Chapter 13

Food Processing and Beverage Industry

13.1 Introduction

> "British food industry alone consumes approximately 900 m^3 of water each day, enough to supply almost three-quarters of all customers' needs in London daily".
>
> The UK's Environment Agency [1]

The food-processing and beverage industry (F&B) plays a vital role in meeting the world's ever-increasing demand for food as discussed in Chapter 1. The pressures of more food to meet population growth, increased urbanisation resulting in growing distance between the producers and the consumers, globalisation, increasing number of supermarkets, increased purchasing power, more choices at the supermarket and the trend towards convenience foods, freshness, "ready to eat", "pre-cut" and lifestyle choices result in manufacturers producing more water-intensive food products which in turn puts greater constraints on available water resources. As a rule of thumb, each calorie consumed as food requires about one litre of water to produce [2]. Diets rich in cereals have a lower water footprint than diets rich in meat. For instance, in Thailand, the daily water required to grow food is 2800 L/person/day. On the other hand, Italians use 3300 L/person/day.

The F&B industry transforms agricultural primary products such as milk, whole fruit and vegetables, grains and meat into products as diverse as liquid skim milk and cheddar cheese, orange juice, beer, fizzy drinks and oil, flour and breakfast cereal, sausages and salami. In the European Union over 70% of raw agricultural food is processed by this sector.

The F&B industry is one of the largest industrial sectors and globally is estimated to be worth US$ 4000 billion per annum [3]. The US food manufacturing sector accounts for US$484 billion and 10% of total manufacturing output. In Australia the F&B sector is the largest manufacturing sector representing 18.1% of manufacturing output and a turnover of A$24 billion annually [3, 4]. Consequently the sector accounts for 34% of the total water consumption of the manufacturing sector equating to 1800 ML every year [4]. In the United Kingdom the F&B sector accounts have a turnover of £70 billion and 500 000 people are employed in the sector [5].

The industry is characterised by being represented by some of the largest multinational vertically integrated companies in the world such as Unilever to small family owned companies. The world's top 30 F&B companies generate a turnover of US$ 373 billion in sales with 14 companies having sales in excess of US$ 10 billion a year [3]. Trade liberalization, increased competition, supplier chain relationships are challenges faced by the industry. One result is the concentration of ownership. For example in the U.S. poultry industry, the four largest chicken processors control 41% of the chicken market and 45% of turkey facilities [6]. The case study below shows that three companies dominate U.S. brewing industry.

Case Study: Snap shot of the US Brewing Industry

The US brewery sector is composed of about 500 companies and over 2000 brewing establishments producing about $20 billion worth of shipments equating to an annual production of roughly 200 million barrels per year. The sector is increasingly moving to economies of scale with large establishments of more than 250 employees accounting for roughly half of the value added in the sector. Three companies, Anheuser – Busch, Miller and Coors account for 83% of total US production.

Adapted from: Galitsky C., Martin M. and Worrell E. *Energy Efficiency Opportunities and Potential Cost Savings for United States Breweries*. Ernest Orlando Lawrence Berkely National Laboratory. Berkley, CA. USA. 2001.

13.2 Water and Energy Usage

13.2.1 Water Usage

The food processing industries are heavy users of water and energy. Water is used as an ingredient, an initial and intermediate cleaning source, an efficient transportation conveyor of raw materials, as a heat transfer medium, and the principal agent used in sanitising plant machinery and areas. As the case study on the UK soft drinks industry demonstrates, often the amount of water in product is only a fraction of the water used in the production process with the carbonates/fruit juices category having the highest water usage and wastewater discharged per cubic metre of product.

Case Study: UK Soft Drinks Industry

In the United Kingdom over 25 billion litres of water is used to produce 10 billion litres of soft drinks that are consumed each year in the United Kingdom. Production, water and wastewater discharged, how the water is used by each category, and specific water consumption and wastewater discharged breakdown is given below.

	Production (%)	Water use (%)	Wastewater discharge (%)
Carbonates or dilutables	84	57	42
Carbonates/fruit juices	8	32	48
Bottled waters	5	5	4
Fruit juices	3	6	6

	Carbonates or dilutables category (%)	Carbonates/ fruit juices category (%)	Bottled water (%)	Fruit juices (%)
In product	78	23	30	27
Equipment preparation	3	7	67	51
Boiler water	4	7		11
Pasteurisers	6	4		4
Cooling water		2		4
Floor washing	1	2		3
Rinsing containers	4	20	2	
Domestic use	3	2	1	
Bottle washing		33		
Other uses	1			
Total	100	100	100	100

Category	Specific water consumption m^3 water/m^3 product	Specific wastewater discharged m^3 water/m^3 product
Carbonates or dilutables	2.3	1.4
Carbonates/fruit juices	6.1	3.6
Bottled waters	1.6	0.8
Fruit juices	3.5	1.5

Adapted from: Envrionmental Technology Best Practice Programme: EG 126 – Water Use in the Soft Drinks Industry. June 1998.

Figure 13.1 shows the water usage intensity of the Australian F&B industry over a 3-year period [7].

Raw water quality is also an important factor for this industry especially in the beverage sector. Many facilities have stringent water quality criteria which sometimes exceed the local water authority's water quality standards.

Additionally, the food processing industries also discharge effluent of high organic strength to public sewers. Consequently, the industry is under increasing pressure to become water efficient as well as pretreat effluent to meet regulatory standards. For an example, in Europe, the European Union legislation governing the discharge of industrial effluents require that by 2007, industries comply with directives such as the Integrated Pollution Prevention and Control (IPPC), Water Framework [8]. The IPPC requires industries to install equipment that satisfies the requirements under the Best Available Technology (BAT) directive. Similar concerns are expressed in the annual survey of members of the Australian Food and Grocery Council as shown in Figure 13.2 [7]. After packaging, 47% of respondents voted water as the next highest priority.

13.2.2 Energy Usage

Energy is a vital input in the food processing sector. For instance, breweries in the United States spend in excess of US $200 million on energy. Electricity is used for pumping and conveying fluids, refrigeration and cooling. Steam is used for heating, drying and evaporating products and for generating hot water for washing. For instance, in the dairy industry, approximately 80% of the plants needs are met by the combustion of fossil fuel to generate hot water and steam. Electricity costs account for over half the energy costs. F&B Plants rarely cogenerate their own electricity with steam. Steam is generated for process use with the exception of breweries. Breweries and dairies can cogenerate electricity with extraction steam turbines. There are also variations in energy usage within the same industry sector. Energy use will depend on the product mix. Processes which depend on drying and evaporation are more energy intensive. For instance, in the milk industry, production of whey is more energy intensive than production of market milk. Similarly energy usage of draught beer is less than for canned beer. Other factors that impact on energy use are

- The size of the production plant. Larger plants tend to use less energy per unit of product.
- Age of the plant.
- Level of automation.
- Operation and maintenance practices.

