

LECTURE ON ASKAREL AND DRY TYPE TRANSFORMERS

BY

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ASKAREL AND DRY TYPE TRANSFORMERS

A. ASKAREL TRANSFORMERS

In the late 1920's and early 1930's the demand for electric power in office and public buildings was increasing very rapidly. The same was true to an even greater degree for power in factories. To provide such power transformers of larger sizes had to be provided. It was desirable to locate them inside the building or factory in order to reduce the length of secondary bus runs for the purpose of reducing power losses and improving regulation. To do so with oil filled transformers, in which the oil may cause an explosion and a fire, for safety reasons, the transformer must be located in a fireproof concrete vault which is expensive to provide.

To provide a solution to this problem transformer manufacturers in the United States began development programs in the period from 1930 to 1936. The first solution to become commercially available was a transformer using a non-flammable liquid instead of oil. This liquid, called by the trade name Pyranol, had no flash point and would not burn and was developed by the General Electric Co. The basic fluid used consisted of chemicals called aeroclers, and trichlorobenzene. In order to be competitive other manufacturers developed similar liquids. The one with which I am familiar is that of the Westinghouse Electric Corp. which is called Inerteen. As a class nonflammable insulating liquids are called Askarels.

Askarel transformers at one time were used quite extensively in the United States, perhaps for 5 to 10 percent of the production in the range from 100 to 1500 KVA. for voltages up to 35 KV. There is still a considerable activity in these sizes for network and power center transformers. However, dry type transformers designed for 80°C temperature rise as measured by resistance, have replaced the Askarel transformer for most applications. Askarel network transformers have to some extent resisted the change over to dry type construction because of the space limitation on network applications.

Over oil insulated transformers the Askarel had one, and essentially only one, advantage; Askarel will not burn and the transformer can be used without a fireproof concrete vault inside buildings and factories. Askarel has good power frequency dielectric strength. The dielectric constant of Askarel is 2.4 as compared to 2.2 for transformer oil which gives it an advantage over oil in insulating barriers made up of sheets of pressboard separated by ducts. In a uniform dielectric field the stress in dielectrics is inversely as the dielectric constant of the materials. For an oil and pressboard barrier the stress in volts per inch is twice as great in the oil as it is in the pressboard. With pressboard and Askarel the stress is nearly the same in the Askarel as in the pressboard. Askarel can be used in transformers up to 34.5 KV maximum.

A typical Askarel has properties as follows:

Pour point -32°C

Flash point none

Viscosity at 37.8°C 5 to 2 centipoise

Thermal capacity 0.251 calories per gram per °C

Resistivity 10¹² ohms/cm²

Dielectric constant 2.4 to 4.5 (average)

Heat conductivity $30^{\circ}\text{C} \times 100 \times$: gram-calories/ $^{\circ}\text{C}/\text{min}$
Density 3.57 kg/liter

type of electrodes	separation inches	Dielectric strength-kV			
		60 cycle rms.		Full wave impulse	
		oil	askarel	oil	askarel
disc to plane	.25	35	40	133	150
	.50	52	67.5	190	215
	1.00	73	95	280	280
	2.00	107	116	410	340 (.83)
turn to turn	.02	16.25	17.5	39	36 (.92)
turn	.04	27.0	29.3	65	54 (.83)
with paper	.08	44.5	50.0	100	80 (.74)
tape	.16	74.0	-	177	-

Disadvantages of Askarel

1. Cost

The per unit cost of askarel was 5 to 7 times that of oil when it was first introduced. I do not have a comparative cost for the present time which would show the effect of the recent soaring cost of petroleum products. The cost of askarel transformers is further increased by the necessity for duplicate systems for storing, filtering, pumping and processing oil and askarel. Cost of askarel is further increased by the double pass welds required for all tank and radiator seams.

2. Power Factor

Askarel has a much higher power factor than transformer oil. Inertien for example has a power factor of .05 as compared to .001 for good transformer oil. Askarel is extremely sensitive to contaminants and the power factor can only be maintained at an acceptable value by keeping all materials in the core and coil structure and the interior surfaces of the tank and coolers clean. Ordinary varnishes, gums, glue of paint can not be used.

3. Chemically Active

Askarel is chemically very active and reacts with varnishes, paints, and transformer oil, with increases in power factor and decreased dielectric strength. All tank welds must be double pass welds to prevent leaks. Practically it is necessary to determine by test just what materials are compatible with the particular form of askarel which it is proposed to use. Initially some grades of pressboard were found to contaminate the askarel liquid and for a time two grades of pressboard were stocked, one for oil and one for askarel transformers. After some years of use a list of compatible materials can be accumulated.

