Cleaning-in-Place

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Cleaning-in-Place

Dairy, Food and Beverage Operations

Third Edition

Edited by

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SDT

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Preface to Technical Series

For more than 60 years, the Society of Dairy Technology (SDT) has sought to provide education and training in the dairy field, disseminating knowledge and fostering personal development through symposia, conferences, residential courses, publications, and its journal, the *International Journal of Dairy Technology* (previously known as the *Journal of the Society of Dairy Technology*).

In recent years there have been significant advances in our understanding of milk systems, probably the most complex natural food available to man. Improvements in process technology have been accompanied by massive changes in the scale of many milk-processing operations, and the manufacture of a wide range of dairy and other related products.

The Society has now embarked on a project with Wiley-Blackwell to produce a Technical Series of dairy-related books to provide an invaluable source of information for practising dairy scientists and technologists, covering the range from small enterprises to modern large-scale operation. This fifth volume in the series, the third edition of *Cleaning-in-Place: Dairy, Food and Beverage Operations*, now under the editorship of Dr Adnan Tamime, provides a timely and comprehensive update on the principles and practice of the cleaning-in-place of process equipment. Thanks to the perishability of milk and many milk products, the dairy industry has been in the vanguard of the development of cleaning techniques and associated hygiene requirements. These are equally valid for other sectors of the food and bioprocessing industries, and this book will provide a valuable resource for food and dairy technologists.

Andrew Wilbey
Chairman of the Publications Committee, SDT

Preface to Third Edition

The first edition of this book was published in 1959 by the Society of Dairy Technology (SDT), and was entitled *Cleaning-In-Place (CIP) of Dairy Equipment*. An updated second edition, edited by A.J.D. Romney, was published in 1990.

Although the original title of the publication was orientated towards the dairy industry, the technical aspects of cleaning-in-place allow a broadening of the target audience towards readers concerned with food and beverage operations. The processed food industry has seen a major shift towards CIP over the past 10–15 years, and the beverage industry, which has been broadly in line with dairy industry technology, has seen increased demands from customers with regard to CIP verification and validation, and the attendant improvements in plant hygiene and related efficiency.

The book has been extensively revised and updated in this new edition. The two chapters on Chemistry of Detergents and Chemistry of Disinfectants have been combined into one chapter, and sections on Fluid Flow Dynamics and Laboratory Test Methods now appear as separate chapters. One new chapter on the subject of Membrane Cleaning has been added. This is a relatively new area and requires specialised cleaning products and procedures.

Authors have been selected from within the industry, allied suppliers and academia to provide a balanced and leading-edge assessment of the subject matter. Whilst the second edition has been a very popular publication, it is now rather outdated, and this revision is timely. The book will be a valuable addition to the SDT's Technical Series, offering the latest information on CIP to readers within the dairy, food and beverage processing industries internationally.

A.Y. Tamime

Preface to Second Edition

Following the highly successful rewriting of the Society's *Pasteurizing Plant Manual* in 1983, a need was identified to update the manual on *In-Place-Cleaning of Dairy Equipment*, published in 1959 and out of print for some years.

To this end, a decision was taken by the Council to reconstitute the Dairy Equipment and Standardisation Committee disbanded in 1974; this committee was re-formed in 1985 under the new title of the Dairy Equipment Advisory Committee (DEAC), part of its brief to progress this task.

A listing of the proposed chapter headings and possible authors was drawn up, and I was invited to take on the role of both coordinating and editing the new work.

To all those who have contributed to the text and provided the illustrations for this project I extend most hearty thanks, both on my own behalf and on that of the Society. My gratitude goes also to my good friend and mentor, Tom Ashton, both for the Foreword to this edition and for his guidance and support in the past.

It is the hope of the Council, of all the members of the DEAC and of myself that this work will prove of value, to dairy managers and quality assurance staff as well as to students entering our industry.

A.J.D. Romney
1990

Preface to First Edition

In 1953, the Society of Dairy Technology published the *Pasteurizing Plant Manual*. The success of that venture encouraged the Dairy Equipment and Standardisation Committee to consider what could be done further in this new field of the Society's activities. Once again the inspiration, and much of the preliminary work, came from the late J.R. Cuttell. In producing this book, the Drafting Committee has been guided by the inspiration and has endeavoured to achieve a result worthy of the original conception.

The text has been written by Dr T.R. Ashton, Mr G.H. Botham, Dr L.F.L. Clegg, Mr H.C. Cooper, the late Mr J.R. Cuttell, Mr H.S. Hall, Mr H.C. Hillman, Mr P.A. Lincoln, Dr R.J. MacWalter and Mr W.W. Ritchie assisted by their colleagues on the Drafting Committee, Mr T.A. Hole, Mr E.L. Jarvis, Mr J.R. Rowling, Mr W. Rushton and Mr G.E. Taylor. The task of editing has again been taken by Dr J.G. Davis.