Given the large reliance on water to generate steam, hot water, washing and sanitation and electricity for refrigeration, energy reduction measures go hand

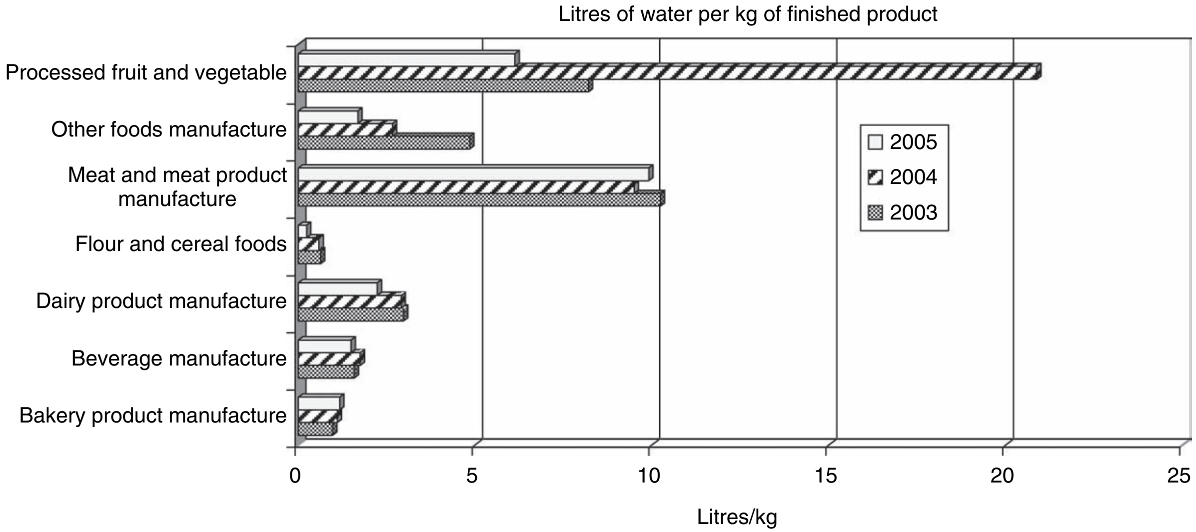

Figure 13.1 Water usage in Litres per kg [7]

Adapted from the Australian Food and Grocery Council's 2005 Environment Report.

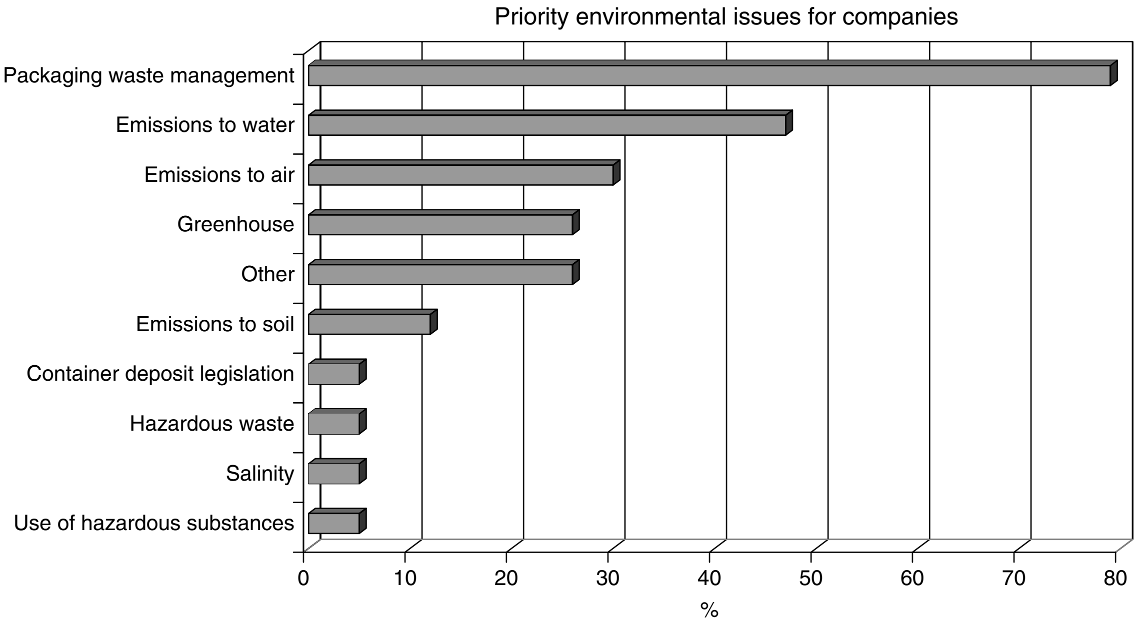

Figure 13.2 Priority environmental issues for companies [7]

Adapted from the Australian Food and Grocery Council's 2005 Environment Report.

in hand with water conservation strategies. Strategies include capturing waste heat from ammonia refrigeration systems to produce hot water, condensate capture and optimisation of the steam and refrigeration systems.

To become water efficient it is necessary to undertake the steps given in Chapter 3.

These are

- understanding the process and determining where water is used
- benchmark water usage and compare it against best practice
- identify water-saving measures.

13.3 Understanding the Process and Where Water is Used

Figure 13.3 gives a typical breakdown of average water usage in the food-processing sector based on 22 audits carried out by Sydney Water's Every Drop Counts Business Program. The average water usage in these facilities was 474 m^3/day. The pie chart shows that the majority of the water goes into the processing of the food rather than the product itself, followed by washdown including clean in place (CIP), product usage, utilities, leakage and lastly amenities.

A flow diagram is a good way to understand how water is used in industry. Figure 13.4 shows the flow diagram of a typical poultry processor. These steps are further described in Table 13.1. Therefore, using poultry processing as an example, a business could target the high water-using areas for water minimisation.

