NOT COMPLETE see page 3

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Section A
Transformer Askarel

I. Introduction

The term "askarel" as defined by IEEE, ASTM and the National Electrical Code generally describes a broad class of non-flammable synthetic chlorinated hydrocarbon insulating liquids widely used in transformers, reactors and accessory equipment operated at power frequencies. Askarels of various compositional types are in use. (For the general properties and types see ASTM D-2283.) Under arcing conditions the gases produced, while consisting of predominantly non-combustible hydrogen chloride, can contain varying amounts of combustible gases depending upon the askarel type.

This manual describes the operating characteristics of transformer askarel liquid insulation and how it differs from mineral oil. Appropriate handling and disposal procedures for both scrap askarel liquid and impregnated solid materials are given in accordance with the guidelines recommended by the American National Standards Institute.

The information is based on facts gathered by Monsanto over 40 years as a producer of askarel, plus knowledge gained from the experience of transformer manufacturers and users. This guide outlines the very simple maintenance required for askarel fluid in "modern" transformers and offers suggestions for sealing and maintaining askarel in old units. By following this guide, we believe users will obtain maximum service from askarel insulation with a reasonable minimum of maintenance. If questions arise relating to the designing and building of transformers, these should be referred to regular transformer suppliers.

Monsanto gratefully acknowledges the assistance, guidance and the contributions of certain data by the following:

Edward L. Raab – General Electric
Dr. T. K. Sloat – Westinghouse Electric

Other brand names used by electrical manufacturers to designate transformer askarels used in their products include:

Asbestol**
Chlorextol***
Inerteen
No-Flamol
Saf-T-Kuhl

Westinghouse Electric Corporation uses their brand name, Inerteen.**

II. History of Trade Name Types

"Askarel" is the generic name for the non-combustible liquid insulation and coolant first used by General Electric Company in 1932 for their Pyranol* brand name fire-resistant transformers.

~~Other brand names used by electrical manufacturers to designate transformer askarels used in their products include:~~

~~Asbestol**~~
~~Chlorextol***~~
~~Inerteen~~
~~No-Flamol~~
~~Saf-T-Kuhl~~

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**Trademark of Carbola Chemical Company, Inc.
***Trademark of Allis-Chalmers

Whatever the trademarked brand, the askarel contains chlorinated biphenyl – one of the best liquid insulations developed by science. This inert material is chemically stable, fire-resistant, heat stable, non-corrosive, and has high dielectric strength under the operating conditions encountered in transformers.

In addition to manufacturing Aroclor® (chlorinated biphenyl), Monsanto also mixes this dielectric fluid with chlorobenzenes to produce the presently used Inerteen and Pyranol blends described in Table I.

**Trademark of Westinghouse Electric Corporation

*Trademark of General Electric Company
~~**Trademark of Carbola Chemical Company, Inc.~~
~~***Trademark of Allis-Chalmers~~
®Registered trademark of Monsanto Company

Table I
The Composition of Transformer Askarels

	Method ASTM D 2283		
	Type D	Type E	Type K
Trade Names	Inerteen 54201KA Inerteen 70-30	Inerteen 54201CM Inerteen 100-42	Pyranol A1383B
Ingredients (% by wt.)			
Aroclor® 1254, pentachlorobiphenyl	70	–	48 to 60
Aroclor® 1242, trichlorobiphenyl	–	100	–
trichlorobenzene	30	–	40
tri-tetrachlorobenzene	–	–	55 –
phenoxypropene oxide scavenger, diepoxide			
scavenger	0.18	0.18 to 0.22	0.115 to 0.135

*Method ASTM D-2283 (Epoxide scavenger)

ASTM Method D-2283, titled *"Chlorinated Aroli... ic Hydrocarbons (Askarels) For Transformers"*, also lists the composition of all transformer askarels used at various times since 1932.

Monsanto manufactures similar transformer askarel fluids in England where the trade name Pyroclor is used.

III. Interchangeability

In general all transformer askarels are interchangeable. However, it is suggested that the transformer manufacturer be consulted prior to mixing in significant proportions or total substitution.

IV. Official Transformer Askarel Shipping Specifications

The official shipping specifications for the three modern transformer askarel fluids are shown in Table II.

V. Ordering Instructions

Monsanto's current policy is to sell askarel transformer fluids only to transformer manufacturers. Others interested in these fluids should contact the manufacturers of askarel transformers and not Monsanto. The transformer name plate indicates the transformer maker and usually gives sufficient data to identify the specific askarel fluid used.

VI. Stability

Askarel liquid insulation is highly pure, fire-resistant liquid made under close chemical control to meet the exacting specifications as shown in Table II. It does not vary in composition like the commercial range of mineral oils.

Askarel insulation must never be mixed with mineral oil. Over two percent of mineral oil by volume in askarel begins to lower its fire resistance.

Askarel does not deteriorate when exposed to air, heat, hot metal; it does not break down over long use to form conducting or corrosive chemicals; it does not oxidize or sludge. Askarel will remain perfectly stable year after year unless broken down by severe electrical discharge.

In modern transformers, the only real "enemy" of askarel is contamination by water. Keeping askarel water-free will insure long-time service.

MONS 075254

Askarel is heavier than water. If water gets into askarel insulation, only

Table II

Official Transformer Askarel Shipping Specifications

Specification Properties	General Electric Co. Transformer Pyranol A1383B* ASTM D2283 Type E	Westinghouse Transformer Inerteen 54201KA or Inerteen 70-38 ASTM D2283 Type D	Westinghouse Transformer Inerteen 54201CM or Inerteen 100-42 ASTM D2283 Type E
Color, APHA	150 max.	150 max.	60 max.
Condition	Clear	Clear	Clear
Water content, ppm (ASTM D1533-60)	30 max.	30 max.	35 max.
Acidity, mg KOH/g (ASTM D974-55)	0.014 max.	0.014 max.	0.01 max.
Dielectric Strength, 25°C, 0.1 in. gap (ASTM D877-49)	35 KV, min.	35 KV, min.	35 KV, min.
Dielectric Constant, 100°C, 60 Hz (ASTM D924-49)	~~4.2 to 4.6~~	4.2 to 4.5	4.7 to 4.9
Volume Resistivity, 100°C, 500 volts DC 0.1 inch gap, 10^9 ohm-cm (ASTM D1169)	100	100	100
Inorganic chlorides, ppm (ASTM D1821 and G.E. Method E4C418)	0.10 max.	0.10 max.	0.05 max.
Refractive index, 25°C (ASTM D1807)	~~1.6060 to 1.6070~~	1.6153 to 1.6173	1.6240 to 1.6260
Viscosity at 37.8°C (ASTM D88-56) Saybolt Universal Seconds	~~38 to 49~~	56 to 61	82 to 92
Pour Point °C (ASTM D-97-57)	~~-38~~	-30 or lower	-17 or lower
Specific gravity 25/15.5°C (ASTM D1810)	~~-43~~ or lower	1.518 to 1.528	1.381 to 1.392
Burn point (ASTM D92)	1.515 to 1.526	None to boiling	None to boiling
Distillation range (ASTM D20-56) corrected for stem and barometric pressure	None to boiling ~~1st drop 240°C min.~~ ~~35% 240 to 270~~ ~~55% 290 to 330~~ ~~65% 355 to 380~~ ~~95% 375 to 395~~	1st drop 200°C min. 35% below 270°C 90% 379 to 394	10% 325°C min. 90% 360 max.
Fixed chlorine	~~58.5 ± 6%~~	55.6% min.	43 ± 0.5%

After heating with aluminum for 6 hrs. at 200 to 220°C, the aluminum must not be corroded on either visual or weight inspection and the askarel should meet the following specifications:

Corrosion test			
Color, APHA	200 max.	200 max.	200 max.
Acidity, mg KOH/g	0.014 max.	0.014 max.	0.01 max.
Inorganic chlorides ppm	0.15 max.	2.0 max.	0.15 max.
Condition	Clear	Clear	Clear
Scavenger content	0.115 to 0.135% Diepoxide	0.18 to 0.22% phenoxy propene oxide	0.18 to 0.22% phenoxy propene oxide
Typical Properties			
Coefficient of Thermal Expansion (ASTM D1903), $cm^2/cm^2/C$	0.0007	0.0007	0.00068
Arc formed gases	Askarels of various compositional types are used. Under arcing conditions the gases produced, while consisting predominantly of non-combustible hydrogen chloride, can include varying amounts of combustible gases depending upon the askarel type. Insulation systems incorporating these askarels and cellulosic or other organic materials may, when arced, produce gaseous mixtures which are moderately flammable. As a precaution, such gases should be removed from the askarel by bubbling dry nitrogen through the askarel and flushing the gas space with dry nitrogen before any work is performed on the apparatus.		