The Drafting Committee wishes to acknowledge gratefully the substantial contributions to its work by Mr P. O'Niell, who has acted as Secretary, and Miss E.G. Dunworth, who has undertaken the typing and duplicating work. The Committee greatly appreciates the facilities provided by the National Dairymen's Association, in whose offices all the meetings have been held.

Illustration material has kindly been provided by the APV Co. Ltd, Clarke-Built Ltd, CP Equipment Ltd, Dairy Pipe Lines Ltd and Talbot Stead Tube Co. Ltd. Mr H.C. Cooper has designed the cleaning circuit illustrations.

It is the hope of the Drafting Committee that this book will serve as an introduction to what is a comparatively new subject and so pave the way to the wider use of modern techniques.

H.S. Hall
1959

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1 Principles of Cleaning-in-Place (CIP)

M. Walton

1.1 Introduction

Cleaning-in-place (CIP) is now a commonplace activity in almost all dairy, beverage and processed-food production plants. The processed food industry has seen a major shift towards CIP over the past 10–15 years, and the beverage industry, which has been broadly in line with the dairy industry technology, has seen increased demands from customers in terms of CIP verification and validation to provide improvements in plant hygiene, finished product quality, and related shelf-life and microbiological considerations.

The highest standards of plant hygiene are an essential prerequisite for the production of any high-quality product being produced for human consumption. The cleaning and subsequent disinfection or sterilisation of any item of processing plant or equipment must be carried out with the utmost care and attention if the final product quality is to be fully assured. In earlier days, cleaning tended to be a manual process; indeed, it still is today in many small-scale operations, especially in the processed food sector, where a combination of manual strip-down clean and rebuild is common. Where manual cleaning is still practised, it is vital that there is meticulous attention to detail, because – for reasons of the health and safety of the operative – only mild and comparatively cool chemical solutions, detergents and disinfectants can be used, and strict adherence to cleaning procedures is critical. In larger-scale operations, and where more complex plant and equipment may be involved, the most usual approach today is to employ CIP, and it is to this aspect of cleaning technology that this book is primarily devoted, with a view to providing an understanding of the concepts and application of CIP in the processed food, pharmaceutical, dairy and beverage sectors.

1.2 Cleaning-in-place (CIP): definition

In the 1990 edition of the Society of Dairy Technology manual *CIP: Cleaning in Place*, CIP was defined as:

> *The cleaning of complete items of plant or pipeline circuits without dismantling or opening of the equipment and with little or no manual involvement on the part of the operator. The process involves the jetting or spraying of surfaces or circulation of cleaning solutions through the plant under conditions of increased turbulence and flow velocity.*

This was taken from the National Dairyman's Association (NDA) Chemical Safety Code, which was published in 1985; although the NDA has been superseded, their definition of CIP is still felt to be quite appropriate.

1.3 CIP systems: hardware

CIP units comprise vessels for storage and recovery of cleaning solutions, along with valves, pumps, pipelines and field instrumentation to allow cleaning to take place, usually automatically. They vary in complexity and degree of automation, and hence their efficiency and cost-effectiveness are also variable. For example, the single-use CIP units tend to be very expensive to operate (detergent, water and energy requirements are high), but can be much more hygienic as the chance of cross-contamination and potential spore formation is greatly reduced. Full recovery systems with large detergent storage tanks are usually multifunctional and tend to be relatively economic in operation, but need to be closely monitored to prevent the build-up of soil residues in the dilute detergent or recovered rinse tanks due either to the inherent recovery efficiency of the set or perhaps to poor pre-rinsing. It is therefore very important to refresh cleaning solutions on a regular basis.

1.4 The processes of cleaning

The cleaning processes, whether manual or automated and throughout all industry sectors, tend to follow similar principles, and will usually consist of a series of discrete stages or cycles, generally including:

- removal of gross debris (product recovery)
- pre-rinse
- detergent recirculation
- intermediate rinse
- second detergent recirculation (optional)
- intermediate rinse
- disinfection
- final rinse

1.4.1 *Removal of gross debris (product recovery)*

In manual cleaning operations, this tends to refer to removal of any residual product by mechanical means prior to introduction of a water rinse. In CIP applications, removal of gross debris generally involves draining product from the system to be cleaned under gravity, or physically displacing the product using various media, such as compressed air, water or a mechanical pigging device. This stage is often incorporated into the pre-rinse cycle of the cleaning programme with the addition of a divert valve system to facilitate product recovery into a suitable vessel or direct routeing to drain. Control of this feature is quite often via automated valve and timer, but it is also possible to use more sophisticated methods, such as turbidity or conductivity sensors in the return line. It is important to include an override timer into these systems as a 'failsafe' in order to avoid filling a product recovery tank with pre-rinse water if the system fails to activate the divert valve: this is not an uncommon situation, with probe and controller maintenance being a critical aspect of successful operation. Product recovery systems are becoming more sophisticated with the introduction of membrane plants that are designed to remove high levels of water from the effluent stream – often termed 'white water' in the dairy sector – to allow the recovered solids to be sold on for re-processing: these plants are effective at reducing effluent loading, and can form part of site pollution prevention and control (PPC) systems (e.g. The Environmental Protection Act; Anonymous, 1990).

