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Aerospace series — Fluid, hydraulic, phosphate ester-base, fire resistant — Technical specification

Série aérospatiale — Fluide, hydraulique, esters phosphoriques, résistant au feu — Spécification technique

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 10, *Aerospace fluid systems and components.*

Aerospace series — Fluid, hydraulic, phosphate ester-base, fire resistant — Technical specification

1 Scope

This International Standard defines technical requirements, qualification and quality control conditions (product qualification, batch control, acceptance) test and measurement methods to be used by manufacturers for qualification of fire-resistant phosphate-ester-base fluids used for hydraulic transmissions in aircrafts.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 37, *Rubber, vulcanized or thermoplastic — Determination of tensile stress-strain properties*

ISO 48, *Rubber, vulcanized or thermoplastic — Determination of hardness (hardness between 10 IRHD and 100 IRHD)*

ISO 1817, *Rubber, vulcanized or thermoplastic — Determination of the effect of liquids*

ISO 2592, *Determination of flash and fire points — Cleveland open cup method*

ISO 2921, *Rubber, vulcanized — Determination of low-temperature retraction (TR test)*

ISO 3016, *Petroleum products — Determination of pour point*

ISO 3104, *Petroleum products — Transparent and opaque liquids — Determination of kinematic viscosity and calculation of dynamic viscosity*

ISO 3116, *Magnesium and magnesium alloys — Wrought magnesium alloys*

ISO 3675, *Crude petroleum and liquid petroleum products — Laboratory determination of density — Hydrometer method*

ISO 3696, *Water for analytical laboratory use — Specification and test methods*

ISO 4407, *Hydraulic fluid power — Fluid contamination — Determination of particulate contamination by the counting method using an optical microscope*

ISO 6247, *Petroleum products — Determination of foaming characteristics of lubricating oils*

ISO 6618, *Petroleum products and lubricants — Determination of acid or base number — Colour-indicator titration method*

ISO 6619, *Petroleum products and lubricants — Neutralization number — Potentiometric titration method*

ISO 11171, *Hydraulic fluid power — Calibration of automatic particle counters for liquids*

ISO 11218, *Aerospace — Cleanliness classification for hydraulic fluids*

ISO 11500, *Hydraulic fluid power — Determination of the particulate contamination level of a liquid sample by automatic particle counting using the light-extinction principle*

ISO 12185, *Crude petroleum and petroleum products — Determination of density — Oscillating U-tube method*

ISO 12937, *Petroleum products — Determination of water — Coulometric Karl Fischer titration method*

ISO 13357-2, *Petroleum products — Determination of the filterability of lubricating oils — Part 2: Procedure for dry oils*

ISO 13573:2012, *Corrosion of metals and alloys — Test method for thermal-cycling exposure testing under high-temperature corrosion conditions for metallic materials*

ISO 14935, *Petroleum and related products — Determination of wick flame persistence of fire-resistant fluids*

ISO 15029-1, *Petroleum and related products — Determination of spray ignition characteristics of fire-resistant fluids — Part 1: Spray flame persistence — Hollow-cone nozzle method*

ISO 15597, *Petroleum and related products — Determination of chlorine and bromine content — Wavelength-dispersive X-ray fluorescence spectrometry*

ISO 20823, *Petroleum and related products — Determination of the flammability characteristics of fluids in contact with hot surfaces — Manifold ignition test*

EN 1652, *Copper and copper alloys — Plate, sheet, strip and circles for general purposes*

EN 2395, *Aerospace series — Aluminium alloy AL-P2024A — T4 or T42 — Sheet and strip — 0,4 mm ≤ a ≤ 6 mm*

EN 10130, *Cold rolled low carbon steel flat products for cold forming — Technical delivery conditions*

ASTM D 92[1)], *Standard Test Method for Flash and Fire Points by Cleveland Open Cup Tester*

ASTM D 97[1)], *Standard Test Method for Pour Point of Petroleum Products*

ASTM D 445[1)], *Standard Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity)*

ASTM D 664[1)], *Standard Test Method for Acid Number of Petroleum Products by Potentiometric Titration*

ASTM D 877[1)], *Standard Test Method for Dielectric Breakdown Voltage of Insulating Liquids Using Disk Electrodes*

ASTM D 892[1)], *Standard Test Method for Foaming Characteristics of Lubricating Oils*

ASTM D 974[1)], *Standard Test Method for Acid and Base Number by Color-Indicator Titration*

ASTM D 1217[1)], *Standard Test Method for Density and Relative Density (Specific Gravity) of Liquids by Bingham Pycnometer*

ASTM D 1298[1)], *Standard Test Method for Density, Relative Density, or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method*

ASTM D 2155[1)], *Standard Test Method for Determination of Fire Resistance of Aircraft Hydraulic Fluids by Autoignition Temperature*

ASTM D 4052[1)], *Standard Test Method for Density, Relative Density, and API Gravity of Liquids by Digital Density Meter*

ASTM D 4172[1)], *Standard Test Method for Wear Preventive Characteristics of Lubricating Fluid (Four-Ball Method)*

ASTM D 4636[1)], *Standard Test Method for Corrosiveness and Oxidation Stability of Hydraulic Oils, Aircraft Turbine Engine Lubricants, and Other Highly Refined Oils*

1) Published by: ASTM International www.astm.org

ASTM D 5621[1)], *Standard Test Method for Sonic Shear Stability of Hydraulic Fluids*

ASTM D 6304[1)], *Standard Test Method for Determination of Water in Petroleum Products, Lubricating Oils, and Additives by Coulometric Karl Fischer Titration*

ASTM D 6443[2)], *Test Method for Determination of Calcium, Chlorine, Copper, Magnesium, Phosphorus, Sulfur, and Zinc in Unused Lubricating Oils and Additives by Wavelength Dispersive X-ray Fluorescence Spectrometry (Mathematical Correction Procedure)*

ASTM D 6793[2)], *Standard Test Method for Determination of Isothermal Secant and Tangent Bulk Modulus*

ASTM E 1269[2)], *Standard Test Method for Determining Specific Heat Capacity by Differential Scanning Calorimetry*

DEF STAN 03-19[3)], *Electro-Deposition of Cadmium*

3 Technical requirements

3.1 General

The product shall be a fire resistant, phosphate ester-base fluid for hydraulic power transmissions. Its chemical composition (additives, contaminants) and intrinsic physical and chemical properties shall be in strict compliance with the requirements of this International Standard.