*Method ASTM D2283 pending

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a tiny amount (approximately 125 ppm) dissolves – the rest floats on top. Askarel is very insoluble in water, only about 200 parts per billion of askarel dissolve in water, at normal temperatures.

VII. Precautions When Handling Drums, Tankcars, and When Opening Transformers

The American Institute of Electrical and Electronic Engineers Guide No. 76, December, 1968 has been revised to give more detailed instructions and guidance *"For Acceptance and Maintenance of Transformer Askarel in Equipment"*. This guide is published by the Institute of Electrical & Electronics Engineers, Inc., 345 East 47th Street, New York, New York 10017.

The following are significant precautions:

A. Keep Dry During Handling:
In handling, storing, sampling and inspecting askarel – and in operating askarel transformers – take every precaution to guard the askarel insulation from exposure to high humidity and moisture contamination. Keep 5, 30 or 55 gallon drums of askarel dry; lay stored drums on their sides with the bung at the highest point from floor to keep water off the drum head (which can be sucked into the askarel by the drum "breathing"). This precaution is not necessary when drums are stored indoors, which is the preferred place for storage.

To avoid leakage the drums used for askarel are of heavy construction. Sixteen gauge metal is used, with special rim seal and bung construction. The drums should be drained as completely as possible and then flushed twice with kerosene type solvent to remove all of the askarel. Accumulated liquids and washings should be collected and should be incinerated at high temperatures, e.g., about 2000°F, to destroy the polychlorinated biphenyls (PCBs). See Section A, VIII.

Tank cars used to transport askarels are in exclusive service and not used interchangeably for other products. All cars must be unloaded through the top (dome fitting) either by pumping or with controlled pressure using dry air or dry nitrogen. If nitrogen has been used for unloading it is necessary to advise the shipper so that when the car returns the nitrogen can be replaced with dry air before any one may enter the car. If the car is to be unloaded by pumping it will be necessary to use a dryer on the air intake line to remove moisture.

All tank cars are fitted with steam coils, which are available for unloading under extreme low temperature conditions.

Convenient handling and pumping temperatures and the related approximate viscosity ranges are given in Table III.

B. Use Ordinary Personal Precautions:
Transformer askarel has been made, handled, and used for over 40 years. It can be handled safely with recommended precautions. If accidentally spilled on hands, no serious skin irritation will occur. However, liquid askarel has a solvent action (similar to paint

Table III

Product	Unloading, Handling and Pumping Temperature °C	Approximate Viscosity SUS
Pyranol A1383E	20-55 ~~15-40~~	100 - 40
Inerteen 54201KA	20 - 55	100 - 40
Inerteen 54201CM	35 - 75	100 - 40

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thinner) on the fats and oils of the skin and prolonged contact may lead to drying and chapping of the skin.

In case of contact, wash the skin with soap and water; remove and dry clean saturated clothing. Clean up spills with rags, sawdust and absorbent clay. Eye contact may result in painful irritation but no permanent damage to tissues. If askarel gets in the eyes, flush with large amounts of water. As with all eye first aid, refer to a physician. To relieve irritation, physicians have used an opthalmic anesthetic solution as well as opthalmic cortisone acetate solution, or castor oil.

Infrequent exposure to askarel vapors will not cause ill effects. However, prolonged exposure to high vapor concentrations should be avoided. If hot askarel must be handled in a closed or confined area, provide the area with mechanical exhaust ventilation – or wear an organic cartridge respirator approved by the U.S. Bureau of Mines.

C. Precautions On Opening an Askarel Transformer:
Askarels of various compositional types are used. Under arcing conditions the gases produced, while consisting of predominantly non-combustible hydrogen chloride, can yield varying amounts of combustible gases depending upon the askarel type.

Insulation systems incorporating these askarels and cellulosic or other organic materials may, when arced, produce gaseous mixtures which are moderately flammable. As a precaution, such gases should be removed from the askarel by bubbling dry nitrogen through the askarel and flushing the gas space with dry nitrogen before any work is performed on the apparatus.

VIII. Avoid Environmental Pollution

Transformer askarels contain polychlorinated biphenyls (PCBs) which have been used in the United States and elsewhere over the past 40 years for many industrial and consumer applications. During the past several years evidence has accumulated to indicate that PCBs are widely dispersed throughout the environment and that they can have adverse ecological and toxicological effects.

The United States Government's Interdepartmental Task Force on PCBs, Com-72-10419, in their March 20, 1972 report titled, *"Polychlorinated Biphenyls and the Environment"*, recommended restricting PCBs to use in capacitors and transformers.

This report is distributed by the National Technical Information Service, U.S. Department of Commerce, Springfield, Virginia 22151.

A document titled, *"Guidelines for Handling and Disposal of Capacitor and Transformer Grade Askarels, Containing Polychlorinated Biphenyls"*, has been prepared and is available from the American National Standards Institute, Committee C107, 155 East 44th Street, New York, New York 10017.

The scope, objectives and the composition of this committee are:

ANSI Committee C107 MONS 075257

Scope:
Procedures and guides for safe use, maintenance and disposal of askarel and askarel-soaked materials used in electrical equipment.

Objectives:
1. Source of technical information and advice for Federal, State, local authorities and all others concerned.
2. Encourage development of suitable disposal facilities and keep all concerned informed.
3. Serve as the advisory group for United States participation in international organizations: CEE, IEC, CIGRE.

Composition:

Organizations active in or represented by this ANSI committee include: National Electrical Manufacturers Association, Electronic Industries Association, Institute of Electrical and Electronic Engineers, American Society for Testing and Materials; Electric Light and Power Association; Certified Ballast Manufacturers Association; Environmental Protection Agency; Office of Environmental Affairs; General Services Administration; National Bureau of Standards; Department of the Army; Rural Electrification Administration; Division of Environmental Research, TVA; American Public Power Association, Water Pollution Control Federation; Food and Drug Administration; National Fire Protection Association; Underwriters Laboratories; and several sections of the U.S. Department of Interior.

The following are pertinent excerpts taken from the ANSI Guidelines for askarel transformers:

1. LABELING ASKAREL TRANSFORMERS
"All new askarel transformers should be labeled:

Caution

The Insulating Liquid In This Transformer Contains Polychlorinated Biphenyls (PCBs). Care Should Be Taken To Prevent Entry Into The Environment. In Case Of Malfunction Or Leaks, Consult The Instruction Manual Or The Manufacturer.

The transformer manufacturer should make similar warning labels available for use on previously installed transformers."

2. DISPOSAL OF LIQUID AND SOLID WASTES
"Disposal of askarel fluid and askarel-soaked materials must be accomplished by means in which there is no significant release of askarel to the environment. At present, disposal is accomplished by carefully controlled high temperature incineration of liquids and soaked software; and by controlled dry land-fill burial of apparatus and other hardware from which askarel has been previously drained and washed.

