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Hydraulic fluid power — Fire-resistant (FR) fluids — Guidelines for use

Transmissions hydrauliques — Fluides difficilement inflammables — Principes directeurs pour leur utilisation

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Foreword

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International Standard ISO 7745 was prepared by Technical Committee ISO/TC 131, *Fluid power systems*.

Users should note that all International Standards undergo revision from time to time and that any reference made herein to any other International Standard implies its latest edition, unless otherwise stated.

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Hydraulic fluid power — Fire-resistant (FR) fluids — Guidelines for use

0 Introduction

In hydraulic fluid power systems, power is transmitted and controlled through a liquid under pressure within an enclosed circuit. One kind of fluid is a fire-resistant fluid (see clause 3 for definition). Fire-resistant properties vary widely among the types of fluids.

1 Scope and field of application

This International Standard provides guidelines detailing, for the various categories of fire-resistant fluids, operational characteristics, advantages and disadvantages, and the factors affecting the choice to be made amongst these various categories.

This International Standard also specifies precautions which should be adopted to reduce difficulties arising from the use of such fluids, as well as the precautions which are necessary when replacing fluids with fluids from different categories.

The installation of hydraulic circuits with respect to fire-resistant fluids is also described in this International Standard.

2 References

ISO 1629, *Rubber and latices — Nomenclature*.

ISO 3448, *Industrial liquid lubricants — ISO viscosity classification*.

ISO 5598, *Fluid power systems and components — Vocabulary*.

ISO 6072, *Hydraulic fluid power — Compatibility between elastomeric materials and fluids*.

ISO 6743-4, *Lubricants, industrial oils and related products (class L) — Classification — Part 4: Family H (Hydraulic systems)*.

3 Definitions

For the purposes of this International Standard, the definitions given in ISO 5598 and the following definition apply.

fire-resistant (FR) fluid: Fluid difficult to ignite which shows little tendency to propagate flame.

NOTE — The definition of "fire-resistant fluid" given is taken from ISO 5598, but it is repeated here for the sake of convenience.

4 Hydraulic systems — Applications, hazards and general precautions

4.1 General

Normal fluid pressures in hydraulic power systems range up to 4 000 kPa[1] (400 bar). It follows that any lack of integrity in the construction of a system or any burst or even small leak can lead to a projection of fluid over a considerable distance. Should the fluid be flammable, this can in many circumstances give rise to a serious fire hazard.

4.2 Causes of fire

Failure of piping (particularly at joints), failure of valves, gaskets or fittings, pulling out of tubing from fittings, and rupture of flexible hoses have been the principal causes of fluid being released from a system.

The release of fluid under pressure where there is an ignition source, for example molten metal, gas burners, sparks, electrical equipment and hot metal surfaces have been the cause of many hydraulic fluid fires. Even frictional heating may produce temperatures sufficient to cause spontaneous combustion (auto-ignition) of fluid. Fires have occurred due to the accidental or mistaken disconnection of hydraulic piping or hose while under pressure. Slow leaks into absorbent surfaces, such as lagging, may also support combustion.

1) 1 Pa = 1 N/m^2; 1 bar = 10^5 Pa

4.3 General precautions

4.3.1 Major hazards

It will be appreciated that the summary of major hazards given below is not exhaustive and also that the comment is merely good engineering practice applicable equally to systems where either mineral oils or fire-resistant fluids are in use. The following constitute major hazards:

a) leaks (see 4.3.2);

b) high fluid temperature (see 4.3.3);

c) fluid degradation (see 4.3.4);

d) faulty installation and maintenance (see 4.3.5).

4.3.2 Leaks

Leaks can be caused by the following occurrences:

a) failure of a sealing device (see 8.7.3);

b) failure of the fluid conductor — pipes, hoses, couplings, etc.;

c) faulty assembly work.

4.3.2.1 Sealing materials

Only sealing materials that are compatible with the fluid shall be used. Such devices shall be installed and used correctly in accordance with the supplier's recommendations.

4.3.2.2 Fluid conductors

Conductors shall be mounted and secured in such a way as to reduce the effect of vibration. Careful consideration shall be given to the siting of components and routing of conductors to avoid the possibility of physical damage. In many instances the provision of protective channelling or metal guards is recommended. Wherever possible conductors should not be routed adjacent to other services, particularly electrical supplies.

4.3.2.3 Assembly work

It is essential that work carried out on hydraulic installations be undertaken and supervised by competent staff.