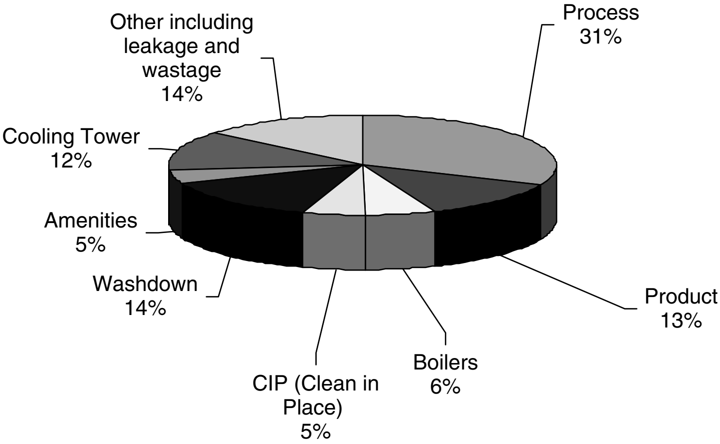

Figure 13.3 Breakdown of water usage in a typical food-manufacturing facility

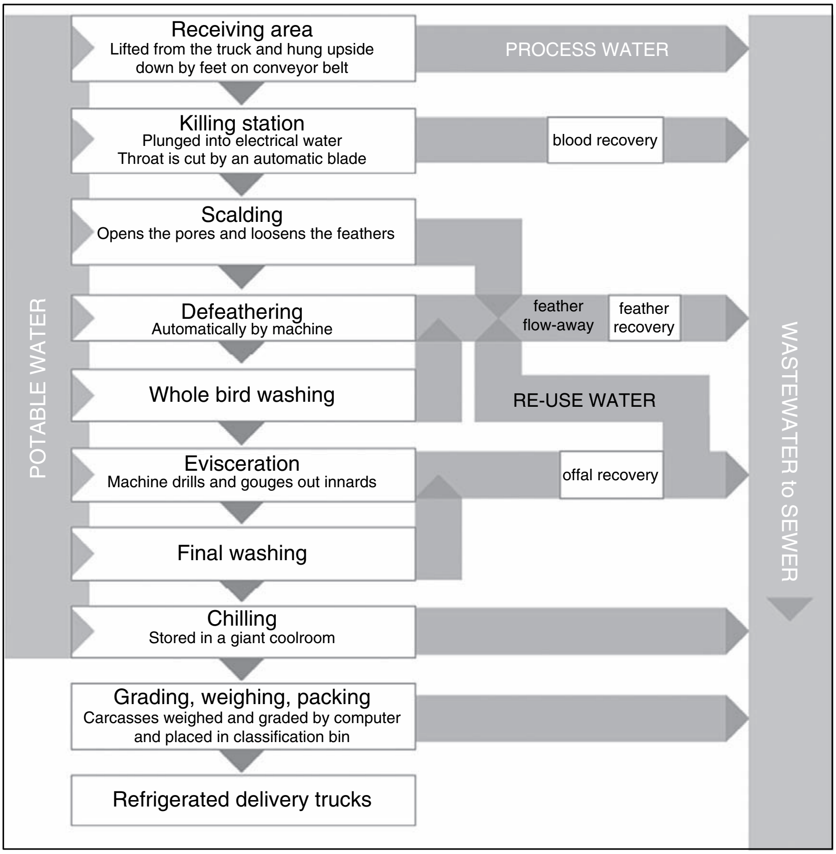

Figure 13.4 Flow diagram of water usage in a typical poultry-processing plant

Courtesy of Sydney Water *The Conserver* 2006. Issue 10.

13.4 Benchmarking Water Usage and Comparing it Against Best Practice

Benchmarking water usage can be done either using kg or litres (lbs or gallons) of raw product or as finished product or as whole units such as L/ bird. There is no accepted convention.

It is important to remember that when comparing against other plants, there will be discrepancies since it depends on the following factors:

i) Process type. For example, in the poultry industry chilling can be done by using air chilling or immersion chilling. The water usage for these two processors will be dramatically different.
ii) Animal size and type.
iii) Slaughter technique

Table 13.1 Description of poultry processing

Step	Description
1. Receiving Area	Chickens removed from crates/cages and placed in shackles (hung upside down). Crates are washed using automatic crate washers, semi-automatic or manually.
2. Stunning	Birds are electrically stunned by dropping them into a water bath, although other methods are available such as gassing (for turkeys).
3. Slaughtering	Birds are slaughtered by cutting the neck and bleeding out (typically 2–3 minutes). The blood is collected and removed.
4. Scalding	Carcasses are immersed in a hot water tank at temperatures of 50–65° C (122–149° F) to loosen the feathers to facilitate plucking. Temperature of the scald tank is critical and varies depending on poultry species and production methods (i.e. needs to be high enough to loosen feathers but not too high as to damage the carcass). USDA requirement is 0.9 L/bird (0.25 US gal./bird) [9].
5. Defeathering	Feathers are removed from the carcass – using equipment comprising a bank of counter-rotating steel discs (automated production line) or rotating steel drums (manual production) with mounted rubber fingers.
6. Washing	Water is constantly sprayed to flush away removed feathers. Remaining feathers are removed by hand.
7. Evisceration	Evisceration involves cutting around the vent and insertion of a spoon-shaped device to remove the viscera. Can be done either mechanically or by hand, but care must be taken to ensure the viscera is not damaged or ruptured as this can lead to significant contamination of the carcass.
8. Washing step	Eviscerated carcass is washed internally and externally.
9. Chilling	To minimise microbial proliferation from *Salmonella and Camhylobacter*, the carcass is chilled immediately to a temperature of 4° C (40° F). Removal of carcass heat using air-chilling, water immersion (spin chilling) or spray chilling. Water immersion chilling is the most common method practiced in the US and Australia, with the carcass placed in counter-current flow of chlorinated (50–70 ppm total available chlorine, 0.4–4.0 ppm free available chlorine) cold water (~ 0° C). In Europe air chilling is more popular. Water flow rate for immersion chilling differ from country to country. USDA requirement is for 1.9 L/bird (0.5 US gal./bird) [9] to 5 L/bird. Water discharged contains parts of flesh, grease and blood.
10. Grading Weighing and Packing	Birds are replaced on overhead conveyors to allow excess moisture to drain. No fresh water is used. Giblets are put back and weighed.

iv) Degree of automation
v) Cleanup and housekeeping procedures
vi) Conveyance means.

The benchmark need not be against an industry standard but can be a year-on-year comparison for the whole site, process or product. This eliminates differences in production processes. Table 13.2 gives typical and best practice figures for selected industries.

Table 13.2 **Typical and best Practice figures for selected industries**

Industry	Typical water use	Best practice water consumption
Chicken	13–37.8 L/bird [9]	8–15 L/bird [10]
Turkey	41–87.0 L/bird [9]	40–60 L/bird [10]
Dairy	1.3–2.5 L/L of raw milk	0.8–1 L water/L raw milk [11]
Ice cream	3.6–10.3 L/kg	
Red meat abattoir	6–15 m^3/ton hot standard carcass weight (HSCW) [12]	8 m^3/ton HSCW [12]
Beer	5–7 L/L of Beer [13, 14] For bottled beer – 10 L/L of beer	2–3.5 L/L of Beer [13]
Soft drinks – Cola	1.5 L–3.9 L/FBL [15]	1.30 L/L per finished beverage (FBL) [16]

Case Study: Coca-Cola Amatil Northmead Plant Australia – Achieving Best Practice

The Coca-Cola Company is the world's largest beverage manufacturer with production plants in 741 locations. The Global Water Initiative was launched in 2004 to reduce water usage and since then has made steady progress. Coca-Cola Amatil's Northmead plant since 2003 has saved over 230 m^3/day of potable water. Through a partnership with Sydney Water's *Every Drop Counts Business Program* in 2004 they reduced their benchmark to 1.37 L/FBL.

Coca-Cola Amatil's water usage benchmark is compared to other Coca Cola plants in the table below.

Country	**Water usage in 2005 L/FBL (finished beverage litre)**
Coca-Cola Amatil Australia	1.58 (actual)
Coca-Cola UK	1.50 (target)
Coca-Cola Enterprises Inc, USA	1.86 (actual)
Coca-Cola Company (average for all worldwide 741 beverage production locations)	2.60 (actual)
Coca-Cola India	3.90 (2004 usage)

Sources:
Coca-Cola UK 2005 Environment Report
Coca-Cola Company 2005 Environment Report
Coca-Cola Enterprises Inc. 2005 Environment Report
Coca-Cola Amatil website –www.ccamatil.com/AusWaterRedTargets.asp

Note to the reader:
However in making these comparisons it needs to be borne in mind that the product mix and age of the plant may make direct comparisons difficult and therefore is only given as a guide and not to be taken that every plant can achieve the same efficiencies

Courtesy of Coca-Cola Amatil Australia.

13.5 Water Minimisation Measures in the Food-Processing Industry

Tables 13.1 and 13.2 show that most of the water usage is for cleaning operations to maintain sanitary conditions in order to comply with health, integrity of the product and food safety regulations. Therefore water-use efficiency and reuse measures need to be considered in the light of not compromising food safety whilst minimising water usage. In assessing opportunities, consider the water-minimisation hierarchy of avoid, reduce, reuse and recycle as shown in Figure 13.5. However, recycle is not a practical option for food-processing plants.

13.5.1 Avoiding Water Usage

The objective of preventing food or other waste from becoming water-borne is to keep *dry waste dry and wet waste wet*. Approaches currently used include the following.

