(54) Title: PROTECTIVE HOSE ASSEMBLY HAVING FIRE RESISTANCE CAPABILITIES FOR FLUID DELIVERY SYSTEMS AND APPLICATIONS

(57) Abstract: A fire resistant hose assembly having fire resistance capabilities for low flow, high temperature fluid applications, such as for fluid delivery systems and applications. The fire resistant hose assembly meets fire test requirements for no- or low-flow applications without the need of an external covering. The fire resistant hose assembly generally comprises a length of composite hose comprising a flexible bulk hose material, a silicon fire sleeve extruded or otherwise molded over the flexible bulk hose material, and a slip-on fire sleeve covering at least a portion of the silicon sleeve. The fire resistant hose assembly further comprises a removable or retractable fire protective boot adjacent to an end of the composite hose and covering a nut or other metallic connecting member coupled to the end of the composite hose, thereby providing further fire resistance capabilities.

![Fig. 1](image-url)
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PROTECTIVE HOSE ASSEMBLY HAVING FIRE RESISTANCE CAPABILITIES FOR
FLUID DELIVERY SYSTEMS AND APPLICATIONS

RELATED APPLICATIONS

The present application claims the benefit of U.S. Provisional Application No. 61/858,599 filed July 25, 2013, U.S. Provisional Application No. 61/859,170 filed July 26, 2013, and U.S. Provisional Application No. 61/975,306 filed April 4, 2014, each of which is incorporated herein in its entirety by reference.

TECHNICAL FIELD

The invention relates generally to hose assemblies, and more particularly to flexible hose assemblies for fluid lines including, but not limited to, fuel lines, hydraulic lines, and/or fueldraulic lines, the hose assemblies having fire resistance capabilities.

BACKGROUND OF THE INVENTION

There are a number of applications in which combustible or flammable fluids are delivered or communicated throughout a system or assembly via a network of fluid lines or hoses. In certain applications, such as with gas combustion engines, high temperature environments are sometimes encountered such that a fluid delivery assembly and fluid lines or hoses must pass certification fire test requirements to prevent or reduce the risk of igniting the combustible fluid, and ultimately to protect the fluid source, such as a fueling station. Such fluids can include, but are not limited to, fuels, hydraulics, and/or fueldraulics.

In particular to engines, gas turbine engines generally include, in series, a fan through which ambient air is propelled, a compressor section for pressurizing the air, and a combustion section in which the compressed air is mixed with fuel atomized into a combustion chamber by a fuel injection system or fuel delivery system. The mixture is ignited for generating hot combustion gases before passing through a turbine section for extracting energy from the combustion gases. Such gas turbine engines are found in passenger and industrial vehicles, aviation vehicles such as jet planes, and auxiliary power units, for example.

Gas turbine engines incorporate a large number of tubes and hoses to connect the different parts of the engine and to delivery fuel or fluid to various parts of the engine. For example, the fuel or fluid delivery system of the combustion engine generally comprises a fuel manifold having a plurality of fuel injector nozzles, a hose or pipe assembly for fluidly
connecting the nozzles to one another, and another hose or pipe assembly for connecting the manifold to a fuel supply, such as a fuel tank. The fuel injector nozzles or spray tips atomize the fuel into the combustion section for combustion. Fuel is supplied to the manifold for distribution to the nozzles through one or more fluid inlet conduits of the manifold via a first hose assembly, and the one or more conduit(s) of the manifold are connected to the fuel supply via a second hose assembly.

Due to the high temperature environment of the combustion chamber, the fluid delivery assembly, including the manifold and any fuel line or hose assembly incorporated into the engine, must pass certification fire test requirements to prevent or reduce the risk of igniting the fuel, and the fuel source. Specifically in the case of no- or low flow, high temperature fluid delivery systems, all connection joints and fuel lines in the fuel delivery assembly, including spray nozzle connections, fuel inlet connections, fuel supply connections, and the like, must pass certification fire test requirements for commercial viability.

Currently, methods used to meet the fire test requirement are difficult, inefficient and time consuming, heavy, and/or expensive. For example, currently employed methods do not lend to visual inspection and maintenance of various components of the engine or other fluid delivery system, requiring time-consuming and costly disassembly of the engine or system to access a particular part or section for inspection or repair.

Rigid fuel or fluid line assemblies, such as metal tubes, offer fire resistance capabilities for fluid delivery systems that meet fire test requirements without the need for an external covering to maintain. However, the rigid nature of the tubing creates unwanted or undesirable added weight to the assembly or engine. Furthermore, rigid fluid lines are often difficult or time-consuming to install and maintain because the line is not easily moved or re-positioned, compared to flexible tubing. Also, rigid fluid lines create difficulties in accessing other areas of the engine, such as parts or sections located behind the rigid fluid line, thereby requiring disassembly of the fluid line to access the part or section. Rigid fluid lines also do not significantly absorb the vibrations and heat of the engine, such that wear and tear can be more rapid than with flexible fluid lines. For example, rigid fluid lines are connected to other lines or parts via a braze joint. Excessive heat and/or vibration of the engine can cause the braze or weld to fatigue and crack, resulting in a fluid line leak.

There remains a need for a flexible fluid line hose assembly that meets certification fire testing for localized fire events without the need for an external covering.
SUMMARY OF THE INVENTION

Embodiments of the invention are directed to a flexible, fire resistant hose assembly that solves many of the inherent deficiencies of existing fluid delivery lines and systems described above. The flexible, fire resistant hose assembly includes fire resistance capabilities for fluid delivery systems and fluid lines, such as, but not limited to fuel lines, hydraulic lines, and/or fueldraulic lines, for use with flammable or inflammable fluids or fuels to minimize the occurrence of localized fire events. The hose assemblies according to embodiments of the invention can be incorporated anywhere in which a fuel or fluid line is necessary, i.e. anywhere fluid is communicated from one location to another, such as in an engine compartment, hydraulic systems such as airframes, or any of an unlimited variety of applications. In certain embodiments, the hose assemblies are suitable for low flow, high temperature fuel applications, such as for fuel or fluid manifold applications. In embodiments, the flexible fire resistant hose assembly meets fire test requirements for no- or low-flow applications without the need of an external covering.

