Cheese Process Control

A Thesis Presented for the Degree of Master of Engineering in Chemical and Process Engineering

Benjamin J. Jones
University of Canterbury
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Abstract

The cheese making process at Anchor Products Hautapu was having difficulty reaching the now outdated New Zealand Dairy Board uniformity targets. Even though there is no longer a direct financial benefit in reaching these targets consistently, there is the benefit of being able to show the customer that the product which they are receiving is as consistent as possible.

This project was carried out by systematically investigating each section of the cheese making process, looking for variations that were likely to affect the final product. Where variations were found methods for eliminating them or minimising their effect on the final product were developed.

The largest source of variation was found to be caused by fluctuations in the curd depths on the belts of the Alf-O-Matic cheddaring machine. Overlapping the ends of consecutive cheese making tanks as well as the re-calculations of the pump out flow rates have been proposed to remedy this problem.

Where the curd is drawn off from the end of the Alf-O-Matic cheddaring machine was also found to be causing variation in the product due to particle stratification affecting the salt levels of blocks that were being produced. Recommendations for methods to reduce the level of stratification have been suggested including using a capacitance probe to control the curd level.

Further variations were occurring within the cheese making tanks with cutting and stirring speeds differing from tank to tank. The tanks were also being flushed with cold water causing moisture spikes in the product. Both of these problems have been eliminated by changes to the PLC program.

Small improvements have been seen in the process with the changes that have already been carried out. Large improvements are expected if the rest of the recommendations are implemented. The largest improvements should be seen with the realisation of an overlapped pump out system.

Preface

The majority of the time spent on this Masters project was spent at the Anchor Products Hautapu, Cheese Factory, near Cambridge, Waikato. Because the project was carried out in a production facility a large number of people from Hautapu site were involved in my project. These people helped in a number of areas, from data collection and process changes, to help with pointing my solutions in the right direction if they became a little wayward or unrealistic.

The help of all these people was necessary and definitely beneficial to the project. These people have been acknowledged wherever possible throughout this thesis. They are also listed in the acknowledgments.

It should also be noted that some of the references used during this project were internal files, and others were confidential to the New Zealand Dairy Industry. For these reasons not all references will be available to all readers.

Acknowledgments

I would like to thank Dr Ken Morison (University of Canterbury) for being my project supervisor.

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Finally I would like to thank my parents and Alice Baucke for being so tolerant to my transient lifestyle throughout the duration of this project.

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1. Introduction

1.1 Project Aims

The aim of this Masters project was to determine the sources of variation within the cheese making process at the Anchor Products Hautapu cheese factory, and then to try to eliminate these variations wherever possible in order to gain better uniformity. Uniformity is defined as the smallest possible variation in the final product throughout a day. For this reason the natural variation of protein and fat that occurs within the milk throughout the season has been ignored. Appropriate changes to the process by a skilled cheese maker should eliminate these variations.

The cheese making process is a batch – semi-continuous process. The process can be broken down into a number of process steps, some of which are semi-continuous, others of which are batch processes. To gain the best possible control of the process and therefore the most uniform product, it is important to maintain the smoothest possible transition from the semi-continuous process to the batch process and vice versa. For the purpose of this project the excess cream and whey streams have been ignored as the project is aimed at reducing the variation in the final product, cheese.

1.2 Process Overview

The cheese making process is inherently a difficult process to control. Cheese is made using the main traditional methods of preserving foods - fermentation, dehydration and salting. It also contains a phase change operation, which increases the complexity of the problem. Due to the biological nature of the process no two batches or two blocks will be identical. Also due to the complexity at a biological and chemical level it is not possible to completely eliminate variation in the final product, but it is possible to minimise the variation as much as possible by trying to obtain identical processing conditions at all times.

The cheese plant at Anchor Products Hautapu site processes 1.2 million litres of milk per day and produces 34,000 tonnes of cheese per season. The factory makes a number of different products, which include Edam, Colby, Shreddar, Cheddar, Kaimai, Gouda and Egmont cheeses. There are a number of different specifications within each of these product groups. Due to the frequency of product changes it is important to have good control over the factory so as to minimise variations and to adapt to new products rapidly.

The process at the Hautapu factory can be broken down into the following batch and semi – continuous processes:

1.	Tanker reception	Batch
2.	Milk storage	Batch
3.	Separation and pasteurisation	Semi – Continuous
4.	OST tank filling	Semi – Continuous
5.	Starter and rennet addition	Batch
6.	Setting, cutting, cooking and stirring	Batch
7.	Transfer to the Alf-O-Matic	Batch
8.	De-wheying, salting and mellowing	Semi – Continuous
9.	Block forming and packaging	Batch

Figure 1.1 on the following page is a flow diagram of the cheese making process as it occurs at the Anchor Products Hautapu, cheese factory.

1.2.1 Raw Milk Pick Up and Reception

A fleet of Anchor Milk tankers, each with a capacity of 26,000 L, picks up the raw milk from farm dairies around the local area. The tankers transport the milk to the reception where the milk is transferred into one of ten 225,000 L silos. Milk for cheese production is generally taken from silos 4, 5, 9 & 10. Variation in the composition of milk provided by different farms has been ignored due to the volumes being mixed together, in the tankers and in the silos.

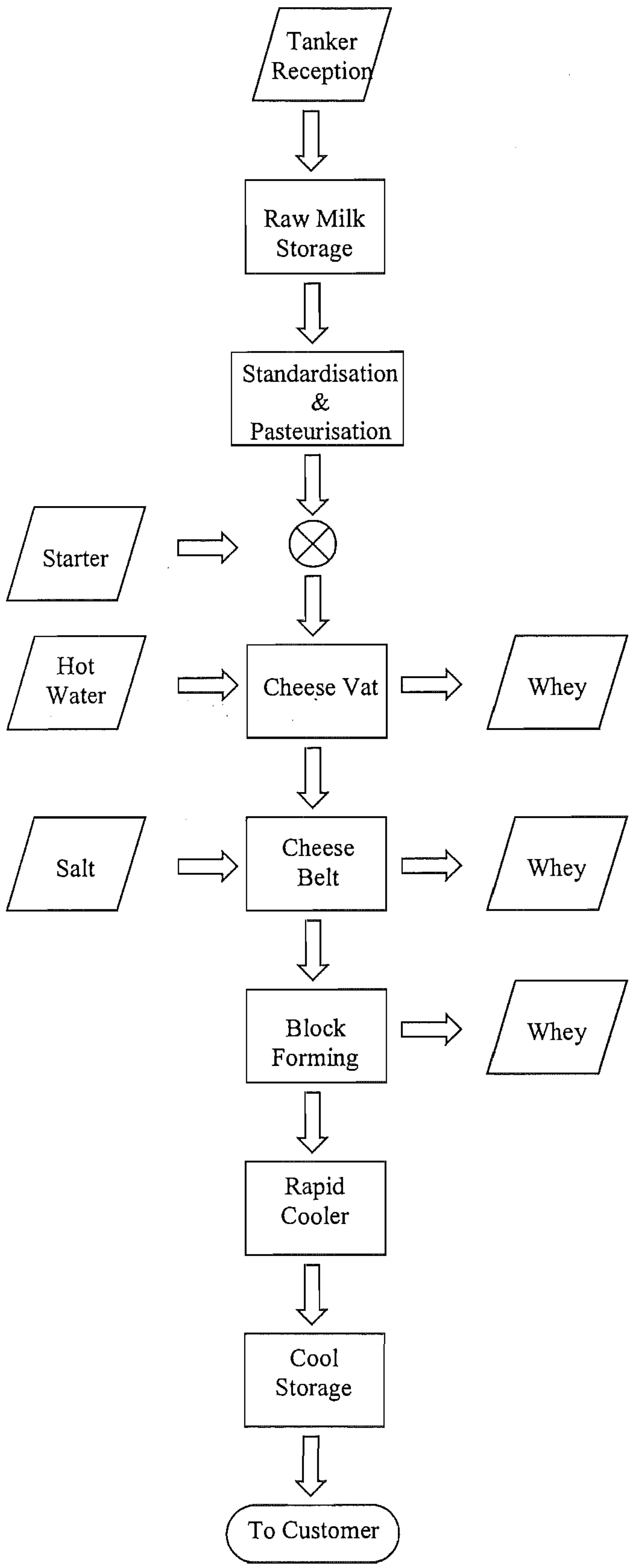


Figure 1.1 - Flow diagram of the cheese making process used at Anchor Products Hautapu

In the storage silos the volume and mixing is assumed to remove any variation that may occur within the raw milk fed to that silo. Variation between silos does occur but it is eliminated by changing the standardisation value on the Alfa Laval (*Lund, Sweden*) ADS (Automatic Direct Standardisation) system to obtain the correct protein to fat ratio.

1.2.2 Separation and Pasteurisation

Milk from the silos is fed into two identical Westfalia (*Oelde, Germany*) AG Oelde Type MSD 200-01-076 centrifugal separators at a constant rate of approximately 33,000 L/hr per separator. The raw milk is separated into skim milk (0.08% fat) and cream (42% fat).

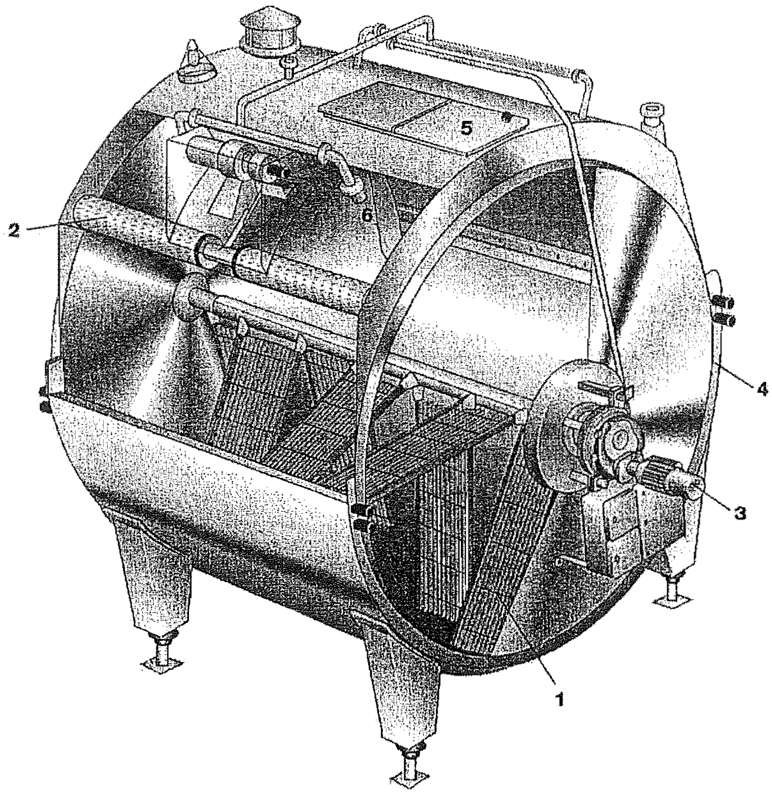
The skim milk is then standardised by re-mixing the correct fraction of cream back into the skim milk flow to obtain the desired protein to fat ratio. The standardisation of the cheese milk is carried out by a Alfa Laval ADS system. The excess cream is sent to a cream silo with the cream from the other 6 separators, where it is stored until it is trucked to another site to be processed (Hautapu site processes only protein based products).

The standardised milk is then pasteurised at a temperature of 72.5°C. It is held at that temperature for 15 seconds, in holding tubes in compliance with Ministry of Agriculture and Forestry (MAF) regulations. It is then cooled to the required cheese making temperature of approximately 32°C.

From the pasteuriser, the standardised cheese milk is pumped across to the OST tanks. This is the first of the semi continuous – batch transitions. When 40% of the OST tanks volume has been pumped across, the starter for that batch is injected into the milk line.

1.2.3 OST Tanks

At Hautapu there are 12 cheese vats known in the industry as OST tanks. Each tank has a total volume of 22,500 L and they are generally filled to 20,000 L. Figure 1.2 shows a diagram of an OST tank, similar to the ones used at the Hautapu factory. These tanks have nine knives/stirrers, depending on the direction of the rotation. Figure 1.3 shows diagrams of the knives/stirrers.



1. Combined cutting and stirring knives
2. Strainer for whey drainage
3. Frequency-controlled motor drive
4. Jacket for heating
5. Manhole
6. CIP nozzles

Figure 1.2 - An OST tank horizontal cheese vat. (Tetra Pak, 1995)

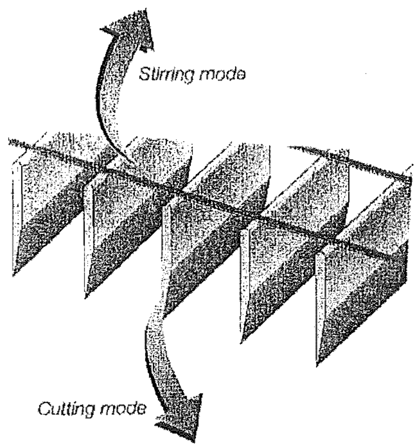


Figure 1.3 - A section of the knives/stirrers used in the OST tanks. (Tetra Pak, 1995)

It is important that the OST tanks are filled continuously as the separators and pasteuriser must run continuously. If the pasteuriser is put on hold it causes unnecessary down time in the plant and hence lost production. This however is not normally a problem, as there is generally a 40 minute gap between the end of an OST tanks clean in place (CIP) cycle and its place in the queue to be refilled with milk for its next batch.

Once the standardised cheese milk and the starter have been pumped into the OST tank, the tank is stirred thoroughly to ensure that the starter is evenly distributed in the solution. Natural calf rennet (*New Zealand Rennet Company, Eltham, New Zealand*) is then added via three nozzles at the top of the vat. The contents of the vat are mixed again to ensure that the rennet is mixed in completely. The solution is then left to coagulate for a set period of time of around 40 minutes.

Cheese curd is formed by enzymatic coagulation using rennet as the enzyme source. Rennet is a mixture of the enzymes chymosin (>90%) and pepsin. It is the chymosin that breaks down the casein.

Milk is essentially made up of proteins (both whey and casein), fat, sugar, minerals and water. Casein is in the form of casein micelles, which are highly hydrated, spherical particles made up of casein proteins, minerals and water.

The casein micelles are made up of α-casein, β-casein and κ-casein. A micelle will grow until its surface is completely made up of κ-casein. A casein micelle is shown in Figure 1.4. Part of the κ-casein called a macropeptide protrudes from the micelle and forms a hairy layer, which sticks out in to the aqueous phase of the milk. This hairy layer acts as a barrier and prevents the micelles joining together, making the casein micelles very stable.

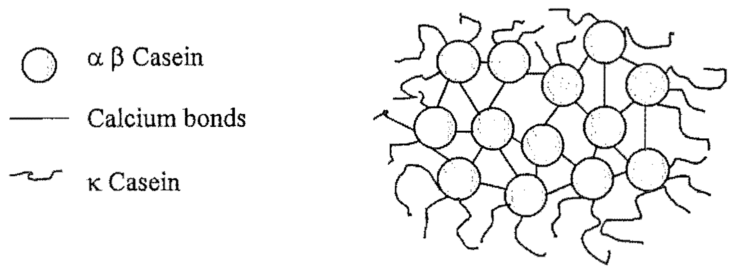


Figure 1.4 – Casein micelle (based on Tetra Pak, 1995)

The chymosin attacks the κ-casein, which is broken down into para-κ-casein and macropeptide. This then allows coagulation to occur as the destabilised casein micelles can now bond to one another to form a gel.

When the gel is strong enough (this is what determines the coagulation time) it is ready to be cut. The gel is cut continuously for a period of ten minutes. It is then cut intermittently for five minutes. When the tank is being cut intermittently the knives rotate 180°, then pause for one second before continuing for another 180°.

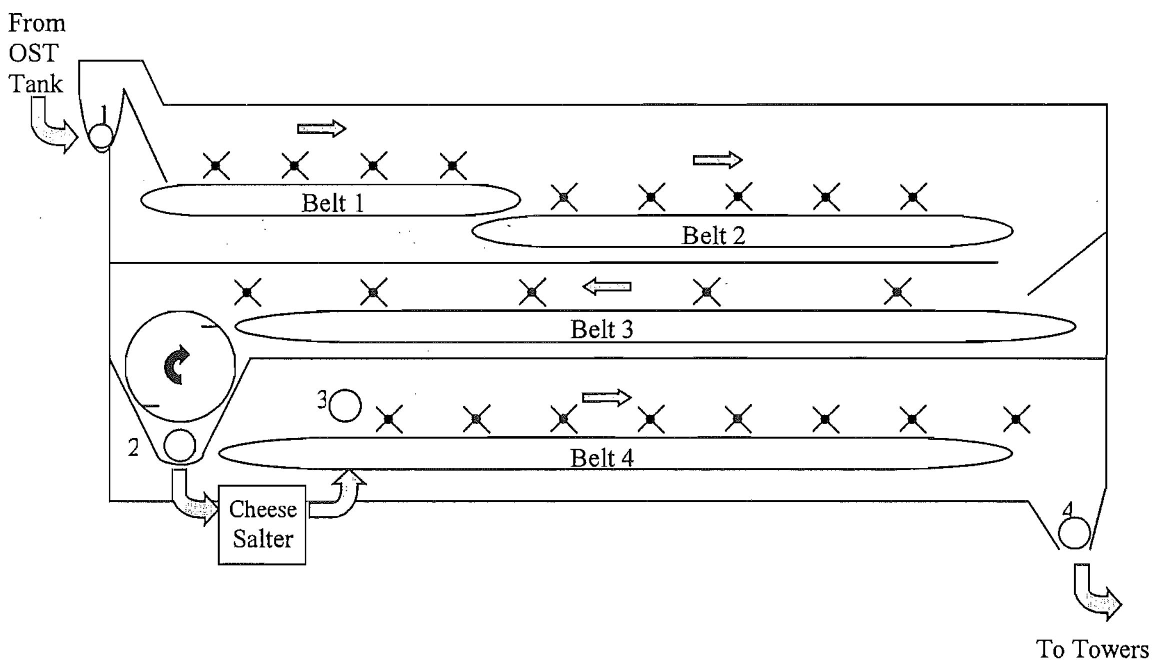
The curds and whey suspension is then stirred for a further 7 minutes. If a washed curd cheese is being produced then the tank is left to settle. Once the tank has settled a percentage of the whey is drawn off (normally 25% of the volume in the vat, 5000L). The vat is then stirred for 90 seconds before the volume of whey removed is replaced with 40°C water.

Once the hot water addition is complete the temperature of the OST tanks is ramped to the cooking temperature of 37-38°C. The OST tank is cooked for 40 minutes. When the cooking is complete there is a final stirring step which can be up to 20 minutes depending on the rate of pH development. If the pH development is fast, the final stirring time may be reduced substantially.

When the final stir is complete, the second batch to semi-continuous transition occurs when the OST tank is pumped across to the Alf-O-Matic.

1.2.4 Alf-O-Matic

The curds and whey are pumped from the OST tanks across to the Alf-O-Matic draining and cheddaring belts, where the whey is separated from the curd by a dewheying screen.



1. Weir box where curds and whey enter the Alf-O-Matic together before passing down over the dewheying screen.
2. Auger feed from the chip mill to the cheese salter.
3. Auger feed from the salter back onto belt 4.
4. Mixing auger before the curd is sucked to the towers.

Figure 1.5 - The general layout of the Alf-O-Matic, including curd directional flow.

The Alf-O-Matic has four belts, the first two belts have perforated stainless steel slats. Belts 3 and 4 have solid stainless steel slats. There are a number of stirrers on each of the belts. The number of stirrers going depends on the product being produced.

For example, there will be no stirrers going on belts 2 and 3 when the plant is producing cheddar cheese. Belts 2 and 3 are known as the cheddaring belts. The number of stirrers going can also be used to help control the moisture level of the curd.

At the end of belt 3 the curd is passed through a rotating chip mill. The chip mill is very important in the production of cheddar cheeses, as the mat has to be chipped before salting to insure that even salting occurs. Chipping is not so important in the production of granular cheeses, as the curd is already in particles with an average size between 10 - 15 mm.

From the chip mill the curd is fed to the continuous salter, over a weigh belt which calculates the amount of salt to apply to the curd. The curd is then fed back onto belt 4, known as the mellowing belt, by two rotating augers.

The cheese curd can take anywhere from 1 hour 30 minutes to 2 hours 40 minutes to travel through the Alf-O-Matic. This depends on the product being produced, with cheddar being the slowest cheese type to pass through.

Once the curd reaches the end of the Alf-O-Matic it is fed into an auger box where it is mixed to ensure an even distribution of curd from different positions across the mellowing belt. From the auger box, the curd is drawn to the block forming towers through vacuum lines.

1.2.5 Block forming Towers

There are 9 block forming towers at the Hautapu Cheese Factory. 3 different types of block forming towers are used:

- 4 × 1 tonne/hr
- 2 × 1.6 tonne/hr (twin vac)
- 3 × 0.75 tonne/hr

There is normally a maximum of 8 towers running at any one time, with one kept on stand-by as a reserve in case a break down occurs on one of the other towers.

Curd is drawn to the towers using a vacuum. The curd enters the towers from the top where it is compressed under its own weight. The tower is kept under a vacuum to draw away excess whey and to assist in maintaining good block shape. A guillotine at the base of the tower cuts a block from the column, before it is pushed out into a plastic bag that has been placed on the external bag horn.

The bag then has its weight checked manually by an operator and is topped up if required before being vacuum-sealed, placed in a carton and sent to the rapid cool tunnel.

1.2.6 Rapid Cool Tunnel

The final product is placed in the rapid cool for 24 hours, to reduce the block temperature from approximately 32°C to 18°C. The rapid cool is maintained at a temperature of 7°C. Rapid cooling is achieved because the blocks are stacked in racks in such a way that allows good airflow around the blocks to achieve the most efficient cooling possible.

Rapid cooling of cheese inhibits the growth of yeast, moulds and most importantly non-starter lactic acid bacteria.

1.2.7 Cool stores

Once the cheese has been in the rapid cool tunnel for 24 hours, it is either palletised or placed in a bin. The pellets of cheese are then placed in a cool store at 10°C to ripen. The time that the cheese spends in the cool store is once again very dependent on the product. Below is a table showing the typical ripening time for cheddar type cheeses.

Very Mild	3	months
Medium	6-9	months
Tasty	9-12	months
Vintage	24	months

1.2.8 Product Quality

There are 5 variables that are measured in order to determine how well the cheese conforms to the specification, these are:

1. pH
2. Salt
3. Moisture
4. Fat
5. Sensory evaluation

The first 4 variables can be easily tested in a laboratory using standard test methods.

After the cheese has been packed and has been placed in the rapid cool for 24 hr, it is sampled for final product testing with tests for fat, moisture, salt and pH. From this information the ratios fat to dry matter (FDM), salt to moisture (S/M) and the moisture non-fat solids (MNFS) can be calculated. The primary use of these values is to determine whether the product is within specification. Effective standardisation of protein to fat in the cheese milk is required to achieve consistent values of FDM. Good control of the moisture within the process is required to achieve consistent MNFS.

$$FDM = \left(\frac{Fat}{100 - Moisture}\right) \times 100$$

$$S/M = \frac{Salt}{Moisture} \times 100$$

$$MNFS = \left(\frac{Moisture}{100 - Fat}\right) \times 100$$

Consistency of product is the most important criterion as a lot of the cheese produced ends up as an ingredient in processed cheese or other products. Therefore it is important for the customer to know that consistency is being maintained in the product which they are receiving, so that it does not affect the quality of their products.

The target variations for the physical cheese properties throughout a day are based on the now outdated New Zealand Dairy Board uniformity targets. These targets are no longer in place so have no effect on the price paid for the cheese, but the customer can be assured that they are getting a high quality product with little variation if these targets can be met. The target standard deviations are as follows:

Moisture %	Fat %	pH	Salt %	MNFS	S/M
0.50	0.50	0.03	0.06	0.49	0.19

After 35-40 days, AgriQuality NZ graders grade the product. Sensory evaluation parameters include:

- Colour
- Texture (bend, break, firmness, stickiness, smoothness, crumbliness)
- Taste (salt, acid, bitter)
- Flavours

As the sensory evaluation can not be carried out immediately, it is not a variable that has been taken into account in this project.

1.2.9 Control System

In the winter of 1998 the Cheese Factory at Anchor Products Hautapu had its Alfa Laval *(Lund, Sweden)* Alert 500 control system was replaced by a PLC (Programmable Logic Controller) system.

The control system now in place consists of some Modicon *(Schneider Automation Ltd, North Andover, Massachusetts, USA)* 800 Series PLC's but mainly Modicon Quantum series PLC's. The PLC's are programmed using Modsoft Version 2.4. *(Modular Software Corporation, Laguna Hills, California, USA)*

The human-machine interface (HMI) used is Intouch (Version 7) *(Wonderware, Irvine, California, USA)*, which is a Microsoft® Windows NT™ based product.

