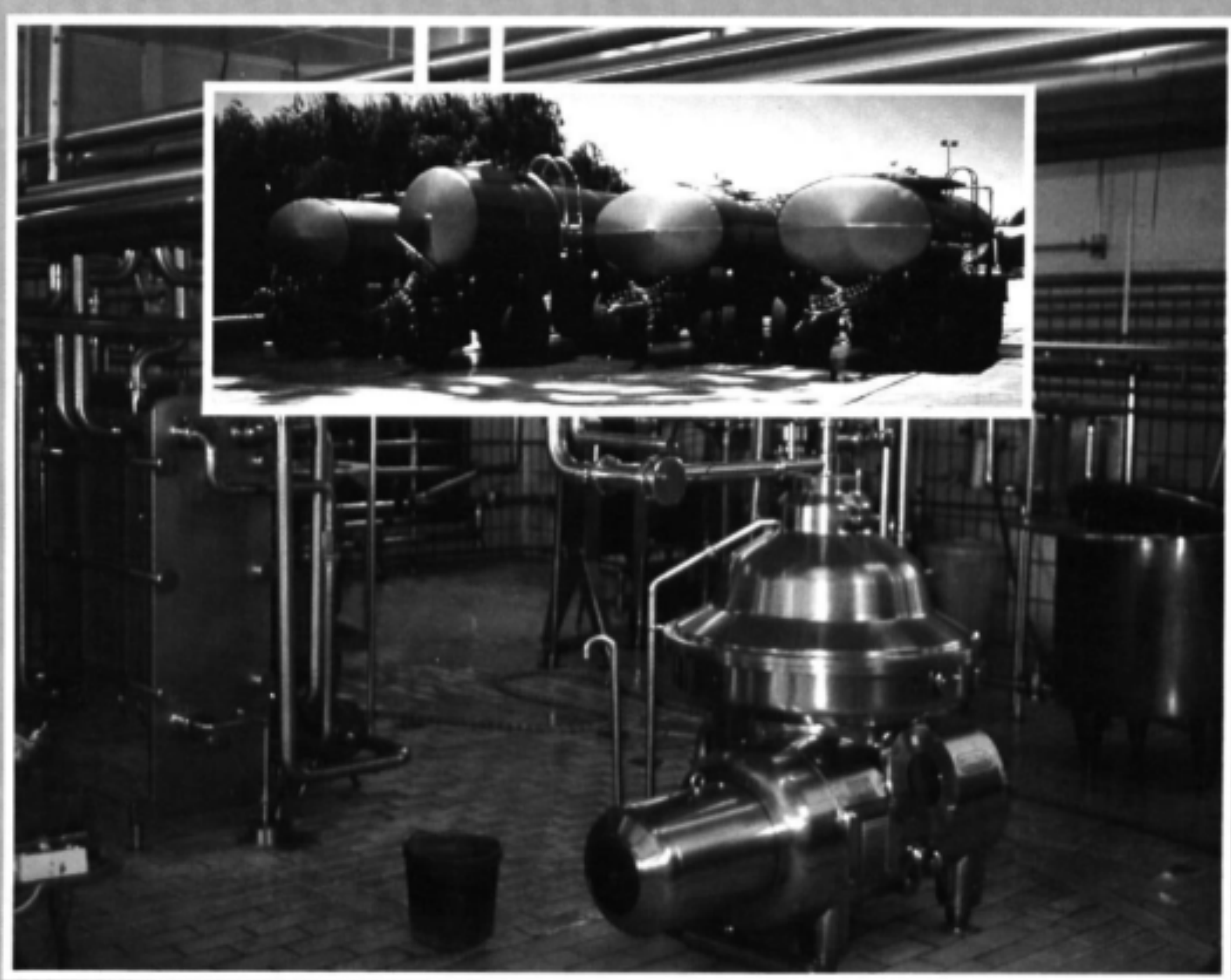
NATSURV 4

WATER AND WASTE-WATER MANAGEMENT IN THE DAIRY INDUSTRY



NATSURV 4

WATER AND WASTE-WATER MANAGEMENT

IN THE DAIRY INDUSTRY

Prepared for the
Water Research Commission

By

STEFFEN, ROBERTSON AND KIRSTEN INC
Consulting Engineers

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FOREWORD

The need for guidelines to reduce water intake and waste-water disposal by industry is in the national interest in view of South Africa's water scarcity.

To establish norms for water intake and waste-water disposal, the Water Research Commission (WRC) in collaboration with the Department of Water Affairs (DWA) contracted Binnie and Partners (now amalgamated with Steffen, Robertson and Kirsten), a firm of consulting engineers, to undertake a National Industrial Water and Waste-water Survey (NATSURV) of all classes of industry.

The consultants identified 75 industrial groupings in South Africa, one of which is the dairy industry. The results obtained in the survey of the dairy industry form the basis of this Guide on **Water and Waste-water Management in the Dairy Industry.**

It is hoped that this guide will be of value to the industry itself and to other interested parties such as municipalities, administrators, researchers and consultants in the water and effluent fields.

ACKNOWLEDGEMENTS

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SUMMARY

The dairy industry consumes approximately 4,5 million m^3 of water per annum in over 150 dairies in the RSA. The general heading of dairy industry actually accounts for a group of industries with a wide range of different products. Between 75% and 95% of the water intake is discharged as effluent.

Table 1 : Summary of specific water intakes and specific water usages

(All units vol/vol unless otherwise stated)

PRODUCT	SPECIFIC PARAMETERS	TARGET
Pasteurized milk - bulk production	1,6*	0,75*
Pasteurized milk packed in		
sachets	1,7*	1,1*
cartons	2,2*	1,5*
bottles	3,0*	2,0*
Other milk products (all carton or plastic tub packed)		
- cultured products	10,2	6,3
- fruit juices and mixes	2,7	1,7
- sterilized/UHT products	3,7	2,0
- skim milk	3,6*	2,1*
"Dry" milk products		
- milk powder	11,8 m^3/t*	8,7 m^3/t*
- cheese	23,0 m^3/t*	20,0 m^3/t*
- butter	1,5 m^3/t	1,3 m^3/t
- ice cream	2,5	1,9
- condensed milk	4,4 m^3/t*	3,5 m^3/t*

The figures marked * in Table 1 are for products produced from raw milk and include the water consumed in the reception stage. Those not marked * are for products produced from intermediate materials. The reception function has also been treated separately and a specific water usage of 0,6 has

been found for reception only. A target of 0,4 is proposed. The specific water usage for reception has been based on the volume of raw milk received.

The majority of water usage in the dairy industry is associated with the various cleaning processes. Two major sources of improvement in this area are the optimal design and operation of purpose-built vehicle washing facilities and improvement of water management and control in the bottle and crate washing facilities.

From a water usage point of view, it is recommended that the use of plastic sachets for the sale of milk be encouraged. With the mean specific water intake for sachet milk being considerably lower than that for bottled milk, a significant reduction in water consumption, effluent volume and load would occur.

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GLOSSARY

CULTURED PRODUCTS - Buttermilk, maas, yoghurt and drinking yoghurt.

CURING ROOMS - Temperature and humidity controlled rooms for the ageing of cheese.

DRY PRODUCTS - Cheese (except cottage cheese) and full cream, low fat or skim milk powder as well as whey powder, butter, ice-cream and condensed milk.

FRUIT JUICE MIXES - A mixture of fruit juice, skim milk and other additives.

GHEE - A butter oil made by boiling butter to remove the water fraction.

OTHER MILK PRODUCTS - A general term for the following dairy products - cultured products, fruit juice and sterilized/ultra high temperature products.

PASTEURIZED MILK - Milk free from harmful bacteria as sold to the general public.

RAW MILK - Milk as collected from the farm, prior to any form of treatment.

SPECIFIC POLLUTION LOAD - The mass of given pollutant for a particular period divided by the product volume/mass for the same period.

SPECIFIC WATER INTAKE - The total water intake for a particular period divided by the product volume or mass for the same period.

SPECIFIC WATER USAGE - The water usage for a particular period divided by the product volume or mass for the same period for a product produced from intermediate materials.

STERIMILK - Any plain or flavoured sterilized milk products sterilized in the final pack.

ULTRA-HIGH TEMPERATURE PRODUCTS - Any liquid milk products that have been treated by the ultra-high temperature process and packed aseptically.