The flexible nature of the hose assemblies allows for ease of installation, repositioning, and movement for access to otherwise covered areas. This flexible nature also allows for repetitive removal of the hose assembly members without compromising the fire resistance capabilities. That is, the hose assemblies are easily disassembled or opened for inspection, maintenance, or the like, and reinstalled or repositioned back to their original position and integrity. Furthermore, the flexible fire hose assemblies are lighter than many of the rigid assemblies, resulting in lower overall weight of the system into which they are incorporated. The flexibility of the hose assembly also aids in absorbing vibrations of the system, such as an engine, to reduce the occurrence of fatigue or cracks in connections.

According to embodiments, the fire resistant hose assembly generally comprises a length of composite hose comprising a flexible bulk hose material, a silicon fire sleeve extruded or otherwise molded over the flexible bulk hose material, and a slip-on fire sleeve covering at least a portion of the silicon sleeve. The flexible bulk hose material can comprise, for example, polytetrafluoroethylene (PFTE), such as commercially available TEFLON by DuPont Co., and meets Aerospace Standard (AS) 1946 (Rev. D), incorporated herein by reference in its entirety, and discussed in more detail below. The slip-on fire sleeve can comprise, for example, a standard fire sleeve meeting AS1072 (Rev. E), incorporated herein by reference in its entirety, and discussed in more detail below, and is generally formed from a woven or braided fiberglass
material having a silicon or silicon rubber layer covering and at least partially penetrating the woven fiberglass material.

In one embodiment, the bulk hose material includes a collar covering and extending from at least one end of the bulk hose. The collar can be metal, metal alloy, and/or composite material. The collar can optionally be threaded on an interior and/or exterior thereof for threaded engagement to a correspondingly threaded connecting member. The silicon fire sleeve covering the length of the bulk hose material is then "stepped-up" to a larger diameter to cover the collar, thereby creating a cuff at the end of the composite hose. The slip-on fire sleeve is placed over both the non-stepped-up region as well as the cuff.

The flexible fire resistant hose assembly further comprises a removable or retractable fire protective boot adjacent to or near an end of the composite hose for removably covering at least a portion of a nut, gage pin assembly, or other metallic connecting member adjacent to and operably coupled to an end of the composite hose, thereby providing further fire resistance capabilities to the assembly. Without such protection, in the presence of heat or a flame, the metallic connecting member can rapidly conduct heat directly to the bulk hose material, which can then degrade, causing failure of the hose assembly.

In one non-limiting embodiment, the boot can comprise a cylinder having a length or annular wall of a multi-ply silicon impregnated fiberglass mesh material. A linear separation or slit is formed along a length or the longitudinal axis of the cylinder so that the boot is removable and can be repositioned with overlap adjacent to or near the end of the composite hose and over a metallic connecting member, such as a nut, for easy access to the nut and/or other protected part covered by the boot. The overlap provides 360 degrees or more of protection over the nut independent of where the separation or slit is. In another embodiment, the boot has an un-bonded overlapping opening running along the length or a longitudinal axis of the boot. In yet another embodiment, the boot has one or more interlocking notches and a living hinge running along the length or a longitudinal axis of the boot configured to provide 360 degrees or more of protection over the nut.

The boot is secured adjacent to the end of the composite hose and over the connecting member or nut via mechanical means, such as a releasable, separable, or reusable clamp, such as, for example, an aerospace grade hose clamp. The removable boot provides the ability for readily available visible access to the nut or other protected part for visual inspection or other maintenance without the need for complete disassembly of the fluid delivery system or other component in which the hoses are utilized.
According to embodiments, the fire resistant hose assemblies of the invention are particularly suited for any of a variety of fluid delivery systems in which a fuel or fluid is communicated into, out of, and/or throughout. For example, the hose assemblies of the invention can be used for, but not limited to, fuel lines (such as in gas turbine or gas combustion engines), hydraulic lines, or fueldraulic lines in which energy drawn from the fuel pressure is used to control motion via actuators, instead of a separate hydraulic line, resulting in weight savings. The fluid communicated through the hose assemblies of the current invention can be flammable such that the fire resistance capabilities are critical; alternatively inflammable fluids can be used.

In one non-limiting example, the hose assemblies can be used throughout a fuel manifold for low flow, high temperature delivery systems. The fuel manifold can include a plurality of spray nozzle assemblies joined and in fluid communication with each other via a hose assembly, and/or a fuel inlet for supplying fuel to the manifold.

Particular to the manifold embodiment, the spray nozzle assembly comprises a rigid hollow section, such as a metal pipe having a first end and a second end in fluid communication with each other, and separated by the rigid hollow section, and a third end extending generally perpendicular from the rigid hollow section and in fluid communication with both the first and second ends, similar in shape to a T-section pipe. A spray nozzle is connected to the third end via a nut, for example, such as by threaded engagement of the nut on the third end, and the spray nozzle to the nut. Each end can further comprise a ferrule-type portion for crimping engagement with the collar of the hose assembly.

Upon assembly of the manifold, the first or second end of the spray nozzle assembly is placed within an interior of the composite hose assembly. The portion of the collar extending from the end of the bulk hose material is then crimped to the metallic end portion of the spray nozzle assembly creating metal to metal contact. The silicon cuff of the fire sleeve layer thereby covers the crimp, providing fire protection thereto. A fire protective boot with overlap is then placed over the nut or other connection joint such that it is adjacent to or near the composite hose (with silicon fire sleeve and slip-on fire sleeve), thereby creating a fire resistant hose assembly. Each spray nozzle assembly is connected to another spray nozzle assembly via the hose assembly described above, in which a boot is coupled to the nut adjacent each end of the hose assembly.
The above summary of the invention is not intended to describe each illustrated embodiment or every implementation of the present invention. The figures and the detailed description that follow more particularly exemplify these embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

The embodiments of the present invention may be more completely understood in consideration of the following detailed description of various embodiments in connection with the accompanying drawings, in which:

Figure 1 depicts a top partial view of a bulk hose material with silicon fire sleeve according to an embodiment of the invention.

