HOSE AND MANUAL COUPLINGS - BEST PRACTICES

Revision 01

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Executive Summary

This document is a result of work done in the ORV3 Blind Mate Liquid Cooling Interfaces Group in the Open Compute Project. This document is meant to provide background information on hose and manual couplings. This is meant as a best practices and reference document to help the community when selecting appropriate hoses and manual couplings.

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Introduction

The Open Compute Project (OCP) ORV3 Blind Mate Liquid Cooling Interfaces Group put together this white paper to help educate the community. The information provided is meant to provide the OCP community with useful reference information and best practices with respect to manual coupling and hose assemblies. This is not a specification.

Figure 1 depicts connections required at the rack-level to interface different liquid-cooling components (note the RPU or reservoir and pumping unit, or CDU can be used interchangeably in this diagram). Dotted lines in the side view represent large, manual hoses and couplings that complete the rack-level circuit. Interface/connections with facility-level coolant (or FWS, facility water system as outlined by **ASHRAE TC9.9**) are not shown here as rack-level connections are independent of whether this closed system exhausts heat to facility water or air.

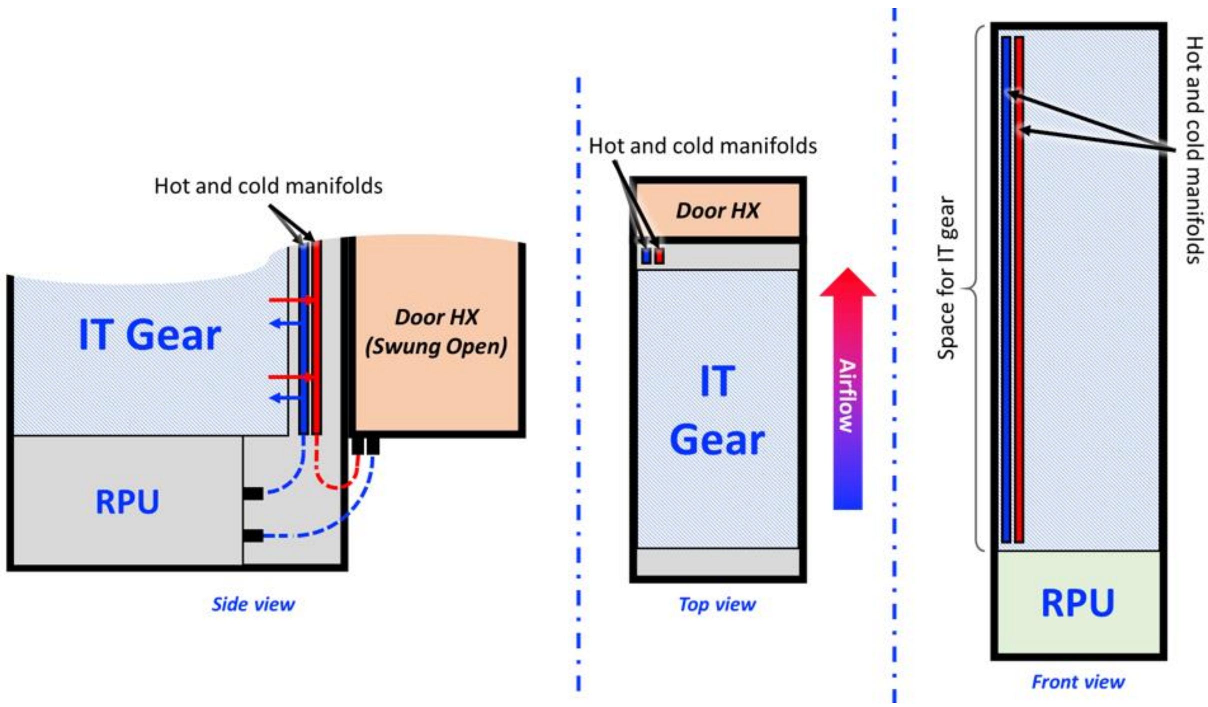


Fig. 1. Door heat exchanger mounted to a rack and coupled with RPU (or CDU) and manifolds to form a closed secondary coolant loop

OCP Specification for Reservoir and Pumping Unit, Work-in-Progress (not published yet 6/11/20)

