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TRICRESYL PHOSPHATE-CHLORINATED BIPHENYL FUNCTIONAL FLUID IMPROVED BY ALKYLATED POLYSTYRENE

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The present invention relates to flame-resistant functional fluid compositions of improved viscosity characteristics and composed of synthetic organic compounds comprising certain chlorinated biphenyls, tricresyl phosphate and certain alkylated polystyrenes.

The functional fluids of this invention broadly include, but are not limited to, liquid compositions of the synthetic organic compounds which are used as force transmission fluids for the transmission of pressure, power or torque in fluid pressure or torque actuated mechanisms, such as for example, the "hydraulic fluids" for transmitting fluid pressure to the ram cylinders of hydraulic presses or in devices for the absorption and dissipation of energy such as shock absorbers or recoil mechanisms, or for transmission of torque through torque converter types of fluid couplings. The functional fluids of this invention may also be used as damping fluids which are the liquid compositions used for damping mechanical vibrations or resisting other rapid mechanical movements. The functional fluids of this invention are also suitable for use as synthetic lubricants between relatively moving mechanical parts, as bases for synthetic greases and as the liquid material in the filters of air conditioning systems.

When functional fluids are used as force transmission fluids in such industrial equipment as die-casting machines, hydroelectric turbines, glass-drawing machinery, hydraulic presses or other fluid actuated mechanisms, greatest consideration must be given to the selection of the proper functional fluid, particularly for the flame-resistant qualities and pumpability under varying pressures over the temperature ranges normally encountered, in addition to properties of good lubricity, resistance to mechanical shear and chemical breakdown and also inertness to the common metals of construction.

In industrial uses of functional fluids for force transmission, the flame-resistant properties of the fluid are of utmost importance due to the fact that the functional fluids are commonly pumped at high pressures of the order of 1,000 to 5,000 pounds per square inch through pipe lines in close proximity to extremely hot surfaces or incandescent materials. Under these conditions, if a functional fluid line should rupture, or a leak should otherwise occur in the high pressure functional fluid system, the fluid may be sprayed under high pressure onto the hot surfaces or incandescent materials resulting in disastrous fires unless the functional fluids possess a high degree of flame-resistance and do not decompose under such conditions to yield combustible decomposition products. Industrial installations wherein the high pressure functional fluid systems are commonly employed in close proximity to extremely hot or incandescent materials are illustrated by hydraulic die-casting machines, hydraulic glass-drawing machines, hydraulic operated forging machines and hydraulic actuated electrode positioners for electric arc furnaces.

Hydrocarbon oils have been used as the functional fluids in such installations, but are obviously undesirable because hydrocarbon oils under high pressure present a dangerous situation in close proximity to incandescent materials. Likewise, many synthetic organic compounds which have been proposed for use in the formulation of synthetic functional fluids have undesirable properties of low flame-resistance in themselves or their thermal decomposition products are highly flammable when the fluids are sprayed under high pressure onto a hot metal or other hot surfaces.

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Tricresyl phosphate alone has been used as the functional fluid in many industrial installations, and while tricresyl phosphate has good lubricity characteristics under pressure and is normally considered to be flame-resistant, tricresyl phosphate alone when sprayed under high pressure onto an incandescent surface has been known to decompose yielding flammable decomposition products. Chlorinated biphenyls containing 40 to 55% by weight of combined chlorine have also been used as synthetic functional fluids because they possess lubricity and outstanding flame-resistance even under decomposition conditions, however, the pour points of such chlorinated biphenyls are considered to be too high for many industrial applications, and moreover, the viscosity indexes of such chlorinated biphenyls are generally negative and therefore are not deemed desirable for use in many hydraulic pressure systems. By combining tricresyl phosphate and chlorinated biphenyls containing 40 to 55% combined chlorine, functional fluids can be produced having substantially the flame-resistance characteristics of the chlorinated biphenyl, high lubricity for the relatively moving mechanical surfaces employed with the functional fluids and satisfactory pour points, however, the viscosity-temperature characteristics of mixtures of tricresyl phosphate and such chlorinated biphenyls for use as functional fluids are still deficient over the temperature ranges normally encountered in industrial installations.

To obtain satisfactory performance for a large part of the industrial installations using vane, gear or piston type pumps or piston or gear type of fluid motors, it is usually recommended that the functional fluids have viscosities within the range of 150 to 350 S. S. U. (Saybolt Seconds universal) at 100° F. and also have viscosity-temperature characteristics between the temperatures of 100 and 200° F. such that the viscosity indexes are within the range of 0 to +150. However, some industrial installations now require that the functional fluids have very high viscosities of the order of 800, 900, 1,000 and 1,200 S. S. U. at 100° F., and viscosity indexes within the range of 0 to +150. A negative viscosity index indicates that the viscosity change with temperature characteristics are such that the performance of the fluid would not be entirely satisfactory throughout the temperature range normally encountered, and therefore the most satisfactory functional fluid must have positive viscosity index values.

It is an object of this invention therefore, to provide functional fluids comprising chlorinated biphenyl containing 40 to 60% of combined chlorine, tricresyl phosphate and certain alkylated polystyrene and which fluids possess the desirable properties of good flame-resistance, chemical stability, inertness to the common metals of construction, good lubricity and which have improved viscosity characteristics over the range of temperatures normally encountered in industrial applications of functional fluids.