4.3.3 High fluid temperature

The operating temperature of a well-designed hydraulic system should not normally exceed 50 °C (pump inlet temperature). Any deviation from this shall be the subject of agreement between the supplier and the purchaser and in any such agreement the fluid type, operating and ambient temperature and any other special conditions which apply should be specified.

High operating temperatures reduce fluid viscosity which greatly increases the potential leakage rate and may render the system less efficient. It is recommended that thermal shut-off devices be incorporated within the hydraulic reservoir to operate in the event of high fluid temperatures occurring.

4.3.4 Fluid degradation

Chemical changes can take place in the fluid during use, particularly at abnormal operating temperatures. The presence of contaminants accelerates the degradation process. When installations require reservoir heating for cold start-up, the rating of the heater shall be strictly controlled to avoid thermal degradation.

4.3.5 Faulty installation and maintenance

Many failures of hydraulic equipment can be attributed to faulty installation and/or maintenance.

Failure to observe basic precautions in the storage and handling of fluid, failure to take adequate precautions to prevent the ingress of contaminants during servicing, etc. are typical examples.

4.3.6 Fluid disposal

Fire-resistant fluids shall be disposed of in accordance with the national regulations in force.

5 Requirements for fire-resistant hydraulic fluids

5.1 Property requirements

To perform satisfactorily in hydraulic systems the functional fluid shall be fire-resistant and possess the properties specified in 5.1.1 to 5.1.10.

5.1.1 The functional fluid shall be fluid enough at all working temperatures to flow readily through the system and to accommodate rapid changes in velocity and pressure.

5.1.2 At the same time the fluid shall be viscous enough at all working temperatures to prevent unwanted leakage across working clearances wherever a pressure differential exists across them.

5.1.3 The fluid shall be of sufficient viscosity and adequate film strength to lubricate working parts effectively under both hydrodynamic and boundary conditions over the working temperature range.

5.1.4 The fluid shall be compatible with construction materials used in the system and shall be non-corrosive.

5.1.5 The fluid shall have thermal stability and be suitable for use at the highest expected operating temperature.

5.1.6 The fluid shall have chemical stability to give adequate working life.

5.1.7 The fluid shall release entrained air readily and not provide a stable foam.

5.1.8 The fluid shall separate readily from contaminants encountered in normal use without chemical reaction.

5.1.9 The surface tension of the fluid shall be low enough to give "wettability" but not low enough to make sealing difficult.

5.1.10 The fluid should preferably be shear stable, i.e. its viscosity should not permanently change unduly with applied shear in a system.

5.2 Other requirements

The following fluid characteristics, at first use and in the course of use, shall be considered in system design:

a) case of filtration;

b) relative density in relation to suction head of pump;

c) vapour pressure which should not give rise to cavitation at pump suction inlet;

d) fire-resistant qualities;

e) non-toxicity of the fluid and vapours produced.

6 Characteristics of fire-resistant hydraulic fluids and factors affecting choice

6.1 General

6.1.1 Fire-resistant (FR) fluids have been designed for safety reasons to replace conventional mineral oils in all applications where hydraulic systems are operating in close proximity to naked flames, molten material or other high-temperature sources, or specifically in hazardous environments where fire and/or explosion risks have to be reduced to a minimum. It is also necessary that such fluids shall resist spontaneous combustion if allowed to come into contact with hot surfaces or absorbent materials into which the fluid may have become impregnated.

6.1.2 Fluids used as fire-resistant hydraulic media obtain their fire resistance by one of two following means

either from the presence of water, or

from their chemical composition.

Water, readily available and truly non-flammable, was used in the earliest systems but water has a very low viscosity and is a poor lubricant. Apart from the obvious temperature limitation, the use of water also gave rise to problems of corrosion and erosion. For these reasons, plain water cannot be used in systems the components of which need to be lubricated by the hydraulic fluid.

6.1.3 Fire-resistant fluids are assigned four categories:

- HFAE
- HFB
- HFC
- HFD

classified in ISO 6743-4.

Each category is divided into seven viscosity grades except for category HFAE, which is divided into five viscosity grades (see 6.2.1), taken from those specified in ISO 3448:

- ISO VG 10
- ISO VG 15
- ISO VG 22
- ISO VG 32
- ISO VG 46
- ISO VG 68
- ISO VG 100

These grades correspond to the mean viscosity of the grade defined by a minimum-maximum viscosity range expressed at 40 °C.

