Chapter 6

Hygienic Design of Open Food Processing Equipment

F. Moerman[1] **and K. Lorenzen**[2]
[1]Catholic University of Leuven – KU Leuven, Leuven, Belgium, [2]European Hygienic Engineering & Design Group, Frankfurt, Germany

6.1 INTRODUCTION

Food legislation developed in many countries around the globe requires that microbiologically safe food shall be produced by means of process equipment that minimizes the risk of contamination and that is easily cleanable. Good hygienic engineering and design practices have become the tools to reduce or exclude microbial (e.g., pathogens), chemical (e.g., lubricating fluids, cleaning and disinfectant chemicals), or physical (e.g., glass, wood) contamination of food. Good hygienic equipment design also allows to eliminate food product "held up" within the process equipment that could deteriorate and affect product quality on rejoining the main product flow. So, also cross-contamination of one batch by a previous batch can be avoided by means of good hygienic design practices. Although initially more expensive than poorly designed equipment, hygienically designed equipment is more cost effective in the long term because it may reduce the downtime required for an item of process equipment to be cleaned, disinfected, or maintained.

Open processes include many different types of equipment according to the product (e.g., dairy, alcoholic and nonalcoholic drinks, ice cream, sweet oil, nutrient fat, coffee, sugar, cereals, vegetables, fruits, bakery products, ready meals, meat, and fish). During open processing, contamination may additionally occur from microorganisms present in the factory and so the operating environment also becomes an important factor. The type and level of product contamination and the stage of the manufacturing process must also be taken into account.

This chapter intends to inform food safety professionals and inspectors/auditors about the risks associated with poor hygienic design of open process equipment. Along with typical examples of poor hygienic design, the necessary technical and practical guidance is given to identify and control open

Food Protection and Security. DOI: http://dx.doi.org/10.1016/B978-1-78242-251-8.00006-0

food processing equipment-related food safety hazards. This chapter may help the food manufacturer to select the most suitable food processing equipment, to construct a food production line that meets all current and future hygienic requirements, and to set up an appropriate food safety management plan (e.g., HACCP) intended to eliminate or control all food safety hazards along the food chain.

In Section 6.2, an overview is given of the current legislation and standards dealing with the hygienic design of food processing equipment. Section 6.3 lists the basic hygienic design requirements that food processing equipment must meet to produce microbiologically safe food products. Section 6.4 describes the hygienic and food-grade materials that can be used in the manufacturing of food processing equipment; Section 6.5 outlines the requirements for the food contact surface finish. In the next sections, we discuss the hygienic design of several open food processing equipment (components) such as open vessels, containers and bins (Section 6.6), framework (Section 6.7), feet (Section 6.8) and casters (Section 6.9), belt conveyors (Section 6.10), motors (Section 6.11), covers and guards (Section 6.12), electrical equipment enclosures and cabling (Section 6.13), human interfaces (Section 6.14), and stairs, raised walkways, and platforms (Section 6.15).

6.2 LEGISLATION, STANDARDS AND GUIDELINES COVERING HYGIENIC DESIGN

6.2.1 Legislation

Annex I of the Machine Directive 2006/42/EC & 98/37/EC (formerly 89/392/EEC and its amendments 91/368/EEC & 93/44/EEC) and Annex V of Council Directive 93/43/EEC on the Hygiene of Foodstuffs require that all equipment used to handle food should be hygienically designed: (a) be so constructed, be of such materials, and be kept in such good order, repair and condition as to minimize any risk of contamination of the food; (b) with the exception of nonreturnable containers and packaging, be so constructed, be of such materials, and be kept in such good order, repair, and condition as to enable them to be kept thoroughly cleaned and, where necessary, disinfected, sufficient for the purposes intended; (c) be installed in such a manner as to allow adequate cleaning of the surrounding area.

6.2.2 US Standards and Guidelines

In the United States, the American Meat Institute (AMI), United States Department of Agriculture (USDA) and 3-A are considered to be the experts in sanitary design. “Sanitary design” in the United States has the same meaning as “hygienic design” in Europe.

6.2.3 European Standards and Guidelines

In Europe, the European Hygienic Engineering & Design Group (EHEDG) is the most experienced organization in the field of hygienic design. Besides these guidelines, many food and equipment manufacturers have developed their own hygiene standards for internal use.

6.3 BASIC HYGIENIC DESIGN REQUIREMENTS

In all stages of design, construction, installation and maintenance of food processing equipment, hygienic design aims to reduce the buildup of food material or microorganisms in individual items of equipment and the complete line, and to ensure that all detectable soil is removed after cleaning (and disinfection). According to European Standard EN1672-2, soil is "any matter, including product residues, microorganisms, residual detergents or disinfecting agents." Food processing equipment should at least meet the following basic hygienic requirements (Moerman & Kastelein, 2014):

- To avoid bimetallic corrosion, the right combination of steels, alloys or metals in the assembly of food processing equipment and food processing support systems must be used. So, piping and components should be constructed out of the same materials to prevent contact corrosion between dissimilar metals (Fig. 6.1). However, this is not always possible.
- Product contact surfaces (including the welds) must be smooth, enabling them to be easily cleaned.
- The design of food processing equipment must prevent bacterial ingress, survival, growth and reproduction on both product and nonproduct contact surfaces. The food processing equipment also must be constructed so as to ensure effective and efficient cleaning over the lifetime of the equipment (Fig. 6.2).

FIGURE 6.1 In this part of the food processing equipment, galvanized steel plate is combined with stainless steel bolts, giving rise to galvanic corrosion between the stainless and galvanized steel components.

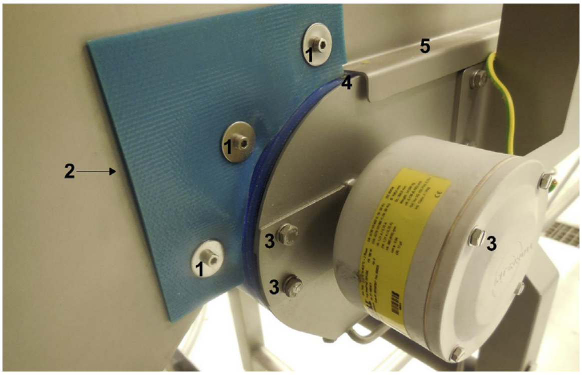


FIGURE 6.2 The blue sheet of plastic used to reduce product spillage is fixed on the equipment surface by means of rivets (1), leaving behind holes in which dirt may accumulate. Dirt built up behind the blue plastic sheet (2) cannot be removed during cleaning procedures. Bolt heads create a lot of crevices (3) where dirt may collect, while reducing the cleanability. Part of the conveyor belt is running beneath the product guide (4), prohibiting effective cleaning of the whole conveyor belt. The product guide also provides a horizontal ledge (5) on which product may lodge. *Frank Moerman, © 2016.*

FIGURE 6.3 Welds must be continuous and smooth, free of pits and cracks. Gaps, lap seams, bolts, and threads will accumulate dirt and will make this equipment not cleanable. *Photo left, courtesy of John Butts, Land O'Frost, © 2016; photo right, courtesy of Joe Stout, Commercial Food Sanitation LLC - Intralox, ©2016.*

- Welding or continuous bonding is preferred over fastenings. Avoid exposed screw threads, nuts, bolts, and rivets whenever possible, certainly in product contact areas. Alternative methods of fastening can be used where the washer has a rubber compressible insert to form a bacteria-tight seal.
- Welds must be continuous and smooth, free of pits and cracks (Fig. 6.3).

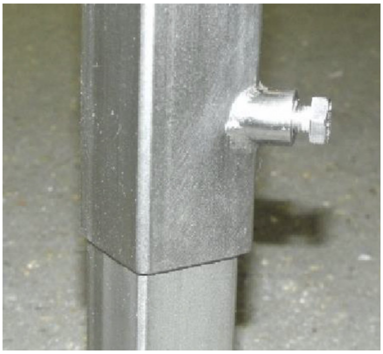


FIGURE 6.4 Penetration of hollow sections of equipment such as frames with bolts is not allowed. Hollow sections shall be hermetically sealed (Kold et al., 2016).

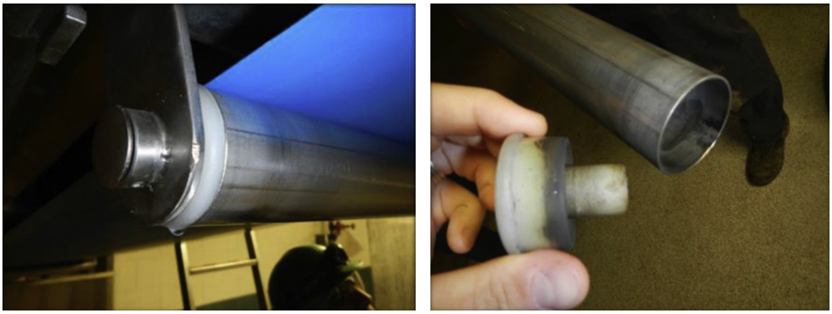


FIGURE 6.5 Hollow roller. *Organization Sanitary Design Workshop, © 2016.*

- In design, construction, installation, and maintenance, hollow areas of equipment such as frames (Fig. 6.4) and rollers (Fig. 6.5) must be eliminated or they shall be hermetically sealed. As such, studs, mounting plates, brackets, junction boxes, end caps, sleeves, and other such items must be continuously welded to the surface, and shall not be attached via drilled and tapped holes.
- Fastening of nameplates on the equipment should be avoided in favor of direct continuous welding (Fig. 6.6). As a further improvement, direct application of graphics on equipment components by laser engraving eliminates the need for identification plates.
- Niches (Figs. 6.2–6.5) such as pits, cracks, crevices, open seams, gaps, lap seams, inside threads, holes that may accumulate dirt and hamper the cleanability of the food processing equipment are not allowed.
- Avoid dead areas, pockets or other conditions that may trap food and harbor contamination. They prohibit effective cleaning and disinfection, and allow for cross-contamination.

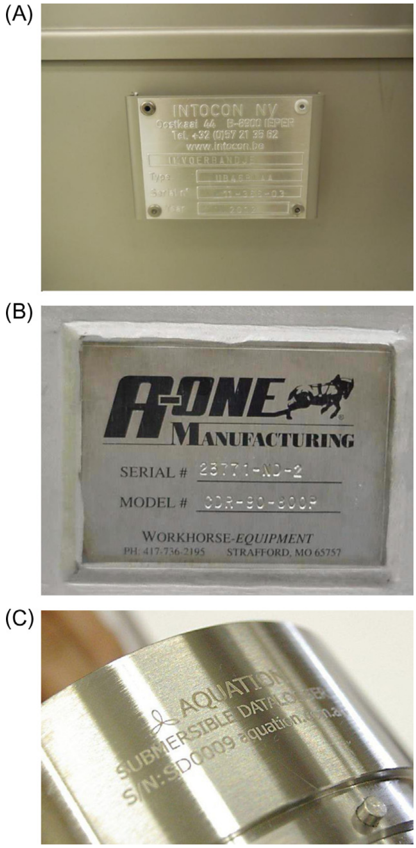


FIGURE 6.6 (A) Nameplates are often fastened to the surface of process equipment by means of rivets. (B) Continuous welding of nameplates onto the equipment surface is possible, but (C) direct application of graphics on equipment components by laser engraving is preferable.

- All inaccessible horizontal flat areas, ledges (Fig. 6.2), projections, protrusions, recesses, edges, etc. where product residues can accumulate should be eliminated.
- The exterior of indirect product contact surfaces should be so arranged that harboring of contamination in and on the equipment itself, as well as in its contact with other equipment, floors, walls, or hanging supports, is prevented.
- For the same reason and to facilitate cleaning, internal angles, and corners should be well radiused.
- All equipment surfaces in the product zone must be so arranged that they are self-draining (Fig. 6.7) to minimize contamination and corrosion risks when liquid food, cleaning and disinfection solutions, and rinsing water are retained during idle periods. Microbes can flourish in stagnant pools

FIGURE 6.7 Equipment surfaces in the product zone must be self-draining, and internal angles and corners well radiused. *Courtesy of Krones AG.*

of water, especially when nutrients are trapped in the internal pockets. Moreover, accumulated and pooling cleaning and disinfection solutions may contaminate food products.

- Equipment design, therefore, should not permit the formation of condensate that may enter the food zone and contaminate product or product-contact surfaces.
- All parts of the equipment shall be readily accessible for inspection (Fig. 6.8), so as to facilitate the detection of all potential contaminants on representative surfaces throughout the product contact zone. So, all surfaces in the product zone must be immediately visible for inspection, or the design of the equipment shall allow easy dismantling without use of any tools.
- Equipment surfaces must be readily accessible for manual cleaning and disinfection (Fig. 6.9), unless it can be demonstrated that the result of in-place cleaning and disinfection procedures without dismantling is equivalent to the result of dismantled and manual cleaning procedures. All potential obstructions to cleaning, disinfection, and maintenance should be avoided or minimized.
- Instruments not only must be hygienically designed, but also hygienically installed.
- Equipment design must ensure hygienic compatibility with other equipment and systems, such as hydraulics and electrical, steam, air, and water systems.
- Maintenance equipment enclosures and human machine interfaces, such as push buttons, valve handles, switches, and touchscreens, must be designed to ensure food product and water or liquid product do not penetrate in or accumulate on the enclosure or interface. The enclosures should be sloped to an outside edge to avoid use as storage areas. Doors,

FIGURE 6.8 Despite their general acceptance over the last two decades and their mechanical versatility, modular belts, relying as they do on hinges and pins, versatility, modular belts, relying as they do on hinges and pins, are difficult to clean. Especially, the pinholes in the hinges and pins are major dirt and bacteria traps. Hence, all parts of modular conveyor belts at the running side shall be readily accessible for inspection so as to facilitate the detection of all potential contaminants, as well as cleaning procedures.

covers, and panels must prevent entry and/or accumulation of soil. To facilitate cleaning, they should be easy to remove.

- Bearings should be mounted outside the product area to avoid contamination of food products by lubricants and to exclude the ingress of bacteria. When the bearing is within the product area, its design should allow the passage of cleaning fluid.
- Food grade lubricant (Fig. 6.10) should be used, and leaking of lubricant onto food product must be excluded (Fig. 6.11). To protect the product zone, a drip pan should be used, or motors driving equipment components such as belt drives should be placed outside the product area. If they are within the splash area, they should be protected by a removable cover.

FIGURE 6.9 Belt lifting device used to provide improved access for cleaning and disinfection of the conveyor bed (frame and wear strips), as well as the bottom side of the conveyor belt. *Courtesy of Intralox.*

FIGURE 6.10 The process equipment is overlubricated with a nonfood-grade red grease. *Courtesy of John Butts, Land O'Frost, © 2016.*

FIGURE 6.11 This motor without drip pan is positioned above the product stream, increasing the risk of lubricant dripping onto the food product. Dirt also may build up in the chain guard.

6.4 MATERIALS OF CONSTRUCTION

6.4.1 General Recommendations

Construction materials for open processing equipment should be as hygienic (smooth, nonabsorbent, nontoxic, easily cleanable, impervious and nonmold supporting), as chemical resistant (nondegrading and maintaining its original surface finish after sustained contact with product, process chemicals, cleaning agents), as physically durable and mechanically stable (resistant to steam, moisture, cold, the actions of cleaning and disinfecting agents, abrasion and corrosion resistant, resistant to chipping, unbreakable), and as easy to maintain (Hauser et al., 2004a; Partington et al., 2005) as possible. Table 6.1 gives an overview of the corrosion durability of the most frequently used materials in the construction of open equipment.

6.4.2 Use of Metals and Alloys

Nonferrous and ferrous metals and alloys are used in the construction of equipment and services for the food industry. Alloys for food contact may only contain aluminum, chromium, copper, gold, iron, magnesium, manganese, molybdenum, nickel, platinum, silicon, silver, tin, titanium, cobalt, vanadium, and carbon (EDQM, 2013). The austenitic chrome-nickel or chrome-nickel-molybdenum stainless steels are used for the construction of open equipment, as well as ancillary support systems in the food industry. Because AISI SS 304/304(L) suffers from some corrosion over a long time period, especially in the presence of chloride (e.g., salt, sodium hypochlorite), stainless steel AISI SS 316(L) is commonly used as construction material for food processing equipment. Galvanized steel should be avoided in the product contact area (the splash area included), as the zinc coating may peel off and is easily dissolved in diluted acids and bases, releasing zinc and traces of cadmium and lead. Painted steel (Fig. 6.12) should never be used in contact with food, because paints can crack or peel off. Brass, bronze, and copper quickly react with strong alkaline detergents, sodium hypochlorite, acid, and salty food, making them not suitable in the food contact zone. Aluminum is attacked by alkaline detergents, sodium hypochlorite, and acid food, but anodized aluminum is acceptable in the food contact area (Moerman & Partington, 2014).

