Fire-Resistant Hydraulic Fluids

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Topics

• Introduction

• Classifications of Fire-Resistant Hydraulic Fluids

• Fire-Resistant Hydraulic Fluids

• Fire-Resistance Evaluation

• References
Introduction
Why Use Fire-Resistant Hydraulic Fluids

• Increased risk of industrial fires
• Required by customers and insurance companies
Increased Risk for Industrial Fires

• Increasing Application Temperatures
• Increasing Hydraulic System Pressures
• Decreasing Hydraulic Reservoir Volumes
• Reducing Work Force to Minimize Costs
• Scaling Back Maintenance Schedules to Meet Budget Targets
Approaches to the Problem of Potential Fires

• Redesign or relocate machines to remove or isolate sources of ignition
• Install fire control measures such as fire suppression devices to ensure personnel safety and prevent or localize property damage
• Use a FRHF
• Adopt one or a combination depending on cost and other factors
Flame Propagation

- **Small leaks** in high-pressure hydraulic systems produce a **finely atomized spray**
- This spray can travel **significant distances**
- If an ignition source is encountered, **complete ignition** of the spray can occur
- This could cause a serious fire
  - Major property damage
  - Personnel injury or death
Industry Ignition Sources

• Open flame
• Sparks
• Hot metal
Industry Ignition Sources

• Ignition Sources – Typical Applications
  – Die-casting operations
  – Continuous casting hydraulics, e.g., in steel mills
  – Presses that are operated near furnaces or ovens
  – Foundries, e.g., in auto manufacturing facilities
  – Food processing operations
  – Kilns

• Ignition Sources - Special Applications
  – Underground mines and tunnels
  – Commercial aviation
  – Power generation
  – Military
HYDRAULIC FLUID SELECTION

- Selection Factors
  - System compatibility
  - Cost
  - Lubrication
  - Operating Temperature
  - Maintenance Requirements
  - Load Capacity
  - Operating Pressure
  - Health, safety and environmental concerns
  - Fire-resistance
Classification of Fire-Resistant Hydraulic Fluids
Classification Systems

- General
- International Organization for Standardization (ISO)
General

- Emulsion
- Water-Glycol
- Synthetic
# Fire-Resistant Fluids – ISO 6743-4

<table>
<thead>
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<th>Types of Fire Resistant Fluid</th>
<th>Type</th>
<th>Composition</th>
<th>Typical Applications</th>
<th>Operating Temperature Range</th>
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<tr>
<td>HFAE</td>
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<td>Oil-in-water emulsions. Emulsifying oil content &lt;20 mass%; typically 1 to 5 mass %.</td>
<td>Hydraulic systems in continuous casting plant, mine roof supports.</td>
<td>5C to 50C</td>
</tr>
<tr>
<td>HFAS</td>
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<td>Chemical solutions in water. Concentrate content &lt;20 mass%; typically 1 to 5 mass %.</td>
<td>Hydraulic systems in continuous casting plant, mine roof supports.</td>
<td>5C to 50C</td>
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<tr>
<td>HFB &amp; HFB LT</td>
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<td>Water-in-oil (&quot;invert&quot;) emulsions. Mineral oil content ~60 mass %. LT indicates emulsions that are stable at low temperatures.</td>
<td>Hydrostatic systems in coal mines.</td>
<td>5C to 50C</td>
</tr>
<tr>
<td>HFC</td>
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<td>Water polymer (e.g., water-glycol) solutions. Water content not &lt;35 mass%.</td>
<td>Hydrostatic systems in steel plants and coal mines.</td>
<td>-20C to 50C</td>
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</table>
## Fire-Resistant Fluids – ISO 6743-4

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<tr>
<td>2. Anhydrous Fluids</td>
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<tr>
<td>HFDR</td>
<td>Synthetic fluids containing no water and consisting of phosphate esters.</td>
<td>Hydrodynamic couplings.</td>
<td>Up to 150°C</td>
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<td>Hydrostatic transmissions.</td>
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</tr>
<tr>
<td>HFDU</td>
<td>Synthetic fluids containing on water and of other composition (typically synthetic esters, e.g., polyol ester).</td>
<td>Hydrostatic transmissions.</td>
<td>-20°C to 70°C</td>
</tr>
</tbody>
</table>
Fire-Resistant Hydraulic Fluids

