Some Experiences in the Fabrication of Dairy Equipment

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I Introduction :

A modern dairy is equipped in general with milk reception, processing, storage, and bottling equipment. Besides there may be other specialised plant and equipment such as butter making, cheese making equipment, milk powder plants, and reconstitution plants. Milk reception equipment comprises of items such as milk weighing scale, weigh bowl, dump tank, plate milk cooler, raw milk storage tank etc.

Processing equipment comprises typically balance tank, milk pump, flow controller, preheaters, uperiser steam injector, expansion vessel, level reservoir, aseptic product extraction pump, homogeniser, product cooler, condenser, condensate pump, etc. Bottling plant is used to pack the products in suitable packages such as cartons, bottles, portion packs. The equipment may work in conjunction with aseptic tank which keeps the product in a sterilised condition.

Besides the above, a dairy installation may be provided with butter making equipment such as butter churns, butter milk pump, butter packing machine ; ghee making equipment such as ghee boiler, ghee settling tank ; ghee pump, casein making equipment such as casein vat, casein hoop, casein dryer etc. Milk powder making equipment consists of evaporation plants, spray drying or roller drying plants, etc. and packing facilities.

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Fig I gives the process flow chart in a typical dairy installation.

Plant and equipment in a dairy installation are generally made out of thin sheets and plates as the design does not involve high pressure and temperature. The sizes of the vessels too do not demand the use of thicker sections. In case of dump tank, storage tank, aseptic tank, milk tankers etc., where moderate to large sizes of vessels are employed, adequate reinforcement at suitable locations generally obviate the need of thicker material. Except certain component such as end plates of plate heat exchangers, supporting structures of vessels and equipment, flanges and fittings, etc., dairy fabrications are made in sheets varying from 1 to 5 mm thick.

However, certain rigid requirements the equipments have to satisfy, such as freedom from crevices, absolute passivity of the product contact surfaces, ease of cleaning and maintenance of clean surfaces by cleaning in place, freedom from corrosion and stress corrosion cracking, etc. have made fabrication in the dairy industry a challenge to the fabricator. This paper deals with various materials and fabrication aspects specially of stainless steels for use in dairy service.

II Material Selection, Metallurgical & Corrosion Aspects:

Stainless steels of 18 Cr-8 Ni and 18 Cr-10 Ni-2.5 Mo type have extensively been used in the dairy industry due to their high corrosion resistance, ease of cleaning, and negligible chances of contamination of the product.