6.4.3 Use of Plastics

Plastic materials may be used to preclude metal-to-metal contact (e.g., for bearing surfaces), because of their plasticity and corrosion resistance, and because of their smaller thermal mass as compared to metals. The latter may be advantageous to reduce the pull-down load in freezers. Plastics must have high mechanical strength (resistant to aging, creep, brittleness, fatigue,

TABLE 6.1 Corrosion Durability Classes

Class	Materials
1	• Stainless steel AISI 304(L), AISI 316(L) • Hastelloy B & C • Titanium • Polyvinyl chloride (PVC) • Teflon (PTFE) • Polypropylene (PP) • Polyethylene (LDPE, HDPE) • Polyvinylidene fluoride (PVDF) • Polysulfone (PES) • Polyetheretherketone (PEEK) • Polystyrene (PS) • Poly(methyl methacrylate) (PMMA) • Epoxy resin • Neoprene rubber • Ethylene propylene diene monomer (EPDM)-rubber
2	• Hard chromium plated steel • Nickel-plated steel • Nickel-plated brass • Anodized aluminum • Nickel • Acrylonitrile butadiene styrene (ABS) • Polyamide (PA) • Polyacetal plastics (POM) • Phenolic resins (PF) • Ureum and melamine resins (UF, MF) • Polyurethane rubber (PU) • Nitrile rubber (NBR)
3	• Galvanized, carbon and painted steel • Cast iron • Bronze and brass • Copper • Zinc • Aluminum • Polycarbonate

1 = highly durable, 2 = moderate, acceptable durability, 3 = sensitive to chemical attack.

etc.). Plastic components which shatter under adverse tensile or bending loads, or under impact, can cause food product contamination with sharp particles that are not detected by common in-line metal detectors. Such materials therefore represent a similar hazard to glass.

Most plastics (especially PA and ABS) can absorb moisture. In extreme cases, and in addition to simple porosity effects, swelling becomes visibly noticeable and the mechanical performance will degrade. When food

FIGURE 6.12 Paints can crack or peel off.

components diffuse into the plastic, they subsequently may leak back out into "later" food, causing a loss of the perceived quality of the food, such as changes in visual appearance or organoleptic qualities (sometimes called *tainting* of the flavor). Application of formaldehyde resins in the food contact area of food processing equipment is not at all recommended due to formaldehyde that may be released or migrate into the food products produced. Free phenolic compounds (phenol, cresol and/or tertiary-butyl phenol) present in phenolic resins may migrate into food products. Melamine-formaldehyde resins may release melamine and formaldehyde. Also plastics containing plasticizers (e.g., plasticized PVC) are not recommended and should only be used in the nonproduct contact zone. The use of glass-reinforced plastic products should be avoided as it is known that components of glass-reinforced plastic can react with certain wetting agents in detergents. Plastics applied outside the food contact area require no special approval, but they should be easy to clean and resistant to chemicals and temperatures occurring within their immediate installed environment. Porous plastics, which may harbor microorganisms, require special cleaning/disinfection procedures and periodic inspections.

When using a plastic material (belt, gaskets, electric cables, etc.), it is of utmost importance to make sure that the material is able to withstand all temperatures from −50°C to temperatures as high as 121°C (steam sterilization) without cracking or breaking. Moreover, the plastic material must be chemically resistant to alcohols, acid, alkaline, reducing and oxidizing agents, cleaning and disinfection agents, and corrosive food gases at these temperatures.

6.4.4 Use of Rubbers

Rubber products are widely used in food processing equipment, such as for seals, gaskets, hoses, conveyor belting, skirting, milk liners, and feather pluckers. Elastomers must be chemically resistant to fat, cleaning agents and disinfectants. Rubbers which are not in direct contact with food product and located outside the contact area do in principle not require special approval, but they should be easy to clean and resistant to the chemicals and temperatures occurring within their immediate installed environment. Preferably, gaskets and seals should be of a removable type, because they may be degraded by product or cleaning agents or damaged by excessive mechanical or thermal compression leading to severe deformation. In both cases, their cleanability will be adversely affected and ingress of liquids containing chlorides under the gaskets and seals may cause severe corrosion problems, even with stainless steel. Elastomers also must be abrasion resistant (e.g., rotary shaft seals, or seals in static applications subjected to abrasion) and retain their surface and conformational characteristics (no loss of elasticity, no embrittlement, no rubbed-off parts and crevices, etc.). PTFE (Teflon), EPDM, natural (white) silicone, neoprene, nitrile, and nitrile/butyl rubber are usually applied. Note, however, that PTFE elastomers do not have enough elasticity to assure resealing, and EPDM is sensitive to grease and oil.

6.4.5 Other Materials

As it can retain microorganisms which can subsequently grow in the presence of product nutrients, wood is not allowed within the product contact area. Exceptions are butcher's blocks and wooden barrels for ripening of cheese or for producing wines and vinegar. Take care of wood splinters which can result in foreign body contamination. Certain types of insulation are not allowed within the product contact area. To avoid their exposure to the outside, they must be permanently and tightly sealed off from the product zone. Glass may be used as a food contact surface, but its application is not recommended due to the potential for breakage. Ceramics can be applied in the coating of other stable materials and processing equipment for very sensitive food products. They are very hard, but may suffer from porosity and brittleness. All ceramic surfaces in direct contact with food must have smooth, unbroken and lead-free glassy surfaces, entirely free of crazing (small hairline cracks) and blemishes.

6.5 SURFACE FINISH

Product contact surfaces must be finished to a degree of surface roughness that is smooth enough to enable them to be easily cleaned and disinfected. The surface finish must have a roughness area R_a as low as practicable and without cracks, pits or cavities where water or soil might be retained. Although a surface finish $R_a < 0.3$ μm is a minimum requirement in the pharmaceutical industry, a surface roughness $R_a \leq 0.8$ μm is considered as acceptable for the food industry. Surface roughness, R_a, of enclosures in hygienic production areas should not exceed 2.5 μm. As surfaces deteriorate with time, their cleaning becomes more difficult (Hauser et al., 2004a).

The technique used for achieving the appropriate surface finish is of great importance. Although a surface roughness of Ra 0.8 μm can be achieved with different surface finish techniques (glass blasting, ceramic beats blasting, electropolishing, pickling), the topography/structure of the surface can differ a lot, giving different cleaning results.

6.6 HYGIENIC DESIGN OF OPEN VESSELS, CONTAINERS, AND BINS

6.6.1 Interior and Exterior Design of Open Vessels, Containers, and Bins

Appropriately designed and installed open vessels, containers, and bins shall meet the following recommendations (Moerman & Kastelein, 2014):

- Equipment without bottom outlets must be pivoted (Fig. 6.13) over an angle of at least 93 degrees for fully discharging product and cleaning solution. While fully drainable, contaminants from the exterior of the open vessel, container, or bin (e.g., dirt from casters) may not gain access to the food product being discharged.
- The vessel, container, and bin tipped for discharge must be designed for improved cleanability. Vessel corners should be well rounded and hinges must allow for maximum cleanability.

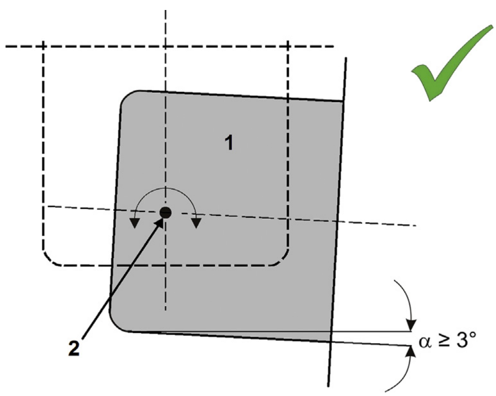


FIGURE 6.13 To fully empty containers without bottom outlet, they must tip over an angle of at least 93 degrees. The interior and exterior of the container must be designed to exclude any contamination of the food product when it is drained. Vessel should have well-rounded bottom corners, with hinges designed for maximum cleanability (Lelieveld et al., 2003; Hauser et al., 2004b).

- Open vessels, containers, and bins with bottom outlets must have their discharge outlet at the lowest level and their bottom shall be sloped (more than 3 degrees toward the outlet). Their corners shall be well-rounded, with a radius equal to or larger than 3 mm (Fig. 6.14).
- The design of the top rims of product-containing equipment (e.g., open tanks, chutes, boxes) must avoid ledges where product can lodge and which are difficult to clean (Figs. 6.15 and Fig. 6.16A). Open top rim designs must be rounded and sloped for drainage (Fig. 6.16B). If the top rim is welded to the wall, the weld must be flush and polished to provide a smooth surface and the rim must be totally closed. Any holes, therefore, must be sealed by welding or by fitting sealed caps (Fig. 6.16B).

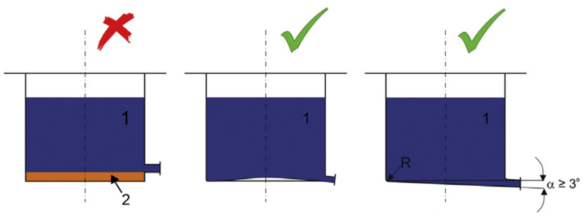


FIGURE 6.14 For good drainability and cleanability, open vessels, containers, and bins used in the processing of food (1) shall have their discharge outlet at the lowest level. Their bottom shall be sloped (more than 3 degrees toward the outlet), and their corners shall be well-rounded. Where food product and cleaning solutions are not allowed to drain, residual soil (2) will be left. Sharp corners (≤90 degrees) must be avoided (Lelieveld et al., 2003; Hauser et al., 2004b).

FIGURE 6.15 A badly designed rolled-over part of top rim provides a ledge where product debris can lodge. *Don Graham, Graham Sanitary Design Consulting LCC, ©2010.*

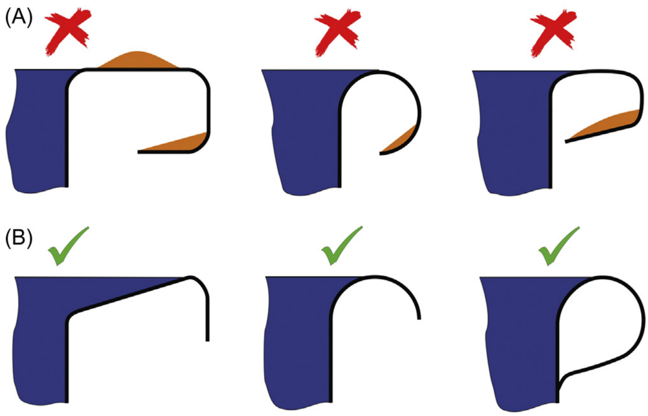


FIGURE 6.16 Top rims may impart rigidity to the construction. (A) However, a rim with an upper horizontal part provides a surface where debris may collect. When the rolled-over part of the rim is badly designed, it may provide a ledge where product debris can lodge. This soil can indirectly affect the product. (B) Open top rims must be rounded in a way that at one side the product drains back in the bulk of the product, while the more exterior part of the rim must allow drainage to the outside. Where preference is given to closed top rims, the top rim should be welded correctly to the wall over its full length. The weld must be flush and polished to provide a smooth surface. The rim must be totally closed and any holes sealed by welding or by fitting sealed caps (Hauser et al., 2004b).

6.6.2 Installation of Agitators in Open Vessels (e.g., Kettles)

Installation of agitators in open vessels should occur as follow (Moerman & Kastelein, 2014):

- Stirrers, homogenizers, or mixers installed via the bottom side or a side wall require sealing of the shaft at the product side. The problem is that seals may wear with time resulting in leakage of product to the outside and product contamination. Parts of the seal may get lost in the product as a foreign body contaminant (Fig. 6.17). Moreover, when the seal gets damaged, product buildup around the shaft will occur, providing nutrients for microorganisms to grow. These microorganisms may subsequently flow back into the product.
- Where mounting of the equipment outside the product zone is possible, the mixer used to mix open product should be fixed beside the equipment, not only to prevent the contamination of the product with dripping oil, but also to avoid the introduction of soil, and concomitantly spoiling microorganisms and pathogens into the product along with overhanging electrical cabling (Fig. 6.18).

6.7 FRAMEWORK

The number of support legs and cross-bracings should be reduced but shall be of sufficient number and strength and so spaced that the process

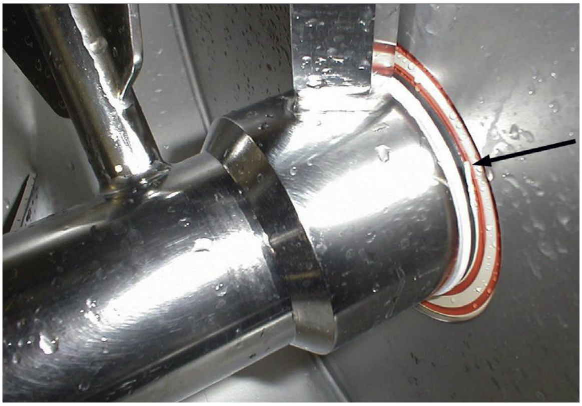


FIGURE 6.17 Stirrers, homogenizers, or mixers installed via a side wall require sealing of the shaft at the product side. When the seal is worn, however, leakage of product to the outside and product contamination may occur. Particles of the broken seal act as foreign body contaminants, and the food may be spoiled with microorganisms migrating out of the gap in which they could grow due to the presence of nutrients. *www.ourfood.com, courtesy of Karl Heinz Wilm, © 2016.*

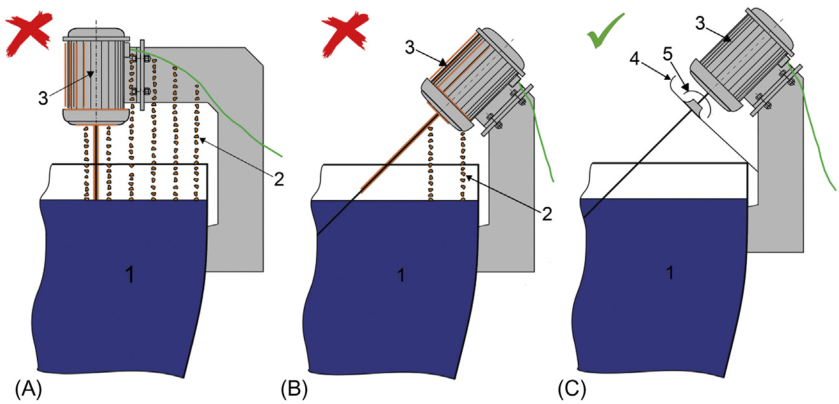


FIGURE 6.18 (A) A motor and cabling mounted over any exposed product (1) can contaminate it by soil, condensate, or lubricants (2). (B) The motor drive (3) and power line should be placed beside the recipient. But without drip protection, soil, condensate, and lubricants still can contaminate the product. (C) A self-draining protection sheet with "upstand" (4) in combination with a cowl (5) on the shaft must exclude any food safety risk. The bottom side of the thrower ring (cowl) should be made inspectable (Lelieveld et al., 2003; Hauser et al., 2004b; Moerman, 2011).

equipment will be adequately supported. Where applied, cross-bracers should be fitted in a diamond configuration. Solid cross-members as structural components are preferred over hollow section members, while sealed hollow section members are usually more preferable over open profile angle or channel sections (Fig. 6.19A). Round section members or square section members turned through 45 degrees provide sloping surfaces (Fig. 6.19B). For vertical

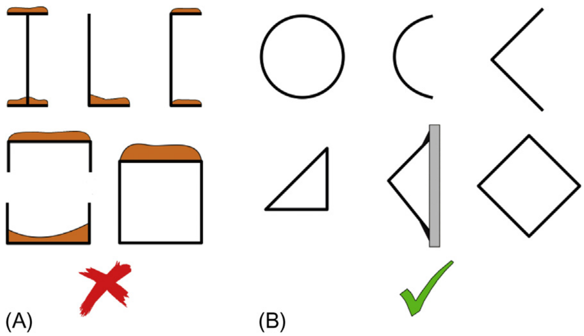


FIGURE 6.19 (A) In the horizontal plane, flat open and closed support members allow debris and liquids to lodge. (B) Structural components with round section and square section members turned through 45 degrees may prohibit buildup of dirt when installed in the horizontal plane. Open profile members with sloped surfaces should have the folding turned outward in both the horizontal and vertical plane, so as to facilitate cleaning (Hauser et al., 2004b).

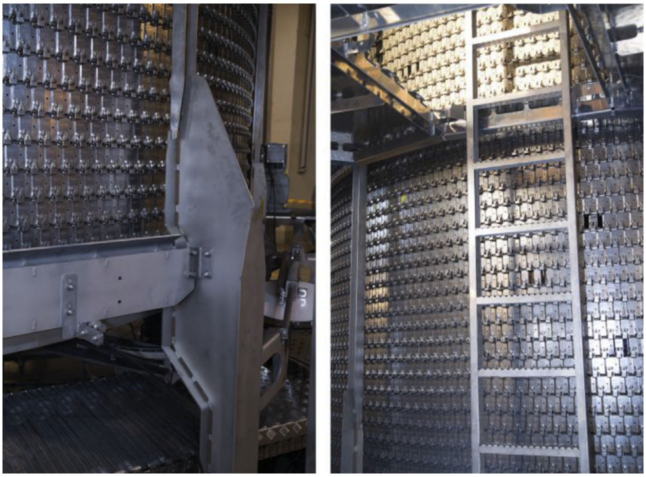


FIGURE 6.20 A metal sheet frame and subframe ending in metal sheet legs may provide higher strength than hollow framework members. The open profile framework members of this spiral freezer are still perfectly cleanable as they are turned outward. *Courtesy of JBT FoodTech, a Frigoscandia freezer.*

parts of frames all the cross sections shown in Fig. 6.19 can be used. When legs and supports are designed with open profiles, the folding should be turned outward for easy cleaning.

Because small fatigue cracks can arise from vibration in hollow sections, allowing penetration of moisture, soil, and microorganisms, an outward turned open profile construction should be considered for framework exposed to continuous vibrations (Figs. 6.20 and 6.21), even when installed

FIGURE 6.21 Channelized frame construction eliminating hollow tubes and threaded leg adjusters. *Courtesy of Rudi Groppe, Heinzen Manufacturing International, © 2016.*

in the horizontal plane. Furthermore, in temperature conditions <0°C, water inside hollow sections may freeze to form ice. As ice expands, it may cause hollow sections to crack and split. From that point of view, it is important to install hollow sections in such a manner that liquids accumulated on the inside are allowed to drain.

