyranol used in transformers, it can be done in a manner similar to that used in filtering insulating oil; that is, by the use of either a filter press or a specially arranged centrifuge.

BUSHINGS

The bushings furnished on Pyranol transformer are pressure-tight and are located in the cover or in the tank wall. The standard arrangement for any particular rating is shown in the tabulation at the bottom of each data page 12 to 1

VENT PIPES AND GAS ABSORBER

Pyranol transformers under normal operation produce no gases. Under abnormal conditions, in the event of an arc inside the tank, gases will be generated by disintegration of Pyranol. Because these gases are noninflammable, it is practical to provide a relief vent in the form of a frangible diaphragm. This diaphragm, regularly furnished on Pyranol transformers above 25 kva, is designed to burst at an internal pressure of 12 pounds per square inch, and meets the National Electrical Code's requirements for transformers installed in well-ventilated areas.

VENT PIPES

The upper steel clamping ring, which fastens the diaphragm to the transformer, is provided with tapped holes to permit the easy attachment

of a vent pipe for discharging gases into the outside air, into a chimney, or into other ventilating flues. (See Fig. 13.) In some cases the Code requires that a vent pipe be connected to such a ventilating flue for units above 25 kva installed in poorly ventilated places.

It is recommended that the diameter of the vent pipe be no smaller than the clear diameter of the frangible diaphragm from which it is extended; that is, either 6 or 8 inches, as shown in (Fig. 12). It should be made of material not lighter than No. 16 gage, and there should be as few bends as possible so that gases can flow freely through it. Provision should be made for inspecting the diaphragm and for removing any moisture that may accumulate on it; proper arrangement of the pipe will generally prevent such accumulation of moisture.

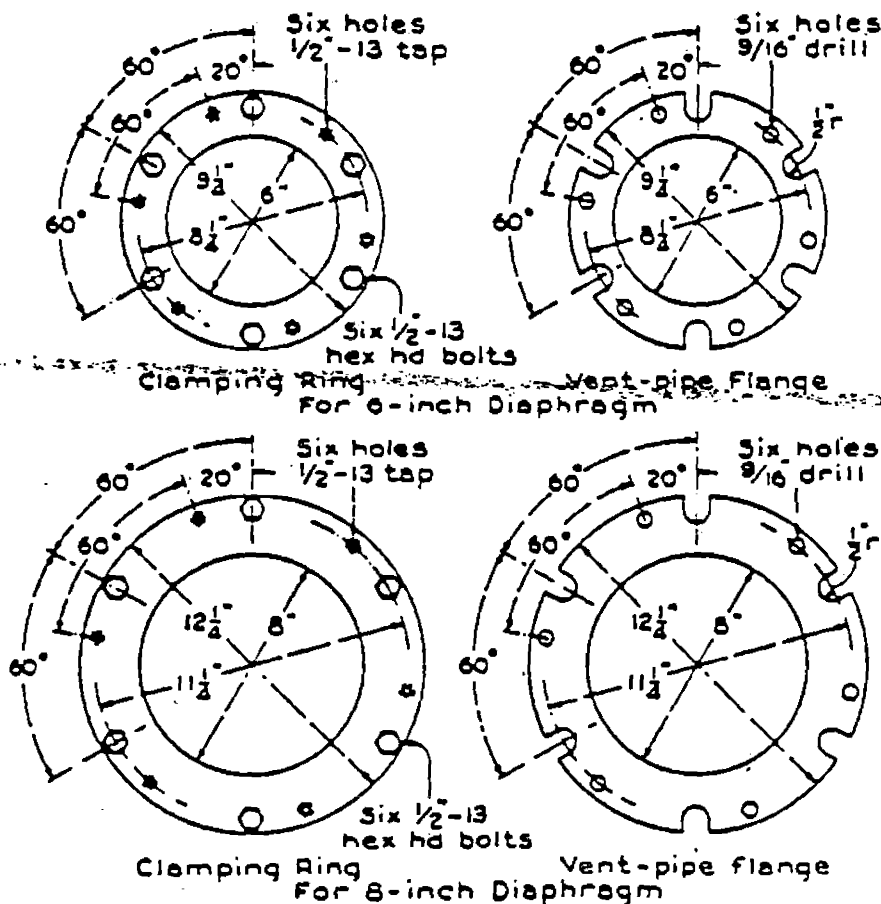


Fig. 12. Details of flanges for vent diaphragms and vent pipes



Fig. 13. Close up of relief-diaphragm assembly

FOR PYRANOL TRANSFORMERS

GAS ABSORBERS

Where it is not economical to install a vent pipe, a gas absorber can be installed on the flange over the frangible diaphragm, as shown in Fig. 14 and 15. It is designed to absorb the gases produced by arc disintegration of part of the Pyranol in the transformer; 2 per cent of the Pyranol in distribution and power transformers, and 5 per cent for a-c network transformers.

The absorber has a steel tank with a mounting flange at the bottom for attachment to the relief vent of the transformer tank, and, at the top, a separate diaphragm with a protecting cover. This tank contains several perforated-bottom steel trays, fastened together, one above the other, by a center bolt to facilitate assembly. The bottom tray is filled with chipped marble, and the upper trays contain soda lime. Should an internal arc generate sufficient gas to break the diaphragm on the transformer, the gas will pass up into the tank and be absorbed by the soda lime. Any liquid carried by the gas will be stopped by the chipped marble and will drain back into the transformer. If the quantity of gas exceeds the absorber capacity, the top diaphragm will break to relieve the pressure.

APPLICATION

Under the provisions of the 1940 National Electrical Code, either vent pipes or absorbers may be required for a given installation. Influencing factors are: the energy available in the circuit to which the transformers are connected; the type of protective equipment; the area, volume, and ventilation facilities of the room in which the transformers are installed; the number and proximity of employees in the area.

When absorbers are used, it is recommended that one be used with each transformer. If a single absorber is connected to two or more transformers by means of a common header, it is possible that if more than one transformer should experience trouble simultaneously, the gas produced might exceed the capacity of the one absorber.

The absorber should be inspected at intervals to see that the diaphragms are intact and that the compound in the absorber has not become damp or caked.

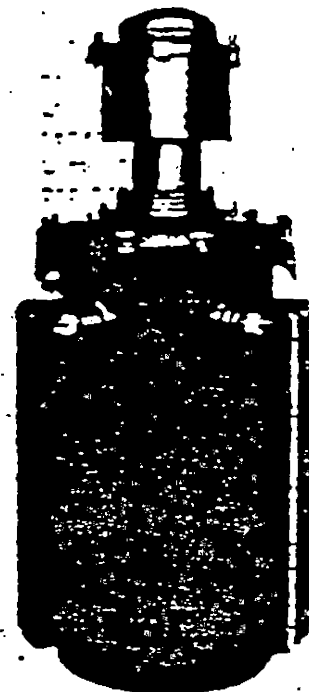


Fig. 14. Single-phase 75-kva Pyranol transformer with gas absorber

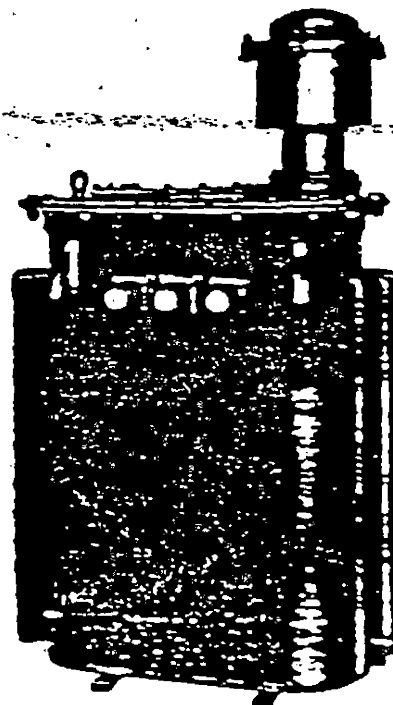


Fig. 15. Three-phase 50-kva Pyranol transformer with gas absorber

Monsanto

ORGANIC CHEMICALS DIVISION

Monsanto Company
800 N. Lindbergh Boulevard
St. Louis, Missouri 63166
(314) Oxford 4-1000

March 3, 1969

Mr. Edward L. Raab
General Electric Company
100 Woodlawn
Pittsfield, Massachusetts 01201

Dear Mr. Raab:

On February 24, the San Francisco Chronicle carried a major feature about "a menacing new pollutant" found in the San Francisco Bay area. The article was based on marine life research carried out by Dr. Robert Risebrough of the University of California. It stated that residues of polychlorinated biphenyl (PCB) were killing certain marine birds and posed a long-term threat to humans.

This story has caused considerable comment on the West Coast and its claims may be repeated elsewhere. As you know, Monsanto manufactures polychlorinated biphenyl and markets it under our Aroclor trade name. We, therefore, would like to present some additional facts.

The work done by Dr. Risebrough dates back to earlier research by other scientists to analyze the amount of pesticides in wildlife, soil and water. The initial pesticide research was extremely difficult since any search to detect materials in the parts-per-billion range also brings out other "interfering" substances.

Several years ago, two Swedish scientists at Stockholm University's Institution of Analytical Chemistry, Professor Gunnar Widmark and Søren Jensen, reported they had identified the other substances which were appearing during analysis of chlorinated pesticide residues. They said some of the materials were polychlorinated biphenyls or PCB. The amount reported was in the parts-per-billion range, or less. Since PCB's are not "broadcast" or spread around the land as are pesticides, the scientists theorized that the source must be the industrial wastes of PCB users.

Dr. Risebrough's more recent work reports the identification of PCB, along with DDT and DDE pesticides, in the tissues of birds and fish on the West Coast.

The conclusions of these scientists are puzzling from several aspects. Polychlorinated biphenyls are stable chemical compounds which are essentially insoluble in water. Their use does not make them easily released into the natural environment.

A principal market for PCB is in electrical applications where they are used as insulating fluids for transformers and capacitors. In this use, the chemical is completely sealed in metal containers. Another market is for heat transfer applications where the PCB fluid functions in a closed system.

PCB's are also used in several "plastic type" applications. Here the chemical is incorporated into the polymer as an integral part of the solid material. This applies whether the polymer is used as an adhesive, an elastomer or a surface coating.

The Swedish and American scientists also imply that polychlorinated biphenyls are "highly toxic" chemicals. This is simply not true. The toxicity of any material, whether it be chemicals, drugs, natural plants or even foods, is relative. Compared to the thousands of industrial chemicals and home products, PCB's are not toxic unless they are mishandled or misused. During more than thirty years of U. S. production and use, cases of any toxic effect have been extremely rare -- and then only where the simple precautions recommended for use were not followed.

To our knowledge, polychlorinated biphenyls are not sprayed or dusted on crops, woodlands or any other areas, as are pesticides. It is, therefore, not only puzzling, but extremely difficult to conceive how commercially produced PCB can show up in wildlife as DDT and other pesticides appear to be. This raises the question whether the substance identified in the Swedish work, and now in California, is actually PCB -- or whether they are materials which, due to the metabolism of other materials in the marine environment, appears to be PCB.

Unfortunately, even though techniques for analyzing tissue samples have become quite precise, the ability to analyze the possible impact of naturally occurring substances in the food cycle of living organisms has not made comparable advances.

Monsanto has a research program to confirm the identity of the compounds reported to be PCB by the Swedish and California scientists. We also cooperate, on a regular basis, with federal, state and university laboratories in their analysis of chlorinated hydrocarbon residues.

Additionally, Monsanto will continue to exercise the highest degree of control in its manufacturing, shipping and storage of PCB -- as we do with all products. In the functional fluids market, we have carried out a program for several years for the reclamation of used PCB's to avoid disposal of these valuable materials.

The source of the marine life residue identified as PCB is not yet known. It will take extensive research, on a worldwide basis, to confirm or deny the initial scientific conclusions. We will keep you advised of our own research and are available to answer questions as they may arise.

Very truly yours,



Elmer P. Wheeler
Manager Environmental Health

/ecd

GENERAL ELECTRIC
COMPANY

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Dr. E. M. Kline
NEW YORK OFFICE

EDWARD M. KLINE, M.D.

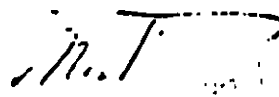
Dear Ed:

I have been in telephone conversation with Dr. Emmet Kelly and Ed Wheeler, Medical Director and Industrial Hygienist respectively of Monsanto Chemical Co. in St. Louis. They are concerned over some recent technical and newspaper articles relating to the presence of polychlorobiphenyl products in widely dispersed fish and wildlife. The increasing interest in the effects of pesticides, especially chlorinated ones, on the ecosystem has raised the question of what adverse effects, even the pico-gran quantities of the polychlorobiphenyl compounds found in birds' livers and eggs and in fish livers, can have on the normal development of these species. At present, there is little to indicate whether these compounds have been dispersed atmospherically or have been waterborne.

The General Electric Co. purchases its chlorinated polyphenyls from Monsanto Co., modifies it, and uses it under the name of Pyranol. I believe the major application for this material in our Company is as a dielectric for certain types of transformers and capacitors. Dr. Kelly was not sounding a tocsin, but thought that the proper people in our organization should be alerted to the possibility that questions may be aimed at us, or that we may want to make some attempt to determine to what degree the Components using this material discharge it as either liquid or solid waste, or as an air contaminant.

I am attaching several articles on this subject which you may wish to pass on to the proper person or persons. One individual who is highly knowledgeable about the uses of Pyranol is A. Raab at the Laboratory in Pittsfield, Massachusetts. Dr. Raab may be a good person to contact first.

Best personal regards,


I. Matelsky
Industrial Hygienist
#116.2C.

DM:ejp
Attachments
cc: JW Loney, M.D.

is terminated and the completed chain released from the ribosome-mRNA complex to which it is bound. The tRNA molecule carrying the last amino-acid is released. There must be a mechanism for reading the chain terminating codon (three codons UAA, UAG, UGA can code for chain termination) and cleaving the peptidyl-tRNA bond. In *Biochem. Biophys. Res. Comm.*, 28, 773 (1967) he describes an experimental system devised to give a rapid assay for chain termination and in *Proc. US Nat. Acad. Sci.*, 53, 1144 (1967) reports the discovery of an enzyme required for termination.

The assay for termination employs the RNA from a mutant of the coat protein gene of the RNA bacteriophage R17. This mutant has an amber codon, UGA, at the position of the sixth amino-acid, a glutamine residue, in the R17 coat protein molecule. In a *trans* system the mutant RNA directs the synthesis of a small N-terminal peptide of the coat protein with the sequence N-formylmet-ala-ser-asn-phe-thr; the last amino-acid in the coat protein is glutamine, but with the mutant RNA the amber codon causes premature termination of synthesis and the release of the peptide. The great virtue of this system is that the terminated peptide still attached to the peptidyl-tRNA can be distinguished from the terminated peptide released from the tRNA and the amounts of each measured. Furthermore, starving the system for any one of the six amino-acids in the peptide arrests the translation machinery before it reaches the UAG codon so termination can be controlled.

Exploiting this procedure, Capecchi isolated a complex of ribosome, mRNA and pentapeptide

attached by the phenylalanyl tRNA simply by starving for threonine. With this he has been able to define the conditions necessary for termination; incubating the complex under suitable conditions with or without threonine or supernatant enzymes showed that to get release it is necessary but not sufficient to complete the peptide by incorporating threonine and that release is not solely dependent on the transfer enzymes required to move the ribosome from the threonyl codon to the UAG terminating codon. Release does, however, depend upon the presence of a supernatant factor. This factor, with a molecular weight of between 40,000 and 50,000, sediments between 3.5S and 4.5S. Because its releasing activity is not affected by RNase, it cannot be an RNA-protein complex. Apparently the substrate of the release enzyme is the ribosome-mRNA-peptidyl-tRNA complex so that it must act directly at the ribosome and not cleave the tRNA from peptidyl-tRNA already released into the supernatant, which was the other possibility.

Capecchi does not yet know whether the release enzyme works alone or in conjunction with other factors, in particular a hypothetical chain termination tRNA which reads the termination codon but does not carry an amino-acid. Many people, including Capecchi, have searched in vain for such a tRNA species, and although negative results can never exclude the possibility that such tRNA exists it is reasonable to think about alternative models in which the terminating codons are read either by the ribosome or the release enzyme or in which nonsense codons function simply because they cannot be read at all. Further characterization of the release enzyme could well decide the issue.

Chlorinated Hydrocarbons in British Wildlife

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Polychlorobiphenyl compounds have been detected in British wildlife. In birds' livers and eggs they are often in greater quantities than organochlorine pesticide residues. Polychlorobiphenyls are known to be toxic, and their detection in wildlife raises the question of the adverse effect they may have.

When wild birds' eggs or the livers of British wildlife are analysed by gas-liquid chromatography (GLC) using flame-capture detection, peaks corresponding to such organochlorine pesticides as BHC, dieldrin and DDT, and their metabolites and breakdown products, often appear in the resultant chromatograms. These peaks sometimes represent amounts which are significant from a toxicological point of view, but the sensitivity of modern instruments also enables completely insignificant amounts to be detected. Analysis concerned with the determination of organochlorine pesticides in wildlife, however, have long known that it is not unusual for an additional series of as many as ten peaks, corresponding to unidentified compounds, also to appear on these chromatograms. It is known of the structure and origin of these compounds, but Roburn established that they are organo-

chlorine in nature, with a substantial chlorine content, and consequently possess electron-capturing properties.

On silicone or 'Apiezon' GLC columns, the series of peaks for these compounds normally begins at the point at which pp'-TDE and pp'-DDT are emerging from the column and extends, in terms of retention times, to four or five times that of pp'-DDT, which is the last of the commonly occurring pesticides to emerge.

Before examination by GLC, samples have normally been subjected to a fairly rigorous clean-up procedure, such as that of de Fombert Maunder *et al.*, which includes a dimethylformamide-hexane partition and passage through a column of prepared alumina. Because these unknown compounds are similar in nature and properties to the organochlorine pesticides, they also pass through this and similar clean-up procedures; consequently, they

often interfere seriously with determinations of pp'-TDE and pp'-DDT in wildlife because of overlapping of the chromatographic peaks. Suitable procedures have been devised to overcome this difficulty of interfering peaks. One method is to effect a better resolution of these particular peaks by choice of a suitable stationary phase for GLC⁴. Another method, which also demonstrates the presence of these compounds in the sample, is the use of a preliminary thin-layer chromatographic treatment⁵. The cleaned-up extracts are examined on silica gel chromatoplates using a 1 per cent solution of acetone in hexane as mobile phase⁶. Spots corresponding to the compounds can then be found at R_f values between 0.8 and 1.0, whereas the commonly occurring organochlorine pesticides and their metabolites produce spots of lower R_f values. A similar separation can also be shown with reverse phase paper chromatography⁷ whereby the unknown compounds move only a very short distance from the base line compared with the pesticides and their metabolites.

Gas-liquid chromatography using dual channel detection systems with separate electron-capture and flame-ionization detectors has also been used to demonstrate the presence of large amounts of weakly electron-capturing material, in addition to known pesticide residues, in the eggs of oyster catchers (*Haematopus ostralegus*)⁸.

Experience in this laboratory has shown that these compounds occur most frequently and in the largest proportions in the livers, fat and eggs of birds, particularly terrestrial predators such as sparrowhawks (*Accipiter nisus*) and kestrels (*Falco tinnunculus*) and marine feeders such as guillemots (*Uria aalge*) and kittiwakes (*Rissa tridactyla*); they also commonly occur in freshwater fish. We have detected small amounts in human and animal fat samples, but less frequently and in much smaller proportions than in avian samples.

A similar series of chromatographic peaks has been observed by Holden^{9,10} when examining extracts of seals and fish taken in Scottish waters. He found that the peaks given by the extracts of fresh and sea-water fish represented fairly low concentrations, but those given by extracts of seal blubber corresponded to much larger proportions, of the order found by this laboratory in birds' eggs.

Despite considerable curiosity about the identity of these compounds, little progress has been made in identifying them, but there has long been a general supposition that they were either further breakdown or condensation products of the organochlorine pesticides or possibly loose compounds of these with natural products such as protein matter.

Jonson, however, succeeded in identifying a series of such peaks as corresponding to polychlorobiphenyl compounds, in 200 pike taken in different parts of Sweden, and in an eagle¹¹. We have now been able to show that the long retention time compounds occurring in British wildlife are also polychlorobiphenyl compounds.

Polychlorinated biphenyl has been in common commercial use for some time as a plasticizer in paints, resins and plastics. It also has electrical insulating properties and can be used for a number of other protective purposes. Commercial preparations of this material are usually graded according to the degree of chlorination, but all of them are substantially complex mixtures of polychlorobiphenyl compounds that could be expected to resemble the organochlorine pesticides in their chemical and physical

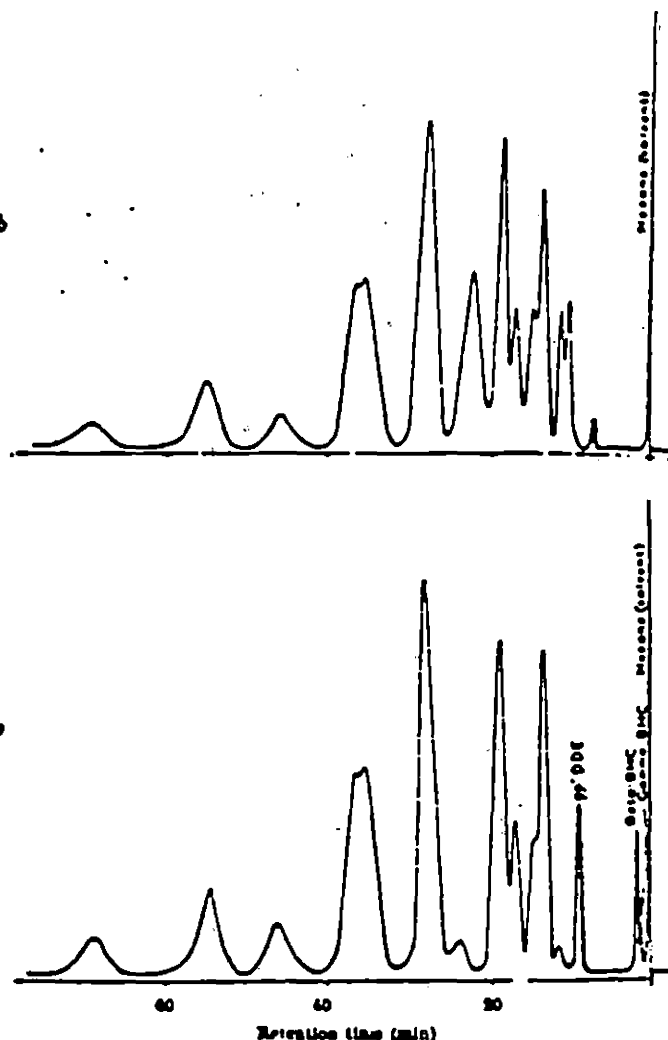


Fig. 1. Gas-liquid chromatograms of (a) extract of kestrel liver and (b) a commercial polychlorobiphenyl resin.

properties. In the prescribed extraction and GLC conditions, these mixtures produce a series of chromatographic peaks of the type in question.

The compounds occurring in British wildlife compared to the more highly chlorinated biphenyl compounds¹² than the more lightly chlorinated types. These chlorinated biphenyls also occur to some extent in analogous polychloroterphenyl preparations which is commercial use similar to those of polychlorobiphenyl. It is possible that some of the compounds with very long retention times occurring in British wildlife are highly chlorinated polychloroterphenyl compounds.

Fig. 1a shows the gas-liquid chromatogram of an extract from a kestrel liver. The peaks corresponding to pp'-DDT (0.43 ng), p,p'-DDE (0.33 ng) and p,p'-DDE (0.03 ng) are labelled. The other peaks form the series referred to above and until now would have been regarded simply as "unknown organochlorine compounds". Corresponding to any known pesticide or its metabolite. Fig. 1b shows the analogous chromatogram of a commercial polychlorobiphenyl resin. So far as retention times are concerned and apart from the pesticide peaks, the is exact matching for all but a few peaks in the chromatograms.

The chromatograms shown were obtained by use of silicone gum (SE-30) column, but this proved no correspondence between the retention times of the peaks of the unknown compounds and those from the polychlorobiphenyl resin has also been demonstrated on a

TABLE 1. RELATIVE RETENTION TIMES ON THREE DIFFERENT GAS COLUMNS (Excluding times for known pesticides)

OV-17 60		Apiezon L		Cyanosilicone	
RET.	PCB	RET.	PCB	RET.	PCB
1.45	1.45	2.31	2.33	1.21	1.21
1.75	1.73	2.47	2.47	1.45	1.43
1.81	1.80	2.64	2.65	2.25	2.15
1.91	2.51	2.65	2.65	2.25	2.25
2.29	2.34	2.76	2.76	2.27	2.27
2.71	2.70	2.87	2.88	2.63	2.60
2.84	2.84			2.63	2.63
2.85	2.85			2.63	2.63
2.90	2.90			2.63	2.63

RET. Known liver extract; PCB, polychlorobiphenyl resins.

on cyanosilicone columns. The actual retention times recorded for the peaks on these three types of column are given in Table 1.

Further confirmation as to the identity of these compounds has been obtained by a study of their behaviour on thin-layer chromatoplates, alumina and silica gel absorption columns and reverse phase chromatograms. In addition, these compounds have been shown to resemble the polychlorobiphenyl compounds in their chemical inertness. Thus they are not easily modified by simple chemical reactions to produce readily identifiable peaks in their retention times on GLC as can be done, for instance, to *pp'*-DDT by hydrolysing it to *pp'*-DDE or to *pp'*-DDD by oxidizing it to dieldrin.

A number of livers and eggs taken from birds in the British Isles or their coastal waters have been examined in this laboratory with results similar to those obtained from the kestrel livers referred to earlier. While the identification of these compounds in British wildlife may solve the mystery of these peaks on GLC chromatograms, it raises, however, many other questions. Why, for example, do these compounds seem to be accumulated, most frequently and in the largest proportions, in certain types of wildlife such as birds, seals and fish, and only, at the most in very small proportions in man or his domestic animals such as mice or sheep? In this respect they seem to differ markedly from the organochlorine pesticides which seem to have invaded nearly all aspects of our environment and

to which they bear a strong resemblance chemically and physically.

Some of the samples of birds examined in this laboratory have seemed to contain higher proportions of polychlorobiphenyl compounds than organochlorine pesticides. For example, the peaks on the chromatogram for the kestrel liver shown in Fig. 1 were estimated to be equivalent to about 12 ng of polychlorobiphenyl compounds. This must be contrasted against the organochlorine pesticide residues listed above. These total only about 0.8 ng of which 0.33 ng is beta-BHC, an isomer of BHC which is generally regarded as non-toxic to wildlife.

Great concern has often been expressed by conservationists about the effects of pesticides on wildlife, particularly birds. The identification of these other organochlorine compounds in wildlife prompts enquiries as to the possible toxic effects they may be having. That these compounds are toxic is generally agreed^{10,11}; the polychlorobiphenyls are in fact regarded as an industrial hazard and threshold limits for them in air have been advised¹².

We thank the Nature Conservancy for samples of wildlife and Monsanto Chemicals Ltd. for samples of polychlorobiphenyl resins.

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Quasi-stellar Sources, Supernovae and Novae

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By considering the opacity of a surface layer of a star, the author concludes that quasi-stellar sources, supernovae and novae may be different manifestations of the same mechanism.

It is usually considered that the outbursts of novae and supernovae are fundamentally different processes; but I shall here propose a mechanism which can account for both phenomena, and which at the same time can account for other problems concerned with quasi-stellar sources (quasars). In particular, I suggest that these outbursts are likely to be anisotropic (as indeed they are observed to be for novae). Because the energy released during a quasar outburst is comparable with the stellar rest energy, an anisotropic outburst could mean that the star is accelerated to relativistic velocity in order to conserve momentum, thus affording a Doppler explanation of the red-shifts of the quasi-stellar sources.

Consider the opacity of a layer, L , at the surface of a star. Let ΔR be the thickness and R the radius of L , and let L contain plasma at temperature, T , with electron and ion densities N_e and N_i respectively. L will be opaque to radiation of wavelength λ provided that τ is about 1, where τ is the optical depth of L . A major contribution to τ is τ_{ff} , the optical thickness due to free-free

absorptions. It is known that $\tau_{ff} \propto \lambda^{-2} N_e N_i \Delta R$ (ref. 1), where induced emissions are included. Suppose, now, that L is compressed or dilated without changing the total number of ions; that is, ΔR is varied under conditions which maintain constant $6\pi R^2 \Delta R N_i$, so that $\Delta R N_i = \text{constant}$. Evidently $\tau_{ff} \propto N_e N_i \Delta R \propto N_e / \Delta R$. Thus compression of L increases its opacity, while dilation reduces the opacity.

Of course, the total number of ions will not remain constant in practice, because the recombination rate is proportional to $N_e N_i$. If the percentage of atoms ionized is large, the density of unionized atoms, N_u , will therefore be proportional to $N_e N_i$. This means that the contribution to the opacity made by bound-bound and bound-free transitions within unionized atoms is also proportional to $N_e N_i \Delta R$. This effect, recognized to be important for stellar pulsation², further increases the opacity of L on compression.

Some consequences of this variable surface opacity will now be examined. Under equilibrium condition

Fractions and Multiples

fraction	prefix	symbol
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

multiple	prefix	symbol
10	deka	da
10^2	hecto	h
10^3	kilo	k
10^6	mega	M
10^9	giga	G
10^{12}	tera	T

To be restricted as much as possible.

Compound prefixes should not be used. Thus 10^{-6} metre is represented by 1 μ m, not 1 mm . The attaching of a prefix to a unit in effect constitutes a new unit, so that

$$1 \text{ km}^3 = 1 (\text{km})^3 = 10^9 \text{ m}^3$$

$$\text{not } 1 \text{ k}(\text{m}^3) = 10^3 \text{ m}^3.$$

Where possible any numerical prefix should appear in the numerator of an expression.

Examples of Units Contrary to SI, with their Equivalents

physical quantity	unit	equivalent
length	ångström	10^{-10} m
	inch	0.0254 m
	foot	0.3048 m
	yard	0.9144 m
	nautical mile	1.609 34 km
	square inch	645.16 mm^2
	square foot	0.092 903 m^2
area	square yard	0.836 127 m^2
	square mile	2.589 90 km^2
	cubic inch	1.638 71 $\times 10^{-4} \text{ m}^3$
	cubic foot	0.028 316 m^3
	U.K. gallon	0.004 546 092 m^3
volume	pound	0.453 592 37 kg
	slug	14.593 9 kg
	pound/cubic inch	2.767 99 $\times 10^4 \text{ kg m}^{-3}$
mass	pound/cubic foot	16.0165 kg m^{-3}
	dyne	10^{-5} N
	poundal	0.138 255 N
density	pound-force	4.448 22 N
	kilogramme-force	9.806 65 N
	atmosphere	101.325 N m^{-2}
force	torr	133.322 N m^{-2}
	pound (f)/sq.in.	6894.76 N m^{-2}
pressure		

Organochlorine Pesticides in Seals and Porpoises

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K. MARSDEN

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Seals and porpoises in Scotland and Canada, far from the sites of application of pesticides, can accumulate high concentrations of residues in their blubber. These chemicals are spreading through the long food chain which ends with seals and porpoises and obviously cannot be confined to their place of discharge.

