AN INVESTIGATION INTO SHORT PRODUCTION RUNS IN SPRAY DRYING PLANTS OF THE NEW ZEALAND DAIRY INDUSTRY

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THE ROAD NOT TAKEN

Two roads diverged in a yellow wood,
And sorry I could not travel both
And be one traveler, long I stood
And looked down one as far as I could
To where it bent in the undergrowth;

Then took the other, as just as fair,
And having perhaps the better claim,
Because it was grassy and wanted wear;
Though as for that the passing there
Had worn them really about the same,

And both that morning equally lay
In leaves no step had trodden black.
Oh, I kept the first for another day!
Yet knowing how way leads on to way,
I doubted if I should ever come back.

I shall be telling this with a sigh
Somewhere ages and ages hence:
Two roads diverged in a wood, and I -
I took the one less traveled by,
And that has made all the difference.

Robert Frost

ABSTRACT

The features of short production runs in spray-drying plants of the New Zealand Dairy Industry were examined and some methods developed to help improve productivity in dealing with them.

In particular a survey was carried out of the managers of all spray-drying plants in order to establish quantitative and qualitative information on short production runs. It was found that short production runs could be classified into those caused by interruptions to runs, such as mechanical breakdown, those caused by specification changes, and those caused by the decision to run the plant for a limited period, usually as a result of the limited milk available for processing.

The effect of capacity utilisation on spray-drying plants and the costs of smoothed milk flow were examined and it was found that smoothed milk flow could not be justified on economic grounds alone.

The occurrence of short runs due to specification changes in other industries is documented as are methods to overcome their costs. It was concluded that the major effects in spray-drying plants were likely to be through set-up cost and learning behaviour. However, it was found that neither of these seriously affected cost of powder manufacture, short production runs due to specification changes were dealt with without excess costs over normal manufacture.

The relationship between run length and energy consumption and run length and processing rate were examined and quantified. A computer based management information system was developed to assist in the control of costs in general and short production runs in particular in spray-drying plants.

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1. New Zealand Dairy Research Institute

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LIST OF ABBREVIATIONS

B.M.P.	Buttermilk powder
C.I.P.	Clean in place
Co-op	Co-operative
E.E.C.	European Economic Community
hr	hour
kg	Kilogram
k.w.h.	Kilowatt hour
M.V.R.	Mechanical vapour recompression
N.S.P.O.	Non-standard purchase order
N.Z.C.D.C.	New Zealand Co-operative Dairy Company Limited
N.Z.D.B.	New Zealand Dairy Board
N.Z.D.R.I.	New Zealand Dairy Research Institute
R.O.	Reverse Osmosis
R.P.D.	Rangitaiki Plains Co-operative Dairy Company Limited
S.M.P.	Skim milk powder
Spec	Specification
U.K.	United Kingdom
W.M.P.	Whole milk powder
W.P.N.I.	Whey protein nitrogen index
N.C.	Numerical control

GLOSSARY OF MILK POWDER SPECIFICATIONS

Product	Specification	Description
Skim milk powder	600, 633, M301	Medium heat
	602, 607	Low heat
	662	High heat
	672	Heat stable
Whole milk powder	800	Basic, conventional
	801, 802, 803	Limited bulk density range
	821, 823	Vitaminised
Special (whole milk) products	900, 930, 934, SMA	

CHAPTER ONE

INTRODUCTION

The primary aim of this research is to find means to bring about improvements in productivity in spray-drying plants of the New Zealand Dairy Industry. In order to give an appreciation of the focus of the work, the relationship between productivity, management and the other factors of production will be explained.

Productivity is the ratio between output and input and may be a measure of the use of land, materials, plant, machines, the services of men or all of these things. Many people have been misled into believing productivity exclusively concerns the productivity of labour. Productivity as discussed here involves making the best use of all available resources. In order to increase productivity it is necessary to increase output with the same inputs or to reduce input for the same output. In a manufacturing enterprise, the manager is responsible for ensuring that the best possible use is made of all resources.

The manufacture of a product is the result of the input of a large number of resources. Efforts to improve productivity are based on the precept that some of the inputs are in fact superfluous. The goods could be manufactured without them. Such superfluous resource uses include work added as a result of defects in design or specification, inefficient management practices, ineffective time added by the worker, or even inefficiency due to some cause completely outside the manufacturing unit.

In order to increase productivity, action must be taken by management, with the co-operation of workers together with extra scientific or technical knowledge. The results of the action will be a reduction in the unnecessary use of resources, thereby achieving improved productivity.

The Short Production Run

New Zealand, as much as being the "Land of the Long White Cloud" is the land of the Short Production Run. Its population is relatively small and is geographically isolated into even smaller markets. New Zealand Industry, in attempting to satisfy the needs of its highly educated, affluent and diverse population, is often involved in manufacture of short production runs. High costs per unit of production are incurred by setting up specialised machinery, tuning the machinery and operators to high standards of quality and conformity of production, and then running for a comparatively short period. Capital is tied up in specialised plant, a higher level of skill is required to meet the demands of change, and many overhead costs are multiplied.

It was considered by Scott (1) that "central to the consideration of production costs is the question of the short production run. The portion of the cost (of an article) arising from the cost of setting up a production facility, is large when there is a low volume of production. A traditional New Zealand problem has been the magnitude of this type of cost...".

In a discussion on the optimum variety of products for a firm, Easterfield (2) suggested that there was a number of costs that would rise with variety irrespective of the quantities produced, such as the cost of an extra item in the catalogue, an extra place in the store, an extra set of drawings or specifications, and an extra set of jigs or tools. However, he considered the most important cost effects to stem from the consequential changes in batch size with changes in variety and the resulting effects on direct production costs and methods.

Thus it can be seen that short production runs can cause low productivity in industry in general and that they have long been a feature of New Zealand Industry.

The New Zealand Dairy Industry

The New Zealand Dairy Industry remains one of the country's leading exporters, accounting for about 16% of all export receipts in the year to June 1980. Milk powders represent just over one quarter of this with an export earning of $222.8 million in the same period. This comprised 21,173 tonnes of Butter Milk Powder (BMP), 172,052 tonnes of Skim Milk Powder (SMP) and 61,398 tonnes of Whole Milk Powder (WMP). Additionally, 4,200 tonnes BMP, 5,600 tonnes SMP and 5,900 tonnes of WMP and condensed milk, were supplied to the New Zealand market. (3)

Recently, the short production run has become a feature of the traditionally high volume, export-oriented Dairy Processing Industry. With the reduction of access to the traditional market, Britain, the New Zealand Dairy Industry has been forced to seek new markets. No longer is it possible to manufacture huge volumes of similar product for one insatiable market. Plants intended for such application have had to adapt to change.

A shift has occurred in the Dairy Industry from a production orientation to a market orientation. In seeking to sell dairy products in new market places, it has been necessary to adapt products to the needs of the customers. This has been particularly so in the case of milk powders. There has been a major effort to increase the value of each tonne of milk powder sold by improving quality standards, packing and presentation, formulation of speciality products for individual markets, promoting New Zealand as a seller of bulk powders to specification, and promoting sale of consumer brands of New Zealand milk powder and baby foods.

"New Zealand has now moved into the position where 80% of milk powder products and 85% of skim-milk powder are of the special formulation kind. The New Zealand Dairy Board offers 40 specifications of skim milk powder, 30 specifications for baby foods and special fat bearing products, and 18 specifications for whole milk powder. The New Zealand Dairy Industry produces the biggest range and the biggest volume of specification powders of any international seller."(4)

As a result of a greater number of product specifications, there will be a reduction in production run length. Short production runs in terms of product specification will occur.

In addition to the specification change aspect of short production runs there is another short production run problem of concern. New Zealand dairy farming has long been unusual in its ability to winter animals out of doors with minimal supplementary feed. This has made a significant contribution to the low cost of milk products. However, the corresponding necessity to suit the cow's lactation cycle to the availability of feed has also had ramifications in low capacity utilisation in dairy processing plants, leading to a high proportion of short production runs in terms of daily running time.

With the expected pressure on capital resources in the short and medium term future due to energy related development projects, the cost of low capital utilisation in dairy processing plants needs re-assessment.

Understanding of short production run problems is not merely a matter of concern for spray-drying plants but is relevant to the whole spectrum of New Zealand Industry. However, spray-drying plants have been traditionally involved in long production runs (in terms of product specification) and thus practice in this area may be sub-optimal. Additional pressures have been placed on the traditional practice of low capacity utilisation so that the opportunity has arisen for the examination of its effects in the spray-drying plant.

Rather than the technical characteristics of plant items this research is concerned with the way the plant is used and the reflection of that on productivity in its widest sense. It is intended that improvements in productivity be brought about in the existing situation. Thus studies must be made with data that is already collected or readily available in spray-drying factories. Such an approach ensures a true, real result for it is well known that the very measurement of a process changes the process itself. Additionally such an approach ensures the practicabilities of obtaining such a result in practice, in spray-drying plants.

The problem of short production runs can be viewed from a positive aspect. It is a feature of the production activities of New Zealand's competitors too, and thus an improvement in New Zealand's ability to deal with short production runs may give an advantage over competition.

This research examines the occurrence of short production runs in spray-drying plants and seeks methods of improving the ability to deal with them, in the factory, so that they incur minimum cost.

Content of thesis

Bearing in mind the vital role of the manager in productivity improvement and focussing on the activities inside the spray-drying factory[1,2] the occurrence, features and costs of short production runs are to be examined with the intention of determining means to increase productivity.

The occurrence of short production runs in other industries are to be studied in order to establish testable hypotheses with regard to the occurrence of short runs in spray-drying plants. These hypotheses and other questions are to be tested by means of a survey of the Industry and studies in some individual spray-drying factories.

The spray-drying plant is part of a wider production, processing, marketing system. The causes of short runs may originate in these other parts of the system. Thus the production and marketing aspects are to be examined in light of their effect on short runs in the spray-drying plant.

The spray-drying plant itself is to be the main focus for this research and the effects of the external influences on it, as well as the effects of future technological change are to be examined.

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1. A distinction is made between the spray-drying factory which comprises all the spray-drying equipment on one site and the spray-drying plant which comprises one process, including one evaporator and one dryer.
2. A brief description of a spray-drying plant is included in Appendix 1.

In particular the relationships between energy consumption and run length and processing rate and run length are to be studied. Finally some measures to deal with short production run[1] problems are to be proposed.

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1. The term 'production run' is used interchangeably throughout this text to mean 'the uninterrupted processing time during one day' and 'the period, sometimes comprising many days, over which a specification of powder is produced without interruption by change of specification' or both of these meanings.
The context will indicate the sense.

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CHAPTER TWO

THE SHORT PRODUCTION RUN IN INDUSTRY

2.1 THE COMMONALITY OF METHODS OF MANAGEMENT OF PRODUCTION

Although in its widest sense production may involve the creation of goods and services, in this study production will be used synonymously with manufacture. Thus production involves, the intentional act of making articles by means of physical labour or machinery. Production involves a change in the form of an input that results in increased utility to the user.

The articles produced can vary from marbles to missiles, the people involved can vary from a family group to the employees of a multi-national company, the production machinery can vary from a potters wheel to a complex computer controlled factory. As Riggs (1) states, "Despite apparent differences in raw materials, generating processes, and ultimate output there exist many similarities. These mutual considerations form the basis for production studies by which the resources of nature are conserved and made more useful."

The management of production involves the co-ordination of the inputs to the production process to meet predetermined objectives. If there was a perfect production system then it could be expected that all orders would be carried out exactly as planned and there would be no need for follow-up and control. This is seldom the case. There are always disturbances that enter the system and cause problems. Orders are misunderstood, purchased parts do not arrive on schedule, breakdowns occur, workers are sick and so on. Thus management involves both planning and control. The manner of action of the production manager is represented diagrammatically in Figure 2.1. It was stated by Wild (2) that "It has been found that

management of transformation processes is, to some extent, independent of the technology involved."
"Problems of location, layout, stock control, scheduling and replacement are important features of (all) these systems."

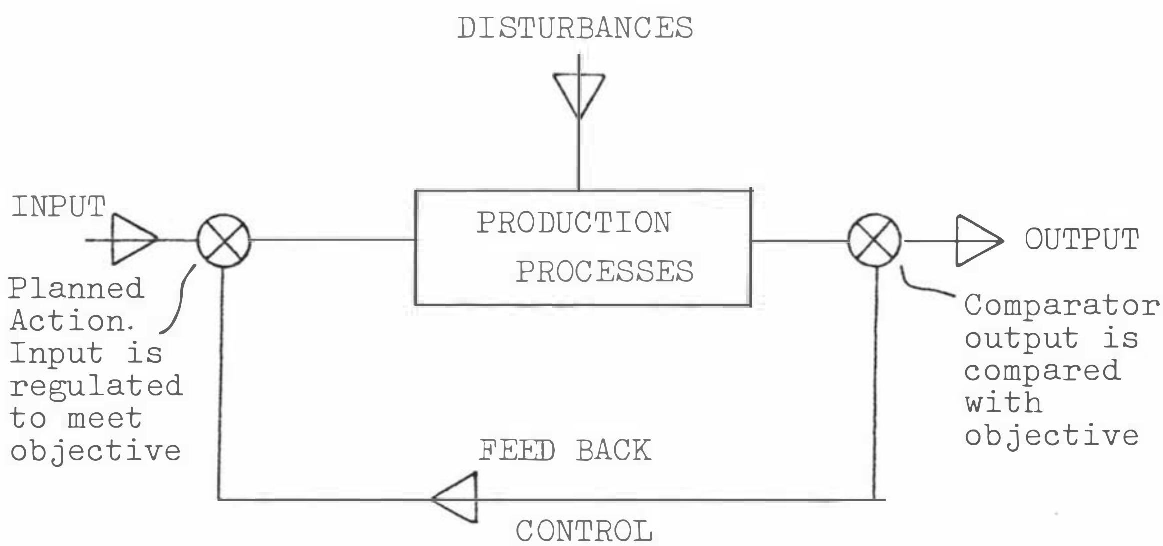

FIGURE 2.1 The manner of action of production management

Naturally, the problems encountered by a production manager in the manufacture of soaps are different, at least in complexity and relative importance, from those faced by the production manager of a metal-working foundry. Nevertheless, all managers must deal with the co-ordination of men, machinery and materials in order to meet the production objective.

Thus a study of the occurrence and features of a particular management problem, the short production run, in a number of production systems can indicate possible effects and solutions in a production system which has not previously been examined. An examination of the novel industry with an awareness of such effects and solutions can confirm or reject them in that particular case. Thus the examination of the occurrence of short production runs in other industries assists in the formation of testable hypotheses with regard to the production system under study.

2.2 THE OCCURRENCE OF SHORT PRODUCTION RUNS

Short production runs occur in many types of industry. They result from the use of manufacturing equipment to produce goods in a smaller volume than it was originally intended the equipment should produce, or in a smaller volume than is normal. There is an implied inefficiency as a result of the shortness of the production run and a consequent cost of production above the minimum.

Easterfield (3) in a discussion on optimum variety, noted that batch size (i.e. run length) appeared to affect cost through three main effects:

i. through allowing different technical processes to become economic;

ii. through the spreading of overheads;

iii. through learning.

He suggested that as batch size increased, more specialised plant and machinery, with higher initial and/or set-up cost became economical. Also the flexibility of plant needed could be reduced.

With respect to spreading of overheads he said that the idea that each batch will incur some set-up cost that must be absorbed by it was widely understood, although few firms had costs recorded in such a way as to make such a distribution of cost practicable.

The learning effect[1], or continued reduction in labour content per unit with increased production volume, is said to occur as a result of technical progress during a run, such as the invention and introduction of new techniques, reduced average costs for organising production and greater manual dexterity brought about by experience (4).

Additionally, Easterfield (5) discussed the effect of variety on stock-holding, suggesting that the total safety stock held will tend to rise with the number of

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1. For a more complete description of the learning effect, see Chapter 6.

varieties.

As stated above, runs are short only in relation to the capacity of the plant. Plants tend to be large because of the expected economies of scale. These expected economies were described by Pratten (6) as arising from indivisibilities, economies of increased dimensions, economies of specialisation, economies of massed resources, superior techniques or organisation of production, the learning effect, and economies through the control of markets and supplies.

However, the extent of the consequences of any of these features of manufacturing in terms of cost will vary depending upon the particular technology involved. For example, in a highly labour intensive type of industry, such as white-ware assembly, learning effects could be expected to be appreciable, whereas they would not be so evident in a fully automated transfer line.

In this chapter the classification of manufacturing will be related to the effects of short production runs and measures used to deal with them.

2.3 CLASSIFICATION OF MANUFACTURING SYSTEMS

Prior to the industrial revolution almost all manufacture was performed by master craftsmen who manufactured each item individually. In the 18th century the French Academy of Sciences' classic work "The Description of Arts and Crafts", described the manufacture of pins using the division of labour and specialised tools to reduce production costs. Among other effects, this lowered the required skill level. The adoption of standardised parts was exemplified by the gunsmith, Eli Whitney, who manufactured flintlocks with completely interchangeable parts (7). Thus the important principles of standardisation of components and division of labour were established, enabling the development of mass production systems.

Woodward (8) in a study of 100 firms which was concerned with the relationship between organisational structure and production technology, arrived at a classification system, in which a differentiation was made between those firms making integral products and those making dimensional products, measured by weight, capacity or volume. Dimensional products, such as chemicals, were manufactured by process production.

Both dimensional and integral products could be manufactured in a continuous, or mass production fashion or in a batch fashion. Additionally a distinction was made between products which were of a one-off kind and those where production was standardised. This classification is shown in figure 2.2

```
                                                  PRODUCTION
                                                  ENGINEERING
                                              CLASSIFICATION
                      (Production of units to    )
                      (customer requirements.    )JOBBING
           (UNIT AND  (Production of prototypes. )
           (SMALL     (Fabrication of large      )
           (BATCH     (equipment in stages.
           (PRODUCTION(Production of small
INTEGRAL   (          (batches to customer orders.)
           (                                      )
PRODUCTS   (                                      )
           ( LARGE    ( Production of large       )BATCH
           (BATCH AND ( batches.                  )
           (MASS      ( Production of large       )
           (PRODUCTION( batches on assembly lines.)
                      ( Mass production.            MASS

           (          (Intermittent production of BATCH
DIMENSIONAL(PROCESS   (chemicals in multi-purpose
           (PRODUCTION(plant.
 PRODUCTS  (          (Continuous flow production  MASS
           (          (of liquids, gases, and
           (          (crystalline substances.
```

FIGURE 2.2 Production Systems (After Woodward (8))

A classification similar to that of Woodward but more closely focussed on the relationship between run length and production system was made by Wild (9). Production was classified as jobbing, batch or mass, the three groups overlapping. Pure jobbing production most closely corresponded to Woodward's "Production of units to customer requirements". It involved absolute intermittent production, which comprised the manufacture of unique items with absolutely no repetition. Mass production in its purest form most closely corresponded to Woodward's "Continuous flow production of liquids, gases and crystalline substances". It involved the continuous production, twenty-four hours per day and 365 days per year of a single type of item.

Wild further subdivided mass production into quantity production and two types of flow production. Quantity production involved the mass production of single-piece items or components, perhaps destined for use in the manufacture of more complex products. Examples of such production would be the use of a drop forge or an injection moulding machine.

Flow production depends upon a product flow for the manufacture of the product. Items produced are usually the result of a long series of complex operations, often involving other types of production. Flow production is most easily achieved for materials that flow naturally, such as oil and other chemicals. This type of production Wild called Flow Process. Hard discrete items must be made to flow and provision must be made for the interchangeability of parts. This type of production Wild called Flow line.

While no one classification system can deal with every production system in that there are, for example, mixed systems of dimensional and integral product manufacture such as brick production or pharmaceutical manufacture, a combination of these classification systems can provide a basis for discussion of the effects of short production runs and methods to deal with them.[1] The different production systems will involve varying proportions of contribution to the production process by the different factors of production, men, materials and machinery. Thus measures to deal with the dis-economies of short production runs in different types of production will involve techniques to deal with the most problematic factor(s).

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1. See Figure 2.3

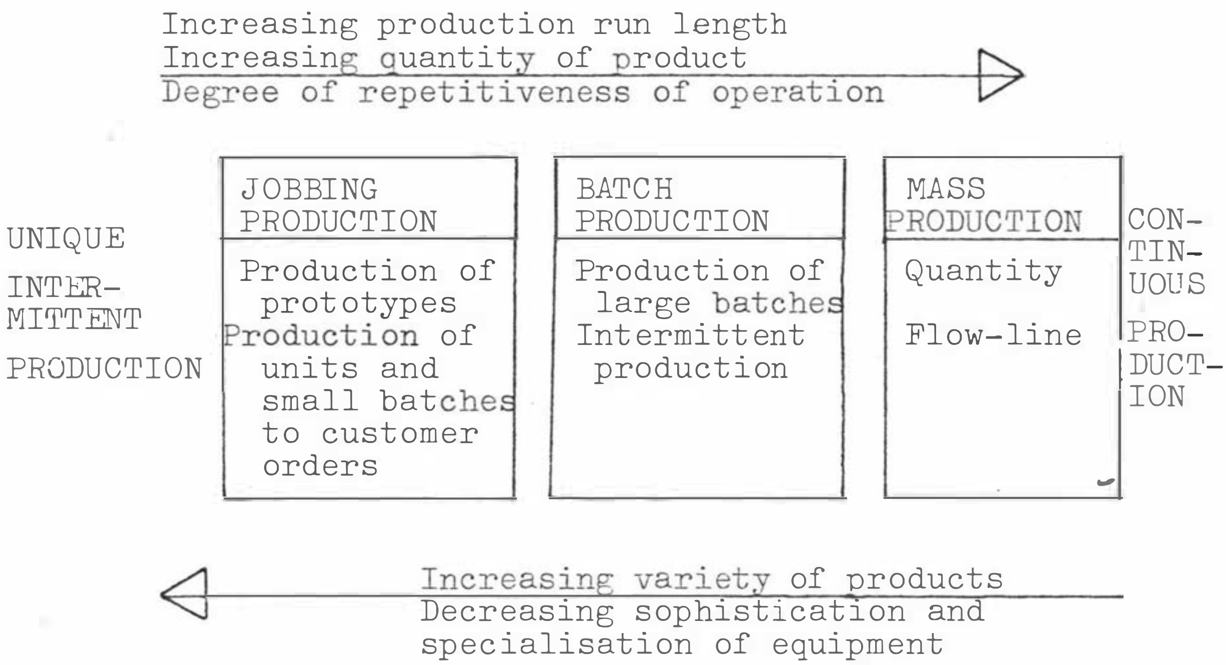

FIGURE 2.3 The Production Continuum

2.4 BATCH PRODUCTION

Batch production, as discussed here, involves the movement of a given quantity of items or material through a number of process steps and the total volume emerges simultaneously at the end of the production cycle. According to New (10), batch production can be classified as having either functional or group organisation.

Under functional organisation the production facilities are grouped together by type. For example, all the lathes are together in a department separate to all the milling machines and so on. This has been the classic method of batch production.

Group organisation or technology involves the set-up of a group or cell of facilities to produce a range of items with similar facility requirements. The items produced in a cell may not require all the facilities of the cell but they are chosen so that the minimum of re-setting is required between different items.

Despite group technology having been a recognised system of manufacture since the turn of the century, most United States plants are still functionally organised, according to Teresko (11). This results in high in-process inventories, long production time, and slow response to orders. He suggests that group technology has enabled improvements in engineering design, manufacturing engineering, materials control, production and job enrichment. Group technology is also highly amenable to use in Computer Aided Design and Computer Aided Manufacture systems and is said to be "the underlying organisational principle of the computer-integrated manufacturing system of the future".(12)

A flexible manufacturing system that is completely automated is described by Hutchinson and Wynne (13) and a similar development in West Germany is described by Bey.(14) The system comprises a large number of direct numerical control machines, served by an automated materials handling system, and an on-line computer system which manages both the numerically controlled machines and the materials handling system. Such a system is said to possess many of the advantages of a fixed-sequence, high-volume transfer line while attaining the inherent adaptability of traditional job-shop operations. It is said to be able to handle volume and variety at relatively low costs.

Another group technology approach advocates the use of robots and a hierarchy of computers. Black (15) states that Boeing estimates that such a centre for the production of sheet-metal parts could reduce production-time labour by 80%, and set-up labour by 90%. He suggests that mass-production efficiencies will be attainable in plants where short runs are the rule and volumes are high enough to justify "flexible" automation.

Rathmill et al (16) predict that the future desire for greater variety will mean that manufacturing in the future will not be dominated by mass production but will, of necessity, involve batch production. However, Toffler (17) opposes this view in describing the great variety of products possible to produce by modern (mass production) technology. He gives an example of the possibilities in that it was calculated that by using all possible combinations of styles, options and colours available on a certain new family car there were 25 million different versions possible.

Batch production systems will undoubtedly have an important role to play. Rathmill et al predict that future batch production systems will have the following features:

i. High importance attached to capacity utilisation;

ii. Variability in demand will result in a degree of variability in both product mix and component requirements;

iii. Product demand for batch generally small to medium sizes;

iv. Levels of component complexity commensurate with those of today;

v. Extreme importance attached to the environment and the role of the industrial worker.

vi. Greatly diminished availability of highly skilled labour;

vii. Marked reduction in cost of data processing and storage.

They suggest that the major disadvantages of functional layout will be overcome by the use of computers to control work in progress and flow discipline. The major advantage of functional layout is in its flexibility in terms of meeting variable requirements and the ability to quickly re-route work when required.

The advent of numerically controlled machines has meant that short runs can be produced efficiently. A Numerically Controlled machine user is quoted as saying "It means never having to do a one-off again. We can keep the tape and it becomes automated. We have put our expertise on that job on file." (18)

Small, autonomous N.C. work areas within large machine shops can be used to produce short runs of items. For example, a plant which received an original order for several thousand parts is requested to produce a further 200. Although parts were turned out at one every twelve seconds on the large lines, it would require two days to set up. A Numerically Controlled machine may take as long as five minutes per part but the set-up time is only thirty minutes. (19).

In discussing production control in metal working factories, Moore and Jablonski (20) observe that short-run orders waste both man and machine time because they cause so many set-ups. Staff on piece work do not like them because they cannot get into the swing of production and earn bonuses, and short runs take an undue amount of production control work. They suggest that strategies to deal with short-run production could be:

i. put them through a miniature short-run factory;

ii. put them through the company's experimental shop;

iii. put them through the toolroom or maintenance department's machine shop;

iv. sub-contract them outside.

Short-run sheet-metal forming methods used in the aircraft industry are described by Noble (21). Because aircraft components are not mass-produced in terms of numbers , yet require a high degree of precision and repeatability, the aircraft industry has developed such techniques as deformation by short bombardment, explosive forming which eliminates the need for a press, fluid tooling and casting in eutectic alloy of the tool inside the press, and infinitely variable tooling to avoid high tooling costs.

The use of superplastic aluminium alloys in manufacture of articles from sheet has improved short production run economics by a substantial reduction in tooling cost and leads to a marked decrease in lead times between order and delivery of goods. An example is given of the tooling costs for a vehicle such as a Range Rover with fourteen body panels which would cost about £1.5 million using conventional tooling but only about £50,000 using superplastic aluminium. This material is most suitable for run lengths between 1000 and 5000 but can compete seriously between 50 and 50,000. (22)

Spincasting is a technique highly suited to short production runs. It has a long history in the fields of dental and jewelry metalwork but recent advances in new silicone rubbers, used for the moulds, have enabled it to be extended to the production of zinc and even aluminium articles. The cost of a complete spincasting system is less than the cost of many individual dies produced for high-pressure diecasting. It is extremely quick in that production of parts can be made on the same day as a product is conceived. Using a high-temperature zinc alloy the moulds can stand up to hundreds of casting shots although only 20 to 30 shots of aluminium. (23)

These methods of coping with the short production run involve means of avoiding the chief cost of the short production run in the batch production situation, the set-up cost. Set-up involves the use of the scarce resource of skilled labour and represents potentially productive time when the plant is idle. Means of avoiding or reducing the set-up cost as discussed above, involve:

i. Changing the organisational pattern to one which enables short runs to be made more easily through improved communication, simplification of planning and labour flexibility[1].

ii. The use of increased capital in the form of flexible automation using computers and direct numerical control machines or robots with a computer-controlled material-handling system to provide ability to change rapidly and easily, with a small on-going labour content.

iii. The use of individual or small groups of numerically controlled machines where set-up time is eliminated because the set-up is stored in a readily retrievable form.

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1. Teresko (11) states that the grouping of workers as a consequence of group technology makes them tend to become expert on all the equipment in their cell. He says " Almost magically set-ups that once required skilled people are done routinely by anyone in the work cell."

iv. The use of unconventional methods of manufacture which avoid high tooling cost.

v. The use of a different material that allows the avoidance of high tooling costs for more conventional materials.

vi. The use of a sub-contractor who may use many orders from different firms or different production techniques to attain economies.

Interestingly, the examples of the spincasting technique and the aluminium forming above, show that Easterfield's comments that increasing batch size allows different technical processes to become economic can, in fact, be a process which occurs with both decreased volume as well as increased volume.

2.5 MASS PRODUCTION

Mass production is "....methods of organising the manufacturing processes so as to attain high rates of production at decreasing unit cost". (7)

Flow-line production, involving the manufacture of discrete items, and flow-process production, involving the manufacture of dimensional products will be discussed.

Flow-line production

This type of mass production involves the manufacture of discrete, integral items. The process of production involves the use of the line type of organisation[1] which is highly dedicated to the manufacture of one or a small number of products. Low unit cost is achieved by specialisation and production of large volumes, thus when it is necessary to produce short runs, dis-economies occur.

1. Line organisation is described by New (10) as having the characteristic of unidirectional flow through facilities. The line is specific to a single item or a set of physically very similar items and in general all the items require all the facilities on the line. Complex resetting is required when the line is changed between different items.

The classic example of mass production is the manufacture of motor cars. Mass production was first brought to wide notice as Ford made innovations resulting in greatly reduced unit cost in his production of "Model T" cars in the early 20th century. Ford's first assembly line was used for the manufacture of magnetos. With one workman doing a complete job, he could assemble from thirty to forty pieces in a nine-hour day, that is about 20 minutes each magneto. When the assembly was split into twenty-nine operations, the assembly time was cut to thirteen minutes ten seconds. The height of the line was raised eight inches, cutting the time to seven minutes. Further developments cut the time to five minutes per magneto. As the result of such principles being applied throughout the production process, the cost of the "Model T" fell from $780 in 1910 to $290 in 1924. (24) In present-day plants manufacturing costs per car have been related to output per year.(25) Economies result through use of more automated tools for assembly, reduction in initial costs (development) per car, purchasing economies through larger orders for bought out materials, competition among such suppliers and the reduction in per unit capital cost. Pratten (26) has estimated these economies as listed in Table 2.1 for a UK manufacturer producing a single model at varying levels of output on one site.

Output (thousands/year)	100	250	500	1000
Initial costs for model £m	15	20	28	38
		Costs per vehicle.		
Initial costs	38	20	14	10
Materials & components bought out	265	250	240	235
Labour (direct & indirect)	102	90	86	83
Capital charges for fixed & working capital	60	53	50	48
Total ex-works cost	465	413	390	376
Index	100	89	84	81

TABLE 2.1 Illustrative estimates of Costs and Scale in car manufacture

(After Pratten, 1971, p 141)

When small volumes of vehicles must be produced very different techniques to those of the large manufacturers described above, must be used. Norbye (27) gives an example of a West German firm which specialises in manufacture of small volumes of special vehicles. The production of such vehicles is achieved economically through special techniques and measures such as:

i. Production machinery is quickly adjustable over a wide range;
ii. Standard machine tools (not special purpose equipment intended for processing greater numbers in shorter time);
iii. Use of fibreglass body panels;
iv. Short, slow-moving assembly lines;
v. Use of modular design units and modular construction;
vi. Use of bought-in engines, gear-boxes and other components.

The aircraft assembly industry was the scene of the discovery and quantification of the learning curve. Studies of aircraft assembly showed that the fourth plane required only 80% as much direct labour as the second, the eighth plan only 80% as much as the fourth and so on. (28). Thus in aircraft assembly, short production runs bear the penalty of additional labour content per unit.

It has been shown that learning rate is proportional to labour input per lb of aircraft (29). Thus it would be expected that learning curves would be most apparent in production processes with high labour content. Nevertheless, Hirschmann (30) has shown that there is evidence to suggest that learning curves occur even in a flow-process industry, such as oil refining.

The use of measures to increase the rate of learning of assembly workers as used in the electronic assembly industry was reported by Young and Tanner (31). A system of modular production stations was used to provide flexibility to meet changing demands. They claimed a 35% higher rate of set-up using modular production stations. A series of photographs of the first piece sample was made at various stages of assembly, the item numbers from the parts list were ballooned out from the photographs. Alternatively an assembly drawing was used. On the drawing a starting point was identified and a line was drawn to each successive part. In assembly of wire harnesses, tape recordings were used to give instructions. It was found that operators could lay wire satisfactorily 30% quicker than previously, when written instructions were used.

It was suggested by Keggerreis (32) that a relatively short cycle time should be used in assembly operations to improve learning rate. However he also suggested that too short a cycle time would lead to fatigue. He stated that conveyor cycle times should fall between 15 seconds minimum and 3 1/2 minutes maximum.

Product design can play a role in easing the costs of short production runs. Probine (33) reported methods used at Fisher and Paykel's white-ware assembly plant. He described how their 11 models of refrigerator used only 4 basic doors and 2 depths. The chest-type models were made to the same folds as the vertical models. The use of ABS plastic with expanded foam insulator eliminated costly welding and metal-forming used in refrigerators manufactured overseas. Sizes were also designed for maximum utilisation of container space as a large proportion of production was for export. Additionally Fisher and Paykel used small computers to alter machine settings to enable the rapid changeover from one product to another on the same production line. (34).

A pharmaceutical packaging factory maintained efficiency despite runs varying from 5,000 to 100,000 units by:

i. Keeping plant floors and layouts open, for fast, easy shifts of operations;

ii. Keeping line mechanisation at a minimum by resisting the temptation to add equipment which in the long run would reduce versatility.

iii. Having an on-going training programme for crews and supervisors so that anyone could do any job (35)

Einbinder (36) reported that a cosmetic packaging company minimised the cost of set-ups by ensuring that there were sufficient lines to enable a new run to be set-up before a crew had to move to the line. The firm also put great emphasis on ensuring the line was set up correctly, pointing out that "The additional time of the set-up man is far outweighed by the man-hours of several operators wasting time or doing unnecessary work to compensate for a bad set-up."

In flow-line production involving the manufacture of complex products such as aircraft, production-planning to ensure that all resources are co-ordinated is a highly complex process. This can be further compounded by short production runs. Warterbury (37) reported that Lockheed use a highly sophisticated computer-based planning system called "Genplan" to generate manufacturing process plans.

Measures to deal with short production runs in flow-line production are aimed at reducing the set-up cost and increasing the rate of learning of operators as well as reducing the complications of the planning task. These objectives were met through:

i. Use of flexible non-specialised machinery;

ii. Substitution of labour for capital inputs to increase flexibility;

iii. Use of modular units in design and production.

iv. Use of photographs and other pictorial methods to increase the rate of learning.

v. Use of tape recordings to increase the rate of learning.

vi. Selection of appropriate cycle time to minimise the effect of learning.

vii. Standardisation of parts to minimise set-up costs.

viii. Selection of materials which have low tooling cost.

ix. Training staff to improve flexibility.

x. Use of computers to assist in complex production planning.

Flow-process production

Flow process production involves the continuous or semi-continuous manufacture of dimensional products. It is the most recently developed form of production. It is highly capital intensive and requires relatively highly skilled operators. Examples of such production include the manufacture of chemicals such as sulphuric acid, continuous fermentation process to produce alcohol, printing processes using web-fed presses and many food production processes.

Woodward (38) reported that in the study of 100 firms, classified as in Figure 2.1 (where process production corresponds most closely to flow-process production), the following emerged:

i. there was more delegation of authority in process than other types of production;

ii. the length of the line of command (number of levels of hierarchy) was greatest in process production;

iii. the span of control of the chief executive was greatest in process production, he acted as a chairman rather than an authoritarian figure;

iv. the proportion of turnover in wages and salaries was least in process production and industrial relations were generally better, probably due to less tension and pressure, smaller working groups and small spans of control in middle management;

v. the ratio of managers to total personnel was much greater in process industry (1:8 process, 1:16 large batch and mass, 1:23 unit). Additionally managers were better qualified with a large proportion of graduates in line management.

vi. There was a greater proportion of indirect labour to direct labour in process production.

vii. There was a greater proportion of clerical and administrative labour to manual labour in process production.

viii. There was a larger number of skilled workers[1] in process and unit production than large batch and mass production.

Learning behaviour has been observed in flow-process production. Baloff and Kennelly (39) reported that in a recent study of process start-ups in the steel industry, steady state productivity was reached that was 1.6 to 11 times greater than the average productivity of the first month of operation. Hirschmann (30) reported that over a period of ten years, the time required to put a Whiting refinery fluid cracking unit on-stream dropped to less than half the time initially required.

The cotton industry in Britain was plagued by a great variety of specifications and consequent short run lengths according to Robson (40). He suggested that economies could be achieved from a reduction of variety by:

i. reducing administrative and clerical expenses;

ii. reducing the amount of stock holding necessary;

iii. reducing the time when machines or men were idle through difficulties in dovetailing one order into another;

iv. reducing the proportion of time spent in machine setting as against machine running;

---

1. There was some problem in obtaining the skilled operators necessary as although they were often highly skilled in that situation, they were not recognised as skilled outside the firm.

v. by permitting an optimum deployment of labour and more generally, of all the factors of production.

In addition he suggested there may be a saving from the increased skill of management and operators leading to an improved flow of output and a reduction in faults.

In the past, gravure-printing has been restricted to use in largest circulation in the publishing field and longer runs in packaging due to a great extent to the cost of the gravure cylinder. However, a new gravure cylinder production process, reported by Purdy (41) has reduced the cost of cylinder manufacture by about one half. The cylinders also take significantly less time to engrave thus making it possible to produce short runs more economically.

The relationship of various process and product parameters to run length in a naptha cracking heater has been examined by Mol (42). The end of a run can be caused by coking of the cracking coils or by fouling of the transfer line exchanger. Mol examined the relationship of film effect and tube-wall temperature, feedstock, outlet temperature, outlet pressure, dilution steam, coil design and size, burner type and layout, tube material, and tube length and arrangement to run length and was able to recommend operating strategies to improve run length.

Measures to deal with short production runs in flow-process production must deal with the high set-up costs and improve learning rate where possible. Additionally, Mol's article indicated a run-length feature unique to this type of manufacture: the interaction of the material and the process plant.

There is relatively little published information dealing with this class of production and so, bearing in mind the special nature of this production, methods to bring about solutions to the short production run problem must be extrapolated from other forms of production or be completely novel.

2.6 SHORT RUNS IN SPRAY DRYING PLANTS

The commonality of many problems in a wide range of manufacturing has been discussed. In all situations a production manager must plan and control to meet objectives. He must co-ordinate men, machinery and materials in the face of unexpected disturbances in order to manufacture a satisfactory product.