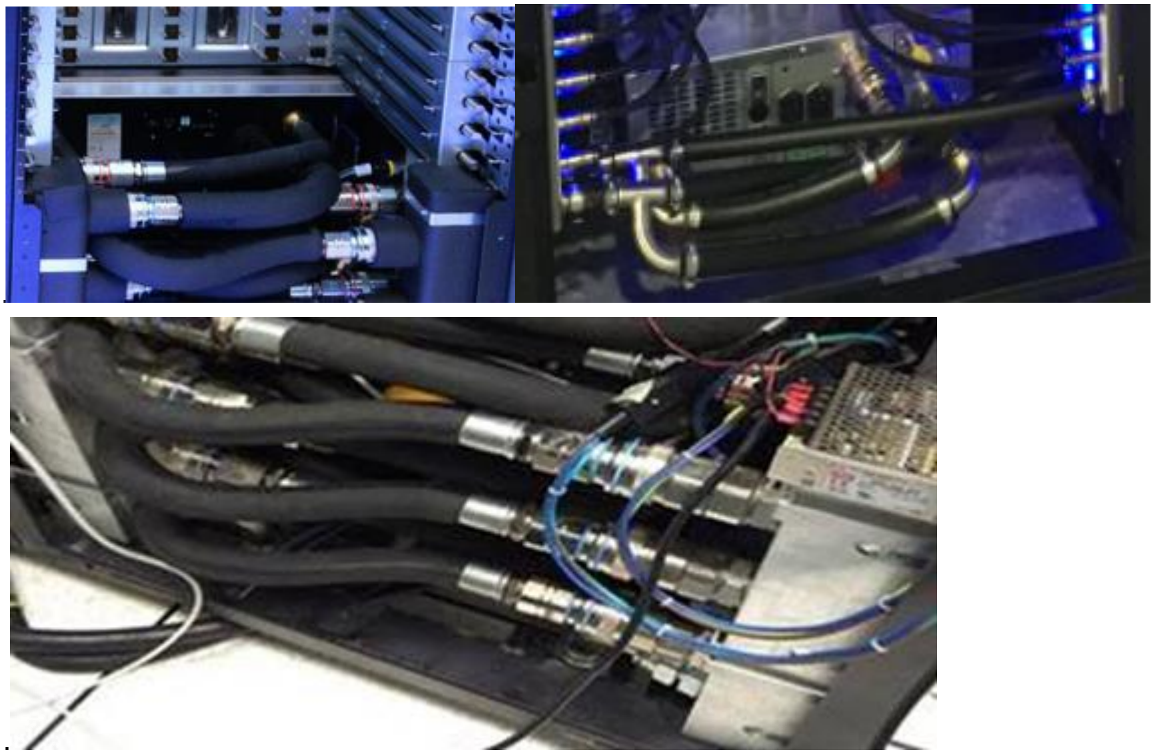


Fig. 2. Liquid Cooling Connections Using Quick Connect Couplings from Andrew Wasielewski (iPhone), *CEJN, 3 Dec. 2015.*

Fig. 3. Thermal Control Data server cell, *CEJN, Cejn.com, 15* Dec. 2019, https://www.cejn.com/en-us/articles/data-server-producer-use-modular-no-spill-coupling-for-cooling.

1 Basics of Hose Construction

The term “hose” refers to reinforced flexible piping. The basic components of a hose are (1) the tube (innermost liner), (2) the reinforcement (tension-bearing material helically wound around the tube to support pressure loading), and (3) cover (outermost layer which protects the reinforcement). The tube and cover layers are typically constructed from rubber or thermoplastic materials. Important note: a hose should not be confused with flexible tubing which is comprised of a homogeneous material (either rubber or thermoplastic) without composite reinforcement. The pressure resistance of tubing is determined solely by the strength of the polymeric material. Both hose and tubing are specified by inside diameter (ID). Hose dimensions are controlled by ID and OD (outside diameter), whereas tubing dimensions are typically controlled by ID and wall thickness.

Thermoplastic hoses utilize melt-processable plastics which do not require cross-linking to achieve their finished physical properties. Historically, thermoplastic hoses can have a variety of advantages when compared to rubber hose such as chemical resistance, permeation resistance, vibrant colors, and smooth surface finishes. Thermoplastic material choices are made considering the specific application. Examples include custom blends of PVC, polyamide, urethane, polyester, and flourinated thermoplastics.

Rubber hose is constructed from a range of thermoset polymers such as EPDM, nitrile, polychloroprene, chlorinated polyethylene, butyl, natural rubber, SBR, and flourinated rubber, each of which can be custom compounded for specific applications. Traditionally, advantages of rubber hose over thermoplastic hose includes; flexibility, expanded temperature range without working pressure degradation, resistance to compression set and UV resistance.

Reinforcing materials that can be used in either thermoplastic or rubber hose include synthetic filament fibers or tire cord fabrics like polyester, PVA, nylon and aramid. Higher pressure hoses traditionally utilize drawn wire from high tensile carbon steel or stainless steel.

The manufacturing processes used to produce hoses include extrusion and wrapping processes for tube and cover layers. Reinforcing layers can be braided, spiral wound or wrapped. The manufacturing process for each layer is often dictated by the material type. Further, the dimensional control and tolerances of the finished product are determined by the manufacturing process.

Hose designs for computer coolant will typically be low pressure rubber hose products with fiber reinforcement. Properties and performance characteristics of this type of hose will be discussed in more detail in the sections below. For more information about hose constructions, please review **ARPM IP-2 “Hose Handbook”.**

2 Basics of Manual Coupling Construction

Manual quick couplings are available in many different versions, from straight thru couplings without valves, couplings with poppet type valves that have a spillage at connection disconnection, to a non-spill design. The last type of coupling is the most common type used in the thermal control applications. These spillage free couplings go under many different names: Flat-face, Non-drip, Flush-face, non-spill, dry break, etc.

Fig. 4.

Fig. 5.

Fig. 4. Thermal-control/Ultraflow series, *CEJN,* Cejn.com, Dec. 2019, https://www.cejn.com/en-us/products/thermal-control/ultraflow-thermal-control/series-487-dn8-ultraflow/.

Fig. 5. Parker Dry Break Quick Connect Couplings, *Parker Hannifin*: Parker.com, May 2020, https://ph.parker.com/us/en/dry-break-quick-connect-coupling-series-nsi

Other possible versions include couplings with a combined ball valve function that require a two-step function during connection and disconnection. One more feature that separates the coupling types are the locking mechanism between the female and male halves; the majority of quick couplings use a ball lock where the ball's position is controlled by an external sleeve (locking sleeve) that is pulled back to release the male and female parts. Other popular locking mechanisms are screw type, button type and for larger size couplings cam-style and bayonet locking.

