



Linear Motion Design for Washdown Applications

Selecting the Right Components for Spray, Rinse, Steam, Caustic, and Food Processing Equipment

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Introduction

The design and build of processing, packaging, handling, and automation equipment in a washdown environment creates challenges for the Design Engineer specifying the components within the system. Adding additional pressure in industries that handle food, beverages, or pharmaceuticals are the regulations, standards, and inspections required to produce and maintain a piece of equipment. Specifically in this white paper, there is an examination of the sound engineering practices and design principles needed to ensure the performance of mechanical linear motion components in sanitary, washdown, or chemically cleaned environments.

A "washdown environment" is one that utilizes either by hand or by automatic means, cleaning with water, chemicals, or a mixture of these. This washdown process can be as simple as a cloth and bucket, use of a hose to spray clean, or it can be under sophisticated high pressure and controlled systems. The automatic cleaning operation on industrial equipment is often called CIP (clean-in-place) or SIP (steam-in-place). The goal of these washdown operations is to kill and eliminate bacteria or other micro-organisms that can cause and spread disease. In recent years, examples of incidents such as e-coli breakouts and mad cow disease have rightfully led to greater scrutiny on processing equipment that may contain areas where unwanted bacteria can develop.

The following areas will be covered:

- What regulations / agencies are in place?
- What are the best washdown compatible materials?
- What are the best design practices for mounting linear motion in a washdown environment?
- What are the best linear motion components for use in a washdown application?

Regulatory Agencies and Standards for Washdown Design

While there is no specific agency or standard that “approves” or “disapproves” a linear motion system, there are multiple sources on local, state, and federal levels that will inspect equipment that is installed and in use. Many of these organizations publish standards and guidelines that a manufacturer needs to “comply” with in order for the finished equipment to meet acceptable performance and cleanliness standards. Compliance or compatibility of the materials selected for use in a machine is the responsibility of the material or product manufacturer, as well as the equipment Design Engineer.

Regulatory Agencies and Standards Organizations:

FDA (Food and Drug Administration)



The FDA is the regulatory division within the Health and Human Services Department of the United States Government. They determine the standards for materials that are used in relation to contact with food and food products. They publish the *Code of Federal Regulations (CFR)* which is the code of general rules covering a broad range of areas. Within that code, *Title 21 – Food and Drugs*, contains nine volumes which have divisions that cover things such as indirect additives from contact with components made of polymers, production aids, sanitizers, etc. The FDA does not have a department that is responsible for inspections or oversight of the materials a company produces. However, they provide specifications for the makeup and properties of materials used in processing equipment. A material that meets the standards set forth can be considered “FDA compliant”. It is the responsibility of the material producer and machine builder to ensure that the materials used are compliant with the FDA guidelines.

For further information and downloads from the FDA, visit www.fda.gov

USDA (United States Department of Agriculture)



The USDA is responsible for the regulations and enforcement within food agriculture, meat, and poultry processing. They cover the manufacture, handling, and packaging of food items. The USDA requirements for materials are satisfied by being FDA compliant (see FDA details), but may require a letter of guarantee that the products are manufactured in accordance with regulations be on file if they are used in direct food contact. Then a material or components could be considered to be “USDA compliant”.

For further information and downloads from the USDA, visit www.usda.gov

3-A Sanitary Standard, Inc.



3-A SSI is an independent, not-for-profit organization that was created to help set standards and best practices for the equipment and process used in the dairy industry. It is composed of many varied representatives from government agencies, manufacturers, and processors. Many states have now required



HACCP (Hazard Analysis & Critical Control Points) – *sometimes pronounced “hass-sip”*

- A management system dealing with the analysis and control of hazards in raw food processing, handling, manufacturing, distribution, etc.
- Certified auditors inspect processing plants and their equipment and much like ISO or AS9100, grade them on their performance to the system.

GRAS (Generally Recognized As Safe)

- A voluntary notification of ingredients that are in substances intentionally used as food additives. The term is sometimes used in an overall sense to describe historically and scientifically acceptable materials and practices.



that dairy equipment meet the 3-A standards and that their symbol is prominently displayed. In order for a material or piece of equipment to display the 3-A symbol, it must use 3-A approved materials. They publish annually a list by product, grade, form, and supplier and these materials may not be replaced by a generic alternative.

For more information and downloads from 3-A, visit www.3-a.org

NSF International (formerly the National Sanitation Foundation)



An independent organization, NSF sets the standards in regard to all direct and indirect drinking water additives. In order to display the NSF symbol, a manufacturer needs to submit an application for approval. These approvals are for a finished product or device, not for specific materials or components. However, all components within the device must comply with the standards.

For more information, submission guidelines, and downloads from NSF, visit www.nsf.org

ASTM (American Society for Testing and Materials)



ASTM is an independent, not-for-profit organization designed to voluntarily establish standards for a range of products, systems, and materials. Their guidelines are strictly voluntary and do not become binding in a legal sense unless they are referenced by a government body in a regulation or they are referenced in a specific contract.