Spray drying plants are different from the other types of production that have been discussed. There are a number of features that make them different. These include:

i. The seasonal pattern of milk flow.
Manufacturing is dependent on the production of the raw material which occurs in a seasonal pattern with a peak of twice the average flow.

ii. Perishability of raw material.
The short life of the raw material due to rapid microbiological attack makes storage impracticable and necessitates prompt processing.

iii. A relatively small labour force.
A small number of people are responsible for the major portion of the processing.

iv. Limited variation in plant and product.
All raw material must pass through the basic steps of separation, evaporation, drying and packing. To bring about variation minor plant items are added in various combinations and flow rates and temperatures altered.

v. Limited plant running time.
The plant's running time is limited by scale build up in the evaporator and microbiological growth so that for practical purposes, a large part of it must be cleaned completely every 24 hours.

vi. Raw material and product are both fluid.

vii. A high proportion of cost is fixed.

The labour cost is fixed. Plant must be staffed to handle thepeak flow and because of the skill involved cannot readily be shed and replaced. Also plants are often in areas which do not have a ready labour market. There is a daily cost of start-up, shut down and cleaning regardless of volume of product, with the evaporator consequently running for several hours without product. Finally, the plant itself is an expensive major single item and parts cannot be readily shed or acquired to alter capacity.

These features and others distinguish spray drying plants from other types of production. However, spray drying plants also have many similarities with other types of production. Their sophisticated process technology, high capital, and low labour content and free-flowing product and raw material appear to be a classic case of a flow-process industry. However, they also have features of batch types of production. There is a limited volume that can be processed before cleaning, there is a daily start-up and shut-down, and the equipment is relatively general purpose in that all three major types of product, namely SMP, WMP and BMP can be processed in the one plant with only minor additions and control alterations.

It must be concluded that production in spray drying plants is a hybrid process and short production runs may involve problems and draw solutions from a variety of types of manufacturing.

From the study of batch production it was concluded that set-up cost was a major factor in short runs. An examination of set-ups in spray drying plants must be made to determine if this is the case, and if the time taken for set-up is a critical factor. If set-ups proved to be a problem could flexible automation or computers be of assistance? Could the use of unconventional equipment or processes avoid such set-up costs or could the Dairy Board organise the allocation of orders differently to attain economies?

In flow-line production, measures to deal with short production runs are aimed at increasing the rate of learning as well as reducing set-up cost. Does learning behaviour occur in spray drying plants? Could the substitution of labour inputs for capital equipment increase flexibility? Can the operators be trained better to adapt more easily to changing product specifications, can computers be used to assist in complex production planning?

Flow process production studies indicated that in this type of production there is an interaction between the plant and the material. Can this relationship be quantified, can it be used to produce short runs more efficiently? Can advantage be taken of the different management structure in this type of processing in order to improve short run economies?

Many questions have been posed by this study of the occurrence of short runs in other industries. They have indicated where the problems of short runs lie and where to look for solutions. Only a detailed study of spray drying plants can resolve these questions.

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CHAPTER THREE

THE OCCURRENCE OF SHORT PRODUCTION RUNS IN SPRAY DRYING PLANTS

3.1 PREPARATION OF THE SURVEY

Introduction

It was considered necessary to undertake a survey of the occurrence of short production runs in spray drying plants of the New Zealand Dairy Industry because the information sought was not available from any other source. It was desired to determine:

i. How short production runs could be defined.
ii. What caused short production runs.
iii. How many short production runs occurred.
iv. If short production runs were seen to be a problem in the factories.
v. What problems were caused by short production runs.
vi. What might be the potential means for improvement.

The survey was carried out in two parts. A written, postal questionnaire was followed by an interview. The results are presented here in that order because the questions asked in each case were respectively quantitative and qualitative, providing a natural classification.

Familiarisation with the Industry

In order to determine the best method of seeking the information and to be familiar with the technical nature of the Spray Drying Industry, a number of visits were made to Spray Drying Factories where the problems of short production runs were discussed with various staff members. In addition the operations of a spray drying factory were observed at first hand by attending several shifts with plant staff. In addition short production runs in spray drying plants were discussed with Dairy

Board, Dairy Research Institute and Massey University staff.

Preliminary Data Analysis

A preliminary analysis of the distribution of production run lengths was able to be made on data provided by the Dairy Board.(1) This was done with the aim of assisting in the understanding of the data requirements for the proposed survey.

The Dairy Board data comprised monthly production statistics by factory and by specification for the 1978-79 season. It enabled some estimates to be made of the extent of short production run occurrence due to changes of specification.

There were some important points immediately raised with regard to the inadequacy of this Dairy Board data:

i. Production which failed to meet specification (and thus was not submitted to the Dairy Board) was not included.

ii. It was not possible to determine whether a product specification (and hence a run) had been produced deliberately or as a result of a re-classification of the product.

iii. In the case of factories with more than one plant, it did not distinguish which plant was used.

iv. It did not indicate whether the tonnage for a month was produced as one run, as a number of runs, or as part of a run extending into more than one month.

The data was analysed under a number of assumptions. Briefly, the conclusions reached were that:

i. Generally there appeared to be the greatest number of short runs in SMP and BMP production, followed by WMP, followed by the protein group.

ii. If it was assumed that factories only used their smallest drying plant, then this assumption resulted in a similar distribution to that which would be obtained if it was assumed that groups of similar specification were produced as one production run.

iii. In WMP and protein groups, the distribution of run lengths did not change with time of year. With SMP and BMP groups there was an increase in average run lengths during the flush period, with shorter run lengths in July-August and February-March-April.

iv. Standard specification products exhibit a different run length distribution to non-standard specifications. There was a larger proportion of short runs and very long runs in the standard specifications.

v. There were some companies that produced a different proportion of short runs to the industry average.

vi. The distribution of run lengths was as follows:

25 to 50% of all runs were long runs (>150 hours)
45 to 60% of all runs were short runs (15-150 hrs)
15 to 45% of all runs were extremely short runs (<15 hours)

(The percentage depended on what assumptions were made.)

This analysis indicated that it was likely that large numbers of relatively short runs were occurring. It also showed the need to collect information in such a way as to eliminate the assumptions that were necessary as a result of the inadequacy of this data.

Method of Data Collection

There are two recognised methods of data collection for this type of situation, the interview and the written questionnaire.

The Interview

The interview has the advantage of assuring a high response rate, ensuring that the respondent is able to supply a response to the correctly interpreted question, enabling the expression of views that may not have been possible in a written form, and enabling the interviewer to make an assessment of the authority of the view.

It has the disadvantages of taking a great deal of time and expense in physically visiting the respondents.

It is also subject to being affected by stress, strains and other factors affecting the interviewer and the respondent.

The Written Questionnaire

The advantages of the written questionnaire are that it is a relatively inexpensive form of data collection, the respondent can complete the questionnaire at his leisure and each respondent is presented with a standardised, unemotional situation.

The disadvantages are that it does not allow the respondent the freedom to express his views as well as the interview, it has less likelihood of being completed due to the lack of personal contact, it must be relatively short and it must be clearly worded to avoid mis-interpretation and ambiguities. (2)

It was decided that a combination of the two techniques would best meet the needs of the research. As there were only thirty-six factories in the Industry, a successful survey would require an extraordinarily high response rate. Thus the promise of a personal visit after the written questionnaire was an incentive to complete it. Additionally, the information required clearly fell into two groups.

Quantitative information could best be collected by the written questionnaire enabling the respondent to perform any necessary calculations or collection of information at his leisure. Writing would also be minimised, thus allowing a greater volume of information to be collected in a shorter time. It was decided to use a small portable tape recorder to collect the results of the interview questionnaire to allow a free-flowing, natural conversation to occur, facilitating the expression of ideas. (3)

Construction of Questionnaires

Bearing in mind the facts that were required to be determined, listed above, a long list of questions was generated. They were aimed at the production manager of each factory as being a unique individual in each factory, who was in a position to be aware of the technical nature of the plant's operation as well as having knowledge of wider management issues. (4)

In order to reduce the questions to a manageable number and ensure that the right questions were asked, without duplicating information already available, the list of questions was presented to Dairy Board Technical staff, Dairy Research Institute staff and others, for criticism.

With the help of this criticism (5), the questionnaires were prepared for pilot-testing. It was felt that it was not desirable to use more than one factory for this purpose, in view of the small total population. This was done and the questionnaires were thus corrected and finalised.

Method of Carrying Out Survey

An introductory letter, emphasising the importance of the questionnaire, indicating the expected time of completion, and that some useful results would be returned to the respondent, was prepared and endorsed by Dr Sanderson, Assistant Director of the Dairy Research Institute.[1]

The introductory letter, along with the questionnaire booklet[1] and a return addressed and stamped envelope were mailed at the beginning of April to a list of production managers, prepared with the help of Dairy Board Technical staff. (6) This date was chosen to coincide with the end of the production season, permitting the collection of data from the past season while it was fresh in the minds of the managers, and at a time of the year when their work load would be expected to be low. The required completion date was April 25th.

When approximately two-thirds of the questionnaires had been returned preliminary results were calculated and each respondent was sent a copy with a letter expressing

1. See Appendix 2 for copies of letters and booklet.

thanks and proposing an interview date. Reminder letters and additional questionnaire booklets were sent to those factories which had failed to return questionnaires. A few days prior to the proposed interview, each production manager was contacted by telephone to confirm or re-arrange the interview.

Extent of Response

Completed written questionnaires were received from thirty-one factories. In addition the results from the one factory used as a pilot-test were included. Two factories indicated that they did not wish to complete the questionnaire as they were currently involved solely in caseinate manufacture, and one factory did not respond.

Interviews were completed at thirty-two factories (including the pilot). At two factories the staff were unavailable for interview for a period about the proposed visit time, and one factory was not visited because of its geographical isolation.

3.2 RESULTS OF WRITTEN QUESTIONNAIRE

Introductory Note

This section contains the results of the written questionnaire on short production runs in the New Zealand (Dairy) Spray Drying Industry. The figures refer to the 1979-80 season and are the result of the data supplied from thirty-two of the thirty-five factories in the Industry.

Some questions have a section recording statistics on "Estimate", "Production Record", or "No Answer" responses. These were used to indicate the degree of reliability of the results listed in that question. The "No Answer" category includes those respondents who did not tick either the "Production Record" or the "Estimate" box, as well as those who did not answer the question.

Responses to question one were not listed here because insufficient replies were made to draw a representative description of the size of plants in the industry.[1]

1. An analysis of the capacity of plants is made in Ch. 8.

Question 2

What is your definition of a Short Production Run?

Results

Twenty-four respondents defined a Short Production Run as being a period of less than one day's run (up to 24 hours). The shortest period considered to be a short run was one hour.

Six respondents defined a short run as being a period of greater than 24 hours run but less than a week's run.

No respondents defined a Short Run as being greater than a week.

Two respondents did not answer this question.

Question 3

Are there any particular product specs that involve Short Production Runs? Please specify and note why.

Product Spec	Reason that it is produced in Short Runs
Buttermilk Powders	Small quantities available for processing and short storage life. One respondent indicated problems of out of spec. on flavour as a result of two days storage before processing. Insufficient steam to dry buttermilk on roller plant, thus do Short Run on Spray Drier after casein manufacturing is finished.
Yeast Powder Goats' milk pdr Lactose Permeate Lactalbumin	Small quantities available for processing at any one time
Baby Foods and local market products	Small market requirements and limitations on associated plant.
Agglomerated types	Depends on Dairy Board Marketing
Health Foods	Expiry date on product
Some Skim Milk Powder Specs	Fouling of Evaporator
Various	Trials and test runs

Question 4

Are there any product specs that are particularly difficult to produce a Short Run of? Please specify and note why.

Results

Shortness of run was felt to magnify yield losses. This was especially important with high value products.
Some Health Foods were considered difficult to produce in Short Runs because of the length of time taken for Protein and various analytical Tests (up to 6 hours).
Problems could also be experienced with Skim Milk Powders of restricted WPNI because of the lag time between production of powder and results from WPNI tests.
Two respondents felt that any product was difficult to produce in a Short Run because of the need to "settle plant and obtain results".
After production of runs of Buttermilk Powder (usually short) problems were sometimes experienced with fatty powder in the plant (when producing SMP).
Some Babyfoods were considered difficult to produce in short runs because of the uncertainty of the quality of some of the non-milk ingredients.
On buttermilk powder the evaporator produces a surplus of concentrate because it was designed for Skim Milk. Also, the drier overloads the transport system.
On production of instant powders, there is a production of about 1/2 tonne of non-instant product each start-up/ shut-down. This loss is magnified in Short Runs. There is also the settling down of staff.

Question 5

Below are listed some possible causes of Short Production Runs.

I Add any causes not listed

II Note beside each how many Short Runs are caused by it per year.

Estimate 14 Production Record 8 No answer 10

Results

Ranking of causes of Short Production Runs

Rank	Cause	No. of respondents
1	Trials, test runs	17
2	Seasonal variation in milk quantity	14
3	Small order allocated factory by Dairy Board	11
4	Management decision	8
5	Failure to meet product spec in earlier run	7
6	Seasonal variation in milk qualities and properties	6
7	Seasonal variation in milk quality	4

Other factors which were felt to cause Short Production Runs were:

making show powder:

normal Buttermilk Powder Manufacture:

no or poor refrigeration eliminating skip-a-day pick up:

small order caused by local sales:

small amount of concentrate available to dry:

local market customer requirements.

In questions 5 and 6, it was difficult to establish just how many Short Runs were caused by any one factor because respondents had widely differing views. As a result an arithmetic average would have been meaningless. Instead the causes were ranked in the order of the number of respondents that noted this factor to be a cause of Short Production Runs.

Question 6

Below are listed some possible causes of interruptions to production runs.

I Add any causes not listed

II Note beside each cause how many occurrences of it there are per year.

Estimate 15	Production Record 10	No answer 11

Results

Ranking of causes of interruptions to production runs

Rank	Cause	No. of respondents
1	Failure of electricity supply (external)	29
2	Failure in plant (mechanical)	28
3	Failure in plant (electrical)	26
4	Boiler breakdown	19
5	Water shortage	12
6	Late tankers cause run out of milk	10
7	Failure of fuel oil to arrive in time	3
8	Failure in external gas supply	1

Additional causes of interruptions to runs were:

product functional causes (instant problems)
blocked driers
staff
product mixing problems from batch to batch
out of spec product causes
negligence

Question 7

Approximately how many product runs per annum are made of each of the following run lengths in hours? (excluding start-up, shut-down and cleaning)

Estimate 11	Production record 11	No answer 10

Results

Average number of runs in class

0-3	4-9	10-21	22-29	30-49	50-74	75-99	100-149	150-240
16	13	20	5	25	3	4	2	1

------days----------

11-21	22-35	35
4	2	1

Number of responses used to calculate above result: 12

Questions 7 and 9 were beset with some problems of definition and understanding. Some respondents did not realise that what was wanted was the total run lengths rather than the daily run length. Also, a large number of respondents answered correctly in terms of the definition in saying they made a different run each day because of the daily production of buttermilk powder. A special exclusion should have been made for Buttermilk Powder in the definition. Thus, only those factories that did not product buttermilk powder gave the statistics that were required. This accounts for the small number of factories used in the results displayed.

Question 8

Approximately how many days per year would daily running time be of the following lengths in hours? (excluding start-up, shut-down and cleaning)

Estimate 11 Production Record 10 No answer 11

Results

Industry average number of days spent at a particular run length

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
0	1	2	4	5	6	7	14	19	12	16	22	5	9	13	21	10	38	11

20	21	22	23	24	24
24	13	4	1	1	2

Average number of days plant is running: 260

Question 9

How many production runs of each spec that has been produced have been made in the last year?

Results

Multi-plant factories nearly always run more than 1 plant on the same spec.

One respondent did use one plant for SMP only and one plant for WMP only. Two, three or four runs were made of about 14 specifications per plant during the year.

The average number of different specs produced per plant was 8.

The average number of different products (e.g. WMP, SMP, BMP are three) produced per plant was two.

The average number of runs per specification was three (in those plants where buttermilk did not cause daily spec changes).

One factory, using their small evaporator-drier for the local market, did an average of four runs of each of eight specifications.

Question 10

What is the average number of specs produced in....

Estimate 8	Production record 17	No answer 7

Results

For the industry, the average number of specs produced per plant was as follows:

	minimum	average	maximum
a day	1.2	1.6	2.4
a week	1.3	1.7	2.8

Question 11

Approximately what would the average daily running time be (in hours) for each of the following months? (excluding start-up, shut-down and cleaning)

Estimate	10	Production record	12	No answer	10

Results

Average daily running time for the industry each month is

Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
.6	2.2	8.8	13.6	16.4	17.1	15.5	13.4	11.8	10.4	7.1	4.8

Question 12

What is the maximum time your evaporator can run between washes and on what spec?

Estimate	11	Production record	18	No answer	11

Results

Average Maximum Time evaporator can run between washes is 19.5 hours

Short Maximum Time is 7-8 hours on a low heat SMP

Longest Maximum Time is 50 hours on spec 600.

Question 13

How long does it take on average to....

Estimate	9	Production record	8	No answer	15

Results

Average time to perform the following tasks (SSMP) were:

	hr	min
Start up evaporator	0	44
Start up drier	0	27
Shut down drier (excluding clean)	0	20
Shut down evaporator (including CIP)	2	00
Wash drier (full wet wash)	2	50
Wash fluid beds	2	45
Wash cyclones	4	20

Question 14

How frequently are the following given a full wet wash?

Results

On SMP the following are given a full wet wash as follows:

drier daily:12 2 days:1 3 days:1 4 days:1
weekly:7 less often:7

fluid beds monthly or more frequently:6
2-6 times/year:3 1/year:1

cyclones monthly or more frequently:10
2-6 times/year:9 1/year:5

In general, cleaning appears to be similar or with greater frequency on WMP and other products to the above.

Question 15

On which product and product spec changes do the following not need to be cleaned? (Please list indicating specification to specification)

Results

Evaporator. The evaporator does not need cleaning on changes from:

whey powder to SMP or BMP
SMP to BMP and vice versa
SMP to WMP
BMP to WMP and vice versa

Two respondents said they do not change spec during a day's run, that is to say, they change at the end of the day and therefore the evaporator is washed anyway.

One respondent always washes the evaporator between specs as a matter of company policy.

Drier. The drier is said not to need cleaning on the above spec changes and also from:

WMP to half cream powder
half cream powder to SMP
low to high fat powder and vice versa
SMP to SMP
low lactose to high lactose
caseinate to WMP
WMP to SMP

One respondent said both drier and evaporator are usually cleaned before a spec change.

Question 16 [1]

Approximately how much chemical is used each time the following is washed?

Estimate	10	Production record	6	No answer	17

Results

Caustic use (kg of NaOH)

	kg	n
silos	.48	8
standardising vessels	.1	1
separators	.78	10
drier	.8	6
fluid beds	.3	2
evaporator	2.0	10

concentration used was from 1 to 3.5%

Nitric use (kg of Nitric Acid)

	kg	n
silos	.34	3
standardising vessels	-	-
separators	.25	7
drier	0.0	5
fluid beds	0.0	5
evaporator	.52	8

concentration used was from .75 to 3%

Sanitizer etc. use

Use of sanitizer and other additives appears to vary widely in types and dosage rates, including whether it is applied at all.

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1. Volumes and concentrations of cleaning materials used appeared to vary greatly. When kg of active ingredient were calculated, there were differences of up to 1000 times between some plants. In order to arrive at an average figure, only those responses that appeared to be in close agreement were used. The figure, "n", is the number of responses that were used to calculate the average.

Question 17

How long in addition to normal start-up, shut-down and cleaning does it take to change...

Estimate	12	Production record	3	No answer 13

Results

Specification changes within one product type:

Change	(hrs) Longest	Average	Minimum
Agglomerated to non-agglomerated	6	4	2
603 to 672	6	4	2
low heat to medium heat	2	1.5	1
	1	.75	.5
602 to 652	1	.75	.7
600 to 672B	1	.5	.167

Product type changes:

WMP to SMP	16	12	10
WMP to BMP	.7	.5	.167
	1	.33	.25
	.5	.33	.25
672B to 800	1	.33	.167
SMP to WMP	-	.75	.33
	1.5	1	.75
WMP to caseinate	16		

Question 18

How many staff per shift are there on....

Results

Function	No. per plant
Supervisory	.60
Separation	.61
Standardisation	.64
Evaporation	.88
Drier	.78
Packing off	4.99
Boiler	.74
Lab	1.44

Question 19

How many shifts are run of....

Results

	Normal	at peak	at end of season
Process staff	2.37	2.59	1.82
Packing staff	1.38	1.51	1.16

Question 20

Do you have any special arrangements for staffing, e.g. extra clean-up staff not covered by the above questions, if so, please describe?

A number of factories have at least one extra person involved in clean up.

Question 21

What percentage of total off-specification product would you attribute to Short Production Runs?

Results

Estimates of off-spec product due to short runs ranged from none to 100% as follows:

0%	10
0-10%	9
10-15%	1
25%	1
50%	2
90%	1
100%	1
No answer	7

3.3 RESULTS OF THE INTERVIEW QUESTIONNAIRE

Introduction

This section contains the results of the interview questionnaire presented to powder production managers of thirtytwo factories by the author during June and July 1980. The results are preceded by a table listing the questions and the corresponding information sought.

TABLE 3.1 INTERVIEW QUESTIONS AND THE INFORMATION SOUGHT

Interview Question	What was sought
1. What are the objectives of the company?	Does the manager have a clear idea of what he is trying to achieve? What is he trying to achieve? Is the research going to help him?
2. How do you judge how well these objectives have been met?	Is there any feedback control? What form does it take?
3. How does the company evaluate the economics of run length?	Does the company evaluate the costs of short runs? Who does it? How is it done? Is the company aware of the excess costs of short runs?
4. What measures are taken to deal with short runs?	Are there any novel solutions to the problem

5.	How long is the minimum daily running time your factory would run and why?	What are the factors that cause a plant to be run for a short period each day? What idea has the manager as to what is uneconomic? Are efforts made to maximise daily running time?
6.	What measures are taken to deal with short daily running time?	Are there any novel solutions to this problem?
7.	Do you divert milk to other units sometimes or receive milk from them, and on what occasions?	Is this used as a means of increasing daily running time? How much co-operation is there between companies?
8.	Who decides on the factory's production plan?	Who does? How much say has the production manager? What sort of factors are taken into account?
9.	How does the company decide which spray dried products it would like to produce?	How big a part do plant economics play in deciding the products? What are the other factors? How much say does the company have?
10.	Are there any particular specs that your company is better at producing than most other companies and why?	Does the manager know if his company has advantages over others and exploit it? Are such advantages used in determining what products are produced? How much specialisation is there?
11.	What is the maximum period milk can be held before processing it?	How long can it be held? Is this used to help increase daily running time? What problems can it cause?
12.	How long can the plant be shut down before it requires additional cleaning prior to start-up?	Does holding milk cause extra plant costs?
13.	What quantity tested by the lab takes longest to test and is most often reason for out of spec?	What takes longest? What causes most problems?
14.	Do you propose any alterations to plant capacity, how much and when?	Is there a trend to more flexible or bigger plants?
15.	Do you intend to diversify the product spec range you produce and if so, into what areas?	Is the present pattern of production likely to change? Is the ability of plants to produce a variety of products going to change?

16.	Do you have documentation on how to set up the plant for different specs, who writes it and who is it available to?	Do the operators know how to get the plant on spec? Is the information kept up to date?

17. What would be the advantages and disadvantages if....

i.	Supply of milk is constant throughout the year	What advantages and disadvantages does this have? Is it possible? What can be done?
ii.	Individual spray drying factories specialise in making only 2 or 3 specs.	ditto
iii.	Reduce time of start up, shut-down and clean by one hour?	Are managers aware of this cost? Are they doing anything about it? What can be done?

18.	What area do you feel holds most potential for efficiency improvement in spray drying plants?	What is wrong at present? How could it be improved? Is this research important? What else should be done?

Answers to the interview questionnaire.

1. What are the objectives of the company?

Answers to this question included the following:

a. To maximise the return to the farmers through efficient production.

b. Payout

c. To produce a milk product which will give the best return to the farmer.

d. Short Term. To economically process milk to provide maximum return to the shareholders.
Long Term. To economically process whatever products are produced on the land around here.

e. To manufacture the best product we can with the equipment we've got. To be as viable as possible.

f. To maximise return to the farmer and secondary are the long term maximisation of return to farmers and we recognise a role in providing employment.

g. To maximise long term profitability and to preserve identity (vs nearby larger company).
To be in specification (powder plant objective).

h. None. Currently in process of merger talks.

i. To process milk as cheaply as possible to give maximum return. Welfare of staff, to make it more than just a job. Quality, yields, costs and staff.

j. To make good quality powder.

Most respondents answered in terms of maximising payout to the suppliers. A very small number went on to relate that to what had to be done in the plant, in terms of maximising use of resources and minimising costs. Some respondents' responses were not as wide ranging as were expected. Many respondents put an artificial limit on the scope of their possible action. Some limited themselves to existing technology, e.g. answer 'e'; others limited themselves to processing milk or products of the land.

There was little evidence of market orientation. Some spoke of quality as an objective but this was more related to payment from the Dairy Board than to the products' acceptability in the market place. No one mentioned satisfaction of consumers as being part of their objective.(This is perhaps less surprising than it appears in that the Dairy Board is the market to the companies.)

2. How do you judge how well these objectives have been met?

Most respondents answered that they compared their company payout with that of other companies in a similar position. NZCDC has recently begun to use a monthly reporting system on several factors of production, compared with predicted levels. All NZCDC managers said that they thought this was a good system.

Four other companies have some form of monthly report. The remainder have none.

Some respondents mentioned "percent premium grade" as being their measure of performance.

3. How does the Company evaluate the economics of run length?

The following are examples of answers received to this question.

a. The cost accountants go to work. They ask me for information on staffing, tonnes per day, and composition of product. They find out what the Board is going to pay and work out if it's going to be economic.

b. It depends on the premium payments. If it's going to be something big later on, then we'd definitely do it.

c. We have never had any small orders from the Dairy Board.

d. We'll make it providing the Board pays the cost.

e. We see a spin off in doing short runs in that we want the Board to see we're prepared to manufacture these products.

f. Small tonnages are unsettling. Staff have a reluctance to change from week to week. Often a change is to the detriment of quality.

g. We have a good costing system for different parts of the factory. We put in steam meters and power meters on reception, separators, casein wash, casein dry, evaporator and spray drier. Costs are broken up into wash-up and actual running. We estimate chemical consumption and drying rate.

h. .....and cost out the difference in direct and indirect costs (from a standard product)....

i. We're still groping in that area. We have the information on costs we've accumulated over the past few years. We used to do short runs to please the Dairy Board, but now we don't do it because it upsets the whole operation, staff, costs, total inconvenience. The effect on morale is a thing you can't quantify.

There are a majority of plants that do not get asked to do short runs. Of those that did short runs, most respondents answered that they assessed the costs and compared this with the price the Dairy Board was prepared to pay. Some factories have a very good idea of their costs in detail. Others can

only use the costs incurred the last time the product was made.
The costs are usually assessed by someone other than the powder production manager, either a higher manager or an accountant.
Only one respondent mentioned the additional indirect costs due to producing a short run.
Some companies mentioned that their willingness to produce short runs was as a result of their desire to be seen by the Dairy Board as a suitable company to produce high premium, non-standard products.

4. What measures are taken to deal with short runs?
In general discussion on question 3 pre-empted the raising of this question.
One measure that was mentioned was the production of two months' requirements at the end of the first month, in one run. This was only possible where it fitted with shipping deadlines and time constraints.
One respondent said that he was unwilling to produce less than a full day's run of a product.
Respondents said that it would be most undesirable to do short runs at the peak of the season, when capacity was stretched. Short runs should be scheduled for non-peak times if at all possible.

5. How long is the minimum daily running time your factory would run, and why?

2 - 3 hours	2 times a week
3 - 4 hours	2-3 times a week
4 hours	2 times a week
4 - 5 hours	2 times a week
5 hours	3 times a week
6 hours	
6 hours	
8 -10 hours	
10 hours	(on 1 plant of 2)

Most managers said that running time was not the main criterion for continuing or ceasing production.

The reasons were as follows:

a. How much maintenance or capital works had to be done during the shut-down.
b. Depends on the season and whether we have met our market commitments.
c. Can't tip the milk down the drain, thus process it.
d. Quality drops off seriously.
e. Ratio of protein to lactose alters (protein increases, lactose decreases) making it more difficult to achieve the desired solubility and instant properties.
f. Must process the town milk supply anyway.
g. It might be cheaper for the factory to run at a loss than freight the milk elsewhere.
h. Prefer to do a short, sharp burst of production each day to give continuity of work for the staff.
i. Tanker collection determines when bi-daily production starts.
j. It is a head office decision.
k. Prefer short running time at the start of the season to get any problems of new plant or modifications sorted out.

Most managers try to run the plant as long as possible when they do run. This depends to some extent on the milk collection routine. Most factories do not have refrigerated silos whereas milk is refrigerated on the farm.

Plants producing WMP would not do so on a bi-daily basis because of the danger of flavour problems due to the quality drop on storage. These were the plants that said they would not run less than 10 hours per day (on WMP).

6. What measures are taken to deal with short daily running time?

Most companies ran every second day or with a lower frequency during the ends of the season. Some groups of companies co-operated to process all their buttermilk or milk in one factory. Some respondents said they used their casein factory to handle the small volumes of low quality milk that were available at the season's end. Factories that had multiple plants said it was possible to use fewer than the maximum number of plants or 1 plant of 2. However, this strategy was limited in NZCDC plants because of the co-generation of electricity. There were two problems.

1. Importation of electricity was necessary if less than full steam was used.
2. Large volumes of low pressure steam ex the turbo-alternator had to be exhausted to atmosphere instead of being used for drying if only say 1 of 3 plants was run.

These problems resulted in it being considered more economic to run all plants for a short time rather than one for a long period.
Another problem was that boilers become less efficient when producing much less than their intended level of steam production.

7. Do you divert milk to other processing unit sometimes, or receive milk from them, and on what occasions?

NZCDC does divert milk to whatever factories it considers would bring the best return from it. Matangi has a virtually constant milk supply as a result of this.
Te Awamutu had its maximum milk intake of the year in May when all the other factories had shut down. There are a number of problems at Te Awamutu caused by this.
Some companies do divert milk at the end of the season as mentioned above.
There are several companies that are so isolated geographically that it would be a very expensive operation to divert milk to other factories.
A possible reason for diversion of milk is a major break down. Most factories have other plants within the complex that could take the milk if the spray drying plant broke down.

8. Who decides on the factory's production plan?
Companies submit a plan to the Dairy Board of what their proposed production would be, based on standard products. The company also submits a plan of production involving non-standard products it would like to produce. The Dairy Board then tells the company what products it can produce. This may change through the season as orders for non-standard products change.
The plan submitted to the Dairy Board is prepared by the General Manager, Supervising Manager or the Chief Executive, who is senior to the Powder Production Manager. The production manager may have some say in the submissions and in the final detailed arrangement of theproduction within monthly periods.

9. How does the company decide which spray dried products it would like to produce?
The major factors deciding which products are to be manufactured are:

i. The capabilities of the plant and the availability of alternative processing plants (to make different types of product).
ii. Dairy Board product differentials.
    The Dairy Board pays the companies principally on 3 bases:
    a. Manufacturing cost allowance. The average manufacturing cost of a product through the industry is paid to manufacturers of that product on a per tonne basis.
    b. A payment for the milk on a cents per kilogram of milkfat basis. This payment can be modified by the addition of a differential, intended to encourage the product mix that the Dairy Board requires. For example, in the 1980-81 season, casein was the desired product and it received an additional 5c per kg of milkfat over the base price. Skim milk powder was not required so it was paid only the base price.
    c. Incentives and grade premiums

iii. Costs relative to other companies. Because the Dairy Board pays average costs, if there are companies producing the same product, one of whom has a significant advantage then the average is lower and the company without that advantage might be reluctant to make that product.

Other factors that affect whether a company will produce a product include the seasonal variations in milk composition and quality, also the rate of throughput of the product.

10. Are there any particular product specs your company is better at producing that other companies and why?

About one third of respondents said that their factory was not particularly better than others in any respect.
Some said they had a minor advantage with respect to a particular spec and buyer.
One respondent said they had an advantage in producing high energy content products because of the availability of cheap coal.
Two respondents said that their plants' ability to manufacture high bulk density product was an advantage.
One respondent said that as his factory was set up to handle products that required standardising, this was an advantage in the production of standardised products.

11. What is the maximum period milk can be held before processing it?

Estimates of how long milk could be held before processing varied from two days to about six days. Many companies collect milk on a bi-daily basis throughout the season to reduce transport costs.
It was noted that overseas, collection may be once every four days or a week but it was felt that in New Zealand, holding milk for up to six days was only possible with extremely good quality milk as produced in the flush period.
The view was expressed that town milk was of better quality and thus could be kept for longer than factory supply milk.

It was expected that quality would improve with the introduction of the standard plate count test.
Most respondents said that it was best to hold milk on farms because vats were refrigerated whereas some factory silos were not. Also, if there was a problem such as an industrial stoppage, the effects of dumping many individual tanks of milk was not as great as that of a factory silo. How long milk could be held also depended on the acidity specs of the product manufactured, and the product itself. Manufacturers of WMP were reluctant to hold milk at all, whereas casein was less critical.
Most factories did use the holding over of milk to increase daily running time.

12. How long can the plant be shut down before it requires additional cleaning prior to start up?

Most respondents answered that 24 hours to three days or greater shut down required an additional evaporator clean prior to start up. It was felt that driers could be closed up for 1-2 weeks before needing a wet wash prior to start up.
Some plants were washed with acid or sanitizer before start up as a matter of course.

13. What quality tested by the lab takes longest to test and is most often reason for out of spec?

Table 3.2 Quality Test Problem Areas

Longest to test		Most often reason for out of spec
Yeast and mould	4-5 days	Coliforms
Bacteria	3 days	Bacteria
WPNI	3-5 hrs	Fat
Oven moisture	5 hrs	Moisture
Vitamins	1 week	Scorched particles
Viscosity	1 week	Solubility Index
Foam test	3 week	Microbiological
		Wettability

Yeast and Mould, Bacteria and WPNI were listed at most factories as taking longest to test. The times given to perform these tests were all within the ranges given.

The last four items in the "longest to test" list were given by individual respondents.
The cause which resulted in "out of spec" most frequently was microbiological. Scorched particles were mentioned in three cases. The remainder were isolated occurrences.

14. Do you propose any alterations to plant capacity, how much and when?

Nineteen respondents said they did not intend to increase capacity.
Three respondents said that planned upgrading would result in increases up to 10%.
Other positive responses were:

a. Possibly. The (smaller) dryer is very old. We could replace it by increasing the capacity of the (larger) dryer.
b. An exercise is being looked at to install secondary drying. It is expected this would increase throughput 20-25%.
c. No. But if we're short of anything, it's a plant to give us a small throughput.....the economics are not there to go out and buy one.
d. If the increase in milk supply continues next year, we will have to consider it.
e. We would like to have a bigger dryer because we store concentrate now.
f. Yes. About four tonnes per hour, 6 effect with mechanical vapour recompression (possibly). To handle our peak and effluent problem.

In general there appears to be little change or investment planned. However, obviously such a matter would be highly confidential and thus it is difficult to say whether there will be major changes.
At present under construction at Waitoa are two plants for manufacture of whey products and baby foods.
There appears to be excess capacity in Taranaki.

15. Do you intend to diversity the product spec range you produce, and if so, into what areas?

Two respondents said they were intending to install equipment to allow them to produce high heat/heat stable SMP. One noted that there appeared to be a trend away from low heat powder to high heat/heat stable SMP.
Three respondents mentioned the possibility of producing whey products.
Two respondents said it was possible they would make WMP.
One factory was in the process of obtaining equipment to allow it to manufacture instant powders.
It appears that more factories intend to change the kind of product they produce than their capacity. Changes are to high heat/heat stable SMP, WMP, Instant Powders and to whey-based powders. As this does not in general involve complete new plants, it can be said that existing plants are becoming more flexible.

16. Do you have documentation on how to set up the plant for different specs, who writes it, and to whom is it available?

Most plants use log books from the previous time a product was made to help in setting temperatures, flow rates and pressures to be used.
Some plants have additional information in the form of a plant manual or card index systems referring to individual specifications. These are usually kept up to date by one person, such as the plant chemist, the senior first assistant or the powder manager.
Spec changes are supervised by the powders manager or a senior operator, in several plants.
It appears that operators do have access to information on how to get the plant on spec. However, changes from season to season and within a season, render logged set points approximate guides only.

17\. i. Supply of milk to the factory is constant throughout the year.

Most respondents said they thought even milk production throughout the year would be advantageous. The following reasons were given:

1. Invested capital would be reduced
2. Economy of operation (no short runs)
3. Staff benefit from set routine
4. Reduced management worries
5. Staffing level constant and optimal
6. Staff fully utilised
7. Staff don't want overtime, this would render it unnecessary
8. Reduced transport costs through optimisation of pattern of collection
9. Cost more easily controlled due to simple comparison with standard
10. Composition of milk stabilised
11. Machinery not sitting idle and deteriorating during winter break
12. Predictability

The following were given as disadvantages:

1. At least one month's shut-down required for maintenance
2. Farmers don't want to milk cows in winter
3. The maximum return to the farmer is to chase the available feed
4. Cost of diversion of milk when maintenance required
5. Staff like a break from shift work
6. Some products have different rates of throughput.

ii. Individual spray drying factories specialise in making only two or three product specs.

Advantages	Disadvantages
Quality more consistent- higher premium	Change in market could result in lack or excess of equipment
Wouldn't have to keep altering plant	How to pay out to companies
Could fine-tune the plant	Inability to produce some products at certain times of the year
Could tailor staff level to needs. At present have to cater for product with maximum numbers of staff	Management find it invigorating to do something new occasionally
Reduced capital outlay	A change seems to do the plant good
Simplified stock holding	Loss of versatility in staff

It is possible to specialise to some extent at present. For example, Mid Northland D.C. produces SMP and BMP at Maungataoroto and WMP at Maungatapere.
About half the respondents were in favour, in principal, with the idea but the main barrier was considered to be the sharing out of NSPO premiums.

iii. Reduce time of start-up, shut-down and cleaning.

Two respondents didn't think it would be an advantage to reduce this time.
The remainder thought it would be an advantage. Some made suggestions as to how to reduce this time. These were:

a. "Improve plant design to reduce fouling and build-up."

b. "Every year I cut more doors, holes and windows in the plant." (to improve access and ease of inspection)

c. "At first we used to wash the whole plant but now we only wash the critical parts."

d. "We have tried processing 1.5 days milk at a time."

e. "Some companies are bringing out CIP units that instead of boiling them (evaporators) under running conditions, you just CIP them."

One respondent felt that major improvements could be made in devising CIP systems for the ancilliary plant associated with the dryer which at present has to be dis-assembled and cleaned by hand.