Fig. 6. Coupling Locking Mechanisms from Andrew Wasielewski (iPhone), *CEJN,* 13 Apr. 2020.

Regardless of coupling type used the user has to apply a force to connect and disconnect the couplings. The most important force is the force to connect, since many times the couplings can be situated in confined spaces, this force depends of a couple of factors;

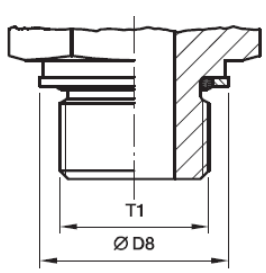
- Size and mass of the coupling; a larger coupling will give a higher connection force.
- The couplings valve type will give different connection forces, a ball valve style coupling has a very low connection force but then the user has to apply a second step with a larger force to open the ball valves on each half.
- A coupling with a flat-face / non spill design has a higher connection force than a coupling with a poppet valve type. The reason for the higher force is a more complex valve design with more components and more seals giving higher friction, those friction forces have to be compensated for with larger spring forces on the valve to ensure a proper sealing at disconnection, this spring force results in a larger connection force.
- The third components in the connection force is the pressure inside the male female coupling, this pressure is acting on the valves sealing area creating a force that is contributing to the connection force. Since the pressure used in thermal control applications are low it becomes normally a significant factor on couplings with DN 12 and up.
- The actual locking mechanism has less impact on the connection force.

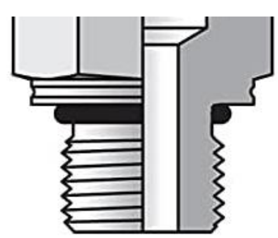
When a coupling uses threads to connect the mating halves, the manufacturer should be consulted to determine the proper threaded connection torque. For applications that must comply with UL 62368-1, the document provides for a force limit for skilled technicians and ordinary operators.

Some coupling types follow an ISO standardisation to secure interchange and performance parameters between different brands. The ISO standards originated from the hydraulic industry which demand much higher pressures and impact resistance than what's required within the thermal control industry. In the thermal control Industry, we normally seek other parameters such as flow optimisation and minimum pressure drop to keep energy losses at a minimum.
Couplings for thermal control applications are typically made from 3 different materials: Stainless steel, brass with nickel or chrome plating, and aluminium with hard anodization. The choice of material is usually done based on coolant media and other material used in the fluid loop to make sure galvanic problems are avoided.

As sealing elements between the coupling halves and on the different valve components, O-rings of different rubber material are typically used. In some cases, more special designed Lip seals or glide ring sealings can also be used. When choosing a sealing material, such as O-rings, you must check the application to see if a UL-157 standard is required to ensure all system components and criteria specifications are met. The most common sealing material for thermal control applications is EPDM rubber, which provides a good combination of temperature flexibility, chemical and aging resistance. Other materials such as NBR and FVMQ are also used depending on media and temperature range.

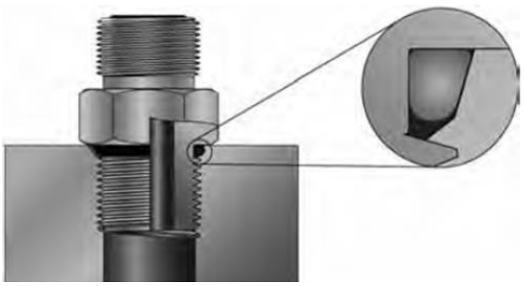
To connect the manual quick coupling to a hose end or a manifold usually a male or female thread connection is chosen. It is important for thermal control applications to choose a connection method that is soft sealed, either a Metric, BSP or SAE thread with an integrated seal such as **ISO 6149-1, ISO 1179-1, SAE J1926/1.**





ISO 1179 Male connection **ISO 6149 Male connection**

Fig. 7. Threaded Ports, Ports with truncated housing for O-Ring Seal, *ISO 6149-1:2019(en), ISO 1179-1:2013, Apr. 2020.*



Typical ORB Connection per ISO 11926-3

Fig. 8. UN/UNF Threads, typical o'ring boss port, Parker Catalog 4300, pg F5, Feb. 2017.

Other Connection Options

Fig. 9 Fitting/ Connection Configurations from Andrew Wasielewski (iPhone), *CEJN,* 15 Apr. 2020.

If a hose is connected, there is also an option to direct connect the male or female coupling to the hose with a hose barb. The hose is then secured on the barb with an external compression sleeve or by using a self-grip hose type Push-Lok etc.

One problem with using manual quick connect couplings is the possibility to cross connect the system at assembly, if this is done the flow direction in the system will be wrong leading to a potential overheat situation. The normal way of eliminating cross connection is to use one male and one female coupling on the inlet and outlet position of the manifold. This will give a "poka yoke" safe connection. Color-coding red and blue on the coupling halves is another popular way to eliminate cross connection, all though it is not 100% fool proof.

a. Spillage

Upon disconnection, couplings will spill a small amount of fluid as dictated by their interface geometries. The amount can vary by the type of coupling and for applications that are sensitive to this spillage, non-spill couplings have been developed. These couplings will typically only leave behind a wet face of the coupling and will not spill enough fluid for a drop to form. Typical spillage upon disconnect is 0.10 cc (ml/cycle) maximum for a ¾" dry break style coupler. Please use **ISO 18869:2017** for reference on test methods.

