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Miyoshi et al.

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[45] **Aug. 14, 1973**

[54] **INDUCTIVE ELECTRIC APPARATUS**

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[73] Assignees: **Hitachi, Ltd.; Kureka Industry Co.,** both of Tokyo, Japan

[22] Filed: **Dec. 28, 1970**

[21] Appl. No.: **101,686**

[30] **Foreign Application Priority Data**

Dec. 29, 1969 Japan 44/1120

[52] U.S. Cl. ..... **340/146.1 AJ,** 235/61.11 E, 235/61.7 A

[51] **Int. Cl.** **H01f 27/02**

[58] **Field of Search** 208/14, 19; 336/94; 252/63

[56] **References Cited**

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Primary Examiner—Herbert Levine

Attorney—Craig, Antonelli, Stewart & Hill

[57] **ABSTRACT**

An inductive electric apparatus which comprises a polycylic hydrocarbon oil mixture having a flash point of more than 150°C and consisting of polycyclic naphtenic hydrocarbons having two to five rings and polycyclic aromatic hydrocarbons having two to four rings, each side chain alkyl group attached to said rings having not more than four carbon atoms, an electroconductive coil and a cellulose insulator in combination. The inductive electric apparatus can have a larger increase in allowable temperature than that of a combination of the ordinary hydrocarbon insulating oil and the cellulose insulator, and accordingly it is possible to make the apparatus smaller and lighter.