4. Dermatitis

A minor disadvantage of askarel is that many people are allergic to it and it may cause a skin rash. In such cases the use of a protective ointment or rubber gloves can give relief. Most people are not affected.

5. Specific Gravity

Not a particular disadvantage is the fact that askarel is heavier than water. Any water which enters the transformer or which may be formed by heating and aging of cellulose insulation will rise to the top surface of the askarel. Sampling valves used to obtain samples of the askarel to test for water content must be located in the top level.

of the askarel. It is undesirable that the water being in the outtest part of the askarel tends to flow down through the cooling tubes of radiators and then rises again through the coils where it can be absorbed by the cellulose insulation.

6. Decomposition by an Electric Arc

A most serious defect of askarel is that short circuits or internal faults which cause arcing in the liquid produce water vapor and hydrogen chloride (HCL) which in combination form hydrochloric acid. After a fault in an askarel transformer if the core and coils are not immediately removed from the tank and cleaned with a solvent such as benzene the core and coils will be ruined. Steel parts such as the core and the inside of the tank and radiators corrode rapidly following an arcing fault. For a minor fault, such as ^{turned to} turn which produces intermittent arcing for a considerable period of time without a complete break down, the production of hydrogen chloride may badly damage the transformer before the trouble is discovered. Faulty electrical contacts at bolted joints or even faulty brases and pressure contacts can produce so called stowing arcs over long periods of time without complete breakdown. To at least partially protect against these effects a chemical "GETTER", or scavenger is usually added as a component of askarel. The scavenger reacts with and neutralizes the HCL until it is used up. This is helpful when the stowing arc does not continue for too long a time.

7. Impulse Strength

Although askarels have high dielectric strength against power frequencies the impulse strength against lightning or switching surges is considerably lower than that of oil. For a 5 centimeter gap between a flat disc and a ground plane the impulse strength of askarel is only 83 percent of that for oil.

The type of turn strength between paper typed electrical insulators with 3 millimeters of paper turn to turn has an impulse strength in askarel of only 74 percent of that in oil.

When askarel transformers are designed for basic impulse levels higher than 150 KVA, the insulation clearances must be those of the next higher basic impulse level. So far as I know askarel is not used for transformers over 200 basic level (34.5KV. class).

8. Explosions

Askarel liquids will not burn nor support combustion, but when subjected to high temperature or to an electric arc gaseous decomposition products are produced. For the case of a high energy internal fault enough gas can be produced to rupture the transformer tank. There cannot, however, be a secondary explosion due to ignition of the decomposition products such as can occur with oil transformers. In the United States askarel transformers are generally supplied with a pressure relief device mounted on a hand-hole on the transformer cover. This is set to open at a pressure below that which would rupture the transformer tank. It is fitted with a flange which permits the attachment of piping to carry the released gas and vapor to the air outside the building or vault. These devices are designed to reveal as soon as the internal pressure is relieved which prevents the entrance of moisture into the transformer tank.

5. DRY TYPE TRANSFORMERS

Another solution to the problem of a power transformer which can safely be installed inside buildings and factories close to the load it serves was developed by the Westinghouse Electric Corporation and put into production in 1936. This was the

dry type transformer designed for a temperature rise by resistance of 80°C. In the very first transformer produced and in all subsequent designs every effort was made to eliminate organic materials from the design. For use in factories and buildings the dry type transformer has largely replaced askarel transformer, which are now used mainly for some network transformers and small power center transformers. For use in factories the use of dry type transformers is almost universal in the United States. They have been manufactured in sizes up to 5000 KVA, three phase at 15000 volts in self cooled designs. With fans the rating of a self cooled design can at low cost be nearly doubled. A modified design can be built and hermetically sealed in a case filled with dry nitrogen or a high molecular weight fluoro-carbon gas which can be used outdoors or in atmospheres where explosive or excessive dust is present. This transformer represents the ultimate in transformer safety. Safety tests made on such a transformer are discussed in, the transactions of the American Institute of Electrical Engineers, technical paper No. 53-245, April 1953.

Like any other machine design which must be a compromise between cost, the desirable design features which can be included, and the undesirable features which must be excluded, the 80°C rise dry type transformer has advantages and disadvantages when compared to other types of transformers.

ADVANTAGES OF DRY TYPE POWER TRANSFORMERS

1. Safety

Safety is the primary advantage of the dry type power transformer. Such transformers can be and are located on platforms in the factory directly over the machine for which they supply the voltage. They are completely explosion proof and essentially fire proof. While the moisture proofing varnish on the coils and core can be made to burn at very high temperatures, it is present in very small quantity, and burns feebly and is nearly self extinguishing when the power is switched off. Since it contains no liquid the transformer can safely be mounted in a light weight sheet metal case lowered for ventilation.