Figure 2 depicts a top partial view of the bulk hose material with silicon fire sleeve of Figure 1 with the addition of a slip-on fire sleeve according to an embodiment of the invention.

Figure 3 depicts a fire protective boot according to an embodiment of the invention.

Figure 4 depicts an end view of a fire protective boot according to an alternative embodiment of the invention.

Figure 5 depicts a partially cut away view of a fire resistant hose assembly with a boot adjacent to a first end, and no boot on a second end.

Figure 6A depicts an end view of a fire protective boot according to an alternative embodiment of the invention in a closed position.

Figure 6B depicts a top view of fire protective boot shown in Figure 6A in an open position.

Figure 6C depicts an end view of fire protective boot shown in Figure 6A in an open position.

Figure 7A depicts an end view of a curved fire protective boot according to an alternative embodiment of the invention in a closed position.

Figure 7B depicts a top view of fire protective boot shown in Figure 7A in an open position.

Figure 7C depicts an end view of fire protective boot shown in Figure 7A in an open position.

While the present invention is amenable to various modifications and alternative forms, specifics thereof have been shown by way of example in the drawings and will be described in detail. It should be understood, however, that the intention is not to limit the present invention to the particular embodiments described. On the contrary, the intention is to cover all
modifications, equivalents, and alternatives falling within the spirit and scope of the present invention.

DETAILED DESCRIPTION OF THE DRAWINGS

Referring to Figure 5, a flexible, fire resistant hose assembly 100 comprises a composite hose 102 having multiple layers of fire protective material and a fire protective boot 116 for protecting or shielding connecting members, such as metallic nut, adjacent to hose 102 from flame and excessive heat that can otherwise rapidly conduct heat to non-fire protected interior portions of composite hose 102. Composite hose 102 generally comprises a standard flexible bulk hose material layer or inner core 104, a silicon fire sleeve 106 extruded or otherwise molded over the flexible bulk hose material 102, and a slip-on fire sleeve 108 covering silicon fire sleeve 106.

Referring to Figure 1, flexible bulk hose material layer or inner core 104 can comprise a tubular sidewall formed from, for example, a polytetrafluoroethylene (PTFE) material, such as commercially available TEFLOX by DuPont Co. In one particular embodiment, flexible inner core 104 can comprise an extruded smoothbore or corrugated PTFE tube, providing excellent chemical resistance and is optionally conductive. Inner core 104 can optionally include one or more reinforcing layers 104a, such as, for example, a braided layer, such as a corrosion resistant stainless steel (CRES) wire braid, a flame resistant meta-aramid fiber braid such as commercially available NOMEX by DuPont Co., a para-aramid fiber braid such as commercially available KEVLAR by DuPont Co., fiberglass wire braid, or combinations thereof.

In an embodiment, flexible bulk hose inner core 104 preferably meets current Aerospace Standard (AS) 1946 standards for size, weight, and performance requirements for hose assemblies, for example. This standard covers the requirements for PTFE hose assemblies for use in aerospace hydraulic, fuel, and lubricating oil systems at temperatures between -65°F and 450°F for corrosion resistant stainless steel (CRES), nickel alloy, or titanium combination fittings or assemblies (Class I), and -65°F and 275°F for aluminum or combination aluminum alloy and corrosion resistant steel fittings or assemblies (Class II), at nominal pressures of up to 1500 psi. The hose assemblies may also be suitable for use within the same temperature and pressure limitations in aerospace pneumatic systems where some gaseous diffusion through the wall of the PTFE inner core can be tolerated. The fittings can be classified as permanently attached fittings (Type A) or field attachable (re-usable) fittings (Type B).

Bulk hose material inner core 104 can comprise any of a variety of lengths and diameters, according to the desired end-use application. For example, hose material layer 104 can comprise
0.1875" inner diameter for use in low to no-flow applications. However, any of a variety of hose diameters and lengths can be contemplated based on the end-use application. For example, a total inner core 104 can have an inner diameter ranging from about 0.1 to about 2.0 inches, and an outer diameter ranging from about 0.2 to about 2.5 inches. The hose assembly 100 can have a room temperature burst pressure ranging from about 800 psi to about 21,000 psi, and a high temperature burst pressure ranging from about 600 psi to about 16,000 psi.

Each end of bulk hose material inner core 104 includes an attachment collar or fitting 105 covering at least a portion of the end of bulk hose material layer 104. Collar 105 can comprise, for example, metal, metal alloys, and/or composites, such as, for example, corrosion resistant stainless steel (CRES), aluminum, carbon steel, titanium, or copper nickel. Collar 105 includes an extending portion 107 extending beyond the end of bulk hose material layer 104, as shown in Figure 5. Collar 105 is adapted to be crimped or otherwise engaged with a ferrule-type or metal insert portion 120b of adjacent metallic connecting member 120. Connecting member 120 can comprise a nut, for example, or a portion of a spray nozzle assembly when used in a fluid or fuel manifold application for connecting spray nozzles. In one embodiment not shown, collar 105 is threaded, for engaging external connecting members, such as an adjacent nut or spray nozzle assembly.

Referring back to Figure 1, integral silicon fire sleeve 106 covers substantially the length of the bulk hose material 102. Silicon fire sleeve 106 further comprises a first diameter 110a along a substantially length of bulk hose material 102, and a second, larger diameter 110b or cuff 112 at an end of bulk hose material 102 to accommodate a collar 105. The transition from first diameter 110a to second diameter 110b can be continuous or tapered, or can be a discrete, "step-up" to cuff 112, thereby creating shoulder 114.

Referring to Figure 2, slip-on, or slip-in fire sleeve 108 covers all or substantially most of silicon fire sleeve 106, including cuff 112. Slip-on fire sleeve 108 can comprise, for example, a standard fire sleeve meeting AS1072, incorporated herein by reference, for 5-15 minutes duration and is generally formed of a woven or braided fiberglass material having a silicon layer covering and at least partially penetrating the woven fiberglass material.