All delivered hydraulic fluids shall be fully compatible with any other phosphate ester-base fluid already qualified, whatever the mixture proportions.

In the following clauses, the International Standard appearing in brackets shall be considered as an alternative method to the preceding standard, e.g. ISO 3104 (ASTM D 445); ASTM D 445 is an alternative standard to ISO 3104.

3.2 Fluid types

Fluids types covered by this International Standard are listed in the Table 1 with their corresponding properties.

Table 1 — Type of fluid and properties

Type of fluid		Fluid properties
IV	"HD" (High Density)	Fire resistant, low water content, anti-erosion, high viscosity at low temperature and high density
	"LD" (Low Density)	Fire resistant, low water content, anti-erosion, low density
V		Fire resistant, low water content, low density, anti-erosion, improved thermal stability and in service lifetime.

3.3 Physical and chemical properties

The main physical and chemical properties of the fluid covered by this International Standard are listed in the Table 2.

2) Published by: ASTM International www.astm.org

3) Published by: MINISTRY OF DEFENCE (United Kingdom) www.gov.uk/government/organisations/ministry-of-defence

3.4 Products and manufacturers qualification

The qualified products list appears in the AMM (Aircraft Maintenance Manual).

3.5 Approved laboratories

All laboratories used should be ISO 9001 registered and AS/EN/JIS Q 9100 compliant.

Table 2 — Main characteristics and properties

Property	Unit Symbol	Condition	Requirements TYPE IV	Requirements TYPE V	Test method(s) Preferred International Standard	Test method(s) Alternative International Standard	Sub clause
Absolute kinematic viscosity	$mm^2 \cdot s^{-1}$ (centiStokes) "ν"	−54 °C (−65 °F) 38 °C (100 °F) 99 °C (210 °F) Atmospheric pressure	HD: ≤ 2 900 LD: ≤ 2 000	LD: ≤ 2 000	ISO 3104	ASTM D 445	4.1
			∈ [9,00; 12,50] ∈ [3,00; 4,00]				
Water content	H_2O % mass or ppm[a]	—	≤0,20 or 2 000		ISO 12937[b]	ASTM D 6304	4.2
Density	$kg \cdot m^{-3}$ "ρ"	(23 ± 3) °C	1 021 ≤ HD ≤ 1 066 LD: ≤ 1 020	LD:≤ 1 020	ISO 3675 or ISO 12185	ASTM D 1298 D 4052 or D 1217	4.3
Acid number Acidity index	mg KOH per g of fluid	—	≤0,10		ISO 6618 or ISO 6619	ASTM D 974 or D 664	4.4
Electrical conductivity	$\mu S \cdot cm^{-1}$ "γ"	20 °C (−10 °C to 100 °C)	≥0,30 ∈ [0,02 ; 6,00]		ISO 9940	—	4.5
Chlorine content	Cl^- ppm[a]	Tot. chlorine	≤50		ISO 15597	ASTM D 6443	4.6
Pour point temperature	°C (°F)	—	≤ −62 (−80)		ISO 3016	ASTM D 97	4.7
Flash point temperature			≥160 (320)		ISO 2592	ASTM D 92	4.8
Fire point temperature			≥177 (350)				
Auto ignition temperature			≥399 (750) ≥460 (860) for HD	≥399 (750)	ASTM D 2155	—	4.9
Flammability	Seconds	5 s, 10 s, 20 s and 30 s	Mean persistence time of the flame < 7,5 s		ISO 14935	—	4.10.1
	Seconds	—	Time elapsed between removal of the igniting flame and extinction of the spray along the spray pattern ≤ 4 s		ISO 15029-1	—	4.10.2
	Ignition category	700 °C ± 5 °C	$k_m \geq 10$		ISO 20823	—	4.10.3

[a] ppm = parts per million = $\mu g \cdot g^{-1}$ (10^{-6}).

[b] Deviation to ISO 12937 is granted for water content above 0,1.

Table 2 *(continued)*

Property	Unit	Condition	Requirements		Test method(s)		Sub clause
	Symbol		TYPE IV	TYPE V	Preferred International Standard	Alternative International Standard	
Colour condition	—	—	Purple Clear appearance		—	—	4.11
Isothermal secant Bulk Modulus	Pa	38 °C, $20{,}6 \cdot 10^6$ Pa	Mini value: $1\,450 \cdot 10^6$ Pa		ASTM D 6793	—	4.12
Thermal expansion	$°C^{-1}$ "α"	−25 °C to 99 °C	$\leq 1 \cdot 10^{-3}$		ASTM D 1217	—	4.13
		−54 °C to 110 °C	Curve to provide				
Solid particulate contamination (counting)	Cleanliness class	—	≤7		ISO 11218 ISO 11171 ISO 11500 or ISO 4407	—	4.16
Filterability	F	—	∈ [1,00 ; 1,60]		ISO 13357-2	—	
Foaming	cm^3	24 °C 93 °C 24 °C	After 5 min ≤250 ≤150 ≤450	Persistence ≤100 s ≤50 s 250 s	ISO 6247	ASTM D 892	4.17

[a] ppm = parts per million = $\mu g \cdot g^{-1}$ (10^{-6}).

[b] Deviation to ISO 12937 is granted for water content above 0,1.