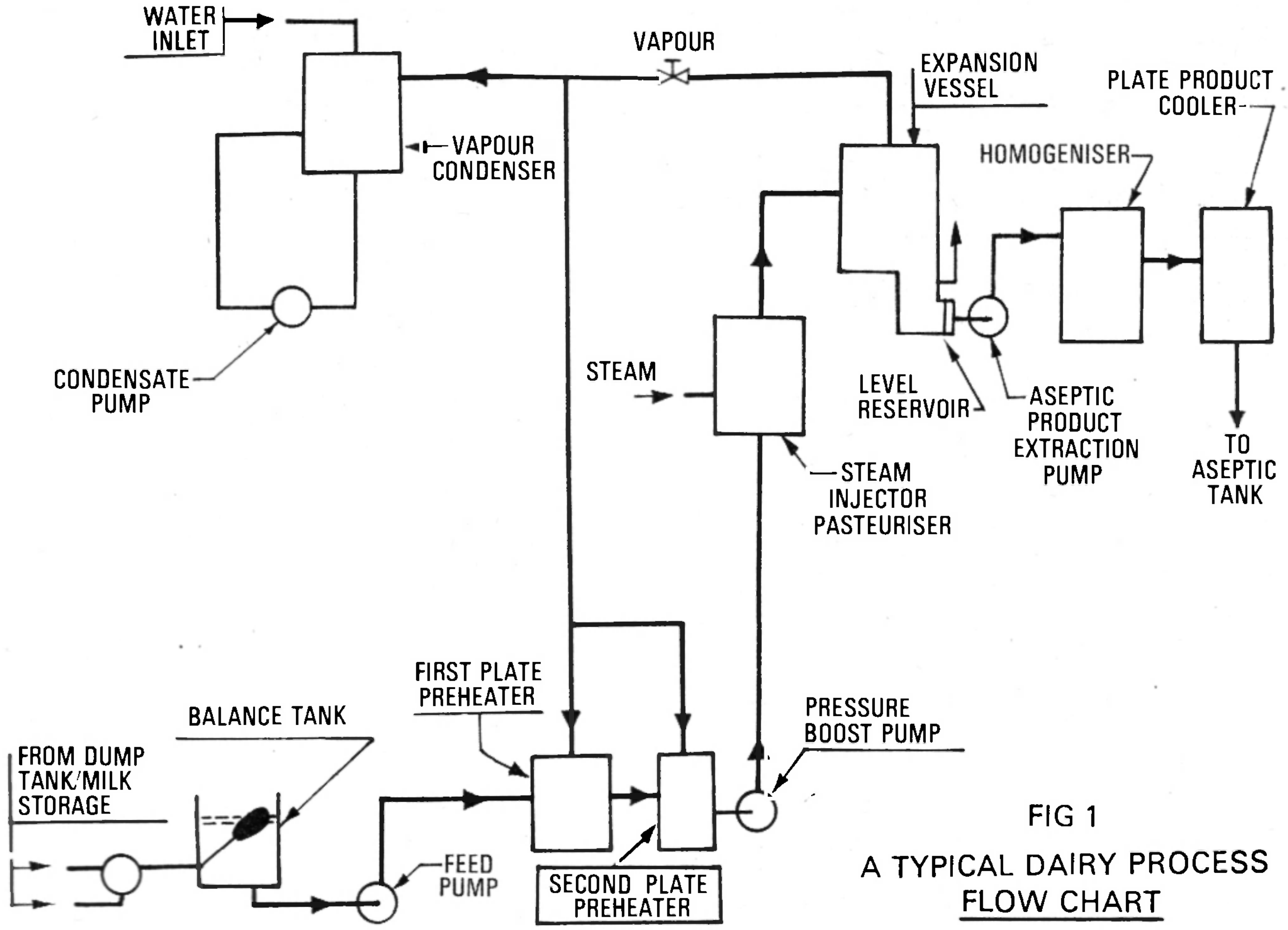

FIG 1
A TYPICAL DAIRY PROCESS FLOW CHART

They have excellent resistance to products as well as to the cleaning agents. However, certain chemicals and products can cause corrosion damage unless proper precautions are taken to guard against them. Such potential corrodents can be categorised as below :

1. Cleaning Agents—This includes sodium hydroxide solutions at certain concn. and temp., mineral acids, sulphuric acid etc.

2. Service liquids—Such as water supplies, refrigerant brines etc.

3. Sterilising agents—Such as sodium hypochlorite, halogen release agents etc.

4. Specific Products—Certain products can cause corrosion such as acid whey, salted butter and cheese.

Some of the acid cleaning agents which give rise to corrosion attack are sulphuric acid and hydrochloric acids. Sulphuric acid even of 0.25% concn. at room temperature is enough to give corrosion of 304 grade of unacceptable magnitude. SS 316 is slightly more resistant. It is however preferable not to use this acid.

Some data collected on corrosivity of H_2SO_4 to 316 grade SS is reproduced in Table I. It shows that the rates are rather erratic and unpredictable.

Table I

Material	Corrosion Rate, mils/year, in 0.5% H_2SO_4 at 100°C	1% H_2SO_4 at 100°C
E 308 Weld Metal	22.0	32.3
E 316 Weld Metal	0.76	43.3
E 316 L Weld Metal	25.0	71.0

Hydrochloric acid even in minute concentrations give rise to measurable corrosion rates along with pitting and should not be employed. Nitric acid and phosphoric acids upto 2% concn. are normally employed. In case of nitric acid, the use of organic seals and gaskets such as those in plate heat exchangers, milk pumps etc., put a limit to the maximum concn. that can be used and it is generally restricted to 0.5% max. Sulfamic acid upto 5% concn. is rather innocuous to stainless steels and can safely be used provided such solutions are not stored at elevated temperature when the acid hydrolyses to ammonium hydrogen sulphate, NH_4 HSO_4 The latter product behaves like sulphuric acid and is not compatible with 304 and 316 grades.

In the dairy industry, sterilisation is carried out with hot water and frequently with sodium hypochlorite which is far more effective and saves considerable time with desired level of sterility. Sodium hypochlorite is potentially corrosive to SS. Certain precautions however can ensure corrosion free operation such as :

(a) Maxm. concn. should be limited to 150 ppm available chlorine.
Maxm. contact time to be limited to 20 mins.
Maxm. contact temp. to 40°C.

(b) Before introduction of hypochlorite, other residue must be removed scrupulously by proper rinsing. Sodium hypochlorite will react with acids readily to give out elemental chlorine which is intensely corrosive to stainless steels.

(c) The equipment should be brought down to preferably room temperature before introduction of this agent. This will very effectively lower the chances of corrosion as the chemical activity is reduced substantially by reduction of temperature.

(d) The hypochlorite solution should be drained out immediately after sterilisation followed by high rate of rinsing to remove the agent effectively and within the shortest time possible.