The presence of organochlorine residues in marine life in many areas of the world, including the Antarctic, has been reported recently^{1,2}. In British waters the accumulation of residue in the eggs of sea birds³ and the process of concentration of pesticides through certain food chains in the marine environment⁴ have been studied. Analyses of various species of marine fish and mammals from Scottish waters during the past 5 years^{5,6} have shown that organochlorine residues are now a normal occurrence, the highest concentrations being found in organs or tissues with the highest lipid content. Thus the muscle tissue of salmonids, the livers of cod and the blubber of seals act as storage sites for these residues.

The aquatic mammals, such as whales, seals and porpoises, have a relatively high proportion of the body weight in the form of subcutaneous fat (blubber). Seals feed chiefly on gadoids and salmonids, and porpoises chiefly on small gadoids and clupeoids. The process of concentration of pesticides through their food chain might be expected to result in high pesticide levels in the fat of these mammals, and samples analysed at this laboratory confirm this expectation. In recent years specimens of the grey seal (*Halichoerus grypus*), common seal (*Phoca vitulina*) and porpoise (*Phocoena phocoena*) have been sampled from coasts of Scotland. Samples of blubber were available from all the specimens examined, and in a few cases other organs were also available. As well as recognized pesticide residues, other electron-capturing substances have been detected by gas-liquid chromatography and, in order to establish whether such substances are as widely distributed as the pesticides, blubber samples from grey seals and

harp seals (*Phoca groenlandica*) on the Canadian Atlantic coast have also been examined and the results of these analyses are reported here. Examination of samples of seal blubber from other areas is continuing in order to assess the variation between different regions of the marine environment.

All tissue samples from Scottish waters were frozen at -18°C until required for analysis. The samples were preserved in 10 per cent formalin, which showed no evidence of any influence on the analysis procedure, and in this and other cases involving blubber has not affected the efficiency of recovery of pesticide residues. Aliquots of the samples (5 g) were ground to powder with anhydrous crystalline sodium sulphate (grade) and extracted in a Soxhlet apparatus with distilled AR grade n-hexane (previously tested and found to be free of electron-capturing materials by gas chromatography). The hexane extracts were made up to 10 ml and 25 ml aliquots were subjected to clean up by the hexane-dimethylformamide partition method of Faubert-Maunders *et al.*, followed by column chromatography using alumina containing 5 per cent water. The pesticide residues from fat extracts so treated are up to 20 per cent, but, as is customary in pesticide analysis, no correction has been made for such losses in the clean up process.

The cleaned-up hexane extracts were analysed by liquid chromatography on a Varian Aerograph 2100 instrument employing two glass columns 5 ft long and 1/8 in. outer diameter. One column was packed with 100 mesh WAW/DJCS 80-100 mesh coated with 10 per cent

200 silicone oil, and the other with the same support with 5 per cent DC-203 + 7.5 per cent QP-1 silicone. The oven temperature was 200°C, the air flow 60 ml./min and the column resolution equivalent to 1,600 theoretical plates. There was no significant degradation of DDT on the column. Complete separation of the common pesticide peaks is possible on one or either of these columns. Interference by polychlorinated biphenyl (PCB) residues in p,p'-TDE and p,p'-DDT peaks necessitated a further chemical stage. Aliquots (5 ml.) of some of the extracts were evaporated to dryness in a stream of cold filtered air, the residues refluxed with 2 ml. of 2.5 per cent potassium hydroxide for 15 min on a water bath. After cooling, 5 ml. of n-hexane was added, mixing, followed by 40 ml. of 2 per cent sodium hydroxide solution. The supernatant hexane layer was analysed by gas-liquid chromatography. By this technique, quantitative conversion of p,p'-DDT to p,p'-TDE and of p,p'-TDE to p,p'-MDE (=DDMU), is obtained, and the conversion products confirm the identity of original residues. The residual peaks in the p,p'-DDT and p,p'-TDE positions, where present, can be subtracted from the values of the pesticides originally determined at three positions. Hydrolysis also destroys α and γ -BHC, but present, but polychlorinated biphenyls are unaffected. A cyanosilicone (XE-60) column has also been used to separate p,p'-DDT and p,p'-TDE from PCB residues, confirming the latter.

The principal pesticide residues found in all samples examined were those of the DDT group, with dieldrin in much smaller quantities. Canadian seals contained lower concentrations of dieldrin than Scottish seals, while British porpoises contained remarkably high concentrations of all pesticide residues (see Table 1). Interference on a 200 silicone column in the p,p'-TDE position caused a non-hydrolysable residue was responsible for about 10 per cent of the total estimated p,p'-TDE in the Canadian and Scottish samples examined. In the p,p'-DDT position, the non-hydrolysable residue constituted about 10 per cent in the Canadian samples and about 15 per cent in the Scottish samples examined for this purpose. The total amount of non-hydrolysable material being smaller in the Canadian samples. The values in Table 1 have not been corrected for this interference, for only a proportion of the samples were hydrolysed. Results from the various species of seals were not appreciably different in a given area, and have been tabulated in Table 1.

TABLE 1. CONCENTRATIONS (RANGE OF CONCENTRATIONS) RESIDUES IN FAT OF SEALS AND PORPOISES (P.P.M.) (Means in parentheses)

Area and type of sample	No. in sample	Dieldrin	p,p'-DDE	p,p'-TDE	p,p'-DDT
West coast, adult (1963-64)	18	0.15-2.1 (0.70)	1.0-11.1 (3.9)	0.27-3.0 (1.2)	1.4-23.8 (7.8)
West W. Scotland (1963-64)	8	0.06-0.30 (0.20)	1.2-7.0 (3.4)	0.17-0.83 (0.41)	1.2-7.7 (3.8)
West W. Scotland (1965-66)	9	0.06-0.44 (0.18)	1.0-4.0 (2.4)	0.13-0.36 (0.22)	1.1-3.7 (2.3)
Magdalen Is., male and adult seals (1967)	2	0.02-0.04 (0.03)	0.07-1.8 (1.2)	0.04-0.16 (0.12)	0.06-0.43 (0.24)
Orkney Islands, male and adult (1967)	8	0.03-0.10 (0.07)	1.2-17.3 (3.9)	0.35-2.1 (0.78)	2.1-15.6 (5.6)
Orkney, male (1967)	1	0.10	1.1	0.44	2.8
Porpoise (1967)	1	4.0-18.0 (9.0)	9.0-15.3 (12.6)	8.2-14.3 (9.9)	13.1-25.7 (21.1)

Contamination by pesticides is greater in the seals on the west coast of Scotland (taken in an area roughly from Aberdeen to the Tay estuary) than in specimens from the east and north coasts, including the Orkney Islands. Pups from the Orkney and Harris (west coast) breeding grounds contained only slightly lower residues than adults from the same areas. By comparison, the Canadian samples from the Magdalen Islands (Gulf of St. Lawrence)

contained very low levels of both dieldrin and the DDT group, while seals from the Cabot Straits (Gulf of St. Lawrence) contained little dieldrin but higher DDT group residues, similar to those of Scottish seals. Of the few porpoises examined, that from Orkney was the least contaminated, but the three taken on the east coast of Scotland had markedly higher contents of all the residues measured. One specimen contained a total residue concentration (dieldrin and DDT group) of 73.3 p.p.m. Analyses of a few tissues other than the blubber have been made, but concentrations in the blubber have always been found to be the highest (Table 2). Concentrations in other tissues seem likely to be consistent with their lower lipid contents.

Table 2. TOTAL DDT CONCENTRATIONS (P.P.M.) IN VARIOUS TISSUES

Sample	Blubber	Liver	Brain	Kidney	Spleen	Muscle
Orkney, adult	8.8	0.77	0.22	—	—	—
Orkney, adult	0.2	0.25	0.13	—	—	—
Orkney, adult	14.0	0.07	0.24	—	0.13	—
Orkney, adult	4.4	0.46	0.17	—	0.13	—
Orkney, adult	2.4	0.11	0.07	—	0.08	—
Porpoise	3.8	0.18	0.02	0.04	0.10	0.14

The proportion of blubber extractable by hexane was determined for some samples. Values ranged from 72 to 88 per cent (mean 80 per cent) for the Canadian seals, and from 85 to 93 per cent (mean 93 per cent) for Scottish seals samples on the breeding grounds off the west coast. (Values for other seal samples were not estimated.) Concentrations of pesticides in terms of extractable fat for these samples would thus be up to 40 per cent greater than the values in Table 1, but the general comparison is not significantly affected. The lower extractable fat values for the Canadian samples may possibly be a result of being preserved in formalin.

Concentrations of pesticide residues in the extractable fat of various organs and tissues of one porpoise show an important relationship (Table 3). While the concentrations of the DDT group in the original tissues vary widely, those expressed in terms of extractable fat are in much closer agreement, with the sole exception of the brain. A similar anomaly for tissues of trout was described by Holden¹¹. It seems likely that a large proportion of the lipid fraction of the brain may not contain pesticides, and the brain lipid composition is known to differ considerably from that of depot fat.

Table 3. CONCENTRATIONS OF TOTAL DDT (P.P.M.) IN TISSUES OF PORPOISE

Tissue of organ	Blubber	Muscle	Liver	Spleen	Kidney	Brain
Concentration in tissue	3.8	0.14	0.14	0.13	0.04	0.02
Percentage extractable fat	87.0	0.1	13.2	6.1	1.4	0.8
Concentration in extractable fat	4.4	0.2	1.8	0.4	2.0	0.27

The unidentified peaks on the chromatograms seem to be similar to those produced by polychlorinated biphenyls and, to enable comparison to be made, the ratios (R_x) of the retention times of all regularly occurring peaks (relative to dieldrin = 100) have been calculated for the operating column temperature of 200°C, these values being temperature-dependent. The R_x values of PCB compounds from commercial PCB formulations were also determined for both types of column (Table 4). At least seven PCB-type peaks were found, including those which interfere with p,p'-TDE and p,p'-DDT. Heptachlor epoxide and p,p'-MDE could not be confirmed on both columns and are not therefore recorded.

The most significant aspect of the results is that, although seals and porpoises inhabit an environment far removed from the site of application or discharge of pesticides, they can contain much greater concentrations of dieldrin and DDT group residues than those recorded for most other species, including man. Robinson and Hunter¹² found a mean concentration of dieldrin of 0.22 p.p.m. (range 0.10-0.73 p.p.m.) and a mean total con-

concentration of DDT of 4.0 p.p.m. (range 1.0-11.1 p.p.m.) in samples of human depot fat in England in 1965. No evidence of any significant change was found during 1962-65.

Table 4. RELATIVE RETENTION VALUES (R.V. OF RESIDUE (ORIGINAL = 100)

Residue	Sample	Residue	Sample
PCB	83.5	PCB	76
p,p'-DDE	100	p,p'-DDE	100
p,p'-DDD	121	p,p'-DDD	100
p,p'-TDE	129	p,p'-TDE	121
p,p'-DDD	146	p,p'-DDD	121
p,p'-DDT	170	p,p'-DDT	147
PCB	174	PCB	151
PCB	205	PCB	200
PCB	222	PCB	222
PCB	230	PCB	230

The seals and porpoises from the east coast of Scotland were usually more seriously contaminated than those from the north and west coasts. This, at least in respect of seals, may be because, as is believed, the populations in the two areas come from different breeding sites. The seals south of Aberdeen breed principally on the Farne Islands, off the north-east coast of England, while the seals of north and west Scotland are primarily from the breeding grounds of the Orkney Islands in the north, and other islands off the west coast of Scotland. The sea off eastern Scotland is also likely to receive more contamination from estuarine discharges than that off north and west Scotland. Similarly, the two separate seal populations sampled off the east coast of Canada may inhabit areas with different levels of contamination. Pups contain pesticide residues in concentrations only slightly lower than in the parent population. Common seals in Holland have been found with concentrations of residue similar to those of seals on the Scottish east coast¹².

While the residue concentrations in subcutaneous fat are high, those of other tissues and organs are found to be much lower. This suggests that there is no risk of physiological effects, unless the metabolism of much of the fat in times of stress leads to a considerable increase in the concentration of the residue in circulating lipids, and thus in residue concentrations in other organs or tissues.

Grey seals on the coast of the Scottish mainland live primarily on salmon (*Salmo salar*) and cod (*Gadus morhua*). The highest concentrations of pesticides in the marine environment have so far been found in sea trout (*S. trutta*) on the east coast with up to 0.2 p.p.m. (dieldrin + total DDT) in muscle tissue, a salmon from the same area would probably have similar contents. Cod examined from the east coast have contained up to 0.35 p.p.m. (dieldrin + total DDT) in muscle tissue (mean 0.12 p.p.m.) and from the west coast up to 0.56 p.p.m. (mean 0.22 p.p.m.), while cod livers contained up to 4.6 p.p.m. and 12.0 p.p.m., respectively. Grey seals are estimated to eat about 15 lb. of food daily, and thus an adult seal could consume its own weight in food in 20 days. Assuming a high proportion of the pesticide residue to be stored in body fat rather than to be excreted or metabolized, an increase of two orders of magnitude in pesticide concentration from food to body fat within a few years is feasible. This degree of accumulation of residue in an environment not deliberately contaminated, and in species ecologically far distant from the target organisms of persistent pesticides, underlines the possibility of confining such chemicals to the area of application.

We thank Dr B. B. Rae for obtaining the Scottish samples, and Dr C. J. Kerwill for the Canadian samples.

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The North Pacific: an Example of Tectonics on a Sphere

by

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Individual aseismic areas move as rigid plates on the surface of a sphere. Application of the Mercator projection to slip vectors shows that the paving stone theory of world tectonics is correct and applies to about a quarter of the Earth's surface.

THE linear magnetic anomalies¹ which parallel all active ridges can only be produced by reversals of the Earth's magnetic field if the oceanic crust is formed close to the ridge axis². Models³ have shown that the anomalies cannot be observed in the North Atlantic unless most dyke intrusion, and hence crustal production, occurs within 8 km of the ridge axis. The spreading sea floor then carries these anomalies for great horizontal distances with little if any deformation. The epicentres of earthquakes also accurately follow the axis and are offset with it by transform faults⁴. The structure of island arcs is less clear, though the narrow band of shallow earthquakes suggests that crust is consumed along a linear feature.

These observations are explained if the area moves as a rigid plate, and interacts with other plates in tectonically active regions which also show recent tectonic activity. For the purposes of this article, ridges and trenches are respectively defined as lines where new crust is produced and destroyed. They need not show topographic features. Transform faults occur between plates and are lines of pure slip. They are always parallel to the relative velocity vector between the plates, a most useful property. We have tested the paving stone theory of world tectonics in the North Pacific, where it works well. Less detailed studies of other regions support the theory.

Pesticides: Transatlantic Movements In the Northwest Trades

Abstract. Concentrations of chlorinated hydrocarbons in airborne dust carried by the trade winds from the European-African land areas to Barbados range from less than 1 to 164 parts per billion. The lower limit of the average content of 1 cubic meter of air is 7.8×10^{-14} gram. The contributions of river-borne and atmospherically transported pesticides to parts of the marine environment are calculated approximately and compared. The amounts of pesticides contributed to the tropical Atlantic by the trade winds appear to be comparable to those carried to the sea by major river systems.

The transport and distribution of pesticides through the world ecosystem have been attributed to a combination of atmospheric and hydrospheric (oceanic and fluvial) currents (1), yet their relative contributions remain unclear. The high concentrations of residues of pesticides found in shearwaters *Puffinus tenuirostris* and *P. griseus* from the Pacific Ocean and skuas *Catharacta skua* from Antarctica suggest that coastal areas are not the sites of ingestion (1).

Various lines of evidence indicate air transport: (i) the codistillation of chlorinated hydrocarbons with water (2), and (ii) their detection in air and rainwater (3) and in atmospheric dust originating in Texas and subsequently deposited in Ohio (4). These observations, however, are not sufficient to support the hypothesis that much of the pesticides present in marine organisms was atmospherically transported to the oceans from the continents.

Complementing such work is the observation that the mineral tale that is used as a carrier and diluent for pesticides occurs in the solid-mineral phases of rains, glaciers, and rivers and in dusts recovered from the atmosphere in concentrations much higher than expected from natural occurrences (5); its existence in airborne particulate matter over

the sea (6) suggests a link with the global dispersion of pesticides.

Although tale is perhaps diagnostic of the presence of insecticides, its use as a quantitative tracer is not fully warranted; it is gradually being displaced in pesticides by water or light petroleum base. Furthermore, some insecticides are dispersed in Fuller's earth, a mixture of minerals not readily analyzed by x-ray diffraction.

Large-scale tropospheric transport from continents to oceans can best be approached by investigation of the three main zones of movement of air masses: the equatorial easterlies, the temperate westerlies, and the polar easterlies. Gram quantities of airborne particulate matter carried by the equatorial easterlies, the trade winds, over 6000 km from Europe and Africa across the Atlantic to Barbados were collected (7). Pronounced seasonal variations in the magnetic and biological fractions correlated with wind patterns off the African coast. Mineralogical and biological observations pointed to a continental origin of the solids, with Europe and Africa as the most likely sources. Each sample comprised a large fraction of the particulate material in several million cubic meters of air. An input rate of solid phases to the tropical Atlantic sediments of 0.6×10^{-4} cm/year was suggested (6). Knowledge of the pesticide levels in such materials would permit similar calculations of their inputs, for which purpose the Barbados samples have been analyzed.

The collecting screens (8), facing the wind, were made of 0.5-mm-diameter monofilament nylon woven to give about 50 percent voids; they were coated with a 50-percent water solution of glycerin for our work; collection efficiency was about 50 percent for particles larger than 1 μ . Rigorous standards of cleanliness minimized contamination by local dusts, which has always proved to be trivial. For blank runs for the pesticide analyses, acetone-washed dust was applied to screens, with subsequent treatment as for the real samples. Less than 100 pg of any of the DDT compounds (8) or other pesticides per gram of sample was found.

The dust samples were Soxhlet-extracted for 6 hours with a 2:1 mixture of hexane and acetone. Blank runs, using the same solvent volumes, extraction times, and glassware, were made before and several times during the course of the analyses; less than 250

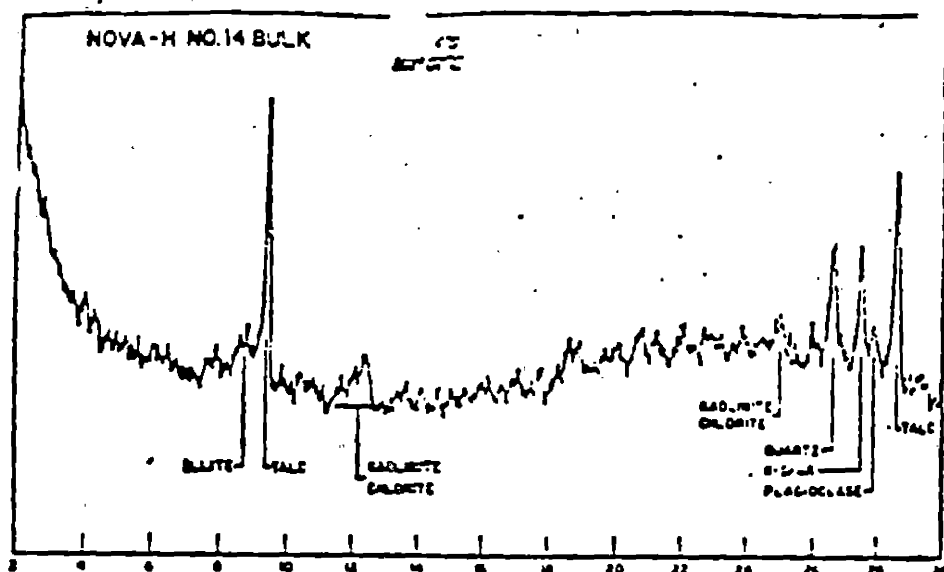


Fig. 1. X-ray diffractogram (CuK α radiation) of atmospheric dust collected over the Coral Sea, with talc predominating.

pg of any pesticide per gram of sample was present in the control.

The extracts were concentrated and analyzed with a Micro Tek-220 gas chromatograph equipped with Ni-63 and H-3 electron-capture detectors. Two columns, a 5-percent QF-1 and a 10-percent DC-200, both on hexamethyl disilazane-treated Chromosorb W, 80-100-mesh, were used simultaneously.

Differences in retention time between the polar and nonpolar columns, combined with occasional spiking of extracts with standards, initially confirmed the identities of several of the peaks observed. Peaks of unknown compounds fluctuating in intensity over the year were present in all Barbados ex-

tracts and occasionally interfered with determination of *p,p'*-DDE and *o,p'*-DDT.

Extracts of samples between January and September were pooled and placed on a thin-layer plate covered with silica gel G that had been washed until chromatographically clean. A small fraction of the sample extract, mixed with standards, was applied to another area of the plate. After development with 10 percent ethyl ether in hexane, the plate was divided into two sets of 13 1-cm strips which were scraped off and washed with petroleum ether. A concentrate of the petroleum ether was then injected into both columns of the gas chromatograph.

Dieldrin, *p,p'*-DDT, and *p,p'*-DDD were quantitatively recovered from the corresponding areas of the plate occupied by the standards. In several extracts the interfering peaks made measurements of *p,p'*-DDE and of *o,p'*-DDT impossible; the thin-layer recoveries of these compounds were 150 percent. A trace amount of a compound having the retention times of *o,p'*-DDE was also recovered, but a small peak provisionally attributed to heptachlor epoxide in one extract was not confirmed by thin-layer techniques. None of the unidentified peaks had retention times equivalent to those of the polychlorinated biphenyls (PCB), industrial pollutants widely dispersed in marine ecosystems (9). No attempt was made to isolate chemically pure pesticides from the thin-layer extracts in order to obtain infrared spectra; instead, several of the thin-layer extracts were treated with alcoholic KOH under conditions such that *p,p'*-DDT, *o,p'*-DDT, and *p,p'*-DDD are converted to their dehydrochlorinated derivatives, which have characteristic retention times on QF-1 and DC-200 columns.

The thin-layer extracts containing most of the *p,p'*-DDT, *p,p'*-DDD, *o,p'*-DDT, and dieldrin peaks were evaporated almost to dryness in a graduated test tube to which 1 ml of 10 percent KOH in ethyl alcohol was added. After heating for 5 minutes in a steam bath, water and hexane were added and the solution was swirled. Analysis of the hexane layer showed that the *p,p'*-DDT, *p,p'*-DDD, and *o,p'*-DDT peaks had

Table 1. Pesticides in airborne particles over Barbados. Concentrations in air are based on 50-percent efficiency of the collecting net; ND, not detected.

Date (1965-66)	Air volume ($\times 10^3 \text{ m}^3$)	Material dry wt (g)		Pesticide concentrations						Total in air ($\text{g} \times 10^{-10}/\text{m}^3$)
		Total	Analyzed	In samples (ppb)					Total	
				<i>p,p'</i> -DDT	<i>p,p'</i> -DDE	<i>o,p'</i> -DDT	DDD	Dieldrin		
4-6 Oct.	2.3		0.52	32	12	13	7	3.4	87	150-380*
26-28 Oct.	2.3	17.2	9.70	<1.2	ND	ND	ND	ND	<1.2	<131
7-21 Nov.	16.3	8.9	2.67	71	19	ND	ND	ND	90	99
1-15 Dec.	16.1	3.2	2.62	10	ND	ND	ND	ND	40	63
23-25 Dec.	2.3	1.7	1.33	88	49	13	8	6	164	242
26-28 Jan.	2.3	1.6	0.97	30	ND	ND	10.7	8.1	49	42
15-17 Feb.	2.3	2.3	3.32	18	13	6	ND	ND	37	77
19 Feb.	2.9	1.4	1.42	67	ND	17	ND	4.8	96	912
27 Mar.	2.4	1.3	1.04	14	2.1	ND	6.3	2.1	23	27
14 Apr.	2.8	4.7	3.10	11	ND	ND	ND	ND	11	37
14-16 May	1.5	9.0	3.43	2.7	ND	ND	ND	1.3	4.9	48
11-13 June	2.1	2.6	2.69	7.6	ND	ND	ND	3.7	10.7	23
21-23 July	1.5	6.8	2.29	5.4	3.4	0.9	1.1	1.3	12.1	110
10-12 Aug.	1.9	8.6	4.39	4.3	3.1	.4	1.4	1.2	10.4	90
13-15 Sept.	1.7	7.3	4.15	8.3	1.5	1.1	1.0	1.5	13.4	120

* Total dry weight not measured.

† Zero dust collected on 12 previous days.

‡ Peak, with retention time of

also present, 7.3

disappeared, but peaks having the retention times of *p,p'*-DDE, *p,p'*-DDX, and *o,p'*-DDE had appeared in the respective extracts. The recoveries of the dehydrochlorinated derivatives were equivalent to those obtained in the epoxidation of chromatographically pure standards. No other breakdown products producing peaks in the electron-capture detector were identified. The dieldrin peak was not affected by the alkaline-alcohol treatment but could not be found after concentrated sulfuric acid was added to the evaporated extract.

All extracts were analyzed with both DC-200 and QF-1 columns, and each value presented (Table 1) is the average from two or more injections of a sample. The total concentrations of the chlorinated hydrocarbons in the dust were higher during the winter months, but the total pesticide content of the air displayed no evident seasonal changes during 1 year. A relatively high content of magnetic dust had been reported (6) for September, October, and April when the wind circulations suggest that the dust originates in Morocco; on the other hand, the content was less between October and March, when the dust probably comes from tropical Africa south of the Sahara. Most of the biological material was present in the winter samples; fungal hyphae abounded, and bacteria, fragments of vascular plants, and marine and freshwater diatoms were observed. Among the last were *Melosira granulata*, which is worldwide in distribution, and *Denticula elegans*, which is found in the running waters of cold mountainous regions. There was no correlation between the pesticide content of the air and either the magnetic content or the number of fungal hyphae reported (6).

The pesticide concentration in air averages 7.8×10^{-14} g/m³, or 41 ppb (parts per billion) by weight in the dust. Utilizing the sedimentation calculations on this dust (6), we can calculate the introduction of pesticides to the equatorial Atlantic by atmospheric transport the following way. We assume that the area involved in dissemination by the trade winds lies between the equator and 30°N latitude, covering 1.94×10^{17} cm². The reported (6) rate of sedimentation for this area is 0.06 cm/1000 years, equivalent to an annual input of dust solids of 9.70×10^{12} g (density of dust, 2.5 g/cm³; water content of the sediments, 50 percent). The value of

41 ppb of insecticides in the dust yields 600 kg/year.

The input of pesticides into San Francisco Bay, measured by the average total concentration in the San Joaquin River at Antioch (10) (0.1 µg/liter) and the mean outflow of 18.9×10^{12} liter/year, amounts to 1900 kg/year. A similar calculation for the Mississippi yields an input into the Gulf of Mexico of 10^4 kg/year (11).

These rates of input indicate the relative significance of wind and river transport to the marine environment. The atmospheric rate is clearly an underestimate inasmuch as the method of collection of the dusts fractionates against materials carried on particles of less than several microns or as vapors. We must conclude that the atmosphere can transport significant quantities of pesticides to the open-ocean ecosystem; where ocean currents and river drainages cannot explain the presence of residues, wind systems may provide conveyance from continents.

Similarly we have examined samples of airborne particulate matter from the central Pacific collected on glycerin-coated nylon nets mounted on the mast of R.V. *Argo* (12) at 12 stations between 17°N and 18°S near 180° longitude during the summer of 1967. No sample carried a detectable pesticide residue, but the weight of each sample did not exceed 1 or 2 mg, and less than 1 part per million or 1 ng of a pesticide would have been undetectable. However, the presence of talc, the most important distracting mineral, suggested the presence of pesticides (Fig. 1).

Dust collected from an ocean pier at La Jolla, California, between June and October 1967 yielded total pesticide contents in air ranging from 6 to 270×10^{-12} g/m³ and averaging 7.0×10^{-11} g/m³; the prevailing winds are landward, with an unknown admixture of air from neighboring agricultural areas. This average value is 1000 times greater than its Barbadian counterpart. Such is the difference in pesticide load between marine air adjacent to agricultural areas in which pesticides are used intensively and marine air remote from sites of application.

Extracts of the La Jolla dust samples were pooled, concentrated to a volume of about 1 ml, and refluxed for 10 minutes in 100 ml of 5 percent KOH in ethyl alcohol before 100 ml of hexane and 300 ml of concentrated aqueous solution of NaCl were added. The hexane layer, after concentration to a small

volume, was then analyzed for PCB. Such treatment of extracts of marine fish from coastal waters in California reveals the characteristic profile, on gas chromatograms, of the PCB peaks (9); PCB are present in higher concentrations in marine birds, and the profile of the various peaks is usually evident in unsaponified extracts. No PCB, however, was detectable in the La Jolla dust samples if PCB was present, its maximum concentration in the airborne particulates was 5 ppb—10,000 times lower than that of total pesticides. The PCB are toxic compounds widely used in industry in the manufacture of plastics, paints, and many other products, and are components of industrial air. Unlike the chlorinated-hydrocarbon pesticides, which they resemble somewhat in chemical structure, they apparently persist to a greater extent in the vapor phase. The concentration ratios of total PCB to total DDT in many seabirds, including two species of Pacific shearwaters that nest in Alaska, and in petrels and resident peregrine falcons from remote areas of Baja California are of the same order of magnitude (9); this fact suggests that PCB and pesticides are similarly dispersed. With other pollutants, including products of atomic explosions (13), they are probably universally present in air; thus their distribution in marine and terrestrial ecosystems remote from sites of application can be expected to depend on the prevailing patterns of wind circulation and the rates of fallout.

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showing the microstructure of undisturbed marine clays; he concluded that the microstructure of such clays "corresponds to the cardhouse structure suggested by Goldschmidt and later by Lambe, and in fact exactly corresponds to the imaginative drawing of Tan." Use of the same technique for studying illitic Pleistocene clays led to a similar conclusion (7).

Whereas the electron microscope offers the best means available for study of sediment microstructure in detail, the replication technique does not provide easily interpretable results. My purpose is to illustrate the microstructure in samples of sediment from the Gulf of Mexico as revealed by ultrathin sections of the sediment, and to point out that this technique provides more easily interpretable results.

The samples (Table I) came from cores taken by R.V. *Alamitas* (8). Only cores were selected that had been properly sealed and stored to preserve as well as possible the natural state of the sediment. From each core a cubic sample of 2 to 5 cm was carefully cut with a thin-bladed knife or spatula. A larger portion was cut initially in order to retain an undisturbed portion in the center of the sample; likewise, the sample itself was taken from the center of each core. From each sample, smaller samples (1 to 2 cm by 2 to 3 mm²) were cut with a taut, very thin wire; the outer, disturbed portion of each large sample was first trimmed with the wire to expose the inner, undisturbed portion. The small samples were freeze-dried; this technique is recommended (6, 9) because it entails less particle disturbance due to effects of surface tension than do standard oven- or air-drying techniques.

Microstructure of Sediments: Investigation with Ultrathin Sections

Abstract. Examination of ultrathin sections of "undisturbed" marine sediments from the Gulf of Mexico indicates that they are characterized by a loose, open, random arrangement of particles. The microstructures do not appear to conform entirely to either cardhouse or honeycomb structures.

The microstructure ("fabric") of marine sediments has received little attention from geological oceanographers. Two popular theories prevail as to the nature of the particle arrangement in sediments. Terzaghi (1) suggested a "honeycomb" structure, with adhesive forces causing the particles of clay mineral to stick together on contact; each

cell of the structure consists of many adhering particles (Fig. 1A). Later was suggested (2, 3) a somewhat different structure in which the clay-mineral aggregates, having a platy morphology, were arranged generally in an edge-to-face fashion forming a "cardhouse" structure (Fig. 1B). Tan (4) presented a three-dimensional idealization of cardhouse structure (Fig. 1C).