It has now been discovered that functional fluids for industrial applications such as force transmission fluids and synthetic lubricants and having viscosities within the required range of 150 to 1,200 S. S. U. at 100° F. and viscosity indexes within the preferred range of 0 to +150 may be obtained using the following components in the indicated proportions in parts by weight:

	Parts
Tricresyl phosphate -----	40 to 55
Chlorinated biphenyl containing a total of 40 to 60% by weight of combined chlorine -----	45 to 60
Alkylated polystyrene made by alkylating polystyrene having a molecular weight between 10,000 and 150,000 with 0.2 to 0.8 parts by weight of olefins containing 6 to 15 carbon atoms -----	0.4 to 2

While the functional fluids of this invention are comprised essentially of tricresyl phosphate, the chlorinated biphenyls and the alkylated polystyrenes, it will be understood that minor amounts of other "additives" may be also incorporated into the functional fluids of this invention, in addition to the three principal components as described. Such other additives may be minor but effective amounts of anti-foaming agents, corrosion inhibitors, anti-rusting agents, detergent additives, extreme

pressure additives and organic or inorganic flame-snuffers, whenever specific uses require such additives.

The alkylated polystyrene as has been defined herein is generally sold in commerce in the form of a solution in an organic solvent and such solvents are commonly mineral oil fractions, chlorinated aliphatics or chlorinated aromatics such as the chlorobenzenes or chlorinated biphenyl. Due to the fact that the functional fluids of this invention are compatible with these solvents which are commonly used to make up the commercial solutions of the alkylated polystyrene, the alkylated polystyrene in such solution form may be used to make up the functional fluids of this invention. For example, alkylated polystyrene is very commonly sold in commerce as a solution in a mineral oil fraction of lubricating viscosity containing about 20% of the alkylated polystyrene. So long as a sufficient amount of the commercial solution of the alkylated polystyrene is used so that the amount of the alkylated polystyrene polymer present is within the range as indicated for the functional fluids of this invention, the amount of the solvent which is also present generally does not significantly effect the viscosity characteristics of the functional fluid as compared with a functional fluid made up with the alkylated polystyrene polymer which is not in solution form. Therefore, the critical point is that the tricresyl phosphate, the chlorinated biphenyl and the alkylated polystyrene be present in the proportions by weight as indicated, and the polymer can be incorporated into the formulation either as the resinous material or in the form of a solution as is commonly available in commerce. Of course, it would be preferred to obtain the alkylated polystyrene in solution with a solvent such as the chlorinated biphenyl which is also a required component of the functional fluids of this invention. However, as pointed out before, the alkylated polystyrene may be used in solution with a solvent which is not common to the components of the functional fluid without significant adverse effects.

It has been pointed out that the alkylated polystyrenes which are suitable for use as a component in the functional fluids of this invention are generally the alkylated polystyrenes made by alkylating polystyrene having a molecular weight between 10,000 and 150,000 with 0.2 to 0.8 part by weight of olefins containing 6 to 15 carbon atoms. However, there is a preferred range of alkylated polystyrene within the broad range as indicated above which is preferred for use in the formulation of the functional fluids of this invention. The preferred alkylated polystyrene is made by alkylating polystyrene having a molecular weight between 60,000 and 80,000 with 0.2 to 0.8 part by weight of olefins containing 8 to 10 carbon atoms, including those olefins prepared by the polymerization of C₂ or C₃ olefins or mixtures thereof. Generally speaking, polystyrene having a molecular weight of less than 20,000 yield an alkylated polystyrene which is less desirable for use in the functional fluids of this invention and on the other hand alkylated polystyrenes made from polystyrene of molecular weights in excess of 80,000 frequently become degraded during use, particularly where the functional fluid is subjected to severe shearing stress, such as in gear pumps for developing the pressures on force transmission systems. It is preferred therefore, that the alkylated polystyrenes for use as a component in the functional fluids of this invention be prepared from polystyrene having molecular weights between 60,000 and 80,000. While polystyrene which has been alkylated with 0.2 to 0.8 part by weight of olefin is generally suitable for use in the functional fluids of this invention, it is pointed out that where functional fluids of relatively lower viscosity are desired it is preferred to use polystyrene which has been alkylated with from 0.2 to 0.5 part by weight of olefin. However, where functional fluids of relatively higher viscosity are desired, it is preferred that the polystyrene be alkylated with about 0.4 to 0.8 part by weight of olefin. These factors which influence the selection of an alkylated polystyrene having a particular alkylating olefin to polystyrene weight ratio for use in the functional fluids of this invention apply equally well to the polystyrene having a molecular weight within the broad range of 10,000 to 150,000 as well as within the preferred range of 60,000 to 80,000.