18. Which area do you feel provides most potential for efficiency improvement in spray drying plants?

Evaporation

Effective in-line standardisation
Additional effects
Reverse osmosis as the first effect
Evaporator solids-solubility limits too tough
Mechanical recompression
More sophisticated control systems
Milk straight from separator to evaporator
Shorten start-up, shut-down times of evaporators and dryers
Design of plant for - reduced fouling
- longer running at greater throughput
- prevent heat losses
Economies of scale for evaporators and dryers
Much longer runs - 5 days

Drying

Heating inlet air - with Q-dot matrix from exhaust
- evaporator condensate and radiators
Direct firing
Reduce stack losses - better recovery systems
In-line moisture metering
Flexible dryer to do all products
Increase dryer inlet air temperature
Increase role of secondary drying

Packing

Automated packing line

Bulk packs

Better bag-weight control

Other Areas

Training program for operators

Improved instrumentation

Five days per week manufacture

Use of cheaper energy sources, e.g. wood chips

Improve keeping ability of powder

Twenty four hour milk collection

More rapid microbiological tests

Use of heat pumps

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CHAPTER FOUR

ANALYSIS OF THE OCCURRENCE OF SHORT PRODUCTION RUNS

4.1 INTRODUCTION

In setting out to collect information from the Spray Drying Industry, the following questions were to be answered:

i. What is a short production run?
ii. How many short production runs are there?
iii. What are the causes of short production runs?
iv. What are the effects of short production runs?
v. What can be done to deal with short production runs?

In this chapter what has been learnt about the above questions is summarised and the proposed courses of action are presented. The information is brought together under the headings of the three principle types of short production run in spray drying plants, namely:

i. Interruptions to production runs.
ii. Short production runs caused by specification changes.
iii. Short daily running time.

A further section deals with points not falling within these specific headings.

4.2 INTERRUPTIONS TO PRODUCTION RUNS

Interruptions to production runs cause short runs as the result of a failure. Their occurrence is random and unexpected.

Interruptions to runs may cause losses in some or all of the following areas:

i. Damaged equipment;
ii. Cost of cleaning materials;
iii. Labour idle during repairs;
iv. Labour cost in clean-up;
v. Loss of product;
vi. Loss of raw material;
vii. Effluent disposal costs;
viii. Diversion costs of material unable to be processed;
ix. Administrative costs;
x. Lost recovery of overheads;
xi. Additional start-up cost;
xii. Energy costs while plant stands by.

In Table 4.1 a more detailed breakdown of the frequency of occurrence of each of the major causes of interruptions is given. The range of occurrence of each of the causes is given. Means including and excluding the highest value are given to indicate its effect on them.

Cause	Range	No.of factories with ≥ 1 Occurrence	Mean Occurrence
Failure in plant (mechanical)	300-2	28	36.1(inc.300), 24.6
Failure in plant (electrical)	150-1	26	17.7(inc.150), 11.95
Failure of electricity supply(external)	20-2	29	7.6
Boiler breakdown	50-1	19	5.9(inc.50), 3.9
Late tanker causes run out of milk	12-2	10	2.0
Water shortage	5 -1	12	0.72
Others		11	2.0
Total			51

TABLE 4.1: Occurrence of interruptions to Production Runs

It should be noted that of all factories, only one did not suffer at least one electricity supply failure during the year. The occurrence of water shortages, while of a relatively low mean occurrence, did affect 12 factories at least once.[1]

The main point that arises from the close study of the occurrence of the various interruptions to runs, is that the cause of interruptions varies greatly from one plant to another. The large ranges of frequency of occurrence indicate this. What is a serious problem in some plants is not even considered a problem in others.

Conclusion

Although the occurrence of interruptions to runs is high on average in all plants, the reasons for the interruptions vary greatly from plant to plant. Measures to deal with such problems could not be generalised throughout the industry except that it appears that:

i. More thorough programs of preventive maintenance may be warranted;

ii. Electrical distribution authorities should be consulted to improve the continuity of supply.

In order to assess the viability of preventive maintenance programs, management information would be required indicating the extent of present losses. This could be a problem as, as will be discussed below, management information systems are not well developed in spray drying plants. Losses caused by failure in electricity supply are in some cases partially recoverable with regard to product losses but not the other categories noted above.(2) Improved access to the magnitude of such costs may assist in their recovery from electrical distribution authorities.

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1. Pratten (1) noted that one of the dis-economies of scale was the supply of water. It appears that this may be a limiting factor in further growth in the size of some spray drying plants.

4.3 SHORT PRODUCTION RUNS CAUSED BY SPECIFICATION CHANGES

Although short production runs caused by specification changes occur for a number of reasons they are deliberate acts, under the direct control of management.

Managers defined short production runs in terms of the number of hours of such a run. Sixteen respondents defined them in terms of a period of less than ten hours, thus showing an appreciation of additional costs involved in an extra plant clean. Four respondents defined a short run as being in the period 20 to 48 hours, thus again showing an awareness of cleaning cost and additional plant set-up cost. A further four respondents defined a short run as being a period from two to seven days. This last group may consider that there is some learning effect evident or non-optimal plant running during the first few days of a run.

It was found that there were on average 14.6 runs per plant per year, with an average of 5.5 specifications per plant, in other words about 3 runs per specification. The outstanding factories in terms of the numbers of specifications and runs produced are shown in Table 4.2

Factory	No.of specs.	No.of runs	No.of plants	Average run length (days)
Cambridge	8	42	1	6.02
N.Wairoa	11	35	1	6.2
Kaipara	14	37	2	9.0(on one plant)
Te Rapa	25	75	3	10.4
Midhirst	6	24	1	11.25
Kerepehi	28	42	2	12.4

TABLE 4.2 Factories with short run lengths

The production run lengths given in Table 4.2 can be compared with the Industry average of 17.8 days.

Cambridge produced 28 runs of 4 specifications. All these were agglomerated and three were instant powders. The major differences between them were in the vitamin additions and a different bulk density for the non-instant specification. Also, one had a lower fat content. Changes between these specifications would involve relatively minor adjustments. All powders produced were whole milk powders.

Northern Wairoa produced 23 of its runs on 3 specifications that were almost identifical except for the presence of vitamins and different fat levels. A further 7 runs were of specifications that were identical except for the presence or absence of vitamins and lecithin. Changes within these groups of specifications would not require major changes to plant or production methods.

Thus, in these two factories' cases, the number of short runs would effectively be reduced and the run length correspondingly increased.

Kerepehi appeared to produce a large variety of different specifications although producing a relatively small number of runs of each. It also used one plant to produce solely skim milk powders and another to produce whole milk powders and preparations.

Te Rapa had the most complicated production pattern, producing whole milk and special preparations on one drier, skim milk and whole milk on the second, and all three types on the third drier.

Although Cambridge and Northern Wairoa appeared to have a short average run length, they produced a number of specifications which were quite similar, thus minimising the effects of specification changes and effectively increasing their run lengths.

Taranaki's Midhirst Plant did produce a variety of product specifications but the average run length appeared to be quite long.

Kerepehi produced a wide variety of products with only a few runs of each.

Kaipara produced a wide variety of specifications for the local market, this accounted for only 15-20% of their total production and a small old plant was used.

Te Rapa easily had the greatest variety of specifications produced in the one factory and would be made subject to the effects of short runs.

Thus the ranking in the order of production of short runs would be:

1. Te Rapa
2. Kerepehi
3. Kaipara
4. Midhirst
5. Cambridge and Northern Wairoa

Thus it can be concluded that short production runs due to specification changes are likely to be a major factor in only a small number of plants although a small number per year may occur in a large number of plants.

Short production runs due to specification changes occur:

i. To meet market requirements;
ii. Because of failure to meet specification in an earlier run ;
iii. Because small volumes of a component (e.g. whey) are available at a time;
iv. As trials and test runs are carried out.

Some factories are willing to do short production runs because they see this as a demonstration of their competence to the Dairy Board and hope that the Dairy Board will thus allocate that factory non-standard specifications with premiums.

The effects of the short production run due to a change of specification fall into several groups. Firstly, there is the time taken to physically change the layout of the plant. This may vary from practically no time at all in the case of some specifications to several hours, as in the change from a simple SMP specification to an instantized, agglomerated, whole milk specification. The actual changes to the plant are not costly but the time taken to do so could be important at the peak of the season or when capacity was stretched to its limit.

In some cases it is necessary to wash the plant when changing specifications, for example from a high fat to a non-fat product. Such a wash can magnify yield losses in addition to incurring the energy, cleaning materials and other costs. However, such changes during a day's production are normally avoided, the wash coinciding with the normal daily wash.

There can be some quality control problems in production of short runs in that some specifications require tests that take several hours to perform, for example, various analytical tests and whey protein nitrogen assays. Most microbiological tests take several days. Thus, by the time a test has been completed, a large proportion of the run may have been manufactured.

Some respondents felt that short production runs were unsettling to staff as well as detrimental to quality and that it took time to 'settle plant and obtain results', implying reduced rate and efficiency of processing at the commencements of runs.

Some product specifications required additional staff in the packing section and it was felt undesirable to produce short runs of these specifications because of the complications and expense involved in employing such staff.

Where possible, changes were made from low fat to high fat products. For example in the daily manufacture of buttermilk powder on a plant normally producing SMP, the buttermilk was produced at the end of the SMP run.

In one case two months' production of a special product specification was made at the end of one and beginning of the next month but this was only possible when it fitted with shipping deadlines.

Conclusions

From the information above a number of conclusions may be drawn with regard to possible measures to deal with short production runs caused by specification changes and areas that require further investigation.

i. The principal costs of short production runs appear to be in plant cleaning, low quality and sub-optimal processing rates. The cost of setting up the plant may not be large, providing there is adequate capacity available to process the milk in addition to the time spent on set up. However, where additional costs are incurred because of milk diversion to another plant or even another factory due to strained capacity, then this should be considered to be a short production run cost.

ii. The extent of the costs of plant cleaning and the relationship between specification change and processing rate and specification change and quality, should be investigated.

iii. Specification changes were said to be "unsettling to staff". This could mean that learning behaviour occurs through a run. Additionally learning behaviour was implied in some definitions of short production runs. Thus the occurrence of learning behaviour in spray drying plants should be examined.

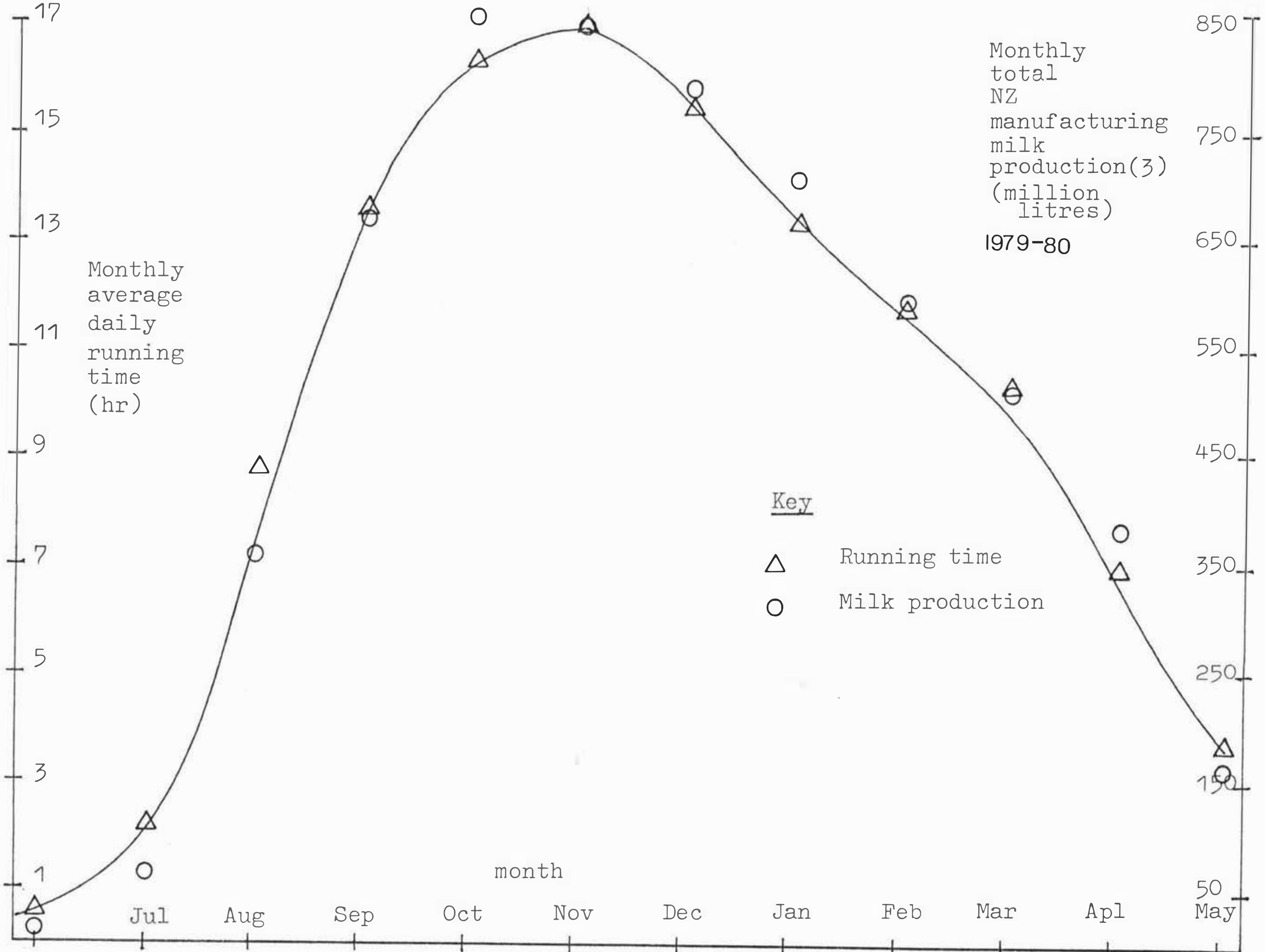
iv. Product characteristics requiring the longest time to test, that is microbiological characteristics, are also the most common reason for out of specification product. A small run of product could be complete before its microbiological characteristics were taken. Additionally "failure to meet specification in an earlier run" is a major cause of short production runs. Thus methods to ensure microbiological acceptability and improved speed in methods of microbiological testing should be sought.

v. The market's demands, transmitted through the Dairy Board are the overriding cause of short production runs due to specification changes.

4.4 SHORT DAILY RUNNING TIME

Short daily running time is a result of the seasonal pattern of milk production on dairy farms which supply New Zealand's manufacturing milk industry. Ideally processing plants would run 24 hours a day, 365 days a year in order to minimise fixed costs per tonne of product, but in the past it has always been more economic from a system point of view to have processing plants under-utilised for large portions of the year in order to minimise farm costs in milk production.[1]

1. See Chapter 5 for a more complete description.



GRAPH 4.1: Monthly average daily running time

Although some companies are able to smooth milk supply to their spray-drying plants by taking milk from other supply areas and closing down other factories, this is possible only with the larger companies. The milk producing cow still wags the factory tail as seen in Graph 4.1 which shows the average running time of all spray-drying factories for each month of the year. It can be seen by comparing the average daily running times with the milk production each month that there is no appreciable smoothing effect evident in the industry average, in other words, such smoothing must only occur in a small number of factories.

As can be seen from Graph 4, the volume of milk available for processing builds up rapidly and tapers off more slowly. Thus at the end of the season relatively small volumes of milk must be processed. The minimum time a plant was said to be run for was 2 to 3 hours twice a week. Milk is usually held on the farms because the farm vats are refrigerated (and factory silos are generally not). It is collected as infrequently as practicable to minimise transport costs. This is part of the reason for holding the milk, in addition to the dis-economies of processing a small volume.

The decision must be made as to when the volume of milk is insufficient to warrant processing. The reasons given by managers for continuation or cessation of production were generally not related to processing economies.[1] No manager said that production ceased because production costs were too high.

Most companies do run every second day or with a lower frequency in order to keep processing volumes as large as possible. In factories with several plants, only one of two plants was run to increase run length (in some cases).

One group of companies co-operated by transporting all milk to one factory for processing during the winter, thus enabling the others to close down, however, there

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1. See interview questionnaire, question 5.

are several companies so isolated geographically that this is not feasible.

It is considered desirable to manufacture some products at non-peak times of the year because of their reduced throughput. For example, when caseinate is dried the rate of throughput is 23-26% of the rate of throughput of medium heat skim milk powder.

It was concluded from the responses to questions 8 and 19 of the written questionnaire that some factories employ sufficient staff to man three shifts and most man two shifts, expecting operators to work overtime at the peak of the season. Packing is normally a one-shift operation but where instant powder is produced, it is necessary to pack product straight from the drier, with no storage, thus requiring extra staff.[1]

Conclusions

Processing in spray-drying factories does closely conform to the seasonal pattern of milk production. Although some measures are taken to increase running time at the ends of the season by storing milk and running the plant less frequently, no firm economic criterion is used for determining when a production run is not economic. Production managers need to be given information that will enable such a decision to be made on the basis of economic information in addition to the more qualitative reasons now used.

Additionally, production managers see a number of advantages in a smoother milk flow to the factory. (See responses to question 17i of the interview questionnaire.) A calculation of the effects on the cost of powder production of the seasonal pattern of milk production may assist in assessing the overall situation.

4.5 ADDITIONAL INFORMATION

The following points arose from the interview questionnaire results:

i. Most managers saw the objectives of the company in terms of attaining the highest possible return to the suppliers. None of the respondents mentioned the

1. This may not be the case with the increasing use of bulk bins.

satisfaction of consumers as being part of their objective. Thus it must be concluded that production managers in spray-drying plants are highly production oriented. (Probably as a result of the Dairy Board's position.)

ii. There is very little formalised management information which allows the closing of the management control loop.[1] Most managers relied on the annual statement of accounts as an indication of performance. Clearly this is a case of "too little and too late". The annual accounts reflect the result of a great number of management decisions and are produced after the end of the season when it is too late to take any corrective action. Production managers in spray-drying plants are in great need of management information that is detailed, immediate and regular to enable them to control the plant to meet payout objectives.

iii. The cost of producing powder is assessed on an "average for the season" basis, however at different times of the year the true cost per tonne varies because fixed costs, such as that of start-up and shut-down, should be carried by a greater or lesser volume of product. The economies of production runs are generally not assessed by the production manager. If the production manager was readily able to assess the cost of runs, he would be in a better position to try new strategies to reduce costs.

iv. Although companies are able to suggest to the Dairy Board what they would like to produce, the Dairy Board is in the deciding position and thus is able to allocate runs to factories.

v. Modifications to plants will make them more flexible. Thus more plants will be in a position to produce a greater variety of specifications in future.

vi. In many factories old log books are used to help set up the plant to produce a different

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1. See Figure 2.1

specification. If such data were kept in a special book or file, a more thorough and complete record could be kept, avoiding more pitfalls of the past and thus enabling specification changes to occur more smoothly.

vii. While many technological changes were suggested as having potential for efficiency improvement, no respondent mentioned the possibility of management itself as being a potential area for improvement. Thus this area of research taps what, for production managers in spray-drying plants, is a novel source.

4.6 SUMMARY

Interruptions to Production Runs

The large variation in the frequency and occurrence of the various causes of interruptions to production runs from factory to factory, leads to the conclusion that no one measure can have a significant effect on the industry as a whole unless it be extremely general. Thus measures to deal with this type of short production run in particular should not be sought in this research, except in that measures such as improved management information and an awareness by production managers of fixed costs may contribute to efforts to deal with such problems by assisting in the evaluation of alternatives.

Management Information Systems

It has become apparent that production managers in spray-drying plants are poorly served with management information. Only one company had a monthly management reporting system in operation. Thus managers are not in a position to make optimum decisions with regard to the mode of operation of their plant.

Additionally to the reasons above, the basis for decisions to close plants at the end of the season did not include economic factors relating to the cost of short daily running time. Improved availability of information should enable the decision to be made on a more informed basis.

Capacity Utilisation

Most managers felt that there were gains to be made in the factory through elimination of the seasonal pattern of milk flow. However, many of these gains were difficult to quantify, such as better planning, improved labour utilisation, improved labour relations. An assessment of the potential gains in processing cost through increased run length and possible capital cost savings, could be made to enable a more quantitative assessment to be made.

Start-up and Shut-down

The major component of cost due to a short production run of all types was the start-up and shut-down cost. It has been established that this process takes on average 2.75 hours. The extent of the consumption of cleaning materials and the labour content have also been established. Thus if an estimate can be made of energy consumption, the cost of start-up and shut-down can be determined, enabling the effect of run length (daily running time) on product costs to be made.

Specification Changes

It was found that the principal costs of specification changes were in plant cleaning, low quality and sub-optimal processing rates. It was felt that operator learning may have been a factor in causing the latter two costs. Thus quality, operator learning and processing rates at the commencement of runs should be investigated.

External influences

The occurrence of short production runs in spray-drying plants is largely as a result of the effects of external influences. The market transmits its needs through the Dairy Board. The seasonal pattern of milk production is a result of the search for efficiencies in the production of milk. The very size of the plant itself has an effect on run length because what may be a short run in a large plant will equally be a long run in a small plant. The basis for the occurrence of short runs must be examined if it is desired to optimise the performance of the system as a whole.

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CHAPTER FIVE

THE EFFECTS OF SOME ASPECTS OF DAIRY INDUSTRY INFRASTRUCTURE ON THE SHORT RUN PROBLEM

5.1 INTRODUCTION

In this chapter the interactions of the spray drying plant with the wider production, processing, marketing system will be discussed in so far as they affect the occurrence of short production runs.[1] It has been shown that short production runs in the plant are largely caused by external factors.

The effect of the seasonal pattern of production of milk is to cause short daily running time for a large proportion of the year and consequent poor plant utilisation. The reasons for this pattern of production and the costs of producing milk in a smoothed flow will be discussed.

There have been a great many changes in the market for New Zealand's dairy product in the last 30 years. The extent of these market changes and their reasons, as well as the Dairy Board's role will be discussed in order to show how they result in the occurrence of short runs in the spray drying plant.

5.2 THE DETERMINANTS OF NEW ZEALAND'S PATTERN OF AGRICULTURAL PRODUCTION

In order to understand the reasons for the seasonal pattern of milk production an appreciation of the agricultural economic forces must be gained.

Prior to 1890 dairy production was largely limited by local consumption but with the advent of refrigeration there occurred rapid economic progress with the development

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1. For a more detailed analysis of these factors See Appendix 5.

of trade with the United Kingdom in meat, wool associated with lamb production and dairy products.

New Zealand was able to grow crops such as wheat, and livestock products, better than Northern Hemisphere countries because of a more favourable climate. It had an absolute advantage in both. However, New Zealand's mild winters meant that livestock did not have to be expensively housed so additionally New Zealand had a comparative advantage in livestock production.(1)

The highest returns per acre were enjoyed by dairy products but dairy production required more than 40 inches (1000 mm) of rain per year with a good distribution over summer. It also required flat or gently undulating land which could be ploughed to enable sowing of the correct grasses and clovers and easy terrain to facilitate the daily transport of milk to the factory. Large areas such as Northland, South Auckland, Bay of Plenty, Taranki and Southland were suitable. The main feature distinguishing New Zealand's agriculture is the low labour use per unit area. In the formative stages there was plenty of land available with relatively little labour. This along with a progressive and enlightened education system which made farmers receptive to new ideas and techniques led to a highly efficient farming pattern.

The returns determine the use of agricultural land. They are dependent on prices received versus costs of production. Costs of production are low because of the high efficiency discussed above and the seasonal pattern of milk production. Because cows are not milked in winter there is no need to purchase expensive grain supplements for feed. The necessity for continuous cropping, which exhausts soil fertility and requires the use of expensive nitrogen fertilisers, is avoided. Thus the seasonal pattern of milk production is determined.

5.3 COMPARISON OF COSTS OF SEASONAL MILK PRODUCTION WITH SMOOTHED PRODUCTION

In order to assess the likely costs if it was required to smooth milk flow to avoid short daily running times in the processing plant, a comparison was made between costs on the average factory supply farm, and those on the average town milk supply farm, which supplies a relatively constant volume of milk throughout the year.

The additional costs on the town milk farm were as a result of:

i. The necessity to store a greater volume of feed for winter in the form of hay and silage, and supplement this with other feeds such as grain.

ii. The additional labour content in milking and rearing calves for twelve months of the year.

iii. The additional cost of running the milking shed and farm equipment for twelve months of the year.

iv. The use of a "run-off" area to rear dry stock which may be some distance from the main farm.

v. The greater number of stock transactions as greater control over stock numbers is required.

The consequence of these additional costs was that town milk farm costs were $41,245 as opposed to $24,100 on the factory supply farm. Gross income was $60,788 on the town milk farm as opposed to $37,384 on the factory supply farm.(2) When a correction was made to equate the number of cows on each farm, the factory payout necessary to provide income to the town milk farm was 1.7 times that of the factory supply farm.

This means that in order to justify a smoothed milk supply to the factory, the increased payout would have to be 1.7 times the present. This is obviously a crude estimate because if this was all that was required then farmers now involved in factory supply would be clamouring to become town supply farmers. Nor is the additional management skill in town milk supply taken into account.

5.4 PRESSURES CAUSING A HIGHER PEAK MILK SUPPLY

Recently, it has been suggested as being advantageous to farmers to undertake management practices which cause a sharpening in the peak milk supply and a reduction in the length of the annual period of milking. Such practices may cause a further worsening in the capacity utilisation of milk processing plants. Concern at such a trend has been expressed by the New Zealand Co-operative Dairy Company.(3)

The normal lactation period has in the past lasted for up to ten months from the date of calving. However Campbell (4) has suggested that cows should be dried off earlier if necessary, to ensure correct body condition and liveweight at calving. This is expected to compensate for the reduced lactation length by increasing the output immediately after calving. This strategy is also considered advantageous in terms of a reduced necessity to make hay or silage for winter feed. The grass is instead fed to the cows in spring, thereby increasing peak production.

Campbell also suggests that there are a number of advantages to the farmer in a more concentrated calving period. The chore of calf raising is compressed, better selection of replacement stock is enabled because of more similar liveweights at the same time, and simplified grazing management is brought about because the "mob of drys" is eliminated more quickly.

For these reasons, and the fact that a single factory serves a limited geographical area in which the optimum calving date is likely to be similar for all suppliers, the peak of milk supply in some factories has been increasing and the tails reducing. For these reasons New Zealand Co-operative Dairy Company has sounded warnings, Rangitaiki Plains Dairy Company offers incentives for smoother production, and the difference in calving dates between Taranaki and Kiwi Dairy Companies' suppliers was an important consideration in their merger.(5)

5.5 THE MARKET FOR MILK POWDERS

From the inception of large scale dairying in New Zealand, the chief market has been the United Kingdom. During the two World Wars Britain and New Zealand had an agreement whereby almost all New Zealand's export dairy produce was compulsorily purchased by Britain. It was not until 1954 that this agreement ended. In 1950 the British market accounted for 96% of butter, 89.5% of cheese and 78.7% of dried and condensed milk export sales.[1]

Changes in the market have largely been forced upon New Zealand by the entry of Britain into the E.E.C. with a consequent diminution of the volume of product able to be sold there. The changes in the milk powder market have been as follows:

i. The main market has changed from Britain to Malaysia and the Phillipines. No milk powder is now marketed in Britain.

ii. There has been a great expansion in the market for milk powders from 70,000 tonnes in 1960 to 200,000 tonnes in 1979. (6)

iii. There has been a great diversification in market destinations. Principal areas are now South East Asia, Japan and Central and South America. Markets have both increased in size and number.

iv. There has been a spectacular growth in the market for fat-bearing milk powders which has grown nine-fold from 1960 to 1979. (6)

v. There has been a growth in the variety of specifications produced. From the situation where most product was of a standard nature, designed for one market, in the 1977/78 season 85% of all skim milk powder was of the non-standard type. (7)

These changes have been as a result of a number of complementary reasons. There has been a growth in the

1. Derived from New Zealand Official Year Book, 1953

recombining trade as developing countries in tropical areas have instituted public health programmes involving milk. There was a consequent need to suit the product to local tastes. The vagaries of the international market for milk products have resulted in efforts to differentiate New Zealand product from the large volumes of cheap, subsidised product by producing to customer specifications. There has been a growth in the use of wholemilk powder as a consumer product and for recombining. It has found markets as infant milk foods, in health foods and pharmaceuticals, and has replaced liquid milk in some areas because of the reduced necessity for refrigeration. The development of whole milk powder markets has coincided with the need to find an outlet for fat as a result of the contracting British market.

Thus the milk powder market has greatly increased in size and complexity, leading to the necessity to manufacture smaller volumes of more specialised products to specifications to suit individual customers.

5.6 THE NEW ZEALAND DAIRY BOARD'S EFFECT ON SHORT RUNS

The Dairy Board is the administrative head and export marketing agency of the manufacturing dairy industry. The Board is empowered to acquire or control all dairy products which are to be marketed overseas. The Board passes on the returns for sales to the manufacturing companies, less marketing costs, and the companies in turn distribute returns to the milk suppliers, less processing costs.

Having received orders from the market, the Dairy Board is able to allocate them to the companies. This allocation is based on plans of what the companies would like to produce submitted by the companies in the light of product differentials set by the Board. The Board also takes into account the company's past performance, its technical capability, the previous proportion of non-standard products and the need to spread expertise and risk.

Complications causing short production runs may arise because of a customer changing his order, or the requirements for some milk powders to be of limited age when shipped. Many consumer products must be canned and so production runs must fit with the canning plant's schedule. Any off-specification product results in further short runs to make up the short fall and further complications with the canning plant.

The system of allocation of orders may itself cause short production runs or certainly lead companies to be willing to produce what may be uneconomic short runs. The Dairy Board encourages the production of non-standard products by offering a premium to compensate for the difficulties met in complying with a special specification. Payments are based on average manufacturing costs of the industry, thus encouraging efficient manufacture. Companies seek to manufacture products in which they are relatively efficient and thus are able to pay a higher return to farmers. Thus they are able to attract suppliers from a lower paying company.

The lower paying company then desires to increase its payout and so seeks to manufacture non-standard products. In order to prove its ability to do so to the Dairy Board it is willing to manufacture short runs. If it is able to obtain orders for non-standard products it succeeds in receiving high premiums and preventing its competitor from obtaining these premiums. As a result the production process may not be the most efficient possible, and short runs may result if the plant is large.

5.7 CONCLUSION

It has been shown that the pressures to produce short production runs in spray drying plants arise from both the producer and the market, and to a much smaller extent, the system of distribution of orders.

The economics of dairy farming determine the seasonal pattern of production. The need to differentiate the product in the face of competition and to satisfy individual customer needs has led to a proliferation in product specifications.

The result of these effects has been the undeniable necessity for short production runs in the factory. From the market point of view the reasons for short run production are compelling beyond the ability of the New Zealand Dairy Industry to change. However, the control of the pattern of production is in the Industry's hands. The decision to change must be based on economic grounds. Thus in the next chapter the costs of the seasonal pattern of production in the factory will be examined, and methods developed to assist in the determination and control of the costs of short production runs.

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CHAPTER SIX

THE EFFECTS OF SHORT PRODUCTION RUNS IN THE SPRAY DRYING PLANT

6.1 INTRODUCTION

The production manager of a spray drying plant must ensure that milk produced on farms is processed into milk powder to meet the objective of maximising payout to the suppliers.

The manager has little flexibility in terms of equipment, which is a large, single, indivisible plant. He has little control over milk supply as he must process whatever arrives each day. It has been shown that this follows a seasonal pattern and the plant must be sized to handle a peak milk flow that is more than twice the average flow. It has also been shown that the demands of the market must be followed in order to maintain New Zealand's competitive position and thus the pressure to produce short runs of various specifications is beyond his control. He has no control over the export market as all interaction with the export market is handled by the Dairy Board. The normal market forces apply to production for the New Zealand consumer, but this is a small proportion of the total market.

The production manager's task involves planning and control of costs by the co-ordination of men, materials and machines in order to maximise returns to members of the co-operative. In so doing he ensures the long-term survival of his company in the face of competition from others, both in New Zealand and on the world market place.

This study is concerned with the effects and the control of the effects of short production runs in spray drying plants. An examination of the occurrence of short runs in other industries and an examination of other parts of the production system, have led to a number of questions and conclusions with regard to possible courses of action. The principal areas that are suggested, are as follows:

i. Set-up cost. From batch and flow line production studies it was learned that set-up cost was considered to be an important factor in the cost of short production runs. However, the survey indicated that on many specification changes there is virtually no set-up necessary and when there is, it involves the re-arrangement of some minor plant items. This involves a relatively short period of time and would only be important where capacity was hard pressed such as at the peak of the season.

It could be considered that the daily start-up, shut-down and clean is a set-up cost. Certainly it must be an important part of the spray drying plant's cost structure as it has been shown that it takes an average 2.75 hours per day.[1] Additionally it is a feature of both short daily running time and some specification changes. For these reasons closer investigation was considered necessary.

ii. Learning behaviour. In flow line production, the learning process is considered to be an important part of short production run costs. Additionally some factory managers indicated that they considered learning behaviour occurred in the wake of a specification change. Specification changes were said to be "unsettling to staff" and learning behaviour was implied in some definitions of short production runs. Thus the occurrence of learning should be examined.

iii. Seasonal pattern of milk flow. Processing in spray drying factories has been shown to closely follow the seasonal pattern of milk production. Thus costs are incurred because of the consequent low capacity utilisation. Production managers said that they saw a number of

1. Short Production Run written questionnaire, Question 13.

advantages in a smoothed milk flow other than the gains from better capacity utilisation. However, these were difficult to quantify. Certainly any argument to change the system must be based on economic criteria. Thus calculation of the gains from smoothed milk flow in the factory may assist in assessing the whole situation.

iv. Management information. It has become apparent that there is very little formalised management information available to production managers in spray drying plants. This information is necessary to complete the control loop so that management of the plant can be carried out effectively. This will be discussed further in Chapter 7.

In this chapter set-up cost in terms of the daily start-up, shut-down and clean, learning behaviour and the costs of the seasonal pattern of milk flow will be examined, in order to indicate means for the control of the cost of short production runs in spray drying plants.

6.2 SPRAY DRYING FACTORY COST STRUCTURES

In order to determine the effects of short runs on factory costs and the likely effects of any strategies to deal with them, it is necessary to have a knowledge of the broad factory cost structure. Such information is published by each factory in their annual reports, usually under a series of similar category headings, so this data was used to establish an industry average cost structure.

This method of assessing cost structures does have some weaknesses in that:

i. It is not certain just what was included for each category.

ii. No account is taken of the difference between what should have been used and what actually was used.

iii. In times of inflation, costs do not accurately reflect units of input.

However the major advantage of this data is that it is readily, and publicly available and the alternative of obtaining detailed information directly from each factory is still open to the criticisms above (even if to a lesser extent) and it would be a mammoth task , out of proportion to the gain from it.

The data chosen was that for the five seasons 1974-75 to 1978-79. The inclusion of a company was determined by the ready availability of data. A group of 16 companies comprising 24 factories from a total of 35 in the industry, was compiled. Data was not used from some companies because data was not reported in a sufficiently detailed form, costs for casein were included in the account or the company had not produced WMP or SMP during the period in question. There were some anomalies in the data that was reported:

i. Some companies did not include such items as effluent disposal, tanker collection costs, Dairy Board Levy, and Farm Dairy Instruction costs or at least did not list them under separate headings.

ii. Some companies did include such items as promotional expenses, farm vat depreciation costs and others under separate headings. . These items were omitted.

iii. Some companies included costs of roller process powder in the account but as the volume was usually less than 5% of the total this was ignored.

iv. Some companies divided their accounts into SMP, BMP and WMP. In these cases the SMP account was taken as being representative and the total tonnage used for calculation of the utilisation index.

v. New Zealand Co-operative Dairy Company included condensed milk in the powder production costs but this was ignored as being negligible in comparison to powder production.

vi. Three companies included data that was from more than one factory, thus their contributions to the average were weighted by the appropriate number of factories.

Method of Calculation

The data was collected under a series of categories and then converted to dollars per tonne and percentage of total cost.

The dollars per tonne for each category in the 1978-79 season were averaged and the percentage cost structure was calculated as displayed in Table 6.1.

Category	$/tonne	% total cost
Total income	577.1	-
Milk collection	30.9	13.0
Wages	40.3	16.9
Materials	11.3	4.8
Fuel/power/steam	58.7	24.7
Sundry	5.8	2.4
Depreciation	24.3	10.2
Repairs, mtce., consumable stores	23.2	9.8
Rates	0.6	0.3
Insurance	1.8	0.8
Effluent disposal	0.9	0.4
Cartage	15.5	6.5
Handling and storage	8.5	3.6
Grading	2.3	1.0
Administration	6.3	2.6
Directors fees and expenses	0.6	0.3
Audit	0.2	0.1
Interest	6.1	2.6
Farm dairy instruction	0.1	0.0
Dairy Board Levy	0.9	0.4
Total cost[1]	237.4	100.0

Table 6.1 1978-79 Season, average costs in dollars per tonne and percent

The percentage cost structure for each company for each of the five years was calculated and the average for each year was calculated along with a five-year average of these. (See Table 6.2) The average total cost per tonne for each of the five years was used to calculate an inflation index for the industry. This is displayed in Table 6.3

1 Note that totals ≒ sums of items due to rounding

	Percentage cost structure 5-yr % basis	Percentage cost structure 78/79 $/tonne basis
Fuel/power/steam	21.7	24.7
Wages	17.4	16.9
Milk collection	15.1	13.0
Depreciation	10.9	10.2
Repairs, Mtce, consumable stores	9.0	9.8
Materials	7.8	4.8
Cartage	6.0	6.5
Interest	2.4	2.6
Remainder	9.7	11.5
Total	100.0	100.0

Table 6.2: Overall average percentage cost structure

	74-75	75-76	76-77	77-78	78-79
Average cost/tonne	138	150	188	214	221
Index	100	109	136	155	160
Annual change in index	-	+9	+27	+19	+ 5
Annual change in cost	-	9%	25%	14%	3%

Table 6.3: Spray drying factory inflation rate

Conclusion

It can be seen that the cost structures calculated in both ways are very similar. Energy has increased in importance recently. Materials have decreased in share. In fact it is only as a result of NZCDC's high material cost that they remain at 4.8%. If NZCDC were counted as one factory instead of seven, then the average material cost would be 2.1%.

Five major items account for almost 75% of total costs in spray drying factories. Milk collection costs are not an area where a spray drying factory production manager can have influence but the remaining four, Energy, Labour, Depreciation and Repairs certainly are under his control.

6.3 COST OF START-UP AND SHUT DOWN IN A SPRAY DRYING PLANT

The cost of start-up and shut down, including cleaning of the spray drying plant has been identified as a major cost component. It is a feature of both the short production run due to seasonal milk flow variation and in changing specification. Thus an assessment of its cost is important in establishing the costs of short production runs.

The cost was estimated using the results of the written questionnaire as well as other sources which are indicated.

Labour Content

	Number per plant[1]
dryer	0.78
evaporator	0.88
supervisor	0.60
boiler	0.74
	3.00

Start up of evaporator takes 44 mins[2]
Start up of dryer takes 27 mins
The maximum will be used, i.e. 3/4 hour
hence start-up takes 3 x 3/4 = 2 1/4 man hours.

