FOOD MICROBIOLOGY AND
HYGIENE; V. 2. 2ND ED.

Chapter 7

DESIGN OF FOOD PROCESSING EQUIPMENT

7.1. INTRODUCTION

Until comparatively recently manufacturers have concerned themselves almost exclusively with the mechanical design and operational requirements of food processing equipment and have tended to neglect hygiene considerations. Equipment should be designed and constructed so that cleaning, maintenance and inspection are facilitated. Parts of the equipment that come into contact with food should be capable of being easily dismantled, (unless clean-in-place systems are being considered), thoroughly cleaned and, if necessary, sterilized. Equipment should protect the food from both external and internal contamination as well as perform the function for which it was originally designed.

Clearly reliability, performance and cost implications must be assessed. Often when the cheapest equipment is purchased it proves difficult to clean, may be unreliable and soon has to be replaced; well-designed, reliable equipment, even if more expensive initially, usually saves money in the long run.

What exactly is meant by hygienically designed equipment? Shore & Jowitt (1971) summarized it in the following way:

> The production of plant which will remain clean during operation or which can be restored to the desired degree of cleanliness with the minimum cleaning effort.

Although this statement emphasizes the gist of the question there is a whole range of factors requiring assessment when considering design and operation parameters for food processing equipment. Different authors and advisory bodies list many desirable features for equipment but, whilst there is general agreement on key points, the complexity of such lists varies enormously.

The seven basic principles for hygienic design agreed by the Working Party appointed by the Joint Technical Committee of the Food Manufacturers Federation (FMF) and the Food Machinery Association (FMA) included in their publication *Hygienic Design of Food Plant* (1967) are a useful starting point in any discussion on hygiene. The principles are:

1. All surfaces in contact with food must be inert to the food under the conditions of use and must not migrate to or be absorbed by the food.
2. All surfaces in contact with food must be smooth and non-porous so that tiny particles of food, bacteria, or insect eggs are not caught in microscopic surface crevices and become difficult to dislodge, thus becoming a potential source of contamination.
3. All surfaces in contact with the food must be visible for inspection, or the equipment must be readily disassembled for inspection, or it must be demonstrated that routine cleaning procedures eliminate possibility of contamination from bacteria or insects.
4. All surfaces in contact with food must be readily accessible for manual cleaning, or if not readily accessible, then readily disassembled for manual cleaning, or if clean-in-place techniques are used, it must be demonstrated that the results achieved without disassembly are the equivalent of those obtained with disassembly and manual cleaning.
5. All interior surfaces in contact with food must be so arranged that the equipment is self emptying or self draining.
6. Equipment must be so designed as to protect the contents from external contamination.
7. The exterior or non-product contact surfaces should be arranged to prevent harbouring of soils, bacteria or pests in and on the equipment itself as well as in its contact with other equipment, floors, walls or hanging supports.

Implicit although perhaps not obvious from these principles is the requirement that equipment should be free of recesses, dead ends, corners and similar areas where microbial growth is likely in entrapped food material.

In this chapter these and other requirements will be considered in more detail but at this stage a paragraph in *Hygienic Design of Food Plant* is apposite and well worth quoting:

> There is no substitute for common sense, and no specification can be complete enough to ensure an hygienic design. Good design requires much attention to detail. It is seldom that a single plant item can be considered in isolation; one must consider the process itself, the environment in which the equipment is placed and, of course, the maintenance which will be provided throughout the life of the equipment. The compatibility of the equipment with the product, the environment and also the cleaning fluids are of vital importance.

7.2. LEGISLATION

In the UK there are no regulations dealing specifically with the design of food processing equipment although there are British and International Standards for certain items such as pipes and couplings which have become widely accepted; in addition, a European Commission Directive, dealing mainly with safety aspects but also including hygienic design principles for certain types of machinery, has been introduced more recently (Machinery Directive, 1989). The legislation that exists is concerned almost exclusively with cleanliness and methods of cleaning. Thus the Food Hygiene (General) Regulations (1970) state that articles of equipment in contact with food must be kept clean and in good repair. They must be made of non-absorbent materials and should be constructed so that cleaning is facilitated. This theme is repeated in more recent legislation concerned with raw meats. Thus the Slaughterhouses (Hygiene) Regulations, 1977, and the Fresh Meat Export (Hygiene and Inspection) Regulations, 1981, state that equipment and fittings should 'be of a durable and impervious material resistant to corrosion and of such construction as to enable them to be kept clean'. The slaughterhouse regulations also require that items such as chopping blocks and cutting surfaces should not be made of wood.