The chlorinated biphenyls of commerce generally contain about 42%, 48%, 54% or 60% of combined chlorine

and these products correspond approximately to tri-, tetra-, penta- and hexa-chlorobiphenyl, respectively. The expression "chlorinated biphenyl containing a total of 40 to 60% of combined chlorine" is used herein as not only including these direct chlorination products but also blends of one or more of the chlorinated biphenyls whereby the total chlorine content is within the range of 40 to 60% by weight. For example, a chlorinated biphenyl containing a total of 45% by weight of combined chlorine can be effectively prepared, for the purpose of this invention, by blending together 50 parts by weight of chlorinated biphenyl containing 42% by weight of combined chlorine and 50 parts by weight of chlorinated biphenyl containing 48% by weight of combined chlorine. In a similar manner, to further illustrate, chlorinated biphenyl containing a total of 58% by weight of combined chlorine, for purposes of this invention, may be effectively prepared by blending together 25 parts by weight of chlorinated biphenyl containing 52% by weight of combined chlorine and 75 parts by weight of chlorinated biphenyl containing 60% by weight of combined chlorine. Therefore, for the purposes of this invention, the chlorinated biphenyl containing 40 to 60% by weight of combined chlorine may be obtained either by direct chlorination of the biphenyl to obtain the desired combined chlorine content, or a satisfactory material may be obtained by blending together two or more chlorinated biphenyls to obtain a resulting blend of chlorinated biphenyl containing an effective quantity of combined chlorine within the required range of 40 to 60% by weight.

It is now pointed out that care must be exercised in the formulation of the functional fluids of this invention in order to obtain homogeneous solutions which are stable against separation of any of the three principal components. The alkylated polystyrenes as called for by this invention, are apparently insoluble in tricresyl phosphate and will not go into solution with tricresyl phosphate alone to form a homogeneous fluid without subsequent separation. While the described alkylated polystyrenes can be dissolved in a mixture of tricresyl phosphate and the chlorinated biphenyls in the weight ratios as indicated, it is preferred to first dissolve the alkylated polystyrene into the chlorinated biphenyl in proportions within the ranges as have been set out, and then blend the solution of the alkylated polystyrene in the chlorinated biphenyl with tricresyl phosphate to produce functional fluid compositions having viscosities within the range of 150 to 1,200 S. S. U. at 100° F. and viscosity indexes within the range of 0 to 150. Functional fluids prepared in this manner are true solutions and there is no evidence of incompatibility of the components over a temperature range of from their pour points to temperatures upwards of 225° F. which is the temperature range normally encountered by the functional fluids used in industrial installations.

The improved viscosity characteristics of the functional fluids of this invention may be more readily understood by a consideration of the properties of the essential components of the functional fluids of this invention.

Tricresyl phosphate

Tricresyl phosphate is industrially obtained by the esterification of phosphorus oxychloride with an industrial or commercial grade of cresol. Commercial cresol is usually a mixture of at least two isomeric cresols and in addition varying minor amounts of other phenols such as phenol and xlenols. In view of this fact, the properties of technical tricresyl phosphate may vary from one producer to another and even among various batches of the same producer, however, the properties of a typical commercial lot of tricresyl phosphate are as follows:

Specific gravity 25/25° C.	1.161
Viscosity at 100° F., S. S. U.	163
Viscosity at 210° F., S. S. U.	41
Viscosity index	—44
Fire point, ° F.	645
Pour point, ° F.	—15

It will be observed that the viscosity index of tricresyl phosphate as indicated above is —44 and generally a commercial tricresyl phosphate will have a viscosity index within the range of about —40 to —45. The negative

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viscosity index is indicative of the fact that the viscosity-temperature characteristics over the range of 100° F. to 210° F. are such as to render tricresyl phosphate itself deficient in its viscosity properties for many applications as a functional fluid in industrial hydraulic systems.

Chlorinated biphenyl containing 42% combined chlorine

Typical properties of chlorinated biphenyl containing 42% combined chlorine are represented as follows:

Specific gravity 25/25° C.....	1.379
Viscosity at 100° F., S. S. U.....	79
Viscosity at 210° F., S. S. U.....	34
Viscosity index.....	-250
Fire point, ° F.....	630
Pour point, ° F.....	0

Chlorinated biphenyl containing 48% combined chlorine

Typical properties of chlorinated biphenyl containing 48% combined chlorine are represented as follows:

Specific gravity 25/25° C.....	1.451.
Viscosity at 100° F., S. S. U.....	199.
Viscosity at 210° F., S. S. U.....	37.
Viscosity index.....	-610.
Fire point.....	Greater than 660° F. which is the boiling point of this material.
Pour point.....	+20° F.
Autogenous ignition temperature..	1,299° F.

Chlorinated biphenyl containing 54% combined chlorine

Typical properties of chlorinated biphenyl containing 54% combined chlorine are represented as follows:

Specific gravity 25/25° C.....	1.539.
Viscosity at 100° F., S. S. U.....	1727.
Viscosity at 210° F., S. S. U.....	45.
Viscosity index.....	-1650.
Flash point.....	None.
Fire point.....	Greater than 700° F. the boiling point of this material.
Pour point.....	+50° F.

A consideration of the properties of the various chlorinated biphenyls as described above reveals that such chlorinated biphenyls have viscosity indexes of the order of -250 to -1650. When it is considered that functional fluids for most industrial applications should have a viscosity index within the range of 0 to +150, it is immediately evident that the viscosity characteristics of such chlorinated biphenyls as indicated by the extremely large negative viscosity indexes are deficient for many applications.