Rolled hollow sections (e.g., legs) must be sealed with great care by welding that should be filled by foaming or made drainable away from the product zone. Allowing drainage to the floor via the bottom of the hollow sections is better than trying to seal them (e.g., plastic plugs). Hollow sections shall not be penetrated by fasteners, and hence drilled and tapped holes are not allowed. Preference should be given to welded plugs when fastening to hollow sections. Welded studs and tapping plates are not recommended. Welding framework members together is more preferable than bolted overlapping constructions.

6.8 FEET

Feet begin at the point where they attach to the leg or the body of the equipment and end at the support point on the floor. These feet are indirect-product contact surfaces but have a hygienic significance because they may become a harborage of soil and create a source of secondary contamination to the products (e.g., during high-pressure cleaning of equipment and especially floors, and dirt present on the feet may splash on the food contact surfaces).

Use a minimum number of support legs/floor mountings, because they are important obstacles for cleaning and service personnel. However, feet must be sufficient in number and strength and so spaced that the equipment

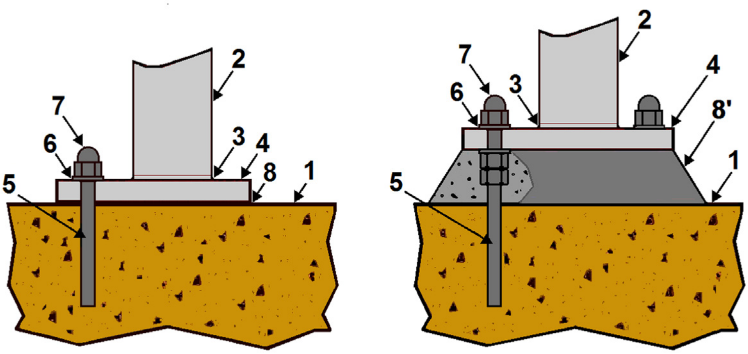


FIGURE 6.22 If the equipment is heavy, the contact face of the foot (2) with the floor (1) must be sufficient to absorb the pressure. To distribute the load, feet should be provided with a footplate (4) welded to the foot leg (3). The foot may be fastened to the floor by means of (a) stainless steel anchor bolt(s) (5) which must have (a) seal washer(s) (6) and (a) dome nut(s) (7) fitted. When the equipment must be bolted to the floor, floorplates shall be sealed with polymer material (e.g., epoxy) to the floor (figure left, 8). The bolting hole(s) must be sealed so that water and dirt are not allowed to leak into the hole(s). Grouting with concrete (figure right, 8′) is not recommended (Moerman & Kastelein, 2014).

will be adequately supported. The general rule is to minimize the floor contact area, but the contact face of the foot must be sufficient to absorb the pressure of the equipment. Skid-proof antislip feet or feet with a footplate fastened to the floor can be used. The latter are applied when the load of heavy equipment must be distributed over a larger surface of contact with the floor. When anchored to the floor, the equipment can't move from its designated position during operation. However, it is better to avoid fastening to the floor because of hygiene issues. The manner in which feet are fastened to the floor depends on the type of floor and the presence of equipment (e.g., machinery producing heat) or services (e.g., electricity) immediately below the surface. When the process equipment must be bolted to the floor requiring floor slab penetration, footplates shall be additionally sealed to the floor with polymer material (e.g., epoxy) (Fig. 6.22 left and Fig. 6.23). Grouting with concrete (Fig. 6.22, right) is not recommended, as practice in the food industry has proven that the concrete grouting can break, allowing food residue to accumulate and bacteria to find a niche in the cracks and crevices of the concrete. Chemical anchors without bolting (fixing to floors by means of a polymer seal) are more recommended. Care must be taken during installation to assure that the footplate does not span over cracks, grout lines, or other floor imperfections.

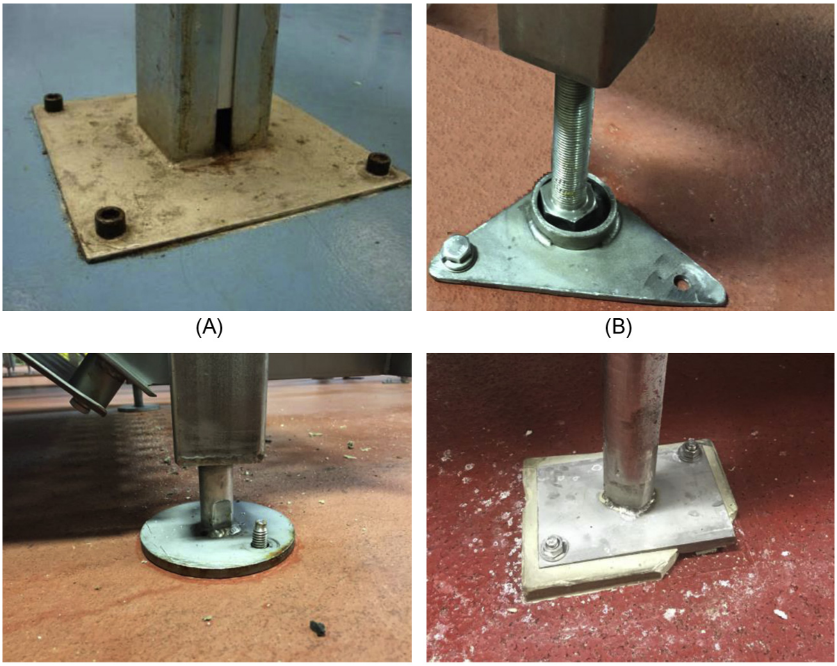
The footbase of foot ends may either have flat (not recommended) or sloped (recommended) surfaces. Provide only fixing holes where bolting to the floor is necessary, and avoid the use of extra brackets. Avoid all unnecessary (sharp) corners and edges, as well as crevices at the fixing point. When installed on the

FIGURE 6.23 By anchoring the process equipment to the floor, it cannot move from its designated position during operation. Foot anchors should be polymer sealed into the floor. Grouting foot anchors into a concrete floor may give rise to unhygienic conditions with time. *Courtesy of Surface Solutions, Inc.*

FIGURE 6.24 The foot has plenty of pits, folds and other imperfections where dirt and liquids may build up. In particular the exposed treads, bolt nuts and washers create a lot of crevices. The footbase forms a difficult-to-drain flat surface, and dirt and water may penetrate under the footplate. In this manner, they form a niche where microorganisms may grow. *Photo left, courtesy of Mondelez International, 2016; photo right, American Meat Institute, © 2016.*

machinery and within the specified load conditions, all exposed surfaces shall be free of pits, folds, cracks, crevices, and other imperfections in the final fabricated form. A smooth finish is required such that soil may be cleaned from the surface using manual cleaning techniques. Several examples of nonhygienically designed feet are shown in Figs. 6.24 and 6.25.

Equipment should be adequately located in position, with all its feet having a contact face that is even, so as to ensure complete contact with or to allow fixation to the floor. Where the floor is flat, hygienic nonadjustable feet can be used (Figs. 6.26 and 6.27).



(A) (B) (C) (D)

FIGURE 6.25 Foot ends with a flat footbase (footplate) are not recommended. The use of a bush (welded to a footplate, and either open or closed) to insert the legs of the equipment or the foot spindle is a proof of bad hygienic design practice because debris and water may collect into the bush (A & B). Welds to fix the equipment leg or foot spindle onto the foot base must be smooth, without pits and folds where dirt and liquids may build up (C & D). Holes in the footplate should be omitted where bolting to the floor is not necessary. Exposed threads such as threaded foot spindles (B) and bolting screws without dome nut (C, D) are not allowed. Countersunk screws with slots or other drive configurations (A) and bolts with flat hexagon bolt heads (B) are not recommended. Bolts with hexagon dome nuts and seal washers must be used instead of flat open hexagon nuts (D). Because the footplate is not provided with an antislip rubber pad or polymer sealed onto the floor, dirt and water may penetrate under the footplate, forming a niche where microorganisms may grow. Concrete pads should not be used, as the concrete may crack (D).

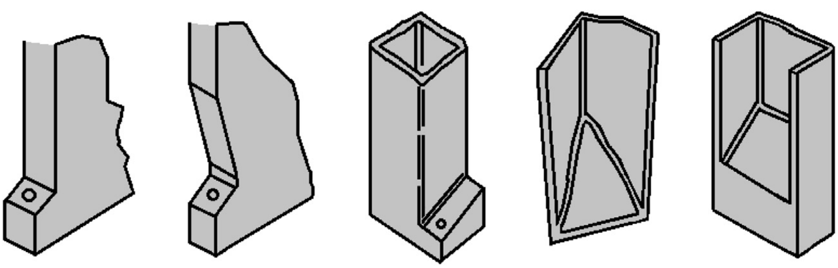


FIGURE 6.26 Nonadjustable feet with sloped surfaces, rounded corners and smooth welds for maximum drainability should be used (APV Baker, 2001).

(A) (B) (C)

FIGURE 6.27 (A) Foot with a smooth radiused leg-footbase transition (Frank Moerman, © 2016). (B) Foot radiused down to the foot base. (C) Foot spindle smoothly welded to the foot-plate and the hermetically closed leg. *Photo right, courtesy of Joe Stout, Commercial Food Sanitation LLC - Intralox, © 2016.*

(A) (B) (C)

FIGURE 6.28 Ball feet with the threaded surface covered by an adjustable sleeve (A) and other foot designs without threads (B & C) provide easily cleanable designs. However, mechanically they will almost destroy the floor, because they exert a (very) high pressure locally, especially if they are used to support heavy equipment prone to vibration/oscillatory movement. Ball feet should only be used to support low-weight equipment. *Photo left, courtesy of Koss Industrial, Inc.*

Notice that ball feet (Fig. 6.28A & B) or other foot designs exerting high punctual loads on the floor (Fig. 6.28C) are not recommended. They leave uncleanable crevices between the floor and the foot. Moreover, mechanically they will almost destroy the floor, because—due to their very small contact surface with the floor—they exert a very high pressure locally. If the process equipment is heavy and prone to vibration, the floor will break up very quickly.

Foot ends with a ball-socket arrangement (Figs. 6.29 and 6.30) have a spindle with ball end that may freely swivel in a socket or internal cavity of

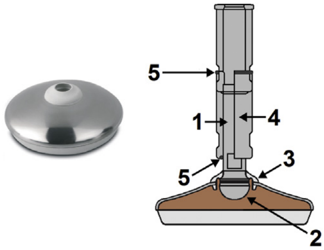


FIGURE 6.29 Hygienic adjustable equipment feet admitting slopes up to 10 degrees on floors. Footbase and spindle are two separate entities. The ball-end of the spindle (1) fits in the diametrically centered depression (socket or internal cavity) (2) in the footbase. The gasket (3) at the junction between the foot spindle and footbase plate (ball-socket joint) prevents any dirt from entering the socket or internal cavity. The adjustment sleeve (4) which covers the threaded surface also functions as a nut. O-rings (5) inserted inside the adjustment sleeve at both ends prevent dirt from entering the thread.

FIGURE 6.30 Heavy-duty adjustable feet with the threaded spindle completely covered by a sleeve provided with O-rings. By adhering to the smooth surface of the screw, this gasket prohibits any intrusion of dirt. Where required, the spindle can be welded to the footplate to avoid liquids or product residues from gathering in the hole in the footplate. *Photo left, courtesy of Martin S.R.L., photo right, courtesy of NGI A/S.*

a separate load-bearing footbase. Such a design provides stability under load (the load is evenly distributed about the entire spherical surface of the socket), as well as vibration/oscillatory movement absorption capacity and the ability to support the equipment on an uneven floor. To prevent any dirt from entering the socket or internal cavity of the load-bearing footbase, a rubber gasket at the junction of the footbase with the spindle (ball-socket joint) is essential. In other designs, the foot spindle has a concave end which can swivel over a diametrically centered convex elevation in the load-bearing footbase plate (Fig. 6.31). An O-ring fitted in the concave spindle end must prevent access of impurities, filth or bacteria in the joint. The load-bearing

FIGURE 6.31 Hygienic adjustable equipment feet admitting slopes up to 15 degrees on floors. Footbase plate and spindle are two separate entities. The concave end of the spindle fits in a diametrically centered elevation of the footbase plate, having the form of a spherical dome. An O-ring fitted in the concave spindle end must prevent access of impurities, filth or bacteria in the joint. The adjustment sleeve covers the threaded surface, and at the same time functions as a nut. The O-rings inserted inside the adjustment sleeve adhere tightly to the smooth surface of the screw, and prevent dirt from entering the thread section. *Courtesy of NGI A/S.*

foot may also include a rubber layer underneath or rubber can be embedded in the load-bearing foot. The elastomeric material may dampen the vibrations of the operating equipment and may prevent slipping of the foot on the support surface. The rubber pad may also prevent liquids and dirt from getting under the footbase due to the fact that the rubber compensates for the roughness and irregularities of the floor. A sufficiently low Durometer rubber provides a tight continuous seal with the flooring material.

For proper installation on uneven or inclined floors, it is not allowed to level food processing equipment with improvised shimming either with metal sheet (Fig. 6.32A) or a wooden plank (Fig. 6.32B). Equipment feet adjustable by min. ± 75 mm should be used. Adjustable feet may not leave (threads) (Fig. 6.33). When adjustable feet are used, the threaded spindle for leveling should be completely concealed in closed profiles/pipes (Fig. 6.34) or enclosed by a sleeve (Figs. 6.29–6.31), so as not to cause accumulation of dirt or contaminants in the thread and to facilitate the cleaning of the foot (Fig. 6.35). O-rings inserted inside the adjustment sleeve must prevent dirt from entering the thread section. USDA has imposed a new safety feature to prevent exposed thread parts due to overscrewing the sleeve (Fig. 6.36).

Also the fixation of feet to legs must be done in a hygienic way. Sometimes it is better to leave the leg end half open. In refrigeration

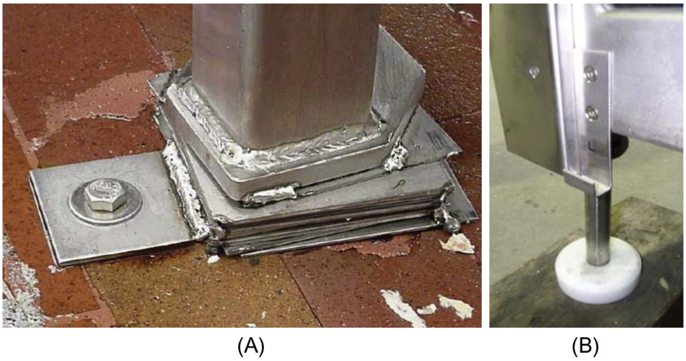
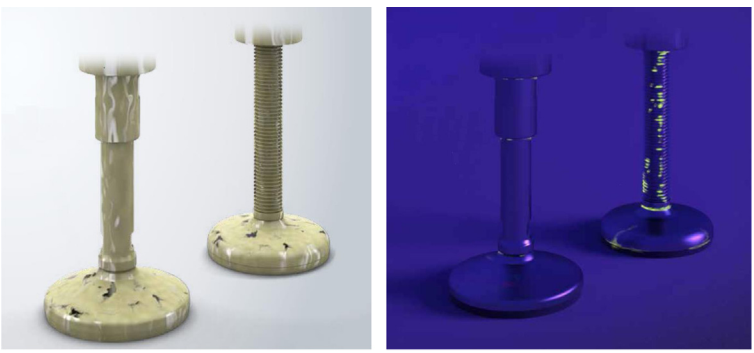


FIGURE 6.32 Leveling food processing and packaging equipment with improvised shimming creates an unhygienic mess. In case (A), several sheets of metal create plenty of metal-to-metal crevices in which dirt and liquids may collect (Don Graham, Graham Sanitary Design Consulting LCC, © 2010). In case (B), although wood may absorb moisture and food debris, a wooden plank is used to level the equipment. With time, this wood becomes prone to rot. The foot is fixed to the equipment subframe by means of rivets in an overlapping sheet construction. The horizontal section may accumulate dirt.

FIGURE 6.33 Adjustable feet with exposed threaded spindle easily become prone to contamination and are difficult to clean. Lower middle photo shows a hollow leg which is not hermetically closed. *Photo at lower center courtesy of Joe Stout, Commercial Food Sanitation LLC - Intralox, © 2016.*

FIGURE 6.34 Adjustable feet with the threaded spindle completely concealed in closed profiles/pipes. In the first example (photo on the left), the thread of the foot is covered by the closed pipe, welded in a sheet metal leg *(courtesy of Den Rustfri Stålindustris Kompetencecenter)*. In the second example (photo in the middle), the foot can be screwed in and out at the bottom of the frame's legs *(courtesy of Alfa-Laval AB)*, while the thread still remains covered in the leg. In the third example (photo right), the leveling foot is screwed in leveling foot mount *(courtesy of Schenck Process LLC)*. In the second and third examples, the contact surface of the feet with the floor is rather small, which will locally exert a (very) high pressure, especially if used to support heavy equipment prone to vibration/oscillatory movement.