While some orientation studies, using polarized light and x-ray diffraction techniques (5), can reveal gross trends toward preferred or random orientation of particles, they do not reveal details of the microstructure. Most information has come from the electron microscope. Rosenquist (6) used the electron microscope and the replication technique to obtain stereomicrographs



Fig. 1. (A) Honeycomb structure (after Terzaghi (1)). (B) Cardhouse structure (after Lambe (3)). (C) Cardhouse structure (after Tan (4)).

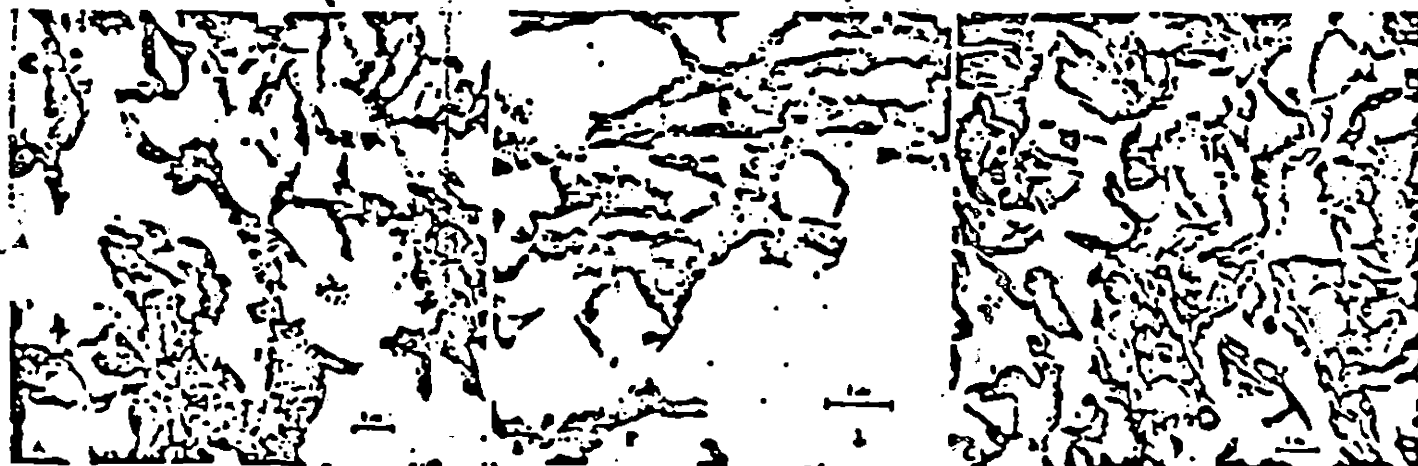


Fig. 2. Ultrathin sections showing the microstructures of undisturbed sediments from an abyssal plain (A), continental slope (B), and a continental shelf (C).

PCB: AN INDUSTRY PROBLEM

Outline

1. Origin of Current Concern - Ecological Effects
2. Toxicity, Fire and Other Health Hazards
3. General Electric Usage
4. Disposal Practices
5. Questions to be Answered
6. A Proposed Program

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October 30, 1969

PCB: AN INDUSTRY PROBLEM?

1. Origin of Current Concern - Ecological Effects

Late in February, 1969, a West Coast newspaper carried a major feature about "a menacing new pollutant" found in the San Francisco Bay area. The article was based on marine life research carried out by Dr. Robert Risebrough of the University of California. The article stated that residues of pesticides (DDT and DDE) and polychlorinated biphenyl (PCB) were threatening the welfare of certain birds and posed long-term threat to humans.¹

The following is Nature's synopsis of Dr. Risebrough's paper:²

Polychlorinated biphenyls are widely dispersed in the global ecosystem, and are powerful inducers of hepatic enzymes which degrade estradiol. Together with other chlorinated biocides, such as DDT, they could account for a large part of the aberration in calcium metabolism which has been observed in many species of birds since the Second World War.

These excerpts are representative of press coverage:³

PCB's are produced under the trade name Aroclor by Monsanto Chemical Company, St. Louis. They were first identified in European birds by Swedish scientists. They apparently are released into the atmosphere and waterways by vaporizing, from factory smokestacks, by discharge into rivers and oceans....

A team of University of California and Cornell University scientists has determined that PCB's are five times more powerful than DDT in hormone-destroying activity. Like DDT, they are found throughout the environment and their quantities are increasing rapidly. They have been found in the milk of nursing mothers in Colorado and in marine life off California, as well as in European birds....

What effects PCB's will have on man is not known, although in vapor form these chemicals are highly toxic....the federal government has not set tolerance limits....Monsanto Company spokesmen say only that their scientists and sales executives are studying the problem....

2. Toxicity, Fire and Other Health Hazards

Company literature has long contained cautionary notes on the handling of Pyranol (the G. E. registered trademark for chlorinated diphenyls). For example:⁴

1. From a Statement by the Monsanto Company, St. Louis, Mo., 3-3-69
2. "Polychlorinated Biphenyls in the Global Ecosystem", by Risebrough, Rieche, Peakall, Herman, and Kirven, Nature, Vol. 220, Dec. 14, 1968.
3. Gainesville, Florida, Sun, April 25, 1969
4. Instructions GEI-65080 (II-54 LM): Pyranol Insulating Liquid and Tre Dryinz.

Transformer Pyranol can be handled in the same manner as mineral oil. Although continued exposure to liquid Pyranol may produce local skin irritation, cleanliness among workmen constitutes an adequate safeguard against such effects.... As with most volatile materials, exposure to concentrated Pyranol vapors in unventilated rooms should be avoided.

CAUTION—Hydrogen chloride gas is formed when Pyranol is decomposed by an electrical arc....

Early this year, an inquiry was received by Mr. John J. Ferry, Specialist-Environmental Health Engineering, Schenectady from an industrial hygienist at Ford Motor Company, as to the toxicity and fire hazard of transformer askarel. The following is extracted from the Medium Transformer Department's reply to the Ford questionnaire:5

Material: Pyranol A50P52L

Components: trichlorobiphenyl 80%
trichlorobenzene 14.5%
tetrachlorobenzene 5.5%
diepoxide scavenger 0.125%

Toxicity: ingestion — highly toxic
inhalation — moderate
respiratory tract — moderate

Skin Sensitizer: No.

~~Estimated threshold limit value: 0.5 to 1 mg/cubic meter.~~

Is material flammable? No.

What products might be formed in the event of fire or abnormal temperature? In an incinerator burner designed for the disposal of chlorinated solvents, the products of combustion will be HCL and CO₂.

In considering the question of flammability, it should be kept in mind that askarels are chosen for insulation applications partly because they are, "by definition", non-flammable liquids which, when decomposed by electric arc, evolve only non-explosive gaseous mixtures. Recently discovered exceptions have been reported, and Medium Transformer Department has at least temporarily abandoned the use of A50P52L, based on Aroclor 1242, in favor of the "classical" Aroclor 1254 (EPTIS A13B3B).6

Some people have sensitivity to Pyranol such that their skin erupts in a rash upon exposure. When discovered in the factory, they are transferred to

5. Transmitted with letter from F. J. McCann, Medium Transformer Department to R. G. Anderson, Ford Motor Company, 2-5-69.

6. See letters from G. G. Poulsen, Mgr.-Engrg., MDT to Glassanos Haywood, Pozefsky, and Deck, under dates of 5-27-69 and 8-5-69.

other lines of work and their symptoms disappear.

The broad class of materials we are dealing with here, polycyclic aromatics, contains known or suspected carcinogens. This aspect has been considered in the industrial hygiene or medical review of operations in at least one plant.

3. General Electric Usage

EPIS specifications list seven different formulations of Pyranol. The basic material is chlorinated diphenyl purchased from Monsanto under the designation Aroclor 1254, Aroclor 1242, and Aroclor 1260. These are blended with other chlorinated aromatics, inhibitors, and scavengers to produce other askarels with different characteristics, all designated by the GE registered trademark, Pyranol. Product responsibility is assigned to the Medium Transformer Department, Rome, Georgia, presumably because MTD sells Pyranol to customers who fill their transformers or other equipment in their own shops.

The following is a list of departments assumed to be using Pyranol in the dielectric systems of products manufactured in-house:

- Industrial and Power Capacitor Department
- Specialty Transformer Department?
- Wire and Cable Department?
- Commercial Distribution Transformer Department
- Lighting Systems Department?
- Medium Transformer Department
- Power Transformer Department
- Canadian General Electric Company
- Service Shops

Total usage has not been ascertained. The Transformer Departments have in recent years cut their relative use of Pyranol, limiting it to cases where the non-flammability property is very important, such as indoor applications. (They are using aliphatic hydrocarbons, especially one known as "LD-C".) As a result of this trend, the Power Transformer Department at Pittsfield uses Pyranol in only about 5% of its units, and Residential Distribution Transformer Department, at Hickory, uses none.

No search has been made for non-dielectric applications of Pyranol. Such may conceivably include use as a hydraulic fluid (e.g. in aircraft or materials-handling systems); heat transfer applications; and as a plasticizer in the production of polymers used as adhesives, elastomers, or surface coatings.

The largest user is the Industrial and Power Capacitor Department, Hudson Falls, N. Y., which uses 10 million pounds per year — probably more than the rest of the Company, combined.

4. Disposal Practices

The Industrial and Power Capacitor Department purchases approximately 10 million pounds per year, of which 9 million pounds are accounted for in terms of products shipped. Waste is handled in the following manner:

Reclaimable material returned to Monsanto 200,000 lb./yr.

Badly contaminated material hauled away by
a New Jersey scavenger (recommended by
Monsanto) 800,000

Contained in scrapped small industrial
units disposed in town dump, where daily
burial is thought to be the practice 60,000
Total waste and scrap, approx. 1,060,000 lb./yr.

At various times in the past, other disposal methods have been used, including sale to a manufacturer of insecticide; in the recent past, at least one representative of the Monsanto Company was recommending its use, alone or in combination with mineral oils, as a road spray to allay dust.⁷

At Pittsfield, there has been some experimentation with a decomposition chamber which fires at 3000 F., but the bulk of contaminated material is sold; at Rome, waste is buried on the Company site. Although nearby neighbors have shallow wells, no complaints have been registered.⁸

5. Questions to be Answered

It is apparent from the above discussion that our knowledge of chlorinated diphenyl formulations and possible deleterious effects is not as complete as is desirable in today's climate of concern for maintaining and improving the quality of life in its environmental aspects, with regard to worker protection, and in terms of product safety. Nevertheless, it is not responsive to suggest that "other materials be substituted" until all doubts are resolved. It must be remembered that virtually all applications of Pyranol are the end product of intensive research directed toward finding the best material for the application; that substitution would involve trade-offs, not only with performance factors and economic factors, but with product safety considerations themselves — i.e., flammability and explosion possibilities.

While it is desirable to attain a better quantitative expression of the toxic effect of PCB and its various additives, and a better understanding of the flammability of degradation products, the most important question, long range, appears to be, "does industrial use of PCB represent a credible ecological threat?"

7. Letter from T. W. Oneson, Monsanto Sales Representative, to V. R. Mulhall, Canadian General Electric Co., Ltd., Peterborough, 11-12-68.

8. Letter, Dr. J. S. Anderson (RECO) to Mr. V. R. Mulhall, CGE, 12-20-68.

One circumstance which makes it difficult to answer the question of ecological effects is that PCB has not been found alone in any of the reported observations of nature, but always accompanied by larger quantities of DDT or DDE. In the work previously cited, Dr. Risebrough has shown, by direct intra-muscular injection, that PCB has "the capacity to produce sublethal physiological effects in birds" — but this is not the same thing as saying that it does, in fact, do so outside of the laboratory. Scientific examination of this question degenerated, at the Wisconsin hearings on DDT, into a shouting contest between partisans of conservation (who seem willing to ban any chemical, regardless of its otherwise beneficent results, if it is suspected of harm); the makers of insecticides (e.g., Shell Company); and the producer of PCB (Monsanto). The same witnesses have been quoted on both sides of the question. The reader may choose between the following statements, each attributed by the press to Dr. Risebrough:

- (a) (PCB is) apparently playing a role in the decline of the peregrine falcon and it may have abetted the disappearance from the Gulf Coast of the brown pelican. (San Francisco Examiner, Feb. 25, 1969).
- (b) Tests with eggs...showed mathematically by correlation with eggshell thickness that DDE and not PCB's were to blame. (Milwaukee Sentinel, May 13, 1969). Ironically, the second statement was made when Dr. Risebrough was called to the stand by the attorney defending the insecticide interests.

Should it be established that PCB is to blame for ecological damage, it remains to trace the transport mechanism and determine at least plausible sources and sets of conditions for propagation into the environment. Estimating from GE capacitor usage, total industry usage might be 20 to 40 million pounds, most of which ends up in closed systems from which dispersion is at a very low rate. This contrasts with much larger usage of DDT — 180 million pounds in 1963, 103 million pounds in 1967 — most of which is broadcast on the land, in the atmosphere.

Monsanto has a research program to identify the compounds reported to be PCB by the Swedish and California scientists. This involves precise analysis of environmental samples of water, air, soil and wildlife, including metabolic studies. Also under way are studies to determine the biological effects of deliberate dosage of PCB's on fish, birds, and mammalian animals. Special emphasis is being paid to endocrinological effects, mineral metabolism and reproduction physiology.¹

As we become more pollution conscious, we wish to know what volume of unused Askarel is being buried, sequestered or incinerated on the North American continent, particularly, and what hazards does it present. What degree of responsibility should Monsanto shoulder in this affair? Will it be necessary to diligently collect unusable Askarel, including Askarel-saturated fuller's earth, and develop techniques to destroy it? Should we return it to our factories for chemical decomposition? We must answer these questions soon. 7

The above quotations indicate Monsanto's concern with the ecological effects and state some of the questions to be answered. Monsanto is the only U. S. supplier, but additional information may be sought from European and Japanese suppliers. Prodelec, in France, is the principal continental source of PCB, and maintains a large toxicological laboratory. About three months ago, Mr. M. E. Scoville, Product Safety Representative of the Industrial and Power Capacitor Department, wrote to Mr. Pierre Jay, Manager-Dielectric Fluids Development for Prodelec, calling attention to the Risebrough research and asking for comments and further information. No reply has been received as yet.

6. A Proposed Program

The Company's stance on the PCB situation must take into consideration not only the need for technical assessment of hazards, but the need to guard against well-motivated but possibly needless or precipitate legislative action, e.g., to tack a PCB rider onto an anti-DDT bill.

As a first step, it is suggested that an outside consultant, with more freedom to operate than our own people, be engaged to sort through the conflicting evidence, touch base with the people doing the research at Monsanto, and give us his views as to whether the Company needs to do anything further at this time. This consultant would combine, ideally, the disciplines of analytical chemistry, ecology and toxicology. He would be asked to spend not more than two weeks on this initial survey, and report informally to interested departments and Corporate functional components.

Depending upon his findings, a possible second step would be to engage the electrical industry in cooperative investigation of the problem, through an appropriate industry technical body (e.g., the dielectric committee of NEMA).

The above recommendation is the outcome of discussions between Drs. Anderson and Murphy of RECO (environmental pollution); Mr. E. N. Deck (Safety and Plant Protection); and Messrs. Marquis and Nelson (Product Safety). It has been reviewed at length with Dr. Pozefsky, Dr. George, Mr. Scoville and others at Hudson Falls, and briefly with Mr. Alimansky and Dr. Osthoff at Pittsfield, all of whom have expressed general agreement.

Mr. Deck has suggested that we consider Dr. Horace W. Gerard, a toxicologist at Fairleigh Dickinson University for the assignment as our liaison scientist. Dr. Gerard is a hydrocarbon expert who does much work for the Mobil Company and has carried out assignments for GE in the past.

J. S. Nelson
October 30, 1969

THE USE AND DISPOSAL OF ELECTRICAL INSULATING LIQUIDS

Prepared by Corporate Staff
General Electric Company
December 21, 1970

ADM 007720

THE USE AND DISPOSAL OF ELECTRICAL INSULATING LIQUIDS

Abstract

Electrical insulating liquids (EIL), their application and disposal are studied against a background of similar information relating to petroleum products in total. Lubricating oils are selected for particular attention because of their chemical and physical similarity to petroleum insulating liquids.

Naphthenic mineral oils are found to comprise over 60 percent by volume of the total usage of EIL. Polybutenes are second, at almost 10 percent. Thus, 90 percent of EIL are petroleum-based. Being relatively nontoxic and biodegradable, they represent no environmental threat when subjected to conventional secondary waste treatment.

The third largest-volume EIL group is the askarels, or polychlorobiphenyls. This group has some toxic properties and contains members which have recently become suspect ecologically. Accordingly, the report contains recommendations regarding the control and disposition of askarels.

ADM 007721

INTRODUCTION

This study of the use and disposal of electrical insulating liquids has been undertaken in support of the objectives of the Electric and Nuclear Sub-Council of the National Industrial Pollution Control Council. Its purpose is to examine electrical insulating liquids (EIL) for their possible toxicological or ecological impact and, as appropriate, to provide information which may lead to advice concerning government programs which would facilitate private sector efforts directed at environmental improvement, or voluntary actions by industry. Specific areas of interest include pollution which may occur from the plants where EIL are used in manufacture of electrical apparatus, and that which may occur during use or disposal.

A variety of insulating liquids is used in electrical apparatus such as transformers, circuit breakers, capacitors, and high-voltage cable in order to optimize, for each application, a range of design parameters typified by dielectric strength, losses, dissipation factor, arc and flame suppression, heat transfer coefficient, and product life expectancy. Requirements and conditions to be met will, in a given instance, quickly narrow the practical options available to the designer down to a very few or even to a single fluid. For this reason it should be borne in mind that, even though a particular electrical insulating liquid may be characterized as containing the potential of contributing to the pollution of the environment, the socially-desirable and economically correct action may lie in the adoption of precautions and control measures rather than in the substitution of a material which would not perform the required function as well.

Representatives of many organizations, both in industry and in government (see, SOURCES OF INFORMATION), have contributed information and suggestions; their cooperation and helpfulness are acknowledged with thanks.

ADM 007722

1.0 Total Flow of Petroleum Products

Because a high percentage of the total volume of electrical insulating liquids is petroleum based, the use and disposition of EIL can best be understood against a background of the quantities of petroleum products used throughout the economy, and how they are disposed of.

Table No. 1 displays the quantities and uses of petroleum products in the U.S. for 1968 (the most recent year for which relatively complete data could be searched out). The quantity on this table of greatest interest is item 3.12, Electrical Insulating Oil. The quantity shown, 1.4 million barrels, is the total of naphthenic and polybutene EIL, and corresponds to 0.04% of "all oils."

1.1 Lubricating Oil

Lubricating oil (Table 1, Item 3.7) was chosen for a comparative study because of its similarity to electrical insulating grades of petroleum oil, and because data are available from which a reasonable estimate can be formed of what happens to lubricants throughout their life history.

Lubricants may be classified conveniently in two groups: automotive and industrial. Table No. 2 is an estimate of the usage, waste generation, and disposition of automotive lubricants throughout the country, and Table No. 3 presents similar data for industrial lubricating oils. A large portion of the waste generated is collected by scavenging firms, and the fate of this portion is indicated in Table No. 4. Table No. 5 summarizes the results of the investigation of lubricating oil waste practices. It will be noted that a little over half of all lubricating oil ends as waste, and of this half, more than half is simply dumped on the ground in one way or another -- as locally disposed waste, as road oil, in town dumps, etc.

2.0 Quantities and Usage of Electrical Insulating Liquids

Table No. 6 contains a breakdown of the principal uses of naphthenic mineral oil as an insulating liquid. The information on transformer and cable oils was derived from the market estimates of several oil producers (Reference: SOURCES OF INFORMATION, Item 1.1). Switchgear (circuit-breaker) data and capacitor data were estimated from General Electric usage and assumed market position. The second column of data, that on field use, is a measure of the generation of waste oil during the use of the apparatus. The total, 8 1/2 million gallons, is equivalent to 0.8% of the waste lubricant oil shown on the previous Table (No. 5).

ADM 007723

Table No. 7 is similarly derived and presents an analysis of the total quantity of EIL according to the apparatus in which it is used. The first two entries, naphthenic oil and polybutene liquid, were added together to produce the total recorded as Item 3.12 in Table No. 1 (i.e., 57.26 million gallons is equal to 1.36 million petroleum barrels). This subtotal is 91% of the total estimated annual usage of EIL. The total is 63 million gallons, or 1.5 million barrels.

The chlorinated benzenes shown are not used alone, but as diluents for the askarels, in some applications. The category, "other", includes relatively small quantities of such materials as dibutyl sebacate and silicone oil, used in specialized apparatus of low production quantities.

Specifications and general characterization of the principal EIL are shown in Table No. 8.

3.0 Toxicology

Mineral oils and polybutenes are essentially nontoxic. The only reported danger is from inhalation of vapor or mists, in which the maximum allowable concentration is 5 parts per million.

The askarels are regarded as somewhat toxic with regard to ingestion, skin absorption, and inhalation. The maximum allowable concentration for inhalation is 0.5 parts per million. Because of the low volatility, there is little chance of harmful atmospheric concentration being developed at ordinary temperatures. Askarels may produce local skin irritations in susceptible individuals, but ordinary cleanliness constitutes an adequate safeguard against such effects. A drop of castor oil will neutralize any irritation caused by contact with the eyes. The response to excessive ingestion is to induce vomiting and see a physician.

4.0 Ecology

Mr. Claude E. ZoBell has written,

"Mineral oils are susceptible to microbial oxidation, and certain fractions undergo autoxidation. This seems to be Nature's way of remedying oil pollution in soil as well as in sea water... In controlled laboratory experiments, we find that oil-oxidizing bacteria convert an average of 30-40 percent of the carbon content of hydrocarbons into bacterial cell substance or protoplasm." (Ref. b-12).

Mineral oils and polybutenes are not known to have a long time effect upon the ecology. In the short term, the effect of large scale dumping of hydrocarbons has been well advertised in the press. Small amounts have no detrimental effects. The materials, in short, are biodegradable, exist naturally in the ecology, and are not thought to be a problem in the context of this study.

ADM 007724

The askarels, particularly those with more than 50% chlorination, have recently been identified as a possible ecological threat to marine and bird life. The attention of the industry was called to this subject in a widely distributed letter from the Monsanto Chemical Company (sole U.S. producer), under the date of February 18, 1970. Askarels introduced into the ecology are believed to act in a manner somewhat analogous to the persistent pesticides, being concentrated in successive links of the food chain.

For the short term, effects of askarels may be kept from the environment by application only in closed systems (of which transformers and capacitors are examples) and by the exercise of suitable precautions in the disposition of waste, as outlined below. For the longer term, the manufacturer is working to develop modified chlorinated biphenyls which will be biodegradable. This means that even if minute quantities are released to the environment by accidental spills, it will be possible to remove them from waste water streams in conventional secondary treatment facilities. (Reference b-15, quoting a letter from Monsanto to Congressman Ryan, June 30, 1970.)

5.0 Recommendations

In view of the suspected ecological hazard presented by polychlorinated biphenyls, it is recommended that the electrical industry employ the following guidelines in their use:

1. Provision is to be made for qualified destruction of PCB waste materials such that there will be no release of materials to the atmosphere or to ground or surface water significant from the standpoint of toxicity or adverse ecological impact. Initially, the only process which appears to meet these requirements is incineration under carefully controlled conditions. With proper adjustment of temperature, residence time in the incinerator, and other parameters, products of combustion will be limited to HCl, CO₂, and H₂O (in the form of steam). The hydrochloric acid may be absorbed in a scrubber and the resultant solution neutralized with lime to form calcium chloride solution, CaCl₂. In the process described, the only effluents to the environment will be a plume of steam, carbon dioxide, and brine.
2. All liquid waste is to be held in impervious containers pending disposal.
3. Solids contaminated by PCB's are to be held in impervious containers pending disposal or purging. Purging may be accomplished by cleaning with proper fluids. The resulting contaminated liquids may be incinerated as above.

As a result of the Monsanto letter to the industry cited above, the industry is believed to have progressed a long way toward the implementation of these recommendations.

ADM 007725

GENERAL ELECTRIC COMPANY

INDUSTRIAL AND POWER
CAPACITOR DEPARTMENT

JOHN STREET, HUDSON FALLS, NEW YORK 12839 . . . AREA CODE 518, TELEPHONE 747-3241

April 12, 1972

—Mr. P. G. Benignus, Monsanto Company
Mr. N. R. Clark, Universal Manufacturing Company
Mr. A. S. Doty, P. R. Mallory Co., Inc.
Mr. E. G. Hammer, McGraw-Edison Power Systems Division
Mr. J. F. Kuzela, Sangamo Electric Company
Mr. F. R. Lengefeld, Union Electric Company
Mr. R. D. McClain, Westinghouse Electric Corp.
Dr. E. M. Moore, Electric Utilities Company
Mr. W. P. Papageorge, Monsanto Company
Mr. R. L. Rollins, Jard, Inc.
Mr. E. L. Raab, General Electric Company
Mr. A. M. Salazar, NEMA
Mr. John Sodalski, Electronic Industries Assoc.

Enclosed is what I hope will be the final revised Guideline for the Capacitor Group on Askarel Disposal.

The Preface has been taken from the Transformer Guideline.

There are areas where both the Transformer and Capacitor Guidelines read essentially the same. However, I anticipate that both Guidelines will be issued and used separately in many cases, so that there should be no problem in redundancy.

I have discussed with Al Salazar the possibility of using the Guideline on an interim basis under NEMA and/or EIA sponsorship until such time as the Guideline is issued officially by ANSI. We should attempt to reach a decision on this at the next meeting.

I expect that the full ANSI Committee should be meeting within about a month to finally approve the guidelines for review by government and other members of the committee.


A. Pozefsky
Manager-Engineering

PE
Enc.

ADM 007210

MAY 3 1973

31

bcc: J. P. Stapleton

May 2, 1973

11 X Copy
R.F.S.
21210

Dr. A. Pokofsky
General Electric Company
Industrial & Power Capacitor
Products Department
John Street
Hudson Falls, New York 12839

Mr. E. L. Nash
General Electric Company
Transformer Division
Building 11-223
100 Woodlawn Avenue
Pittsfield, Massachusetts 01201

Gentlemen:

A recent incident in which askarel fluid in a transformer on its way to the customer was permitted to drain onto farmland dramatically highlights the need for specific instructions that can be made available to private and public carriers to instruct them in the proper handling of askarels during emergency conditions.

I recommend that your two committees jointly consider appropriate guidelines that would apply to this type of situation and which would be included in the ANSI Committee C-107 askarel guidelines.

Sincerely,

W. B. Papageorge
Chairman
ANSI Committee C-107

WBP/bt

cc: Mr. P. B. Benignus
Steering Committee Chairman
ANSI Committee C-107

Mr. A. M. Salazar, Secretary
Transformer Section
and ANSI C-107

ADM 007711

GENERAL ELECTRIC

GENERAL ELECTRIC COMPANY, ONE RIVER ROAD, SCHENECTADY, NEW YORK 12345
Phone (518) 374-2211

REAL ESTATE
AND CONSTRUCTION
OPERATION

November 21, 1973

Dr. C. Hugh Thompson, Chairman
Hazardous and Toxic Substance
Regulation Task Force
Office of Water Program Operations
Environmental Protection Agency
Washington, D.C. 20460

SUBJECT: COMMENTS ON TOXIC POLLUTANT EFFLUENT
STANDARDS (38 FR 21342, Sept. 7, 1973)

Dear Dr. Thompson:

In the above Federal Register announcement, the Environmental Protection Agency invited comments that might assist it in setting effluent standards for the pollutants on EPA's first list of toxic pollutants. On behalf of the General Electric Company, I am pleased to submit for your consideration the following comments that we believe are relevant to the establishment of effluent standards for polychlorinated biphenyls (PCBs). The General Electric Company is a major manufacturer of sealed capacitors and transformers that incorporate PCBs as insulating liquids.

COMMENTS

In promulgating its list of toxic pollutants, EPA stated that "Polychlorinated biphenyls are on the list because of their high order of toxicity to man and aquatic organisms, and because of their bio-accumulative potential. The data are adequate, and the point source discharges require prompt control." (underlinings added)

In an earlier section of this same promulgation (I, 3), which explains the criteria of toxicity, appears the statement that "substances which have an oral LD50 of 50 mg/kg of body weight or less ... are defined as highly toxic to mammals ...". This definition would seem to exclude PCBs, because the LD50's of all commercial preparations are many times greater, that of a typical material (Aroclor 1242) being 8650 mg/kg (1).

(1) PCBs and the Environment, Interdepartmental Task Force on PCBs, May 1972, p. 131.



SERVING
PROGRESS

ADM 007200

GENERAL ELECTRIC

Dr. C. Hugh Thompson

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November 21, 1973

The low order of toxicity to man is supported by several decades of experience in the U.S. electrical industry.

In addition, the foregoing statements about PCBs quoted from the promulgation receive little support from EPA's subsequent publication in October of its "Proposed Criteria for Water Quality - Vol. I." (2) These criteria "are defined as the acceptable limits of constituents in receiving waters based upon an evaluation of the latest scientific information by the Environmental Protection Agency" (p. 12) and "are based upon current knowledge of the effects on health and welfare of the presence of various pollutants in receiving waters" (p. 18). Criteria for PCBs are discussed under four categories of water use (pages 121, 180, 224, and 320) along with the rationale for the recommended limits. None of these discussions suggests biological effects that could be described as a "high order of toxicity to man and aquatic organisms"; most of the rationales represent far from "adequate" data; and none of them leads to the conclusion that "point source discharges require prompt control."

The only numerical value suggested is a maximum acceptable concentration of PCBs in fresh water of 0.002 μ g/l (0.002 ppb) (p. 121). The rationale given for this level is based upon an exceedingly tenuous chain of reasoning beginning with a PCB residue level that has been suggested (not demonstrated) as the threshold for salmon egg mortality and continuing through several other vaguely defined multiplicative factors. Further, this number has no operational significance because no analytical techniques are available for the reliable determination of so low a concentration of PCBs in water.

Section 304 (a) (1) of The Federal Water Pollution Control Act Amendments of 1972 requires that criteria for water quality should accurately reflect the latest scientific knowledge "on the kind and extent of all identifiable effects on health and welfare ... which may be expected from the presence of pollutants in any body of water ...". We submit that none of the water quality criteria proposed for PCBs, which presumably reflect the latest scientific knowledge, provides an adequate basis for establishing effluent standards for PCBs. Other bases than water quality should be used and are discussed later on in this letter. In our opinion, however, the recommendation that "the body burdens of PCB's in birds and mammals should not be increased over present levels in order to maintain acceptable levels" does represent a reasonable goal for any PCB control program (Ref. 2, p. 180).

The Proposed Criteria for Water Quality acknowledge (Ref. 2, pp 17-18) that other considerations are important in "establishing particular standards and control measures" for pollutants that "may be listed as toxic pollutants under subsection 307 (a)."

(2) Proposed Criteria for Water Quality, Vol. I, U.S. Environmental Protection Agency, October 1973.

GENERAL ELECTRIC

Dr. C. Hugh Thompson

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"Some of the more important considerations are:

- (1) The nature of the environmental effect of the presence of pollutants in water (e.g., long or short term, temporary or permanent, localized or widespread, etc.).
- (2) The economic and social impact of the standards and control measures and the impact of the environmental damage to be alleviated.
- (3) The practicality and enforceability of the standards and control measures, including the availability of techniques and instrumentation for determining whether particular standards are being met."

