PLASTICIZER APPLICATION GROUP

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For The Transformer Industry

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INTRODUCTION

Electrical transformers consist of soft iron cores wound with two or more coils of copper wire. Their purpose is to change electricity from one voltage and amperage to another voltage and amperage. All parts are insulated from each other, but current surging through one coil induces an electrical current in the other coil. The iron core helps this induction process.

It is easier to transmit electricity over long power lines at very high voltages (from several thousand to several hundred thousand volts), so transformers are used to convert electricity generated at a few hundred volts into the very high voltages needed for long distance transmission. At the consumer end of the power lines, other transformers bring the very high voltages down to those commonly used by industry and private consumers. Thus, transformers are very important to our way of living. They range in bulk from teacup size doorbell transformers to industrial giants several stories high.

In spite of their simplicity of operation, large transformers present difficult design problems involving heat dissipation, dirt and moisture leakage, and the hazard of internal arcing caused by insulation breakdowns, lightning strokes, malfunction of circuit breakers, etc. Heat dissipation problems are handled by building vents, radiators, or blowers into the transformer case or housing. Insulation problems are handled by a proper choice of dielectric (nonconducting) material. Dielectrics commonly used are air (for both its cooling and insulation properties), "Class A" insulation materials (paper, cardboard, cotton, nylon, etc.), "Class B" materials (glass, porcelain, asbestos, mica, etc.), "Class H" materials (silicone derivatives), mineral oil (where the fire hazard can be controlled) and "Askarel" nonflammable fluids.

"Askarel" is a generic name used to describe dielectric fluids used in transformers and capacitors (electrical condensers). These fluids are usually chlorinated hydrocarbons of which Monsanto Aroclors are an important series. The Aroclors are mixed with chlorobenzenes. Such mixtures are usually trade marked items and a descriptive list will be found at the end of this bulletin.

The Aroclors, then, are Monsanto's major contribution to the transformer industry. This bulletin is meant to acquaint you with both the industry itself and the Aroclors which find use as "Askarels".

SALES AND APPLICATION PICTURE FOR
ASKAREL (Aroclor-Chlorinated Benzene Filled) TRANSFORMERS

Askarel, fire-resistant dielectric and cooling media for transformers, was introduced commercially in 1932 by General Electric Company under their trade name, "Pyranol". Subsequently, General Electric licensees have been using the same materials under their own various trade names. These transformer fluids are mixtures of Aroclor and chlorinated benzene. Usually they contain a small amount of HCl scavenger which protects the transformer shell from excessive corrosion in case the transformer arcs (thereby producing some free HCl by deterioration of the chlorinated hydrocarbons).

In terms of Pyranol alone, since 1932 more than 35,000 Pyranol transformers ranging in size from 1-1/2 to 27,000 KVA (kilovolt amperes) and totaling more than 10,000,000 KVA capacity have established an excellent operating record. These installations include both current transformers and potential transformers. In 1938 the first Pyranol induction type voltage regulators were built and there are now more than 1250 such units in service with a total capacity exceeding 110,000 KVA.

These figures, applicable to Pyranol alone, and reported several years ago, are growing larger each year and are given as a general indication of the scope of this business which accounts for a large portion of our Aroclor sales.

Mineral oil filled transformers, including power and distribution types, account for about 75% to 80% of transformer construction. However, due to the flammability of mineral oil, these units are used outdoors, mainly. Mineral oil transformers are the least expensive of the fluid types. Nevertheless, in confined areas (buildings etc.) where it would be necessary to enclose this type of transformer in a safety vault (concrete, etc.), the overall installation cost becomes much greater than the cost of using either Askarel or a dry type transformer unit which provides the safety required without vault enclosure.

Consequently, for many industrial (factories) and commercial (office buildings) installations, the Askarel and dry type transformers are used rather than the mineral oil type transformers. In this type of installation the voltage ranges used are met most adequately by the Askarel transformers. The KVA class range in which Askarel units are most commonly used is about 50 to 1,000 KVA. However, as mentioned previously, they have ranged up to 27,000 KVA in a few cases.

The above information establishes the principal field of application for Askarel transformers and serves to indicate that their direct competition is the dry type transformer, and very seldom, mineral oil transformers.