- Characteristics
- Applications
- Equipment Considerations
- Fluid Monitoring
- Compatibility
HFAE

- Characteristics
  - Oil-in water (conventional) emulsion
  - Contain about ninety-five percent water
  - Very low in viscosity
  - Water is the continuous phase surrounding finely-dispersed droplets of oil
  - Can be attacked by bacteria introduced by air, water, dust, or other sources
    - Cause odor
    - Darken the emulsion
    - Impair rust prevention
    - Promote oil-water separation
  - Four approaches to controlling bacteria
    - Improve plant cleanliness
    - Aerate the emulsion
    - Maintaining proper pH (>8.5)
    - Treating with bactericide
  - Shelf life – 12 months
HFAE

• Applications
  – Primarily intended for large, low-pressure, non-critical hydraulic systems where anti-wear properties are not essential
    • Hydraulic presses to 2,000 psi
    • Central accumulator hydraulic system using plunger or centrifugal pumps designed for water operation
    • Large forging presses and extrusion presses
      – with vertical in-line pumps or special axial piston pumps
      – operating at 2,000 to 3,000 psi (136 to 204 bar).
    • Coal mining to 1,000 psi
    • Machine tools to 800 psi
    • Automotive plants to 800 psi
HFAS

• Characteristics
  – Conventional high water content fluids (HWCFs)
  – Sometimes referred to as 95/5 fluids
  – Water that contains 2 to 5% water soluble chemicals that impart for specially designed pumps, valves, packing glands, and cylinders some
    • Lubricity
    • Rust protection
    • Wear protection
  – Operating temperatures must be limited to avoid excessive loss of water by evaporation

• Applications
  – Reciprocating plunger pumps to 10,000 psi (680 bar)
HFAB

- Characteristics
  - Water-oil (invert) emulsion
  - Contains about 40% water
  - Oil is the continuous phase surrounding finely-divided droplets of water uniformly dispersed throughout the mixture
  - Viscosity increases as water content increases
  - Important to maintain proper water content to avoid
    - System wear (if too little water)
    - Sluggish system operation (if too much water)
    - Loss of fire-resistance
  - Good anti-wear protection up to 49C (120F)
  - Effective rust protection
  - Excellent resistance to oil and water separation
HFAB

- Characteristics (continued)
  - Can be attacked by bacteria introduced by air, water, dust, or other sources
    - Cause odor
    - Darken the emulsion
    - Impair rust prevention
    - Promote oil-water separation
  - Four approaches to controlling bacteria
    - Improve plant cleanliness
    - Aerate the emulsion
    - Maintaining proper pH (>8.5)
    - Treating with bactericide

- Shelf life – 6 months
HFAB

- Applications
  - Continuous miners and ram shuttle cars
  - Steel mills to 2,000 psi
  - Automatic welding machines
  - Die casting to 3,000 psi
  - Certain gear, vane, and piston pumps
设备考虑

- 水蒸气压力较高。
- 为了避免泵的气蚀，泵的吸入口压力应比矿物油规定的压力高5英寸（125毫米）Hg绝对值。
- 使用40到60目丝网吸入口过滤器，其额定容量至少为泵容量的两倍。
- 管道应允许每秒2到4英尺（0.6到1.2米）的流量。
- 污染物在过滤器元件中可能造成问题。
• Fluid Monitoring
  – Addition of water
    • Make-up water must eventually be added
    • Water content must be accurately determined
    • Frequency of sampling depends on operating temperature and exposure to air currents
    • Check monthly in systems operating up to 49C (120F)
    • Water is slowly added at 5% of the rated pump capacity
    • Operate pump for at least one hour
  – Inspect and clean the suction strainer, service the magnets or magnetic filters, and return or
HFAB

- Compatibility with paints and coatings
  - Tendency to dissolve or soften most petroleum-compatible paints, enamels, and varnishes: these should be removed before conversion.

- Compatibility with other hydraulic fluids
  - The emulsion stability can be adversely affected by contaminants such as mineral oil, straight synthetic, or water-glycol fire-resistant fluids.

- Compatibility with certain metals
  - Should not be used where it can come into contact with pyrophoric materials such as molten magnesium, sodium, or other alkali or alkaline earth metals, because the water in the emulsion may act as a source of ignition.