"Present knowledge indicates that proper incineration should involve a suitable balance between dwell time and temperature in the incinerator plus oxygen availability and finally suitable scrubbers to remove HCl formed; e.g., (1) two-second dwell time at approximately 2000°F and 3% excess oxygen in stack gas; (2) 1-1½ second dwell time at 2700°F and 2% excess oxygen in stack gas."

The ANSI Guide lists the locations of facilities that conform with the above requirements. Monsanto has such an incinerator at the W. G. Krummrich Plant, Department A-248, Sauget, Illinois 62201, where arrangements can be made for scrap askarel liquid disposal for a modest fee, currently 3 cents per pound. For disposal of solid scrap a controlled dry land-fill can be used where permitted by Federal, State and local regulations.

3. CONDITIONING OF NEW OR RECYCLED ASKAREL
Conditioning of new askarel or recycled askarel requires Fuller's earth treatment. The spent Fuller's earth in cartridges or bags when replaced should be allowed to thoroughly drain over drip pans to remove as much liquid askarel as possible. The cartridge units of steel mesh construction should be placed in the "Steel Contaminated with Askarel" container for disposition. Cloth bags filled with Fuller's earth should be placed in the "Scrap Burnable Askarel Waste" container for disposition.

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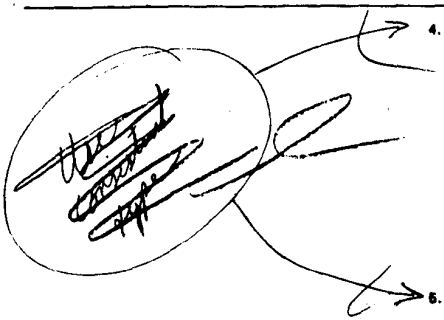

4. TEARDOWN OF TRANSFORMERS FOR REPAIR OR SCRAP

a. Drain all askarel from the unit either into a holding tank for reuse or into the drum labeled "Scrap Askarel" for disposition, then allow sufficient time for all the askarel to drain from the core and coils.

b. Remove the core and coil assembly from the transformer and place it on the floor. Sufficient absorbent material should be placed on the floor to absorb any askarel fluid that still drips from the transformer.

c. Place all materials in the appropriate salvage containers during the dismantling for later disposition.

d. All used materials, including rags, sawdust, tape, etc., regardless of quantity, should be put into the appropriate containers for disposition.

5. TRANSFORMER DISPOSAL

The ultimate disposal of an askarel-filled transformer may be accomplished in either of two ways.

a. Complete drainage and dismantling with the proper disposal of the askarel liquid and askarel-soaked components as described above.

b. Disposition of askarel transformers by means of junk or scrap dealers should be avoided unless a transformer is first drained, followed by soaking of the interior with a suitable solvent, such as kerosene. Accumulated liquids and washings are to be disposed of as described earlier.

IX. Expected Service Life

Manufacturers indicate that properly designed and installed askarel transformers are expected to give trouble-free service for at least 30 years. Since their introduction in 1932, the manufacturers report finding the overall failure rate to be less than 0.5% for all units under test and service conditions. The Edison Electric Institute's report (1956-1958) on their member utilities publishes the failure rate for askarel transformers as 0.13 per hundred banks per year.

Mr. Frank M. Clark, who invented transformer askarels at the General Electric Company in the early 1930s, made the highly pertinent comment based on his many years of experience with G.E. Pyranol (askarel type) transformers that –

"The important thing is to keep them dry – otherwise leave them alone".

These words of wisdom became especially applicable in more recent years when welding shut rather than gasketing became the main method of sealing askarel transformers. These units are sold with the understanding that the liquid is in a normally hermetically closed system.

X. General Characteristics of Transformer Askarel Fluid

Appreciation of the following characteristics, as given in the IEEE Guide, leads to understanding the reasons for selecting dielectric breakdown voltage and moisture as the prime practical tests to judge the quality of transformer askarel fluid. Also, due to these characteristics the power factor of transformer askarel will be normally much higher than the corresponding values for mineral oil.

In comparison to mineral insulating oil, askarel is a relatively polar material; i.e., its molecules are dipoles, free to rotate around their axes and responsive to orientation by electrical forces. Askarel also exhibits a much higher dielectric constant and capacitance than insulating oil, and these differences must be kept in mind when interpreting electrical test data.

Because it is relatively polar, and possesses high solvency power, askarel is much more electrically sensitive than mineral oil to traces of extraneous soluble polar materials, and consequently the choice of

ither change them marked line to read

nds the over-all failure rate to be less than 0.5% for all

ither change them marked line to read

nds the over-all failure rate to be less than 0.5% for all

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constructional materials destined for use in askarel is very critical. This sensitivity is reflected in the power factor and resistivity (specific resistance) of the askarel.

It is important to note that, with the exception of water, the dielectric breakdown voltage of askarel is not generally adversely affected by many of the soluble polar materials to which its power factor and resistivity (specific resistance) are so sensitive. In fact, the dielectric breakdown voltage of askarel is somewhat greater than that of insulating oil. Therefore, the values assigned these dielectric fluids in newly supplied transformers are 30 KV min. and 26 KV min., respectively.

As with insulating oil, askarel must be kept dry. It can pick up moisture from exposure to humid atmosphere. Under similar conditions of exposure, askarel can pick up nearly twice as much moisture when measured on a parts per million weight basis.

XI. Sampling Transformer Askarel Fluid

The following precautions about sampling are quoted from the IEEE Guide.

"Representative samples, whether of the complete contents or only parts thereof, are extremely important from the standpoint of evaluation of the quality of the product sampled. Obviously careless sampling procedure or contamination in the sampling equipment will result in a sample that is not truly representative. This generally leads to erroneous conclusions concerning quality and incurs loss of time, effort, and expense involved in securing, transporting, and testing the sample. It is strongly recommended that all of the procedures and precautions outlined in the latest revision of ASTM D 923 (Sampling Electrical Insulating Liquids) be followed.

"Because of the high specific gravity (relative density) of askarel (greater than 1), water and some other impurities are most likely to be found at or near the surface. The top sample, therefore, is considered to represent the worst condition."

XII. Evaluation of Askarel Received in New Equipment

Some users of askarel equipment find it desirable to make "as received tests" on all equipment. It is quite common to use the dielectric breakdown voltage test and visual appearance as the most significant tests. If suitable equipment and trained personnel are available additional information may be obtained from the power factor, color, and moisture content tests.

In sampling askarel contained in apparatus extreme care must be exercised in order to obtain a representative sample. ASTM Method D 923 should be followed.

New equipment with askarel exhibiting the following characteristics is considered acceptable:

		ASTM Methods
Dielectric Breakdown Voltage	30 KV min.	D 877
Color	300 max. (Straw color)	D 2129
Condition - Visual	Clear	D 1702
Water Content	35 ppm max.	D 1533
Power Factor at 25C	*	D 924, D 150

*"The power factor of askarel taken from new transformers, reactors and accessory equipment can reflect the presence of moisture, dissolved polar compounds, or other contaminants and may vary with the type of equipment from which the sample was taken due to the different ratios of liquid-to-solid insulation and to the high solvency power of the askarel. Given an acceptable water content and dielectric breakdown voltage of the askarel as indicated above, a high power factor seldom impairs the serviceability of the askarel within rather broad limits and is

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indicative of the degree of extraneous soluble polar materials present.

Recognizing the possibility of a wide range of power factors being recorded for askarel in new equipment, it is difficult to establish a single limit which would be acceptable to both suppliers and users for all applications. However, as a broad guide, power factors up to about 10% at 25C and 60 cycles per second (hertz) do not in general indicate any abnormal contamination providing that the other criteria (water content, dielectric breakdown voltage, etc.) are met. Much higher power factors may indicate excessive contamination or the misapplication of the solid materials used in manufacture in contact with the askarel and should be investigated.