HOW TRANSFORMER TYPES ARE SELECTED FOR A GIVEN APPLICATION

Cost is one of the most important factors in selecting a transformer. A general idea of cost, but by no means a conclusive one, may be gathered from the following generalizations:

1. Sealed dry type transformers which require silicone (Class H) insulation for temperature operation at 180°C. cost about 25% more than open, dry type transformers.

2. Open, dry type units which, for operation at 55°C. over ambient temperature (normal room temperature), may use cotton, nylon, etc., insulation, cost about the same as Askarel units. However, for operation at 80°C. over ambient temperatures, glass and porcelain insulation (Class B) is required and these units are as much as 10%-15% higher in cost than Askarel types.

3. Askarel transformers which use cotton, paper, cardboard, etc. (Class A insulation) cost about 15% more than mineral oil transformers.

Mineral oil units use oleo-resinous and other common types of varnish and Formvar insulation coatings. Because of this and other construction factors, it is not satisfactory to use Askarel in a transformer designed or specified for mineral oil use. On the other hand, mineral oil can be used, usually, in units insulated to handle Askarel.

Many other factors, in addition to first cost, affect the selection of the transformer type for a given application. For example, prompt availability or supply and servicing must be considered. The following section gives a typical analysis of indoor transformers considering their various operating characteristics as a basis for selecting the specific type best suited for the job.

ANALYSIS OF INDOOR TRANSFORMER CHARACTERISTICS

A modern trend in indoor distribution involves the transmission of power to centers of electrical load at voltages higher than utilization levels, then reducing the voltage through power-center transformers. This is the long distance power transmission principle applied to indoor installations.

By carrying power through the plant at higher voltages, considerable savings result from copper reductions. Voltage drop is minimized with corresponding improvement in the performance of motor and lighting installations. The cost of power centers and secondary distribution transformers is more than offset by savings resulting from the elimination of long, heavy distribution runs inside the plant.

Incoming primary currents generally are 3-phase at 13,800 volts or lower (common voltages include 13,200, 7200, 4160, and 2400). Secondary distribution is usually at 480 volts or 208Y/120 volts 4-wire, with short conductor runs to individual loads. Where the motor load is the governing factor, distribution at 480 volts is usually more economical, with lighting circuits at 240/120 volts 3-wire supplied through step-down transformers. However, where the lighting load is the major consideration, distribution is generally at 208Y/120 volts 4-wire, with motor loads supplied at 480 volts through step-up transformers.

A variety of equipment is available to protect indoor power center transformers, such as high voltage air-break switches in ratings to interrupt full-load current or simply the transformer exciting current. For added protection, fuses may be protected by various combinations of main and feeder breakers in metal-clad compartments, thermal magnetic breakers, safety plug-in units, fused plug-in units, or a variety of switching or interrupting devices between the transformer and the individual load.

The impedances (opposition to flow of alternating current) of the transformer itself may be used to advantage when circuit protection is considered. Impedances in the range of 5.0% to 5.5% have been accepted as a compromise between better voltage regulation and limitation of fault currents. Impedance of this order limits short circuit stresses yet permits the burning clear of many fault currents that may occur in the secondary circuit.

The transformer may be supplied with various accessories for its own protection. Temperature indicators show the temperature of the windings under various loads. Thermal relays provide overload protection by automatically operating cooling fans, signal lights and alarms, or tripping the main circuit breaker if an excessive load or short circuit should occur. If it is desirable to prevent operation of the primary disconnect switch while the secondary breaker is closed, interlocking devices may be used. Such precautions are important for the safety of personnel and for protection of the primary disconnect switch.

Maximum service life is obtained by incorporating adequate protection of equipment into the electrical power distribution system. Hazards to personnel are reduced to a minimum by enclosing busbars, wiring, switch equipment and transformers. Sheet metal enclosures, bus duct, and conduit prevent contact with live parts, accidental short circuits, collection of dirt, dust and moisture, wear and damage. Enclosed electrical equipment is safer, requires less maintenance and gives evidence of careful and orderly workmanship.

COMPARISONS BETWEEN LIQUID FILLED AND DRY TYPE INDOOR UNITS

Transformers using mineral oil as a dielectric and cooling medium have a serious disadvantage for indoor use. The oil will support combustion and serious fires and explosions may result from internal arcing or ignition from any external source. Earlier practice required a sturdy fireproof wall, usually of concrete, around the transformer when located in or near a building. Construction of the vault alone is costly and terminal connections away from the transformer were complicated. An added concern is provision for ventilation. Therefore mineral oil transformers are seldom used indoors.