- Compatibility with fibers
HFAB

- Compatibility with seals
  - Will not soften packing or seals made with nitrile rubber (however, confirm acrylonitrile content) or fluoroelastomers.
  - Avoid butyl rubber (used with synthetic fire-resistant fluids), cork, or leather.
HFAC

- Characteristics
  - True solution (as opposed to an emulsion) containing
    - 40 to 50% water and glycol
    - Additives to impart specific performance levels
      - Liquid and vapor phase rust inhibitors
      - Anti-wear additives
  - Water content controls
    - Viscosity
    - Fire-resistance
  - Inherently high resistance to bacterial growth
HFAC

• Applications
  – High-temperature steel mill, automotive, and metal industry applications
    • Forging systems
    • Die-casting machines
    • Welders
    • Loaders
    • Lathing operations
    • Trim presses
    • Billet-casting equipment
  – Where pressures do not exceed 2,000 psi for vane pumps
HFAC

- Equipment Considerations
  - For many applications, a hydraulic system designed for oil use can be readily adapted to water glycol, particularly with regard to water seals, hoses, and packing.
  - Performance considerations exist that may require de-rating the pump’s maximum allowable pressure, speed, and operating temperature.
  - If the system has been in extended service, filter elements must be changed.
  - Obvious leaks must be repaired.
  - New fluid may loosen or clean residual dirt and debris, so reservoir and filters should
HFAC

• Fluid Maintenance
  – Maintain water content between 39% and 43%
  – Excessive loss of water can cause abnormally high viscosity impeding flow and hydraulic response
  – Make-up water
    • Distilled water, soft-deionized water, or boiler condensate
    • Hardness should not exceed 5 ppm, as calcium and magnesium react with the lubricant additive to form a soapy solid
    • Hard water damage is permanent, so
HFAC

• Typical Used Fluid Maintenance Testing
  – Appearance
  – Viscosity
  – Reserve Alkalinity
  – pH
  – Dirt
  – Wear
  – Water Content
  – Pentane Insolubles
HFAC

- Compatibility with paints and coatings
  - Tendency to dissolve or soften most petroleum-compatible paints, enamels, and varnishes: these should be removed before conversion.
- Compatibility with other hydraulic fluids
  - Small amounts of oil do not interfere with performance but may reduce fire-resistance.
- Compatibility with metals
  - Excellent compatibility with aluminum, brass, bronze, copper.
  - Can attack zinc, cadmium, magnesium, and silver forming sticky or gummy residues that can plug strainers and cause valves or pumps to malfunction.
- Avoid parts plated with these materials e.g., galvanized
HFAC

• Compatibility with seals
  – Excellent – butadiene, styrene, nitrile rubber (e.g., Buna N), fluororubber (e.g., Viton®), Synthetic and Natural Isoprene, chlorosulfonated polyethylene (e.g., Dow Chemical Hypalon™), polytetrafluoroethylene (e.g., Dupont Teflon®).
  – Poor – alky acrylate rubber, urethane, cork, leather.
HFDR

• Characteristics
  – High performance phosphate ester
  – Resistant to oxidation and sludge formation
  – Long-term rust protection (if excessive water contamination is avoided)
  – Good anti-wear protection
  – Very resistant to shear
  – Immiscible with mineral oil
  – Heavier than mineral oil
  – Shelf life – 36 months
HFDR

• Applications
  – Aluminum die casting machines.
  – Tilting systems of cast iron induction melting furnaces.
  – Various steel industry hydraulic applications.
  – Coal mining equipment.
  – Steam/gas turbines (except for governor control systems)

• Special Application
  – Electrohydraulic governor control systems of steam turbines.
  – Formulation specific (specific ester versus ester mixture).
HFDR

• Equipment Considerations
  – Requires special care
  – Requires retrofitting all elastomers
  – Generally requires no de-rating of component performance
  – Not miscible with mineral oil
HFDR

- Fluid Monitoring (typical applications)
  - TAN due to increase in acidity
  - Moisture Level
  - May loosen or clear residual dirt and debris requiring monitoring of reservoir and filters for increased dirt loads

- Fluid Monitoring (electrohydraulic governor control)
  - Ensure maximum residence time in reservoir
  - Keep level of metal soaps/mineral oil in fluid as low as possible
HFDR

