OPEN Compute Project

Material Compatibility in Immersion Cooling

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1. Glossary

This glossary provides definitions **within the context** of immersion technology within data centers.

Dielectric fluid	A fluid which functions as an insulating substance to allow the immersion of electronics with the purpose of heat transfer.
Dielectric strength	The maximum electric field that the material can withstand under ideal conditions without breaking down.
Dynamic viscosity	The ease in which a substance flows in Pascal-second (Pa.s). It is also referred to in units as poise or centipoise (cP).
Enclosed chassis	Solution type with which dielectric fluid is circulated through a sealed server chassis.
Fire point	The lowest temperature at which the vapor of that fuel will continue to burn for at least 5 seconds after ignition by an open flame.
Flash point	The lowest temperature at which vapors of the material will ignite, when given an ignition source.
Fluorochemicals	Class of dielectric fluids characterized by the predominance of Fluorine in their molecular structure.
Hydrocarbons	Organic compounds consisting of predominantly hydrogen and carbon. These can also be described as polymers, oils or organic compounds.
Natural Esters	Organic compounds containing carbon, hydrogen, and oxygen that are generally extracted and purified from plant oil seeds. Generally, this includes triglycerides of glycerin and fatty acid. The properties are dependent upon the source of oil.
(M)SDS	(Material) Safety Data Sheet is a document that lists information relating to occupational safety and health for the use of chemicals.

Open bath	Solution type with which dielectric fluid is shared across multiple electronic systems in a horizontal bath style container and an open fluid-air interface.
Pour point	The temperature below which the fluid loses its flow characteristics.
Single-phase	Fluid application in which the state of matter is not intended to change.
Specific heat	The amount of thermal energy (in Joules) which is required to be added to 1 kg of a substance to achieve a 1°K temperature increase.
Synthetic Esters	Organic compounds containing carbon, hydrogen, and oxygen formed from a hydroxyl compound and one or more carboxylic acids to form a single product or mixture of isomers. The properties are dependent upon the selection of starting components.
TDS	Technical Data Sheet is a document that lists all required technical information for chemicals.
Two-phase	Fluid application in which the state of matter is designed to change from fluid to gas, and back to fluid.
Vapor	A substance in the gas phase at a temperature lower than its critical temperature, which means that the vapor can easily be condensed to a fluid by increasing pressure on it or by reducing the temperature.

2. Introduction

This Open Compute Project (OCP) whitepaper is written for current and potential designers, manufacturers, integrators and end users of immersion-cooled OCP-ready equipment. Integrators and component suppliers will find useful information specific to their preparation for immersion-cooled OCP systems. This document outlines the guidelines related to Material compatibility in immersion technologies which should be considered for implementation in Open Compute Environments.

The nature of immersion cooling requires attention to all wetted components and materials that will come into contact with dielectric fluids. This OCP Immersion workstream discusses considerations for cooling with dielectric fluids to accommodate fluid compatibility. The origin of this topic on immersion was due to work previously published on “Design Guidelines for Immersion Optimized IT Equipment”. The current workstream on material compatibility is a direct spin-off of that work.

Immersion systems are supported through enclosed chassis for vertical racking, open or sealed tank-style for horizontal racking (often still referred to as racks). These systems are designed to work with single or two-phase fluids as the dielectric cooling medium. Immersing servers and Information Technology Equipment (ITE) in a dielectric fluid enables substantial energy savings and accommodates growing load densities. The existing proprietary immersion cooling solutions and numerous case studies have established the effectiveness and energy savings for new construction or a retrofit from the device to the facility level.

Immersion cooling of data center equipment has the potential to improve reliability and overall equipment life, with lower service and repair costs. In published white paper on “Design Guidelines for Immersion-Cooled IT Equipment”, it is reported immersion cooling greatly reduces failures such as solder joint failures, oxidation and corrosion of electrical contacts, electrostatic discharge, and ambient particulate. It allows for much more consistent and controlled operating temperature and substantially alleviates humidity considerations for the environment surrounding the immersion technology.

Bill of materials (BOM) component count and cost reductions are intrinsic to immersion too, as fans, conventional heat sinks, and operating environment controls such as humidity sensors are eliminated. These reliability advances include a reduction in corrosion and electrochemical migration, lessening of environmental contamination like dust, debris, and particulates, reduced thermal shock, and mitigation of tin and zinc whiskers. Furthermore, the improved thermal management of components due to the increased heat capacity of fluids, can provide a significant increase in compute performance.

This report is a guideline document and not a requirement. This document classifies common immersion fluids, defines material compatibility with the parameters and implications, and describes guidance to commonized test procedures with which IT component materials can be tested. It should be noted that while several generic fluid types are mentioned there remains considerable variability of specific fluids within each generic classification, and as such all qualitative assessments within this document shall be considered as informative and not to be taken as absolute compatibility between any specific fluid and material.

2.1 Purpose

The purpose of this document is to promote awareness and identify minimum considerations for assuring compatibility of immersion fluids and wetted ITE materials in which fluids may interact. This document may be taken as recommendations or as guidelines for best practice when evaluating compatibility of immersion fluids. The user groups for this document include fluid manufacturers, server and other ITE system OEMs, producers of immersion technologies and end users. The burden of compatibility testing is anticipated to primarily fall on fluid manufactures, OEMs and producers of immersion technologies. However, end users will also benefit from use of this document to gain better awareness of fluid compatibility topics.

2.2 Scope

This document shall address known fluid types in common use as immersion cooling fluids, both single phase and two phase, for compatibility of materials known for common use in ITE equipment (servers, storage, networking, power supplies, etc.) that would be wetted by the dielectric fluid when used with immersion cooling. The recommended test methodologies applicable to specific compatibility attributes have been identified to assure consistent approach to compatibility testing. This document shall include a summary matrix of various fluids versus wetted materials for relative compatibility. The criteria for material compatibility selection for the single and two phase fluids has been identified, irrespective of the application in terms of levels such as acceptable, unacceptable and case-by-case basis when tested against with different IT components. The classes of fluids to be considered shall include single phase and two phase fluids. Following are the types of fluids that are classified under single phased fluids that include Synthetic Hydrocarbons (HC) involving Gas-to-Liquid (GTL), Polyalphaolefin (PAO), Synthetic Esters, and Biobased hydrocarbon fluids such as Natural Esters and Bio-based Renewable hydrocarbons. Whereas Perfluoropolyether (PFPE), and Perfluorocarbons (PFCs) are classified under two phase fluids. The fluorochemicals with higher boiling points can also be used for single phase immersion cooling. Furthermore, the scope shall include synthetic and natural variants of fluids as applicable.

3. Immersion Cooling Fluids Classification

Fluid cooling within the data center is the process wherein heat is extracted by a fluid rather than air. When a fluid is in direct contact with the electronics this is fluid immersion cooling. There are a variety of fluid immersion technologies available to cool electronics within the data center. The common denominator for each immersion system is that a dielectric fluid is used to completely immerse the heat-generating electronic components.

The dielectric fluid is thermally conductive with good insulating properties (poor electrical conductivity) making it possible for use with electronic components. The dielectric fluid comes into direct contact with the electronic components to capture and transport the heat to the data center facility heat rejection equipment. A range of heat rejection methods varies by facility and requires interfaces to connect to the cooling system. The terminology defined by American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) assists with determining the classification of fluid cooling infrastructure. The main immersion technology differentiators between fluid technologies are based on single or two phase, enclosed chassis and open bath systems.

Immersion fluids offer potential reduced maintenance and operational costs. The use of such dielectric fluids will help in high density heat removal; this in turn subsequently displaces considerable volumes of high velocity air and eliminates maintenance issues from accumulation of dust and debris on the cooling surfaces of computer components. System design can extend the life of chipsets by improved distribution of cooling capacity at controlled temperatures. Different dielectric fluids could be evaluated through compatibility testing for potential effects on system components, such as stiffening cable sheathing, removing identification markings, softening or dissolving adhesives or plastics, or interacting with metal components.

3.1 Single Phase Fluids

Single phase fluids are homogenous, non-volatile fluids at and above the operating temperatures of the system. Rather than cooling through a boiling process using overhead cooling condenser systems, single phase fluids use direct heat exchange processes for redistributing heat away from the circuit board. The heat exchanger is immersed in the fluid and can use an exchange interface or cooling loop to remove heat. These single phase fluids can be mineral oil derived; synthetic fluids, such as synthetic hydrocarbons, GTL (Gas to liquid), PAOs (polyalphaolefin), synthetic esters, or other non-volatile synthetic fluids such as fluorocarbons, specialized polymeric fluids, or functionalized derivatives; or can be bio-based fluids such as natural esters (plant derived oils) and their derivatives. Non-volatile additives may be present for added stability or performance. Below further information about the different types of single phase fluids that can be found:

Mineral Oils are hydrocarbons refined from crude petroleum. They mostly consist of longer chained alkanes (saturated hydrocarbons), but they also contain many impurities including sulphur, nitrogen and aromatic compounds. These impurities create material compatibility problems, and for this reason they are not recommended for use in immersion cooling.

Synthetic Hydrocarbons are hydrocarbons that are formed from chemical reactions. These include gas to liquid (GTL) hydrocarbons and polyalphaolefin (PAOs). GTL fluids are produced from reacting methane with oxygen to create synthesis gas, then the synthesis gas is converted in a Fischer-Tropsch process into long chain hydrocarbons characterized by their uniform and well-defined isoparaffinic molecular chemical structure. PAOs are formed by the oligomerization and subsequent hydrogenation of alkenes. Both GTL fluids and PAOs are characterized by their uniform and well-defined isoparaffinic chemical structures. In contrast to mineral oils, synthetic hydrocarbons contain almost no sulphur, aromatics and nitrogen impurities.

Natural Esters are compounds that are generally extracted and purified from plant oil seeds. Generally consisting of triglycerides of glycerin and a biologically determined mixture of fatty acids, the properties are dependent upon the source of oil seed. Oils with sites of unsaturation are generally used in systems closed to free air exchange. Derivatives of natural esters are similar to and considered synthetic esters.