6.1.4 The mixing of fire-resistant fluids of different categories shall not take place. It is also ill-advised to mix fluids of the same category but of different origins, unless the compatibility of such has been clearly established.

Moreover, the replacement of hydraulic fluids of different categories calls for special precautions and as such reference shall be made to clause 9.

6.2 Classification of fluids

6.2.1 Oil-in-water emulsions (category HFAE)

NOTE — The classification in ISO 6743-4 divides category HFA into two sub-categories, HFAE (oil-in-water emulsions) and HFAS (chemical solutions in water).

Oil-in-water emulsions, which have only minimal lubricating value, are used in many systems. Their major advantage over plain water is their ability to provide a measure of rust protection.

These materials are very fire-resistant, but are generally unsuitable for use in high-rated systems due to their low viscosity and poor lubricity. Having such high proportions of water, they also have temperature limitations.

Oil-in-water emulsions normally contain up to a maximum of 10 % of soluble oil dispersed in water.

A minimum concentration of the emulsion is necessary to ensure satisfactory corrosion protection.

Such emulsions are normally prepared on site by the user, according to the fluid supplier's recommendation.

Category HFAE is divided into viscosity grades 10, 15, 22, 32 and 46.

6.2.2 Water-in-oil emulsions (invert emulsions) (category HFB)

Water-in-oil emulsions are dispersions of finely divided water droplets in a continuous phase of mineral oil with special emulsifiers, stabilizers and inhibitors. They are supplied ready for use and normally contain approximately 40 % of water. Changes in water content can reduce stability and/or fire resistance.

Water-in-oil emulsions have viscosities similar to normal mineral hydraulic oils and exhibit quite good lubricating and anti-corrosive properties. The viscosity is non-Newtonian and may vary from one part of a system to another according to the shear forces applied. Due to this viscosity characteristic and high vapour pressure, pump inlet conditions have to be carefully designed so as to avoid cavitation.

Category HFB is divided into viscosity grades 22, 32, 46, 68 and 100.

Fire resistance is impaired by continuous water evaporation or emulsion instability.

6.2.3 Water polymer solutions (category HFC)

NOTE — ISO 6743-4 designates HFC fluids as "water polymer solutions"; they are also known as "glycol solutions", "polyglycol solutions" or "water glycols".

These solutions derive their fire-resistant qualities from the presence of approximately 45 % of water. These fluids are true solutions and not emulsions as the categories previously described, i.e. HFAE and HFB.

They have good viscosity/temperature characteristics, and can be used at lower temperatures than water-in-oil emulsions but have approximately the same upper temperature limits.

Category HFC is divided into viscosity grades 15, 22, 32, 46, 68 and 100.

While they are acceptable lubricants, they provide for reduced fatigue life of rolling contact bearings. Anti-corrosive properties of fluids in this category are generally good.

While there are few material incompatibilities, the use of zinc, cadmium, non-anodized aluminium and magnesium alloys should be examined prior to their use. The indiscriminate use of internal reservoir coatings and sealing materials is not recommended.

6.2.4 Synthetic fluids containing no water (category HFD)

NOTE — ISO 6743-4 designates HFD fluids as "synthetic fluids containing no water"; they are also known as "anhydrous synthetic fluids" or "non-water-containing synthetic fluids".

This category of fire-resistant fluids is sub-divided into four sub-categories distinguished by the nature of the synthetic products. These sub-categories are designated as follows:

— HFDR: synthetic fluids containing no water and consisting of phosphate esters.

— HFDS: synthetic fluids containing no water and consisting of chlorinated hydrocarbons.

— HFDT: synthetic fluids containing no water and consisting of mixtures of phosphate ester and chlorinated hydrocarbons.

— HFDU: synthetic fluids containing no water and of other compositions.

This category is divided into viscosity grades 15, 22, 32, 46, 68 and 100.

This category of fire-resistant fluids has good lubricating and anti-wear properties, good storage stability and resistance to high temperatures. In certain cases temperatures up to 150 °C can be permitted, but at such temperatures the fluid may be subject to rapid deterioration and shall be checked frequently.

Category HFD fluids are fire-resistant by virtue of their chemical composition and, when suitably inhibited, are compatible with most metals and give good protection against rust and corrosion. HFD fluids are variable in their toxicity. Generally speaking, they exhibit poor viscosity/temperature relationships, although certain products do contain viscosity index improvers.

The majority of HFD fluids are sensitive to the presence of water or humidity, capable of causing corrosion and affecting the chemical stability of the product.

