No health risk with askarel insulated distribution transformers

A review of the technical and economic advantages and disadvantages with particular reference to safety

by J. M. Thomson*

Perhaps because few electrical engineers are also chemists, many engineers are not familiar with the use of askarel fluid in distribution transformers. Even the difference between transformer oil and askarel is often not understood by transformer users. The two insulants are of course not alike but this goes beyond the obvious difference that oil burns and askarel is fire resistant. Differences extend to insulation values, operating characteristics, maintenance and reliability.

The ASTM definition of askarels indicates their important features as being " synthetic fire-resistant type insulating liquids which when decomposed by electric arc evolve only non-explosive gaseous mixtures."[1] Although there are many liquids which satisfy this definition, for a fluid to be successfully used as a transformer dielectric coolant, it is necessary to meet many more requirements such as stability, freedom from corrosion, dielectric strength and low cost. For these reasons the askarels currently produced are blended from a class of chemical compounds known as chlorinated aromatic hydrocarbons.

Chemical hazard examined

One of the factors involved in the acceptance of askarels as transformer fluids is that a new or unknown chemical hazard might be introduced, either during normal operation, or under fault conditions. Experience has shown that no serious hazard is met.

If a transformer is of the sealed type (and this is the type that is most widely used), there is no escape of vapour as the askarel is fully contained. There is then no possibility of contact between liquid and personnel during normal operation.

Under fault conditions in which the arc is struck below the surface of the askarel the fluid is decomposed with the liberation of hydrogen chloride and carbon. Clark[2] has reported the composition of the gases evolved by an arc under askarel, see Table 1.

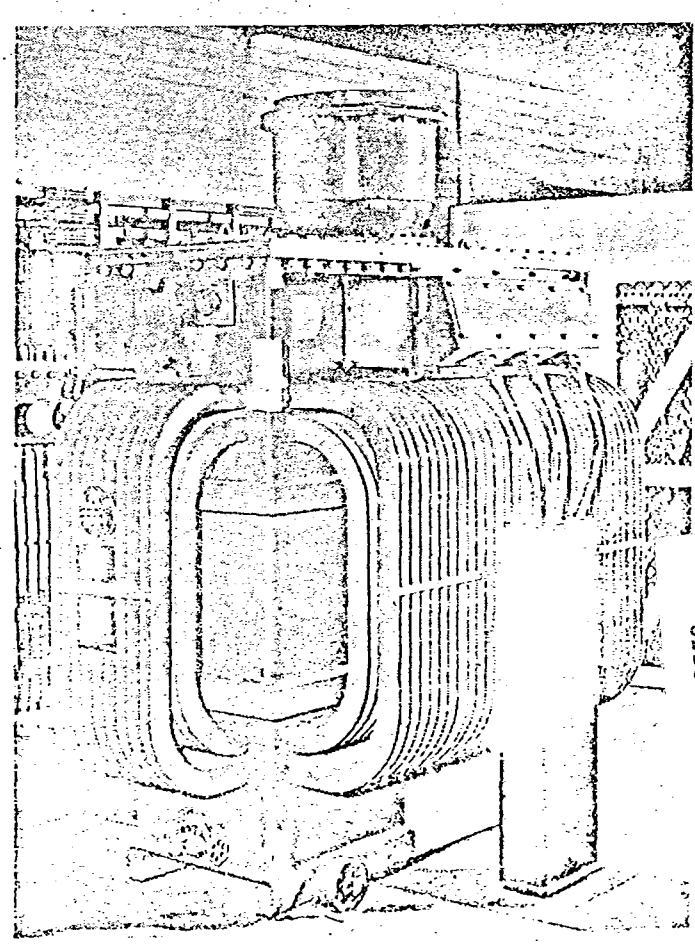
Hydrogen chloride is a colourless gas with a pungent smell and its maximum allowable concentration in a human environment is 5 ppm (by volume) or 7 mg/m³. On account of its high solubility in humid air it is quickly dispersed. For this reason and because it is most unpleasant to breathe, making its presence easily detectable, it is very unlikely that any injury would result from this source in spite of its relatively low maximum allowable concentration. In any case transformers are normally located in well ventilated areas to assist heat dispersion.