In alternative embodiments (not shown), integral fire sleeve 106 or slip-on fire sleeve 108 is optional, such that both are not present.

Referring to Figures 3-5, a fire resistant hose assembly 100 comprises fire protective boot 116. Boot 116 is cylindrical in shape having a length along a longitudinal axis, and a
substantially circular cross-section, such that it easily fits over connecting members, such as a metallic nut or collar, adjacent to or near an end of composite hose 102.

In one embodiment, and referring to Figure 3, boot 116 can comprise a single or multiply, split configuration. More specifically, boot 116 comprises one or more plies of a fire protective material, such as a silicon-impregnated fiberglass material. A liner separation 125, such as a slit, is formed in along the entire length of sidewall 116a of boot 116. Slit or split 125 can be opened or peeled open and positioned adjacent to or near an end of composite hose 102 and completely over the metallic connecting member. Split 125 is then closed in overlapping fashion as shown to create 360 degrees of protection around the metallic connecting member that it covers, independent of the location of split 125. Boot 116 is further secured via a re-closable, re-sealable, or reusable clamp 122 (shown in Figure 5), such as an aerospace grade hose clamp. The combination of overlapping split 125 with re-closable or re-sealable clamp 122 allows for repetitive repositioning and/or removal of boot 116 adjacent to or near an end of access hose 102 and over the metallic connecting member without compromising the fire resistance capabilities. That is, boot 116 can be removed and replaced back to its original, fire resistant configuration repeated times, without compromising the fire resistance properties.

In an alternative embodiment, and referring to Figure 4, boot 116 can comprise a multiply configuration having an un-bonded overlapping region that defines a re-sealable opening to the interior space of boot 116. More specifically, boot 116 comprises at least four plies of a fire protective material, such as a silicon-impregnated fiberglass material. A first region 117 of the sidewall of boot 116 is made up of four plies 118a-118d bonded together. A second region 119 of the sidewall includes only the two most internal plies 118a and 118b. A third region 121 of the sidewall includes only the two most external plies 118c and 118d. A fourth region 123 includes most external ply 118d unbounded to and overlapping the two most internal plies 118a and 118b. Upon application to composite hose 102 and/or a metallic connecting member, external ply 118d is peeled away from internal plies 118a and 118b in fourth region 123, and then internal plies 118a and 118b are also pulled away, creating an opening so that boot 116 can be positioned adjacent to or near an end of composite hose 102 and entirely surrounding or covering the metallic connecting member. Once positioned on the connecting members, the internal plies 118a and 118b are returned to their original position, and then external ply 118d is placed over the internal plies 118a and 118b to form a continuous covering by boot 116.

In another embodiment, and referring to Figures 6A-C and 7A-C, boot 116 can comprise one or more plies of a fire protective material, such as a silicon-impregnated fiberglass material
or a molded silicon rubber material, having one or more interlocking notches 128, 130 and a
living hinge 132. More specifically, boot 116 can comprise a first portion 134 and a second
portion 136 hingedly coupled to one another by a living hinge 132, which can be a flexible
portion of the same material. In some embodiments, first portion 134, second portion 136, and
living hinge 132 can be formed of as a single unit of continuous fire protective material, with no
seam between the first portion 134, second portion 136, and living hinge 132. The portions of
interlocking notches 128, 130 of respective first portion 134 and second portion 136 can be
keyed to fit together in an interlocking manner when the first portion 134 and second portion 136
are brought together. In this manner, boot 116 creates 360 degrees of protection around the
metallic connecting member that it covers, independent of the location of split 125. In one
embodiment, and referring to Figures 7A-7C, boot 116 can be curved, so as to be formed to
contain a curved portion 140 along the conduit of boot 116.

Referring to Figure 5, boot 116 is secured adjacent to an end of composite hose 102, in
the location of the, crimp, nut or other connecting member 120 via re-closable or re-sealable
clamp 122, such as an aerospace grade hose clamp, as described above with respect to Figure 3.

Boot 116 provides flame and heat shielding to the metallic connecting parts adjacent to or
operably coupled to an interior of the composite hose. Without such protection, if the spray
nozzle, metal nut, or other connecting member is in the presence of extreme heat and/or flame,
heat is quickly conducted via the metal nut to the metal insert and collar, and to the PTFE
interior layer of the composite hose. This is of particular importance because PTFE degrades at
a temperature of about 450°F, which is often lower than the flame temperature in flammable
fluid applications such that, if the nut is not protected, the extreme heat can cause rapid failure of
the hose assembly.

By providing a composite hose with multiple layers of fire resistance, in combination
with the fire protective boot over connecting members adjacent to the ends of the hose assembly,
the hose assembly according to embodiments of the invention provides the requisite fire
resistance capabilities, and passes rigid certification fire testing, such that it can be used for fluid
delivery systems and fluid lines, such as, for example, fuel, hydraulic fluids, and/or fueldraulics,
and in particular for, but not limited to, low flow, high temperature applications, such as
manifold applications.

Various hose assemblies according to embodiments of the invention were tested using a
fire test similar to AS 1055. Descriptions of the tested hose assemblies are captured in Table 1
below:
Table 1: Assemblies tested