With the development of the fire-resistant, liquid dielectric Askarel (Aroclor-TCB mixture), and the dry type transformer, it became a safe practice to install these transformers indoors without the need of expensive fireproof vaults. Both Askarel filled and dry type transformers have become very popular for indoor use. Each has certain advantages and disadvantages.

The liquid Askarel has a dielectric strength comparable to that of mineral oil and thus may be incorporated without difficulty into designs to withstand the same 60 cycle and impulse dielectric tests as are standard for oil filled transformers. The following table lists ASA standard dielectric tests for liquid filled and dry type transformers.

Type of Transformer	KVA Class	60 Cycle 1 Minute Test Rating	Full Wave Impulse Test Rating
Dry	5	12 KV	25 KV
	8.7	19 KV	35 KV
	15	31 KV	50 KV
Askarel or Oil Filled	5	19 KV	60 KV
	8.7	26 KV	75 KV
	15	34 KV	95 KV

It will be noted that dry type impulse (heavy surge currents) levels are roughly one-half as high as the level for liquid filled transformers. Sixty cycle tests are also lower though very nearly equal for the 15 KV class. However, installed indoors where danger from lightning is considerably reduced, the precautions necessary for surge protection are not as important as for the outdoor transformer.

The dry type transformer must rely upon clearances in air for its insulation strength. If an attempt were made to design the dry type transformer with impulse levels equal to liquid filled transformers, cost, weights, dimensions and losses would be considerably increased. The resultant loss of economy is not considered justified. So higher impulse levels are obtained with liquid dielectrics.

Although it is not a great disadvantage, the power factor of Askarel is somewhat higher than that of mineral oil. Experience has shown that the power factor of the complete insulation structure of oil filled units is in the range of 1 to 2%. Askarel filled transformers are found to vary between 3 and 8%*. Askarel has a somewhat erratic behavior at higher voltages but applications up to and including 44,000 volts are in satisfactory service and the upper limit on voltage may be about 69 KV.

Askarel filled transformers require periodic sampling of the liquid to check the dielectric strength which becomes impaired when moisture is present. Because of the high specific gravity of Askarel, moisture or free water will accumulate above the liquid level. Porcelain tubes on H.V. leads to terminals are used to protect against failure over this low resistance moisture film. As the top is the region of highest temperature in the transformer tank, the Askarel may become saturated with moisture. The saturated Askarel circulates by thermal action and the moisture is absorbed in the innermost regions of the insulation structure. Water vapor may form in the top of the tank if cooled sufficiently. This vapor deposited on porcelain or other parts above the liquid level will reduce effective spacings and creepage distances.

Filtering at intervals is necessary to remove any moisture and impurities, often a special absorbing agent, such as activated clay, is required to remove impurities in solution as well as any moisture present.

While arcing of the Askarel transformer is a possibility and would cause gassing if continued, a properly installed and protected Askarel unit has only a very remote chance for this occurence.

The following table indicates the approximate volume of Askarel transformer fluid required to fill units of the given KVA ratings:

Ratings	Gallons
5 KVA	6
15 KVA	18 - 20
750 KVA	375
1000 KVA	425
1500 KVA	500
2000 KVA	600
6/7000 KVA	1600

Due to the high specific gravity of Askarel - 13 lbs. per gallon - transformers using this liquid are relatively heavy. Their weight is roughly 30 to 40% higher than a dry type transformer

* These figures are relative and subject to change with frequency and temperature.

of equivalent rating. Such added weight may be a consideration when moving or installing the transformer onto platforms or other levels.

Floor space required offers little advantage for either type. Cooling tubes extend from the tank wall of Askarel filled units and add to the overall dimensions. In the same manner, dry type transformers require liberal insulation clearances in air. The dry type transformer enclosure may be conveniently matched to the height of incoming primary and secondary switchgear enclosures for uniform dimensions and pleasing appearance of the complete unit substations.

CAUSE AND CONTROL OF VIBRATION AND NOISE

The main source of transformer noise is the crowding of magnetic waves (magnetostriction) in the iron core. When an alternating magnetizing current is applied, there are rapid minute contractions and elongations of the core laminations. Vibrations are set up in the core and coil supporting frames and transmitted to the tank or enclosure and produce noises varying from a characteristic hum to a loud rattle.

