EHEDG Update

For food processing to be carried out hygienically, it is important that the initial design takes into account factors affecting the hygienic operation and cleanability of the plant. In this paper, the 16th in a series of EHEDG Updates to appear in *Trends in Food Science & Technology*, we summarize the guidelines for the hygienic design of equipment for open processing plants, as recommended by the European Hygienic Equipment Design Group (EHEDG) subgroup on Design Principles and approved by the EHEDG. The EHEDG is an independent consortium formed to develop guidelines and test methods for various aspects of the safe and hygienic processing of food; the group includes representatives from research institutes, the food industry, equipment manufacturers and government organizations in Europe*.

The risk of contamination of food products with relevant microorganisms during open processing increases with the opportunity to grow in poorly designed equipment, as well as with the concentration of the microorganisms in the environment. This means that, in open plants, environmental conditions, in addition to appropriate equipment design, have an important influence on hygienic operation. In addition, the type of product and the stage of the manufacturing process must be taken into consideration. Open processes incorporate many different types of equipment, including machines for the preparation of dairy products, alcoholic and non-alcoholic drinks, ice-cream products, sweet oils, nutrient fat, coffee products, sugar, cereals, vegetables, fruit, bakery products, meat and fish.

Different levels of hygienic requirements can be demanded during different stages of processing and manufacturing, for example when handling raw products that have to be heat treated, as compared with microbially unstable ready-made products and consumer goods. In principle, the design of the equipment and the environmental conditions must exclude any increase in the concentration of relevant microorganisms in the products.

Scope

The Design Principles subgroup of the European Hygienic Equipment Design Group (EHEDG) has produced in previous papers guidelines on general hygienic design principles[1], hygienic welding[2] and the hygienic design of equipment for closed processing[3]. The guidelines have been approved by the EHEDG.

This paper deals with the principal hygienic requirements for equipment for open processing. It describes methods of construction and fabrication, giving examples as to how the principal design criteria can be met in open process equipment. In the case of machines

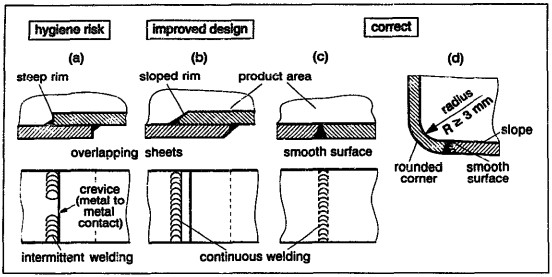

Fig. 1

Welded joints. (a), Overlapped sheets with intermittently welded seams create crevices and metal-to-metal contact areas between the seams. (b), An improved design of overlapped sheets must have continuous welds and sloped rims for easy cleaning. (c), Correct design is characterized by smooth, continuously welded sheets. (d), For welded joints in corners, smoothly rounded corners and correctly welded seams in the adjacent planar area are recommended.

and more compact and dense surface layers. In addition, before using plated materials for a given application their corrosion resistance in relation to the properties of the products and cleaning detergents must be considered.

Plastic materials are used to protect tools and implements from metal-to-metal contact (e.g. for shear edges of cutters), as guides and covers, or for hoses because of their plasticity and corrosion resistance (for recommendations, see Ref. 1). It must be noted that some plastics are porous and can therefore absorb product constituents and harbour microorganisms. Special attention must be paid to this effect by careful cleaning and periodic inspection.

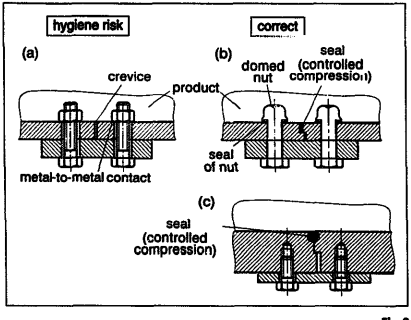

Fig. 2

Dismountable joints. (a), Hazards arise from overlapped screw joints owing to crevices between the sheet rims, exposed poorly designed nuts or screw heads, and non-sealed screw threads. (b), If the exposure of screws to product is unavoidable, domed nuts, metal-backed seals and sealed rims on the overlapped sheets characterize hygienic design. (c), Optimal design uses sealed sheet rims and screw joints at the reverse side, away from the product.

Rubber materials and other elastomers are commonly used for gaskets, seals, scrapers, etc. Excessive mechanical or thermal compression or deformation causes damage to such materials, adversely affecting their cleanability (for recommended materials, see Ref. 1).