1.4.2 *Pre-rinse*

Pre-rinse cycles often utilise recovered 'water' from the intermediate rinse stage (see Section 1.4.4). This serves two purposes: first, to reduce total water consumption (and effluent generation); and second, to utilise any heat energy and possible residual detergent solution carried into the recovered rinse tank during the rinse recovery stage. It is not uncommon to find heated pre-rinse systems in certain applications, such as cream production, where the hot pre-rinse solution provides a greatly enhanced method of product residue removal. The pre-rinse stage is important because it is not desirable to introduce excessive soiling into the dilute detergent tank. This stage is generally controlled via a timer, sometimes split between product recovery and drain, and these timers are often set at excessive levels to ensure maximum product removal. However, this may not be cost-effective in circumstances where water and effluent costs are high. In general, the pre-rinse cycle for tanks, silos or vessels consists of several 'burst' or 'pulsed' rinses, as this both improves rinsing efficiency and can reduce water consumption significantly.

1.4.3 *Detergent circulation*

This is where the main task of cleaning takes place, resulting in the soil being lifted from the plant surface and held suspended or dissolved in the detergent solution; for the selection of suitable detergents see Section 1.5.5, but an important attribute of the detergent should be the ability to prevent any soil from being redeposited during recirculation. Recirculation timings need to be assessed by experimentation and a degree of experience, with timing generally varying from 15 min up to 1 h, where exceptionally large and complex circuits are being cleaned. Contact times can be reduced by offsetting the potentially reduced cleaning effectiveness with higher temperatures, higher concentrations, or the use of more sophisticated (and expensive) detergent formulations. Cycle timers are often set to start counting down once the temperature set point has been reached in the return leg: this can lead to excessive cleaning times if the efficiency of the heating system is inadequate. It is important, for example, to ensure that tanks incorporating a water-cooling jacket have the jacket drained prior to CIP. Depending on detergent formulation, foaming can sometimes be a problem, and it is often associated with product contamination. It can also be caused by many other factors, including air entrainment via leaking pump seals; the use of totally softened water supplies can also be a contributory factor. It is also possible to utilise an acidic detergent for the main cleaning step: this is quite common in both the dairy and beverage sectors, where milk residues in 'cold/raw' milk areas respond well to acidic detergents, and in the brewing sector, where acidic detergents have significant advantages over alkaline detergents in their ability to clean under CO_2 environments without loss of activity. Combined detergent/disinfectant chemical blends may be used in the cleaning cycle itself, though this approach has comparatively limited application, as they can be adversely affected by high soil loading, and the ratio of detergent to disinfectant can become imbalanced.

1.4.4 *Intermediate rinse*

The intermediate rinse serves to remove all traces of detergent and entrained soil from the plant being cleaned and, in a partial recovery situation, to recover as much detergent (and thermal energy) back to the dilute detergent tank as possible; it also may need to be sufficient to cool the plant down ready for disinfection and/or refilling. The intermediate rinse should use potable water, and is normally cold, although – if a warm secondary detergent step is being incorporated – it may be desirable to use hot water (if available from sources such as recovered and suitably treated condensate). The intermediate rinse is often recovered and reused as the pre-rinse for the next cleaning cycle.

1.4.5 *Second detergent circulation (optional)*

Some systems utilise a secondary detergent cycle, often an acidic detergent to follow an alkaline product in the first detergent stage. This is common practice where built detergents are not being used (sodium hydroxide liquor followed by nitric acid was once very common), and also where there are high levels of process-generated soils, such as in heat exchangers and cheese vats.

1.4.6 *Second intermediate rinse*

This second intermediate rinse will almost always use cold potable water. The quality of this water is critical, if there is to be no disinfection stage. Some sites that do not use a discrete disinfection stage in the CIP cycle ensure the quality of their potable water by treating it with chlorine dioxide.

1.4.7 *Disinfection*

The disinfection cycle is usually undertaken cold, and often uses an oxidising biocide, such as sodium hypochlorite or peracetic acid solution (equilibrium mixture of acetic acid and hydrogen peroxide). Some non-oxidising biocides are also available, but they must be low foaming and fast acting in cold water in order to be effective for CIP. It is also possible to use hot water at the disinfection stage rather than a chemical agent; this is also very effective, but requires a high thermal energy input, which can prove costly.