Internal surfaces of a system should not be painted. External surfaces should be protected by a fully compatible coating, for example epoxy phenolic or nylon-based, etc. The supplier should be consulted on these matters.

Seals, hoses, packings and accumulator bladders shall be manufactured from compatible materials such as fluoro-elastomers, PTFE and silicone rubber. Ethylene propylene and butyl elastomers may be suitable for some fluids, but the supplier should be consulted.

7 Precautions to be taken when introducing or using fire-resistant fluids

7.1 Oil-in-water emulsions (category HFAE)

7.1.1 Compatibility with constructional units and equipment

7.1.1.1 Compatibility with elastomers

Seals, hoses, packings and accumulator bladders which are compatible with mineral oils are generally suitable. Cork, asbestos and packings manufactured from leather are not considered suitable (see 8.7.3).

7.1.2 Handling

7.1.2.1 Storage

As the emulsifiers contained in certain fluids are sensitive to low temperatures, it is recommended that the fluids be stored at temperatures higher than or at least equal to 0 °C.

7.1.2.2 Preparation of the mixture

It is preferable to use water with a low content of mineral salts in order to obtain a stable emulsion. However, where difficult or hard waters have to be employed due to availability, it is necessary to select an emulsifying oil capable of coping with such. It is advised that the fluid supplier be consulted for his specific recommendations.

Once the specific emulsifing oil has been selected, no additional precautions need to be taken with automatic proportioning, apart from correct regulation of the oil delivery.

In the case of hand proportioning, the mixture shall be established by adding the oil slowly to the water, the fluid being shaken.

The indiscriminate incorporation of additional ingredients may adversely affect the characteristics of the fluid.

7.1.2.3 Use

The normal temperature of use ranges from +5 to +50 °C.

Owing to their limited lubricating properties, fluids of this category are normally used for installations where only marginal lubrication is required.

NOTE — Increasing the oil content of these emulsions does not substantially improve the lubricating power of the mixture.

7.1.2.4 Precautions in operation

The oil content shall remain constant within the limits specified by the emulsifying oil supplier.

Any fluid accidentally ejected from a hydraulic system shall flow away normally and not accumulate, otherwise the risk of splitting the emulsion exists and the formation of separated oil will provide a flammable layer of material.

The check on the oil content of an emulsion in operation can be undertaken by using either laboratory methods or by an on-site pocket refractometer.

7.1.2.5 Drained installations (storage)

Special precautions shall be taken with equipment during storage, owing to the potential risk of corrosion which may occur after draining. There are various methods of protection available, such as the use of an anti-rust oil or the incorporation of special emulsions with additional corrosion inhibitors.

7.2 Water-in-oil emulsions (category HFB)

7.2.1 Compatibility with constructional units and equipment

7.2.1.1 Compatibility with metals and alloys

Most HFB fluids are compatible with metals and alloys normally used with mineral oils; however, the use of zinc, cadmium and magnesium alloys shall be examined prior to their use.

7.2.1.2 Compatibility with elastomers

Seals, hoses, packings and accumulator bladders which are compatible with mineral oils are generally suitable. Cork, asbestos and packings manufactured from leather are not considered suitable (see 8.7.3).

7.2.1.3 Filtration

HFB fluids tend to retain contaminant particles in suspension and effective filtration is essential. Inlet strainers and pressure filters should have maximum screen or pore opening sizes of approximately 70 and 10 µm respectively. Filters (strainers) should have a nominal flow capacity approximately two to three times the rated pump capacity; fluid viscosity, working temperature, flow rates and permitted pressure drop shall be taken into account. Metal filters, either wire mesh or sintered, are normally compatible with emulsions but paper filter elements should be of a resin-impregnated type recommended by the fluid and/or filter supplier. Earth filtration or felt elements should be avoided.

7.2.2 Handling

7.2.2.1 Working temperatures

The normal temperature of use ranges from +5 to +50 °C. Most types of HFB fluids are recommended for use within the above range although low-temperature types which incorporate glycol can be used as low as −10 °C. Tank heating should be avoided, but, if essential, the heating surface shall not emit more than 3 W/cm^2 otherwise the stability of the emulsion may be affected. Water-in-oil emulsions shall not be stored at temperatures below 0 °C.

7.2.2.2 Precautions in operation

A check shall be kept on the water content of the fluid which shall be maintained within specified limits to avoid a reduction in fire resistance qualities and to prevent unacceptable changes in the fluid viscosity from occurring.