The almost total absence of legislation dealing with food plant design could be a source of criticism. However, the seven basic principles for hygienic design detailed previously may be usefully regarded as a recommended code of practice. Unfortunately, the working party responsible limited themselves to the design of tanks, pumps and pipework and were thus concerned primarily with the handling of liquids. Furthermore, the Joint Technical Committee of the FMF/FMA subsequently disbanded so that no significant progress was made until a fresh working party was appointed by the FMF, the Process Plant Association (formally the FMA) and the Association of Public Health Inspectors. From their deliberations a new set of six principles was agreed in 1978 for the hygienic design of food processing equipment. However the two sets of principles are largely the same and for brevity the latter set (Cook, 1980) is excluded. Of greater interest to-day are the principles listed in the Machinery Directive (1989) mentioned above. The machinery covered in the Directive is classed as 'agri-foodstuffs' machinery, perhaps an example of translation shortcomings of which there are others in the seven principles ('hygiene rules') listed below which must be observed.

(a) Materials in contact, or intended to come into contact, with the foodstuffs must satisfy the conditions set down in the relevant Directives and must be clean before each use.
(b) All surfaces including their joinings must be smooth, and must have neither ridges nor crevices which could harbour organic materials.
(c) Assemblies must be designed in such a way as to reduce projections, edges and recesses to a minimum. They should preferably be made by welding or continuous bonding. Screws, screwheads and rivets may not be used except where technically unavoidable.
(d) All surfaces in contact with the foodstuffs must be easily cleaned and disinfected, where possible after removing easily dismantled parts. The inside surfaces must have curves of a radius sufficient to allow thorough cleaning.
(e) Liquid deriving from foodstuffs as well as cleaning, disinfecting and rinsing fluids should be able to be discharged from the machine without inpediment (possibly in a 'clean' position).
(f) Precautions must be taken to prevent any insects or liquids entering inaccessible parts of machinery.
(g) Machinery must be so designed and constructed that no lubricants other than edible lubricants can come into contact with foodstuffs. Where necessary, continuing compliance with this requirement must be checked regularly.

A comparison of the above Directive hygiene rules with the 1967 principles shows a substantial degree of similarity. The Directive is more specific in its requirement (c) concerning the means by which smooth surfaces are obtained and it also specifies that screws, screwheads and rivets may only be used in exceptional circumstances. A further stipulation in the Directive is that non-edible lubricants must not come into contact with foodstuffs. Omitted from the Directive, however, is the recommendation that surfaces in contact with food should be visible for inspection. It is worth noting that the Directive requires Member States to introduce appropriate legislation by the end of 1992.

The position in the UK contrasts sharply with that in the USA. In the USA, standards for the construction and use of a variety of food processing equipment have been established by organizations such as the 3-A Sanitary Standards Committee, the National Canners Association, the American Society of Mechanical Engineers and the Baking Industry Sanitary Standards Committee. The first named organization represents three associations, viz. the US Public Health Service, the International Association of Milk and Food Sanitarians and the Dairy Industry Committee. The 3-A standards were originally introduced for dairy equipment but have become adopted by food processing equipment manufacturers generally in the USA (N.B. copies of published standards are obtainable from the *Journal of Food Protection*, PO Box 701, Ames, Iowa 50010). In fact, the FMF/FMA Working Party's original seven principles were based on those of the 3-A Sanitary Standards Committee although the latter's standards are far more detailed and cover a greater range of components.

As a further example of the detailed legislation extant in the USA, the American Society of Mechanical Engineers could be cited. This society formed a committee concerned with design, construction and manufacturing standards for food equipment; their recommended standards can be accepted as American National Standards. Of particular interest is their publication *Food, Drug and Beverage Equipment* (ASME, 1987) which includes a Standard (ASME/ANSI F2.1—1986) for food equipment of help to manufacturers, users and health and safety authorities; in addition advice is included for users in the selection and installation of equipment, and in modifications to it. The general objectives of this Standard are to provide design criteria which will result in equipment that is:

(a) able to be quickly exposed, using simple tools used by operating or cleaning personnel, for cleaning or inspection when needed.