Wood is appropriate only in a limited number of cases, for example when it plays a favourable role in relative humidity regulation and/or microbiological ecology (cheese ripening, or the production of wine, vinegar, etc.), or when its mechanical properties cannot be obtained with other available materials (e.g. butcher's blocks). Wooden surfaces must be cleaned and disinfected effectively because they can contain microorganisms that can grow on nutrients found in products. Splinters can result in foreign body contamination.

Surfaces

All surfaces in contact with foodstuffs must be easy to clean. Therefore, they must be smooth, continuous and free from cracks, crevices, scratches and pits, which can harbour and retain soil and/or microorganisms after cleaning. The recommended surface finish for stainless steel is $R_a \leq 0.8\,\mu m$ (Ref. 1). It should be maintained during the usable life of the equipment.

Joints

It is preferable to use permanent joints, rather than dismountable ones, to reduce hygienic risks posed by projections, protrusions, edges, recesses, metal-to-metal contact and crevices of sealing gaskets.

Permanent joints in equipment should preferably be welded. Several types of common defects arise in welds (e.g. misalignment, cracking, porosity, inclusions) that can act as a source of microbiological problems. The principal hygienic requirements for the welding process, including welding seams, were published in Ref. 2.

The product-contact surface of welds must be smooth (ground flush with the surrounding surface). To avoid crevices by metal-to-metal contact, the welded seams must not be intermittent but continuous. Overlapped welded joints should not be used because they may retain soil and form areas at the overlap edge that are difficult to clean. If overlapping is unavoidable, reliable draining and cleaning conditions of the 'shadow' area must be taken into consideration. The welded seams should be ground flush and smooth. In the case of thick sheets, the edge of the upper plate must be sloped. If necessary, welds must be ground smooth as shown in Fig. 1.

Welding in sharp corners of equipment must be avoided, as this creates non-cleanable areas similar to those depicted in Fig. 1a. Rounded corners (radius

≥3 mm) and correctly welded seams (as in Fig. 1d) in the adjacent planar area are recommended for hygienic design.

If adhesives are used for permanent joints, they must be compatible with surfaces, products and also cleaning and/or disinfecting materials with which they are in contact. All bonds must be continuous and mechanically sound so that the adhesives do not separate from the base materials to which they are bonded.

Dismountable joints (e.g. of plates or appendages) fixed by fasteners (e.g. screws or bolts) must only be used if dismantling is unavoidable. The ends of the overlapped edges of metal-to-metal contact surfaces must be carefully sealed taking the defined compression of the seals into consideration. There must be no exposed screw threads on product-contact surfaces. If a connection or fastening must be made with screws and bolts, poor design of the screws and nuts creating crevices, grooves or dead areas must be avoided (Fig. 2a). The hygienic design of the equipment with enclosed threads requires screw heads or nuts that are suited to mechanical cleaning or cleaning in-place (e.g. domed nuts; Fig. 2b). Metal-to-metal contact must be avoided by the use of metal-backed elastomer gaskets (Fig. 2b) to seal the threads. If applicable, any risk can be avoided by using a stud welded at the non-product side (Fig. 2c).

Drainability

Food-containing equipment (tanks, containers, vessels, troughs, reservoirs, hoppers, bins, chutes) with discharge openings must be fully self-drainable, as demonstrated by the examples shown in Fig. 3c–f. For good drainability and cleanability, sharp corners must be avoided. Sharp corners and horizontal walls cannot be cleaned easily; to avoid any hazards corners must be well rounded, with a radius of ≥3 mm (see also recommendations in Ref. 2), and horizontal walls must have a slope of ≥3° towards the outlet. Equipment without an outlet must be pivoted for discharging of product and cleaning solution. Such equipment must also have well-rounded corners, be fully drainable, and be easy to clean (including the hinge), and the hinge must tilt the equipment sufficiently to provide a slope of ≥3° towards the outlet.

Top rims

The design of the top rims of product-containing equipment (e.g. containers, chutes, boxes) must avoid ledges, where product can lodge and which are difficult to clean (Fig. 4a–c). Open-top rim design must be rounded and sloped for draining (Fig. 4d and 4e). If the top rim is welded to the wall, the weld must be flush and polished to provide a smooth surface. In this case, the rim must be totally closed. Any holes must therefore be sealed by welding (Fig. 4f) or by gaskets or plastic caps.