XIII. Dielectric Breakdown Voltage – Moisture Relationship

The dielectric breakdown voltage of askarel is highly sensitive to excess moisture; not sensitive to ordinary dissolved polar materials. While the dielectric breakdown voltage can also be lowered by severe arcing, askarel turns noticeably black or has particles of sooty carbon floating in it if arcing has occurred. Then the transformer should be repaired and the askarel replaced.

If the dielectric breakdown voltage is checked periodically and decreases significantly – this indicates moisture pick-up, arcing, or both. When the dielectric breakdown voltage has dropped to 26 KV or less, an analysis for water is necessary. If water is found in excess of 40 ppm at room temperature, its source should be located and corrections made.

When the moisture content approaches 125 ppm (saturation level at room temperature), the dielectric breakdown voltage of askarel drops below the value required for efficient insulating. The moisture content should not be allowed to rise over 70 ppm, sampled at operating temperature. If the moisture content is found to be in a satisfactory range and the dielectric breakdown voltage is low, the transformer manufacturer should be consulted.

Table IV shows the relationship of dielectric breakdown voltage vs. moisture and Table V indicates the approximate water solubility limits in askarel and mineral oil.

Table IV
Relation of Dielectric Breakdown Voltage to Amount of Dissolved Water in Askarel and Mineral Oil (ASTM D877)

Water Content (PPM)	Breakdown Voltage (~~ASTM~~) Askarel	Mineral Oil
0	70 KV	50 KV
20	55	39
40	47	30
60	40	26
80	38	22
110	10	6

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Table V
Approximate Solubility of Water in Transformer
Askarel and Mineral Oil

°C.	°F.	Amount of Water (PPM) Dissolved	
		Askarel	Mineral Oil
-30	-22	6	8
-20	-4	16	10
-10	14	28	13
0	32	41	20
10	50	65	33
20	68	94	58
30	86	128	85
40	104	170	130

XIV. Turbidity

. . . may be the visual sign of undissolved water, or may indicate dirt. Cloudiness may also result from cold precipitation of tin tetraphenyl "scavenger" that was used in the earlier Pyranol transformers. This scavenger begins to come out of solution around 15°F above zero. To redissolve it requires heating to 150-200°F and agitation.

High dielectric breakdown voltage will quickly indicate that any turbidity present is not moisture; that the insulating efficiency of the askarel is still excellent. However, if the dielectric strength is below 26 KV, moisture should be determined, using the Karl Fischer method (ASTM D1533-60).

The dielectric breakdown voltage test for askarel serves primarily as an indicator for moisture. It is by far the most important maintenance test for transformer askarel.

XV. Check Points for Maintaining Askarel Insulation

A. General Considerations:

Modern askarel transformers with welded construction or silicone or Viton* gaskets (hand hole-cover, switch and terminal compartment covers) and with properly constructed bushings require little or no maintenance. With properly constructed transformers, annual or semi-annual visual inspection and dielectric breakdown voltage test of the askarel fluid should suffice for routine maintenance checking over many years of service.

However, many askarel units were installed in the early 1930s – before the development of some of the better modern gasketing materials and before improved designs were developed for sealing out moisture. Such early units should be, and can be, modernized. Leaky or deteriorated gaskets should be replaced. If the askarel has become contaminated, it should be reconditioned. At the same time, a general clean-up of the unit and possible refinishing may be desirable.

If it is not convenient to take an old transformer out of service for general repairs, leaky gaskets can be sealed temporarily by painting over the leaky area with epoxy cement.

A survey of users indicates a good number of early-built askarel transformers (over 20 years old) are kept in continuous service in critical installations by the following steps (instead of modernization).

The operating units are equipped with compound pressure gauges for reading pressure above and below atmospheric. Positive

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*Trademark of E. I. DuPont DeNemours & Company, Inc.

pressure is maintained on the shell by introducing nitrogen at 2 to 3 pounds above atmospheric. Regular workmen in the area daily record the temperature and pressure. If a sudden pressure drop is noted more nitrogen is introduced and the gaskets are checked for leaks with soap solution. Leaks are sealed by applying epoxy cement.

B. Modern Sealing Procedures:
Transformer purchasers should specify the following modern techniques for sealing:

1. Welding Construction: Covers, radiator connections, switch and terminal housings, instrument connections, etc. should be welded.
2. Bushing Connections: A number of bushings have been developed to obtain a proper seal for the electrical connection through the tank wall. They are classified as follows:
   1) Welded Type - (Bushing flange welded to tank wall)
      a. Cast resin bushing with a molded seal to the bushing stud and external stainless steel or copper flanges.
      b. Rolled flange bushing with the metal to porcelain seal at the cap and flange made by being rolled into grooves in the porcelain over silicone rubber rings. The seal between the cap and stud is made by welding.
      c. Porcelain or glass bushings with metal to glass or metal to porcelain seals.
   2) Bolted Type - (Bolted to tank wall)
      a. Cast resin bushings with either cast or metal flanges containing recessed gasket grooves.
      b. Porcelain or glass bushings with flanges containing recessed grooves or gasket stop.

The gaskets may be either of rectangular or circular cross-section, usually ¼ inch thick. Bushings with recessed grooves are suitable to use with cork, cork-nitrile rubber combinations or nitrile rubber as well as gasket materials such as silicone or Viton.

3. Small Size Connections: When not possible to weld, small size connection seals should be made with Flexitallic* stainless steel rings. The surfaces must be machined and parallel. The filler between the steel laminations of the Flexitallic ring should be either silicone or Viton.
4. Gaskets for Hand-Hole Covers: Modern design specified silicone gaskets. Such gaskets must be retained in a groove. The groove preferably is machined into the flange or cover. However, it can also be formed by welding concentric steel strips to the flange or the cover. Generally the gaskets should be 5/16 to 1/2 in. thick for covers, depending on the depth of the groove or stop. A rectangular cross-section is usually used.

   The silicone material should be Dow-Corning No. 50 Silastic** or equivalent. This is a low compression set material. For best sealing 20-25% compression is recommended, with ample clearance in the groove or stop to allow for this compression.

   No cement is required. With reasonable care the gasket is removable without damage and is reuseable.

   Silastic 50 is slightly swelled by askarel which contributes to the tightness of the seal. It is not deteriorated by askarel fluid or vapors. It resists weathering and it is thermally stable and

*Trademark of Flexitallic Gasket Company
**Trademark of Dow Corning

flexible at all operating temperatures. It is an excellent moisture barrier.

NOTE: Dow-Corning, Midland, Michigan will supply a list of Silastic 50 gasket fabricators to all transformer manufacturers or users. They will also furnish technical data. See Appendix K: Seals, Properties and Procurements.

C. The Older Sealing Arrangements:
The older type gaskets consist of either cork or cork-nitrile rubber combinations or straight nitrile rubber.

1. Cork-Nitrile Combinations: Covers for the main tank, hand-holes, switch and terminal chambers, relief diaphrams, etc., are held in place by studs welded to the flange or by bolts. The gaskets are cut with openings and placed over the bolts. Often Shellac (Westinghouse Style No. 1150419, or General Electric Company's Glyptal* 1276) is used to cement the cork to the flanges.

   The following is recommended for sealing with the cork – nitrile rubber combinations:

   Use Armstrong NC-757 cork-nitrile material or equivalent. The gasket can be cut from a single sheet or by scarfing strips of the material. A convenient method for joining strips is to make a Keystone Type joint. For this purpose, Westinghouse, Sharon, Pennsylvania, offers their gasket cutter Style No. 328 B614 G01, (about $15).

   The joints – and also the gasket – should be cemented to the flange, using one of the above cements. Excess cement should not be allowed to reach the interior of the transformer.

   After installation and bolting, the outside edge of the gasket should be coated thoroughly with epoxy cement to increase weather resistance.