4 Qualification requirements

4.1 Absolute kinematic viscosity "ν"

Absolute kinematic viscosity "ν" of the fluid shall be determined at the temperatures indicated below and at atmospheric pressure using viscosimetric capillary tubes in accordance with ISO 3104 (ASTM D 445). The limits values are in $mm^2 \cdot s^{-1}$ (centiStokes), see Table 3.

Table 3 — Viscosity limit values

Temperatures		Type	
°C	°F	IV High Density	IV & V Low Density
−54	−65	$\nu \leq 2\,900$	$\nu \leq 2\,000$
−40	−40	Values to be measured and provided	
−15	5		
38	100	$9{,}00 \leq \nu \leq 12{,}50$	
99	210	$3{,}00 \leq \nu \leq 4{,}00$	

Measurements shall be taken in a thermostatic bath at accurate temperatures, controlled using an accurate contacting thermometer in accordance with ISO 3104 (ASTM D 445).

NOTE At low temperatures, viscosimetric tubes may be connected to dehydration tubes to avoid condensation forming inside.

An evolution curve "Viscosity vs. Temperature" from −54 °C to 99 °C is requested.

4.2 Water content "[H_2O]"

The water content [H_2O] shall be determined

— by using the electrochemical method "KARL FISCHER" in compliance with ISO 12937 (ASTM D 6304).

The limit value shall be

— [H_2O] ≤ 0,20 % mass, or

— [H_2O] ≤ 2 000 ppm.

4.3 Density "ρ"

The density "ρ" shall be determined at (23 ± 3) °C in compliance with ISO 3675 (ASTM D 1298) or ASTM D 1217 (Pycnometer) or ISO 12185 (ASTM D 4052) (this method is based on the measurement of the harmonic period of fluid in a U-shape tube).

The corrected limit values at 20 °C, in $kg \cdot m^{-3}$, shall be as follows:

— Type IV High Density: 1 021 ≤ ρ ≤ 1 066;

— Type IV & V Low Density: ρ ≤ 1 020.

An evolution curve "Density vs. Temperature" from −40 °C to 100 °C is requested.

4.4 Acidity index "*AI*" — Acid number "*AN*"

The Acid number "*AN*" of the fluid shall be determined using the colour indicator titration method in accordance with ISO 6618 (ASTM D 974) or the Acidity index "*AI*" of the fluid shall be determined using the potentiometric titration method in accordance with ISO 6619 (ASTM D 664).

The limit value, in mg KOH per gram of fluid shall be:

AI or *AN* ≤ 0,10

4.5 Electrical conductivity "γ"

Test equipment:

— cell immersed in hydraulic fluid

— impedance bridge (conductimeter)

Measurement conditions:

— frequency: 50 Hz

— temperature = (20 ± 3) °C

— cell constant $K \in [0,7; 1,2]$ cm

Electrical resistance "*R*" shall be measured across the terminals of the cell.

The electrical conductivity is:

$$\gamma = L \cdot R^{-1} \cdot S^{-1} = K \cdot R \quad (1)$$

where

R is the resistance, in Ohms (Ω);

K is the cell constant, in cm = $S \cdot L^{-1}$;

S is the surface area of electrodes, in cm^2;

L is the gap between electrodes, in cm.

The corrected value at 20 °C in µS cm^{-1}, shall be

— Normal limit: $\gamma \geq 0{,}30$.

The value between −10 °C and 100 °C in µS cm^{-1}, shall be

— $\gamma \in [0{,}02; 6{,}00]$ (µS = microSiemens = 10^{-6} Siemens = 10^{-6} Ω^{-1} = 10^{-6} Mho).

An evolution curve “Conductivity vs. Temperature” from −40 °C to 100 °C is requested.

4.6 Chemical content

4.6.1 Chlorine

The Total Chlorine concentration limit shall be:

Total Chlorine ≤ 50 ppm

Methods to be used are Wavelength dispersive X-ray fluorescence spectrometry (see ISO 15597 or ASTM D 6443) or other methods provided acceptable to aircraft manufacturer.

4.6.2 Other components

During qualification, chemical contents (all fluids) in ppm (parts per million) or µg·g^{-1} (10^{-6}) as Calcium, Potassium, Sulphur, Sodium shall be duly identified when these elements are formulation additives and their fluid limit concentration shall be determined by fluid manufacturers. All other additives not duly identified in the fluid manufacturer formulation will be considered as contaminant and consequently prohibited, except total chlorine when its concentration is as follows:

— TYPE IV/[CL] ≤ 50 ppm;

— TYPE V/[CL] ≤ 50 ppm.

Method to be used is Wavelength Dispersive X-Ray Fluorescence spectrometry (ASTM D 6443) or other methods provided acceptable to aircraft manufacturer.

4.7 Pour point temperature

Pour point temperature shall be determined in compliance with ISO 3016 (ASTM D 97).

— Pour point ≤ −62 °C (−80 °F)

4.8 Flash point and fire point temperatures

Flash point and fire point temperatures shall be determined in an open vessel using the CLEVELAND method in compliance with ISO 2592 (ASTM D 92).

— Flash point: ≥160 °C (320 °F)

— Fire point: ≥177 °C (351 °F)

To determine degradation of these characteristics, fluid shall be tested in laboratory conditions in accordance with "1 Litre-Container" test method described in 4.20.3 until an Acidity index of 1,5 ± 0,3 has been reached (in keeping with the required time-temperature exposure under linked water and chlorine contamination conditions).

4.9 Auto-ignition temperature

Auto-ignition temperature shall be determined in compliance with ASTM D 2155.

— Auto-ignition: ≥399 °C (750 °F) Type IV Low Density and Type V

— Auto-ignition: ≥460 °C (860 °F) Type IV High Density

4.10 Flammability test

4.10.1 Determination of wick flame persistence

This determination of wick flame persistence is in accordance with ISO 14935, except the limits and pass criteria.

The limits and pass criteria shall be

— mean persistence time of flame MP < (7,5 ± 0,1) s.