7 Claims, 3 Drawing Figures

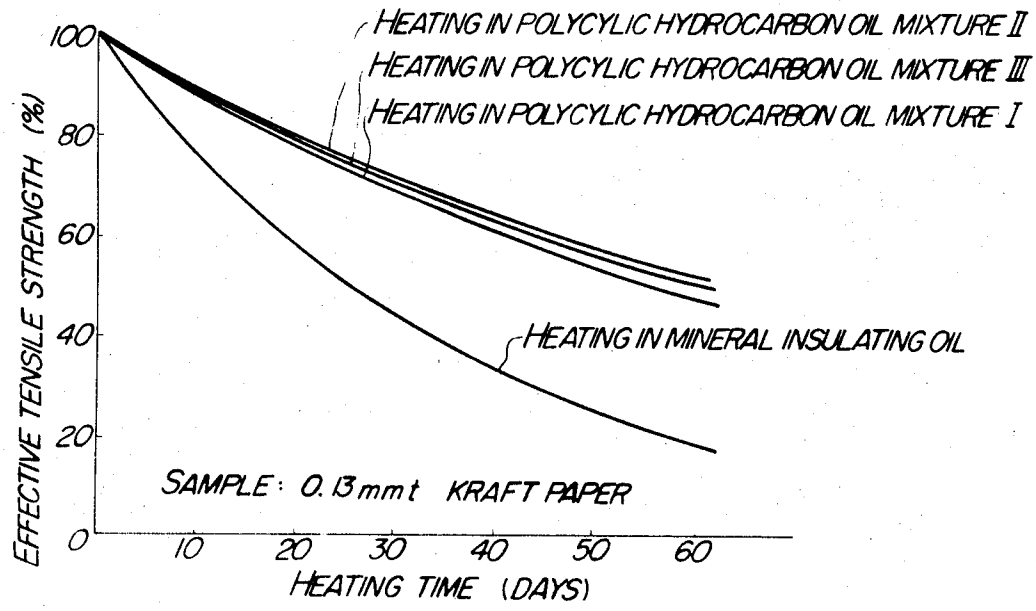


FIG. 2

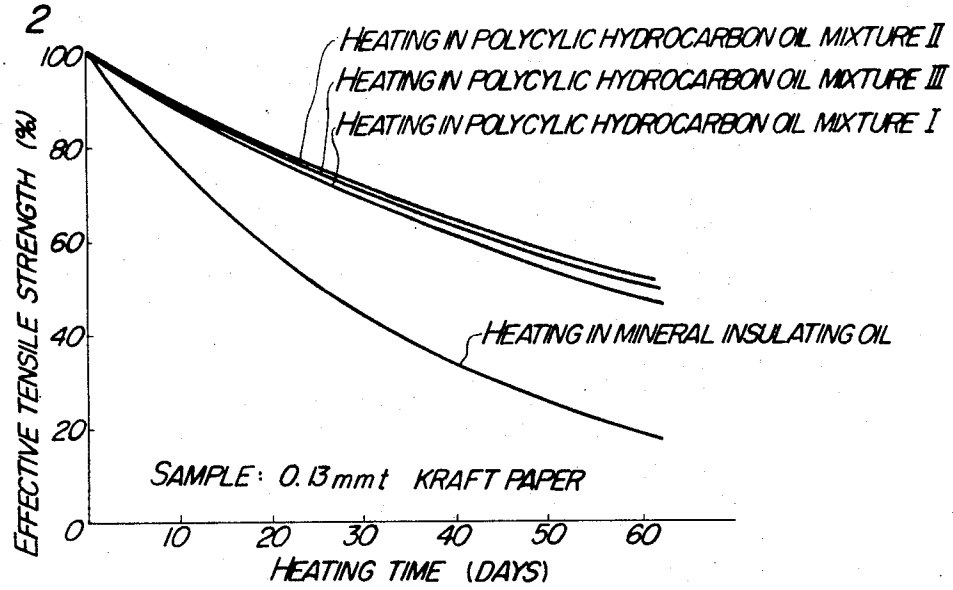


FIG. 3

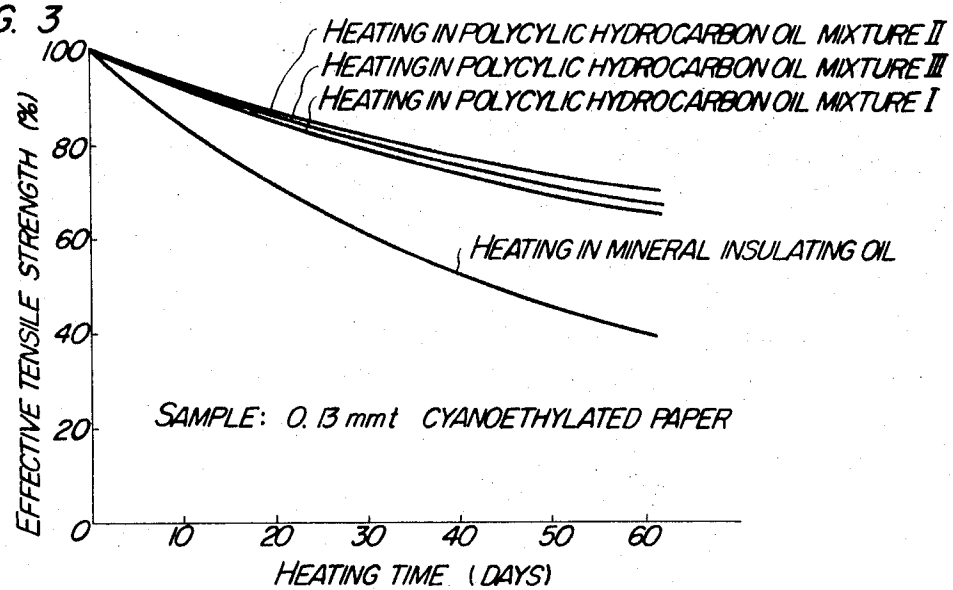
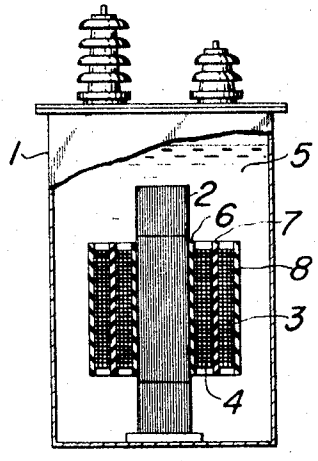


FIG. 1



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INDUCTIVE ELECTRIC APPARATUS

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to an inductive electric apparatus whose coil is insulated by a hydrocarbon insulating oil and a cellulose material, for example, a transformer or a reactor.