Regarding the third consideration, we have already indicated that there is no practical method of enforcing a standard based upon the recommended maximum concentration of 0.002 ppb of PCBs for fresh water.

The following additional points, which we believe should be considered in establishing effluent standards for PCBs, are germane to the other two considerations.

(1) In 1971 the Monsanto Company (the sole U.S. producer of PCBs) began a program that has led to a total ban on sales of PCBs for all uses except the manufacture of sealed electrical equipment (capacitors and transformers). As a result there has been a large decrease in the number of point source discharges of PCBs. Since ~~there are probably not more than 25 major users of PCBs throughout~~ the country, current production-type discharges of PCBs are no longer as ubiquitous as when PCBs were a component of paints, inks, plastics, adhesives, textile coatings, hydraulic and heat transfer fluids, etc. Indeed, "production and sales figures for PCBs in 1971 were roughly half of those for 1970, when these volumes were at their peak ... (and) projections for 1972 indicate an even lower volume " (Ref. 1, pp. 5-10).

Thus, even apart from the introduction of improved control measures by present PCB-users, there has been a major decrease in the amount of PCBs to which the environment can possibly be exposed. Although current PCB discharges can and should be more carefully controlled, the situation is one whose magnitude is decreasing. There is, therefore, no need for emergency-type controls, which might be reflected in technically infeasible standards and compliance schedules.

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GENERAL ELECTRIC

Dr. C. Hugh Thompson

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November 21, 1973

(2) PCBs are not a unique chemical species. More than 100 isomers are possible, and major commercial products may contain as many as 18 distinct compounds. As pointed out by the Interdepartmental Task Force on PCBs:

"Full evaluation of actual or potential effects in the environment is hampered by the complex nature of the mixtures that compose PCBs, and by the inclusion of contaminants in these mixtures. As experimental studies have been conducted with the unaltered products, as sold, the results may not properly reflect the effects of the components as they exist in the environment." (Ref. 1, p. 19).

Furthermore, it was reported to the Interdepartmental Task Force

"... that all PCB products cannot be lumped together in terms of either their environmental impact or persistence." (3)

Other points made in this report to the Task Force are:

(1) As the degree of chlorination (of PCBs) decreases, the bacterial degradation rate increases. (Ref. 3, p. 4).

(2) The residue storage levels (in albino rats) decrease exponentially as the weight percent chlorine decreases. (Ref. 3, p. 6)

(3) PCB residues found in wild life are dominantly penta-, hexa-, hepta-, and octa- chloro biphenyls. (Ref. 3, Chart 4).

In recent years the Monsanto Company has developed a special product, Aroclor 1016, which is the only grade of Aroclor now used in capacitor manufacture. Although its gross chlorine content is almost the same as that of Aroclor 1242 (i.e. about 42% of Cl), Aroclor 1016 has been specially distilled to remove most of the higher boiling homologs, which are found in wild life residues. Indeed, more than 99% of Aroclor 1016 comprises homologs with 4 or less chlorine atoms per biphenyl (Ref. 3, Chart 1); and these homologs have not been found in wild life residues.

In light of the foregoing we recommend that the specific commercial preparation, Aroclor 1016, not be considered as a toxic pollutant. We are encouraged to see that in promulgating its list of toxic pollutants, EPA has recognized that not all compounds of cadmium and cyanide are toxic and has stated that distinctions will be made when the final

(3) Tucker, E.S., "Assessment of the Biological Persistence of Polychlorinated Biphenyls," from Presentation to the Interdepartmental Task Force on PCBs by Monsanto Company, May 15, 1972, p. 2.

effluent standards are published. We recommend that similar distinctions be made in writing effluent standards for PCBs.

(3) The "economic and social impact" (consideration number 2) of a uniform effluent standard would be much more severe upon an existing plant than upon a new plant. Most of the existing plants that manufacture sealed electrical equipment containing PCBs were in operation for many years before there was any recognition of the possible environmental hazards of PCBs, and during these years no special precautions were taken concerning the handling and disposal of these liquids. Thus, accumulations of PCBs over the years in and around the drainage systems of these plants could result in continued discharge of PCBs even if the plants were to eliminate PCBs from their current operations. Elimination of such reservoirs of PCBs might well require a major and prohibitively expensive renovation of plant and site. However, with the institution of internal control measures such as described in proposed American National Standard Guidelines ⁽⁴⁾, older plants are preventing further build-up of such reservoirs.

WHAT EFFLUENT STANDARDS ARE FEASIBLE FOR THE ELECTRICAL MANUFACTURING INDUSTRY

We have already noted that the Monsanto Company now sells PCBs only to manufacturers of sealed electrical equipment, such as capacitors and transformers. The soundness of this decision is supported by the findings of the Interdepartmental Task Force on PCBs (Ref. 1, p. 4) and the regulation promulgated by the Food and Drug Administration (38 FR 18096, July 6, 1973). These documents recognize the unique combination of fire safety and design efficiency that the use of PCBs imparts to capacitors and transformers and the minimal risk of environmental contamination associated with such use.

We believe that the special conditions pertaining to the past and present use of PCBs in the electrical industry warrant recognition in the setting of effluent discharge standards. These should not necessarily be identical to those deemed appropriate for the chemical industry.

The manufacture of transformers and capacitors involves a multiplicity of operations including vacuum impregnation, heat treatment, filling, sealing, washing operations and the like. Provision must be made for the handling of large apparatus containing up to 1500 gallons/unit (in the case of transformers) and for the filling and sealing of millions of small units per year (in the case of capacitors).

Control of PCB discharges in such electrical manufacturing plants requires a combination of process design and good housekeeping. For example, waste lines and operating procedures may be designed to eliminate contact between PCBs and water not directly used in the PCB operations themselves (e.g. cooling water). No effective end-of-line treatment has been demonstrated on a plant scale.

(4) Official Standards Proposal. Proposed American National Standard Guidelines for Handling and Disposal of Capacitor- and Transformer-Grade Askarels Containing Polychlorinated Biphenyls, C107.1- (), National Electrical Manufacturers Association Pub. No. CP-P1-1973 and Pub. No. TR-PC-1973, January 25, 1973.

Segregation of operations and waste lines is feasible in the design and construction of a new plant but would be prohibitively expensive for an old plant. If such controls are incorporated into a new transformer or capacitor plant on a new site, it should be possible to limit the discharge of PCBs to less than 5 pounds per day depending upon the volume and complexity of the production processes. The attainable discharge from an existing plant that had already been in production before the mid-60's may be as much as 15 pounds higher as the background level, depending on the size of the plant, its age, and the nature of its earlier operations, all of which would have affected the location and extent of its reservoirs of PCBs. Such a plant could install the control measures mentioned above and still be unable to reach the discharge levels for a new plant at a new site.

We believe that the foregoing numbers can provide the basis for realistic effluent standards because they reflect the actual technology of the capacitor and transformer industry. As we have mentioned earlier, the recommended water quality standards provide no practical basis for effluent standards.

SUMMARY

In the foregoing comments we have raised the following points:

- 1) Available data do not support categorizing PCBs as a "highly toxic" material, nor setting standards on the basis of this arbitrarily assigned hazard rating.
- 2) The maximum recommended concentration of 0.002 ppb of PCBs in fresh water is an operationally meaningless number that is unsupported by convincing ecological data. Any effluent standards based upon such a water quality standard could not be attained in existing plants and could lead to shut-down of capacitor and transformer operations.
- 3) Actions already taken by Monsanto and PCB users in the electrical industry have substantially reduced the exposure of the environment to PCBs and should result in a decreasing impact of PCBs in the environment.
- 4) Existing data suggest that Aroclor 1016 should not be considered a toxic pollutant.
- 5) Older plant sites will continue to have significant background levels of PCBs in their discharges because of accumulated reservoirs from years of operation before anyone recognized the possible environmental hazards of PCBs. These background levels should be considered apart from those levels contributed by current operating procedures.

GENERAL ELECTRIC

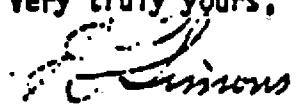
Dr. C. Hugh Thompson

-7-

November 21, 1973

We appreciate the opportunity to submit these comments and hope that they will be of assistance to EPA in setting effluent standards for PCBs.

Very truly yours,


Dr. E. L. Simons, Manager
Environmental Protection Operation

ELS:1

ADM 007200

GENERAL ELECTRIC

PRODUCT

QUALITY

STAFF

GENERAL ELECTRIC COMPANY, 1 RIVER ROAD, SCHENECTADY, NEW YORK 12345
Phone (518) 374-2211

Subject: Effluent Limitations for Items on
Toxic Substances List: Economic
Impact of a Ban on PCB

November 21, 1973

Dr. Martha Sager
Chairman, Effluent Standards
and Water Quality Information
Advisory Committee
Environmental Protection Agency
Room 821, Crystal Mall, Bldg. #2
Washington, D. C. 20460

Dear Dr. Sager:

With reference to your forthcoming meeting (38FR30577) and pursuant to our understanding that the Committee has expressed an interest in knowing the economic impact of a possible ban of polychlorinated biphenyls (or a restriction tantamount to a ban), we have the following comments to offer:

The value of the annual production of PCB transformers in the U.S. is approximately \$45 million and that of capacitors \$140 million. Neither of these figures forms an appropriate base for assessing the socio-economic effect of regulations having the force of a ban on further production. Should such a ban occur in the near future (i.e., within five years) the impact of PCB transformer unavailability would be felt primarily in terms of disruption of building construction, electric distribution, and railroad equipment projects; and interruption of the supply of PCB capacitors would impact most heavily on the electrical supply situation, exacerbating the "energy crisis."

Most PCB transformers are installed in industrial, commercial, and residential substation applications. A considerable number are installed on electric railway passenger commuter cars serving major metropolitan areas. In all applications, these transformers distribute electric power reliably without risk of fire and explosion, and in compliance with specific laws, codes, and insurance restrictions mandating non-flammable liquid content. There is no readily available alternative for many applications where construction is under way or plans are complete. As much as \$1 billion of construction projects could be seriously delayed, involving schools, factories, office buildings, apartment houses, and commuter trains.

ADM 007249

GENERAL ELECTRIC

Dr. Martha Sager

- 2 -

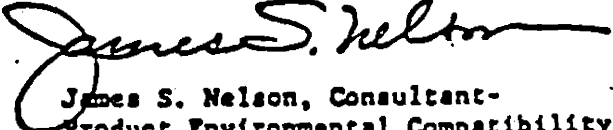
The PCB capacitors produced in the U.S. annually have a major effect in reducing the electric current which would otherwise have to be generated to serve industrial and public needs. The saving may be approximated by summing up the incremental cost of oversize generators and that portion of transmission and distribution system equipment which is thermally limited. Equipment in these classes, corresponding to the 44 million kilovars of new capacitors installed annually, has a value of approximately \$1 billion. A forced conversion to a non-PCB capacitor would be hampered by shortages of basic capacitor materials and factory production capability, thus placing in jeopardy about half of this annual saving. Additionally, there would be serious dislocations in the lighting and air-conditioning industries due to shortages and mismatches of capacitors required in those systems.

The enclosed paper, "The Role of Polychlorinated Biphenyls in Electrical Equipment", February 4, 1972, was prepared originally for the Office of Science and Technology and is included here for further information on the economic value of these devices. In addition, we have updated the information about capacitors and addressed ourselves specifically to the consequences of unavailability of PCB capacitors in the enclosed new study entitled, "The Impact of a 'Ban' on the Use of PCB in Capacitors," November 19, 1973.

Important as are economic considerations, we feel that the case for continued use of PCB's in capacitors and transformers rests less on these factors than upon the lack of substantiated need for any tighter constraints on the handling of these materials than those already in use or assumed as goals by the electrical industry. These aspects are discussed in the enclosed letter from Dr. Simons of General Electric to Dr. Thompson of E.P.A., commenting upon toxic pollutant effluent standards (reference, 38FR21342).

We hope this discussion will be of use to your committee.

Very truly yours,


James S. Nelson, Consultant-
Product Environmental Compatibility

JSN:ev
Enclosures

cc: Dr. C. Hugh Thompson
Chairman-Hazardous and Toxic Substance
Regulation Task Force
Office of Water Program Operations
Environmental Protection Agency
Washington, D. C. 20460

ADM G07250

THE IMPACT OF A "BAN" ON THE
USE OF PCB IN CAPACITORS

SUMMARY

The PCB-impregnated capacitors produced in the U.S. annually have a major effect in reducing the electric current which must be generated to serve industrial and public needs for power. The annual saving may be viewed as equivalent to 44 large electric generators, each of the 1000 megawatt size, which do not need to be installed - an aggregation comparable to the nation's annual growth requirement.

The following consequences will result from a PCB effluent standard so strict as to have the effect of a ban:

- If the industry is forced to convert to a non-PCB impregnant, low dielectric-constant liquids, such as mineral oil, offer the best initial fallback position.
- Mineral oil would roughly double the pounds of capacitor grade dielectric paper and aluminum foil needed to produce present capacitor requirements. Current world-wide shortages of capacitor paper and foil would not support this.
- Materials availability would support about 50% of the current capacitor requirements using mineral oil.
- If adequate materials supplies were somehow attained, current capacitor manufacturing facilities could produce at best only 50% of capacitor unit requirements.
- ~~Forced conversion to a non-PCB would result in capacitor shortages~~ and major production cutbacks in the lighting, air conditioner, and power supply industries, and in their customer operations.
- Doubling the size of capacitors would present serious replacement problems where PCB capacitors had been used.
- Ballast and air conditioner manufacturers would have to redesign certain products to accept the larger capacitors.
- Power system stability would be adversely affected by a shortage of capacitors, and black-outs could be expected.
- New non-PCB's, such as G.E.'s Econol, could substantially reduce the magnitude of the materials problem. However, Econol still represents an unknown risk in reliability and safety in the major consumer application areas. A mass conversion is not justified at this time.

I. INTRODUCTION

This is a forecast of the consequences of a PCB effluent standard which cannot be met by capacitor manufacturers, and consequently becomes an effective ban. It is submitted by the General Electric Company to assist in the determination of appropriate effluent standards relative to capacitor grade PCB.

II. BACKGROUND

In the U.S., an impregnated capacitor can be very simply described as:

- Aluminum foil (around 0.22 mil thick) which serves as the electrodes.
- Sheets of dielectric consisting of capacitor grade paper or combinations of this paper with plastic film. The dielectric is positioned between the aluminum electrodes as it is wound into rolls.
- An appropriate liquid impregnant.
- A sealed container for the capacitor roll and impregnant.

The choice of dielectric materials, the number of sheets, and their thicknesses are all the result of many years of research and testing for reliability and consumer use safety. About 90-95% of liquid impregnated capacitors contain PCB, and are critical components to the fluorescent and mercury vapor lighting, the electric motor and air conditioning industries, and power transmission by electric utilities. The dielectric paper and plastic films (primarily polypropylene), aluminum foil, and PCB have all been specially developed and controlled for capacitor use and are produced as "specialty" materials.

Capacitor grade PCB is Aroclor 1016, manufactured only by Monsanto. It is primarily trichlorobiphenyl. It differs from all previously used formulations in that practically all of the higher boiling homologs--which have given rise to reports of PCB in wild-life residues--have been removed. Introduced in 1971, it is now the only PCB used by the U.S. capacitor industry. Compared to other formulations,

- it has a higher degree of biodegradability;
- it has a lower degree of persistence in the environment.

III. CONSEQUENCES OF A "BAN" TO THE CAPACITOR INDUSTRY

This evaluation addresses itself to the situation wherein the capacitor industry is effectively banned from using PCB's.

A. Alternative Impregnants

Alternative impregnants are unproved in the U.S. capacitor industry. Mineral oil was the major impregnant before PCB's, and it appears to represent the best immediate fallback position. Even though mineral oil technology would put the industry back 30-40 years in progress, it still represents the best combination of known technology, materials availability, and reliability. For these reasons, mineral oil impregnant has been selected at this time as the basis of comparison with PCB's.

There have been a number of very active programs to develop non-PCB impregnants, especially after the environmental problem was recognized. These programs are continuing in the industry, and it is expected that an improvement will be found which would be more acceptable than mineral oil. As an example, General Electric is using a phthalate ester as the base for its non-PCB Econol impregnant. Econol capacitors are being sold commercially where special situations require a non-PCB. This is the case where U.S. electrical equipment, such as computers, is to be shipped to Japan where PCB's are banned.

Econol has a higher dielectric constant (see next Section B for discussion of this property) than mineral oil, and consequently will require less additional materials and manufacturing capacity. However, limited availability of the phthalate ester, lack of appropriate manufacturing facilities, need for developing new efficient manufacturing processes, and particularly the unknown factors of reliability and safety in the broad consumer use areas such as lighting and air conditioners are some of the problems that prevent a near-term substitution.

Unless considerable time for the development and evaluation of alternative liquids is permitted, the most suitable immediate stratagem appears to be the use of mineral oil.

The virtues of PCB impregnant and the disadvantages of mineral oil have been discussed in detail in a number of recent documents. Among these documents are the report of the Interdepartmental Task Force on PCB's (COM-72-10419), a paper titled, "The Role of Polychlorinated Biphenyls in Electrical Equipment" presented by General Electric on February 4, 1972, and NEMA's Official Standards Proposal CP-P1-1973/TR-P6-1973, dated January 25, 1973.

All of these documents have pointed out that PCB-impregnated capacitors are significantly smaller, more reliable and safer than mineral oil impregnated capacitors and that use of mineral oil would return

capacitor technology to its pre-1932 level. The substitution of mineral oil for PCB impregnants would necessitate redesign of end equipment to utilize the larger capacitors, large increases in capacitor manufacturing facilities (both plant and equipment) and would result in increased use of basic materials which are presently in short supply.

The following is an attempt to quantify some of the consequences related to the use of mineral oil as an alternative impregnant.

B. Capacitor Manufacturing Capacity

Mineral oil impregnated capacitor sizes relative to PCB capacitors are shown in Table 1.

Table 1 - Relative Size Comparisons

<u>Types*</u>	<u>AROCLO 1016</u>	<u>Mineral Oil</u>
Small Industrial	1.0	2-2.5
Power	1.0	2.5-3.2

*Small Industrial - Used in lighting, air conditioning, motors and electronics.

Power - Large capacitors used by electric utilities and by industry for induction furnaces and power factor correction.

The dielectric constant of a capacitor's dielectric system is the ratio of its ability to store electrostatic energy relative to air. The dielectric constant of PCB impregnant is 5.85 while that of mineral oil is 2.25. Use of the lower dielectric constant mineral oil in a paper dielectric system, assuming no change in the thickness of the paper dielectric, would result in a capacitor which is 60% larger than the PCB impregnated design. Additionally, however, use of mineral oil requires that the thickness of the paper dielectric be increased to reduce the operating stress on the system if equal life and reliability are to be attained. In the case of lower voltage industrial type capacitors, such as those used in fluorescent ballast and air conditioning applications, the dielectric thickness must be increased 10 to 25%. In power capacitors operating at higher voltages, the dielectric thickness must be increased 25 to 40%. The larger increase in the high voltage units is related to the fact that corona initiation and extinction voltages of mineral oil impregnated dielectric systems are lower than those of PCB impregnated systems.

The approximate doubling of physical size results in about half the throughput of capacitors in existing manufacturing equipment. The capacitor industry currently has little if any excess capacity to handle this, even if adequate capacitor materials supplies are assumed to be available.

CONSEQUENCE - THE CAPACITY AND OUTPUT OF THE CAPACITOR INDUSTRY WILL BE CUT APPROXIMATELY IN HALF.

C. Capacitor Materials Availability

The following Table 2 estimates the capacitor industry requirements for paper, foil, and impregnant based on the currently used AROCLOR 1016 and for mineral oil.

Table 2 - 1974 Capacitor Materials Requirements (lbs. in millions)

	<u>AROCLOR 1016</u>	<u>Mineral Oil</u>	<u>% Change</u>
Paper	26	52-65	100-150%
Al Foil	18	32-36	80-100%
Impregnant	26	35-42	35-60%

There is a worldwide shortage of capacitor grade paper and aluminum foil. The capacitor paper supply is expected to continue at its present level of availability. Mineral oil impregnation will require at least twice the amount of materials to produce the same capacitance as with PCB's. Using the most optimistic of the above numbers, the total capacitor industry's requirements of Kraft paper dielectric, all of it using imported pulp for its production, would increase by 2 to 2.5 times and its requirements for aluminum electrode foil would increase by 1.80 to 2 times.

Total industry requirements in 1974 for paper dielectric in PCB impregnated capacitors is estimated at 26 million pounds. Based on recent experience, this requirement is the limit that suppliers of this type of paper can produce with existing equipment. Adding facilities to more than double the present domestic output of paper is a task that could not be completed in less than 4 to 5 years and the total investment required by the paper manufacturers is estimated to exceed \$200 million. It is questionable that the paper industry would make this investment, factor the probability that future impregnant and design developments would negate its need.

Aluminum foil is also in short supply. Some investment in foil-rolling equipment is already under way at General Electric to alleviate the shortage but an adequate continuing supply of reroll aluminum stock from which the the gauges of aluminum electrode material are made cannot presently be assured.

The supply of dielectric-grade mineral oil required to replace PCB impregnants is also unassured. Doubling the size of capacitors would

approximately double the volume of impregnant required. The sole manufacturer of dielectric-grade mineral oil has recently announced that its manufacture is being discontinued. The feasibility of supplying the capacitor industry on a timely basis with 35 million pounds annually, starting from a production rate of zero, is doubtful to say the least.

CONSEQUENCE - THE CAPACITOR INDUSTRY WOULD BE ABLE TO SUPPLY ONLY ABOUT 50% OF THE CURRENT CAPACITOR DEMAND BECAUSE OF MATERIAL SHORTAGE.

D. Costs

U.S. impregnated capacitor sales for 1974 are shown in Table 3.

Table 3 - Estimated 1974 Total Impregnated Capacitor Sales

	<u>\$ Millions</u>
Small Industrial	100
Power	55

About 90-95% of these are PCB impregnated capacitors. It is estimated that the cost of capacitors would increase by at least 100% in going to mineral oil. It is likely that there would be an added inflationary force with demand far exceeding supply.

CONSEQUENCE - COST OF CAPACITORS WOULD AT LEAST DOUBLE. AT CURRENT PCB CAPACITOR SALES LEVELS, THIS WOULD ADD ABOUT \$145 MILLION IN CAPACITOR COSTS TO EQUIPMENT MANUFACTURERS. TO THIS WOULD BE ADDED AT LEAST ANOTHER \$200 MILLION IN COSTS AT THE END-CONSUMER LEVEL.

E. Reliability and Warranty

The life expectancy of capacitors exceeds 10 years for lighting applications and more than 20 years in electric utility power transmission applications. Although capacitors are considered long-lived products, there is an ever present danger of short life and early failure. This can be caused by a number of factors such as poor process control, materials quality, mis-application, and new product introduction with inadequate knowledge and experience of reliability.

The General Electric Company warrants its capacitors for one year, and has extended this warranty where capacitor failures have been excessive and due to shortcomings in capacitor quality. The major reliability and warranty problems lie in the small industrial type capacitor

such as used for lighting, motors, and power supplies. The capacitor industry produces in the order of 100 million capacitors per year. The majority of these units sell in the price range of 50¢ to \$4. The service cost for replacing a failed capacitor is \$20 to \$25. The in-warranty failure rate of General Electric capacitors during the first year is well under 0.5%. We believe that this reliability is typical of the capacitor industry in general. This performance has been attained after many years of developing the PCB capacitor, and establishing expected norms for failure rates and service life.

The capacitor industry historically is very careful in introducing product and process changes because small changes in failure rate, which are extremely difficult to determine without years of service experience and statistics, could result in excessive complaint and replacement costs. For example, Table 4 shows the replacement cost if the failure rate during the warranty period increased by different levels.

Table 4 - Replacement Costs for Early Failures

% of Annually Installed Capacitors Failing, over Existing Rate

<u>Increase in Percentage Points</u>	<u>Millions Replaced</u>	<u>Cost at \$25/Service Call</u>
1.0	1.0	\$25 million
2.0	2.0	\$50 "
3.0	3.0	\$75 "

~~In order to avoid the consequences of such warranty costs, the capacitor industry would design any new non-PCB products on the conservative side. However, there would still be a substantial risk associated with a mass changeover to a new impregnant, especially in the end-consumer product area with essentially no experience on reliability and safety.~~

CONSEQUENCE - IF THE FAILURE RATE OF THE 100 MILLION CAPACITORS PRODUCED IN ONE YEAR WERE TO INCREASE BY 1 TO 3 PERCENTAGE POINTS, THE REPLACEMENT COSTS AT \$25 PER SERVICE CALL WOULD RUN FROM \$25 to \$75 MILLION. THIS IS THE MAGNITUDE OF THE CAPACITOR INDUSTRY'S EXPOSURE IN GOING TO A NEW, UNTRIED IMPREGNANT ON A MASS BASIS.

IV. CONSEQUENCES OF A "BAN" TO CAPACITOR USERS

This section estimates the effect of a PCB ban on customers and users of capacitors.

CRITICAL COMPONENT AVAILABILITY

Capacitors are a critical and necessary component in end-user equipment, particularly in small industrial applications. Without the capacitor, the end product would not operate as designed. The capacitor shortage resulting from a "ban" on PCB capacitors would force a reduction by at least half from the normal production rate in the plants of capacitor users.

CONSEQUENCE - INCREASED LAYOFF AND UNEMPLOYMENT AS MANUFACTURERS ADJUST TO THE SHORTAGE.

ELECTRIC POWER SYSTEM SAVINGS

The magnitude of the energy levels under discussion can be assessed from the following:

- The U.S. capacitor industry produces the equivalent of 55 million kilovar per year.
- A kilovar is equivalent to at least 1 kilowatt of generating capacity (some estimates place this ratio of kilowatt/kilovar at up to 1.4).

About 20% of the capacitors are for replacement purposes, and the remaining 80% are for new service. Thus, 44 million kilovars are installed on new systems. Without these capacitors, the steam turbines and fuel requirements would be relatively unaffected, but generators would be larger to handle more current, and certain components of transmission and distribution systems (e.g., step-down transformers) would have to be larger to prevent burn-out. The additional generating capacity for 44 million kilovolt-amperes, priced incrementally, would amount to about \$300 million; the additional transmission and distribution equipment would amount to about \$700 million.

CONSEQUENCE - REDUCED AVAILABILITY OF CAPACITORS WOULD ADD FURTHER SUBSTANTIAL BURDEN TO THE ENERGY SUPPLY SITUATION.

POWER SYSTEM STABILITY

The preceding discussion indicates that electrical energy requirements could theoretically be met by using fewer capacitors and building oversize generation, transmission and distribution components (at a severe economic penalty). Such a system would be operating at low power factor -- or, in other words, the system would be carrying a large component of useless reactive volt-amperes in addition to the in-phase component that represents

energy delivery. Systems studies have shown (see Economics of Kilovar Supply by Campbell, Ros, and Tice, General Electric Company, June 20, 1973) that low power factor severely limits the capability of a power pool to import power from its neighbors during a loss-of-generation emergency.

CONSEQUENCE - CAPACITOR SHORTAGES WOULD MAKE LARGE POWER SYSTEMS SUBJECT TO CASCADING OUTAGES, OR "BLACK-OUTS."

SIZE AND REPLACEMENT

As pointed out earlier, the size and cost of mineral oil impregnated capacitors would be at least twice that of PCB capacitors. The lighting industry has designed their ballasts for the small size PCB capacitors. Approximately 20% of ballast capacitors are used in the replacement market. Many room air conditioners have no space for a larger capacitor if a replacement is required. The capacitor industry has continually moved to reduce the size of capacitors. Equipment manufacturers have taken advantage of these size reductions, and have no room for size increases. In certain cases, size limitations in the replacement market would force the scrapping of good light fixtures and air conditioners.

CONSEQUENCE - UNAVAILABILITY OF SMALL SIZE CAPACITORS WOULD FORCE THE EARLY OBSOLESCENCE OF GOOD, FUNCTIONAL EQUIPMENT.

General Electric Company
November 19, 1973

ADM 007259

John F. Welch
Vice-President, General Electric Company

January 14, 1976

General Electric welcomes the opportunity to participate in today's proceedings and wishes to compliment Mr. Train and the EPA for the constructive manner in which they have approached this very complex PCB issue. A cooperative effort between government and industry can avoid the delays brought about by adversary proceedings and should truly benefit the public at large.

As the leading industrial user of PCB's in the manufacture of capacitor and transformer products, we have pursued a parallel course both to reduce the PCB discharges from our manufacturing plants and to find an acceptable substitute for their use in electrical apparatus.

The public record shows that we have made excellent progress in lowering PCB discharge levels at all related manufacturing sites. Our technological developments have positioned these facilities to achieve discharge levels in the ounces-per-day range. However, progress has been more difficult in the search for a PCB substitute.

General Electric for the past 30 years has attempted to find a suitable substitute. In the early years, this effort was directed to improving the economy and performance of its electrical apparatus, but in the past several years, the emphasis has been to provide a more environmentally acceptable substitute. We have tested over a hundred fluids representing the full spectrum of chemical substances, and although there are promising leads, they all require additional long-term testing for reliability, safety and environmental compatibility.

For example, in capacitors, all known potential substitutes, unlike PCB's, are flammable. This characteristic presents a significant problem to the users of capacitors: the appliance, lighting and several other consumer-related industries.

Consumer product safety is just one of the many complex issues which have to be resolved in evaluating a PCB substitute. Environmentally, as a minimum, we must be satisfied that any substitute considered is a significant improvement over PCB's.

As we stated at the outset, General Electric is most willing and indeed anxious to cooperate with EPA in their goal of finding a satisfactory substitute for PCB's in electrical apparatus. However, we urge that the complexity of this issue and the potential consequences of precipitous action be thoroughly and thoughtfully

considered. Industry and government have the opportunity to demonstrate, on this highly visible PCB issue, that they can work together in solving environmental questions in the best interest of the public.

GEN ERAL ELECTRIC

CORPORATE
FACILITIES
SERVICES

GENERAL ELECTRIC COMPANY, 1 RIVER ROAD, SCHENECTADY, NEW YORK 12345
Phone (518) 374-2211

January 15, 1974

Hearing Clerk
U. S. Environmental Protection Agency
Washington, D. C. 20460

Re: 40 CFR 129 (Subpart I)

Gentlemen:

On December 27 (38 FR 35388), EPA proposed an effluent standard for polychlorinated biphenyls, and made the proposal applicable to capacitor and (we infer) transformer manufacturers. Persons adversely affected by the proposal were instructed to file objections by January 18, in accordance with 40 CFR 104 (39 FR 1027).

The General Electric Company (G.E.) is engaged in the manufacture of industrial and power capacitors, as well as power and distribution transformers. PCBs are widely used as insulating liquids in both categories; hence, our operations will be vitally affected by the final regulations.

The degree of our reliance upon PCBs, their essentiality, and the economic impact of an effective ban on their usage have been addressed in our recent letters to Dr. Martha Sager (Chairwoman, Effluent Standards and Water Quality Information Advisory Committee) and Dr. C. Hugh Thompson (Chairman, Hazardous and Toxic Substance Regulation Task Force). Copies of both letters are attached hereto.

The proposed standard was apparently based solely on toxicological data that appear in EPA's Proposed Criteria for Water Quality (38 FR 29646). If so, we are concerned about the paucity of data upon which the standard was based, the relevance of existing data to the creation of a toxic pollutant standard, and indeed - the validity of EPA's extrapolations from such data. More specifically, we find (1) an unnecessarily stringent standard, (2) a failure to distinguish among different PCB compounds, and (3) a failure to consider the exemption of residual PCBs from the standard.