4.10.2 Spray ignition test

This spray ignition test is in accordance with ISO 15029-1, except the limits and pass criteria.

Limits and pass criteria shall be as follows:

— flashes readily and self-extinguishes;

— maximum time, to the nearest 0,1 s, between removal of the igniting flame and extinction of the spray combustion, at different positions along the length of a pressurized spray of fluid under the conditions specified in ISO 15029-1 shall not exceed 4 s.

4.10.3 Manifold-Ignition test on a hot element

The test equipment is in accordance with ISO 20823, except the limits and pass criteria.

The limits and pass criteria k_m (Points of Part a + Part b) shall be in accordance with Table 4, with the exposure of the fluid within (35 ± 5) s on to the surface.

Table 4 — Flammability conditions and criteria

Fluid poured on	Part	Appreciation	Points	k_m
a) the tube	a	Burns does not burn	0 +5	a + b ≥ +10
b) the bottom of the protector	b	Burns lights up does not burn	0 +5 +10	

4.11 Colour — Condition

The new fluid shall be of a purple colour.

New fluid shall be clear and homogeneous without any solid suspended matter.

The colour and condition of the new fluid shall be inspected under white light shone through a glass test tube approximately 45 mm in diameter, filled with fluid.

4.12 Bulk modulus (Isothermal secant)

The average bulk modulus will be determined in accordance with method given below, or by an alternate method described and based on ASTM D 6793.

The isothermal secant bulk modulus β_{is} is defined by Formula (2).

$$\beta_{is} = -\left[V_0 \cdot \left(\frac{\Delta P}{\Delta V}\right)\right]_T \tag{2}$$

where

ΔP is the difference between final and initial pressure;

ΔV is the difference between final and initial volumes of the hydraulic fluid;

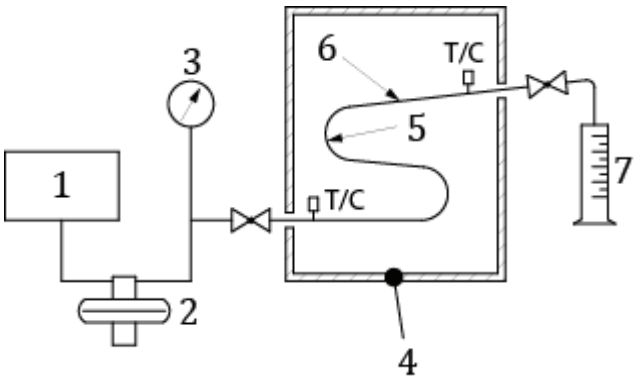
V_0 is the initial volume of the hydraulic fluid.

Test set-up:

a) A coil of (12,7 ± 0,254) mm by (1,244 6 ± 0,050 8) mm [(0,5 ± 0,01) inch by (0,049 ± 0,002) inch] 304 stainless steel tubing is used as the fluid receiver. This coil is installed in an oven, which is used as a heat source.

b) The test fluid is pumped into the receiver with an air driven pump and the pressure is read on a pressure gauge (graduated in 0,69 bar increments). The fluid temperature is monitored with thermocouples inserted into the top and bottom of the coil.

Bulk modulus determination set-up shall be in accordance with Figure 1.



Key

1	reservoir	5	0,50 inch long by 0,049 inch diameter tubing
2	pump	6	V_0 = 1 195 cm^3
3	pressure gauge(0 to 34,47·10^6) Pa [(0 to 350) bars]	7	100 ml graduated cylinder
4	temperature controlled chamber		

Figure 1 — Bulk modulus determination set-up

Test procedure:

a) After determining the volume of the fluid receiver by filling it with water and then draining into a beaker, determine the coefficient of expansion of the test fluid. This is done by heating (60 ± 1) cm^3 of the test fluid in a 100 ml graduated cylinder and recording the increase in temperature required to increase the volume 1 cm^3.

b) After the receiver has been filled and bled of air, adjust the system to (20,6 ± 0,17) MPa and (38 ± 3) °C. Then close the inlet valve and open the outlet valve.

c) The compressed fluid expands to atmospheric pressure, and the volume of fluid associated with raising the pressure in the receiver to the desired level is recorded. Collect the effluent until the temperature of the fluid in the coil returns to 38 °C (100 °F). Special attention shall be made to the time required for the fluid to return to 38 °C. This time shall be as short as possible preventing any influence of the fluid relaxation (thermoviscoelasticity) on the measured volume. Record this value along with the temperature of the effluent at the time of reading.

Method of computation:

a) The secant bulk modulus is the total change in fluid pressure, divided by the total change in fluid volume per unit volume, under pressure.

$$B = -V_0 \cdot \left(\frac{P - P_0}{V - V_0} \right) \tag{3}$$

where

B is the isothermal secant bulk modulus, in Pa;

P is the pressure, in Pa;

P_0 is the initial pressure, in Pa (usually atmospheric pressure);

V_0 is the volume at P_0 (receiver volume);

V is the volume at P (V_0 minus effluent volume).

b) Correct the volume of the receiver for changes due to pressure and temperature. Correct the effluent volume for the difference between its temperature at the time of reading and its temperature when it is in the receiver.

c) Report the average Isothermal secant bulk modulus.

4.13 Thermal expansion coefficient "α"

Thermal expansion shall be determined in compliance with the method described in ASTM D 1217.

Thermal expansion "α" shall be $\leq 1 \cdot 10^{-3}$ °C^{-1} for Δt of between –25 °C to 99 °C.

The complete curve between –54 °C and 110 °C has to be provided.

4.14 Dielectric resistance

Dielectric resistance shall be determined in compliance with the method ASTM D 877.

The fluid manufacturer shall indicate the value measured on the test fluid.

4.15 Specific heat "*Cp*"

Specific heat "*Cp*" shall be determined at atmospheric pressure in compliance with ASTM E 1269 method (Differential Scanning Calorimetric method).

