Considerations for Evaluating Transformer Askarel

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Few electrical experts are also chemists. Perhaps that's why so many transformer operators (and buyers) make the mistake of thinking transformer "oil" and "askarel" are alike. They are not—the differences in these two kinds of liquid insulation go beyond the obvious difference that oil burns and askarel does not. The differences also extend to their insulating power, operating characteristics, and manner of maintenance inspection. Due to the mistaken belief that transformer askarel and mineral oil are similar, there has been a great deal of confusion concerning maintenance procedures and operating characteristics of the two fluids. To put an end to misconceptions, our firm is printing an easy-to-follow maintenance guide based on evaluation experience with askarel over 30 years of service. The service history study shows that askarel users generally are confused over several major points; these are discussed here in the hope that they will benefit all operators of askarel transformers.

Some of the earliest askarel transformers were first made around 1930. Many of these are still in service. After so many years of use, the outside appearance of some of these units would not warrant a prize, but their interiors remain clean. The original fill of askarel insulation is still in use and there has been little or no maintenance. They are giving the 30 years of trouble-free service life promised by the manufacturer.

However, as with any type of equipment, over the past quarter century there have been a few instances of unexpected failure. In every case, investigation proved that the breakdown could have been avoided.

A review of certain facts of operation and thorough inspection, without exception in the cases examined, showed the reason for every askarel transformer failure to be the same: the entrance of moisture. However, it is obvious that any transformer can fail from inadequate design, overvoltage, damaged insulation, etc.

Since askarel (and mineral oil type) transformers are often selected for use in damp areas, sometimes directly exposed to the elements, and frequently operated where flooding may be expected—the need to exclude moisture entry calls for optimum transformer design-engineering to assure dryness.

Monsanto's interest in transformer askarel is twofold: we manufacture and supply the dielectric fluid and we use a large number of askarel transformers in dozens of plant locations to benefit from their dependability, economy, and fire safety.

Since we neither design nor build transformers, specific design detail on new equipment is left to experts in the field. But, the general facts relating to the moisture problem must be considered from the viewpoint of the maintenance engineer. There are many thousands of askarel transformers now installed, many only five or less years old.

Recently, an authority on askarel transformers was asked what he considered to be the most important point of maintenance. His reply: "Keep 'em dry, then leave 'em alone."

Keeping the transformer interior dry is indeed the watchword and not merely an oversimplification of fact. If steps are taken to keep moisture out of askarel, the liquid insulation will undergo no change and the transformer will operate trouble-free for 30 years or more.

Comparison of Askarel and Mineral Oil

Transformer users who are not aware of the marked difference between askarel and mineral oil have a tendency to evaluate askarel liquid insulation in terms of the more familiar properties of mineral oil. This is the cause of much confusion. The "check point" values of oil and askarel are different; the interpretation of the test values is different. The previously mentioned "Maintenance Guide" attempts to end the confusion by pointing out the difference in operating characteristics and check tests of the two fluids. However, such literature is necessarily more directive than explanatory. With a minimum of "reasons why" the askarel maintenance guide directs the engineer to make just three simple visual inspections of the askarel fluid and determine its dielectric strength. Moisture determination by the Karl Fischer method is suggested only if the dielectric strength is found to be less than 20 to 25 KV at 25°C. This simplified checking, which can be easily carried out by any user, comes remarkably close to "leaving 'em alone." Unlike oil, periodic power factor and volume resistivity determinations are not needed for askarel check testing, and if run, the values obtained are completely unrelated to what these values would mean when applied to mineral oil. The reason is: oil and askarel are completely different chemical substances.

The following explains why power factor and resistivity tests are relatively unimportant, while dielectric strength is most important—in inspecting and judging askarel insulation.

Evaluating Power Factor

The power factor of freshly made

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transformer askarel is close to 0.1 percent at 100°C and 1 kc (the conditions of measurement in our quality control laboratories). This same value level, or even slightly lower, is found when accurately measured in the field, usually at 20°C and 60 cycles.

This initial low power factor of new askarel is essentially the same level normally found in newly-made, dielectric grade mineral oils. Such striking similarity of values in both types of liquid insulation misleads many users into assuming that the power factor of these two entirely different fluids should run parallel throughout their respective service lives. But this does not happen. In service, the power factor of askarel goes up to a greater extent than that of mineral insulating oil—but the rise has little or no significance.