For further information and downloads from ASTM, visit www.astm.org

European Organizations

The European Hygienic Design Group (EHEDG) published guidelines for the manufacture of food processing equipment, but does not issue standards. Some European countries require that equipment be tested and approved by the EHEDG, based on its ability to be cleaned.

The International Dairy Federation (IDF) and the International Standards Organization (ISO) are also involved in setting cleanliness standards for some European countries.



Best Materials for Washdown Design

One key to successful linear motion design for a washdown environment is the choice of the materials used for the bearing, shaft or rail, and seal components. To achieve the requirements needed for corrosion resistance, proper standard and regulation compliance, and machine performance requires the right selection of materials.

Stainless steel is typically the preferred material for general use in direct food contact areas because of its corrosion resistance and durability. However, there are variations in stainless steel grades mostly in the levels of chromium and nickel.

Compliance or compatibility of the materials selected for use in a machine is the responsibility of the material or product manufacturer, as well as the equipment Design Engineer.

300 Series Stainless Steel

In general, 300 series stainless steel is the most widely accepted material for food grade and medical applications. It is relatively soft, cannot be hardened, and is also non-magnetic. Each of the grades below can have different types that have slightly different formulations with varying strengths and weakness based on the addition to the mixtures.

303 – also referred to as “A1” under ISO standards, it is a free machining version of 304 due to added sulphur and phosphorus.

304 – also known as “A2” under ISO or “18/8” due to the 18% chromium and 8% nickel in its makeup, 304 is the most common grade of stainless steel.

316 – also known as “A4” under ISO standards or “18/10”, is the most commonly used alloy for food and pharmaceutical grade applications. The addition of up to a maximum of 3% molybdenum aids in the prevention of corrosion from industrial chemicals and solvents, particularly pitting that can be caused by chlorides.

400 Series Stainless Steel

There are several types of 400 series materials available, but the most widely available and most used in industry is the 440.

440 – can be heat treated and hardened. It is often used for cutlery, linear shafting, and in applications requiring good wear resistance. It can be hardened up to approximately RC58; however, due to added carbon in its makeup, 440 will oxidize under washdown conditions.

Stainless steels do not rust with a red colored oxide on the surface the way that “rust” is normally observed. If these types of particles appear on a stainless surface, it is most likely due to iron particulate that has contaminated that surface or is coming from fillers within the bearing. To cleanse that surface, a solution of 10% nitric acid and 2% hydrofluoric acid at room temperature can be effective.

Aluminum and Coatings

Aluminum can be used in some areas of a washdown environment where weight is a concern. However, be aware that bare aluminum will have poor corrosion resistance and is susceptible to pitting and cracking. In washdown conditions, aluminum **MUST** be coated for protection. Often anodizing, ceramic coating, or other types of coatings with PTFE or other fillers are used, but may not provide the resistance or life that stainless steel offers. In more caustic chemical washdown environments, stainless steel is the preferred material.

Refer to the [Chemical Reaction Chart](#) for specific information on anodized aluminum interaction with a variety of mixtures.

Electroless Nickel Coatings

These coatings have become increasingly popular because of their corrosion and wear resistance combined with a smooth polished appearance. Some forms include a PTFE infusion to aid in non-sticking properties. Most forms of this coating are FDA compliant as well.

Plastics, Polymers, and Fillers

These non-metal materials tend not to have the corrosion resistance and durability of metal surfaces such as stainless steel over time, and are

To achieve the requirements needed for corrosion resistance, proper standard and regulation compliance as well as machine performance requires the right selection of materials.

thus not used as often as major components in food and pharmaceutical equipment. However, due to cost, weight, manufacturability, etc., they are increasingly being used “under the hood”, inside of mechanical drive components, guides, bearings, fasteners, and more. Many solid plastics, such as injection molded bearing inserts, can present drawbacks in washdown applications in that most will absorb liquid, causing the component to swell and increasing the potential for binding and failure.

Also, be aware that each of the standards organizations covered earlier has extensive information on a wide variety of plastic materials that are acceptable. However, along with the base plastic, each polymeric material will usually have fillers blended in by the manufacturer. These fillers are added to enhance performance in areas such as increased load capacity, lower coefficient of friction, etc. Be sure that these fillers also are in compliance with the standards.

Best Design Practices for Linear Motion in a Washdown

Linear motion components offer their own unique challenges when being designed for washdown applications. Rotating components need to be mounted and sealed within a limited area, but because the moving component of a bearing, slide, or actuator system travels in a linear fashion, the space needing to be sealed or cleaned will be far greater; often up to several feet. Below are some tips on how to minimize areas of potential bacteria buildup and maximize cleanability.

Linear Bearing & Guide Design

Linear Re-Circulating Ball Bearings – use only stainless steel sealed bearings that have “compliant” seal materials and approved lubrication.