2. Description of the Prior Art

Heretofore, an insulating oil of mineral oil origin, which is refined from petroleum has been used as an insulating and cooling medium for the ordinary coil of the oil-immersed type inductive electric apparatus, and a cellulose substance such as kraft paper has been mainly used between layers of a coil or for earth insulation. As is well known, these insulating materials have a poor heat resistance, and when these materials are heated to more than some temperature by a heat release of the coil during the service period, these insulating materials undergo heat decomposition and rapid deterioration. As a result, organic acids and sludge are formed from the insulating oil, and the mechanical strength of the cellulosic material is lowered. That is, the cellulosic material fails to withstand a mechanical impact generated at the short circuit of the coil, and consequently loses its proper function. Though there have been already employed enamel-coated electric wires having heat resistances equivalent or superior to grade B of the insulation code for the coils, the overall insulating classification of an inductive electric apparatus using an insulating oil of mineral oil origin and a cellulosic material as the insulating material is grade A, and therefore the allowable temperature increase at the ambient temperature of 40°C is repressed to 55° – 65°C.

Furthermore, the flash point of the insulating oil of mineral oil origin now employed is about 140°C and the Grade B insulation (allowable temperature increase to 75°C) is not applicable to the prior art inductive electric apparatus in this respect, either.

Recently, every effort has been made to improve the heat resistance of the insulating material to be used so as to make smaller and lighter such inductive electric apparatuses as transformers, etc., and as one of the measures, there have been developed various antioxidants to be added to the insulating oil. However, when an oil admixed with the antioxidant is used in the inductive electric apparatus, it is difficult to control the antioxidant to be added to a proper amount in exchanging the oil deteriorated during the service period, and furthermore there is a problem in the maintenance of the apparatus. Furthermore, the antioxidant is not useful for enhancing the flash point of the oil itself.

On the other hand, cyanoethylated paper or paper treated with amines or other chemical-admixed paper has been developed to improve the heat resistance of the cellulosic insulating materials such as kraft paper, but a cost increase of the paper or deterioration of mechanical properties of the paper itself resulting from the special treatment of the paper has been a problem. Therefore, these papers have not yet been widely utilized.

SUMMARY OF THE INVENTION

An object of the present invention is to provide an inductive electric apparatus insulated by a novel synthetic insulating hydrocarbon oil and cellulosic material having a good heat resistance.

Other object of the present invention is to provide an inductive electric apparatus capable of undergoing continuous service at a high temperature corresponding to or approximate to that of Grade B by using a relatively cheap insulating material.

Another object of the present invention is to provide a thermally stable, inductive electric apparatus having a good reliability.

Further object of the present invention is to provide an improved inductive electric apparatus capable of controlling a heat deterioration in an insulating oil without applying any special treatment to the cellulosic insulating material to intensify the heat resistance.

Still further object of the present invention is to provide an inductive electric apparatus of easy maintenance without adding any antioxidant at the exchange of oil.

Other objects of the present invention will be readily understandable from the following explanation.

According to the present invention, an inductive electric apparatus comprises an oil of polycyclic hydrocarbon mixture having a flash point of 150°C or more and consisting of (A) polycyclic naphthenic hydrocarbons having two to five rings and (B) polycyclic aromatic hydrocarbons having two to four rings as a synthetic insulating oil, each side chain alkyl group attached to the rings having not more than four carbon atoms, preferably a mixing ratio of said (A) to (B) being in a range of 50 : 50 – 70 : 30 by volume; a cellulosic material; an electrically conductive coil, the cellulosic material being combined with the electrically conductve coil, and the cellulosic material and the electrically conductive coil being immersed in the insulating oil and being constantly in contact therewith.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an elevation of partially cut-away power transformer shown as one embodiment of the present invention.