Shut down of dryer takes 20 mins
Shut down of evaporator takes 2 hours (inc.clean)
The maximum will be used i.e. 2 hours
hence shut down takes 3 x 2 = 6 man hours

Total = 8 1/4 man hours.

1. Labour contents established in Written Questionnaire, Question 18 (Chapter 3).
2. Times taken established in Written Questionnaire, Question 13 (Chapter 3).

Cleaning materials

The drier is washed on average once per week[1]. On a per day basis, this is a consumption of:

1/7 x 0.8 kg of 100% caustic[2]

The evaporator is washed each start-up, shut down using:

2 kg of 100% caustic

and 0.52 kg of 100% nitric.

Fluid beds are washed so infrequently that materials consumption is negligible.

Total 2.1 kg of 100% caustic

0.52 kg of 100% nitric.

Energy

Average energy consumption on start-up, shut down at the Pahiatua Plant[3] of the Tui Co-operative Dairy Company is:

Oil 2920 litre per start-up, shut down and clean

Electricity 3064 kWh per start-up, shut down and clean

Adjusting this to the industry's average sized plant and converting it to S.I. energy units:

$$1.86/2.70 \times (0.04 \times 2920 + 0.0036 \times 3064)$$

$$= 88.1 \text{ GJ per start-up, shut down and clean.}$$

Alternatively, from Vickers and Shannon (1), measured energy requirement for processing proper for skim milk powder is:

Fuel	13.04 GJ/tonne
Electricity	0.4 GJ/tonne

Average size dryer is 1.86 tonne/hr

Assuming the dryer uses 40% and the evaporator 60% of the energy and assuming rate of consumption on start-up shut down is the same as in processing then:

Evaporator uses:

$$2.75 \times 0.6 \times (13.04+0.4) \times 1.86 \text{ hr.GJ.T}^{-1}\text{.T.hr}^{-1} = 41.2 \text{ GJ}$$

1. Washing frequency established in Written Questionnaire, Question 14,(Chapter 3).
2. Consumption of cleaning materials established in Written Questionnaire, Question 16 (Chapter 3).
3. The source of this estimate will be discussed in chapter 7.

and dryer uses:

$(0.75 + 1/7 \times 2.8) \times 0.4 \times 13.44 \times 1.86 \text{ hr GJ.T}^{-1}\text{.T.hr}^{-1}$

$= 11.82$ GJ

Thus total = 53 GJ per start-up, shut down and clean.

It will be assumed that the energy consumption is in fact close to the figure calculated from the Tui data because the second figure does not allow for bringing the plant up to temperature and running cleaning equipment. Thus a figure of 80 GJ is probably realistic.

Energy Consumption = 80 GJ per start-up, shut down and clean

Product and raw material losses

Parkin (2) estimated that average losses of milk solids in a spray drying plant were as follows:

	kg milk solids
Start-up	40 - 112
Shut down	100 - 250
CIP	120 - 240
Total	260 - 602
Mid range	430

Summary of costs of start-up and shut down

	Quantity	Approx.value in 1980 prices
Labour	8.25 man hours	80
Cleaning materials	2.1 kg 100% caustic 0.52 kg 100% nitric acid	54[1]
Energy	80 GJ	700[2]
Milk solids	430 kg	260[3] (skim milk)

Approximate total value in 1980 prices is \$1094.

1. Estimated from costs given in a personal communication from R. Nielson of NZDRI.
2. Estimated from energy costs in a personal communication from P. Read of Tui Co-op Dairy Co.
3. Assuming a SMP price of \$600/tonne.

6.4 LEARNING EFFECTS IN SPRAY DRYING PLANTS

From the examination of short production runs in other types of industry, discussed in Chapter 2, it was found that one of the major effects of short production runs was dis-economies of learning in terms of initial low labour productivity and potential poor quality.

It is a well known truism that "practice makes perfect". This is as true in an industrial situation as elsewhere. The effect in industry has been quantified and given the name "learning curve". It was first noticed in the aircraft assembly industry that the fourth plane required only 80% as much labour as the second, the eighth plane required only 80% as much as the fourth, the fiftieth plane required only 80% as much as the twenty-fifth, and so on. (3).

The learning curve model is a power function relationship between manufacturing productivity and cumulative product output of the form

$$y = a x^b$$

where y = productivity

x = cumulative product

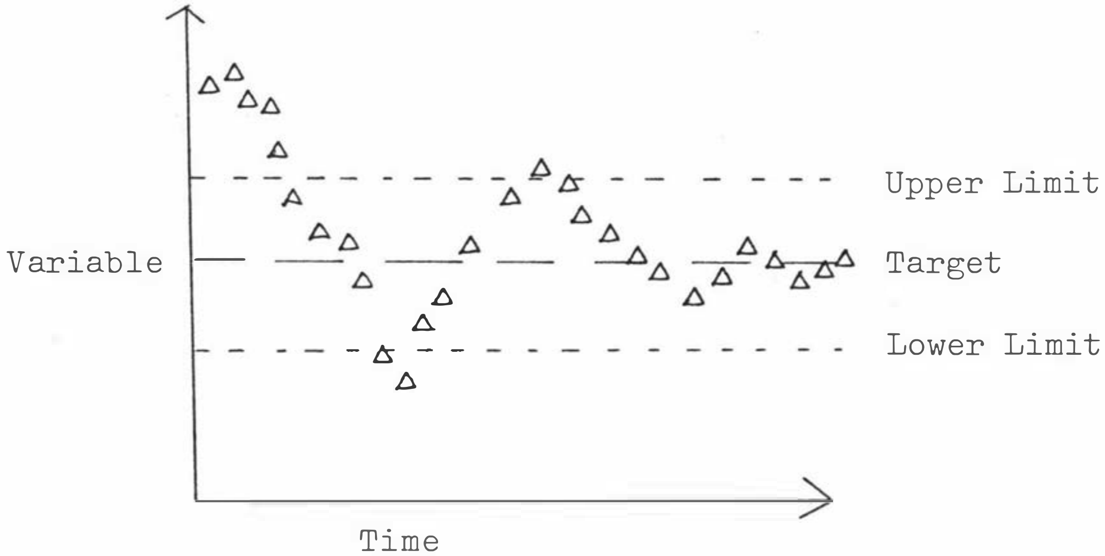
a and b are parameters of the model.

The possibility of ultimately reaching a steady state level of productivity is not recognised in the model, but in practice it has been shown that a steady state is eventually reached. (4).

The rate of improvement with time has been linked to the proportion of labour content in the job. The higher the labour content, the greater the rate of learning. In a paper suggesting a method for evaluating the loss in learning between production runs, Anderlohr (5) listed five factors as being the components of learning economies. These were personnel learning, supervisory learning, continuity of production, methods and special tooling.

However, both Hirschman (3) and Baloff and Kennelly (4) suggest that the occurrence of learning behaviour is not restricted to assembly type industries. Examples were given of improvements in the capacity of petroleum refineries over a number of years, increases in productivity occurring over periods up to 43 months in start-ups of steel industry plants and also similar occurrences in glass, paper and electrical products industries.

Thus it was suggested that learning behaviour may have been evident in spray drying plants. Possible areas for the occurrence of learning behaviour would be in plant start-up at the beginning of the season and in product specification changes. The former will be discussed in the next chapter.[1] The occurrence of learning in product specification changes could be evident in terms of the diminished occurrence of quality problems as operators become more familiar with a product. It would be expected that the spread of a process variable would decrease as an operator brought the plant under better control through learning. An example of the sort of result expected if learning behaviour were occurring is shown in Graph 6.1.



Graph 6.1: Theoretically expected result of learning behaviour

1. See sections 7.2 and 7.3

Examination of learning behaviour in spray drying factories

Data on a range of variables was available from three factories. These were Te Rapa, Matangi and Pahiatua. The data comprised hourly readings of fat, moisture, protein and total solids ex-evaporator at the Matangi factory, hourly readings of belt powder moisture and density at Te Rapa, and hourly fat and moisture at Pahiatua. This data was plotted in a similar fashion to Graph 6.1.

The data and results are summarised in Table 6.4.

In five of the fourteen runs studied, there appeared to be some evidence of improvement. However, this was in each case in only one of the variables studied. Thus in only five of twenty-seven cases was there any evidence of learning behaviour, and in two of these cases it was only in the first six to eight hours of the run of three days. In two other cases there was learning behaviour on each of the two days as the total solids level was in each case brought from a value which was too high to being under control. Thus this learning was not necessarily associated with the change of specification. It may have been a daily occurrence, a feature of the way in which the plant was operated.

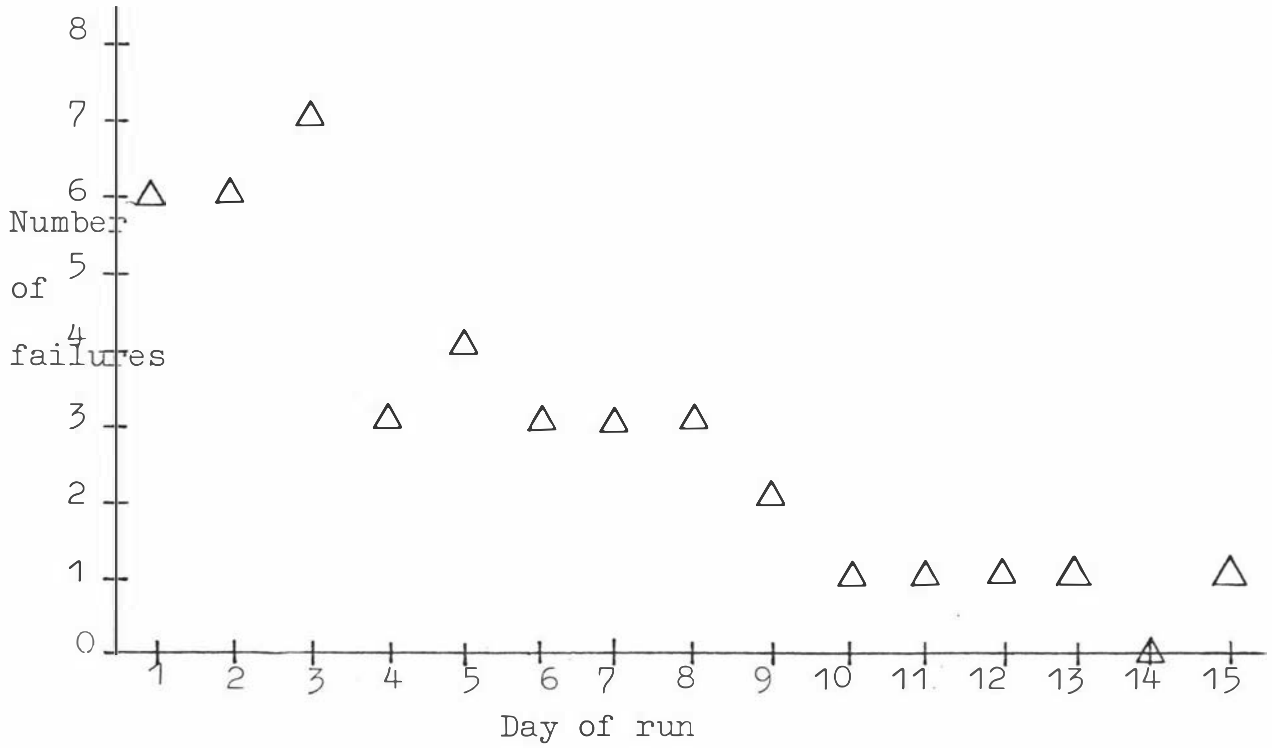
Thus it was concluded that this data did not support the hypothesis that learning behaviour occurs after a specification change in terms of improvement in operator controlled variables.

Relationship between product, failures and day in run

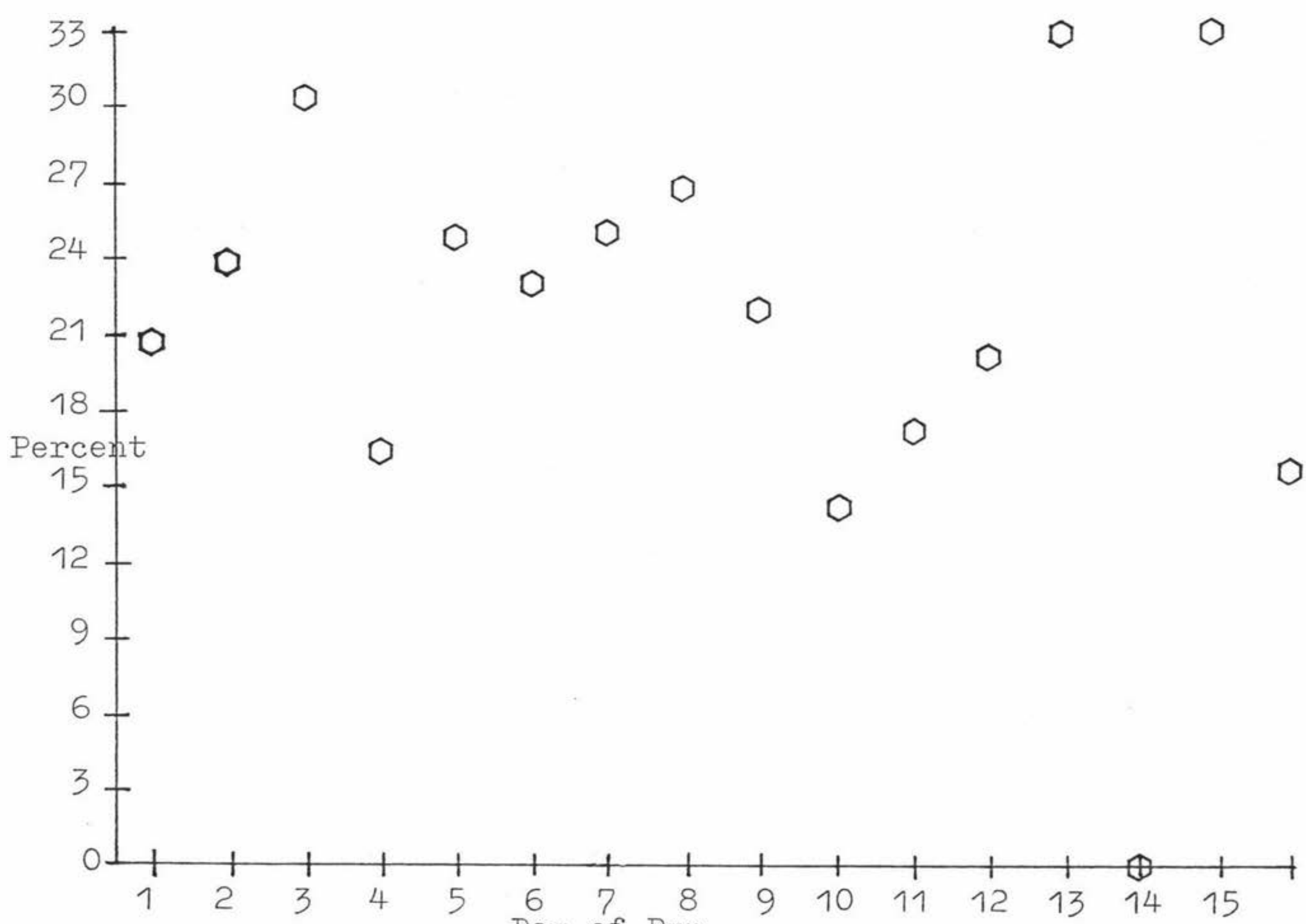
Data was examined on the daily occurrence of quality failures for a complete season (1978-79) for the Midhirst spray drying plant. This was examined for the relationship between failures and the day number of the run. Thus all failures on the first day of runs were summed, all failures on the second day of runs, and so on. Then the total number of first days was summed, the number of second days and so on. Failures were expressed as a percentage of the number of days, for example there

Factory	Product	Dates	Variables	Evidence
Matangi	900	20,21 Sept.78	Moisture	- -
			Protein	-
			Fat	-
			Total solids	Start-up each day
	900	17,18 Nov.78	Moisture	-
			Protein	-
			Fat	-
			Total solids	Start-up each day
	S.M.A.	15,16 Dec.78	Moisture	Improves through the period. Range decreases
			Fat	-
	Rennet whey	4,5,6 Jan.79	Moisture	-
			Total solids	-
	S.M.A.	15,16 Feb.79	Moisture	-
	900	1,2,3 Apl.79	Moisture	Control on first day's start
			Protein	First day
			Fat	-
			Total solids	Rapid control on start up
	900	9,10 Aug.79	Moisture	-
Te Rapa	802	9,10,11 Oct.79	Belt moisture	-
	930	15,16 Oct.79	Belt moisture	-
			Belt density	-
	803	17,18 Oct.79	Belt moisture	-
	M301	18 Oct.79	Belt moisture	Range converges
	802	26 Oct.79	Belt moisture	-
	934	27,28 Oct.79	Belt moisture	-
Pahiatua	821	5-18 Sep.79	Moisture	-
		6-14 Sep.79	Fat	-

Table 6.4 Results of examination of various runs for learning behaviour.



GRAPH 6.2: Number of failures per day vs day of run



GRAPH 6.3 Number of failures per day as percent of all days of that number vs day of run

were six failures on the first day of a run and there were 29 first days. Thus on 6/29 x 100/1 = 20.7% of first days there was a failure. This enabled a comparison of the proportion of failures on each day as runs progressed. The results were displayed in graphs 6.2 and 6.3.

It was concluded that although the total number of failures on first days of runs appeared to be high, when considered as a proportion of the total number of first days, it was not. Thus it could not be said that quality failures occurred as a result of specification change, nor was there an appreciable decrease in the proportion of failures as runs progressed, that is to say, learning effects in terms of improved quality were not evident.

Conclusion

The evidence examined did not support the hypothesis that learning behaviour occurs after specification changes or that specification changes cause poor quality. It is suggested that learning effects are not evident in this situation because operators are used to controlling all the variables that can be altered in changing from one specification to another. The situation that occurs when the specification is changed is not appreciably different from the situation which occurs each day when there is no specification change. Routine changes between various specifications including from whole milk to skim or buttermilk products are just that, routine. Changes to plant variables must be made when cleaning, shutting down and starting up, thus operators are used to controlling the plant. Their learning behaviour has occurred during training.

6.5 CAPACITY UTILISATION IN SPRAY DRYING PLANTS

One of the effects of the seasonal pattern of milk flow on spray drying plants which was discussed in Chapter 4, is a low capacity utilisation which theoretically would be expected to result in increased costs to dairy companies. This is certainly the case in the brick industry. Bower (6) reported that cost of production per brick at one third capacity was 1.61 times the cost when the plant was operated at full capacity. He attributed this to the high fixed operating cost. High fixed operating cost is also a feature of spray drying plants as already noted.

The relationship between capacity utilisation and cost in spray drying factories was examined by using published data on costs and volumes of production from dairy company annual reports.

It was expected that the cost per tonne would be reduced as the plant was more highly utilised as the greater tonnage from the same plant would result in a reduced fixed cost per tonne of product, and consequently a lower total cost.

Method

A utilisation index was calculated based on the assumption that the maximum time available to factories was 11 months of 20 hours per day, that is 6,680 hours.

Thus:

$$\text{Utilisation Index} = \frac{\text{Annual Production in tonnes}}{\text{Rated capacity per hour x 6680}}$$

Costs were brought to a common basis by dividing by an industry inflation factor,[1] based on the average industry costs in each year.

The data for five years was examined. The first method of determining whether such a relationship existed was to examine each company's figures to see if the lowest utilisation corresponded with the highest cost and/or the

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1. The inflation factor was described in Table 6.3

highest utilisation corresponded with the lowest cost. The results were summarised in Table 6.5.

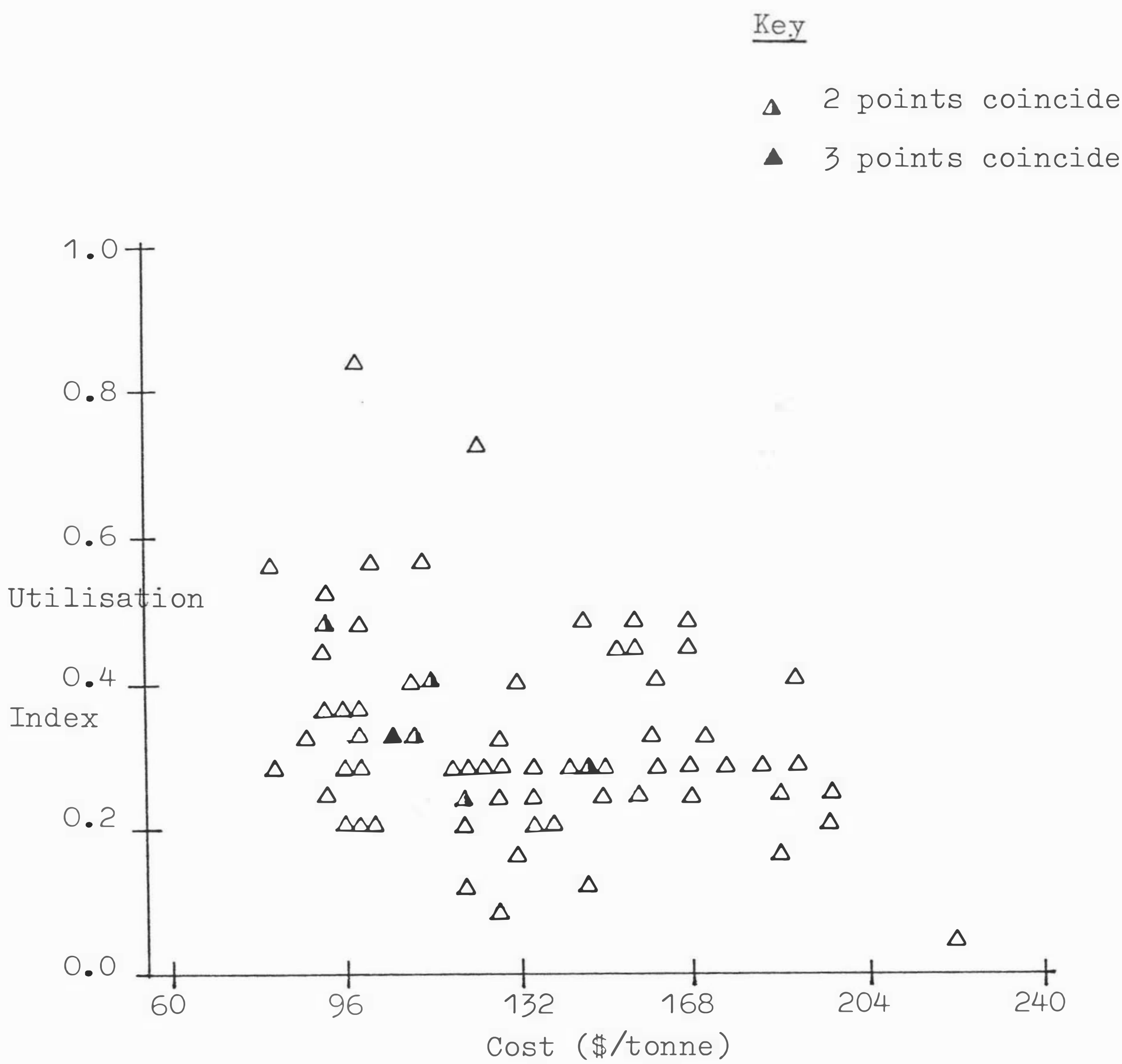
Company	Highest Cost & Lowest Utilisation	Vice Versa*	Lowest cost & Highest Utilisation	Vice Versa*
Bay of Islands	-	-	-	-
Cambridge	Yes	-	Yes	-
East Tamaki	Second lowest	-	-	-
Hikurangi	Second lowest	-	-	-
Kaipara	Yes	-	Yes	-
Manawatu	Yes	-	Yes	-
Mid-Northland	-	-	-	Yes
Moa	-	Second highest	-	Yes
N.Z.C.D.C.	-	Yes	-	-
N.Wairoa	Yes	-	-	-
R.P.D.	-		-	Yes
Taranaki	-	Second highest	-	-
Te Awamutu	Second lowest	-	Second highest	-
Tui	Yes	-	Yes	-
Waimea	Second lowest	-	Yes	-
Westland	Yes		Second highest	-

* Note: Vice versa means highest cost and highest utilisation or lowest cost and lowest utilisation respectively.

<u>Table 6.5: Summary of results showing relationship between cost per tonne and capacity utilisation</u>

It can be seen from Table 6.5 that five companies have some obvious tendency to the reverse of the expected situation with either high costs coinciding with high utilisation or low costs coinciding with low utilisation. One company appears to be unaffected either way and the remaining ten show a clear tendency to high cost with low utilisation and low cost with high utilisation.

Attempts were made to regress the utilisation index on the cost per tonne in the case of both the complete data



GRAPH 6.4: Utilisation Index vs cost per tonne

and the data of the ten companies that did appear to follow the expected relationship. However these were unsuccessful, with extremely low values of the coefficient of determination occurring in both cases. Thus a numerical relationship could not be established.

A plot of utilisation index versus cost per tonne was made. (See Graph 6.4). It is interesting to note that no company had a high cost associated with a high utilisation index although many had low costs associated with low utilisation indices. This phenomenon may be a result of the application of average costings established in large volume producing years to low volume producing years. The mass of data does bear out the expected relationship to a limited extent.

Discussion and Conclusions

This study had some numerical problems because of the assumptions on which it was based not necessarily being true. The costs from year to year may be affected by factors other than the capacity utilisation or the rate of inflation. For example, a change in the energy source powering the spray drying plant could have major effects, or merely a change in the product mix. The latter must have occurred with the growing volume of production of wholemilk powders discussed in Chapter 5. Also the inflation index is an average and though based on the combined effects in all plants, may not accurately reflect the actual situation in any individual plant. The effect of fixed costs may vary widely from plant to plant. In old plants, the capital component may be very small or in relatively new plants it may be extremely high.

Additionally it is possible that there were some anomalies in the base data due to variations in cost allocation systems from company to company.

It does appear that there is a strong relationship in individual factories between capacity utilisation and cost per tonne but it is difficult to quantify the the relationship in general.

6.6 COST EFFECTS OF SEASONAL MILK FLOW IN SPRAY DRYING PLANTS

Introduction

Virtually all dairy farms in New Zealand are managed around a system of pasture grazing. Except for farms on which milk is produced for liquid consumption, the whole herd is mated to calve during a short period in the early spring, in order to fit their feed requirements as closely as possible with pasture growth (7). The herd does not produce any milk at all for a period of about two months in winter.

Milk production in most cows reaches a peak 8 to 12 weeks after calving and then gradually falls until milking ceases 250-300 days after calving (8). It has been shown that in some circumstances an even shorter production season can be more profitable to farmers because of lower drought risk and the possibilities of alternative utilisation of resources.[1] These factors result in a milk production pattern where peak production is about twice the 12 month average.

Effects of the seasonal pattern of milk flow are felt in the downstream production and marketing activities.

In the production area, seasonal effects are as follows (9):

1. Milk and product quality problems in early and late season.
2. A throughput limitation at the peak of the season, reducing flexibility to respond to market opportunities and possibly affecting quality due to production pressure.
3. A limited season for manufacture of some products and an inability to make some products at all (some cheese types).
4. Mediocre capital equipment utilisation.
5. Winter maintenance is possible and limited back-up equipment is required.

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1. See Chapter 5 and Appendix 5

Capital costs form the most visible part of these problems, accounting for 10-11% of total milk powder manufacturing costs. (7) Capacity utilisation in whole milk powder plants has been estimated at only 24.6% and at only 29.8% in skim milk powder plants. (10) This is partly due to seasonal effects, and partly due to excess installed capacity, permitting company diversification.

It was estimated that on average, spray drying factories run 10.14 hours per day (over 12 months)[1] thus capacity utilisation is less than 50% and capital cost per tonne of milk powder is more than twice what it could ultimately be.

The effect of the seasonal production pattern on the market is possibly more serious. As our products become more specialised we develop a closer relationship with the consumer and the cost of an inability to meet his requirements for part of the year may be high. (9)

<u>The effects of the seasonal pattern of milk on spray drying factory costs</u>

In order to evaluate the cost effects of the seasonal pattern of milk flow on spray drying plants, two comparisons were made. In the first comparison, a plant running the average number of hours per month as found in the Written Questionnaire, question 11, except for a complete shut down in June was compared with a theoretical plant running 20 hours per day, with a one month shut down which was sized so as to process the same volume of milk.

Time	Average	Theoretical
Hours in year	8760	8760
Hours running	3677	6680
Hours running as % of hours in year	42	76

<u>Size of plant</u>

To process the same volume of milk in the greater

1. Based on Written Questionnaire, Question 11

time the theoretical plant would be $\frac{3677}{6680} = 0.55$ times the size of the average plant.

Capital cost of theoretical plant

Using the "0.6 rule"

$$\text{Capital cost of theoretical plant} = \left(\frac{0.55}{1.0}\right)^{.6}$$

$$= 0.7 \text{ times the}$$

capital cost of the average plant.

Energy consumed during cleaning

Assuming one plant clean and start-up/shut down per day in both cases then:

Total hours cleaning etc $= 334 \times 2.75$[1]

$= 918.5$

Assuming the theoretical plant uses only .55 times as much energy per hour then energy consumed in cleaning is:

	Average	Theoretical
(Units are hours of average plant energy consumption)	$\frac{918.5}{918.5 + 3677}$	$\frac{918.5 \times .55}{918.5 \times .55 + 3677}$

Total energy consumption is reduced by

$$\frac{918.5 - 918.5 \times .55}{918.5 + 3677} \times \frac{100}{1} = 9\%$$

(Assuming that the same volume of milk will take the same energy to process in both plants.)

Labour

Processing staff would need to be increased by one shift in the theoretical plant because the plant will be operational 24 hours per day instead of a peak of $17.1 + 2.75 = 19.85$ hours, which would be handled by two shifts.

Thus labour content would be

Average	Theoretical
8	11
5	5
13	16

An increase of 23%.

1. Average time on start-up, shut down and clean is 2.75 hours from Written Questionnaire, question 13.

Milk collection costs

Because the peak would be reduced, fewer tankers and drivers would be required to handle it. Thus the same total volume of milk would be picked up by 55% of the existing tankers and drivers. Costs attributable to tanker capital cost and drivers account for 46% of milk collection costs thus milk collection costs would be reduced to

$.55 \times 46 + 54 = 79.3\%$ of present

Total Cost

	Cost, $ per tonne[1] in average plant	in theoretical plant
Energy	58.7	53.4
Wages	40.3	49.3
Milk collection	30.9	24.5
Depreciation	24.3	17.0
Others[2]	83.2	80.8
	237.4	225.0

There is a reduction of about 5% in total cost per tonne in the theoretical plant.

Discussion

There may be other effects which should be taken into account but are likely to be more difficult to quantify. These include:

i. Where plants are charged for electricity on the basis of their peak load this would be reduced in the theoretical plant.

ii. Many plants already employ three shifts. If an increase in labour was not necessary then cost per tonne would be about 9% lower in the theoretical plant.

iii. A steady flow of milk to the factory would allow an even work cycle for all employees for a large portion of the year, enabling holidays to be taken when required and enabling the employment of a regular work

1. Based on figures for 1978-79 season given in Table 6.2.
2. Reduction in "Others" is a result of changes in insurance and interest.

force for the packing gang.

iv. Plant management and operation would be better able to be optimised because of the comparability of one day to the next and predictability of future conditions.

Second comparison

In the second comparison, the average plant described above is compared with a plant of identical capacity utilised 20 hours per day for 11 months. This situation could arise where a company was faced with the options of closing down an old factory and building a new plant or fitting the milk supply into an existing plant by smoothing the flow. Thus in addition to cost savings through better utilisation of the existing plant, a company would be saving the capital and overhead costs of a complete new factory.

The throughput of the highly utilised factory would be $\frac{6680}{3677}$ = 1.8 times the throughput of the existing plant.

Gains would be made in fixed costs, energy consumption on cleaning, milk collection costs and labour costs.

Fixed Costs

	$/tonne
Depreciation	24.3
Rates	0.6
Insurance	1.8
Effluent disposal	0.9
Administration	6.3
Directors' fees and expenses	0.6
Interest	6.1
Total	40.6

These costs would be spread over 1.8 times the tonnage so cost per tonne would be reduced to

$$\frac{40.6}{1.8} = 22.6 \text{ \$/tonne}$$

Energy consumption on cleaning

Total hours cleaning etc $= 334 \times 2.75$

$= 918.5$

This is currently $\frac{918.5}{3677 + 918.5} \times \frac{100}{1} = 20\%$ of total energy consumption or

$$\frac{20}{100} \times 58.7 = 11.74 \text{ \$/tonne}$$

Thus energy cost per tonne would be reduced to

$$\frac{11.74}{1.8} + 0.8 \times 58.7 = 53.5 \text{ \$/tonne}$$

Milk collection costs

Obviously if a greater volume of milk is to be collected then collection costs will be higher. However, the proportion of collection costs attributable to drivers and tankers will go up only by

$$\frac{20}{17.1} = 1.17$$ times, because existing tankers and drivers will be better utilised. Thus 1.17 times the cost will be distributed over 1.8 times the volume of milk, so the cost per tonne of product will be reduced to

$$\frac{1.17 \times 0.46 \times 30.9}{1.8} = 9.24 \text{ \$/tonne}$$

(from 14.2 \$/tonne)

and the total collection cost will be

$$9.24 + 0.54 \times 30.9 = 25.9 \text{ \$/tonne.}$$

Labour costs

The 23% increase in labour calculated for the previous comparison would occur but would be spread over 1.8 times the volume of product thus cost of labour would be reduced to

$$\frac{1.23 \times 40.3}{1.8} = 27.5 \text{ \$/tonne}$$

Total cost per tonne

	Seasonal pattern	Smoothed flow (1.8 times the milk)
Energy	58.7	53.5
Wages	40.3	27.5
Milk collection	30.9	25.9
Fixed costs	40.6	22.6
Others	66.9	66.9
Total	237.4	196.4

Thus there would be a reduction in cost of about 17% in that plant. The savings in terms of not operating an additional plant of 0.8 times the capacity of the present plant are briefly estimated as follows:

	$/tonne	Notes
Fixed costs	40.6	All fixed costs
Energy	11.7	All energy in cleaning etc.
Labour	40.3	All labour (additional labour already allowed for)
Milk collection	14.2	All fixed cost + drivers wages
Total	106.8	

This saving would be on .8x of the total 1.8x tonnes of the smoothed plant so the saving would be an additional 0.8 / 1.8 x 106.8 = 47.5 $/tonne.

Giving a total saving of 88.5 $/tonne or 37.3% of the original cost per tonne. This would mean that returns to the farmer could be increased from 577 - 237 = 240 $/tonne to 329 $/tonne[1]

Conclusion

It appears that there are significant gains to be made in some situations by smoothing the milk flow to a factory. The results show that a deliberate change to a smaller factory would not be warranted in view of the expected relatively small savings. The second comparison shows that if a company were in such a situation as described, it could have expected to pay out an additional 44 cents per kilogram of milk fat (approximately and assuming the powder produced was whole milk powder). This would have been about an additional 35%.

Whether such a change would be warranted would depend on the unique circumstances of a company and the cost and willingness of suppliers to respond. Although it is probably not warranted throughout the industry, it is possible that in some situations this mode of operation

1. Note that all figures are based on 1978-79 season averages listed in Table 6.1.

may be worthwhile.

6.7 SIMULATION OF SMOOTHING MILK SUPPLY

Introduction

In the existing manufacturing milk supply industry, all herds are inseminated to calve about the same date to coincide with the spring availability of pasture. Naturally this leads to a sharp peak in the milk supply, and factories must be sized to handle this peak.

One method of smoothing the milk supply would be to do as in the town milk industry where individual farmers smooth their own milk supply. An alternative, discussed briefly here, is if a factory's complete dairy herd (all suppliers) was split into a number of groups with different calving dates. This would have the following effects:

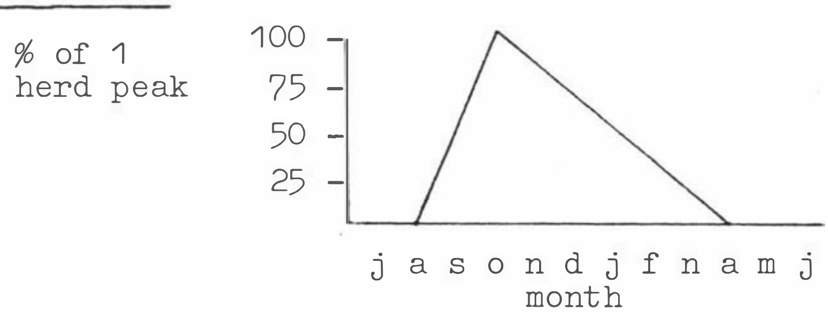
i. Peak supply to the factory would be reduced.

ii. Supply to the factory would be smoothed.

iii. Costs to some farmers would be increased.

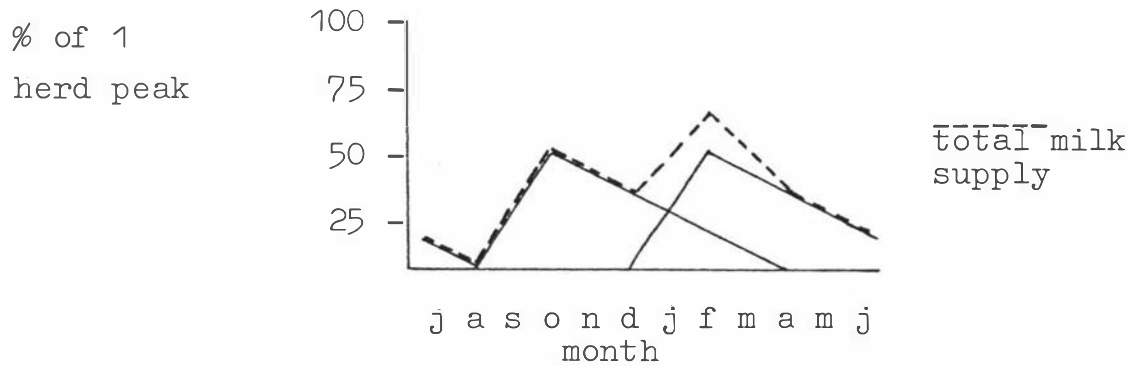
In order to demonstrate the effect on capacity requirements of such changes in the pattern of milk production, a small computer simulation model was prepared.

Simulation



Here the milk supply commences two months before the peak and continues for six months after the peak, but these periods can be selected on each run of the model.