<table>
<thead>
<tr>
<th>Test Log #</th>
<th>Serial #</th>
<th>STS Test Part Number</th>
<th>Representative Production Part Number</th>
<th>Description</th>
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<td>T23102</td>
<td>184736-01</td>
<td>119885-015FTEST</td>
<td>119885-015</td>
<td>240 Series Size 6 Hose Assembly with Size 6 Straight NAS Fittings on both ends and covered with Molded Silicone Fire Sleeve and a AS1072 End Cuff.</td>
</tr>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T23104</td>
<td>184736-03</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T23099</td>
<td>184695-01</td>
<td>119885-017FTEST</td>
<td>119885-017</td>
<td>240 Series Size 6 Hose Assembly with Size 4 Straight NAS Fittings on both ends and covered with Molded Silicone Fire Sleeve and a AS1072 End Cuff.</td>
</tr>
<tr>
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<td>184695-02</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T23101</td>
<td>184695-03</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T23108</td>
<td>184737-01</td>
<td>119885-021FTEST</td>
<td>119885-021</td>
<td>240 Series Size 12 Extruded Silicone Fire Sleeve Hose Assembly with Molded Cuffs and Size 12 Straight NAS fittings on both ends</td>
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<td>T23109</td>
<td>184737-02</td>
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<td></td>
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<td>T23106</td>
<td>184738-02</td>
<td>119885-023FTEST</td>
<td>119885-023</td>
<td>240 Series Size 10 Extruded Silicone Fire Sleeve Hose Assembly with Molded Cuffs and Size 10 Straight NAS fittings on both ends. This Assembly also has a AS1072 Slip in fire sleeve covering from Collar to Collar.</td>
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<tr>
<td>T23107</td>
<td>184738-03</td>
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For testing, the fluid or oil utilized was Mobil DTE 26 Hydraulic Oil with a specified viscosity rating of SAE No. 20. Table 2 below summarizes the test results.

Table 2: Test results

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<tr>
<th>Test Log #</th>
<th>Serial Number</th>
<th>Part Numbers</th>
<th>Thermo Cycle</th>
<th>Flame Intensity</th>
<th>OIL Temp (°F)</th>
<th>Flame Temp and Intensity</th>
<th>Test Results</th>
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<td>0.002</td>
<td>4.00</td>
<td>50</td>
<td>4.06</td>
</tr>
</tbody>
</table>

The fire tests were all correctly set-up and successfully tested with no leakage detected from 5 feet away within the 5 minute minimum test duration.
The test set-up and details are as follows:

1. Burner Location - The burner location was set at a distance to the vertical and horizontal positions as specified and with Flame Temperature and Intensity readings taken for each individual test.

   • Vertical Position - The Burner Barrel Extension is positioned nominally Centerline to Test Assembly and Calibration tube.

   • Horizontal Position - The Burner Barrel Extension is positioned .500" +/- .500" from the Burner Barrel Extension edge to the end of the fitting. It was also set 4.0" +/- .125: from the end of the Burner Barrel Extension to the Test Hose Assemblies and Calibration Tube.

2. Flame Temperature and Size

   • Thermocouples - The flame temperature was measured from an array of 8 thermocouples spread equally over 7" minimum set at 4" +/- .125" from the burner barrel face and a vertical centerline +/- .125 to both the Hose Assemblies and calibration tube.

   • Flame Temperature - Temperature readings were taken at the pre-test calibration and post test completion, with each individual thermocouple reading 2000°F +/- 150°F with an overall average of 2000°F minimum.

3. Flame Intensity

   • Flame BTU Measurement - The heat content was measured on a 15" long, ½" X .032 refrigerator type copper tube with a reported setting of 1.0gpm to 1.02 gpm flow of water at an incoming temperature of a reported 65.6°F. The temperature difference of incoming water to out going water was measured and calculated within the machine controls to achieve 4500 BTU minimum.

   • Air Velocity - Air ducting fpm was reported at 393 fpm over both the hose assembly and calibration tube as mounted in the 25" X 25" hood equipped with downstream exhaust fans.

   • Air Temperature - The Air Temperature was measured and monitored during the entire calibration sequence and test, the air temperature was reported to be between 40°F to 100°F.

4. The test conditions were as follows:

   • Test Assembly - The hose assembly was mounted horizontally with a 90° bend and within a 25" X 25" hood.
• Vibration - Vibration was introduced longitudinally with a fixed dimension amplitude of .062" min both sides of neutral. The Frequency was held continuously at 2000 CPM +/- 40 throughout the entire test cycle.

• Oil Temperature - The hose assembly was fully filled and flowed with heated SAE No 20 oil at 200°F to 230°F at the start of the test.

Note: The Oil Utilized was a Mobil DTE 26 Hydraulic Oil with a specified viscosity rating of SAE No. 20.

• Oil Flow - Oil Flow was stopped with specified pressure maintained prior to introducing Flame to the Test Article.

• Oil Pressure - The oil pressure was set and maintained throughout the test to the stated working pressure of 3050psi +/-50psi for the 119883-017FTEST and 120psi +/--50psi for all other test assemblies.

A hose assembly according to the invention including a boot covering a nut adjacent to the end of the hose was tested in 3 flame tests. The test set-up was as follows:

The samples were pressurized with SAE 20W oil at 835 PSI +/- 100 PSI, with a minimum pressure of 825 PSI, and a maximum pressure of 840 PSI. The oil temperature was 200°F, with a minimum temperature of 200°F and a maximum of 230°F. The flow rate was set at 0.003 GPM +/- 3% (min = 0.002 GPM; max = 0.003 GPM). The flame temperature was 2000°F +/- 150°F.

The thermocouple and burner barrel set up was as follows:

Test #1 Set-up:

• Thermocouples set to 6.00' ± .125 along horizontal plane
  o Actual: 6.00

• Thermocouples set to centerline in a vertical plane ± .125
  o Actual: -0.025

• Thermocouples set to 4.00" ± .125 from end of Burner Barrel Extension
  o Actual: 4.00

• Burner Barrel Extension edge 0.500 ± .100 from mounting fitting at vibration end. This assures fitting is within flame.
  o Actual: 0.500

• Burner Barrel Extension face set to 4.00" ± .125 to edge of hose and calibration tube.
  o Calibration Tube Actual: 4.00
Hose Actual: 4.00

- Vibration Frequency 2000 cpm ± 40 cpm
  - Actual: 2000
- Vibration longitudinal amplitude measured to 0.062 either side of neutral.
  - Left actual: 0.062
  - Right actual: 0.063

- Air velocity set to 380 to 400 ft/min at calibration tube and hose.
  - Calibration Tube Actual: 383
  - Hose Actual: 393