Hydrogen chloride gas is generated in an askarel transformer only when an arc has been struck and immediately this arc is broken gas formation ceases. Thus only a limited amount of gas is formed which is proportionate to the intensity of the arc. To prevent build up of hydrogen chloride gas in the transformer as a result of either small internal corona discharge or major fault arcing, askarel fluid is formulated with a highly efficient chemical scavenger which neutralises any small amounts of HCl gas formed, thus preventing any pressure build up even in sealed units.

Hydrogen chloride gas forms hydrochloric acid only in association with water and although there are always

Table I.—Composition of gases evolved by an arc under askarel

Gas	Percentage
Hydrogen	0
Saturated hydrocarbons	0
Unsaturated hydrocarbons	0·5
Carbon monoxide	0·25
Carbon dioxide	0
Oxygen	0·25
Nitrogen	2·0
Hydrogen chloride	97·0



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This 1,000 kVA askarel transformer was installed in the basement of the Birmingham Civic Centre in 1936 and is still operating satisfactorily with the original fluid charge

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minute quantities of water present in even a sealed transformer, generally the absorption of both the gas and the acid by the askarel is so efficient that falls in acidity after extended periods of operation have been observed. The results in Table 2 were obtained from a sample taken from a sealed transformer after 34 years of operation.

It is sometimes thought that the decomposition of askarel by an arc results in the formation of chlorine or phosgene but investigations have shown that this is not so. The matter has been extensively investigated in Germany by the Chemische-Technische Reichsanstalt[3] and in France by P. Jay.[4] The Chemische-Technische Reichsanstalt carried out a series of tests in which askarel was: (i) heated with metals up to 96-98°C; (ii) dropped on to heated metals up to 800°C; (iii) vaporised and passed over metals heated to 500-740°C in the presence of air; and (iv) decomposed by an electric arc (high and low voltage) both with and without the presence of air. In none of these tests was the presence of chlorine or phosgene detected.

While transformer askarels have been used in the electrical industry for over 35 years, they are chlorinated hydrocarbons and it is wise to take suitable precautions when handling them. The liquid has a solvent-like action on the fats of the skin in a similar manner to paint thinners and dry cleaning solvents. Therefore when an askarel comes into contact with the skin it should be washed off with plenty of soap and water at the earliest opportunity. Saturated clothing should be removed and dry cleaned. Infrequent exposure to askarel vapours will not cause any ill-effect but prolonged exposure to a high vapour content should be avoided.

Table 2.—Analysis of a sample taken from a sealed askarel-filled transformer after 34 years in service

Test	Method	Transformer Fluid Tested	IEEE Survey*		New Askarel Specification
			Average	Range	
Acidity mg KOH/g	Monsanto	0·006	0·12	0·05-0·5	0·01 max