— *Cp* isothermal curve for the following temperatures: (–15; 20; 38; 99; 120) °C.

The manufacturer shall indicate the values measured on the test fluid. No limit value is set.

4.16 Solid particulate contamination

4.16.1 General

The filtering membranes compatible with phosphate esters (PA 6.6, PTFE, POM...) with a pore dimension of 1 µm will be used with trichloroethylene or petroleum spirit filtered at 1 µm as a solvent.

4.16.2 Particle counting

Particle counting shall be determined in compliance with the method described in ISO 4407 for an optical microscope particle counts and in ISO 11171 and ISO 11500 for an automatic particle counting. Contamination class expressed according to ISO 11218 shall be less than or equal to class 7 as described in Table 5.

Table 5 — Characteristics for new fluid

Particle size µm[a] or µm(c)[b]	Particles/100 cm³
(5 incl. to 15 incl.) µm or (6 incl. to 14 incl.) µm(c)	≤32 000
(15 excl. to 25 incl.) µm or (14 excl. to 21 incl.) µm(c)	≤5 700
(25 excl. to 50 incl.) µm or (21 excl. to 38 incl.) µm(c)	≤1 012
(50 excl. to 100 incl.) µm or (38 excl. to 70 incl.) µm(c)	≤180
Over 100 µm(Including fibres) — or over 70 µm(c)	≤32
Contamination class	≤7

NOTE Limits: incl. = included
excl. = excluded

[a] Size range, optical microscope particle counts, based on longest dimension as measured per ISO 4407.

[b] Size range, automatic particle count with an APC calibrated per ISO 11171 and used per ISO 11500 or an optical or electron microscope with image analysis software, based on projected area equivalent diameter.

4.16.3 Filterability "*F*"

The filterability test is performed in accordance with ISO 13357-2, with the exception that only membranes, compatible with phosphate esters, are to be used.

Suggestion use: PTFE filtering membranes welded to a polyethylene grid, pore dimension 1 µm, Ø = 47 mm, (example: MILLIPORE/Type FA/Ref. FALP 047FI).

NOTE Filterability is not strictly an intrinsic physical property of the fluid but rather a means of gauging its hydraulic behaviour. The method, with a repeatability of 5 %, consists in comparing the flow rate under constant pressure of a fluid through different filters, during the test.

4.17 Foaming

A foaming test shall be performed in accordance with ISO 6247 (ASTM D 892) on a first test sample at 24 °C, and on a second test sample at 93 °C and at 24 °C once the foam has disappeared.

Test equipment: bubbling apparatus

a) Tendency to foam: Volume of foam shall be measured after bubbling for 5 min. Maximum volume of foam is given in Table 6.

b) Foam persistence: No foam shall remain after bubbling past a certain period of time given in Table 6.

Table 6 — Foaming conditions and criteria

Sample	Temperature °C	Tendency to foam cm³	Foam persistence time s
First	24	≤250	≤100
Second	93	≤150	≤50
	24	≤450	≤250

4.18 Toxicity

The manufacturer shall specify the toxicity characteristics of the hydraulic fluid according to the local and national regulations.

4.19 Stability

4.19.1 Shear stability

Shear stability using a sonic oscillator shall be determined in compliance with ASTM D 5621.

After testing, the absolute kinematic viscosity of the fluid shall be measured at (38 ± 0,02) °C and atmospheric pressure as indicated in 4.1.

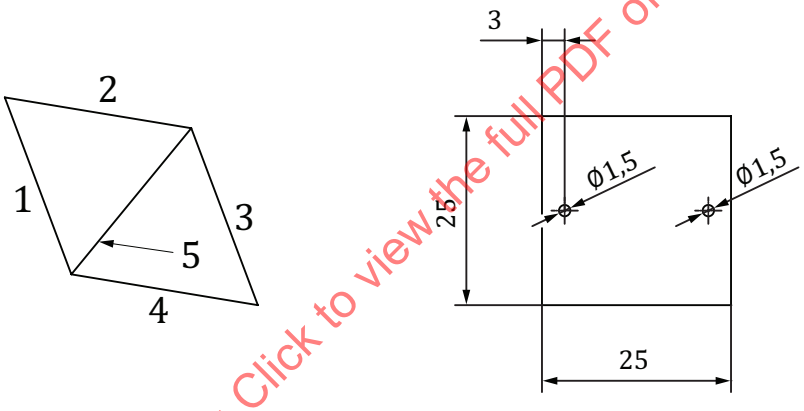
The value measured shall not vary by more than 25 % with respect to that obtained with a new fluid, also at (38 ± 0,02) °C.

4.19.2 Thermal, corrosion and oxidation stability

4.19.2.1 Test conditions and requirements

The fluid shall be tested after immersion of metal test pieces (see Table 7) assembled in accordance with Figure 2.

Dimensions in mm



Key

1	Al	4	Cu
2	Mg	5	Cadmium-plated steel
3	Steel		

Figure 2 — Arrangement of metal test pieces

The metal test pieces materials definitions are described in Table 7. The polishing of the metal test pieces shall be finished by machining in accordance with ISO 13573:2012, 4.1.1.

Table 7 — Metal test piece material definition

Tests conditions	Surface finish	Requirements in accordance with ASTM D 4636		Figure 2 reference
Materials	Polished	Cu-ETP R240	According to EN 1652	4
	Polished	Al-P2024A-T4	According to EN 2395	1
	Polished	ISO-MgAl3Zn1(A)-0 (annealed)	According to ISO 3116	2
	Polished	Steel DC04	According to EN 10130	3
	Unpolished	Cadmium plated but not passivated	According to DEF-STAN 03-19	5

Tests shall be performed on metal test pieces after immersion in the fluid. The magnesium, aluminium, copper and steel test pieces shall be placed so that they form a diamond, and the cadmium-plated steel test piece placed diagonally, keeping strictly to the order indicated. The edges around the holes of the metal test pieces may be touching, but the magnesium test piece shall not touch the copper piece under any circumstances in order to avoid galvanic coupling. The metal test pieces assembly shall be held in place by threads that are not affected by phosphate esters (polyamide 6.6, flax fibre, etc.).