- Oil temperature set to 200 to 230°F at start of test.
  - Actual: 200°F

- Calibration Tube Water Injet Water Temperature (50 to 70°F)
  - Actual: 62°F

- Calibration Tube Water Flow (Approximately 1 gpm):
  - Actual: 1.00

**Test #2 Set-up:**

- Thermocouples set to 6.00' ± .125 along horizontal plane
  - Actual: 6.00

- Thermocouples set to centerline in a vertical plane ± .125
  - Actual: ±0.025
- Thermocouples set to 4.00" ± .125 from end of Burner Barrel Extension
  - Actual: 4.00

- Burner Barrel Extension edge 0.500 ± .100 from mounting fitting at vibration end. This assures fitting is within flame.
  - Actual: 0.500

- Burner Barrel Extension face set to 4.00" ± .125 to edge of hose and calibration tube.
  - Calibration Tube Actual: 4.00
  - Hose Actual: 4.00

- Vibration Frequency 2000 cpm ± 40 cpm
  - Actual: 2000

- Vibration longitudinal amplitude measured to 0.062 either side of neutral.
• Air velocity set to 380 to 400 ft/min at calibration tube and hose.
  o Calibration Tube Actual: 383
  o Hose Actual: 393
• Oil temperature set to 200 to 230°F at start of test.
  o Actual: 200°F
• Calibration Tube Water Injet Water Temperature (50 to 70°F)
  o Actual: 62°F
  o Calibration Tube Water Flow (Approximately 1 gpm):
    o Actual: 1.00

Test #3 Set-up:
• Thermocouples set to 6.00' ± .125 along horizontal plane
  o Actual: 6.00
• Thermocouples set to centerline in a vertical plane ± .125
  o Actual: -0.025
• Thermocouples set to 4.00" ± .125 from end of Burner Barrel Extension
  o Actual: 4.00
• Burner Barrel Extension edge 0.500 ± .100 from mounting fitting at vibration end. This assures fitting is within flame.
  o Actual: 0.500
• Burner Barrel Extension face set to 4.00" ± .125 to edge of hose and calibration tube.
  o Calibration Tube Actual: 4.00
  o Hose Actual: 4.00
• Vibration Frequency 2000 cpm ± 40 cpm
  o Actual: 2000
• Vibration longitudinal amplitude measured to 0.062 either side of neutral.
  o Left actual: 0.062
  o Right actual: 0.063
• Air velocity set to 380 to 400 ft/min at calibration tube and hose.
  o Calibration Tube Actual: 383
  o Hose Actual: 393
• Oil temperature set to 200 to 230°F at start of test.
  - Actual: 200°F
• Calibration Tube Water Injet Water Temperature (50 to 70°F)
  - Actual: 62°F
• Calibration Tube Water Flow (Approximately 1 gpm):
  - Actual: 1.00

The flame calibration was as follows:

Test #1:
• Flame Calibration temperature (2000°F Minimum).
  - Actual Average: 2012°F
• Post Test Flame Temperature (2000°F Average).
  - Actual after 2 Minutes: 2012°F

Test #2:
• Flame Calibration temperature (2000°F Minimum).
  - Actual Average: 2009°F
• Post Test Flame Temperature (2000°F Average).
  - Actual after 2 Minutes: 2009°F

Test #3:
• Flame Calibration temperature (2000°F Minimum).
  - Actual Average: 2008°F
• Post Test Flame Temperature (2000°F Average).
  - Actual after 2 Minutes: 2008°F
The flame intensity or BTU content (after initial warm up period of 2 minutes) was as follows (4500 Btu/h minimum):

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<th>BTU Test 3</th>
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<td>3685</td>
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<td>3861</td>
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<tr>
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<td>7192</td>
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<td>6945</td>
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<tr>
<td>4 min</td>
<td>6620</td>
<td>6340</td>
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<td>4 min 30 sec</td>
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<td>6440</td>
</tr>
<tr>
<td>5 min</td>
<td>6258</td>
<td>5964</td>
<td>6267</td>
</tr>
<tr>
<td>Average BTU</td>
<td>6316</td>
<td>6016</td>
<td>6391</td>
</tr>
</tbody>
</table>

Each hose assembly did not fail (i.e. no leakage or burst) after at least 5 minutes, and exposure to a flame intensity of at least 4500 BTU/hour, and average flame temperature of 2000°F minimum indicating passing fire test compliance, at high pressure (825 PSIG) and low fluid flow rate (0-0.003 gallons per minute (GPM)).

Standards

As discussed above, the flexible bulk hose material can comprise, for example, polytetrafluoroethylene (PFTE), and meets Aerospace Standard (AS) 1946 (Rev. D). This standard classifies hose assemblies: Class I: All corrosion resistant steel, or nickel alloy or titanium combination fittings, 450 °F; and Class II: Combination aluminum alloy and corrosion resistant steel fittings, 275 °F, size -08 and larger. They are further typed as: Type A: Permanently attached fittings; and Type B: Field attachable (re-usable) fittings, size -04 and larger.

Per the standard, metals used in the hose shall be corrosion-resistant steel, and fittings shall be aluminum alloy, corrosion-resistant steel, titanium, or nickel alloy suitably treated to resist corrosion when in storage or during normal service use. For bars and forgings, this includes corrosion resistant steel, austenitic, annealed or as rolled; heat stabilized corrosion resistant steel, austenitic, annealed or as rolled; precipitation hardening corrosion resistant steel - resolution heat treated and artificially aged condition; titanium; nickel alloy; and/or aluminum alloy. For tubing, this includes aluminum alloy; corrosion resistant steel, austenitic, seamless or welded, annealed; heat stabilized corrosion resistant steel, austenitic, seamless or welded;
titanium; and/or nickel alloy. For wire, this includes corrosion resistant steel, austenitic, cold drawn.

Per the standard, the hose assembly shall include a seamless PTFE inner tube, corrosion-resistant steel-wire reinforcement, and aluminum, corrosion-resistant steel, titanium, or nickel alloy end fittings as required to meet the construction and performance requirements of the standard, and as required for its intended use. The inner tube shall be of a seamless construction of virgin PTFE resin of uniform gage. It shall have a smooth bore and shall be free from pitting or projections on the inner surface. Additives may be included in the compound from which the tube is extruded. The reinforcement shall consist of corrosion-resistant steel wires. The wires shall be so arranged over the inner tube as to provide sufficient strength to ensure conformance to the requirements specified within the standard.