(A) (B)

FIGURE 6.35 Difference in cleaning results between (A) a hygienic leveling foot having the spindle covered by a sleeve and an arrangement of O-ring silicone seals in all the mobile joints (left) and a standard fully threaded foot (right). Both feet were soiled with sour yogurt containing fluorescents *(courtesy of NGI A/S)*. After rinsing to remove a large part of the soil, the feet were cleaned with detergent. In a postrinse step, the feet were flushed with water until visibly clean. (B) Both feet look visibly clean to the human eye. Opposite to the hygienic leveling foot (left), which was found to be free of residual soil and bacteria under UV light, the foot with exposed spindle thread (right) still contained residual soil and bacteria, visible as fluorescent spots under UV light.

equipment operating below 0°C, it is essential that any liquid entering the hollow leg can be drained to prevent cracking of the leg when ice forms at the inside (Fig. 6.37). But preferably, hollow legs must be hermetically closed, requiring adequate sealing of the points where the feet enter the

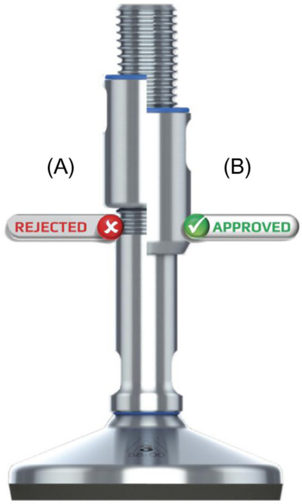


FIGURE 6.36 (left) Overscrewing the lock/sleeve may result in exposure of the thread in the area just below the sleeve. USDA therefore requires an additional feature to avoid overscrewing by blocking the sleeve or counter nut. *Courtesy of NGI A/S.*

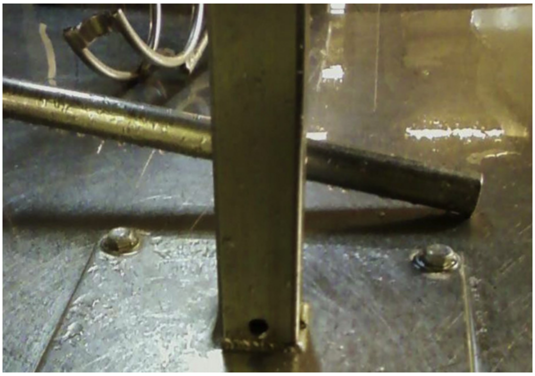
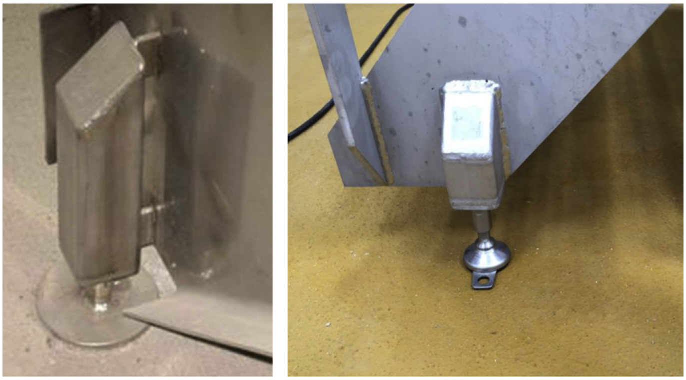


FIGURE 6.37 The leg end is provided with a drain hole to allow draining of any liquids entering the hollow leg. However, in this design, dirt can get in the leg end and complete draining is not possible. The leg end may provide a niche where microorganisms can grow. Despite the drain hole, at below 0°C temperatures, the leg end can still crack under the impact of ice formed within the leg end. The footplate is also not hygienically fastened to the stainless steel floor plate. *Courtesy of Stephanie Olmsted, Safeway Inc.,© 2016.*

hollow leg (Fig. 6.38). Fixation of the leveling feet onto open profile legs may not leave thread parts exposed, requiring a top sleeve with O-ring seal and round top to cover the exposed thread parts (Fig. 6.39). Threadless adjustable feet are also available (Fig. 6.40).



(A) (B)

FIGURE 6.38 Fixation to the equipment or equipment legs must be done in a hygienic manner. (A) Stair riser leg, totally sealed, with sloped top and set off the riser *(courtesy of Joe Stout, Commercial Food Sanitation LLC - Intralox, © 2016)*. (B) The stringers of staircases make no floor contact due to the fixing of hygienically designed leveling feet on the stair riser legs welded onto the stringers (*courtesy NGI A/S*).

(A) (B)

FIGURE 6.39 (A) Fixation of the leveling feet onto open profile legs may not leave thread parts exposed. (B) A top sleeve with O-ring seal and round top must be used to cover the exposed thread parts. *Courtesy of NGI A/S.*

FIGURE 6.40 Threadless adjustable feet hygienically fixed onto open profile legs. *Courtesy of Rudi Groppe, Heinzen Manufacturing International, © 2016.*

6.9 CASTERS

Although preference should be given to feet rather than to casters, casters are used in those places where process equipment must be mobile in order to facilitate inspection and cleaning of the equipment and process rooms. Transportable equipment also allows changing of the layout of process lines in function of the food products that their customers want to be produced. Casters are excellent for increasing the flexibility of production processes (e.g., frozen vegetable industry).

6.9.1 Materials of Construction

6.9.1.1 Durable Materials of Construction Providing the Casters a Sufficient Load Rating

To prevent premature failure of wheels due to overloading, caster wheels should be constructed out of a material giving them a sufficiently safe load rating for the intended task. A safe load rating incorporates a safety factor for dynamic loading. On poor floor surfaces, casters experience dynamic loads well in excess of the static load. Hence, if the rating of the casters only just meets the minimum failure load, rapid deterioration of the casters will occur. Casters should thus be made of a material that suits the floor quality, the expected loading and the frequency of movement. If underspecified casters are used, the body of their wheels can break up due to being overloaded. To choose the best caster, the maximum load capacity that the casters are required to bear should be determined. That figure is commonly defined as the weight of the food processing equipment including the weight of the food product itself, divided by a number one less than the total number of casters needed. Casters shall further be made of a durable material that is corrosion resistant to food products, water, steam, cleaning agents, disinfectants, etc. They should be self-finish or dull-nickel plated, because the use of paint is not recommended. Based on these parameters and requirements, a caster made of a suitable material of construction that meets that specification can be selected.

6.9.1.2 Cast-Iron Casters

Although cast-iron wheels are virtually indestructible and are able to withstand the highest loads, their use in the food industry is not recommended (not acceptable), because they are prone to general corrosion of the caster components and because of the damage which they do to floor surfaces. Floor surfaces may break up, if wear is allowed to progress. Damaged floor surfaces then become an excellent harbor for contaminants and microorganisms.

6.9.1.3 Zinc-Plated Mild Steel Casters

Casters manufactured from zinc-plated mild steel should be avoided. When the zinc coating on the wheels wears away, corrosion will occur quickly, which may result in increased friction between the wheels and the caster forks (horns). Casters manufactured from zinc-plated mild steel require the swivel bearing to remain lubricated to prevent it from corroding. If corrosion of the swivel bearing occurs, it will prevent the caster from swiveling efficiently; as a consequence increased side loads will be applied to the caster components, which can result in premature failure of the caster. Zinc-plated mild steel casters with different types of swivel bearing seal arrangements are available that allow lubrication-in-place, and that prevent contamination of the bearing and loss of lubrication during the cleaning of the process equipment. But if lubrication is not regularly and properly done, corrosion and increased play still will be observed in these swivel bearings, with the result that, after a certain time, the caster will start to squeak until it stops swiveling again.

6.9.1.4 Stainless Steel Casters

Casters (body, mounting plate, etc.) manufactured from stainless steel with stainless steel swivel bearings need no lubrication to prevent corrosion. Although stainless steel axles in combination with an outer PTFE bushing provide self-lubrication of the wheel/axle surfaces, they still need to be replaced periodically. But PTFE bushes are relatively cheap and easy to replace, and are less time-consuming in maintenance than manual lubrication.

6.9.1.5 Casters With Full Thermosetting Plastic Wheels

Thermosetting plastics, particularly phenolics, are widely used in the food industry because they withstand high temperatures and can carry high loads. However, they can become damaged by poor quality flooring and by defects in floors, such as concrete joints and ridges. Phenolic wheeled caster types are often worn to a flatter profile or their tread is spalling. Some phenolic wheels may suffer from breakup due to impact damage, while others may absorb water when subject to damp or wet conditions for long periods. Hence, the correct type of phenolic must be selected if washing is carried out routinely.

6.9.1.6 Casters With Full Thermoplastic Wheels

Thermoplastic wheels have better impact resistance than phenolic wheeled casters, but they have poor resistance to higher temperatures. They are applicable in the food industry where high temperatures are not part of the environment.

6.9.1.7 Rubber-Wheeled Casters

An alternative to the phenolic wheel is the high-temperature rubber-wheeled caster. These wheels have a high-temperature thermoplastic center with a bonded high-temperature rubber tire. As with phenolic wheels, they will wear and may be damaged by poor or abrasive surfaces. They also have slightly lower load ratings than an equivalent diameter phenolic wheel because of their lower shear strength. A major drawback of rubber-wheeled casters is their poor resistance to acids, oils, chemicals and other substances harmful to rubber. These soft tread wheels, however, may ride more easily over bumps, level changes, joints, drainage gullies, etc., and are less destructive to tiled, linoleum, etc., floors. They also provide better shock absorption and traction.

6.9.2 Hygienic Design Requirements

Swivel casters (Fig. 6.41) only function well when they are securely mounted to a rigid frame so the swivel bearing kingpin axis remains vertical at all times. Rigid casters must be mounted (welded, sealed, or readily removable) in such a way that their axis and wheels are in alignment. All structural members (mounting plate and horn) shall have a minimum of horizontal flat surfaces. The plate mounting shall be constructed to have a flat top surface. The angle between the top surface and the edge of the plate shall be 90 degrees or less. Mounting holes and other devices provided for installation shall be so designed as to prevent the formation of pockets or areas difficult to clean. The horn assembly or fork shall be constructed so that the surface facing the wheel shall have no concave surface except that part joining the horn plate. Included angles between all surfaces should have a minimum radius of 6 mm. Kingpin assemblies, which have the nuts or rivets at the bottom, shall have suitable caps covering the ends. The minimum clearance

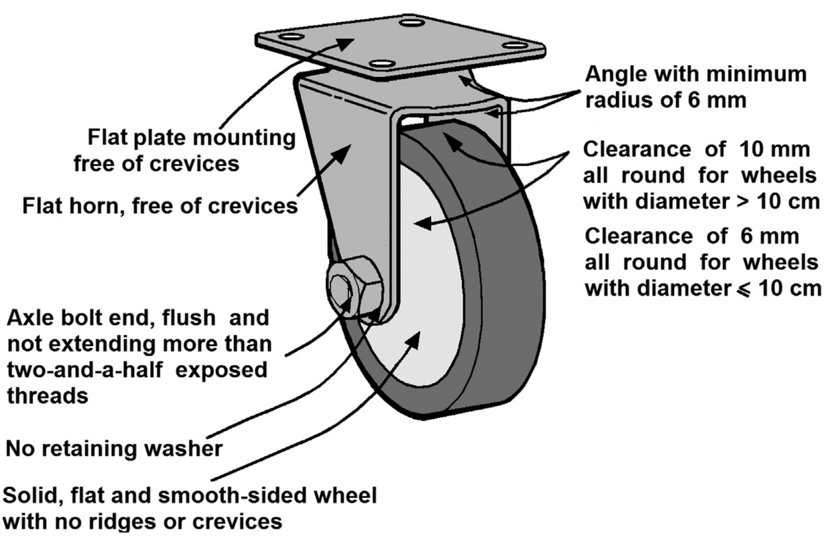


FIGURE 6.41 Hygiene design requirements that casters in the food industry must meet (APV Baker, 2001).

between horn assembly and wheel should be 6 mm all round, for wheels equal to or less than 10 cm in diameter, while the minimum clearance should be 10−12 mm all round for wheels with diameter larger than 10 cm. Brakes and locking devices should comply with the hygienic requirements mentioned previously.

6.9.3 Inspection and Maintenance of Casters

The frame and fasteners of casters should be regularly checked for distortions, loose bolts and nuts, and broken welds or deck boards. Where rigid casters are used, they should be inspected for bent caster horns. Wheel surfaces must be checked for chemical damage and tread wear. Flat spots may indicate foreign material, a loose caster or a frozen wheel, requiring the wheel to be replaced. Swivel assemblies should be regularly checked and replaced if they are loose. If they don't turn freely, bearing raceways should be checked for corrosion or dirt. Secure fastening of the king bolt nut should be verified

If no self-lubricating bearings (stainless steel with PTFE bushing) are used, wheel and swivel bearings should be lubricated every six months; while lubrication of bearings in corrosive environments is required once a month. In the food industry where the lubricant is washed away by daily cleaning, lubrication is sometimes even required after each washing. Single seals used to contain oil or grease in bearings will wear, ultimately allowing leakage. Therefore their integrity must be regularly checked, and their replacement at defined maintenance intervals is required.

6.10 BELT CONVEYOR

6.10.1 Conveyor Frame

Conveyor frames should have an open structure with a minimum of hidden areas/surfaces. But guards are required in places where a drive station, a pulley, rollers or the conveyor belt may cause injury. The guards, however, should be easy to dismount to allow for complete cleaning. Solid cross members as structural members are preferred over hollow section members. Open profile angle or channel sections must be installed in a manner such that horizontal ledges and crevices are absent. Where open profiles are used, the folding should be turned outward for easy cleaning (Fig. 6.42). Welding is preferred over fastening.

6.10.2 Conveyor Bed

Conveying surfaces shall be supported by a minimum amount of carrying surface or bed (Fig. 6.44) as required. The use of solid plate that expands the whole top surface of the conveyor table to provide support to a belt is likely

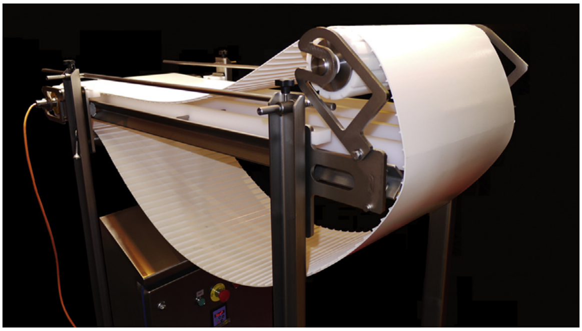


FIGURE 6.42 The conveyor frame and subframe should have an open structure without horizontal surfaces and with a minimum of hidden areas/surfaces. At the outside, the framework consists of open profile members turned outward for easy cleaning. The conveyor frame is an all-welded construction with flat cross-members welded at the outside framework. The cross-members not only act as structural frame members, but also as belt supports. The weld-on flat cross-members are provided with gaps to accommodate the freely located plastic wear strips that help to support the conveyor belt. No bolts, holes or nuts were used for fastening the ultra-high-molecular-weight (UHMW) polyethylene wear strips. The swivel-mounted roller permits release of the belt tension, hence providing improved access for cleaning the bottom side of the belt as well as the bearing strips. *Courtesy of Interroll.*

to increase contamination problems and cause excessive wear of the belt. Nonremovable bearing surfaces for belts cannot be cleaned easily. Rollers shall be used where practical, or line supports that are easily removable for cleaning. The conveyor belt should have minimal debris retention, and running under turned over sections of side cladding (overhanging belt edges) is not allowed because the whole surface of the belt cannot be cleaned, and the belt cannot be lifted up to allow cleaning and inspection of internal surfaces and support members (Fig. 6.2). But also pivoted covers can't be cleaned easily if continuous hinges are used. In continuous hinges, food debris and microbial slime are strongly retained in the hinge segments (Fig. 6.43). Side guides used to contain product should be capable of being removed. So, pivoting guides using pin hinges with removable pins are acceptable. But removable guides also may cause problems because of the possibility of the fastening system working loose. The conveyor frame must be designed so that the sides of the belt are turned up to form an integral guide to the belt. Besides this guide, cladding can be made removable allowing for effective cleaning (Fig. 6.44).

The most common design of a drive station is placing the drive pulley between two bearings, one at each side of the conveyor. Open bearings have low Ingress Protection (IP), making them sensitive for the removal of lubricant during cleaning operations (Fig. 6.45). Because they require more frequent lubrication, the risk of overlubrication increases. Self-aligning pillow block bearings or flange bearings with covers and constructed from materials

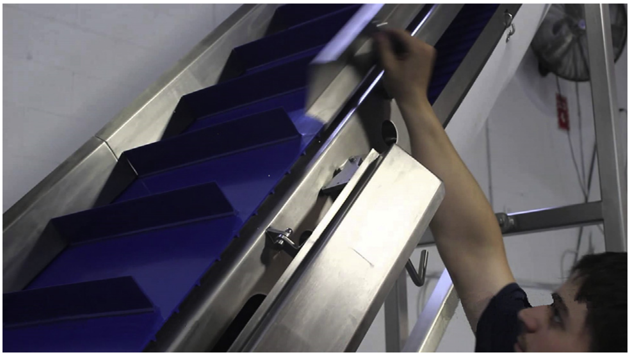


FIGURE 6.43 The conveyor belt running under turned over section of side cladding (overhanging belt edges) is not allowed because the whole surface of the belt cannot be cleaned, and the belt cannot be lifted up to allow cleaning and inspection of internal surfaces and support members. In this example, the side guides serve both as belt and product guide. They may pivot to the outside due to the hinge segments. Pin hinges with removable pins are used, which allows for minimal debris retention and excludes the likeliness of microbial growth and concomitant slime production. *Courtesy of PaxiomWeighPack Systems Inc.*

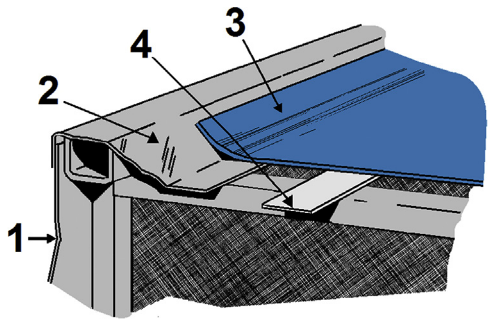


FIGURE 6.44 The conveyor frame (1) must be designed so that the sides of the belt are turned up to form an integral guide (2) to the belt (3). Besides this guide, cladding can be made removable allowing for effective cleaning. The conveyor belt shall be supported by a minimum amount of carrying surface or bed (4) as required. Rods, slats, rollers, or like supports shall be used where practical (CFPRA, 1983; Hauser et al., 2004b).

approved for food contact may provide waterproof and corrosion-free designs. The higher IP rating prevents lubricant inside bearings being removed during cleaning operations, making overlubrication less likely. Lubricated bearings, including permanent sealed types, should be located outside the direct product contact surface area with adequate clearance open for inspection between the bearing and any product contact surface (Kold et al., 2016).