However, disassembly should not be assumed to be necessary for cleaning all equipment and components where specifically designed to be cleaned and/or inspected by other means;

(b) cleanable and able to be easily sanitized;
(c) made of materials which do not deteriorate in their use environment or cause degradation or contamination of the product;
(d) made to protect the product, while in the equipment, from entrance of and contact with contaminants from any external source. If good design practices indicate that such protection need not necessarily be an integral part of the equipment, then such protection may be external to the equipment;
(e) safe for use by operating, cleaning, and maintenance personnel;
(f) free of areas, inside and out, where product or contaminants can be trapped and stagnate;
(g) free of areas that may harbour vermin.

The Standard goes on to deal with many aspects of hygienic and safety design of equipment including construction materials to be used and concludes with sections on more specific criteria for different categories of food processing equipment.

The above is an example of an American National Standard but other standards may be used only as voluntary guidelines; many guidelines are, however, incorporated as mandatory standards by federal, state or local regulatory agencies.

7.3. CONSTRUCTION MATERIALS

7.3.1. General Requirements

It is necessary to ensure that all surfaces in contact with food should be inert to the food and to cleaning and sterilizing agents under normal conditions of use. Surface material constituents must be non-toxic and must not migrate to or be absorbed by foods. Surfaces in contact with foods should also be smooth, hard, continuous and free from pitting, cracks and crevices. It should be borne in mind that the smoother the surface the easier the cleaning, although the relationship is a complex one depending on the cleaning process employed and the method of obtaining the surface; in this respect electropolishing is preferable to mechanical polishing (Milledge & Jowitt, 1980). One of the principal aims must be to facilitate the removal of food residues during cleaning so that microbial growth is rendered impossible. Construction materials that are used for surfaces in contact with foods should allow the original finish to be maintained and no porosity should develop; in addition, materials should be resistant to deformation, denting, chipping, flaking and delamination (Joint Technical Committee FMF/FMA, 1967).

Surfaces not normally in contact with foods should also be smoothly finished, easily cleanable and made of corrosion-resistant material or rendered corrosion-resistant. Painting of machinery must be limited to non-contact surfaces and such surfaces should not be located above exposed food materials.

With the above requirements in mind it is not surprising that the range of construction materials available is rather limited. Materials commonly used are now considered individually.

7.3.2. Stainless Steel

Austenitic stainless steels are the preferred and most widely used of all surface materials that come into contact with foods. These steels have high percentages of certain alloying elements such as chromium and nickel but have a very low content of carbon. A wide range of stainless steels is available although the so-called 18–8 group (*ca* 18% chromium and 8% nickel) is used extensively. Of this group, alloy grades in the 300 range (e.g. 304 and 316) meet most requirements. Grade 304 is not corroded by most foods or cleaning agents, it produces no product discolouration, cleaning is easy and it is relatively cheap. Where greater corrosion problems are likely to be encountered, such as with brine and markedly acidic foods like vinegar, Grade 316 should be used; this steel has an increased nickel content (*ca* 10%) and also contains molybdenum (2–3%). Virtually complete corrosion resistance is claimed for Hastelloy which contains nickel (56%), chromium and molybdenum (both 16%), iron (5%) and tungsten (4%), although its high cost limits its use.

Stainless steels can also have different surface finishes from descaled to mirror depending on the degree to which they have been ground and polished. Smooth surfaces are required where clean-in-place techniques are used for pipework (e.g. the dairy industry) but it has been found that the surface finish is less important where pressure jet cleaning (see Section 9.10.1) is employed (Timperley, 1984).

7.3.3. Corrosion of Stainless Steel

The comparative resistance of stainless steel to corrosion is due to a protective film of chromium oxide which is formed in the presence of air (i.e. oxygen); however, even the most resistant grades will corrode if not properly maintained. The following types of corrosion are most commonly encountered in the food industry.

7.3.3.1. Pitting

Any damage to the film of chromium oxide may induce corrosion although a self-repair mechanism operates provided sufficient oxygen is available. Food debris or even dust left on the surface can induce corrosion due to the exclusion of oxygen; with food the problem is greater as bacteria growing on the organic matter may well produce acids which increase the extent of the pitting. Pitting can also be induced by physical damage and any rust spot or rough area can easily lead to more serious damage if not treated.