Perform the following at the end of each immersion cycle indicated in 4.19.2.2.

— Examine each metal test piece for corrosion.

— Determine the fluid's oxidation resistance.

— Evaluate the physical and chemical characteristics of the unfiltered fluid.

— Metal test pieces shall be examined for corrosion after removing any traces of grease, and their corrosion stability determined by measuring the variation in mass per surface area in $mg \cdot cm^{-2}$. No pitting, corrosion attacks or discoloration shall be visible on the surface of the metals when examined at a magnification of 20.

— The fluid's oxidation resistance shall be determined by identifying variations in its viscosimetric properties, acidity index, visual appearance (precipitation of insoluble substances, gumming, turbidity, etc.) and discoloration.

— Fluid loss through evaporation shall be ≤8 % in weight.

— Absolute kinematic viscosity measured as defined in 4.1 above shall not deviate from the value measured on new fluid by more than

  a) ±3,00 $mm^2 \cdot s^{-1}$ maximum at (38 ± 0,02) °C, and

  b) ±1,00 $mm^2 \cdot s^{-1}$ maximum at (99 ± 0,02) °C.

— The increase of acid number per gram of fluid, measured as defined in 4.4, shall be: $\Delta AN \leq 0{,}5$ mg KOH/g.

The test conditions will be specified subsequently.

4.19.2.2 Thermal stability

The test shall be performed in initial condition with a maximum value of: i.e. $[H_2O]$ = 1 000 ppm and the set-up conditions are defined in 4.19.2.1.

Test containers: flasks containing 1 litre of unfiltered fluid in delivery condition and divided into equal quantities in glass flasks, with air present above the fluid. The flasks shall be sealed with a tapered, ground glass stopper.

Test soaks:

— (135 ± 5) °C;

— (0; 150; 300; 600; 1 000; 1 500) h.

Six test flasks shall be exposed to dry heat at (135 ± 5) °C and soaked at each duration indicated above.

After each artificial ageing, soak

— absolute kinematic viscosity at (38 ± 0,02) °C and (99 ± 0,02) °C shall be measured (see 4.1), criteria is given in 4.19.2.1,

— the water content shall be measured (see 4.2), and

— acid number shall be measured (see 4.4), criteria is given in 4.19.2.1.

4.19.2.3 Corrosion and oxidation stability

The set-up conditions for metal test pieces are defined in 4.19.2.1.

Test shall be performed in accordance with ASTM D 4636 standard for 168 h at the temperature of (80 ± 1) °C.

The following items shall be measured:

— absolute kinematic viscosity at (38 ± 0,02) °C and (99 ± 0,02) °C (see 4.1), criteria is given in 4.19.2.1;

— the water content (see 4.2);

— acid number (see 4.4), criteria is given in 4.19.2.1;

— metal test pieces variation in weight per surface area, see Table 8.

Table 8 — Acceptable variation in weight per surface area

Metals in contact with the fluid	Acceptable variation in weight per surface area ($mg \cdot cm^{-2}$)
Electrolytic copper	≤0,4
Aluminium 2024	≤0,1
Magnesium G-A3Z1	≤0,2
Steel XC18S	≤0,1
Cadmium-plated steel	≤0,4

4.20 In-service lifetime

4.20.1 General

Hereafter, both methods shall be used: the first, to determine the hydraulic fluid lifetime curves in Ampoules; and the second, to determine the Flash and Fire Point Temperature values in a 1 litre (L) container (due to the need of sufficient quantity of fluid for testing).

Therefore, the 1 litre container will be opened to measure the Flash and Fire Point Temperatures once the acid number reaches (1,5 ± 0,3) mg KOH/g.

4.20.2 Ampoule test method

4.20.2.1 General

This test method determines the time necessary for obtaining a variation of chemical properties of the fluid at a defined temperature. This method of test can be repeated at different isotherms.

4.20.2.2 Equipment

— borosilicate glass test tubes (50 ml);

— hypodermic syringe (50 ml with 90 mm needle);

— test tube rack;

— pipe cleaner;

— tweezers;

— glass paper (600 grain);

— paper towels;

— water complying with ISO 3696 grade 3;

— four glass pipettes with polyethylene capsules;

— rubber stopper;

— goggles;

— indelible marker pen “ONYX”;

— 250 ml glass beaker;

— acetone;

— steel wire, diameter 1,60 mm[4)];

— copper wire, diameter 1,60 mm[4)];

— ruler;

— cotton cloth;

— metal file;

— eight flasks (2 ml).

4.20.2.3 Test method

— Obtain the required fluid water content (following measurement method in 4.2).

— Fill test tubes until approximately 85 % of fluid.

— Put a piece of copper wire and steel wire each test tube (cut to length to fit inside tube) and seal.

— Place the test tubes in an oven pre-heated to the required constant temperature and remove each test tube after exposing for the required period of time.

4) Used to simulate the metals in hydraulic systems that would tend to catalyse the hydrolysis reactions.