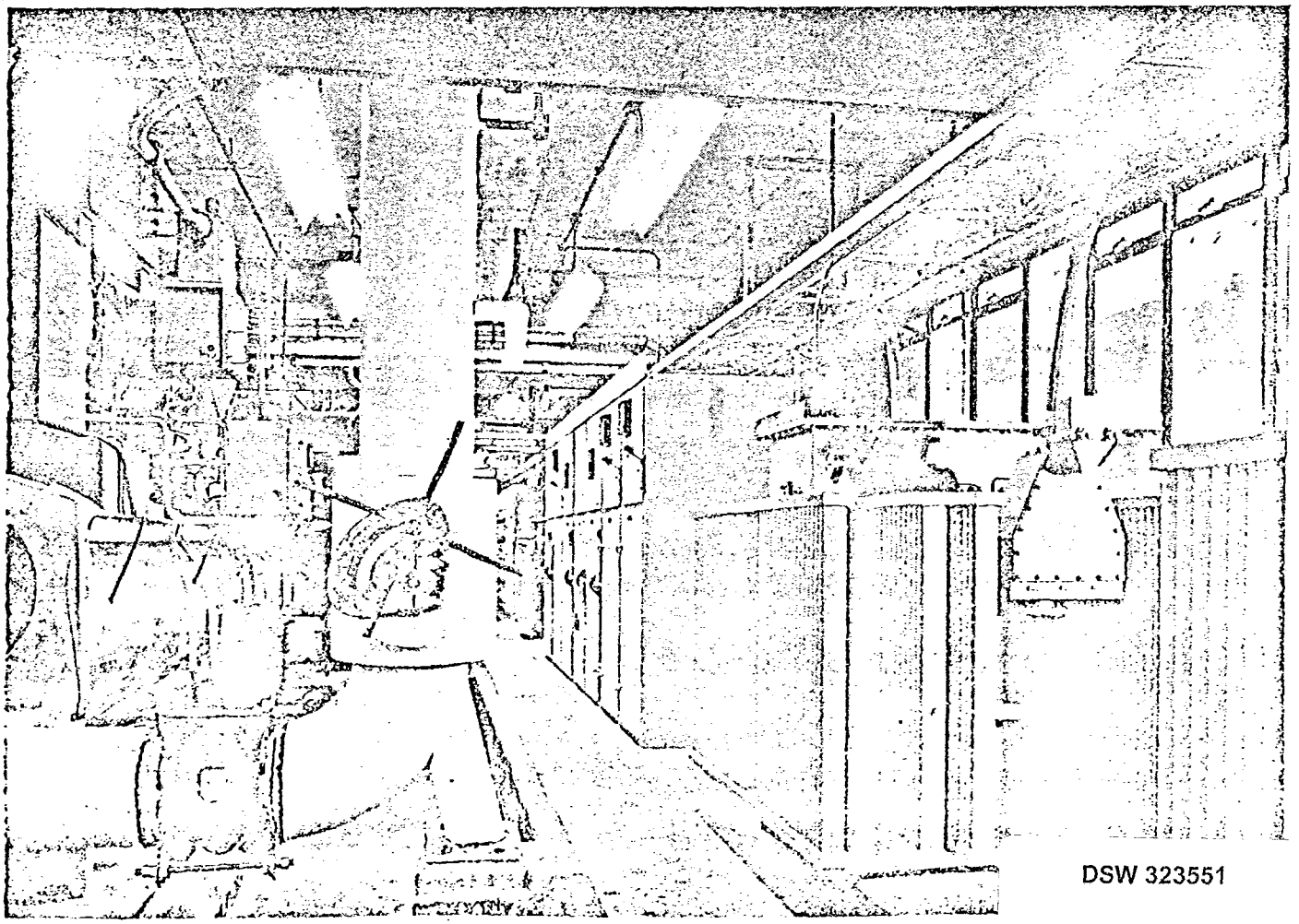
* Mineral oil-filled transformers.

The main advantages of askarel-insulated transformers are as follows:—

Fire Resistance. Transformer askarel was designed to have similar physical characteristics to mineral oils since it was intended that the use of askarel should require minimal redesign of the transformer. The most important advantage askarel has over oil is fire resistance, that is, it will not support combustion. However, the possibility of a general fire started elsewhere and involving a transformer should also be considered.

A tank containing many hundreds of gallons of flammable fluid will add substantially to the extent of fire damage. The number of fires started by transformers is very low but a far greater number of transformers are involved in and contribute to fire damage. In addition, it should be remembered that oil decomposes under arc, evolving a mixture of hydrogen and hydrocarbons which unlike gases evolved from askarel—is both flammable and explosive over a wide range of gas/air mixtures.

Freedom of Siting. Because of the safety features of askarel transformers they can be placed anywhere. No fire precautions have to be taken nor is there any necessity



Askarel transformers at the load centre in the Daily Express *building in Fleet Street*

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at the load centre if desired. Because there is no risk from atmospheric contamination they can also be installed before construction is complete.