b. Pressure Drop

The inner diameter of the coupler and flow rate of the media will determine the pressure drop experienced at each connection point. As there may be multiple types and sizes of connections, it's important during the system design to consider total pressure loss throughout the system. Consider a QD with a high flow coefficient (Cv) for the required peak flow rate. Please use **ISO 18869:2017** for reference on test methods.

c. Pressure Rating

Pressure rating for couplings is most commonly a 4:1 safety factor determined by burst testing. This is the general case for industrial applications and is usually defined by industry standards such as **ISO 7241**. However, for lower pressure applications it can be evaluated for the need. The lowest most suppliers would consider offering would be a 3:1 safety factor. Below that, the long-term use of the part may compromise the part to function at the lower safety factor. The larger the safety factor correlating to pressure rating, the more overdesigned the product which of course impacts cost. Please use **ISO 18869:2017** for reference on test methods.

d. Fluid Compatibility

The critical features that impact fluid compatibility in couplings are the seals, or O-rings. Seals are typically a configurable feature within couplings to allow the correct seal for the correct fluid. Many suppliers will have charts available for Chemical Compatibility. These charts are derived from the polymer providers for chemical compatibility so for general material options the charts should be consistent among suppliers. However, for specific material compounds, this is more likely to vary based on supplier due to sourcing the same compound from multiple sources. One supplier may have worked with a polymer supplier to provide a specific compound for an application, whereas another supplier would not have been involved to incorporate that compound in their portfolio. See below for a typical compatibility chart. However, please consult the appropriate chart from the suppliers you plan to use for precise recommendations (see table 1).

Table 1

Fluid Compatibility

Source: Eaton, *Eaton Quick Disconnect Couplings Master Catalog*, Aug 2017, p. 4.

This charts below are intended for reference use only. The information in this chart pertains strictly to material compatibility and is not intended to be used as an application guide.

E=Excellent
G=Good
C=Conditional
U=Unsatisfactory

Fluid	Seals				Metal			
	Buna-N	Neoprene	EPDM	FKM	Steel	Brass	Stainless Steel	Aluminum
Acetaldehyde	U	C	C	U	G	E	E	E
Acetic Acid, 10%	U	U	E	G	U	U	C	C
Acetic Acid, Glacial	U	U	C	U	U	U	C	C
Acetone	U	U	G	U	E	E	E	E
Acetophenone	U	U	E	U	E	E	E	C
Acetyl Acetone	U	U	G	U	U	C	C	C
Acetyl Chloride	U	U	U	E	C	C	C	U
Acetylene (1)	G	U	G	E	E	E	E	E
Air, Hot (Up to +160°F)	E	E	E	E	E	E	E	E
Air, Hot (161°F – 200°F)	C	G	E	E	E	E	E	E
Air, Hot (201°F – 300°F)	U	U	G	E	E	E	E	E
Air Wet, below 160°F	E	E	E	E	U	G	E	E
Aluminum Chloride, 10% aq	E	E	E	E	U	U	U	U
Aluminum Fluoride, 10% aq	E	E	E	E	U	U	U	E
Aluminum Nitrate, 10% aq	E	E	E	E	U	U	C	C

Fluid	Seals				Metal			
	Buna-N	Neoprene	EPDM	FKM	Steel	Brass	Stainless Steel	Aluminum
Aluminum Sulfate, 10% aq	E	E	E	E	U	C	E	C
Alums, 10% aq	E	E	E	E	U	C	E	C
Ammonia, Cold	E	E	E	U	E	U	E	E
Ammonia, Hot	U	G	G	U	E	U	E	E
Ammonia, Anhydrous	G	G	E	U	E	U	E	E
Ammonia, Aqueous	E	E	E	U	E	U	E	E
Ammonium Carbonate, 10% aq	U	E	E	U	C	U	C	C
Ammonium Chloride, 10% aq	E	E	E	U	U	U	C	U
Ammonium Hydroxide, 10% aq	C	C	E	C	G	U	C	C
Ammonium Nitrate, 10% aq	E	G	E	U	G	U	G	G
Ammonium Phosphate, 10% aq	E	E	E	–	U	C	G	U
Ammonium Sulfate/Sulfide, 10% aq	E	E	E	U	U	U	G	U
Amyl Acetate	U	U	G	U	E	E	E	E
Amyl Alcohol	G	C	E	G	G	G	E	U
Aniline, Aniline Oil	U	U	G	U	E	U	E	G

3 Hose Properties

a. Durability

Durability of a hose can be interpreted to refer to a range of characteristics such as resistance to the following: an over-pressure condition, repeated pressure fluctuations, or temperature extremes. These elements will be addressed separately in sections below. For the purposes of this discussion, we will consider durability to be the resistance of the hose to exterior forces. Hoses can be damaged by exposure to sharp edges or rough surfaces.

Routing of the hose should avoid sharp edges that can cut into the cover layer, potentially damaging the reinforcement leading to a hose rupture. The hose routing can be secured with hose clamps to reduce the chance of contact with sharp edges. When cut-resistance to protect against fluid leakage from a puncture or laceration is required, there are some options that can be explored in both hose construction and guarding. The hose construction can use a cut resistance cover such as a stainless-steel wire over-braid or a fiber over-braid. Using wire reinforcement under a rubber cover can also provide protection from cuts compromising the inner liner (tube). Woven nylon or spiral plastic guards can also be assembled to the hose cover to give added protection at particular locations.