The deficiencies of tricresyl phosphate and these chlorinated biphenyls from the standpoint of their viscosity-temperature characteristics are not overcome by merely mixing tricresyl phosphate and the chlorinated biphenyls as illustrated by the following Examples I to III:

Example I

A fluid composition was made up of 50% by weight of tricresyl phosphate and 50% by weight of chlorinated biphenyl containing 42% by weight of combined chlorine and the following properties were determined:

Specific gravity 25/25° C.....	1.261
Viscosity at 100° F., S. S. U.....	117
Viscosity at 210° F., S. S. U.....	37
Viscosity index.....	-149
Pour point ° F.....	-10

It is noted that this fluid is deficient in two respects, from the standpoint of use in industrial hydraulic systems, due to the fact that the viscosity at 100° F. is below 150 S. S. U. and moreover the viscosity changes with respect to temperature as indicated by the viscosity index of -149 indicated the fluid is deficient in this respect.

Example II

A fluid composition containing 50% by weight of tri-

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cresyl phosphate and 50% by weight of a chlorinated biphenyl containing 48% of combined chlorine had the following properties:

Specific gravity 25/25° C.....	1.289
Viscosity at 100° F., S. S. U.....	188
Viscosity at 210° F., S. S. U.....	39
Viscosity index.....	-251

While the above fluid composition has a satisfactory viscosity at 100° F., it will be noted that this fluid also has a viscosity index of -251 which is far outside of the desired range of 0 to +150.

Example III

A fluid composition containing 50% by weight of tricresyl phosphate and 50% by weight of a chlorinated biphenyl containing 54% chlorine had the following properties:

Specific gravity 25/25° C.....	1.323
Viscosity at 100° F., S. S. U.....	350
Viscosity at 210° F., S. S. U.....	42
Viscosity index.....	-315

Again, this large negative viscosity index is indicative of the deficiencies of the viscosity-temperature characteristics of this fluid.

The following examples will illustrate the improved functional fluids prepared in accordance with this invention and it will be noted that these fluids have viscosities at 100° F. within the required range of 150 to 1,200 S. S. U. and have viscosity indexes within the preferred range of 0 to +150.

Example IV

An improved functional fluid having a viscosity of the order of 150 S. S. U. at 100° F. was prepared by blending together 3.5 parts by weight of a commercial 20% solution of the alkylated polystyrene in chlorobenzene with 56.5 parts by weight of chlorinated biphenyl containing 42% by weight of combined chlorine to form a solution of the alkylated polystyrene in the chlorinated biphenyl, and thereafter, 60 parts by weight of this solution was blended with 40 parts by weight of tricresyl phosphate. The alkylated polystyrene used in the fluid of this example was polystyrene having a molecular weight of about 60,000 alkylated with about 0.3 part by weight of C₈ olefin.

This improved functional fluid had the following properties:

Specific gravity 25/25° C.....	1.259
Viscosity at 100° F., S. S. U.....	158
Viscosity at 210° F., S. S. U.....	41
Viscosity index.....	+22
Pour point, ° F.....	-5

Example V

An improved functional fluid was prepared by first dissolving one part by weight of an alkylated polystyrene made by alkylating one part by weight of polystyrene having a molecular weight of about 80,000 with about 0.4 part by weight of a mixture of C₈-C₁₀ olefins, into 64 parts by weight of chlorinated biphenyl containing 42% by weight of combined chlorine, and thereafter, 52 parts by weight of this solution of the alkylated polystyrene dissolved in the chlorinated biphenyl was combined with 48 parts by weight of tricresyl phosphate to provide an improved functional fluid which had the following properties:

Specific gravity 25/25° C.....	1.242
Viscosity at 100° F., S. S. U.....	173
Viscosity at 210° F., S. S. U.....	43
Viscosity index.....	+48
Pour point, ° F.....	-10

In contrast with the properties of the fluid of Example I, the viscosity at 100° F. has been raised to 173 S. S. U. and the viscosity index of +48 is within the preferred range of 0 to +150, in contrast to the -149 viscosity index of Example I, and therefore this improved functional fluid is ideally suitable for use in most industrial hydraulic systems. As an indication of the flame resistance of this fluid, when it was dripped on a hot metal surface at 1,000° F., the fluid did not burn.

Example VI

An improved functional fluid having a viscosity of the order of 200 S. S. U. at 100° F. was prepared by dissolving one part by weight of the alkylated polystyrene into 64 parts by weight of chlorinated biphenyl containing 45% by weight of combined chlorine to form a solution of the alkylated polystyrene in the chlorinated biphenyl, and thereafter, 52 parts by weight of this solution was blended with 48 parts by weight of tricresyl phosphate. The alkylated polystyrene used in the fluid of this example was polystyrene having a molecular weight of about 65,000 alkylated with about 0.4 part by weight of C₈-C₁₀ olefin.

The chlorinated biphenyl containing 45% by weight of combined chlorine was prepared by blending together equal parts by weight of chlorinated biphenyl containing 42% combined chlorine and chlorinated biphenyl containing 48% combined chlorine.