FIG. 2 and FIG. 3 are diagrams showing relations between an effective tensile strength of the insulating paper and a heating time when heat deterioration tests are carried out with the insulating paper and said oil of polycyclic hydrocarbon mixtures to be used in the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

A power transformer as shown in FIG. 2 comprises an oil-sealed tank 1, an iron core 2, a primary coil 3, a secondary coil 4 and an insulating oil 5 filled around the iron core and coils. The coils 3 and 4 are prepared by coiling an electrically conductive material coated with an enamel, for example, a polyvinyl formal resin in a plurality of layers, while inserting a cellulosic material such as a kraft paper between the layers according to the well known method. An insulating layer 6 between the coil 3 and the iron core 1, an insulating material 7 between the coils 3 and 4, and an outermost insulating material 8 of the coil 4 are also made from a cellulosic material such as the kraft paper.

These cellulosic materials are immersed in the insulating oil **5**, together with the coils, and are always kept in contact with the insulating oil **5**.

A small amount of air may be retained over the oil surface within the tank **1**, but it is more preferable that an inert gas such as nitrogen is sealed over the oil surface in place of the air.

As the insulating oil **5**, the above-mentioned oil of polycyclic hydrocarbon mixture is used.

As a result of experiments and studies, the present inventors have newly found that said oil of polycyclic hydrocarbon mixture has a high flash point corresponding to the Grade B insulation and an excellent oxidation stability, and further that the heat deterioration of the cellulosic material takes place remarkably less in said oil of polycyclic hydrocarbon mixture than in the conventional insulating oil of hydrocarbon origin.

The component (A) of said oil of polycyclic hydrocarbon mixture, that is, polycyclic naphthenic hydrocarbons, is a mixture of a plurality of polycyclic hydrocarbons having two to five rings prepared by thermally cracking petroleum hydrocarbons at 700° – 2,300°C, hydrogenating the resulting tar fraction rich in polycyclic aromatics in the presence of a catalyst or desulfurizing said tar fraction, if necessary, then alkylating the resulting with lower olefins in the presence of a catalyst and further hydrogenating the resulting product in the presence of a catalyst according to methods of U.S. Patent application Ser. No. 800,710 (assignee: Kureha Chemical Industry Co., Ltd.) filed on February 19, 1969 and U.S. Patent application Ser. No. 23,962 (assignee: Kureha Chemical Industry Co., Ltd.) filed on Mar. 30, 1970, to obtain a plurality of polycyclic hydrocarbons, or a mixture of a plurality of lower alkyl derivatives of the polycyclic hydrocarbons, or a mixture of the polycyclic hydrocarbons and the lower alkyl derivatives thereof, and has the following properties:

Specific gravity (d_4^{15}) : 0.85 – 0.99
(values measured at 4°C are converted to those at 15°C)
Refractive index (n_D^{20}) : 1.45 – 1.60
(values measured at 20°C by D spectrum of nitrogen gas)
Viscosity (30°C) : 10 – 40 CST
Atomic ratio of hydrogen/carbon : 1.75 – 2.00
Flash point : 125°C or higher
Pour point : (−30°C) – (−60°C)

The other component (B) of said oil of polycyclic hydrocarbn mixture, that is, polycyclic aromatic hydrocarbons, is a mixture of a plurality of polycyclic hydrocarbons of two to four rings prepared by thermally cracking petroleum hydrocarbons at 700° – 2,300°C, desulfurizing the resulting tar fraction rich in polycyclic aromatics, if necessary and then subjecting the resulting to lower olefins in the presence of a catalyst of silica-alumina system, or zeolite system, to obtain a mixture of a plurality of polycyclic aromatic hydrocarbons, or a mixture of lower alkyl derivatives of the polycyclic hydrocarbons, or a mixture of the polycyclic hydrocarbons and the lower alkyl derivatives thereof, and has the following properties:

Specific gravity (d_4^{15}) : 1.00–1.20
Refractive index (n_d^{20}): 1.50 – 1.68
Viscosity (30°C): 10–25 CST
Flash point: 150°C or higher
Pour point: −40°C or less

Said oil of polycyclic hydrocarbon mixture consisting of said two components is different from the conventional insulating oil of mineral oil origin, and is a novel hydrocarbon insulating oil quite free of thermally unstable paraffins and isoparaffins. Among others, it has been found that the oil of polycyclic hydrocarbon mixture having a mixing ratio of the component A to the component B of 50 : 50 – 70 : 30 by volume has a very preferable property for an insulating oil for such in inductive electric apparatus as a transformer. Its typical physical properties are given below:

Specific gravity (d_4^{15}) : 0.900 – 1.050
Refractive index (n_D^{25}) : 1.45 – 1.58
(values measured at 25°C by D spectrum of nitrogen gas)
Viscosity, CST (20°C) : 10 – 120
Pour point, °C: −10 or less
Flash point, °C: 150 – 210
Dielectric constant (80°C) : 2.00 – 3.00
Dielectric loss, % (80°C): 0.002 – 0.30
Volume resistivity, Ω cm (80°C) : 10^{12} – 10^{16}
Dielectric breakdown voltage, kV/2.5 mm : 40 or higher

To compare the heat resistance of said oil of polycyclic hydrocarbon mixture with that of the insulating oil now employed, different samples I, II and III of said oil of polycyclic hydrocarbon mixture were prepared, and the initial characteristics and deterioration characteristics of the samples I, II and III and the insulating oil of mineral oil origin now employed [an equivalent to the insulating oil set forth in Japanese Industrial Standard (JIS) No. 2] were measured. As the initial characteristics, a flash point, viscosity, dielectric breakdown voltage and volume resistivity, which are important characteristics for an insulating oil for the transformer, were measured and their results are given in Table 1.

As is seen from Table 1, the flash point of said oil of polycyclic hydrocarbon mixture is as high as 160°C or higher than 160°C, which corresponds to the value of the Grade B insulation.

TABLE 1

Sample	I	II	III	Insulating oil now employed
Structure:				
Ring number of polycyclic naphthenic hydrocarbons, A	3–5	4–5	3–4	----------
Ring number of polycyclic aromatic hydrocarbons, B	2–3	3–4	2–3	----------
Mixing ratio of A/B	70/30	70/30	50/50	----------
Flash point, °C.	170	176	166	142
Viscosity, CST:				
30° C.	79.0	100.2	63.3	13.5
80° C.	8.1	11.5	6.2	3.0
Dielectric breakdown voltage, kv./2.5 mm.	57.7	58.5	60.0	55.0
Volume resistivity, Ω cm. (80° C.)	4.0×10^{15}	1.9×10^{14}	1.1×10^{15}	4×10^{14}

The deterioration characteristics of samples are compared in terms of the amount of sludge formed and total acid value after the heating at 120°C for 100 hours, at 135°C for 100 hours, and at 150°C for 100 hours, respectively. The results are shown in Table 2.

It has been found that said oil of polycyclic hydrocarbon mixture has less deterioration even after the heating at 150°C for 100 hours than the insulating oil of mineral oil origin now employed after the heating at 120°C for 100 hours, and has an excellent oxidation stability.