If the specification of the gear motor allows it, the bearing on the gear motor side of the conveyor can be omitted, using the output shaft of the gear as a bearing. In this case the gear motor has to be fixed to the side of the

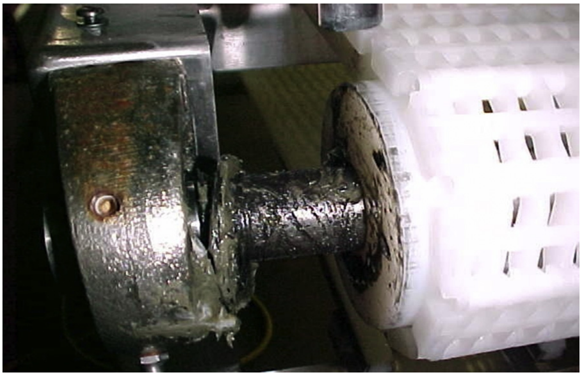


FIGURE 6.45 Lubricated bearings should be located outside the direct product contact surface area with adequate clearance between the bearing and any product contact surface. Open bearings have low Ingress Protection (IP), making them sensitive to the removal of lubricant during cleaning operations. Because they require more frequent lubrication, the risk of overlubrication increases. Excessive lubricant and grease should be removed to prevent them from coming into contact with the product. *Courtesy of John Butts, Land O'Frost.*

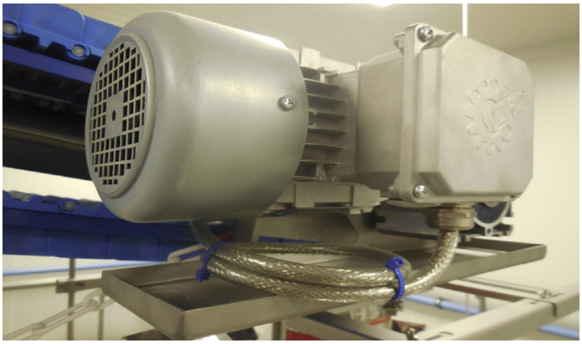


FIGURE 6.46 Although the drive motor has a drip pan, the difficult-to-clean motor is located too close to the product flow, because the fan may blow dust and dustborne microbes around and onto the food. *Frank Moerman, © 2016.*

conveyor (=direct drive motor). Drive motors should be located below the line of the product flow because the exposed motor may have a fan that will blow dust and dustborne microbes around (Fig. 6.46). It is also possible to place the gear motor away from the drive drum, driving it by means of a chain or toothed belt, for example. Such a design requires a guard around the chain or belt to avoid any contamination of food product, as well as for occupational safety reasons. However, a chain guard, when open, may provide a place where product may accumulate, allowing microbes to multiply in large numbers and so posing a contamination hazard for the food product on the belt (Fig. 6.47). Measures have to be taken to make the drive guard

FIGURE 6.47 The drive motor is located below the line of the product flow. Gears, chains (stainless steel or polyacetal), and motors of belt drives must be covered to avoid any contamination of product. However, a chain guard (essential from an occupational safety point of view), when open, may provide a place where product may accumulate, allowing microbes to multiply to large numbers and so posing a contamination risk for the food product on the belt. A transparent chain guard may allow detection of any product debris inside the chain guard. *Courtesy of Dorner Mfg. Corp.*

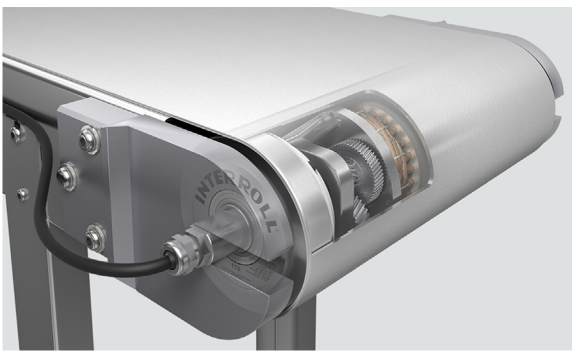


FIGURE 6.48 Drum motors make external gears and chains redundant. *Courtesy of Interroll.*

using a hygienic and easy-to-clean design (e.g., hermetically sealed housing). Furthermore, the guard must be designed in a way that the generated heat from the gear motor can be conducted away.

The drive motor is often of a type that cannot be washed with a high-pressure hose using water and cleaning agents. However, IP54/55/67 sealed wash-down or easy-clean motors which do not require ventilation or housings are available. There should be enough air space around the motor for cleaning and disinfection, maintenance and repair. Where possible, use drum motors (motorized pulleys) (Fig. 6.48) that are fully closed, nonventilated, conveyor belt drives where motor and gearwheels are at the inside, submerged in a bath of food-grade lubricant, providing at the same time lubrication and cooling. Drum motors make gears and chains redundant.

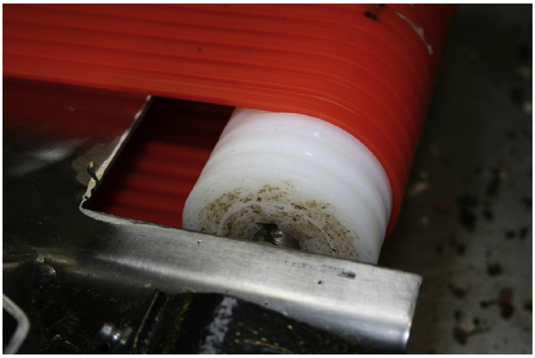


FIGURE 6.49 Rollers and pulleys shall not have hollow parts. *Don Graham, Graham Sanitary Design Consulting LCC, © 2010.*

FIGURE 6.50 Hollow rollers and pulleys shall not be used. *Courtesy of General Mills.*

Rollers and pulleys shall not have hollow parts (Fig. 6.49). The design of rollers, pulleys and sprockets shall be closed if hollow (Figs. 6.50 and 6.51) and shall be free of end recesses (Fig. 6.49). A welded construction should be preferred to a sealed design (Fig. 6.51).

Embedded reinforcements, as well as fabric backing materials in conveyor belts, must be covered to avoid contact with the product. Cut edges of belts which incorporate reinforcing materials must be sealed to prevent penetration by wicking (capillary action) of liquids into the interior (Fig. 6.52).

6.11 MOTORS

Motors made of aluminum or cast iron are prone to corrosion, while painted units create a hygienic hazard because paint may flake off. Motors with cooling ribs have a lot of hooks, corners, and dead spots, making them difficult to clean.

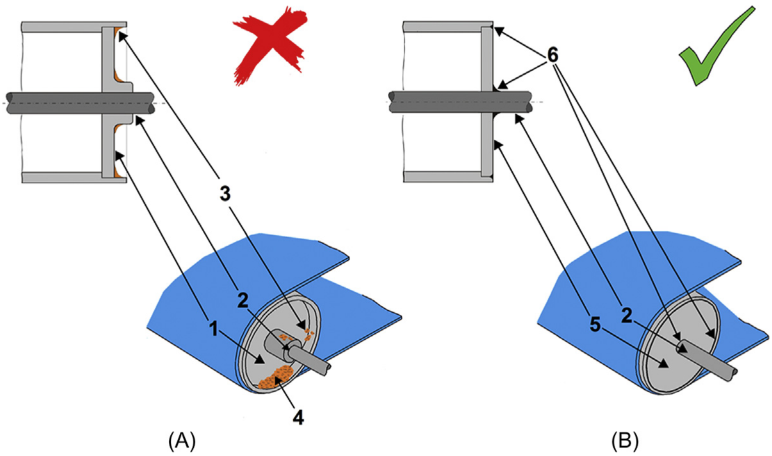


FIGURE 6.51 (A) Pressed-in roller ends (1) create dead areas and crevices (3), where residues of product and soil (4) may accumulate. (B) Flush roller ends (5) which are properly welded (6) to the roller and to the shaft (2) avoid any hazard and can be cleaned easily (CFPRA, 1983; Hauser et al., 2004b).

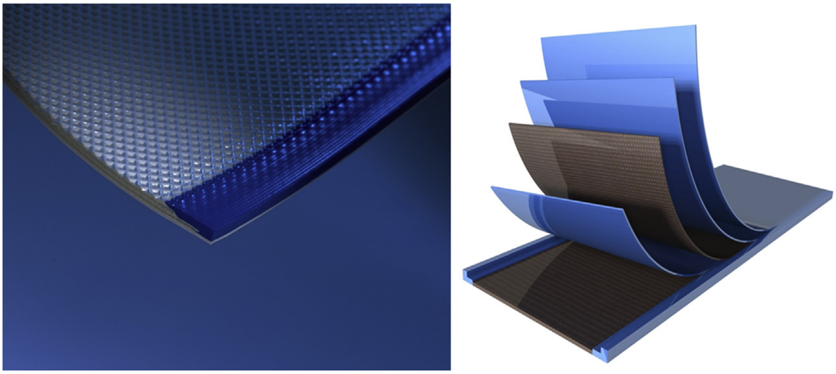


FIGURE 6.52 Cut edges of belts that incorporate reinforcing materials (e.g., fabric) are prone to penetration of liquids into the interior by wicking (capillary action). Therefore, embedded reinforcements, as well as fabric backing materials in conveyor belts, must be covered to avoid contact with the product. The edge should be suitably sealed and covered in a way that the covered edge is shaped with a round rim. *Courtesy of Ammeraal Beltech Holding BV.*

A cooling fan that ventilates the heat produced by the motor to the outside may act as a source of contamination, because—along with the cooling air—it concomitantly releases dust and dustborne microorganisms accumulated inside the electrical equipment in the process environment. Hence, such motors should not be installed in the product area (including the splash area). Installed over the product flow (Fig. 6.53), the motor also may contaminate the product with lubricants, condensate, or dirt discharged from the drive system.

FIGURE 6.53 Drive motor is installed above the manhole of the process vessel. When the manhole cover is open, the product may become contaminated with lubricants, condensate, or dirt discharged from the drive motor *(organization Sanitary Design Workshop, © 2016).*

FIGURE 6.54 Wash-down motor. However, it is preferable to avoid hosing of motors, outlets, and electrical cables. The electrical connection to the motor should be waterproof and the cable gland of the motor should be positioned in a direction pointing away from the food contact zone and away from direct spraying when cleaning. *Courtesy of CES NV.*

Stainless steel motors (Fig. 6.54) with smooth surfaces (e.g., milled, ground or polished) and without complex geometries or features (such as cooling ribs, screw heads, grooves in the gear assembly, unused or threaded holes) should be used. Hygienic motor assemblies ask for domed cap nuts and metal-backed gaskets under the nuts. A wash-down motor is a sealed electric motor that is designed to allow complete washing with a high-pressure hose, using water and cleaning agents, with no difference in operating characteristics at the end of the wash-down cycle.

As an alternative, easy-clean motors have been designed and built to reduce obstructions to cleaning, as far as operation and economics allow. However, easy-clean motors don't meet the standard completely. They can be washed down only if caustic solutions are not used (Moerman, 2011).

6.12 COVERS AND GUARDS

Chains, motors, gearboxes, sprocket wheels, etc. must be guarded or covered for the following reasons:

- To prohibit injury to operators during inspection, cleaning, disinfection, and maintenance.
- To protect difficult to clean machine components (e.g., drive parts) against contamination by food debris.
- To prevent liquids (e.g., cleaning solutions, condensate) from intruding into water-sensitive machine components.
- To prohibit damage to machinery components.
- To protect the food product from contact with drive parts such as lubricated chains and sprocket wheels.

However, the requirements of guarding or covering machinery to ensure safety in operation may easily conflict with the recommendations of EN 1672-2 as well as other hygiene requirements. By their nature, covers and guards may compromise food safety, unless considerable care is taken in their design, construction, installation, and maintenance.

6.12.1 Covers

Good hygienic design and a stringent cleaning/disinfection regime can solve many problems. Covers and panels must be designed so as to prevent entry and/or accumulation of soil and liquids. Upturned sections, that may provide a tray in which dirt and liquids may accumulate, are not allowed. To ensure good drainability, covers must be contoured to avoid horizontal surfaces and provided with an angle of 5 degrees away from food areas. Where horizontal surfaces can't be excluded, avoid panel joints and provide overlap where possible. Reduce exposed fixings to a minimum. Covers on their own—although practical—can often make cleaning more difficult. Wherever covers are used around drive parts such as chains and sprockets, they should be easily removable to provide access for cleaning, either by opening or unhinging them (Moerman et al., 2005).

Totally removable covers or cladding are not recommended as they may not be put back or they may be damaged during removal. Without covers, operators in the environment of the process equipment and exposed food products are at risk. Where possible, hinged covers that pivot outboard should be used. But use as few hinges as possible, and use concealed hinges with

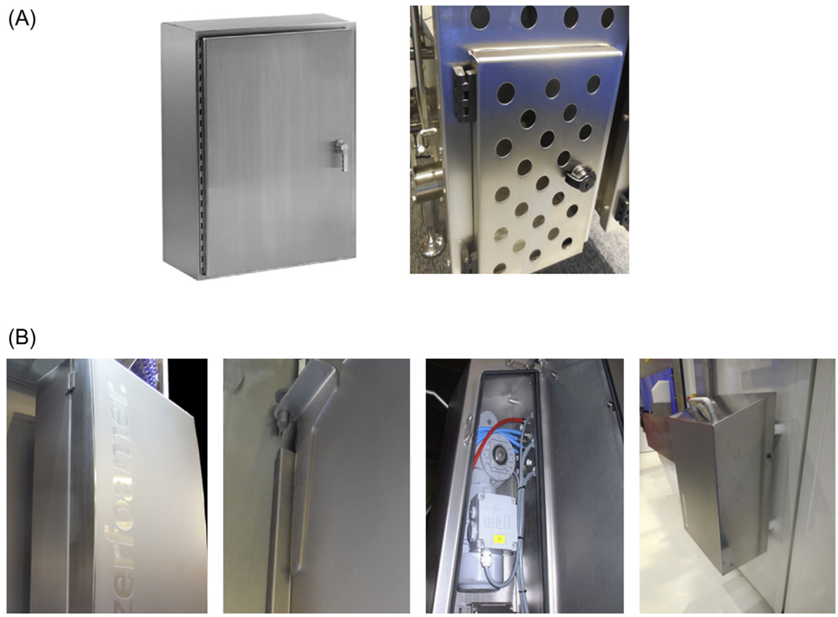


FIGURE 6.55 (A) Continuous and piano hinges are not allowed (Frank Moerman, © 2016). (B) From left to right: block hinges lift-off type, pin hinges with removable pins or concealed hinges should be used. An alternative could be a hingeless cover fixed by means of two small screws at both sides. *First and second photo, courtesy of Heinen Freezing GmbH & Co. KG; third photo, courtesy Den Rustfri Stålindustris Kompetencecenter; fourth photo, courtesy IQF Frost AB; Frank Moerman, ©2016.*

the least number of parts. In view of cleaning and disinfection, continuous and piano hinges (Fig. 6.55A) are not allowed. Block or pin hinges are a possible option but should have removable hinge pins or be of the lift-off type (Fig. 6.55B). Sliding covers are not recommended and if they are used, tracks and guides for covers must be designed to minimize retention of food particles, condensation water, spillage, and soil. As an example, the grooves shall be rounded. For small covers, a "D" handle mounted to the cover is acceptable (Fig. 6.56) (Moerman et al., 2005).

Clear plastic covers (Fig. 6.57) should be made of shatter-resistant material. Polycarbonate is especially prone to cracking if not installed properly (e.g., lack of room for expansion). To maintain the clarity of the transparent material over the life of the equipment, it must be resistant to cleaning agents and disinfectants, and—where necessary—hot water and steam. Acrylic and polycarbonate should be at least, respectively, 12 mm and 5 mm thick. Transparent covers preferably should be mounted unframed; however, for large covers a frame is often required. The frame should be mounted spaced away from that transparent cover and should be provided with a handle or rail to hinge open the cover without putting

FIGURE 6.56 Products transported by a conveyor belt are protected from the environment by means of covers provided with "D" handles at their sides. *Courtesy of Bay State Industrial Welding & Fabrication, Inc.*

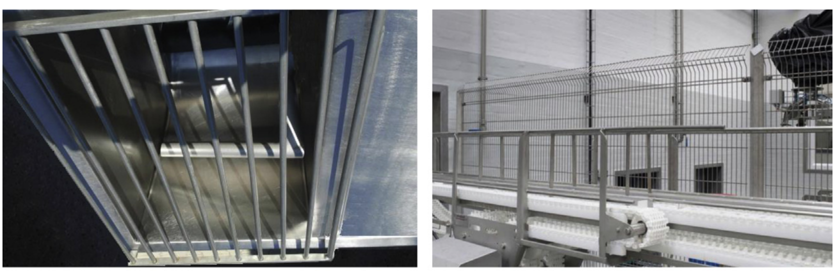
FIGURE 6.57 Clear plastic covers/guard. *Frank Moerman, ©2016.*

stress on it. Plastic covers should not be used where frequent removal of covers is required (APV Baker, 2001).