Synthetic Esters are compounds formally derived from an oxoacid and an alcohol, phenol, heteroarenol, or enol by linking with formal loss of water from the carboxylic group of the former and a hydrogen atom from the hydroxyl group of the latter (IUPAC). Manufactured from carboxylic acids and alcohols by a hydrolysis process, dielectric synthetic esters can have a wide range of structural and performance possibilities, tailored for various electrical and power electronic applications.

Biobased Renewable hydrocarbons are iso-paraffinic hydrocarbons (carbon chain length C15-C18) that are produced using waste and residue oils and fats as a feedstock. Through pretreatment, hydrodeoxygenation and subsequent isomerization a biobased hydrocarbon is produced that is equal to synthetic hydrocarbons in properties. This refined hydrocarbon is free from impurities (metal, sulphur, chlorine), double bonds, naphthenics, aromatics (<1000ppm) and water (<50ppm). These hydrocarbons are from non-fossil resources and have a significantly reduced carbon footprint.

3.2 Two Phase Fluids

Fluorochemical fluids, generally with a lower boiling point, are predominantly used for two phase immersion cooling, and have higher heat transfer performance compared to single phase fluids using natural convection heat transfers. In two phase immersion cooling, heat is removed by boiling, which may yield lower and uniform component temperatures and enables operation at higher heat densities. These fluids are typically colorless, odorless, non-oil-based, non-flammable, non-combustible and non-corrosive. Further typical attributes include wide operating temperature ranges, low toxicity, outstanding thermal/chemical stability, and good dielectric properties. Below further information about the different types of fluids can be found:

Perfluorocarbons (PFCs) are synthetic compounds containing just fluorine and carbon. They are generally colorless, odorless non-flammable fluids at typical operating temperatures, have good dielectric properties and for the most part are chemically unreactive. PFCs with higher boiling points can also be used for single-phase immersion cooling.

Perfluoropolyether (PFPE) is a family of inert, high-performance, fluorinated fluids that offer good dielectric properties, exceptional chemical stability, and the capacity to operate at very low as well as elevated temperatures in aggressive conditions, making them useful in many industrial applications.

Fluoroketones (FKs) are synthetic compounds containing fluorine, carbon and oxygen. Some of the most commonly used FKs in immersion cooling have very good dielectric properties, very low Global Warming Potential (GWP), are non-flammable and low toxicity.

Hydrofluoroolefins (HFOs) are unsaturated organic compounds composed of hydrogen, fluorine and carbon. While hydrofluorocarbons (HFCs) and chlorofluorocarbons (CFCs) are saturated, HFOs are olefins or unsaturated, characterized by one or more double bonds between carbon atoms in the molecule. Commercially used HFOs are mostly inert, chemically stable, low toxicity and non-flammable or mildly-flammable. They also offer significantly lower GWP than HFCs and CFCs due to their short life in the atmosphere and have zero ozone depletion potential (ODP). Due to their wide range of boiling points, they can be used as a heat transfer fluid, and immersion cooling fluid, for powered electronics.

3.3 Required Fluid Specifications

In addition to full material safety data sheet (MSDS) and technical data sheet (TDS) documentation, the following summarized specifications as shown in Table 1 shall be made available for anyone who needs to evaluate health and safety protocols, fire safety or electronics compatibility and any recipient (users or customers) or operators. The source for the below referenced Table 1 is from the published document on immersion requirements revision 2.

Table 1 Testing Requirements for Immersion Cooling Fluids

Specification	**Test method(s)**	**Format**
Dielectric strength, 1 mm (May be estimated based on 2,5 mm)	ASTM D 1816 (IEC 60156)	kV/mm (kV, est. kV/mm)
Dielectric Constant (Relative permittivity) *Measured at:* ● *5 VAC* ● *20 GHz and 40 GHz* ● *20°C and 70°C*	*There is no prescribed method at this point. IEC 60247 may or may not provide a basis for this testing procedure* *NB: The high temperature 70°C test can be lowered in line with evaporation temperatures of 2-phase fluids*	#.## @# GHz and #°C
Loss tangent	*Data must be associated with tests conducted for Dielectric Constant with the referenced properties*	#.#### @# GHz and #°C
Resistivity	ASTM D1169	#.## GΩm
Maximum moisture content for dielectric breakdown	(100% Water saturation point, ASTM D1533-20)	# ppm
Specific heat capacity	ASTM E 1269	# kJ/kg*K @ 40°C

Thermal conductivity	ASTM D 7896	# W/m*K @40°C
Density at any °C	ISO 12185	#.## kg/m3 @ #°C
Volumetric expansion	ASTM D 1903	#.####/°C
Kinematic viscosity curve (or list following)	ASTM D7042	Graph
0°C		#.# mm^2/s (cSt)
20°C		#.# mm^2/s (cSt)
40°C		#.# mm^2/s (cSt)
60°C		#.# mm^2/s (cSt)
Vapor Pressure at 60°C	ASTM D2879	# mbar
Pour point	ASTM D 97 / ISO 3016	# °C
Flash point Cleveland (Closed Cup)	ASTM D 93 / ISO 2719	# °C
Fire point	ASTM D 92 / 2592	# °C
Auto ignition point	DIN 51794/ ASTM E659	# °C
Sulfur content	ISO 14596	#,# ppm
Acidity	IEC 62021-2 / IEC 62021-1	#.## mg KOH/g
NSF Nonfood Compounds certification	NSF certificate	Yes/No
Odor	n/a	{TDS spec}
Color	ASTM D 156 / ISO 2211	SDS{MSDS spec}
Hazard statements	GHS Classification	SDS{MSDS spec}
Specific Target Organic Toxicity (STOT) - single exposure	Safety Data Sheet	SDS{MSDS spec}
STOT - repeated exposure	Safety Data Sheet	SDS{MSDS spec}
Biodegradability	OECD 301	{MSDS spec}

Oxidation Stability	IEC 61125	Values per method
Global warming potential (GWP)	IPCC 2007	#.#
Ozone Depletion Potential	PNNL-16813	Yes/No

3.4 Minimum Dielectric Requirements for Single and Two Phase Fluids

Table 2 presents the minimum requirements which shall be met for any dielectric fluid to facilitate the safe operation of electronics. The specifications and requirements may be different for varying applications and technological solutions. The source for the below referenced Table 2 is from the published document on immersion requirements revision 2.

Table 2 Minimum Dielectric Requirements for Single and Two Phase Fluids

Property	**Unused fluid minimum requirements**	**Lifetime fluid minimum requirements**
Dielectric strength	-	≥6 kV/mm
Resistivity	≥2.00 GΩm	≥0.20 GΩm
Flash point (Closed Cup)	≥150°C	≥150°C
Auto ignition point	≥300°C	≥300°C
Sulphur content	<10 ppm	-
Acidity: hydrocarbons natural esters synthetic esters fluorocarbons	 ≤0.01 mg KOH/g ≤0.06 mg KOH/g ≤0.03 mg KOH/g ≤0.001 mg KOH/g	-
Odor (unsealed solutions only)	≤Slight	≤Slight

4. Defining Material Compatibility

4.1 Material Compatibility for Single Phase Fluids

Each immersion technology must comply with all certification regulations which are applicable to the geographic location where it is implemented. These requirements are different for each territory and well out of the scope of this document.

The objective of this section is to explain the mechanisms by which material compatibility issues can arise. This would help the end-user understand potential risks and identify or resolve issues while using or developing immersion cooled solutions for data centers. The mechanisms for single phase and two phase fluid are explained in more detail in sections 5.2 and 5.3, respectively.

4.2 Defining Material Compatibility for Single Phase Fluids

Material compatibility for single phase fluids can be broadly categorized into direct interactions and indirect interactions. Direct interactions are mechanisms that result from the fluid itself. They can occur in the fluid or when the fluid affects a material used in a component of the system. Direct interactions can lead to failure of a part or the whole system. Indirect interactions do not result from the fluid itself, but from the chemicals released or produced from direct interactions with IT components.

Direct Interactions

There are six main mechanisms by which direct interactions occur in case of single phase fluids, as explained in Table 3 below. It can be noted that the level of interactions could be different depending on the fluid type and specification. Each of these mechanisms has been briefly explained below.

a) Dissolution, one of the most common types of fluid-material interaction, in which materials, additives or plasticizers from components gradually dissolve/leach-out into the dielectric fluid. This could result in a detrimental effect on the component's performance and could potentially cause a system failure over time. This phenomenon could also lead to deterioration of the dielectric properties of the fluid. Dissolution is generally more severe at higher temperatures that are closer to glass transition temperature of material. A common example is additive/plasticizer leaching out of PVC cables at elevated temperatures over time, causing the cable to harden or embrittle.

b) Absorption/Swelling, another common type of fluid-material interaction in which components absorb the dielectric fluid and swell. This swelling could have an effect on the component's performance and lead to system failures. Swelling occurs by a diffusion-absorption process and swell rate is faster at higher temperatures. For example, excessive swelling of EPDM rubber hoses could result in system leakage.

c) Chemical interaction of materials with dielectric fluids is a rare phenomenon owing to the inert nature of commonly used single phase dielectric coolants. However, cases of metal corrosion or polymer degradation are possible arising mainly from interactions with chemical additives or impurities within the fluid. For example, sulfur compounds in fluids can interact with metals and cause corrosion.

d) Environmental Stress Cracking (ESC) is exhibited in certain mechanically stressed amorphous and semi-crystalline polymers e.g. Polycarbonate, ABS, PVC etc. that are in direct contact with the fluid. ESC is more severe at higher temperatures, closer to glass transition temperature of materials. Sudden failure of PVC pipes or Polycarbonate pump unions are examples of this phenomenon.

e) Fluid aging, a phenomenon that deteriorates the dielectric properties of the fluid and results in system failures (short circuits).

f) Oxidation in presence of humidity (moisture) and elevated temperature leads to fluid aging. Oxidation results in formation of free acids and sludge which in turn could cause indirect interaction with other components in the system.