As is clear from the foregoing explanation and test results, the present inductive electric apparatus based on a combination of said oil of polycyclic hydrocarbon mixture and a cellulosic insulating material is workable at a high temperature equal to or approximate to that of the Grade B insulation for a long period of time, and

TABLE 2

Items measured	Sample I		Sample II		Sample III		Insulating oil now employed	
	Sludge (percent)	Total acid value (mg. KOH/g.)	Sludge (percent)	Total acid value (mg. KOH/g.)	Sludge (percent)	Total acid value (mg. KOH/g.)	Sludge (percent)	Total acid value (mg. KOH/g.)
Condition for measurement:								
120° C., 100 hr.	0.04	0.08	0.04	0.06			0.14	0.31
135° C., 100 hr.	0.06	0.10	0.05	0.03			0.39	0.87
150° C., 100 hr.	0.13	0.20	0.26	0.10	0.063	0.36		

The present synthetic insulating oil was heated together with a cellulosic material to determine the influence of the deterioration of oil upon the cellulosic material. 75 g each of insulating papers of typical cellulosic materials (the ordinary kraft paper and cyanoethylated paper) was placed in individual vessels together with 800 cc each of said oil of polycyclic hydrocarbon mixture (Samples I, II and III) and the insulating oil of mineral oil origin now employed (an equivalent to the insulating oil set forth in JIS No. 2) individually and the vessels were sealed while retaining the air above the oil surface and heated at 130°C for 60 days. During said period of 60 days, changes in tensile strength of the insulating papers were measured. The results are shown in FIGS. 2 and 3. That is to say, in the case of the ordinary kraft paper which was not subjected to a treatment for intensifying the heat resistance, the tensile strength after the heating for 60 days drops to 20 percent or less of the initial value in the insulating oil now employed, but retains about 50 percent of the initial tensile strength, even after the heating for 60 days, in said oil of polycyclic hydrocarbon mixture, which is almost equal to the effective tensile strength of the cyanoethylated paper after the heating for 60 days in the insulating oil now employed. A combination of the cyanoethylated paper with said oil of polycyclic hydrocarbon mixture can increase the effective tensile strength after the heating for 60 days to 70 percent or higher of the initial tensile strength. It is seen from these results, that even a service temperature of the ordinary kraft paper having a relatively low heat resistance can be elevated, when used together with said oil of polycyclic hydrocarbon mixture, almost to the service temperature of the cyanoethylated paper when used together with the insulating oil of mineral oil origin now employed.

The present inventors have newly found that the present synthetic insulating oil has an unexpected effect upon an increase in the heat resistance of the insulating paper when used together. Though a still further study will be necessary for elucidating the reason why such an effect can be brought about upon the increase in the heat resistance of the insulating paper, the present inventors assume that a good oxidation stability of said oil of polycyclic hydrocarbon mixture helps to decrease the deterioration of the insulating paper due to the decomposition product, for example, organic acids, etc., of the insulating oil.

as a result, the entirety of the present apparatus can be made considerably smaller and lighter by the elevation of the allowable service temperature than the entirety of the conventional inductive electric apparatus based on the conventional insulating oil of mineral oil origin and the cellulosic insulating material.

When the present apparatus is used at a service temperature equal to that of the Grade A insulation, the heat-resisting life of the present apparatus is remarkably prolonged and the reliability of the apparatus is greatly enhanced. Furthermore, in replacing the insulating oil by a user, only the specified kind of insulating oil is used according to the present invention. That is, there is no trouble in maintenance, as seen in the case that an antioxidant is added to he insulating oil now employed. Furthermore, the heat resistance not only of the oil itself, but also of the cellulosic material used together with the oil, can be increased according to the present invention, and a good heat resistance substantially equivalent to that of the cyanoethylated paper now employed can be effectively brought about even by using the ordinary kraft paper of a low cost and a high initial tensile strength.

Said oil of polycyclic hydrocarbon mixture can be used properly in a mixture of the insulating oil of mineral oil origin now employed, and such mode of practice is, of course, included in the scope of the present invention.

Since said oil of polycyclic hydrocarbon mixture can be prepared from such abundant raw materials as tar fraction produced in the course of petroleum refining, said oil can be obtained at a lower cost as an insulating oil having a higher heat resistance than other inorganic synthetic insulating oil.