6.12.2 Guards

As compared to covers, the main function of guards is providing a physical barrier to prevent access of personnel into potentially hazardous areas or equipment such as moving equipment components. Although casings, maintenance enclosures, covers and doors also may function as guards, real guards have a more open surface, allowing observation of objects located behind the guard. Although the guards must comply with current health and safety legislation, they must be quite open to permit access for cleaning and disinfection by spray nozzles or hosing down procedures. Typically, the equipment components to protect are less or not water sensitive and are less likely to contaminate the food product (Moerman & Fikiin, 2016).

Bars (Fig. 6.58), perforated/punched sheet (Fig. 6.59) and weld mesh stainless steel guards (Fig. 6.60) with an open area of 40–50% give good protection from moving equipment parts. Expamet expanded metal mesh should not be used. Bars must be made of full stock rod (never hollow sections), preferably with small cross section and positioned in a vertical direction (easily cleanable from all directions) (Fig. 6.58A). In a vertical position, bars should have a round, diamond, rectangular (with small side turned outward) or triangular (with flat face turned outward) cross section. Bars with square cross section or a triangular cross section with flat face turned inward are not recommended, because their backside—without opening the guard—is difficult to clean. Guards should have a minimum number of horizontal parts. If installed in the horizontal plane, bars should not form ledges where dirt may accumulate. Placed horizontally, full stock small round cross section rods, full stock square or rectangular section members mounted at 45 degrees and parts having a triangular cross section with flat face turned outward are



(A) (B)

FIGURE 6.58 (A) Bars made of full stock rod preferably with small cross section and positioned in a vertical direction (easily cleanable from all directions). (B) If weld mesh guards are used, they should have a minimum number of horizontally running wires. *Courtesy of NTF-Aalborg A/S.*

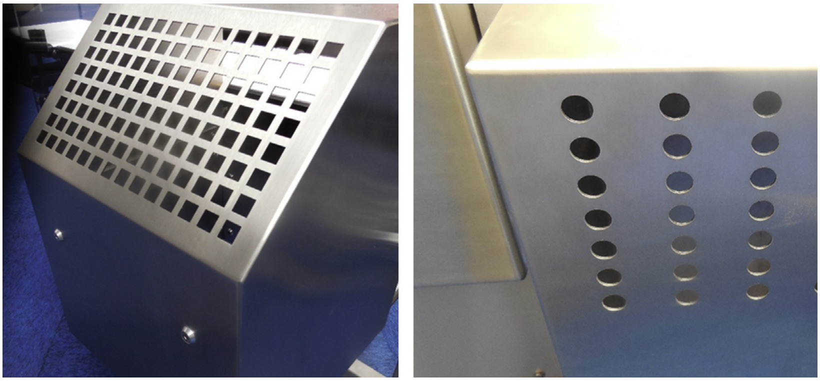


FIGURE 6.59 Punched stainless steel guards with 40/50% open area maximum. They must be opened for cleaning the inside. *Frank Moerman, © 2016.*

(A) (B)

FIGURE 6.60 Stainless steel guards: (A) Punched sheet (>95% open) gives good protection against the centrifugal fan, while allowing access for cleaning and disinfection. (B) Weld mesh guards positioned around the centrifugal fans have a sloped top surface. The fans themselves are positioned inclined on a sloped surface, allowing maximum drainage of condensate and cleaning liquids to the front side.

preferred, while bars with square or rectangular (with small side turned outward) cross section that provide a horizontal ledge are not recommended. Care should always be taken to pitch the bar according to safety requirements. If weld mesh guards are used, they should have a minimum number of horizontally running wires (Fig. 6.58B). Perforated/punched sheet guards with 40/50% open area (Fig. 6.59) must be opened to allow regular inspection and cleaning at the inside by a competent person. The fixing and removal of guards should reflect the frequency of necessary removal (e.g., for cleaning): interlocked guards should be used for high-frequency tasks (e.g., one shift a day) and fixed guards should be used for low-frequency tasks (e.g., monthly). Punched sheet guards (>95% open) and weld mesh stainless steel guards must not be removed for cleaning and disinfection.

6.13 ELECTRICAL EQUIPMENT, CABINETS, AND FIELD BOXES

Electrical and control installations should be limited to those that are necessary for the safe and correct operation of the process equipment. However, a significant part of both the electrical and control installations is still located within the process area, e.g., cabling to power motors of plant machinery, control cables connecting sensors via field boxes/cabinets to the plant control system, etc. But, little by little, wireless transfer of data between instruments and control equipment and battery-supplied low-energy sensors and actuators are finding their way in the industry.

6.13.1 Electrical Equipment

Electrical equipment should have an IP55 rating at a minimum. Preference is given to dust- and moisture-tight electrical equipment that can be hosed down with powerful water jets (IP66) or even better (IP67 & IP67K). IP69K rating, to German standard DIN 40050-9, is required for high-pressure, high-temperature, wash-down applications. Electrical equipment must be protected from things falling or product spilling on it. During cleaning, covering of electrical equipment with polyethylene or equivalent film is recommended.

Electrical equipment usually produces heat, and therefore must be in the possession of a dedicated cooling device. Fans ventilate (blow) heat out of the equipment in the environment by drawing in cooler outside air, circulating it throughout the case and expelling it to the outside. But along with the cooler air comes dust, microorganisms and eventually moisture, which easily accumulate in dry electrical equipment (Fig. 6.61). To avoid heat, dust and microorganisms being blown on the food during processing, the electrical equipment should be positioned away from the product zone. A more recommended alternative to ventilators is the use of the self-cooling capabilities of a casing by means of creating an internal air circulation and achieving temperature reduction through the casing surface. If this does not provide sufficient cooling, then additional cooling could be provided by fixing an air-to-water type heat exchanger to the casing (Moerman, 2011).

Direct or indirect incidental contact between the electrical installation and food cannot always be fully excluded and may possibly result in contamination of the food product. In all cases where product contact cannot be fully excluded, electrical installations have to be used that are suitable for these sensitive areas. Electronic devices positioned in the food contact area (direct and indirect) should be smooth, of a cleanable type and resistant against corrosive cleaning agents.

6.13.2 Electrical Cabinets and Field Boxes

Appropriate materials to construct field boxes and electrical cabinets are stainless steel AISI 304 or coated mild steel and plastic, provided they have

FIGURE 6.61 A cooling device that ventilates the heat produced by electrical equipment to the outside concomitantly accumulates dust and dustborne microorganisms inside the electrical equipment. Moisture- and dust-tight casings with high IP rating will reduce inside buildup of dirt, and therefore are especially recommended in dry material handling areas with high dust loads. Regular cleaning of the interior of electrical devices by vacuum is also a suitable option, but blowing with compressed air even in the presence of a dust extraction system is not recommended (Moerman, 2011).

a smooth finish. Enclosures (e.g., electric cabinets, junction and field boxes, as well as pneumatic/hydraulic enclosures) should have minimum ingress protection IP55. Any junction box expected to perform outside of an enclosure or cabinet and exposed directly to a hose-down needs an IP67 rating, at minimum. Although mounted in a moisture-proof housing, electrical distribution systems located in cold areas should be further protected against the formation of any condensate inside the cabinet by using an anticondensation heater within the cabinet. However, the heat generated by the electronic apparatus within the cabinet is often sufficient to avoid condensation (Moerman, 2011).

The design and installation of enclosures must prevent product, product liquid or water from accumulating onto the enclosure. As an example, in Figs. 6.62 and 6.63, the electric cabinet and field boxes are mounted at 30 to 45 degrees. However, a top roof with a minimum 30-degree inclination toward the front also allows water to run off and prevents tools being placed on the top of the cabinet. The front edge of the inclining cabinet top should reach beyond the front door and the seal, which preferably should be of a removable type to inspect for any potential dirt buildup under the seal (Figs. 6.64 and 6.65). Hinges must be located inside the sealing zone (Fig. 6.65) or shall be of the simple, take-apart type. When taken apart, hinges should be free of cracks or crevices.

The cabinets and field boxes must be mounted where they will be least exposed to splashes and hence they should not be placed in or above the

FIGURE 6.62 The electric cabinet is mounted at 30−45 degrees, preventing debris or liquids from accumulating on the top surface. The gaps formed by electric cables entering or leaving the enclosure can be closed by means of plastic caps. However, in this example, liquid tightness is not completely guaranteed. *Courtesy of Central States Industrial, www.pipetite.us.*

FIGURE 6.63 Sufficient distance is maintained between the cabinet base and the floor. The cabinet is positioned at a considerable distance from the wall of the enclosure. The top roof is sloped toward the front. The field boxes in smooth plastic are mounted at 45 degrees and sealed to the wall of the enclosure. Connections of cables and wires to field boxes are sealed. *Courtesy of GEA Group.*

food contact area. Placing in or above the food contact area would also result in condensate dripping from the field box of enclosure into the product. Field boxes and electrical enclosures also should be located such that easy access for maintenance and cleaning is practicable. It should be possible to open enclosure doors up to 90 degrees. Electrical control cabinets and field

FIGURE 6.64 Enclosure with a top roof having a minimum 30-degree inclination. *Courtesy of Rittal GmbH & Co. KG.*

FIGURE 6.65 Seal with folded lip along the top inside edge of the door should be of a removable type, and hinges installed inside the sealing zone create an easy-clean design on the outside. *Courtesy of Rittal GmbH & Co. KG.*

boxes mounted on the exterior of the equipment shall be sealed to the supporting member or equipment wall with food-standard silicon seal (Fig. 6.63) or spaced sufficiently away from the member/equipment wall to permit cleaning of all surfaces. In the latter case, a minimum of 20 mm between the enclosure and supporting member or equipment wall shall be provided. The distance between the cabinet base and the floor should be no less than 0.3 m. Dead spaces under cabinets or under false bottoms of electrical control cabinets, switching panels, or even computer closures should be regularly inspected for pest harborages, and treated with pesticide when necessary (Moerman, 2011).

All connections (e.g., cable ladders or wire trays, conduit, cable) to cabinets, field boxes, motors, and motor disconnects should be made via the bottom side. Occasionally, cable inlets can be made from the side. Connections must be made in a way that cables remain correctly separated (Fig. 6.66).

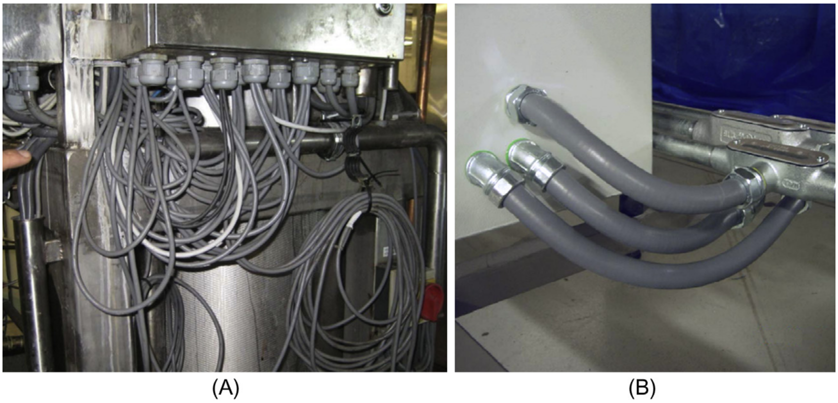


FIGURE 6.66 (A) Unhygienic connection of cables to the enclosure. (B) Connections must be made in a way that cables remain correctly separated. Flexible silicone paste appropriately applied between the fitting and the enclosure provides a watertight acceptable connection. *Courtesy of Mondelēz International, © 2016.*

FIGURE 6.67 Hygiene compatible cable glands with seal (blue) directly at the cable entry. The outside of the gland has minimum radii on the hexagon. The connection does not leave an external thread. Due to the presence of a seal with square cross section, the termination between the cap nuts and the enclosure is flush. *Photo left: courtesy of Rittal GmbH & Co. KG; photo right: courtesy of Pflitsch GmbH & Co. KG.*

Watertight connections of cables and wires to housings are essential because production stoppages may occur by water seeping into electrical machine parts through the cable connection. For cable assemblies used in wet industrial applications, overmolded connectors—whose material chemically bonds to the cable's outer jacket during manufacture—provide a watertight seal. In older designs, food-standard flexible silicone paste appropriately applied between the fitting, coupling or gland and the enclosure provides a watertight acceptable connection. Nowadays, hygiene compatible cable glands could be used, as well as hygienic connectors (Fig. 6.67).

6.13.3 Electrical Cabling

As cables are exposed, they must withstand mechanical (abrasion, impact and other trauma) and chemical stress (cleaning and disinfection agents, water, and foodstuffs like vegetable oil, fat, acid, and salty food), as well as high temperatures (warm water and steam) and in some cases below 0°C temperatures (Fig. 6.68). With respect to the outer cable jacket, natural rubber or neoprene was for many years preferred for its superior abrasion resistance and flexibility. However, modern thermoplastic technology has produced a number of PUR and PVC compounds that are soft and flexible but also very tough. In a food processing plant where there is a significant amount of splashdown used daily to achieve hygienic standards, PVC is a better choice than PUR because it is more resistant to water and harsh cleaning chemicals. It is of utmost importance that the outer cable jacket can withstand corrosive cleaning agents and disinfectants to prevent it becoming porous. In areas at very low temperatures (e.g., cold-storage warehouse), cold-resistant jacket materials must be used such as PA, PUR, PTFE, neoprene, nitrile butadiene rubber, silicone rubber, and EPDM rubber. Neoprene, nitrile, and silicone rubber behave excellently in the presence of edible oils and fats; EPDM rubber cannot be applied in such an environment. The outer cable jacket should be of a smooth type without longitudinal crevices, and only electrical cables with a round cross section should be used. Corrugated cable housings and spiral wound power lines shall never be used in the food processing area, as they may accumulate a lot of dirt and be very difficult to clean.

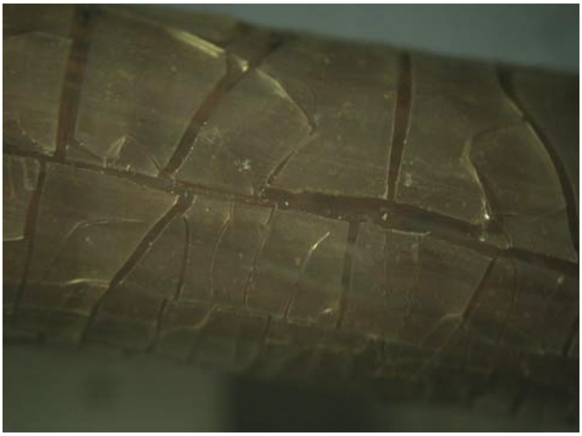


FIGURE 6.68 PVC-insulated wire after exposure to hot pressurized water of 130°C. The surface of the insulation has suffered from severe cracking. In an environment of high moisture content and high temperature, insulating materials are prone to hydrolysis. Hydrolytic attack is not concerned only with absorption of water, but with a chemical reaction in which the original insulating material is turned into a new material that no longer acts as an electrical insulator. If only water absorption occurs without hydrolysis, only a small decrease in its dielectric properties will occur, which can be tolerated.

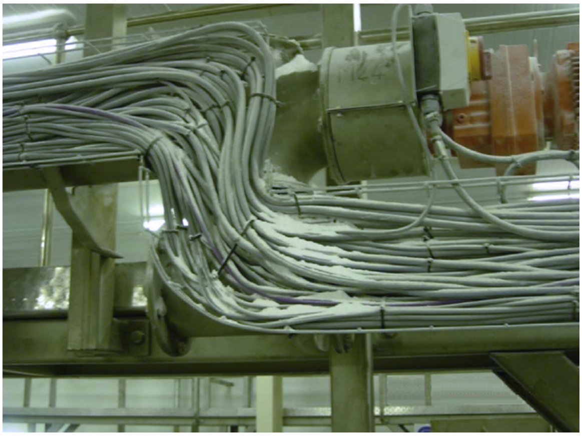
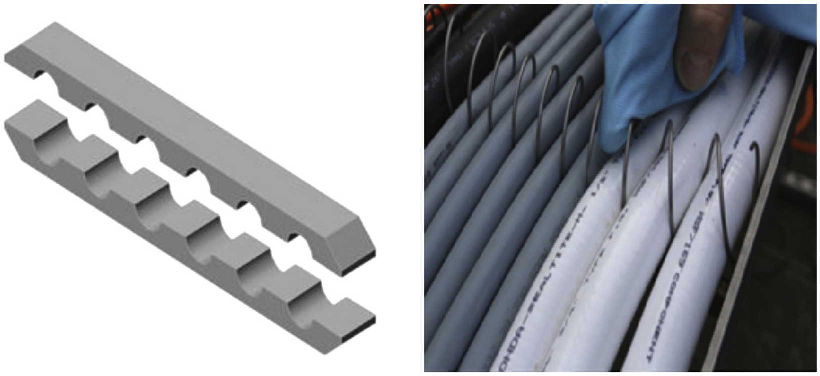


FIGURE 6.69 Entangled cable arrangements may accumulate dirt, hamper inspection and appropriate cleaning, and become breeding grounds for vermin and pests. *Courtesy of Mondelēz International, © 2016.*

Tangled cable arrangements (Fig. 6.69), which may become breeding grounds for vermin and pests, should be avoided. These bundles of cables may also be the cause of accumulating product residue and may give rise to the development of microorganisms. Generally speaking, cables, hoses, etc. should be routed in a way that makes it possible to see dirt—e.g., the routings should be as open and visible as possible to facilitate cleaning around and between them. Therefore, electrical cables must be fastened individually at a distance from each other (no less than 25 mm) (Fig. 6.70) but cable binders should be avoided because they impede the effectiveness of cleaning operations. If strips are used, they should preferably be of a stainless steel type that can be detected by means of a metal detector. Alternatively, a plastic strip of a color that is not omnipresent in the food product and food factory could be used, which in most cases is blue. Nowadays, plastic strips are available with metal content dispersed throughout the head and strap, but it has been proven that cut-off sections cannot always be detected by means of metal detection.