Table 3: Direct interaction mechanisms in Single Phase fluids

No.	Type	Issue	Phenomenon	Impact	Examples
1	Fluid/ Material	Dissolution	Materials/components/additives/plasticizers dissolve in the dielectric fluid.	a) Affects component performance, and b) Affects fluid's dielectric performance	PVC cables, plastics
2	Fluid/ Material	Absorption/ Swelling	Materials/components absorbs and swells in the fluid	a) Affects component performance, and b) Leakages in seals/gaskets	Rubbers, seals
3	Fluid/ Material	Chemical interaction	Materials/components chemically interacts with the fluid	a) Affects component performance, and b) Affects fluid's dielectric performance	Corrosion in metals
4	Fluid/ Material	Environmental Stress Cracking	Materials/components crack under high mechanical stress in presence of fluid	a) Failure of components	Certain amorphous polymers like PC, ABS
5	Fluid	Ageing	Dielectric fluid oxidizes creating by-products	a) Effects fluid's dielectric performance	Acids from fluid aging, short-circuit
6	Fluid	Moisture intake	Fluid absorbs atmospheric moisture	a) Effects fluid's dielectric performance	Short-circuits

Indirect interactions

There are two main mechanisms by which indirect interactions occur in case of single phase fluids as shown in Table 4 below. The mechanisms are briefly explained below.

a) Dissolved materials, additives or plasticizers from the components present in the fluid could further interact with other components in the system and affect performance of these components. As an example, sulfur, commonly used as an additive in polymers/rubbers, could leach out into the fluid and interact with components used in IT equipment. This could potentially affect IT equipment performance and lead to system failures.
b) Fluid aging raises the acid value of fluids. Some of these acids could be detrimental to materials used in the system. However, acids are formed in traces and therefore, secondary interaction is not a common phenomenon. Similarly, other by-products produced from fluid oxidation and aging could be detrimental to materials used in the system.

Table 4: Indirect interaction mechanisms in Single Phase fluids

No.	Type	Issue	Phenomenon	Impact	Examples
1	Fluid/ Material	Dissolution	Materials/components/additives/plasticizers dissolve in the dielectric fluid.	a) Dissolved additives affecting performance of other components	Sulfur from rubbers causing corrosion
2	Fluid	Aging	Dielectric fluid oxidizes creating by-products	a) By-products could affect component performance by interacting with the materials.	Acids from fluid aging

4.3 Material Compatibility for Two Phase Fluids

Material compatibility may be defined as the measure of how stable two or more substances are when in contact with each other. Fluorochemicals are inert and they don't react with other materials, but they may have a physical interaction. These fluids can physically interact with a variety of components in an immersion cooling system in two ways: Primary material compatibility and Secondary Material compatibility issues as explained in detail in Table 5 and 6, respectively. Both primary and secondary material incompatibilities could result in change of component properties in an immersion cooling system, and consequently influence the overall performance and health of the system and thus, it is important to learn the physics behind these material incompatibilities.

a) Primary material compatibility issue refers to the direct effect of the fluid on a material as they interact. It is also known as Fluid-Material compatibility.

b) Secondary material compatibility issue refers to the effect that one material can have on another material using the fluid as a vector. It is also known as Material-Material compatibility. Secondary compatibility issue concerns the effect that arises when an extracted substance (Primary compatibility) migrates to another material via the fluid, resulting in property change.

Table 5: Primary material compatibility issues: Fluid-Material Interactions

	Extraction	Absorption
Definition	❖ Fluid can extract certain low molecular weight compounds from materials	❖ Fluid can diffuse into and be absorbed by the polymer matrix of materials
Implications	❖ May result in shrinkage/weight loss of material which could cause change in material's performance ❖ Limited by the low solubility that Fluorochemicals have for these compounds	❖ May result in swelling/weight gain of materials which could cause change in material's performance ❖ Diffusion through material can result in fluid loss
Examples	❖ Plasticizers extraction from the polymeric matrix of materials like elastomers ❖ Plasticizer extraction from O-Rings, can result in shrinkage and stiffening ❖ DOP extraction from PVC insulation, can result in stiffening	❖ Primarily a concern with fluoropolymers (Teflon™, Viton™) or porous hydrocarbon elastomers like silicone. Compatibility with PTFE is poor because the molecular structure is very similar to Fluorinert™. These materials can easily absorb fluorochemicals and swell.

Table 6: Secondary material compatibility issues: Material-Material Interactions

Contamination Sources	Risk of the secondary compatibility Issue
Extracted "Inert" hydrocarbons such as dioctylpthalate (DOP), Polydimethylsiloxane (PDMS), etc. from PVC wire insulation, silicone Rubber, Solder Flux, etc.	The "Inert" hydrocarbon contaminants can be absorbed and swell other materials.
Residual Solder flux left over from the manufacturing process can be soluble at low levels and could potentially increase risk to the hardware in combination with other contaminants.	The chemically active compounds can assist in the failure of components, but they are effectively non-mobile in the two phase fluids used today. The active compounds are reliant on a non-active hydrocarbon source to concentrate the active compounds or metal salts to increase the risk of failure due to electrochemical migration. And can cause Printed Circuit board (PCB) to fail in two major ways: 1. Electrical open circuits 2. Electrical short circuiting
Particulate contaminants from Residual manufacturing residue	Particulate contaminants can cause short circuiting and dielectric breakdown.
In two phase systems, the contaminants like non-volatile hydrocarbons often have much higher boiling points than fluid, so they collect via distillation	Hydrocarbon build-up on boiling surfaces leads to reduction in thermal performance. Organic acids (e.g., from solder flux) will tend to collect in these locations and lead to metal corrosion.

The boiling and condensation processes inherent to two phase cooling have important implications for material compatibility and system health. The most common sources for fluid contamination in an immersion system is shown in Table 7.

During boiling, for example, the relatively non-volatile hydrocarbon contaminants dissolved in the fluid are deposited on boiling surfaces by distillation in much the same way that lime accumulates in a tea kettle from boiling ‘hard’ water over time. Accumulation of hydrocarbons on the boiling surfaces over time results in reduced heat transfer coefficients, causing components to run hotter. The vapor evolved by boiling the fluid, being freshly distilled, is free of hydrocarbon contaminants and once condensed, has a high affinity for them. If this condensate comes into contact with elastomers containing hydrocarbon contaminants, the fluid will extract or solvate these substances and upon returning to the boiling fluid, leave the oil behind. It may be important to note that the distillation of the contaminants on a boiling surface and the resultant increase in component temperature is a reversible process when adequate filtration is returned to a system.

This mechanism for transporting relatively non-volatile contaminants from one part of the system to another is unique to two phase systems and forms the basis for Soxhlet extraction, a technique by which a fluid is used to extract mobile compounds from a solid phase. It is used, for example, to extract essential oils from plants, or lipids from food samples to assess fat content. This quick and inexpensive lab test for assessing material compatibility in both single and two phase applications using fluorochemicals should be done as explained in Section 7.

Table 7: Most common sources of fluid contamination in an immersion system

Material Source of Contaminant	Conformal coatings	Elastomers	Electrical isolation pads	Foam Rubber	Hot melt adhesive	Heat shrink tubing	PVC Insulation	Silicone RTV	Thermal interface	Thermal interface grease	Thermal pads
Component Containing Contaminant	Often applied to PSU PCB	Tank O-rings, seals, etc	Used on PSU FTEs and diodes	Airflow guides	Wire retention	Wiring, cable assemblies	Power cables, ethernet, wiring	FTE potting, vibration damping	CP, GPU and ASIC heat sink attach	Low power BGA device	Heat sinks for FETs, diodes, etc
Comment	Not necessary	Minimize or preclean	Not necessary	Not necessary	May not be necessary	Minimize	Eliminate where possible.	May not be necessary	Can be used. Alternatives are available	Not necessary in two-phase immersion cooling	Not necessary in two-phase immersion cooling
PSU	Yes	No	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes
Server	No	No	No	Yes	No	Yes	Yes	No	Yes	No	Yes
Cabling	No	No	No	No	No	Yes	Yes	No	No	No	No
Tank	No	Yes	No	No	No	No	Yes	No	No	No	No

5. Recommended Test Methods

To allow comparison between different technologies, several metrics and classifications are defined, which can be adopted by each technology.

For single and two phase fluids, the test methodology required to be followed for fluid aging test is listed in the below Table 8. These tests are required to be carried out to better understand the material compatibility of the various IT components with the selected fluid type. Following are the list of test parameters required to be followed for fluid aging test involving testing temperature, duration, fluid volume, fluid sample loading rates depending on the shape and size of IT component to be tested, sample handling apparatus, and properties of fluids to be tested for pre-and post-aging test.

Table 8 Methodology for Fluid Aging Test

Parameter	**Value**
Temperature (°C)	80*
Duration (Hours)	336
Fluid volume (Liters)	0.8
Fluid properties to measure (pre- and post-test)	Color, breakdown voltage, DDF, Acid value
Sample properties to measure (pre- and post-test)	Dimensions, weight, color, Shore A/D hardness as appropriate for material hardness
Fluid sample loading rates (%)	Even and Uneven shape Materials – 1% Max.
Sample-handling apparatus **	Oven, forced draft, adjustable to 80°C ± 1°C
Sample container	Glass, fitted with glass or aluminum foil cover

Note - *Unless boiling point temperature of the fluid is < 80°C, then perform test at lower temperature

** For two phase immersion cooling using fluorochemicals, it is highly recommended to perform the Soxhlet Extraction test method as provided in Section 7 to determine the material compatibility along with the above methodology.

5.1 Material Compatibility Criteria Selection

The fluid aging test criteria is a means to evaluate interactions between various constituent materials commonly found in servers and specific candidate dielectric fluids of interest. The results may be used to suggest alternate materials for servers are required and/or a different fluid may be needed if alternate server materials are not practical. Following are the recommendations by the experts in the industry to be followed for evaluating the criteria for selecting the material compatibility specification limits (irrespective of the application selected) as listed below:

a) Acceptable (<10%),
b) Case-by-case basis (10%-20%), and
c) Unacceptable (>20%) for all the parameters (including for fluids and materials).