WHEY - Liquid left once curd has coagulated in the cheese manufacturing process.

ABBREVIATIONS

BOD	-	Biological oxygen demand
CIP	-	Cleaning-in-place
COD	-	Chemical oxygen demand
EC	-	Electrical conductivity
OA	-	Oxygen absorbed (permanganate value)
PO_4	-	Phosphate
SS	-	Suspended solids
SPL	-	Specific pollution load
SWI	-	Specific water intake
SWU	-	Specific water usage
TDS	-	Total dissolved solids
TEL	-	Total effluent load
TEV	-	Total effluent volume
TKN	-	Total Kjeldahl nitrogen
TOC	-	Total organic carbon
UHT	-	Ultra-high temperature (processed)

1 INTRODUCTION

The dairy industry has an annual consumption of approximately 4,5 million m^3 of water (1986). In recent years milk consumption has been increasing by approximately 10% per annum, and is expected to continue at this rate for the foreseeable future.

At present there are in excess of 150 dairies in the RSA producing a wide range of products such as fresh milk, butter, cheese, yoghurt, milk powder, ice-cream, condensed milk and various milk-based desserts.

Whilst most of the major pasteurized milk factories are located near urban centres, most of the product factories are in the rural areas. There is also an extensive network of distribution centres throughout the country including doorstep delivery services in the major centres.

Dairies are responsible for discharging large quantities of effluent arising from either the process itself or cleaning processes, the ratio being dependent on the particular products made at the dairy. In the case of the pasteurized milk sector, the effluent discharge is often 85 to 90% of intake, for milk powder and condensed milk production this may rise to over 100%. For butter and cheese factories, effluent discharge varies from 90 to 95% of water intake. Whilst a number of constituents may be present, the major contaminants of interest from an effluent quality viewpoint are OA, COD, TDS and pH. Final effluent OAs of between 200 and 10 000 mg/l have been recorded.

The dairy industry in the Republic of South Africa is a significant one, both from a water intake and effluent discharge point of view. The information presented in this guide has been collected from dairies throughout South Africa, representing approximately 550 000 m^3 intake of raw milk per annum (1986). For the same year the total raw milk intake in South Africa was 1,04 million m^3.

For the purposes of this document, it was decided to concentrate on 10 dairies for pasteurized milk production and a further 9 to indicate the difference in the production of other dairy products.

2 PROCESS RÉSUMÉ

Introduction

Dairy processes are as diverse as dairy products. In this section an overview is given of the main processing stages involved in the production of common dairy products.

2.1 The major steps in the production of pasteurized milk:

a) Raw milk reception;
b) pasteurization;
c) standardization;
d) de-aeration;
e) homogenization;
f) cooling and packing.

Standardization may occur before, during or after pasteurization.

Pasteurized milk dairies usually also produce associated liquid milk products. Figure 1 shows the major process steps in the production of pasteurized full cream milk, pasteurized skim milk and cream.

2.1.1 Raw milk reception

This stage is common to all dairy processing regardless of what the final product is. For the purposes of this guide reception has been taken to include the stages of chilling and storage as well as vehicle washing CIP (inside tankers).

2.1.2 Pasteurization

This process involves heating the incoming raw milk to approximately 75°C and holding the temperature steady for a period of time. This results in the destruction of harmful bacteria which can often be found in raw milk. Due to the destruction of these bacteria the 'shelf-life' of pasteurized milk is increased beyond that of raw milk.

Fig 1

JOB No. 161480	PROCESS FLOW DIAGRAM FOR THE PRODUCTION OF PASTEURIZED FULL CREAM MILK, PASTEURIZED SKIM MILK AND CREAM	FIG Nº 1

2.1.3 Standardization

Raw milk as received from the farm contains varying quantities of solids and milk fat. In order to produce a standard product, the raw milk is fed to a centrifugal separator where any excess cream is separated for incorporating into other dairy products or for retail purposes. The amount of cream produced will vary with the fat content of the incoming milk, and on the fat content desired in the end product.

2.1.4 De-aeration

After pasteurization a de-aeration step is often included to expel unwanted gases and malodorous substances.

2.1.5 Homogenization

Homogenization is necessary to ensure that the milk has a uniform fat distribution. This is done by subjecting warm milk to intensive shear forces to break up the fat globules. This results in an even dispersion of fat in the milk and a more consistent appearance and taste.

2.1.6 Cooling and packing

Since pasteurized milk still contains a number of bacteria and enzymes, further biological reaction leads to milk 'going-off'. As with most common biological phenomena a reduction in temperature results in a reduction in reaction rate and hence a longer 'shelf-life'. Therefore pasteurized milk is cooled to approximately 4°C and stored or transported at this temperature.

Filling may occur in glass bottles, plastic bottles, waxed cardboard cartons or plastic sachets. The choice of package may significantly affect the ratio of water used to milk produced, as will be seen later.

2.2 The major steps in the production of powder products

The 'dry' products considered here are milk and whey powders. Butter, ice-cream, cheese and condensed milk are considered separately.

Whey powder is produced as a by-product of cheese manufacture and is used as a raw material in food manufacturing. Alternatively, whey is supplied to farmers for livestock feeding or disposed of as effluent. Typical steps in the production of milk and whey powders are shown in Figures 2 and 3.

2.2.1 Evaporation

This process entails the removal of approximately 87% of the water from the milk by boiling it off under vacuum in a multi-stage falling film evaporator.

2.2.2 Spray drying

The remaining water is removed by spray drying. This process takes place in three stages: a) dispersion of the concentrate into very fine droplets; b) mixing of the dispersion into a stream of hot air which quickly evaporates the water; c) separation of the dry milk particles from the drying air.