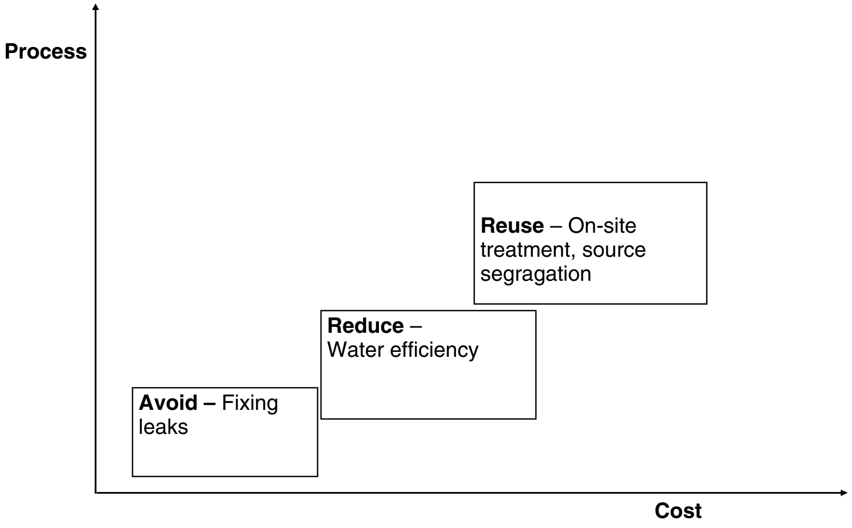

Figure 13.5 Water-minimisation hierarchy.

- Install sub-meters to detect leaks. Connect these to an electronic monitoring system so that excessive water usage from leaks, tank overflows and faulty valves can be detected and acted upon immediately.
- Use brooms, brushes, vacuum cleaners and squeegees before floor rinsing.
- Dry-cleaning vessels before rinsing to remove solids for recovery or disposal.
- Change of production procedures to minimise product or by-product wastage such as installing spill collection trays to collect solids at appropriate places in the production line.
- Install solenoid valves to link sprays to machines so that the sprays operate only when the machines are running.
- Link operation of vacuum pumps to usage through pneumatic timer switches.
- Water-based conveyor systems can be replaced by mechanical systems. "Pigging" of lines rather than using water to clean lines. When multiple products are made in the process vessels it is necessary to clean the lines before sending another product. By sending a silicon bullet, it pushes the extra product down the line and into the processing equipment negating the need to use high pressure jets.
- Use air-cooled chillers to replace wet-cooling towers and evaporative condensers if practical.
- Air thawing or microwave technology rather than water thawing if practical.
- Air chilling rather than water chilling.
- Using synthetic lubricants rather than water-based lubricants.
- Repair leaks.
- Dry peeling rather than wet peeling
- Air rinsing of bottles and cans rather than with water.
- Replacing liquid ring vacuum pumps with dry vacuum pumps (see Section 13.4.5)
- Reduce the size of nozzles if practical.

The added advantage from these measures is that the wastewater loads are reduced. Given that food-processing plants have biological loading, frequently this becomes the driving force for such capital investment.

Case Study: Air rinsing of bottles and cans at Diageo, Huntingwood, Sydney, Australia.

Diageo is the world's largest manufacturer of alcoholic beverages. In the past three years Diageo's Huntingwood site has trebled its production output while reducing its water product ratio by 30%.

One of those measures was to change over to air rinsing of bottling and can lines. By December 2004, three of the four lines have been converted to air rinsing. Saving 36 000 m^3/yr of water. A 20% reduction in water usage.

"We regard water as a key performance indicator," said plant manager Chris King. "We have reduced our use of water from 2.1 L per product in 2001 to less than 1.4 L per product in 2004."

Adapted from: Sydney Water. *Raising a glass for Water Conservation. The Conserver,* Issue 6. December 2004.

Case Study: Hans Continental Foods, Sydney – Hot air thawing

A water audit showed that one-third of all water is used for thawing of frozen meat products with continuously running water. The company commissioned a new process – controlled atmospheric thawing which passes hot air in a temperature- and humidity-controlled environment.

The benefits were immediate. The plant cut its water use by more than 30% and is now saving more than 130 000 L/day and at least $100 000 annually.

The new process also delivers better results with a higher level of retained proteins. Plus it adds extra capacity to the plant, improves the quality of the wastewater and reduces the cost of wastewater treatment.

Adapted from: Sydney Water. *The Conserver*. Issue 7. April 2005.

13.5.2 Reducing Water Usage – Spray Nozzles

Spray nozzles are used widely for cleaning and a variety of other applications within the food-processing industry. And yet they are one of the most overlooked items. It is reported that a reduction of 20% in water usage can be achieved by improving the spraying systems. The benefits of using spray nozzles are

- efficient and effective cleaning
- reduced water consumption
- reduced operating costs
- reduced cleaning time
- ability to restrict sprays to specific flow rates.

To achieve these benefits spray nozzle selection needs to be based on

- flow rate – volume of fluid sprayed at a given pressure
- spray pattern – the dimensions and uniformity of coverage

- pressure and pressure drop
- droplet size – particle size
- the material to be cleaned
- spray impact and spray velocity
- matching cleaning fluid characteristics with nozzle material.

Failure to consider the above factors can result in the following:

- High flow rates increases moisture in the air, creating a hospitable environment for micro-organisms to persist and even proliferate.
- Incorrect selection and incorrect use such as high pressure flows may disperse micro-organisms to the air (aerosols).
- Using the wrong spray pattern. For quick cooling a hollow cone with large droplets may be better suited than other patterns.
- Misting and overspray results when the droplet size is too small.
- Improper placement of spray nozzles results in poor coverage of target area.
- Abrasion from particles in the cleaning fluid can increase nozzle wear and tear.
- Aluminium and brass nozzles are cheaper than stainless steel and hardened stainless steel nozzles. However, the latter are more abrasion resistant than aluminium or brass nozzles and therefore will provide better performance over time easily justifying the added expense. Table 13.3 shows the approximate abrasion resistance ratios of typical spray nozzle materials.

(i) Use the recommended spray for the application – The proper spray pattern is required to achieve the cleaning objectives. A piece of

Table 13.3 Approximate abrasion resistance ratios of typical spray nozzle materials

Material	Abrasion resistance ratios
Aluminium	1
Brass	1
Steel/Iron	1.5–2
MONEL®	2–3
Stainless steel	4–6
HASTELLOY®	4–6
Hardened Stainless Steel	10–15
STELLITE®	10–15
Silicon Carbide (Nitride bonded)	90–130
Ceramics	90–200
Carbides	180–250

Courtesy of Spraying Systems Pty Ltd. – Spray Nozzle Maintenance Handbook. 1992.

metal pipe with drilled holes may lead to excessive water usage and increase cleaning times. Excessive water and hot water usage not only increases the dissolution of meat, fat and other valuable food ingredients but also increases hydraulic and pollutant loadings of the wastewater treatment plant. This in turn increases trade waste charges and compliance fines. The case study given below illustrates how Coca-Cola Amatil in Sydney NSW was able to save $78 500 yr.

Case Study: Benefit to Coca-Cola Amatil

Coca-Cola Amatil Northmead site in Sydney, Australia, has been actively seeking ways to reduce water consumption. One such opportunity was discovered at the bottling rinsing area. Before filling bottles with product, rinsing with treated town water is required. The rinse water is then sent to waste treatment and finally to sewer.