   This epoxy cement is a paste to which a curing catalyst is added immediately before use. Typical are:

   a. Epoxy Patch Kit #1-C
      Hysol Corporation, Olean, New York
   b. Scotchcast** Resin #4
      Minnesota Mining & Manufacturing Company
      St. Paul, Minnesota
   c. Adhesive A-1 and Activator Type B
      Armstrong Products Company
      Argonne Road, Warsaw, Indiana
   d. Adhesive 9860-1, Synthetics Organic Company, Cleveland, Ohio, used with activator diethylene triamine (Carbide and Carbon Chemical Company)

2. Straight Nitrile Rubber: When straight nitrile rubber was originally used, invariably the gasket was recessed in a groove. This was to prevent gasket flow and to protect the material against excessive compression. Although this type seal was not cemented, the nitrile rubber gasket is not reuseable.

   Since grooves or stops have already been provided for the nitrile rubber seal, Silastic 50 can be easily substituted and is recommended. This conforms with modern practice.

XVI. Periodic Fluid Inspection and What Checkpoints Mean

On a regular schedule – at six, nine, or twelve-month intervals – make a simple visual inspection of your askarel insulation and run a dielectric breakdown voltage check.

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**Trademark of Minnesota Mining & Manufacturing Company

A. Visual Inspection:

Askarel is a clear, faint-yellow liquid. After long-term use this color may gradually intensify to light brown. The fluid should remain clear and free from turbidity or cloudiness.

Any color change – such as to a green, red or blue cast – indicates extraction of impurities (color materials) from the solid insulation. If a distinct foreign color pick-up is noted, check the complete range of electrical characteristics and notify the transformer maker. Blackening of the askarel may indicate an arcing condition. Other color changes alone are not danger signals since the dielectric breakdown voltage is not likely to be impaired.

B. Dielectric Breakdown Voltage

If the dielectric breakdown voltage has decreased significantly from the last inspection, or if it has gradually decreased below 26 KV range (at 25°C) – RUN A CHECK FOR MOISTURE. Use ASTM D1533 (Karl Fischer Method).

The dielectric breakdown voltage of askarel is the major indicator to the operating efficiency of your liquid insulation. Besides the visual inspection tests, dielectric breakdown voltage is the only test necessary to run on a routine basis. Well-sealed askarel transformers have service records of 25 to 30 years on the original askarel.

XVII. Inspection Checklist

1. If askarel is clear – even though darkened to light brown, has no sediment or turbidity, has dielectric breakdown voltage over 26 KV – give it the inspection "OK".

2. If askarel is clear, but has foreign color of blue, green, red . . . it is "extracting color" from internal materials. This is not, of itself, an operating hazard when the dielectric breakdown voltage stays over 26 KV and moisture remains low. However, this rare occurrence calls for checking into the condition of the interior construction and consulting the transformer maker. However, when sampling the fluid care should be taken to avoid getting color into the askarel from paint that may be inside or outside of the sample valve.

3. If the moisture content is found to be above 70 ppm at operating temperature, then sampling should be done at more frequent intervals to establish a possible trend, particularly on outdoor installations.

4. If askarel is clear, but dielectric breakdown voltage drops to 22 or lower KV, and moisture rises over 80 ppm when sampled at operating temperature . . . the askarel is ready for simple "refining". If the moisture is near the saturation level (about 125 ppm at room temperature) a thorough inspection should be made for water droplets in the transformer tank, and even for "globules" of water floating on the askarel surface. If found, the transformer manufacturer should be consulted for reconditioning both the transformer and the fluid.

5. If askarel is dark brown to black, if black particles of carbon are seen, and dielectric strength is low . . . the askarel has been broken down by arcing. It cannot be refined and should be removed and incinerated under proper conditions. (See ANSI Committee C107 report on *Use and Disposal of Askarel and Askarel-Soaked Materials*. 115 East 44th Street, New York, New York 10017).

~~RICH — Shouldn't that say 5???~~
~~these five simple inspection~~

five/

If any of these ~~four~~ simple inspection tests appear out of the ordinary or the relationship between appearance and test values is abnormal, contact your transformer supplier for a complete analysis.

Whenever a sample is to be shipped to Monsanto, please follow the directions shown under: "SAMPLING ASKAREL".

XVIII. Contamination in Transformers

Moisture, particulate matter and arced decomposition products are known to be serious contaminating influences on transformer askarel.

The power factor test normally used for the detection of contamination in *mineral oil filled* transformers is of little use for this purpose in askarel filled transformers, due to the extreme effect of extraneous soluble polar materials. This increase in power factor as illustrated in Table VI has no adverse effect on dielectric breakdown voltage.

Table VI
Effect of Common Insulation Materials on Power Factor and Dielectric Strength
(Heat Aged 96 Hours in Askarel at 100°C.)

	Askarel After Exposure	
Material Immersed	Power Factor, Percent at 60 cyc., 100°C	Dielectric Strength 25°C.
None (control)	1.0	35 KV
Black varnished cloth	85.0	42
Copper	1.5	40
Pressboard	2.0	37
Manila paper	1.5	39
Phenol formaldehyde resins	1.8	41
Shellac	6.0	36
Iron	5.0	39
Synthetic rubber	70.0	39

Similarly, trace contaminants from commonly used construction materials can lower the volume-resistivity of askarel, without affecting its dielectric breakdown voltage. This is shown in Table VII.

Table VII
Effect of Common Insulation Materials on Volume Resistivity of Askarel

Sample	Volume Resistivity x 10^9 ohm-cm (at 100°C., 500 Volts DC., 0.1" gap)
1. New askarel before heat aging	2,000
2. New askarel after heat aging 96 hours at 100°C	1,900
3. After heat aging with 1 sq. inch specimens of:	
a. Phenolic resin tap changer material	1,200
b. Paper	750
c. Grade A press board (tan)	500
d. Grade A press board (gray)	500
e. Grade A press board, laminated strip	400
f. Cotton wrapping 110°C	300
g. Glyptal 1276 cement, cured 48 hrs. at 150°C	100

While trace contamination easily lowers volume resistivity from high levels, it is important to note that heavy contamination (as when arced) does not lower the resistivity below the order of 10^9 ohm-cm. at 100°C.

The different behavior of askarel vs. mineral oil in these respects can be summarized as follows:

High power factor and low volume resistivity in transformer mineral oils are commonly regarded as "danger signals" that the oil has deteriorated and broken down chemically or excessive moisture is present.

This is NOT TRUE of askarel liquid insulation unless the dielectric breakdown voltage is low or the moisture content is high.

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Manufacturers of askarel type transformers point out that it is quite well known that askarel transformers with initial power factor of the askarel fluid in excess of 50% at room temperature and 60 Hz are giving satisfactory service life. However, there needs to be assurance that both dielectric breakdown voltage and moisture are at satisfactory levels and do not show adverse trends.

XIX. ASTM Method For Investigating The Compatibility of Transformer Insulation and Construction Materials in Askarels

This method[2] uses the change of electrical and/or chemical characteristics of transformer askarel resulting from its controlled exposure to insulation and construction materials, in order to evaluate their immediate major "contamination" effect on the askarel fluid. Delayed or long time contamination effects may not be detected.

The method also utilizes various physical tests on the insulation and construction materials after controlled exposure to the askarel to determine the compatibility of these materials with transformer askarel.

Properly proportioned specimens of the insulation or structural materials are immersed in refined askarel for 168 hours at 100 ± 1°C in a forced draft oven. Changes in electrical and chemical properties of the transformer askarel are compared against a control sample of the askarel treated in the same manner, in absence of the test specimens.

Dissipation factor (ASTM D 924) change is one of the criteria used. The askarel fluid is refined by absorbtive treatment to a dissipation factor level of 0.05 max. at 100°C and 60 Hz and 0.01 max. at 25°C and 60 Hz. Corresponding values of the askarel fluid after heating 168 hours at 100°C in absence of a test specimen are 0.075 and 0.02 respectively. The maximum dissipation factor levels suggested for the askarel after heating in presence of the test specimen are 0.20 at 100°C and 60 Hz and 0.04 at 25°C and 60 Hz.