The prime reason why the power factor of askarel and oil do not go hand-in-hand is that unlike mineral oil, askarel is a relatively polar medium. For example, the dielectric constant of transformer askarel is about 4, or nearly twice as high as the dielectric constant of mineral oil. Infinitesimal amounts of ionic conducting impurities in askarel can markedly increase its power factor. The same impurity may not affect the power factor of mineral oil. But despite this sensitivity, askarel's insulating value is unimpaired.

Experts know that to correctly measure the low power factor of new askarel requires exceptional cleanliness of the test cell and strict adherence to the proper techniques (ASTM method D-924).

One leading counselor correctly states that the critical technique required to accurately measure the power factor of askarel is impractical for field use. Experience shows that the unskilled or not-too-careful attempts to determine the power factor of new askarel in the field lead to unreliable results. The testing should be done with the greatest care, exactly as specified by either the ASTM method (or by a similar methodology) to eliminate trace contamination and must be carried out in a well-equipped laboratory.

With a power factor so sensitive to traces of contamination, it stands to reason that when the askarel is put into a new transformer, the power factor of the fluid can be expected to increase immediately on contacting the insulation which contains traces of soluble ionizable compounds. Various transformer manufacturers dictate that the power factor of askarel in a new transformer should not exceed two percent at 20°C and 60 or 70 cycles. While this arbitrary limit is about 10 times as high as the power factor of newly made askarel, considerable care in check testing is still required to obtain an approximately correct power factor reading within even this higher level limitation.

Authorities with years of experience with askarel agree that after years of continuous service, the askarel's power factor will be high, as much as 20 to 80 percent (or more) at 100°C and 60 cycles, or about one-tenth of this if measured at 20°C and 60 cycles.

The majority of electrical engineers and maintenance operators have found that a high power factor in askarel is not important, however much alarm such a high value would warrant if found in mineral oil. The only qualification to be added is this: while high power factor in itself is unimportant, some of the possible causes of high power factor may warrant investigation. However, in the absence of other test data that can indicate the advisability of thorough inspection, relatively high power factor is to be expected.

On the other hand, a high power factor when found in mineral oil usually indicates chemical and hence electrical deterioration. This is true of askarel *only if* it has undergone strong arcing, readily detected by darkening and sedimentation.

Volume Resistivity Requirements

The resistivity of askarel in properly constructed new or rebuilt transformers will not be significantly lower than the 100 x 10^9 ohm-cm, at 100°C, 500 v, d-c; 0.1-inch gap, specification limit. However, this value can be expected to decline fairly rapidly even in a normally operating transformer. Resistivity should not drop below about 25 x 10^9 ohm-cm, and ample experience shows it does not fall below 5 or 10 x 10^9 ohm-cm, even in the presence of unusually heavy contamination, *other than water* contamination. The reason for this is that askarel, by its chemical nature, is practically completely inert from an electrical standpoint—it simply does not conduct current. In consequence,

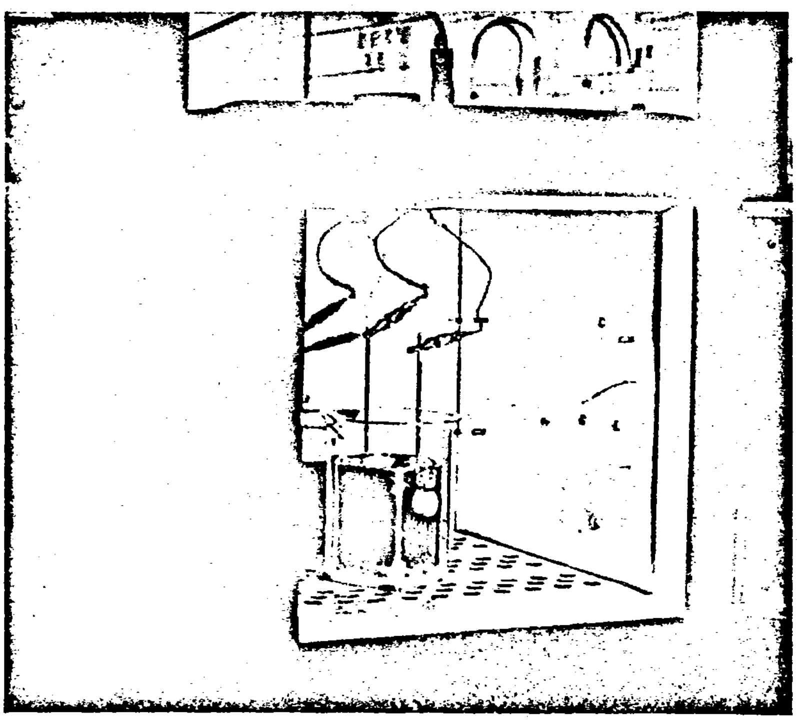

Figure 1, a specially air-conditioned room and test cell shown above is used at Monsanto to measure the power factor and resistivity of askarel.