It was recognised that the rinser nozzles were not designed with water efficiency in mind. Coca-Cola Amatil sourced a spray nozzle that delivered a far more efficient spray, providing excellent coverage, yet minimising water usage.

The new nozzles reduced water usage on two lines by 176 L/min – a reduction of 46%! The annual projected savings are 37 400 m^3 and $78 500. Plans are now in place to retrofit spray nozzles in their Smithfield plant.

Source: Sydney Water Fact Sheet. *Spray Nozzles*

(ii) Maintenance of Spray nozzles – Spray nozzles become clogged, corrode or get damaged due to heat. The end result is spray pattern that is not ideal either wasting water or not performing to design. When sprays become clogged then drills are commonly used to clean them. This increases the nozzle size. Doubling the diameter quadruples the water flow rate. Therefore it is important to inspect them regularly and replace when necessary.

Nozzle maintenance check list should include

- measuring flow rate
- checking spray pattern
- checking spray pressure.

Figure 13.6 shows a comparison between clogged, corroded and a new nozzle.

A simple example can indicate just how much poor maintenance could be costing a company.

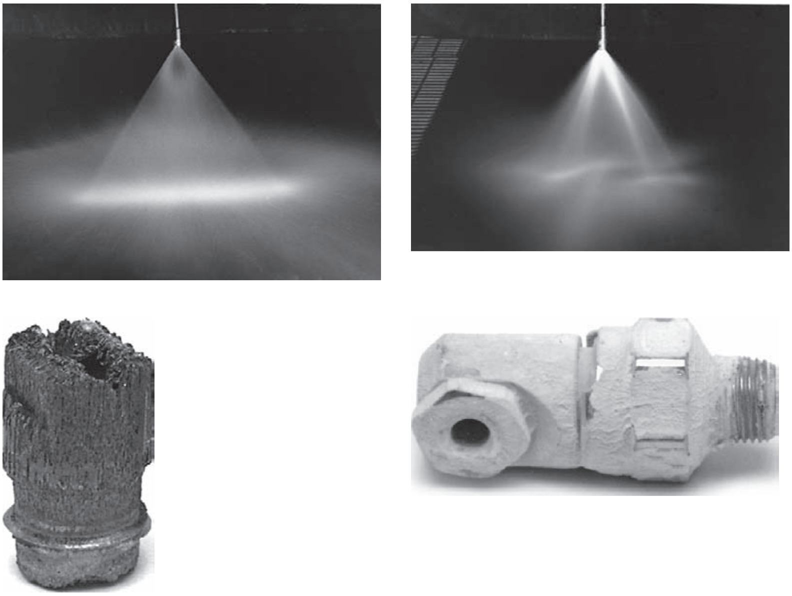

Figure 13.6 A Comparison between a good flat spray pattern (left) and a spray from a clogged nozzle and photos of a corroded and clogged flat spray nozzles.

Courtesy of Spraying Systems Pty Ltd.

(iii) Automation of sanitising regime – In food-processing plants it is a common practice for sanitising to be done at night using portable sprayers. Manual application results in inconsistent spray applications, labour time and wastage of chemicals if over sprayed, and if under sprayed sanitation is compromised. In these applications proper spray application is dependent on the operator. An investment in an automated fogging system with a dedicated spray controller and air atomising nozzles will improve the situation.

Worked example: Cost of worn spray nozzles

Number of sprays	30 nozzles
Operating time	16 hrs/day
Number of days operated/yr	300
Typical nozzle flow	10 L/min
Typical wastage with worn nozzle	15%
Increased water wastage	12 960 m^3/yr
Cost of additional water	$31 104/yr*

*At $2.40/$m^3$ of water and wastewater. Additional power and chemical costs for effluent treatment have not been included.

13.5.3 Reducing Water Usage – Washing

Bottle washing is an area where there can be a high demand for water. The common causes are excessive flow rates; lack of solenoids in valves and spray nozzles having too high flow rates (read the Coca-Cola case study). Install timers on lines so that during non-operating hours water is not wasted. Investigate the possibility of air rinsing rather than water rinsing. Only final rinse needs to be with fresh water. For pre-rinse reuse the final rinse to capture water and heat.

For crate washing consider installing an automatic crate washer.

Case Study: National Foods installs automatic crate washer and a unique tanker washer

Washing crates is part and parcel of National Foods, Australia's largest dairy's daily routine. At it's Penrith Plant in Sydney, a large portion of the plant's total water usage is in the washing of over 34 000 crates per day. Around 60 m^3/day went straight to the drains but is now filtered and fully reused, delivering savings of over A$ 100 000 per annum.

At the milk intake point, savings are being made in both washing tankers internally and externally. A dual-washing system that used over 1000 L/truck has been replaced with a purpose built system that uses just 70 L and is more effective and twice as fast. The subsequent truck washing is now controlled by a time limited token system.

This and other water reduction measures has helped National Foods to better their benchmark for market milk beyond international best practice water usage target of 0.9–1.0 L/L.

Source: Sydney Water. *National Foods Timely Management Delivers Big Cost Reductions*. The Conserver. Issue 4. 2004.

For cleaning of floors and equipment install trigger-operated spray guns to hoses. A common model of a trigger-operated spray gun will deliver 20 L/min compared to a standard hose flow rate of 30 L/min. The problem associated with spray guns like the type shown in Figure 13.7 is theft. These are more expensive than domestic trigger guns and therefore are an easy target for theft. Some employees may resist using the guns. Education and training will help in these instances. One company solved the problem by giving each operator a domestic trigger gun before installing the industrial variants.

13.5.4 Reducing Water Usage – Clean-in-Place

Clean-in-place (CIP) technology offers significant advantages to food-processing and other manufacturing plants to efficiently and economically clean process equipment, tanks and piping, improved hygiene and product

Figure 13.7 A Water-efficient spray gun

Courtesy of Spraying Systems Pty Ltd.

quality. The ability to do so without dismantling plant equipment significantly reduces cleaning-time efficiency and increases operator safety through reduced chemical handling allowing the use of higher strength detergents and hotter temperatures.

The cleaning solutions are generally distributed to the CIP circuits from a central CIP station consisting of several tanks for storing of the cleaning solutions. The solutions are heated by steam and their concentration is constantly monitored and adjusted. The cleaning programme differs according to the equipment to be cleaned, but the main steps are

- Pre-rinse cycle – Soiled equipment is cleaned with warm water for 3–10 minutes to remove loose solids.
- Cleaning cycle – Removal of residual solids from equipment surfaces by optimising the four factors mentioned above. An alkaline detergent (typically 0.5–1.5% sodium hydroxide) at 75° C is circulated for about 10 minutes or longer.
- Post rinse – Rinsing all surfaces with cold to hot water depending on the temperature of the cleaning cycle to remove residual chemical solutions and contaminants.
- Acid rinse – A mild acid rinse to neutralise any alkaline residues. Hard to remove proteins may require other additives (peptising) and wetting agents to aid removal.
- Disinfection – Normally carried out immediately before the production line is to be used again. Hot water at 90°–95° C or chemical disinfectants are used. Chemical disinfectants can be sodium hypochlorite, peracetic acid (PAA) or quaternary ammonium compounds.

- Cooling – Cooling with water to rinse out disinfectant residuals (to eliminate the chemical contamination of food and to minimise corrosion to piping and equipment) or cooling of equipment.

The designs vary from single-pass to recirculating systems. The single-pass systems whilst inexpensive and have a smaller footprint uses more water chemicals and heat. Figure 13.8 shows a schematic of a single use CIP system.