Hoses contacting rough surfaces can lead to hose cover abrasion that can eventually lead to reinforcement damage and early hose failure. The abrasion resistance of the hose cover can be quantified for comparison purposes using the test methods outlined in **SAE J2006 or ISO 6945.** The hose cover material can be individually characterized for abrasion resistance using the test method outline in **ASTM D5963-04 or ISO 4649.** For improved abrasion resistance, a plastic layer can be used on the outer cover of the hose. Another cover choice for high abrasion resistance is to use a rubber/plastic polymer blended cover such as NBR/PVC. The abrasion resistance of the hose can also be influenced by the thickness of the hose cover which can be specified to have a minimum wall thickness. Proper routing of the hose to eliminate contact with vibrating or moving objects while allowing for slight movement of the hose due to pressure fluctuations will reduce the likelihood of hose cover wear.

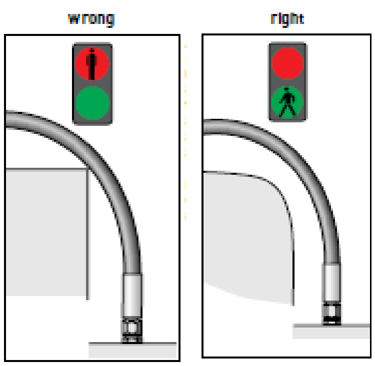


Fig. 10. Hose routing to avoid abrasion, *Hose, Fitting, and Equipment, Catalog 4400: Hose Installation Tips, Parker Hannifin*, Jun. 2017, p. E-12.

b. Permeability

There is currently no industry standard test method to quantify fluid loss through the hose due to permeation. As such, the permeation of the hose materials can be researched. Traditionally for mobile applications, rubber and thermoplastic materials are suitable for use in closed loop systems that contain an appropriately sized coolant reservoir. For coolant loops that use silicone hose, special considerations should be made due to the relatively high permeation rate of water/coolant mixtures through the hose wall.

Standards that can be used to evaluate the permeation resistance of a specific material include the gravimetric (weight loss) techniques can be used (reference **ASTM D814**). Another gravimetric method for measuring liquid permeation of a rubber compound would be using a Thwing-Albert cup per **ASTM E96 / E96M-16.** Both test methods use a disk of material to seal a liquid filled jar. The jar is inverted to expose the liquid directly to the rubber surface. The jar is weighed periodically to track the mass loss of liquid to determine a permeation rate for the rubber with the specific liquid. The temperature at which the test is conducted has significant influence on the permeation rate as rubber becomes more permeable at higher temperatures.

A review of the material technical data can help predict permeation resistance. Cross-linked synthetic rubber is composed of a network of polymer chains. The polymer type, filler material and polarity of the rubber vs polarity of the fluid are all factors that impact the ability of the rubber to limit the fluid/vapor from passing through the hose wall. For low permeation, it is common to choose a polymer with a polarity trait that opposes the polarity of the fluid. For instance, non-polar polymers such as butyl and EPDM are very resistive to permeation of polar fluids such as water. Water mixed with ethylene glycol can be semi-polar depending on the mixture ratio whereas propylene glycol/water mixtures tend to be more polar. Permeability of the hose can be an important consideration for closed loop liquid coolant systems. This is especially true where the addition of coolant is a costly or difficult maintenance procedure. Historically, silicone coolant hose is a concern for this type of system due to its relatively poor permeation resistance (highly polar polymer) and is best suited for open loop coolant systems where the coolant reservoir is continually replenished.

Rubber hose typically serves as a sufficient barrier in preventing oxygen ingression which is the transmission of oxygen from the atmosphere, through the hose wall, and into the fluid stream. The ingression of oxygen into the liquid can begin to degrade the coolant in an acid-producing reaction. This can lead to corrosion of metallic components in the fluid loop including fittings, valves, and the pump. This is typically a consideration for fluid loops that use a large quantity of flexible hose that will be in operation for many years such as hydronic or radiant heating systems in residential and commercial structures. The oxygen transmission rate (OTR) test from **ASTM D3985** can be used to quantify the resistance of thin film materials to oxygen ingression. This type of testing is common for materials used for films in food packaging.

c. Ozone Resistance

Ozone resistance of rubber refers to its ability to resist oxidation of the polymer chain which results in spider web-like micro cracks. The side wall of old tires can develop this type of cracking also referred to as crazing. Some polymers like EPDM are naturally ozone resistant, whereas other polymers like SBR and nitrile require anti-ozonate additives included in the rubber compound to provide protection against ozone attack. Ozone resistance testing can be conducted on either the rubber cover or the entire finished hose. The test requires stressing the hose or rubber (stretching in tension) and placing it in a warm, ozone rich environment with periodic inspections for cracks using a 7x magnifying lens. The test methods outlined in **ASTM D380** and **ASTM D1149** are typically used to evaluate ozone resistance on hose or rubber, respectively.

d. Hose Assembly Tensile Strength

A hose assembly is comprised of the hose, the end fittings which are typically barbed on one end and threaded on the other, and the hose retention component that holds the hose to the barbed ended fitting. This retention component can be a clamp, a crimp shell, or any other means of delivering compression to the hose wall. The hose retention method is typically chosen to withstand the end load that the fluid pressure exerts on the hose fitting. The amount of end load is proportional to the fluid pressure and the hose ID. The hose manufacturer will typically recommend barb and clamp combinations or crimp fittings that have been tested for retention. Socket-less fittings are also an option to evaluate for this application. Clamp manufacturers also provide guidelines for sizing assembly to flexible hose.