Askarel with its high specific gravity adds considerable mass to the transformer assembly. The combination of internal parts and fluid dielectric tends to make the complete interior a solid structure which dampens or attenuates the vibrations originating in the core.

Enclosures for the dry type transformer are made of lighter gauge sheet metal. The panels are in removable sections with ventilating openings. The enclosures are intended only to protect the transformer from falling dust, dirt, water, rodents and damage from ordinary movement of men and equipment. They are essentially light frameworks and of little value in reducing the noise level and may even amplify it.

A comparison of established sound levels for the two types of transformers are listed below:

Transformer Sound Levels

KVA Rating	Liquid Filled	Dry Type
200 - 300	56 Decibels	66 Decibels
301 - 500	58 Decibels	68 Decibels
501 - 700	60 Decibels	70 Decibels
701 -1000	62 Decibels	72 Decibels

In a factory where the general ambient sound level is high, the noise from the transformer may not be noticed. In a school, office building, or hospital, the same noise level may be objectionable. Vibrations may be transmitted through steel structural members, walls, or other parts of the building. It may be necessary to erect sound absorbing barriers, line the interior of rooms with sound absorbing material or mount the transformer on sound-deadening supports to prevent vibration from being transmitted.

The sound level of the transformer varies in relation to the magnetic flux density at which the core is operated. Any substantial reduction in noise level would require a transformer of special design. In such a special transformer, it must be expected that the core loss would be low but, cost, weight, copper loss and impedance would be high. If price and performance is of no consideration, it is possible to design a transformer with any desired low noise level.

In general, the Askarel filled transformer is preferred for locations where excessive dirt or moisture is present or when a minimum noise level is desired without added cost. For suitable applications where reduced weight and a minimum of maintenance is desired, the dry type transformer is preferred. For distribution to smaller individual loads, such as lighting circuits, machine tools or special devices, the ease of mounting and simplicity of connections is an advantage of dry type transformers.

DEVELOPMENTS IN DRY TYPE TRANSFORMERS

Originally dry type transformers were insulated with class A organic materials such as cotton, paper, fiber, fullerboard, and insulation board all of which were readily combustible. As the temperature rise of the windings was limited to 55°C. over ambient, substantial ventilation was required, necessitating many ducts in the coil. Expanded metal was generally used to enclose and partially protect the coils. Current densities in the conductors were low.

With the development of Class B insulation permitting a temperature rise of 80°C., it was possible to operate the coil conductors at higher current densities. It was also possible to reduce the area of coil exposed for ventilation, and sheet metal enclosures generally replaced expanded metal ones.

The class B dry type transformer is smaller and lighter than the older class A types. It is explosion-proof and essentially fireproof. The insulation consists of porcelain, mica, asbestos, fibreglass and similar inorganic materials with an organic binder. After treatment in a special varnish, the coils are baked to give a glossy, tough finish highly resistant to moisture and penetration by collections of dirt and dust. Usually the only maintenance required is cleaning off the accumulations of dust. Such maintenance is fairly simple as the panels are easily removed for access to the internal parts. Excessive moisture or condensation on the coils must be guarded against and, if present, a special drying out process is required. The ventilated dry type transformer is not adapted to locations where water could enter or submerge the enclosure; or where excessive dirt and lint is encountered.

A more recent transformer development has been the hermetically sealed dry type transformer. The construction consists of a large smooth tank enclosing the core and coils with glass sealed bushings and welded joints to completely seal the interior from the atmosphere.

Without benefit of ventilation through the core and coil structure, all heat losses must be dissipated by radiation and natural convection of gas flow from core and coil to tank. The operating temperature for a practical design is increased beyond the permissible 80°C. rise for class B insulation.

Development of class H insulation has made possible the sealed dry type transformer with higher operating temperature. Class H insulation, of which the silicones are most common, permits operation at 180°C., a limit which has been tentatively (and probably conservatively) established as these units will withstand emergency exposure to even higher temperatures. Silicones have chemical compositions similar to glass, mica, and quartz.