2.3 The major steps in the production of butter

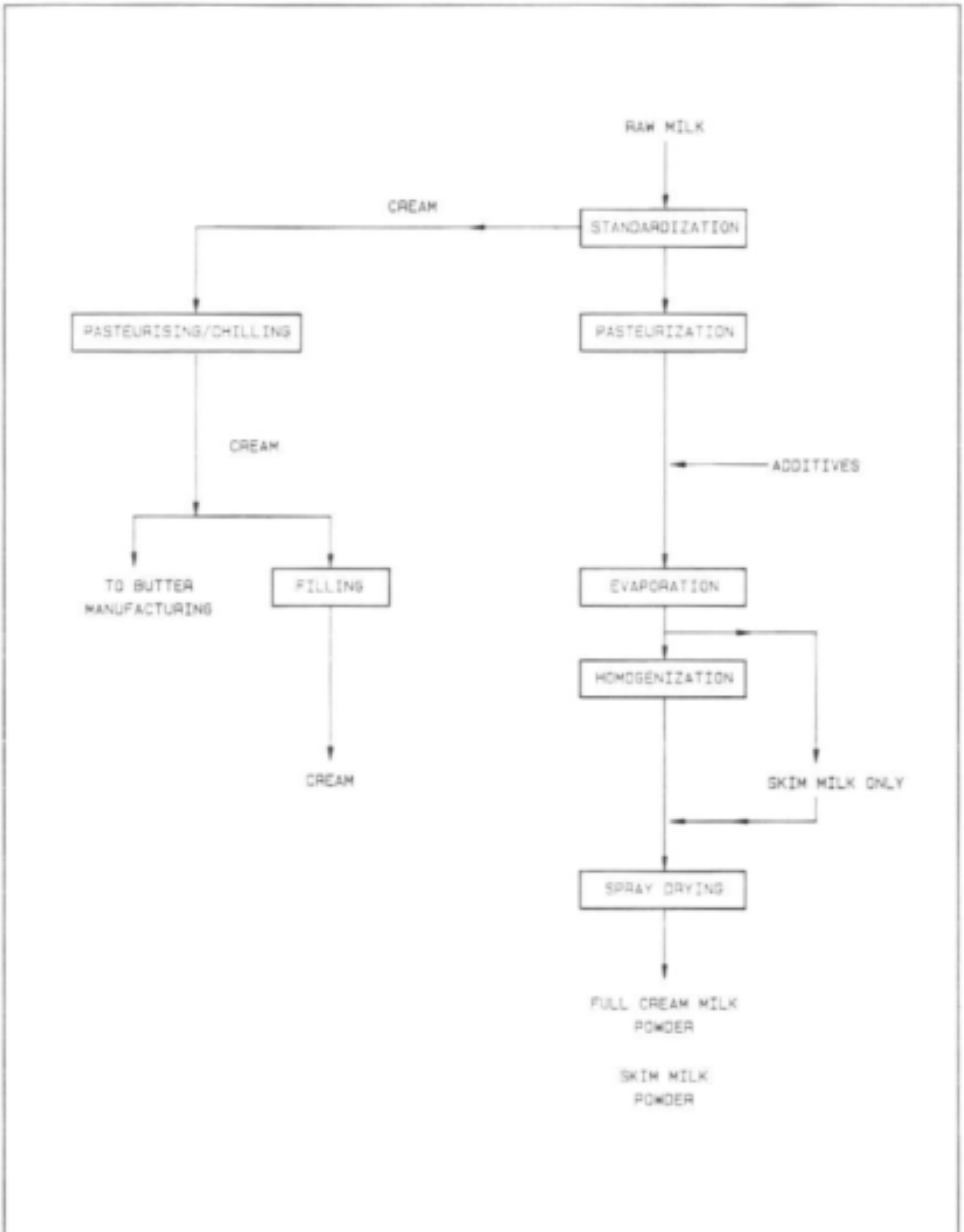
2.3.1 Raw materials

Butter manufacture does not use milk as a raw material. The major raw material for butter manufacture is cream which can either be obtained from other processes carried out on the same dairy site or can be tankered in from other dairies (see Figure 4).

2.3.2 Churning

In the production of butter, cream is mixed with salt and then passed to a continuous churn. Here the mechanical action causes the cream to separate into butter and buttermilk. The butter is extruded continuously while the buttermilk is drained to a receptacle. The butter is then packed and stored for distribution while the buttermilk may either be powdered, cooled and packed for sale or exceptionally, discharged as an effluent.

Fig 2



JOB No.		FIG Nº
161480	PROCESS FLOW DIAGRAM FOR THE PRODUCTION OF FULL CREAM AND SKIM MILK POWDER	2

Fig 3

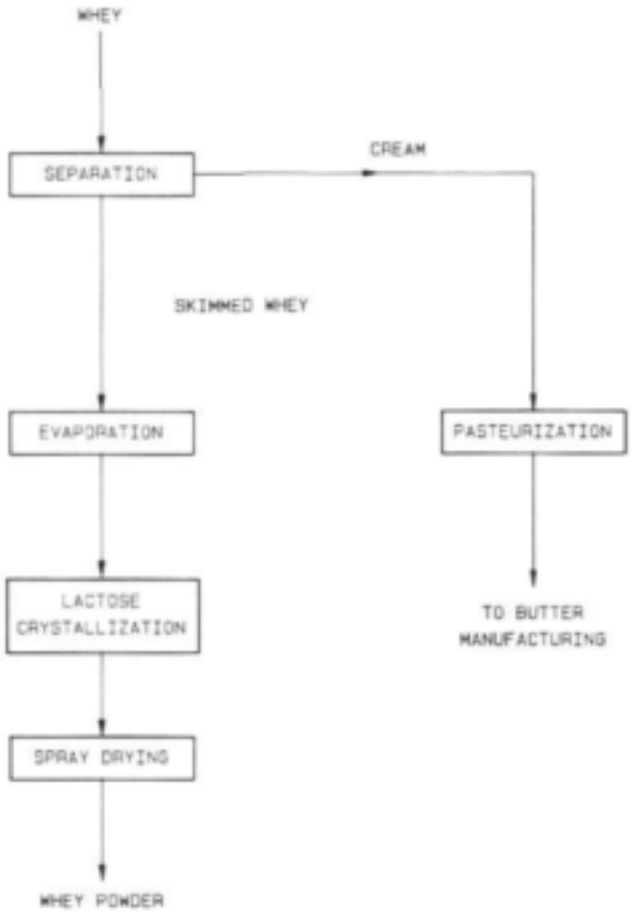


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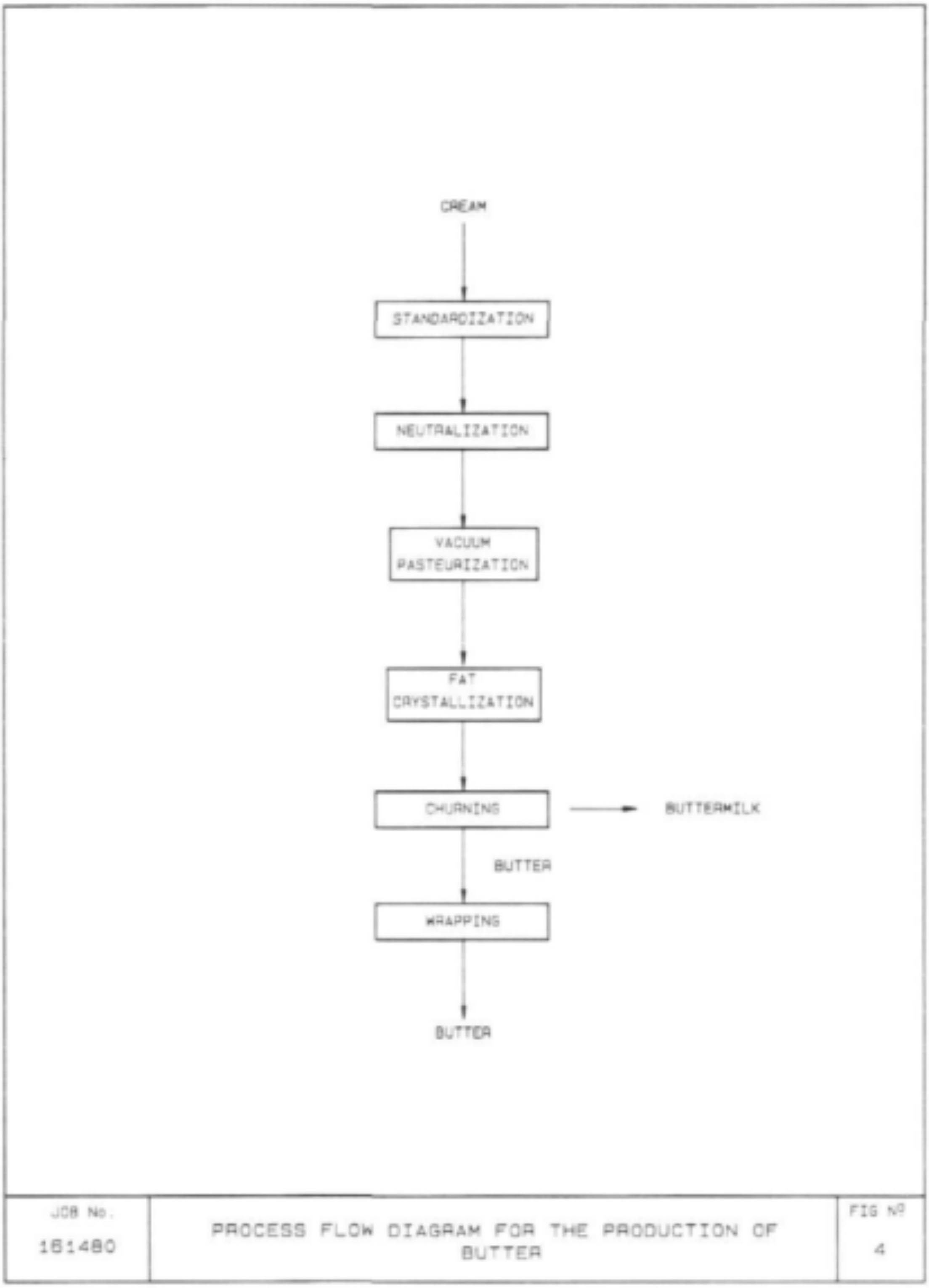
Fig 4


CREAM
STANDARDIZATION
NEUTRALIZATION
VACUUM PASTEURIZATION
FAT CRYSTALLIZATION
CHURNING
BUTTERMILK
BUTTER
WRAPPING
BUTTER
JOB No.
161480
PROCESS FLOW DIAGRAM FOR THE PRODUCTION OF BUTTER
FIG Nº
4

2.4 The major steps in the production of ice-cream

2.4.1 Raw materials

Ice-cream manufacturing also uses cream as a raw material but the major raw materials are butter and milk powder (see Figure 5).