If the factory's herds were split into two groups with peaks in October and February, milk supply pattern would be as follows:

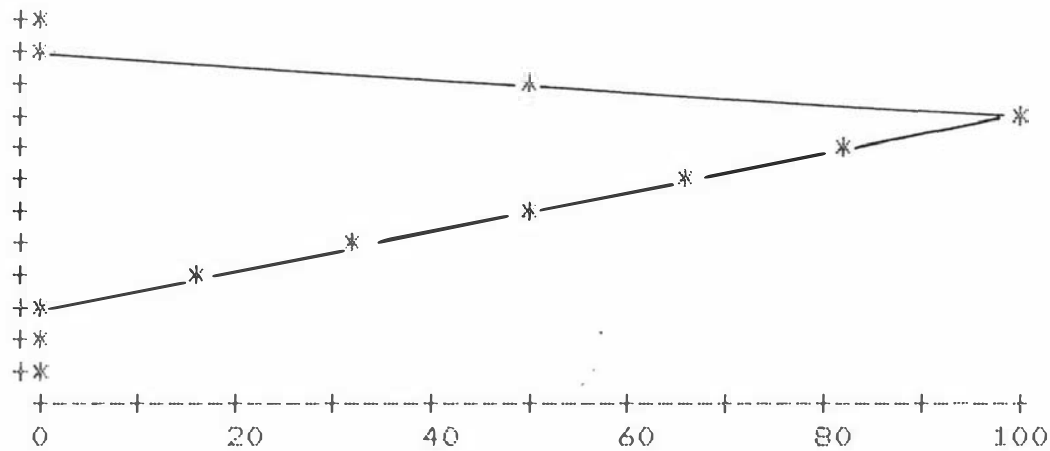


It can be seen that peak supply now occurs in February but that it is reduced to two-thirds of the peak values of one herd. Computer printouts of these two situations are given below. Note that the x and y axes are interchanged from the above two figures.

```
HOW MANY....                                     HERDS ? 1
MONTHS BEFORE PEAK DOES MILK SUPPLY START          ? 2
MONTHS AFTER PEAK DOES MILK SUPPLY CONTINUE        ? 6
 1=JUL      2=AUG      3=SEP      4=OCT      5=NOV      6=DEC
 7=JAN      8=FEB      9=MAR      10=APR     11=MAY     12=JUN
PEAK FOR HERD  1 ? 4

PEAK FOR HERD  1  IS OCT

JUL    0
AUG    0
SEP    .5
OCT    1
NOV    .833333
DEC    .666667
JAN    .5
FEB    .333333
MAR    .166667
APR    0
MAY    0
JUN    0
```




```
HOW MANY....                                     HERDS ? 2
MONTHS BEFORE PEAK DOES MILK SUPPLY START          ? 2
MONTHS AFTER PEAK DOES MILK SUPPLY CONTINUE        ? 6
 1=JUL      2=AUG      3=SEP      4=OCT      5=NOV      6=DEC
 7=JAN      8=FEB      9=MAR      10=APR     11=MAY     12=JUN
PEAK FOR HERD  1 ? 4
PEAK FOR HERD  2 ? 8

PEAK FOR HERD  1  IS OCT
PEAK FOR HERD  2  IS FEB

JUL    .0833333
AUG    0
SEP    .25
OCT    .5
NOV    .416667
DEC    .333333
JAN    .5
FEB    .666667
MAR    .5
APR    .333333
MAY    .25
JUN    .166667
```

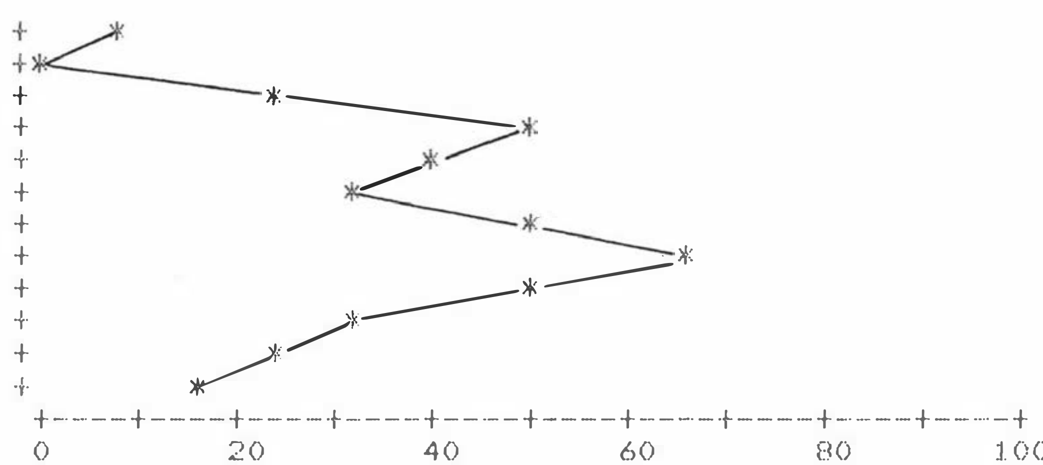


FIGURE 6.1: Examples of computer printouts from simulation

Investigations

It can be seen that the program allows the herd to be split into any number of groups with each peak of the group specified. Thus it was possible to investigate such questions as:

i. If the herd were split into a number of equal groups with equal periods between them, what effect would this have on the pattern of milk supply?

Groups	Max flow	Min flow	Range	Range as % of Max flow
2	50	16.67	33.33	66.7
3	44.4	22.2	22.2	50
4	37.5	29.16	8.34	22
6	33.3	33.3	0	0

Table 6.6 Results summary - Equal groups at equal periods

ii. What would be the effect on the peak flow of splitting the herd in two groups and separating calving dates by less than six months?

separation months	peak value
1	91.67
2	83.33
3	75.0
4	66.7
5	58.3
6	50.0

Table 6.7 Results Summary - Two herds at various separations

iii. What would be the effect if the herd were split into three groups with 2/3 calving normally and 1/3 at a later date?

months later	peak value flow	peak month
1	88.88	Nov
2	77.77	Dec
3	66.67	Oct, Jan
4	66.67	Oct
5	66.67	Oct

Table 6.8 Results Summary - One third of herd calves later.

Conclusion

These illustrations show that it would be possible to quickly evaluate the effect on plant capacity requirements of a number of alternatives with the result that a smaller number of schemes could be chosen for more detailed analysis.

6.8 CONCLUSION

A number of features and consequences of various types of short production run in spray drying plants have been examined.

The examination of cost structures in spray drying plants and the cost of the daily start-up, shut down and clean led to the conclusion that the control of energy must lead to improvements in the control of cost effects of short production runs in spray drying plants.

The occurrence of learning behaviour was examined in order to determine if there were adverse consequences from specification changes. Learning behaviour was considered to be insignificant in its effect on a number of product qualities. (Its effect on processing rate remains to be examined.) Additionally it was found that there was no discernible relationship between run length and quality problems. As many quality problems occurred on the nth day of a run as the first.

It was found that spray drying plant costs do respond to capacity utilisation. It was estimated that considerable savings could be made in production costs in certain situations through smoothed milk production. A method of estimating the effects of various manipulations of calving date on the capacity utilisation of a factory was proposed.

As was indicated in the introduction to this chapter, the necessity for management information in the spray drying plant is great. It has been shown here that control of energy is an important factor in all types of short run costs. In the following chapter, the behaviour of a plant in consumption of energy and the control of energy and other plant costs will be examined.

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CHAPTER SEVEN

CONTROL OF THE EFFECTS OF SHORT PRODUCTION RUNS IN SPRAY DRYING PLANTS

7.1 INTRODUCTION

The costs that a production manager is able to control are limited. The major components he is able to influence include the utilisation of milk,[1] energy, and plant. The labour force is relatively fixed although good management can avoid some overtime cost. In such a capital intensive situation, flexibility with respect to labour is limited.

It has been shown that the major cost component under the manager's control is energy. It has also been shown to be the major component of start-up, shut-down and cleaning cost, which is in turn of importance in the costs of short production runs. A study of energy in a spray-drying plant also reflects actions of operators and their effects on the plant, thus reflecting efficiencies in general. A model permitting the prediction of energy costs at various daily running times, for various individual specifications will enable a manager to make soundly based decisions on the strategy of operation of the plant. Any costs of unusual actions such as changes of specification should be reflected in energy consumption. Thus there are many reasons for its study.

The rate of processing in spray drying plants is also a key factor in determining plant efficiency. It answers the question "Is the plant being used at the highest feasible capacity?" Production rate has also been indicated as being an area where short production run effects are reflected. It has been suggested that short runs result in a reduced rate of processing. This effect must be separated from others in order to test the truth of the hypothesis.

1. Losses caused by waste of product and material have been studied by NZDRI staff (1) and will not be considered here.

Thus a model of processing rate should give insights into the true effects of run length.

Study of energy and processing rate in spray-drying plants should lead to enlightened management practices. In order to maintain such effects a regularly and frequently based management information system must be provided. Specifically with regard to this study, managers need such information in order to be able to assess the viability of preventive maintenance programmes and assist in recovery of losses due to power cuts from electrical distribution authorities. Also such information would enable the use of economic criteria in determining when a plant should be closed at the end of the season.

Development of a computer-based management information system was carried out as a means of demonstrating how such a tool could be used by a production manager in his continuing efforts to control production costs.

7.2 DETERMINATION OF THE RELATIONSHIP BETWEEN ENERGY CONSUMPTION AND DAILY RUN LENGTH

Introduction

Data was collected by the staff of Tui Dairy Company's Pahiatua plant on the daily consumption of oil and electricity. As the spray-drying plant was the only plant on site the data was of a suitable form to enable an investigation to be carried out to relate the energy consumption per unit of product with the daily run length.

As the first step in this process a model of the relationship between energy consumption and the milk volume entering the plant was created. This was used as a basis for the calculation of the energy consumption per unit of product at various daily run lengths.

The data concerns five different product specifications produced since early December 1978, including four of skim milk powder and one whole milk powder.

The plant comprises a Weigand evaporator and Niro dryer with fluid bed secondary drying and a rated capacity of 2.7 tonnes of powder per hour. The air heater and the boilers are oil fired.

The Model

In all cases it was assumed that energy consumption could be described by a fixed component and a variable component. The fixed component would represent energy used for start-up, shut-down and cleaning of the plant and any other loads that did not vary in proportion to the volume of milk processed.

The variable component would vary in proportion to volume of milk processed and would include the energy used for evaporation, drying and separation and associated pumps and any other loads that varied in proportion to the volume of milk processed.

Thus the model was of the form:

$$y = B_0 + B_1X_1$$

where, for example

y = total oil consumption in litres

B_1 = rate of consumption of oil per litre of milk

B_0 = fixed volume of oil consumed in litres

X_1 = volume of milk processed in litres

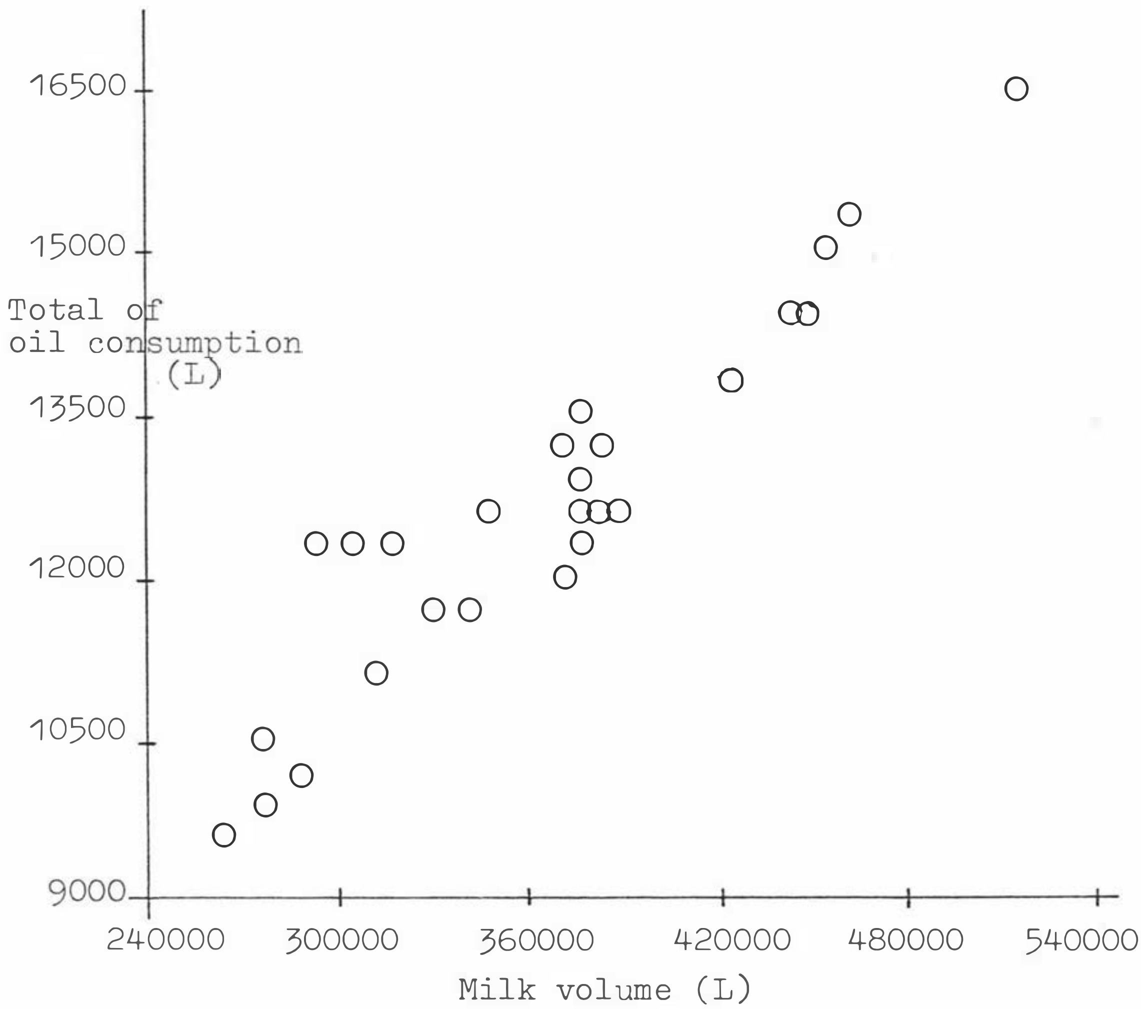
It was assumed that:

1. The efficiency of consumption of energy was invariant within each product run.
2. The model was a true representation of the situation.
3. Factors causing variation from the average in energy consumption occur at random, their effect evening out over the period of a run of several days.
4. There was one start-up and shut-down per day with no mid-run rinses.

Methods of Calculation

i. Calculation of the terms in the model

The actual data did not fall exactly on a straight line but had a certain amount of scatter, due to random occurrences. (See graph 7.1) Thus a technique had to be used to determine a line, the model, that best fitted the data. A mathematical technique known as the "method of



GRAPH 7.1: Example of scatter plot of daily total oil consumption vs daily milk volume (for spec.607)

least squares" was used. This technique minimises the sum of the squares of the distances of the data points to a line. A computer packaged called "Minitab" was used to perform these calculations.

Data was available on:

1. The plant running time. This is the time when the plant is actually manufacturing product, excluding start-up, shut-down and cleaning.

2. The raw milk volume in litres. This is the milk that arrives at the factory from the farm. The raw milk must subsequently be separated into a fat fraction and a skim fraction. Then if whole milk powder is to be produced the fat and skim are recombined with a controlled fat content.

3. Oil consumption of boiler and burner in litres per day.

4. Electricity consumption in units (kWh) per day.

Some data was also available on the volume of powder produced per day. However, powder is only packed off to the nearest pallet each day so it was not certain within $\pm.75$ tonnes how much powder was produced in a particular day.

Regressions were performed on

1. Time versus raw milk volume
2. Boiler oil consumption vs raw milk volume
3. Burner oil consumption vs raw milk volume
4. Total oil consumption vs raw milk volume
5. Electricity consumption vs raw milk volume

The results are displayed in Table 7.1.

ii. Energy consumption per unit of product

Once models of energy consumption were obtained, it was possible to express the results in a more useful form by calculating energy consumption per unit of product at different daily production run lengths. This enabled the costs and advantages (in terms of energy) of operating the plant according to various strategies to be seen.

The fixed component of energy consumption occurs without the manufacture of any product, therefore its cost

Regression		Time vs Milk Vol.			Boiler Oil vs Milk Vol.			Burner Oil vs Milk Vol.			Total Oil vs Milk Vol.			Electricity vs Milk Vol.		
Spec		B_1	B_0	R^2	B_1	B_0	R^2	B_1	B_0	R^2	B_1	B_0	R^2	B_1	B_0	R^2
600	14	3.82×10^{-5}	-0.454	92.9	0.0274	1017	81.9	0.0031	1728	4.2	0.0305	2746	94.2	0.0246	2884	86.6
633	31	3.23×10^{-5}	0.999	81.4	0.0201	1506	77.2	0.0078	667.5	77.8	0.0279	2174	83.2	0.0321	292.8	92.1
607	26	2.94×10^{-5}	1.20	97.0	0.0194	1971	86.2	0.0048	1721	27.8	0.0242	3692	89.2	0.0212	4929	85.8
821	36	4.26×10^{-5}	1.51	90.7	0.0191	3016	66.1	0.0143	52.17	46.5	0.034	3068	85.9	0.0263	4150	81.7

TABLE 7.1 :Summary of Results of Regression Analysis

must be borne by the product that is made. If only a small volume of product is made, then the fixed component per unit product will be high. If a large volume is made, the fixed component per unit will be low. Thus, the longer the daily run length, the smaller is the fixed component per unit, and the lower is the total energy consumption per unit of product.

To calculate the energy consumption per unit, the equations derived in the first part of this study were used. An average yield for each specification was calculated by dividing the total weight of product in a run by the total raw milk volume used in that run.[1]

For example, the calculations were as follows:

Spec.633, total oil consumption per unit of product

Yield = 0.0847 kg/ℓ

From table 7.1, oil consumption = 0.0279 x raw milk vol + 2174

The amount of product from a particular volume of milk is found by

total product (kg) = milk volume x .0847

Thus, oil consumption/kg $= \dfrac{0.0279 \times \text{raw milk vol} + 2174}{\text{raw milk vol} \times 0.0847}$

e.g. for raw milk vol = 70,000 litres per day

oil used/kg $= \dfrac{0.0279 \times 70{,}000 + 2174}{70{,}000 \times 0.0847}$

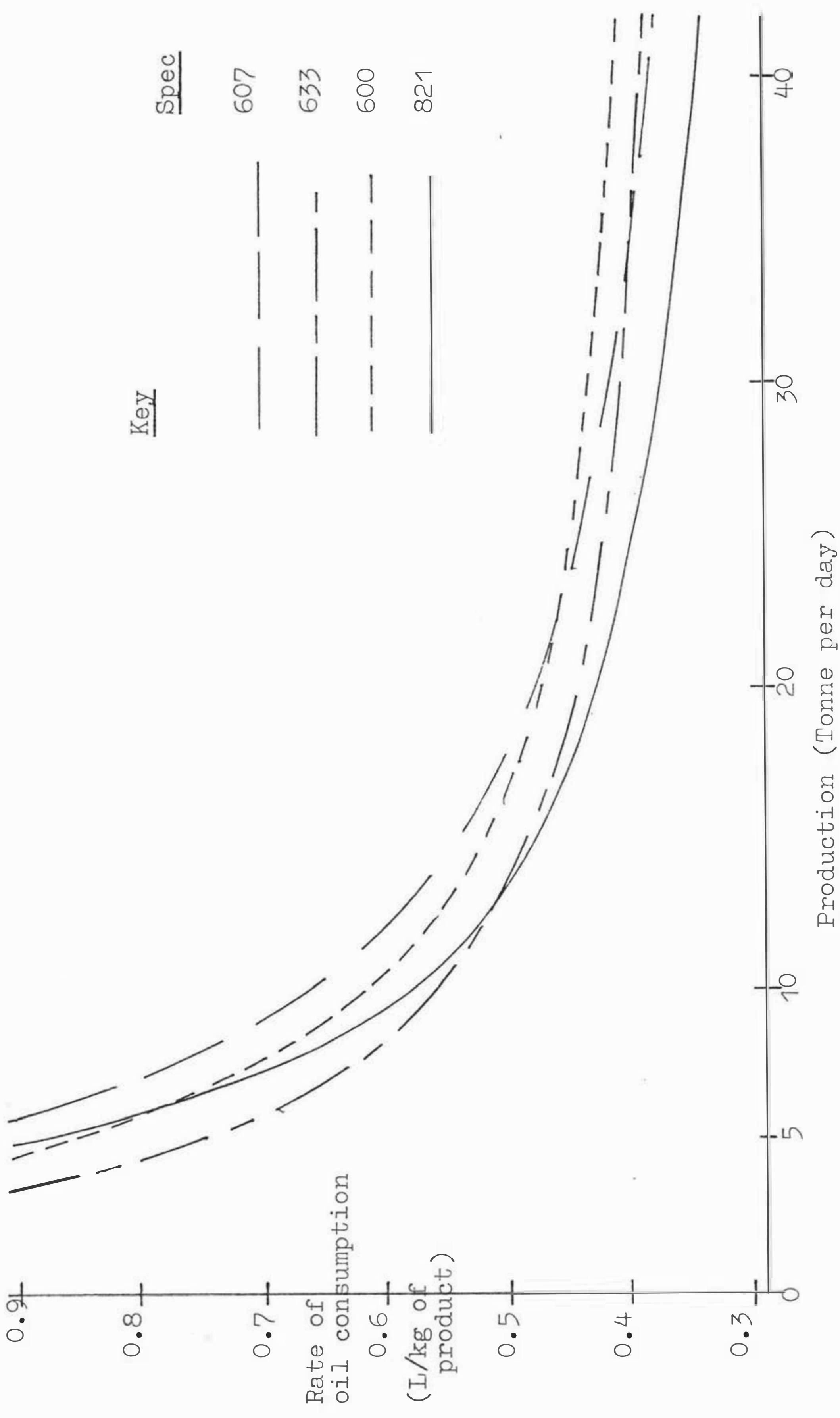
$= 5$ ℓ/kg

In practice these calculations were performed by means of the "Minitab" computer package. Summaries of the results are shown in Graphs 7.2, 7.3, 7.4.

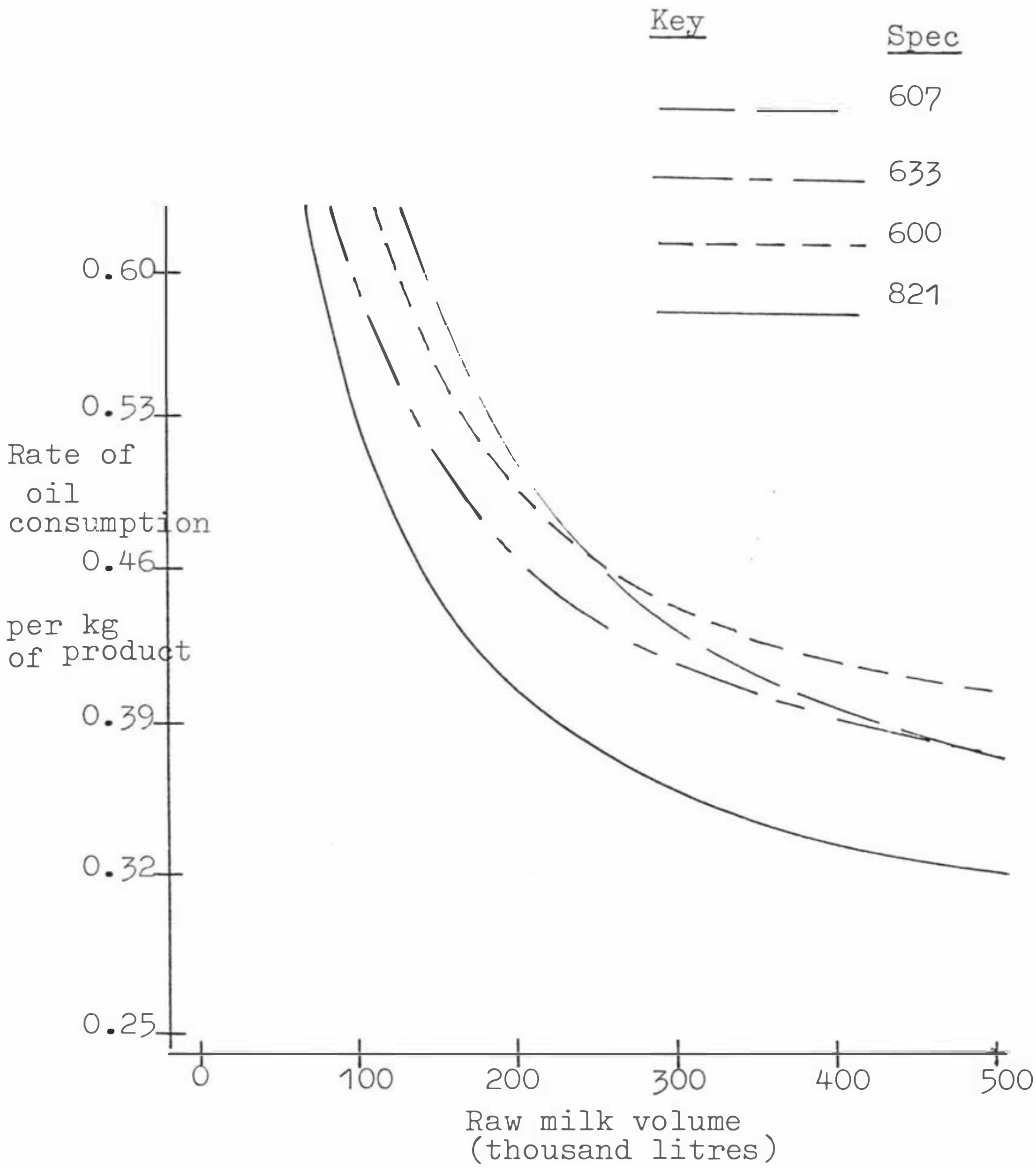
Spec	Yield kg/1000ℓ
607	83.829
633	84.709
600	89.337
821	123.25

TABLE 7.2: Yield of product per litre of raw milk

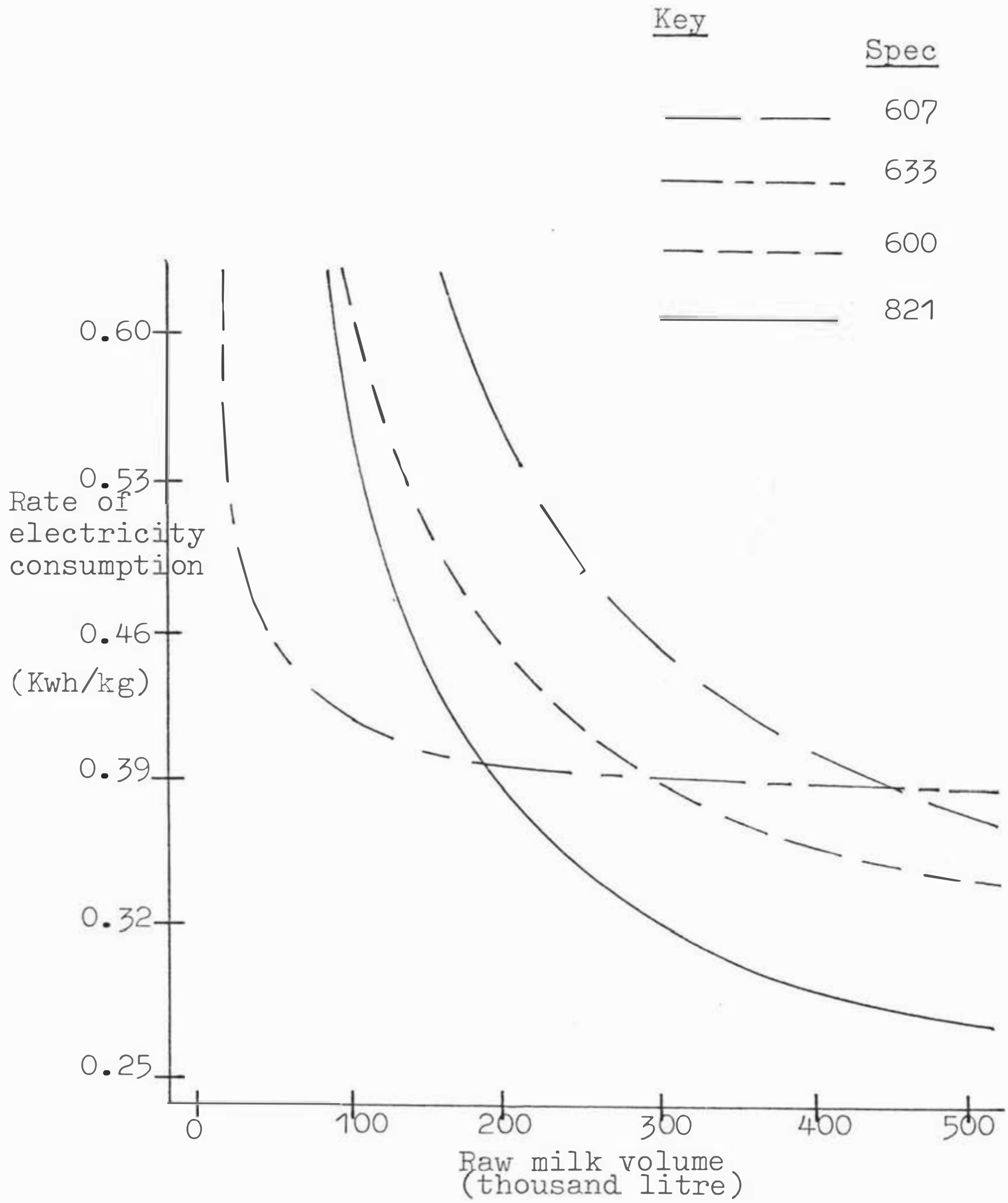
1. See Table 7.2



GRAPH 7.2: Rate of oil consumption per kilogram of product versus production volume per day



GRAPH 7.3: Rate of oil consumption per kg of product vs raw milk volume



GRAPH 7.4: Rate of electricity consumption per kg of product vs raw milk volume

Variability of the Data

As has already been noted, there was a certain amount of variability in the data. The following reasons were suggested for major variation in the recorded data values from the regression lines.

Higher than expected oil consumption.

- Failure to clean air-heater tubes
- Held-over milk also processed
- Operator less skilled than average
- Cleaning of drier or fluid beds
- More cleaning of evaporator than usual
- Breakdown causes running on water

Lower than expected oil consumption

- Operator more skilled than average
- Less cleaning than normal, e.g. just caustic wash
- Milk held over for processing next day

Higher than expected electricity consumption

- Cleaning of drier or fluid beds
- Running drier on water while waiting for evaporator
- Extra refrigeration load due to
  - left on overnight
  - humid conditions effect on cooling tower

Lower than expected electricity consumption

- Refrigeration left off

General

- Milk quality variation with time of year or weather
- Read meters at wrong time of day
- Oil tank level variation due to
  - air temperature
  - oil delivery causing change in temperature

Discussion on results of regression analysis

In general, all relationships studied showed a high correlation except the burner oil vs milk volume. There was also low correlation in the relationship between boiler oil consumption and milk volume for spec. 821. This is the specification that has been produced most recently and thus this may indicate that the boiler meter is becoming less accurate.

Burner oil consumption

From the Results Summary, Table 7.1, it can be seen that the co-efficients of determination were lowest for burner oil consumption. This is because it is measured indirectly. It is the difference between total oil consumption and boiler oil consumption. Thus there are cumulative errors from these sources plus it is a relatively small (numerically) quantity so that the error represents a high percentage of the quantity.

Time vs milk volume

In the cases of specifications 600 and 633, the constant term is not statistically significantly different from zero. This means that all the time spent running the plant results in consumption of milk in proportion to that time. However, this is not true for specifications 607 and 821. Here the constant term is significantly different from zero, in other words, part of the running time cannot be attributed to processing milk. This time must be attributed to a daily non-productive effort such as a mid-run rinse, or running on water. The significance is not extremely high so it may be that this unproductive time is of the order of ¼ to ½ hour per day.

It is interesting to note that different specifications appear to be processed at different rates. However, the differences are not sufficient to warrant planning on this basis.

Electricity consumption vs milk volume

The regression line for specification 633 shows the most surprising result. There appears to be very little fixed consumption of electricity with a very high variable rate of consumption. This may be attributed to the dependence of the regression line on four extreme value data points. It seems unlikely that the actual fixed consumption of electricity would be so small in comparison with the other three products.

Specification 821

This is the only whole milk powder in the study. With the higher proportion of solids arriving at the evaporator in the production of whole milk powder, the evaporator must be "turned down", that is to say, less evaporative capacity is required and thus less steam. It is found that in fact variable consumption of oil is only slightly lower than the skim milk products. (See graph 7.3)

This is because

(i) The evaporator operates less efficiently when turned down as there are greater heat losses.

(ii) The concentrate is evaporated to a lower total solids percentage thus increasing the drier's load. The drier is about ten times less efficient than the evaporator.

Note in Table 7.1 that the rate of oil consumption in the burner is appreciably higher in the use of specification 821 than the skim milk powder specifications.

Specification 672

On analysis of the data for specification 672, for which there were 31 data points, regression equations between raw milk volume and energy consumption could not be found. Also relationships between time and energy consumption were not found except in the case of burner oil versus time. In this case there was an excellent correlation. It has been suggested[1] that the lack of relationship is due to the extensive and varied plant cleaning times required on this product. The burner oil is closely related to the running time because the drier is not involved in extensive cleaning, that is to say, its fixed component is small anyway.

Electricity consumption on non-product days

Near the end of the season the evaporator and drier were operated once every two days. It was thought that the pattern of electricity consumption on these days may give an

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1. A. Wolland, Personal Communication

indication of how much of the fixed and variable consumption could be attributed to separation, tanker bay and refrigeration.

There was no variable component evident thus indicating that the above factors form only a small part of the variable electricity load. The average consumption of electricity was 2725.3 kWh. This accounts for a large proportion of the total fixed electricity consumption, 16% for specification 600, 55% for specification 607, and 66% for specification 821.

How the models can be used.

The models derived should be used cautiously, with due consideration to the fact that they are only models and based on certain assumptions. Also, it should be noted that:

(i) Extremely short run lengths and long run lengths were not encountered, thus calculations in these regions are theoretical extrapolations. Information within the range of the original data is more reliable.

(ii) The differences between specifications are not proven to be different from the variations we could expect to find from one run to another of the same specification. Thus such differences should be regarded cautiously.

The models were based on the raw milk volume so that they could be used in a predictive fashion. The expected daily milk flow in a particular period may be predicted with some accuracy from past data. Thus, knowing the expected milk volume, it would be possible to predict, with the help of the models, the expected consumption of oil and electricity for each of the specifications studied, and also the time required to process the milk.

For example,

How much oil and electricity will be required to process 354,000 litres of milk into specification 633 on one day?

From Table 7.1, the co-efficients are:

$$B_1 = 0.0279$$

$$B_0 = 2174$$

the model is $y = B_0 + B_1X_1$

where y = oil consumption in litres

X_1 = volume of raw milk in litres

thus $y = 2174 + 0.0279 \times 354{,}000$

$\doteqdot$ 12,000 litres

Similarly, it is found that

electric power consumption $= 292.8 + 0.0321 \times 354{,}000$

$\doteqdot$ 11,600 kWh

And it is found that

time taken $= 0.999 + 3.22 \times 10^{-5} \times 354{,}000$

= 12.4 hours, plus start-up and shut-down

Further, the models were used to determine the consumption of oil and electricity per unit of product at various levels of daily milk flow. This energy consumption per unit of product can be predicted at expected daily milk flows. For example:

What would be the additional cost in energy of producing 120 tonnes of specification 821 in six days of 20 tonnes versus three days of 40 tonnes?

(Milk flows of 160,000 litres/day and 325,000 litres per day respectively, found by using yield factors in Table 7.2)

(i) Oil Consumption

From Graph 7.2

At 20 tonnes per day, oil consumption is .42 litres/kg

At 40 tonnes per day, oil consumption is .345 litres/kg

Thus oil cost per kg of product is

$$= \frac{.42 - .345}{.345} \times \frac{100}{1}$$

$$= \frac{.075}{.345} \times \frac{100}{1}$$

= 22% higher

(ii) Electricity consumption

From Graph 7.4.

At 20 tonnes per day (i.e. 160,000 litres) electricity consumption is .42 kWh/kg.

At 40 tonnes per day (i.e. 325,000 litres) electricity consumption is .317 kWh/kg.

Thus electricity cost per kg of product is

$$\frac{.42 - .317}{.317} \times 100$$

$$= \frac{.103}{.317} \times 100$$

$$= 32\% \text{ higher}$$

Conclusion

Fixed and variable energy consumption were determined for three skim milk powder specifications and one whole milk powder specification. Based on this, the energy consumption per unit of product at various daily production volumes was found. The results indicated that the rate of energy consumption per unit of product may vary greatly depending on the volume of raw milk available. The effects of varying daily run length on energy consumption are readily predictable.

7.3 FACTORS AFFECTING THE RATE OF MILK PROCESSING IN A SPRAY-DRYING PLANT

Introduction

Processing or production rate is central to the question of whether a plant is being run at minimum production cost. Processing rate could be expected to reflect plant and operator failures in terms of a reduced rate.

A fixed relationship between rate of processing and other factors would enable the prediction of costs and thus a plan of operations to minimise costs.

In one of the two plants studied data was not available on rate of production because of imprecise production volume figures. Milk volume into the evaporator was recorded as was the time the evaporator was processing milk, thus a study of processing rate could be made.

It was expected that the rate of processing would reduce with increasing running time because of fouling of the evaporator.

The following questions were examined.

i. What was a suitable model for the relationship between processing rate and processing time?

ii. What were the effects of specification on processing rate?

iii. Were there any seasonal effects on processing rate?

iv. What were the effects of changes of specification on processing rate?

The first set of data examined was that from Tui Dairy Company's Pahiatua plant.

<u>The relationship between rate of processing and processing time</u>.

<u>The season's data</u>.

Three methods were used to smooth the season's data in order to simplify the discovery of relationships between processing rate and processing time. These were:

1. Tukey Median Smoothing.

The points plotted are the medians of the current point, its predecessor and its successor.[1]

2. Moving Average.

A five-point moving average of the current point and its four succeeding points is plotted.

3. Cumulative Sum.

The cumulative sum of differences from the mean value is plotted.

<u>Tukey Median Plots of milk processing rate and processing time</u> (Graph 7.5)

Points noted were as follows:

i. In a large number of cases, processing time was clearly inversely proportional to processing rate.

ii. In some cases processing time and rate did not appear to affect each other, for example, days 69-83, 91-92, 103-110.

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1. For a more complete description see Tukey, W.T. <u>Exploratory Data Analysis</u>, Philippines, Addison Wesley, 1977

GRAPH 7.5: Tukey plots of processing rate and processing time vs day number

Key
* = processing rate
x = processing time

WELL?
WELL?

iii. From day 119 to 157, although there was a gradual reduction in processing time, rate was not affected, although it appeared to respond to daily fluctuations.

Moving Average Plots of processing rate and processing time. (Graph 7.6)

It was clear from an examination of these graphs that processing rate was highly sensitive to processing time in an inverse relationship. Additionally the following points were noted:

i. Rate was fairly constant despite an increase in processing time during days 69 to 85.

ii. An increase in rate occurred despite an increase in processing time during days 93 to 100.

iii. Processing time on days 88 to 90 corresponded to that about day 102, yet processing rate was appreciably lower.

iv. The reduction in processing time day 139 to 152 did not correspond with an increase in processing rate.

v. At the commencement of the run of specification 823 from day 184 onwards the steady increase in daily running time did not correspond to a decrease in rate initially.