In comparison, dry type transformers are limited in this flexibility of location because of their susceptibility to atmospheric contamination. Additionally, installation costs usually run much higher with dry type transformers than with askarel units especially if sound proofiing or protection from atmospheric contamination is required. Due to their nature, open dry type units may require a great deal of maintenance, have a high noise level, be expensive to operate and have a low impulse strength and overload capacity. In practice, dry type transformers have been found to be less dependable because of these operational disadvantages combined with their susceptibility to atmospheric contamination.

Maintenance. If moisture is kept out of the askarel the liquid insulation should undergo no change and the transformer unit should give trouble-free operation for 30 years or more.

The main disadvantages of askarel-insulated transformers are as follows:—

Cost. An askarel transformer costs approximately 40 per cent more than an equivalent mineral oil transformer but about a similar amount less than a dry type transformer of the equivalent rating. But when installation costs are included the askarel transformer can well prove to be the least expensive choice of the three types.

Weight. Askarel is about twice the weight of oil. Typical relative weight difference of the three different types of transformer as manufactured in Britain are given in Table 3. In practice the extra weight rarely presents a constructional problem.

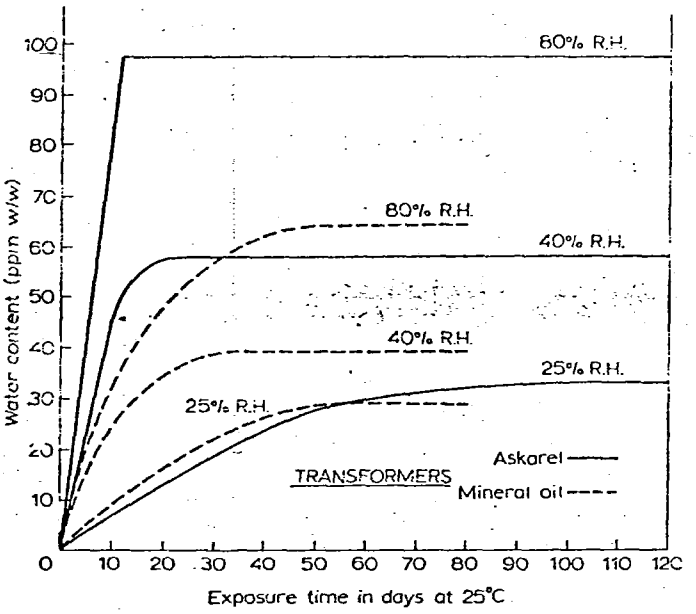
Switchgear and Tap Changers. Askarel transformers are not normally constructed with on load tap changers nor are askarels suitable for use in switchgear because askarel does not possess the same arc quenching properties as oil.

Contamination by Oil. Mineral oil is soluble in askarel and any contamination of the askarel by oil will degrade its fire resistance. A maximum mineral oil content of 2 per cent by volume can be tolerated without seriously affecting the fire resistance. Askarel transformers should never be topped up with oil.

Effects on design and costs

Askarel transformers have been made to operate at voltages as high as 120 kV but since they are normally employed indoors as distribution transformers their voltage rarely exceeds 11 kV. One of the largest askarel transformers to be designed and built in Britain has recently been completed. It operates at 33 kV and has a rating of 14 MVA. An important factor in the design of askarel units is the relatively high cost of the fluid compared with oil. Efficient design is, therefore, necessary to keep the volume to a minimum.

As water is askarel's greatest enemy completely sealed transformers are generally used. The introduction of all-welded, as opposed to gasketed, transformer tanks has resulted in the frequent specification of this type of construction for askarel transformers. Where gasket seals are needed, for example, for hand hole openings, they should be designed with a recessed fitting to prevent the gasket softening and extruding out of its seat.