It may be advisable in some installations to leave the fluid circulating in the hydraulic circuit during extended periods of in-operation to avoid stratification of the major phases, i.e. water and oil.

7.3 Water polymer solutions (category HFC)

7.3.1 Compatibility with constructional units and equipment

7.3.1.1 Compatibility with metals

HFC fluids are compatible with most metals normally used with mineral oils; however, the use of zinc, magnesium, non-anodized aluminium and cadmium shall be examined prior to their use.

7.3.1.2 Compatibility with elastomers

Seals, hoses, packings and accumulator bladders which are compatible with mineral oils are generally suitable. Cork, asbestos and packings manufactured from leather are not considered suitable (see 8.7.3).

7.3.2 Handling

7.3.2.1 Use

The normal temperature of use ranges from − 20 to + 50 °C.

7.3.2.2 Precautions in operation

A check shall be kept on the water content of the fluid which shall be maintained within specified limits to avoid a reduction in fire resistance qualities and to prevent unacceptable changes in the fluid viscosity from occurring. Suppliers shall provide information making it possible to determine the quantity of water to be added to the solution to restore normal water content. For this purpose, distilled or deionized water shall be used.

7.4 Synthetic fluids containing no water (category HFD)

7.4.1 Compatibility with constructional units and equipment

7.4.1.1 Compatibility with metals

HFD fluids are compatible with most metals normally used with mineral oils, although specific reference shall be made to the equipment and/or fluid supplier where any doubt exists.

7.4.1.2 Compatibility with elastomers

The properties of many conventional elastomers deteriorate rapidly when in contact with HFD fluids. High working temperatures increase the rate of such deterioration (see 8.7.3).

7.4.2 Handling

7.4.2.1 Use

The normal temperature of use ranges from − 20 to + 70 °C. In certain cases temperatures up to 150 °C can be permitted, but, at such temperatures, the fluid may be subject to rapid deterioration and shall be frequently checked. At low temperatures, it may be necessary to use suitable heating devices.

In high-temperature circuits, i.e. above + 100 °C, special materials may have to be used for seals, packings, hoses, etc.

7.4.2.2 Precautions in operation

The same precautions applied to mineral oils shall also be applied to HFD fluids. In addition, their physiological properties shall be taken in account.

The viscosity, acidity and contamination level of the fluid shall be checked at regular intervals during use.

The fluid shall not be contaminated with water; if water is introduced by accident, it will float on the surface of the fluid and shall be skimmed off.

As far as possible contamination with mineral oil shall be avoided since the addition of such will impair fire resistance qualities.

8 Installation of hydraulic circuits

8.1 Reservoir

A reservoir of sufficiently large dimensions, fitted with a suitable breather and baffles, shall be provided. The fluid return pipe shall be located below the minimum permissible fluid level in order to prevent foaming. A tight-fitting and well-sealed cover will limit water evaporation from fluids of categories HFA, HFB and HFC, and will also serve to minimize contamination.

To assist fluid deaeration, the fluid suction shall be located as far as possible from the return pipe.

8.2 Pipes (fluid conductors)

In the design of fluid conductors, account shall be taken of the higher relative density of fluids in categories HFB, HFC and HFD and also the increased viscosity of HFD fluids at low temperatures. For suction pipes, the applied velocity of fluid flow shall be in accordance with the fluid suppliers' stated parameters.

Consideration shall be given to fluid pressure losses in long lengths of pipework either at design stage or alternatively prior to the selection of specific types of fire-resistant fluids.

8.3 Strainers and filters

For fluids having either a higher relative density or high viscosity in the cold state, which entails slow sedimentation of contaminants, it is recommended to provide filters and strainers of sufficiently large dimensions. When sizing filters, due consideration shall be taken of the effects of high viscosities or higher relative densities since both generally lead to proportionally reduced flow rate through the filter. In principle, the filtration surface should preferably be two to three times larger than for mineral oils.

It is recommended that fine filtration, for example 5 to 10 µm nom., be employed in the pressure or return line of the hydraulic circuit.

Certain filter elements, such as activated earth, absorbent filters, etc., shall not be used.

8.4 Circuit

Care shall be taken to ensure that the fluid is not subjected to temperatures incompatible with its use in order that all risks of freezing, boiling, losses of water and cavitation are avoided.

8.5 Pump suction

Flow velocities through suction pipes shall not be excessive and low pump inlet pressures shall be avoided. Boost pressures are advantageous.