In medium hygienic areas, cable ladders or cable trays should be used instead of conduit as a means to support current carriers over long distances. Furthermore, conduits should not be used in dry production areas; small wire trays should be used here because they allow dry cleaning. However, cable ladders or cable trays are less suitable in high hygienic areas because of the difficulties in cleaning them. In high hygienic areas, conduits can be used for short distances on the condition that they are suitably sealed at both ends by a proprietary cable gland/sealing gland where a cable does pass through. The index of protection for the conduit should not be less than IP55. The use of conduits with unsealed openings in medium hygienic areas is only



(A) (B)

FIGURE 6.70 (A) Cables should be separated by a distance of no less than 25 mm to prevent the buildup of soil and to ease cleaning. Cable separators of the type shown can be installed in wire trays (Moerman, 2011). (B) A hygienically designed cable support system with springs keeps the cables separated at a correct distance from each other. *Courtesy Anamet Europe B.V.*

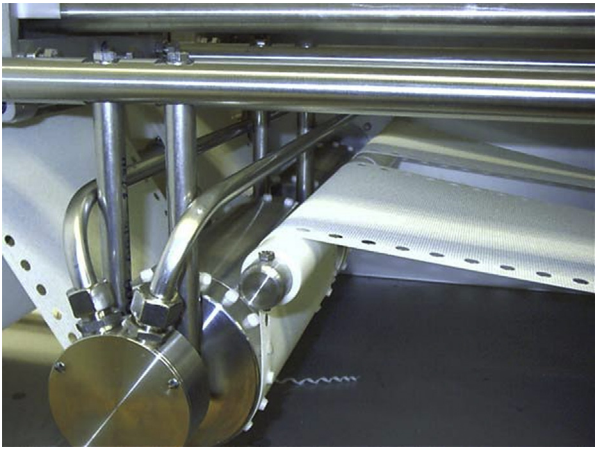


FIGURE 6.71 Cables can be protected from dirt layering and damage by encapsulating them in hermetically closed cable housings such as stainless steel pipes, especially in the neighborhood of the food contact and splash area (Den Rustfri Stålindustris Kompetencecenter, 2006).

acceptable for small distances. When open conduits are used for multiple cables of small diameter sharing the same route, oversizing the conduit to allow for wet cleaning is common practice. Individual cables that do not share a common route with other cables are as hygienic as a single conduit run. However, a cable is usually more difficult to support in a hygienic manner than conduit. In the neighborhood of the food contact and splash area, cables also can be encapsulated in hermetically closed cable housings such as stainless steel, aluminum or hardened plastic pipes (Fig. 6.71) or flexible

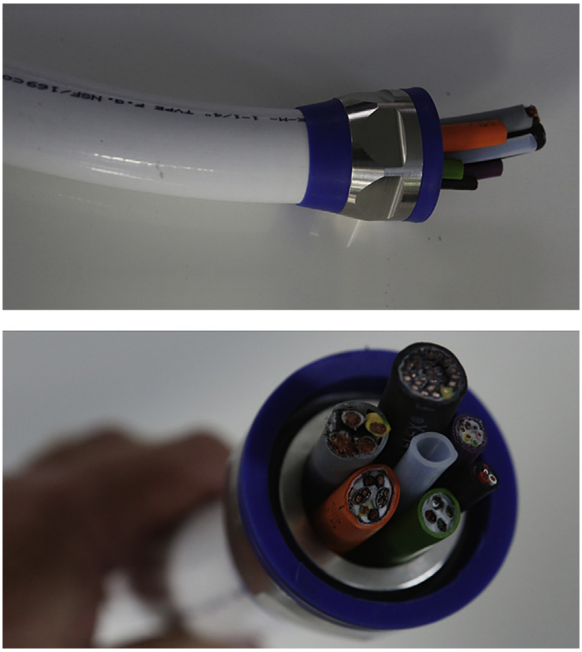


FIGURE 6.72 Multiple cables and wires can be combined in a flexible conduit with a smooth outer surface, further provided with a hygienic connector allowing a watertight connection to the maintenance enclosure or process equipment without visible thread in the screwed state. These hygienically designed conduits may reduce the number of cables that must be individually laid on cable ways, reducing the amount of contaminants that may build up on current carriers and enhancing the cleanability of the cable transport system. These flexible conduits are also suitable for connections to machinery subject to vibration (e.g., motors) (Moerman & Wouters, 2015). *Courtesy Anamet Europe B.V.*

conduits (Fig. 6.72). Cable mounting in pipes, however, still creates a hollow body and hence a hygienic risk when the integrity of the piping system is lost because of unsuitable fittings at cable entries and exits or because of damage to the thin-walled cable housing/pipe due to physical/mechanical impact. However, the flexible conduits (Fig. 6.72) provide a permanent and fluid-tight protection tube for multiple electrical cables and wires, as they are provided at their ends with stainless steel AISI 316 L fittings that allow ingress-protected seal connections with the equipment that must be powered (Moerman, 2011; Moerman & Wouters, 2015).

Cables may not be routed under machines and too close to the floor for the following reasons: (i) food residues may fall onto the cables, (ii) restricted access/visibility for inspection and cleaning, and (iii) liquids and dirt may splash from the floor onto the cables during cleaning operations. Mounting of cables also should be as far as possible away from the splash area. If there is no other choice, cables in the neighborhood of

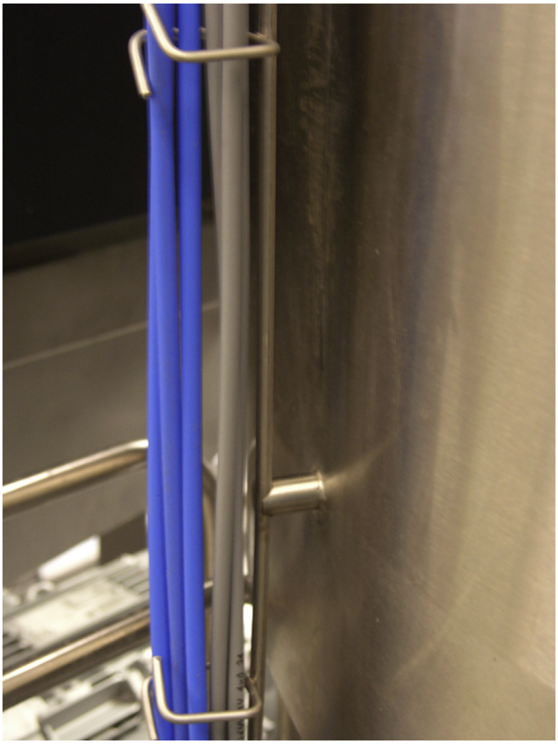


FIGURE 6.73 Cable support system with a minimum number of members. The number of loosely fixed cables should be minimal, to avoid uncleanable entangled cable arrangements.

food processing equipment should be loosely mounted on cleanable open cable trays. To allow for cleaning, cable supports (trays, ladders, conduits, etc.) must be spaced at least 20 mm away from adjacent surfaces (Moerman, 2011).

Cable support systems are usually constructed of the same hygienic material as the equipment being supported (stainless steel AISI 304 L or AISI 316 L) and the exterior finish must be smooth. They should not have sharp edges, recessed corners, uneven surfaces, open hollow sections, unprotected bolt threads and screws. Brackets manufactured from angle or channel must be avoided or minimized. Cable support systems with a minimum number of members should be used where possible (example Fig. 6.73). Eventually horizontally mounted trays can be covered at the top with removable lids, so that dirt settles on the lid instead of between the cables. These lids should be wider than the trays and inclined to allow run off of liquids. It is essential that lids can be removed to allow cleaning of cable supports and cables (Moerman, 2011).

6.14 HUMAN INTERFACES

6.14.1 Hygienic Design and Installation of Switch Boxes

Control boxes should be preferably made of smooth, corrosion-resistant stainless steel plate with low surface roughness, and should be constructed with >6 mm radiused edges and without pits and crevices. Seams should be minimized and bolted connections should be avoided. With an IP67 to IP69K rating, they are protected against the penetration of water or damp during high-pressure hose-down cleaning operations. The switchbox should be mounted to equipment at least 6 cm from the equipment framework (Fig. 6.74), with suspending members constructed of solid steel round tubing.

6.14.2 Hygienic Design and Installation of Control Panels With Control and Indicator Devices

In noncomputer-based control panels, control and indicator devices are the machine components used as interfaces between man and machine. Adequate space should be provided between control and indicator devices for easy cleaning and disinfection (Fig. 6.75). Very often, control panels are provided with more holes than necessary for the installation of control and indicator devices. Unused holes in a control panel can be closed by means of blanking plugs. Installation of control and indicator devices in control panel bore holes that are larger than required can occur by means of adapter rings.

Push buttons, knobs, valve handles, switches and locks must be designed so as to ensure that food product, water or product liquid do not penetrate into the interface or accumulate onto the enclosure. Therefore push buttons,

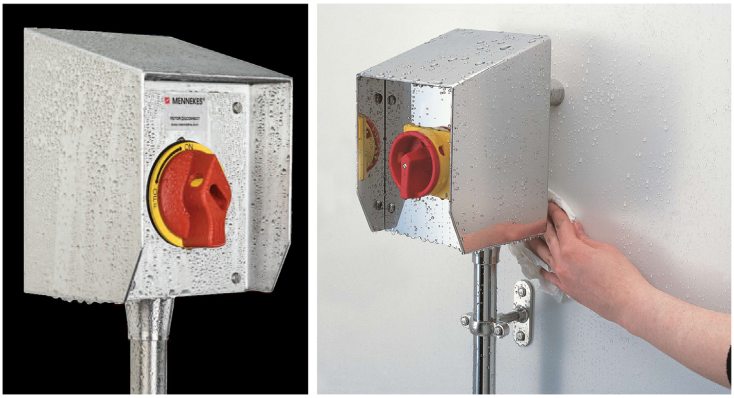


FIGURE 6.74 Control boxes either can stand apart *(courtesy of MENNEKES Electronics, Inc.)* or can be mounted remotely from the equipment framework/wall at a distance of about 6 cm. Suspending members are constructed of solid steel round tubing *(courtesy of Electrix International Ltd).*

FIGURE 6.75 Control panel with hygienic control and indicator devices. An IP67 or IP67K ingress protection rating for control panel enclosures is highly recommended. *Courtesy of K.A. Schmersal GmbH & Co. KG.*

when touched, should not penetrate deeply in the front panel far beyond a protruding frame edge surrounding the button (Fig. 6.76).

Control and indicator devices must be constructed of durable and mechanically stable (unbreakable, resistant to steam, moisture, cleaning agents and disinfectants, abrasion and corrosion resistant) material, such as stainless steel or plastic (polyamide, polycarbonate, polyoxymethylene, silicone, and acrylonitrile butadiene styrene). Antimicrobial push buttons are commercially available. Knurling on hand grips should not be used, and device heads must have crevice-free and easily cleanable surfaces with smooth finish. Actuators of devices with grip or mushroom shape must have curvature radiuses ≥ 3.2 mm at all corners and edges. The device seals of the control devices shown in Fig. 6.77 make contact with the actuator and bezel (gray), hence preventing hygiene-critical gaps. The outer surfaces of the device seals all make a smooth, flush (in the case of push buttons and indicator lights) or continuous (in the case of other device versions) transition from the free outer surface of the actuator to the bezel. Front plate seals inside the control device help to avoid the penetration of pressurized water. Front plate and outer surface of the bezel are at an angle of approximately

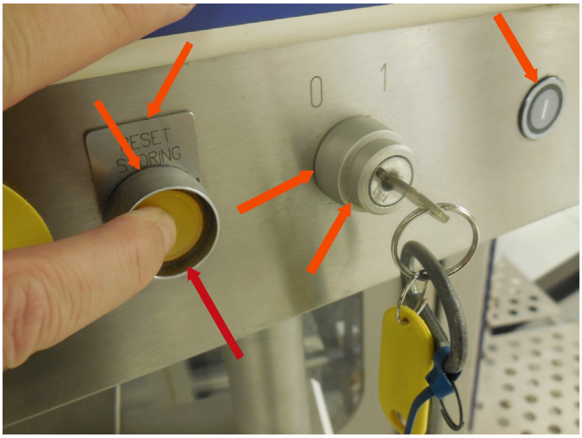


FIGURE 6.76 The push button, when touched, penetrates deeply in the front panel far beyond the protruding frame edge surrounding the button. Every time the button is pushed, food debris built up at the inside cylindrical frame moves deeper to the inside. As the inside of the actuator forms a niche in which microorganisms may grow, the inside of the protruding frame edge becomes heavily contaminated with microorganisms every time the button moves back. Thus, the actuator becomes a serious source of cross-contamination from operator to operator. The sharp corners and gaps, as indicated by the arrows in orange, are areas where, respectively, accumulation or ingress of product residues and cleaning solutions may occur. *Frank Moerman, ©2016.*

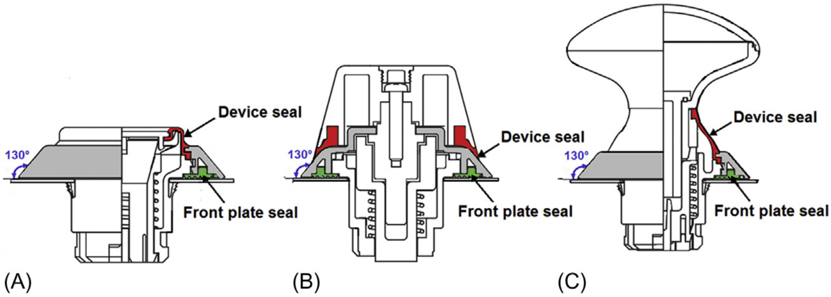


FIGURE 6.77 Control devices such as (A) push buttons, (B) position/selector switches, (C) mushroom buttons finally become integrated in a control panel. They must be shaped in such a manner that no accumulation of dirt and bacteria occurs and cleaning is facilitated. Also device head to front panel transitions must be smooth and without corners and edges. Perfect, hermetic device and front seals prevent the ingress of moisture, dust, and dirt within the control panel. Devices with damaged or destroyed seals should be replaced immediately. *Courtesy of K.A. Schmersal GmbH & Co. KG.*

135 degrees, thereby creating a surface without "sharp" transitions (Elan Schmersal, 2010; Moerman, 2011).

Control panels should be positioned away from the product zone, so that the operator does not have to lean over product to operate. The preferred installation positions for control and indicator devices are declining and

FIGURE 6.78 Touchscreen display installed inclined. *Courtesy of OctoFrost Group; Frank Moerman, ©2016.*

vertical surfaces, such that fluids (splashed food and cleaning solutions) are able to flow from the control panel, at least in the cleaning position.

6.14.3 Hygienic Design and Installation of Electronic Panels

More hygienic alternatives to control panels with push buttons and selection switches are membrane panels with a $\geq 2\%$ inclination or touchscreen displays (Fig. 6.78). Vertically placed touchscreen displays are preferred over membrane panels, although the latter are more suitable when the input of huge amounts of information is needed. Touchscreen displays are often made movable, as they can pivot around a vertical axis fixed on the equipment. Thus, cleaning and maintenance of the equipment and its environment may proceed more easily.

Screens should be covered with an antistatic layer to avoid dust collection. Furthermore, they must be hermetically enclosed in a frame with IP67 or IP67K ingress protection rating and should be flush with the housing (no crevices due to protruding or intruding of screens in the screen housing). Screens, including the more fragile touchscreen displays, must be frequently wiped clean with a soft damp cloth and finally dried with a soft dry cloth. Disinfection may occur with wipes impregnated with 60% isopropyl alcohol and 200−400 ppm quaternary ammonium compound.

6.15 INSTALLATION OF THE FOOD PROCESSING EQUIPMENT IN THE FOOD FACTORY

6.15.1 Clearance With Respect to the Floor, Walls, and Adjacent Equipment

There should be enough clearance under the machine to allow for adequate cleaning and inspection to be carried out effectively. With that purpose, the process equipment should be installed as high off the ground as possible (Fig. 6.79). The minimum height should be a function of the depth of the bottom surface above the floor (indicative: 150−300 mm). For large-sized equipment, greater distances apply (at least 0.5 m from walls), as it is necessary to be able to walk around such equipment and have at least enough room to facilitate cleaning. If the equipment is sealed against the mounting surface, care must be taken to avoid gaps, cracks or crevices where insects or microorganisms can remain/survive after cleaning.