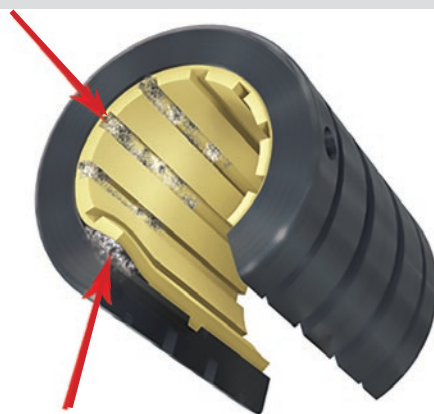
Plain Bearings – there are two basic types to be aware of when considering plain bearings. When using plastic inserts, be aware of moisture absorption that will lead to the bearing material swelling. This can result in binding issues. If the inside diameter is increased to deal with the swelling, it can often cause loose tolerances and inaccuracies in the system.

It is best to avoid open-ended bearings with grooves or inserts in areas that may be susceptible to bacteria buildup. These two-piece type bearings will allow the microscopic bacteria to seat in the crevices, grooves, and to hide between the outer shell of the bearing and the plastic bearing insert. One-piece bonded bearings eliminate this potential for bacteria collection.

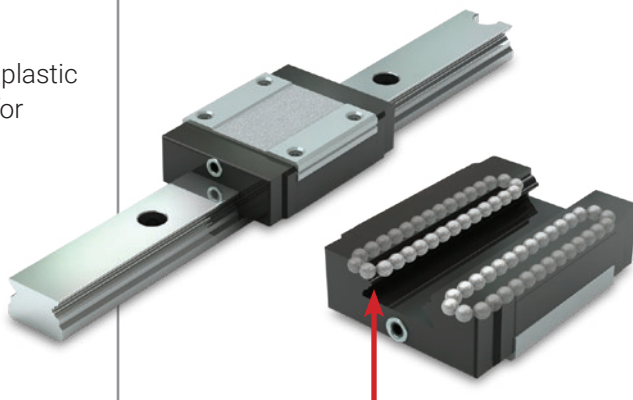
If they are to be used in a food grade environment, ensure that the materials and fillers are “compliant” to applicable standards.

The same principle is true for recirculating ball bearing type products, such as roundway linear ball bearings and profile rails. They provide advantages such as low friction, tight tolerances, and are often available in stainless steel materials with FDA compliant lubrication. However, they can present disadvantages in that they require grease lubrication to be used due to the metal-to-metal contact. This lubrication picks up material from the food items being processed and can then become trapped inside of the multiple crevices and cavities around the balls and in the raceways of the bearing. This can potentially be a breeding ground for unwanted bacteria.

Bacteria builds up in grooves and crevices.



Two-piece bearing allow bacteria build-up between the outer shell and the plastic bearing insert.



Recirculating ball bearings require grease and have numerous crevices where that grease will lodge and be a potential collection point for bacteria growth.

The best solution for most applications is to utilize a one-piece bonded bearing. The bearing materials (discussed later on page 16), are PTFE based, self-lubricating, and require no external lubrication that can collect potentially contaminated material. In addition, there are no grooves, crevices, or space between liner and bearing shell where residue can become lodged allowing bacteria to grow. The bearing material and outer shell are bonded together creating a true one-piece bearing.

In vertical applications such as those found on in-line and carousel bottle filling machines, it is advisable to utilize a bearing that is sealed at the top end. This eliminates contamination and the majority of fluid in the filling and washdown process from penetrating the bearing I.D. Yet it allows the liquids that do get into the bearing system to easily flow through and exit at the bottom of the assembly.