One of the main causes of corrosion is the misuse of cleaning or sterilizing solutions especially sodium hypochlorite. These solutions are sometimes left in contact with surfaces for excessive periods, solutions may be applied at incorrect concentrations or unsuitable agents may be used.

7.3.3.2. Electrolytic Corrosion

Electrolytic or galvanic corrosion occurs when two different metals such as aluminium and iron or even two different grades of stainless steel are moistened by the same solution. Thus if dissimilar metals, comprising part of the same piece of equipment, are treated with a cleaning or sterilizing fluid the fluid may act as an electrolyte and induce this form of corrosion. Electrons flow from the less active (e.g. iron) to the more active metal (e.g. aluminium) and cause corrosion of the latter.

7.3.3.3. Intergranular Corrosion

This form of corrosion is due to the use of a steel with too high a carbon content and can be seen in areas close to welds. It results from carbon being precipitated along grain boundaries as chromium carbide thus reducing the chromium content in the adjacent area and leaving it more susceptible to corrosion; this problem is readily overcome by using low carbon versions of stainless steel, e.g. 304L, in equipment.

7.3.3.4. General Corrosion

This is due to the use of a grade of stainless steel that is insufficiently resistant to the corrosive properties of the food being processed; it can only be corrected by replacing the equipment with equipment constructed with a more resistant grade of steel.

7.3.4. Iron and Mild Steel

Black and cast iron and mild steel have been widely used in the construction of machinery, especially for general framework and for equipment (e.g. retorts) that does not come into direct contact with foods. These materials are very susceptible to corrosion although this can be partially controlled by painting exposed surfaces. Bearings should be nickel plated if there is any chance of contact with food or cleaning agents.

Galvanized iron, which is iron coated with zinc, should not be used for equipment since zinc soon wears off exposing the iron which then corrodes. Furthermore, zinc is toxic (see Chapter 2) and, since it is soluble in fruit acids and in both acid and alkali detergents, its use should be severely restricted in the food processing area. However, galvanized iron is still used in the construction of supporting frames for trays and for trays themselves; this is permissible provided foods do not come into contact with the metal and its shortcomings are fully understood.

7.3.5. Copper and its Alloys

With certain exceptions, such as in brewing, copper is generally unsatisfactory as a construction material for food equipment. With its alloys, brass and bronze, copper is fairly resistant to corrosion and is a particularly good heat conductor. However, vegetables such as peas are discoloured when in contact with copper particularly in the presence of brine. This element also readily forms oxides which not only destroy vitamin C but also oxidize fats and edible oils causing rancidity. If used in food processing equipment copper or brass vessels must be coated with tin.

Monel metal, which is an alloy of nickel and copper (ratio 2:1) has surprising resistance to corrosion in the presence of brine and is used instead of stainless steel for this fluid. However, the presence of copper can still cause the problems mentioned above.

7.3.6. Miscellaneous Metals

As well as zinc, other toxic metals that should not be used are cadmium, antimony, mercury and lead; the last named could be used in solder at no more than 1 part in 20, although welded cans have now replaced the more traditional soldered-seam cans. The use of solder more generally should be strictly limited to joining metal; the solder must be so bonded to the metal that it cannot crack or chip.

Aluminium is popularly used for pots, pans and similar utensils, its low density enabling it to be easily fabricated and its good heat conductance is also an advantage; the use of aluminium is restricted due to corrosion by acids and alkalis. It is also a very active metal and, if present, is often involved in electrolytic corrosion.

Titanium has many advantages but its high cost prohibits its use on a large scale. It has a greater corrosion resistance than high grade stainless steel, is readily cleaned and is much lighter than steel. Tin, like copper, is a durable metal but again should not be used in equipment as a food contact surface; tin plating is, of course, used for the conventional can but this cannot be regarded as equipment.

7.3.7. Plastics

Plastics have become more widely used in the food industry in recent years and there is no doubt they are going to be of increasing importance in the future. They have many advantages being relatively cheap, light, transparent if required, non-toxic and non-tainting, relatively resistant to corrosion, and many are resistant to acids, alkalis and detergents; in addition it is possible to select plastics that are usable over wide temperature ranges. However, plastics are more easily abraded than metals so that cleanability can be adversely affected.