1.4.8 *Final rinse*

The final rinse stage should be undertaken using cold potable water. Again, the quality of this water is critical, as it can lead to post-disinfection contamination and product spoilage.

1.5 Planning a cleaning project

Above all else, the paramount consideration in the planning of any cleaning project must be safety – not only of the plant and personnel involved, but of the product which that plant is required to process. The mid-1980s saw a dramatic reappraisal of many of the standards and practices previously regarded as acceptable within the dairy industry, following incidents – both at home and overseas – of contamination of products by micro-organisms rarely ever encountered as presenting problems of any significance, other than in raw milk supplies, to the average United Kingdom dairyman. Problems of *Salmonella* spp., *Listeria* spp. and *Yersinia* spp. contamination in finished product have all played their part in accentuating the need for stringent food hazard assessment in every field of activity; cleaning technology is not least among these. The interconnection of 'raw' and 'processed' side plant and pipelines into a single cleaning circuit, or the separate cleaning of 'raw' and 'processed' side equipment from a common CIP set – frequently encountered in the days when the fashion was for large, multi-purpose, centralised cleaning systems – is now generally considered to present unacceptable product risks. The trend is now strongly towards the use of smaller units, specifically dedicated to either raw or finished products, or to the cleaning requirements of individual circuits and plant equipment items. The total separation of the 'raw' and 'processed' sides of a factory – the only point at which the two ever come together being the flow diversion valve of the processing plant – should be the basic design objective of every process engineer. This approach may, in some installations, carry a capital cost penalty, but the advantages in quality assurance and generally lower revenue operating costs weigh heavily on the benefit side. Such an approach need not, of course, preclude the use of a common centralised control system; the need for programme safety interlocks between the individual systems is vital to such an approach.

Before embarking on any cleaning project, however, a considerable number of questions have to be answered regarding the actual equipment to be cleaned and the standards of cleanliness to be achieved.

1.5.1 *What is the physical nature of the plant or equipment to be cleaned?*

Any food manufacturing or processing plant will comprise many different items of equipment: for example, dairies and breweries will have plate heat exchangers, storage tanks, vats, pumps, valves, and interconnecting pipework, as well as specialised items, such as bottle and carton fillers or – on the manufacturing side – cheese plant, evaporators, spray dryers and continuous butter-makers. Each of these will have its own cleaning requirements, and pose its own individual cleaning problems. Food processing plants are probably the most diverse sector in terms of equipment design and cleaning requirements, and full consideration needs to be given to the design of this equipment with respect to CIP. Materials of construction must be considered, not only regarding any metal parts, but also items such as gaskets and similar rubber components, and plastic mouldings, to ensure their compatibility with the cleaning chemicals proposed regarding corrosion or degradation. Questions as to temperature and pressure or vacuum limitations of the equipment must be considered, all aimed at answering the overriding question: 'Can the plant be cleaned safely and effectively by in-place methods, achieving acceptable standards of cleanliness without damage to the plant itself?'

1.5.2 *What standards of cleaning are required?*

It is important to understand that various degrees of cleanliness may be appropriate in different circumstances. It is vital that this is clearly recognised, and the target level of cleanliness defined when considering any cleaning project. Levels of cleaning that might be considered are as follows.

- *Physically clean*: This primarily addresses the aesthetic aspect. The surface appears clean, but chemical residues, often deliberately left to achieve a particular desired effect, may have been allowed to remain. Disinfection of the surface has not been considered.
- *Chemically clean*: The surface is rendered totally free from any trace of chemical residues.
- *Microbiologically clean*: This addresses the degree of microbiological contamination remaining on the surface, and may range from plant that has been 'disinfected' – that is, the number of bacteria on the surface of the equipment has been reduced to a level consistent with acceptable quality control and hygienic standards – to surfaces rendered totally sterile, as is essential in ultra-high-temperature (UHT) and similar aseptic operations.

One can thus reach a situation where the surface involved has been physically cleaned and has, perhaps, been rendered microbiologically clean by chemical disinfection, but traces of substantive disinfectant chemical have been deliberately left on the surface to reduce the risk of subsequent microbiological contamination, and the surface is therefore still chemically 'contaminated'.

1.5.3 *What is the nature of the soil to be removed?*

Soil can be considered as the product residues, scale and any other unwanted deposits of foreign matter that have to be removed from the plant surfaces during the cleaning process. Within the manufacturing or processing dairy, such soil may include fat, protein (both denatured and un-denatured: see IDF, 1997), sugar (possibly caramelised), minerals (both from product and from the water supply), fruit cells and various manufacturing ingredients including gums, starches, stabilisers and emulsifiers – all of which will present different and often complex cleaning problems to the detergent chemist. In the dairy context, soil can be divided into two broad general headings: organic soil, which is mainly of plant or animal origin, and is generally most susceptible to attack by alkaline detergents; and inor-