2.4.2 Mixing/freezing (ice-cream)

Milk powder, cream, whey powder, butter and water are mixed. The mixture is then homogenized, pasteurized and transferred to a vat for ageing. Flavourings, colourings and fruit are added immediately prior to freezing.

This mixture is partially frozen in a continuous freezer, packed in plastic tubs, cardboard cartons or waxed boxes and passed through a further continuous freezer. During the primary freezing stage a certain amount of air is incorporated to produce the required texture.

2.5 The major steps in the production of cheese

Cheese manufacture involves a number of main steps which are common to all types of cheese. There are also treatments which are specific to certain varieties of cheese which will not be discussed in this guide.

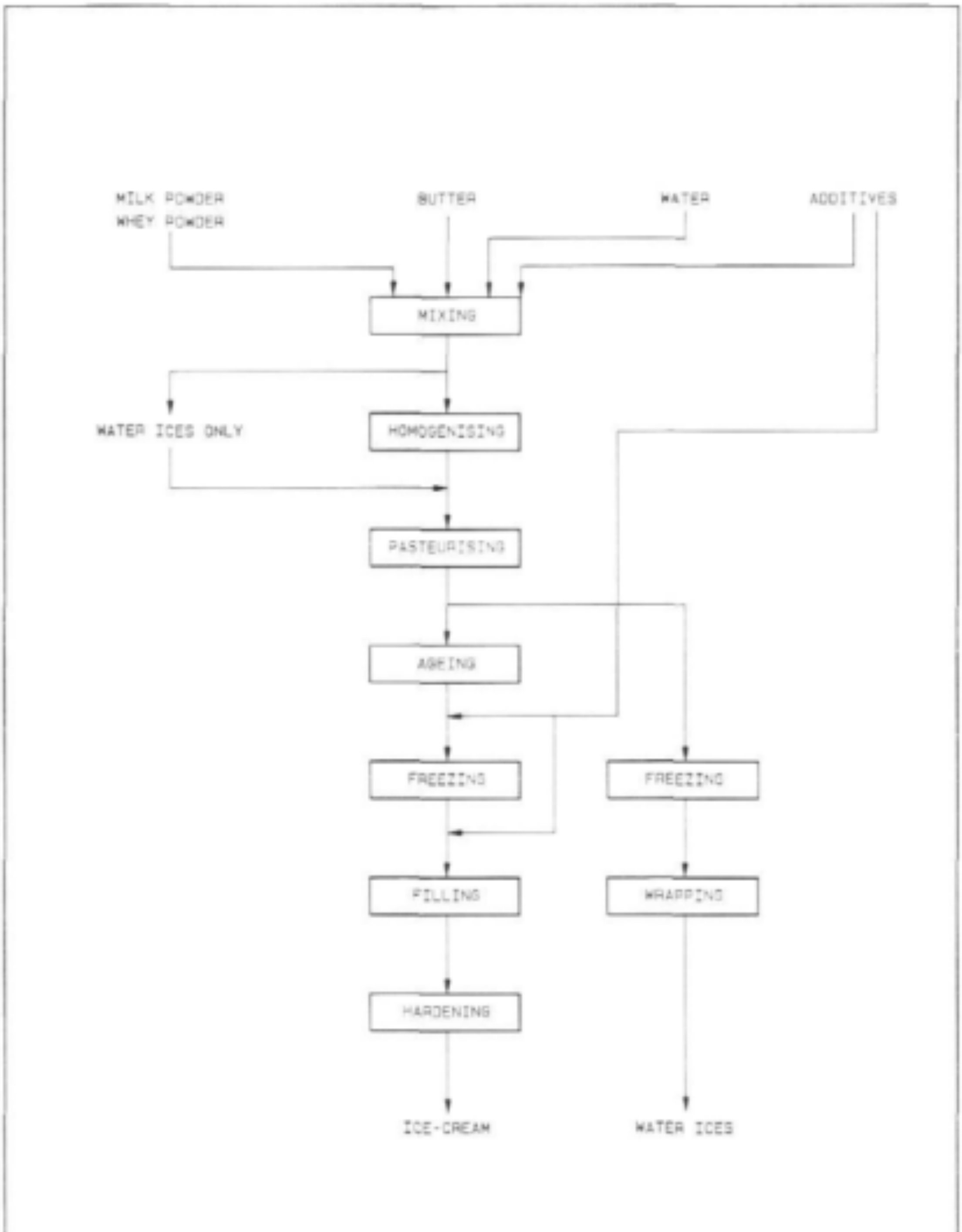
2.5.1 Curd manufacturing

Following standardization and pasteurization (as discussed in Sections 2.1.2 and 2.1.3) the milk is mixed with rennet and culture. The enzyme activity of the rennet causes the milk to coagulate to a solid gel, known as the coagulum. The curd is subjected to heat and mechanical treatment which results in the separation of whey from the curd grains.

2.5.2 Finishing

The finished curd is drained of whey, moulded, salted and pressed. The way in which this is done as well as additional processing steps which may be carried out, determine the final characteristics of the cheese.

Fig 5



JOB No. 161480	PROCESS FLOW DIAGRAM FOR THE PRODUCTION OF ICE-CREAM	FIG Nº 5

Finally cheeses are coated, wrapped or packed. Typical steps in the production of cheese are shown in Figure 6 which shows the main processes involved in producing cheddar and gouda cheeses - by far the most common types manufactured in RSA.

2.6 The major steps in the production of condensed milk

A distinction is drawn between unsweetened (evaporated) and sweetened condensed milk (see Figure 7). Unsweetened condensed milk is a sterilized product with the appearance of cream. Sweetened condensed milk is concentrated milk to which sugar has been added.

For both products the initial stages of production are similar. Firstly there is a precise standardization of the fat content and the dry solids content. This is followed by pasteurization and heat treatment, partly to destroy micro-organisms and also to stabilize the milk in order to avoid coagulation.

At this point the processes diverge considerably. For unsweetened condensed milk the heat-treated milk is concentrated in an evaporator and then homogenized before being cooled. The product is then packaged, sterilized and cooled for storage.

In the manufacture of sweetened condensed milk the heat-treated milk is concentrated in an evaporator. Sugar is added at the evaporation stage and after concentration the product is cooled in a way which allows the lactose to form very small crystals which are undetectable by the tongue. The product is then packaged and stored.