Another group of corrodents which pose a problem in dairy industry is water and brine. Unless water is properly treated, it may contain a high proportion of chlorides which can cause pitting attack as well as stress corrosion cracking in stainless steel. This is particularly true in installations in coastal regions and in places where water is highly saline. Brines used for chilling of milk is another source of attack. Products containing salts such as salted cheese can give rise to corrosive attack unless proper precautions are taken. Wherever heavy concentration of chloride ions is expected, a change of material can be contemplated. Hastelloy and Titanium are practically immune to attack by chlorides. Incolloy 825, Incolloy 800, HV-9/254 SLX, and Carpenter-Cb also can be successfully used for surfaces working in contact with chlorides. When change of material becomes prohibitively expensive or in case of non-availability, the following precautions may be able to avoid any substantial corrosion :

(a) Aeration of the liquid must be avoided as O_2 content in the liquid forms an active agent in corrosion by chloride ions.

(b) When cleaning and sterilising the equipment, all brine residues must be flushed out and the circuit made alkaline. The alkalinity should be maintained till fresh brine is introduced, thus minimising scale formation.

(c) No scale should be allowed to form in sections using brine so that chances of crevice and concentration corrosion are eliminated.

Stress corrosion cracking caused by sodium hydroxide on stainless steel is well known and the limits of concentration and temperature are now well defined. These limits must not be exceeded under any circumstances so as to eliminate the slightest possibility of caustic cracking.

It should be remembered that while employing caustics, precautions should be taken against any leakage in the system such as through gaskets, seals etc., which might give rise to excessive concentration locally, ultimately resulting in stress corrosion cracking.

III Fabrication :

(a) **Preparation of base metal and finish requirements :**

Considerable emphasis is rightly put on the material preparation and finish of the product contact surfaces due to the requirements of strict hygienic conditions during reception, processing and storage of milk and milk products. Stainless steel exhibits its maximum corrosion resistance when it is clean. To prevent accumulation of dirt and waste matter in the minute crevices and depressions, which ultimately leads to deterioration of the corrosion resistance properties, it is necessary to maintain a clean and polished surface. In general, stainless steel sheets come in eight grades of finish-1, 2B, 2D, 3, 4, 6, 7, and 8.

Most of the sanitary codes recommend that all contact surfaces should be prepared to a finish no 4 or better, the no 4 being 120 to 150 grit finish. The surfaces should additionally be free from pits and crevices. In certain parts of equipments, high finish no. 7 or 8 may also be desired and specified. The latter finishes are obtained by buffing with fine buffing rouges. Contact wheels are generally used in polishing for no. 4

finish with 120 to 150 grit abrasive for preparation of base and 180 grit abrasive for final polish. The base for no. 7 or 8 finish is prepared with 240 grit wheel followed by buffing with alumina or chrome oxide buffing compounds. A wheel speed of 4000 to 5000 sfm for polishing and upto 10000 sfm for buffing may be used. Hicycle grinders which operate at 2 to 4 times the normal line frequency or more generated through frequency convertors are preferred for polishing and buffing operations.

In dairy fabrication, the surface finish requirement makes cold rolled sheets more desirable than the hot rolled ones. Cold rolling with medium to marginal reductions imparts better surface finish to the products which can easily be converted to the required dairy finishes, i.e., finish no. 4 and higher. In recent times, paper or plastic coated pre-finished sheets are being manufactured by some steel makers. These sheets need to be carefully handled and fabricated by exposing only the minimum required areas for welding and weld preparations. Post-weld finishing is limited to only the weld adjacent regions.

In rolling, bending, and general working of stainless steel sheets for dairy purposes, strict care need to be exercised on both cleanliness and finish of the rolls, jigs, fixtures etc. on which the sheets are worked. Every precaution is taken to ensure that no damage is caused to the surface of the sheets so that subsequent polishing work is lessened. In welding, adequate care must be exercised to ensure that there is neither too much of weld reinforcement, nor is there undercut and uneven ripples. A smooth flat bead with uniform ripples, no undercuts and porosity and having little or no reinforcement is the ideal. This minimises post weld work of grinding and polishing with substantial saving on labour and fabrication time and costs.

Welding—Processes and Procedures :

In dairy fabrication, the majority of the sheets and plates employed fall in the thickness range of 1.0 to 3.5 mm. Sometimes sheets down to 0.7 mm thick may be employed. This is particularly true for plate type heat exchangers where dimpled plates are used at the lowest possible thickness for higher efficiency in heat-transfer.

The welding processes most popular for welding the thin sheets are :

—Manual Metal Arc (MMA)
—Gas Tungsten Arc (GTA/TIG)
—and to some extent, plasma TIG.

MMA and TIG are equally popular processes. As the quantity of weld metal to be deposited is not substantial, high deposition processes such as MIG, SA. ES. etc. are not so widely adopted. Besides, the intricacy of fabrications and consequently manoeuvrability requirements and restrictions on heat input, put a limitation to the choice of the processes. Plasma TIG and pulsed TIG welding however hold a great future for dairy fabrications and more and more of the same are being gradually used.