Fluid aging testing for either single or two phase should be carried out to identify whether the selected fluid is considered as acceptable, unacceptable, or case-by-case basis. The list of tests required to be carried out to evaluate above listed criteria selection for material compatibility of the selected fluid with respect to listed IT components in the below listed Table 9. Key tests that are required before and after aging tests would involve evaluation for changes in volume, mass, shore hardness for polymers/rubber, color of the IT component, breakdown voltage, dielectric dissipation factor, and color of the selected fluid.

Table 9 Criteria for Material Compatibility Selection

Type of Materials Tested	Fluid and Material Tested							
	ΔV%	ΔM%	ΔD%	Δcolor (material)	ΔBDV	ΔDDF	Acid Value	Δcolor (fluid)
Seals and 'O' Rings / Rubbers								
Gaskets and Jointings								
Metals								
Sleevings								
Plastics								
3D printed plastics								
Cables								
Hose / piping / cooling tubes								
Adhesives / Sealants								
Thermal Insulation								
Others								
Labels								

Note – ΔV- Volume Change, (b) ΔM - Mass Change, (c) ΔD - Shore Hardness for Polymers/Rubber, (d) ΔC - Color for Material, (e) BDV - Breakdown Voltage (f) DDF - Dielectric Dissipation Factor, and (g) ΔC - Color for Fluid.

6. Standardizing Test Methods for Two Phase Fluids

6.1 Soxhlet Extraction Material Compatibility Test

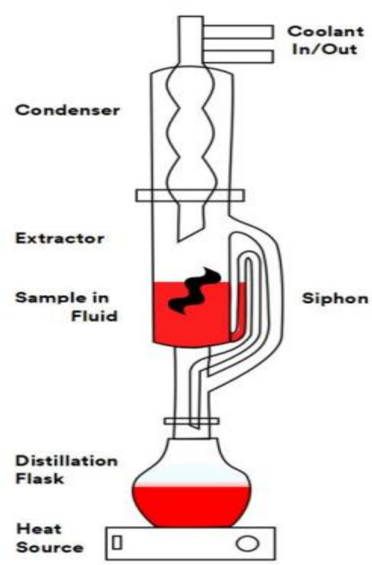
Details of the Soxhlet Extraction Material Compatibility Test can be found in various publications. What differentiates it from more common test methods, such as the ASTM soak tests mentioned earlier, is its ability to mimic the fluid use and two phase immersion operation in an actual tank. This makes the Soxhlet test more useful for assessing material compatibility in immersion cooling, particularly for two phase systems.

For single phase applications using fluorochemicals, the boiling temperature of the fluid is typically hot enough (130°C or higher) to "burn" most organic materials and it does not simulate well the end-use operating temperature. For those reasons, one typically does not run the Soxhlet extraction test with the
actual working fluid for single phase applications.

Fluorochemical fluids with lower boiling temperatures can be substituted, in this case, to allow lower test temperatures. This practice is defensible because smaller fluorochemical molecules are more able to get into a polymer (absorption) and are better solvents for extracting materials than their larger cousins. Their use therefore represents a "worst case."

6.2 Experiment Method

The Soxhlet extraction compatibility test is intended to quantify compatibility by measuring the ability of the fluorinated fluid to extract relatively non-volatile materials such as oils from the sample and the ability of the sample to absorb the fluorinated fluid under atmospheric reflux conditions in a Soxhlet extractor. Its ability to separate extraction ($me\%$) and absorption ($ma\%$) makes the Soxhlet test more useful for assessing compatibility than conventional soak tests which provide only an overall mass change. 48-hour Soxhlet extraction test gives "worst case" results at fluid boiling point.



Evaluation metrics

a) weight loss (extracted);
b) weight gain (swelling).

6.3 Meaning of the test results, extractables

Extractable materials should be as low as possible in the sample. <2% loss by mass indicates very good compatibility, too much mass loss can change the dimension, may also make the material brittle and crack while too much material loss can cause problems elsewhere in the system. This guideline is based on multiple criteria including it should not change physical material properties to an appreciable amount and loading and efficiency of the filtration media. In addition, >6% gain by mass indicates poor material compatibility as the fluid can diffuse through those materials, resulting in a fluid loss.

This interpretation of the Soxhlet test results is a general recommendation to help the system engineer to design correctly. Please consult with supplier technical support for your specific application. It is recommended to have the proper filtration system to mitigate any extractables. Contaminants are managed by scrubbing the fluid with an activated carbon filter, the adsorbent used to purify drinking water. The design of fluid filtration systems to manage contaminants for immersion cooling applications is the subject of another white paper.

Appendix: References

- Immersion Requirements Rev2
  https://www.opencompute.org/documents/ocp-acs-immersion-requirements-rev-2-v1-00-pdf

- Immersion Requirements Rev2 Checklist (including fluid spec-sheets)
  https://drive.google.com/u/0/uc?id=1-XnBAa8uDcvrPQkoEaxnBGHFysUln52z&export=download

- Design Guidelines for Immersion-Cooled IT Equipment
  https://www.opencompute.org/documents/design-guidelines-for-immersion-cooled-it-equipment-revision-1-01-pdf

- Allowable metric prefixes
  https://en.wikipedia.org/wiki/Metric_prefix

- ASHRAE. 2014. fluid cooling guidelines for datacom equipment centers, second edition:
  https://www.ashrae.org/technical-resources/bookstore/datacom-series

- ASHRAE.2019. Water-Cooled servers common designs, components, and processes:
  http://tc0909.ashraetcs.org/documents/ASHRAE_TC0909_Water_Cooled_Servers_11_April_2019.pdf

- Corrosion potentials of different materials
  http://www.atlassteels.com.au/documents/TN7-Galvanic_Corrosion_rev_Aug_2010.pdf

- Example of certification guidelines compliance
  https://www.cemarkingassociation.co.uk/technical-documentation/

- Example of spill management documentation:
  https://smah.uow.edu.au/content/groups/public/@web/@ohs/documents/doc/uow136688.pdf

- Galvanic corrosion background:
  https://en.wikipedia.org/wiki/Galvanic_corrosion

- Global certification compliance requirements:
  https://en.wikipedia.org/wiki/Certification_mark

- Global warming potential
  https://en.wikipedia.org/wiki/Global_warming_potential

- International System of Units:
  https://en.wikipedia.org/wiki/International_System_of_Units

- fluid classifications descriptions:
  https://en.wikipedia.org/wiki/Hydrocarbon
  https://en.wikipedia.org/wiki/Fluorocarbon

- MSDS sample:
  https://www.epc.shell.com/documentRetrieve.asp?documentId=157650261

Appendix: Material Compatibility Charts for Various Single and Two Phase Fluids

Disclaimer: The tables herein were developed using specific fluids and plastic formulations as a guideline of performance. Due to the varying composition and properties of fluids, and variable composition of plastics and components, different results may be obtained. It is recommended that system components be tested with the selected fluid in accordance with the guidelines outlined in this document.

OCP - Material Compatibility Chart - Synthetic Hydrocarbons (GTL)					
Application	**Compatible Materials**	**Properties Tested + Limits**	**Notes: In house test method performed on plastics, metals and elastomers at 100°C during 2 weeks. Other conditions based on ASTM 3455**	**Remarks**	
Seals and 'O' Rings / Rubbers	Nitrile Rubber (>35% Nitrile Content)	Shore Hardness, Weight change, Fluid Properties	Acceptable	Weight increase	
	Fluorocarbon Rubber (Viton/fluoro elastomers)		Acceptable	Weight and volume increase	
	Polyurethane Rubber		Acceptable	Weight and volume increase	
	PTFE (Teflon)		Acceptable	Weight and volume increase	
	Nylon		Acceptable	Not tested; based on the experience	
	EPDM		Unacceptable	Weight increase and dissolution	
	Silicone Rubber		Unacceptable	Weight and Volume increased	
	Neoprene Rubber		Case by Case Basis	Weight and Volume decreased	
	Natural Rubber		Unacceptable	Not tested; based on the experience	
	CR (Chloroprene)		Case by Case Basis	Weight and Volume decreased	
Gaskets and Jointings	Cork Bonded with Nitrile (Nebar Grey and Nebar Purple)	Shore hardness, weight change, dimensional change, fluid properties	Acceptable	Not tested; based on the experience	
	Cork Bonded with Neoprene Rubber (Nebar White and Nebar Orange)		Acceptable	Not tested; based on the experience	
	Nitrile		Acceptable	Not tested; based on the experience	
	Expanded PTFE		Acceptable	Not tested; based on the experience	
Metals	Copper	Corrosion (visual surface change), weight change, fluid properties	Acceptable	almost no change after testing	
	Phosphor Bronze		Acceptable	Not tested; based on the experience	
	Aluminum		Acceptable	almost no change after testing	
	Iron		Acceptable	Not tested; based on the experience	
	Brass		Acceptable	almost no change after testing	