The system also uses Wonderware Industrial SQL Server (Version 7) a real-time relational database to log data from the plant.

1.3 Overview of this Work

Before any data was collected it was important to get an understanding of the Cheese making process in as much detail as possible. This involved spending time with the operators, watching the process and investigating why certain things occur.

From the initial observations it became clear that the process as I was interested in it could be broken down into four sections.

1. Standardisation and Pasteurisation
2. OST tanks
3. Alf-O-Matic
4. Block forming towers.

Each step was observed to identify what variables were involved, and how each variable could be affected by disturbances to the process. It was then important to ascertain whether the disturbances were purely local or if they had a large down stream effect.

If a large effect was suspected further investigations were carried out, including laboratory analysis of the product and analysis of computer logged data. If the source of the problem was determined, further investigations were carried out to develop methods of minimising or eliminating the problems found.

1.4 Literature Review

This project is based solely around cheese production at the Anchor Products, Hautapu, Cheese Factory. Most of the literature reviewed is not specific to any particular factory but to the cheese making process in general.

There have been large amounts of work done on cheese making over the years. The majority of this work has been done on the science of cheese making rather than on improving control or the engineering of cheese making.

Morison (1997) defines the cheese making process as a separation and reaction process. This paper describes the cheese making process as a system of equations based on the mass balances around each of the individual components of the cheese making process. The model is useful for clarification of the process from an engineering point of view.

No relevant work was found on process control approaches to controlling variability within the cheese making process.

A large amount of work has been done in the past to optimise conditions in the cheese vat. Variations in curd production conditions in the cheese vat have been shown to effect the moisture and flavour of the final product. This work is more concerned with the optimisation of methods already in place such as the speed of cutting and cheese vat temperature.

Johnston *et al.* (1990) identified that the cutting speed and duration had a large effect on curd particle size. It is also stated that the variation in the curd particle size has a direct effect on the moisture content of the curd.

It has also been shown that the rennet concentration and the set-to-cut time in the cheese vats has an effect on the curd particle size as well as losses of fat and curd to the whey. (Johnston *et al.*, 1991)

Although both of the papers mentioned above treat the cheese making process as a science, it is important to understand what effect variations in conditions in the cheese vats have on curd properties.

Wiles *et al.* (1997) identified that the Hautapu site had a particle segregation problem. This results from the way that the curd is placed back onto the fourth belt after salting. Although this problem was identified, no engineering solutions to the problem were suggested.

2 Methodology

This methods section explains the methods of data collection, both manual and computer based used through out the project.

All computer logged data was collected using Wonderware Industrial SQL Server. This server collects both analog and discrete data from instruments throughout the plant, with the exception of the block forming towers.

2.1 Particle Distributions

Particle distributions were carried out at the start of the Alf-O-Matic as well as at the end of belt 4. As the curd at these two points are quite different, two different methods of carrying out particle distribution analysis were used. Both methods were variations on the method used by Johnston et al. (1991).

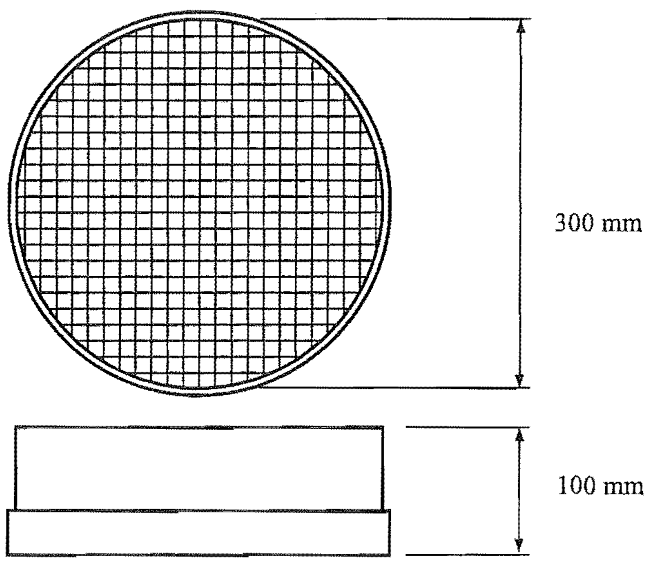


Figure 2.1 - A diagram of the sieves used for finding particle distributions.

The four sieves that were used to carry out the particle size distributions were fabricated out of 316 stainless steel with aperture sizes of 5, 10, 15 and 20 mm. A base for the stack of sieves was also fabricated.

Both the wet and dry methods of finding particle distributions of samples of curd have a large error involved with them. This is due to the nature of the product as the curd particles tend to stick together or break. These methods are used as a guide to identify problem areas rather than to gain exact data.

2.1.1 Wet method.

The wet method was used at the start of Alf-O-Matic to determine cutting variations between OST tanks.

A 5-litre sample of curds and whey was taken from the weir, at the top of the de-wheying screen at the start of the Alf-O-Matic. The sample was then passed through a stack of 3 sieves with aperture sizes of 5, 10, 15 mm and a base collecting all the fines. This was carried out while in a solution of warm water and whey to prevent any further damage to the curd particles, as the curds are still very soft at this stage of the process. Each sieve was then weighed to gain the mass in each size range. The mass distribution could then be calculated.

2.1.2 Dry method

The dry method is to be used on curd after de-wheying has occurred.

A sample of approximately 3-kg can be taken from belt 4 at the second to last porthole, using a small stainless steel shovel. The sample is then passed through 4 sieves with aperture sizes of 5, 10, 15 and 20 mm and a base collecting all the fines. The sieves were shaken in order to get good separation of particles. As with the wet method each sieve was then weighed to gain the mass in each size range. The mass distribution could then be calculated.

2.2 Cheese Properties.

Grab samples were taken from belt 4 from the second to last porthole. The grab samples were taken from approximately the same area each time to try and maintain consistency in sample collection. All samples collected were tested for salt, fat and moisture. The standard test methods were used and these are explained below.

Samples taken from blocks after they had been ejected from the towers were generally taken with a standard cheese sample corer. These samples were also tested for salt, fat and moisture using the standard test methods described below.

2.2.1 Salt Tests

The level of salt in curd is tested using a Mettler DL40RC Memotitrator. 2 ml of 4.0M nitric acid and 40 ml of 60°C hot water are added to a 1 gram sample of grated cheese curd. The sample is then mixed thoroughly using an electric stirrer, to dissolve the curd into the solution. Once complete mixing has been carried out the sample is put on the Memotitrator where it has 0.1M $AgNO_3$ added until the titration set point is reached. From the amount of $AgNO_3$ added and the exact mass of cheese curd in the sample the percentage of salt is calculated automatically. This method is based on NZTM3, Chemical Methods Manual, Issue 1, June 1993, NZDI section 9.6.

2.2.2 Moisture & Fat Tests

An Infrared Engineering, Infralab™ TM5000 was used to carry out moisture and fat tests on the cheese curd. The sample was grated and enough placed in the sample tray to cover the bottom. The results were automatically recorded on a stand alone PC.

3 Performance of the Standardisation and Pasteurisation

At Hautapu there are 4 individual pasteurisers, numbered 1 to 4. Two separators feed each one. The cheese milk pasteuriser is Pasteuriser 1.

If a new silo is not selected when another silo runs out this can cause the balance tank before the separators to run low, the result being air entrained in the cheese milk. If air becomes entrained in the cheese milk, it reduces the ability of the rennet to attack κ–casein, which is required for coagulation as explained in the introduction. This produces open and grainy curd particles.

3.1 Standardisation

Standardisation at the Hautapu cheese factory is currently carried out using an Alfa Laval (*Lund, Sweden*) ADS (Automatic Direct Standardisation) system. The ADS system works on the principle of a mass balance. This system is due to be replaced with a system on the Modicon PLC network. The proposed system has been tried on Pasteuriser 2 so there is the possibility of using it to provide cheese milk if there are any problems with Pasteuriser 1. This system appeared to work well on Pasteuriser 2 so it should just be a matter of copying it for Pasteuriser 1

With the current system setup it is possible for the milk treatment operator to forget to change the setting on the ADS when a silo change occurs or after the first tank of each run. This can be seen in figure 3.1, which shows a fat level change approximately 1 hour after the silo was changed. This is likely to result in cheese with the incorrect fat and moisture levels. On Figure 3.1, label "1" identifies where silo changes occurred and label "2" shows where the ADS setting was changed.

The bottom line shows that the raw milk feed rate remaining constant throughout the period. The top line shows the percentage of raw milk removed as cream in the separators. The flowrate of cream is controlled by back-pressure from a control valve to get the correct fat levels in the cream based on the fat level in the raw milk. In the past cream screws have been used to maintain the correct pressure. An incorrect ADS setting will mean that the cream will have an incorrect fat level. This in turn will result in the error being carried through to the fat level in the standardised cheese milk which will upset the protein to fat ratio.

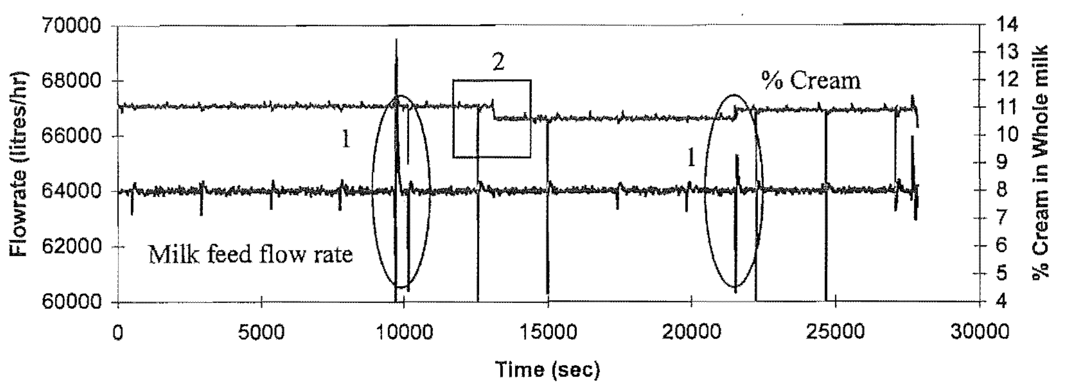


Figure 3.1 - Raw milk feed flowrate and % of cream in the raw milk

The other small blips that can be seen in Figure 3.1 occur when the separators are de-sludged. This occurs approximately every 20 minutes.

The first tank of any run requires a slightly higher protein to fat ratio, to account for extra water that may be in the system. The different protein to fat ratio required for the first tank of each run has to be manually calculated and entered by the operator.

To overcome the two problems outlined above it is proposed that when the standardisation system is set up on the PLC, the protein and fat levels for each silo be entered into the system. When a silo is selected to be used, the fat level required to get the correct protein to fat ratio can be automatically calculated for the product being produced. If the fat and protein values are not available then a default setting will be used and an alarm should come up until the problem has been rectified.

An in-line Near Infra Red (NIR) system has been installed into the pipe work of Pasteuriser 1. It was installed with the intention of using the outputs from it to fine-tune the standardisation loop. The NIR system is not used because of the following problems:

- Results affected by any temperature variation.
- Results affected by pressure variation.
- System found to drift from its set point, which would therefore give incorrect results.

(Commissioning took place a number of years ago, and the results from the commissioning trials were not available.)

3.2 Pasteurisation

The water used in the hot water section of the pasteurisers is supplied from the secondary hot water system. From time to time the load on the secondary hot water system becomes too great, causing a drop in temperature of the water in the secondary loop. This temperature drop of the secondary hot water can cause one or more of the pasteurisers to "divert". If a pasteuriser diverts this means that the temperature of milk coming out of the holding tubes has dropped to below 72.5°C and is therefore diverted back to the balance tank rather than being used in the product. The system then goes into circulation until the temperature returns to its set point. Pasteuriser diverts cause down time and hence lost production as well as upsetting smooth transitions from OST tanks to the Alf-O-Matic by interrupting the continuous filling regime.

Currently the primary hot water is heated by the 3 boilers in the utilities area of the factory, it is then passed through a plate heat exchanger to heat the secondary hot water. This is shown in Figure 3.2.

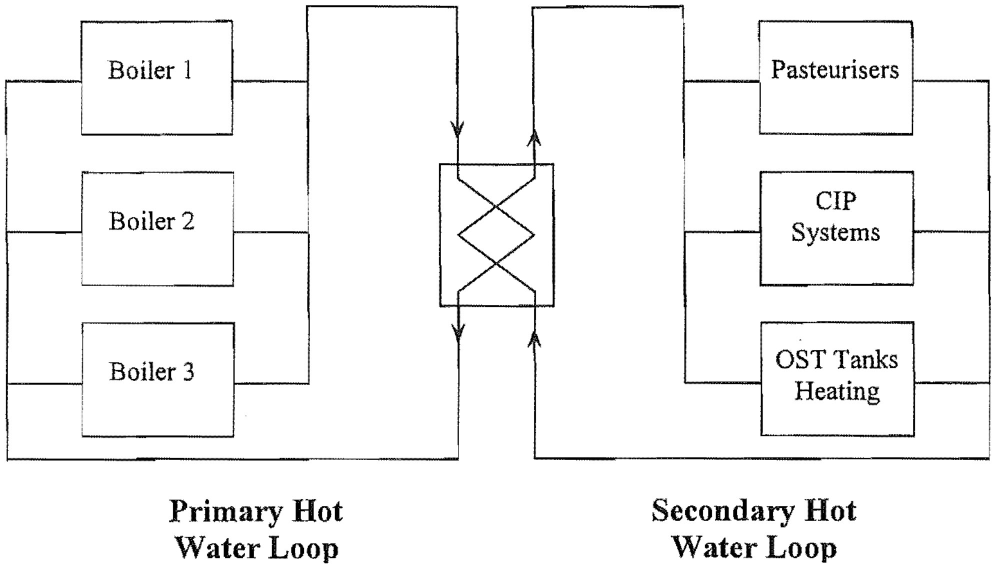


Figure 3.2 - The utilities hot water system.

The secondary hot water is then used throughout the cheese factory and milk treatment in the hot water sections of heat exchangers. There are a number of areas where the secondary hot water is used as the heating medium, including the pasteurisers, CIP systems and heating of the OST tanks. The CIP systems are suspected to be the cause of the large temperature disturbances, especially when they occur in conjunction with a hot water addition and a cooking step of one of the OST tanks.

To try to minimise the number of diverts it is suggested that the hot water sections on the four pasteurisers are supplied by a separate secondary hot water loop. This would allow for better control of the pasteurisers, as it would reduce the number of unexpected disturbances in the system that cause undesirable temperature fluctuations. Depending on the load limits of the boilers, one boiler could be set aside just to supply heat for the pasteurisers. The other two boilers would then be available to provide for the heating requirements for the rest of the plant. This system still requires further investigation.

4 Performance of the OST Tanks

Initial investigations were carried out on the operation of the OST tanks, to see what areas were likely to cause variation from vat to vat. The three input streams to the OST tanks: standardised cheese milk, rennet and starter were eliminated as they all appeared to be well measured. The temperature control of the OST tanks also appeared to be adequate so it was also ignored. This left only two areas of concern, the cutting/stirring speeds and the water flushing.

4.1 Cutting

The curd is cut at the end of the coagulation step of cheese production. The cutting is carried out by the nine sets of knives in each OST tanks. Diagrams of the knives and the OST tanks can be seen in the Process Overview section of the Introduction.

The cutting of the gel is the most important step in the process of determining yield and losses to the whey as well as the retention of moisture, as all of these curd properties are effected by curd particle size. It is also a well-known fact in cheese making that the speed and duration of cutting has an effect on the particle size of the curd. This is further demonstrated in the report by Johnston *et al.* (1990).

If the gel is under-cut this results in large curd particles, which then break apart in the stirring phases of the recipe, this phenomenon being known as curd shattering. The result of curd shattering is a large surface area in comparison to clean cut, which promotes the loss of fat to the whey. If the cut is too fast then small particles are produced, which results in reduced moisture rather than fat losses.

The effect of cutting speed and duration is not as dramatic in OST tanks as in Damrow vats, which are an alternative tank used for cheese making. The reason is the direction of the cutting action, in an OST tank the knives are in a horizontal position, and in a Damrow they are in a vertical position. See Figures 4.1 and 4.2 for diagrams showing the differences in the cutting actions of a Damrow Vat and an OST tank.

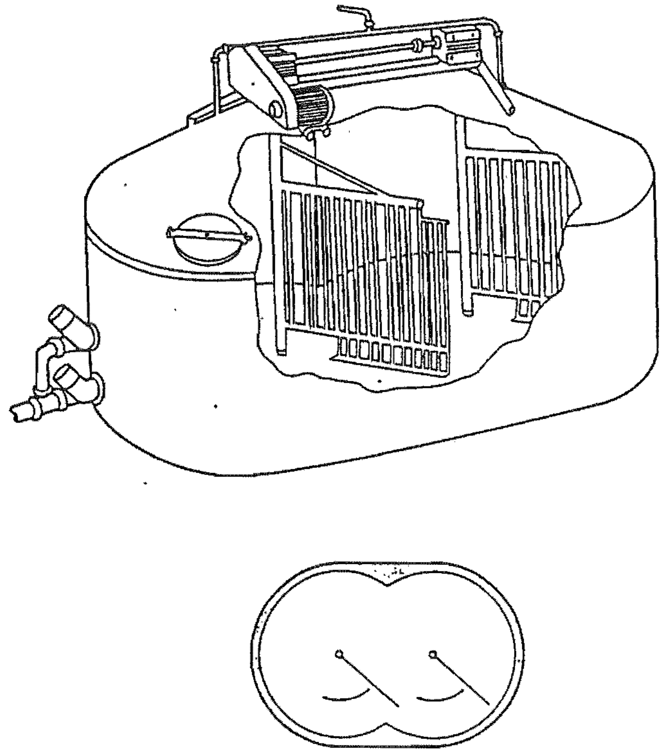


Figure 4.1 - A Damrow vat and the cutting action. Johnston (1987)

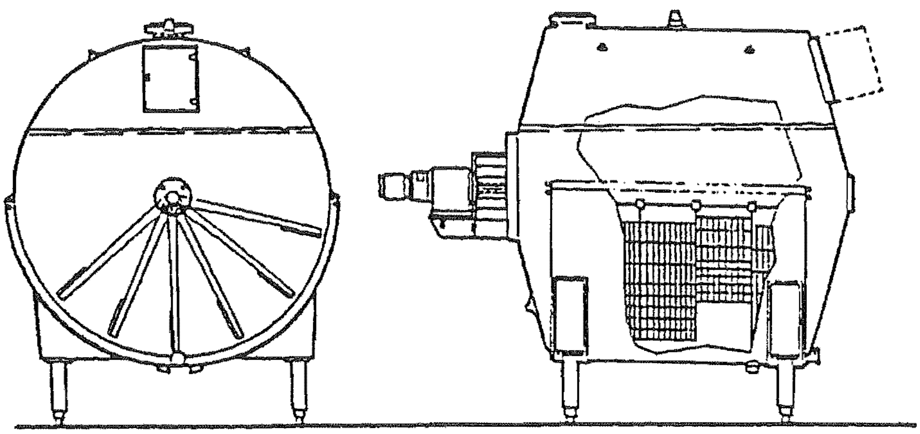


Figure 4.2 - An OST Tank and its cutting action. Johnston (1987)

As this project was aimed at minimising variation within the factory it was assumed that the cutting speeds and duration that were supposed to be being used had already been optimised. Therefore the only area that was of interest was the variation between the OST tanks in the speeds.

Initially curd samples were taken 5 minutes into the pump out of each OST tank, from the weir box at the start of the Alf-O-Matic. These samples were then analysed for particle distribution using the wet curd method as explained in the method section on page 16.

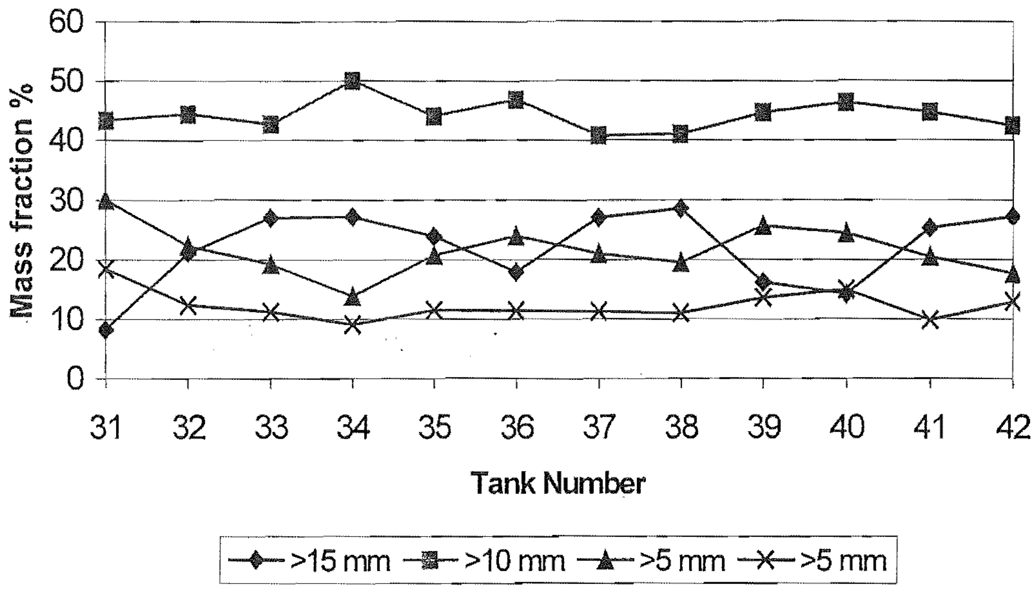


Figure 4.3 - Particle distributions from the weir
(21 October 1998 Egmont Japan 31-200)

The results showed discrepancies in the particle distributions of a number of tanks. Figure 4.3 shows the results from the particle distributions carried out. Further investigation into the cutting regimes revealed that there were variations in the settings in the PLC. There are also 3 different types of gearboxes and two different types of variable speed drive.

The correct PLC setting were recalculated on 2 November 1998 and now all the OST tanks cut at the same speed except OST tank 31 which cuts at a slightly higher speed as explained in the following section.

Figure 4.4 below shows the variations in speed calculated from physical information. A Fluke *(Danaher Corporation, Everett, Washington, USA)* 41B Power Harmonics Analyser was required to check the speed settings for the older variable speed drives. A stopwatch was also used to find the speed of the agitators. The results revealed that the calculations from theoretical data were accurate, these results are not shown as they were only a check and involved a large amount of error.

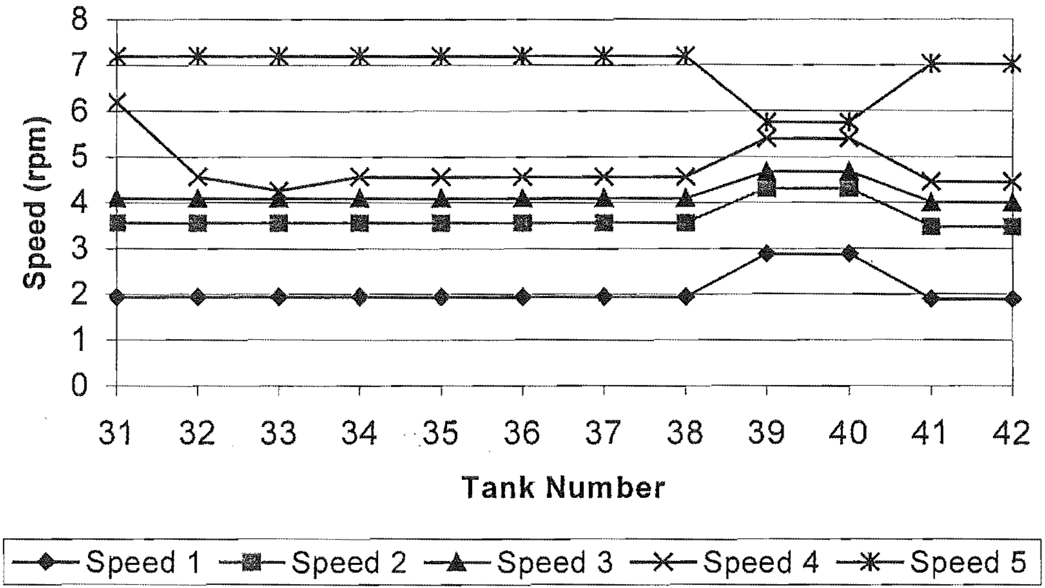


Figure 4:4 - Original agitator speeds for each OST tank.
(21 October 1998)

It can be seen from the graph above that areas of concern were the speeds of the OST tanks 39 & 40. OST tanks 33,41 & 42 also required small adjustments.

It was assumed that tanks 32 and 34 to 38 were cutting at the correct speed and new PLC settings were calculated from that speed, for the other 6 tanks. The cutting speed of OST tank 31 was reduced to half the difference in the cutting speeds. Figure 4.5 shows the new cutting speeds.