XX. Refining Askarel for Re-Use

A. Filtering Through Dry Blotter Paper to Remove Moisture and Extraneous Particles:

Most operators prefer portable refining apparatus, such as a plate press fitted with a dolly, available from Sperkler, Mundelein, Illinois or General Electric Company, Pittsfield, Massachusetts; or the earthen cartridge filter type available from Industrial Filter Corporation, Lebanon, Indiana. Filter paper liners for the plate press are available from Carl Schleicher and Schuell Company, Keene, New Hampshire and manufacturers of filter presses listed above.

The filter paper must be dried immediately before use. For best results, spread the paper for maximum surface exposure in a hot air circulating oven and heat it for 4 to 6 hours at 110°C.

Circulate the askarel hot (but not over 40°C) through the filter fitted with the dry paper liners.

After filtration the dielectric breakdown voltage of the askarel should be 35 KV minimum.

1. Precautions: Filtering should not be done when the relative humidity exceeds 75%.
2. Any flexible hoses and gaskets on the refining equipment should be lined with or made of materials that will not be softened by contact with askarel fluid. (Materials lined with Silicone, Viton or Teflon* or flexible metal materials are suitable.)

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[2] In process of publication by ASTM, as of this writing.

*Trademark of E. I. DuPont DeNemours & Company, Inc.

Transpose

Table VIII
Guide to Rate of Dissolved Water Removal
By Filtering Askarel Through a Paper Press

Passes Through Paper Press	Water in Askarel PPM
0	115
1	35
2	22
3	18
4	12
5	10
6	10

B. Disposal of Solid Wastes:
The ANSI Guide states that, "All Solid wastes which have been saturated with askarel should be disposed of by the following procedure:
1. The saturated wastes should be placed into leak-proof containers and transported to a supervised dry landfill site meeting State requirements. Alternatively, they can be disposed of by incineration in State-approved facilities.
2. Solid absorbents used for spills can be disposed of uncontained in the supervised dry landfill site; transport to the site should be in closed containers. Alternatively, incineration can be used in accordance with par. B (See Section 4 for facilities)."

C. If the solid insulation of the transformer requires drying, consult the transformer manufacturer or an apparatus service shop, as in such case oven drying is preferred.

D. Earth Treatment for Maximum Improvement of Power Factor and Volume-Resistivity:
We question whether pumping and filtering the fluid solely to achieve a change in power factor or volume resistivity alone is justified in today's ecological climate regarding PCBs. We recommend that in these situations the original transformer manufacturer be contacted.
1. Procedure:
The askarel liquid should be relatively dry prior to the following earth filtration.

As a coating on the filter paper surface use finely divided Attapulgus clay or Fuller's earth dried and activated by heating for 12 hours at 300-350°F immediately prior to use. The amount of earth used should be 0.1 to 0.2 percent by weight on the weight of the askarel to be treated. Askarel weighs about 12.5 pounds per gallon.

To deposit the earth evenly, stir one-third of the earth with a small portion of askarel in a clean container. Pump the mixture through the filter and follow with two more one-third portions. Then circulate askarel taken from near the top of the transformer, pass it hot (not over 55-60°C) through the earth-coated filter and feed back through the bottom transformer outlet. Continue circulation until the fluid is clear and test shows that the electrical properties are fully restored.
2. Effect of Earth on Removal of Scavengers
Only slight and insignificant loss by selective absorption of tin tetraphenyl and epoxides occurs when askarel is refined by treatment with 0.1 to 0.2 percent by weight of earth. To remove significant amounts of the scavengers requires repetitious treatment with much larger amounts of earth.

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~~Table IX~~

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TABLE IX

SET LIKE TABLE VIII

Approximate Relationship Showing the Insignificant Effect of Power Factor and Volume-Resistivity on Dielectric Breakdown Voltage of Transformer Askarel.

Power Factor (60 cyc.) 100°C	Power Factor (60 cyc.) 25°C	Volume Resistivity x 10⁹ ohm-cm (at 100°C, 500 Volts DC, 0.1" gap)	Breakdown Voltage 25°C, 0.1" gap
2%	0.05%	1500	35 KV
55%	0.1%	500	35
15%	0.7%	100	35
20-25%	2.0%	80-70	35
40-50%	–	25	35

FOLLOW FORMAT ON PREVIOUS TABLES

XXI. Cleaning Arced Transformers

If a unit has arced so that the askarel is no longer fit for use, a thorough cleaning of the unit is necessary before refilling with new askarel insulation and returning it to service*. Follow this procedure:

A. Drain out all dark, carbon-contaminated askarel. Arrange to have the scrap fluid incinerated under proper conditions. (See ANSI Committee C107 report.)

B. Carefully brush carbon deposits from internal parts and insulation, using a soft bristle brush making sure that insulation is not damaged.

C. Flush thoroughly using new askarel – *not* an oil, *not* a cleaning solvent.

D. Flush a second time with fresh askarel; drain; then fill to the proper level with new askarel.

E. Energize transformer to warm the fluid for 24 to 48 hours; then circulate the askarel through a filter, returning it to the unit filtered and ready for use.

*This assumes that the cause of arcing has been established and corrections made. When severe arcing occurs, major repairs are usually necessary and the unit rebuilt. This procedure can be applied for flushing out the repaired units.

XXII. Sampling Askarel

Take a sample as close to the top of the liquid surface as possible. Many large askarel transformers have a built-in sampling tube near the surface for convenient sampling. Then, to make sure that your sample truly represents your askarel insulation, take another sample from the bottom. If additional sampling tube connections are contrived on the valves for easier sampling, make the tubes of clean glass, stainless steel, aluminum or tin for rigid types; and silicone, or Viton or Teflon tubing for flexible types.

Use NEW containers for the askarel sample. A new and thoroughly pre-dried small-mouth quart glass bottle fitted with a Bakelite* screw cap with aluminum or tin cap liner is recommended for quick, on-site testing. (If complete analysis is to be made, a 5-pint size sample is required.)

Be sure that the new bottle does not stand open to collect dust or moisture. Rinse the sample bottle and cap lining two or three times with askarel from the transformer, then fill it. If the sample will be tested promptly, a clear glass bottle can be used. If sample is to be stored indefinitely, use an amber glass bottle or wrap clear glass with aluminum foil.

A. Select a dry day. Do not sample insulation on a warm, moist day when humidity exceeds 75%, and . . .

*Trademark of Union Carbide Corporation

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B. Make sure that the askarel is at least as warm as the surrounding air. (Cold liquids can condense moisture from humid air.)

C. When sampling askarel from transformers, it is best to take the sample when the unit is warm and operating at average or maximum load, especially for a check on moisture as reflected by a dielectric breakdown voltage test. Sampling the warm askarel more truly represents its condition during operation.

Experience shows that water will migrate from a transformer's solid insulation to the askarel liquid and vice versa, depending on temperature. Therefore, when the transformer is hot, the moisture is most likely to be found in the liquid. This accounts largely for periodic variations in dielectric breakdown voltage. For example, a relatively high dielectric breakdown voltage may be found during winter months and a relatively low dielectric breakdown voltage during the summer months on samples taken from the same unit.

When testing has been completed, the remainder of the fluid sample should be destroyed by high temperature incineration described in Section VIII.

Section B
Askarel Filled Switches and Terminal Chambers

I. Introduction

High voltage leads are usually connected to askarel or mineral oil-filled network transformers and power centers through terminal chambers and switches. In some cases terminal chambers are not used, and the high voltage leads are connected directly to the switch terminals. They may be filled with either askarel or mineral oil. Switches are usually rotary or drum type fitted with a revolving block and porcelain unit as the principal element arranged for three-phase service.