4.20.2.4 Measurement (after fluid exposure)

— Absolute kinematic viscosity "ν", following measurement method in 4.1

— Acid number "*AN*", following measurement method in 4.4

— Electrical conductivity "γ", following measurement method in 4.5

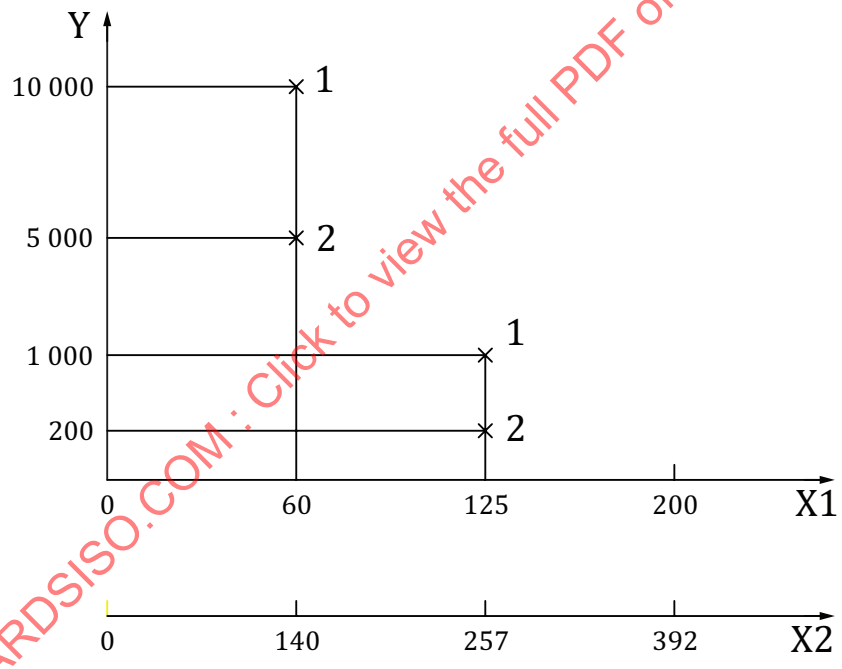
Fluid Lifetime curves shall be provided to show the evolution of fluid intrinsic characteristics ν = f, g (t,T), *AN* = f, g (t,T) and γ = f, g (t,T), up to reach their respective limit values, as specified in Clause 7 of this International Standard, at (60 ± 3) °C (140 °F) and (125 ± 3) °C to 200 °C (392 °F), with the hereafter water [H_2O] and Chlorine [Cl] concentrations (ppm):

[H_2O] = [2 000; 3 500; 5 000] and [Cl] = [25 to 50]

[H_2O] = [2 000; 3 500; 5 000] and [Cl] = [200]

(Adjust the Chlorine content by adding 1,1,1 Trichloroethane or equivalent chlorinated solvent.)

For example, the requirement for fluid lifetime is: for [H_2O] = 5 000 ppm and [Cl] = [25 to 50] ppm minimum, type IV and type V fluid lifetime requirements are shown in Figure 3.



Key

1 Type V fluids
2 Type IV fluids
X1 test temperature *t* in °C
X2 test temperature *t* in °F
Y required Fluid Life Time *T* (h Log Scale) in h

Figure 3 — Requirement on lifetime comparison between Type IV and Type V hydraulic fluids

4.20.3 "1 Litre-Container" Test method for fire resistance requirement in accordance with 4.8

4.20.3.1 Equipment

— 1 litre sample vessel (i. e. Whitey 304L-HDF8-1000 fitted with plug, Swagelok SS-8-P, and male connector and plug, Swagelok SS-1210-1-8 and SS-1210-P);

— oven(s) capable of maintaining samples at required temperature.

4.20.3.2 Sample preparation

— Adjust moisture content of test fluid to (0,50 ± 0,03) % H_2O (by weight).

— Adjust to 25 ppm to 75 ppm of Chlorine by adding 1,1,1 Trichloroethane or other chlorinated solvent (dichloromethane), in accordance with the national legislation.

4.20.3.3 Procedure for laboratory

— Add (900 ± 10) ml of prepared fluid to a clean sample vessel.

— Close sample vessel with a thermosetting screwed caps (example: phenoplast).

— Heat the vessels in the oven until the fluid in the vessels ages, reaching an *AN* of (1,5 ± 0,3) mg KOH/g (to be measured at regular intervals).

4.20.3.4 Fire resistance measurement (after fluid exposure)

The aim of the laboratory test is to ensure that ageing of the fluid-in service shall still maintain the fire resistant properties in accordance with values required in 4.8.

The "1 Litre-Container" test shall be carried out with hydraulic fluid contaminated with [H_2O] = 5 000 ppm and with [Cl] = 25 ppm to 50 ppm, reaching an *AN* of (1,5 ± 0,3) mg KOH/g (measured in the "1 Litre-container"), created by testing at the following temperatures:

— 110 °C (230 °F), 125 °C (257 °F), 140 °C (284 °F).

The minimum temperature values required for flash and fire points after ageing shall be

— 149 °C (300 °F) for Flash Point Temperature, and

— 165 °C (329 °F) for Fire Point Temperature.

NOTE It has been experienced that the results of the above laboratory tests performed in conditions more severe than the in-service conditions were able to meet the required in-service minimum values given in Annex C.

4.21 Material compatibility with qualified fluids (see list provided by the airframe manufacturer)

4.21.1 Compatibility with qualified fluids

4.21.1.1 General

Different phosphate ester-base hydraulic fluid mixtures shall be placed in clean glass receptacles, in proportions of (25/75) %, (50/50) % and (75/25) % by volume, and any visible reactions noted.

The fluid mixtures shall be conditioned in accordance with the following requirements.

— Temperature conditions: (130 to 135) °C exposure

— Duration: all types: 168 h

Leave to cool at room temperature.

4.21.1.2 Miscibility

After mixing the previously qualified fluids in the proportions given above and following conditioning as stated, the fluids shall be observed for colour, turbidity, foaming, suspended particles and any other visual sign of incompatibility. A change in colour is an acceptable reaction.

4.21.1.3 Foaming

Foaming tests shall be performed using the method described in 4.17 on qualified fluids mixed in the three proportions indicated above, and on fluids mixed in equal proportions.

Test equipment: bubbling apparatus

Tendency to foam: Volume of foam shall be measured after bubbling for 5 min. Maximum volume of foam is given in Table 9.

Foam persistence: No foam shall remain after bubbling past a certain period of time given in Table 9.