ADM 007303
EXHIBIT "C"

U. S. Environmental Protection Agency -2-

January 15, 1974

Nonetheless, we cannot render responsible comments or objections as required by 40 CFR 104.6(d) in the absence of EPA's "statement of basis and purpose." A capsule summary of the statement was presented in 38 FR 35388, along with an acknowledgment "that there may in some cases be inadequacies in the underlying data base." However, the complete text was not publicly available, as of January 11. Federal Regulations (40 CFR 104.4) would seem to have required availability by December 27.

EPA states that "the attached standards are not based upon economic considerations," although its own criteria document acknowledges that such considerations are important in "establishing particular standards and control measures" for pollutants that "may be listed as toxic pollutants under subsection 307(a)." See Proposed Criteria for Water Quality, Vol. I, U.S.E.P.A., October 1973.

EPA then claims that "the impact of the standards upon the economy has been examined and does not appear to be great." We disagree. In our judgment EPA's proposed standards would have a major economic impact. Presumably the rationale of EPA's examination also appears in the "statement of basis and purpose." Our analysis of such examination must await our receipt and review of that document.

For the sake of continuity, we plan to make an economic and feasibility presentation in conjunction with our toxicological comments. At that time, we will address the question of relevance, as required by 40 CFR 104.6(d).

In view of the unavailability of essential data it is unreasonable to require G.E. to formulate detailed objections at this time. Therefore, on behalf of G.E., I hereby file a general objection to 40 CFR 129 (Subpart I) and request that the Presiding Officer:

- (1) pursuant to 40 CFR 104.6(a), find that reasonable cause existed for our failure to submit specific objections to 40 CFR 129 (Subpart I) by January 18;
- (2) pursuant to 40 CFR 104.6(a), authorize our subsequent submission of specific objections to 40 CFR 129 (Subpart I), said authorization to terminate no sooner than one month after the aforementioned "statement of basis and purpose" is made available to G.E.; and
- (3) pursuant to 40 CFR 104.8(a), designate G.E. as a party in the subject proceeding.

ADM 007304

EXHIBIT "C"

GENERAL ELECTRIC

U. S. Environmental Protection Agency -3-

January 15, 1974

Please contact me (AC 518/374-2211, ext. 5-9058) if the Presiding Officer rules adversely on any or all of the above requests. Regardless, you may expect my attendance at the January 25 hearing. I will be ready at that time to assist in laying the groundwork for the future conduct of this proceeding.

Sincerely yours,



Stuart M. Richel
Attorney-Environmental Protection

SMR:a

Enclosures

ADM 007305

EXHIBIT "C"

**GENERAL ELECTRIC COMPANY
877TH MEETING OF THE BOARD OF DIRECTORS
NEW YORK, NEW YORK - SEPTEMBER 12, 1975**

A meeting of the Board of Directors of General Electric Company was held, pursuant to due notice, at the offices of the Company, 570 Lexington Avenue, New York, New York, on Friday, September 12, 1975, at 10:55 A. M., Eastern Daylight Savings Time.

There were present:

Messrs. Reginald H. Jones, Chairman	John E. Lawrence
J. Paul Austin	Ralph Lazarus
James G. Boswell, II	Edmund W. Littlefield
Silas S. Cathcart	Jack S. Parker
Walter D. Dance	Samuel R. Pierce, Jr.
Charles D. Dickey, Jr.	Gilbert H. Scribner, Jr.
Henry H. Henley, Jr.	Herman L. Weiss
Henry L. Hillman	Walter B. Wriston
Frederick L. Hovde	Robert M. Estes
Gilbert W. Humphrey	Secretary

Mr. Thomas S. Gates did not attend the meeting.

**9018 APPROVAL OF THE MINUTES OF THE BOARD OF DIRECTORS
MEETING - AUGUST 1, 1975**

The minutes of the meeting of the Board of Directors held on August 1, 1975, copies of which were distributed, were reviewed and approved.

September 12, 1975

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will be known as "GE Supply Company of Saudi Arabia."

Vice Chairman Weiss reported that for the first eight months, sales of the Components and Materials Group were 16 per cent under 1974 and earnings were 40 per cent -- or \$35 million -- below 1974. Inventories were \$76 million lower than the first of the year and cash generated after dividends for eight months totalled \$73 million, an improvement of \$154 million over 1974. Order rates for most of the Group's short cycle businesses continued to strengthen in August. Mr. Weiss also reviewed the impact of recently announced raises in prices of steel and aluminum.

Vice Chairman Weiss noted that Industrial Research Magazine has selected the 100 most significant new technical products each year since 1963. General Electric led the field in 1975; and its total since the inception of the awards is more than twice as high as the next highest company. Vice Chairman Weiss referred particularly to the development of a "super-microbe" which may be useful in the safe and rapid disposal of oil spills. He stated that Dr. Ananda Chakrabarty of the R&D Center had been selected by Industrial Research Magazine as scientist of the year.

Vice Chairman Weiss reviewed in detail the background of recent charges against the Company relating to discharges of PCB from its plants at Hudson Falls and Ft. Edward, N.Y. Mr. Weiss explained the reasons for use of PCB in transformers and capacitors, steps taken by the Company

September 12, 1975

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(including capital expenditures) to reduce discharges since PCB was first associated with effects on health, the compliance with requirements of the Federal Environmental Protection Agency and the progress to further reduce discharges. He stated that the N. Y. State Commissioner of Environmental Conservation had insisted on a Company commitment to a zero discharge, a commitment the Company could not make in good faith because we know of no feasible way to achieve such a discharge. Mr. Weiss stated that the Department of Environmental Conservation had served a formal complaint demanding a zero discharge and outlined the further steps expected in the proceeding.

9022

**REPORT ON MANAGEMENT DEVELOPMENT
AND COMPENSATION COMMITTEE MEETING**

The Chairman of the Management Development and Compensation Committee reported on the highlights of its meeting held earlier this day. A summary of the proceedings is contained in the minutes of that meeting.

9023

**REPORT ON AUDIT AND FINANCE
COMMITTEE MEETING**

The Chairman of the Audit and Finance Committee reported on the highlights of its meeting held earlier this day. A summary of the proceedings is contained in the minutes of that meeting.

September 12, 1975

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IN RE GENERAL ELECTRIC COMPANY, File No. 2833 (N.Y. Dept. of Envir. Conservation Feb. 9, 1976)

In this interim opinion, the hearing officer holds that General Electric Company's (GE) discharges of PCB's (polychlorinated biphenyls) into the upper Hudson River violate the New York Environmental Conservation Law (ECL). The record overwhelmingly establishes violations of ECL provisions prohibiting discharges into state waters which cause violation of applicable water quality standards, these include a proscription on waters containing "toxic wastes and deleterious substances . . . in amounts that will be injurious to wildlife or which in any manner shall adversely affect the flavor, color or odor thereof, or impair the waters for any best usage" assigned, including fishing. GE's PCB discharges are toxic substances, capable of causing skin lesions, destroying body cells, adversely affecting reproduction, and inducing cancer and death. The Department of Environmental Protection, which must establish violations by a preponderance of the evidence, has shown beyond a reasonable doubt the GE is responsible for the heavy concentration of PCB's in the upper Hudson which violate water quality standards by injuring fish and making them dangerous to consume, thus destroying fishing. GE responsibility is shown by the size of its discharges as compared with others in the same area, and by the fact that PCB concentrations downstream of the GE plants are far higher than upstream. As an affirmative defense, GE asserts that its conduct is immunized from state law penalties by virtue of its being specifically authorized in a series of permits granted under the Federal Water Pollution Control Act. This defense must fail, for all GE permits have contained language specifically prohibiting violation of state water quality standards. The hearing officer also rejects GE's claims that its current, reduced levels of PCB discharges are too small to violate the ECL, and that no injunction will lie respecting the high emission levels which GE has already voluntarily abandoned. The claim that GE violated a criminal water pollution provision of the ECL, however, is dismissed, for it was not intended to cover a continuous course of conduct like respondent's. Further hearings will be held to determine what level of PCB discharge GE may be ordered to achieve, to what extent GE should be required to rectify the damage caused by its past discharges, the availability of PCB substitutes and their adequacy and environmental acceptability, and whether GE should be required to post a \$2 million performance bond.

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Natural Resources Defense Council
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Rosemary Nichols
Natural Resources Defense Council
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Sofaer, Hearing Officer

This proceeding was commenced on September 3, 1975 by the Department of Environmental Conservation ("Department") to

enforce against the General Electric Company ("GE") §§17-0501, 17-0511¹ and 17-0503² of the Environmental Conservation Law of the State of New York ("ECL") and of water quality and purity standards promulgated pursuant to ECL 17-0301. The complaint alleges that GE is polluting the waters of the Hudson River by directly and indirectly discharging a toxic substance, polychlorinated biphenyls ("PCB's"), into the river from the Company's facilities at Hudson Falls and Fort Edward (ECL 17-0501, 17-0511), and that the discharged PCB's are injurious to fish life of the Hudson River (ECL 17-0503). The Department seeks far-reaching relief, including an order that GE cease its discharge of PCB's from all point and non-point sources,³ that GE restore the health of the Hudson River and other natural resources to the extent its PCB discharges have spoiled them, and that these objectives be attained through a procedure under Department's supervision, including a requirement that GE file a surety bond of \$2,000,000 to guarantee its compliance.

GE answers that its discharges do not violate the ECL and raises as an affirmative defense compliance with its permit under the National Pollutant Discharge Elimination System (NPDES), now a State Pollutant Discharge Elimination Permit (SPDES), issued originally by the U.S. Environmental Protection Agency (EPA). GE argues that no basis exists for the imposition of any remedy. At the same time, the Company represents that "it is going forward voluntarily with a program to achieve maximum treatment and containment." Reply Brief, p. 1 (Jan. 12, 1976). At the hearing, its manager of Engineering and Product Development, Dr. Michael Modan, testified that GE was in the process of reducing its discharge of PCB's from a claimed daily average of about two pounds, to a maximum daily amount of one hundred grams by the end of 1976. Tr. 1322. These amounts are in sharp contrast to the combined daily discharge level of 30 pounds from the plants at Fort Edward and Hudson Falls described in GE's SPDES permit.

The hearing commenced on October 6, 1975, when petitions to intervene were made by the New York State Department of Commerce ("Commerce") and the Natural Resources Defense Council ("NRDC") in behalf of itself and others.⁴ After oral and written argument, the petitions to intervene were granted on certain conditions, as outlined in an opinion filed on November 19, 1975.⁵ The parties engaged in extensive discovery, after which nine additional days of hearings were held. All witnesses were available for cross-examination, and the parties offered direct as well as rebuttal testimony. A substantial record has been compiled, consisting of several thousands of pages of transcript, prefiled testimony, reports, studies, articles and miscellaneous other exhibits.

1. ECL 17-0501 General prohibition against pollution

It shall be unlawful for any person, directly or indirectly, to throw, drain, run or otherwise discharge into such waters organic or inorganic matter that shall cause or contribute to a condition in contravention of the standards adopted by the department pursuant to section 17-0301.

2. ECL 17-0511 Restrictions on discharge of sewage, industrial waste or other wastes

The use of existing or new outlets or point sources, which discharge sewage, industrial waste or other wastes into waters of this state is prohibited unless such use is in compliance with all standards, criteria, limitations, rules and regulations promulgated or applied by the department pursuant to this article.

3. ECL 17-0503 Polluting streams prohibited

No dyestuffs, coal tar, refuse from a gas house, cheese factory, creamery, condensary or canning factory, sawdust, shavings, tan bark, lime, acid, oil or other deleterious or poisonous substance shall be thrown or allowed to run into any waters, either private or public, in quantities injurious to fish life, protected wildlife or waterfowl inhabiting those waters or injurious to the propagation of fish, protected wildlife or waterfowl therein.

4. ECL 17-0105(16)

"Point source" means any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation or vessel or other floating stock from which pollutants are or may be discharged.

5. The others are the Hudson River Fishermen's Association, Inc., the Hudson River Slope Restoration, Inc. and the Federated Conservationists of Westchester County, Inc. In addition a statement by the United Electrical Workers was made without objection from the parties.

6. 16 ELR 10001. For moving papers, see ELR 65299 - Ed. The opinion and other papers and documents in this litigation are on file with the New York State Department of Environmental Conservation, Office of the General Counsel, 50 Wolf Road, Albany, New York.

The filing of this enforcement action necessitated findings and conclusions on whether GE has violated any or all the statutes invoked. On the other hand, it became clear to all those involved that a hearing and judgment concerning the remedies that should be imposed would become necessary only if GE was found to have acted unlawfully. The parties therefore agreed to defer the complicated remedial issues in this case until violations of law were found.⁷

In summary, the record in this case overwhelmingly demonstrates violations of ECL 17-0501 and 17-0511, within the applicable statutory period. PCB's are toxic substances, capable in sufficient quantities of causing skin lesions, destroying cells in vital body organs, adversely affecting reproduction, and inducing cancer and death. GE has discharged PCB's in quantities that have breached applicable standards of water quality. The PCB's have injured fish, and have destroyed the viability of recreational fishing in various parts of the Hudson River by rendering its fish dangerous to consume. Fish analyses in evidence present a grim picture in which PCB contamination reaches over 100 times the temporary tolerance level established by the U.S. Food and Drug Administration ("FDA") in 1971.

These unlawful consequences are the product of both corporate abuse and regulatory failure: corporate abuse in that GE caused the PCB's to be discharged without exercising sufficient precaution and concern; regulatory failure in that GE informed the responsible federal and state agencies of its activities, and they too exercised insufficient caution and concern until this action was instituted by New York's present Commissioner of Environmental Conservation.

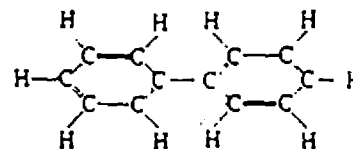
GE is responsible for its conduct and must be compelled to abide by the law. It will at a minimum be ordered drastically to limit its discharges, as it claims itself willing and able to do; to consider and use substitute products wherever feasible; to take other steps that may be appropriate to prevent intentional and non-intentional future discharges; and to rectify the effects of its prior violations where lawfully proper, and economically and environmentally practicable. The public must not be made to pay a continuing price for past bureaucratic insufficiency. But neither should the legislature and public be deceived by this focus on GE's activities into assuming that government has otherwise dealt in a meaningful, institutional fashion with PCB's, or with other hazardous substances being discharged into our environment.⁸ Effective regulatory surveillance would have prevented much of the harm that GE has inflicted. The remedial order ultimately imposed in this case will therefore be constructed with a full and fair appreciation of the fact that, while the damage must cease and be rectified, GE has operated openly and negligently rather than in secret or in disregard of PCB discharge limits set in its permits. For this reason, among others, the charge under ECL 11-0503 is dismissed.

1. PCB's and the Hudson River

A. Composition and Properties of PCB's

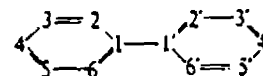
PCB is the abbreviation for a group of chemicals known as polychlorinated biphenyls. Their composition is based on the "biphenyl," a substance made by heating benzene under appropriate conditions. The biphenyl consists of two phenyl molecules, each having six carbon atoms attached in a chain with its two ends hooked together to form a ring, and each with six hydrogen atoms attached to its six carbon atoms.⁹ A biphenyl ring is formed by

breaking the links between one carbon and hydrogen atom on each of two phenyl molecules and making instead a new carbon-to-carbon bond. The result is a compound empirically described as $C_{12}H_{10}$, or by the following structural diagram:



To chlorinate a biphenyl one must replace its hydrogen atoms with chlorine. When only one chlorine atom is added in place of a hydrogen atom, the resulting compound is called a monochlorobiphenyl. When more than one chlorine atom is added, a polychlorinated biphenyl is formed. Since each biphenyl has ten hydrogen atoms, PCB's may have any number of chlorine atoms up to ten, and PCB's with anywhere from one to ten chlorine atoms are called homologs of each other. In manufacturing PCB's, it is generally not possible exclusively to create molecules with a specific number of chlorine atoms. Instead, when chlorine gas and biphenyls are mixed, many homologs of PCB's are formed, and the average number of chlorine atoms with each biphenyl varies with the temperature.

PCB mixtures not only contain different homologs, they also consist of different "isomers." Each biphenyl has several possible sites for chlorine atoms, and the different arrangements of atoms are called isomers of each other. For example, dichlorobiphenyl (two chlorine atoms added) has 12 possible isomers, each with the chlorine atoms at different places on the two phenyl rings. The empirical formula $C_{12}H_{10}Cl_2$ would apply to all these isomers, but structurally they would be different. Chemists express these differences either diagrammatically or more succinctly by describing the location of the chlorine atoms in accordance with the following position numbering system:

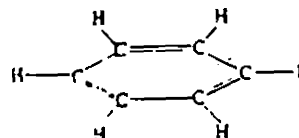


Thus, for example, if the chlorine atoms in a tetrachlorobiphenyl (4Cl-PCB) were located at the "2" and "5" positions of each phenyl molecule the resulting compound could be described as 2, 5, 2', 5' tetrachlorobiphenyl.

The sole manufacturer of PCB's in the United States is the Monsanto Chemical Company. Domestic sales of all PCB's by Monsanto have ranged from 26,061,000 pounds in 1958 to 73,061,000 pounds in 1970; in 1974, sales totalled 34,406,000 pounds. GE Exhibit 19. Until 1971, PCB's were sold for numerous commercial purposes. Monsanto limited PCB sales in 1972, however, to so-called closed applications. The sole application for which PCB's have been used in recent years, according to Monsanto data, are transformers and capacitors. The GE plants at Hudson Falls and Fort Edward manufacture transformers and capacitors, and use PCB's in their preparation. Since 1966, GE has purchased 82,213,000 pounds of PCB's of all types from Monsanto for use in its products. Dep't Exhibit 6.

PCB's, especially mixtures with relatively high percentages of chlorine, have useful physical properties. They are essentially non-flammable. Tr. 1136-37 (Dr. Simons). They are extremely stable; for example, a mixture with an average of five chlorines released only traces of degradation when treated with concentrated sulfuric acid for 255 hours or boiling 10 percent sulfuric acid for 150 hours.

bond with the carbon on one side of it, and a double bond with the carbon on its other side. This configuration leaves each carbon with one unused link, which in the phenyl molecule is occupied by a hydrogen atom. The results can be described as C_6H_5 or by the following structural diagram



See Dep't Exhibit 15, p. 2. The description of PCB's is drawn from the testimony of Dr. Gilman D. Veith, Dep't Exhibit 14 and Dr. E. Tr. 1118-26

7. The Department objected when the Hearing Officer noted that any opinion and findings filed prior to a determination of the relief to be afforded would be tentative and interim. Tr. 1949-1950. The objection was overruled since final and appealable findings and conclusions will and should be filed with the Commissioner only after the proceeding is complete.

8. New York enacted in 1973 a toxic substances control bill which gives the Department authority to promulgate within "not less" than one year rules and regulations to control the discharge and storage of substances determined to be hazardous to the environment. L. 1973, C. 400, ECL 37-0101 *et seq.* No official Department action has yet been taken.

EPA, pursuant to the 1972 Amendments of the FWPCA, is responsible for setting effluent standards for toxic pollutants. FWPCA §307(a)(1), 33 U.S.C. §1317(a). An initial list of pollutants, proposed in 1973, included PCB's. 38 FR 18944 (July 6, 1973). The Act mandates that the Administrator "focus on those 'most serious hazards to man and other organisms inhabiting or consuming water.'" NRDC sued EPA in 1973 to require it to promulgate §307(a) standards. EPA then proposed standards and hearings were held in 1974. See Tr. 1145. No effluent standards have as yet been promulgated.

9. Each carbon atom has the ability to form four links, or bonds, with other atoms. One way in which six carbon atoms combine is for each to have one

Dep't Exhibit 14, p. 7 (Dr. Veith). Finally, electric current can pass through PCB's without affecting or being affected by them.

These properties have made PCB's desirable for use in capacitors and transformers. Transformers are used to change one type of current into another, and consequently dispense with the need to create generating and transmission capacity in all useful forms of current. Capacitors also save considerable electrical energy. Many motors and other electrical devices have parts that must be magnetized to operate, when such a motor draws current, only part of the current is used in rotating the shaft, the rest is required simply to maintain the magnetic field. Without a capacitor, electricity would flow back and forth from the generating station and the motor, as it does in other applications. With a capacitor hooked across a motor's terminals, however, the magnetizing current is captured, rather than sent back to the generating source, and returned to the motor during the next electrical cycle. The net saving of power by using capacitors was estimated without rebuttal as 30 percent, or, to run three air conditioners with capacitors would require the same electrical power required to run two such air conditioners without capacitors. Tr. 1127-35 (Dr. Simons).

Monsanto has sold, and GE has used, PCB's with a variety of chlorine percentages. These mixtures have been merchandized under the trade name "Aroclor," followed by a numerical designation such as Aroclor 1254. The "12" represents the 12 carbon atoms in the biphenyl ring, and the last two digits, "54" for example, indicate the average percent chlorine of the particular mixture. Aroclor 1254 ("A54"), therefore, would have an average of five chlorine atoms for each biphenyl ring, though the mixture will contain PCB's with anywhere from 3 to 7 chlorines. Dep't Exhibit No. 14, p. 6 (Dr. Veith). Until 1971, Monsanto sold large quantities of various Aroclors, especially 1242, 1254 and 1260. In 1971, the company introduced a new mixture, which it designated Aroclor 1016 ("A-1016"). Since then, A-1016 has accounted for an increasing proportion of PCB sales, until in 1975, A-1016 sales are running at a greater rate than the sales of all other Aroclors combined. GE Exhibit 19, p. 3. GE purchases of PCB's from 1965 to 1975 indicate an almost total shift from A-1242 and 1254 to A-1016, and to a minor extent A-1221. Dep't Exhibit 6.

Aroclor "1016" is a deceptive numerical designation for that compound. The chemical has 12 carbons, not 10, and contains over 41 percent chlorine, not 16. Monsanto's Manager of Product Acceptability testified that there was no scientific reason for the designation "1016," and conceded that "following the old nomenclature it should be called Aroclor 1241 plus." Tr. 1232-33. There is a difference between A-1016 and 1242, but it is not in the percent of chlorine. Rather, it is in their homolog composition. Monsanto specifications show a maximum of 4 percent of homologs with five or more chlorines in A-1016, whereas the typical A-1242 mixture contains 6 to 7 percent of such homologs. Dep't Exhibit 19(2) (Letter of W. B. Papageorge, Monsanto to Dr. David L. Stalling, U.S. Dep't of Interior, Oct. 17, 1973). The extent to which this difference has any bearing on toxicity is discussed below.

B. Presence of PCB's in the Hudson River

The Hudson River is some 305 miles long, from its source at Lake Tear of the Clouds to the George Washington Bridge at New York City. This case deals primarily with that part of the river near and downstream of the GE plants at Hudson Falls and Fort Edward. The plants are only about one mile apart.

To determine the amount and type of PCB's in a body of water, or in any other matter, is no easy task. All the evidence produced at this hearing was derived through gas chromatography, the science of separating chemicals by heating them to the points that they become vapors.¹⁰ The parties recognize that this method is not perfect. Furthermore, the fact that analyzed material is found to contain a particular PCB configuration, for example A-1242, does

not necessarily mean that the material originally discharged was A-1242, since PCB homologs have different rates of bioaccumulation and degradation. Further, chromatograms of mixtures with similar chlorine content tend strongly to resemble each other, a circumstance particularly true of A-1242 and 1016. But none of the parties objects to chromatography as a scientifically adequate way of measuring for PCB's.

The record contains substantial evidence of PCB's in the water, sediment, organisms and fish of the Hudson River. During August 1974, employees of the U.S. Environmental Protection Agency ("EPA") conducted an investigation of PCB contamination in the Hudson. They found a concentration in water at the outfall from GE's Fort Edward facility of 2800 ppb (parts per billion or ug/l) A-1016. Sediment at the same sampling station yielded 6700 ppm (parts per million or mg/kg) A-1016, indicating the absorptive capacity and constant exposure of the sediments nearest the outfall. At another station, one-half mile downstream, sediments contained 2980 ppm A-1016, or an accumulation 10⁴ times greater than the recorded outfall concentration. Dep't Exhibit 28, R. J. Nadeau & R. P. Davis, *Investigation of Polychlorinated Biphenyls in the Hudson River*, p. 9. Composites of snails found below the GE discharges were found to contain up to 45 ppm of a PCB analyzed as either A-1242 or 1016. G. D. Veith to R. J. Nadeau, Oct. 23, 1974, in Dep't Exhibit 28, appendix. Shiner minnows had 78 ppm, and a rock bass set what was then regarded as "a new record for PCB contamination of fresh water fish," with 350 ppm. *Id.* 14, 18.

The Department has for several years been aware of the presence of PCB's in New York's waters, including the Hudson. An analysis of fish in 1972 indicated a concentration of PCB's in largemouth bass of 0.66 to 14.62 ppm; in white perch of 0.38 to 15.81 ppm, and in striped bass of 3.70 to 49.63 ppm. Data compiled in 1973 on striped bass indicated that most fish tested contained more than 10 ppm PCB's, ranging up to 49.63 ppm in one sample. Fish from other waters also had high concentrations. GE Exhibit 11, appendices. Beginning on December 4, 1974, the Department's Division of Pure Waters initiated, in conjunction with EPA, a more systematic monitoring program of PCB's in the Upper Hudson River Basin, an area including GE's plants. Water and sediment samples were taken from several sampling stations. Special precautions were taken to assure quality analysis, including a series of interlaboratory comparison studies. A-1016 was found in water below the GE plants at a rate of 3 ppb during mid-winter 1974-75, indicating a river load of that PCB of about 94-97 lbs per day.¹¹ By late August 1975, when the study terminated, sampling at the same station reflected 0.06 ppb A-1016 in the river indicating a river load of less than 14 lbs per day. Sediment and core samples¹² below the GE plants showed concentrations of A-1016 ranging as high as 100 ppm, 201 ppm and 1850 ppm, as well as high concentrations of A-1221 and 1254. Dep't Exhibit 9, pp. 6-7 (R. Mt. Pleasant). This water and sediment monitoring study included no collection and analysis of fish and other organisms. On the basis of the water concentrations observed (not including the effects of sediment, runoff or other sources of PCB's), however, the report predicted that fish flesh concentrations of 3 ppm to 150 ppm of A-1016 would result. Dep't Exhibit 5, pp. 25-26. The Department's contemporaneous study of Hudson River fish overwhelmingly confirmed this anticipated result.

The Department initiated a statewide fish sampling program in August 1975 to ascertain the extent of PCB concentration. Numerous samples were taken from the Hudson River, prepared and analyzed; once again, precautions were taken for quality assurance. Fish captured at stations below the GE plants contained higher amounts of PCB's than previously found. Concentrations of

10. Chemicals introduced in a gas chromatograph will move at different rates, depending on their respective boiling points, and will separate from the chromatograph at different times. Each separation is recorded by a detector, which then draws a peak on a chart paper recorder, resulting eventually in a "gas chromatogram." The intensity of peaks on the chart recorder is proportional to the quantity of the particular chemical escaping from the chromatograph. By comparing a chromatogram of an unknown mixture with those of mixtures whose contents were known, an analyst is able to identify the types and amounts of chemicals in the unknown mixture with those of mixtures whose contents were known. See generally Dep't Exhibit 14, pp. 8-13 (Dr. Veith).

11. The river load of PCB's is the total amount of PCB's from all discharge points that enter the river daily. This figure is derived by measuring the total PCB's suspended in the water column from daily samplings, multiplying this total by the daily volume of river flow which is expressed in cubic feet/second, and then multiplying by 86,400, the number of seconds in a day.

12. Sediment samples are obtained from the top level of the river sediment. The Department set this depth at five centimeters for their program. The sediment is scooped up, with suitable equipment, labeled and later analyzed for PCB content. Dep't Exhibit 5, p. 3. Core samples are taken with equipment which can penetrate the surface of river sediment or land formation. Those core samples taken by the Department ranged from three to eleven inches in depth. The core samples were analyzed for PCB content in one inch sub-samples cut from the originally extracted core. *Id.* App. C, figure 6.

over 20 ppm A-1242/1016 were found common. A composite of ten Yellow Perch had 236.42 ppm A-1242/1016, as well as 62.88 A-1254, a total of 299.30 ppm PCB's. An American eel, captured at Stillwater, was found to contain 403.38 ppm A-1242/1016 and 155.87 ppm A-1254, totaling 559.25 ppm PCB's. Dep't Exhibit 13, *Monitoring of PCB's in Fish Taken from the Hudson River* (Oct. 1975). This figure is over 100 times greater than the temporary tolerance limit set by the FDA in 1971 for PCB's in the edible portion of fish.

GE does not challenge these data. During the hearing, the Company sought to introduce evidence gathered by Ecological Analysts, Inc., a firm that engages for profit in preparing testimony for corporations in environmental litigation. Tr. 1426-1427. The evidence gathered was analyzed by the Woodson-Tenent Laboratories of Memphis, Tennessee, and some initial results were placed in the record through the testimony of Dr. Gerald J. Lauer, Vice President of Ecological Analysts, Inc. These results showed in 13 fish samples, several of which were taken below the GE plants, not a single sample with over 5 ppm PCB's in the edible flesh. After cross-examination, it became apparent that these data were unreliable. GE ultimately terminated its effort to introduce the material and agreed to request the laboratory involved to prepare a complete analysis of all its Hudson River samples.¹³ The new findings, based in part upon reanalysis of the same samples earlier analyzed, are consistent with the Department's conclusions. Several fish had concentrations of A-1016/1242 over 100 ppm in their edible flesh. Concentrations in what GE termed "non-edible" tissue ranged as high as 1178 ppm. NRDC Exhibit 1.

C. GE's Responsibility for PCB's in the Upper Hudson

GE "has not contested that it has been a source of certain PCB's in the Upper Hudson River in the vicinity of its discharges." GE Reply Brief, p. 11. But it claims that "the evidence does not permit... by the legal standards which exclude conjecture as a basis for penalties, a finding that the high levels of PCB's reported in these fish are attributable to Respondent's discharges." In particular, the company asserts there is "no evidence" excluding other PCB sources earlier than September 1975, "no evidence" relating downstream fish concentrations to Respondent's discharges, and "no evidence" as to when the accumulations occurred. *Id.*

The Department has the burden of proof in this proceeding. ECL 17-0905(6). The burden involved is that normally applied in civil and administrative proceedings to prove the alleged violations by a preponderance of the evidence.¹⁴ It may be that, in order to obtain some especially onerous and punitive remedy, the Department would be required to meet a higher standard of proof.¹⁵ But GE's argument that, merely because this is an enforcement proceeding,

13. During cross-examination of Dr. Lauer, NRDC requested the complete results of the sampling program conducted by Ecological Analysts, Inc. This included data from the Upper Hudson, Lower Hudson, Long Island Sound and Chesapeake Bay. GE objected on various grounds. Initially its objection was that the request was for the "furnishing of additional substantive evidence" and therefore not proper within the scope of proceedings where the government has the burden of proof. Tr. 1583. More particularly GE argued it had presented no evidence with respect to whole fish in the Upper Hudson nor any evidence "whatsoever" with respect to any type of investigation concerning PCB's in fish elsewhere. Tr. 1593. GE also claimed the material was privileged, even though it had originally sought to introduce the results of the investigation.