Askarel transformers with attached switches have been in use for about 30 years. When they were first introduced, the availability of insulating and gasketing materials was rather limited and even the best materials at the time had no service history. As a result, inadequate gasketing materials such as cork, nitrile rubber, and nitrile rubber-and-cork particles were used. While satisfactory for a limited period of time, these materials cannot be depended upon for the expected long life of the equipment.

The terminal chamber is usually above or below the switch compartment and separated by a steel wall through which the bushings are inserted. When bushings are properly selected and correctly installed, there is no leakage from one compartment to the other. With poor bushing seals, and the terminal chamber above the switch, potting compounds or cable oil can seep into the askarel. When the terminal chamber is below the switch, askarel can drain into the terminal chamber.

II. Sources of Contamination

There are three possible sources of contamination for askarel in switches and terminal chambers; they rank in this order of frequency: (1) water entering through poor gaskets; (2) decomposition products from arcing when switch is used to break magnetizing current; (3) entrance of pothead or cable compounds through leaky bushing seals.

Unlike an askarel transformer where the amount of contaminant is likely to be very small (probably only trace amounts) in relation to the volume of askarel fluid — in switches or terminal chambers with faulty seals, the amount of contamination can be relatively large.

Experience has shown that, based on the number of installed askarel-switch units, the percentage of failures is extremely small. When investigated, it has been found that most failures originate in the switch chamber. Water is the chief source of contamination. However, heavy contamination of askarel with petrolatum and asphalt material, due to leakage, have caused a few failures.

Petrolatum is used frequently for filling terminal chambers. When either cable oil or petrolatum seeps into askarel, no great harm results. The fire resistance will be somewhat decreased and power factor of the askarel will increase with an accompanying drop in resistivity. While highly undesirable, it is doubtful that failure of the unit results. Where asphaltic compounds are used in place of petrolatum, the danger is increased somewhat because asphaltic contamination may cause excessively high dielectric losses in the askarel.

When the terminal chamber is below the switch chamber, the potting compound can be contaminated by askarel if the bushing seals are leaky. This is undesirable because the askarel will increase the power factor and conductivity of the potting compound or cable oil and develop heat from dielectric loss. If this mixture is drawn into the cable

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insulation, a cable failure is likely. This again emphasizes the importance of tight bushing assemblies.

III. Sealing Switches and Terminal Chambers

Proper bushing construction, use of Silastic seals and welding wherever possible is highly desirable (as covered in Section A). Where an elastomeric seal is to be used in contact with both askarel and petroleum oil, DuPont's Viton is suggested.

For new equipment the user should specify these modern sealing arrangements to keep out contaminants and minimize maintenance.

IV. Askarel Used Under Mild Arcing Conditions

The IEEE Guide for Transformer Askarel calls attention to the following:

"Askarel is used, to some extent, in apparatus where it is subjected to light intermittent arcing, such as in self-contained induction regulators, where operating switches are continually producing slight arcs, in transformer deenergizing switches, etc. Under normal conditions, deterioration of the askarel is very slight. However, improperly adjusted or defective switches in this type of apparatus can produce excessive and prolonged arcing and accelerated deterioration of the askarel. It is recommended that when askarel is used under these conditions, checks of the liquid, especially for moisture and dielectric breakdown voltage made more frequently than when it is used only as a cooling and insulating fluid. Deterioration of this type is indicated by a blackening of the liquid. It can usually be reconditioned as previously described. Special attention should be given to maintaining the scavenger at the appropriate concentration."

V. Maintenance for Askarel Filled Switches

A. Switches used for grounding after power source has been de-energized will not undergo arcing.

B. Switches interrupting magnetizing current will be subject to arcing; the amount of decomposition will depend on power interrupted, time and frequency of operation. As a general rule, the liquid should be checked after 5 to 10 operations.

1. On newly installed switches, check the askarel at 3, 6 and 12 month intervals; if found satisfactory, check once annually thereafter. With proper attention to the gasketing of covers and bushings, experience will probably indicate that less frequent inspection is warranted.
2. Check askarel for:
   a. Dielectric breakdown voltage (ASTM D877): It should be 26 KV minimum. If dielectric breakdown voltage is low, confirm presence of water by Karl Fischer method ASTM D-1533. Filter to remove moisture. Dielectric strength should then be 30 KV minimum.
   b. Presence of carbon from arcing: Fluid should be relatively free of carbon. If badly arced and very black, replace fluid. If only minute amounts of carbon are present, filtration is recommended. Check power factor of liquid (should not be over 5% at 25°C and 60 cycles). Flush out switch chamber with several gallons of fresh askarel before refilling.
3. If there is discoloration, high power factor, detectable change in specific gravity or refractive index, or if fluid flashes below 250°F, there is a possibility of seepage of potting compound into the switch compartment. In this case, correct any leaky bushing seals with proper replacements and fill with new askarel.
4. If terminal chamber is below switch, check potting compound for presence of askarel (can usually be detected by odor or by an increase in specific gravity). If askarel is present, correct any leaky bushing seals with proper replacements, and renew compounds.
5. Examine cover gaskets visually. Deterioration can be detected

— (hyphen)

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by swelling and cracking of the exposed edge. In cases of severe deterioration, liquid seepage is usually present.

6. Check for leakage at packing gland of switching shaft. If leaking, repack with a Silastic ring type gasket.

VI. Askarel Under Excessive Temperature or Fault Conditions

The IEEE Guide also points out that,

"Chlorobenzenes used in transformer askarels begin to boil at temperatures of about 205°C, under atmospheric conditions. If the material is heated to such high temperature in a sealed system, pressure develops. Pressure will also develop in the system if the askarel is arced sufficiently to generate copious hydrogen chloride gas.

"Therefore, it is recommended that wherever possible, sealed askarel filled equipment be provided with pressure relief devices. These devices must be large enough to provide immediate relief at a definite pressure, and to prevent further build up of pressure if decomposition continues. It must be remembered that the presence of devices of this sort does not necessarily preclude the rupturing of containing vessels, since pressure build up can be extremely rapid under violent arcing conditions."

Section C Analytical Services on Transformer Askarel Available From Monsanto

Transformer users not wishing to make their own fluid analyses can obtain the service from Monsanto. Simply contact Monsanto and specify what analyses are wanted. You will be sent the proper-sized, clean sample container, fitted with a proper label. When you receive this, carefully take your sample (following the procedure for sampling in this guide). Send the container to Monsanto's laboratory. Charges listed include sample container, shipping, handling and laboratory costs.

Types of Analyses Available

Analysis 1)
ROUTINE MAINTENANCE CHECK Total Charge: $25.00

To determine the general condition of the fluid and find whether further analysis is necessary. (one-quart sample required)

Properties Tested	Dielectric Breakdown Voltage
Color and Condition	Moisture

You will be notified of the results of this test. If further testing is indicated, and you want a complete analysis, you will be sent a five-pint sample container. This sample will be used for the following series of tests:

Analysis 2)
COMPLETE ANALYSIS Total Charge: $55.00

(a) To determine the extent of fluid contamination, (b) earth refinement to determine what degree of restoration of electrical and insulating properties is possible, (c) check test to see how the fluid responded to earth treatment.

a) Complete Analysis: to determine the extent of contamination

Properties Tested	Free Chlorides
Color and Condition	Acidity
Specific Gravity	Dielectric Breakdown Voltage
Refractive Index	Power Factor, Dielectric Constant, and Resistivity
Water	

b) Earth Refinement Response:
Consists of treatment for 2.5 hours at 50-60°C. with 0.1 to 0.2 percent by weight of properly conditioned Attapulgus clay and then filtration through dry filter paper.

c) Analysis After Laboratory Earth Refinement:

Properties Tested	Acidity
Refractive Index	Dielectric Breakdown Voltage
Water	Power Factor, Dielectric Constant, and Resistivity
Free Chlorides	

You will be notified of the results of this test series on your sample. Then after refining your entire transformer fluid fill you can check on the results by requesting the following analysis:

Analysis 3)
ANALYSIS AFTER EARTH REFINEMENT Total Charge: $35.00
(This charge will not apply when analyses 1 and 2 have already been made.)