An atmosphere of dry nitrogen gas is usually sealed into the tank at low pressure. This inert atmosphere excludes oxygen which would accelerate aging and deterioration of insulation especially at higher temperatures. By sealing, the effects of humidity, water vapor, dirt, dust, and other contaminants are eliminated.

Maintenance for the sealed unit is reduced to a minimum. Only periodic checks of gas pressure and occasional cleaning are required. The tank is smooth without openings or radiator tubes, etc., which simplifies cleaning and maintaining a good appearance. Should the transformer be de-energized for long periods, no precautions need be taken to prevent condensation on the coils nor is a dryout process required before returning to service.

Sound levels are considerably reduced over ventilated dry types of equivalent rating. The confined internal gas space and rigid welded tank reduces the intensity of noise from the core and coil assembly. Weight and dimensions are comparable to ventilated dry types and considerably lower than equivalent Askarel units.

The sealed dry type transformer is adapted to any use or location where either oil filled, Askarel filled, or ventilated dry type transformers of 15 KV class and below are used in network distribution systems. At the present time about the largest such units in service are 2000 KVA network transformers. They are particularly suited for use in underground vaults where flooding regularly occurs, indoors in dirty locations, or in contaminated atmospheres where corrosive action is a hazard. The sealed units may be located in the open or in busy areas without danger to personnel.

The cost of class H Silicone insulation materials at present is much higher than that of class B insulation. Costs are being steadily reduced through improved manufacturing methods and greater volume, but present costs of sealed dry type transformers are 20 to 25% higher than equivalent Askarel filled or open dry type transformers. To date, there are no reliable indications that the sealed dry type at its higher cost will compete with the Askarel type transformer in other than special applications. The Aroclor products suitable for Askarel applications are 1242, 1248, 1254, and 1260. How these Aroclor materials are combined is shown by the following on Askarel nomenclature.

TRANSFORMER AND CAPACITOR
DIELECTRIC NOMENCLATURE

Aroclor used in transformer and capacitor dielectrics is subject to a variety of nomenclature used by various firms. The following breakdown will be useful but should be regarded as confidential as these products and trade names belong to other companies.

ASKAREL is a generic name often used to cover halogenated hydrocarbons, such as Aroclor, used as dielectrics.

General Electric has the following items under their general trade name of Pyranol:

- Pyranol 85-C - GE's low temperature capacitor Pyranol.
- Pyranol R3621-S - Special coating for transformer shells in storage to prevent rusting.
- Pyranol 1432 - (100% Aroclor 1254 + stabilizer), used for DC capacitors.
- Pyranol 1436 - (75% Aroclor 1254 + 25% TCB + stabilizer), used for DC capacitors.
- Pyranol 1467 - (60% Aroclor 1260 + 40% TCB + scavenger), used in transformers.
- Pyranol 1470 - (45% Aroclor 1260 + 55% Tri-Tetrachlorobenzene + scavenger), transformers
- Pyranol 1476 - Aroclor 1254, capacitors.
- Pyranol 1478 - Trichlorobenzene, mixed with Aroclor for transformers and capacitors.

Pyranol 1481 - (75% Aroclor 1254 + 25% TCB), used for AC capacitors.
Pyranol 1482 - Aroclor 1260, mixed with other Askarel for transformers.
Pyranol 1488 - (60% Aroclor 1260 + 40% TCB), transformers.
Pyranol 1498 - Aroclor 1248, capacitors.
Pyranol 1499 - Aroclor 1242, capacitors.

Westinghouse designate their material as Inerteen:

Inerteen 9818-1 - (Aroclor 1242), capacitors.
Inerteen 6935-1 - (Aroclor 1254), capacitors.
Inerteen 7336-9 - (60% Aroclor 1260 + 40% TCB + scavenger), transformers.

Cornell-Dubilier call their material Dykanol:

Dykanol A - (Aroclor 1254), capacitors.

Allis-Chalmers use the name Chlorextol:

Chlorextol - (Same as Pyranol 1470), transformers.

Wagner Electric use the name Noflamol:

Noflamol - (Same as Pyranol 1467), transformers.

Moloney Electric use the name Askarel:

Askarel - (Same as Pyranol 1470), transformers.

Line Material use the name Elemex:

Elemex Liquid A - (Aroclor 1254), capacitors.
Low temp. Elemex - (Same as Pyranol 1481), capacitors.
Part A-67565

*****End of Bulletin*****

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