The Hearing Officer ruled that the material requested for Chesapeake Bay and Long Island Sound samples was outside the scope of the issues raised by the complaint, but directed GE to produce all evidence relating to fish in the Hudson River. Tr. 1660-61. Respondent requested a 48-hour stay of the order to allow "a determination as to whether a review of what amounts to a subpoena order should be taken at this time." A stay was granted. Tr. 1664, but on the following day GE withdrew its objections.

14. McCormick, *Evidence* §§339, 355 (1972). The authorities cited by GE for a more exacting burden are inapposite. For example, Beckett v. Pfaff, 157 N.Y.S. 2d 247 (1st Dep't 1916), indicates that statutes "penal in nature" require stricter proof, but it dealt with a statute that punished its violation with fines and imprisonment. Professor Jaffe's article likewise discusses cases where serious, personal consequences are imposed, such as deportation of long-time resident aliens. L. Jaffe, *Administrative Law: Burden of Proof and Scope of Review*, 79 Harv. L. Rev. 914, 919 (1966).

15. The test for a penal statute in New York is whether the remedy chosen is "impressed for punishment or for redress of injury." *Sicilo v. Prudential Savings Bank of Bklyn.*, 5 N.Y.2d 254, 258, 184 N.Y.S.2d 100, 103 (1959). Even a recovery that exceeds actual loss may not amount to a penal sanction. But the courts have held that an arbitrary exaction, unrelated to actual loss, is a penal sanction. *E.g., Verona Central Cheese Co. v. Muraugh*, 50 N.Y.2d 314 (1972). These standards make clear that the remedies sought against GE are non-penal. The only violation charged that could justify any sanction that could be characterized as penal is ECL 11-0503, discussed below, which has been dismissed.

the Department has to prove its case on the merits by clear and convincing evidence, is untenable.

In any event, the Department has in fact carried its burden on this issue beyond any reasonable doubt. The evidence that GE is responsible for the high concentrations of PCB's in the Upper Hudson's water, sediment, organisms and fish is overwhelming. To begin with, GE has until recently been discharging very large amounts of PCB's into the Upper Hudson. GE applied for a discharge permit on December 18, 1972, stating that it was directly discharging an average of 30 pounds per day of "chlorinated hydrocarbons" (measured using the test for PCB's), and a maximum of 47.6 pounds per day from its two plants. Dep't Exhibit 4, p. 3. GE's Manager of Environmental Operations, Dr. Simons, testified that these figures represented what he believed to have been the actual discharge from the plants. Tr. 1166. At the time, GE was purchasing about 7,900,000 pounds of PCB's each year from Monsanto. Dep't Exhibit 6. Purchases of even greater quantities had occurred at least as far back as 1966. Since the record indicates that GE's discharges have decreased rather than increased in recent years, it is reasonable to assume that it discharged PCB's in 30 lb. per day quantities throughout the 1966-1972 period.¹⁶ In any event, GE obtained the permit it sought, and makes no contention that it significantly altered its discharge levels until early 1975.¹⁷

In March 1975, Clark, Dietz Associates, an engineering firm retained by GE, performed a wastewater monitoring program at GE's plants, and reported total average daily discharge levels of between 5.06 and 7.81 lbs. of PCB's. Dep't Exhibit 8. During late August 1975, both GE and the Department (with EPA) measured the discharge levels, and found a further reduction: GE's data indicate an average discharge from the two most important discharge sources of 5.54 lbs., a figure that includes days in which exceptionally high discharges were recorded; the Department's data are roughly equivalent. Dep't Exhibit 7B(15); Dep't Exhibits 4, 29, 31 and 32. These findings show substantial reductions in PCB discharges as compared to earlier periods. Yet, the amounts are still significant especially when considered as supplementing the large quantities already released, and the totals probably understate total discharges because some sources were not measured, and discharges caused by run-off and percolation were not measured.¹⁸

After this action was commenced, GE made further measurements of its discharges. These indicate a combined average of 3.46 lbs. per day directly discharged from its two plants, through the two main discharges (discounting an unusually high discharge of 116 lbs. on September 13-14; Tr. 1245-48). In addition, however, data collected by GE indicate average discharges of 1.42 pounds PCB's per day into the Hudson Falls Village Sewage Treatment Plant, which in turn discharges into the Hudson. The total daily discharge during the hearing in this case, then, is roughly 4.88 lbs.

Not only has GE been shown to have discharged large quantities of PCB's into the Hudson over long periods of time, the Department has established that other sources contribute negligible amounts of PCB's to the river. During September 1975, as part of its water and sediment study, the Department tested effluent from 28 municipal and industrial discharges in the Upper Hudson. The Hudson Falls Village Treatment Plant showed a discharge of 2.45 lbs. PCB's per day, which has been shown to be attributable to GE. Four other sources had amounts of 0.005, 0.001, 0.22 and 0.095 lbs. per day (of which the 0.22 figure may be overstated, see Tr. 355-56). All the remaining sources indicate no recordable amounts of PCB's. In striking contrast is the study's finding that GE effluent for a virtually contemporaneous period averages a gross discharge

16. 30 lbs. per day would mean over 84,000 lbs. between 1966 and 1973.

17. On February 7, 1974, a GE engineer estimated then current average PCB discharges at 21.4 lbs. per day, and maximum discharge at 65 lbs. per day. Dep't Exhibit 16. A. Pozzlesky to Dr. Simons. On May 8, 1974, Dr. Simons testified under oath at EPA hearings on Proposed Standards for Toxic Substances that GE was discharging 25-30 lbs. per day PCB's from its two plants. Tr. 1165-66. Monsanto sampled the two largest of several discharges at GE's plants on December 12, 1974, and reported a combined total of 18.2 lbs. per day. Dep't Exhibit 7(b)(12).

18. See Dep't Exhibit 4, p. 8, Dep't Exhibit 7A and 7B, Tr. 1279-83. A GE witness testified that run-off discharge through sources other than those monitored was unlikely, but this was based on a cursory visual examination, and was not at all addressed to possible discharge by percolation. See Tr. 1242. Compare Tr. 334-35; 1310-11, 1316-17, and the strong evidence that PCB's in the soil around GE's plants find their way into the river during h. *e.g.*, Dep't Exhibit 5, Table 6.

of 2.12 lbs. per day of A-1016. GE protests that this study shows only that it was the major source of PCB's during August and September 1975. But it makes no effort to prove that other sources of PCB's exist than those studied by the Department, or that those companies that use PCB's used them in greater quantities in past years.

The strongest evidence of GE's responsibility for existing PCB levels is in the contrasting results obtained, in all the studies in evidence, of PCB concentrations upstream as opposed to downstream of GE plants. Thus, in the EPA study during August 1974, a reading of 2800 ppb PCB's in water was taken at the junction of GE's Fort Edward Plant's discharge and the Hudson River. The concentration at a station one-half mile above Bakers Falls, upstream of the GE plants, was less than 1 ppb. The concentrations at stations located .25, .5 and .75 miles downstream of the Fort Edward discharge were 2.2, 3 and less than 1 ppb respectively. Dep't Exhibit 28, p. 17. The Department's water and sediment monitoring project, from December 1974 to August 1975, developed similar results. Water concentrations of PCB's upstream of the GE plants were uniformly (with one anomalous exception, see Dep't Exhibit 5, pp 17-18) less than 0.1 ppb; below the plants, concentrations declined from 3 ppb to 1.5 ppb, but were much higher throughout than upstream concentrations. *Id.* Appendix C, Table 1.

Sediment samples taken above the GE plants also had concentrations of PCB's that were much lower than those below the plants. At the nine upstream stations, PCB's were found in quantities below 3 ppm with one exception at the Glens Falls landfill, where 14.9 ppm A-1221 was recorded. Sediment taken 1500 feet above GE Hudson Falls plant contained 0.6, 2.0 and 2.2 ppm A-1016, 1221 and 1254 respectively. Some of these upstream concentrations cannot be regarded as insignificant, in that they should cause concern for fish and other living things in the river. But the five downstream stations revealed PCB's in much higher quantities, that render the upstream concentrations insignificant by comparison. A sample taken in the vicinity of the Fort Edward discharge contained 100, 6 and 8 ppm A-1016, 1221 and 1254 respectively; a sample from near the Thompson Island Dam, about 13 miles downstream of the Fort Edward discharge, revealed 1850, 1720 and 1372 ppm of the same Aroclors. Dep't Exhibit 9, pp. 5-8 (R. Mt. Pleasant); Dep't Exhibit 5, Appendix C, Figure 6.

Plentiful evidence gathered concerning PCB concentrations in fish also shows that GE's plants are the only important sources of PCB contamination in that area. The August 1974 EPA study showed PCB concentration above the GE plants (but below the Hudson Falls sewage treatment plant) of 17.0, 7.0 and 1.9 ppm PCB's (A-1016/1242, 1248 and 1254) in samples of Yellow Perch, Shiner Minnows and snails respectively. Stations below the GE plants turned up the rock bass earlier referred to with 350 ppm A-1242/1016, as well as Shiner Minnow and two snail samples of 78, 45 and 27 ppm respectively. Dep't Exhibit 28, p. 18. The Department's study during 1975 revealed that, in 29 samples taken from upstream stations (above the Hudson Falls sewage plant), all contained less than 1 ppm PCB's. In contrast, the average concentration for the numerous fish sampled at Fort Edward was 176.83 ppm PCB's for the whole fish, and other, very high concentrations were found at most downstream stations. Dep't Exhibit 12, appendix B-1. An experiment was conducted during October 1975 by the Department in which fish in "live cars" were placed upstream and downstream of the GE plants. After 14 days of exposure, the fish upstream accumulated at most only trace amounts of A-1016 (less than 0.1 ppm) while those downstream accumulated from 1.66 to 376 ppm A-1016. Dep't Exhibit 12 (J. Spagnoli). GE's data are no less supportive in proving its responsibility. All fish taken at upstream stations contained less than 5 ppm in both their edible flesh and "non-edible" parts; fish taken below the GE plants had an average PCB content in their edible flesh of 94.66 ppm, with much higher amounts in their "non-edible" portions (ranging to 658 ppm in one Common Sucker sample). See NRDC Exhibit 1 and Dep't Exhibit 52.

By any reasonable standard, then, GE has been shown to be responsible for the PCB contamination of the Upper Hudson. If others have contributed to that contamination, their contributions are inconsequential by comparison, and they in any case might also be held legally answerable for their actions. The Department cannot be required to prove that specific PCB molecules, discharged by GE, reached specific fish or parts of the river. Compare GE Reily

Brief, p. 12. Given the natural flow of rivers, and the nature of the issues, the evidence of GE's responsibility is more than sufficient.

II. Legal Consequences of GE's PCB Discharges

A. The Violations Charged

The State of New York, and our federal government, have drastically revised common law doctrine that allowed pollution of rivers subject only to the rights of other users and the limited notion of public nuisance. As early as 1881, New York prohibited the discharge of any "noxious, offensive or poisonous substance into any public waters. . . ." Penal Code, §390 (1881). In 1892, the prohibition was expanded to private waters, but limited to "quantities destructive of the life of, or disturbing the habits of fish inhabiting the same." Laws of 1892, c. 488, §100. The "habits" apparently in mind during that more decorous time became clear in 1912, when the phrase was changed to "propagation of fish." L. 1912, c. 318, §247. In addition, a 1903 statute prohibited discharges injurious to human health, aiming particularly at sewage control. Public Health Law, §76 (McKinney 1943).

Major reform was initiated when the legislature in 1946, by concurrent resolution, established a Special Committee of Pollution Abatement. That well-rounded and distinguished group¹⁹ undertook field work and conferences throughout the state, and issued an interim report noting that Americans have been "fouling their own nests," and that public health is the state's "greatest asset" which the legislature should not permit to be endangered or jeopardized. Leg. Doc. No. 59, pp. 22, 25 (1947). The committee considered existing laws inadequate. The provision aimed at protecting fish, by then §213 of the Conservation Law, was too limited, since it required proof that certain specific substances, discharged by a specific person, actually injured fish life. The sewage control statute was found inadequate because actual injury to health had to be proved, and industrial wastes seldom directly injured public health. The committee also reminded the legislature that proposed federal legislation would preempt state control unless New York assumed its own pollution abatement responsibilities. *Id.* 78.

After further study, and with recommendations from the State Conservation and Health Departments, the committee filed a second report containing a proposed Water Pollution Control Act. The bill had a statement of overall public policy calling for use of the state's water resources in "the best interests of the people," and a water classification system for determining the best public usage. Industrial wastes were "inevitable," the committee concluded, but they must be conditioned to avoid deterioration of public waters "for the other purposes for which they are utilized. . . ." Leg. Doc. No. 50, p. 17 (1948).

Hearings followed. Industry spokesmen expressed a preference for dealing with state authorities rather than federal, but they wanted the legislature to determine the specifics of water classification rather than an administrator. An engineering consultant to the committee, Morris M. Cohn, defended the proposed system as realistic and flexible. Pure surface waters is only an ideal, he wrote, which if achieved might result in "no industries or municipalities around to enjoy the beauties of such streams." He therefore saw "pollution" in relative terms, as a "condition which contravenes reasonable standards of quality which have been set up with full consideration of the many (appropriate) factors. . . ." Resume of Hearing on Proposed Pollution Abatement Legislation.

19. Members: Assemblyman Harold C. Ostertag, Chairman, Committee on Interstate Cooperation; Senator Chauncey B. Hammond, Chairman, Senator Floyd E. Anderson, Vice Chairman, Assemblyman Wheeler Milmo, Secretary, Senator Walter J. Mahoney, Assemblyman Elisha T. Barrett, Assemblyman George W. Foy, Assemblyman John S. Thompson, Attorney General Nathanal L. Goldstein, C. Chester Dumond, Commissioner of Agriculture and Markets, Alger B. Chapman, Commissioner of Taxation and Finance. In addition, there were several advisory members from a variety of public and private organizations. See Leg. Doc. No. 51, p. 11 (1948).

20. He explained further:

"Pollution" is not a hard and fast characteristic. It is not like black and white. A sensible definition of pollution takes into consideration what is being polluted. It recognizes that what is pollution at one point of a stream may not be pollution at another point, or certainly not on another stream.

Is it not sensible to define "pollution" as a condition which contravenes reasonable standards of quality which have been set up with full consideration of the many factors described above? . . . If the standards are sensibly established, the criteria of pollution are sensibly as two plus two makes four.

pp. 13-15 (Albany, N.Y. Aug. 11, 1948) (Legislative Reference of the New York State Library, Albany, New York).

The legislation was adopted. It established a pattern that is with us still: a system with the avowed purpose of protecting the environment, but through a methodology that explicitly accepts various degrees of contamination. The act was consolidated with others in 1960, and entitled the Environmental Law. L. 1970, c. 140.

In its present form, the ECL's declaration of policy is "to conserve, improve and protect" New York's natural resources and environment, and to "control" water and other pollution "to enhance the health, safety and welfare of the people of the state and their overall economic and social well being." ECL 1-0101(1). Coordination and cooperation at all levels of government are called for, and the state is to foster and maintain conditions under which men can thrive in harmony and achieve "social, economic and technological progress" by assuring healthful and pleasing surroundings; guaranteeing the "widest range of beneficial uses of the environment ... without risk to health or safety, unnecessary degradation or other undesirable or unintended consequences;" and "promoting patterns of development and technology which minimize adverse impact on the environment. ..." ECL 1-0101(2) & (3). The message conveyed is hardly one-sided. It is basically an expression of concern for the environment, but mixed with strong concern for economic well being and maximum utilization.

At the heart of the ECL's provisions relating to water pollution is the water classification system adopted in 1949, and revised in various respects from time to time. The ECL recognizes, as the engineer Cohen and his committee would have had it recognize, "that due to variable factors, no single standard of quality and purity of the waters is applicable to all waters of the state or to different segments of the same waters." ECL 17-0301(1). To obtain the law's objectives, therefore, the Department is instructed to group designated waters into classes, after notice and hearing. ECL 17-0301(2). Then, after proper study and further hearings, the Department is to "adopt and assign (necessary) standards of quality and purity for each such classification. ..." ECL 17-0301(4). Acting pursuant to this mandate, the Department classified the waters at and immediately below Fort Edward and Hudson Falls as "Class D" waters further downstream are classified "A" and "B". Class D waters must be "suitable for fish survival," though they need not "support the propagation of fish;" among their best usages is "secondary contact recreation," which is defined to include fishing, but only minimal contact and "improbable" ingestion. 6 NYCRR 701. Since 1966, the "best usage" of Class A and B waters also includes fishing. Finally, an overall standard, applicable to waters classified A through D, is that they shall not contain "toxic wastes and deleterious substances ... in amounts that will be injurious to fishlife or which in any manner shall adversely affect the flavor, color or odor thereof, or impair the waters for any best usage" assigned. 6 NYCRR 701.5.

Compliance with these standards is mandated by ECL 17-0501, which GE has been charged with violating. That section makes it unlawful to discharge, "directly or indirectly," any matter that shall "cause or contribute" to a condition in contravention of the water quality standards established pursuant to ECL 17-0301. The issues posed by this provision, therefore, are whether PCB's in the quantities discharged by GE have "caused or contributed" to a breach of standards that (1) prohibit the discharge of "toxic wastes" or "deleterious substances" in amounts "injurious to fish life" or (2) "impair the waters for any best usage," in particular fishing.

The federal government long ago moved to regulate water pollution through effluent limitations, rather than merely the setting of stream standards.²¹ In 1972, the Federal Water Pollution Control Act (FWPCA) was amended to give the states primary responsibility for pollution abatement, but only if they adopted a program based both on stream standards and effluent limitations. 33 U.S.C. §§1251 *et seq.* New York adopted a State Pollution Discharge Elimination System (SPDES), essentially to avoid a federal takeover. See memo to Governor from Law Department, Senate 6394-A (June 21, 1973); *id.* (May 31, 1973) (H. L. Diamond).

Resume of Hearing on Proposed Pollution Abatement Legislation at 14-15 (Aug. 11, 1948).

21 For a history of federal water pollution regulation see I F. Grad, *Treatise on Environmental Law* §303 (1975).

The resulting legal structure requires any would-be discharger of pollutants to seek a certification from the state in which the waters are involved are located. 33 U.S.C. §1341. After state approval, the applicant must obtain a federal discharge permit for the activities permitted by the state. Discharging without a state permit violates ECL 17-0505; and increasing or altering a permitted discharge violates ECL 17-0507. In addition, ECL 17-0511, the second statute under which GE has been charged, prohibits any industrial discharge from outlets or point sources "unless such use is in compliance with all standards, criteria, limitations, rules and regulations promulgated or applied by the department pursuant to this article." The article involved, 17 ECL, includes provisions that make unlawful violations of both the permit and water-classification systems.

B. Effect of SPDES and NPDES Permit

GE applied for a federal permit to discharge into the Hudson River from its plants at Hudson Falls and Fort Edward as early as November 22, 1971. See Refuse Act, §13, 33 U.S.C. §407. After the FWPCA amendments of 1972, GE submitted a revised application to EPA on January 18, 1973. On August 23, 1973, the Department received GE's application under its new SPDES system. The application indicated that a daily average of 30 pounds of "chlorinated hydrocarbons" were being discharged, and in a footnote explained that the "test for the determination of the pounds or concentration from which the pounds were derived, was determined by analysis for PCB's." Tr. 401. This was an unnecessarily obtuse way of indicating its PCB discharges, since GE had been told by Monsanto on July 1, 1970, that "polychlorinated biphenyls ... may be an environmental contaminant," and advised to use its best efforts to prevent them from entering the environment. Tr. 1171 (Dr. E. L. Simons). Nevertheless, the Department does not explicitly contend that it was misled. Department personnel appear to have been well aware by August 1973 of GE's PCB discharges, having already conducted studies of their effects. See GE Exhibit 11.

The Department acted quickly on GE's application. On September 11, 1973, the Department's Acting Assistant Director, Bureau of Industrial Wastes, wrote to an official in the Regional Office of EPA stating that the Department had reviewed GE's permit application, and that "certification will be recommended since the present discharge complies with water quality standards." The letter goes on to specify areas in which the application should be tightened, but does not mention PCB's or "chlorinated hydrocarbons." GE Exhibit 2. On November 13, 1973, the Department certified that no federal effluent limitations or standards under §§301(6), 302, 306 and 307 of the FWPCA were applicable to GE's proposed discharges. It stated, however, that "the classification and standards governing the quality and purity of waters of New York State" are applicable, and set forth certain specific and some general limitation to assure compliance. Among the specifics, for example, was a limit of 75 lbs. per day of Kjeldahl nitrogen, nothing was said specifically concerning PCB's. A general qualification, however, is clearly pertinent. The certification limited effluent of "toxic wastes" or "deleterious substances" in the following manner: "None alone or in combination with other substances or wastes in sufficient amounts or at such temperatures as to prevent fish survival or impair the waters for agricultural purposes or any other best usage as determined for the specific waters which are assigned to this class." The certification then went on to limit discharges "at all times so as to be in full compliance with all applicable requirements of sections 701, 702 and 704 of title 6," NYCRR, the regulations establishing the classification and standards governing New York waters. Dep't Exhibit 2.

The EPA regional office issued a draft NPDES permit to GE on March 22, 1974, and invited comment. The draft proposed authorizing a daily average discharge of "chlorinated hydrocarbons" from the Hudson Falls plant (Discharge 002) of 10 pounds, and from the Fort Edward Plant (Discharge 004) of 20 pounds. It also proposed that chlorinated hydrocarbon discharge be reduced to zero within 21 months of the permit's issuance. GE Exhibit 3, pp. 4-7. The Department filed its comments on April 5, 1974, and as GE asserts did not mention the "chlorinated hydrocarbon" discharges. On the other hand, the Department specifically requested inclusion of the general condition it had placed in its certification requiring compliance with water quality standards. GE Exhibit 3 - 3.

EPA issued an NPDES permit to GE on December 20, 1974. Though it contained no provision specifically requiring compliance with state water quality standards, it did comply in substance (as did the temporary permit) with the requirement that conditions of state certification must appear in the federal permit. FWPCA, §401(d), 33 U.S.C. §1341(d). In paragraph 6, it warns that its issuance does not "authorize... any infringement of Federal, State or local laws or regulations..." And before detailing the applicable limitations in paragraph 9, it recites: "Nothing in this permit shall be deemed to preclude the institution of any legal action nor relieve the permittee from any responsibilities, liabilities or penalties to which the permittee is or may be subject... under any other Federal or state law or regulations." The permit authorized "chlorinated hydrocarbon" discharges of 10 and 20 lbs. from outfall numbers 002 and 004 respectively. At the same time it ordered that discharges from the same points of "Polychlorinated Biphenyls" be limited to 4.54 and 95.3 grams per day (or 3.52 oz.) by May 31, 1977. GE has appealed this limitation, though it represented at the hearing in this case that it intends to withdraw its appeal and will meet this standard by December 31, 1976.

GE claims that it has complied with its state certification and federal permit. Consequently, it asserts, it cannot be found to have violated any statute for its discharges until the permit is duly modified in accordance with the applicable regulations. "If the SPDES permit program is to be meaningful and effective... it cannot, by its very nature as a permit system, allow the imposition of penalties for permitted discharges. It is axiomatic that penalties may not be imposed by a governmental agency for acts permitted by law." GE Brief, p. 21. GE notes that the Department was fully aware of GE's PCB discharges, and thus suggests that it implicitly found them lawful.

GE's argument has more than superficial appeal. The effluent limitation system is intended and well designed to serve as a supplement to the water classification system. Both the state and federal governments are presented, when a discharge application is filed, with an opportunity to regulate so as to insure that water quality objectives are attained. Thus, when GE filed its application the Department should have been made aware that GE proposed to continue discharging PCB's at an average rate of 30 lbs. daily. A relatively simple calculation at that point would have indicated that such a discharge rate was destined to cause the present situation. Had this anticipated result been unacceptable, the Department could then have denied or conditioned its certification. From the viewpoint of the regulated, as well as of the public, a system that mandated such inquiry—and, incidentally, provided the resources to fulfill the mandate—would make much more sense than one that leaves administrators with discretion to approve discharges certain to undermine legislative objectives.

The first answer to GE's contention, however, is that neither the federal nor the state government has established such a system. Administrators are accorded power to include in the very certifications they issue conditions that might in effect preclude the activities apparently permitted. This is not because the legislature intended to allow administrators to avoid making difficult decisions, though that may sometimes be a consequence. Flexibility is preserved because of the numerous ways in which administrators may be unable, despite the best intentions, to regulate effectively through the effluent limitations system. Inadequate information, expertise, personnel or knowledge about the particular discharge, are only some of the reasons a permit might be issued authorizing activity that would contravene some other part of the state or federal government's regulatory scheme. The system seems clearly to place on the would-be discharger, whose influence with the agency might itself cause or contribute to regulatory insufficiency, the burden of insuring that the discharge violates no other federal, state or local prohibitions. It would defeat the legislature's objectives to impose the costs of such failures on the public rather than upon the discharging party.

The FWPCA informs us explicitly of another reason why GE cannot treat its NPDES or SPDES as part of a grant of immunity from other proscriptions. The act places great pressure on the states to adopt an effluent limitation system, but at the same time it guaranteed that the states would be free to impose additional limitations, including those implicit in a water classification approach. Section 401 of the federal act requires that a state's conditions to its own permit become a part of the federal permit because Congress

intended to allow states to include their other prohibitions in the general, undefined way that New York did so in this case. The Senate Report explains:

The provision (401) makes clear that any water quality requirements established under State law, more stringent than those established under this Act, also shall through certification become conditions on any Federal license or permit. The purpose of the certification mechanism provided in this law is to assure that Federal licensing or permitting agencies cannot override State water quality requirements.

Senate Rep. No. 92-414, 92d Cong., 1st Sess. 69 (1971). This provision, moreover, was only part of an overall philosophy favoring a local option to go beyond the federal program's limitations, as §510, 33 U.S.C. §1370, makes abundantly clear:

Except as expressly provided in this chapter, nothing in this chapter shall (1) preclude or deny the right of any state... to adopt or enforce (a) any standard or limitation respecting discharges or pollutants, or (b) any requirement respecting control or abatement of pollution; except that if an effluent limitation, or other limitation... or standard of performance is in effect under this chapter, such State... may not adopt or enforce any effluent limitation, or other limitation... which is less stringent than the effluent limitation or other limitation... under this chapter; or (2) be construed as impairing or in any manner affecting any right or jurisdiction of the States with respect to the waters (including boundary waters) of such States.

The only New York case on this question clearly supports the view that a permit may be conditioned in the manner that GE's is conditioned, and that these conditions become part of the permittee's obligations despite the permit's other terms. In *Begane v. City of Lackawanna*, 80 Misc.2d 816, 365 N.Y.S.2d 107 (Sup. Ct. 1974), *aff'd without opinion*, ___ N.Y.S.2d ___, (4th Dep't. 1975), the commissioner of Environmental Conservation sought an injunction and penalties for defendant's discharging sanitary sewage into a waterway without giving it "effective secondary treatment" as required by ECL 17-0509. The defendant City moved to dismiss the complaint, asserting that it had, and was complying with, an NPDES permit (which, of course, was issued only after state certification). The permit, however, contained the following language, identical in all material respects to paragraph 9 of GE's NPDES permit:

Nothing in this permit shall be construed to preclude the institution of any legal action nor relieve the permittee from any responsibilities, liabilities or penalties established pursuant to any applicable State law or regulation under authority preserved by Section 510 of the Act.

The court rejected the City's argument. "The requirements of obtaining a (NPDES-SPDES) permit (Environmental Conservation Law Sections 17-0701 and 17-0803)," said the court, "and the prohibition against discharging sewage which has not been given effective secondary treatment (Environmental Conservation Law Section 17-0509) are separate and distinct." Indeed, even had the permit contained no language generally incorporating other state prohibitions, the court suggests it would have reached the same result: "regardless of whether it has a permit it cannot discharge sewage which had not been given effective secondary treatment." The same reasoning applies to GE's obligations under ECL 17-0501, 17-0511 and 17-0503.²²

C. The Toxicity of PCB's

A question fundamental to GE's liability under all the violations charged is, whether PCB's are "toxic" or "deleterious" substances. The law does not permit this question to be asked in the abstract. The fact, for example, that humans have been severely harmed by certain quantities of particular PCB's proves it is toxic in the ordinary sense of the word, but not necessarily toxic in the sense used by the legislature. A person violates the law only by discharging PCB's in quantities sufficient to cause the proscribed

22. In light of this conclusion, there is no need to consider whether GE violated its NPDES permit by exceeding its limits for PCB discharges, by discharging PCB's from outlets other than those specified in the permit, or in any manner. See Dep't Reply Brief, pp. 5, 9. If such violations might in themselves constitute a violation of ECL 17-0511

effects—in this case, injury to fish or an adverse effect upon the protected usage of fishing.

The potential toxicity of substances is ascertained in terms of standards accepted in both the scientific and legal worlds. The legislature provides the following definition, which is essentially indistinguishable from the FDA standard, and from the standard propounded by GE's witness, Dr. Golberg:

"[T]oxic pollutant" means those pollutants, or combination of pollutants, including disease-causing agents, which after discharge and upon exposure, ingestion, inhalation or assimilation into any organism, either directly from the environment or indirectly through food chains, will, on the basis of information available to the Department, cause death, disease, behavioral abnormalities, cancer, genetic mutations, physical malfunctions, including malfunctions in reproduction, or physical deformations, in such organisms or their offspring.²³

If consumed in sufficient quantities by fish, animals or men, there is no doubt that PCB's can have the effects described in the ECL as "toxic." Accord. GE Reply Brief 16. Just as PCB's have qualities that make them useful in industry, they have qualities that make them hazardous in the environment. That they are non-biodegradable, for example, may be useful in capacitors, but it also makes them persistent. They are virtually insoluble in water, and their effects in the Hudson are felt long after their discharge into the river. PCB's also bioaccumulate. They are highly soluble in lipids (fats and oils), and therefore are in effect attracted to organisms relatively high in lipid content. They tend to remain suspended in water, attached to plankton and other organisms, or they fall into the river sediment. In either case, they pass into snails and other aquatic organisms, including fish, and become stored in their bodies, particularly in areas with high lipid content. The significance of bioaccumulation is that the PCB's are accumulated in fish and other high lipid organisms to points far higher than the PCB concentrations to which the organisms are exposed. Experimental results introduced at the hearing showed, for example, that Fathead Minnows accumulate A-1254 to a point 200,000 times greater than the concentrations in which they are placed. Dep't Exhibit 36, pp. 8-9. Dr. Veith estimated that the bioaccumulation factor for A-1016 and 1242 in small fish would be about 50,000. This means that, in water containing 1 ppb PCB 1016/1242, such a fish could be expected to accumulate PCB 1016/1242 to a level of about 50 ppm. Accumulation can also occur from PCB's in sediment. Dr. Veith showed that Fathead Minnows placed in a tank with PCB-free water, but with Hudson River sediment containing 166 ppm A-1016, accumulated a concentration of 109 ppm after 6 days. Dep't Exhibit 14, pp. 18-19. Aquatic organisms accumulate PCB's from sediments in direct proportion to the PCB concentrations. Dep't Exhibit 26(1), p. 9 (Hansen).

Bioaccumulation occurs rapidly in fish, and then levels off. The evidence shows that when fish are exposed to a constant concentration of PCB's, they accumulate the chemical for about 20 to 30 days, and then concentration reaches a "steady state." The steady-state concentration is directly proportional to the water concentration; if the concentration is increased, accumulation resumes. See Tr. 599. The evidence indicates that the lesser chlorinated PCB homologs bioconcentrate to a lower degree than the higher chlorinated homologs. This would mean, for example, that A-1254 would accumulate to a higher point than A-1016, making the former more toxic in general. The difference in steady-state levels among the Aroclors, however, is insignificant relative to the high levels of accumulation in them all. Dep't Exhibit 14, p. 16. Also, lower chlorinated homologs tend to accumulate faster than higher ones, because of their relatively greater solubility. Here again, however, the differences are relatively insignificant (they all accumulate quickly) and would matter only in special circumstances.