In some applications, an external tensile loading of the hose assembly is possible. In the case of the liquid cooling system considered here, the hose and manual coupling could see a tensile load if the rack were to be pulled away from the hard-piped CDU plumbing while still connected. Further, if the hoses were used as a tether to pull the rack, the hoses would see significant tensile loading. Tensile loading of hose assemblies can damage the inner tube at the hose barb, fracture the reinforcing fibers, or simply pull the hose away from the end fitting. More subtle degradation of the hose due to this type of loading could be delamination of the hose layers. This means the adhesion between the hose layers has been decreased or fully compromised.

A system designer may wish to require that a hose assembly be able to withstand a maximum tensile load without catastrophic rupture of the hose assembly. However, tensile loading of the hose is certainly not recommended. A tensile test machine can be used to determine the ultimate tensile load of a hose assembly by using the test method outlined in ASTM D380.

e. Material Compatibility with Coolant

Liquid cooling systems for cooling IT gear electronics typically use a mixture of propylene glycol and deionized water. Other coolant mixtures are also possible and can be chosen to be maximize heat transfer over a specified temperature range or protect against phase change (freezing and evaporating). Additionally, biocides and corrosion inhibitors can be added to the coolant. It is recommended to review the fluid compatibility of all the elements of a fluid mixture with the hose manufacturer to be sure the inner liner of the hose (tube) is compatible with the fluid. In many cases, the coolant mixture will contain proprietary additives for which compatibility may be difficult to predict. The best way to verify compatibility is to conduct a physical test of the tube material with the specific coolant mixture.

Compatibility is typically gauged by understanding the impact on the physical properties of the tube material. Besides the permeability considerations mentioned in section "B", changes in the material tensile strength and ultimate elongation, density, or hardness can be quantified after fluid immersion. The temperature and duration of the fluid immersion can be chosen based on the application. A 70hr immersion at the maximum operating temperature will typically give an accurate indication of compatibility although longer durations can be specified where more uncertainty is suspected. Immersion testing per **ASTM D471** can be used in conjunction with the physical property testing from **ASTM D412** to verify fluid compatibility. For applications that require compliance with **UL 62368-1** the document provides a test method and performance limits for materials subjected to an elevated temperature fluid exposure.

f. Bend Radius

One of the important elements to consider when reviewing a hose routing is the minimum bend radius required of the hose. This means the designer should try to identify the location in the hose routing that requires the tightest bend that the hose is required to withstand. The hose manufacturer provides a minimum bend radius for each hose style and size. This dimension is measured against the hose cover closest to the center of the bend.

The minimum bend radius of the hose is influenced by a variety of hose construction variables including the rubber flexibility, hose wall thickness, and method of reinforcement. Exceeding the minimum bend radius could lead to kinking of the hose which will reduce fluid flow and potentially lead to an early hose failure. The use of elbow fittings and adapters can help limit the bend required by the hose material. It should be noted that most hose has a natural curvature due to the manufacturing and/or shipping method. When installing the hose, the natural curve of the hose should be aligned with the bend in the hose routing.

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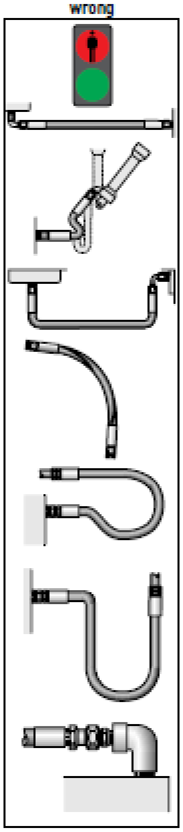

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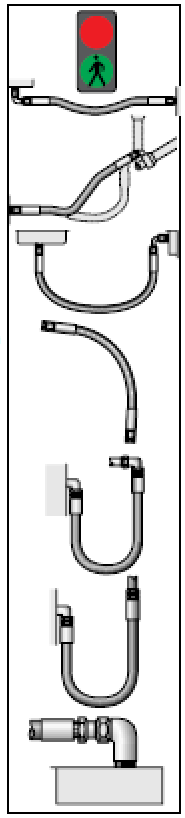

The routing of the hose assembly and the environment in which the hose assembly operates directly influence the service life of the hose assembly. The following diagrams indicate the correct routing of hose assemblies that will maximize its service life and assure a safe working functionality.

When hose installation is straight, there must be enough slack in the hose to allow for changes in length that occur when pressure is applied. When pressurized, hose that is too short may pull loose from its hose fittings or stress the hose fitting connections, causing premature metallic or seal failures.

The hose length must be determined so that the hose assembly has enough slack to allow the system components to move or vibrate without creating tension in the hose.

However, do not to allow too much slack and therefore introduce the risk of the hose snagging on other equipment or rubbing on other components.

Mechanical straining of the hoses needs to be avoided, so the hose must not be bent below its minimum bend radius or twisted during installation. The minimum bending radii for each hose is stated in the hose tables in the catalog.

The plane of movement must also be considered and the hose routing selected accordingly.

Hose routing also plays an important role on the selection of the hose fittings, as the correct fittings can avoid straining the hoses, unnecessary hose length or multiple threaded joints.