	Zinc Plated Steel		Acceptable	almost no change after testing	
	Lead		Acceptable	Not tested; based on the experience	
	Silver		Acceptable	Not tested; based on the experience	
Sleevings	Epoxy / Glass	Shore hardness, etching, separation, weight change, fluid properties	Acceptable	Not tested; based on the experience	
	Silicone Glass		Acceptable	Not tested; based on the experience	
	Polyurethane / Glass		Acceptable	Not tested; based on the experience	
	Polyester / Glass		Acceptable	Not tested; based on the experience	
	Silicone Coated Glass Braided Sleeving (SCGB)			Not tested	
	Nylon		Acceptable	Not tested; based on the experience	
Plastics	boPET (Mylar)	Dimensional change, weight change, shore hardness, fluid properties	Acceptable	Not tested; based on the experience	
	Cellulose Triacetate		Acceptable	Not tested	
	Polyester (Melinex)		Acceptable	Not tested; based on the experience	
	Cotton / Epoxy Resin (TUFNOL 4F / 45)		Acceptable	Not tested; based on the experience	
	Cotton / Phenolic Resin (TUFNOL CARP)			Not tested	
	Glass / Epoxy Resin (HGW)		Acceptable	Not tested; based on the experience	
	Polyetheretherketone Film (APTIV Grade 1000)		Acceptable	Not tested	
	Fibre Reinforced Epoxy Glass (FRP)		Acceptable	Not tested; based on the experience	
	Acetal Copolymer (Ertacetal C)		Acceptable	Not tested	
	Nylon		Acceptable	Weight and Volume increased	
	Polymethyl Methacrylate (Perspex)		Acceptable	Weight and Volume increased	
	Polypropylene		Case by Case Basis	Weight increased	
	Polyethylene		Acceptable	Weight increased	
	PVC		Case by Case Basis	Plasticizer dissolved in fluid, Weight decrease	
	c-PVC		Case by Case Basis	Not tested; based on the experience	
	Cross-linked Polyethylene		Acceptable	Not tested; based on the experience	
	Cross-linked Polyolefin		Acceptable	Not tested; based on the experience	
	Polycarbonates		Acceptable	Not tested; based on the experience	
	Low Density Polyethylene		Case by Case Basis	Not tested; based on the experience	
	ABS		Acceptable	Not tested; based on the experience	

	HDPE without plasticizer		Acceptable	Not tested; based on the experience	
	PETG		Acceptable	Not tested; based on the experience	
	POM (Polyoxymethylene)		Acceptable	Not tested; based on the experience	
	PS (polystyrene)		Acceptable	Not tested; based on the experience	
3D printed plastics	Thermoplastic polyurethane (TPU)	Dimensional change, weight change, shore hardness, fluid properties	Acceptable	Not tested; based on the experience	
	Acrylonitrile butadiene styrene (ABS)		Acceptable	Not tested; based on the experience	
	Polypropylene 30% glass fibre (PP GF)		Case by Case Basis	Not tested; based on the experience	
	Polypropylene (PP)		Case by Case Basis	Not tested; based on the experience	
	Polyamide (PA)		Acceptable	Not tested; based on the experience	
	High temperature polyamide carbon fibre reinforced (CF PA)		Acceptable	Not tested; based on the experience	
	Polyethylene terephthalate glycol-modified (PETG)		Acceptable	Not tested; based on the experience	
Cable	Fluoropolymer (Raychem Flexlite)	Dimensional change, weight change, shore A hardness, flexibility, fluid properties	Acceptable	Not tested; based on the experience	
	PVC (Soflex TQ)		Acceptable	Not tested; based on the experience	
	Cross Linked Modified Polyester (Raychem 99M)		Acceptable	Not tested; based on the experience	
	Silicone			Not tested	
	Polyurethane (PUR/PU/TPU)		Acceptable	Not tested; based on the experience	
	Polyolefin (LSZH)		Case by Case Basis	Not tested; based on the experience	
	Thermoplastic elastomer (TPE)		Acceptable	Not tested; based on the experience	
	Chloroprene (PCP)		Case by Case Basis	Not tested; based on the experience	
	Fluorinated ethylene propylene (FEP)		Acceptable	Not tested; based on the experience	
Hose / piping / cooling tubes	UHMW Polyethylene (Trelleborg Chemikler D-UPE - inner only compatible)	Dimensional change, weight change, Shore hardness or instron, flexibility, fluid properties	Acceptable	Not tested	
	Aramid-reinforced fluoro elastomer (Goodyear SAE J30R3 - inner only compatible)		Acceptable	Not tested	
	EPDM		Unacceptable	Weight increase and dissolution	
	Polyamide		Acceptable	Not tested; based on the experience	
	PTFE		Acceptable	Not tested; based on the experience	
	PVC		Case by Case Basis	Not tested; based on the experience	

	Silicone		Acceptable	Not tested; based on the experience	
Adhesives / Sealants	Bisphenol F-Epoxy Resin (Araldite 2014)	Weight Change, fluid properties, (cast parts can be tested by shore hardness)	Acceptable	Not tested; based on the experience	
	Dimethacrylate Ester (Loctite 601)		Acceptable	Not tested; based on the experience	
	Gum Arabic Adhesive		Acceptable	Not tested; based on the experience	
	Silicone Sealant (Loctite 5920)			Not tested	
	Polysiloxane		Acceptable	Not tested; based on the experience	
	Cyanoacrylate (Loctite 435)		Acceptable	Not tested; based on the experience	
	Polyimide tape (Kapton)		Acceptable	Not tested; based on the experience	
Thermal Insulation	Polyisocyanurate (PIR) 40, aluminum coated	Dimensional change, weight change, shore hardness, fluid properties	Acceptable	Not tested; based on the experience	
	Polyisocyanurate (PIR) B		Acceptable	Not tested; based on the experience	
	Polyisocyanurate (PIR) CASSPIR		Acceptable	Not tested; based on the experience	
	Extruded polystyrene (XPS)		Acceptable	Not tested; based on the experience	
	Polyurethane foam (PUR)		Acceptable	Not tested; based on the experience	
	Mineral wool (Rockwool)		Acceptable	Not tested; based on the experience	
Others	Fabric hook and loop fastener (polyester)	Fluid Properties	Acceptable	Not tested; based on the experience	
	Bakelite FR2 PCB		Acceptable	Not tested; based on the experience	
	FR4 PCB		Acceptable	Not tested; based on the experience	
	Porcelain		Acceptable	Not tested; based on the experience	
	Mica Insulation (Mica)		Acceptable	Not tested; based on the experience	
	Polyurethane Casting Resin		Acceptable	Not tested; based on the experience	
Labels	GA International Lab Tag Corp. Part No. FTT233C13WH "Extended Exposure Xylene and Chemical Resistant Labels"	Adhesion loss, loss of print, paper integrity, fluid properties	Acceptable		

OCP - Material Compatibility Chart - Synthetic Hydrocarbons (PAO)				
Application	**Compatible Materials**	**Properties Tested + Limits**	**Notes: In house test method performed on plastics, metals and elastomers at 100°C during 2 weeks. Other conditions based on ASTM 3455**	**Remarks**
Seals and 'O' Rings / Rubbers	Nitrile Rubber (>35% Nitrile Content)	Fluid: BDV, DDF, colour, foaming. Materials: Weight & dimension change. Hardness in some cases.	Acceptable	Unsure of nitrile content of this sample.
	Fluorocarbon Rubber (Viton/fluoro elastomers)		Acceptable	
	Polyurethane Rubber		Acceptable	Not tested
	PTFE (Teflon)		Acceptable	
	Nylon		Acceptable	
	EPDM		Case by Case Basis	Weight and volume increased.
	Silicone Rubber		Case by Case Basis	Weight and volume increased.
	Neoprene Rubber		Case by Case Basis	Weight and volume increased. Trade name for chloroprene.
	Natural Rubber		Unacceptable	Weight and volume increased. BDV decreased.
	CR (Chloroprene)		Case by Case Basis	Weight and volume increased
Gaskets and Jointings	Cork Bonded with Nitrile (Nebar Grey and Nebar Purple)	Fluid: BDV, DDF, colour, foaming. Materials: Weight & dimension change. Hardness in some cases.		Not tested
	Cork Bonded with Neoprene Rubber (Nebar White and Nebar Orange)			Not tested
	Nitrile		Case by Case Basis	Nitrile sheets: weight and volume increased, hardness decreased. BDV decreased and DDF increased.
	Expanded PTFE		Case by Case Basis	Weight increased.
Metals	Copper		Acceptable	Can increase oxidation rate of the fluid.
	Phosphor Bronze		Acceptable	
	Aluminum		Acceptable	
	Iron		Acceptable	
	Brass		Acceptable	
	Zinc Plated Steel		Acceptable	
	Lead			Not tested
	Silver		Acceptable	
Sleevings	Epoxy / Glass			Not tested
	Silicone Glass			Not tested
	Polyurethane / Glass			Not tested
	Polyester / Glass			Not tested
	Silicone Coated Glass Braided Sleeving (SCGB)			Not tested
	Nylon		Acceptable	
Plastics	boPET (Mylar)		Acceptable	

	Cellulose Triacetate			Not tested
	Polyester (Melinex)			Not tested
	Cotton / Epoxy Resin (TUFNOL 4F / 45)			Not tested
	Cotton / Phenolic Resin (TUFNOL CARP)			Not tested
	Glass / Epoxy Resin (HGW)			Not tested
	Polyetheretherketone Film (APTIV Grade 1000)			Not tested
	Fibre Reinforced Epoxy Glass (FRP)		Acceptable	
	Acetal Copolymer (Ertacetal C)			Not tested
	Nylon		Acceptable	Some types of Nylon may decrease dielectric BDV
	Polymethyl Methacrylate (Perspex)		Acceptable	
	Polypropylene		Case by Case Basis	Weight and volume increased. BDV decreased.
	Polyethylene			
	PVC		Case by Case Basis	Hardness increased
	c-PVC			Not tested
	Cross-linked Polyethylene			Not tested
	Cross-linked Polyolefin		Unacceptable	
	Polycarbonates			Not tested
	Low Density Polyethylene			Not tested
	ABS			Not tested
	HDPE without plasticizer		Acceptable	
	PETG		Acceptable	
	POM (Polyoxymethylene)			Not tested
	PS (polystyrene)		Unacceptable	
3D printed plastics	Thermoplastic polyurethane (TPU)		Acceptable	
	Acrylonitrile butadiene styrene (ABS)		Case by Case Basis	Swells slightly
	Polypropylene 30% glass fibre (PP GF)		Case by Case Basis	Absorbs fluid without changing dimensions significantly
	Polypropylene (PP)		Unacceptable	Swells significantly
	Polyamide (PA)		Unacceptable	Shrinks
	High temperature polyamide carbon fibre reinforced (CF PA)		Unacceptable	Shrinks
	Polyethylene terephthalate glycol-modified (PETG)		Unacceptable	Absorbs fluid and swells
Cable	Fluoropolymer (Raychem Flexlite)		Acceptable	
	PVC (Soflex TQ)		Case by Case Basis	Hardness increased. BDV decreased
	Cross Linked Modified Polyester (Raychem 99M)		Case by Case Basis	
	Silicone		Case by Case Basis	Weight and volume increased. BDV decreased and DDF increased.
	Polyurethane (PUR/PU/TPU)		Acceptable	Weight increased.
	Polyolefin (LSZH)		Case by Case Basis	
	Thermoplastic elastomer (TPE)		Case by Case Basis	