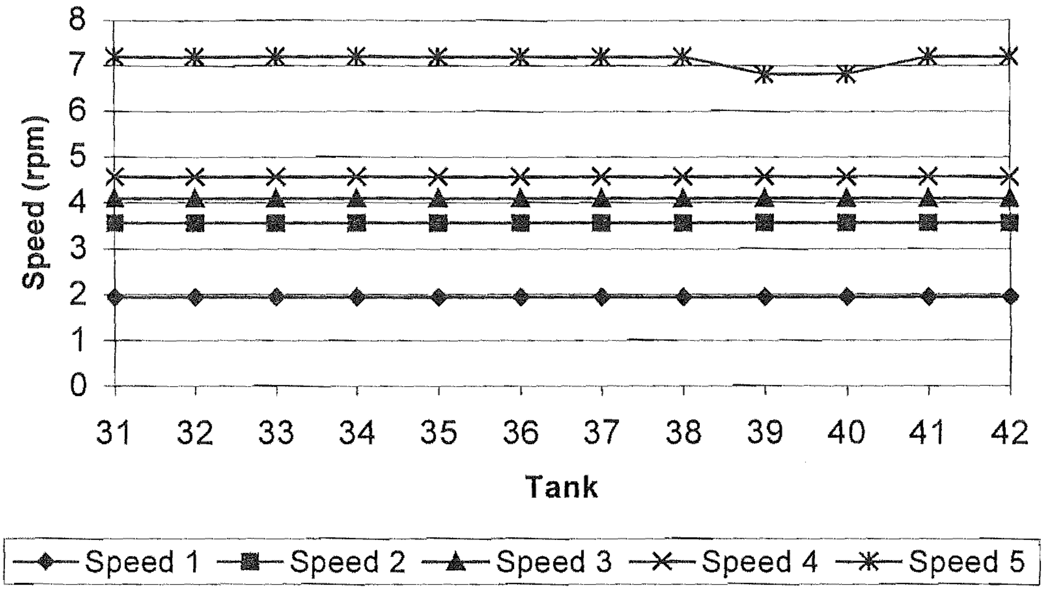


Figure 4.5 - Final agitator speeds for the OST tanks
(2 November 1998)

It should be noted that speed 5 on tanks 39 and 40 is slightly slower than the other tanks. This is because of the old style variable speed drives that are in place on those tanks, and that is the maximum speed that is currently allowed.

Once the changes had been made the further particle distributions were taken from the weir box, 5 minutes in to each pump out. The results for the particle distribution are shown in Figure 4.6.

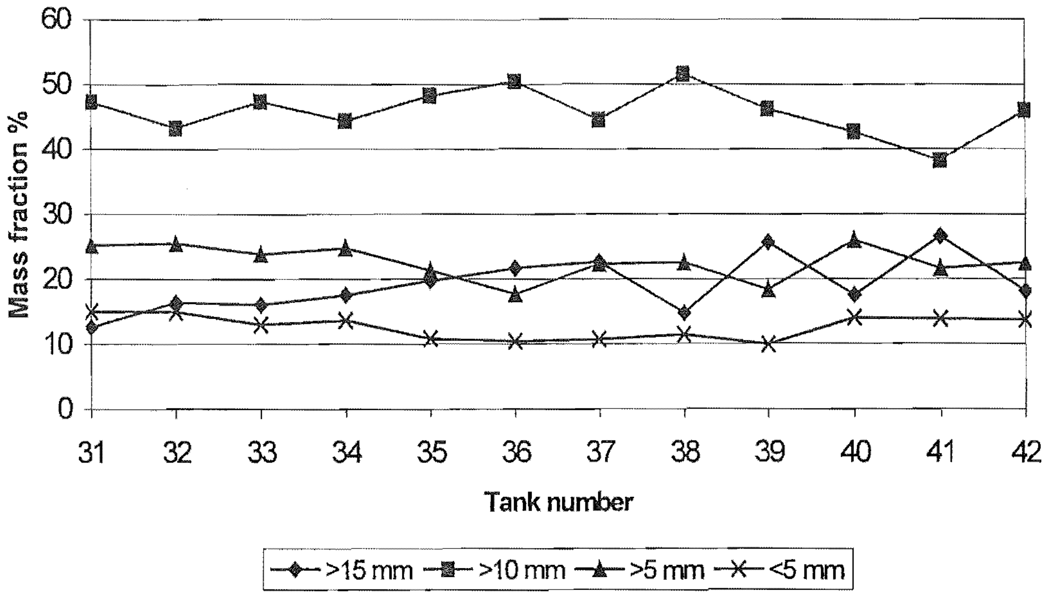


Fig 4.6 - Particle distributions from the weir box

(18 February 1999 Egmont Japan 31-200)

Even with the large error in the test method these results show a slight improvement in the particle size distributions.

4.2 First Tank of the Day

The first tank of the day and the first tank after the mid run clean require a slightly higher cutting speed than the other OST tanks. This is because after a break in production the first tank is likely to have extra water in it, due to water in the line to the OST tank and water in the pasteuriser. This extra water will lead to higher levels of moisture in the curd. If the cut speed is faster this will reduce the curd particles size and therefore increase the syneresis (moisture expulsion) ability of the curd.

Tank 31 is normally used as the first tank of the day, for this reason its cutting speed is set slightly higher than the other OST tanks. This however means that every other batch that uses tank 31 for the rest of the day is also cut at that higher speed, because there is no facility in place to identify the first tank of day or to compensate for it.

It proposed to modify the control program so that any tank can be used as first tank of the day and the rest of the production for that OST tank will be unaffected by the increase in cut speed for the first tank. A number of different variable scalars will be required due to the variations in the gearbox and variable speed drive configurations of the OST tanks.

At the start of the days production or after a period of down time in the filling of vats resulting in the CIP of the pasteuriser, the first tank to be filled should be identified as being so (similar to selecting the last tank of the day). When a tank is selected as being the first tank, the preset motor speeds on the agitator should be multiplied by the scalar for that particular tank.

The required scalars are as follows:

Tank 31 – Tank 38	multiply by	1.356
Tank 39 – Tank 40	multiply by	1.317
Tank 41 – Tank 42	multiply by	1.379

These changes should result in more even curd properties by eliminating unnecessary variation between OST tanks.

Note: Tanks 39 and 40 still have old style variable speed drives. To ensure that the best possible control of these agitators is achieved, these old variable speed drives would need to be replaced.

If the scalar system is introduced then Speed 4 or the cut speed for tank 31 should be reduced to 2416 (ie 0 - 4095 setting) in the PLC, as it is currently set at its higher speed.

4.3 Water Flushing.

Each of the OST tanks is flushed at the end of its pump out to the Alf-O-Matic, to help to move any curd that may still be in the tank. The tank is flushed when the control room operator manually selects a medium level flush for the tank after the "Bridge" operator signals that the tank has low level. The medium level flush lasts for 60 seconds and is approximately 500 litres of water. The tank is flushed from the 4 CIP nozzles in the top of the tank.

For Washed curd cheeses the "hot water addition" water also uses the CIP nozzles to enter the OST tanks. After the re-automation of the cheese factory it was noticed that one OST tank could be in the middle of hot water addition at the same time as another OST tank was being flushed. As both these system use a common line this could mean some tanks were being over washed while others were being under washed. The flow meter that measures the volume into each tank is located in the line before the junction with the flush water from the raw water tank. Including a pause step for the hot water addition if another tank was being flushed eliminated this problem.

Up until 20 January 1999 the OST tanks were flushed with cold water from the raw water tank. Flushing the curd out of the tanks with cold water is not desirable as it reduces the level of syneresis (moisture expulsion), due to cooling of the curd. The increase in moisture at the end of a pump out, where the curd would have come into contact with the cold water can be seen in figure 4.7, which is a moisture profile throughout a pump out with the samples taken from belt 4, at 40 cm intervals.

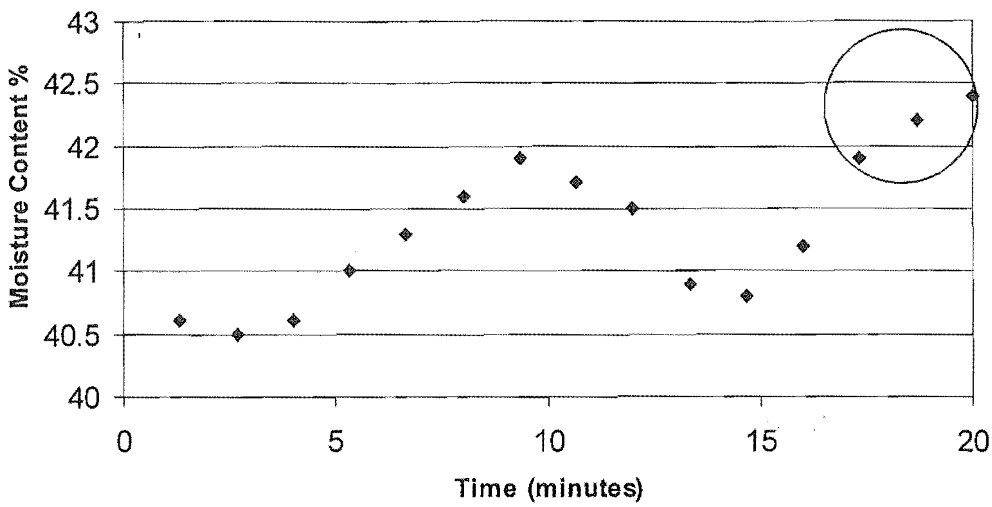


Figure 4.7 - Moisture profile over an OST tank pump out.
(24 November 1998 Egmont Japan 31-200)

It was therefore proposed that all the OST tanks be flushed with water at 40°C, this being the same temperature as the water used for hot water addition. The hot water from Tank 91 (process water), was the obvious choice because the common delivery line would eliminate the need for any pipe work modifications. However this solution did require a small number of programming changes and these were implemented on one tank first to see if there was any effect on the continuity of flow in the process. Once it was clear that the hot water flushing of the OST tanks was possible, it was implemented on the other 11 tanks.

Figure 4.8 shows the reduction of the moisture spike at the end of the pump out. It should also be noted that the levels on the belts have also been smoothed slightly, hence the much more consistent moisture throughout the rest of the pump out. This is explained in detail in the Alf-O-Matic section of this report.

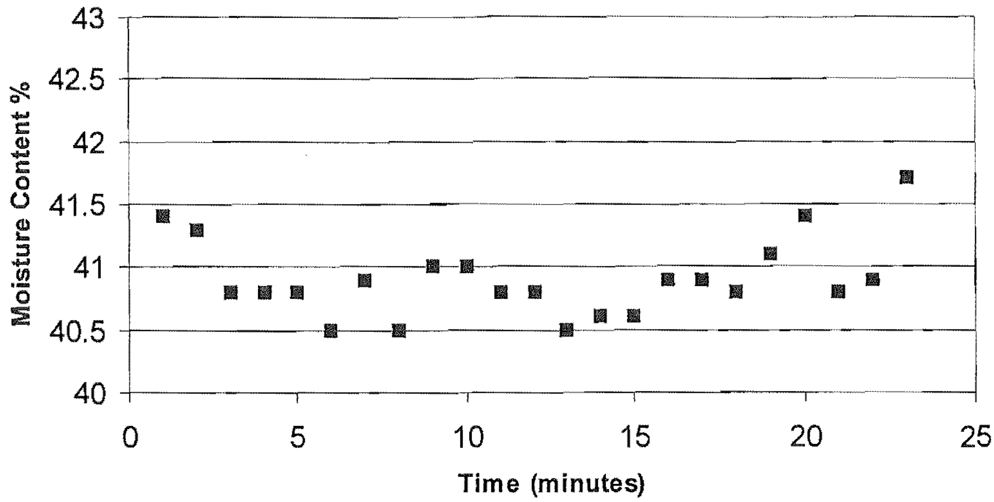


Figure 4.8 - Moisture profile over an OST tank pump out
(17 February 1999 Egmont Japan 31-200)

4.4 Automated Medium Level Flushing

At the end of the pump out of each OST tank the bridge operator indicates to the control room operator that the level in the tank is at a low level. The control room operator then manually selects a medium level flush. Once the tank has been flushed and drained the low-level switch in the gullet of the tank is activated, then the valve cluster is burst rinsed (low-level flush). Once the burst rinse is complete the pumps to the Alf-O-Matic stop automatically until the next tank is ready to run.

The medium level flush used to be automated using low level probes located near the bottom of each OST vat. These probes have been disabled due to false low-level signals causing premature flushes.

The current system is not ideal, as it requires good communication between the bridge operator and the control room operator at all times. This is not always possible due to commitments by both operators in other areas of the factory. On a number of occasions the signal from the bridge operator has been missed which has resulted in an OST tank not being flushed, therefore causing a hold up in production until the problem was corrected. This resulted in the loss of valuable production time.

The proposed solution to this problem is to use a percentage (ie. 98%) of the total flow (based on speed) through the curd pumps, based on either the last time that tank ran or on the previous tank. Used in conjunction with the low-level probes this should eliminate the problem. If the total flow reaches the pre-determined value, it will then check the output from the low-level probe. If it is activated then the tank will flush, if it is not activated then the system should send out an alarm. This will allow the operator to check the level in the tank, to confirm whether the problem is a probe fault or if the tank is not yet ready to flush. With this change, not only will the problem of flushes being missed be eliminated, but also probe faults will be identified early, so that the problem can be rectified.

5 Performance of the Alf-O-Matic

I would like to acknowledge Jane Newbald & Rachael Simms (Anchor Products, Hautapu) for work carried out in this section. Their help was vital in collecting data and other information around the continuous cheese salter and the auger box.

The Alf-O-Matic at the Hautapu cheese factory consists of 4 cheddaring belts the first two of which are perforated stainless steel, the other two are solid stainless steel. There is also a external salter at the end of the 3rd belt. The curd is taken to the salter via an auger situated at the bottom of the mill.

The Alf-O-Matic has been extended and the salting system has been changed since the plant was initailly constructed. The continuous cheese salter that is used was installed in 1994 and replaces a boom type salter that was used on belt 4.

5.1 OST Tank Pump-outs

The transition from a batch process to a semi-continuous process has been identified as an important step in maintaining ideal production conditions. The pump-outs from the OST tanks to the Alf-O-Matic have been identified as an area that needs attention.

The pump out recipe to the Alf-O-Matic affects a number of areas downstream of the OST tanks. The first major effect is on the level of curd on belts of the Alf-O-Matic. It has been discovered that the moisture and fat levels in the curd are related to the level on the belts. This is shown in Figure 5.1, which clearly shows that the moisture is higher at low levels on the belts and vice versa.

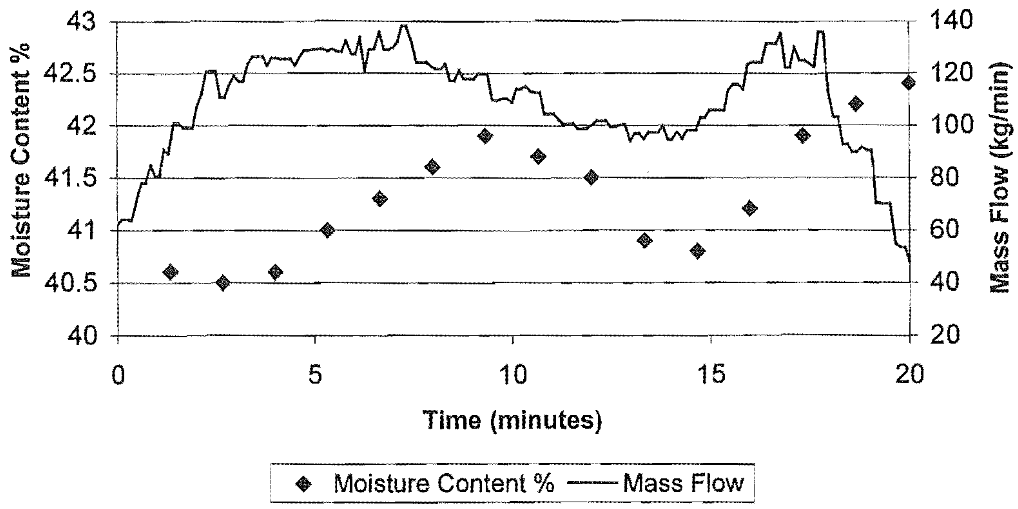


Figure. 5.1 - Moisture profile with mass flow over an OST tank pump out
(24 November 1998 Egmont Japan 31-200)

Figure 5.2 demonstrates as expected an increase in moisture content with decreasing fat content.

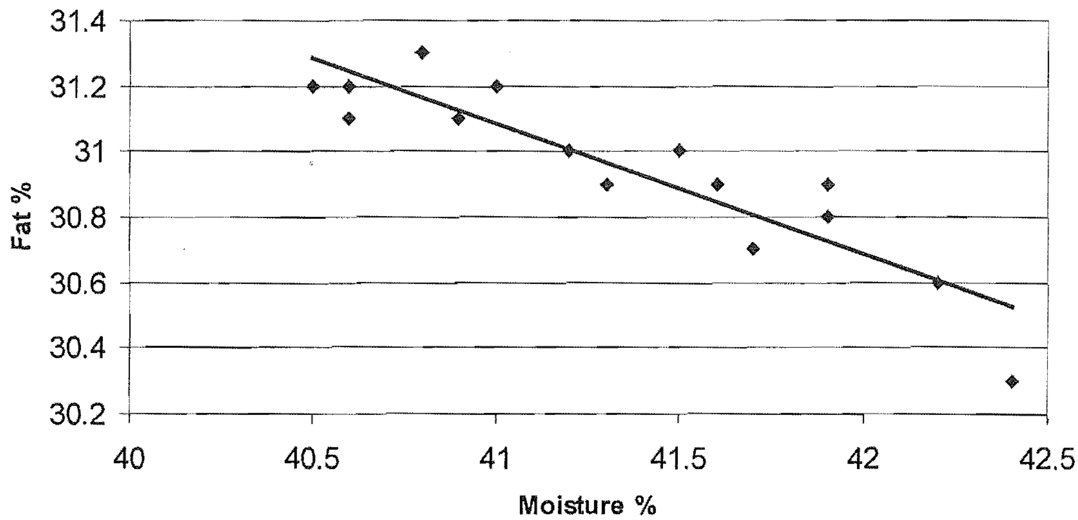


Figure 5.2 - Relationship between fat and moisture levels.
(24 November 1998 Egmont Japan 31-200)

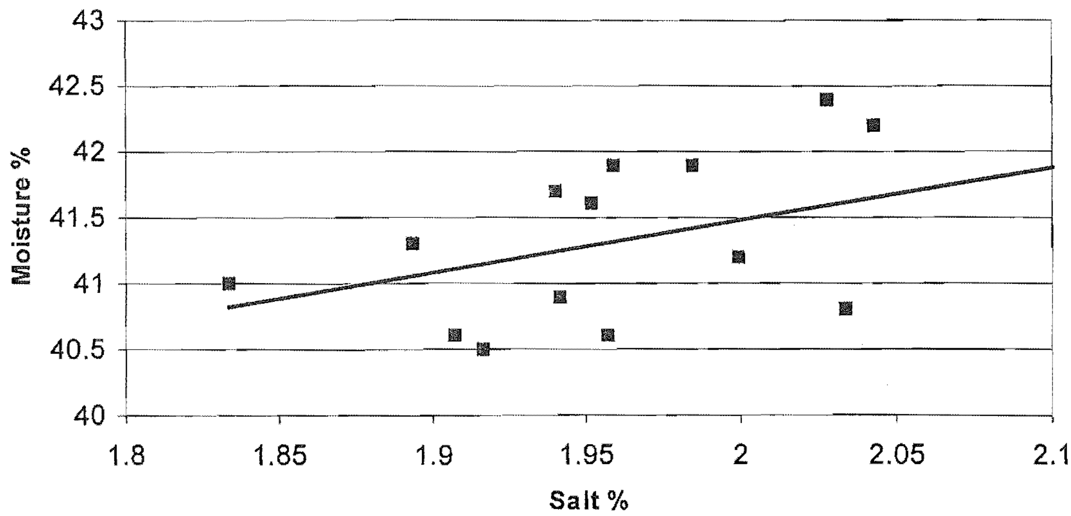


Figure 5.3 - Relationship between moisture and salt levels.
(24/11/98 Egmont Japan 31-200)

Figure 5.3 shows that the salt levels increase as the moisture level increases. This indicates an initial variation in the moisture levels of the curd, rather than moisture levels being related to the level of salt in the curd. The higher the moisture content the higher the salt retention factor will be as the salt will be able to diffuse into the curd much more readily. If the moisture level was consistent and the salting was the major problem, this would result in the inverse of the response found with higher salts at lower moisture levels. This is because increased salt levels promote moisture expulsion from the curd, therefore reducing the moisture level of oversalted curd. With the variations in the curd mass flow having an effect on the curd moisture levels, the variations in mass flow are also indirectly causing variation in the salt levels of the final product.

It would be ideal to have a constant feed of curd to the salter, as this would eliminate the need for the salter wheel to be continually accelerating and decelerating. Although the internal report by Simms *et al.* (1998) has shown that change in speed does not have a significant effect on the continuous salting of the curd, the smallest possible changes in the salter wheel speed would be desirable. Minimising the variation in the curd mass flow on the belts could attain this.

A more consistent mass flow at the end of the Alf-O-Matic would be a major advantage, as it would mean that there would be a much more even feed into the auger box. This in turn would allow the ability to implement a sequential curd drawing to the block forming towers. Level control is currently being investigated to control the height in the auger box to try to prevent stratification of curd particles. This is explained further in section 5.4. Minimising the variation of the curd feed into the auger box will make the control of it much simpler and therefore more robust.

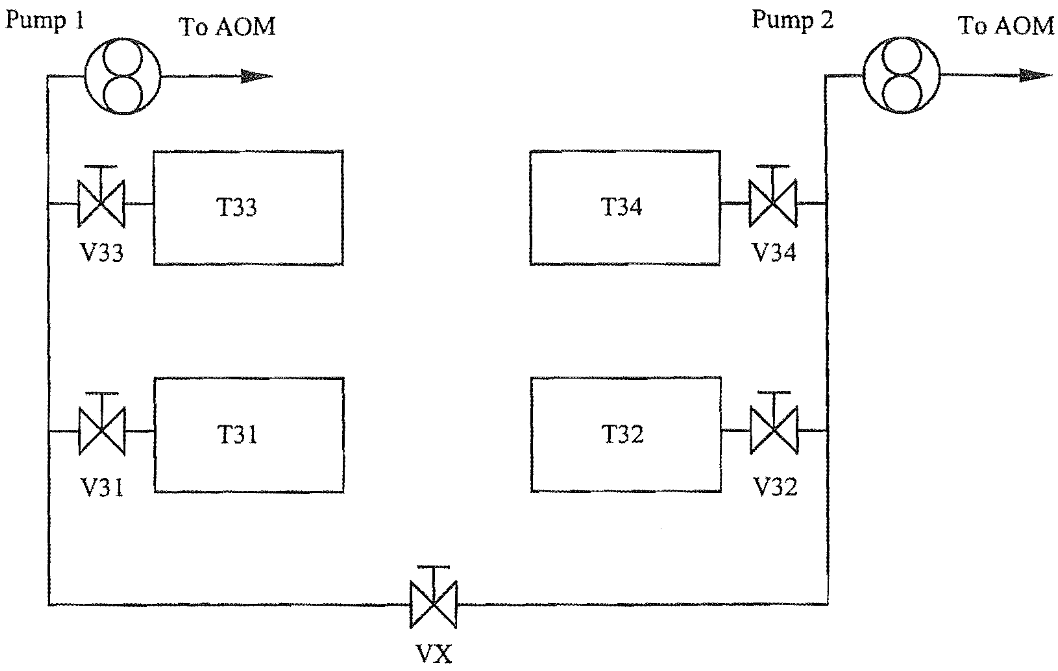
Overlapping pump-outs and recalculating the pump out recipes are the two main areas that are to be used to control the levels on the belts.

The average mass flow on the Alf-O-Matic at any one time has been found to be 100 kg/min with a standard deviation of approximately 27 kg/min. The target standard deviation is less than 10 kg/min.

5.1.1 Overlapped pump-outs

Overlapped pump-outs are currently used successfully, at both of Anchor Products other cheese manufacturing sites at Lichfield and Waitoa. Lichfield overlaps only the ends of each Ost tank, while Waitoa uses a half-and-half overlapped system. At Hautapu overlapping the ends of the pump-outs only will initially be trialed to minimise the effect of extending the pump out times substantially, as would occur if the half-and-half method were to be used. Extension of the pump out time is likely to increase the variation of the pH throughout a vat.

Figure 5.4 below is an abbreviated diagram of the OST tank area. There are twelve vats in total, this diagram shows only the first four.



VX is the valve to be installed, it will include a normally open actuator.

V31-V34 represents the cluster of valves that are already in place, that are required to pump an OST tank to the Alf-O-Matic.