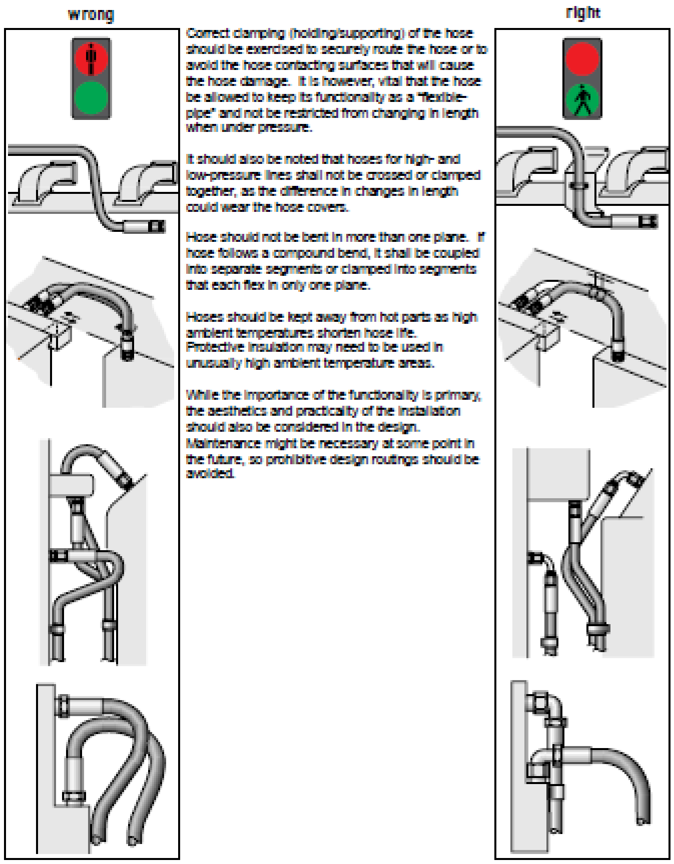

Fig. 11. Examples of proper and improper hose routing, *Hose, Fitting, and Equipment, Catalog 4400: Hose Installation Tips, Parker Hannifin*, Jun. 2017, p. E-11.

g. Typical Hose & Fitting Working Life

A hose assembly should be selected based on the STAMP method which considers the hose Size, Temperature, Application, Media, and Pressure. When properly selected, the hose assembly life can be maximized. The hose life expectancy is difficult to predict but can be monitored with routine inspection. The inspection should focus on any sign of leakage along the length of the hose or at the hose fittings. Kinks, bulges or soft spots along the hose length are an indication that the hose needs to be replaced. Cuts, abrasions or loose hose cover material should be noted. If the reinforcing material is visible, the hose should be replaced.

4 Manual Coupling Hose Termination Options & Considerations

a. Barb Connections

Fitting recommendations for a hose are often specified by the hose manufacturer. For low pressure applications, it is not uncommon to use a simple barb fitting with a hose clamp. The barb fitting can be made from a range of material choices but should be selected to compatible with the system fluid and appropriate for the system pressure. The barb fitting should fit the hose ID snugly and provide an appropriate sealing geometry. The sealing geometry should be free of sharp edges, nicks, burrs, or longitudinal defects (such as a parting line) which could damage the hose inner liner during assembly or interfere with the sealing surface. The system fluid can be used as a lubricant when installing the hose over the barb.

b. Compression Set of Tube/Shell when Clamped

Some hose and barb combinations are meant to function without the use of a hose clamp. When a hose clamp is necessary, there are a variety of styles available. The clamp should be sized so that it can be installed over the hose OD but also compress the hose after it is installed over the barbed or beaded insert. A simple worm gear clamp should be tightened according to the clamp manufacturer's specification. Over time, it is likely that the hose material will creep away from the hose clamp reducing the amount of compression provided by the clamp. This happens frequently when the hose assembly is subjected to high temperatures for long periods of time or subjected to wide temperature swings. In this case, the hose clamp can simply be re-tightened. In cases where maintenance is difficult, a clamp that compensates for hose creep can be utilized. These types of clamps use spring steel, springs, or Belleville washers to compensate for compression loss. The hose material can also be characterized for resistance to creep. The compression set test method from ASTM D395 can be used to quantify a rubber material's resistance to maintain its shape under compression loading and temperature.

Fig. 12. Push-on Hose and Hose Barb (No clamp required), *Hose, Fitting, and Equipment, Catalog 4400: Hose Installation Tips, Parker Hannifin*, Jun. 2017, p. A-44.

Fig. 13. Traditional Hose Barb and Beaded End (Clamp required): Parker 125 HBL, *Parker Hannifin*, Parker.com, 10 Jun. 2020. https://ph.parker.com/us/en/brass-hose-barb-fittings/125hbl-8-12.

Fig. 14. Worm gear, Pinch ear and T-bolt clamps, *Parker Hannifin*, Parker.com, 10 Jun. 2020. https://ph.parker.com/us/15551/en/hc-hose-clamp. https://www.oetiker.com/en/Products/Clamps-and-rings/Ear-Clamps. https://www.fastenal.com/product/pneumatics/clamps-and-collars/t-bolt-clamps.

Fig. 15. Creep compensating clamps, *Parker Hannifin*, Parker.com, 10 Jun. 2020. https://www.rotorclip.com/hose_clamp_overview.php. http://www.breezehoseclamps.com/breeze/constant-torque/.

c. Male / Female coupling convention for supply and return manifold hoses.

In order to error-proof the connection of the fittings, users will commonly key the couplings to avoid connecting the wrong hose to the wrong manifold. In most cases they will also be color-coded; red and blue. Typically, one manifold will have a male coupling half while the other manifold will have a female coupling half so as to avoid any cross connection.