The absorption of water from humid air by askarel and mineral oil

Table 3.—Comparative weights of oil, dry type and askarel-filled transformers manufactured in Britain

Rating (kVA)	Oil-filled (lb)	Askarel-filled (lb)	Dry type Class C (lb)
750	6,600	8,500	5,000
1,000	8,100	11,000	7,300
1,500	14,000	17,000	9,800

Fine grain cork impregnated with nitrile rubber instead of plain or coarse grain cork makes the best material for gasketing. Nitrile rubber alone has been used but the cork impregnated material has been shown to perform better. Additionally, there are a number of other materials which are completely resistant to askarel; these include Teflon and Viton and most silicone rubbers. These materials are often used for smaller gasket applications particularly in the dynamic state.

With the increase in price of copper, the possibility of substituting aluminium for this material becomes more attractive. Aluminium is perfectly compatible with askarel, having been used for many years with similar fluids in capacitor construction.

In general, askarel-resistant materials are no more expensive and no less readily available than oil-resistant materials. In fact askarel/oil transformer production can be standardised to use products including gaskets and tanks that are common to both fluids, thus making for greater versatility and flexibility in the transformer manufacturer's plant.

Experience has shown that silica gel breathers on open transformers are often not maintained and sealed units are therefore preferred to avoid the ingress of water. To relieve tank pressure in the event of a sustained fault condition, graphite bursting discs can be used. Alternative protection can be effected by use of a pressure actuated relief valve that provides both a visual and aural warning. The use of Buchholz relays is not recommended as askarel, unlike mineral oil, is not degassed before filling the transformer. This has been known to lead to false actuation of the relay caused by the escape of air as the fluid heats to operating temperature when the unit is on load.

Because of the hygroscopic nature of the fluid the trans-

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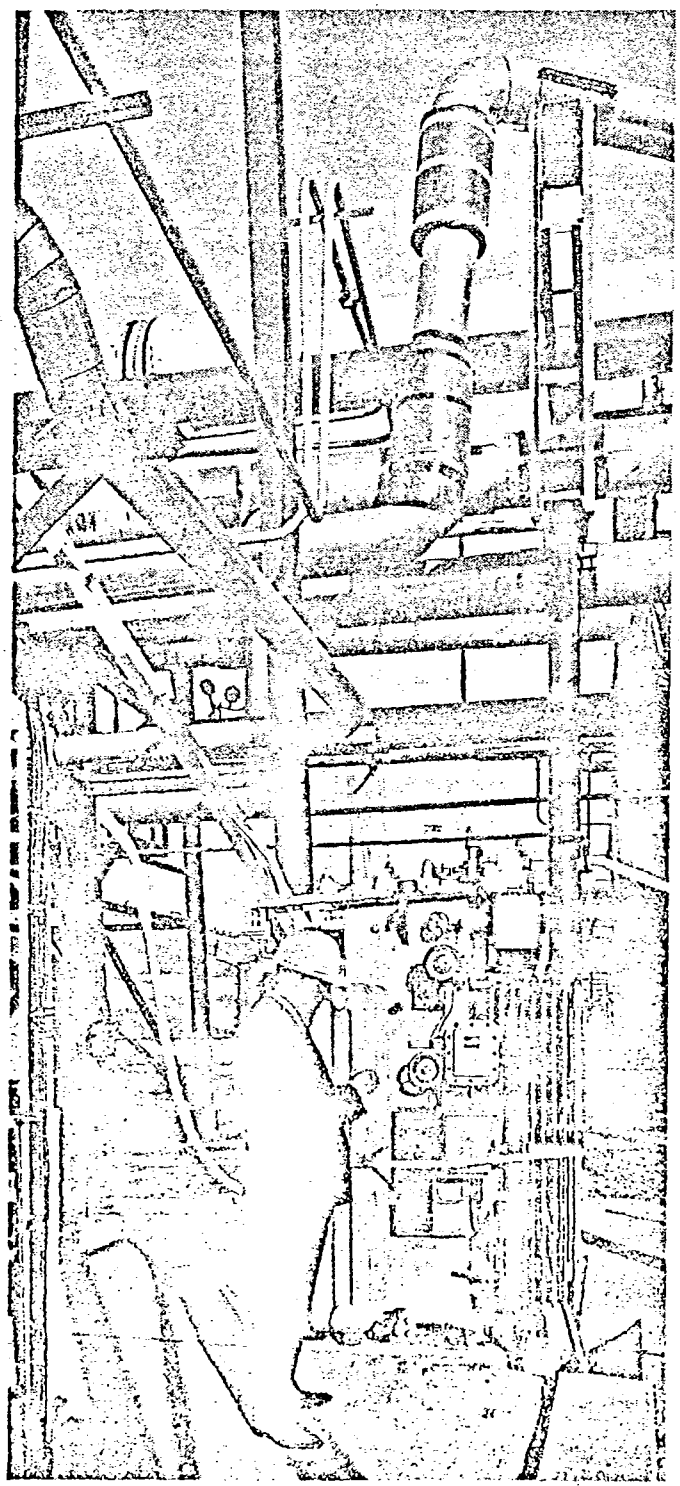
former should never be allowed to stand open during manufacture for any length of time, particularly when the humidity is high. The graph indicates the absorption of water from humid air by transformer askarel and mineral oil.[5] Another important factor that affects design is the solubility of gases in askarel. The calculation of airspace between the surface of the fluid and the top of the tank is basically a function of fluid volume and tank pressure rating. Table 4 gives the relative solubility of various gases in askarel fluids.