Figure 5.4 – Proposed set up of the OST tank out flow ring main.

Features required in the program:

- Good interlocks between OST tanks so that at any time no two vats are emptying while valve VX is open, as this will cause the volumes of the two tanks to equalise.
- The ability for the plant to continue to run in the same manner as it is currently, ie. tanks running one after the other with no overlap, should it be necessary to do so for any reason.
- The overlap time period for each pump out must be able to be easily changed by the operators on the Intouch screen (this is especially important during commissioning).

The new system should run as follows:

Start Up.

The first tank will start off the same as it is currently run with both pumps running. It will however need slightly higher speeds at the beginning of the pump out to maintain a uniform time period required to pump out an OST tank.

Overlap.

An overlap button will be required on one of the screens. If the button is selected then the overlap routine should begin. The overlap button should not be able to be selected when on the last vat. It must also be able to be de-selected at any time.

If Overlap is Selected (example T31 - T32)

- After xxxsec or at the end of step x.
- Valve VX will close.
- T31 will continue to be pumped out by Pump 1
- V32 will open.
- T32 will start to be pumped out by Pump 2.

- When T31 is empty and has been flushed.
- V31 will close.
- VX will open and T32 will continue to be pumped out by both pumps until xxxsec or the end of step x.
- Valve VX will close

Continue through sequence again for the next overlap with tank 33.

When the first tank has finished being pumped out and has been flushed, the valve for that OST tank will shut ready for its CIP. The ring main valve VX will open and curd pump 2 will shut down for 15 seconds and curd pump 1 will continue to pump, to remove the possibility of an air lock. After the 15 seconds has passed, curd pump 2 will restart and continue with its pump-out recipe.

End of Production

When the last vat is selected to run the overlap should automatically be disabled after the second to last tank has been flushed.

The last tank of each run will be overlapped in the same way as the other tanks at the start. This will require having a separate recipe for the final section of the pump out using both pumps.

The overlapped pump out system will not work if an even/odd tank is being pumped out and the next tank select is also an even/odd numbered tank. There should also be a function that will not allow two outlet valves to be open if valve VX is not closed. This is to avoid one OST tank equalising with a second OST tank which is at a lower level.

5.1.2 Re-Calculation of Pump Out Recipes

Improving the pump out recipes minimises the variation that occurs through the middle section of the pump out from each vat.

From the weight belt mass flows new pump speeds were calculated using the following method, for OST tanks that are **not** overlapped:

From the pump recipe used and the known volume of the OST tank, a factor (Z) relating the total revolutions of the positive displacement pump to the volume can be calculated.

$$\text{Volume} = Z \times \int \text{Speed}\, \partial t$$

Where Z is a constant.

Using data logged from the salter weigh belt and the volume being pumped out, a solids fraction can be calculated. The ideal mass flow rate can then is determined by taking the average of the mass fraction found throughout a pump out. The volume required at each step can be calculated to obtain the average mass fraction. A back calculation can be done to find the optimum pump speeds.

This method has been used on a number of different cheese types and the following results have been gained.

Before Changes	Average Mass Flow (kg/min)	Standard Deviation
Edam	90	30.9
Egmont	107	29.2
Shreddar	94.2	28.0

After Changes	Average Mass Flow (kg/min)	Standard Deviation
Edam	105	23.5
Edam (latam)	101	18.5
Egmont C	105.2	23.8
Egmont Hi solids	101	16.1

From the results above it can be seen that there has already been an improvement in reducing the mass flow by using the method described above.

Continual improvements through fine-tuning are being made to these pump out recipes.

To make the continual improvements possible in a way that will insure that any changes made will be as accurate as possible, with minimal input of the operators time. The following method is proposed, which will work well for the pump out system as it is set up at the moment. A separate method will be required when overlapped pump-outs are implemented. The method developed for overlapped pump-outs is also shown on page 44.

This method alters the pump speeds to try and obtain an even mass flow. It cannot however correct for the 'dips' that occur between vats. Elimination of the dips requires the pump-outs to be overlapped. Figure 5.5 shows the variation including the dips between pump-outs.

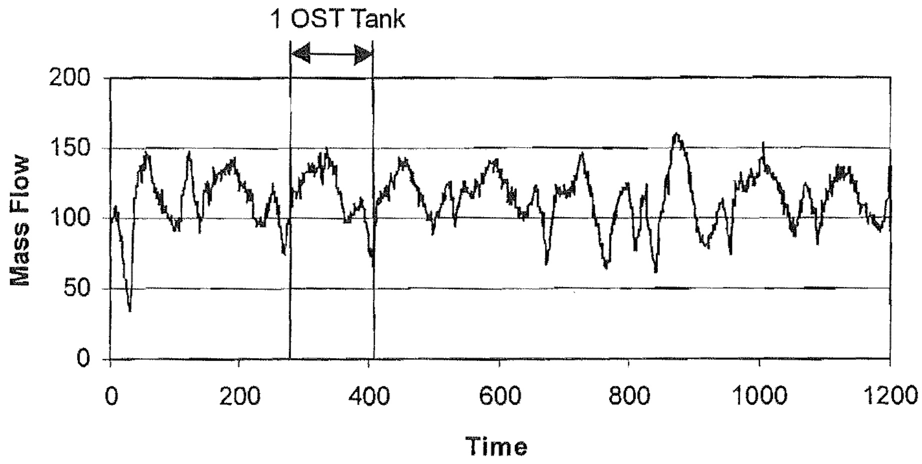


Figure 5.5 – The variation in mass flow on the belts of the Alf-O-Matic

The following method has been trialed using manual calculations and has been found to reduce the standard deviation of the mass flow from approximately 40 kg/min to as low as 12 kg/min.

The Proposed Method:

1. The Operator will be required to select an OST tank, the system will then go to the last time that tank was pumped across to the Alf-O-Matic. It will need to ensure that enough time has passed for all the curd from that OST tank to have passed through the salter.

2. Calculate the start of the curd mass for OST tank X.
   OST tank X start empty + time to salter - time belts were stopped.
   The time to salter is easily calculated using the belt speeds and lengths.

3. Calculate the end of the curd mass for OST tank X.
   OST tank finish empty + time to salter - time belts were stopped

4. Overlay the pump recipe for OST tank X with the mass flow for the same OST tank.

5. The volume of the OST tank X can be obtained from the recipe.

6. Assuming a linear relationship between the speed of the pump and the volume that is pumped, a relationship between the total speed of the pump for that OST tank and the volume pumped can be found. This is the speed/volume ratio.

7. From the speed/volume ratio the volume at each step of the pump out can be calculated.

8. From the volume calculated in step 6 and the mass flow from the mass flow data a mass/volume ratio can be calculated.

9. The average mass flow can be calculated from the salter weigh belt data.

10. The volume required to get the average mass flow at all times, can be calculated using the mass/volume ratio calculated in step 7.

11. Once again using the speed/volume ratio calculated in step 5, the ideal pump speeds can be calculated.

12. Using a table like the one shown below, the timers and pump speeds can be manipulated by the operator to fit the new pump out recipe to the ideal pump speeds.

	Timer (second)	Speed (Hz)
1	150	33
2	50	21
3	180	21
4	60	23
5	300	28
6	130	30
7	120	30
8	30	28
9	160	24
10		31

13. There should also be a CANCEL Button and an IMPLEMENT button. The implement button will replace the active pump out recipe with the new recipe, which has been calculated.

14. For the best possible control a number of iterations may be required.

The operator only needs to select the OST tank, manipulate the timers and pump speeds and then decide whether or not to implement the new recipe.

The VSD on curd pump 1 is an old style type with potentiometer to adjust the maximum speed and acceleration speeds, this would need to be replaced with a similar drive to that used on curd pump 2 to achieve the best possible results.

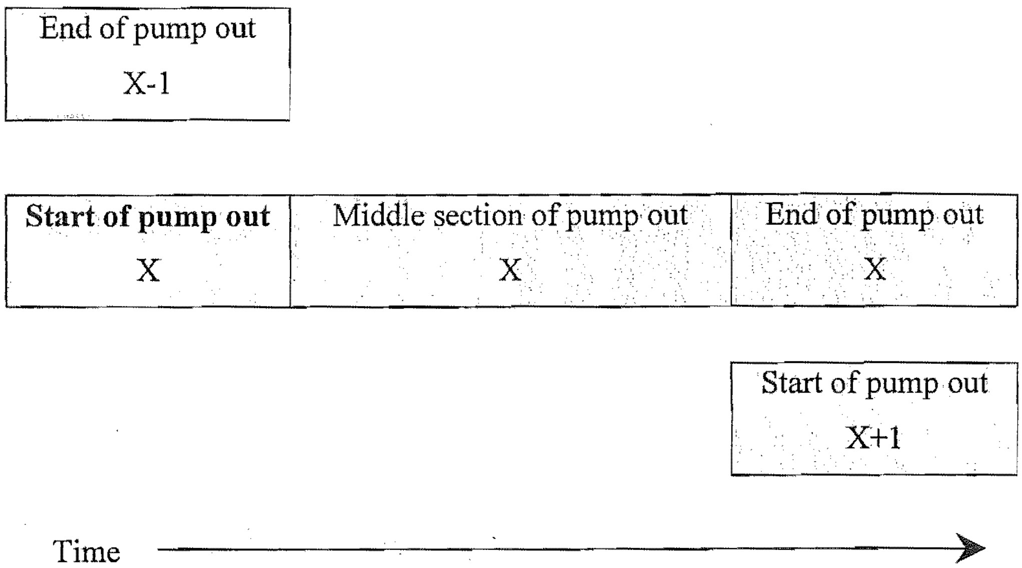
5.1.3 Re-calculation of Pump Out Recipe, With Overlap

Once overlapped pump outs are implemented the method described above will not be suitable as the pump out will be broken down into three sections.

- Start of pump out – one pump.

- Middle section – two pumps.
- End pump out – one pump.

(Except for the first and the last tank of the day)



The start of a pump out and end of a pump out, are both required to have two separate pump recipes, one for each pump, as one pump will be starting a tank and the other pump will be finishing a tank.

Start of Production

The first tank of each run also requires a separate recipe to use both pumps to get an even pump out on the belts. The output from these vats will be required to calculate the approximate mass distribution of curd to whey.

End of Production

The last tank of each run will also require a separate recipe to end the tank with both pumps. Once again the outputs from these tanks are essential for the calculation of the curd to whey mass distribution.

Until the overlapped pump outs are implemented it is difficult to speculate whether this method for control at the ends of the pump out will work. It is an area that will require attention during commissioning.

5.2 Salting.

The curd salter at the Hautapu cheese factory has been blamed for a lot of the variation in the cheese in the past. A lack of understanding of the salting system is the main reason for the blame being placed on this piece of equipment. Work carried out at the end of the 1997/98 season as outlined in the internal report by Simms *et al.* (1998) showed that the salter did in fact have a linear relationship between both curd mass, wheel speed and the salt applied. The results from these trials are shown in Appendix A.

The Salt is supplied by Dominion Salt (*Mt Maunganui*) in 1 tonne bags. The salt is transported to the bulk storage hopper in the cheese make room by an air conveying system. Before the salt is passed into the bulk hopper it is passed through a small cyclone to remove the transport air from the system. The bulk hopper has a valve on the bottom, which opens to release salt into the lower hopper when required.

The lower hopper has a capacity of approximately 50 kg. It is suspended on three load cells and has the salt metering wheel attached to the bottom of it.

Figure 5.6 is a schematic of the salting system at the Hautapu Cheese Factory.

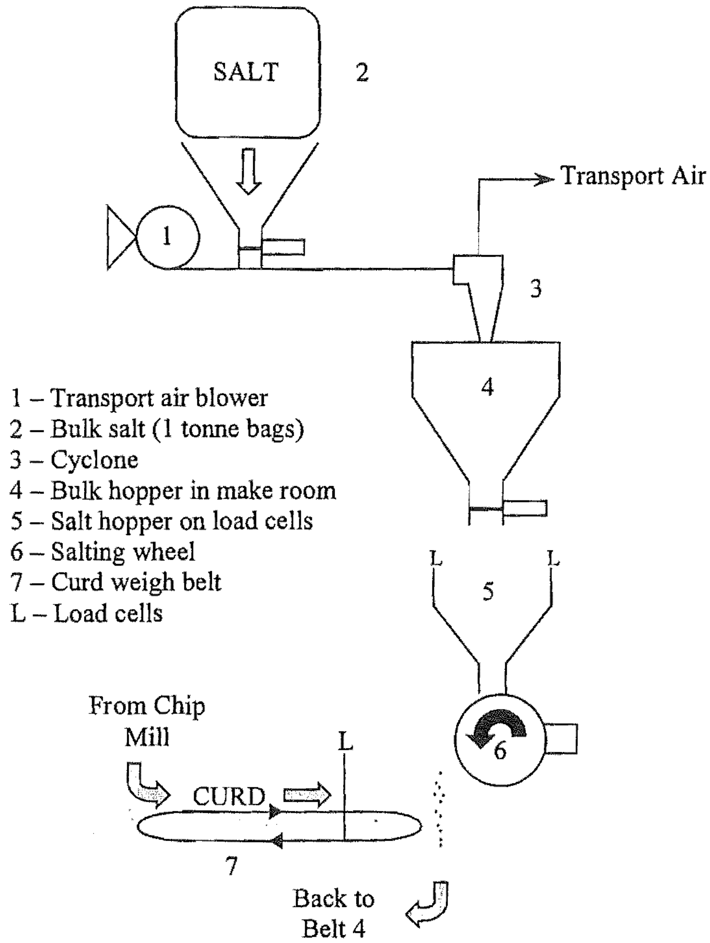


Figure 5.6 - Continuous salting system

Curd enters the salting system via an auger from the bottom of the chip mill. It then passes over a weigh belt so that the mass flow can be calculated. From the mass flow the amount of salt required is calculated. The salt metering wheel driven through a variable speed drive, so the speed can be varied depending on the amount of salt required. A correction factor known as the K factor is used to fine tune the salt wheel speed to ensure that the correct amount of salt is being applied.

5.2.1 K factor

The K factor is a correction factor that is used to eliminate any variation that may occur in the flow properties of the salt, such as moisture variation and salt particle size. The K factor is a changing scalar that directly effects the salt wheel motor speed.

The changing mass of the salt hopper found by the load cells is compared to the calculated amount of salt that should have been added to the curd. The difference in values of calculated mass lost and actual mass lost is used as an input into a PID loop in the PLC, the output of which is the K factor.

The K Factor had a slight oscillatory response, which is indicative of the integral time being too small or the gain being too large. The integral time in the PLC referred to as the reset time of the system was found to be 110 which converts to 1.1 cycles per minute, therefore the integral time was 54.5 seconds. This was thought to be adequate so was left as it was. The proportional band was found to be 190 and was adjusted up, as increasing the proportional band is equivalent to reducing the gain. This is because:

$$\text{Proportional band} = \frac{100}{\text{Gain}}$$

The loop was tuned on 8 December 1998. The reset time was left at 110 = 1.10 cycles per minute ≈ 54.5 seconds. The proportional band was changed from 190 to 350.

Figure 5.7 shows the variation in the K factor that was occurring before the changes to the PID loop were made. Figure 5.8 shows how much the variation in the K factor was reduced by changing the value of the proportional band (note the scales are the same on both graphs).

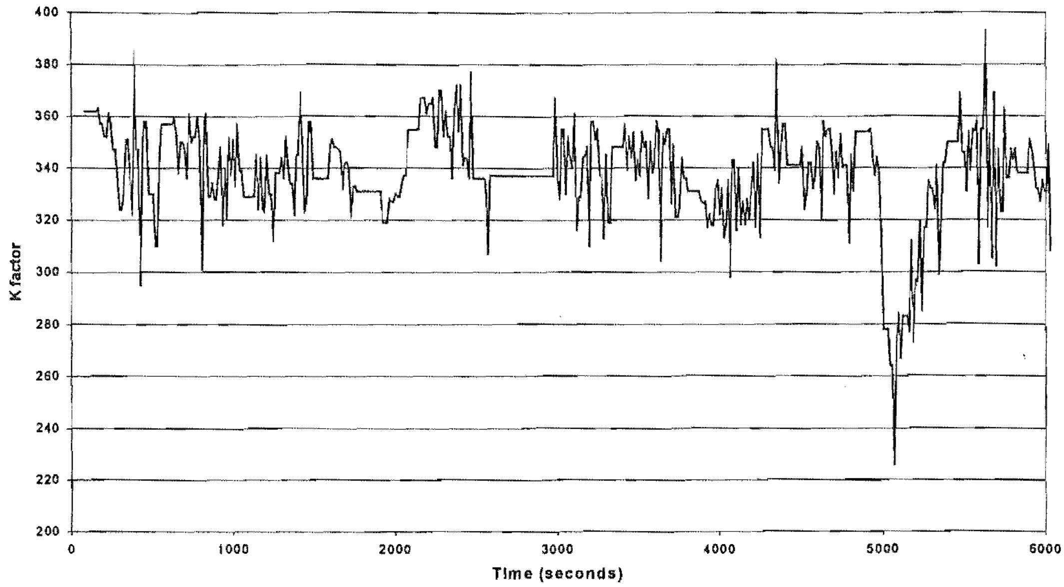


Figure 5.7 - The K factor with Time (23/10/98) before the PID loop was tuned.

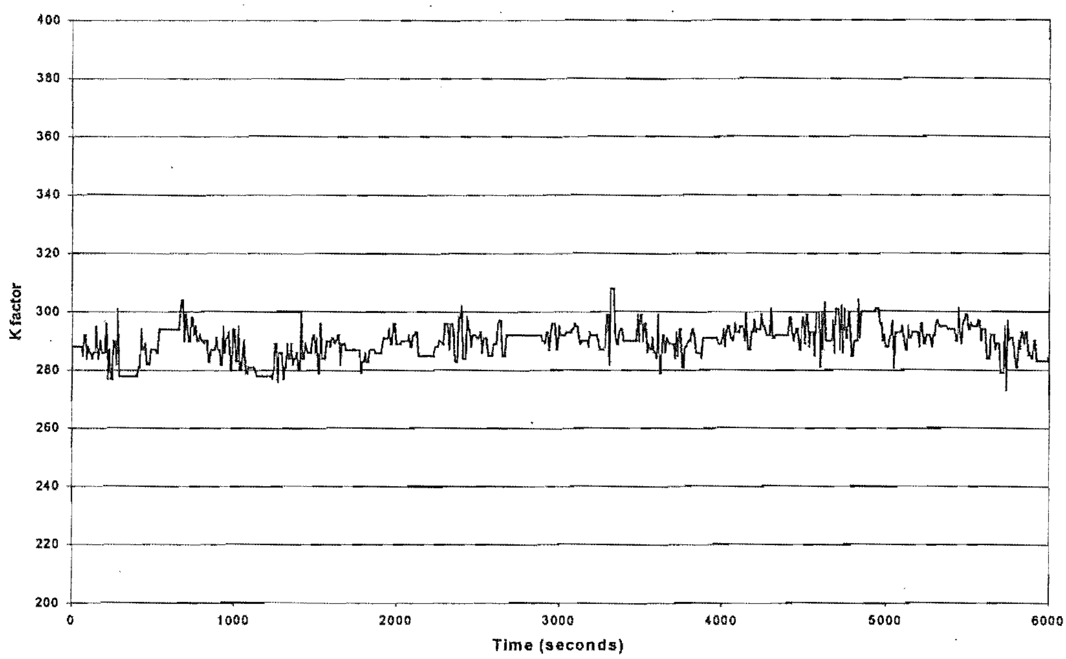


Figure 5.8 - The K factor with time (17/12/98) after the PID loop was tuned.

The difference in the mean value of the K factor is due to the different salt retention factors in the cheese. The major change can be seen to be the significant reduction in the magnitude of the variation.

It was noticed that the K factor sometimes appeared to have rapid and large fluctuations. These fluctuations meant that the salter wheel motor was continually accelerating and decelerating, meaning that even with reasonably consistent curd levels over short periods the salting was very uneven. After further investigations the "Actual salt ratio calculated" was also noted to have a similar response. The salt hopper load cells were found to be giving unstable outputs, due to the caking of salt dust on them.

The caking problem has been reduced with the load cells being washed down each morning with hot water to remove any caked on salt, at the recommendation of the load cell suppliers, *Sensortronic Scale Industries (NZ) Ltd.* The load cells are also "blown" down at mid run each day with compressed air.

The caking problem is due to very fine salt powder, which floats up around the salter enclosure and settles onto anything it can. Some days the problem is worse than others. Dominion Salt (*Mt Maunganui*) supplies the cheese salt. The salt specification is that:

>85% passes through a 500 μm sieve (typically 90 %)

<18% passes through a 250 μm sieve (typically 10 %)

On 3 October 1998 Warren Sutton from the Cheese Development Centre at Hautapu, carried out a particle distribution analysis on 4 samples of the cheese salt being used in the cheese factory. His results were as follows:

Sieve size	Sample 1 % passed	Sample 2 % passed	Sample 3 % passed	Sample 4 % passed
500 μm	97.9	91.7	95.9	95
250 μm	14.4	2.1	10.1	7.2

I repeated this experiment on 4 December 1998. There was not a 500 µm sieve available so I used a 600 µm one. Using three samples, 1 sample from the 4 December and two from 30 November:

Sieve size	Sample 1 % passed	Sample 2 % passed	Sample 3 % passed
600-µm	99.0	98.9	98.1
250-µm	2	13	2

From these results it can be seen that the salt provided is well with in specification, although there is a lot of variation in the product being provided.

It has been suggested that the transport system may be causing the fine dust but this does not correlate to the results found, as all these samples were taken from the salter. The day to day variations in the amount of salt dust visible also points towards a variation in the salt being supplied, rather than a transport system problem causing the dust.

To reduce the problem, a new specification of cheese salt with fewer fines would be ideal. A second possible solution would be to redesign the cyclone that is used to separate the air from the salt, above the top salt hopper, so that it also removes the fine salt dust. This may lead to a disposal problem of up to 500kg of fines per day, if the salt supplied is nearing its fines limit of 18%.

5.3 Particle Distributions

Particle distribution on the Alf-O-Matic has been identified as an area of concern. Particle distributions were carried out on the 4th belt. Samples from each of the distributions were then tested for salt, moisture, fat and pH using the standard test methods. The fat and the moisture variation did not give any conclusive results. However large variations in the pH and salt levels were found.

Samples of washed curd cheese (Colby) were taken on 28 April 1998 and Cheddar samples were taken on 8 May 1998. Figures 5.9 and 5.10 are photographs of the different types of curd particles, in the different size ranges.

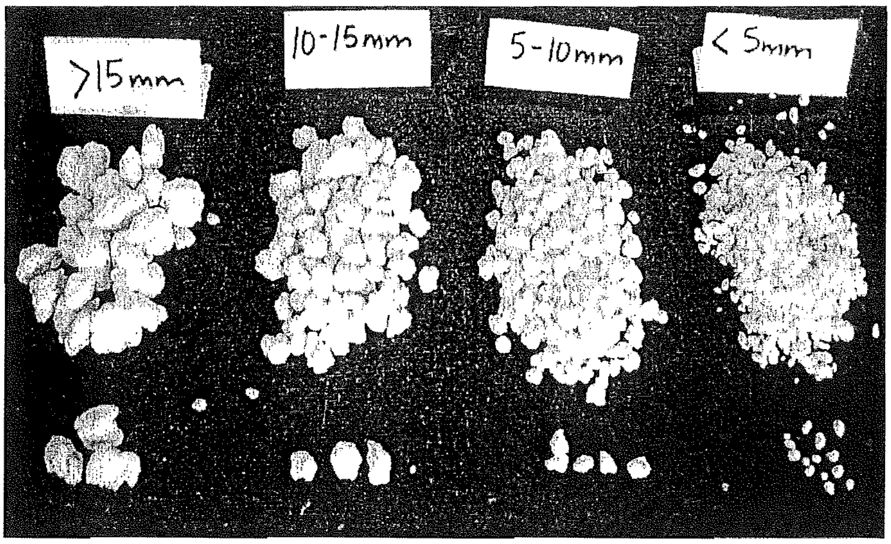


Figure 5.9 – Particle sizes for Colby curd

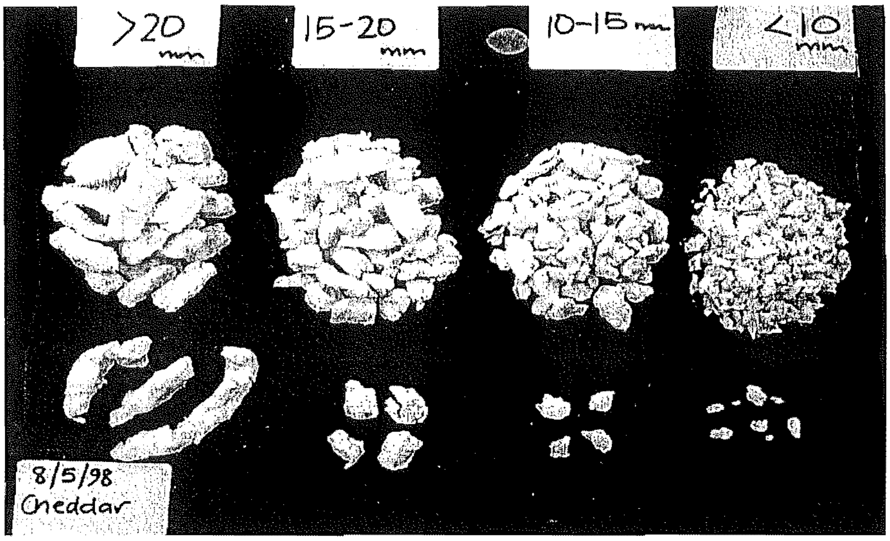


Figure 5.10 – Particle sizes for Cheddar curd

A linear relationship was found between the curd particle size and both pH and salt levels. The large particles have low salt content and a low pH and the opposite is true for the small particles. The pH is related to the level of salt in the curd particle, as increased salt levels reduces the growth of lactic organisms and therefore reduces the rate of acid development. These relationships can be seen for both cheese types in figures 5.11 and 5.12.