To determine whether the entire lot of the askarel fill responded to the same extent as the laboratory sample. (five-pint sample required)

Properties Tested	Free Chlorides
Color and Condition	Acidity
Refractive Index	Dielectric Breakdown Voltage
Water	Power Factor, Dielectric Constant, and Resistivity

To arrange for the tests described above write to the following address:

Paul G. Benignus
Monsanto Company
800 North Lindbergh Blvd.
St. Louis, Missouri 63166

Samples to be tested should be clearly marked for identification and sent directly to:

Monsanto Chemical Company
W. G. Krummrich Laboratory
Sauget, Illinois 62201
Attention: R. Kuster

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CHECK BOARD HEAD

APPENDICES

APPENDIX A

Askarel Stability and Composition of Arc Formed Gas: Askarel insulation is one of the most inert, chemically-stable heat resistant, non-corrosive liquids known. It will not break down, oxidize or sludge when exposed to air and high temperatures, 150°C. or even somewhat higher. Arcing, however, will break down the compound to liberate some hydrogen chloride and small amounts of carbon.

APPROXIMATE COMPOSITION
ARC FORMED GAS FROM TRANSFORMER ASKAREL BLENDS
ASTM TYPES D AND F
(INERTEEN 54201KA AND PYRANOL A13838-2, RESPECTIVELY)

Gas	Amount
carbon monoxide	0.3%
carbon dioxide	0.3%
oxygen	0.6%
inert gases	1.5%
hydrogen chloride	97.3%
(note the absence of phosgene)	

This arc-formed gas from ASTM Type D and Type F transformer askarels is non-flammable and non-combustible.

For all practical purposes, the amount of gas liberated from askarel under a given set of arcing conditions is about 100 cubic centimeters per kilowatt-second.

APPENDIX B

SOLUBILITY OF GAS IN TRANSFORMER ASKARELS
ASTM TYPES D AND F

	Percent of Gas By Volume Corrected to:			
	25°C 760 mm		0°C. 760 mm	
	25°C	100°C	25°C	100°C
Carbon dioxide	71%	47%	—	—
Air	5.7	4.9	5.8	5.0
Nitrogen	6.0	4.8	5.5	4.4
Hydrogen chloride[1]	37.8	50.9	—	—

[1] In absence of scavenger

APPENDIX C

EFFECT OF TEMPERATURE ON DIELECTRIC BREAKDOWN VOLTAGE OF ASKAREL

Temperature °C	Dielectric Breakdown Voltage ASTM D877
−60	67 KV
−40	63
−20	57
0	55
20	50
40	50
60	48
80	45

APPENDIX D

COMPARISON OF THE APPROXIMATE VISCOSITY IN SAYBOLT UNIVERSAL SECONDS OF TRANSFORMER ASKARELS AND MINERAL OIL

Temp. °C	Pyranol A13838-2	10-C Mineral Oil	Inerteen 54201 KA
–20	1,000	1,000	2,800
0	100	150	195
20	70	85	85
40	45	49	50
60	39	40	40
80	34	34	36
100	30	30	33

APPENDIX E

THE DENSITY OF INERTEEN 54201 KA 7336-9 AND TRANSFORMER PYRANOL A13838-2
Approx. Density gm/cc.

Temp. °C	Inerteen 54201 KA	Pyranol A13838-2
0	1.574	1.577
20	1.552	1.555
40	1.529	1.532
60	1.507	1.510
80	1.485	1.488

SAME & ABOVE

APPENDIX F

The thermal conductivity values of transformer Pyranol A13838-2 at 27°C and 58°C are 28.2 and 25.8 x 10-5 calories centimeters^{-1}, degrees centigrade^{-1}, second^{-1}, respectively. Or, approximately 0.08 BTU per (hr.) (sq. ft.) (°F.) per foot. This same approximation applies to Inerteen PPO (7336-9).

APPENDIX G

Heat Capacity

Over the temperature range of 25° to 125°C the specific heat of transformer askarel is close to 0.30 calories per gram per degree.

APPENDIX H

Coefficient of Expansion

The average coefficient of expansion of transformer askarel over the temperature range 20 to 100°C is 0.0007 cc/cc/°C. One gallon would increase to 1.056 gallons on heating from 20 to 100°C.

APPENDIX I

Fire Resistance

Askarels of various compositional types are used. Under arcing conditions the gases produced, while consisting of predominantly non-combustible hydrogen chloride can yield varying amounts of combustible gases depending upon the askarel type.

Insulation systems incorporating these askarels and cellulosic or other organic materials may, when arced, produce gaseous mixtures which are moderately flammable. As a precaution, such gases should be removed from the askarel by bubbling dry nitrogen through the askarel and flushing the gas space with dry nitrogen before any work is performed on the apparatus.

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APPENDIX J

Seals, Properties and Procurement

Dow Corning Corporation, Midland, Michigan with Districts at Atlanta, Boston, Chicago, Cleveland, Dallas, Los Angeles, New York City, Washington, D.C. and Toronto has available Bulletin 09-019, August 1962 entitled "Silastic Design Data". This lists the gasket fabricators throughout the country from whom the "Silastic 50" gasketing can be purchased in sheet, extrusions or molded shapes.

Generally Silastic 50 sheet goods are stocked by local die cutters, hence, could be generally purchased locally. Usually small quantities of gaskets are die cut. If larger quantities are needed, tools are made of the same type used to cut other elastomers.

Where the gasket is extruded for fitting into a machined groove or between gasket stops, Dow-Corning advises use of a scarved joint. This joint is then cemented using Dow Corning's Silastic 140 (clear) or their RTV 731 (white) materials, which air cure.

Dow Corning points out that the local "rubber" fabricators purchase the Silastic 50 in billet form. This is worked on a roll mill in preparation for sheeting or extrusion. Then to obtain the desired physical properties the fabricator must oven cure the Silastic 50 for 24 hours at 480°F.

SPECIFICATIONS*

	Color	White
	Specific Gravity at 77°F	1.20 ± 0.02
ASTM D676	Hardness, Shore A. Scale	45 to 60
ASTM D412	Tensile Strength, psi, min.	800
ASTM D412	Elongation, percent, min.	250
ASTM D395	Compression Set after 22 hrs. at 300°F, percent, max.	30

*All physical properties measured on 0.075 inch thick samples molded 5 minutes at 240°F, and oven cured 24 hours at 480°F.

APPENDIX K

Caution Label

The following or equivalent caution statements should be fixed on all containers of transformer askarels and the transformers themselves:

This product contains Polychlorinated Biphenyls (PCBs). Care should be taken to prevent entry into the environment through spills, leakage, use, vaporization, or disposal of liquid or containers. Avoid prolonged breathing of vapors or mists. Avoid contact with eyes or prolonged contact with skin. If skin contact occurs, remove by washing with soap and water. Following eye contact, flush with water. In case of spillage onto clothing, the clothing should be removed as soon as practical, skin washed, and clothing laundered.

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The information herein regarding obtaining optimum results from askarel fluids in your transformer has been accumulated by Monsanto for over 40 years from the experience of makers and users of askarel transformers and it is believed will be helpful.

Nothing herein shall be construed as applying to other than askarel insulation. Data and maintenance suggestions herein do not apply to the other components of the transformer. All operating and maintenance suggestions recommended by the manufacturer of the transformer should also be carefully followed.

Because these maintenance directions apply only to the askarel insulation, Monsanto disclaims any liability for damage to property or injury to persons arising from transformer operation.