- Typical Used Fluid Maintenance Testing (electrohydraulic governor control)
  - Density
  - Viscosity at 40C
  - Mineral Oil Content
  - Flash Point
  - Autoignition Temperature
  - Acidity
  - Volume Resistivity
  - Cleanliness
  - Foaming
  - Water Content
• Compatibility with paints and coatings
  – Will soften some paints; however, it is compatible with the following paints under certain conditions (check samples before use): alkyd paint (stoved), epoxy paint (cured), polyurethane paint, and vinyl ester. Nitrocellulose is unsuitable. When changing from petroleum oil to a phosphate ester fluid, completely remove the paint from the reservoir and leave the reservoir unpainted. If this is not possible, clean suction screens frequently to prevent pump cavitation or starvation.

• Compatibility with other hydraulic fluids
  – Before mixing with other phosphate ester fluids, consult the equipment manufacturer or fluid supplier. Water-glycol and emulsion-type fluids are not compatible. Systems must be thoroughly drained and flushed before installing a new charge, especially if for the electrohydraulic governor control application.

• Compatibility with metals
  – Compatible with all construction materials. However, aluminum should be hard anodized. The use of copper and copper alloys is acceptable providing manufacturers' limits on fluid acidity in service are followed. Stainless steel and titanium can also be used for the construction of the oil cooler.
HFDR

• Compatibility with wire and cable insulation
  – Include nylon and PTFE (e.g., DuPont Company Teflon®). Polyethylene, polypropylene, and silicone rubber are acceptable under certain conditions (check samples before use). Phenolic resins and PVC are unsuitable.

• Compatibility with seals
  – Recommendations for seals, packing, hoses, and accumulators include butyl rubber, nylon, PTFE (e.g., DuPont Company Teflon®), and fluoroelastomer (e.g., DuPont Company Viton®). Ethylene propylene is acceptable under certain conditions (check samples before use). Natural rubber, Neoprene, nitrile rubber, and silicone rubber are unsuitable.
HFDU

• Characteristics
  – High quality, synthetic, organic esters
  – Carefully selected additives (including anti-wear)
  – Readily biodegradable
  – Non-toxic to aquatic life
  – Compatible and miscible with mineral oil
  – Insoluble in water; lighter than water
  – Useful life comparable to mineral oils
  – Shelf life - 12 months
HFDU

• Applications
  – High pressure (up to 10,000 psi)
  – Hydrostatic transmissions
  – Environmentally sensitive equipment

• Special applications
  – Electrohydraulic governor control systems of steam turbines
HFDU

• Equipment Considerations
  – Readily adapt to hydraulic systems designed originally for oil-based fluid
  – Pump de-rating is not required
  – May loosen or clear residual dirt and debris requiring monitoring of reservoir and filters for increased dirt loads
HFDU

• Compatibility with paints and coatings
  – Compatible with multi-component epoxy coatings. Not compatible with zinc-based coatings. Specific coating and application recommendations can be obtained from coating manufacturers or directly the fluid supplier.

• Compatibility with other hydraulic fluids
  – Miscible and compatible with nearly all mineral oil-type hydraulic fluids. Not miscible or compatible with water-containing fluids. Compatible with some but not all phosphate esters; testing prior to conversion is recommended.

• Compatibility with metals
  – Compatible with iron and steel alloys and most nonferrous metals and their alloys. Not compatible with lead, cadmium, zinc, and alloys containing high levels of these metals.

• Compatibility with fibers
  – Incompatible with certain types of cork, paper, leather, asbestos, and synthetic fibers that soften and swell in the presence of water.
# HFDU – Seal Compatibility

| ISO 1629 | Description                                      | Static   | Mild-Dynamic | Dynamic  |
|=========|==================================================|==========|--------------|==========|
| NBR     | Medium-high Nitrile (>30% acrylonitrile) Rubber  | Compatible| Compatible   | Compatible|
| NBR     | Low Nitrile (<30% acrylonitrile) Rubber          | Satisfactory| Not Compatible| Not Compatible|
| FPM     | Fluoroelastomer                                  | Compatible| Compatible   | Compatible|
| CR      | Neoprene                                         | Satisfactory| Satisfactory | Satisfactory|
| IIR     | Butyl Rubber                                     | Satisfactory| Not Compatible| Not Compatible|
| EPDM    | Ethylene Propylene Rubber                        | Not Compatible| Not Compatible| Not Compatible|
| AU      | Polyurethane                                     | Compatible| Compatible   | Compatible|
| PTFE    | Polytetrafluoroethylene                          | Compatible| Compatible   | Compatible|
HFDU