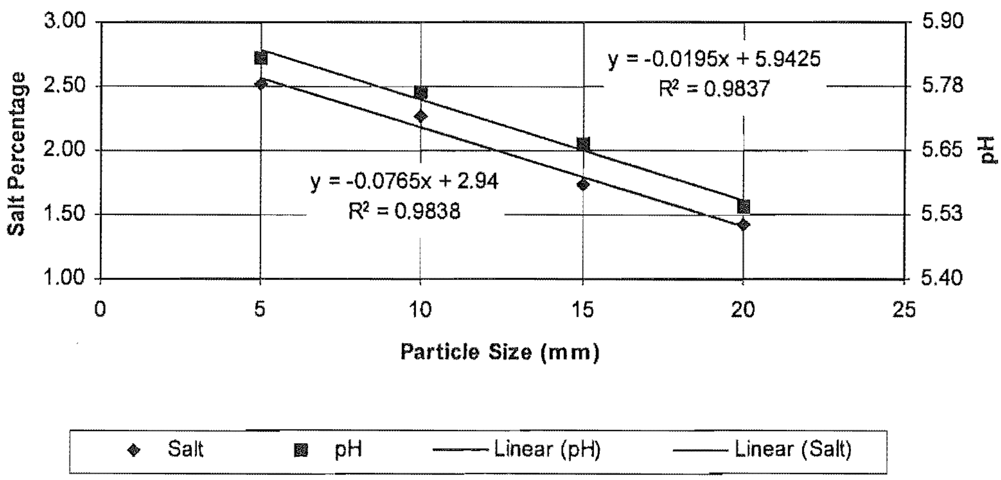


Figure 5.11 – Salt and pH levels with particle size (Colby Curd 28-4-98)

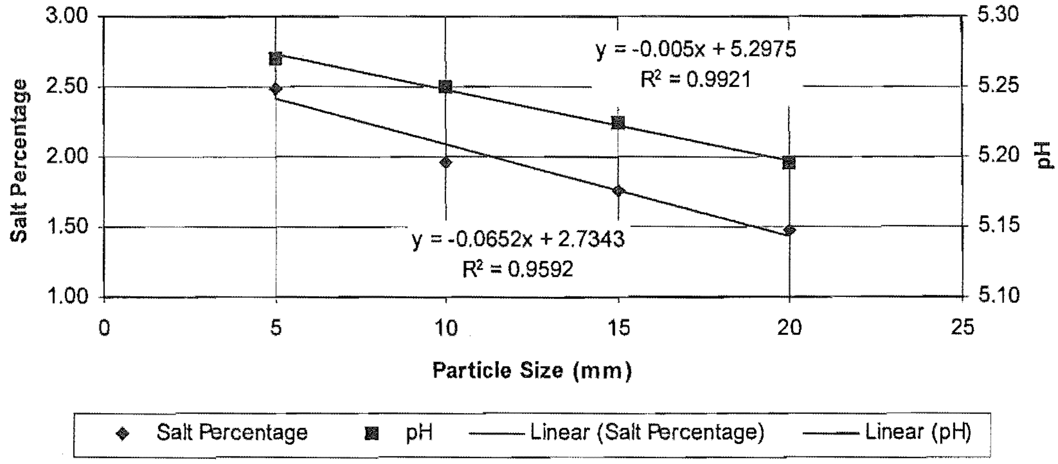


Figure 5.12 – Salt and pH levels with particle size (Cheddar Curd 8-5-98)

From a simple diffusion analysis the salt concentration was expected to be proportional to the area/volume ratio of the curd particles. Thus it was expected that:

$$\text{Salt \%} \propto \frac{1}{\text{Diameter}}$$

The actual relationship between particle size and salt levels was found to be:

$$\text{Salt \%} \propto \frac{1}{\sqrt{\text{Diameter}}}$$

This equation was found to correlate the salt levels to particle size very well for both Colby and Cheddar Cheeses.

The results for variations in the moisture and fat contents are not directly related to particle size, this indicates that they are caused by other variations in the process. These variations are more likely to be occurring because of the variations in curd height on the belts of the Alf-O-Matic (Section 5.1) or variations in the cutting speeds of the OST tanks (Section 4.1).

5.4 Auger Box

The auger box is at the end of the Alf-O-Matic. It collects all the curd for transfer to the block forming towers.

The variation of salt content that has been found should not affect the final product as long as all the block forming towers are fed the same proportions of large, medium and small particles. This mixing was thought to be occurring in the auger box at the end of the Alf-O-Matic. The blocks made up on 28 April 1998 demonstrated this. Figure 5.13 shows the results of blocks made up in the cheese development centre with particles from the different size ranges. The values in the brackets are from 60 day testing.

Size (mm)	Particle Size (%)	Salt (%)	pH	Fat (%)	Moisture (%)
<5	100	2.26 (2.27)	5.85 (5.41)	33.4 (35.3)	36 (41.0)
5-10	100	1.99 (2.13)	5.77 (5.41)	33.3 (35.1)	36.2 (40.1)
10-15	100	1.70 (1.71)	5.66 (5.48)	33.0 (34.8)	36.8 (39.3)
>15	100	1.35 (1.39)	5.54 (5.61)	32.5 (34.5)	37.5 (38.9)
Weighted	17/34/27/22	1.89 (1.84)	5.71 (5.41)	33.2 (35.9)	37.1 (40.4)

Figure 5.13 – Results from the blocks made up from particle in the different size ranges (28 April 1998)

While watching the auger level vary, it was noticed that there was a high level of particle stratification occurring. Due to the way the curd is drawn to the towers this variation in the particle size in the auger box was suspected to be affecting block salt levels.

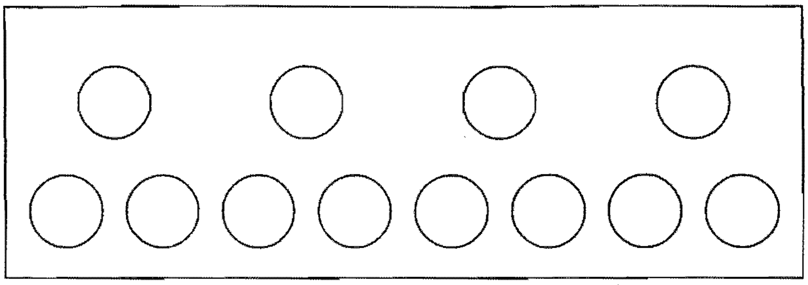


Figure 5.14 – Auger box outlet positions

A trial was carried out to see what effect the level of the auger box had on the salt levels of the blocks from the block forming towers. This trial was carried out on 5 May 1998 on Edam cheese. The level was manipulated by switching on and off towers. The level was recorded by manually estimating the height of curd on a scale of 1-5. 60 blocks were taken as the sample, 54 were from tower 10 (now called tower 7) and 6 from tower 9 (this tower was in the position of the new Twin Vac tower 8)

Each block was analysed for salt and pH.

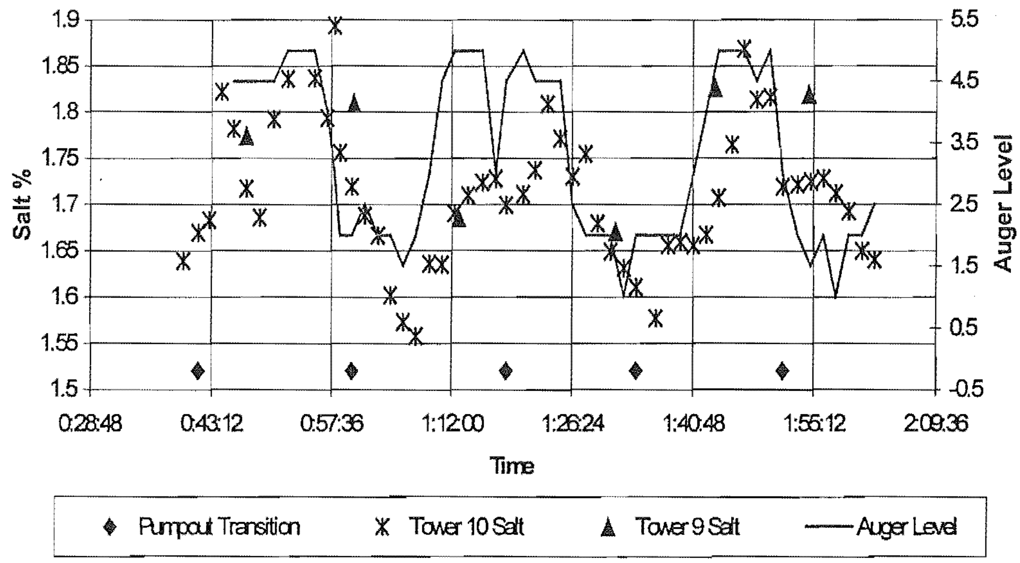


Figure 5.15 - The effect of the auger box level on block salt levels

It was suspected that due to the variation in the salt levels with particle size, particle stratification in the auger box would have a large effect on the salt levels in the block. This relationship is clearly shown in Figure 5.15, to have a major effect in the salt levels of the blocks. When the auger box is at a high level smaller particles with higher salt content are drawn to the towers, hence producing blocks with higher salt content.

Initially it was proposed that the auger box be run at a consistently low level. This idea has been modified to a consistent level, as the block forming towers should not be allowed to suck too much air, because this is suspected to be the cause of cracked blocks (particularly on low fat cheeses, such as low fat cheddar).

It was proposed that a control strategy be developed to allow the level in the auger box be controlled by some method. After investigation of a number of possible options including radar and ultra sound, a capacitance probe appeared to be the only option that would be suitable due to the number of moving parts in the area of the auger box.

A Vega 24 probe and a Drexelbrook 508-45-9 (24 V DC) probe where tested by Jane Newbald (Cheese Development Technologist, Anchor Products Hautapu) and Rachael Simms (Anchor Products Hautapu). Both probes level responses were tested in water and in cheese curd. The probes were also subjected to disturbances that are likely to occur in the auger box such as: curd hitting the probe, the effect of fat build up, slight changes of conductivity, stainless steel in close proximity to the probe, and the effect of a motor running near the probe.

See Appendix B for the results graphs of the probe data.

From the results of the work done the probe worked very well for the purpose intended of indicating curd level. It also seemed very resilient to all of the disturbances introduced to the probe with the exception of stainless steel which can be tuned for during installation.

Once the probe is installed a trial will be carried out to see whether or not it is possible to use the block forming towers to control the height in the auger box, as well as trying to optimise the performance of towers to get more uniform residence time for blocks in all towers.

A method for using a probe to control the towers using sequencing is explained in section 6.3.

The current auger box system is due to be replaced with a Rotary cowl in the upcoming off-season. Work is still continuing on the capacitance probe as level control of the rotary cowl may be required. Sequencing of the towers will definitely be needed to get the best possible performance out of the towers.

Figure 5.16 shows the relationship between the curd height in the Rotary Cowl at the Lichfield Cheese Factory and salt levels in the blocks. It can be seen that variation in the height of a rotary cowl is not as important as it is in the auger box. The level in a rotary cowl is thought to have no affect, as plug flow should be occurring, due to the design.

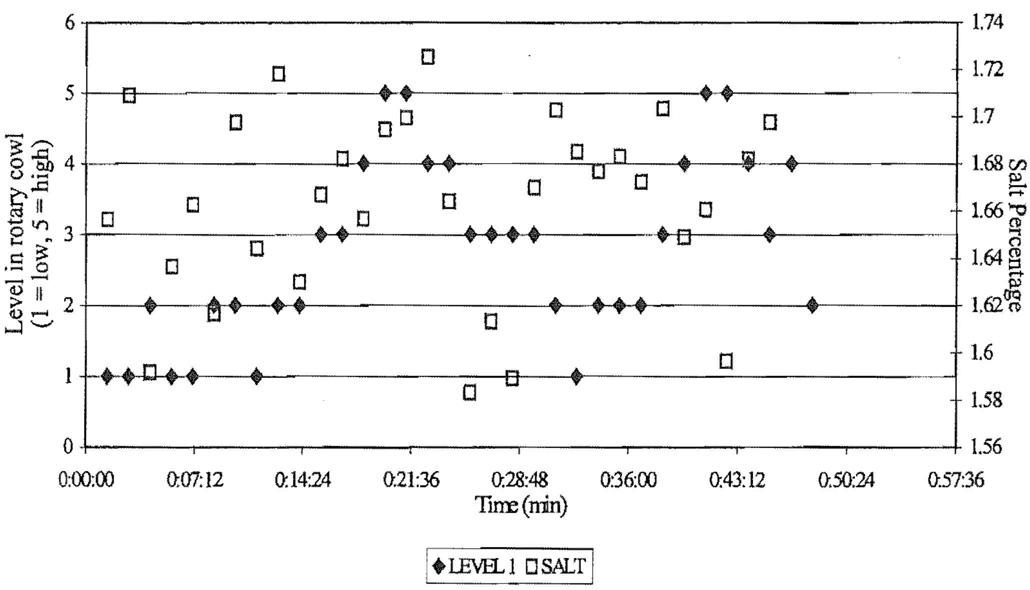


Figure 5.16 – Relationship between salt level in the final cheese block and the level in the rotary cowl at Anchor Products Lichfield.

6 Performance of the Block Forming Towers

The block forming towers at Anchor Products Hautapu are not connected to the site wide PLC network. Therefore it is not possible to easily collect data from the towers. The type of information required is the time elapsed between curd draws from the Alf-O-Matic and block ejection rates.

With this information and a unique bar code with the time and date on it would be possible to trace any block problem, whether it be a microbiological issue such as coliforms or foreign matter, back to the source tank or to the time it was on the Alf-O-Matic. With this information available, it will minimise the time required to find and eliminate the problem.

It would also allow problem areas of a days production such as moisture spikes or large salt variations to be investigated with some certainty. For example, if there is a sample block with low moisture it may be traced back as far as its source silo. It may then become apparent that a silo change had occurred and entrained air may have caused a weak gel which in turn produced very open and grainy curd particles, which will lose moisture and fat easily.

6.1 Cold Curd

It is impossible to look inside a block-forming tower during production. It is suspected that if a tower sucks air for any period of time it will result in the air that comes in with the curd rushing across the top of the curd in the tower before being sucked out the outlet. This air movement will cool down the top layer of curd, so when more curd does arrive it will not bond as well as it should. The result is a large crack in the block produced. Figure 6.1 shows the suspected air movement.

This problem should be reduced with improved level control at the auger box.

1 – In feed from the Alf-O-Matic.

2 – Air drawn out by vacuum system.

3 – Curd already in tower

Arrows – Suspected airflow patterns.

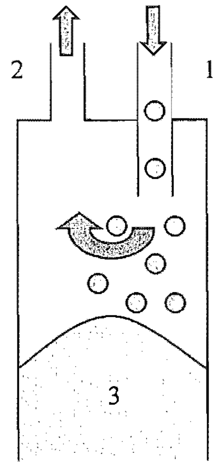


Figure 6.1 – Air flow diagram for the top of the block forming towers.

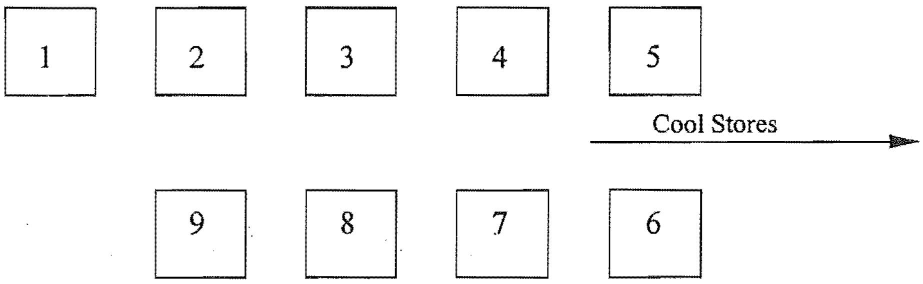
6.2 Tower Sequencing

A bottleneck in the system has been identified at the weight check scales of the block forming towers. The reason for the problem is that there is no set pattern for tower operation therefore it is possible for up to four blocks to be ejected from one side, at any one time which interrupts the smoothness of operations at the scales. This is due to the way that the towers are cycling, as they are all independently controlled. At any one time there may be up to 6 of the 9 towers trying to draw curd from the auger box. This will result in variations in cycle times between towers as some towers will be sucking more air than others (sucking air is also undesirable) and therefore have a longer curd drawing steps than other towers. The variation in curd drawing time will result in the processing conditions varying between blocks, resulting in blocks with different moisture levels and cracks.

It has also been identified that the changing level in the auger box has an effect on the salt levels of the curd due to particle stratification. With the curd draw off running as it is at the moment it seems to be exaggerating the problem by creating an inconsistent demand for the curd. For example at any one time there may be 6/9 towers drawing curd and hence the level in the auger drops rapidly. Then there may be no demand for curd for a period of time, therefore the level in the auger box will increase swiftly.

To solve this problem it is proposed to have the towers suction step controlled by a centralised PLC (PLC on one tower). The control should include a maximum number of towers allowed to be sucking at any one time as well as a number of constraints.

Connection of the block forming towers to the site network would also be desirable, as this would enable the ability to log data from each tower and the weight check scales, as well as the ability to check and change programs from outside the production area.



Figures 6.2 – Order in which the block forming towers are currently set out.

Towers 1, 2 and 9 are the oldest towers and are rated to handle 750 kg/hr. These towers do not have the same control system as the other six towers. They have Wincanton controllers so a relay would be required on each of these towers to enable communication with them for the tower cycling system to include them. Logging data from these towers would not be possible, but this is not a large concern as these towers are only used to make up production capacity. They are also due to be made redundant by increasing the capacity of towers 4, 5, 6 & 7 to 1600 kg/hr.

Towers 3 and 8 are both new "twin vac" towers rated to handle 1600 kg/hr. The last four towers 4, 5, 6 and 7 are rated to produce 1000 kg/hr. The later 6 towers already have the ability to communicate with each other.

The proposed constraints required to get a more continuous draw off of curd from the auger are:

1. Maximum of 4 towers sucking curd at one time.
2. Towers 3 and 8 cannot be drawing curd at the same time.
3. Towers 4 and 5 cannot be drawing curd at the same time.
4. Towers 6 and 7 cannot be drawing curd at the same time.

The first two constraints are suggested to try to maintain an even curd drawing rate from the auger box. The latter two are to eliminate the bottle neck problem by forcing the towers into a pattern that will only allow a maximum of two blocks to be ejected at any time per side.

There should also be a manual/auto switch so the queuing system can be switched off in case of curd build up at the auger.

6.3 Proposed Control System Using a Capacitance Probe

The first constraint as explained in the previous section, which determines the maximum number of towers drawing curd, is the target for the control using a capacitance probe. Figure 6.3 below shows the proposed position of the capacitance probe.

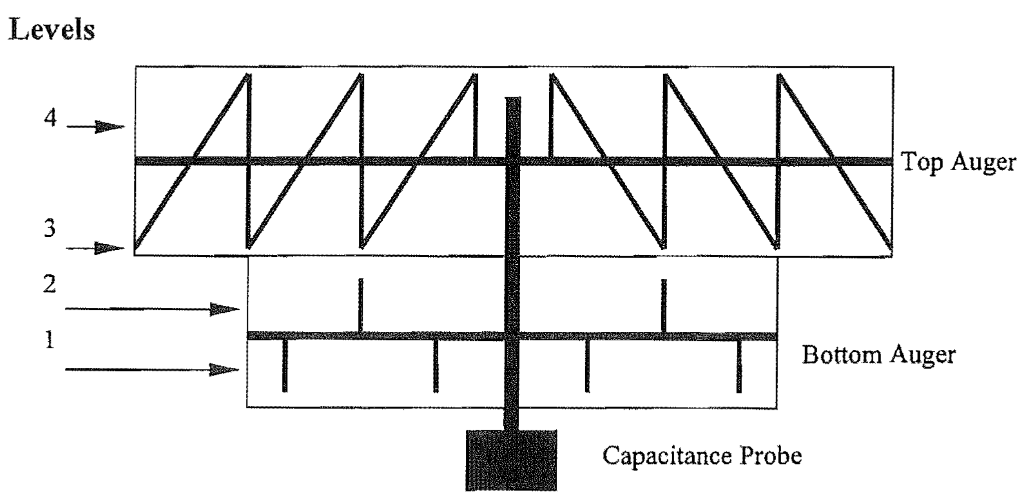


Figure 6.3 – Auger box with capacitance probe installed.

The system will require a start up and shut down procedure as the towers have to be filled and emptied. But is should be run in conjunction with tower sequencing.

For general running the following operations should occur at each of the levels indicated in Figure 6.3.

Level 1

When the curd is at level one on the probe or low level, the maximum number of towers allowed should be reduced by one and a timer started. If the level on the probe reaches another level setting the system should move through that levels algorithm and the timer reset. If the timer reaches its setting (eg. $t>30$sec), then a second tower should be removed from the maximum number of towers allowed to be running and the timer reset. This will continue until the another level setting is reached.

Level 2

If the curd is at level 2 (the optimum auger box level) the system should continue to operate at its current settings until one of the other level settings is reached, and the system then should move on to the new levels algorithm.

Level 3

The level 3 setting is a high level setting and it can be reached from both level 2 and level 4. Therefore level 3 will have two algorithms, one for when the system is coming from level 2 and one for when it is coming from level 4, depending on the last level setting of the system. If the level of the auger box reaches the level setting for either level 2 or 4 the algorithm for the respective level should be followed.

If the system is coming from level 2, one more tower should be added to the maximum number of towers that are allowed to draw curd at any time and the timer reset. If the timer reaches its setting (eg $t>30$sec) then a second tower should be added to the maximum number of towers allowed and the timer reset. This will continue until another level setting is reached.

If the system is coming from level 4, the level 3 algorithm should be ignored as the system should be trying to reach the level 2 setting. Because more towers can be turned on, the system should be left with all towers going until level 2 is reached.

Level 4

If the level 4 setting or extreme high level setting is reached then all available towers should be turned on, so as to rapidly reduce the level in the auger box. Once the level 2 setting is reached the system should move into the level 2 algorithm.

This system may require a number of adjustments during commissioning. Modifications to the operation of the system will also depend on the length of capacitance probe that can be installed into the auger box.

7 Overall Process

7.1 In Process Testing

To gain good control of a process it is important to have good feed back so that one always knows what the plant is doing and how it is affecting the product. This is in addition to the automatic process control already discussed.

The In-process testing feed back that is currently carried out at the Hautapu Cheese Factory is:

1. Whole milk fat, protein, lactose and total solids. One sample per silo. (225,000L)
2. A Delvo test is carried out to detect for the presents of antibiotics (e.g. streptomycin or penicillin) and chemotherapeutic agents in the raw milk, as these may inhibit the growth of starter organisms. 1 sample per silo. (225,000L)
3. Traceable acid test - high temperature storage of the cheese milk can lead to developed acidity and hence poor flavors. It is also important for the pH not to be too high as milk with a pH of above 7 will deactivate the starter. 1 sample per silo. (225,000L)
4. Standardised milk fat and protein. 1 sample every 3 hrs. (≈200,000L)
5. Cut pH – this is done ≈5 minute into the cut. Carried out on each vat.
6. Run pH – this is done when the vat is due to run to the AOM. Carried out on each vat.
7. Dry pH – the sample is taken from belt 1 on the AOM. Carried out on each vat.
8. Mill pH – taken from the salter weigh belt before the salt is applied. Carried out on each vat.
9. Block from tower – salt, moisture, fat and pH. 1 sample every hour. (≈300 blocks).

Feed back from the system includes the following:

1. Milk flow rates.
2. Starter, rennet and process water volumes.
3. Mass flow rates on the belts.

There are a number of areas that more feedback would improve the control of the system.