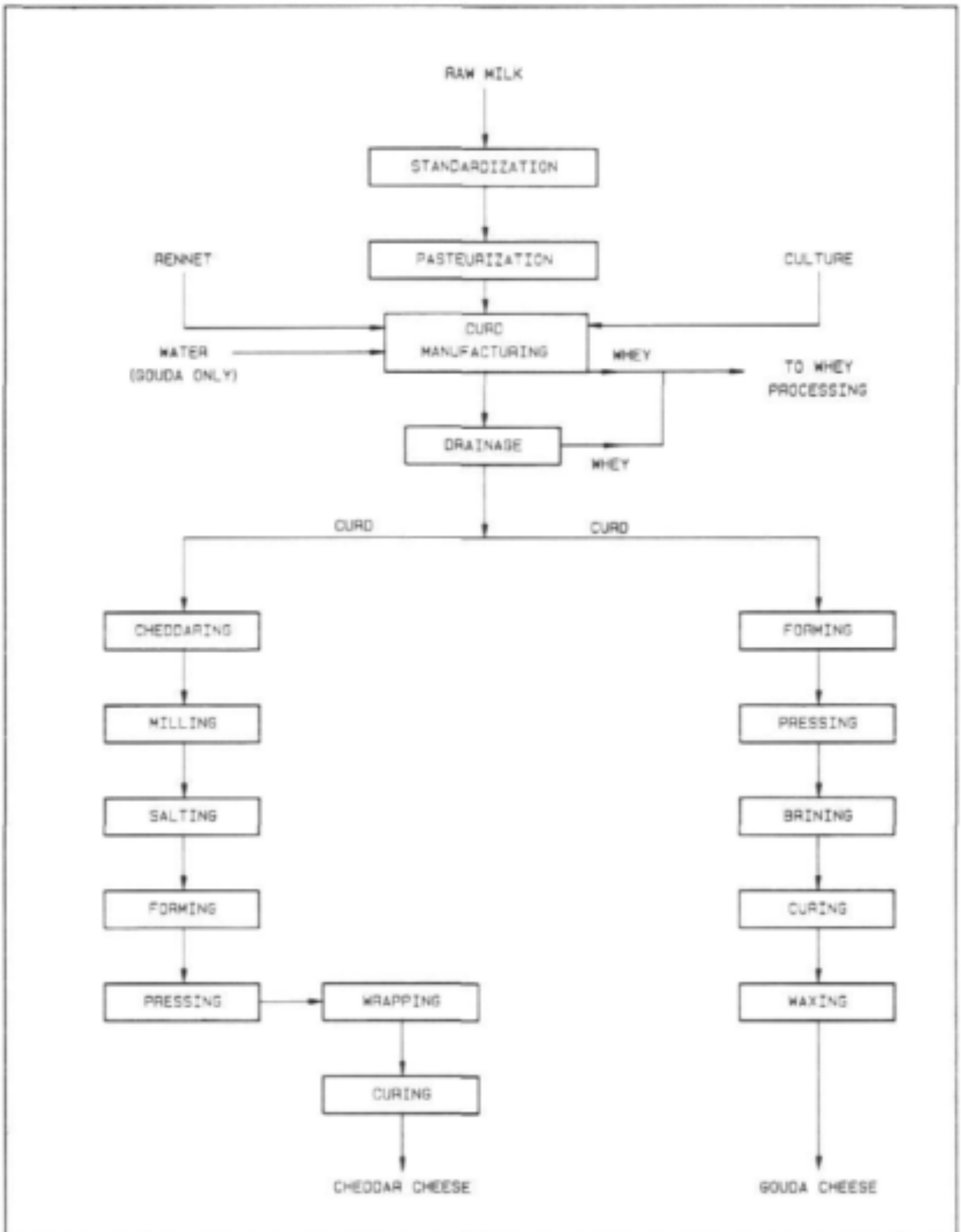
2.7 The major steps in the production of other milk products

The additional steps required for the production of other milk products apart from skim milk and condensed milk which are dealt with already and are shown in Figure 8. These will vary considerably from factory to factory.

2.7.1 Steeping

Steeping of non-dairy additives only applies to the production of cultured products.

Fig 6



JOB No.	PROCESS FLOW DIAGRAM FOR THE PRODUCTION OF CHEESE	FIG No
161480		6

Fig 7

JOB No. 161480	PROCESS FLOW DIAGRAM FOR THE PRODUCTION OF EVAPORATED MILK AND SWEETENED CONDENSED MILK	FIG Nº 7

Fig 8

JOB No.		FIG Nº
161480	PROCESS FLOW DIAGRAM FOR THE PRODUCTION OF DRINKING YOGHURT, STERIMILK, ULTRA HIGH TEMP. PRODUCTS AND DAIRY FRUIT JUICES	8

The fruit is often supplied in a dried form and in this case the dried fruit is steeped in hot water for a period of time to aid reconstitution. This is one area in which water is actually consumed in the process.

2.7.2 Mixing

All four types of other milk products discussed in the guide require a mixing stage where flavourings, preservatives, stabilizers, fruit juice, skim milk, fresh milk and cream are mixed in the appropriate quantities depending on the required product.

2.7.3 Pasteurization

A pasteurization process then takes place similar to that described in Section 2.1.2.

2.7.4 Incubation

This process which relates to the production of cultured products consists of the addition of starter culture and maintaining the product mix at a precise temperature for the desired period of time (the incubation period) to allow growth of the culture organisms.

2.7.5 Cooking

For the UHT process the temperature of some products is raised to up to 80°C (using indirect steam heating) in order to cook them.

2.7.6 Pre-sterilization

In the production of sterilized milk products, the product mix is heated to temperatures as high as 130°C. This is normally done by means of indirect steam heating.

2.7.7 Filling and sterilization

Flavoured sterimilk and plain sterimilk are filled in either plastic or glass. The plastic bottles used may be produced on-site in a dedicated plant. Any glass bottles used will have been washed thoroughly on-site in a dedicated bottle washer. Once filled the final product will be sterilized either in a batch or continuous sterilizer. Batch sterilizers are usually heated by means of a steam jacket with the condensate sometimes being discharged to drain.

2.7.8 Chilling

In the incubation process the culture growth stage is followed by a chilling step in order to stop the growth process.

2.7.9 Ultra-high temperature (UHT)

In the production of UHT products the product is sterilized in heat exchangers by raising the temperature to approximately 150°C for three seconds. This may be done either by means of live steam injection or indirect steam heating. In the case of live steam injection, the sterilization stage is followed by a vacuum distillation step to remove excess water. This method is gradually being replaced by the indirect steam method. The product is then rapidly cooled.

2.8 Process effluents

2.8.1 Milk powder effluents

In the evaporation stage of milk powder production the evaporate is condensed and may be collected. This condensate, depending on its condition, may be used without further treatment for boiler feed water.

2.8.2 Butter effluents

The main effluent in the production of butter is salted buttermilk. Buttermilk can also, in exceptional cases, be discharged as effluent.

2.8.3 Cheese effluents

The production of cheese results in two possible process effluents. The first is liquid whey which may be dried to produce whey powder. Alternatively this may be disposed of as effluent or may be incorporated into animal feedstuffs. For certain types of cheese a second effluent results due to washing of the product.

2.8.4 Effluents from associated processes

The vast majority of water consumption in any liquid product dairy is used in associated processes viz: bottle washing, crate washing, vehicle washing, floor washing and cleaning-in-place of factories and vehicles.

2.8.4.1 Cleaning-in-place

Due to the biodegradable nature of milk and milk products, combined with their tendency to cause fouling of process equipment, regular cleaning of the plant is necessary. This is done without dismantling any equipment and is known as cleaning-in-place. Most CIP systems involve three major steps:

(a) a hot or cold pre-rinse to dislodge any loosely held solids and to flush out any remnants of raw materials or products;

(b) a hot caustic wash to clean the equipment;

(c) a cold final rinse to ensure the removal of all traces of caustic in the system.

With the exception of rinse (a) which is discarded as effluent, the rinses are usually reused. The caustic rinse (b) is returned to its holding tanks and the final rinse (c) should be used as the first rinse (a) on the next cycle. This is sometimes not done and can be a source of water wastage.

2.8.4.2 Bottle and crate washing

Bottle washing can often form a major part of the production process particularly in the smaller dairies concentrating on the production of pasteurized milk. Bottle washers often have:

(i) a cold pre-rinse, the effluent going to drain;

(ii) a hot rinse/wash containing a certain amount of caustic and detergent, all of which is recycled until the solution must be discharged to drain for quality reasons;

(iii) a cold final rinse, the effluent forming the pre-rinse of the next cycle;

Crate washing is more widespread than bottle washing and is similar in nature except that the final rinse is done with hot water.

2.8.4.3 Carton filling

Carton filling machines are invariably supplied with iced water for spraying onto the seal immediately after sealing has occurred. This flow of up to 5 m^3/h often runs whether or not cartons are being sealed and can be a major source of water wastage.

2.8.4.4 Vehicle washing

For primarily aesthetic reasons the outside of all dairy vehicles are washed daily. Sometimes this occurs in specially designed wash-bays but in the majority of cases a hand-held hose is used. This is an area of water usage in the dairy industry where significant wastage occurs.

Washing of the insides of tankers occurs after every delivery. This is obviously very important for hygiene reasons but also wasteful of water when it is carried out using hand-held hoses. CIP cleaning of tankers is more efficient.

3 SUMMARY OF SURVEY RESULTS

3.1 Water intake

The results in this section are summarized in tabular form.

Table 2 shows the water intake based on raw milk processed at 19 dairies in South Africa.

Table 2 : Water intake : Raw milk ratios for dairies in South Africa

Production category milk processed (m^3/month)	Mean water intake/ raw milk intake
1 500 or less	4,6
1 500 - 4000	3,9
more than 4000	2,6

From these 19 dairies the maximum water intake : raw milk ratio was 9,5 and the minimum was 1,4 which is a considerable variation. Some of this can be explained by the fact that different products are produced by many of the dairies. However, it is also an indication of fundamental differences in water management practices.

Table 3 shows product based water usage for fresh milk dairies.