Covers

Covers are used (e.g. for tanks, rims of transport systems or inspection tables) to avoid contamination of the product from the environment during processing or storage. They can be completely detachable for cleaning. Non-dismountable covers must be sloped for drainage. If hinged covers are used, the hinge must be designed in such a way that it can be cleaned easily and so that the accumulation of product, dust and foreign bodies (e.g. insects) is avoided (Fig. 5). Pipes or instruments attached to or through covers must either be welded or carefully sealed (see recommendations given in Ref. 3).

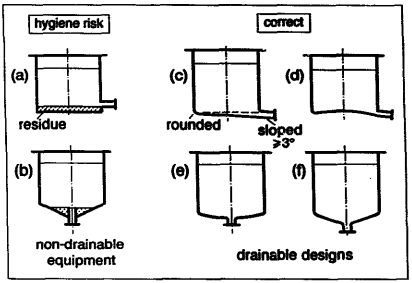

Fig. 3
Drainability of equipment. In (a) and (b), discharge outlets above the lowest level of the equipment prevent self-draining. Diagrams (c)–(f) demonstrate self-drainable designs with discharge openings at the lowest level, sloped bottoms (≥3°) and well-rounded corners.

Arrangement of ancillary equipment

Apparatus such as stirrers, homogenizers or mixers should preferably be arranged in such a way that sealing of shaft passages in the product area is avoided by mounting them above the product area rather than penetrating the equipment. If shaft passages are indispensable, dynamic seals as recommended in Ref. 3 must be used.

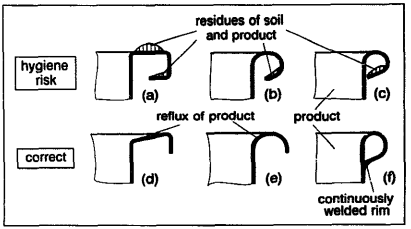

Fig. 4
Top rims of equipment. (a), The upper, horizontal part of the rim is part of the food-contact area and must be drainable. (a)–(c), At the bent parts of the rims outside the equipment, soil can be retained and this can indirectly affect the product. (d)–(f), In hygienically designed equipment, the top rims can drain to the product side and to the outside.

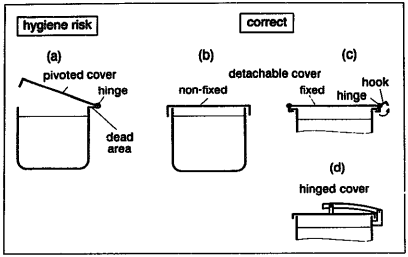

Fig. 5

Covers of equipment. Hinged covers (a) can create dead areas and crevices in the hinge. Detachable, non-fixed covers (b) or covers fixed by clamps (c) can be cleaned easily. In the case of hinged covers (d), the hinges must be easy to clean or dismount.

If the motor drive has to be arranged above the product, it should preferably be placed beside the equipment. The possibility of contamination by lubricants and soil from the motor or gear entering the product area must be avoided by using drip trays in combination with throw rings on the shaft (Fig. 6). The motor should be covered by a hygienically designed cowl.

Shaft ends and couplings

When shaft ends and couplings are in contact with the product, crevices caused by metal-to-metal contact and dead spaces in grooves must be avoided. If adhesives are used for metal-to-metal joints, they and the bonds created by their use must follow the recommendations given for permanent joints. Hubs, nuts and coupling shafts must be carefully sealed[6] under controlled compression to avoid metal-to-metal contact areas and crevices and gaps that can harbour soil. Corners (e.g. hubs and nuts) must be radiused and horizontal areas sloped. To avoid any screwed joints, the blades of appendages (e.g. stirrers, homogenizers, mixers, cutters) should be welded to the hub.

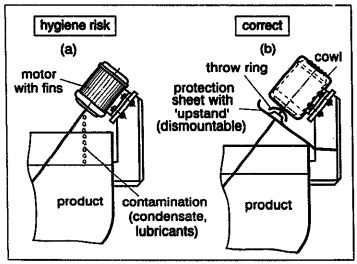

Fig. 6

Protection of product. (a), Parts of equipment mounted over any exposed product can contaminate it by soil, condensate or lubricants. (b), Protection sheets, covers and cowls must be arranged to protect the product.

Bearings

Bearings in the product area should be avoided. If bearings are unavoidable, they must be mounted clear of the base to allow free-flow cleaning of the feet. The shaft must have free space or grooves from top to bottom for lubrication by the product and to facilitate cleaning. Sealed bearings, which must be lubricated by specified lubricants[1] compatible with food, can cause hygiene risks at the sealed areas.