23. 17-0105(19) "Pollutant" is defined to include any "chemical" or "industrial waste." ECL 17-0105(17).

Dr. Kolbye testified that he could perceive no difference between the ECL definition and that applied to the FDA. Tr. 1030.

Dr. Golberg said (Tr. 1768):

We generally consider the toxicity to be a manifestation of the injurious effect of a chemical or physical agent on a living organism as manifested in a variety of possible ways, such as structurally, functionally or in regard to the response of the organs, for instance, behavior

Fish also accumulate PCB's through the food chain, by means of biomagnification. At each level of the food chain, organisms absorb the collected accumulations of PCB's in the lower-level organisms. Fish are relatively high on the chain. Humans are higher. Consequently, PCB levels in fish predicted on the basis of concentration in water alone will tend to understate the actual level of PCB's because of accumulation from sediment and by biomagnification from the food chain. Little wonder that fish were described by the Chief of the Department's Bureau of Environmental Protection as a "sink" for PCB's. Tr. 579 (J. Spagnoli).

Due to these characteristics, PCB's have been observed to cause toxic effects in fish food, a variety of estuarine organisms, fresh water fish, birds, rats, mink, monkeys and humans. In one series of tests, for example, population growth of a ciliate protozoan was reduced significantly by exposure to 1 ppb A-1254, growth in oysters was significantly reduced after 25 weeks of exposure to 5 ppb; various estuarine shrimp were killed by exposure to 0.9, 1.4 and 4.0 ppb; a dose of 1.0 ppb was lethal after two weeks to Longnose Killifish and 5.0 ppb was lethal to Pinfish and Spot. Researchers observed structural changes in tissues of the oysters, fish and shrimp exposed to A-1254, including abnormal invasion of Leukocytes (white blood cells), atrophy, abnormal cell distribution, and the formation of crystalloids in the nuclei of shrimp digestive glands.²⁴ PCB's were found in other experiments to be lethal in low concentrations to the water flea, scud and midge, all important fish foods, as well as to the Fathead Minnow and Flagfish; fish fry and eggs were found particularly susceptible.²⁵

Time of exposure is an especially important factor in ascertaining the effects of PCB's. The LC-50 value for A-1242 (the concentration that will kill 50 percent of the test organisms) was calculated to be 15 ppb for newly hatched minnows in a 96-hour test, but after eight months all the fish were killed at this level. Dep't Exhibit 37(2), p. 566. Rainbow trout showed a decline in LC-50 values from 156 ppb A-1254 at 5 days, to 8 ppb at 10 days. Dep't Exhibit 19(5), p. 162, table 4. In an acute (short-term) test, A-1254 was shown to be one-tenth as toxic as DDT to shrimp, in that 100 ppb Aroclor 1254 was necessary to achieve the same lethal effect (100 percent) as 10 ppb DDT. But in a chronic (longer-term), flowing water test, only 0.94 ppb A-1254 was necessary to kill 51 percent of all juvenile shrimp within 15 days, and 3.5 ppb A-1254 killed 50 percent adult shrimp in the same period. Dep't Exhibit 24(5). A-1254 registered an LC-50 on Rainbow Trout of 156 ppb in 5 days; in just five more days, the LC-50 was 8 ppb.²⁶ Stress is another important variable. The toxic effects of PCB's seem consistently greater when the contaminated organism is under some form of stress, such as a change in water temperature or in the process of reproducing.²⁷

Studies of the effects of PCB's on rats indicate that, at various levels, they affect reproduction, cause enlargement of the liver, interfere with normal metabolism, create growths, some malignant, and can be lethal.²⁸ Mink are especially sensitive animals, and ex-

24. D. R. Nimmo *et al.*, "Toxicity of Aroclor 1254 and its Physiological Activity in Several Estuarine Organisms," 3 Archives of Env. Contamination and Toxicology 22 (1975). Dep't Exhibit 24(2). The authors speculate that the crystalloid inclusions were possibly produced by a virus, because of PCB stress, and refer to another study indicating that "PCB enhanced the pathogenic effects of hepatitis virus in ducks." *Id.* 38, see M. Friend & D. O. Trainer, *Polychlorinated biphenyl: Interaction with duck hepatitis virus*, 17 Science 1314 (1970). A table of the effects of PCB's on various salt water organisms, as reflected in the literature, prepared by Dr. David J. Hansen, is in Dep't Exhibit 26(1).

25. A. V. Nebeker & F. A. Pufes, *Effect of Polychlorinated Biphenyls (PCB's) on Survival and Reproduction of Daphnia Gammareus, and Tanytarsus*, 103 Transactions of the Am. Fisheries Soc. 722 (1974); A. V. Nebeker *et al.*, *Effect of Polychlorinated Biphenyl Compounds on Survival and Reproduction of the Fathead Minnow and Flagfish*, 103 Transactions of the Am. Fisheries Soc. 562 (1974). Dep't Exhibit 37.

26. D. L. Stalling & F. L. Mayer, Jr., *Toxicities of PCB's to Fish and Environmental Residues*, Environmental Health Perspectives, p. 162 (Apr. 1972). Dep't Exhibit 37(8). The authors found bioconcentration factors in fish of over 40,000 times exposure levels, and said that adverse effects on reproduction may occur at 5 ppb or less. *Id.* 163.

27. Dep't Exhibit 37(2), p. 567 (flagfish exposed 40 days to PCB's died when water temperature dropped 4°C); Dep't Exhibit 37(9), p. 13 (flow dietary concentrations of PCB's affect thyroid activity); Dep't Exhibit 25, p. 5 and Exhibit 26(14), p. 428 (shrimp exposed to sub-lethal quantities of PCB's died when water salinity gradually decreased over 8 hour period); Dep't Exhibit 5, p. 194 (juvenile shrimp exposed to PCB's died after molting).

28. Dr. Renate Kimbrough, who has conducted or participated in much o-

periments demonstrate that a diet of a 30 ppm proportional mixture of A-1241, 1248 and 1254 is lethal, and levels of 3.57 ppm and 0.164 ppm A-1254 fed in the meat of cows placed on PCB diets were determined respectively to be lethal and embryotoxic at the 100 percent level.²⁹

The most dramatic—and tragic—known evidence of PCB toxicity is the so-called Yusho ("oil disease") incident. In 1968, an epidemic of a skin disease was reported in parts of Japan. Investigation proved it related to the consumption of cooking oil contaminated with Kanechlor 400 (equivalent to Aroclor 1248). A total of 1,291 reported cases have been counted as of April 1975. The affected individuals consumed an average of 2 grams of the PCB, with the minimum dose estimated as 0.5 grams. The victims had a variety of symptoms, especially acne-like eruptions, pigmentation of skin, increased eye discharge, swelling of upper eyelids and weakness. Nine of ten babies delivered by pregnant victims had unusually grayish, dark-brown stained skin; most had increased eye discharge and less-than-average weight, indicating placental transport. Many of the symptoms have continued to the present in many victims, indicating the persistence of PCB's in the human body. A report of 22 deaths of victims as of September 13, 1973 indicates that 9 "were caused by malignant neoplasms, suggesting a possible excess of deaths from cancer," though more information is needed to test that hypothesis.³⁰

The Yusho incident triggered further investigations of PCB's, including some involving Rhesus monkeys. An initial study, in which monkeys were fed 300 ppm A-1248, led within three to four weeks to their exhibiting symptoms similar to those of Yusho victims: severe acne, swelling of eyelids and loss of hair. Many developed ulcers, and all died within three months. The same results occurred when monkeys were fed 100 ppm A-1248. A further study tested the effects of a diet of 25 ppm, and within one month the primates exhibited the symptoms of PCB intoxication. After two months they were removed from the diet to avoid unnecessary death, one of six died of PCB poisoning two months later, and the infants of those who survived were less-than-average in weight and had detectable levels of PCB's in their tissue at birth, which increased following nursing on their mothers' contaminated milk. Two years later, the animals continued to exhibit some of their original symptoms, and had detectable levels of PCB's in their tissues. A third study was initiated, involving a much lower dosage—5.0 and 2.5 ppm

existing research on this subject, testified at the hearing. A dose of 20 ppm A-1254 enlarged the livers of rats, affecting the cytoplasm of liver cells and inducing dangerous metabolic activity. Dep't Exhibit 45, pp. 3-4. An early study showed a tumor in the bladder of one rat, causing an intensive follow-up in which 200 Sherman Strain rats were fed 100 ppm A-1260 for almost 21 months. Of 184 experimental rats, 170 had abnormal or autonomous growths on their livers. 26 were hepatocellular carcinomas (malignant tumors). None of the 173 control rats had such growths. Dr. Kimbrough concluded that the PCB had elicited a spectrum of response similar to established carcinogens. R. D. Kimbrough et al., "Induction of Liver Tumors in Sherman Strain Female Rats by Polychlorinated Biphenyl Aroclor 1260," in Dep't Exhibit 45(8) (unpublished paper), discussed in Meeting Report, *Report of a Workshop on Classification of Specific Hepatocellular Lesions in Rats*, 35 Cancer Research 3214 (Nov. 1975).

29 Dr. Robert K. Ringer, who conducted and participated in most existing research done regarding PCB's and mink, testified that the experiments yielded similar symptoms: impaired reproduction, internal bleeding, loss of appetite, degeneration of the liver and others. See R. T. Aulerich, R. K. Ringer & S. Iwamoto, *Reproduction Failure and Mortality in Mink Fed on Great Lakes Fish*, 19 J. Reprod. Fert. Suppl. 365 (1973), a study caused by the threat that coho salmon diets posed for the mink ranching industry. The study relating to cow meat is N. S. Platonow & L. H. Karstad, *Dietary Effects of Polychlorinated Biphenyls on Mink*, 37 Can. J. Comp. Med. 391 (1973), Dep't Exhibit 44.

30 M. Kuratsune et al., *Epidemiologic study on Yusho, a Poisoning Caused by Ingestion of Rice Oil Contaminated with a Commercial Brand of Polychlorinated Biphenyls*, Environmental Health Perspectives 119 (Apr. 1972), Dep't Exhibit 42(5); M. Kuratsune et al., "Some of the Recent Findings Concerning Yusho," paper presented at Nat'l Conf. on PCB's, Chicago, Ill., Nov. 19-21, 1975 (GE Exhibit 31). The investigators also reported on a chick edema disease in western Japan, caused by the same rice oil, in which over 400,000 chickens were reportedly killed. Their livers were yellowish and mottled.

GE presented testimony concerning the recent discovery that the Kanechlor involved in the Yusho incident contained polychlorinated dibenzofurans (PCDF's), a highly toxic chemical. Tr. 1774 (Dr. Golberg). This information is discussed by Dr. Kuratsune, et al. in their 1975 paper above. They find the evidence interesting and worth following up, but provide no support for GE's use of the data to undermine the fact that PCB's were the principal causative agent in Yusho. They note, for example, that evidence of the expected effects of PCDF's on the livers of deceased victims is lacking, and they also speculate that the PCDF's, if indeed present, may have been produced from the PCB's themselves when used as a heat transfer agent or in cooking. GE Exhibit 31.

A-1248 to two sets of animals. Within two months, after consuming from 35 to 50 mg PCB, some of the female monkeys began to exhibit the typical symptoms of PCB intoxication; at six months all the females were so affected. Their menstrual cycles were "decidedly altered" after consuming 60 to 120 mg PCB, and their reproductive capabilities were drastically lessened; only 5 of 8 on the 2.5 ppm diet and 1 of 8 on the 5 ppm diet had normal births, whereas 12 of 12 control animals had normal births. The infants were smaller than average, and contained PCB's; they accumulated more PCB's from their mothers' milk and, within four months, 3 of the 6 died of PCB poisoning. One female adult on each diet also died, and the tissue and organs of both were substantially altered, including widespread necrosis in the liver. Males also exhibited symptoms, but less severe ones, perhaps because their greater body weight provided more fatty tissue to store PCB's.³¹

GE contends that, whatever the toxicity of PCB's in general, A-1016 is far less toxic than the mixtures used in most experiments of PCB effects. A-1016 is said to be less toxic, not because it contains a lower percentage of chlorine than other PCB's, but because it contains a relatively low proportion of PCB homologs with 4 or more chlorine atoms. For example, A-1016 contains only 1 percent homologs with 5 or more chlorines whereas A-1242 contains 9 percent of such homologs. A-1248 contains 40 percent and A-1254 contains 77 percent. Dep't Exhibit 39, p. 7; GE Exhibit 13. The evidence in general establishes that the higher homologs are less biodegradable, that they bioaccumulate to higher levels, and in particular that a PCB isomer with 4 chlorines (2, 3, 2', 5' tetrachlorobiphenyl) may be metabolized into highly toxic hydroxylated PCB's. Tr. 1782-1783 (Dr. Golberg). Dr. Kimbrough also testified that, whereas homologs with 5 or more chlorines were carcinogenic to rat livers, it was not yet known whether those with four or less chlorines caused such tumors. See Dep't Exhibits 45(6) and 46(8), p. 14.

The evidence shows, however, that the relative toxicity of PCB mixtures varies depending upon the organisms affected. The lower homologs are more soluble than higher ones, and are therefore more available to, and more rapidly absorbed by, fish swimming in the water. Dep't Exhibit 15(9); Tr. 936-37. Furthermore, A-1016 has been observed to cause effects similar to those caused by other mixtures in many contexts. After a series of experiments designed specifically to test the toxicity of A-1016, because of its increased use, Dr. D. J. Hansen and his coauthors concluded that "Aroclor 1016 is similar to other PCB's in its toxicity to, and uptake and retention by estuarine animals." In a chronic exposure (42 days), for example, Pinfish accumulated 5.1 ppm A-1016 in edible flesh and 11.0 ppm in their whole bodies. Most of those that died exhibited symptoms of poisoning, including changed appearance and behavior. "Acute toxicities of Aroclor 1016 to oysters, brown shrimp, and pinfish," the researchers concluded, "were similar to that of Aroclor 1242 and Aroclor 1254."³²

The Department introduced, through Dr. Alan V. Nebeker, data showing the effects on the water flea of PCB homologs with 3, 4 and 5 chlorines, tested separately. He found "not much difference in toxicity between trichlorobiphenyl and tetrachlorobiphenyl

31 Dr. J. R. Allen, who conducted or participated in these experiments, testified at the hearing that the levels chosen for the most recent experiment were designed to test those set by the FDA as tolerable limits for certain foods. Dep't Exhibit 41. He concluded (Id. 6-7).

Our studies have demonstrated a striking similarity between the signs and lesions produced by PCB's in man and in nonhuman primates. As is the case with man, we have found that the PCB's are extremely toxic to nonhuman primates over a wide range of dosages. Even at levels accepted in certain foods destined for human consumption, PCB's are capable of producing obvious skin changes within two months, and reproductive abnormalities within four to six months. In addition, it has been shown that PCB's transfer through the placenta and are deposited in the fetus. Infants born to exposed mothers are smaller than average and show increasing tissue levels of PCB's following birth due to the consumption of mothers' milk that contains relatively high levels of the compounds. Sufficient PCB's were consumed via their mothers' milk to cause morbidity and mortality in infants.

32 D. J. Hansen, P. R. Parrish & J. Forester, *Aroclor 1016 Toxicity to and Uptake by Estuarine Animals*, Env. Research 363 (1974) Dep't Exhibit 26(8). The authors refer to comparative studies of the other Aroclors. A subsequent study showed that A-1016 was much less toxic to Sheepshead Minnows than A-1254, but the former was nevertheless lethal to adults at 32 ppb. Dep't Exhibit 26(21). Furthermore, an experiment conducted at the National Water Quality Laboratory in Duluth, Minnesota, shows a strong similarity in the lethal effect of A-1016 and A-1242 on Fathead Minnows Fry. Dep't Exhibit 37(6).

homologs which suggests that mixtures such as Aroclor 1016 and Aroclor 1242 would be similar in toxicity." Dep't Exhibit 36, p. 6. Further tests of the relative toxicity of A-1242 and A-1016 on Rainbow Trout and Bluegills made it "apparent" that their toxicity is "similar."³³ Other reliable and unchallenged data show that the toxicity of PCB's to some species (including Catfish and Bluegills) can vary inversely with the percent of chlorines or high homologs.³⁴ Finally, the evidence that tetrachlorobiphenyl may be metabolized into an hydroxylated derivative is inconclusive. A-1016 contains 21 percent tetrachlorobiphenyl, much of which has the isomers that are suspected of being particularly toxic.³⁵

Even if A-1016 is less toxic to some fish than other Aroclors, that fact fails to help GE in this case. The sediment, water and fish of the Hudson downstream of GE's plants are contaminated with substantial quantities of A-1242 and 1254, which have a continuing effect on living organisms in the river. Dep't Exhibit 5, p. 1920 (sediment heavily contaminated). The evidence shows that GE has in prior years purchased and used large quantities of higher chlorinated Aroclors.³⁶ Dr. Simons testified that he began planning PCB abatement steps in 1972. There is every reason to believe, therefore, that GE discharged higher chlorinated PCB wastes into the Hudson throughout the time the company was using those products. Assuming that substantial quantities of the higher chlorinated PCB's were discharged by persons or companies other than GE (of which there is no proof), GE's discharges of A-1016 are added to the PCB's already present and therefore have a greater toxic effect than they otherwise would have. For the same reason, it matters not at all that some of the PCB's were discharged more than three years before the complaint in this case, when GE claims the statute of limitations began to run,³⁷ or before March 24, 1974, when the

definition of Class D waters was amended to include fishing as a best usage. The higher PCB's continue to have an effect—continue to contaminate and pollute—and the toxicity of the more recent discharges must be judged along with the PCB's already present, especially since GE is responsible for their presence. Counting in the effects of all existing PCB mixtures in judging GE's liability is especially necessary, since the record indicates that mixtures of A-1016 and higher chlorinated Aroclors are more toxic than the combined measures of their individual toxicities. See Dep't Exhibit 43, p. 5. Dep't Exhibit 37(1), pp. 723-24, 726. Finally, it is entirely possible that A-1254 has been discharged by GE in the very recent past, because of accumulations in pipes, some of which have been moved in GE's abatement efforts. See Tr. 1279.

D. Violations of ECL 17-0501 and 17-0511

GE has violated ECL 17-0501 and 17-0511, as charged, by causing or contributing to a condition in contravention of the water quality standards adopted pursuant to ECL 17-0301. Two separate standards have been violated: GE has discharged wastes injurious to fish, and the company's conduct has caused and contributed to the impairment of a protected usage of the waters—fishing.

1. Injury to fish

GE argues that the toxic wastes discharged have not been shown to injure fish in that the evidence relied upon is largely based on laboratory tests concerning organisms other than species of fish found in the Hudson; no fish have been shown to have been directly affected, and GE in any event has brought its discharges to the point where no violation is continuing, making inappropriate the imposition of any penalty, including an injunction.

The argument against laboratory testing is inconsistent with the best scientific practice. Dr. Donald I. Mount, Director of the Environmental Protection Agency's National Water Quality Laboratory in Duluth, Minnesota, commented generally that the results of laboratory toxicity work with fish or other organisms correlated within a factor of two to conditions actually found in the field. Tr. 964-66. Dr. Lauer testified for GE that the most accurate way of determining toxicity to fish was through controlled experiments, rather than by examining individual Hudson River fish. Tr. 1635. Dr. Golberg's observation that care must be exercised in tests because fish foods often contain contaminants is a well taken generality, but the evidence clearly shows that the scientists who testified, and whose findings were introduced, exercised adequate care in this regard. GE has voiced no challenge against any laboratory test in evidence on this or any other substantive ground.

Reliance by the Department on evidence concerning organisms and animals other than species of Hudson River fish is also proper. See, e.g., *Synthetic Organic Chem. Manufacturers Ass'n v. Brennan*, 503 F.2d 1155, 1160-61 (3d Cir. 1974) (upholding use of tests showing carcinogenic effects of ethyleneimine in rats and mice to show potential effects on men); *Environmental Defense Fund v. EPA*, 489 F.2d 1247, 1253-54, [4 ELR 20031] (D.C. Cir. 1973) (reliance on general data, laboratory experiments on animals, etc. sufficient basis to prohibit uses of DDT concerning which no specific evidence was presented). Many experiments involved fish, some that are found in the Hudson. Others involved creatures similar to those found in the Hudson and others used animals or organisms available in sufficient numbers and conventionally used to test for toxic effects. The range of PCB effects was such, testified Dr. Mount, that tests involving a variety of organisms was appropriate, and values concerning salt water species, for example, would be predictive of effects in fresh water species. Tr. 968-69. To the extent some creatures were especially sensitive, as mink are, or particularly resistant, as rats may be, the evidence of their reactions may be given less or more weight but is admissible and probative. See generally Judge Leventhal's instructive discussion upholding an extrapolation of the effects of aldrin/dieldrin "from mice to men," *Environmental Defense Fund v. EPA*, 510 F.2d 1292, 1298-99, [5 ELR 20243] (D.C. Cir. 1975).

The record contains ample evidence from which an inference may be drawn that GE has discharged PCB's in quantities injurious to fish. The nature of this case makes it unnecessary that the Department prove that specific fish were directly affected or, as GE puts it, what "actually" took place not what "could" or "might"

33. 13. Dep't Exhibit 37(5)

Comparative toxicity of Aroclor 1242 and 1016, based on data from the Fish-Pesticide Lab. Columbia, Mo., in continuous-flow exposures

Test Organism	1242 (ug/l)		1016 (ug/l)	
	96 hr. LC50 values	LC50 values after-	96 hr. LC50 values	LC50 values after-
Rainbow Trout	67	10 days = 39	100 (5ac fry)	17 days = 49
	109		440 (2.5 g)	23 days = 11
Bluegill	125	15 days = 54	46 (1.8 g)	35 days = 43
	154		420 (0.9 g)	22 days = 14

34. Intermittent-flow bioassays of A-1242, 1248 and 1254 resulted in 14-day LC50 values in Bluegills of 54, 76 and 204 ppb respectively, and in Channel Catfish of 107, 127 and 741 ppb respectively. D. L. Stalling & F. L. Mayer, Jr., *Toxicity of PCB's to Fish and Environmental Residues in Env. Health Perspectives*, pp. 154, 162 (Apr. 1972). Dep't Exhibit 37(8). The same inverse correlation was observed by Dr. Ringer in connection with single doses given to mink. See Dep't Exhibit 43, p. 4, Tr. 1079.

35. Dr. Golberg testified for GE that tetrachlorobiphenyl isomers with chlorine atoms in the 4 position had "special properties," apparently meaning they were potentially more toxic than others. Tr. 1805-06. Dr. Stalling testified that four of six of the most abundant isomers in PCB's contain chlorines in the 4 position.

An article co-authored by Dr. Golberg notes that "lower chlorinated biphenyls are of special interest because their biological degradability might lead to metabolites of increased toxicity." W. Greb et al., *In vitro Metabolism of Polychlorinated Biphenyls*, 13 Bull. of Env. Contamination & Toxicology 424 (1975). Dep't Exhibit 61. See also Dep't Exhibits 60 & 62. Dr. Allen identified 2, 5, 2, 5 tetrachlorobiphenyl as capable of altering DNA and RNA, and therefore as linked with mutagenic, carcinogenic and necrogenic effects. Dep't Exhibit 41, p. 6, Tr. 1047.

36. Dep't Exhibit 6 reflects GE's purchases from Monsanto since 1966.

Years	Lbs in thousands	Aroclor			
		TOTAL	1016	1242	1254
1975 (Jan-Sept)	4162		4146	16	
74	8729		8699	30	
73	9653		9234	384	35
72	7901		7881		20
71	5561		1324	4223	14
70	9682			9589	93
69	8323			8219	104
68	9039			9839	100
67	9496			9395	101
66	8767			8667	100

37. NRDC argues that the applicable statute of limitations is CPLR 213(5), which allows the state to sue for misappropriation of public property either within six years from the time the cause of action accrues or within two years of

the State's discovery of the facts, whichever is later. GE's discharges during the last three years violate ECL 17-0501, so no need arises to decide this question.

have taken place. GE Brief 29 ECL 17-0301 sets a water quality standard, and is part of a plan adopted in part to avoid the rigidity of the law aimed at punishing for harm done to identifiable fish. See discussion *supra*, pp. 30011-12. The experimental results in evidence show that fish, among other living things, have suffered toxic effects from PCB exposures equal to or lower than those to which fish taken from the Hudson were subjected.³⁸

In this regard, no weight need be given to the FDA tolerance limit of 5 ppm for the edible portion of fish. That standard is designed to protect consumers of fish, not the fish themselves. It would appear, on the one hand, that PCB levels of 5 ppm in fish may not be harmful to the fish themselves. Important variables would have to be weighed, including at what places in the fish the PCB's are located, and how sensitive is the particular species. On the other hand, when injury to fish is the relevant inquiry, the edible portions are far less significant than other areas and organs, such as the liver. The record shows that concentrations in the non-edible portions of fish are consistently higher than in the edible portions, and that the non-edible parts include vital organs. See Tr. 1625-29. An ample basis is therefore present in the record to substantiate the un rebutted testimony of Dr. David L. Stalling that, "from what we know about the response to levels, certainly the concentrations in the fish exceeding the 100 micrograms per gram [parts per million] would have a very marked decreased chance for survival if mortality had not already occurred." Tr. 673. Applying GE's proposed test for proof by circumstantial evidence (even though in this context the evidence is scientific rather than based on unverifiable observation or speculation), the circumstances are indeed such "as to lead fairly and reasonably to the conclusion sought to be established and to exclude any other hypothesis fairly and reasonably." *Ruppert v. Brooklyn Heights R.R. Co.*, 154 N.Y. 90, 93 (1897). The hypothesis of non-injury has been fairly and reasonably excluded.

GE would have this charge dismissed on the ground that it is now complying with the law. Its argument is both factually and legally unsound. The Department and NRDC demonstrate in their briefs that, even at present discharge levels, some fish will bioconcentrate PCB's to a level in excess of 5 ppm from the water alone. GE's computations completely exclude, furthermore, the very substantial PCB contamination of sediment, which the evidence shows leads to fish contamination swiftly and to very high levels.³⁹ GE also characterizes as "anomalous" some substantial discharges that have occurred since September 1975 because of heavy rain or because of work associated with abatement efforts, such as moving contaminated pipes. The ECL may allow or even require the Department to disregard discharges caused by an "act of God" or other uncontrollable factors in considering GE's activities, but the relevant section does not exempt GE from its own negligence or willfulness. See ECL 71-1935. The PCB's cannot be attributed to

38 See the sources cited in footnotes 24-32, *supra*, particularly the low dosage Rheus minnow experiments. Dr. Nebeker testified that concentrations as low as 1.5 ppb PCB's kill or retard the growth and reproduction of Minnows, Flagfish and mosquito larvae. Dep't Exhibit 36, p. 9. Dr. Nimmo and others found A-1254 toxic to shrimp in the 1 ppb range. Dep't Exhibit 24(5), p. 197. Water concentration near the GE plants ranged from 1.3 to 3.0 ppb A-1016 between December 1974 and August 1975. Dr. Stalling referred in 1972 to the fact that residues of 500-600 ppm were associated with fish mortality in chronic continuous flow exposures. Dep't Exhibit 19(5), p. 163. Hudson River fish were found with levels this high, and it is safe to assume that even higher levels have been reached in fish that were killed, and that some fish with lower concentrations were injured.

39 Dep't Exhibit 15(28) contains the experiment run by Dr. Veith on the effect of Hudson River sediments on fish in a tank with the sediment, as well as in a tank with just the water overflow from the first tank.

Concentration of PCB's in Fathead Minnows
After 6 Days in Lake Superior Water and Hudson River Sediments

Sample	Number of Fish	PCB's (ug/gmt) as Aroclor 1016
6 Days in Tank Containing Hudson River Sediment ^a	8	109
6 Days in Tank Receiving Overflow from Sediment Tank ^a	6	36.4
Control Fish (Lake Superior Water)	6	Not detectable

^a Sediment contained 116 ug/gmt (dry weight) as Aroclor 1016.

^b Estimate. PCB's in tank B water was 0.45 ug/l as Aroclor 1016.

God, only to GE, and He has provided heavy rains at sufficiently regular intervals to have made predictable those that drained PCB's from the land around GE's plants. GE's abatement activities are commendable, but GE made them necessary and is responsible for consequences that could be expected to occur. There is no reason, moreover, to consider only GE's discharge rate after this suit was brought. GE is responsible for all its discharges for at least the three years preceding the complaint, the period covered by the statute of limitations the company contends is applicable. CPLR 214(2).

The theory on which GE argues in effect that its unlawful conduct should go unremedied is that no injunction may be issued to require a level of discharge that has already been achieved. This is simply incorrect. The Department is not required to accept GE's representations—mainly unsupported and equivocal⁴⁰—as a substitute for an order requiring discharges at a lawful level. Furthermore, while GE's promised discharge rate of 100 grams per day may be lawful if the use of PCB's is commercially necessary, the Department is entitled to attempt to show that adequate substitutes are available. Nor is the Department precluded by any equitable principle from attempting to require GE to take steps to rectify its prior violations. However negligent the Department may have been in granting GE a permit to discharge those large amounts, the permit and the ECL required GE to conform its effluent to stream classification standards. This proceeding is designed to protect public resources, and cannot be made into a forum for determining the relative fault of GE and the Department.

2. Impairment of best usage—recreational fishing

The ECL and its regulations are also violated by discharges that cause or contribute to an impairment of recreational fishing. A violation of water standards sufficient to injure fish would ordinarily seem to impair fishing. This is true here, since GE's discharges are at least "contributing" to a condition in which fishing is impaired. The proscriptions do not entirely overlap, however, since fishing may be impaired even though fish have not been injured in the sense legally required.

Recreational fishing is impaired when fish, though healthy enough to survive, are dangerous to use as food. GE argued at the hearing that recreational fishing does not require fish that are edible. Tr. 986-93. This may be true as a matter of abstract theory, but in reality recreational fishermen frequently consume the fish they catch, as the testimony shows. Tr. 1875, 1880-81 (J. Pickett), Tr. 1885 (E. Nash). Fishing in the Hudson has in fact been greatly reduced since Commissioner Ogden Reid informed the public of PCB contamination, Tr. 1870-73, 1879, 1886, which demonstrates that the activity is undertaken by some only if the fish they hope to catch can safely be eaten. The regulations themselves contemplate fish consumption by prohibiting the discharge of substances that adversely affect the "flavor, color and odor" of fish. 6 NYCRR 701.5. The regulations were therefore intended to protect the fishing activities of fish-eating anglers as well as those who catch fish purely for sport.

Hudson River fish have been rendered inedible by GE's PCB discharges. The Department properly relies in proving this fact in part upon the FDA's temporary tolerance limit of 5 ppm for the edible portion of fish. Dr. Kolbye testified that the FDA derived its present standard to a large extent from the Yusho incident, in which the victims "received an exposure of approximately two grams of PCB's, which is translated to 2,000 milligrams of PCB's."