There will always be locations in non-hazardous areas where an askarel transformer cannot be judged an economic proposition. These locations will nearly always be either isolated substations or outdoor industrial sites where a permanent location can be guaranteed and load centring is not possible.

Gas	Percentage of Gas by Volume Corrected to:			
	25°C 760 mm		0°C 760 mm	
	25°C	100°C	25°C	100°C
Carbon dioxide	71·0	47·0	—	—
Air	5·7	4·9	5·8	5·0
Nitrogen	6·0	4·8	5·5	4·4
Hydrogen chloride*	37·8	50·9	—	—

* In the absence of scavenger.



One of four 750 kVA askarel-filled transformers installed in a flameproof area at the Canvey Island methane terminal.

In certain circumstances it is necessary to locate oil-filled switchgear in the substation and in such situations there would be no point in installing a fire resistant transformer as the presence of oil would already require fire protection apparatus. Oil switchgear can of course be located outdoors or alternatively air-break or SF_6 insulated switchgear can be used indoors. There are many locations where there is a fire risk and space for substation construction is limited. Dry type transformers may be used under such restrictions but only if there is no fear of atmospheric contamination and a thorough maintenance programme is strictly adhered to. In addition, the higher noise levels and lower impulse/overload capabilities of dry type transformers would have to be considered.

Load centres

A fire risk location is not the only place where askarel transformers can be used to advantage. In recent years package substations or load centres incorporating the transformer and associated switchgear have become popular. Initially dry type transformers were used but the lower cost and operational advantages of askarel transformers have resulted in their acceptance in place of the dry type in this application.

Askarel transformers are widely used in multi-storey buildings. Much the same approach as that used in industrial load centring can be taken, locating askarel transformers at the load centres of various floors. Potentially hazardous substations in the basement of the building are avoided and savings are made by eliminating the use of long runs of expensive m.v. cable.

The low noise level of askarel transformers makes them attractive for installation in residential buildings, hospitals, universities and schools. As a rule of thumb askarel transformers produce 75 per cent less noise than the equivalent dry type.

Askarel transformers offer a margin of safety against surge and overload levels and they fully satisfy the British Standard requirements for impulse testing and losses. The same overload protection is obtained as with an oil-filled transformer without the attendant fire hazard.

For over 35 years askarel transformers have served to distribute the power for many industrial and residential areas in Britain and during this time they have established an excellent record of safety, economy and reliability. Over the last five years the sales of askarel transformers have quadrupled in Britain. DSW 323553

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