This improved functional fluid had the following properties:

Specific gravity 25/25° C.....	1.252
Viscosity at 100° F., S. S. U.....	209
Viscosity at 210° F., S. S. U.....	44
Viscosity index	+39
Pour point, ° F.....	-10

Example VII

An improved functional fluid was prepared by first dissolving one part by weight of an alkylated polystyrene, made by alkylating one part by weight of polystyrene having a molecular weight of about 65,000 with about 0.5 part by weight of a C₈ olefin, into 64 parts by weight of chlorinated biphenyl containing about 46.5% by weight of combined chlorine. The chlorinated biphenyl containing about 46.5% combined chlorine was prepared by blending together one part by weight of chlorinated biphenyl containing 42% combined chloride with 3 parts by weight of chlorinated biphenyl containing 48% of combined chloride. Thereafter, 52 parts by weight of the solution of the alkylated polystyrene dissolved in the chlorinated biphenyl were combined with 48 parts by weight of tricresyl phosphate. This improved functional fluid had the following properties:

Specific gravity 25/25° C.....	1.259
Viscosity at 100° F., S. S. U.....	230
Viscosity at 210° F., S. S. U.....	45
Viscosity index	+29
Pour point, ° F.....	-5

The viscosity at 100° F. and the viscosity index of this improved functional fluid are within the preferred ranges for industrial functional fluids and moreover, flame resistance of this fluid is demonstrated by the practical test wherein this fluid was sprayed through a small orifice under 1,000 pounds per square inch pressure through the flame of an oxyacetylene welding torch under which test the fluid did not flash or ignite.

Example VIII

An improved functional fluid having a viscosity of the order of 250 S. S. U. at 100° F. was prepared by dissolving 2 parts by weight of the alkylated polystyrene into 43 parts by weight of chlorinated biphenyl containing 42% by weight of combined chlorine to form a solution of the alkylated polystyrene in the chlorinated biphenyl, and thereafter 45 parts by weight of this solution was blended with 55 parts by weight of tricresyl phosphate. The alkylated polystyrene used in the fluid of this example was polystyrene having a molecular weight of about 80,000 alkylated with about 0.5 part by weight of C₁₀ olefin.

This improved functional fluid had the following properties:

Specific gravity 25/25° C.....	1.191
Viscosity at 100° F., S. S. U.....	252
Viscosity at 210° F., S. S. U.....	54
Viscosity index	+130
Pour point, ° F.....	-5

This example shows how a functional fluid of this invention may be prepared having a viscosity of the order of 250 S. S. U. at 100° F. and a high viscosity index of +130. On the other hand, the following example shows how a functional fluid may be prepared also having a

viscosity of the order of 250 S. S. U. at 100° F., but having a relatively low viscosity index of +25.

Example IX

An improved functional fluid was prepared by first dissolving one part by weight of an alkylated polystyrene made by alkylating one part by weight of polystyrene having a molecular weight of about 70,000 with about 0.5 part by weight of a 9 carbon polymeric C₃ olefin, into 64 parts by weight of chlorinated biphenyl containing 48% by weight of combined chlorine, and thereafter, 52 parts by weight of this solution of the alkylated polystyrene dissolved in the chlorinated biphenyl were combined with 48 parts by weight of tricresyl phosphate. This improved functional fluid was determined to have the following properties:

Specific gravity 25/25° C.....	1.267.
Viscosity at 100° F., S. S. U.....	257.
Viscosity at 210° F., S. S. U.....	46.
Viscosity index	+25.
Pour point, ° F.....	0°.
Autogeneous ignition temperature, ° F.....	Above 1,100.

Not only does the fluid of this example have improved viscosity characteristics over the fluid of Example II and which are within the desired range for industrial functional fluids, but the extreme flame-resistance of this fluid is demonstrated by the following practical tests. The fluid of this example was sprayed on the 1,500° F. molten metal of a die-casting machine, however, the fluid did not flash or ignite. Moreover, no flash was observed nor did this fluid burn when an electrical arc was discharged between a carbon arc wherein one electrode was placed below the surface of the fluid and the other electrode above the surface of the fluid.

Example X

An improved functional fluid having a viscosity of the order of 275 S. S. U. at 100° F. was prepared by dissolving 2 parts by weight of the alkylated polystyrene into 53 parts by weight of chlorinated biphenyl containing 42% by weight of combined chlorine to form a solution of the alkylated polystyrene in the chlorinated biphenyl, and thereafter, 55 parts by weight of this solution was blended with 45 parts by weight of tricresyl phosphate. The alkylated polystyrene used in the fluid of this example was polystyrene having a molecular weight of about 80,000 alkylated with about 0.5 parts by weight of C₁₀ olefin.

This improved functional fluid had the following properties:

Specific gravity 25/25° C.....	1.207
Viscosity at 100° F., S. S. U.....	278
Viscosity at 210° F., S. S. U.....	55
Viscosity index	+125
Pour point, ° F.....	-10

Example XI

An improved functional fluid having a viscosity of the order of 400 S. S. U. at 100° F. was prepared by dissolving 1.2 parts by weight of the alkylated polystyrene into 51.8 parts by weight of chlorinated biphenyl containing 51% by weight of combined chlorine to form a solution of the alkylated polystyrene in the chlorinated biphenyl, and thereafter, 53 parts by weight of this solution was blended with 47 parts by weight of tricresyl phosphate. The alkylated polystyrene used in the fluid of this example was polystyrene having a molecular weight of about 70,000 alkylated with about 0.6 part by weight of C₈-C₁₀ olefin.

The chlorinated biphenyl containing 51% by weight of combined chlorine was prepared by blending together equal parts by weight of chlorinated biphenyl containing 48% combined chlorine and chlorinated biphenyl containing 54% combined chlorine.