The operation of a CIP system requires the control of several conditions. The five factors that need to be considered when designing a CIP system are

- Time – The longer a cleaning solution remains in contact with the equipment surface, the greater the amount of soil that is removed.
- Chemical concentration – These vary depending on the type of chemical used, the type of contaminant and the equipment to be cleaned.
- Temperature – Soiling is affected by varying degrees by temperature. In the presence of a cleaning solution most contaminants become more soluble as the temperature is increased. The temperature can be as high as 95° C.
- Fluid velocity – This aids in removal and typically reduces time, temperature, and concentration requirements. Fluid velocities in process piping are approximately 1.5 m/s (5 ft/s) or higher. In tanks the flow rate may be around 40–600 L/min.
- Spray design – Spray designs may range from small static nozzles to rotational (360°).

These requirements are dictated from sanitising requirements imposed by health authorities. Sanitising of food product contact surfaces means reducing bacterial counts by 99.999% (5 log) reduction. And sanitising non-product contact surfaces require a 99.9% (3 log) reduction of contamination.

Given the importance of CIP, the opportunities to save water in CIP systems are

(i) Internal recycling
Water, chemical and heating costs can be reduced by
    - Collecting rinse water for reuse and recirculating chemical solutions back to a storage tank. Periodic inspection and cleaning of rinse water collection tanks to prevent the build-up of unwanted deposits is required.
    - Collecting hot rinse water maintains equipment temperature, allowing caustic to be introduced more quickly.
    - Conductivity sensors rather than timers to be used to divert caustic detergent to the storage tank instead of the drain.
    - Using membrane filtration to clean contaminated caustic avoiding the need to dispose of the caustic to the drain.

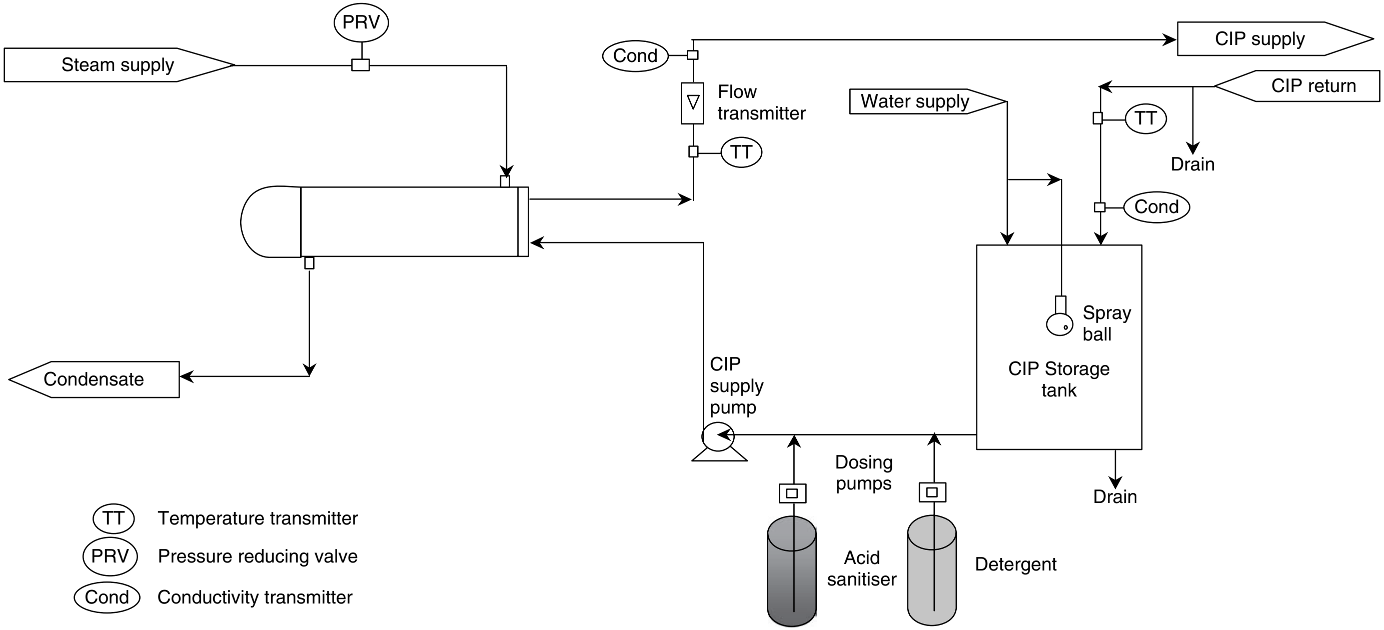

Figure 13.8 Schematic of a single use CIP skid system

(ii) Optimising CIP programmes
Typically 20% water savings can be achieved without compromising cleanliness standards by

- By customising the CIP programme for the size of the plant and type of soiling. Often pre-rinse and post-rinse times are not appropriate for the plant and size of equipment. Consult a reputable CIP detergent supplier to carry out an audit of the CIP system.
- Using software to monitor CIP systems. Software systems provide real-time monitoring and data storage, charting of trends to analyse the performance of the system.
- Improving product scheduling so that similar products are processed sequentially, reducing cleaning requirements.

(iii) Using spray designs that are fit for purpose
Water use can be reduced by using spray nozzles that are fit-for-purpose with regard to spray pattern, temperature and chemical corrosion of materials.

- Self-powered rotating nozzles have a superior performance over fixed spray nozzles as well as using less cleaning chemicals. Figure 13.9 shows a photo of a rotating spray nozzle.

(iv) Removing product and gross soiling before cleaning
Removal of residual product before cleaning with CIP system will save product going to the sewer, water, chemicals, reduce pre-treatment chemical costs as well as trade waste charges. Pigging and air-blowing techniques are commonly used.

(v) Ensuring equipment is correctly designed for CIP cleaning
When a CIP system is connected to the existing pipework or when designing a new processing plant, ensure to minimise 'dead legs', crevices or pockets that cannot be reached by the cleaning solutions. Detergents and sanitisers are not able to reach these areas and thus allow micro-organisms to multiply. Figure 13.10 shows an illustration of incorrect and correct piping design.

13.5.5 Reducing Water Usage – Liquid Ring Vacuum Pumps

Liquid Ring Vacuum Pumps (LRVPs) are used extensively in the food industry for evacuation and evaporative cooling. Evacuation is used to empty the vessel before filling with food product. Evaporative cooling is used to cool the food product to minimise spoiling of food. Typical applications of LRVPs include concentrating fruit juice, adjusting the boiling point (temperature) of water during cooking and flash cooling after a food item has been cooked. Common vacuum technologies are

- steam jet ejectors
- barometric condensers

Figure 13.9 A photo of a rotating spray nozzle

Courtesy of Spraying Systems Pty Ltd.

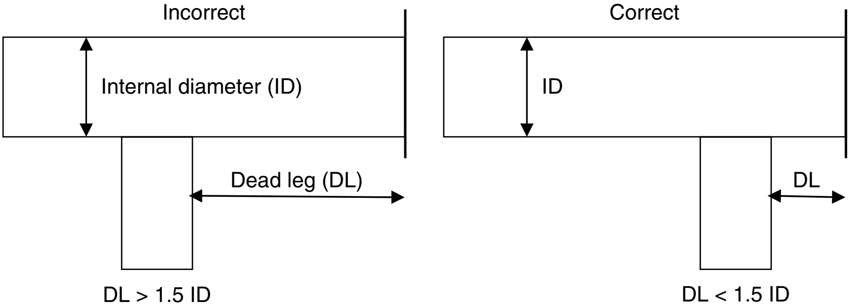

Figure 13.10 Illustration of incorrect and correct piping design

- liquid ring vacuum pumps
- dry vacuum pumps.