- After the coagulation step the gel strength should be checked. This can be done by moving two fingers up through the gel, the way which the curd breaks indicates whether or not the gel is ready to be cut. This method allows the operator to know whether or not the coagulation time is about right or whether it needs to be shortened or extended.
- Another possible solution would be to install an opti-set/coagulite probe, which could possibly relate the opacity of the gel to the gel strength and hence optimise the coagulation time.

It is known that good control over the final product properties must be gained at the vat. Currently at Hautapu the control of the vats is minimal and may need attention.

Due to the nature of the cheese making process there needs to be a considerable amount of operator – process interaction. Cheese making still relies on skilled cheese makers to control the properties of the final product. Therefore it is important to get as much feed back from the process as possible.

If variation occurs the cheese maker may need to change one of the key variables in the process.

- Cook temperature.
- Starter volume.
- Coagulation time.
- Cut speed.

- Final stir time.
- Number of stirrer in operation on the AOM.

7.2 Extra Equipment

The following are pieces that are recommended to help improve the overall control of the process, especially around the OST tanks:

- A control station placed on the bridge. (A water proof touch screen type would be most suitable) This would allow the bridge operator to have input into the process for flushing tanks and holding tanks back to allow the pH to develop further.

- An electronic recording pH probe so that the data is automatically recorded. Currently the pH samples taken by the bridge operator are recorded manually in daily logbooks. If the samples were automatically collected in a database, it would not only eliminate exterior interference with the results but would allow for statistical process control methods to be used to suggest changes in starter levels to be made to the operator.

8 Conclusions

This project has shown that using a systematic approach to go through a process can be very beneficial for identifying problem areas. Some of the variations found may initially seem small but can have large implications further down stream in the process. These larger down stream variations could possibly have been missed if a through understanding of the entire process had not been used. It therefore goes to show the importance of this work in optimising the process.

8.1 Standardisation and Pasteurisation

Implementing a PLC based system that automatically calculates the correct fat content required in the standardised cheese milk could increase the accuracy of the standardisation process.

The secondary hot water system for milk treatment and the cheese factory requires further investigation. This is to try to maintain a constant temperature to the pasteurisers to minimise the number of diverts that occur, resulting in lost production time.

8.2 OST Tanks

Variations in the cutting speeds of the OST tanks were identified as a problem, causing variations in the particle distributions between OST tanks. The cutting speeds were recalculated from the specifications of the motors, gearboxes and variable speed drives on each OST tank. A system has also been proposed for taking into account the increased cutting speed required for the first tank of the day.

Each OST tank was being flushed with 18°C water at the end of each batch. This was undesirable as it reduced the level of moisture expulsion from the curd. This has since been changed and the tanks are now flushed with water at 40°C.

It has also been suggested that the automated low level flushing of the OST tanks be re-implemented.

8.3 Alf-O-Matic

It has been shown that a large proportion of the variation in the cheese making process at Anchor Product Hautapu comes from the Alf-O-Matic. The curd depth on the belts has been found to be contributing to variations in the moisture levels in the curd, which then affects the salt and fat levels. Two solutions have been proposed to eliminate this problem. They are:

1. To overlap the ends of the pump outs between consecutive OST tanks.
2. Continuous re-calculation of the pump out recipes.

The salting system had extensive testing to try to ascertain if it was the source of major variation in the process. The results showed that the salter was performing very well.

The PID loop for the correction factor (K factor) on the salting wheel was found to have a slight oscillatory response. Increasing the gain in the PID block in the PLC has eliminated this oscillatory response.

Salt becoming caked on to the load cells on the salting system, causing poor performance in the salting has been minimised by washing down the load cells with hot water before production begins each day and blowing them down with compressed air at the production mid run break.

Completely removing the salt dust problem would be ideal. This would involve getting a new specification of cheese salt or redesigning the cyclone that is used to remove the transport air from the system so that it would also remove the fine salt dust.

Particle size has been found to affect the salt content of the curd. With particle stratification occurring in the auger box this results in variation in the salt content of the blocks that are produced. The use of a capacitance probe to measure and control the height in the auger is currently being implemented to try to reduce this problem.

8.4 Block Forming Towers

Cracked blocks of cheese produced from the block forming towers is thought to be due to air being sucked from the auger box when it is at a low level. Control of the curd drawn off from the auger box should minimise this problem. The block forming towers require a combined control system to minimise the time spent sucking air and variations in the residence time in each tower. The proposed system is a combination of towers sequencing and making use of the capacitance probe which is to be installed into the auger box.

8.5 Overall Process

Feedback in the cheese making process has been identified as being important. The main area where this information is lacking is around the OST tanks. Further information is required to insure that the optimum coagulation time is used at all times.

Automatic pH recording would also be beneficial to the control of the process and would allow the possibility of using the data for statistical process control of the starter addition. Having the data already collected in a database would also allow easy access to it from anywhere on site for analysis.

9 Recommendations

Recommendations that have already carried out:

- Replacing cold water used for flushing the OST tanks with flush water at 40°C.
- Manual calculations for improving pump-out recipes to reduce the mass-flow variations on the belts of the Alf-O-Matic.
- Eliminating the variation in the cutting speeds between the OST tanks, by recalculating the cutting speed settings taking into account the different mechanical set up on each OST tank.

Recommendations that are currently being worked through in order to implement them:

- Over lapped pump-outs to minimise the variation in the curd depths on the belts of the Alf-O-Matic.
- Connecting the block forming towers to the site wide PLC network, which will allow data logging. The connection to the network will also allow sequencing of the block forming towers to be implemented with ease.
- The use of a capacitance probe to control the curd height in the auger box.

Further recommendations, which will help to minimise the variation in the product:

- Investigation of the secondary hot water system to minimise temperature fluctuations that cause the pasteurisers to divert.
- Re-automation of the standardisation process from the current Alfa Laval Automatic Direct Standardisation (ADS) system to a PLC based standardisation system.
- Automated re-calculation of pump-out recipes so the operators using the Intouch program can do it quickly and easily.
- Replacement of the variable speed drives on the agitators of OST tanks 39 and 40 and curd pump one, with modern types which allow for more accurate control over the motor speeds.

- Electronic data collection of pH values taken by the "bridge" operator, for the purpose of statistical process control of starter levels in the cheese recipe.
- Investigation into methods of optimising the coagulation time, such as using an "opti-set" or "coagulite" probe.

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Salt Application Trials

The continuous salting machine was tested to determine whether it was contributing to the block to block salt variation during cheese manufacture. An initial trial was conducted to determine whether the correct mass of salt was being applied for a given weight of curd passing over the curd weigh belt. As shown in Fig. 3.1, the quantity of salt applied to the curd compared to the calculated amount (based on the curd weigh belt) varied. Oversalting was generally observed, however the amount by which the salter was varying from the required amount was not consistent.

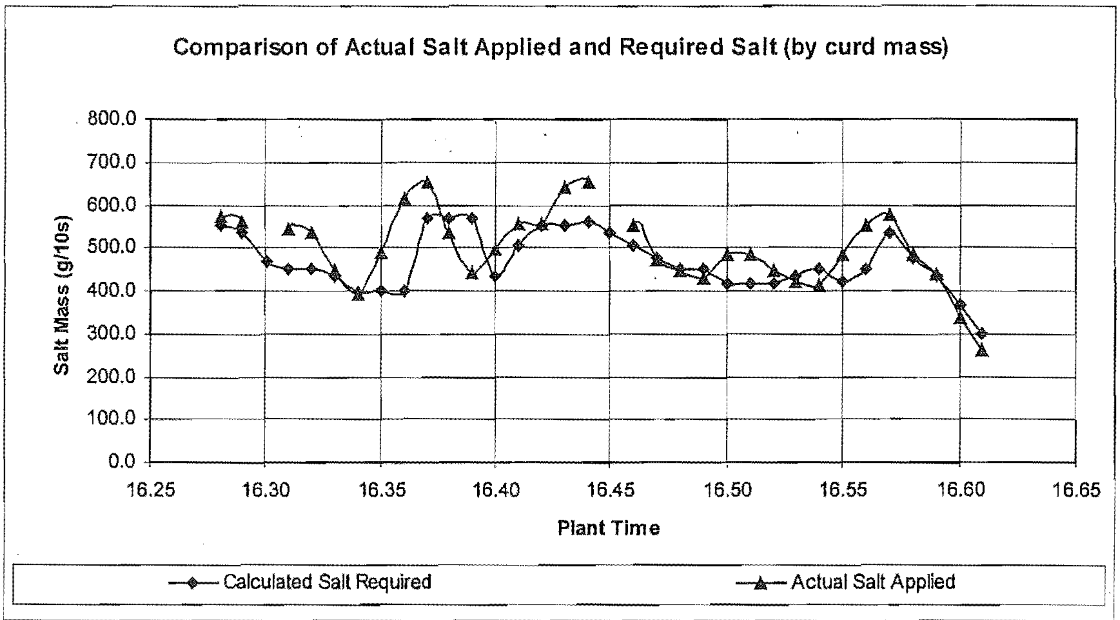


Fig. 3.1: Comparison of the Salt Applied with the Calculated Salt Required

Due to these results showing that there may be variation in the amount of salt applied by the salting system, five features of the salting system were tested to determine if they were operating efficiently.

These were

1. The salt wheel speed.
2. The gap between the salt hopper and the salt wheel.
3. The curd weigh belt accuracy (static and dynamic).
4. The salt wheel motor.

5. The K factor

3.3.1 The Salt Wheel Speed

The salt wheel was tested at set speeds (25-65 Hz) as well as acceleration and deceleration at 0.2 Hz/s. The following trends were observed:

- At a given wheel speed more than the calculated salt mass was applied.
- The linearity of the salt applied in the 45-65 Hz region was acceptable (shown in Fig. 3.2).
- As the wheel speed increases, the variation in the amount of salt applied increases ie. lower wheel speeds release a more accurate quantity of salt over a given time period.

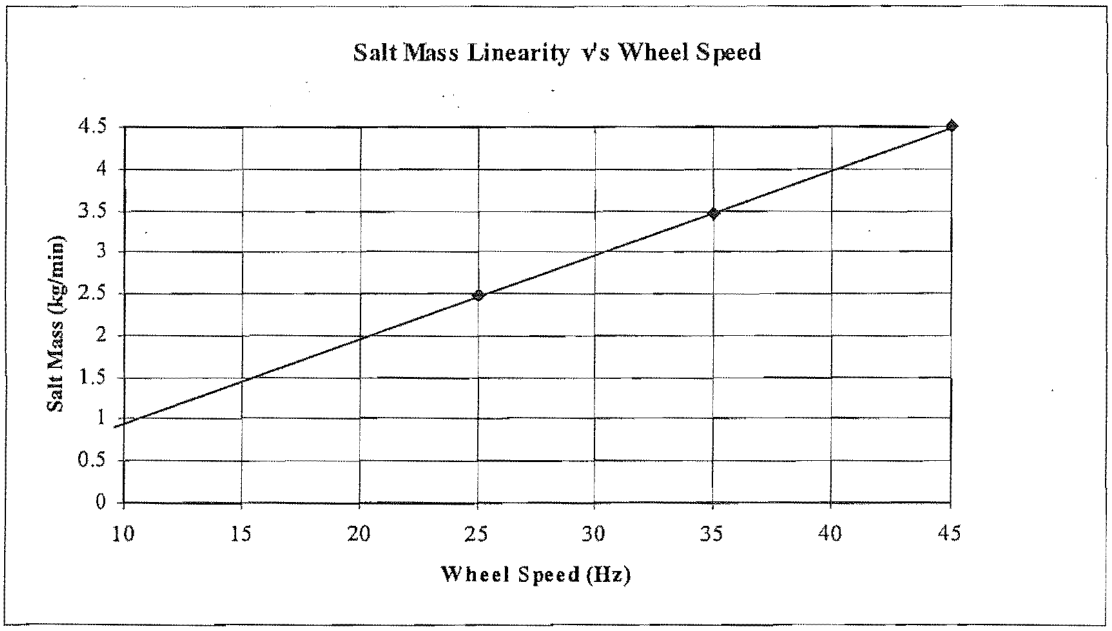


Fig. 3.2: The Linearity of Salt Application by the Salt Wheel

3.3.2 The Gap Size Under the Salt Wheel

The normal gap size of 3.0 mm was trialed (at constant wheel speeds), as well as a large gap of 6.2 mm. The following trends were observed:

- a linear relationship between wheel speed and the salt flowrate is observed, even when the gap size is increased (shown in Fig. 3.3).

- a 35 % increase in the amount of salt applied to the curd was recorded when the gap size was opened from 3.0 mm to 6.2 mm.

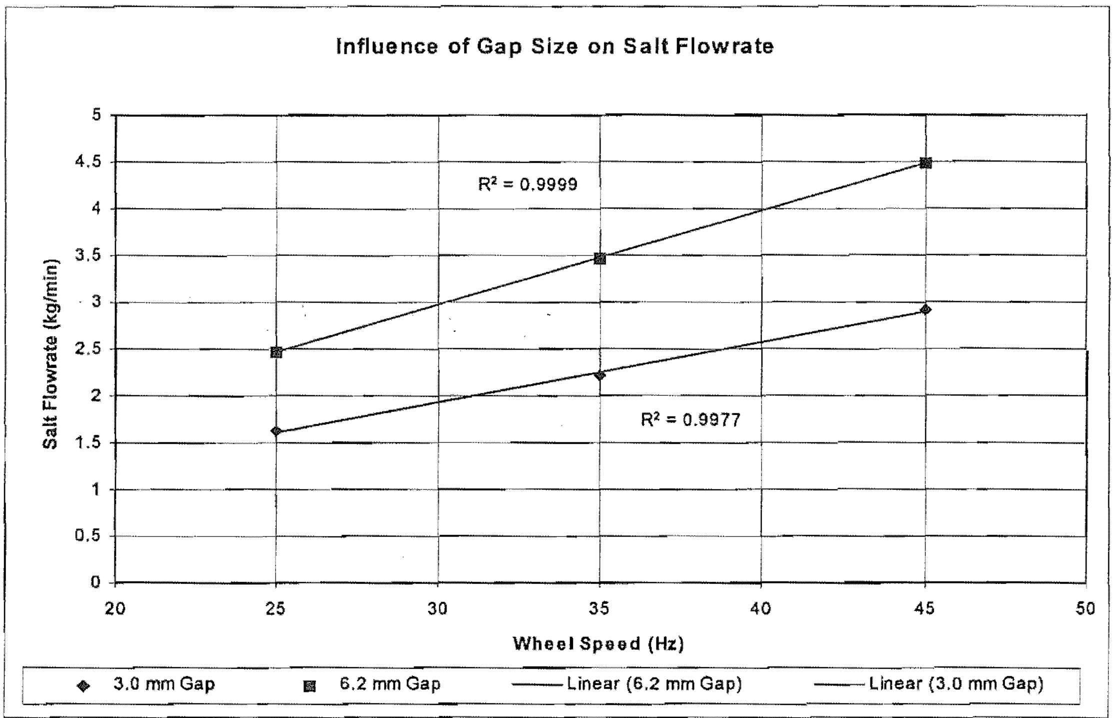


Fig. 3.3: The Effect of the Gap Size on Salt Flowrate

During the salt application trial data (from In Touch trends) was recorded to measure whether the salt wheel speed was reacting fast enough to alter the amount of salt being deposited on the registered curd mass. Fig. 3.4 shows that the salt wheel speed tracks the curd weight very well.

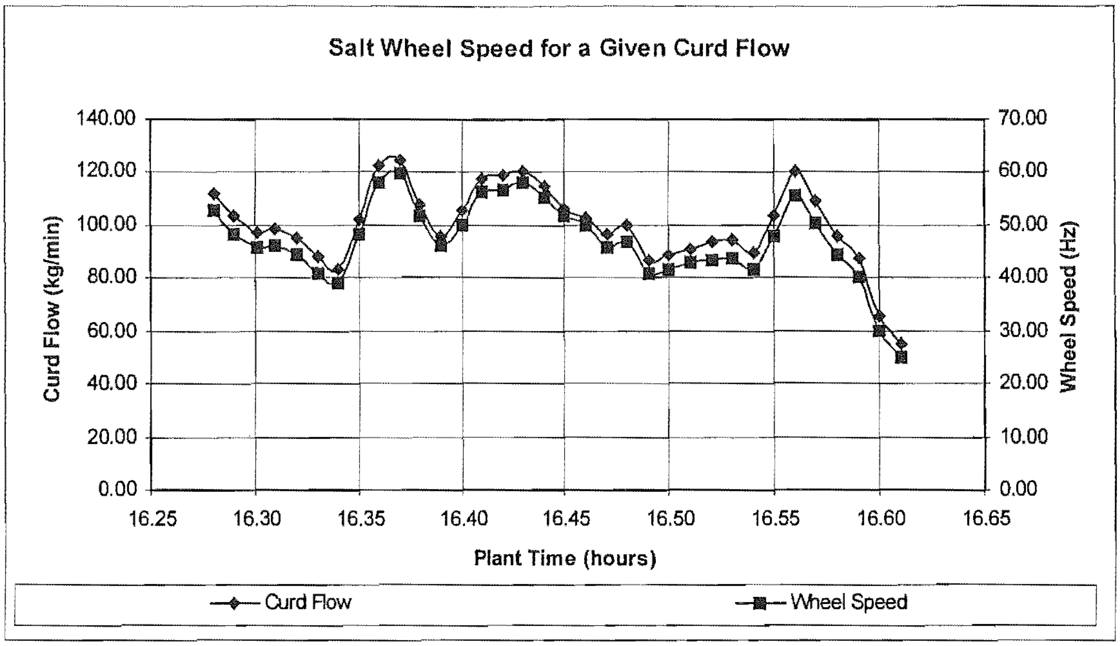


Fig. 3.4: The Salt Wheel Speed for a Given Curd Flowrate

3.3.3 The Curd Weigh Belt

The curd weigh belt was tested statically and dynamically. For the static weight trials, three weights 2.5, 5 and 7.5 kg weights were placed on the load cells. At all of these weights the readings on the process computer were accurate. When the mass on the weigh belt was increased or decreased the unfiltered weight registered immediately in a step change. However, the filtered weigh belt weight slowly changed over a period of 22 s. This indicated that the data filtering (averaging) on the curd weigh belt may be causing a significant delay in recording the curd weight changes in process.

For the dynamic trials pre-weighed quantities of curd were passed over the curd weigh belt at differing flowrates. The weight of curd recorded by the computer was compared to the actual weight of curd. The amount of salt applied to each lot of curd was also recorded. Fig. 3.5 shows the relationship between the salt added and the curd weight.

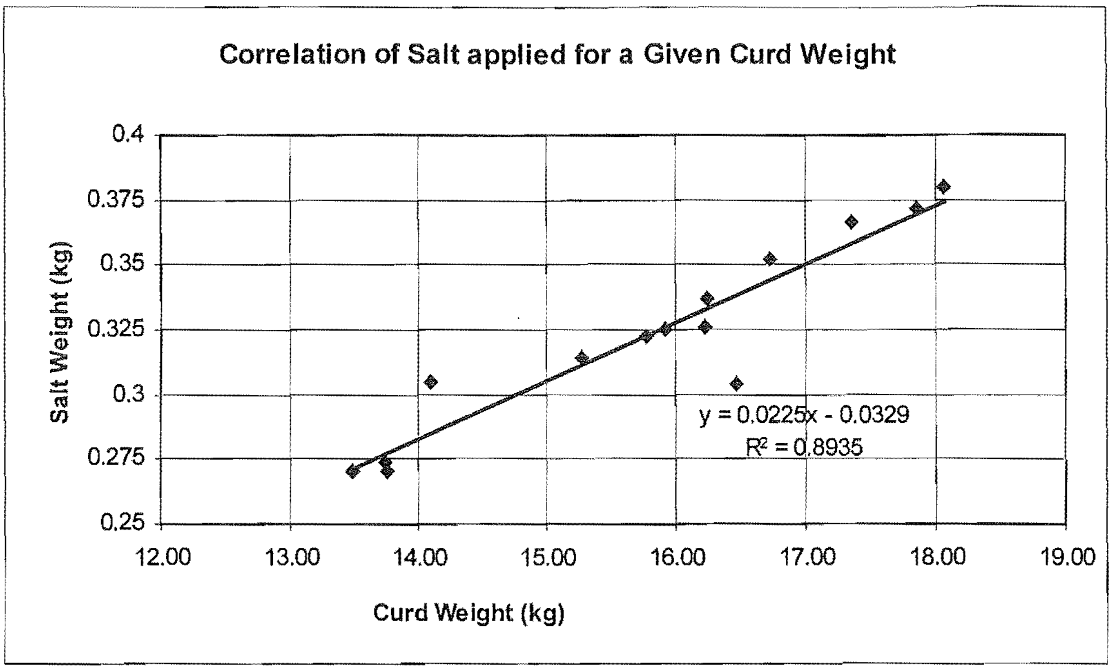


Fig. 3.5: *Percentage Salt Applied for a Given Quantity of Curd*

Figure 3.6 shows the actual weight values plotted against the In Touch weight values. Although the In Touch values (2 s) were recording 1.56 times higher than the actual values (due to multiplication factors in the computer programming) a correlation of 0.98 and a regression of 0.96 was obtained between the two sets of data. This indicates that there is a direct linear relationship between the two sets of data. The In Touch 0.5 s data shows larger variation as there are less points to average than gathered for the 2 s. Therefore it is more accurate to use the 2s data.

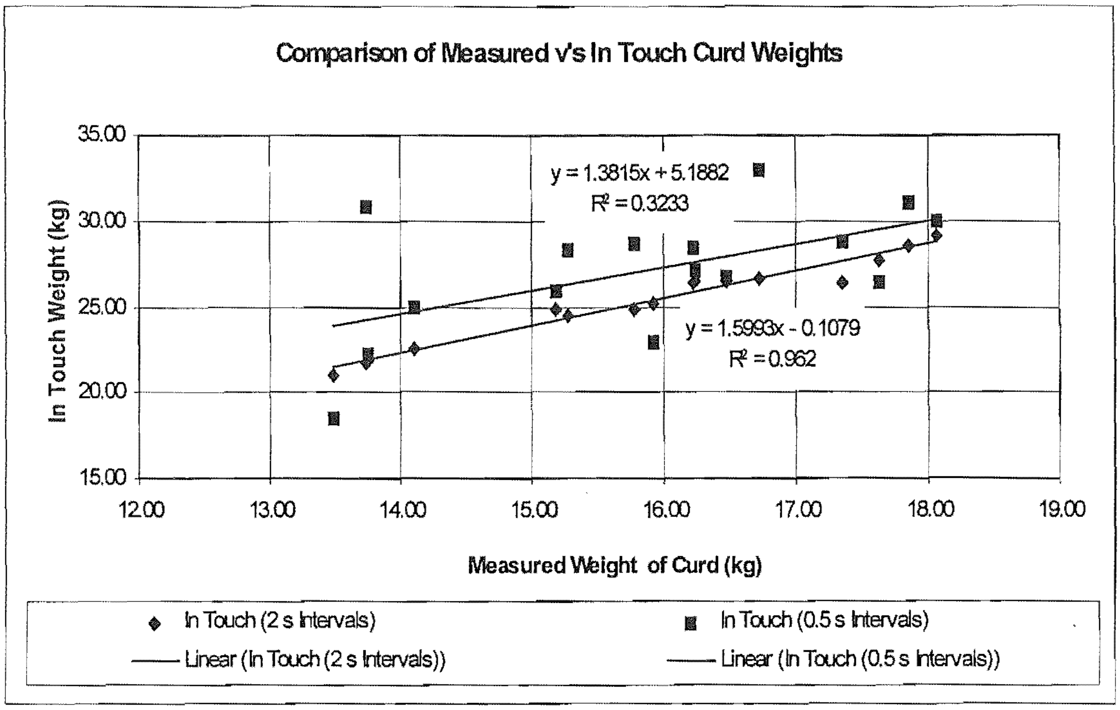


Fig. 3.6: Comparison of the In Touch Data with the Actual Curd Weights

During this trial it was observed that salting begins approximately 2 s after curd starts passing over the end of the weigh belt, therefore at the end of the run salt was being applied when no curd was present. Obviously this may be enhanced by the short trials. However due to the salt application starting late it may mean that there is a 2 s lag during salting, therefore the salt may not be coming into contact with the curd it was meant for.

As a result of the above observation, the operation of the weigh belt was investigated. It was observed that there was a pulsing weight increase every 16 - 20 s (see AOM modification data in Appendix 2). During the production of Egmont High Solids the weight fluctuations were up to 4 kg. However for Egmont Japan, they were up to 1.5 kg. The reason for the pulsing of the curd across the weigh belt was found at the end of belt 3. The agitators that flick the curd into the mill do not extend right across the belt. Therefore the curd was forming a block on one side of the belt which was not being flicked of the belt. Instead it was being dumped off every slat of the belt (approximately 16 s). This surge was then passing through the mill and onto the salter curd weigh belt.