8.6 Equipment performance

Since the overall performance of fire-resistant fluids is accepted as being somewhat inferior to fully inhibited mineral oils, it may be necessary to de-rate certain items of hydraulic equipment or suitably modify the circuit and/or components in order that service life is not unduly impaired.

A preliminary investigation, in conjunction with the maker of the equipment and supplier of the fluid, is recommended in the case of hydraulic units which are difficult to lubricate.

8.7 Compatibility with materials used in installations

8.7.1 Compatibility with metals

Anti-corrosion tests may have to be undertaken with different metals which may be encountered within a hydraulic circuit.

Certain metals which are sensitive to the action of fire-resistant fluids shall be avoided. Certain pair combinations of metals which show a great difference in electrolytic potential, and which may cause anodic corrosion shall also be avoided.

8.7.2 Compatibility with coatings and paint

Internal coatings, which are normally used in circuits operating with mineral oil, may be incompatible with fire-resistant fluids, particularly those of categories HFB, HFC and HFD.

It is difficult to recommend an effective treatment which can be carried out easily for protecting the internal surfaces of reservoirs. However, in view of the good anti-corrosive properties of many fire-resistant fluids, it is possible to use reservoirs without needing to resort to special protective coatings.

NOTE — Certain special resin based paints offer good resistance to fire-resistant fluids, but the application of paints with such properties to new equipment or equipment already in operation is very delicate. They call for special caution in both their selection and application in order that a lasting coating can be obtained.

If a hydraulic system has been protected during storage by a normal anti-rust product, it may be necessary to remove this protective treatment before the system is operated. It is possible, however, to treat the surfaces which require protection with an oil which is compatible both with certain fire-resistant fluids and with those elastomeric materials used in the system.

Some fire-resistant fluids, however, have poor vapour phase inhibition properties, and the air void above the fluid may be a source of contamination in unprotected mild steel reservoirs.

8.7.3 Compatibility with sealing devices

The conventional materials used for seals, packings, hoses and accumulators with mineral oils are not compatible with certain categories of fire-resistant fluids.

Sealing devices of leather, paper, asbestos and cork which may swell and/or disintegrate in the presence of water shall not be used.

Reference shall be made to ISO 6072 for the measurement of the compatibility of fluids for hydraulic transmissions with elastomers.

In addition, table 1 provides a general guide for the choice of elastomer types.

Table 1 — Guidelines as to the compatibility of FR fluids with elastomers

Fluid category	Suitable elastomer types
HFAE	NBR, FPM
HFB	NBR, FPM
HFC	NBR, SBR, EPDM, IIR, NR
HFDR	FPM, EPDM, IIR
HFDS	FPM
HFDT	FPM
HFDU	Compatibility tests need to be undertaken

Key

NBR	— Acrylonitrite-butadienne rubbers
FPM	— Rubbers having fluors and fluoroalkyl or fluoroalkoxy substituent groups in the polymer chain
SBR	— Styrene-butadiene rubbers
EPDM	— Ethylene propylene diene terpolymer rubbers
IIR	— Isobutene-isoprene rubbers
NR	— Natural isoprene rubbers
AU	— Polyester urethanes
EU	— Polyether urethanes

NOTES

1 Elastomers based upon polyurethanes (AU and EU) may be damaged by hydrolysis in the presence of water.

2 The nomenclature and abbreviations used for elastomers are in accordance with ISO 1629, but it should be noted that these names are generic, i.e. a whole variety of different compounds may exist under one name, all of which have certain general properties. It is therefore necessary to stipulate in the specification, in addition to the basic material (for example NBR, FPM, EPDM), the required quality specifications (for example hardness, tensile strength, temperature range, swell performance, etc.).

3 NBR, FPM and AU are compatible with mineral-based oils.

9 Changing the fluid in a hydraulic system

In addition to the change-over procedures specified in 9.1 to 9.4, recommendations for changing fluids in hydraulic systems are given in table 2.

9.1 Change-over procedure from a mineral oil to a category HFAE, HFB or HFC fluid

9.1.1 Compatibility

The design of each of the components in the circuit shall be compatible with the characteristics of the fire-resistant fluid to be introduced into the circuit as a replacement. Seals, packings, hoses and coatings shall also be compatible with the fluid selected.

9.1.2 Draining and cleaning circuit

9.1.2.1 Drain the pipes and blow off with compressed air.

9.1.2.2 Clean the valves and tanks.