Steam jet ejectors use steam through a nozzle which discharges a velocity jet across a chamber that is connected to the equipment to be evacuated.

Barometric condensers create a vacuum by condensing the vapour through contact with cooling water.

In an LRVP as the impeller of the vacuum pump rotates, it throws water by centrifugal force to form a liquid ring concentric with the periphery of the casing which does the work of compression. The eccentric mounting of the impeller with respect to the casing results in increased spacing between the impeller blades at the inlet port and the decreased spacing towards the outlet port. As the vapour (gas) enters the inlet port, it is trapped between the impeller blades and the liquid ring. Then the impeller rotates, the liquid ring compresses the vapour or gas and forces it out the outlet port. Figure 13.11 shows the principle of operation of a liquid ring vacuum pump.

The working principle of the LRVP requires a continuous supply of sealing liquid and in many cases this is water. The sealing water maintains the seal,

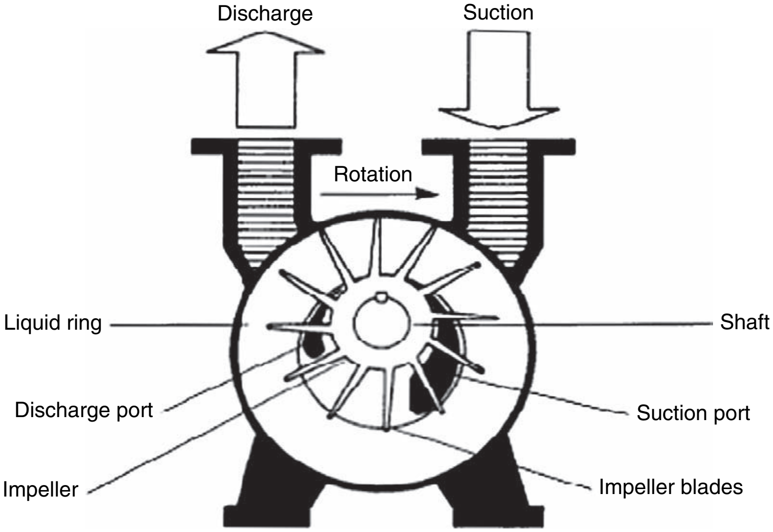

Figure 13.11 Principle of operation of a liquid ring vacuum pump

absorbs the heat of compression, friction and condensation. The clearances are larger in LRVPs and this feature allows them to handle streams containing particulate matter. The temperature of the seal water is critical to the pump's vacuum-generating performance. Figure 13.12 shows that if the temperature of the seal water increases from 15° C to 20° C at a suction pressure of 40 torr, it will reduce pump capacity by 20%.

To maintain constant temperature, the liquid is often used only once before being discharged to the sewer. Depending on the operating principle, it can waste a lot of water. The three ways that seal water can be connected are

1. once through
2. partial recovery
3. closed loop.

In once-through water systems the water is separated from the gas and discharged to the drain. In the partial recovery about 50% of the liquid is recirculated and 50% is sent to the drain. In the closed-loop system the sealing liquid is cooled (through a heat exchanger using cooling water) and then recirculated.

Water-saving options are

1. Converting from once through to a partial recovery or closed-loop system.
2. Ensuring that the vacuum pump is not oversized for the application. To overcome increases in process temperature and a consequent loss in vacuum, LRVPs are frequently oversized.

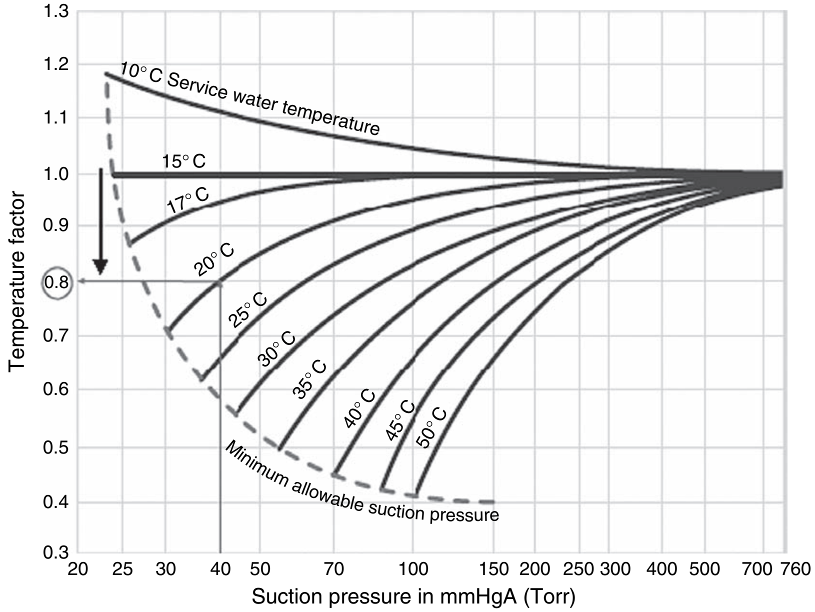

Figure 13.12 Chart showing the relationship between seal water temperature and pump capacity.

Courtesy of Sydney Water. Liquid Ring Fact Sheet October 2004.

3. Investigate the option of changing over to a dry vacuum pump. Dry vacuum pumps require no sealing water. The three types of dry vacuum pumps are hook and claw, lobe and screw. They run hot since there is no liquid to absorb the compression heat and therefore a water jacket will be required. One of the advantages of dry vacuum pumps is that they can handle corrosive vapours by keeping them as vapours and not allowing the vapours to condense. They are also energy efficient since they move air not water. To compensate for the decrease in efficiency, frequently LRVPs are oversized. On the other hand, a claw-type dry vacuum pump is about the 50% the size of an equal LRVP. On recirculated water systems, energy is also consumed to cool and move water around the plant. Since the dry vacuum pumps do not require water for sealing, they can be fabricated of inexpensive cast iron.

   The disadvantages of dry vacuum pumps are that they cannot handle slugs of liquid or particulates; however, in such cases a knockout pot is required upstream of the pump. Polymerisation of product can be a concern because the pumps are running hot (as much as 315° C). The capital cost of dry vacuum pumps are more than LRVPs. However, the lower operating costs during the life of the pump will make up for the higher capital cost. In some industries, dry vacuum pumps may not be acceptable from a perspective of product purity. Their suitability needs to be individually investigated. Figure 13.13 shows a photo and cross section of a screw-type dry vacuum pump.

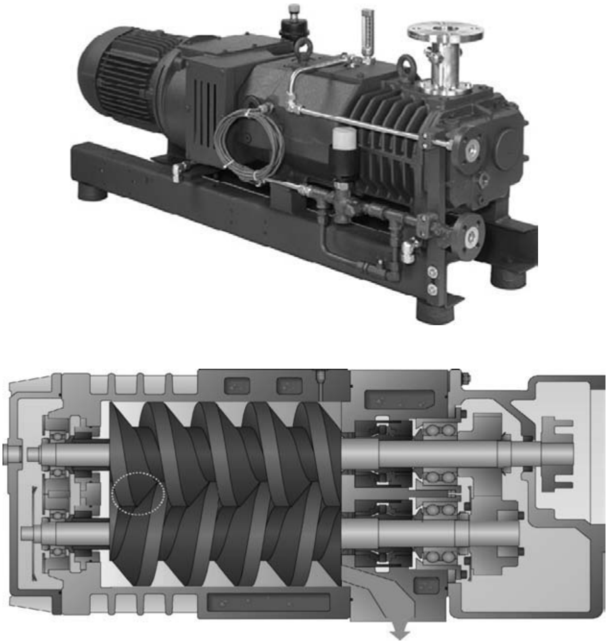

Figure 13.13 Photo and cross section of a screw-type dry vacuum pump

Courtesy of Busch Australia Pty Ltd.