Table 9 — Foaming conditions and criteria

Sample	Temperature °C	Tendency to foam cm^3	Foam persistence time s
First	24	≤400	≤250
Second	93	≤425	≤200
	24	≤425	≤220

4.21.2 Compatibility with elastomeric materials

Tests are performed on O-Ring of EPR (ethylene-propylene rubber) or EPT (Ethylene Propylene Ter Polymer) and nowadays with EPDM (Ethylene Propylene Diene Monomer) types. The tests are performed in accordance with hereafter requirements (refer to A.1 and A.2).The types of seal to be tested will be specified by the aircraft manufacturer.

Standardized test pieces shall be immersed in the fluid according to the ratio

— test piece volume/fluid volume = 1/30.

Initial characteristics shall be determined before immersing the test pieces as per A.1.

Immersion cycles:

— 70 h at (71 ± 5) °C

— 1 000 h at (100 ± 5) °C

— 750 h at (120 ± 5) °C

— 1 440 h at (120 ± 5) °C

Permissible characteristics and variations for elastomeric EPR, EPT or EPDM after immersion in the fluid are given in A.1.

Permissible and other studied characteristics:

— international hardness (IRHD), in accordance with ISO 48 Method M;

— relative mass variations, ΔM%, and volume variations ΔV% in accordance with ISO 1817 Method;

— tensile stress-strain properties in accordance with ISO 37;

— low-temperature retraction procedure (TR test) in accordance with ISO 2921;

NOTE For the characteristics of international hardness, relative mass and volume variations, curves (see A.2) will be provided, to demonstrate the stability of tested Elastomeric materials (plateau to be reached in minimum 200 h).

4.21.3 Compatibility with paints

The test has to be performed according to A/C manufacturer qualified paint system.

It is the responsibility of each A/C manufacturer to define the following:

— the list of paint systems to be tested;

— the conditions of immersion under temperature (duration, temperature, samples size and preparation…);

— the tests to be performed on the paint system samples (before and after immersion);

— the criteria.

4.21.4 Compatibility with electrical aircraft components

It is the responsibility of each A/C manufacturer to define the following:

— the list of electrical components to be tested;

— the conditions of immersion under temperature (duration, temperature, samples size and preparation, cycles…);

— the tests to be performed on the electrical components samples (before and after immersion);

— the criteria.

4.21.5 Compatibility with structural elements: adhesive, metallic parts (including tubes), composites

It is the responsibility of each A/C manufacturer to define the following:

— the list of structural elements to be tested;

— the conditions of immersion under temperature (duration, temperature, samples size and preparation, cycles…);

— the tests to be performed on structural elements samples (before and after immersion);

— the criteria.

NOTE The high temperature effects on metallic parts could be fulfilled according to SAE AS 1241, 4.6.

4.22 Lubrication

The lubrication test shall be carried out on a 4-ball wear tester in accordance with ASTM D 4172 with the conditions noted.

Test conditions:

— temperature: (75 ± 3) °C;

— rotation speed: 600 r/min;

— loads: 4 kg, 10 kg, and 40 kg;

— duration: (60 ± 1) min.

4.23 Erosion tests of the hydraulic fluid

4.23.1 General

This is to be performed after satisfactory results of preliminary stage of qualification.

The aim of the erosion test is to compare the performances of new type fluid to be qualified, to that any type IV fluid already qualified (high and low density), particularly regarding the electro-chemical phenomena on the hydraulic equipment.

The three hereafter-mentioned tests have to be performed and passed, according to specific aircraft manufacturer requirements.

4.23.2 Test 1 — Erosion System Test Bench representative of one aircraft hydraulic system

Performed in accordance with B.1.

4.23.3 Test 2 — Pumping Test

Performed in accordance with B.2.

4.23.4 Test 3 — Erosion Resistance Tests

Performed in accordance with B.3.

5 Batches

A manufacturing batch is constituted with a quantity of fluid derived from a same manufacturing cycle.

6 Quality control

6.1 Hydraulic fluid acceptance tests

The manufacturer will carry out the manufacturing tests described in 6.2 and 6.3 on each manufacturing batch.

The results will be set out in an inspection document and transmitted to the buyer on delivery with the certificate of compliance.

The manufacturer will carry out the following tests, described in Clause 4, on each batch and will provide a Material Safety Data Sheet with each batch.

6.2 Physical characteristics

— Absolute kinematic viscosity (see 4.1) at (−54 ± 0,05) °C, (38 ± 0,02) °C and (99 ± 0,02) °C

— Density at (23 ± 3) °C (see 4.3)

— Pour point temperature (see 4.7)

— Flash point and fire point temperatures in an open vessel (see 4.8)

— Contamination class (see 4.16)

6.3 Chemical characteristics

— Water content (see 4.2)

— Acidity index (see 4.4)

— Chemical contaminants (see 4.6)

— Material Safety Data Sheet

Check test procedure: if a test result does not comply with the values requested, the test will be repeated on three other samples in different recipients which nevertheless belong to the same batch.

This batch will only be accepted if the three check tests are satisfactory.

NOTE The recipient containing the non-compliant product will be withdrawn from the batch.

7 Recommended limits

The hydraulic fluid criterion values in Table 2 are the permissible limits for all fluids.

The In-Service limits values (after A/C delivery) are also specified in the Aircraft Maintenance Manuals; see Annex C, Table C.1.

8 Marking

Unless otherwise specified by contract, marking shall include the following:

a) on recipients:

   1) the manufacturing batch number;

   2) the fill-up date;

b) on the label for each recipient:

   1) the manufacturer's name;

   2) the manufacturer's reference of the fluid (trade mark), with "High Density" mention when applicable;

   3) aircraft manufacturer's reference;

   4) contents (volume) and quantity (mass);

   5) conforms to ISO 9940;

c) plus, where applicable:

   1) sampling precautions;

   2) handling and storage instructions.

9 Packing and storage

The fluid will be delivered and stored in properly sealed containers.

The storage conditions shall be as follows.

— Keep the containers firmly closed.