• Compatibility with seals (continued)
  – Static refers to trapped nonmoving seals such as O-rings and valve subplates and rigid, low pressure hose connections.
  – Mild-Dynamic refers to accumulator bladders and hose linings where the hoses are exposed to high pressure and high flexing.
  – Dynamic refers to cylinder rod seals, pump shaft seals, and constantly flexing hydraulic hose.
HFDU

• Fluid Monitoring
  – Limit water content to 2000 ppm
  – Note tin in the analysis (215 ppm typical) is part of the additive package
  – Limit TAN to a maximum of 8.0
  – Keep viscosity within ISO VG range although somewhat lower not of concern
  – Currently samples are sent to Quaker for routine analysis; Signum is considering analysis
  – Investigative samples may be sent to CTS
Conversion Procedures

- Conversion procedures are available that cover all possible conversions.
  - Drain.
  - One or more flushes.
  - May require the use of a system cleaner.
  - May require testing to insure complete removal of previous fluid.

- Care must be taken when the fluids are compatible to make sure enough previous fluid has been removed to insure fire-resistance.
Fire-Resistance Evaluation
Fire-Resistance

• Fire-resistance does not mean “non-flammable”
  – All commercial hydraulic fluids will ignite if exposed to a high enough temperature
• Fire-resistance does mean a relative comparison
  – Hydraulic fluid types versus mineral oils
  – Inclusive of the fluids themselves
• Abilities
  – Resist ignition
  – Snuff flame / resist propagating flame / prevent from spreading / confine to local area
  – Resist sustaining a flame / self-extinguishing when the source of the flame is removed
Fire-Resistance Testing

• Classifications
  – Fire-resistant property that is being tested
  – The ignition source used in the test
  – The state of the fluid during the test
  – Whether the test simulates an accident condition or measures an intrinsic property of the fluid
Fire-Resistance Property

- Ease of ignition
- Heat release or combustion
- Flame propagation
- Self-extinguishment
- Smoke and combustion products
Ignition Source

- Radiant heat
- Pilot flame
- Hot surface
- Electric arc
Fluid State

• Spray
• Pool
• Soaked substrate
• Fluid Flow
Condition

• Simulated accident
  – Explicitly
  – Implicitly
Fire-Resistance Evaluation

- Common methods
  - Ignition of a pressurized fluid spray (spray flammability test)
  - Ignition of a fluid when sprayed on a hot metal surface (hot surface ignition test)
  - Ignition of a fluid that has impregnated porous or wick type materials (fluid evaporation test)
Fire-Resistance Evaluation

• Spray Flammability Tests
  – Factory Mutual
  – Buxton East of Stabilization
  – British Coal Board
  – MSHA
  – Naval Research
  – Afnor
  – NBS/CFR

• Hot Surface Ignition Test
  – Factory Mutual Hot-Channel Ignition Test

• Fluid Evaporation Test
  – CETOP RP 66H
## Fire-Resistance Testing Standards

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<td>Mine Safety &amp; Health Admin CFR 35</td>
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<td>Effect of Evaporation CETOP RP 64H</td>
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</tr>
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</table>

Source: ExxonMobil

Lubricants & Specialties
Regulatory Bodies

• United States
  – Factory Mutual Research Corporation (FMRC, Factory Mutual Standard 6930)
  – Mine Safety & Health Administration (MSHA)

• Europe
  – International Organization for Standardization (ISO 12922)
  – 7th Luxembourg Committee
  – VDMA - German Power Transmission Engineering Association

• General
  – Insurance Companies
Regulatory Bodies by World Region

- Africa
  - Luxembourg Report/FMRC
- Asia (Australia)
  - Luxembourg Report/FMRC
- Asia (India)
  - FMRC/Luxembourg Report
- Asia (Japan)
  - Neither
- Europe
  - Luxembourg Report
- NAFTA
  - FMRC
Factory Mutual Research Corporation