The properties of plastics obviously vary tremendously depending on the raw material used, types of additive incorporated and method of fabrication. Basically, plastics used in the food industry fall into two categories, thermoplastics and thermosets. The former soften when heated and harden when cooled and this process can be repeated any number of times without any appreciable chemical change. Many thermoplastics are based on ethylene, e.g. polyethylenes, polypropylenes, polyvinyl chloride, fluorcarbon polymers and the acrylics, but some are based on other chemicals, e.g. nylon. They are generally highly resistant to acids, alkalis and cleaning agents, they tolerate wide temperature ranges although heat stabilizers may have to be incorporated, and many resist water absorption; polyvinyl chloride and certain nylons are an exception to the last point and polyvinyl chloride may also suffer from microbial attack. Many of these thermoplastics have been used in the construction of tanks, pipes and fittings, and conveyor belts; wooden cutting boards have been partly replaced by hardened but durable thermoplastics, particularly high density polyethylene and this trend can only be welcomed.

Thermosets differ from the above in that they harden when first heated but if heat is re-applied they may be chemically degraded. Thermosets used as construction materials in food equipment include polyesters, epoxy resins and polyurethanes; these materials are generally usable over wider temperature ranges than the thermoplastics but they tend to be more susceptible to attack by acids and alkalis.

In spite of the increasing use of plastics problems remain so that approval for their use must be obtained (see p. 289). Some plastics contain plasticizers (i.e. organic compounds incorporated into plastics to increase flexibility) which can migrate to foods, particularly fats (see Section 8.5.2). Plastic materials remain less rigid than steel so their physical properties may alter with changes in temperature.

7.3.8. Rubber, Glass and Wood

Food-quality natural or synthetic rubber is still used fairly extensively by the food industry. Rubber is an acceptable material for belting provided it is in good condition; when worn or damaged it should be replaced immediately as it can prove difficult to clean in this state. Rubber is also used for seals, gaskets and piping, and here again selection of the right quality is of paramount importance as is the need for frequent inspection to ensure the rubber remains in good condition. Expanded rubber, with suitable filler, has also become popular in recent years for cutting boards.

Glass only has very limited applications as on no account should it be allowed in food production areas unless incorporated in specially designed equipment; any glass so used must be non-breakable and heat resistant. Its main use is for piping to convey liquids such as high salt concentration brines which might otherwise corrode steel. Where glass piping is installed, clean-in-place (CIP) systems should preferably be used. Glass is also used as a lining material in certain steel tanks and vats.

Wood and absorbent materials in general should not be used in food processing. Wood has been used widely for cutting boards but juices from the foods penetrate its surface and are almost impossible to remove by cleaning. Souring and off-odours develop due to the breakdown of the food residues by entrapped bacteria which are equally difficult to remove. The use of wood should be restricted but its incorporation in fermentation vats is acceptable. Many butchers still insist on using wooden cutting blocks and boards; in this situation the hardest woods like maple must be employed although the alternatives suggested earlier are to be preferred on hygienic grounds.

7.4. GROWTH 'POCKETS'

One of the basic requirements of hygienically designed food processing equipment is that it should not harbour food in 'pockets' or other 'dead' areas where bacterial growth may subsequently arise. Food may be retained in these pockets for many hours, or even days if the pockets are so small that cleaning agents cannot reach the debris. During this time food spoilage will occur to a greater or lesser extent. In consequence, when such food material is discharged intermittently into uncontaminated food it could cause spoilage problems. It is essential, therefore, to ensure that all food material is held in processing equipment for a uniform time. This aim is implicit in principle 2 (see Section 7.1) and in the ASME design criterion (f) (Section 7.2) but perhaps some brief explanation on this issue is desirable in order to consider design criteria that should be adopted.

In designing equipment it is essential that all surfaces that come into contact with food are as smooth and continuous as possible. Corners, crevices and recesses should be avoided therefore by suitable curvatures where food material cannot accumulate and cleaning is facilitated; all internal curvatures at corners and at junctions should have a minimum radius of at least 1 cm, although 2 cm is regarded as the optimum by the American 3-A Sanitary Standards Committee; smaller radii are permitted where the function of small parts would otherwise prove impossible. Tanks and similar equipment should also be constructed so that complete self-draining is achieved.