Installation of large equipment (e.g., freezing equipment, meat curing chambers) on feet is technically not always possible. An alternative is sealing the equipment onto the factory floor. Proper sealing of the perimeter between the equipment and the subfloor must prevent water from accidentally getting

FIGURE 6.79 Process equipment should be installed as high off the ground as possible to facilitate cleaning and reduce the risk of cross-contamination during cleaning operations. In this case, dirt released from the floor during high-pressure cleaning may splash on the process equipment. *Courtesy of Joe Stout, Commercial Food Sanitation LLC - Intralox, © 2016.*

into this space. But sealing, especially with silicone, has not always proven to be successful in excluding wet and unhygienic conditions.

Equipment must not be mounted beneath tanks or vessels so that maintenance and cleaning are impeded but must be easily accessible. Increased elevation of tanks and vessels facilitates cleaning and maintenance operations beneath them but water and condensation running down their sides may allow microbial growth and certainly must not fall onto exposed product.

6.15.2 Stairs, Raised Walkways, and Platforms

Stairs, walkways, and platforms comprising the secondary steelwork in the food factory must be constructed as follows:

- Painted or galvanized mild steel may be used in dry areas, while SS AISI 304, aluminum or galvanized mild steel should be used in wet areas depending on the type of cleaning agents used to clean the equipment in the area concerned. Where the cleaning agents corrode aluminum and galvanized steel, SS AISI 304 should be used. Stainless steel AISI 304 or better AISI 316 L always should be used for all fixed access equipment (e.g., decking, handrails) located in areas where foods are prepared and manufactured.
- Supporting and framing members should be designed to eliminate as many ledges, projections and pockets as possible. Open profiles are preferred over hollow sections, but consideration should be given regarding their orientation. Open profiles installed in the horizontal plane preferably should have their folding turned downward, although outward turned constructions are allowed as long as they are cleanable. In the horizontal plane, open profiles should never have their folding turned upwards. Installed in the vertical plane, open profiles must have their folding turned outward.
- If closed profiles have to be adopted (not recommended), frequent inspection for cracking should be carried out to prevent risk from contamination. Round or square section members turned through 45 degrees (Fig. 6.80A) that provide sloping surfaces are recommended
- If handrails are made from circular tube, they should be welded to the stanchions and any tube joints should also be welded and ground flush. All open ends of tubes must be sealed with a welded plate. All welded junctions must be smooth and continuous. In high hygiene areas, solid handrails could be considered.
- All framework parts of stairs, ladders, raised walkways, and platforms should be accessible for inspection, maintenance and cleaning.
- Connecting the framework of stairs, walkways, or platforms to a floor usually occurs by means of a base plate securely fastened to the floor by means of a fixing bolt (Fig. 6.81). However, to minimize the possibility for microbial presence and growth, a rubber seal between the floor and

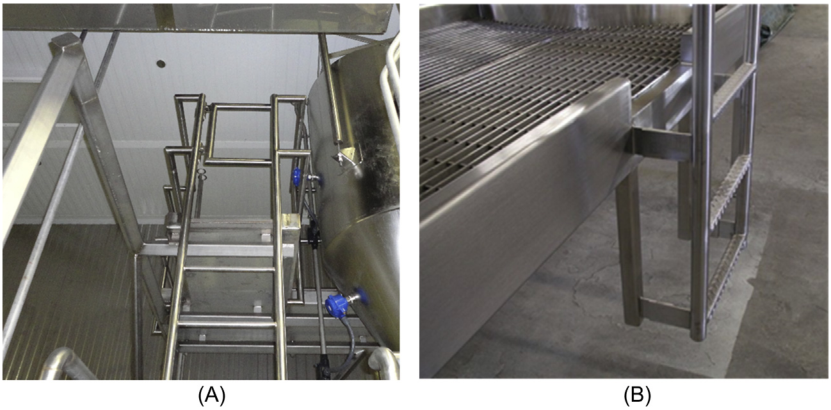


FIGURE 6.80 (A) The framework of the platform consists of closed square section members turned through 45 degrees (diamond configuration). The solid deck plates of the walkway are mounted a distance from these horizontal framework members. Kickplates are installed at the perimeter of the platform deck. Handrails and rungs of the ladder are made of round tubing *(courtesy of The Stellar Group)*. (B) The ladder is installed about 200 mm above ground level. Because the ladder makes no floor contact, the factory floor below the ladder can be cleaned very easily. Ladder rungs are covered with nonslip surfaces. Open metal grid is used as decking, although not recommended, especially if food is passing beneath the platform. However, solid deck plates provide fewer niches for food debris to accumulate and microorganisms to grow, and they are also much easier to clean. *Photo left, courtesy of The Stellar Group; photo right, courtesy of Bay State Industrial Welding & Fabrication, Inc.*

base plate is required to ensure a tight fit, especially because direct mountings onto floors are inevitably uneven. Base plates also can be fixed to a floor plinth (Fig. 6.82), thus prohibiting dirt and liquids from getting under the base plate during process and cleaning operations. Alternatively, the supporting framework members can be embedded in concrete. To facilitate the cleaning of the factory floor, the stringers of staircases should make minimal floor contact, and if possible no floor contact (Fig. 6.82).

- If ladders are used (Fig. 6.80B), provide handrails where possible. Ladder rungs should not be used as handholds, because they are a source of contamination (transfer of contaminants from feet to hands). Provide a safety cage where required (depending on the height of the ladder), and install the ladder in a manner that floor contact is minimized (Fig. 6.80B). Where possible, to facilitate the cleaning of the factory floor, the base of the ladder should not make floor contact, and preferably should be about 200 mm above ground floor level.
- Stairs, raised walkways (Fig. 6.81B and platforms over exposed product should be avoided as much as possible, because dirt may be transferred from clothing or footwear onto production lines beneath.
- The treads of stairs should be constructed from solid plates containing a raised antislip material (e.g., checker plate). Open grating is not allowed.

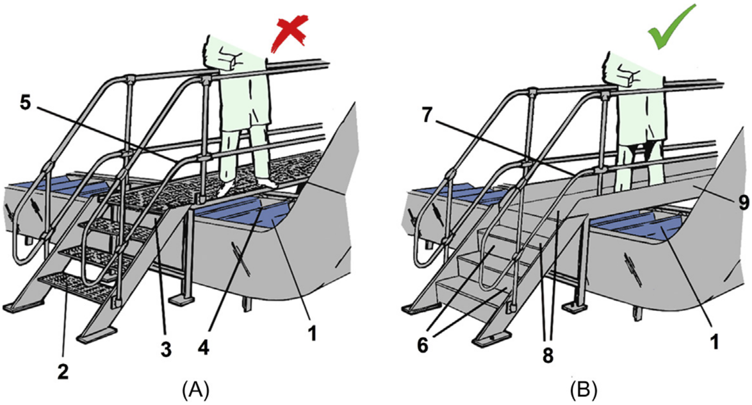


FIGURE 6.81 (A) If not appropriately designed, walkways and stairs over open product (1) may contaminate it. Open-mesh steps (2) that are not enclosed by closed vertical risers (3), the absence of a cover over the product area (4) and the handrail and its mountings hanging (5) over product area put the open food product at risk. (B) Now, the steps are enclosed (6), the handrail is mounted inside the walkway (7), solid antislip steps and floor plates are used (8), and fully welded, continuous kickplates are in place to prevent the open product from getting contaminated (Hauser et al., 2004b).

FIGURE 6.82 (A) Connecting the framework of stairs, walkways, or platforms to a floor usually occurs by means of a base plate securely fastened to the floor by means of a fixing bolt (*courtesy of Holland Applied Technologies*). (B) Base plates also can be fixed to a floor plinth, thus prohibiting dirt and liquids from getting under the base plate during process and cleaning operations. The stringers of staircases make no floor contact, hence facilitating the cleaning of the factory floor. *Photo left, courtesy of Holland Applied Technologies; photo right, courtesy of Bay State Industrial Welding & Fabrication, Inc.)*

The tread plates must have a small inclination (3–5 degrees) for improved drainability (Fig. 6.83).

- Where there is no risk for product contamination, the risers of the stair may be left open, but the stringers still must be of the closed type. Gaps

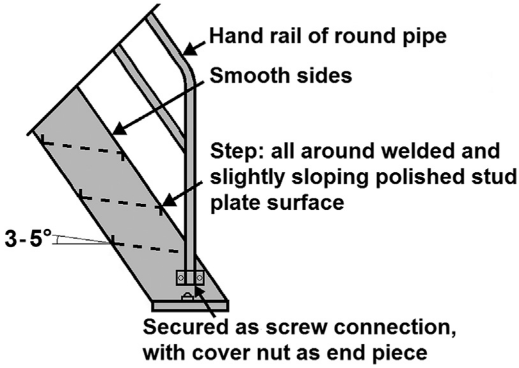


FIGURE 6.83 The tread plates must have an inclination of 3−5 degrees for improved drainability.

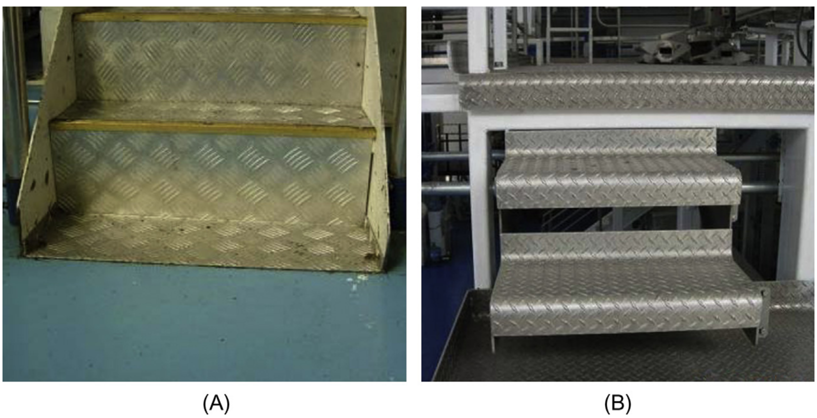


FIGURE 6.84 (A) Decking and adjacent kickplates give rise to difficult-to-clean square corners and crevices. Underneath the tread plate at the base of the stair, dirt and liquids may accumulate. (B) Kickplates and decking designed as a one-piece construction with generous radii in the corners of kickplates. *Courtesy of Mondelēz International,* © *2016.*

between the tread plates and stringers are allowed, as they may preclude buildup of contaminants in sharp corners and improve the cleanability of the stair.

- Where personnel movement is required in areas with exposed food products, the stairs must be totally encased (Fig. 6.81B). Completely closed risers now must form with the solid tread plates and stringers (closed type) an all-welded completely sealed staircase. Risers and tread plates of staircases should be constructed of the same impervious, noncorrodable, easy to clean, and impact-resistant antislip material as the deck. As sharp corners and crevices (Fig. 6.84A) allow food debris to accumulate, all corners must be rounded (Fig. 6.84B).
- When factory employees use walkways and platforms of poor hygienic design as crossovers of conveyor-systems, they may bring the food

beneath at risk. Although covers (Fig. 6.56) may protect the exposed food products, 150 mm high kickplates without any gaps between the kickplates and solid plate decking (containing a raised antislip material) may further preclude spillage of debris and liquids onto food products (Fig. 6.82). Kickplates and decking should be designed as a one-piece construction with generous radii in the corners of kickplates (Fig. 6.84B) to allow proper cleaning and disinfection. Kickplates are provided either by bending the perimeter of the solid deck plate or by full continuous welding. To protect the food processing activities below, it is essential that the kickplates be provided over the whole perimeter of the walkway or platform without leaving gaps and openings from where liquids may spill.

- Handrails should not overhang the walkway and must be attached to the inside of the walkway bridge or platform.
- Drainage of walkways and platforms, etc. is always difficult as the floors are rarely sloped to drains. The drains themselves have then to be piped and led to factory drains in the floor below in a way that does not endanger product safety. Untrapped drain lines shall be provided with an air gap at the discharge to the sewer and shall be removable for cleaning. If possible, the use of water on such structures should be avoided. If unavoidable, safe mechanisms of disposing surface water should be planned at the time of construction.

6.16 CONCLUSIONS

If open food processing equipment is not designed for easy cleaning and disinfection, small amounts of liquid and dirt, as well as microorganisms may become large enough to unroll both chemical/physical contamination and microbial growth. Moreover, the small bits of food debris from a previous product batch can compromise the quality of product (e.g., taste, texture, etc.) produced in a subsequent batch, make food unfit for consumption on religious grounds, affect its authenticity or induce allergic reactions in consumers (if allergens are present). Good hygienic engineering and design practices have proven to successfully reduce these problems, with a final result that costly product recalls can be avoided. Moreover, apart from being effective in preventing one batch cross-contaminating the next one, good equipment design also allows considerable savings during cleaning operations. The time required to clean and disinfect can be minimized and thus prolong the time to produce, and the consumption of water, cleaning chemicals and energy to heat the cleaning solutions can be reduced. These features make hygienically designed, open food processing equipment much more sustainable and cost-effective in a long-term perspective, although it is initially more expensive than poorly designed equipment.

REFERENCES

APV Baker (2001), Hygienic Design Handbook, 2nd edition, Peterborough, United Kingdom, 53 p.

Campden Food Preservation Research Association (CFPRA) (1983), Hygienic Design of Food Processing Equipment, in Dudley, K. (Ed.), Report prepared by the Working Party on Hygienic Design of the Heat Preserved Foods Panel in conjunction with the Research Association, Technical Manual No. 7, Chipping Campden, Gloucestershire, United Kingdom, 93 p.

Den Rustfri Stålindustris Kompetencecenter (2006). Conveyors, with a focus on hygiene, *Guideline N° 3*, version 1.0, Danish Technological Institute, Kolding, Denmark, 60 p.

EDQM (European Directorate for the Quality of Medicines and Healthcare of the Council of Europe) (2013), Technical guide on metals and alloys used in food contact materials and articles, A practical guide for manufacturers and regulators, ISBN 978-92-871-7703-2, Committee of Experts on Packaging Materials for Food and Pharmaceutical Products (P-SC-EMB), 1st edition. Strasbourg, France, 216 p.

Elan Schmersal (2010). Control Devices and Indicator Lights for Food Processing Machines and Heavy-Duty Applications, 22.3 mm Diameter Installation. Catalogue N/09 - Type series N, 34 p.

Hauser, G., Curiel, G.J., Bellin, H.-W., Cnossen, H.J., Hofmann, J., Kastelein, J., et al., 2004a. Hygienic Equipment Design Criteria, EHEDG Guideline N°8, 2nd edition. EHEDG subgroup "Design Principles", EHEDG, Frankfurt, Germany, pp. 1–16.

Hauser, G., Curiel, G.J., Bellin, H.-W., Cnossen, H.J., Hofmann, J., Kastelein, J., et al., 2004b. Hygienic Design of Open Equipment for Processing of Food, *EHEDG Guideline N°13*, 2nd ed. EHEDG subgroup Design Principles, EHEDG, Frankfurt, Germany, pp. 1–24.

Kold, J., Tomsett, R., Hopma Zijlema, P.K., Silverman, C., Lucchi, M., Scheffler, R., et al., 2016. Hygienic design of belod industry. EHEDG guideline N° 43. EHEDG subgroup Conveyors, EHEDG, Frankfurt, Germany, pp. 1–76.

Lelieveld, H.L.M., Mostert, M.A., Curiel, G.J., 2003. Hygienic Equipment Design. In: Lelieveld, H.L.M., Mostert, M.A., Holah, J., White, B. (Eds.), Hygiene in Food Processing, 1st edition. Woodhead Publishing, Cambridge, England, pp. 122–166. Book N°88. (Chapter 8).

Moerman, F., 2011. Hygienic Supply of electricity in food factories. In: Lelieveld, H.L.M., Holah, J. (Eds.), Hygienic Design of Food Factories, N° 216. Woodhead Publishing, Cambridge, United Kingdom, pp. 369–411. (Chapter 19).

Moerman, F., Fikiin, K., 2016. Hygienic design of air nlast freezers. In: Lelieveld, H.L.M., Holah, J., Gabrić, D. (Eds.), Handbook of Hygiene Control in the Food Industry, 2nd ed. Elsevier, Cambridge, United Kingdom, pp. 271–316. (Chapter 22).

Moerman, F., Kastelein, J., 2014. Hygiene design and maintenance of equipment. In: Motarjemi, Y., Lelieveld, H.L.M. (Eds.), Food Safety Management: A Practical Guide for the Industry. Academic Press, San Diego, United States, pp. 673–739. (Chapter 26).

Moerman, F., Partington, E., 2014. Materials of construction for food processing equipment and services: requirements, strengths and weaknesses. J. Hygienic Eng. Design 6, 1–37.

Moerman, F., Wouters, P., 2015. Hygiene concepts in food factory design. In: Leadley, C., Sykes, R. (Eds.), Innovation and Future Trends in Food Manufacturing and Supply Chain Technologies, N° 293, 1st ed. Woodhead Publishing, Cambridge, United Kingdom, pp. 81–133. (Chapter 4).

Moerman, F., Perryment, A., Cain, T., Fröderberg, I., Declerck, D., Berghoff, R., et al., 2005. Hygienic Design of Freezing Equipment, 1st guideline draft. EHEDG subgroup Refrigeration, EHEDG, Frankfurt, Germany, 41 p.

Partington, E., Besuchet, P., Godwin, A., Hall, K., Holah, J., Holland, P., et al., 2005. Materials of construction for equipment in contact with food. EHEDG Guideline N° 32. EHEDG subgroup Materials of Construction, EHEDG, Frankfurt, Germany, pp. 1–48.