	Chloroprene (PCP)		Case by Case Basis	Weight and volume increased, hardness decreased. DDF increased.
	Fluorinated ethylene propylene (FEP)		Case by Case Basis	Weight and volume increased. BDV decreased and DDF increased.
Hose / piping / cooling tubes	UHMW Polyethylene (Trelleborg Chemikler D-UPE - inner only compatible)			Not tested
	Aramid-reinforced fluoro elastomer (Goodyear SAE J30R3 - inner only compatible)			Not tested
	EPDM		Unacceptable	
	Polyamide			Not tested
	PTFE		Acceptable	
	PVC		Case by Case Basis	Weight and volume decreased, hardness increased. DDF increased.
	Silicone		Unacceptable	Weight and volume increased. DDF increased.
Adhesives / Sealants	Bisphenol F-Epoxy Resin (Araldite 2014)			Not tested
	Dimethacrylate Ester (Loctite 601)			Not tested
	Gum Arabic Adhesive			Not tested
	Silicone Sealant (Loctite 5920)		Acceptable	Absorbs small amounts of fluid but maintains adhesive strength
	Polysiloxane		Acceptable	
	Cyanoacrylate (Loctite 435)		Acceptable	
	Polyimide tape (Kapton)		Case by Case Basis	DDF increased
Thermal Insulation	Polyisocyanurate (PIR) 40, aluminium coated		Acceptable	Weight increased.
	Polyisocyanurate (PIR) B		Case by Case Basis	Weight and volume increased.
	Polyisocyanurate (PIR) CASSPIR		Case by Case Basis	Weight and volume increased.
	Extruded polystyrene (XPS)		Case by Case Basis	Good for temperatures <60 °C. At higher temperatures, weight and volume decreased.
	Polyurethane foam (PUR)		Case by Case Basis	Weight and volume increased.

	Mineral wool (Rockwool)		Unacceptable	Weight and volume increased.
Others	Fabric hook and loop fastener (polyester)		Case by Case Basis	Weight decreased. BDV decreased.
	Bakelite FR2 PCB		Acceptable	
	FR4 PCB		Acceptable	
	Porcelain		Acceptable	
	Mica Insulation (Mica)		Acceptable	
	Polyurethane Casting Resin		Acceptable	
Complete			63.80%	
Labels	GA International Lab Tag Corp. Part No. FTT233C13WH "Extended Exposure Xylene and Chemical Resistant Labels"			Not Tested

OCP - Material Compatibility Chart - Synthetic Esters				
Application	**Compatible Materials**	**Properties Tested + Limits**	**Notes: Compatibility assessment is carried out at 100°C which may impact the outcome, especially for plastics and elastomers. Elastomers can have variable composition so individual evaluations for large projects are worthwhile.**	**Remarks**
Seals and 'O' Rings / Rubbers	Nitrile Rubber (>35% Nitrile Content)		Acceptable	
	Fluorocarbon Rubber (Viton/fluoro elastomers)		Acceptable	
	Polyurethane Rubber		Acceptable	
	PTFE (Teflon)		Acceptable	
	Nylon		Acceptable	
	EPDM		Case by Case Basis	Weight and Volume increased
	Silicone Rubber		Case by Case Basis	Weight and Volume increased
	Neoprene Rubber		Unacceptable	Weight and Volume increased
	Natural Rubber		Unacceptable	Weight and Volume increased
	CR (Chloroprene)		Unacceptable	Weight and Volume increased
Gaskets and Jointings	Cork Bonded with Nitrile (Nebar Grey and Nebar Purple)		Acceptable	
	Cork Bonded with Neoprene Rubber (Nebar White and Nebar Orange)		Acceptable	
	Nitrile		Unacceptable	Fluid Discoloration, Acid value rise.
	Expanded PTFE			Not tested
Metals	Copper		Acceptable	
	Phosphor Bronze		Acceptable	
	Aluminum		Acceptable	
	Iron		Acceptable	
	Brass		Acceptable	
	Zinc Plated Steel		Acceptable	
	Lead		Unacceptable	
	Silver			Not tested
Sleevings	Epoxy / Glass		Acceptable	
	Silicone Glass		Acceptable	
	Polyurethane / Glass		Acceptable	
	Polyester / Glass		Acceptable	
	Silicone Coated Glass Braided Sleeving (SCGB)		Acceptable	
	Nylon		Acceptable	
Plastics	boPET (Mylar)		Acceptable	
	Cellulose Triacetate		Acceptable	
	Polyester (Melinex)		Acceptable	
	Cotton / Epoxy Resin (TUFNOL 4F / 45)		Acceptable	
	Cotton / Phenolic Resin (TUFNOL CARP)		Acceptable	
	Glass / Epoxy Resin (HGW)		Acceptable	
	Polyetheretherketone Film (APTIV Grade 1000)		Acceptable	

	Fibre Reinforced Epoxy Glass (FRP)		Acceptable	
	Acetal Copolymer (Ertacetal C)		Acceptable	
	Nylon		Acceptable	
	Polymethyl Methacrylate (Perspex)		Case by Case Basis	
	Polypropylene		Case by Case Basis	
	Polyethylene		Case by Case Basis	
	PVC		Unacceptable (under stress)	Environmental Stress Cracking
	c-PVC		Unacceptable (under stress)	Environmental Stress Cracking
	Cross-linked Polyethylene		Unacceptable (under stress)	Environmental Stress Cracking
	Cross-linked Polyolefin		Unacceptable (under stress)	Environmental Stress Cracking
	Polycarbonates		Unacceptable (under stress)	Environmental Stress Cracking
	Low Density Polyethylene		Unacceptable (under stress)	Environmental Stress Cracking
	ABS		Unacceptable (under stress)	Environmental Stress Cracking
	HDPE without plasticizer		Acceptable	
	PETG			Not tested
	POM (Polyoxymethylene)			Not tested
	PS (polystyrene)		Unacceptable (under stress)	Environmental Stress Cracking
3D printed plastics	Thermoplastic polyurethane (TPU)		Acceptable	
	Acrylonitrile butadiene styrene (ABS)			Not tested
	Polypropylene 30% glass fibre (PP GF)			Not tested
	Polypropylene (PP)			Not tested
	Polyamide (PA)		Acceptable	
	High temperature polyamide carbon fibre reinforced (CF PA)		Acceptable	
	Polyethylene terephthalate glycol-modified (PETG)			Not tested
Cable	Fluoropolymer (Raychem Flexlite)		Acceptable	
	PVC (Soflex TQ)		Acceptable	
	Cross Linked Modified Polyester (Raychem 99M)		Acceptable	
	Silicone		Case by Case Basis	Weight and Volume increased
	Polyurethane (PUR/PU/TPU)		Acceptable	
	Polyolefin (LSZH)			Not tested
	Thermoplastic elastomer (TPE)			Not tested
	Chloroprene (PCP)			Not tested
	Fluorinated ethylene propylene (FEP)			Not tested

Hose / piping / cooling tubes	UHMW Polyethylene (Trelleborg Chemikler D-UPE - inner only compatible)		Acceptable	
	Aramid-reinforced fluoro elastomer (Goodyear SAE J30R3 - inner only compatible)		Acceptable	
	EPDM		Unacceptable	Weight and Volume increased
	Polyamide		Acceptable	
	PTFE		Acceptable	
	PVC		Unacceptable	Weight and Volume increased
	Silicone		Unacceptable	Weight and Volume increased
Adhesives / Sealants	Bisphenol F-Epoxy Resin (Araldite 2014)		Acceptable	
	Dimethacrylate Ester (Loctite 601)		Acceptable	
	Gum Arabic Adhesive		Acceptable	
	Silicone Sealant (Loctite 5920)		Case by Case Basis	
	Polysiloxane		Unacceptable	
	Cyanoacrylate (Loctite 435)			Not tested
	Polyimide tape (Kapton)		Acceptable	
Thermal Insulation	Polyisocyanurate (PIR) 40, aluminum coated			Not tested
	Polyisocyanurate (PIR) B			Not tested
	Polyisocyanurate (PIR) CASSPIR			Not tested
	Extruded polystyrene (XPS)			Not tested
	Polyurethane foam (PUR)		Acceptable	
	Mineral wool (Rockwool)			Not tested
Others	Fabric hook and loop fastener (polyester)			Not tested
	Bakelite FR2 PCB			Not tested
	FR4 PCB			Not tested
	Porcelain		Acceptable	
	Mica Insulation (Mica)		Acceptable	
	Polyurethane Casting Resin		Acceptable	
Complete			69.50%	
Labels	GA International Lab Tag Corp. Part No. FTT233C13WH "Extended Exposure Xylene and Chemical Resistant Labels"			Not tested