Table 1—Comparison of Values Found in Askarel Insulation After Various Stages of Use

Properties	A New askarel	B Askarel in properly* built new or rebuilt units prior to use.	C Typical values after normal operation. (Survey of 50 units mostly 2-5 yrs. old—some 10)	D Non-arced but slightly contaminated askarel in improperly* built units, new or slightly used.	E Same fluid in column D after refining with earth and filtering.	F Heavily arced askarel. Of the very few askarel failures, the majority were due to excess water—remainder due to internal electrical discrepancy
Color	Light straw	Light straw	Light straw	Can have foreign shades, blue, green, red cast.	Foreign shades remain showing extraction of oil soluble color.	Black
Condition	Clear, free from particles	Clear, practically free from particles	Clear, trace of particles	Clear, slight amount of particles	Clear, free from particles	Contains carbon particles
Moisture, 25°C	<30 ppm	<30 ppm	10-70 ppm, all dissolved water	20-100 ppm, all dissolved water	<30 ppm	near or above, saturation level, 125 ppm, partially undissolved water
Dielectric strength, 25°C, 0.1-in. gap	35 kv min	35-48 kv	35-45 kv	30-42 kv	40-45 kv	5-15 kv
Volume resistivity, 100°C, 500 V, d-c, 0.1 inch gap	100 x 10^9 ohm-cm min, usually 500-1,500	20 x 10^9 ohm-cm min, usually at least 100 x 10^9	15-400 x 10^9 ohm-cm	about 5 x 10^9 ohm-cm	at least 1,500 x 10^9 ohm-cm	about 3 x 10^9 ohm-cm
Power Factor: 100°C, 60 cycles 25°C, 60 cycles	 2-5% 0.05-0.1%	 10-25% 0.5-2%	 10 to near 80% 0.5 to near 10%	 30 to 100% about 7 to over 15%	 2-5% 0.1-0.2%	 100% at least 25%

** A properly built unit is defined as one in which the materials of construction are chemically and electrically compatible with askarel.*

Out of too many transformers to count over the years, Monsanto plants had two that failed after 13 and 15 years of service, respectively. These were also inadequately sealed—with cork gaskets that had deteriorated after many years of full outdoor exposure to the elements. Another factor—these units were not required to be constantly on line; their intermittent operation intensified breathing and moisture condensation. The amount of water that entered and accumulated would have caused failure in any type of transformer. These units have since been rebuilt and "modernized" for outdoor service, simply by a welded sealing of top cover, fins, instrument connections, and all other fittings. A blanket of dry nitrogen over the askarel has also been provided and the units are fitted with pressure relief devices and pressure gauges to check on pressure fluctuations.

New Transformers—"Vaccinated" Against Moisture

Transformer makers, aware of the importance of keeping out moisture, now usually offer welded construction at no increased cost over gasketed construction. Where gasket seals are needed for hand-hole openings, they are designed with a recessed fitting to allow only minimum contact with the askarel and with the elements.

For gasketing, instead of plain and coarse grain cork—fine grain cork impregnated with nitrile rubber makes the best material. Nitrile rubber alone has been used, but this polymer is slowly eroded over the years by askarel. There are, however, a number of askarel resistant polymers; these include "Teflon," "Viton," and most silicone "rubbers." While relatively costly, these materials warrant consideration for their long term use, at least for the smaller size gaskets.

Overseas, a well-known conservator construction design is popular; this completely fills the transformers with fluid and thereby eliminates any "air space." This construction greatly minimizes moisture entering units even when located in damp areas.

On indoor installations, normal gasketing of the transformer is, of course, entirely satisfactory unless there is excessive dampness in the environment and wide temperature fluctuations that accentuate the breathing. If the user cannot be certain of a dry atmosphere, it is wise to consider fitting the unit with a dehumidifying breather.

As an example, highly reliable askarel units are used in transformer-rectifier power supply sets, for military communication equipment (tropospheric scatter) in remote areas. These are kept dry by channeling their breathing through a canister of silica-gel attached to the side of the transformer. The canister is fitted acceptable electrical grade askarel is restricted to only a few tenths of one part per million, even under this severe thermal stress at the finished product's boiling point. The chemical stability check allows no more than the same tiny amount of chloride formation when the askarel is treated with warm alcoholic caustic solution (both procedures are documented at ASTM and elsewhere).