Belts

Belts in contact with food are used for conveying or inspecting the product. Embedded reinforcements as well as fabric backing materials must be covered[7] to avoid contact with the product. Cut edges of belts with reinforcing materials must be sealed (Fig. 7a, right) to prevent wicking of liquids into the interior. The whole of the belt must be accessible for cleaning.

The belt edges can be supported by removable and easily cleaned covers (Fig. 7b, right). The design shown in Fig. 7c is an example of overhanging belt edges and a rapid tension-release arrangement for cleaning the belt. The belt can be lifted, plastic tubes placed underneath, and the room between the support construction and belt can easily be cleaned.

Gears and motors of belt drives must be covered to avoid any contamination of the product (Fig. 7d). The design of rollers must avoid dead spaces where product can be retained. The sides of rollers should be aligned and smooth, and aligned front sides should be properly welded to the roller and to the shaft. Welded construction should be preferred to sealed design.

Meshes, screens, gridirons and perforated sheets

Meshes, screens, grids or perforated sheets should be avoided in the product area. Their application (e.g. for guarding, or for processes such as sieving and drying) requires particular attention to ensure cleanability. Special, fully (vacuum) welded gridirons are available that avoid any dead areas.

Non-food-contact equipment

The main aspect of the hygienic design of equipment for open processes that does not come into contact with food is to avoid the accumulation of microorganisms, insects and other vermin in areas and on surfaces that are either difficult to clean or non-cleanable.

Materials and surfaces

Materials for non-food-contact surfaces must be easy to clean, and resistant to the product and also to cleaning detergents and disinfectants. Dissimilar metals must not be placed in contact with each other because of the

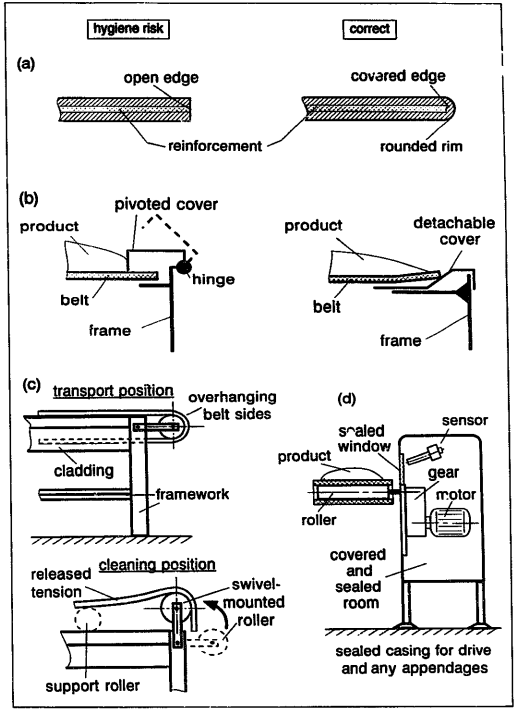

Fig. 7

Conveyor belts. (a), Open edges of belts with reinforcements cause hazards by crevices or wicking of liquids (left); reinforcing materials must therefore be covered at the edges of belts (right). (b), Non-removable bearing surfaces for belts and covers, as well as hinges of pivoted covers cannot easily be cleaned (left); a design with a cover that can be removed for cleaning is preferred (right). (c), Special belt design using swivel-mounted rollers facilitates cleaning by releasing the tension of the belt to create space between the belt and the bearing table. (d), To avoid any hygiene risk, drives of belts and any appendages such as sensors must be covered, and the belt should be clear of framework to give open access to the belt and rollers for cleaning.

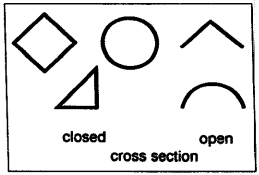

Fig. 8

Cross sections of uncladded framework. Ledges harbour residues of soil when mounted horizontally; therefore, closed or open cross sections must be sloped and self-draining such that soil cannot accumulate.

danger of contact corrosion. In non-food areas, stainless steel is to be preferred. If components are coated (e.g. motors, drives, casings), the coating must be nontoxic and resistant to cracking, chipping or flaking. Coated components should not be positioned directly above open product areas. Insulation must be vapour tight to avoid the growth of microorganisms.