Cumulative Sum plots of processing rate (Graph 7.7)

The cumulative sum plots[1] caused almost too much smoothing of data. Within any specification run it was difficult to notice changes in the rate of processing. Thus it was certain that processing rate was primarily affected by the specification processed. At every change between whole milk and skim milk specifications there was an obvious change from a rate below to above the mean or vice versa.

The plot of processing time showed interesting changes

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1. Cumulative sum plots are of most value in showing changes in the mean. A steady gradient indicates that the data concerned had a relatively constant mean.

GRAPH 7.6: Moving average plots of processing rate and processing time vs day number

Key
* = processing rate
x = processing time

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GRAPH 7.7: Cumulative sum plots of processing rate and processing time versus day number

Key
* = processing rate
x = processing time

WELL?

WELL?

of slope in the periods 86-118, 119 to 157 and 184 to 198.

Initial Conclusions

Behaviour apparent in the moving average plots was not apparent in the Tukey Median Smoothing graphs. For example, the slopes in the moving average plots from day 86-114 were not evident in the median plots.

The cusum plots caused excessive smoothing which disguised all but major changes.

Techniques such as Moving Average and Median Plots are complementary and may emphasise different points. Conclusions must take into account information from all sources.

It can be concluded from the above plots that:

i. Processing rate changes markedly from specification to specification, especially Skim to Whole Milk and vice versa.

ii. Short term variations in processing time are reflected in processing rate, in an inverse fashion.

iii. In some cases processing rate is not affected by long term variations in processing time. Possible causes for this could be that production rate was partially determined by the operators perception of expected processing time, and that the operator compensated for falling rate by altering other plant variables.

Model Building

From the examination of the smoothed date, it was determined that there was an inverse type of relationship between processing rate and processing time. Prior to more detailed examination of the data specification run by specification run, a theoretical basis for a model relating processing rate with processing time was sought.

In an evaporator, the rate of heat transfer, and hence evaporation can be quantified by the equation:

$$q = u.A.\Delta T \qquad (1)$$

where q is the rate of heat transfer
u is the overall heat transfer co-efficient
A is the heat transfer area
ΔT is the temperature drop.

The overall heat transfer co-efficient, u, is strongly influenced by the design and method of operation of the evaporator.

The overall resistance to heat transfer, R, is the sum of five individual resistances:

i. steam film resistance:
ii. scale resistance inside the tubes:
iii. scale resistance outside the tubes:
iv. tube wall resistance:
v. resistance from the boiling liquid.

The overall heat transfer co-efficient is the reciprocal of the overall resistance

i.e. $$u = \frac{1}{R}$$

In most evaporators, and especially those handling viscous materials, the resistance on the liquid side controls the overall rate of heat transfer to the boiling liquid. (2) Assuming the properties of the milk remain constant throughout a run, then the scale resistance inside the tubes controls the overall rate of heat transfer to the milk.

It has long been established (3) that for true scale formation, the overall co-efficient can be expressed as a function of the boiling time of the form

$$\frac{1}{u^2} = a\,t_b + b \qquad (2)$$

where t_b is the time of boiling, seconds
a,b are constants for the particular system
u has dimensions $kW/m^2.K$

If Q is the total heat transferred during boiling time, t_b then from (1)

$$q = \frac{dQ}{dt_b} = u.A.\Delta T \qquad (3)$$

Substituting (2) in (3)

$$\frac{dQ}{dt_b} = \frac{A\Delta T}{(at_b+b)^{0.5}} \qquad (4)$$

Integrating between 0 and Q and 0 and t_b, then

$$Q = (2A\Delta T/a)\left((at_b + b)^{0.5} - b^{0.5}\right)$$

$$\text{let } k = \frac{2A\,\Delta T}{a}$$

$$\text{then } Q = k\,(at_b + b)^{0.5} - k\,b^{0.5} \qquad (5)$$

$$Q^2 = k^2 b + k^2(at_b + b) - 2k^2 b^{0.5}\,(at_b + b)^{0.5} \qquad (6)$$

Now Q is the total heat transferred in time, t_b, so Q is proportional to the total volume of milk processed in time t_b as each unit volume of milk required an equal amount of energy to reduce its moisture content to the required value.

Thus $R_a \propto \frac{Q}{t_b}$ where R_a is the average rate of processing

and $R_a = \frac{V}{t_b}$ V is the total volume processed in time t_b

$$R_a^2 = \frac{k'Q^2}{t_b^2}$$

$$Q^2 = k'' \cdot R_a^2 \cdot t_b^2 \qquad (7)$$

Equating the right hand side of (6) and (7)

$$k''.R_a^2.t_b^2 = k^2 b + k^2(a\,t_b + b) - 2k^2\,b^{0.5}(a\,t_b + b)^{0.5}$$

$$R_a^2 = \frac{k^2}{k''}\left[\frac{b}{t_b^2} + \frac{a}{t_b} + \frac{b}{t_b^2} - 2\left(\frac{ab}{t_b^3} + \frac{b^2}{t_b^4}\right)^{0.5}\right]$$

The final term is ignored because if $b < 1$ then a term in b^2 will be smaller than b, t_b^{-4} will be significantly smaller than a term in t_b^{-3}.

Thus

$$R_a^2 = \frac{k^2}{k''t_b}\left[a + \frac{2b}{t_b} - 2\frac{(ab)^{0.5}}{t_b^{0.5}}\right]$$

$$= \frac{k^2a}{k''t_b}\left[1 + \frac{2b}{at_b} - 2\left(\frac{b}{at_b}\right)^{0.5}\right] \qquad (8)$$

Using the binomial expansion

$$R_a = \left(\frac{k^2a}{k''t_b}\right)^{0.5}\left[1 + \frac{b}{at_b} - \left(\frac{b}{at_b}\right)^{0.5} - \frac{4}{8}\left[\left(\frac{b}{at_b}\right)^2 + \frac{b}{at_b} - 2\left(\frac{b}{at_b}\right)^{1.5}\right]\right]$$

$$= \left(\frac{k^2a}{k''t_b}\right)^{0.5}\left[1 + \frac{b}{2at_b} - \left(\frac{b}{at_b}\right)^{0.5} + \left(\frac{b}{at_b}\right)^{1.5} - \frac{1}{2}\left(\frac{b}{at_b}\right)^2\right]$$

ignoring terms with powers of t_b less than $-3/2$

$$= \left(\frac{k^2a}{k''t_b}\right)^{0.5}\left[1 - \left(\frac{b}{at_b}\right)^{0.5} + \frac{b}{2at_b} + \left(\frac{b}{at_b}\right)^{1.5}\right]$$

$$= \left(\frac{k^2}{k''}\right)^{0.5}\left[\frac{a^{0.5}}{t_b^{0.5}} - \frac{b^{0.5}}{t_b} + \frac{b}{2a^{0.5}.t_b^{1.5}} + \frac{b^{1.5}}{a^{0.5}.t_b^{2}}\right]$$

Hence

$$R_a = \frac{C_1}{t_b^{0.5}} + \frac{C_2}{t_b} + \frac{C_3}{t_b^{1.5}} + \ldots \qquad (9)$$

Determination of the 'best' model

The equation, 9, derived above is an approximation of the real situation. In order to arrive at a model of the relationship that has an adequate degree of accuracy, and the greatest simplicity several models involving one, two and three terms in t_b were tried. The values of R^2 are given in Table 7.3.

Period	$R_a = B0 + \frac{B1}{t_b^{0.5}}$	$R_a = B0 + \frac{B1}{t_b}$	$R_a = B0 + \frac{B1}{t_b^{1.5}}$
105-118	76.8	76.5	76.2
119-138	91.4	91.8	92.0
139-157	67.0	68.6	70.1
169-180	96.7	97.0	97.1
184-197	64.1	63.0	61.8

Period	$R_a = B0 + B1x \frac{1}{t_b^2}$	$R_a = B0 + \frac{B1}{t_b^{0.5}} + \frac{B2}{t_b}$	$R_a = B0 + \frac{B1}{t_b^{0.5}} + \frac{B2}{t_b} + \frac{B3}{t_b^{1.5}}$
105-118	75.9	87.6	78.0
119-138	92.2	92.1	92.1
139-157	71.4	74.4	74.2
169-180	97.1	97.1	97.2
184-197	60.6	68.6	67.4

Table 7.3: Values of co-efficient of determination (R^2) for various regressions of processing rate on processing time.

Values of R^2 are clearly highest on average for the two factor regression, thus this model can be said to best fit the data. However, for the sake of simplicity, the model $R_a = B0 + B1 \times 1/t_b$ would be chosen because the R^2 values are not significantly lower than any of the higher or lower powered single factor models and only slightly less than the two factor model.

An examination of individual specification runs

An examination was made of the data within each individual specification run and compared with the simple linear model, processing rate = B0 + B1 x 1/processing time. Anomalies noted above were examined in greater detail. The results of the regressions are shown in Table 7.4 and graphs 7.8 and 7.9.

Spec. 633 7/9 to 23/9 (Day 69 to 85 inclusive)

This was the first run of the season. Points appeared to be scattered. Processing rate varied as much as 40% within one hour's difference in processing time. The best observable relationship appeared to be processing rate equals average processing rate. In other words, processing rate is not dependent on plant limitations. This pattern is as would be expected in a start-up situation where there are a number of unexpected failures in the plant, and staff are re-learning operation of the plant after winter shut-down.

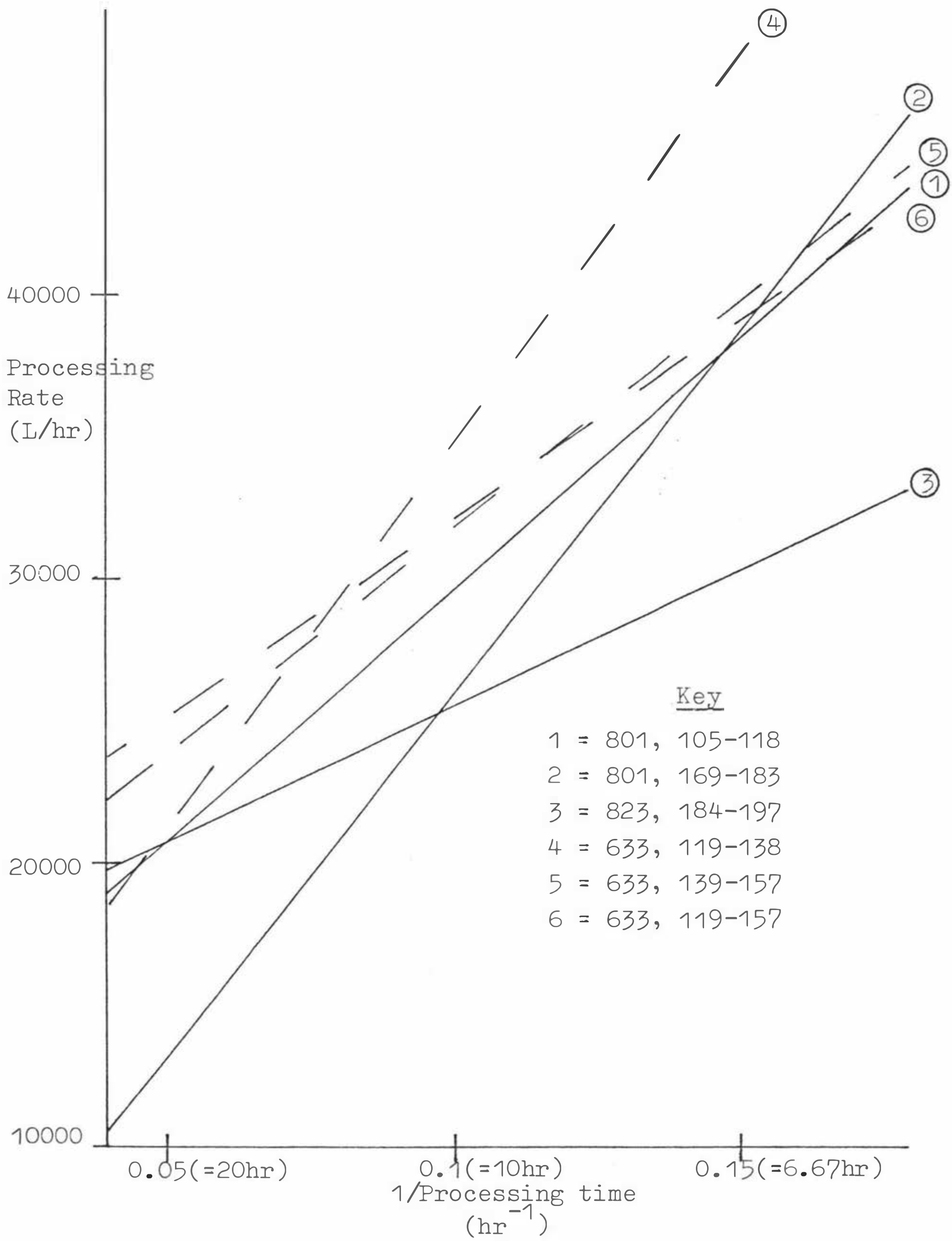
Spec. 801 24/9 to 26/10 (Day 86 - 118)

When this data was first plotted there appeared to be a maximum rate occurring with lower rates each side of a certain time. However, when the data was replotted, indicating the day of the run beside each point, it was found that the data was initially widely scattered, with a corresponding low processing rate and from day 105 onwards a much more consistent pattern emerged, with close agreement to the model.

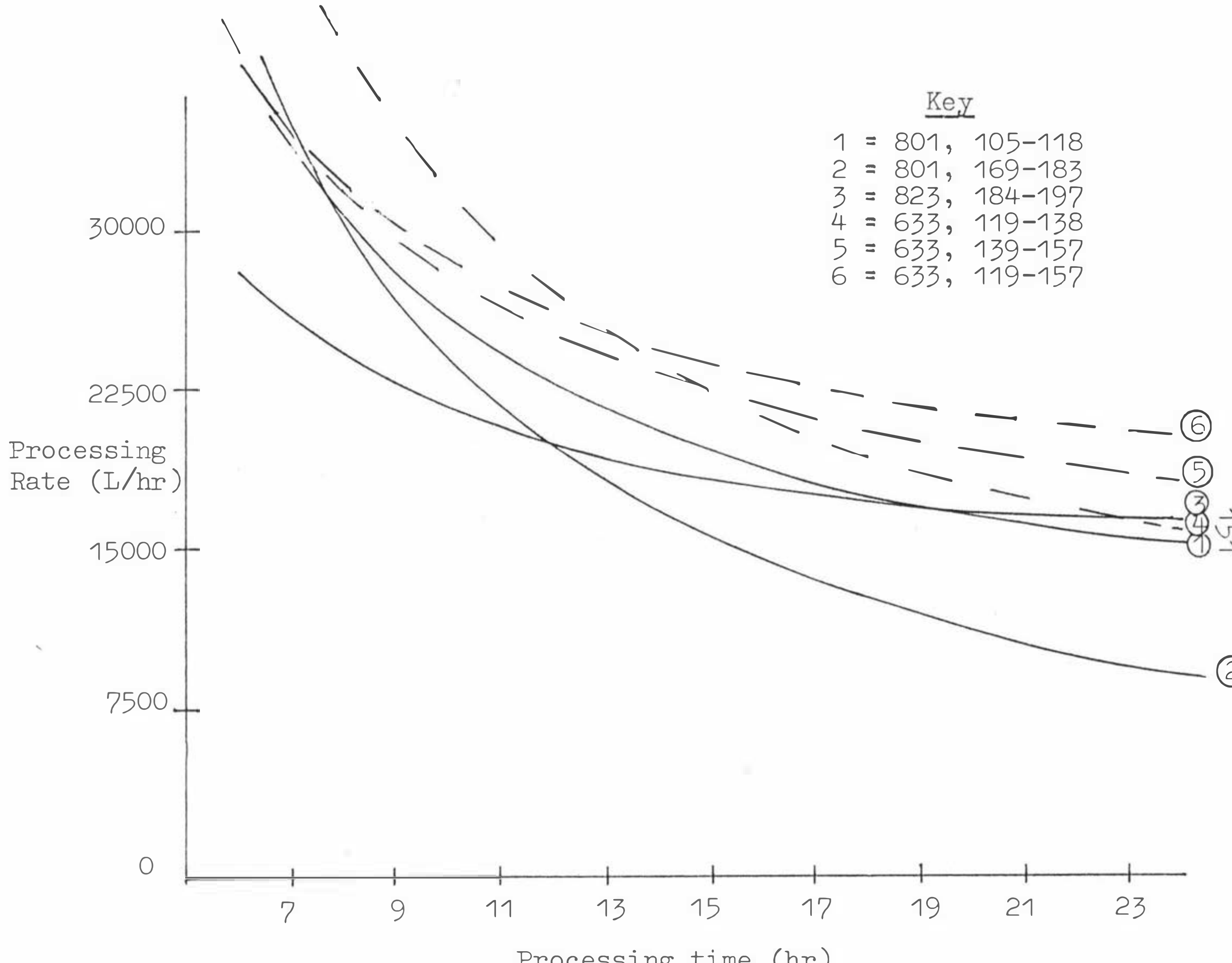
This distribution of data points is consistent with a learning period, during which rate of processing fluctuated and was determined by factors other than the plant's limitations, followed by a period of attainment of the maximum rate limited by the plant constraints.

Day No.	Spec	BO	B1	R^2 (%)	Notes
69-86	633	No observable relationship		0.21	
86-104	801	No obserbable relationship		3.7	First part of run
105-118	801	9734	179856	76.5	Second part of run
119-138	633	5703	274152	91.8	First part of run
139-157	633	13780	158290	68.6	Second part of run
119-157	633	16060	141472	55.7	Whole run
169-183	801	3.75	260616	97.2	Excludes day 181
184-197	823	13769	97856	63.0	
199-218	633	No observable relationship		0.02	Excludes day of zero processing
220-236	823	No observable relationship		14	

TABLE 7.4: Summary of results of regression of processing rate on 1/processing time (hr)



GRAPH 7.8: Regression Lines of processing rate on 1/time



GRAPH 7.9: Predicted processing rate versus processing time

Spec. 633 27/10 to 4/12 (Day 119 to 157)

It was noted previously that during this run, despite a drop in processing time, there was no corresponding increase in processing rate. When data was plotted indicating the day of the run beside each point it was discovered that the data could be split into two groups, from day 119 to 138 and day 139 to 157.

The second group's points were almost all at a lower processing rate for a corresponding processing time than the first group. Possible explanations for this situation are:

> Re-processing was occurring, resulting in greater total solids entering the evaporator and thus causing a more rapid build up of scale, with a corresponding drop in rate.
>
> Operating staff deliberately reduced rate because available milk volume had dropped to a level where they were not required to work overtime or run the plant at maximum rate to avoid overtime. (Running times average 12.23 hr first half, 10.67 hr second half.)
>
> Rate was reduced by staff efforts to remain within solubility specification by reducing the total solids level ex the evaporator.

Spec. 801 16/12 to 30/12 (Day 169 to 183)

This data closely follows the regression model with 97.2% of the variation attributable to the model. (Average processing time was 12.03 hours)

Spec. 823 31/12 to 14/1 (Day 184 to 198)

It is difficult to find a reasonable explanation for the fluctuations in processing rate noticed near the beginning of this run. The fact that it began on December 31st may have some effect in that some non-standard procedures may have been used to get home at a convenient time on New Year's Eve, affecting that and other day's production near this time. The regression model used was calculated by excluding the final day's production (198) which, if included, makes nonsense of the data. There is no apparent explanation for this.

Spec.633 15/1 to 5/2 (Day 199 to 218)

The data points of this run do not conform to a linear trend. Some days have rates far higher than previously exhibited for this specification. One possible explanation that could account for this behaviour is if all the runs of $\geqslant 11.43$ hours were performed with a mid-run rinse, not shown in the logs.

However this would have resulted in rates 5-6000 ℓ/hr greater than recorded. The rates recorded were 5-6000 ℓ/hr higher than predicted by using B0 = 13780, B1 = 158290. An examination of logs showed only slight differences in plant operating conditions to previous runs.

Spec. 823 6/2 to 22/2 (Day 220 to 236)

The data points appear to fall into two groups, at similar processing times but widely differing rates of processing. There did not appear to be reasons for this in terms of the day of the run, staffing of the plant, or drier washing and these groups. It may be that re-processing was occurring on the apparently lower rate days.

Implications of the model

It can be seen from Graph 6.13 that the model chosen results in a form of behaviour of processing rate where the change in processing rate per unit time falls off with increasing time. In physical terms this means that after an initial rapid drop in processing rate, perhaps due to build up on the inside of evaporator tubes, the rate tapers off to a relatively constant lower value and further build up either occurs more slowly or affects rate less. Thus any measures to keep the plant in the initial high rate period would result in a higher overall processing rate.

Effects of specification

As would be expected, because of the removal of cream after the volume entering the process is measured and its lower total solids content, the SMP specification has the highest processing rate. It is difficult to distinguish between the processing rates of the two WMP specifications.

In terms of the regression equations derived for which there were two for specification 801 and one for specification 823, the processing rate for specification 823 is lower than that for 801 up to 11.9 hours in one case and 20.8 in the other case.

The average processing rates for the whole season for each specification were 22018 litre/hour for 801 and 21173 litre/hour for 823. The average processing times were respectively 12.79 and 11.05 hours. It can be seen that in the real situation, 801 was processed at a greater rate and for a longer time on average each day and therefore any correc tion to a common time would tend to increase the separation between the two specifications. In practice 801 was processed at a greater rate than 823.

The weight of evidence suggests that specification 801 is processed at a greater rate than 823 although the difference may not be as great as suggested by the averages for the year.

Seasonal Effects on Processing Rate

Apart from the obvious change in daily running time through the season there appears to be an effect in terms of the variability of data. Data does not conform to a linear model of processing rate at the beginning or end of the season. Possible reasons for this include:

i. Seasonal variation in milk properties may be affecting the plant's ability to process the milk at an optimum rate.

ii. The operators may become less careful in attaining the maximum rate of processing near the ends of the season when there is more than adequate time available to process the milk. This may be because they no longer have to avoid overtime or they wish to continue their operating job rather than perform less attractive plant cleaning or maintenance tasks.

iii. Learning behaviour may be occurring at the beginning of the season as operators re-familiarise themselves with the plant.

Effects of Changes of Specification

It was interesting to note that the three runs where a linear model was evident for the whole run commenced with the following residuals:

Day No.	Spec.	Day 1	Day 2	Day 3	Day 4
119	633	-0.685	-0.43	-1.10	+0.367
169	801	-1.78	+0.699	+1.27	0.054
184	823	-1.93	+0.95	-1.12	-0.075

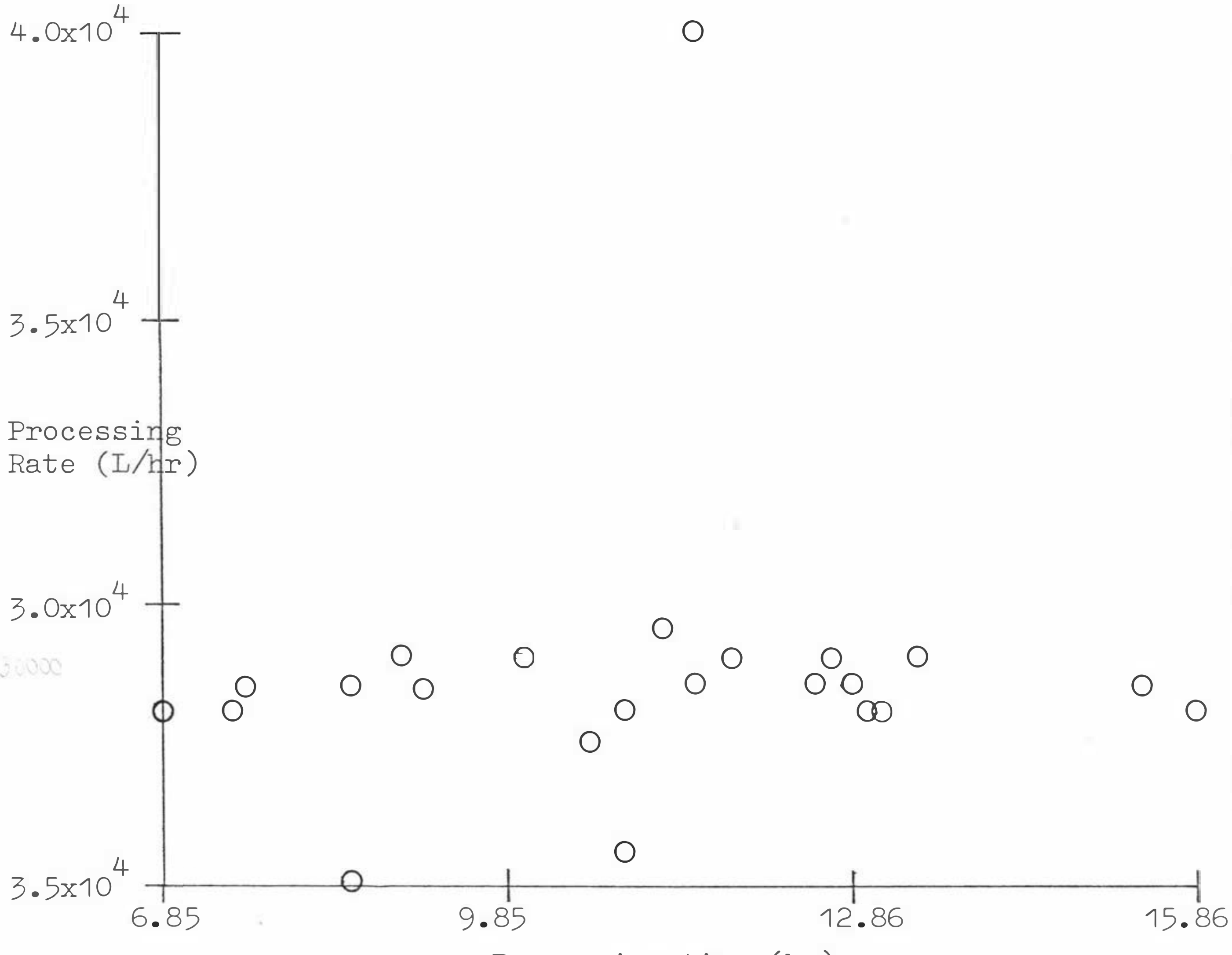
This seemed to indicate that processing rate was below that predicted by the model on the first day of the run. The average reduction in processing rate was 3.8%. However a comparison of actual and predicted rates on the commencing day of every specification run revealed that equal numbers were above and below the predicted rate. Thus it cannot be concluded that change of specification causes a noticeable reduction in processing rate based on this data.

Rate of milk processing at Midhirst Plant

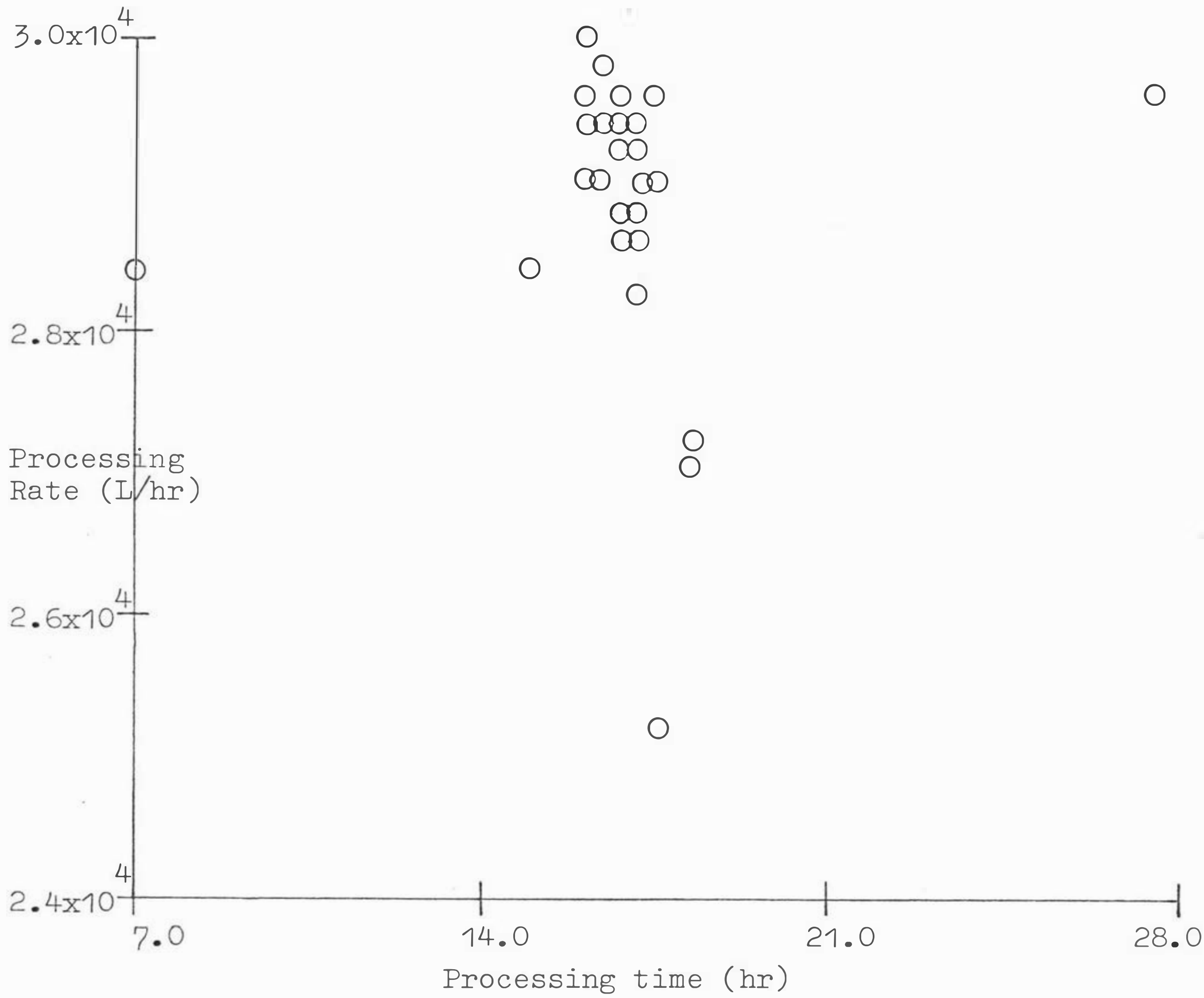
An examination of data from Taranaki Co-operative Dairy Company's Midhirst plant showed that the rate of processing at Midhirst was independent of milk processing time, as opposed to evidence from Tui's Pahiatua Plant and theoretical expectations.

The only explanation of this occurrence is that it may be a result of the practice of changing the high heater at regular 5-7 hourly intervals, a practice that was revealed from an examination of the factory log books. If this part of the evaporator was the rate-limiting step than rate would be effectively returned to maximum after each change. While one high heater was in operation the other was being cleaned and so on. According to plant logs, there was no appreciable drop in flow rate even after 26 hours continuous running.

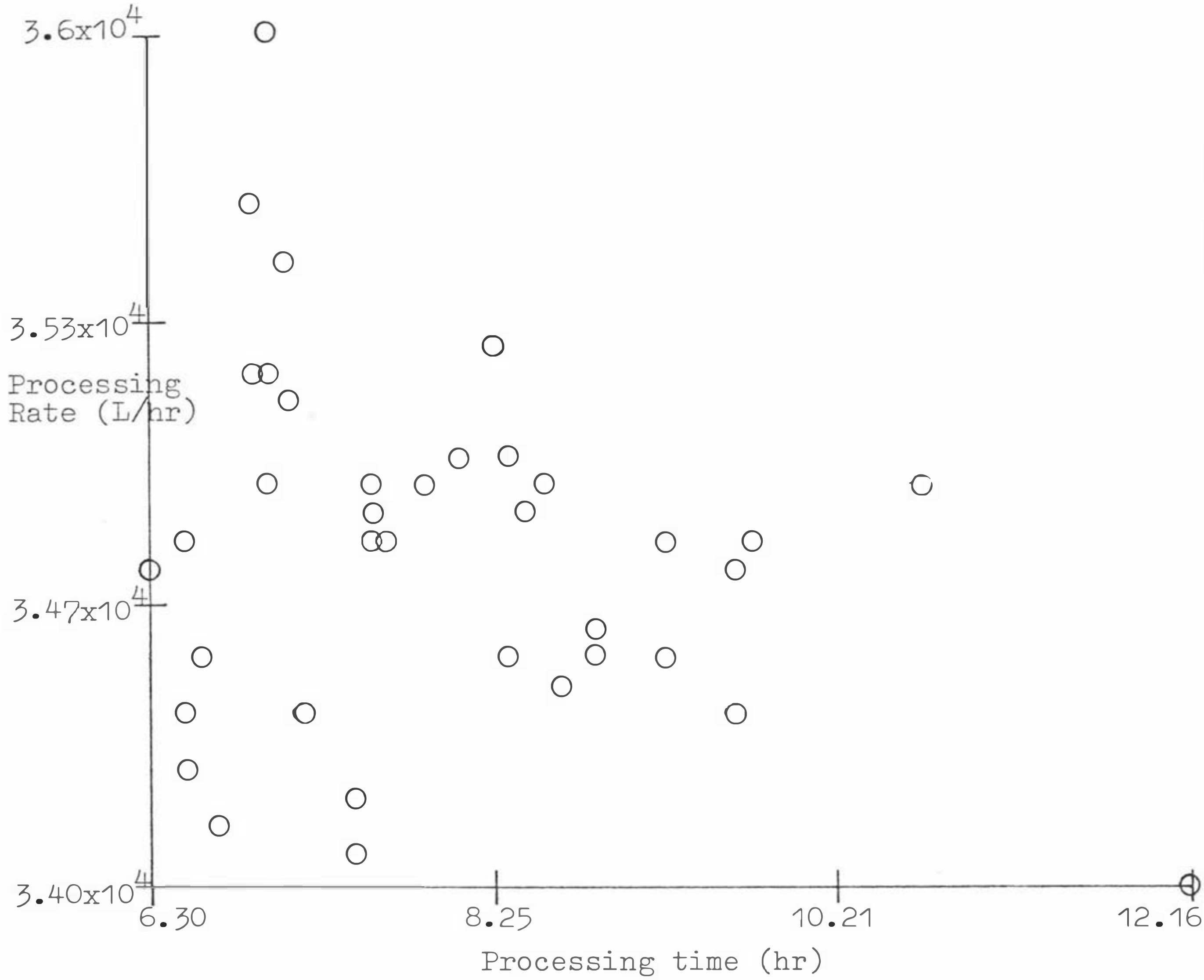
The graphs 7.10 to 7.15, illustrate this indepencence of rate in terms of product/hour and milk in/hour from processing time.