What is claimed is:

1. An inductive electric apparatus, which comprises an oil-sealed tank, an insulating oil filled in said tank, an electrically conductive coil immersed in said insulating oil, and a cellulosic material combined with said coil, said insulating oil being a polycyclic hydrocarbon oil mixture having a flash point of 150°C or higher and consisting of a component (A) comprising polycyclic naphthenic hydrocarbons having two to five rings or their alkyl derivatives and mixtures thereof and component (B) comprising polycyclic aromatic hydrocarbons having two to four rings or their alkyl derivatives and mixtures thereof at a mixing ratio of A/B of 50:50 – 70:30 by volume, and each alkyl group attached to said

rings of components (A) and (B) having not more than four carbon atoms.

2. An inductive electric apparatus according to claim 1, wherein said cellulosic material is selected from kraft paper and cyanoethylated paper.

3. An inductive electric apparatus according to claim 1, wherein said component A of the polycyclic naphthenic hydrocarbons comprises a mixture of a plurality of polycyclic hydrocarbons having two to five rings, or a mixture of a plurality of lower alkyl derivatives thereof, or a mixture of the polycyclic hydrocarbons and the lower alkyl derivatives thereof and has a specific gravity (d_4^{15}) of 0.85 – 0.99, refractive index (n_D^{20}) of 1.45 – 1.60, a viscosity (30°C) of 10 – 40 CST, an atomic ratio of hydrogen to carbon of 1.75 – 2.00, a flash point of 125°C or higher and a pour point of −30° to −60°C.

4. An inductive electric apparatus according to claim 1, wherein said component B of the polycyclic aromatic hydrocarbons comprises a mixture of a plurality of polycyclic aromatic hydrocarbons having two to four rings, a mixture of a plurality of lower alkyl derivatives thereof, or a mixture of the polycyclic aromatic hydrocarbons and the lower alkyl derivatives thereof, and has a specific gravity (d_4^{15}) of 1.00 – 1.20, a refractive index (n_D^{20}) of 1.50 – 1.68, a viscosity (50°C) of 10 – 25 CST, a flash point of 150°C or higher and a pour point of −40°C or less.

5. An inductive electric apparatus according to claim 1, wherein said insulating oil is an oil of polycyclic hydrocarbon mixture consisting of component (A) comprising polycyclic napthenic hydrocarbons having three to five rings and component (B) comprising polycyclic aromatic hydrocarbons having two to three rings at a mixing ratio of A/B of 70/30 by volume.

6. An inductive electric apparatus according to claim 1, wherein said insulating oil is an oil of polycyclic hydrocarbon mixture consisting of component (A) comprising polycyclic naphthenic hydrocarbons having four to five rings and component (B) comprising polycyclic aromatic hydrocarbons having three to four rings at a mixing ratio of (A)/(B) of 70/30 by volume.

7. An inductive electric apparatus according to claim 1, wherein said insulating oil is an oil of polycyclic hydrocarbon mixture consisting of component (A) comprising polycyclic naphthenic hydrocarbons having three to four rings and component (B) comprising polycyclic aromatic hydrocarbons having two to three rings at a mixing ratio of (A)/(B) of 50/50 by volume.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. U.S. 3,753,188 Dated August 14, 1973

Inventor(s) Akira MIYOSHI, Tomio NAGAOKA, Masaaki TAKAHASHI and Kensuke OKUDA

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

In Column 1,

after line 2, delete "Hasaaki" and insert --Masaaki--,

in line 5, delete "Kureka" and insert --Kureha--,

in line 10, delete "Dec. 29, 1969 Japan.....44/1120 and insert --

--Dec. 29, 1969 Japan.....45/1120----

Signed and sealed this 25th day of December 1973.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

RENE D. TEGTMEYER
Acting Commissioner of Patents

USCOMM-DC 60376-P69

UNITED STATES PATENT OFFICE

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