Table 3 : Product based water usage for pasteurized milk dairies

Production category pasteurized milk produced (m^3/month)	SWI (product based)
1 000 or less	3,25
1 000 - 2000	0,98
more than 3000	1,04

Points to note in relation to this table are:

(a) the maximum SWI found was 5,5 and the minimum 0,75;

(b) water usages presented are for milk production until the end of processing including reception and vehicle washing but not including packaging;

(c) the volume produced is not necessarily sold, as part of it may be utilized as a raw material for further processes;

(d) there is a clear difference in the efficiency of small dairies (i.e. producing 1 000 m^3/month or less of pasteurized milk compared with larger dairies producing more than 1 000 m^3/month).

Table 4 illustrates the effect that different packaging processes can have on overall specific water intake. It is clear that packing milk in plastic sachets uses less water than that in waxed cartons, with bottled milk using the most water. Inefficient bottle washer operation can easily double the specific water intake for bottled, pasteurized fresh milk production.

Table 4 : Specific water intake for milk in different packages

	Unpackaged	Bottled	Sacheted	Cartoned
Mean	1,6	3,0	1,7	2,2
Max.	5,5	5,4	3,2	2,6
Min.	0,75	2,0	1,1	1,5

(Produced from raw milk; reception stage included)

Table 5 : Specific water usages for various dairy products

	Cultured products	Fruit juices and mixes	Sterilized/UHT products	Butter (m^3/t)	Ice-cream (m^3/t)
Mean	10,2	2,7	3,7	1,5	2,5
Max.	13,8	5,5	6,2	6,9	3,1
Min.	6,3	0,75	2,0	1,3	1,9

Table 6 : Specific water intake for various dairy products

	Skim milk (m^3/t)	Milk powder (m^3/t)	Cheese (m^3/t)	Condensed milk
Mean	3,6	11,8	23,0	4,4
Max.	5,0	16,6	29,0	5,3
Min.	2,1	8,7	16,4	3,5

Table 5 shows SWU figures for various milk products produced from raw materials other than milk. Table 6 shows SWI figures for various milk products produced from raw milk as a raw material. The figures in Table 6 include water utilized in the reception stage.

It is important to remember when considering these figures that in the case of cheese and milk powder manufacture particularly, large volumes of milk have to be processed to produce a relatively small mass of final product. Hence the SWI is large for these products when compared to other dairy products.

To illustrate the way in which figures from Tables 4, 5 and 6 can be used, a hypothetical example is given below:

A factory producing:

(a) 3 000 m^3/month of pasteurized milk of which 2 000 m^3/month is bottled and 1 000 m^3 is packaged in cartons;

(b) 35 m^3/month of ice-cream (made from raw materials produced in another dairy);

would have a theoretical water intake of (taking the mean figure in each case):

3,0 x 2 000 + 2,2 x 1 000 + 2,5 x 35
= 8 287,5 m^3/month water intake.

Table 7 shows the SWU for various processes associated with dairy operations. The variation in vehicle washing SWU is particularly great and is discussed later. The vehicle washing referred to is concerned with the washing of raw milk tankers (inside and outside) and distribution vehicles. Milk floats/doorstep delivery vehicles are not included.

Table 7 : Specific water usages for associated processes

Bottle washing (ℓ/bottle)	Crate washing (ℓ/crate)	Vehicle washing (ℓ/vehicle)
1,05	1,12	146
4,42	0,52	135
1,70	0,60	-
-	-	79
-	-	550
1,28	0,97	-
1,05	1,08	-
1,86	1,18	39
0,82	2,89	-

3.2 Effluent

In view of the wide variety of processes involved in the dairy industry, it is difficult to generalize about dairy effluents. However, typical final effluent pollution loads from dairies are presented in Table 8.

Table 8 : Typical total effluent loads for dairies in South Africa

Type of dairy	Total effluent volume m^3/month	COD (total) kg/month	TDS kg/month	TKN (soluble) kg/month
Past. milk	2 200	5 600	4 000	39,4
Fruit juice/ milk	4 700	7 000	5 200	47,0
Milk/misc.	12 000	33 000	18 000	96,0
Butter	1 000	4 000	2 000	20,0
Cheese	800	2 400	2 400	20,0

Effluent leaving the dairy could vary between 60% and greater than 100% of the raw water intake. For most dairies this lies in the range 60 to 90% but in the case of dairies producing milk powder, milk concentrate or condensed milk this may rise to greater than 100% due to the recovery of condensate from within the raw material.

Dairy effluent quality can vary enormously from one hour to the next, especially where the production of a variety of products is involved. Great care should therefore be taken with sampling procedures, especially where their analyses form the basis of effluent treatment processes or municipal effluent charges. At one dairy surveyed, effluent quality varied sufficiently over a two hour period to result in a potential variation in effluent tariff charge of 100 times.

3.3 Breakdown of effluent sources

Due to the nature of the dairy industry, breaking down the pollution load on an individual process step basis is extremely difficult and generally uninformative. Instead consideration of sources of effluent better indicates where most improvements can be made. With the exception of blowdown from boilers, cooling towers and evaporative condensers (allied to refrigeration systems) the majority of effluents arise from six main areas:

(i) wastage of milk and milk products;

(ii) plant CIP;

(iii) crate and bottle washing;

(iv) vehicle washing CIP;

(v) cheese washing and whey production; and

(vi) product dumping.

3.3.1 Wastage of milk and milk products

Any wastage of milk and milk products results in an increase in strength of the effluent discharged by a dairy plant. Consequently this results in higher effluent disposal costs whether discharged to sewer or treated on site. In addition, the milk and milk products themselves usually have some value which is also lost if they are discharged as effluent.

It is clear that wastage of milk and milk products in a dairy is a serious economic problem and also contributes greatly to pollution loads discharged by dairies as can be seen from the table below :-

Table 9 : Examples of chemical oxygen demand values for various dairy products compared with domestic sewage[1]

Product	COD (mg/ℓ)
Whole milk	210 000
Skimmed milk	100 000
Cream (30% fat)	860 000
Buttermilk	110 000
Whey	75 000
Domestic sewage	500

3.3.2 Cleaning-in-place

Up to 65% of water intake is used in plant and vehicle CIP. All this water leaves the dairy industry as effluent. In the dairy industry where only fresh milk is produced, a single CIP cycle per day may be used. Depending on the age and size of the factory the final rinse of this cycle may either be recycled to the first rinse of the next cycle or discharged. Effluents from CIP cleaning are often high in COD, PO_4 and TKN with concentrations of up to 2 000, 5,0 and 25 mg/l respectively having been found.

In dairies where a mixture of liquid dairy products are made the overall consumption of water by CIP process can be much larger. Most associated processes are carried out on a batch-continuous basis. This means that each product is produced on a batch basis though whilst a specific product is being manufactured all processing is continuous. All equipment is cleaned between each batch giving rise to a marked increase in water used for CIP purposes.

3.3.3 Bottle and crate washing

Bottle and crate washing are very similar in nature and can use as much water as the bulk pasteurization/homogenization process. Effluents from this source vary greatly in COD with concentrations of between 20 mg/l and 30 000 mg/l having been found. The majority of bottle washing effluents have COD concentrations in the range 100 to 400 mg/1.

3.3.4 Vehicle washing

Vehicle washing uses varying quantities of water of widely differing qualities. All water used for this purpose is ultimately discharged as effluent. The quality of the influent water differs to such an extent that comparisons of the effluent quality for vehicle washing from one factory to another is meaningless.

3.3.5 Cheese washing and whey production

When dairies produce cheese two further effluents occur. The first is whey. Some of this whey may be dried to form whey powder, a raw material used in various food products. A limited quantity may be used by farmers for incorporation into cattle or pig feed. This use is, however, very limited due to the low nutritional value of whey and its high lactose content.

The second additional effluent is from cheese washing. This liquid has no food value and must be discharged as effluent. The washing process is always undertaken batchwise and may comprise 2 to 4 complete washings.

3.4 Effluent parameter ratios

A number of effluent parameter ratios were calculated with a view to examining their consistency. In particular the ratios TDS : EC, COD : TOC and COD : OA were examined closely. The results can be seen in Table 10.