All permanent joints between two surfaces in contact with food should be butt-welded, ground and finished flush with the surrounding surface; all welds should be continuous and smooth, a state that should be checked regularly and so maintained, to prevent any accumulation of food particles in cracks or seams which may otherwise develop.

Dead ends such as thermometer pockets or unused pipework T-pieces must be avoided. The construction materials employed must be robust enough to prevent flexing or bending under process conditions as this may create hollows where foods or cleaning fluids can accumulate. Debris tends to adhere to protruding bolt threads, wing nuts, pot rivets and screws, and these should be avoided where possible in food contact areas. Where construction necessitates some form of bolting the bolt head should preferably be sited on the product side (CFPRA, 1983). Where bolts are used there is always the possibility of a crevice being formed at the junction between the bolt head and the metallic surface of the vessel and this must be avoided by using durable plastic or similar washers. Nuts should always be of the domed type if situated on the product side.

7.5. EASE OF DISMANTLING AND REASSEMBLY OF EQUIPMENT

Whilst both the earlier FMF/FMA principles (Section 7.1) and the 1989 Machinery Directive (Section 7.2) allude to the need for easy dismantling of equipment for cleaning purposes, far too little attention has been paid to this crucial factor. Even with well-designed equipment it is possible for bacteria to build up during a process run and if this build up is accompanied by variations in the residence time of food material a deterioration in the bacteriological quality of the food is inevitable. It is obviously important to minimize increases in bacterial numbers during processing and every opportunity should be taken to use the various break periods for essential cleaning work. Even the short 10–15 min break should be capable of being utilized to clean those equipment surfaces and parts regarded as hygienically hazardous; the cleaning of all surfaces in contact with food should be feasible over the longer break periods.

Unfortunately it takes hours to dismantle many machines for cleaning purposes, complex tools are frequently required and, as a result, cleaning is often delayed. Stripping, cleaning and re-assembly must be made as simple as possible so that those surfaces and parts exposed to hazardous bacterial accumulation can be cleaned within 15 min. To facilitate this aim the number of working parts in food processing equipment should be kept to a reasonable minimum. However, rapid cleaning also entails convenient handling and hence constraints such as the weight and dimensions of individual parts must be borne in mind. Ideally components that require frequent cleaning should be easily managed by one person and suitable racks should be provided to hold dismantled components off the floor. Quick release devices, e.g. captive bolts with coarse threads, should be used to facilitate cleaning; alternatively, clamped joints (Fig. 7.1) may be used and one of their advantages is that they overcome the bacteriological hazards associated with screw threads mentioned earlier. Whatever quick release devices are used it is important to ensure that only the simplest of tools are required, if any, in the dismantling and re-assembly of the equipment.

It may be pointed out here that faulty equipment design is, in part, responsible for large numbers of metal-in-food complaints. As there is often a plethora of nuts, bolts and screws to unfasten when dismantling

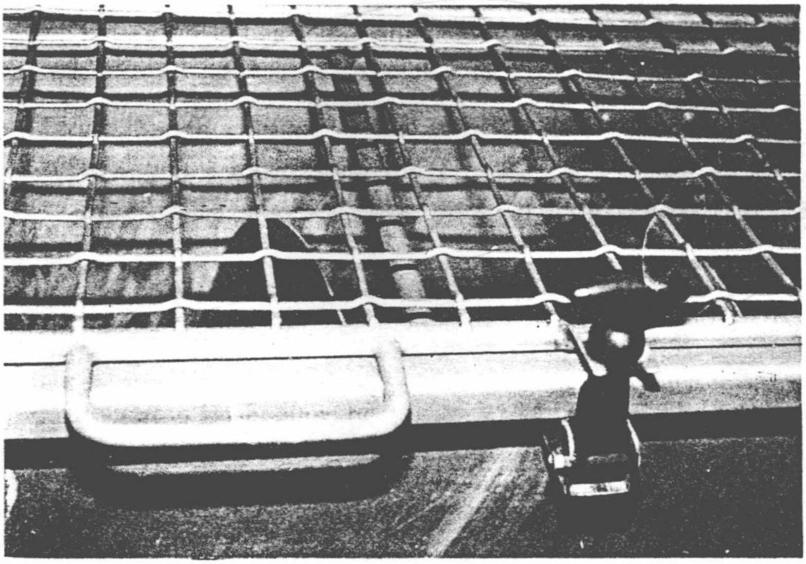

Fig. 7.1. A clamped joint used as a quick release device on a screw conveyor. (By courtesy of Birds Eye Walls Ltd.)

certain items of machinery the cause of these complaints can be easily understood and traced; steps should be taken to rectify the faults in the interests of hygiene and common sense. It must also be emphasized that equipment designed for simple and speedy dismantling and cleaning is going to be cleaned more enthusiastically and efficiently than equipment that proves tedious and difficult to handle.