We consider it essential to carry out this check testing on every lot; to determine all the physical and electrical values; and to record this data for each shipment. Because of these precautions and knowledge of manufacture, the user of askarel insulation can be sure that its chemical and thermal stability conform with the requirements prescribed by the electrical industry.

Without this strict check-up and data recording, it would be difficult to be sure whether any deterioration of the initial electrical values would be due to lack of inherent stability, or due to expected pickup of contaminants, of which moisture is by far the most deleterious. Since we check, test, and prove that the new product has maximum stability—we can be sure that any detrition of electrical properties must be the result of severe arcing or water contamination.

Moisture: Askarel's Greatest Enemy

All users of liquid filled transformers understand that moisture is a major problem, in askarel as well as in mineral oil equipment. The moisture content of new askarel is not over 30 parts per million. This should not be allowed to increase above about 70 parts per million in a normal operating transformer.

The proper test for moisture in askarel is the Karl Fischer method. However, this is not a practical field test because it usually requires laboratory facilities. As a service, Monsanto and various transformer makers can run this test for users whenever dielectric strength loss (in the absence of arcing) indicates moisture contamination.

However, sampling and knowledgeable inspection are highly important.

Only about 125 parts per million of water can dissolve in askarel at room temperature. Obviously, it is possible to have water condensation on the shell or "globules" of water on the insulation surface that have not dissolved in the askarel. Since condensed moisture may not be uniformly distributed on the liquid surface, it is difficult to assay the transformer's interior condition conclusively, even when carefully drawing a surface sample of the askarel. The problem is much the same with mineral oil except water tends to settle to the bottom of the oil. Askarel, the more dense liquid, holds water on the surface.

In the event of a moisture access into a transformer, the problem of detection centers mainly on detecting the undissolved water that has accumulated much more so than in detecting the rise in the limited amount of dissolved water in the dielectric fluid. This rise is gradual, readily detected by dielectric strength checks, and should be considered as the "clue" to when an interior inspection is warranted.

A reliable and suitable method to detect undissolved moisture distributed non-uniformly over the environment has not been developed for either oil or askarel units. Therefore, a moisture check on the fluid, either by the Karl Fischer direct determination or by the indirect check on dielectric strength, must be relied on as an indicator. This requires a periodic check at regular intervals to establish a possible upward trend. A single, one-time analysis unrecorded and uncompared may not reveal the facts.

The very few instances of failure of askarel transformers bring out very clearly: moisture is practically the only troublemaker—in the absence of arcing.

However, the rare instances of failure do not justify saddling the transformer user with an onerous maintenance program that requires complicated, unnecessary testing. Instead, with knowledge and alertness to the indications, the user can zero in on the important moisture factor and thereby simplify maintenance.

As the expert said, the best maintenance advice is to "Keep 'em dry, then leave 'em alone." The significance of this statement has been documented by 30 years of field experience and by the description of askarel properties presented in this article.

For year-after-year of dependable, fire-safe operation with negligible attention, water must be "designed-out" or *kept out* by every practical means. This fact of operating life is equally important to either askarel or mineral oil transformers. By protecting against the entry of moisture, the user solves the majority of the maintenance problems for both types of transformers.

It is important to note (see table 1, sequence A to E) that the dielectric strength of reasonably dry askarel *is not impaired* even though there is a characteristic increase of power factor and reduction of volume resistivity. Power factor and volume resistivity are *unimportant criteria* in evaluating askarel insulation. With little exception, the very few askarel failures over 30 years showed the same major fault:

Improper sealing against moisture caused loss of dielectric strength and insulating values. Moisture contamination, especially beyond 125 ppm saturation level, caused failure.

Reactivating Old Transformers

Perhaps some users can benefit from our own experience with a very early vintage askarel transformer. This was an expensive outdoor installation—where fire and explosion safety was required to protect workers as well as valuable equipment. The outdoor humidity posed a constant threat primarily because of the transformer's outdated and inefficient sealing arrangements.

Unwilling to take out the transformer for modernization, and faced with a constant pressure loss, we solved the problem by bleeding through the "air space" a very small but continuous (bubble) stream of dry nitrogen from a standard cylinder. A little more than enough nitrogen was introduced to compensate for the normal breathing of the unit due to temperature fluctuations. This "gas drying" has been going on for years; the askarel unit is still operating with the original fill of fluid.