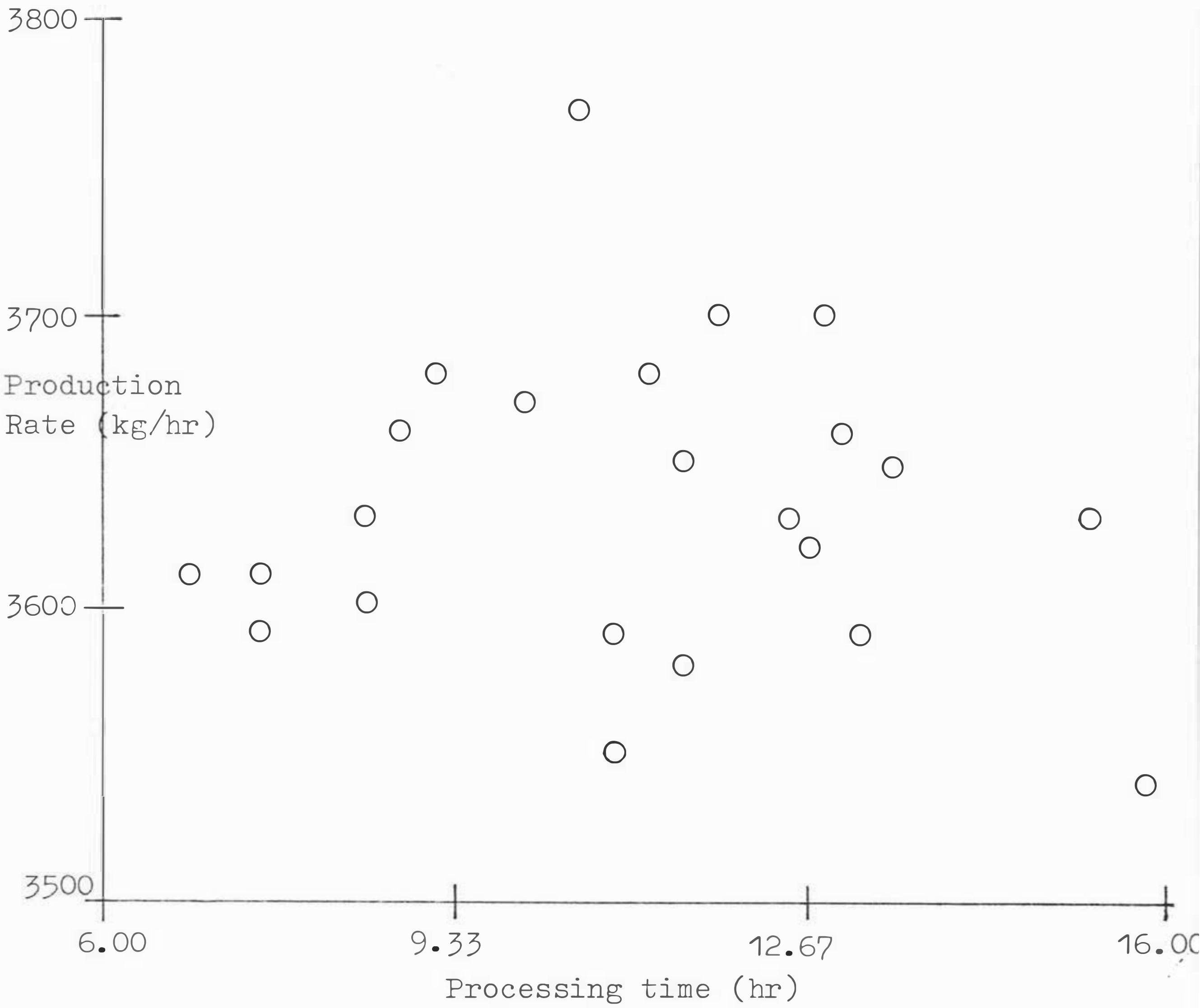
GRAPH 7.10: Processing rate vs processing time, days 69 to 92



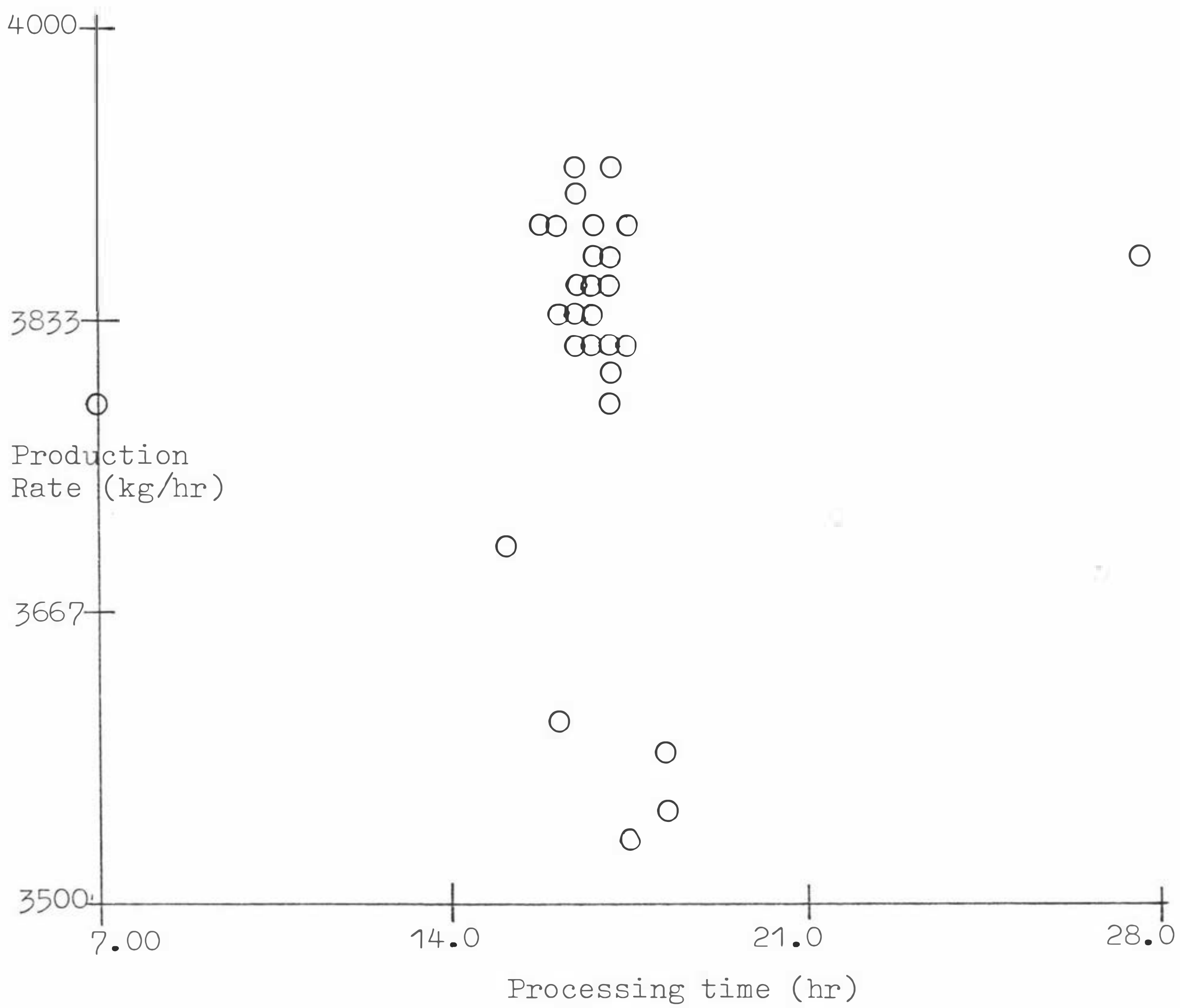
GRAPH 7.11: Processing rate vs processing time, days 106 to 142



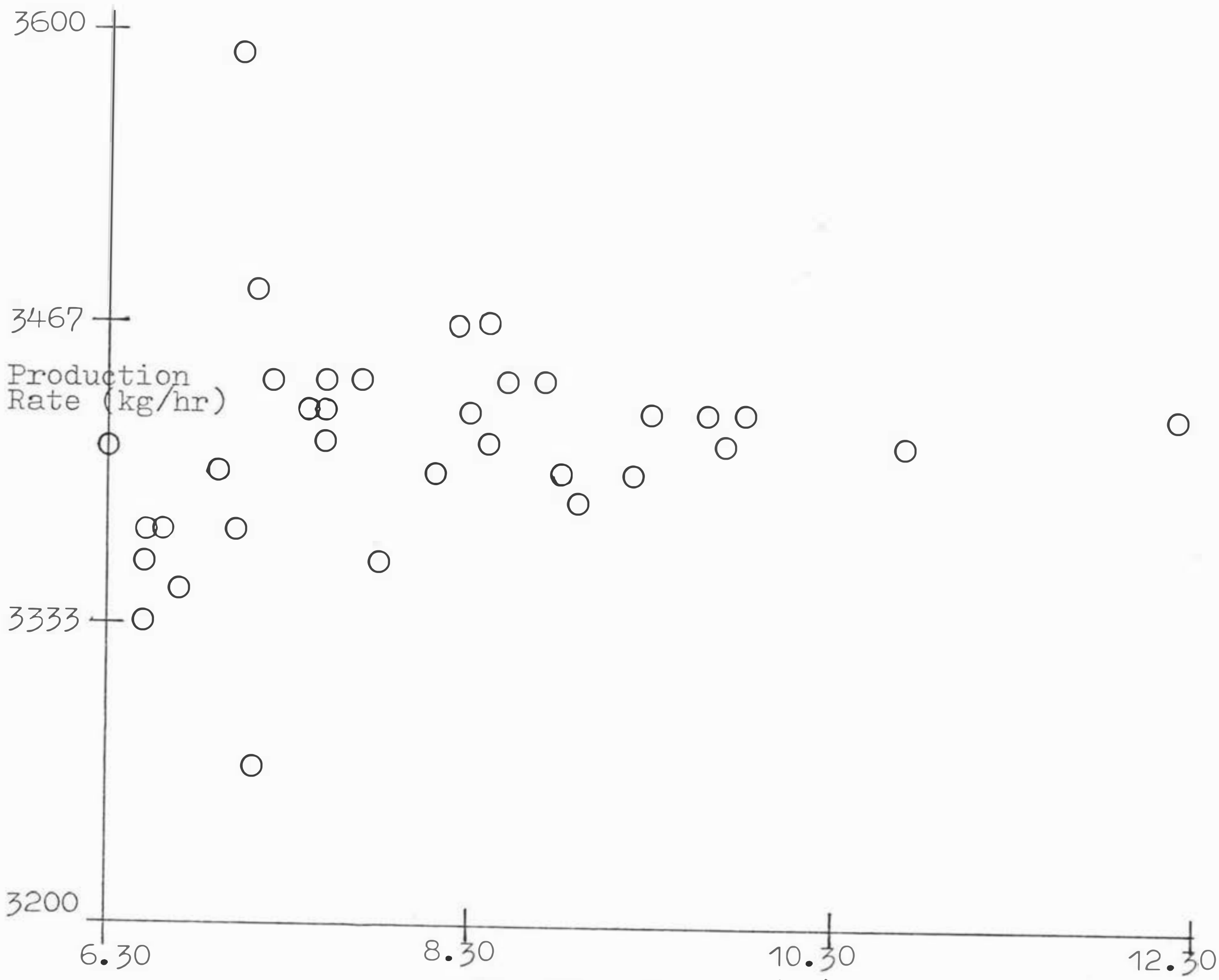
GRAPH 7.12: Processing rate vs processing time, days 173 to 210



GRAPH 7.13: Production rate vs processing time days 69 to 92



GRAPH 7.14: Production rate vs processing time, days 106 to 142



GRAPH 7.15: Production rate vs processing time, days 172 to 210

Conclusions

i. Processing rate at Tui's plant can be predicted by a model involving the inverse of processing time. A consequence of this model is that at short daily running time processing rate is higher than long daily running time.

ii. Processing rate is distinctly different from the skim milk specification to the whole milk specifications.

iii. It appears that specification 801 is processed at a higher rate than specification 823.

iv. There appears to be a start-up phenomenon at the beginning of the season when rate fluctuates independently of processing time. This phenomenon also occurs late in the season. Possible causes could be a seasonal variation in milk qualities such as acidity and the protein/lactose ratio, affecting evaporator operation, or staff reasons such as being in the situation where maximum rate processing is not necessary.

v. There is little evidence for serious effects of changes of specification on processing rate. It is concluded that such effects, it occurring at all, must be limited in duration and that the data examined is not sufficiently sensitive to detect them.

vi. The result with Midhirst's plant suggests that there may be a simple method to effectively maximise processing rate at all times by the use of two sets of high-heating equipment.

7.4 COMPUTER-BASED MANAGEMENT INFORMATION SYSTEM

The studies of processing rate and energy consumption already discussed have shown that it is possible to use factory data to make predictions and to perform analyses of past performance. Obviously such information is of most use when applied regularly and frequently by a production manager in his task of planning and control.

The prime requisite of such information for the production manager is immediacy. He must be able to be in a position to know what has happened and to take action to correct it. Information on the past month's performance while better than an annual review, is still too remote. If a manager can see that a problem has occurred the previous day he can search out the cause and find it easily while it is still fresh in people's minds. The evidence may be still in existence. Action taken with such immediacy can start paying off immediately.

The best way of providing such immediate information is through the use of a computer. This saves time in tedious calculations and can be programmed to show up exceptional behaviour. In order to demonstrate that such information could be provided on a regular and frequent basis, computer programmes were written for Tui Dairy Company.

These programs were designed to assist principally in the control of energy consumption. As has been shown, energy consumption comprises the largest single item of cost in a spray-drying plant. However, there are additional reasons for the study of energy. Besides being the largest single cost in the factory, it reflects behaviour in other areas. For example,[1] if it was noticed that the previous day's energy consumption on plant cleaning was excessively high it could mean that the plant was operated poorly, causing additional burn on of product to normal. Thus energy information pointed to a staff problem and a resulting loss of material as well as the excessive use of energy itself. Obviously such occurrences are not evident from the energy data without the action of the production manager but the energy information allows him to take action in the control of such problems.

Two suites of programs were written. The first set enabled the relatively automatic creation of two types of report of immediate and obvious application. The second suite of programs enabled a more investigative approach to be taken, involving more effort on the part of the person operating the programs, and the manipulation of less specialised information.

Energy report programs

These programs were written to produce two reports. The first report was intended to be produced daily to show energy consumption relative to expected values, and the

1. See also the sub-section entitled "Variability in the data" in the section on energy.

second was a ten-daily report calculating a number of ratios in line with figures currently produced by the production manager for use by the company secretary.

The programs were written so that a person with no previous experience with computers could run them. This was done by using a menu system so that the person was presented with a small number of choices at each step and errors could be detected and corrected easily.

The requirements in terms of data were asked for item by item by the computer and the operator was then able to generate the required reports. Examples of the two reports are given in appendices 3 and 4.

Daily report

Daily consumption of electricity, oil in the boilers, oil in the air heater and total oil, as well as time utilisation are reported. The consumption of each of these is given per kilogram of product and per litre of raw milk. A graph of consumption of the variable versus raw milk volume for the previous ten days, showing the regression line, is given. The latest point is marked by an "L". The percentage difference of the latest point from the value predicted by the regression line is also given.

Ten daily report

The ten daily report can in fact be used to summarise data from any period specified from one day to the year's production. It summarises a number of variables and ratios by product specification run, and also gives the totals for the period specified. The items reported include:

- product manufacture in kg of product
- milk used for each specification run in litres
- a summary of total start-up, shut down, processing and running time
- milk processing rate in litre/hour
- oil consumptions per hour of processing time, per hour of running time, per kilogram of product, per litre of milk
- electricity consumptions as per the oil consumption ratios
- a summary of total electricity and oil costs.

- yields of product in terms of kg of product per kilogram of solids and kg of product per litre of milk in.

This enables comparisons to be made between specification runs of the various product specifications.

Manipulative programs

The manipulative programs were written to enable the production manager to perform investigations into trends in the energy data by providing a quick and relatively simple method of dealing with the large volumes of data involved.

The data for the energy management programs is stored in a large array in the computer. The manipulative programs enable operations to be performed on data in a similar array.

The commands cause operations to be performed on columns of data between specified rows, thus enabling selection of individual product specification runs to be made. (Rows correspond to days in the year while variables correspond to columns.)

The range of commands includes the following

- add
- subtract
- multiply
- divide
- log (base 10)
- log (natural)
- raise to any specified exponent
- set data in a column from the keyboard
- generate data (sequential integers or a constant) into a column
- move sections of data from one column to another
- print the specified columns
- copy data from the energy program's file
- plot a graph of any two columns and optionally include a specified regression line
- perform simple linear regression or

multiple regression

- plot a Tukey median smoothing plot or a cumulative sum plot.

An example of the power and ease of use of such a suite of programs would be if one column of 250 items had to be divided by another and the result plotted against a third column; the commands would be:

```
  DIVIDE COLUMN,7 BY COLUMN,9 AND PUT THE RESULT IN
         COLUMN,10. THE DATA IS BETWEEN ROWS,27 AND,277
PLOT COLUMN,10 AGAINST COLUMN,8 FROM ROW,27 TO, 277
```

This could be shortened to

```
DIV,7,9,10,27,277
PLO,10,8,27,277
```

Thus it can be seen that large volumes of information can be handled both quickly and easily.

7.5 CONCLUSION

The key feature of short production runs is that they are short in time in a particular plant. Thus the relationships between energy and time and processing rate and time have been examined.

The manner of occurrence of energy consumption and the rate of processing were modelled in order to enable managers to make predictions about costs at various running times and thus control them and to examine the effects of changes of specification. It was concluded that costs are affected greatly by running time but that specification changes (as opposed to specifications themselves) cannot be considered to cause appreciable effects.

The control of costs by a production manager requires information that is timely, concise and accurate. A method of providing such information was discussed. This method should result in economies in general but will also show the costs of short production runs of all types and enable their better control in the spray-drying factory.

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CHAPTER EIGHT

THE EFFECTS OF TECHNOLOGICAL CHANGE ON SHORT PRODUCTION RUNS

8.1 INTRODUCTION

The occurrence of short production runs in spray-drying plants has been examined on the basis of the present system. Measures to deal with short production runs have been discussed. It is intended that this study will prove useful both at present and for some time in the future. Nevertheless, no system remains unchanged through time and the importance and occurrence of short runs may fall or rise as technological changes occur.

Although it is likely that the multiple-effect, thermo-compression falling-film evaporator will remain the main contributor to efficient milk drying for many years(1) and the spray-dryer in one form or another will remain the other major process component, there are a number of less major changes that are likely to occur which may affect short production runs. These changes will be as a result of the continued effort to increase efficiency through technical progress and as a result of increasing external pressures such as the rise in energy cost. Thus the effects on short production runs of the change in size of plants, the introduction of new technology such as mechanical vapour recompression, reverse osmosis and computers will be examined here.

8.2 MECHANICAL VAPOUR RECOMPRESSION

A modern approach to operating economy in dairy evaporators is the use of Mechanical Vapour Recompression or MVR. The use of MVR, which involves the mechanical compression of vapour evolved for re-use as the heating medium, eliminates rejection into cooling water of the latent heat of vapourisation of the steam supplied to a multiple effect unit and is therefore very efficient. It is not a new technology in other fields but has not been used until recently in the dairy field because of fears about the reliability of compressors and its relatively high capital cost.

As well as saving energy the use of MVR has the following advantages:

i. If an evaporator has to be run at less than full capacity, for example in the drying of WMP, the energy consumption of a conventional plant is reduced at best, linearly with capacity. That of MVR plants is reduced nearly as the square of capacity. Thus an MVR plant would be of great advantage in a plant that was required to produce a variety of product specifications.

ii. An MVR plant operates at a single boiling temperature, which for most dairy applications could be 68°C. This would reduce deposits due to protein denaturation by reducing the viscosity of the concentrate and thus increase run length before cleaning, the higher temperature (than some effects) also reducing the risk of bacteriological growth.

More recently, an improvement in the performance of compressors has permitted the use of two or three effects within the compression cycle, thus enabling a reduction in compressor size and consequently cost, although increasing the operating temperature range (2).

8.3 REVERSE OSMOSIS

The process of Reverse Osmosis, RO, involves the removal of water from milk by use of a membrane, permeable only to water and other small molecules. It has the advantage of consuming far less energy than evaporation, and would enable the removal of up to the first 50% of milk's water content. The potential uses for this process of concern here are on-farm concentration to reduce transport, refrigeration and storage costs or factory concentration of whole or skim milk, thereby reducing the evaporation load and costs. (3)

If RO was used for on-farm concentration, it would permit a greater volume of milk to be stored before collection and thus less frequent processing at the ends of the season, thereby increasing run length. If RO was used in the factory energy costs for cleaning would be reduced as well as operating costs, thus reducing a major component of the cost of short runs.

8.4 ENERGY DEVELOPMENTS

Because of the increasing real price of energy and the relatively low temperatures required in many processes in spray-drying plants, it is likely that energy conservation developments will occur rapidly. However, not all these will necessarily cause any changes in the relative economics of short production runs.

One development which could preclude electrical supply failures in plants is the adoption of co-generation systems. The New Zealand Co-operative Dairy Company has for many years generated a large proportion of its electricity requirements from coal fired steam turbines. A new cheap source of energy in the form of natural gas has renewed interest in the applicability of co-generation to spray-drying plants.

Vickers (4) found that the most attractive proposition involved the burning of gas in a turbine, thereby driving an alternator. The spent gas was then to be used either directly or indirectly in the heating of air for the spray dryer.

If such a development were to be undertaken in a factory with several plants, a careful analysis of costs should be made in view of the fact that in such a factory, the present system allows the use of fewer plants to increase run length when milk supply is reduced. This method of operation results in a saving in start-up, shut-down and cleaning costs. A co-generation system sized to supply all plants may not run efficiently when supplying fewer than the maximum number of plants.

The introduction of wood chip burning plants at Hikurangi and Reporoa has significantly reduced energy costs in these spray-drying plants. Estimates of the reduction in Hikurangi's fuel costs vary from 70% to 80% (5). Thus such factories are in an advantageous position in the manufacture of energy intensive products and product specification changes involving plant cleaning would not be so costly.

8.5 COMPUTERS AND CONTROL

A great deal has been learnt about control of evaporation and spray dryers by both digital computers and discrete controllers of various types in recent studies at N.Z.D.R.I. (6). This information will enable improvements in the control of plants to meet the increasingly complex specifications and thus assist in the manufacture of short production runs.

The introduction of computer-based sequence controllers promise assistance in the efficiency with which start-up, shut-down, and cleaning can be carried out. (7). This should help in the reduction of costs of both short daily running time and those specification changes involving a plant clean.

The advent of the Dairy Board's computer network should assist in reducing the administrative costs of short production runs. Also, by permitting a quicker turn around of information and providing earlier and more accurate information, the allocation of orders could be improved and some short runs avoided. (8)

8.6 EVAPORATOR CLEANING

It has been shown that a major factor in all types of short production run is the cost of start-up, shut-down and clean of the plant, and particularly the cleaning of the evaporator. Thus any measures to reduce the cost of cleaning the evaporator are important from the point of view of short production runs.

Currently in New Zealand, the cleaning practice for evaporators involves the circulation of cleaning solutions while maintaining vacuum. A method of CIP of falling film evaporators is now available which avoids maintaining vacuum. It involves the installation of fixed spray nozzles in the vapour lines, tube chests and separator sections.

Advantages of this system include improved cleanliness and slightly reduced cleaning time, and of most importance, at least 50% reduction in energy consumption as a result of cleaning the plant in a shut-down condition. (9)

The main disadvantage is the additional capital cost of such a system but it has been estimated that energy and other cost savings whilst cleaning in this manner will offset the cost of the system within three years even if it is installed after the commissioning of the evaporator.(10)

8.7 CHANGES IN THE SIZE OF SPRAY DRYING PLANTS

Many of the changes initiated in the New Zealand Dairy Industry in the past 30 years have been as a result of the change to tanker collection of whole milk. It has resulted in the need to process skim milk and in the ability to transport milk over greater distances, thereby allowing the amalgamation of co-operatives to achieve processing economies of scale. The increase in size of factories has permitted the use of plants of greater capacity, thus resulting in a trend towards shorter production runs. An order for 18 tonnes of product may take only four hours to produce on the biggest plant in the industry whereas it would take more than 18 hours on at least one quarter of the plants.

Since 1963 there has been a steady rise in the average size of evaporator and dryer in the New Zealand Dairy Industry. Average dryer capacity has risen from 827 kg/hr in 1963 to 1858 kg/hr in 1976.[1] Since 1972 there have been 18 dryers installed each with a capacity of greater than 2700 kg/hr. As would be expected, the pattern of growth of evaporators closely follows that of dryers. (11)

The economies permitted by this increase in plant size as a result of tanker collection of milk arise from a number of factors. These include economies from the centralisation of activities as well as the economies of scale in the plant itself.

Centralisation of Activities

This concept involves the collection of the total range of dairy processing plants on the one site, for instance including butter, AMF, powder, casein, caseinate, cheese and whey processing. The advantages of this arrangement include:

i. The facility for maximum product diversification, enabling the company to gain the greatest return for its milk.

ii. Reduced labour costs due to economical use of greater mechanisation in processing and storage.

iii. Introduction of better instrumentation and control equipment in the plant and laboratory without duplication.

iv. Larger companies can afford better technical staff.

v. Processing and service equipment are not duplicated and are better utilised.

vi. Supervision of milk collection, storage, transportation and handling of consumable goods is simplified.

vii. Maintenance is reduced because there are fewer buildings and items of equipment. There are greater possibilities of training.

viii. Whey processing is made economic because of the large quantities available at one site.

ix. Company administration costs are reduced and communication problems are reduced. (12)

Because there is the need for full diversification, all product arriving at the plant must be able to be handled in any individual process. Thus the spray-drying plant must have the capacity to handle milk from the equivalent of a number of smaller plants that the complex replaced, and to achieve the maximum economies of scale, as described below, should be a large single plant.

Economies of scale in spray-drying plants

In general there are a number of reasons for economies of scale. These include indivisibilities, the economies of increased dimensions, the economies of specialisation, the economies of massed resources, superior techniques of organisation of production, the learning effect, and economies through control of markets. (13)

In spray-drying plants, the economies of scale were examined by O'Dwyer (14). He found that both labour and capital costs declined with size of plant in the range studied from 0.7 tonne/hr to 3.3 tonne/hr. In particular it was noted that labour costs in terms of operators were invariant with the size of plant.

A commonly used scale factor for capital in process industries is the "6/10 Rule". The capital cost of a larger plant is found from the capital cost of the smaller plant by multiplying by a ratio of the large to the small plant capacity, raised to the power of 0.6. In the case of O'Dwyer's data the power appeared to be approximately 0.8 for both capital and operating cost, thus although economies are not as great as in general, they are still significant.

In a further study, O'Dwyer (15) suggested that the economies of size should be looked at from a broader point of view and that it would be found that the limits on size of plant were set by the balance between increases in transport costs in milk collection and the scale economies gained.

It has also been noted in this study[1] that a number of plants suffered water shortages. This may be a further limit to continued expansion in the case of New Zealand spray-drying plants.

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1. Written Questionnaire, Question 6.

It appears likely that many of the smaller, older plants will be replaced by larger plants because of the economies above. Already there has been a "searching study" of dairy industry organisation in the South Auckland, Waikato and Bay of Plenty areas, with the optimum re-organisation path appearing to be the change to six major companies instead of the eleven existing at present. (16) It is possible that there will be further increases in the size of individual plants if collection costs are reduced by such a change as the introduction of Reverse Osmosis plants on farms.

Thus it can be expected that the average length of runs in terms of plant running time will decrease further in future as a result of both increases in technical efficiency and organisational changes.

8.8 CONCLUSION

Changes in technology in spray-drying plants appear to be likely to be of a developmental nature rather than resulting in a complete radical change. Nevertheless, the occurrence of short runs appears likely to be affected in a number of ways.

The use of improved control methods along with mechanical vapour recompression may lead to the ability to make longer runs un-interrupted by plant cleaning. The concentration of milk by Reverse Osmosis could enable the storage of greater volumes before processing thus assisting in this regard.

The consumption of energy in spray-drying plants will undoubtedly receive greater and greater attention. In so doing care should be taken that the flexibility of spray-drying plants should not be compromised. Those plants with access to low cost energy will be in a strong position to be able to change specification as required and will enjoy lower costs of short daily running time. The present cost of many short production runs could be reduced by improved methods of evaporator cleaning.

The trend to larger and larger plants has been shown to be strongly motivated, thus even if orders remain of similar tonnages, run length in terms of hours will be reduced in future larger plants.

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CHAPTER NINE

SUMMARY AND CONCLUSIONS

In all types of production, from unique, intermittent production to pure continuous production, the process of production requires the co-ordination of men, materials and machinery to reach the desired objective. A study of the problems and solutions to short production runs in industry in general can thus lead to the establishment of hypotheses with regard to the industry in question, the Milk Spray-Drying Industry in New Zealand.[1]

The spray-drying industry appeared to be a hybrid class of industry, containing some of the features of flow process production and some features of batch production. In these types of industry, it was found that short run problems involved the high set-up cost, learning behaviour and the interaction between plant and the processed material.[2]

Thus the questions were posed as to whether set-up cost is important, if learning behaviour occurred, and whether the interaction between plant and material had an important effect in spray-drying plants and if any or all of these proved to be the case, if the measures used in other industries to deal with such situations could be applied to spray-drying plants.

In order to characterise short production runs in spray-drying plants a survey was undertaken of the spray-drying industry. It was found that short production runs in the spray-drying industry could be classified into those caused by interruptions to runs, those caused by deliberate specification changes and those resulting

1. Section 2.1
2. Sections 2.4, 2.5, 2.6

from the seasonal pattern of milk production.[1]

Short production runs caused by interruptions to runs were found to average 51 per plant per year. Their reasons were many and what was a major problem in one plant was not even considered in another. Preventive maintenance programmes may be of some assistance in some cases and greater reliability in electricity supplies would also be advantageous in many cases. Because of the diversity and highly variable frequency of the causes of failures, no one measure would be generally applicable except in that improved management information as to the cost of such interruptions would increase awareness of the importance and enable assessment of measures to deal with such short runs.[2]

Short production runs caused by specification changes were largely as a result of market requirements. Managers considered their effects to be in the time to physically change the plant, in some cases to wash the plant, in resulting quality problems, and in reduced processing rate as a result of unsettling staff. Providing there was adequate time available the physical set-up cost was not great.[3]

Processing in spray-drying factories in general does closely follow the seasonal pattern of milk production although some companies are able to modify this by diverting milk from other collection areas. Some efforts are made to increase running times at the ends of the season by holding milk, however no firm economic criterion is used to determine when a production run is not economic and thus when the plant should shut down.[4]

Production managers saw a number of advantages to the factory in a smooth milk supply in addition to the obvious ones of improved capacity utilisation.[5] It was determined to assess the advantages of such a smoothed milk supply in economic terms because it is only on such a basis that a change will be made.

1. Chapter 3
2. Section 4.2
3. Section 4.3
4. Section 4.4
5. Interview Questionnaire, Question 17i.

It was found that although managers had an appreciation in general terms of the cost of a plant start-up and shut-down, they had no detailed information. Thus they had no detailed appreciation of the effect of production run length on the cost of product. Production managers were not called upon to assess production costs.

Additionally it was found that production managers had very little formalised management information available to them. They had no means available to determine the effects of any of a variety of factors on production costs.[1]

A need was perceived for both specific information on cost relationships in the spray-drying factory and on-going management information system to provide the necessary information to control the plant to meet objectives.

Apart from the interruptions to production run, short runs in spray-drying plants were brought about by external causes. The necessity for the seasonal pattern of production is a result of efforts to minimise the cost of milk production by providing minimal and cheap winter feed and no housing for stock. The peak has recently been further sharpened by research suggesting a shorter milking period, condensed calving period, and pronounced peak production are advantageous to the individual farmer.[2]

A study was made of the relationship between capacity utilisation and cost of powder production by means of data from dairy company annual reports. Although no numerical relationship could be found in general there was a clear reduction in cost per tonne with increased utilisation in some individual companies.[3]

As a means of estimating the cost of a smoothed milk flow to spray-drying factories a comparison was made between costs on factory supply and town milk supply farms. It was found that in order to provide a similar income to town milk farms to that presently provided to them, payout from the dairy factory would have to be increased to 1.7

1. Interview Questionnaire, Question 2
2. Sections 5.2, 5.4
3. Section 6.5

times its present level.[1]

In estimating the gains to be made by smoothed milk flow to factories several situations were considered. If an existing plant were replaced by one with a smaller hourly capacity and smoothed milk flow, still processing the same volume of milk in a season, savings were in the order of 5-9% of costs of milk powder manufacture. If an existing factory were supplied with a greater volume of milk so that it was fully utilised the gain was about 17% reduction in powder manufacturing costs. If this milk was supplied by closing down an old factory and the savings from not needing to replace such a factory were included, then cost of powder manufacture was reduced by about 37%. This last case would increase payout by about 1.35 times.[2]

Thus it can be seen that even in the best case for smoothed milk supply the 1.7 times payout is not reached and thus a smoothing in milk supply would need to be at a lower cost to be viable on economic grounds alone.

The market for milk powders has changed over the past 30 years with the entry of Britain to the E.E.C. There has been a great diversification in specifications in hand with product destinations as new markets have been found. The total volume of powder and especially fat-bearing powder has greatly increased and efforts have been made to increase the value of powder by suiting it to individual market needs and also by so doing, to differentiate it from the large volumes of cheap, dumped product on the International Market. Thus the number of product specifications has greatly increased.[3]

It has already been shown that set-up cost is not a major problem in short runs in spray-drying plants. Another factor that was considered to be of importance in other types of industry and was suggested by responses to the questionnaires was learning behaviour. It was expected that operators would improve performance in quality of conformity

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1. Section 5.3
2. Section 6.6
3. Section 5.5

and consequent improved processing rate as a run progressed.

A number of process variables under the control of operators were studied in data from three factories. There proved to be some appreciable improvement with time in only 5 of 27 cases and in two of these cases, it was only evident in the first 6 to 8 hours of the run. Thus it was concluded that this data did not support the hypothesis that learning behaviour, in terms of operator controlled variables, occurred after a specification change.[1]

The relationship between quality failures and the day of the run was also studied to determine if there was a greater number of failures immediately following a specification change. It was found that there was no appreciable difference between the number of failures on any day of a run.[2]

A study of processing rates also confirmed that there was no appreciable learning behaviour in terms of improved processing rate as runs progressed.[3]

The only situation where it did appear that learning behaviour was occurring was in runs near the commencement of the season. In these situations processing rate did not conform to the pattern which was evident at other parts of the season when processing rate could be related to processing time. A possible reason for such non-conformance would be learning type behaviour as operators re-familiarised themselves with the plant and start-up machinery failures occurred. However, there were also other possible explanations such as milk composition and other staff reasons.[4]

It must be concluded that learning behaviour after product specification changes has no appreciable effect on spray-drying plant costs.

A study of the production costs in spray-drying factories revealed that energy was the single largest cost representing about 25% of the total.[5] The costs of the daily start-up, shut-down and clean were also estimated,

1. Section 6.4
2. Section 6.4
3. Section 7.3
4. Section 7.3
5. Section 6.2

and it was found that energy represented about two-thirds of that cost.[1]

These factors along with the need for management information on the effect of various factors on cost that was discussed above led to a detailed study of the relationship between energy consumption and the volume of milk processed in a day in a particular milk powder plant. It was found that energy consumption per kilogram of product did vary appreciably with daily run length. As a result methods were developed to enable the prediction of energy consumption per kilogram of product at any specified daily run length,[2] based on data that was readily available in a factory situation.

The occurrence of an interaction between plant and the material processed in a flow process plant has already been discussed. In the case of a spray-drying plant the critical effect involves the fouling of the evaporator and consequent reduction in flow rate, due to protein and other deposits. This necessitates regular cleaning of the plant. Thus the relationship between processing rate and processing time was studied,[3] using data from a practical factory situation.

It was found that a model of the form

$$\text{processing rate} = \frac{\text{constant a}}{\text{processing time}} + \text{constant b}$$

best represented the situation in a spray-drying plant. A consequence of this model is that at a short daily running time, processing rate is higher than a long daily running time but the rate of processing approaches a constant low level asymptotically, thus changes in processing rate at long running times are not appreciable.

It was found that this model did not fit data from Taranaki Dairy Company's Midhirst plant where processing rate was apparently independent of running time. It was suggested that this was due to the frequent and regular

1. Section 6.3
2. Section 7.2
3. Section 7.3

cleaning of the high heater which was practised at Midhirst.

Thus it appears that the fall off in processing rate may be reversible and thus may not be of critical importance in determining plant running time between cleaning.

In order to control the costs in a spray-drying plant, the production manager needs information which will enable him to compare the plant's performance with objectives and thereby take the appropriate control action. Such information must be timely, concise and in a readily usable form.

The fact that this information does not presently exist was one of the major findings of the Short Production Run Questionnaires. The manager needs such information to assess on economic grounds when the plant should be closed at the end of the season, to assess the viability of alternative manufacturing strategies, to determine what preventive maintenance measures are suitable, to help in the recovery of costs of a power failure from electrical distribution authorities, to know when negotiating a price what true costs are, and as stated above, to control the plant to meet cost objectives.

A computer based management information system centred on the control of energy was written to demonstrate how such a management tool could be used. Energy is controlled because it is not only the single most important factor in the cost structure of a spray-drying plant but it also reflects other costs such as inefficient use of labour and product and raw material wastage.[1]

The programs written permit production of daily reports on energy consumption relative to a predicted value as well as summaries of energy consumption for any specified period. Additionally, programs were written to enable investigative manipulation of the data to be performed in order to answer "what if..." questions.

1. Section 7.4

By using such tools a production manager would be in a stronger position to control costs in general and those of short production runs in particular.

In conclusion it can be said that short production runs due to specification changes are not so costly as might have been expected by comparison with the situation in other industries. It appears that operation of the flow process plant in the daily cycle of start-up, process, clean and shut-down, results in the operators gaining great skill in the control of the plant to meet whatever specifications are set. The possible permutations of problems to the operator are limited by the nature of the plant itself. Thus there is no major set-up cost and no sub-optimal behaviour as a result of learning effects due to specification change.

The situation where specification changes may be costly is where capacity is stretched to the limit. Then the down time required to set the plant up for the new specification may be costly in terms of diverted milk and its possible use in a less valuable product. Under the present system there is more than adequate capacity available.

Short production runs of all types in milk spray-drying plants of the New Zealand Dairy Industry have been investigated and some measures proposed to deal with them. The studies were based on real factory information that was freely available in the factories studied. Thus the results are readily applicable to the spray-drying factory situation throughout the Industry. It is hoped that implementation of the proposed measures by production management and the greater awareness of the features and effects of short production runs created by this investigation will assist in improving productivity in this industry.

APPENDIX 1

The spray-drying plant

The spray-drying process as used in the manufacture of milk powder involves the removal of water from liquid milk to form a product of low moisture content which is thereby preserved from biological and chemical degradation. There are two major items of equipment involved in this process along with a number of less major but important components. The main items are the evaporator, which reduces moisture until the product is approximately 50% total solids, 50% water, and the dryer, which removes most of the remaining moisture to a moisture level of about 3-5%.

The major process steps are:

i. Standardisation. Constituents are brought to a constant level, particularly by the use of a separator to control fat level.

ii. Preheating. Bacteria are killed and some protein is denatured in order to give some required end use properties to the powder.

iii. Evaporation. Vacuum evaporation removes water to form concentrate at about 50% total solids.

iv. Drying. Hot air is used to dry droplets of milk to about 6% moisture.

v. Secondary drying. More gentle hot air drying reduces moisture to a final level of 2.5-3.0%.

vi. Powder handling. Powder is transported, sifted and stored or carried to the packing off point.

vii. Packaging. Powder is packed in multi-wall bags, bulk bins or cans.

The major plant items are shown in Figure A1.1.

Almost all evaporators now in use in New Zealand Dairy Industry are of the multiple effect falling film type and the majority of spray driers are of the conical base type, with some of these having the tall form. Atomisation is by rotary atomiser or pressure nozzle. Secondary drying by means of fluid beds is practised in a large proportion of plants.

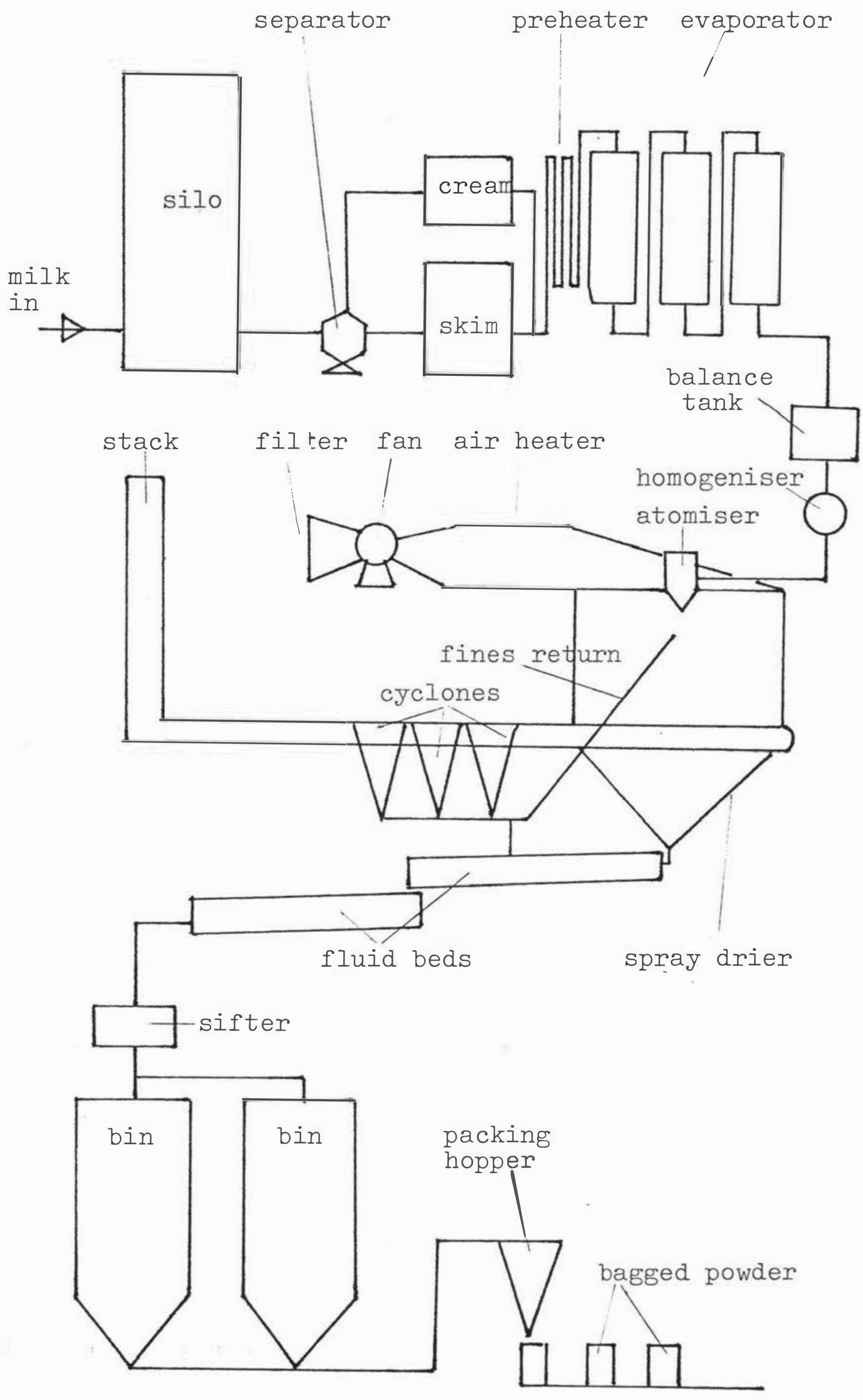


Figure A1.1 Diagram of spray-drying process

APPENDIX 2: Questionnaire letters and copy of written questionnaire booklet.