40 When GE received its NPDES permit on December 31, 1974, the maximum daily discharge of PCB's was set at 100 grams to be achieved by May 31, 1977. GE filed with EPA a request for an adjudicatory hearing on this effluent limitation—in effect staving its applicability until the question was litigated. GE Exhibit 17. Since filing the request, on the basis of "new experimental data," GE contends that an abatement system can be designed that will keep the PCB daily discharge below the 100 gram level. Tr. 1144. In addition GE contends that, but for the uncertainty presented by the PCB limit that may be imposed in this proceeding, they are now prepared to withdraw their hearing request. Dr. Modan, responsible for keeping the treatment system, testified that based on his engineering judgment, the bench scale studies of the system indicate that the 100 gram daily maximum is achievable. Tr. 1305. These studies and other material developed in connection with this system have not yet been seen by the Hearing Officer or the other parties, although their production was promised. Tr. 1321-22. Neither had GE withdrawn its request for a hearing at EPA on the 100 gram level as of January 1976. *Electrolux Corp. v. Volkswagen Inc.*, 6 N.Y.2d 556, 1976 N.Y.S.2d 947, 1976 N.Y.2d 947, and other similar cases are distinguishable, given the facts as to GE's continuing discharges and the continuing effects of its past discharges.

He said the FDA employed a safety factor of 10, and therefore estimated that human beings could tolerate "without adverse effects on health ... roughly 200 milligrams spread out over 1,000 days." Tr. 993. In adopting this standard during September 1971, the FDA contemplated that consumption of PCB's would taper off and cease after 1000 days, as PCB discharges were reduced or eliminated. It recognized that exposures over a longer period would enhance the possibility of toxic effects. Dep't Exhibit 39, p. 4. The standard promulgated by FDA concerning fish was unchallenged by any party when issued, and was not meaningfully attacked by GE in this proceeding. Dr. Kolbye said the standard is under review in light of new evidence of PCB's carcinogenic effects and of its continued persistence in the environment at high levels. Tr. 1023-24. His conclusion regarding Hudson River fish was unambiguous. "The FDA is extremely concerned about the problem of PCB's in Hudson River fish," he testified, "since the regular ingestion of fish containing PCB's above 5 ppm represents a potential public health problem with unknown long range consequences." Exhibit 39, p. 10. A single 200 gram meal of fish containing 100 ppm PCB's, according to his estimates, would result in the ingestion of 20 mg. PCB's, or 10 percent of the total 1000 day exposure deemed tolerable for adults, and 40 percent of the total allowable exposure (50 mg) for children. See *id.* 9. Significantly, the average PCB content of fish sampled by GE downstream of its plants was 94 to 100 ppm in their edible flesh, which excluded the PCB's in their skin. A single, 200 gram meal of the eel captured by the Department at Stillwater and found to contain 559.25 ppm PCB's in its edible parts would contaminate an adult with over 50 percent of the FDA estimated lifetime limit, and a child with 200 percent of its allowable lifetime exposure.

Any doubts raised by the evidence in this record concerning the FDA standard indicate that it is dangerously low rather than high. The FDA relied on an estimate of PCB consumption by Yusho victims of 2 grams. The published analysis of the incident by members of the study group that examined its consequences reports, however, that 2 grams was the average consumption. The same report estimates that the minimum consumed by a "patient" was 5 grams, or 500 milligrams PCB's. Moreover, the average consumption of oil by Yusho victims was 800 ml., but the researchers found that "the attack rate" for consumers of less than 720 ml. of oil was 88 percent, for those who consumed over 720 ml. oil, that attack rate was 100 percent. Finally, while the Yusho results find a strong correlation between amount of PCB's consumed and clinical severity, it is important to note that 38 percent of those who consumed less than 720 ml. oil contracted "severe" as opposed to "light" cases of poisoning. M. Kuratsune *et al.*, *supra*, pp. 123-25. It is clear, therefore, that the ten-fold margin of safety adopted by FDA is based on a statistical average, and affords much less than ten-fold protection to just about half the potential victims, many of whom are likely to suffer severe attacks. And the ten-fold safety factor appears itself to be far lower than safety factors adopted in other, similar contexts."

GE's argument that it is now in compliance with the ECL has

41. See *Society of Plastics Ind. v. OSHA*, 509 F.2d 1301, 1308, [5 ELR 20157] 12d Cir. 1975; testimony by Dr. Kraybill of the Nat'l Cancer Institute that a 50-fold standard was insufficient for the highly toxic carcinogen vinyl chloride, since a 100-fold margin was used for non-carcinogens.

The history of vinyl chloride regulation is generally instructive. Evidence of its toxic effects led Dow Chemical Company to recommend a maximum exposure to workers of 50 ppm. The industry refused to give up its 500 ppm standard then, and even as further evidence of carcinogenicity accumulated, partly on the ground that extrapolations from experiments involving rats was improper. By 1972 when the industry agreed to finance a study, the first deaths of American workers due to VCM exposure were recorded. By 1974 thirteen workers had been killed. No sooner had the federal government been led to adopt the 50 ppm standard than evidence established it was too high. After a hearing before an administrative judge, a standard of 1 ppm was proposed, with some variance allowed. Industry protested the standard was unnecessary and infeasible. The D.C. Circuit upheld the standard, however, noting that no safe levels had been established, that human lives were at stake, and that experience had shown that the industry had greatly underestimated its technological capacity to reduce exposure levels. 509 F.2d at 1305-10.

The present case also involves a carcinogen of unknown potential effects, and human health is at stake. GE has managed to reduce discharge from a daily average of 1000 lbs. to a projected daily maximum of 127 grams, once its resources were turned to coping with the problem. Some 49 GE employees between 1960 and 1975 were diagnosed as having developed chloracne or dermatitis reactions from PCB contact. Another 16 reported various dizziness and eye and nasal irritations. Dep't Exhibit 45. Follow-up studies are obviously called for.

been dealt with above. The contention is particularly inappropriate in connection with the impairment of fishing. Fishing has been a protected use in Class D waters since March 24, 1974. Furthermore, fishing was a protected use in Class A and B waters long before then, and the waters into which GE has discharged PCB's flow into Class A and B waters.⁴² The act requires that GE be found liable for impairing that protected use, and ordered to cease contributing to the condition it has caused.

E. Alleged Violation of ECL 11-0503(1)

The Department claims GE has violated ECL 11-0503(1) by discharging a poisonous or deleterious substance into a public water in quantities "injurious" to fish or wildlife, or to the propagation of fish or protected wildlife. The evidence that proves a violation of ECL 17-0501 and 17-0511, the Department contends, likewise proves a violation of ECL 11-0503(1). Further, it offers proof that mink reside in the Hudson River basin, and that they are wildlife that would be injured and whose propagation would be adversely affected if they consumed fish with the quantities of PCB's shown to exist in the river.

ECL 11-0503(1) is, however, very different in background and purpose than ECL 17-0501 and 17-0511. The former has nineteenth century roots, and is an isolated provision aimed specifically at protecting fish and wildlife. The latter are relatively modern parts of an overall system of water classification. As we have seen, the water classification program was adopted pursuant to a committee recommendation based in part on the narrow scope of ECL 11-0503(1). The committee's perception of the statute, as requiring proof of injury by a specific substance on a particular occasion, is hardly entitled to binding weight. But a relatively narrow purpose for the provision is also strongly suggested by ECL 71-0925(5), which states that "any act" in violation of ECL 11-0503(1) may be punished by a fine of from \$500 to \$1,000 "for each offense and an additional penalty of ten dollars for each fish killed in violation thereof...." The statute seems aimed at specific, identifiable "acts" and "offenses" that injure or kill fish.

A further characteristic of ECL 11-0503(1) is that its violation is punishable (and apparently in the case of wildlife must be punished) as a misdemeanor. ECL 71-0919 incorporates by reference this penal remedy in ECL 71-0921(d), and the punishment for each offense is up to a \$500 fine and 1 year imprisonment, ECL 71-0921(3)(a). Thus, ECL 11-0503(1) seems aimed, not only at episodes of toxic discharge, but also wilful or grossly negligent episodes, where severe penalties are appropriate. The potential unfairness is compounded by the fact that ECL 11-0503(1) makes it unlawful adversely to affect the reproduction of fish or wildlife, whereas the water classification regulations specifically provide that Class D waters need not be suitable for reproduction. 6 NYCRR 701.4.

GE's conduct is not the sort against which ECL 11-0503 was written. The company engaged in a continuing practice, in which discharges at any particular time or day have not been shown in themselves to be injurious to fish or wildlife. Unlike ECL 17-0501, moreover, under ECL 11-0503 GE's insistence that injury to specific fish be shown has considerable merit. GE's activities were in addition revealed to the relevant state and federal agencies. The company may be have acted at its own risk, but its conduct could hardly be characterized as wilful in the criminal sense. Circumstances may arise where ECL 11-0503 should be applied although no specific fish can be identified as injured, and even in conjunction with ECL 17-0501, but the present case does not fit the anticipated pattern. *Cf. People v. Consolidated Ed. Co.*, 34 N.Y.2d 646, 355 N.Y.S.2d 379 (1974).

The Department has shown injury to fish, but not in a context to which ECL 11-0503 should be applied. As to the proof concerning wildlife, the Department's case, as GE properly notes, is based entirely upon hearsay evidence. A Department witness testified that he had read books stating that mink existed in the Hudson River basin, and that unidentified citizens of unascertained expertise had reported sighting mink. This is not only hearsay, but hearsay of unproven reliability. Even if believed, it would prove only

42. See 6 NYCRR §701.4. The Hudson River from Baiten Kill to Lock J is designated Class B, from Lock J to the Confluence of the Mohawk it is designated Class A. The Lower Hudson from Conesville to Chelsea is Class A, and from Chelsea south to Westchester Co. and Dutchess County is Class B. Dep't Exhibit 11.

that mink existed, in unknown quantities, in a very large area encompassing many thousands of potential food sources other than the Hudson River. An inference of injury cannot as readily be drawn in this context as in the case of fish, essentially trapped in the PCB contaminated waters, and actually shown to have absorbed PCB's in quantities demonstrably high enough to be injurious to themselves and potentially to their consumers. The allegation must be dismissed as inappropriate and unproven.

III Outstanding Remedial Issues

The Department has proven violations of ECL 17-0501 and 17-0511. It has also shown itself entitled at the very least to an order requiring GE to reduce its PCB discharges to a lawful level. Whether the levels GE represents it has and can attain are lawful is only the first of several issues to be examined when this proceeding reconvenes. Other issues include:

1. The extent to which GE should be ordered to rectify the effects of its prior discharges, including whether any practicable and environmentally safe method exists or can be devised to remove PCB's from the river bottom, and the expected duration and extent of PCB contamination if no remedial steps are taken;
2. The extent to which GE should be required to remove PCB-contaminated earth and equipment from around its plants and the manner in which this operation should be conducted.
3. The existence of substitutes for PCB's, including their adequacy and environmental acceptability.

4. Whether GE is presently utilizing proper care in its manufacturing and sales processes to avoid PCB contamination, including what controls GE has in effect if any to insure that PCB-impregnated equipment is not being permitted to become a hazard to the environment after use; and

5. Whether the system of supervision proposed by the Department would be lawful and adequate, particularly the legality and necessity for a bond as requested.

An aspect of all these questions is the cost involved in proceeding in one way or another. The Department of Commerce will hopefully provide assistance in this regard, by analyzing the costs of alternatives. The Department of Commerce should, in this connection, note that the extreme prospect of closing down GE's plants has not been suggested by any party as warranted or necessary. The Department and NRDC have heretofore relied in advocating a zero PCB discharge on their claims that adequate alternatives exist.

These are complicated matters that will require technical proof. The Department will have to go forward on these issues. GE is hereby ordered, however, to provide the parties and the Hearing Officer, within two weeks of the date of this opinion, with as comprehensive as possible a description of its present abatement plans. The hearing should proceed with a full appreciation for what GE is prepared to accomplish without compulsion. The Department should inform the parties as soon as possible when it will be prepared to present its proof. After the forthcoming hearing, a proposed order will be prepared and submitted to the Commissioner, containing all the findings made and conclusions drawn at both parts of this proceeding. Meanwhile, this opinion shall constitute the interim findings and conclusions on GE's liability.

Spirometric Findings in Capacitor Workers Occupationally Exposed to Polychlorinated Biphenyls (PCBs)

Richard W. Lawton, MD; Marie R. Ross, RN; and Joseph Feingold, MD

Spirometric findings (forced vital capacity [FVC], forced expiratory volume at one second [FEV₁], FEV₁/FVC) in a population of capacitor workers with occupational exposure to polychlorinated biphenyls (PCBs) are described during active PCB use (1976) and following the PCB ban (1979 and 1983). The initial finding of restrictive impairment (16%) in 1976 was not supported by chest roentgenogram findings, nor confirmed in 1979 and 1983, and was interpreted as artifactual to test operator inexperience and inadequate expiratory efforts. Obstructive impairment was consistently found in 15% of the total population in 1976 and 1979. A history of respiratory illness and/or symptomatology and reduced FEV₁/FVC was correlated with PCB exposure and serum PCB levels (lower homologs) in females in 1976, but not in males. Smoking was correlated with reduced FEV₁ values. No correlation of spirometric variables with past exposure or serum PCB levels was found for either sex in 1979.

In spirometric studies of a group of capacitor workers (N = 243), some of whom had high direct occupational exposure to PCBs, Warshaw et al¹ found a substantial prevalence of reduced vital capacity (FVC < 79.5% of predicted value). The prevalence (14%) was

reported by them as equivalent to that of asbestos workers (12.1%). Of those showing FVC reductions, 80% showed a restrictive pattern (FEV₁/FVC > 0.70) without radiologic changes. PCBs were not reported as acute direct pulmonary irritants, although eight-hour time-weighted average air levels in the workplace areas of PCB use varied from 0.6 to 11.0 mg/m³.²

The present paper reports a spirometry study of capacitor workers, drawn from the same plant population as that of Warshaw et al, but involving only workers with current occupational PCB exposure in 1976. Spirometry was repeated in 1979, 1981, and 1983 and provided longitudinal data on a selected population.

Methods and Materials

The study population consisted of all capacitor workers with direct work-related PCB exposure in two plants in upper New York state. This population, when selected in 1976, consisted of 194 workers (152 males, 42 females) representing approximately 10% of the work force. Ages extended from 22 to 66 years and service times from 1 to 35 years. The cohort was examined in 1976, 1979, 1981, and 1983. Exposure was defined in three categories: (1) high exposure: jobs requiring dermal contact in high air level zones (handling and sealing wet capacitors, capacitor salvage and repair); (2) medium exposure: jobs requiring brief high exposure and contact such as maintenance men; and (3) low exposure: jobs not involving dermal contact but in or at the periphery of the high-exposure zone.

The initial examination consisted of a medical history, physical examination, chest roentgenograms, ECG, sequential multichannel autoanalyzer (SMA-26) blood analysis, hematology, urinalysis, and spirometry. Body weight was obtained in light indoor clothing and height

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was determined without shoes. Subsequent examinations consisted of blood workup, changes in body weight and blood pressure, and spirometry. Chest roentgenograms, ECG, and physical examination were repeated in 1983. Smoking classification (smokers, ex-smokers and nonsmokers) was obtained in 1976. Detailed smoking histories (cigarettes per day, years smoked, etc) were not obtained until 1979 (N = 165). These were generally confirmed in 1983 and the 1979 data were used throughout the analysis with no account taken of the few reports of change in habit over the period. Chest roentgenograms were classified according to the International Labor Organization classification of radiographs (form OMB No. 68-5 1322). With two exceptions all roentgenograms with positive findings were classified in section 4.

Serum PCB levels were obtained in 1976 and 1979 (analysed by Hazleton Laboratories America, Inc, Madison, WI) using methods previously described.³ Pulmonary function was evaluated in 1976 using a Vanguard spirometer with a disposable filter paper flow sensor (Life Support Engineering Corp, Woburn, MA). In 1979 an updated version (Vanguard DS502) with a preprogrammed computer printout was used. Measurements were made in the standing position and the nose closed with the fingers. The calibrating source was a VS300 3-l syringe and calibration conducted at various volumes and rates as recommended.⁴ For each worker the maximum expiratory volume-time curve was recorded and examined for freedom from test artifacts.⁵ At least three trials were performed by each worker and reproducibility of the expiratory effort was accepted at the 10% vel.

Measurements were made of forced vital capacity (FVC), the forced expiratory volume at one second (FEV₁) and the ratio (FEV₁/FVC) using the highest test of the three trials. The data were evaluated as the percent of predicted values using the tabulated predictions of Knudson et al.^{6,7} The spirometric patterns were classified as restrictive (FVC < 80% of predicted, FEV₁/FVC > 70%); obstructive (FVC ≥ 80% of predicted, FEV₁/FVC ≤ 70%); or mixed (FVC < 80% of predicted, FEV₁/FVC ≤ 70%).

Initially (1976) the nurse conducting the test had had little spirometric training and only subsequently was certified (1978) for pulmonary screening. Retrospective review of the 1976 expiratory spiograms indicated 15 tests (7.7%) to be unacceptable due to technical error. Subsequently, only two workers' test results were unacceptable: one due to thoracic arthritis and another due to poorly fitting dentures. Nine workers' test results were unacceptable in 1976 but were acceptable in 1979.

Statistical analysis was performed on a Honeywell Series 600/6000 computer using available time-sharing applications programs.⁸ Regression analyses were conducted using STATPAC, a versatile statistical package⁹ for distribution plotting and the derivation of coefficients and correlations by multiple stepwise regression. An incremental F-ratio of 3.9 was used for entering and removing variables so that variables significant at the 5% level were included. Only one marginal association

was found and this was treated as significant. PCB exposure was described in terms of the exposure category, treated as a dummy variable, or the serum PCB level, either as reported, or as the concentration in total serum lipids.³

As a consequence of dropouts due to retirement or employee separation, rejected tests, refusal of the procedure, or death, the number and composition of the participating population changed during the three examination periods. For these reasons, and because of incompleteness of detailed smoking data, the analysis focused on 136 workers for whom complete data were available for the 1976, 1979, and 1983 time periods. In addition, 93 workers were examined at some point in 1981 so that a total of 80 workers had four sets of measurements. These subgroups provided a longitudinal assessment of the spirometry changes with time and of the reliability of the procedure. The entire available population was used to assess abnormal spirometric findings and for the relations with serum PCB levels.

Results

Workers in the study population were overweight (50% of the workers had body weights above the normal "desirable" range for large-framed individuals¹⁰) and heavy smokers. Those who smoked or had smoked (71.4% of males, 54.2% of females) averaged a pack a day for 18 to 20 years.

In 1976 there were seven cases of clinically recognized emphysema and 12 workers were told by their physicians they had chronic bronchitis, although only two complained of current shortness of breath, cough, or sputum production. Past histories of significant pulmonary infections were reported in 16 cases. Chronic upper respiratory tract infections and allergies were prevalent. Four workers (heavy smokers) reported leukoplakia and/or laryngeal polyps. On chest roentgenogram examination emphysema was suspected in six cases. The predominant finding was evidence for past pulmonary infection (granulomata, calcifications, scarring). A coin lesion (malignant) was discovered in one worker. Evidence for fibrosis was found in only two workers. One worker (with carcinoma of the lung) showed bilateral circumscribed pleural thickening; another worker showed old healed pleural thickening at the left base. Mean 1979 serum PCB levels were elevated 35 to 40 times the normal background community levels in humans. The levels for PCBs were higher in the female subgroup.

The Figure shows spirometry data converted to percent of predicted value for 80 workers who had measurements made at four periods during this study. The plotted points are means ± the 95% confidence limits for the population average. For the males, (N = 75) the mean FVC value rose between 1976 and 1979 (4.53 L to 4.90 L) and then declined (4.70 L in 1983). With the smaller accompanying change in FEV₁, the FEV₁/FVC ratio fell in 1979 and then returned to its 1976 value. However, as indicated in the Figure, only the FEV₁ population average appeared to be significantly less

in 100% of the predicted value in 1976. These data indicated a continuing improvement in the reliability of the measurements with experience of both the operator and the workers.

Using the predictions of Knudson et al.⁶ workers were divided into restrictive ($FVC \leq 80\%$; $FEV_1/FVC \geq 70\%$) and obstructive ($FEV_1 \leq 80\%$; $FEV_1/FVC \leq 70\%$) categories.

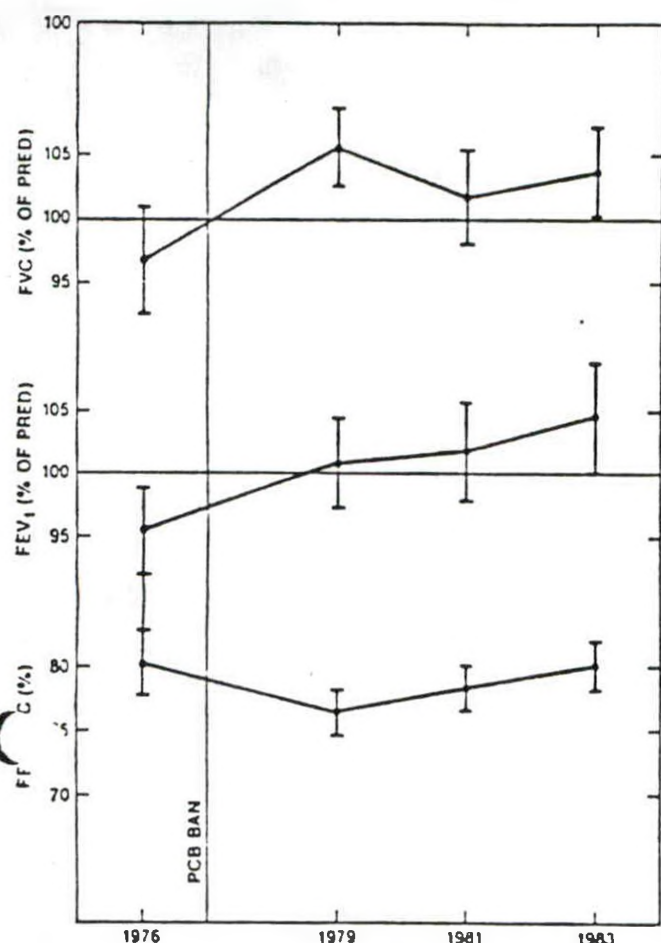


Figure 1. FVC, FEV₁, and FEV₁/FVC as percent of predicted value⁶ for portion of study population with four spirometry tests (N = 80). Means and 95% confidence limits.

egories (Table). In 1976 for the total population (N = 179) we found that 16.2% of the population showed restrictive impairment. In 1979 the percent of the population showing this finding declined to 2.9%. In contrast, the obstructive category was relatively constant (15.6% and 15.3%) with 2.2% to 3.4% of the population showing a mixed result (FVC and FEV_1 both $\leq 80\%$ and $FEV_1/FVC \leq 70\%$). Obstructive defects were more prevalent in smokers and ex-smokers. Of those with $FEV_1/FVC \leq 70\%$ about 70% had values between 65% and 70% and the ventilatory impairment was considered mild. Four of the 25 workers not returning for the test in 1979 were known to have clinical chronic obstructive lung disease. Because the study dropouts in 1983 made up such a large percentage of the population (21%), scoring for these data provided a lower estimate of the obstructive category.

Using multiple stepwise regression we examined the significant partial correlations of the measured spirometric parameters with the conventionally used variables (sex, age, body height), as well as those of interest in this study (smoking, respiratory history, and PCB exposure). Although the number of workers with satisfactory spirometry and complete data varied for the three examinations, we found strong and complete regressions for FVC and FEV₁, but incomplete and weaker equations for FEV₁/FVC. Spirometric variables were inversely associated with smoking in all cases except FEV₁/FVC in 1976. Body weight was inversely associated with FVC in 1979 and 1983. This latter relation was characteristic of the male subpopulation. The presence of a history of respiratory infection and/or symptomatology was significantly associated with a decreased FEV₁ and FEV₁/FVC in 1979 and 1983. High exposure to PCBs in the workplace, as measured either by the exposure category or the serum PCB level, was significantly associated with a decreased FEV₁/FVC in 1976, a period of active PCB use. However, this association of exposure and FEV₁/FVC was found only for the female subpopulation. There were no significant associations for the serum PCB level and the spirometric parameters in 1979 for either sex.

The Pearson product-movement correlation coefficient

TABLE
Restrictive, obstructive and mixed spirometric findings in total population in 1976 and 1979 using predictions of Knudson et al.⁶

	1976						1979					
	Male		Female		Total		Male		Female		Total	
	Smokers and Ex-smokers	Non-smokers	Smokers and Ex-smokers	Non-smokers	No.	%	Smokers and Ex-smokers	Non-smokers	Smokers and Ex-smokers	Non-smokers	No.	%
N	103	39	22	15	179	100.0	94	38	22	16	170	100.0
Restrictive ($FVC \leq 80\%$; $FEV_1/FVC \geq 70\%$)	19	6	2	2	29	16.2	2	0	1	2	5	2.9
Obstructive ($FVC \geq 80\%$; $FEV_1/FVC \leq 70\%$)	14	3	9	2	28	15.6	14	2	9	1	25	15.3
Mixed ($FVC \leq 80\%$; $FEV_1/FVC \leq 70\%$)	4	0	1	1	6	3.4	2	0	2	0	4	2.4

cients for the constant population ($N = 136$) in 1976 and 1979 indicated an association of exposure with respiratory history and symptomatology in females, although the relation was marginally significant ($P = .12\%$). In males we found the respiratory history to be significantly associated with smoking. Smoking was also associated with a reduced FEV_1 in males in 1976 and 1979 but only for females in 1979.

Discussion

Medical surveillance of a group of capacitor workers directly exposed to PCBs was undertaken in 1976 to assess the workers' general health. The medical examination included spirometry, which was repeated in 1979 and 1983, and on a part of the group in 1981. We found pulmonary-function testing to be one of the most difficult procedures to perform well in the industrial medical setting. The procedure requires a trained and certified nurse or technician, functional and properly calibrated equipment, and motivated and cooperative workers if adequate data are to be obtained. These conditions were not fulfilled at the inception of this study: the nurse had little spirometric training and testing experience and worked in cramped quarters with new equipment. The test was new for the workers whose motivation was uncertain, given the intense media coverage of PCBs at the time. As a consequence only 179 out of 194 workers tested (92%) had apparently satisfactory forced expiratory volume-time curves on retrospective review. Following nurse certification and repeated worker experience with the procedure, unsatisfactory data were obtained in 1% or less of tested cases in 1979, 1981, and 1983.

Because of the technical deficiencies in the spirometry procedures and the uncertainties associated with the serum PCB measurements in 1976,³ we were inclined to reject the data. However, these observations were obtained during the period of active PCB use and were characterized by high serum PCB levels in the workers. In addition, the observations coincided in time with those of Warshaw et al.¹ In their studies (1976), as well as in ours, reduced FVCs were observed. FVCs < 80% of predicted with normal FEV_1/FVC (>70%) were found in 14% of the population studied by Warshaw et al and in 16.2% of our study population. In both studies there were no radiologic evidences of pulmonary fibrosis to account for the restrictive impairment observed.

In our study, based on longitudinal observations, we believe the finding to be artifactual. FVC values as percent of predicted for the population in 1976 were normally distributed over the range, indicating a systematic decrease, which could have resulted from generally poor coaching and inadequate expiratory effort. In addition, regression studies indicated substantial divergence of the prediction coefficients and a higher degree of variability of the 1976 data compared with that found on subsequent testing. We know of no reversible restrictive pulmonary pathology that could account for these findings.

The principal and consistent respiratory finding in this work force exposed to PCBs was obstructive impairment which was found in approximately 15% of the

population. In the female subgroup we found a significant relation between exposure in the workplace and respiratory history and symptomatology in 1976. The serum PCB levels in females were 11% higher than in the males in 1976 and 50% higher in 1979. These elevated levels were related initially to the women's employment as capacitor sealers (solderers) and in salvage and repair, jobs with relatively high exposure levels, and subsequently perhaps to a diminished PCB metabolism compared with that of males. The association of serum PCB level and/or exposure and reduced FEV_1/FVC in females in 1976 appeared as an isolated finding, and no other correlation with spirometry in males or females was found.

The present study provided no compelling evidence that PCB exposure, as measured by exposure category or serum PCB levels, was correlated with the occurrence of persistent spirometric abnormalities. The restrictive impairments observed in 1976 were transient and were interpreted in terms of inadequate expiratory effort rather than pulmonary fibrosis. The past histories of respiratory illness and symptomatology, and the observed obstructive impairment by spirometry appear most likely to be coupled with heavy smoking, a complex of industrial exposures both prior to and during employment,¹¹ and rural upstate New York demographic factors.^{12,13} Our 1976 data, however, are suspect and this study serves to emphasize the importance of nurse/technician training in the conduct of spirometry.

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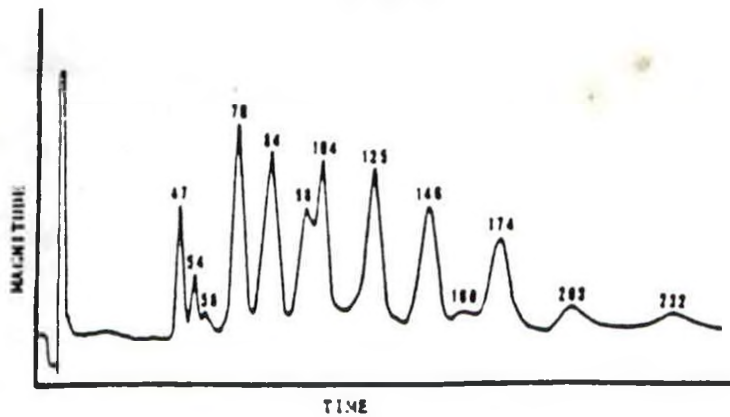


FIGURE 1 - CHROMATOGRAM FOR AROCLOR 1254 USING AN ELECTRON CAPTURE DETECTOR.

A partial list of laboratories available for PCB analysis is provided in Table IV-1.

C. Handling PCB Materials

Detailed information on the handling and the exposure to PCBs should be obtained from the GE-Pittsfield Medical Center (Building 11).

General handling information is as follows:

- Always wear rubber or vinyl gloves.
- Wear a face shield or safety glasses as appropriate when handling hazardous material or drilling.
- Wear disposable shoe covers and coveralls when handling large quantities of PCB-containing material.
- Wear an approved respirator as specified by the Medical Director.
- Do not touch or contaminate anything to be eaten.
- If skin is contacted with PCBs, clean off with paste-type waterless hand cleaner and wipe off with paper towels. Dispose of towels as a PCB solid waste (refer to Section VI of this manual).
- If PCBs get in the eyes, flush with water.
- Report any exposure or contact with PCBs to the Medical Center.

GENERAL ELECTRIC
PITTSFIELD, MASS.

PCB INFORMATION AND
COMPLIANCE MANUAL

ISSUED: August 1982
BY: JM Rhodes
REVISED: April 1983

PCB YEARLY SALES TOTALS
GENERAL ELECTRIC - ALL LOCATIONS
ALL PCB PRODUCTS
1954 - 1977

1954

9,799,459 lbs

1955

10,779,019 lbs

1956

13,711,535 lbs

1957

10,375,310 lbs

1958

8,813,870 lbs

1959

9,639,679 lbs

1960

9,849,831 lbs

1961

8,929,560 lbs

1962

7,743,100 lbs

1963

8,267,202 lbs

1964

10,064,525 lbs

1965

14,422,371 lbs

1966

16,658,107 lbs

1967

15,258,874 lbs

1968

15,243,031 lbs

1969

11,472,988 lbs

1970

13,384,352 lbs

1971

9,349,428 lbs

1972

11,841,805 lbs

1973

13,688,365 lbs

1974

12,905,681 lbs

1975

12,888,722 lbs

1976

8,858,605 lbs

1977

3,105,225 lbs

Total All Years: 267,050,689 lbs