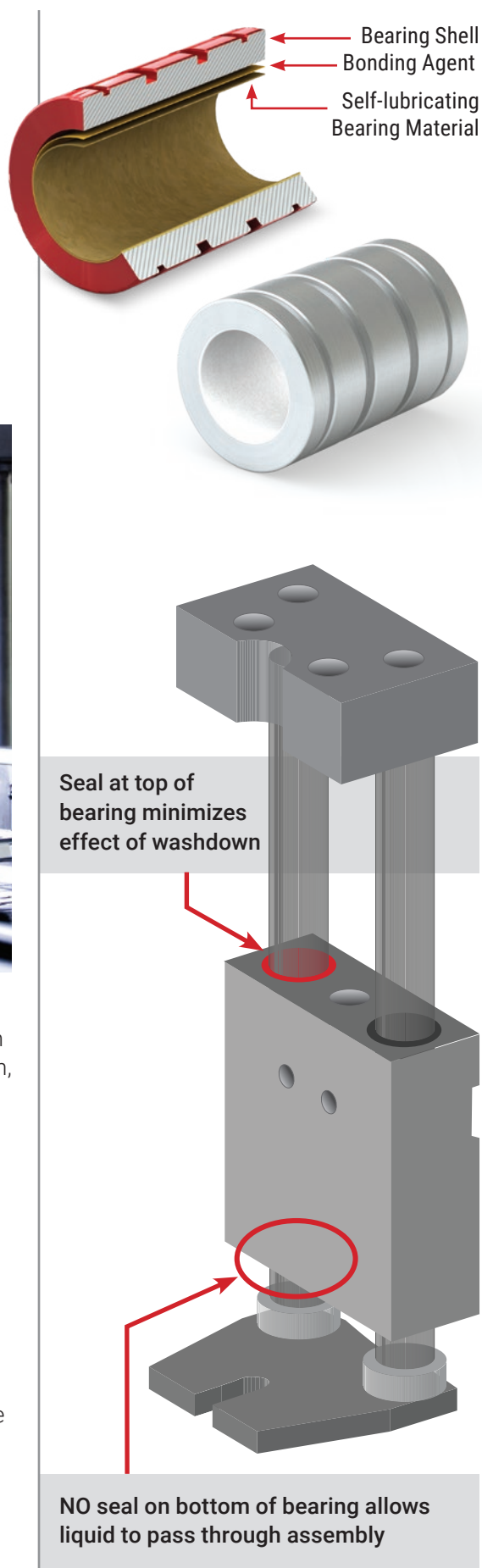


Another area of potential concern in this type of configuration is that the many multiple component sub-assemblies utilizing a parallel shaft design can experience bearing binding problems due to misalignment. In addition, these multiple components are also susceptible to bacteria buildup around the connectors and joints. Newer technology that incorporates dual rail load capacities and functionality into a single rail design can eliminate potential areas of contamination collection. See the following *Rail Design / Selection* section for more details.

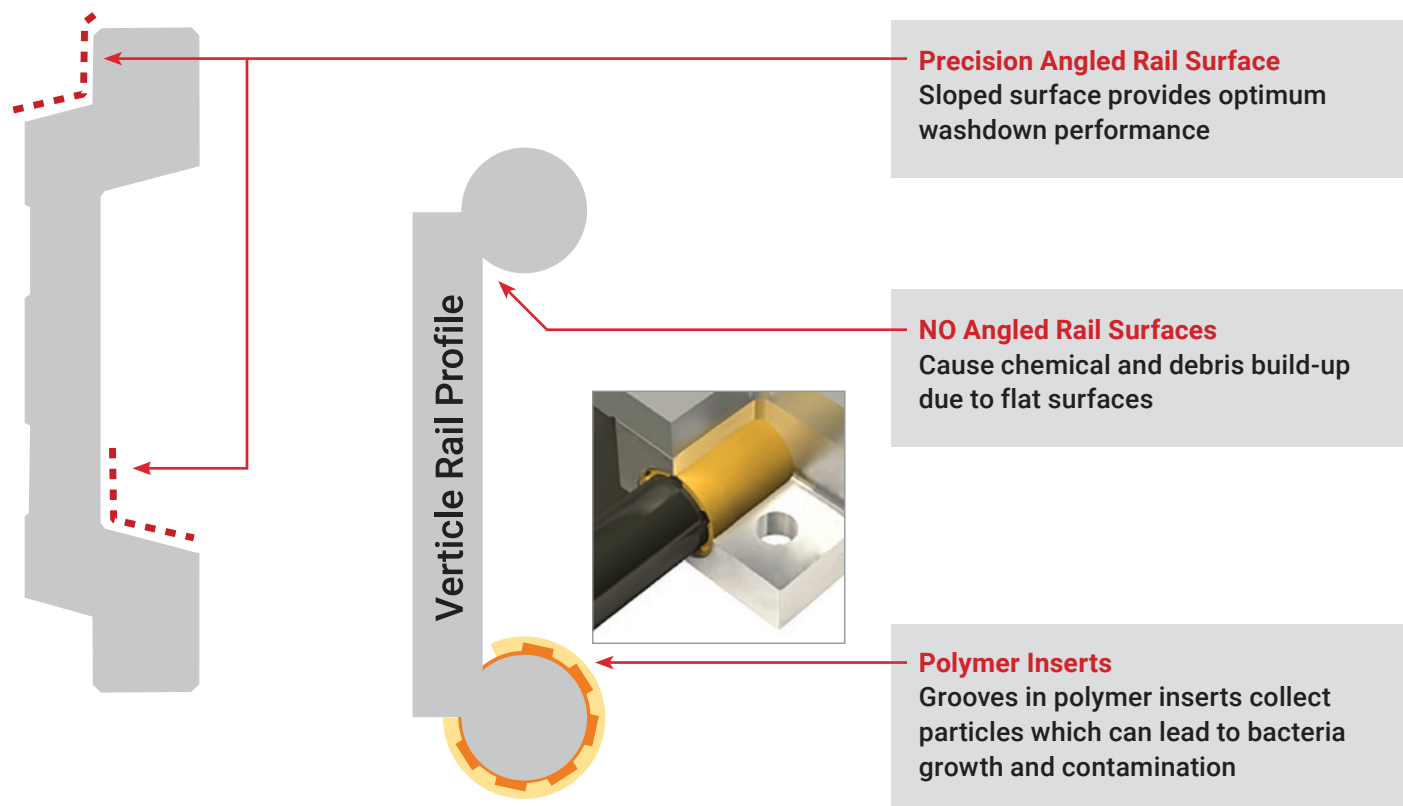
Rail Design / Selection

It is best to avoid as much component assembly as possible in a washdown environment. Traditional methods for linear assemblies utilize a shaft and support rail bolted together, which are then bolted to a mounting plate or carriage. Each of these connection points creates a joint, crack, or crevice and a potential location where liquids can penetrate or where bacteria can begin to cling and buildup over time.