This improved functional fluid had the following properties:

Specific gravity 25/25° C.....	1.268
Viscosity at 100° F., S. S. U.....	392
Viscosity at 210° F., S. S. U.....	52
Viscosity index	54
Pour point, ° F.....	+5

Example XII

An improved functional fluid having a viscosity of the order of 475 S. S. U. at 100° F. was prepared by blending together 10 parts by weight of a commercial 20% solution of the alkylated polystyrene in S. A. E. 10 lubricating oil with 35 parts by weight of chlorinated biphenyl containing 54% by weight of combined chlorine to form a solution of the alkylated polystyrene in the chlorinated biphenyl, and thereafter, 45 parts by weight of this solution was blended with 55 parts by weight of tricresyl phosphate. The alkylated polystyrene used in the fluid of this example was polystyrene having a molecular weight of about 80,000 alkylated with about 0.6 part by weight of C₉ olefin.

This improved functional fluid had the following properties:

Specific gravity 25/25° C.	1.231
Viscosity at 100° F., S. S. U.	481
Viscosity at 210° F., S. S. U.	64
Viscosity index	103
Pour point, ° F.	+5

Example XIII

An improved functional fluid was prepared by first adding one part by weight of a commercial 20% solution of S. A. E. 10 lubricating oil of an alkylated polystyrene, made by alkylating one part by weight of polystyrene having a molecular weight of about 80,000 with about 0.6 parts by weight of a mixture of C₈-C₁₀ olefins, to 5.75 parts by weight of chlorinated biphenyl containing 54% of combined chlorine, and thereafter 54 parts by weight of this solution of the alkylated polystyrene dissolved in the chlorinated biphenyl were combined with 46 parts by weight of tricresyl phosphate. This improved functional fluid has the following properties:

Specific gravity 25/25° C.	1.273
Viscosity at 100° F., S. S. U.	619
Viscosity at 210° F., S. S. U.	62
Viscosity index	62
Pour point, ° F.	+15

These properties established that this improved functional fluid has the viscosity characteristics required for use in industrial functional fluid systems, and moreover, when this fluid was sprayed through a 1/8" orifice at pressure of the order of 200 pounds per square inch through an electrical arc between two carbon electrodes, there was no observed flash nor did the fluid burn.

Example XIV

An improved functional fluid having a viscosity of the order of 700 S. S. U. at 100° F. was prepared by blending together 8 parts by weight of a commercial 20% solution of the alkylated polystyrene in S. A. E. 10 lubricating oil with 46 parts by weight of chlorinated biphenyl containing 55.5% by weight of combined chlorine to form a solution of the alkylated polystyrene in the chlorinated biphenyl, and thereafter, 54 parts by weight of this solution was blended with 46 parts by weight of tricresyl phosphate. The alkylated polystyrene used in the fluid of this example was polystyrene having a molecular weight of about 60,000 alkylated with about 0.7 part by weight of C₈ olefin.

The chlorinated biphenyl containing 55.5% by weight of combined chlorine was prepared by blending together 1 part by weight of chlorinated biphenyl containing 60% combined chlorine and 3 parts by weight of chlorinated biphenyl containing 54% combined chlorine.

This improved functional fluid had the following properties:

Specific gravity 25/25° C.	1.278
Viscosity at 100° F., S. S. U.	703
Viscosity at 210° F., S. S. U.	65
Viscosity index	+57
Pour point, ° F.	+15

Example XV

An improved functional fluid having a viscosity of the order of 800 S. S. U. at 100° F. can be prepared by mixing together 30 parts by weight of chlorinated biphenyl containing 54% combined chlorine with 15 parts by weight of chlorinated biphenyl containing 60% combined chlorine to form a chlorinated biphenyl containing 56%

by weight of combined chlorine, 2 parts by weight of the alkylated polystyrene (polystyrene of a molecular weight of about 70,000 alkylated with about 0.6 parts by weight of C₈-C₁₀ olefin) was dissolved into 53 parts by weight of the chlorinated biphenyl containing 56% by weight of combined chlorine, and thereafter 55 parts by weight of this solution of the alkylated polystyrene in the chlorinated biphenyl was blended 45 parts by weight of tricresyl phosphate to produce an improved functional fluid having the following properties:

Specific gravity 25/25° C.	1.270
Viscosity at 100° F., S. S. U.	810
Viscosity at 210° F., S. S. U.	72
Viscosity index	+72
Pour point, ° F.	+15

Example XVI

An improved functional fluid having a viscosity of the order of 900 S. S. U. at 100° F. can be prepared by dissolving 10 parts by weight of a 20% solution in dichlorodiphenyl of the alkylated polystyrene (polystyrene of a molecular weight of about 80,000 alkylated with about 0.6 parts by weight of C₉ olefin), into 45 parts by weight of chlorinated biphenyl containing 57% by weight of combined chlorine, to which is then added 45 parts by weight of tricresyl phosphate. This improved functional fluid had the following properties:

Specific gravity 25/25° C.	1.274
Viscosity at 100° F., S. S. U.	911
Viscosity at 210° F., S. S. U.	76
Viscosity index	+71
Pour point, ° F.	+15