Per the standard, regarding the PTFE inner tube, the specific gravity values of the hose inner tube shall not exceed 2.155 apparent and 2.210 relative when tested in accordance with AS2078. When tested in accordance with AS2078, the longitudinal tensile strength for all sizes of tubes shall be 3000 psi minimum. The transverse tensile strength for sizes -10 and larger shall be 2500 psi minimum. For sizes under -10, the transverse strength need not be tested. When tested in accordance with AS2078, the elongation shall be a minimum of 200%. The tube shall not leak, split, burst, or show any evidence of malfunction, when tested through the sequence as specified in AS2078. When tested in accordance with AS2078, the electrical current of the inner tube shall be equal to or greater than 10 µA for sizes -03 through -08, and equal to or greater than 20 µA for sizes -10 and over.

Per the standard, the hose assembly (including inner tube and braided or reinforcing layer(s)) has a minimum inner diameter requirement ranging from 0.110 inches to 1.344 inches, a minimum outer diameter requirement ranging from 0.234 inches to 1.637 inches, and a maximum outer diameter requirement ranging from 0.285 inches to 1.707 inches. The inner tube alone (unbraided) has a minimum wall thickness requirement ranging from 0.035 to 0.065 inches, and a maximum wall thickness requirement ranging from 0.047 to 0.077 inches. The number of braided or reinforcing layers can be 1-2 depending on the hose size. Per the standard, the hose weight maximum requirement ranges from 0.005 lb/in to 0.084 lb/in. The burst pressure requirement ranges from 4,000 to 12,000 psig (room temperature minimum) and 3,000-7,000 psig (high temperature minimum).

Per section 3.11.18 of the standard, hose assemblies are fitted with fire sleeves per AS1072 or an extrusion silicone fire sleeve, and are tested in accordance with AS1055,
incorporated herein by reference. The hose assemblies shall withstand the effects of the flame without leakage for the following periods as appropriate: 1. Fire resistant assemblies: 5 minutes 2. Fire proof assemblies: 15 minutes.

As discussed above, the slip-on fire sleeve can comprise, for example, a standard fire sleeve meeting AS1072 (Rev. E). Per the standard, the sleeves are either Type 1: Butyl Rubber Composite; or Type 2: Silicone Rubber Composite. For Type 1, the coating of the fiberglass firesleeve shall be butyl rubber with minimum .03 in (0.8 mm) thickness. This sleeve shall be functional after casual (nonsubmerged) exposure to following fluids in a normal aircraft environment when tested as required in AS1055: a. Phosphate ester type hydraulic fluids; b. MIL-H-5606 hydraulic fluid; c. MIL-T-5624 jet fuel; d. MIL-L-7808 lubricating oil; e. MIL-L-23699 lubricating oil; and f. MIL-H-83282 hydraulic fluid. The Type 1 sleeve shall be usable in the range of -65 °F (-54 °C) to +250 °F (+120 °C).

For Type 2, the coating of the fiberglass sleeve shall be silicone rubber with minimum .03 in (0.8 mm) thickness. This sleeve shall be functional after casual (nonsubmerged) exposure to following fluids in a normal aircraft environment when tested as required in AS1055: a. Phosphate ester type hydraulic fluids; b. MIL-H-5606 hydraulic fluid; c. MIL-T-5624 jet fuel; d. MIL-L-6082 lubricating oil; e. MIL-L-7808 lubricating oil; f. MIL-L-23699 lubricating oil; and g. MIL-H-83282 hydraulic fluid. The Type 1 sleeve shall be usable in the range of -65 °F (-54 °C) to +250 °F (+120 °C).

Per the standard, the sleeve has an inner diameter minimum requirement ranging from 0.21 inches (5.3 mm) to 4.46 inches (113.3 mm), and an outer diameter maximum ranging 0.56 inches (14.2 mm) to 4.90 inches (124.5 mm). The maximum weight per the standard ranges from 0.08 lb/ft (0.12 kg/m) to 1.32 lb/ft (1.96 kg/m).

The foregoing descriptions present numerous specific details that provide a thorough understanding of various embodiments of the invention. It will be apparent to one skilled in the art that various embodiments, having been disclosed herein, may be practiced without some or all of these specific details. In other instances, components as are known to those of ordinary skill in the art have not been described in detail herein in order to avoid unnecessarily obscuring the present invention. It is to be understood that even though numerous characteristics and advantages of various embodiments are set forth in the foregoing description, together with details of the structure and function of various embodiments, this disclosure is illustrative only.
Other embodiments may be constructed that nevertheless employ the principles and spirit of the present invention. Accordingly, this application is intended to cover any adaptations or variations of the invention.

For purposes of interpreting the claims for the present invention, it is expressly intended that the provisions of 35 U.S.C. § 112, sixth paragraph, are not to be invoked unless the specific terms "means for" or "step for" are recited in a claim.
CLAIMS

What is claimed is:

1. A protective hose assembly having fire resistance capabilities, the hose assembly comprising:

   a composite hose including -

   a flexible hose inner core having a tubular sidewall and a first end and a second end, and a collar coupled to at least one of the first and second ends and extending therefrom,

   a silicon fire sleeve covering at least a portion of the flexible hose inner core, and

   a braided fire sleeve covering at least a portion of the silicon fire sleeve; and

   a fire protective boot removably securable over a coupling or connecting member adjacent to a first end of the composite hose when the hose assembly is coupled at the first end to the coupling member.

2. The hose assembly of claim 1, wherein the tubular sidewall of the flexible hose inner core comprises polytetrafluoroethylene (PFTE).

3. The hose assembly of claim 1, wherein the flexible hose inner core includes one or more reinforcing layers positioned over the tubular sidewall.