2. Low Installation and Maintenance cost

Since the insulation in a dry type transformer is mainly air the size and weight of the core and coils is somewhat greater than that of an equivalent oil or askarel transformer. However the combination of the heavy liquid and use of a light weight sheet metal case results in an over all weight reduction. The transformer can be located on a platform over factory machines. Bus runs of either bus duct or insulated cables in conduit can be used. No provision for handling liquid insulation are required.

If the transformer is supplied with fans arranged to blow air through the coil ventilating duct the weight reduction over equivalent liquid installations is quite large. In the dry type transformer the cooling air flows directly over the heat generating surfaces, and is much more efficient than the cooling fans directed on external tank or radiator surfaces.

The dry type transformer is nearly maintenance free. Usually all that is required is to periodically check to see that the coil surfaces do not become covered with dust. If dust does accumulate it must be wiped off or blown off with dry compressed air.

3. Use as Power Centers

In the United States dry type transformers are frequently provided with a load bank

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air switch on the high voltage side. This switch is mounted in an extension of the transformer case. It can be provided with cable terminals for connection to either lead covered or rubber insulated power cables. Also it can be provided with expulsion fuses. The case design is made to match that of standard steel clad low voltage switchgear. In such a power center the high voltage switch compartment, the air cooled dry type transformer, and low voltage switchgear can be bolted together to form a small power center or substation.

DISADVANTAGES OF DRY TYPE TRANSFORMERS

1. Cost

A self cooled dry type transformer has a cost comparable to that of an askarel transformer of equivalent rating. The higher cost is due to the larger insulation clearances which are required by air insulation and by the high cost of insulating materials capable of with-standing a temperature of 150°C. These factors are partially compensated by the elimination of liquid insulation and by the lower cost of the transformer case.

Dry type transformers provided with fans can on a cost per KVA basis be built with costs comparable with oil filled transformers.

A few words about the insulation materials used for dry type transformer at present and in the past might clarify the reasons for higher costs. For turn insulation highly purified asbestos paper, glass, fiber covered wire applied with a varnish, and a paper made of fibers of poly-amideimide have been used. Asbestos is an erratic insulator and is hygroscopic. Fiber glass provides no insulation but maintains an air separation which is the insulation. It has been successful for voltage up to 15 KV. Special coating machines are required to apply glass fiber to the conductor. Polyamideimide paper such as Nomex made by Dupont Co. is an excellent insulation and can be applied with standard paper taping machines. It is possible to make 25 KV. transformer with this material.

Radial spacers between disc type coils may be made of porcelain blocks 9/16" thick for windings up to 15 KV. Plates of glass-plastic such as Glastic can also be used.

Spacers for vertical oil ducts can be made from pyrex glass tubes or Glastic type glass-plastic strips.

The end blocks for the coils are best made of cylindrical porcelain insulators with sharp edges corrugations.

Up to 15 KV. the high to low and low to ground barriers can be made of a high-grade paper-phenolic tube thoroughly cured by baking. Designs can be made by omitting the low to ground barrier but by providing a clear air duct. In the high to low space a clear air duct may be used if glass-silicone or silastic sheets are wrapped around the outside of the L.V. coil and coiled inside the H.V. coil.

For protection against moisture both the core and coils of dry type transformers must be coated with a high temperature varnish. A Westinghouse varnish based on polyamideimides and called Doryl is excellent. There are also available silicone varnishes.

2. Impulse Strength

Dry type transformers do not have impulse strengths as high as do liquid

filled transformers. The American Standards permit a lower basic impulse level and a lower power frequency test as follows:

Insulation Class KV	Basic Impulse levels		Con Pns Test	
	Liquid	Dry type	Liquid	Dry Type
1.2	30	10	10	4
5.0	75	25	19	12
8.66	95	35	26	19
15	110	50	34	31

The justification is based on economics and on the fact that the transformers are used inside buildings and factories on protected circuits. Usually the connection to the transmission circuit is by means of cables and a lightning arrester is required to be located at the pole where the connection is made. Millions of connected KVA. and years of service have justified this practice.

Sealed dry type transformers which are suitable for outdoor use have the same insulation levels as liquid filled transformer.

3. Limited Voltage Range

Ventilated dry type transformers were originally made for voltages 15 KV. and below. Later the use of nonex paper turn insulation and interleaved windings have permitted designs for 25 KV. In the United States higher voltages are seldom used inside buildings and factories.

4. When installed in locations where there is excessive dust such as cement mills, explosive dust as in grain elevators, explosive gases as in mines, or corrosive gases, the ventilated dry type transformer cannot be used unless such materials are excluded and a supply of clean cooling air is piped to the transformer.