OCP - Material Compatibility Chart - Natural Esters				
Application	**Compatible Materials**	**Properties Tested + Limits**	**Notes:**	**Remarks**
Seals and 'O' Rings / Rubbers	Nitrile Rubber (>35% Nitrile Content)		Acceptable	
	Fluorocarbon Rubber (Viton/fluoro elastomers)		Acceptable	
	Polyurethane Rubber		Acceptable	
	PTFE (Teflon)		Acceptable	
	Nylon		Acceptable	
	EPDM		Acceptable	
	Silicone Rubber		Acceptable	
	Neoprene Rubber		Acceptable	
	Natural Rubber		Unacceptable	Increased AV, Weight and volume increase, hardness decrease
	CR (Chloroprene)		Case by Case Basis	Weight and volume increase, hardness decrease <15%
Gaskets and Jointings	Cork Bonded with Nitrile (Nebar Grey and Nebar Purple)		Acceptable	
	Cork Bonded with Neoprene Rubber (Nebar White and Nebar Orange)		Acceptable	
	Nitrile		Acceptable	
	Expanded PTFE		Acceptable	
Metals	Copper		Acceptable	
	Phosphor Bronze		Acceptable	
	Aluminium		Acceptable	
	Iron		Acceptable	
	Brass		Acceptable	
	Zinc Plated Steel		Acceptable	
	Lead		Not Tested	
	Silver		Not Tested	
Sleevings	Epoxy / Glass		Acceptable	
	Silicone Glass		Not Tested	
	Polyurethane / Glass		Not Tested	
	Polyester / Glass		Case by Case Basis	
	Silicone Coated Glass Braided Sleeving (SCGB)		Not Tested	
	Nylon		Acceptable	
Plastics	boPET (Mylar)		Acceptable	
	Cellulose Triacetate		Acceptable	
	Polyester (Melinex)		Acceptable	
	Cotton / Epoxy Resin (TUFNOL 4F / 45)		Acceptable	
	Cotton / Phenolic Resin (TUFNOL CARP)		Acceptable	
	Glass / Epoxy Resin (HGW)		Acceptable	
	Polyetheretherketone Film (APTIV Grade 1000)		Acceptable	
	Fibre Reinforced Epoxy Glass (FRP)		Acceptable	
	Acetal Copolymer (Ertacetal C)		Acceptable	
	Nylon		Acceptable	
	Polymethyl Methacrylate (Perspex)		Acceptable	

	Polypropylene		Acceptable	
	Polyethylene		Acceptable	
	PVC		Case by Case Basis	
	c-PVC		Case by Case Basis	
	Cross-linked Polyethylene		Acceptable	
	Cross-linked Polyolefin		Unacceptable	
	Polycarbonates		Acceptable	
	Low Density Polyethylene		Acceptable	
	ABS		Acceptable	
	HDPE without plasticizer		Acceptable	
	PETG		Acceptable	
	POM (Polyoxymethylene)		Unacceptable	
	PS (polystyrene)		Unacceptable	
3D printed plastics	Thermoplastic polyurethane (TPU)		Acceptable	Significant color change to fluid
	Acrylonitrile butadiene styrene (ABS)		Acceptable	
	Polypropylene 30% glass fibre (PP GF)		Not Tested	
	Polypropylene (PP)		Acceptable	
	Polyamide (PA)		Acceptable	
	High temperature polyamide carbon fibre reinforced (CF PA)		Acceptable	
	Polyethylene terephthalate glycol-modified (PETG)		Acceptable	
Cable	Fluoropolymer (Raychem Flexlite)		Acceptable	
	PVC (Soflex TQ)		Case by Case Basis	
	Cross Linked Modified Polyester (Raychem 99M)		Acceptable	
	Silicone		Acceptable	
	Polyurethane (PUR/PU/TPU)		Unacceptable	
	Polyolefin (LSZH)		Unacceptable	
	Thermoplastic elastomer (TPE)		Acceptable	
	Chloroprene (PCP)		Case by Case Basis	
	Fluorinated ethylene propylene (FEP)		Acceptable	
Hose / piping / cooling tubes	UHMW Polyethylene (Trelleborg Chemikler D-UPE - inner only compatible)		not tested	
	Aramid-reinforced fluoro elastomer (Goodyear SAE J30R3 - inner only compatible)		Not tested	
	EPDM		Case by Case Basis	DDF change, all others acceptable
	Polyamide		Not tested	
	PTFE		Acceptable	
	PVC		Case by Case Basis	
	Silicone		Acceptable	

Adhesives / Sealants	Bisphenol F-Epoxy Resin (Araldite 2014)		Not tested	Expected to pass
	Dimethacrylate Ester (Loctite 601)		Not tested	
	Gum Arabic Adhesive		Not tested	
	Silicone Sealant (Loctite 5920)		Acceptable	
	Polysiloxane		Not tested	
	Cyanoacrylate (Loctite 435)		Acceptable	
	Polyimide tape (Kapton)		Acceptable	
Thermal Insulation	Polyisocyanurate (PIR) 40, aluminum coated		Not tested	
	Polyisocyanurate (PIR) B		Case by Case Basis	
	Polyisocyanurate (PIR) CASSPIR		Case by Case Basis	
	Extruded polystyrene (XPS)		Unacceptable	
	Polyurethane foam (PUR)		Unacceptable	
	Mineral wool (Rockwool)		Acceptable	
Others	Fabric hook and loop fastener (polyester)		Not Tested	
	Bakelite FR2 PCB		Not Tested	Expected to pass
	FR4 PCB		Acceptable	
	Porcelain		Acceptable	
	Mica Insulation (Mica)		Acceptable	
	Polyurethane Casting Resin		Not Tested	
Complete			72.40%	
Labels	GA International Lab Tag Corp. Part No. FTT233C13WH "Extended Exposure Xylene and Chemical Resistant Labels"		Acceptable	

OCP - Material Compatibility Chart - Biobased Renewable Hydrocarbon				
Application	**Compatible Materials**	**Properties Tested + Limits**	**Notes:**	**Remarks**
Seals and 'O' Rings / Rubbers	Nitrile Rubber (>35% Nitrile Content)		Acceptable	
	Fluorocarbon Rubber (Viton/fluoroelastomers)		Acceptable	
	Polyurethane Rubber		Acceptable	
	PTFE (Teflon)		Acceptable	
	Nylon		Acceptable	Not bench tested; based on the experience and literature data
	EPDM		Unacceptable	
	Silicone Rubber		Unacceptable	
	Neoprene Rubber		Acceptable	
	Natural Rubber		Unacceptable	Not bench tested; based on the experience and literature data
	CR (Chloroprene)		Case by Case Basis	
Gaskets and Jointings	Cork Bonded with Nitrile (Nebar Grey and Nebar Purple)		Acceptable	Not bench tested; based on the experience and literature data
	Cork Bonded with Neoprene Rubber (Nebar White and Nebar Orange)		Acceptable	Not bench tested; based on the experience and literature data
	Nitrile		Acceptable	Sheet material
	Expanded PTFE		Acceptable	Sheet material
Metals	Copper		Acceptable	Virtually no change
	Phosphor Bronze		Acceptable	Not bench tested; based on the experience and literature data
	Aluminium		Acceptable	Virtually no change
	Iron		Acceptable	Not bench tested; based on the experience and literature data
	Brass		Acceptable	Not bench tested; based on the experience and literature data
	Zinc Plated Steel		Acceptable	Not bench tested; based on the experience and literature data
	Lead		Acceptable	Not bench tested; based on the experience and literature data

	Silver		Acceptable	Not bench tested; based on the experience and literature data
Sleevings	Epoxy / Glass		Acceptable	Not bench tested; based on the experience and literature data
	Silicone Glass		Acceptable	Not bench tested; based on the experience and literature data
	Polyurethane / Glass		Acceptable	Not bench tested; based on the experience and literature data
	Polyester / Glass		Acceptable	Not bench tested; based on the experience and literature data
	Silicone Coated Glass Braided Sleeving (SCGB)		Acceptable	Not bench tested; based on the experience and literature data
	Nylon		Acceptable	Not bench tested; based on the experience and literature data
Plastics	boPET (Mylar)			Not tested
	Cellulose Triacetate			Not tested
	Polyester (Melinex)			Not tested
	Cotton / Epoxy Resin (TUFNOL 4F / 45)			Not tested
	Cotton / Phenolic Resin (TUFNOL CARP)			Not tested
	Glass / Epoxy Resin (HGW)		Acceptable	Not bench tested; based on the experience and literature data
	Polyetheretherketone Film (APTIV Grade 1000)			Not tested
	Fibre Reinforced Epoxy Glass (FRP)			Not tested
	Acetal Copolymer (Ertacetal C)		Acceptable	Not bench tested; based on the experience and literature data
	Nylon		Acceptable	
	Polymethyl Methacrylate (Perspex)		Acceptable	Not bench tested; based on the experience and literature data
	Polypropylene		Acceptable	Not bench tested; based on the experience and literature data
	Polyethylene		Acceptable	Not bench tested; based on the experience and literature data

	PVC		Case by Case Basis	Not bench tested; based on the experience and literature data
	c-PVC		Case by Case Basis	Not bench tested; based on the experience and literature data
	Cross-linked Polyethylene		Acceptable	Not bench tested; based on the experience and literature data
	Cross-linked Polyolefin		Acceptable	Not bench tested; based on the experience and literature data
	Polycarbonates		Acceptable	
	Low Density Polyethylene		Case by Case Basis	Not bench tested; based on the experience and literature data
	ABS		Acceptable	
	HDPE without plasticizer		Acceptable	
	PETG		Acceptable	Not bench tested; based on the experience and literature data
	POM (Polyoxymethylene)		Acceptable	Not bench tested; based on the experience and literature data
	PS (polystyrene)		Case by Case Basis	Not bench tested; based on the experience and literature data
3D printed plastics	Thermoplastic polyurethane (TPU)		Acceptable	Not bench tested; based on the experience and literature data
	Acrylonitrile butadiene styrene (ABS)		Acceptable	
	Polypropylene 30% glass fibre (PP GF)		Case by Case Basis	Not bench tested; based on the experience and literature data
	Polypropylene (PP)		Acceptable	
	Polyamide (PA)		Acceptable	
	High temperature polyamide carbon fibre reinforced (CF PA)		Acceptable	Not bench tested; based on the experience and literature data
	Polyethylene terephthalate glycol-modified (PETG)		Acceptable	Not bench tested; based on the experience and literature data
Cable	Fluoropolymer (Raychem Flexlite)		Acceptable	Sheet material