New technology in linear motion has created slide assemblies that eliminate the need for traditional multiple components and connectors. Unique 2-piece slide systems are an ideal solution for washdown



environments. In addition, these new style linear motion components are designed with smoothly curved edges that do not have recesses where buildup can occur.



Linear Roller Bearings (cam follower style) – typically used with a v-guide type rail or as a cam follower, these bearings have the internal bearing raceways lubricated for life and are permanently sealed with either a rubber seal or stainless steel shield. If they are to be used in a food grade environment, be sure the seal and lubricant is “compliant” with the applicable standards.

Shafting and Rails – many different materials are available; 303, 304, 316, 440, coated aluminum, and more. Be sure that the grade selected is compatible with the washdown conditions and regulations in the particular environment.

Linear Slides – these are typically twin-rail systems that are built up on a mounting plate, utilize round rail or profile rails with recirculating ball bearings, and have a top plate. These slides can be built with a variety of washdown compatible materials. For food grade type applications, they can also be built up with “compliant” materials.

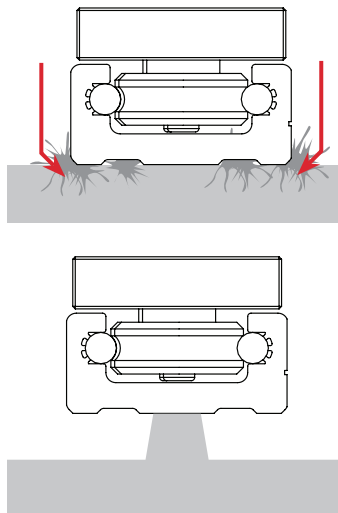
Linear Actuators – typically the outer housing for a belt driven linear actuator is anodized aluminum. As discussed earlier, aluminum can be susceptible to pitting and corrosion, so these types of linear motion are not ideally suited for washdown applications.

It is best to avoid as much component assembly as possible in a washdown environment.

Standoffs

When mounting linear rails, it is a good practice in washdown applications, especially where contamination and bacteria buildup are a concern, to use standoffs as a way to maximize cleanability around the linear motion system. Below is an exaggerated example of good practice when mounting with standoffs.

NOTE: Be sure to calculate shaft or rail deflection when using standoffs to ensure proper operation.

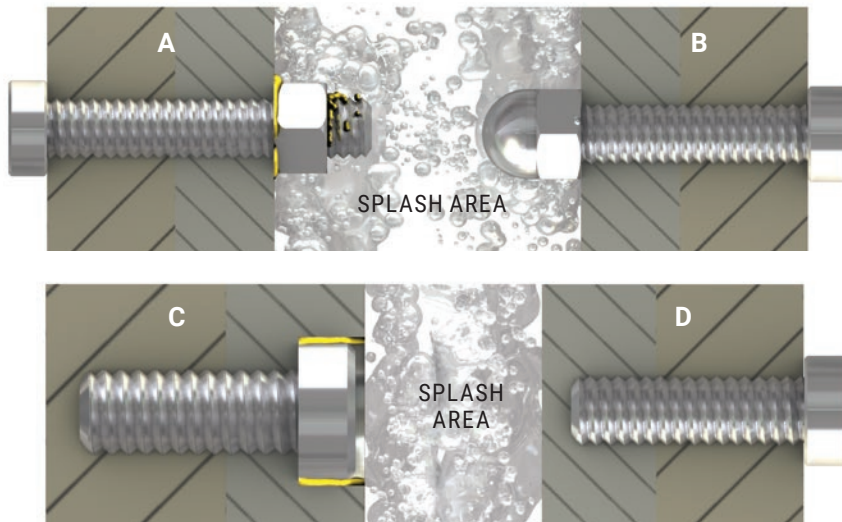


◀ Areas of potential build-up behind rail

◀ Easy access to clean behind the rail

Fastener Location

When possible, avoid mounting connectors from the washdown side. They protrude and create another area where contamination can collect. It is best to bring the connector up through the bottom of the rail to be mounted. If necessary and connectors enter the washdown area, use a domed nut for easier cleaning.