Cladding and framework

Cladding of equipment must be smooth, continuous and without crevices to ensure that it is easy to clean. Ledges, projections and pockets must be avoided because they may retain soil. If unavoidable, horizontal ledges and projections should be sloped. A minimum slope of 30° is required to avoid the accumulation of dust and to allow drainage. Cladding must provide a clearance between the lowest part and the floor of ≥30 cm.

Uncladded framework constructions should preferably be composed of hollow square or round section members. Open ends of such framework must be closed by welded ends or plastic caps. For the design of framework that will be exposed to continuous vibration (e.g. drying towers), the use of open-profile construction should be considered. Small cracks can arise from vibrations, causing the inclusion of moisture, soil and microorganisms in closed profiles. To avoid soil being trapped on the horizontal surfaces of frames, open and closed cross sections must be self-drainable and easy to clean (Fig. 8).

Installation

Where support structures of equipment are attached to the floor or to walls, either a minimum clearance for cleaning and inspection must be applied or the

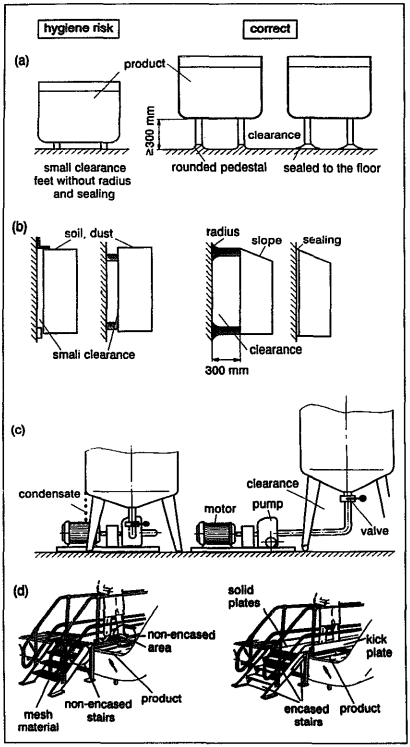

Fig. 9

Installation. (a), For equipment that is fixed to floors, cleaning underneath equipment with small clearance to the floor will be complicated, and non-radiused, improperly fixed feet, sharp corners and crevices at the fixing spot cause hygiene risks (left); feet properly fixed to rounded pedestals or sealed to the floor with sufficient clearance characterize hygienic design (right). (b), For equipment that is fixed to walls, any horizontal surfaces or the ledges of fasteners can retain soil, and small clearance hampers cleaning between the walls and the equipment (left); horizontal supports should be radiused and properly fixed to the wall, ensuring sufficient clearance, or directly fixed at the wall using sealing materials (right). (c), Equipment must not be mounted beneath tanks or vessels so that maintenance and cleaning are not possible (left); accessible equipment can be maintained easily and leaves open space with sufficient clearance for handling and cleaning beneath tanks (right). (d), Raised walkways over product areas cause hazards by contamination from personnel (left); if walkways are unavoidable, they must have a fully enclosed design (right).

equipment must be properly sealed (Fig. 9a and 9b). Care must be taken to avoid gaps, cracks or crevices where microorganisms or insects can survive after cleaning.

Equipment must be accessible for inspection and maintenance (Fig. 9c). The increased elevation of tanks and vessels facilitates cleaning operations beneath the equipment[8]. Furthermore, water and condensation running down the equipment wall may result in a hazard for motors and electrical parts.

Raised walkways or stairs over any exposed product should be avoided because dirt may be transferred from the clothing or footwear of personnel onto product lines beneath. If the movement of personnel is required in these areas, the equipment should be constructed to be fully enclosed. Kick plates should be designed as a single-piece construction. The decking should be constructed from solid plates containing a raised anti-slip surface. Risers in staircases must be encased. Steps should be constructed of the same anti-slip material as the deck. The use of expanded metal or mesh must be avoided to prevent soil being transferred into the product (Fig. 9d).

Acknowledgement

The authors gratefully acknowledge the contributions of members of the 3-A Steering Committee, resulting from cooperation between this organization and the EHEDG.

This paper summarizes the guidelines recommended by the European Hygienic Equipment Design Group (EHEDG) subgroup on Design Principles. The full report, by G.J. Curiel, G. Hauser and D.A. Timperley, is available from the EHEDG Secretary: J.T. Holah, Campden & Chorleywood Food Research Association (CCFRA), Chipping Campden, UK GL55 6LD (tel. +44-1386-840319; fax; +44-1386-841306).

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