The flickers do not extend right across the belt due to the whey drain above them (belt 1), being too low. Therefore another stirrer peg could not be attached. Instead a piece of stainless steel was welded to the side of the AOM to direct all of the curd under the agitators. The result of this modification was a slight decrease in the pulsing variation across the weigh belt. However druing the production of Egmont Japan (lower curd depth than high solids) curd is still sticking to the belt, below the depth of the flickers. It is then removed by the scraper on the underside of the belt and is being dumped straight into the auger. This means that although the pulsing has been minimised, it is still observed.

IT IS ADVISED THAT BEFORE THE PRODUCTION OF CHEDDAR THAT THIS MODIFICATION IS REMOVED.

Fluctuations on the curd weigh belt were at least partially due to actual curd variation, as opposed to noise on the load cells. Therefore the data averaging on the weigh belt was believed to actually be filtering some of the actual curd mass (not noise). The time averaging on the Modsoft PLC programme was reduced by the electricians. All changes are recorded in the Software Modification Folder in Milk Treatment.

The timers that were changed were:

- 40101 changed from 75 to 45 (reduced filtering on weigh belt from 0.75 s to 0.45 s).
- 40930 changed from 10 to 5 (reduced the number of data points averaged on the weigh belt from 10 to 5).
- 40487 changed from 5 to 2 (reduced timer from 5 s to 2 s).

The effect of these changes was observed on the In Touch trending as a much closer tracking between the weigh belt weight (filtered) and the weigh belt weight (unfiltered).

New Zealand Dairy
Marketing & Customer Services

CONTROL OF THE AUGER BOX LEVEL IN CHEESE FACTORY AT ANCHOR PRODUCTS HAUTAPU

PART 1 - Capacitance Probe Trial

Prepared by: Rachael Simms & Jane Newbald

Date: 12 November 1998

Distribution List:

Anchor Products Hautapu	Gary Smith Gordon Baker Hugh Waters Ben Jones Vernon May Hautapu Cheese Supervisors
Cheese Development Centre	Mike Hedley Peter Brian

SUMMARY

An investigation was carried out to determine whether the use of a capacitance probe would be suitable as a level indicator in the cheese curd auger box at the Hautapu Cheese Factory.

The probe was subjected to a number of actions and disturbances to mimic as closely as possible the environment present in the auger box. The results show that the capacitance probe was a linear measure of curd level. The probe is not sensitive to the following disturbances; curd hitting the probe, stainless steel movement close to the probe, small differences in conductivity, fat build up on the probe and pump and motor action. However the results show some disturbance when stainless steel is stationary close to the probe. This disturbance can be removed by a simple calibration during installation.

Therefore the capacitance probe is suitable for use as a level indicator in the curd auger box. At present quotes are being obtained for the purchase of a probe.

INTRODUCTION

The control of the auger box level in the Cheese Factory at Anchor Products Hautapu has been shown to have a significant influence on cheese uniformity, in particular salt levels. Particle size stratification occurs in the auger box prior to the blockforming towers. At higher curd levels, the large particles move towards the top of the box and the small particles to the bottom. Combined with the salt variation due to particle size, large variations in the salt content of the cheese occur with fluctuations in the auger box level. As the auger box level does not reach equilibrium, the particle size stratification that occurs causes tracking of the final block salt content with the auger box level.

A project was therefore initiated to control the auger box level.

This investigation looks at the use of a capacitance probe, which could ultimately feed a response to the towers to automatically switch on and off when required (at present the towers are manually controlled by the operators).

METHOD

Capacitance Probes

Both of the capacitance probes are manufactured to give a 4-20 mA output as a level indicator. They were calibrated on water and set up to give a percentage output over the 4-20 mA scale. Two readouts were obtained one being a trend directly to the server (scale 0-1,000) and the other an output to a visual readout unit (0-100) close to the probe. These are described as computer and manual outputs respectively in figures and discussion. During the trial the visual readout (manual) was used to monitor effects.

Vega Probe: Vega 24

***Drexelbrook Probe*:** 508-45-9 (24 V DC)

Probe Linearity

Vega Probe – 14/10/98
Drexelbrook Probe – 29/10/98

1. A trial was set up with a plastic bucket containing curd. The probe was inserted to a certain level, measured and allowed to sit for 2 minutes. The probe was then pulled out and again allowed to sit for 1-2 minutes, to allow easy identification from the server trends.

2. The above trial was repeated replacing the plastic bucket with a stainless steel 4-inch pipe blanked off at one end and filled with curd. The stainless steel vessel was required to earth the probe.

3. The above trial was repeated replacing curd with water.

Effect of Curd Movement on the Probe

Vega Probe – 22/10/98
Drexelbrook Probe – 29/10/98 & 6/11/98

1. A small stainless steel balance tank was set up with the probe screwed into the bottom.

2. The following were tested:

Table 1: Curd Movement Trials

Action To Mimic	*How Mimicked*
Curd falling off the belt and falling on top of the probe.	Sprinkled curd with hands on to the probe.
Curd hitting the side of the probe.	Throwing curd at the probe from the sides.
Auger moving the curd up and down the probe.	Using hands to manoeuvre curd up and down, testing at two levels and two intensities.

Effect of Salt Concentration on the Probe

Vega Probe – 22/10/98
Drexelbrook Probe – 29/10/98

1. Three trials were carried out using the same method as the linearity trial. Salt solutions (1 %, 2 % and 3 % NaCl in water) were used for the trials.

Effect of Fat Build Up, Stainless Steel and Vibration on the Probe

Drexelbrook Probe – 6/11/98

1. A trial was carried out to determine if a build up of fat on the probe, or the presence of metal (stationary or moving) caused any disturbances. The trial was run twice (with and without fat), each tested at 4 levels on the probe. Butter was smeared on the probe to mimic an extreme case of fat build up on the probe.

2. The following was tested:

Table 2: Probe Disturbance Trials

Action To Mimic	*How Mimicked*
Fat build-up from contact with cheese curd on the probe.	Butter smeared over the probe.
Stainless steel auger movements near the probe.	Moving a piece of 1" pipe around the vicinity of the probe.
Stainless steel close to the probe.	The 1" pipe was held approximately 0.5 cm from the side of the probe.
Stainless steel close to the probe.	The 1" pipe was placed over the probe, covering it completely.
Vibration disturbances	Probe placed next to a pump, which was switched on, and off.

RESULTS AND DISCUSSION

Probe Linearity

Appendix 1 (fig. 1-4) shows the graphs obtained for water and curd for, both the Vega and Drexelbrook probe (manual and computer output). The following was found:

- Linear relationship obtained for both probes with curd and water.
- A discrepancy was found between the computer and manual output that is enhanced at higher readings. Fig 1 and 2 (Vega) and 3 and 4 (Drexelbrook) show that the values at a given level are higher for water than for curd. This is due to the original calibration of the meters on water. For use in the factory calibration against curd would be required.
- The Drexelbrook and Vega probes showed regressions of 0.998 and 0.973 respectively.
- There is strong reason to conclude that both capacitance probes are linear for water and curd.

Effect of Curd Movement on the Probe

It was necessary to mimic what the probe would experience in the auger box. The methods section describes how these were done.

The following was found:

Curd falling off belt on top of the probe. (Appendix 1 Fig. 5 & 6)

- Curd hitting the top of the probe did not make any fluctuations in the output for either probe.
- The graphs show steady increases due to the level of curd rising.

Curd hitting the side of the probe. (Appendix 1, Fig.7 & 8)

- Curd hitting the side of the probe lightly or intensely did not effect the output.

Auger moving the curd up and down the probe. (Appendix 1, Fig. 9 & 10)

- Slight fluctuations were recorded when imitating the auger action (due to curd movement).
- The fluctuations were small, the two distinct levels (high and low) did not overlap at any stage.

Effect of Salt Concentration on the Probe (Appendix 1, Fig. 11 & 12)

Each probe was tested to see if it was sensitive to different salt concentrations. Three salt solutions were made up, (1%, 2% and 3%), and tested in the same way as water in the linearity trials. The following was found:

- The Vega probe;
  - There were slight differences in output between the salt solutions.
  - An increase in salt percentage caused a slight increase in the output reading.
  - At 100% immersion the reading went off the scale (calibration would solve this problem).
- The Drexelbrook;
  - Less sensitive to conductivity than the Vega probe.
  - No significant differences between salt solution and output

Effect of Fat Build Up on the Probe

The layer of butter smeared over the Drexelbrook probe surface generally caused a slight decrease (average of 1.1 %) in the output compared with no butter at a given level. Fig. 13 in Appendix 1 shows that the effect of fat build up on the probe is minimal and this would not cause a problem in a process situation.

Effect of Stainless Steel near the Probe

The Drexelbrook probe was tested to determine its sensitivity to the presence and movement of stainless steel. Refer to appendix 1,fig.13.

- Movement of stainless steel near the probe (<10 cm) had no effect on the output at given curd levels.
- Resting the stainless steel near the probe (<1 cm) slightly increased the output at given curd levels. As the level of the water on the probe increased the effect of the stainless decreased (9%, 6.6% and 2.1% respectively for levels of 0, 1/3 and 2/3).
- Placing a 1 inch stainless steel pipe over the probe showed the greatest increase at a given curd level. As the level of the water on the probe increased the effect of the stainless decreased (16.1%, 13.7% and 7.5% respectively for levels of 0, 1/3 and 2/3).
- After installation of the probe in the auger box calibration to remove the effect of stationary stainless steel i.e. the auger box housing, near the probe would be required. The presence of moving augers near the probe should have little influence on the output.

Effect of Vibration and Electric Motors on the Probe

Placement of the probe between the pump and its motor had no influence on the output from the probe when the pump was turned on and off a few.

CONCLUSIONS AND RECOMMENDATIONS

The work carried out has tried to mimic as closely as possible the actions and disturbances the probe would experience if installed into the auger box. It has been found that the probe is not sensitive to the following disturbances; curd hitting the probe, stainless steel movement close to the probe, small differences in conductivity, fat build up on the probe and pump and motor action. The results show some disturbance when stainless steel is stationary close to the probe. This disturbance can be removed by a simple calibration during installation. The results indicate that a capacitance probe is suitable for use as a level indicator in the curd auger box.

Both probes trialed, Drexelbrook and Vega behaved similarly, neither one being better than the other.

At present quotes are being sourced for purchase of a capacitance probe. The initial estimated purchase price of the Vega and Drexelbrook probes are $ 2,441 and approximately $ 4,000 (a full quote is arriving this week) respectively. The price difference is due to the Drexelbrook probe being fitted with a remote mounting for the electronics.

Contact with another firm, Applied Instruments, has been made and they offer similar products. The have verbally offered a probe for a 2 month trial in the factory. This would be a chance to install in the factory with no obligation to purchase if it proves unsuccessful.

APPENDIX 1

Figure 1: Vega Capacitance Probe for Curd in Stainless Pipe 14/10/98

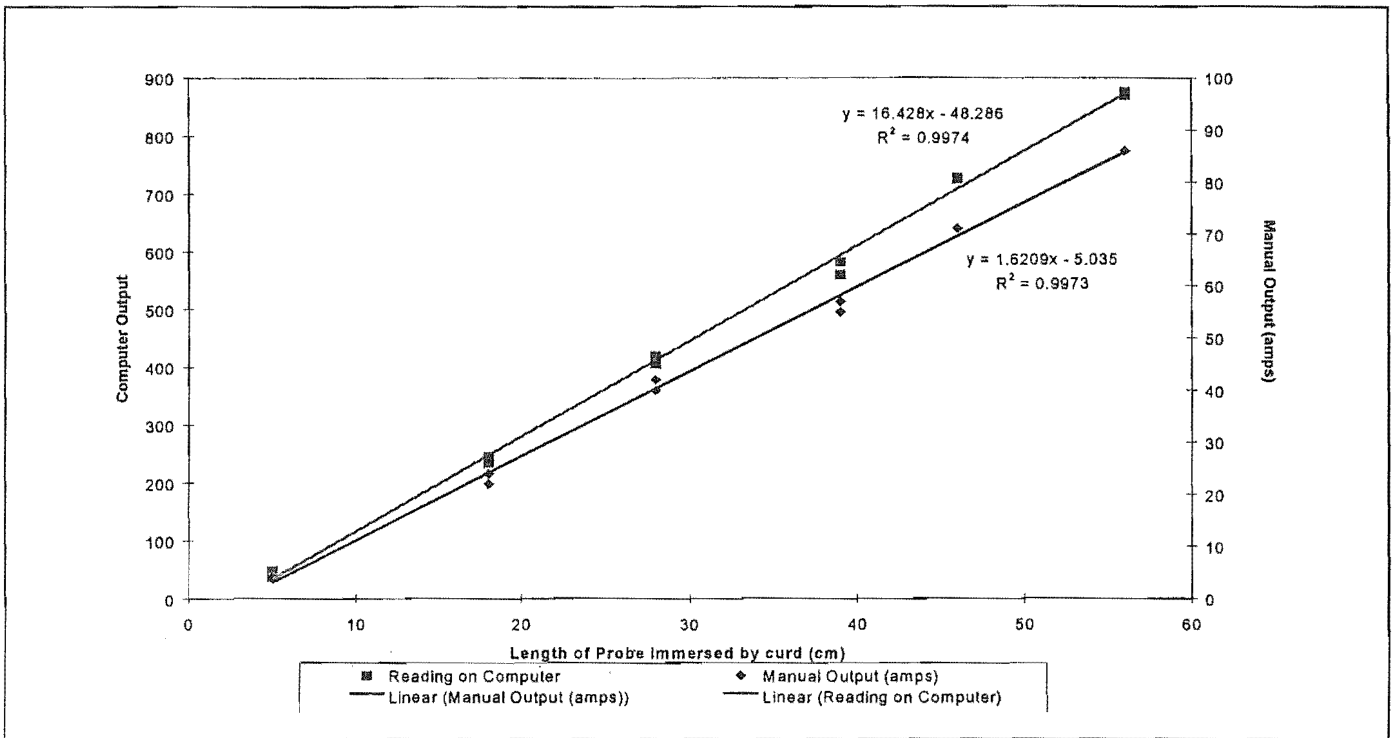


Figure 2: Vega Capacitance Probe for Water in Stainless Pipe – 14/10/98

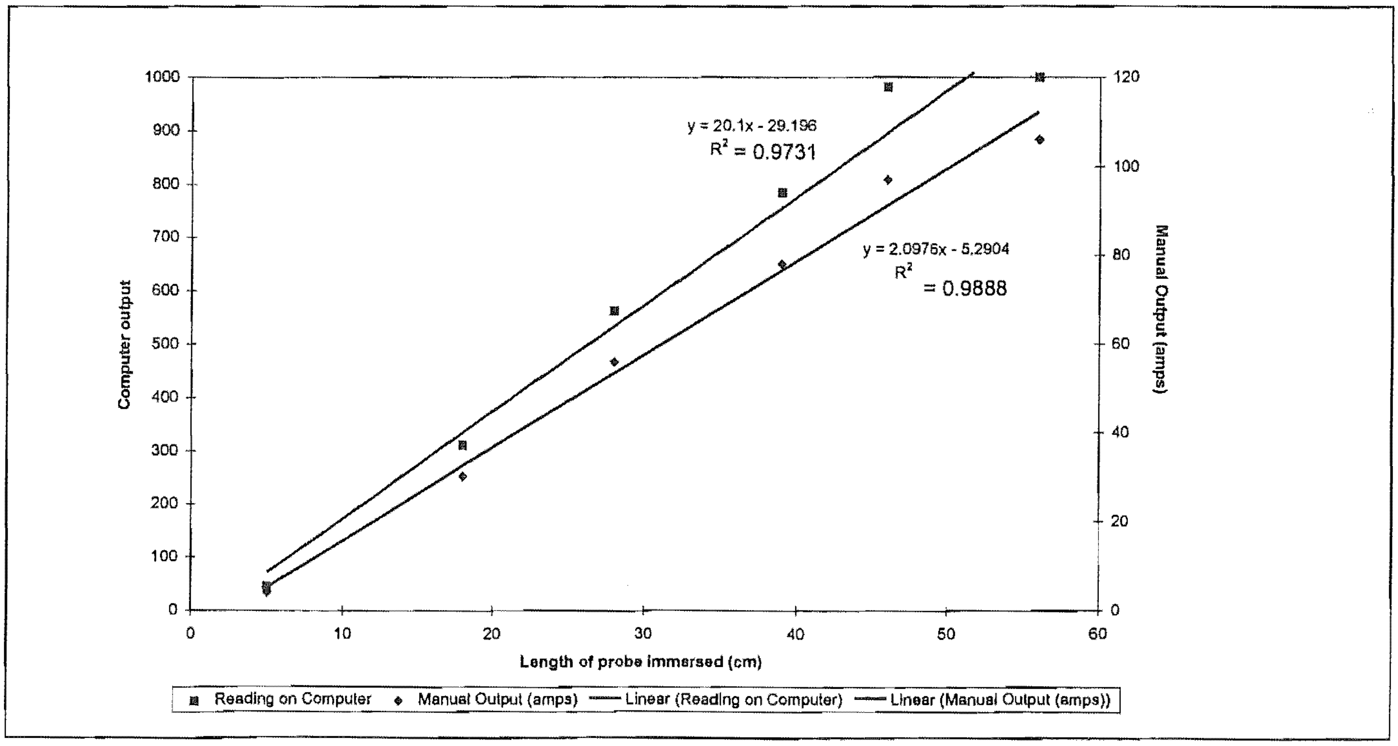


Figure 3: Drexelbrook Probe for Water in Stainless Steel Balance Tank – 29/10/98

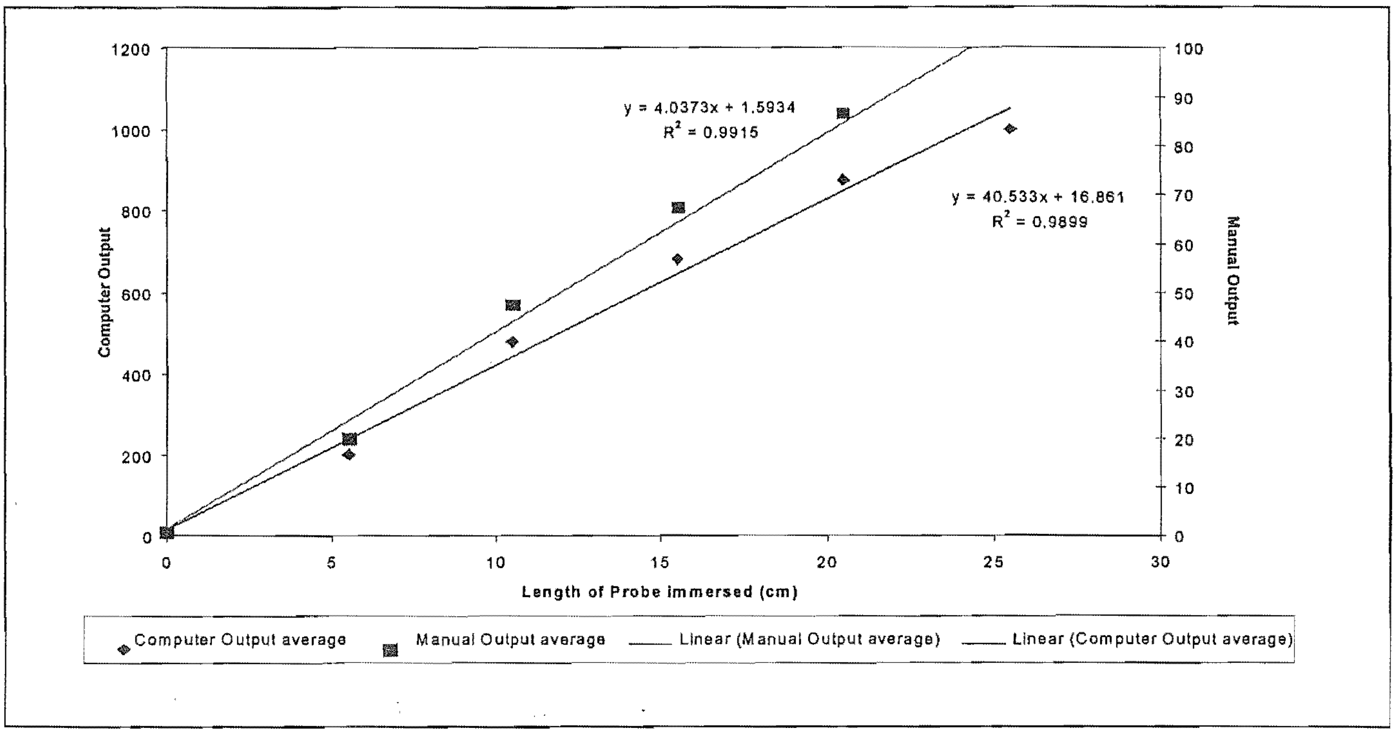
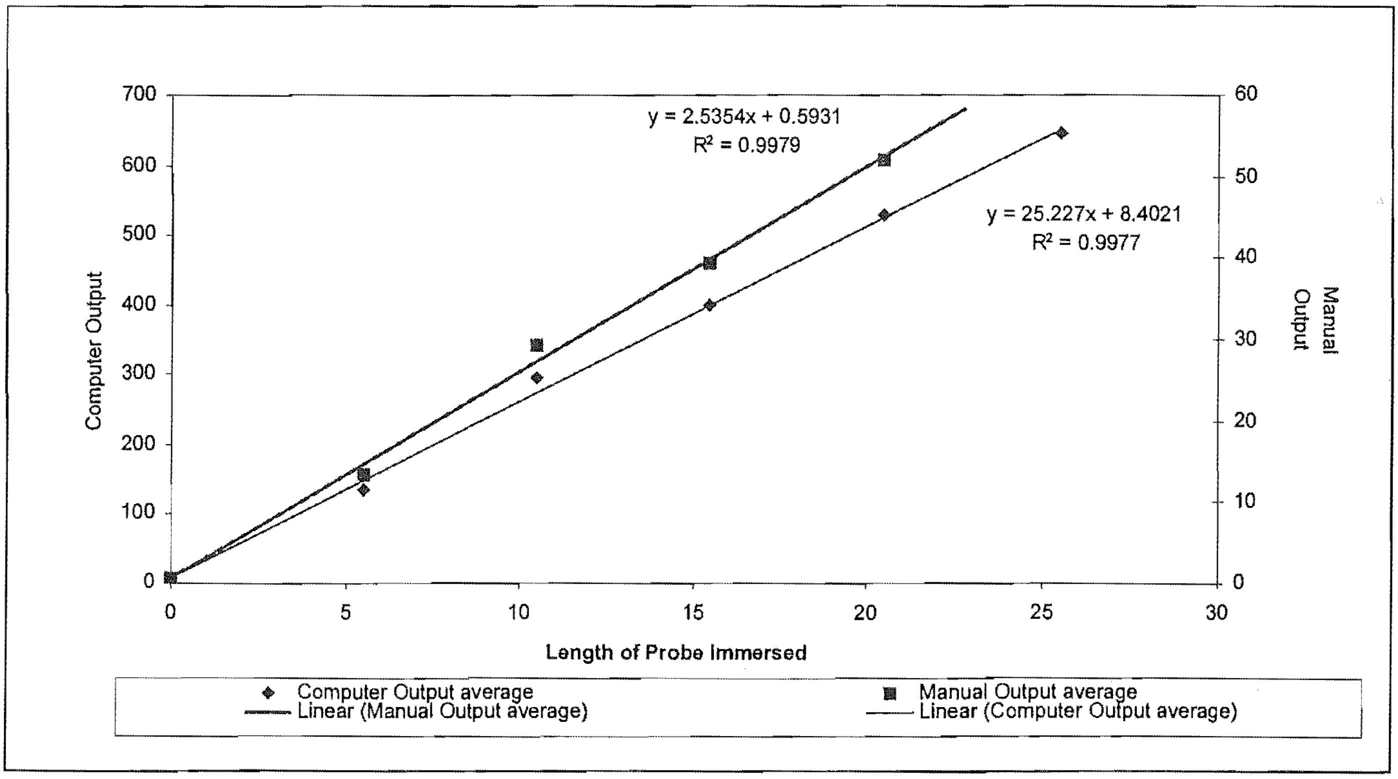


Figure 4: Drexelbrook Probe for Curd in Stainless Steel Balance Tank – 29/10/98



Note: When referring to graphs 5 to 8 note the following;
Flat regions = breaks within a trial to distinguish between levels used for the trial.
Sloping regions = curd sprinkling over probe leading to gradual rise in level. Small fluctuations mean that the probe is not influenced by curd hitting the probe.