◀ Potential for bacteria buildup (A) vs Domed nut for cleanability (B)

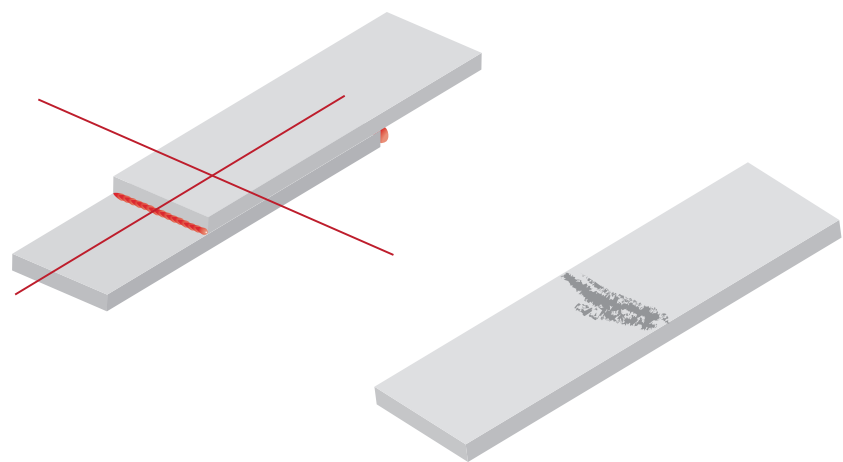
◀ Potential for bacteria buildup (C) vs no exposure to splash area (B)

Location of Linear Components

Particularly in food grade applications, it is important to consider the location where the linear motion device is to be mounted in relation to the food being processed. When components that are not FDA compliant or that do not meet other regulations for food contact, are used over the open food path or in a position where it could potentially come into contact with the food items being processed, risk can be eliminated by installing a stainless steel shield or cover over the components.

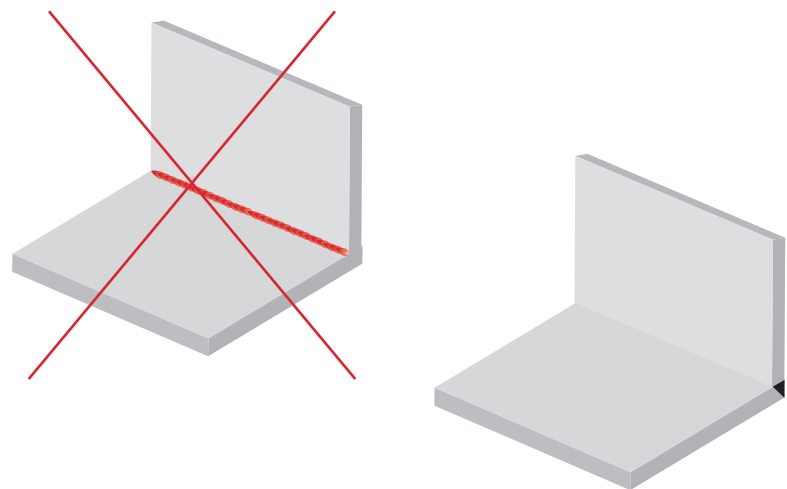
When constructing shields and other covers, it is important to give consideration as to how the panels and plates are to be connected or welded together. Small collection points for moisture and the potential for corrosion and bacteria buildup are the result of leaving the irregular

surface of a weld exposed to the splash area. Whenever possible, the best case scenario is to radius all corners.



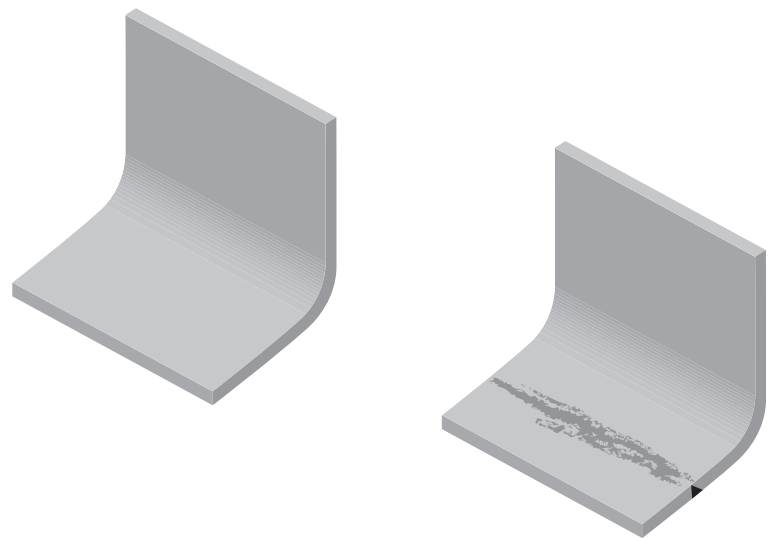
◀ Exposed irregular weld can collect moisture and lead to corrosion of bacteria buildup.

◀ Hide weld behind plate out of splash area and polish exposed surfaces smooth.



◀ Exposed weld leads to corrosion and bacteria buildup.

◀ Hide weld line behind plate out of splash area.