Table 10 : Effluent parameter ratios

Dairy	TDS/EC	COD/TOC	COD/OA
A	1,25	5,44	11,6
B	1,16	5,39	8,6
C	1,09	7,75	10,8
D	2,15	3,77	-
E	1,35	4,76	12,0
F	0,67	3,47	13,3
G	0,40	-	9,1
H	1,90	7,20	13,4
I	0,57	3,02	9,8
J	0,53	4,51	-
K	2,17	2,85	6,7
L	0.70	-	-
M	0,16	5,34	11,9
N	2,56	5,04	-
O	0,84	5,30	-
P	0,65	-	15,5
Q	0,65	-	-
Mean	1,11	4,91	11,15
Std deviation	0,70	1,46	2,50

It is interesting to consider also the ratios reported in IDF Bulletin, Document 138 (1981). Unfortunately only COD : BOD(1,16 - 1,57) and TOC : BOD(0,3 - 0,9) are reported which prevents direct comparison with the ratios reported in Table 10. However, the general conclusions drawn from this report are also applicable to the ratios reported in Table 10. These can be summarized as:

(a) A fairly constant effluent parameter ratio can be established in cases where the composition of effluent is fairly uniform e.g. in samples taken in the same plant with a constant or only slightly varying production programme.

(b) An effluent parameter ratio established in one dairy plant cannot be transferred with sufficient reliability to another plant.

3.5 Solid waste

Solid waste in the dairy industry is primarily restricted to coal ash from boilers, paper and cardboard wastes from the packaging process and fats from traps. These wastes are normally disposed of by the local municipality at a waste disposal site.

4 CONCLUSIONS AND RECOMMENDATIONS

4.1 Water intake

Dairies in the RSA have a mean water intake : raw milk ratio of 4,6 for dairies processing 1 500 m^3/month raw milk or less, 3,9 for dairies processing 1 500 - 4 000 m^3/month and 2,6 for dairies processing more than 4 000 m^3/month. It is clear from these figures that larger dairies are in general more efficient in their water management than smaller ones. The overall range for the same ratio for all dairies was 1,4 to 9,5 and the overall mean was 3,6. It is worthy of note that the largest ratio of 9,5 was recorded at a relatively large dairy processing over 3 000 m^3/month of raw milk indicating that it is not only the smaller dairies who need to review their water management practices.

For dairies producing pasteurized milk there was also a large difference in SWI between dairies producing 1 000 m^3/month or less and those producing more than this. Again this is largely due to the fact that larger dairies are in general more efficient than smaller ones. Also most of the larger dairies in this category only produce pasteurized milk. Dairies producing a mixture of products tend to require greater water consumption for cleaning.

For packaged milk the mean SWI was found to be 3,0 for bottled milk, 2,2 for cartoned milk and 1,7 for sacheted milk. Comparison with figures quoted by Funke (1970) who reported an SWI range of 1,8 to 10,2 with a mean of 4,9 for packaged milk shows that the dairy industry has made considerable progress in water management. An important factor is the increase in the use of non-returnable packaging i.e. cartons and sachets, which as the SWI shows requires considerably less water than bottles. At the time of the work done by Funke most fresh milk produced was packaged in bottles. Also there have been improvements in technology with respect to bottle washing compared with that available in 1970.

Reception, which for the purposes of this document includes chilling, storage and vehicle washing (inside tankers) was found to have a mean SWU of 0,6.

Wide variations in specific parameters were found for other milk products and dry milk products as can be seen in Tables 5 and 6. The mean value for cultured products was 10,2 for fruit juices and mixes 2,7, for sterilized/UHT products 3,7 and for skim milk 3,6. In the dry milk products category the mean figures were 11,8 for milk powder, 23,0 for cheese, 1,5 for butter, 2,5 for ice-cream and 4,4 for condensed milk.

The wide range of specific parameters encountered is not surprising due to the diversity of the products manufactured. Even within each product category there are so many different types and methods of manufacture that to discuss them in detail would be beyond the scope of this document. Cheese manufacture for example differs enormously depending on the quality of the raw milk used and the type of cheese finally required. The figures quoted for these categories should therefore only be taken as general guidelines for the industry.

From the results obtained during the course of this survey target SWIs for the dairy industry to aim at achieving are proposed below in Table 11.

Table 11 : Proposed specific water intake targets for the dairy industry

Product	Targets
Pasteurized milk - bulk production	0,75
Pasteurized milk packed in sachets	1,1
cartons	1,5
bottles	2,0
Cultured products	6,3
Fruit juices and mixes	1,7
Sterilized/UHT products	2,0
Skim milk	2,1
Milk powder	8,7 m^3/t
Cheese	20 m^3/t
Butter	1,3 m^3/t
Ice-cream	1,9
Condensed milk	3,5 m^3/t

4.2 Potential methods of reducing water intake [1] [2]

The following steps may be taken to reduce water intake in dairies:

(a) Minimizing water usage through optimal overall pasteurizer-separator- homogenizer configuration and design. A number of dairies waste both energy and water through individual heating and cooling of the above-mentioned three steps.

(b) The use of a hot water/indirect steam heater for the pasteurizer. The use of hot water to heat the milk in the pasteurizer results in better temperature control. Using a hot water/steam heater attached to the pasteurizer results in optimal steam usage and assuming that the condensate is returned to the boiler, minimum water consumption.

(c) Elimination of a separate heating circuit for the separator is possible and has no detrimental effects on the final product.

(d) Modern homogenization systems require no additional heat supply therefore requiring less steam production.

(e) Water consumption in packaging may be reduced by a number of methods including:

  (i) use of secondary water for crate washing;

  (ii) prevention of electrostatic charge build-up on crates; and

  (iii) prevention of excessive use of chilled water for sealing during process stoppages - auto cut-off.

(f) The major area where a reduction in water consumption is possible is in the CIP systems. Adopting the latest computerized control systems for CIP results in a major water saving. The use of final rinse water should be maximized by using it as a first rinse. Rinse times should be minimized.

(g) Vehicle washing is one area of consumption where every dairy can make an improvement. Purpose designed vehicle wash-bays should be constructed and used. High pressure cleaning hoses should be provided and automatic cut-off valves must be fitted to all hoses used for vehicle washing. The use of spent water for vehicle washing (external) should be considered. Possible sources are:

(i) condensates unfit for return to boilers;

(ii) blowdowns from boilers and/or cooling towers;

(iii) condensate from milk powder evaporate;

(iv) bottle washing effluents; and

(v) carton and sachet sealant effluents.

(h) Incoming water meters should be checked regularly and water balances carried out periodically to detect any faulty water meters and possible leaks.

(i) Mixed compressed air and water hoses could be used for factory and vehicle cleaning.

(j) Pressure regulators should be installed on main water intake lines as increases in mains pressure can cause ball valve leaks.

(k) For the UHT process better control of temperatures and improved recovery of heat from the product would reduce the requirement for cooling waters. In view of the fact that it is not always necessary to cool the final product to room temperature quickly the cooling water circuit may be eliminated. This should be combined with optimization of heat recovery.

(l) In the production of miscellaneous sterilized products the use of indirect steam heating should be encouraged as improved condensate return would result.

(m) As far as plain and flavoured sterimilk production is concerned the use of plastic as a packaging material should be encouraged as it makes possible the elimination of the requirement for a bottle washer.

(n) Carton sealant cooling effluents can be recycled. With the introduction of accurate conductivity-based control systems the potential for clogging spray jets or cross contamination of products would be considerably reduced. At the dairies surveyed water consumption rates of up to 600 l/h were observed for coolant consumption at each packing machine. With up to 9 packing machines running for 8 to 16 hours per day recycling could result in a reduction in intake of 40 to 80 m^3/d at some dairies.

(o) When milk powder is being produced multi-stage evaporators can be used and depending on the degree of control exercised over the evaporator, the resulting condensate can be used for boiler feed purposes or for vehicle washing. Conductivity-based control can effectively be used to protect boilers from product carry-over and under any other conditions the condensate is an ideal quality for boiler feed. In one dairy surveyed the first stage condensate fed the boiler and the third stage condensate fed vehicle washing whilst conductivity control determined the use which the second stage condensate could be put to.

(p) In cheese production correct determination and control of washwater quantities results in minimum water consumption for this operation.