- Factory Mutual (New) Standard 6930
  - Issued January 2002
  - Effective Date July 1, 2003
- Fluids are tested and classified in three groups
  - Based on spray flammability parameter (old) – all were passes
    - Group 0 – nonflammable
    - Group 1 – unable to stabilize a spray flame
    - Group 2 – less flammable than mineral oils, but may stabilize a spray flame under certain conditions
  - Based on spray flammability parameter (proposed)
    - Factory Mutual Approved Fluids
      - Group 0 – nonflammable
Factory Mutual Research Corporation

- Spray Flammability Parameter (SFP) Basis
  - FM Chemical Heat Release Rate ($Q_{ch}$) Test
  - FM Critical Heat Flux for Ignition ($q_{cr}$) Test
  - Density ($p_r$) of the fluid
  - Fluid mass flow rate ($m_i$) during the chemical heat release rate measurement
  - $SFP = 11.02 \times 10^6 \times \frac{Q_{ch}}{(p_r q_{cr} m_i)}$

- Factory Mutual Approval Requirements
  - In-house facilities and procedures audit
  - Inspection of facility QC program
  - Witnessing the production of fluid test samples
  - Examination and tests on the witnessed samples to determine flammability
  - Annual unannounced follow-up facilities and procedures audits
Factory Mutual Research Corporation

- **Group 0**
  - HFAE – oil-in-water
  - HFAS - HWCFs
- **Group 1**
  - HFAB – water-in-oil (invert) emulsion)
  - HFAC – water-glycol
- **Groups 1 and 2**
  - HFDR – phosphate ester
  - HFDU – polyol ester, polyalkylene glycol
Mine Safety & Health Administration (MSHA)

- Evaluation program in place for many years for fluids that are used underground, primarily in coal mines
- MSHA testing is similar to FMRC: spray mist of candidate fluid is generated
- Ignition method somewhat different than FMRC
- Spray mist is directed continuously at a variety of ignition sources
  - Open gas flame
  - Welding arc
  - Burning rags
- To pass
  - Localized burning in the spray mist must extinguish within 5 seconds
  - There can be no sustained propagation along the spray axis
- Also have
  - Autoignition test
  - Wick test to assess the rate of evaporation of water from candidate product
Mine Safety & Health Administration (MSHA)

- MSHA tests have a relatively high rate of product rejections

- MSHA has a comprehensive manufacturer auditing program
  - Monitor and evaluate quality assurance programs through on-site inspections
  - Retest approved fluids
7th Luxembourg Committee

- European Commission – Safety and Health Commission for the Mining and Other Extractive Industries
- Methods of Testing Fire-Resistance
  - One pressurized spray test (AMS 3150C or ISO 15029-1), and
  - Spray test in accordance with the “stabilized flame heat release” method Luxembourg Report 3.1.3, and
  - Test for persistence of flame on a wick (CETOP RP 66H) or Determination of Flame Propagation in a Fluid Coal Dust Mixture test method Luxembourg Report 3.2.2
# Fluid Performance in Different Spray Tests

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<th>Test</th>
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<th>HFB</th>
<th>HFC</th>
<th>HFDR</th>
<th>HFDU</th>
<th>Mineral Oil</th>
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<tr>
<td><strong>Section 3.1.1</strong></td>
<td>Pass</td>
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<td><strong>Section 3.1.3</strong></td>
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<td>Class B-C</td>
<td>Class D-E</td>
<td>Class G-H</td>
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Note: Classification by ISO 6743/4, ISO/CD 12922, ISO/CD 15380-E
References

- Approval Standard for Flammability Classification of Industrial Fluids, Class Number 6930, January 2002, FM Global Technologies LLC
- Fire-resistant hydraulic fluids – Classification and specification – Guideline on selection for the protection of safety, health and the environment, prCEN/TR 14489, European Committee For Standardization, 2005
- Fire Resistant Hydraulic Fluids: Shifting Definitions and Standards, NCFP 105-8.3, Michael D. Zink, Quaker Chemical Corporation
- Property and Performance Requirements of General Industrial Fire-Resistant Hydraulic Fluids from a Global Perspective, May 18, 2004, J. V. Sherman, BASF Corporation
- Quaker Chemical Quintolubric 888 Series Product Brochure