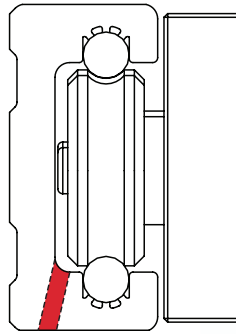


◀ A radius in the corners eliminates sharp joints that are difficult to clean.

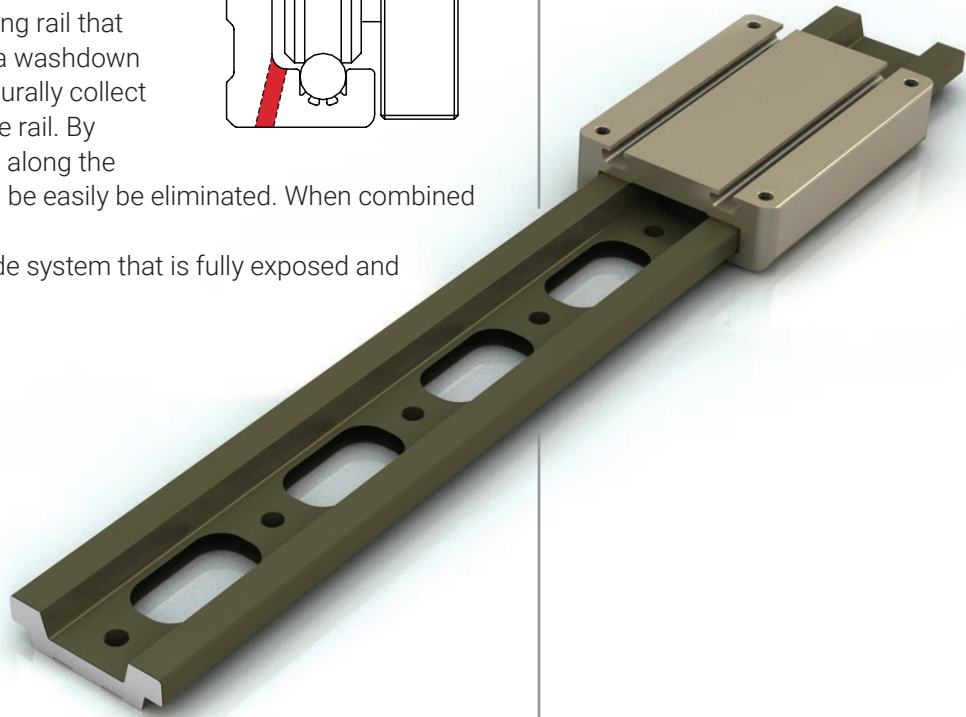
◀ If a weld is needed, utilize material with a radius and move the joint away from the corner.

Another tactic used to help in the management of moisture and fluids around linear motion components is to add weep holes, drainage channels, slots, or other porting features designed to channel the moisture away from potential pooling areas.

The example below shows a long rail that often is mounted laying flat in a washdown environment. Liquids could naturally collect and pool along the length of the rail. By adding slots at strategic points along the rail, these collection points can be easily be eliminated. When combined with standoffs, this type of rail feature creates a linear guide system that is fully exposed and can be sanitized completely.



◀ The addition of periodic weep holes along the length can aid in draining liquids away from the linear rail.



PBC Linear Products for Washdown Design

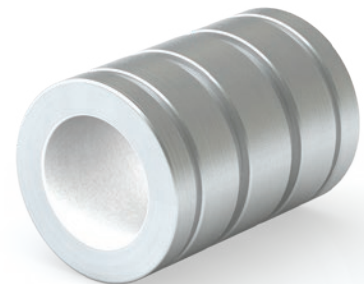
PBC Linear offers a wide range of linear motion solutions for washdown and food processing applications. The key is to know your application and match up the correct components based on the industry standards and chemical makeup of the washdown you utilize.

RST – Round Shaft Technology – Simplicity Self-lubricating Bearings

“FL” Inch / “FM” Metric Series – The outer shell of the standard bearings is anodized aluminum. For washdown and food grade bearings, it is best to use the optional 316 stainless steel bearing shell. The part number is noted with an “S” (Example ... FLS16).

Along with not absorbing water and being affected by swelling, the bearing liner materials are *self-lubricating* and eliminate the need for external lubrication. Not requiring lubricants, even food grade type grease and oil, decreases the amount of material deposits and buildup on the shaft surface, and the potential for bacteria buildup.

- **FrelonGOLD®** – The FrelonGOLD bearing liner has good chemical resistance, but is **NOT** FDA compliant for direct food contact*. It can be used in wet environments, but due to the composition of the fillers, over a period of time, surface oxidation may appear. Do not use it with deionized water. The FrelonGOLD material is compatible with RC60 steel, ceramic-coated aluminum, and 440 stainless steel shafting.