4. The hose assembly of claim 3, wherein the one or more reinforcing layers comprise a braided layer comprising corrosion resistant stainless steel (CRES) wire braid, a flame resistant meta-aramid fiber braid, a para-aramid fiber braid, a fiberglass wire braid, or combinations thereof.

5. The hose assembly of claim 1, wherein the braided fire sleeve comprises a slip-over or slip-on silicon sleeve.

6. The hose assembly of claim 1, wherein the fire protective boot comprises a hollow elongate member having a length along a longitudinal axis, and a substantially circular cross-section.

7. The hose assembly of claim 6, wherein the elongate member is substantially linear.
8. The hose assembly of claim 6, wherein the elongate member has a least a first bend or curve such that the boot is substantially non-linear.

9. The hose assembly of claim 6, wherein the elongate member includes a slit extending substantially parallel to the longitudinal axis, wherein the elongate member is shiftable between a closed position in which the fire protective boot is removably secured over the coupling or connecting member adjacent to a first end of the composite hose, and an open position in which the fire protective boot is positionable over the coupling or connecting member.

10. The hose assembly of claim 9, wherein a first lateral edge of the elongate member overlaps a second lateral edge of the elongate member when in the closed position.

11. The hose assembly of claim 9, wherein the fire protective boot is further secured over the coupling or connecting member with a re-closeable clamp.

12. The hose assembly of claim 6, wherein the elongate member comprises one or more plies silicon-impregnated fiberglass material.

13. The hose assembly of claim 6, wherein the elongate member comprises a multi-ply configuration having an un-bonded overlapping region that defines a re-sealable opening.

14. The hose assembly of claim 13, wherein the elongate member comprises four discontinuous plies defining a sidewall of the elongate member, wherein the sidewall comprises a first circumferential region in which all four plies are bonded together, a second circumferential region which includes only two innermost plies bonded together, a third circumferential region which includes only two outermost plies bonded together, and a fourth circumferential region in which the outermost plies bonded together overlap the two innermost plies bonded together, such that the fourth region is shiftable between closed position in which the outermost layers are proximate the innermost layers such that the fire protective boot is removably secured over the coupling or connecting member adjacent to a first end of the composite hose, and an open position in which the outermost layers are distal from the innermost layers such that the fire protective boot is positionable over the coupling or connecting member.
15. The hose assembly of claim 14, wherein the fire protective boot is further secured over the coupling or connecting member with a re-closeable clamp.

16. The hose assembly of claim 6, wherein the elongate member comprises a first circumferential portion hingedly coupled to a second circumferential portion of the elongate member by a living hinge.

17. The hose assembly of claim 6, wherein the first portion terminates at a first end defining a first interlocking notch, and the second portion terminates at a second end proximate to the first end of the first portion, wherein the second end defines a second interlocking notch complementary to the first interlocking notch.

18. The hose assembly of claim 17, wherein the living hinge comprises a flexible section extending between the first and second ends.

19. The hose assembly of claim 16, wherein the first and second portions of the elongate member and the living hinge comprise one or more plies silicon-impregnated fiberglass material.

20. The hose assembly of claim 16 wherein the first and second portions comprises molded silicone rubber.

21. A protective fire boot for securing over at least a portion of a connection between a fire resistant hose assembly and a coupling or connecting member of a fluid delivery system, the protective fire boot comprising:

    a hollow elongate member having a linear or non-linear length extending along a longitudinal axis, the elongate member including a first circumferential portion hingedly coupled to a circumferential second portion, and a living hinge hingedly coupling the first and second portions.

22. The boot of claim 21, wherein the first portion terminates at a first end defining a first interlocking notch, and the second portion terminates at a second end proximate to the first end
of the first portion, wherein the second end defines a second interlocking notch complementary to the first interlocking notch.

23. The boot of claim 22, wherein the living hinge comprises a flexible section extending between the first and second ends.

24. The boot of claim 21, wherein the first and second portions of the elongate member and the living hinge comprise one or more plies silicon-impregnated fiberglass material.

25. The boot of claim 21, wherein the first and second portions comprises molded silicone rubber.
**INTERNATIONAL SEARCH REPORT**

**PCT/US2014/048200**

### A. CLASSIFICATION OF SUBJECT MATTER

**F16L 57/04(2006.01)i, F16L 57/02(2006.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

### B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F16L 57/04; B32B 1/08; F16L 5/00; F16L 39/02; D04C 1/06; F16L 41/00; F16L 11/00; A62C 2/00; F16L 57/02

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: protective hose, fire resistance, flexible, silicon, braid, collar and boot

### C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
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<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
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<td>US 2012-0227851 Al (STROEMPL et al.) 13 Sept ember 2012 See abstract, paragraphs [0025], [0032], [0033], [0037], [0044], [0049], claim 1 and figures 1, 2.</td>
<td>1-12, 16-20</td>
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<td>A</td>
<td>US 4367889 A (REDL, PHILIP J.) 11 January 1983 See abstract, column 1, line 54 - column 2, line 34.</td>
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<td>Y</td>
<td>US 2004-0069507 Al (IMAMURA et al.) 15 Apr il 2004 See abstract, paragraph [0038] and figures 2-5.</td>
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<td>Y</td>
<td>US 2012-0040114 Al (CHEN, MING-MING) 16 February 2012 See abstract, paragraph [0013] and figure 1A.</td>
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<td>X</td>
<td>US 2002-0096881 Al (DESANTO SR., NICHOLAS) 25 July 2002 See abstract, paragraphs [0039], [0043] and figures 8, 9, 16, 17.</td>
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<td>16-20, 24, 25</td>
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Further documents are listed in the continuation of Box C. See patent family annex.

* Special categories of cited documents:
  *"A"* document defining the general state of the art which is not considered to be of particular relevance
  *"E"* earlier application or patent but published on or after the international filing date
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  *"O"* document referring to an oral disclosure, use, exhibition or other means
  *"P"* document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

07 November 2014 (07.11.2014)

Date of mailing of the international search report

07 November 2014 (07.11.2014)

Name and mailing address of the ISA/KR

International Application Division
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Authorized officer

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