	PVC (Soflex TQ)		Acceptable	Not bench tested; based on the experience and literature data
	Cross Linked Modified Polyester (Raychem 99M)			Not tested
	Silicone		Case by Case Basis	Not bench tested; based on the experience and literature data
	Polyurethane (PUR/PU/TPU)		Acceptable	Not bench tested; based on the experience and literature data
	Polyolefin (LSZH)		Case by Case Basis	Not bench tested; based on the experience and literature data
	Thermoplastic elastomer (TPE)			Not tested
	Chloroprene (PCP)		Acceptable	Not bench tested; based on the experience and literature data
	Fluorinated ethylene propylene (FEP)		Acceptable	Not bench tested; based on the experience and literature data
Hose / piping / cooling tubes	UHMW Polyethylene (Trelleborg Chemikler D-UPE - inner only compatible)			Not tested
	Aramid-reinforced fluoro elastomer (Goodyear SAE J30R3 - inner only compatible)			Not tested
	EPDM		Unacceptable	
	Polyamide		Acceptable	Not bench tested; based on the experience and literature data
	PTFE		Acceptable	
	PVC		Case by Case Basis	Not bench tested; based on the experience and literature data
	Silicone		Unacceptable	
Adhesives / Sealants	Bisphenol F-Epoxy Resin (Araldite 2014)		Acceptable	Not bench tested; based on the experience and literature data
	Dimethacrylate Ester (Loctite 601)		Acceptable	Not bench tested; based on the experience and literature data
	Gum Arabic Adhesive			Not tested
	Silicone Sealant (Loctite 5920)		Unacceptable	

	Polysiloxane			Not tested
	Cyanoacrylate (Loctite 435)		Case by Case Basis	Not bench tested; based on the experience and literature data
	Polyimide tape (Kapton)		Acceptable	Not bench tested; based on the experience and literature data
				Not tested
Thermal Insulation	Polyisocyanurate (PIR) 40, aluminium coated			Not tested
	Polyisocyanurate (PIR) B			Not tested
	Polyisocyanurate (PIR) CASSPIR			Not tested
	Extruded polystyrene (XPS)		Case by Case Basis	Not tested; based on the experience
	Polyurethane foam (PUR)		Acceptable	Not bench tested; based on the experience and literature data
	Mineral wool (Rockwool)		Acceptable	Not bench tested; based on the experience and literature data
Others	Fabric hook and loop fastener (polyester)		Acceptable	Not bench tested; based on the experience and literature data
	Bakelite FR2 PCB		Acceptable	Not bench tested; based on the experience and literature data
	FR4 PCB			Not bench tested; based on the experience and literature data
	Porcelain		Acceptable	Not bench tested; based on the experience and literature data
	Mica Insulation (Mica)		Acceptable	Not bench tested; based on the experience and literature data
	Polyurethane Casting Resin		Acceptable	Not bench tested; based on the experience and literature data
Complete			74.30%	
Labels	GA International Lab Tag Corp. Part No. FTT233C13WH "Extended Exposure Xylene and Chemical Resistant Labels"			

OCP - Material Compatibility Chart - Perfluorocarbons (PFCs)				
Application	**Compatible Materials**	**Properties Tested + Limits**	**Notes: In house test method similar to ASTM 3455 but carried out at 75°C for 50-hrs.**	**Remarks**
Seals and 'O' Rings / Rubbers	Nitrile Rubber (>35% Nitrile Content)		Acceptable	Unsure of nitrile content of this sample.
	Fluorocarbon Rubber (Viton/fluoroelastomers)		Acceptable	
	Polyurethane Rubber		Acceptable	
	PTFE (Teflon)		Case by Case Basis	Weight increased/Volume increase
	Nylon		Acceptable	
	EPDM		Acceptable	
	Silicone Rubber		Acceptable	
	Neoprene Rubber		Acceptable	
	Natural Rubber		Acceptable	
	CR (Chloroprene)		Acceptable	
Gaskets and Jointings	Cork Bonded with Nitrile (Nebar Grey and Nebar Purple)		not tested	Not tested
	Cork Bonded with Neoprene Rubber (Nebar White and Nebar Orange)		not tested	Not tested
	Nitrile		Acceptable	Nitrile sheets: weight and volume increased, hardness decreased. DDF increased.
	Expanded PTFE		Case by Case Basis	Weight increased/Volume increase
Metals	Copper		Acceptable	
	Phosphor Bronze		Acceptable	
	Aluminium		Acceptable	
	Iron		Acceptable	
	Brass		Acceptable	
	Zinc Plated Steel		Acceptable	
	Lead		Acceptable	
	Silver		Acceptable	
Sleevings	Epoxy / Glass		Acceptable	
	Silicone Glass		Acceptable	
	Polyurethane / Glass		Acceptable	
	Polyester / Glass		Acceptable	
	Silicone Coated Glass Braided Sleeving (SCGB)		Acceptable	
	Nylon		Acceptable	
Plastics	boPET (Mylar)		Acceptable	
	Cellulose Triacetate		Acceptable	
	Polyester (Melinex)		Acceptable	
	Cotton / Epoxy Resin (TUFNOL 4F / 45)		Acceptable	
	Cotton / Phenolic Resin (TUFNOL CARP)		Acceptable	
	Glass / Epoxy Resin (HGW)		Acceptable	
	Polyetheretherketone Film (APTIV Grade 1000)		Acceptable	
	Fibre Reinforced Epoxy Glass (FRP)		Acceptable	

	Acetal Copolymer (Ertacetal C)		Acceptable	
	Nylon		Acceptable	
	Polymethyl Methacrylate (Perspex)		Acceptable	
	Polypropylene		Acceptable	
	Polyethylene		Acceptable	
	PVC		Acceptable	
	c-PVC		Acceptable	
	Cross-linked Polyethylene		Acceptable	
	Cross-linked Polyolefin		Acceptable	
	Polycarbonates		Acceptable	
	Low Density Polyethylene		Acceptable	
	ABS		Acceptable	
	HDPE without plasticizer		Acceptable	
	PETG		Acceptable	
	POM (Polyoxymethylene)		Acceptable	
	PS (polystyrene)		Acceptable	
3D printed plastics	Thermoplastic polyurethane (TPU)		Acceptable	Not tested / No issue expected
	Acrylonitrile butadiene styrene (ABS)		Acceptable	Not tested / No issue expected
	Polypropylene 30% glass fibre (PP GF)		Acceptable	Not tested / No issue expected
	Polypropylene (PP)		Acceptable	Not tested / No issue expected
	Polyamide (PA)		Acceptable	Not tested / No issue expected
	High temperature polyamide carbon fibre reinforced (CF PA)		Acceptable	Not tested / No issue expected
	Polyethylene terephthalate glycol-modified (PETG)		Acceptable	Not tested / No issue expected
Cable	Fluoropolymer (Raychem Flexlite)		Case by Case Basis	Not tested / No issue expected
	PVC (Soflex TQ)		Case by Case Basis	Not tested / No issue expected
	Cross Linked Modified Polyester (Raychem 99M)		Acceptable	
	Silicone		Acceptable	
	Polyurethane (PUR/PU/TPU)		Acceptable	
	Polyolefin (LSZH)		Acceptable	
	Thermoplastic elastomer (TPE)		Acceptable	
	Chloroprene (PCP)		Acceptable	
	Fluorinated ethylene propylene (FEP)		Case by Case Basis	Not tested / No issue expected
Hose / piping / cooling tubes	UHMW Polyethylene (Trelleborg Chemikler D-UPE - inner only compatible)		Not tested	expect no issues
	Aramid-reinforced fluoro elastomer (Goodyear SAE J30R3 - inner only compatible)		Not tested	expect no issues

	EPDM		Not tested	expect no issues
	Polyamide		Not tested	expect no issues
	PTFE		Not tested	expect no issues
	PVC		Not tested	expect no issues
	Silicone		Not tested	expect no issues
Adhesives / Sealants	Bisphenol F-Epoxy Resin (Araldite 2014)		Acceptable	
	Dimethacrylate Ester (Loctite 601)		Acceptable	
	Gum Arabic Adhesive		Acceptable	
	Silicone Sealant (Loctite 5920)		Acceptable	
	Polysiloxane		Acceptable	
	Cyanoacrylate (Loctite 435)		Acceptable	
	Polyimide tape (Kapton)		Acceptable	
Thermal Insulation	Polyisocyanurate (PIR) 40, aluminium coated		Acceptable	Not tested / No issue expected
	Polyisocyanurate (PIR) B		Acceptable	Not tested / No issue expected
	Polyisocyanurate (PIR) CASSPIR		Acceptable	Not tested / No issue expected
	Extruded polystyrene (XPS)		Acceptable	Not tested / No issue expected
	Polyurethane foam (PUR)		Acceptable	Not tested / No issue expected
	Mineral wool (Rockwool)		Acceptable	Not tested / No issue expected
Others	Fabric hook and loop fastener (polyester)		Acceptable	Not tested / No issue expected
	Bakelite FR2 PCB		Acceptable	Not tested / No issue expected
	FR4 PCB		Acceptable	Not tested / No issue expected
	Porcelain		Acceptable	Not tested / No issue expected
	Mica Insulation (Mica)		Acceptable	Not tested / No issue expected
	Polyurethane Casting Resin		Acceptable	Not tested / No issue expected
Complete			88.60%	
Labels	GA International Lab Tag Corp. Part No. FTT233C13WH "Extended Exposure Xylene and Chemical Resistant Labels"			Not Tested

About Open Compute Project

The Open Compute Project Foundation is a 501(c)(6) organization which was founded in 2011 by Facebook, Intel, and Rackspace. Our mission is to apply the benefits of open source to hardware and rapidly increase the pace of innovation in, near and around the data center and beyond. The Open Compute Project (OCP) is a collaborative community focused on redesigning hardware technology to efficiently support the growing demands on compute infrastructure. For more information about OCP, please visit us at http://www.opencompute.org