(q) Good water management practices could include regular visual inspection of water-related equipment, incentives for maintenance of good housekeeping practices, regular night-watch inspections of factory water meters, and investigation of the feasibility of floor washing with buckets and mops or mobile washing units rather than with hosepipes.

4.3 Effluent production

Very few dairies in the RSA produce only pasteurized milk. The vast majority of pasteurized milk dairies produce a variety of other milk products including UHT products, sterimilk products, yoghurt, soft cheese and flavoured milk drinks. In the majority of dairies surveyed no provision was made for the sampling of effluents from individual sections of the factory. A comparison of SPLs from the dairies is therefore meaningless.

Final effluent loads and volumes are presented in Table 8 for various types of dairies according to product. The figures given are for typical dairies and therefore large deviations from these values can be expected, especially in the case of fruit juice/milk and cheese producing dairies.

A large difference in total effluent volume between milk/miscellaneous products and cheese dairies is immediately apparent. The milk/miscellaneous dairies are normally found around large urban centres and consequently the discharge of these effluent volumes (12 000 m^3/month) to municipal sewers does not represent a major environmental hazard. Cheese producing dairies are usually located in rural areas and as such, the discharge of their relatively small effluent volumes (800 m^3/month) may cause serious environmental problems.

The pollution load figures also vary widely, both with the dairy size and type. Again, where the effluent is discharged to a large municipal sewage works this poses little problem, but where this is discharged to the environment via irrigation or a small sewage works, serious environmental problems may result. Thus the monthly pollution load of 33 000 kg COD at milk/miscellaneous dairies is potentially less problematic than the 2 400 kg COD from cheese producing dairies.

Much of the effluent produced at a dairy consists of spillages or CIP effluents which may carry considerable off-specification product or residues. One thing which many of these contributory sources have in common is relatively high TKN and calcium levels. The TKN concentrations recorded ranged from 0 mg/l to 23 mg/l with a mean value of 9,5 mg/l. For dairies the presence of TKN in the effluent should be used to indicate the presence of product in the effluent. Particularly high levels could indicate continuous loss of product. The corresponding range of calcium concentrations is 6 mg/l to 57 mg/l. Again, high levels may indicate the continuous loss of product.

4.4 Phosphate levels in dairy effluent

Phosphate levels in dairy effluents are sufficient to pose a potential pollution hazard through resultant eutrophication. Levels recorded in final effluents sampled during the course of the survey range from 1,6 mg/l to 35,4 mg/l with a mean of 12,6 mg/l. The major sources of phosphate are the cleaners used in dairies (in conjunction with the CIP cycles). However high concentrations of acidic whey, produced as a waste material from cottage cheese manufacture or cheese manufacture also result in high phosphate concentrations.

4.5 Potential methods of effluent volume and load reduction [1][2]

A reduction in effluent volumes and loads may be achieved by:

(a) Improved usage of condensate through recycling. Care must be taken to ensure that returned condensate does not lead to increased scale-up of boilers. Technology does exist to protect against such an eventuality.

(b) For instances when condensate cannot be returned to the steam cycle, various uses exist for the 'second quality' water including external vehicle washing, crate washing, floor washing and often garden watering.

(c) The increased recycle of CIP first rinse waters.

(d) Improved plant design with the objective of reducing CIP effluent quantity and significant cost savings.

(e) Improved management of bottle and crate washing processes and optimal design and operation of both bottle and crate washers which may lead to a significant reduction in effluent loads. Based on the SWUs for bottle washing encountered during the course of this survey this reduction may be up to 2 l/l of milk bottled.

(f) Regular maintenance of fittings, valves, cocks and seals to ensure that no milk or milk products are leaking.

(g) Keeping spillages of milk or milk products to a minimum. For example, use of level regulators when filling vessels.

(h) Never filling vessels to such a level that product overflows during agitation.

(i) Vessels should be well designed with rounded corners, be well sealed and be easy to empty and rinse.

(j) Transport tankers should be allowed adequate time to drain. The quantity of milk adhering after 10 seconds drainage in tankers is reported as being equivalent to 1-2 l of milk.

(k) Maintaining packaging machines in good condition to avoid jams and product spillage.

(l) Equipping fillers with drip and spill savers.

(m) Ensuring that a minimum of butter is left adhering to the insides of process pipelines. This can be done by inserting a plug of butter, hardened by refrigeration but not frozen, into the pipeline to be cleaned and driving the butter plug through the pipeline with compressed air so that the butter inside is thoroughly stripped out.

(n) Minimizing the discharge of cheese brine to the sewer. It can contribute a COD of 30 000 mg/l and a chloride content of 20 000 mg/l to the effluent and 70 kg of brine could be expected to be discharged for every 1 000 kg of Gouda cheese. Cheese brine should therefore be diluted with other effluents and only discharged if no other disposed options are viable.

(o) Sugar spillage should be avoided. One kg of sugar (sucrose) has a COD of 1.1 kg.

(p) Avoiding discharge of bottle labels and glue to the sewer. Glues can have a COD of up to 725 g/kg product.

(q) Regular cleaning of fat traps (see Funke [2] for design and operability).

(r) Air or water flushing of pipelines and tankers to remove milk solids and recover them into product.

Special reference is made here to two very useful IDF publications - Document 124 entitled "Guide for Dairy Managers on Wastage Prevention in Dairy Plants" (1980) and Document 184 which contains the proceedings of the IDF seminar on dairy effluents, 1984. These can be obtained from The Secretary, SA National Committee of IDF, SA Dairy Foundation, PO Box 72300, Lynwood Ridge, 0011 (Mr Kritzinger).

For information on anaerobic digestion of deproteinated cheese whey, the reader is referred to the work of De Haast, Britz et al, Department of Dairy Science and Microbiology, University of the Orange Free State.

4.6 **Effluent treatment**

Dairy effluents are usually high in organics, phosphates, TKN and suspended solids. They are also highly biodegradable. Due to the nature of the effluent particles they are particularly difficult to precipitate with normal precipitating agents. Preliminary work using complex polymeric coagulants is encouraging but much further work is necessary before this form of treatment is recommended. The second stage of this process would be the flocculation/flotation of the solids and their removal in a fat trap. The resulting effluent would be more amenable to irrigation or evaporation in those places where the effluent cannot be discharged to the sewer.

All factories in the dairy industry should be provided with a correctly designed scum/fat trap. Fat traps prior to discharge to sewer should be utilized, both as a method of ensuring lower effluent charges and as a precaution against sewer blockage from the coagulation of discharged fats.

Screens should be installed to prevent the blockage of both on and off-site drains by solids such as bottle tops, labels and substandard cartons. It is recommended that solids traps be installed at all floor drain points rather than at the final outlet, thus providing a much greater degree of protection of on-site drains.

Most large dairies are sited in areas where adequate sewer connections to correctly designed and operated sewage works are available. In these cases the dairies should be encouraged to discharge their effluents to the municipal sewer, bearing in mind the cost implications which should be regularly re-evaluated in the light of both increasing municipal tariffs and improving technology.

In some areas however, either no sewer connection is available or the sewage works it is connected to has not been designed to accept dairy wastes (e.g. oxidation ponds in many rural areas). In these cases it is essential that suitable effluent treatment processes are installed and operated by the dairy. Both activated sludge and biofilter systems are suitable for this application with the majority of treatment coming from aerobic reactions. The choice of the most appropriate system depends on the specific effluent quality and quantity. The resulting final effluent is normally suitable for disposal to the surface water environment, or may even be recycled to the factory for further use.

4.7 Potential research

Effluent treatment processes currently used by the dairy industry are either capital intensive, unreliable or very basic pretreatment processes. Most total treatment processes are based on variations of trickling filters and activated sludge plant. Their reliability or effectiveness is often poor due to the great variations in effluent quality over a given period. Correctly designed sludge/biological filter/aeration processes could lead to a marked decrease in effluent loads from dairies and possibly even in water intake. Further research into preliminary treatment processes could result in improved performance of municipal sewage works, improved lifetime of sewers and increased production of by-products.

5 REFERENCES

1. Guide for Dairy Managers on Wastage Prevention in Dairy Plants. Doc 124, IDF, 1980.

2. Proceedings of the 1984 IDF Seminar on Dairy Effluents. Doc 184, IDF.

3. Funke, J W. Industrial water and effluent management in the milk processing industry. CSIR Guide K12, 1970.