Larger parts of equipment must also be designed so that cleaning, inspection and maintenance are facilitated. All parts requiring cleaning should be cleanable within an hour. Heavier components may be more suitably moved by some form of hoist, on safety grounds, as workers should not have to struggle with parts that are difficult to handle.

In general, equipment used in batch processing is simpler than that used in continuous processing and the former should therefore be easier to design for ready access and cleaning. However, there are many items of equipment (e.g. meat slicing machines, mincers, cream dispensers) where bacteriological build up is rapid and where cleaning difficulties arise because of design failures; it is axiomatic that preferred models must be easily cleanable.

There is no doubt that clean-in-place (CIP) techniques will become more widespread in the future and where prolonged or continuous processing is performed CIP is essential. Until recently these techniques have been used almost exclusively for liquids and pipework but continuous cleaning devices for solid food processing equipment are being introduced. There is no doubt this welcome innovation will, in time, become the norm. Some increase in the price of equipment must be anticipated but if labour costs are reduced an overall saving should be made (Holm, 1980).

7.6. ACCESSIBILITY AND THE SUPPORTING FRAMEWORK

Much of what has been said in the previous section is pertinent to the problems of accessibility of surfaces and components of food processing machinery. This issue has been discussed before but, for convenience, the main points are reiterated: normally equipment should be sited at a distance of *ca* 100 cm from the nearest ceiling, wall and adjacent equipment although greater gaps may be required; in addition, equipment should be raised at least 20 cm off the floor to facilitate cleaning, inspection and maintenance.

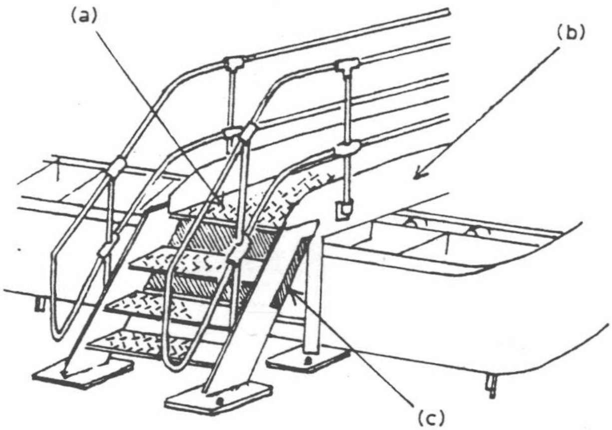

Fig. 7.2. A catwalk illustrating desirable features: (a) non-slip solid plate decking; (b) angled kick-stop; (c) protective backplate. (After CFPRA, 1983.)

Easy access is also helped by reducing floor and wall mountings and supporting framework to a minimum. Framework should be made of circular cross-section tubular steel rather than angle or channel iron as cleaning of the former is easier, it has no horizontal surfaces to collect dust and debris, corrosion is reduced and, because it is stronger and lighter, less supporting framework may be needed. All framework should have the ends sealed or capped to prevent food debris gaining access and it should be welded or otherwise sealed throughout its length to facilitate cleaning.

Supports for heavier floor-mounted equipment should be sealed to the floor so that food debris and pests are excluded and the edging to the seal should be coved to prevent debris accumulating. Where legs are used to support equipment they should be made of tubular steel which should be sealed or have ball feet fitted. The minimum number of such legs should be used and cross-bracing should likewise be reduced to a minimum; a single pedestal floor mounting is to be preferred.

Larger food processing plant such as air driers and cooling tunnels must include entry portals permitting easy access for maintenance and cleaning personnel; such portals should be at least 60 cm in diameter. Taller equipment such as spray driers often presents difficulties but easy and safe entry must be ensured through the provision of ladders or catwalks.