Case Study: World's first application of dry vacuum pump at 140° C

Snow confectionery, based in Sydney, is one of Australia's largest producers of sweets, candy, toffees and jellies. LRVPs are used to extract moisture out of the sugar syrup to reduce the cooking time. Their 3 LRVPs were consuming 48 m^3/day as sealing water. This was approximately half the site's water usage. The water temperature exiting the LRVPs were as high as 55° C. They were interested in reducing their water usage as well as the effluent discharge temperature. The cause of the high water temperature was the seal water discharged from the liquid ring vacuum pumps connected to the high temperature vacuum cookers operating above 140° C. Dry running vacuum pumps were investigated but they rarely operate at liquid temperatures above 80° C. Busch Australia replaced one LRVP with a dry vacuum pump to test their suitability in this challenging application. To prevent sugar jamming the pumps they designed a system to inject oil to the pump. 12 months later the pump is using only 13.5 kW compared to 17 kW the LRVP was using, the effluent discharge temperatures are lower and when all three cookers are connected water usage will decrease by 50% or 7 million litres a year. The reduction will also assist in Snow Confectionery achieving its target of 1.5 L/kg of confectionery produced.

Adapted from: Waste Management and Environment, *Dry times ahead as costs rise*. July 2006 and Sydney Water. *The Conserver* Snow Confectionery to halve its water use. Issue August. 2005.

13.5.6 Reducing Water Usage – Amenities Blocks

Food-processing facilities require the maintenance of good hygiene standards and therefore washing of hands before entering the plant is essential. These facilities can be a source of water wastage. Replace these with on-demand systems or paddle-operated systems. Install meters. Toilet blocks can also be retrofitted. Refer to Chapter 10.

13.5.7 Reducing Water Usage – Evaporative Condensers and Cooling Towers

Refrigeration, air-conditioning and compressor systems play a major role in a food-processing plant. Reducing the refrigerant temperature in the condenser is important to reduce energy costs. A 1° C drop in temperature will reduce electricity costs by 2–4%. Maintaining clean heat transfer surfaces in the condenser and optimising water treatment are discussed in Chapters 5 and 6.

Some common strategies to save water are

- Eliminate once-through water systems.
- Ensure that the cooling towers are not overflowing.
- Maintain bleed levels at the optimum levels.
- Minimise drift or splashing.
- Install variable speed fan drives in cooling tower.
- Investigate the potential for air-cooled chillers or better hybrid cooling towers rather than wet cooling towers. Refer to Chapter 6 for more details.
- Optimise compressed air usage. For every 1 kWh of compressed air used 10 kWh of electricity is required and these require cooling water to keep the system cool.

Refer to the case study on Red Lea Chicken, Chapter 6.

13.5.8 Reducing Water Usage – Steam Systems

Steam systems play a large role in food-processing plants. Chapter 7 discusses some of the common strategies to be undertaken.

A common strategy is to recover steam condensate. Often oil-contaminated condensate is sent to the drain. There are ways of removing the oil and reusing the condensate for its energy- and water-saving value. Capturing flash steam and recovering steam from evaporators are other commonly employed strategies.

13.5.9 Reusing Water

There are several options to reuse water in a food-processing facility. These can be divided into those that do not contact food products and those that do contact food products. Non-contact water-reuse applications are numerous and can easily be implemented. When the reuse water comes into contact with food a key issue that must be addressed and assessed is whether this presents any associated increased risk of microbiological contamination of food and the production environment by pathogenic micro-organisms. Most food-processing companies are reluctant to investigate such options given the risk to their brand name from microbial contamination. Microbial pathogens of concern include *Salmonella, Campylobacter, Listeria*, pathogenic strains of *E. coli, Giardia, Cryptosporidium* and viruses.

To alleviate these concerns regulatory standards require that reuse water meet drinking water-quality standards. A validated and verifiable systematic food safety management tool such as a Hazard Analysis Critical Control Point (HACCP) system will be required to satisfy these food safety obligations. The HACCP system consists of the following seven principles (CODEX Alimentarius Commission, 1997):

- Principle # 1 Conduct a Hazard Analysis.
- Principle # 2 Identify the Critical Control Points (CCP)
- Principle # 3 Establish Critical Limits s at each CCP
- Principle # 4 Establish monitoring procedures
- Principle # 5 Establish corrective action to be taken when monitoring indicates that there is a deviation from a Critical Limit.
- Principle # 6 Establish verification procedures
- Principle # 7 Establish record keeping procedures

The advantage of the HACCP approach is that it incorporates food safety control as a management tool rather than relying only on the end-product testing.

For water reuse the CODEX guidelines specify the following:

- Reuse water shall be safe for intended use and not jeopardise the safety of the product through the introduction of chemical, microbiological or physical contaminants in amounts that represent a health risk to the consumer.

- Reuse water should not adversely affect the quality (flavour, colour or texture) of the product.
- Reuse water intended for incorporation into a food product shall at least meet the microbiological and as deemed necessary chemical specifications for potable water.
- Reuse water shall be subjected to ongoing monitoring to ensure its safety and quality.

Food processors considering the use of reuse water that comes into contact with food are well advised to engage the appropriate food regulatory authority early into discussion.

13.5.10 Notes on Water-Reuse Applications

Appropriate technologies are described in Chapter 8. Turbidity in water is often due to the presence of organic matter. Some decontaminating methods are ineffective in the presence of turbidity to reduce micro-organisms since the microbes can embed themselves inside particulate matter. A comparison of microbial decontamination methods and their sensitivity to turbidity is shown in Table 13.4.

Table 13.4 A comparison of water-reuse technologies for microbial decontamination.

	Membrane processes	Heat treatment	UV – radiation	Hypochlorite	Chlorine dioxide	Ozone
Recommended concentration	NA	NA	25–40 mWs/cm^2	50–100 mg/L (total chlorine)	> 2 mg/L	< 1 mg/L
Contact time	NA	Sterilisation requires a temperature of 121° C and a holding time of 20 minutes. Pasteurisation requires a temperature of 65° C for 10 minutes or 72° C for 2 minutes.	0.5–5 seconds	10–20 mins	15 min	2–4 mins
Sensitivity to turbidity	Low. Membranes remove turbidity.	None	Highest	High	Medium	High

End-of-pipe treatment is a more expensive than source reduction. The wastewater of food-processing plants have high organic strength (BOD). Treating this water is expensive. High BOD is frequently an indication of lost product. For an example, in a dairy plant (BOD_5 of milk is 104600 mg/L), it has been estimated that **1 kg of BOD is equivalent to 9 kg of milk lost**. Milk product losses typically range from 0.5% in large modern dairy plants to 2.5% in small plants [18]. Wastewater discharged best practice levels are 0.8–1.7 L/L of milk. One food processors adopted the slogan "Lets not wash our profits drown the drain".

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