Example XVII

An improved functional fluid having a viscosity at 100° F. of about 1050 S. S. U. can be prepared by dissolving 1 part by weight of the alkylated polystyrene (polystyrene of a molecular weight of about 80,000 alkylated with about 0.7 part by weight of C₈-C₁₀ olefin) into 32.7 parts by weight of chlorinated biphenyl containing 60% by weight of combined chlorine, and thereafter blending 54 parts by weight of this solution of the alkylated polystyrene in the chlorinated biphenyl with 46 parts of tricresyl phosphate. This produced an improved functional fluid having the following properties:

Specific gravity 25/25° C.	1.300
Viscosity at 100° F., S. S. U.	1056
Viscosity at 210° F., S. S. U.	72
Viscosity index	+34
Pour point, ° F.	+25

Example XVIII

An improved functional fluid having a viscosity at 100° F. of about 1200 S. S. U., which approaches the upper limit for viscosity for functional fluids for industrial installations can be prepared by dissolving 10 parts by weight of a 20% solution in S. A. E. 10 mineral oil of the alkylated polystyrene (polystyrene of a molecular weight of about 80,000 alkylated with about 0.8 part by weight of C₁₅ polymerized C₃ olefin) into 45 parts by weight of chlorinated biphenyl containing 60% by weight of combined chlorine, and thereafter, blending 55 parts by weight of this solution with 45 parts of tricresyl phosphate. A functional fluid so prepared had the following properties:

Specific gravity 25/25° C.	1.286
Viscosity at 100° F., S. S. U.	1197
Viscosity at 210° F., S. S. U.	82
Viscosity index	59
Pour point, ° F.	+25

Example XIX

An improved functional fluid having a viscosity at 100° F. of about 350 S. S. U., which is about the upper limit of the viscosity range for functional fluids more commonly used in industrial installations, can be prepared by blending together 8 parts by weight of a 20% solution in S. A. E. 10 mineral lubricating oil of the alkylated polystyrene (polystyrene of a molecular weight of about 75,000 alkylated with about 0.5 part by weight of C₉ polymerized C₃ olefin) with 46 parts by weight of chlo-

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minated biphenyl containing 48% by weight of combined chlorine, and thereafter, blending 54 parts by weight of this solution with 46 parts by weight of tricresyl phosphate. A functional fluid so prepared had the following properties:

Specific gravity 25/25° C.-----	1.246
Viscosity at 100° F., S. S. U.-----	351
Viscosity at 210° F., S. S. U.-----	55
Viscosity index-----	+91
Pour point, °F-----	0

The suitability of the functional fluids of this invention for use as synthetic lubricants for relatively moving mechanical parts, even independent of their use as force transmission fluids, is indicated by the fact that representative fluids, such as those of Examples V, VI, VII, VIII, IX and X, when subjected to continuous pumping tests in both piston and vane types of pumps, exhibited as good as or better wear resistance as petroleum based fluids, and moreover, these fluids have film strengths of the order of 17,000 pounds per square inch as determined by a seizure load on a Timken machine. These tests reflect the high lubricity of these fluids and indicate their utility as synthetic flame-resistant lubricants. The chemical inertness of these fluids to the common metals of construction is reflected by the results of corrosion and oxidation stability tests carried out in accordance with the test method described in AN-VV-O-366b, wherein iron, aluminum and magnesium in contact with these fluids underwent no visual change and the weight change of these metals was only +0.01 to 0.02 mg./cm.². When copper was subjected to the same test, there was only a slight darkening of the metal surface and the weight change of the copper was of the order of only -0.15 mg./cm.².

The functional fluids of this invention are also excellent bases for the preparation of grease-like lubricants which may be prepared by adding various or combinations of thickening agents or swelling agents to the functional fluids, such as any one of the known sodium, barium, lithium, potassium or calcium soaps, or other agents such as the C₁₆-C₁₈ dialkyl quaternary ammonium salts of montmorillonite. When the functional fluids of this invention are thickened with such agents, the resulting compositions have a grease-like consistency of good lubricating properties.

As a result of the excellent physical properties of the functional fluids particularly described in the preceding examples, improved hydraulic pressure devices can be prepared in accordance with this invention which compromise in combination a fluid chamber, a moveable member actuated by a functional fluid in said chamber, said fluid comprising a mixture of tricresyl phosphate, the chlorinated biphenyls and the alkylated polystyrenes as hereinbefore described. In such a hydraulic apparatus wherein a moveable member is actuated by the above described functional fluid, performance characteristics are obtainable which are superior to those heretofore obtainable.

Because of the excellent flame-resistant characteristics of the functional fluids of this invention, and high inherent lubricity, the functional fluids of this invention may be utilized in those hydraulic systems wherein power must be transmitted and the relatively moving mechanical parts of the system lubricated by the hydraulic fluid utilized. Thus, the novel functional fluids of this invention find exceptional utility in the transmission of power in a hydraulic system having a pump therein supplying the power for the system. In such a system, the parts which are so lubricated include the relatively moving mechanical surfaces of the source of power, namely, the pump, valves, operating pistons and cylinders, fluid motors, and in some cases, for machine tools, the ways, tables and slides. The hydraulic system may be of either the constant-volume or the variable-volume type of system.