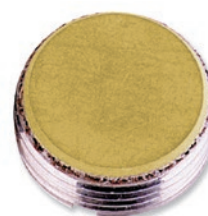


◀ Frelon GOLD®

- **Frelon® J** (optional liner material) – This is a polymeric based material that is **NOT** FDA compliant, but performs extremely well in washdown and caustic applications. It is compatible with 300 series stainless steel and clear anodized shafting.

*(*NOTE: FrelonGOLD and Frelon J lined bearings can be used in food processing applications when they are to the side or below the food items and will not come into contact. If the FrelonGOLD or J bearings are above food items that have not been packaged, a shield is required.)*

- **Frelon® W** (optional special order liner material) – This is an **FDA compliant** material that is suited for direct food contact and is available as a special order item from PBC Linear. It is compatible with 300 series stainless shafting.



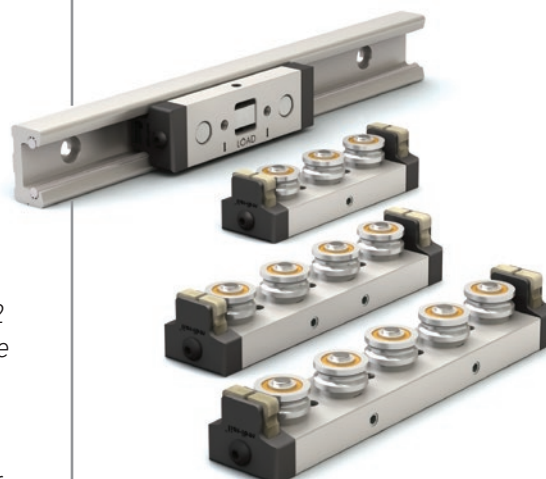
◀ Frelon® J



◀ Frelon® W

Redi-Rail® – (CRT) Cam Roller Technology Linear Guides

Highly resistant to corrosion in washdown applications, the rail is composed of an aluminum base that is coated with an “antimicrobial powder coating”. 440 stainless steel shafts are embedded in the aluminum and provide a hard raceway. The 3, 4, and 5-wheel slider has 440 stainless bearings and stainless hardware for the preload adjustment feature. The stainless end caps have a seal that is NSF registered for H1 & H2 applications. *(NOTE: H1 indicates that it may be used in applications where there may be incidental contact with food. H2 indicates that it may be used in food processing applications where there is no direct contact with food.)*



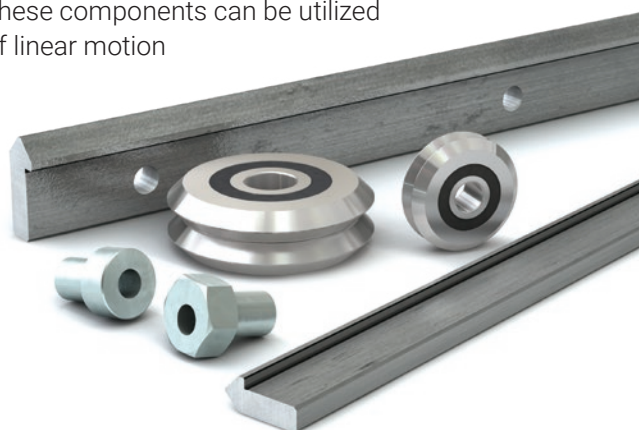
Commercial Rail Linear Guides

These guides are non-precision, cost effective linear guide solutions for washdown applications. Roll formed 304 stainless steel rails guide a 3-wheel slider composed of 440 stainless steel bearings.



V-Guide System – (CRT) Cam Roller Technology V-Wheel Bearings and Linear Guide Rails

For washdown application, the V-Guide System offers 400 series stainless steel rails. The V-wheel bearings are constructed of 420 stainless steel raceways and 304 stainless steel shields or nitrile rubber seals. The concentric and eccentric wheel or mounting bushings are composed of 303 stainless steel. These components can be utilized to build up a variety of linear motion configurations.



Conclusion

Whether in an outdoor environment, a simple water washdown, or in a location working to eliminate bacteria and other contaminants through the use of chemical solvent mixtures or caustics, the Design Engineer, processing equipment, maintenance teams, sub-assemblies, and the moving components installed are increasingly being asked to meet difficult challenges.

A good understanding of the environment, life expectancy, standards, and other parameters along with the knowledge of the materials that meet these challenges and regulations is important to select the right components for the conditions.

PBC Linear has experience in a variety of outdoor, washdown, and food processing applications. In addition, a broad range of products are available that provide an engineer or maintenance technician multiple options to solve the problems associated with liquid and chemical interactions. Utilizing these products, application experience, and best practices for working in washdowns, predictable life for the linear motion components and assemblies can be achieved.

Further Information

If you're still having difficulties, contact a PBC Linear Application Engineer to discuss your application. You can contact an engineer directly by calling 1.800.962.8979 (from within the USA) or +1.815.389.5600 (from outside the USA). If you prefer, e-mail an engineer at: appeng@pbclinear.com

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