5 Safety Considerations

a. Flame Resistance

The flame resistance of a hose may be a consideration for certain installations. There are a number of test methods that can be used to evaluate the flame resistance of hose or materials including **UL 1820**, **UL 723, UL 224, UL 94, ISO 15540** and **MSHA (reference CFR 30, Part 18)**. The Mine Safety and Health Administration (MSHA) is used to set the flame requirements for the hose cover material to be used in mining application. DNV (Det Norske Veritas) uses the fire resistance test from **ISO 15540** to set the requirement for hose used on commercial shipping vessels. The **UL224** Vertical Wire Burn Test (VW-1) can be modified to evaluate the flame resistance of the hose as a finished product.

UL94 is a common test method used to quantify the flame resistance for commercial building materials. It provides for a both horizontal and vertical burn tests which can be conducted on a singular material or on the entire hose wall cross section. The horizontal flame test investigates the ability of the hose material to resist a flame's ability to propagate along a horizontal length of material. The UL vertical burn test requires a higher level of flame resistance and investigates a material's ability to resist combustion or self-extinguish.

Federal, State, and Local building codes should be consulted for determining the applicable flame requirement for the hose material used in electronic cooling applications. For applications that require compliance with **UL 62368-1**, a compliance engineer should be consulted for interpretation of the flame resistance requirement.

b. Pressure/Burst

When selecting a hose for an application, the designer should determine the maximum system pressure possible during operation. This can be limited by the pump capacity or pressure relief valve setting. Once the maximum possible system pressure has been determined, a hose should be selected with a manufacturer's maximum operating pressure rating that is equivalent or greater than the maximum system pressure. The burst pressure of the hose refers to the minimum pressure that should be achievable during a test of unaged hose that progressively pressurizes the hose to failure. The minimum burst pressure considers a safety factor over the maximum operating pressure of the hose. The safety factor may vary based on the application but 4:1 is a typical safety factor for industrial fluid systems. The burst test method details can be found in **ASTM D380**. For applications that require compliance with **UL 62368-1**, the hydrostatic pressure test method may be applicable. These test methods include heat exposure and thermal cycling pre-conditioning of components prior to the hydrostatic test. Refer to **UL 62368-1** for specific exposure conditions and test methods.

c. Misc. Consideration

For applications that require compliance with **UL 62368-1**, the document should be reviewed for the test methods and performance limits for vibration resistance and thermal cycling resistance.

d. Fail Safe Considerations

Fluid exposure to electrical components can create an unsafe condition. System designers should consider insulation, barrier materials or other means to effectively isolate electrical components from potential coolant leaks that could develop from the different components of the coolant loop. Reference **UL 62368-1** for fluid leak fail safe compliance requirements.

6 Storage/Shipping Considerations

a. Environmental Conditions Impact on life of hoses

Rubber hose can be degraded by exposure to temperature extremes, humidity, ozone, sunlight, liquids, and even insects or rodents. The storage and shipping conditions should typically be cool, dry, and dark. Where possible, bulk hose should be stored in its original packaging. Additional storage details can be found in the **ARPM Hose Handbook IP-2.**

The shipping environment can also impact the hose selection. Shipping temperatures can vary widely so the hose temperature ratings should be reviewed for compliance with this temperature range. If the system is filled with fluid, the shipping environment and fluid selection will need to be such that fluid freezing is not possible or is accounted for by the system design. Additionally, the hose length connected to the barb manifold should be securely held to the rack frame in a manner that does not kink or damage the hose. The location of the hose should be such that it is protected against damage from snagging, crushing, or cutting during shipping and handling.

b. Environmental Conditions Impact on life of Couplings

Storage should be in a clean, dry environment, and prolonged exposure to direct sunlight or areas of high ozone should be avoided. Extended exposure to harsh conditions can cause premature aging of seals, degradation and shortened life of the product. Exposure to excessive moisture or a humid environment can affect the outside metal surfaces.

The life of a coupling set can be extended by utilizing two different levels of protection. The first level is a protective dust cap engineered to fit both the coupling and the nipple which safeguards the mating surfaces from dirt and contaminants while in the disconnected position. The second level entails generic, disposable protective caps or plugs used in shipping, transporting or preassembly. In most cases, the end customer will likely request their preferences.

c. Shipping with Coolant; Environmental Considerations

Shipping without fluid places responsibility upon the assembly technician to maintain a contaminant-free environment, and cleanliness of the coolant during hoses/couplings assembly. When shipping with fluid (prefilled), if traveling by air, ocean, or rail without protection from cold harsh environment, there is a chance of the coolant freezing and damaging couplings/hoses. If units ship with hoses and couplings in a non-connected position, proper precaution must be taken to protect the couplings (dust caps) and hoses (strapping/supports). Proper packaging, reinforced crating and other protective support should be applied to mitigate the chance of shifting or movement during transportation.

7 Conclusion

This document was written as a collaborative effort from participants contributing to the ORV3 Blind Mate Liquid Cooling Interfaces Group in the Open Compute Project. There is currently no industry standard that provides design and performance requirements for hoses and manual couplings for use in liquid computer cooling applications. As such, this document is meant to provide foundational information about flexible hoses and manual coupling that are used to connect the ORV3 rack manifold to the coolant supply loop. Many options and best practices were highlighted for system designers to consider when selecting components. Additionally, information regarding performance attributes, environmental conditions, shipping considerations, and safety/compliance guidelines have been provided. As the field of liquid cooling for electronics progresses, application experiences and observations can be added to this document to provide additional guidance.

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9 About Open Compute Foundation

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