Because of thinness of the plates, a common weld preparation is the square butt configuration with a root gap of around 1.5 mm to ensure adequate root fusion. The problems which face a dairy welder are, however, many and the most important one is distortion. Porosity type of defect, undercuts, and excessive reinforcement are other defects which need to be skilfully tackled.

Production of uniform and smooth beads is a must for minimising subsequent processing time. The requirements of skill, proper selection of process, storage and handling of filler metal etc. are very important for dairy fabrications and can sometimes make a difference between survival and death of the unit as a whole. Distortion being a vital aspect in dairy welding, it is discussed separately below.

(c) **Distortion Control** :

Stainless steels have approx. 50% greater co-eff. of elongation than carbon steels. In welding of thin material, this causes considerable difficulties in warpage control and needs elaborate precautions both in jigging and fixturing and in welding techniques and sequence.

Some of the fabrication practices widely adopted for prevention of distortion are :

1. Hold the abutting plates as rigidly as possible with the help of jigs and fixtures.
2. Use close tacks and sequence the tacks in such a way that the nodal points are secured first.
3. Use the lowest heat input possible to prevent rise in temperature of base metal. Use the lowest possible amperage and select the smallest diameter of consumables commensurate with low heat input without sacrificing, however, optimum productivity.

The following table may serve as a guide for manual metal arc practice.

Table II

Sheet thickness in mm	Electrode diam. mm	Current Range Amp.
Upto 1.5 mm	2.0 mm	35-55
2.0 mm	2.0 or 2.5 mm	35-55/55-80
2.5 mm	2.5 mm	55-80
3.0 mm	3.15 mm	75-100
3.5 mm	3.15 mm	75-100

Electrodes of diameter 1.5 mm may be used for very thin sheets less than 1.0 mm thick. However, TIG welding would be preferable.

(d) **Post weld heat treatments** :

Stainless steels do not generally require post weld heat treatments. Under certain conditions of service in process industries and chemical plants, post weld heat-treatments may be desired. For service in dairies such conditions are practically non-existent.

Besides, because of thinness of the sheets and plates employed and the possibilities of warpage in heat-treatment of stainless steels, post weld heat-treatments are practically unheard of in the dairy industry. Milk, milk-stones, sour milk and the cleaning solutions, etc. are not corrosive to the extent of attacking the weld heat affected zones. Also, the temperatures of the fluids are kept sufficiently low so as not to induce any attack in these zones.

IV **Inspection** :

Dairy equipments are thoroughly inspected from the following angles :

1. Dimensions.
2. Finish of product contact surfaces as well as other surfaces.
3. Freedom from porosity and crevices.
4. General workmanship.
5. Pressure and vacuum tests.

Finish of the contact surfaces of dairy equipment is often inspected by visual methods. A better method would be to employ a surface roughness measuring apparatus such as Dr. Forster's apparatus. Reflectivity of the surfaces particularly at higher finishes is also an indication of the quality of finish. Most of the dairy equipment fabricators are now equipped with optical surface finish comparator charts which provide guide lines for inspection and comparison. If necessary this could be incorporated in the contract.

The welds should be examined thoroughly for porosity, undercuts, lack of penetration, burn through, etc. Unless the welder is properly skilled in thin sheet welding and the storage and handling conditions of consumables are proper, very often porosity and undercut type of defects are met with. Undercut is a very serious defect for a dairy equipment, as this leads to crevice corrosion. Usually no undercuts, porosity, and pinholes are permitted.

A high degree of general workmanship is desired in dairy equipments. Even surfaces where no product contact takes place, should have a workman-like high quality finish. This takes care of exigencies like splashing of products, and gives rise to user confidence, may be psychological, on the internal quality of the equipments.

V **Conclusion** :

In this article an attempt has been made to analyse the various aspects of material selection, fabrication, and an understanding of the equipment and processes in a dairy installation.

Fabrication of dairy equipment is a challenging job in its own right. The high degree of skill involved, proper selection of welding process, the technology required to obtain weldments of high degree of finish and soundness requirements, elaborate pre-planning, proper precautions at every stage, etc. makes dairy equipment a challenge to a modern fabricator and materials specialist. In dairy fabrications, productivity is closely linked with proper planning and skill and care taken from raw material in-take to finished product delivery stage can make all the difference between success and failure of a fabrication unit.

Further insight gained through research and development work on process, materials, and products and service agents met with in a dairy has proved that simplest grades of stainless steel may not serve all the application requirements as was thought earlier. Use of more sophisticated materials may be desirable and imperative under certain conditions. Hastelloys, Incolloys and Titanium have already been employed in dairy industry and their uses may spread in future in preference to the established stainless steels as time passes. This will further need higher technology for welding and fabrication.

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