Figure5: Vega Probe – Sprinkling Curd onto Top of Probe 22/10/98

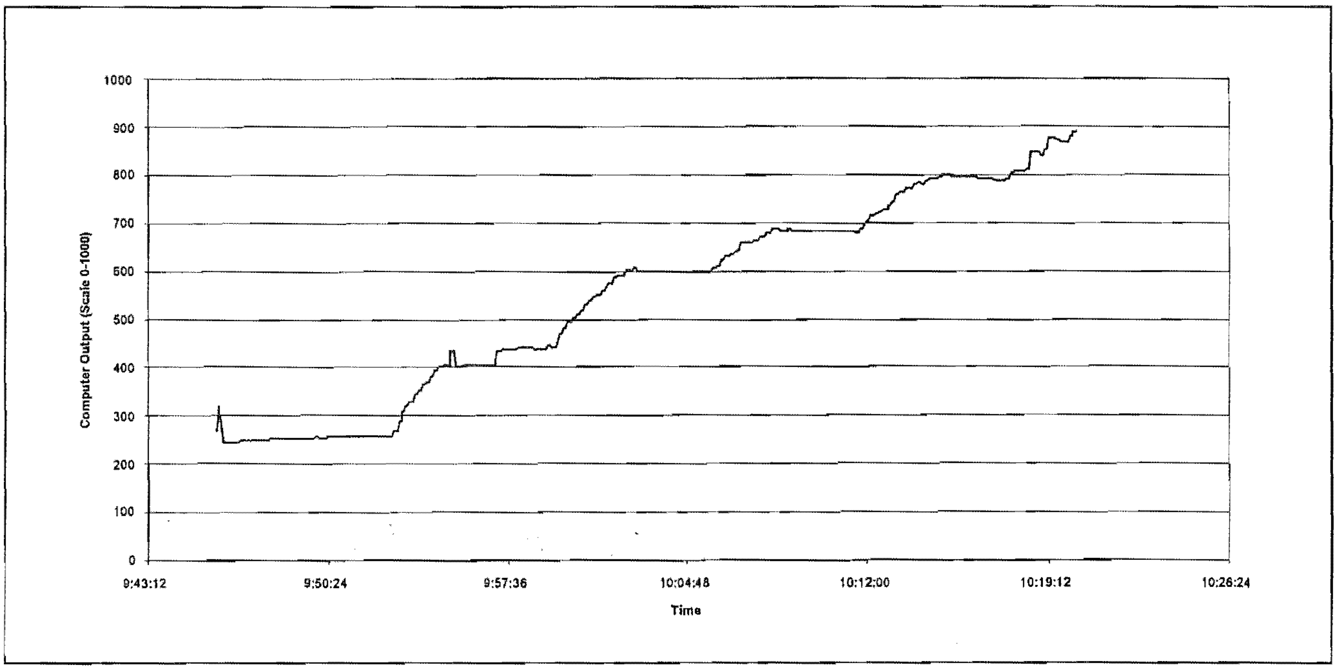


Figure 6 : Dexelbrook Probe – Sprinkling Curd onto Top of Probe 29/10/98

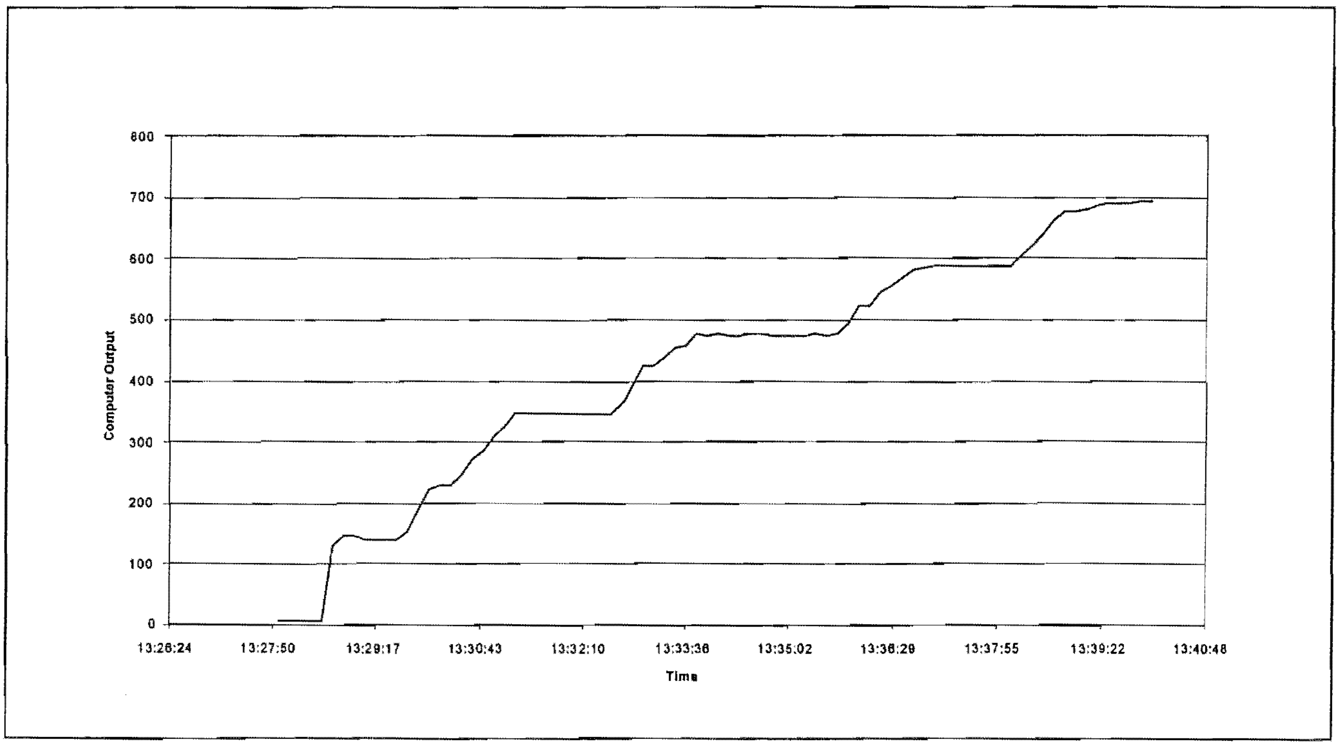


Figure 7: Vega Probe — Curd Hitting side of Probe 22/10/98

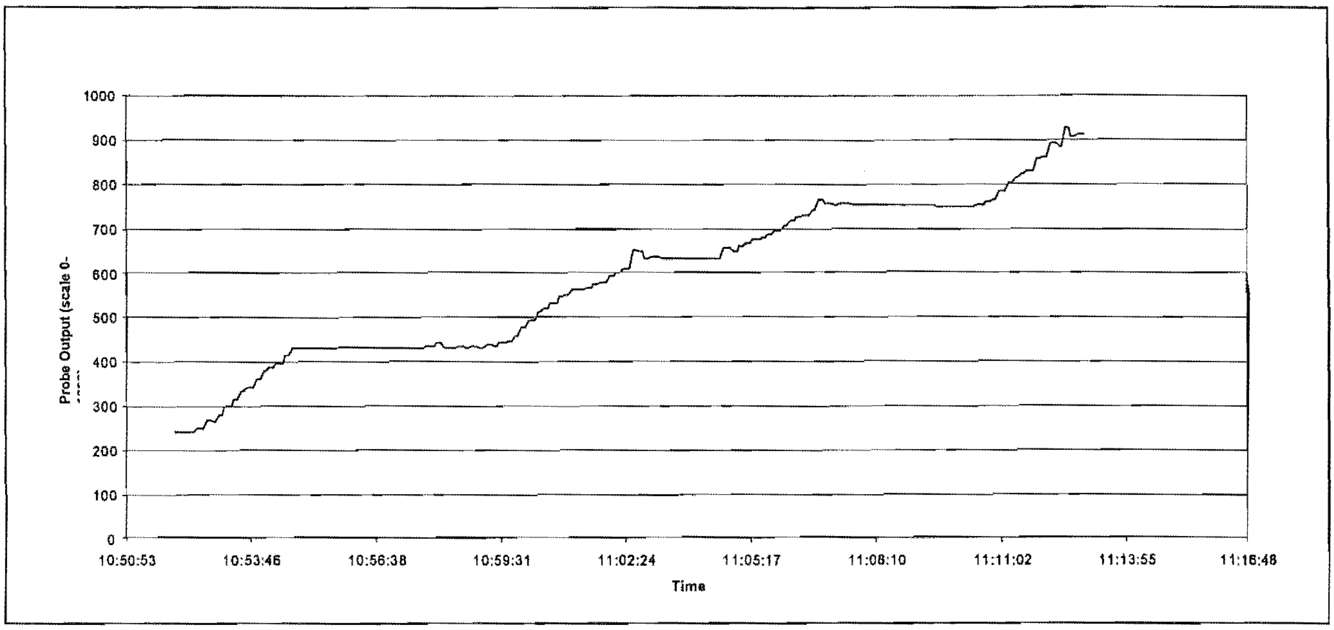


Figure 8: Drexelbrook Probe – Curd Hitting side of Probe – 29/10/98

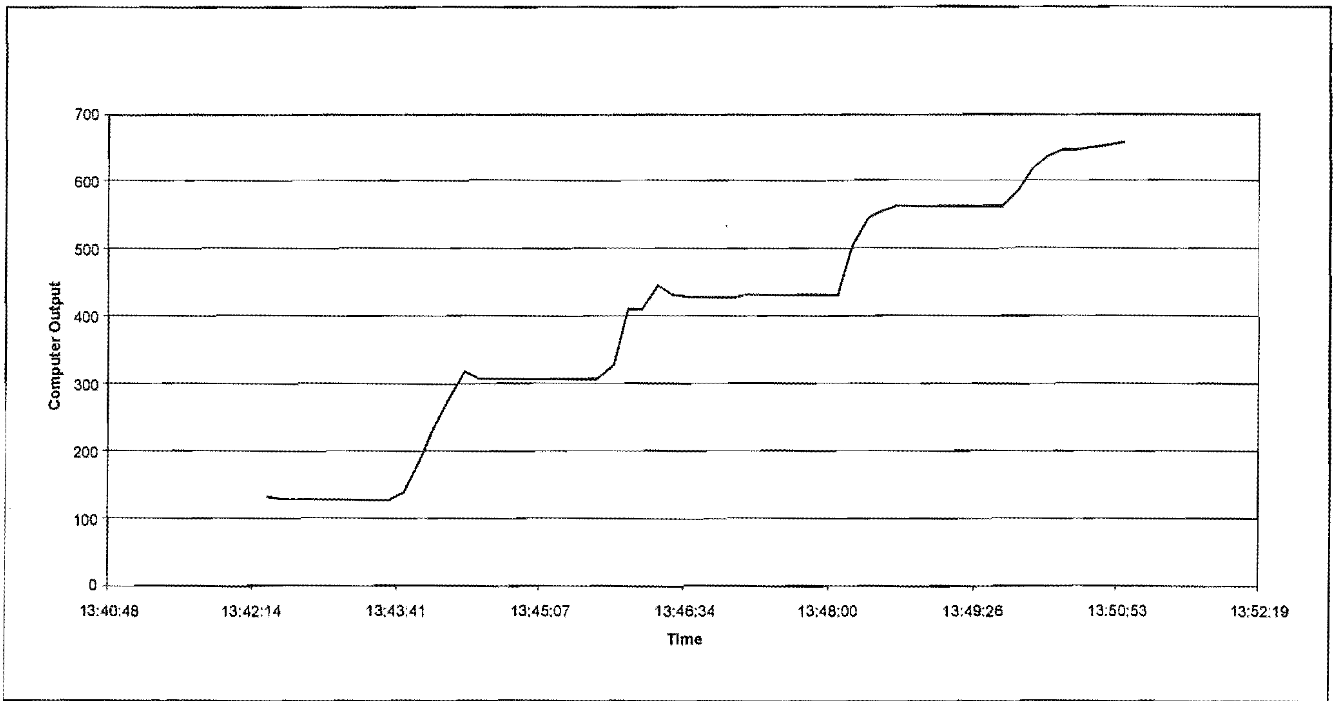


Figure 9: Vega Probe Auger Imitation – 22/10/98

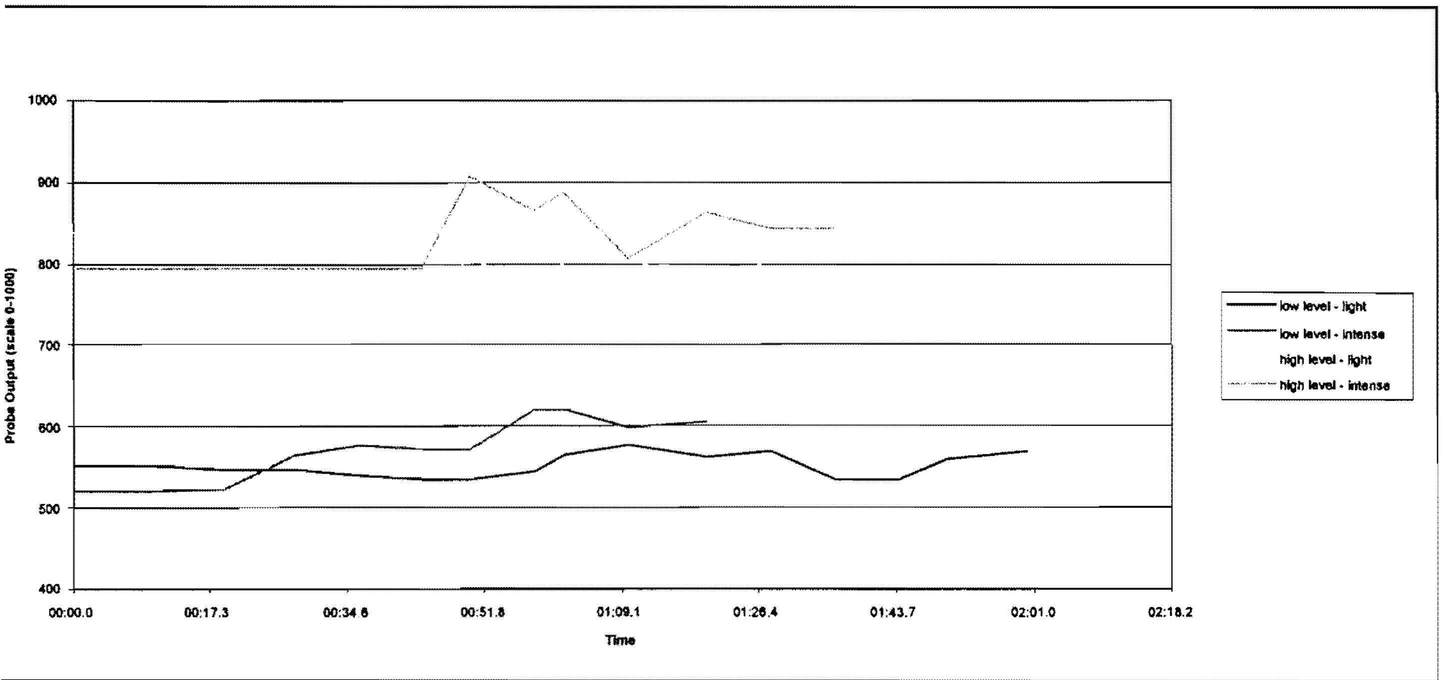


Figure 10 : Dexelbrook Probe Auger Imitation – 29/10/98

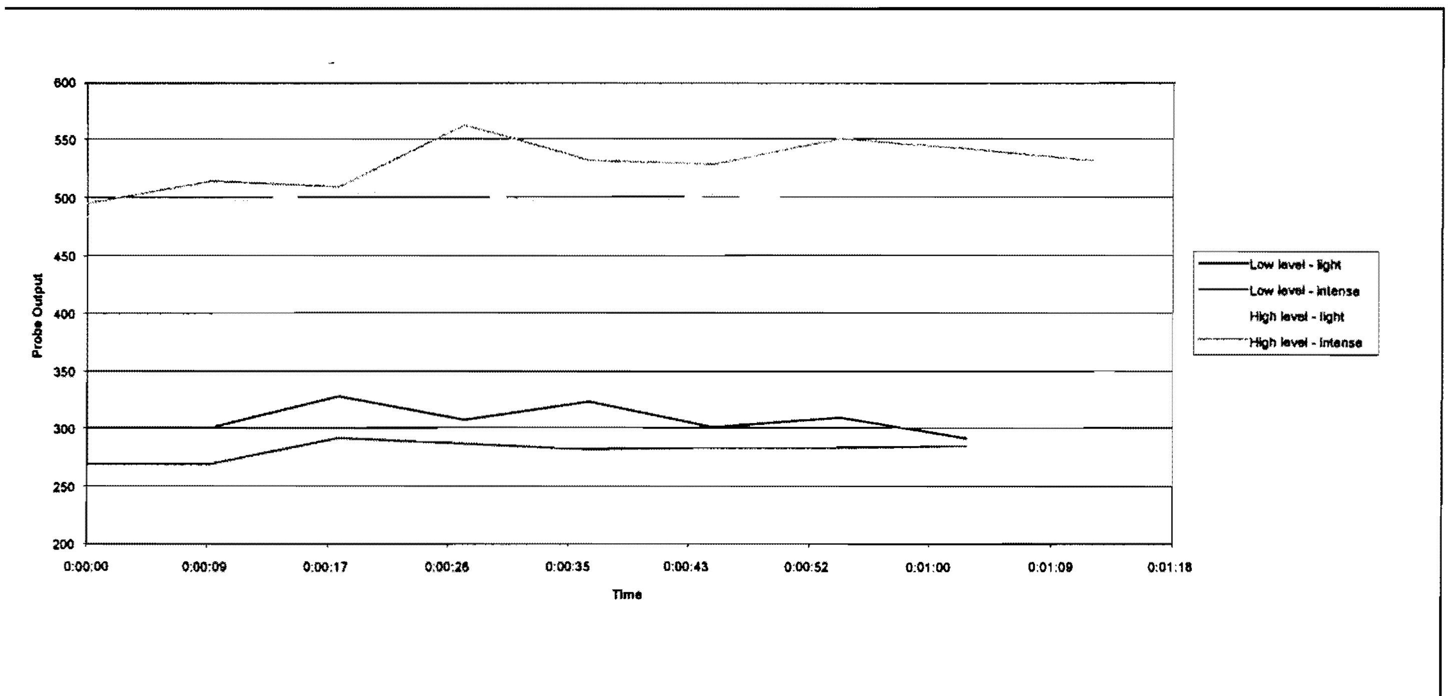


Figure 11 : Vega Probe Conductivity – 22/10/98

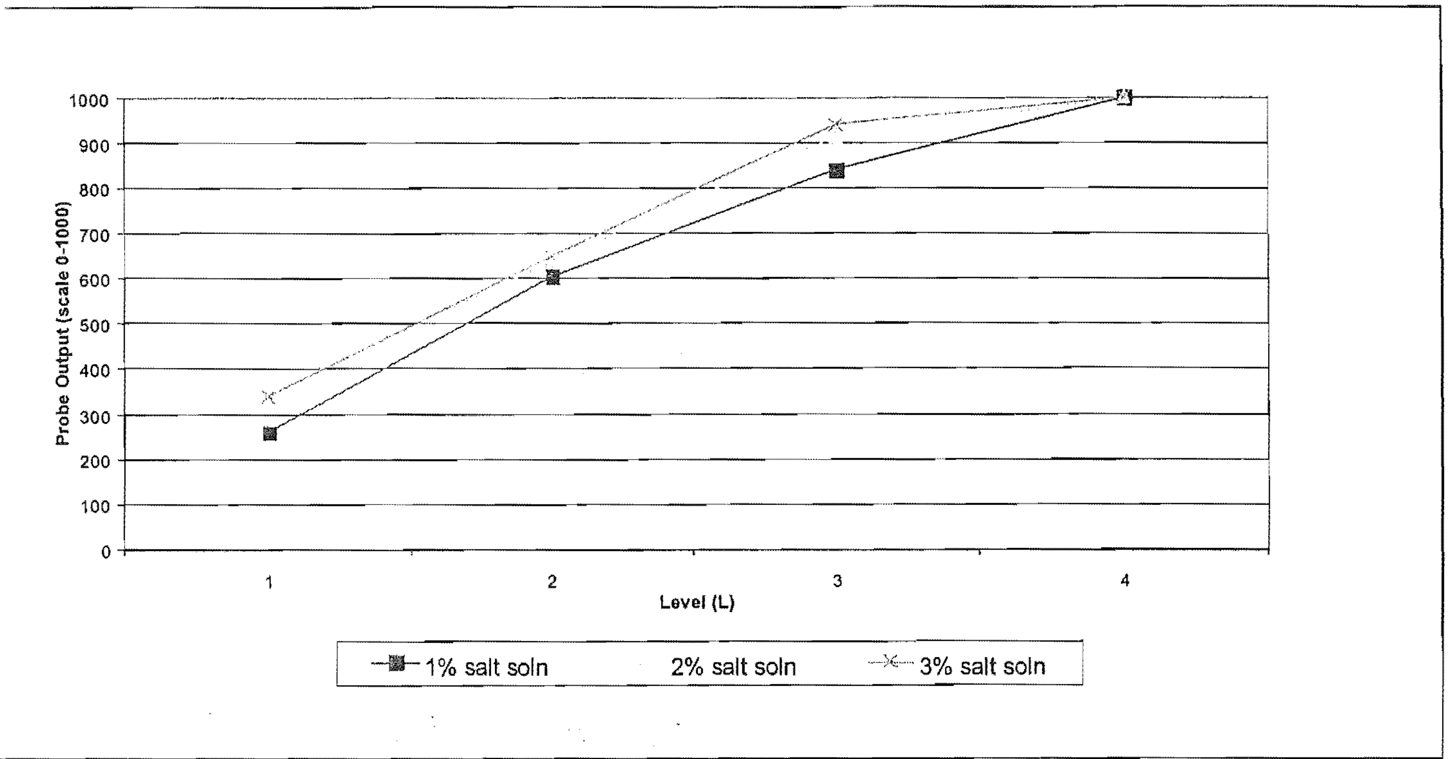


Figure 12 : Dexelbrook Probe Conductivity – 29/10/98

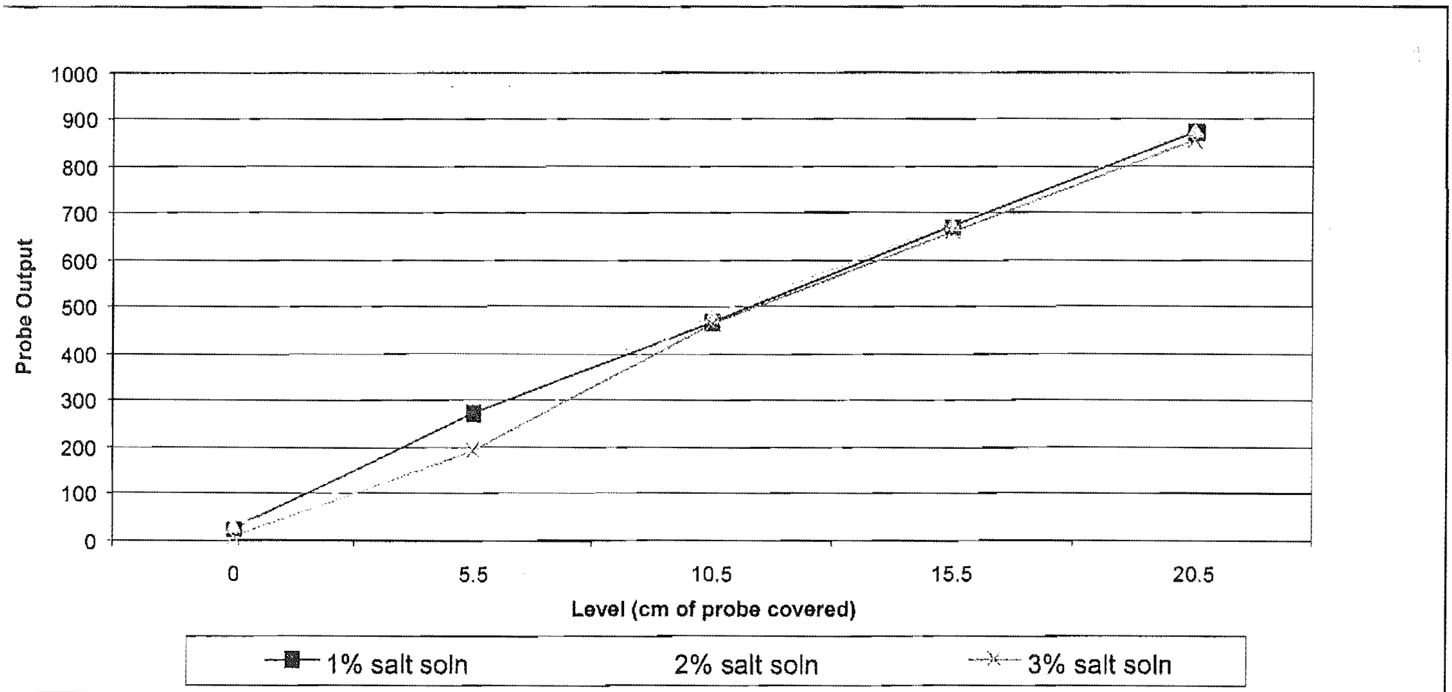


Figure 13: Probe Sensitivity to Metal Disturbances and Fat Build Up