The pumps may be of various types, including the piston-type pump, more particularly the variable-stroke piston pump, the variable-discharge or variable displacement piston pump, radial-piston pump, axial-piston pump, in which a pivoted cylinder block is adjusted at various angles with the piston assembly, for example, the Vickers Axial-Piston Pump, or in which the mechanism which drives the piston is set at an angle ad-

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justable with the cylinder block; gear-type pump, which may be spur, helical or herringbone gears, variations of internal gears, or a screw pump; or vane pumps. The valves may be stop valves, reversing valves, pilot valves, throttling valves, sequence valves or relief valves. Fluid motors are usually constant- or variable-discharge piston pumps caused to rotate by the pressure of the hydraulic fluid of the system with the power supplied by the pump power source. Such a hydraulic motor may be used in connection with a variable-discharge pump to form a variable-speed transmission.

What is claimed is:

1. A functional fluid comprising in parts by weight, 40 to 55 parts of tricresyl phosphate, 45 to 60 parts of chlorinated biphenyl containing a total of 40 to 60% by weight of combined chlorine and 0.4 to 2 parts of alkylated polystyrene made by alkylating polystyrene having a molecular weight of between 10,000 and 150,000 with about 0.2 to 0.8 part by weight of olefins containing 6 to 15 carbon atoms, said functional fluid having a viscosity at 100° F. within the range of 150 to 1200 S. S. U. and a viscosity index within the range of 0 to +150.

2. A functional fluid comprising in parts by weight, 40 to 55 parts of tricresyl phosphate, 45 to 60 parts of chlorinated biphenyl containing a total of 40 to 60% by weight of combined chlorine and 0.4 to 2 parts of alkylated polystyrene made by alkylating polystyrene having a molecular weight of between 60,000 to 80,000 with about 0.2 to 0.8 part by weight of olefins containing 8 to 10 carbon atoms, said functional fluid having a viscosity at 100° F. within the range of 150 to 1200 S. S. U. and a viscosity index within the range of 0 to +150.

3. A functional fluid comprising in parts by weight, 40 to 55 parts of tricresyl phosphate, 45 to 60 parts of chlorinated biphenyl containing a total of 40 to 60% by weight of combined chlorine and 0.8 to 2 parts of alkylated polystyrene made by alkylating polystyrene having a molecular weight of between 60,000 to 80,000 with about 0.2 to 0.8 part by weight of olefins containing 8 to 10 carbon atoms, said functional fluid having a viscosity at 100° F. within the range of 150 to 1200 S. S. U. and a viscosity index within the range of 0 to +150.

4. A functional fluid comprising in parts by weight, 40 to 55 parts of tricresyl phosphate, 45 to 60 parts of chlorinated biphenyl containing a total of 40 to 60% by weight of combined chlorine and 4 to 10 parts of a substantially 20% solution in mineral oil of alkylated polystyrene made by alkylating polystyrene having a molecular weight of between 60,000 to 80,000 with about 0.2 to 0.8 parts by weight of olefins containing 8 to 10 carbon atoms, said functional fluid having a viscosity at 100° F. within the range of 150 to 1200 S. S. U. and a viscosity index within the range of 0 to +150.

5. A functional fluid comprising in parts by weight, 45 to 50 parts of tricresyl phosphate, 45 to 50 parts of chlorinated biphenyl containing a total of 40 to 50% by weight of combined chlorine and 4 to 10 parts of a substantially 20% solution in S. A. E. 10 mineral lubricating oil of alkylated polystyrene made by alkylating polystyrene having a molecular weight of between 60,000 to 80,000 with about 0.4 to 0.8 part by weight of C₉ olefins, said functional fluid having a viscosity at 100° F. within the range of 150 to about 350 S. S. U. and a viscosity index within the range of 0 to +150.

6. A method for the preparation of functional fluids having a viscosity at 10° F. within the range of 150 to 1200 S. S. U. and a viscosity index within the range of 0 to +150, the steps comprising adding a solution of one part of alkylated polystyrene in 22.5 to 150 parts by weight of chlorinated biphenyl containing a total of 40 to 60% by weight of combined chlorine to tricresyl phosphate until the resulting fluid composition has a viscosity at 100° F. within the range of 150 to 1200 S. S. U. and a viscosity index within the range of 0 to +150, said alkylated polystyrene being polystyrene of a molecular weight of between 10,000 and 150,000 alkylated with 0.2 to 0.8 part by weight of olefins containing 6 to 15 carbon atoms.

7. A method for the preparation of functional fluids having a viscosity at 100° F. within the range of 150 to 1200 S. S. U. and a viscosity index within the range

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of 0 to +150, the steps comprising adding a solution of one part of alkylated polystyrene in 22.5 to 75 parts by weight of chlorinated biphenyl containing a total of 40 to 60% by weight of combined chlorine to tricresyl phosphate until the resulting fluid composition has a viscosity at 100° F. within the range of 150 to 1200 S. S. U. and a viscosity index within the range of 0 to +150, said alkylated polystyrene being polystyrene of a molecular weight of between 60,000 and 80,000 alkylated with 0.4 to 0.8 part by weight of olefins containing 8 to 10 carbon atoms.

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2,245,649
2,413,170
2,421,082
2,423,927
2,509,620
2,528,347
2,549,270
2,636,862

10

14

References Cited in the file of this patent

UNITED STATES PATENTS

Caprio	June 17, 1941
Clark	Dec. 24, 1946
Pier et al.	May 27, 1947
Burk et al.	July 15, 1947
Watson	May 30, 1950
Dennison et al.	Oct. 31, 1950
Watson et al.	Apr. 17, 1951
Watson	Apr. 28, 1953