NEW ZEALAND DAIRY RESEARCH INSTITUTE

PRIVATE BAG ■ PALMERSTON NORTH ■ NEW ZEALAND

Telegrams: DAISEARCH
Telex: Daisearch NZ3960
Telephone: (63) 74 129

Please Quote:

2 April 1980

Dear Sir

SHORT PRODUCTION RUNS OF MILKPOWDER

One of the problems facing most milkpowder drying companies is short production runs. The costs of start up and shut down procedures in terms of energy costs and product problems can lead to very high costs per tonne of output when only a small volume is being produced in a single run.

Robert Kay is doing a Doctorate at Massey Universite on this topic and is supported financially by the Dairy Research Institute. The full title of the work is "An Investigation into the Costs and Quality of Spray Dried Dairy Products due to Short Production Runs, and Possible Improvements." We are all well aware that there are difficulties associated with short production runs but few companies can assess with accuracy what those costs are and so are unable to use such information in determining the economics of making different specifications. Perhaps just as importantly we have no picture as to how these matters look over the total industry and some accurate data could well change the industry's manufacturing and even marketing strategy.

Attached to this letter is a questionnaire which of necessity is somewhat lengthy. (In tests, it has taken about half an hour to fill in.) Could you please answer it as accurately as possible and send Robert the completed questionnaire no later than 25 April. He may also be contacting you regarding a personal visit to follow up on some of the information you provide.

The information that you give will, of course, be strictly confidential to your company and we hope to be able to return you some data of use to you in the near future, including general data covering the whole of the industry, which will enable you to compare yourself with industry averages. If you have any questions about the questionnaire or research, please do not hestiate to contact me or Robert.

Yours faithfully

W.B. Sanderson
Assistant Director

Massey University

PALMERSTON NORTH, NEW ZEALAND

TELEPHONES, 69-099, 69-089.

In reply please quote:

Department of Industrial
Management and Engineering
Phone Extension 834

SHORT PRODUCTION RUN QUESTIONNAIRE

A few weeks ago I mailed you a questionnaire concerning short production runs in spray drying plants. As there are such a small number of spray-drying factories in New Zealand, it is vitally important that I receive results from every plant in the industry.

At the time of writing this letter, I have not received a completed questionnaire from your company. So that analysis of results can get under way, I would be most grateful if you would return the completed questionnaire in the very near future.

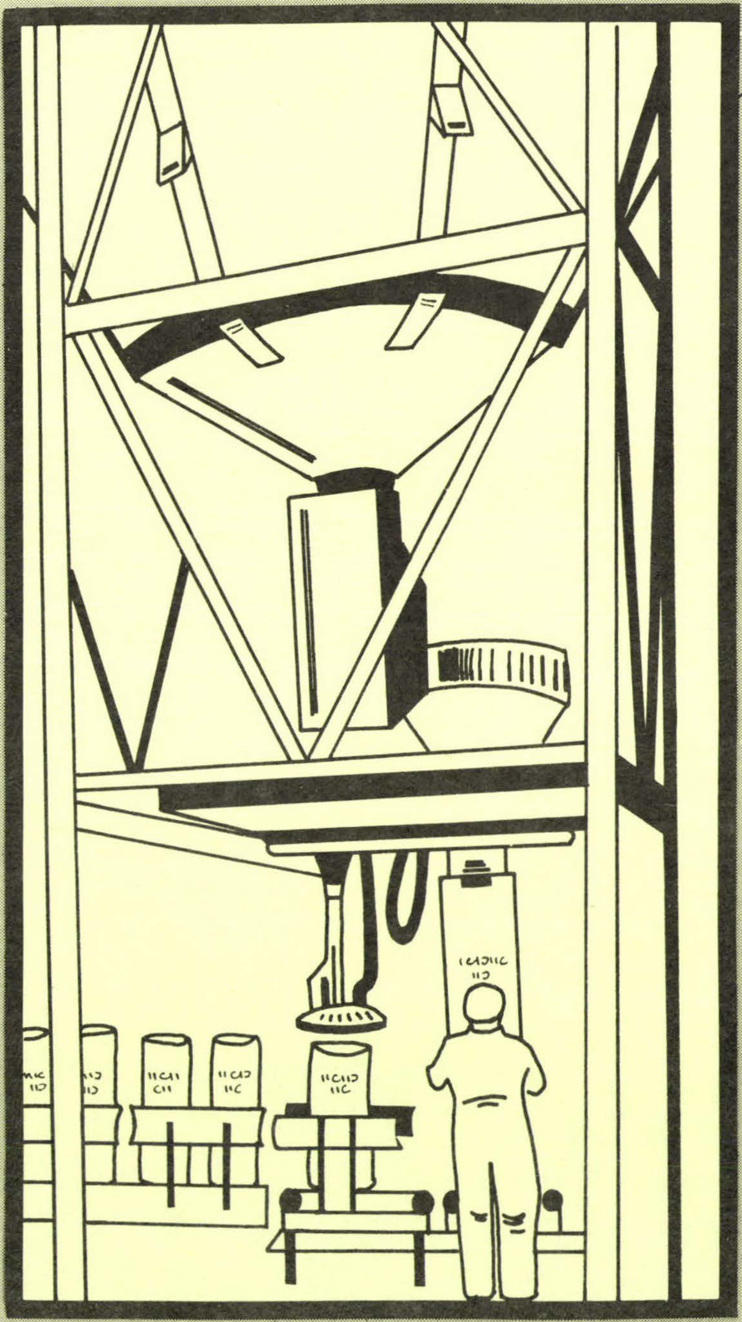
I will ring you up in a few days time to check that you have not met with difficulties in filling in the questionnaire. Also please find enclosed an extra copy of the questionnaire in case you have misplaced the first one.

Thankyou for your help.

Yours faithfully,

Robert Kay
Research Student.

SHORT PRODUCTION RUN QUESTIONNAIRE



Massey University

SHORT PRODUCTION RUN QUESTIONNAIRE

Instructions:

Please read the definitions below, especially noting the difference between "Production run" and "Daily running time".

In filling out the questionnaire I don't want you to spend hours searching for and calculating exact figures. If such figures are readily available please use them, but if not, try to make a good estimate. Thus please tick the appropriate "Estimate/Production Record" box beside the question.

Please write the required information in the units suggested in the question, or if you want to use other units, please write what they are beside the answer.

Definitions:

PRODUCTION RUN. Length of time in hours spent on manufacture of one product spec., excluding time spent on start-up, shut-down and cleaning, without changing to another product specification.

START-UP. Length of time from when plant is cold until it is manufacturing product (excluding cleaning).

SHUT-DOWN. Length of time from when plant finishes manufacturing product or being washed to when there are no further energy inputs to it.

WASHING. Process of removal of some products of manufacture which would otherwise prove deterimental to the performance of the plant by means of circulating a non-milk solution.

DAILY RUNNING TIME. Total length of time spent on manufacture, excluding start-up, shut-down and cleaning time during one calendar day.

1. Please describe your plant(s) under the following headings:

Plant	Evaporator type	Drier type	Actual Drier Throughput in Kg SSMP per hour
1			
2			
3			

2. What is your definition of a short production run?

3. Are there any particular product specs that involve short production runs? Please specify and note why.

Specification	Reasons for this product being produced in short runs

4. Are there any product specs that are particularly difficult to produce a short run of? Please specify and note why.

Specification	Reasons for difficulty in producing short run

5. Below are listed some possible causes of short production runs.
   I. Add any causes not listed
   II. Note beside each how many short runs are caused by it per year.

(Please tick)

Estimate	
Production Record	

	i.	Seasonal variation in milk quality
	ii.	Seasonal variation in milk qualities and properties
	iii.	Small order allocated to factory by Dairy Board
	iv	Management decision
	v	Trials, test runs
	vi	Failure to meet product spec in earlier run
	vii	Seasonal variation in milk quantity
	viii	
	ix	
	x	

6. Below are listed some possible causes of interruptions to production runs
   I. Add any causes not listed
   II. Note beside each cause how many occurrences there are per year

Est.	
P.R.	

i.	Failure of gas supply (external)	
ii	Failure of electricity supply (external)	
iii.	Failure of fuel oil to arrive in time	
iv.	Failure in plant (mechanical)	
v.	Failure in plant (electrical)	
vi	Water shortage	
vii.	Boiler breakdown	
viii.	Late tanker causes run out of milk	
ix.		
x.		
xi.		
xii.		

7. Approximately how many production runs per annum are made of each of the following run lengths in hours? (excluding start-up, shut-down and cleaning)

Est.	
P.R.	

									days		
0-3	4-9	10-21	22-29	30-49	50-74	75-99	100-149	150-240	11-21	22-35	>35

8. Approximately how many days per year would daily running time be of the following lengths in hours? (excluding start-up, shut-down and cleaning)

Est	
P.R.	

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	>24

9. How many production runs of each spec that has been produced have been made in the last year?

Est	
P.R.	

Plant 1		Plant 2		Plant 3	
Spec	No.of runs	Spec.	No. of runs	Spec.	No. of runs

10. What is the number of product specs produced in...

Est	
P.R.	

	Plant 1			Plant 2			Plant 3		
	min.	av.	max.	min.	av.	max.	min.	av.	max.
a week									
a day									

11. Approximately what would the average daily running time be (in hours) for each of the following months? (excluding start-up, shut-down, and cleaning time)

Est	
P.R.	

	jun	jly	aug	sep	oct	nov	dec	jan	feb	mar	apr	may
Plant 1												
Plant 2												
Plant 3												

12. What is the maximum time your evaporator(s) can run between washes and on what spec.?

Est.	
P.R.	

	Spec.	time (hours)
Plant 1		
Plant 2		
Plant 3		

13. How long does it take on average to...

Est.	
P.R.	

	SSMP	SWMP	Other(please specify)
Start-up evaporator			
Start-up drier			
Shut-down drier (excluding clean)			
Shut-down evaporator (including C.I.P.)			
Wash drier (full wet wash)			
Wash fluid beds			
Wash cyclones			

14. How frequently are the following given a full wet wash?

	SSMP	SWMP	Other(please specify)
Drier			
Fluid beds			
Cyclones			

15. On which product + product spec changes do the following not need to be cleaned? (Please list, indicating specification to specification)

i. evaporator spec to spec	ii. drier spec to spec

16. Approximately how much chemical is used each time the following is washed?

Est.	
P.R.	

	caustic	nitric	sanitizer	other (please specify)
silos				
standardising vessels				
separators				
one drier				
fluid beds (one plant)				
one evaporator				
silos of one plant				
PLEASE NOTE CONCENTRATION				

17. How long in addition to normal start-up, shut-down and clean does it take to change...

Est.	
P.R.	

i. from one spec to another?

	time	change to spec
longest		
average		
shortest		

ii. from one product to another (e.g. SSMP to SWMP)

	time	change to spec
longest		
average		
shortest		

18. How many staff per shift are there on.....

	plant 1	plant 2	plant 3
supervisory			
separation			
standardisation			
evaporation			
dryer			
packing off			
(for categories below count the number in proportion to the plant's use of that resource)			
boiler			
laboratory			
caseinating and precipitation			

19. How many shifts are run of.....

	normal	at peak	at end of season
process staff			
packing staff			

20. Do you have any special arrangements for staffing, e.g. extra clean-up staff not covered by the above questions, if so, please describe?

21. What percentage of total off-specification product would you attribute to short production runs?

Thank you for your help in filling out the questionnaire. Please make any additional comments on the research or the questionnaire, below, and return it to me by 25 April in the attached envelope.

My grateful thanks,

Robert Kay
(Research Student)

APPENDIX 3

ENERGY REPORT FOR PERIOD 7 SEP TO 22 FEB

A) PRODUCT MANUFACTURE

SPEC.	KG OF PRODUCT
633	270000
801	1.20300E+06
633	1.12350E+06
823	141950
633	88500
823	94500
801	405000
633	17125
801	63000
823	527000
633	379500
823	372250
TOTAL	4.68533E+06

B) MILK RECEIVED WAS 4.38181E+07 LITRES

MILK USED FOR EACH SPEC WAS:

SPEC	MILK INTO EVAPORATOR(LITRES)
633	3.21155E+06
801	9.64844E+06
633	1.26790E+07
823	1.05621E+06
633	1.01255E+06
823	766150
801	3.12990E+06
633	255885
801	519560
823	4.04370E+06
633	4.40039E+06
823	3.17064E+06
TOTAL	4.38940E+07

C) TIME SUMMARY

TOTAL START-UP TIME WAS 168 HR;AN AVERAGE OF 1 HR/DAY
TOTAL SHUT-DOWN TIME WAS 504 HR;AN AVERAGE OF 3 HR/DAY
TOTAL PROCESSING TIME WAS 1793.39 HR;AN AVERAGE OF 10.6749 HR/DAY
TOTAL RUNNING TIME WAS 2466.59 HR;AN AVERAGE OF 14.6821 HR/DAY

D) MILK PROCESSING RATE

OVERALL AVERAGE PROCESSING RATE WAS 24433.1 LITRE/HR

PROCESSING RATES ON EACH SPEC WERE:

SPEC.	RATE(LITRE/HR)
633	27334.7
801	22275.1
633	28437.2
823	20791.5
633	27779
823	22613.6
801	21527.6
633	33982.1
801	22298.7
823	20888
633	28704.4
823	20770.6

E) OIL CONSUMPTIONS

OIL CONSUMPTIONS WERE:

TOTAL	1.71549E+06	LITRE
BOILER	1.28053E+06	LITRE
AIR HEATER	434962	LITRE

PER HOUR OF RUNNING TIME

SPEC	BOILER	AIR HEATER	TOTAL
633	550.693	168.295	718.988
801	511.895	196.093	707.988
633	567.042	189.547	756.59
823	565.359	158.084	723.443
633	578.951	173.136	752.088
823	485.004	189.167	674.172
801	486.251	180.671	666.922
633	571.206	178.317	749.523
801	493.802	184.856	678.658
823	479.522	136.003	615.525
633	494.227	147.539	641.761
823	461.55	172.241	633.791
TOTAL	519.148	176.341	695.489

PER HOUR OF PROCESSING TIME

SPEC	BOILER	AIR HEATER	TOTAL
633	869.419	265.699	1135.12
801	669.311	256.394	925.705
633	765.442	255.867	1021.31
823	743.425	207.874	951.299
633	833.086	249.136	1082.22
823	656.789	256.169	912.957
801	646.784	240.319	887.104
633	874.635	273.041	1147.68
801	663.348	248.326	911.674
823	628.142	178.155	806.297
633	765.036	228.382	993.412
823	667.154	248.968	916.122
TOTAL	714.025	242.536	956.56

F) ELECTRICITY CONSUMPTION

ELECTRICITY CONSUMPTIONS WERE:

TOTAL	1.69997E+06	KWH
FACTORY	1.69997E+06	KWH
LAB	0	KWH
MILK	0	KWH
LAUNDRY	0	KWH
GARAGE	0	KWH

PER HOUR OF RUNNING TIME

SPEC	TOTAL	FACTORY
633	986.995	986.995
801	853.88	853.88
633	935.121	935.121
823	905.236	905.236
633	1055.86	1055.86
823	1060.6	1060.6
801	913.378	913.378
633	1164.28	1164.28
801	997.554	997.554
823	928.886	928.886
633	1107.01	1107.01
823	1064.35	1064.35
TOTAL	947.906	947.906

SPEC	LAB	MILK	LAUNDRY	GARAGE
633	0	0	0	0
801	0	0	0	0
633	0	0	0	0
823	0	0	0	0
633	0	0	0	0
823	0	0	0	0
801	0	0	0	0
633	0	0	0	0
801	0	0	0	0
823	0	0	0	0
633	0	0	0	0
823	0	0	0	0
TOTAL	0	0	0	0

PER KG OF PRODUCT

SPEC	BOILER	AIR HEATER	TOTAL
633	.378326	.115619	.493944
801	.240991	.0923167	.333308
633	.303765	.101541	.405306
823	.266051	.0743924	.340444
633	.343119	.10261	.445729
823	.235471	.0918413	.327312
801	.232188	.0862716	.318459
633	.384584	.120058	.504642
801	.245333	.0918413	.337175
823	.230744	.065444	.296188
633	.309038	.0922556	.401291
823	.273582	.102095	.375678
TOTAL	.273305	.092835	.36614

PER LITRE OF MILK INTO THE EVAPORATOR

SPEC	BOILER	AIR HEATER	TOTAL
633	.0318064	9.72022E-03	.0415267
801	.0300475	.0115104	.0415579
633	.0269169	8.99763E-03	.0359146
823	.0357561	9.99801E-03	.0457542
633	.0299898	8.96849E-03	.0389583
823	.0290439	.0113281	.040372
801	.0300444	.0111633	.0412077
633	.0257381	8.03486E-03	.033773
801	.0297482	.0111363	.0408846
823	.0300719	8.52906E-03	.038601
633	.0266522	7.95634E-03	.0346083
823	.03212	.0119866	.0441066
TOTAL	.0291731	9.90937E-03	.0390825

PER KG OF PRODUCT

SPEC	TOTAL	FACTORY
633	.429489	.429489
801	.307446	.307446
633	.371102	.371102
823	.323959	.323959
633	.43487	.43487
823	.380243	.380243
801	.327891	.327891
633	.511942	.511942
801	.368937	.368937
823	.34122	.34122
633	.447181	.447181
823	.436462	.436462
TOTAL	.362828	.362828

SPEC	LAB	MILK	LAUNDRY	GARAGE
633	0	0	0	0
801	0	0	0	0
633	0	0	0	0
823	0	0	0	0
633	0	0	0	0
823	0	0	0	0
801	0	0	0	0
633	0	0	0	0
801	0	0	0	0
823	0	0	0	0
633	0	0	0	0
823	0	0	0	0
TOTAL	0	0	0	0

PER LITRE OF MILK INTO THE EVAPORATOR

SPEC	TOTAL	FACTORY
633	.0361078	.0361078
801	.0383334	.0383334
633	.0328837	.0328837
823	.0435387	.0435387
633	.0380092	.0380092
823	.0469007	.0469007
801	.0424282	.0424282
633	.0342615	.0342615
801	.0447359	.0447359
823	.0444699	.0444699
633	.0385659	.0385659
823	.051243	.051243
TOTAL	.0387289	.0387289

SPEC	LAB	MILK	LAUNDRY	GARAGE
633	0	0	0	0
801	0	0	0	0
633	0	0	0	0
823	0	0	0	0
633	0	0	0	0
823	0	0	0	0
801	0	0	0	0
633	0	0	0	0
801	0	0	0	0
823	0	0	0	0
633	0	0	0	0
823	0	0	0	0
TOTAL	0	0	0	0

G) COSTS

COST OF ELECTRICITY FOR THIS PERIOD WAS $ 424991 AT $ .25 PER KWH
COST OF OIL FOR THIS PERIOD WAS $ 4.28872E+06 AT $ .4 PER LITRE

H) YIELDS

SPEC	KG OUT/KG IN	KG OUT/LITRE MILK IN
633	.934128	.0840715
801	1.38537	.124683
633	.984567	.088611
823	1.49328	.134396
633	.97115	.0874035
823	1.37049	.123344
801	1.43775	.129397
633	.743607	.0669246
801	1.34729	.121256
823	1.44807	.130326
633	.958248	.0862424
823	1.3045	.117405
TOTAL	1.18602	.106742

APPENDIX 4

>

DAILY REPORT FOR 22 SEP
=======================

SUMMARY OF RESULTS
==================

	PER LITRE OF MILK	PER KG OF PRODUCT
ELECTRICITY CONSUMPTION	.0326582	.450167
BOILER OIL CONSUMPTION	.0271487	.374222
BURNER OIL CONSUMPTION	.0139008	.191611
TOTAL OIL CONSUMPTION	.0410495	.565833
RUNNING TIME	5.23951E-05	7.22222E-04

@@@

REGRESSION OF TOTAL BOILER OIL CONSUMPTION(LITRE) ON THE
PREDICTOR MILK RECEIVED(LITRE)
FROM DATA FOR SPEC 633

FOR THE PAST TEN DAYS...
AVERAGE TOTAL BOILER OIL CONSUMPTION LITRE PER
LITRE DURING PROCESSING WAS... .0179508
AVERAGE CONSUMPTION ON START-UP/SHUT-DOWN WAS 2480.38 LITRE

THE REGRESSION EQUATION IS... Y = 2480.38 + .0179508 X

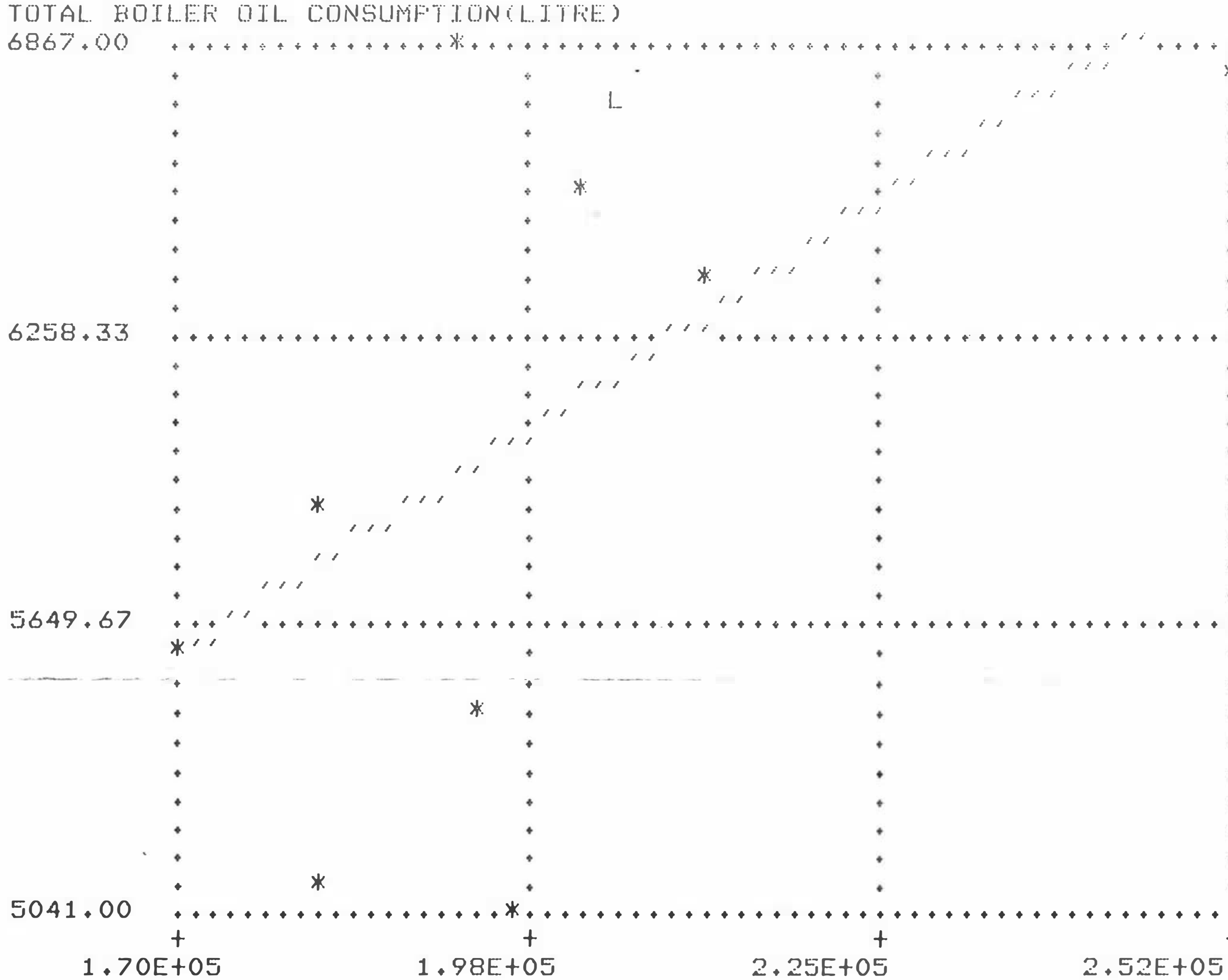
TODAY'S TOTAL BOILER OIL CONSUMPTION WAS 6736 LITRE
THE PREDICTED VALUE WAS 6144.4 LITRE
ACTUAL USE WAS GREATER THAN PREDICTED USE BY 9.62833 %

R-SQUARED = 31.8092 PERCENT

PLOT OF MILK RECEIVED(LITRE) VERSUS TOTAL BOILER OIL CONSUMPTION(LITRE

(FROM DATA FOR SPEC 633)

TOTAL BOILER OIL CONSUMPTION(LITRE)



MILK RECEIVED(LITRE)

@@@

REGRESSION OF TOTAL OIL CONSUMPTION(LITRE) ON THE
PREDICTOR MILK RECEIVED(LITRE)
FROM DATA FOR SPEC 633

FOR THE PAST TEN DAYS...
AVERAGE TOTAL OIL CONSUMPTION LITRE PER
LITRE DURING PROCESSING WAS... .0239115
AVERAGE CONSUMPTION ON START-UP/SHUT-DOWN WAS 3318.38 LITRE

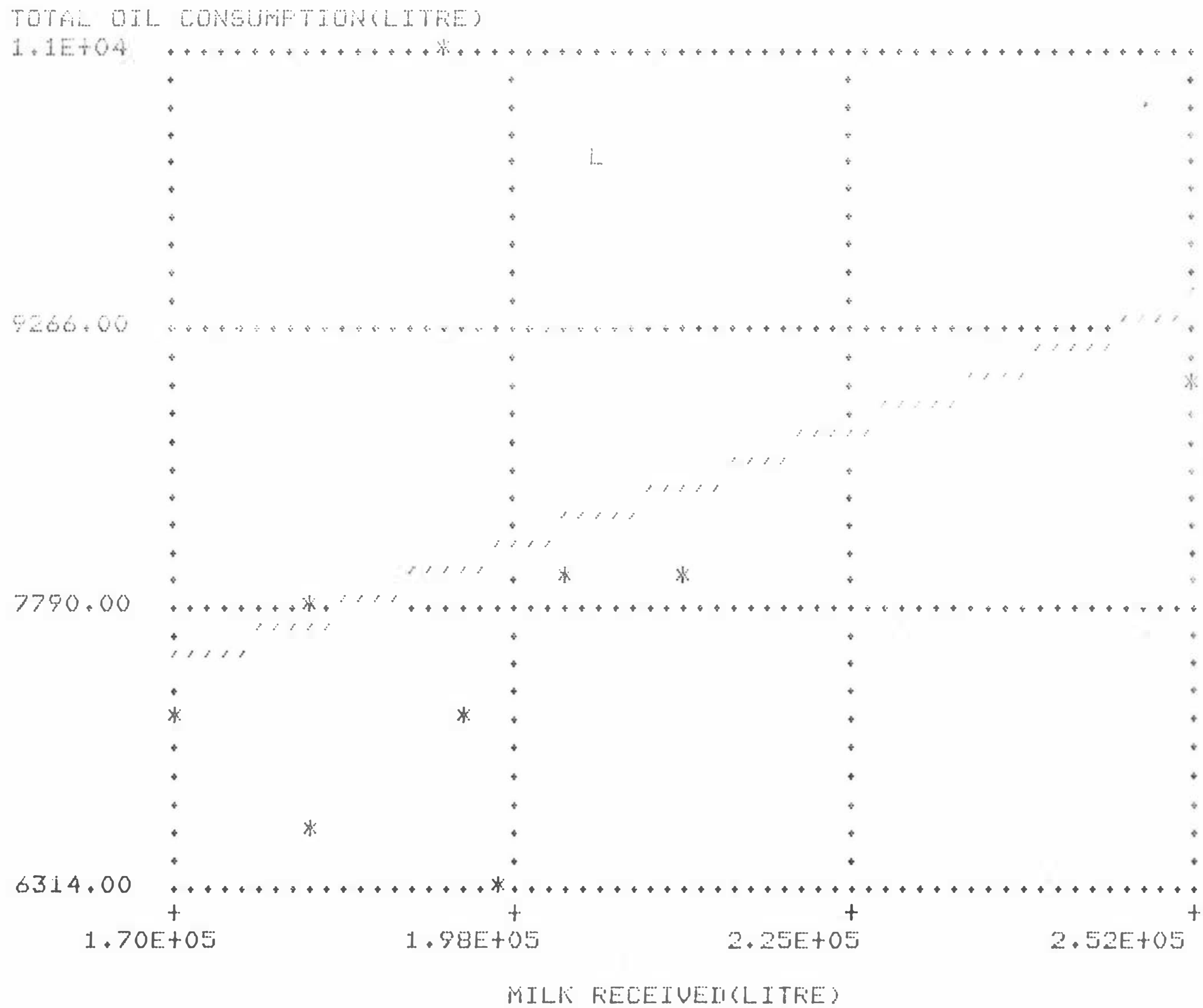
THE REGRESSION EQUATION IS... Y = 3318.38 + .0239115 X

TODAY'S TOTAL OIL CONSUMPTION WAS 10185 LITRE
THE PREDICTED VALUE WAS 8199.07 LITRE
ACTUAL USE WAS GREATER THAN PREDICTED USE BY 24.2215 %

R-SQUARED = 13.0181 PERCENT

PLOT OF MILK RECEIVED(LITRE) VERSUS TOTAL OIL CONSUMPTION(LITRE)

(FROM DATA FOR SPEC 633)



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REGRESSION OF FACTORY ELECTRICITY CONSUMPTION(KWH) ON THE
PREDICTOR MILK RECEIVED(LITRE)
FROM DATA FOR SPEC 633

FOR THE PAST TEN DAYS...
AVERAGE FACTORY ELECTRICITY CONSUMPTION KWH PER
LITRE DURING PROCESSING WAS... .011524
AVERAGE CONSUMPTION ON START-UP/SHUT-DOWN WAS 4688.5 KWH

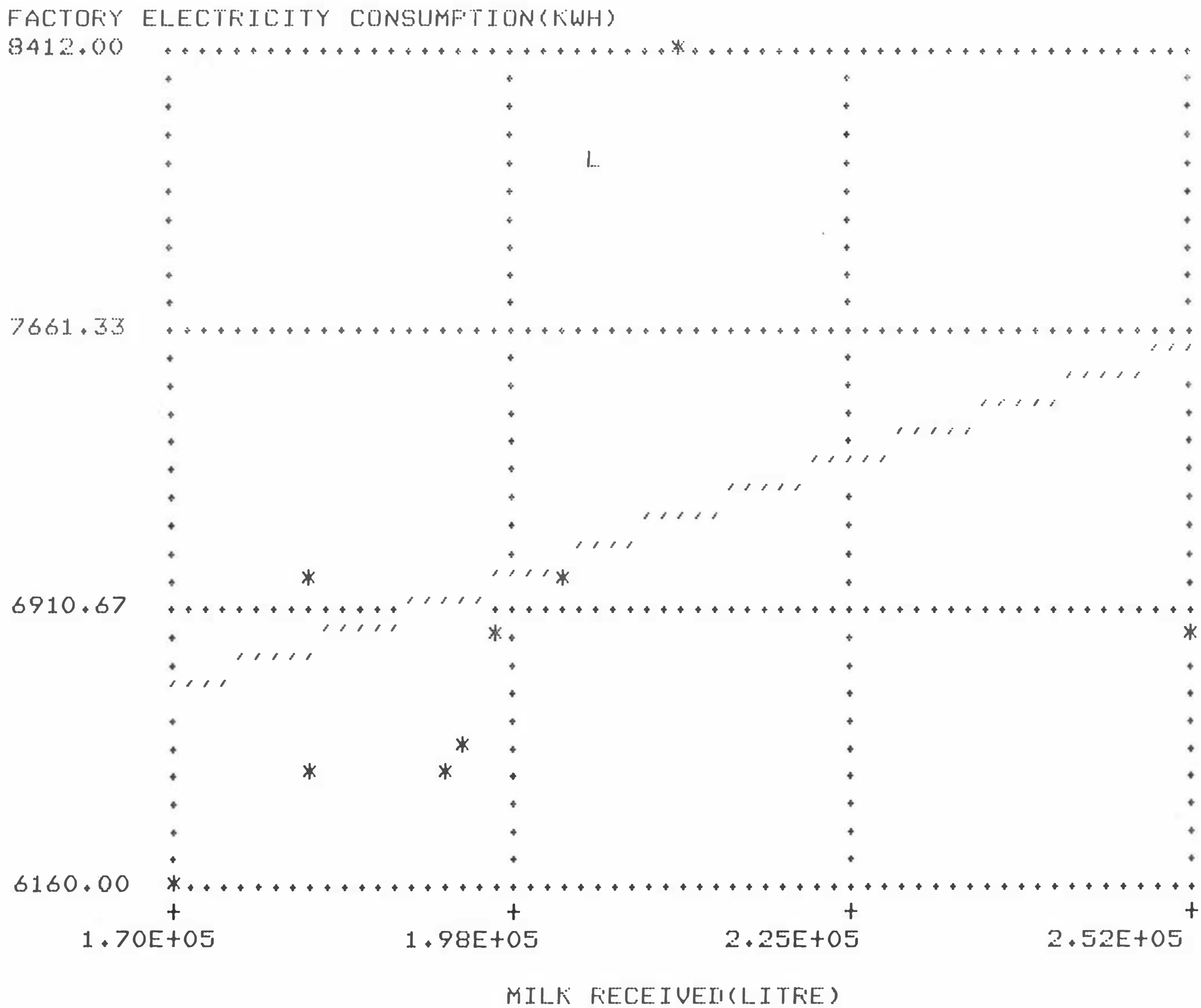
THE REGRESSION EQUATION IS... Y = 4688.5 + .011524 X

TODAY'S FACTORY ELECTRICITY CONSUMPTION WAS 8103 KWH
THE PREDICTED VALUE WAS 7040.71 KWH
ACTUAL USE WAS GREATER THAN PREDICTED USE BY 15.0878 %

R-SQUARED = 12.6149 PERCENT

PLOT OF MILK RECEIVED(LITRE) VERSUS FACTORY ELECTRICITY CONSUMPTION(KWH

(FROM DATA FOR SPEC 633)



EXPECTED NUMBER OF BAGS TOMORROW IS 727

APPENDIX 5

BACKGROUND TO THE EFFECTS OF SOME ASPECTS OF DAIRY INDUSTRY INFRASTRUCTURE ON THE SHORT RUN PROBLEM

INTRODUCTION

The spray drying plant is part of a wider production, processing and marketing system and its interactions with the other parts of the system cannot be ignored. No part of the system is independent. The spray drying plant receives inputs from both the market and the supplying farm. The plant receives both milk and a demand for the best possible return from its co-operative owners. The plant receives demand for product and directions as to what to make from the market, through the Dairy Board. The effects of these inputs on the production of short runs in the spray drying plant will be discussed here.

With regard to the producer's effect, the reasons for the existing pattern of seasonal milk production will be discussed, and a comparison will be made between the costs in this pattern of farm production with the costs of a smoothed milk flow, exemplified by the average Town Milk supplying farm. The reasons for a recent trend towards a further increase in the peak of seasonal supply will also be examined.

There have been a great many changes in the market for New Zealand's dairy products in the last 20 to 30 years. The extent of these changes and the reasons for them will be discussed. The Dairy Board's role in acting as the intermediary between producer and consumer will also be examined with regard to its effect on the production of short runs.

The Determinants of New Zealand's Pattern of Agricultural Production

Prior to 1890, dairy production in New Zealand was largely limited to the production of cheese, butter and liquid milk for local consumption. With the advent of refrigeration in 1890 there occurred rapid economic progress as the volume of dairy production increased an average of 5% per year up till 1920, when the main features of the pattern of New Zealand agriculture were formed. The contributing factors to this pattern of production were the use of the available resources and the choice of products. (1)

Use of Resources

The main characteristic distinguishing New Zealand agriculture is the low labour use per unit area. In the formative stages there was plenty of land available but relatively little labour. As would be expected by economic principles, relatively more of the abundant resource was used and less of the scarce resource, thus resulting in New Zealand having the highest output per man but the lowest output per unit area.

The advent of refrigeration and the rapid development of the meat and dairy industries started a trend toward greater intensity of labour per acre. This was given an impetus by the Liberal-Labour government in the early years of this century which legislated for closer settlement by providing leasehold and easing finance. Thus the ease of acquisition of farms by farm labourers encouraged the adoption of one man farms which became a permanent characteristic of New Zealand farming. As a result, although land use was more intensive than pre-1890, it was still more extensive than overseas.

New Zealand's progressive and enlightened education system made farmers receptive to new ideas and techniques dessiminated by research and extension agencies.

Choice of Products

In order to understand the reasons for New Zealand's seasonal pattern of milk production, an appreciation of the alternative farming possibilities and an understanding of prevailing economic forces must be gained. Wool and wheat were the chief agricultural products before 1890, but refrigeration enabled the development of meat, dairy products and the wool associated with lamb production.

New Zealand had an absolute advantage, because of its more suitable climate, in production of wheat and livestock relative to USA and Europe. However, the Northern winters disadvantaged the production of livestock there. New Zealand's mild winter climate meant that it had a comparative advantage in the production of livestock as well as an absolute advantage.

The highest net returns per acre were yielded by dairy products but satisfactory conditions for milk production required more than 40 inches (1000 mm) of rain per year with a good distribution over summer. Dairying also required flat or gentle undulating country which could be ploughed to enable the sowing of the correct grasses and clovers. Easy terrain was also required to facilitate daily transport of milk to the factories. Areas with these conditions were North and South Auckland, Bay of Plenty, Taranaki and Southland.

Meat production provided the next highest returns per acre. Rainfall was less critical but good spring growth was required to fatten lambs. Easy terrain was required for sowing grasses. Sheep were preferred because they provided both meat and wool income, beef were mainly used for pasture control. The major meat producing areas were Hawkes Bay, Waikato, Rangitikei and Southland.

Meat and cropping can be carried out in areas of low rainfall with dry summers. Pastures deteriorate due to summer drought and they need renewal for which a cash crop such as wheat or seed is used. These areas were Canterbury and other Eastern parts of the South Island.

Wool and store sheep were produced on hilly areas with low natural fertility which were improved only with the advent of aerial topdressing.

Returns

The advent of refrigeration made the above pattern of farming possible and the use of land in this way gave the highest net returns per acre compared to other products that could or were being produced.

Net returns were affected by

i. the price received

ii. the costs of production.

In the period leading up to 1920 both of the above factors were favourable to meat and dairy production. Wheat price whereas lamb, cheese and butter prices rose with the increasing population and living standards in the United Kingdom.

Costs were dependent on

i. the productivity of the land

ii. the costs of non-land inputs.

New Zealand's productivity of animal products is high because of a suitable climate, not the soil which in most areas is deficient in phosphorus and other minerals. The temperate climate is suited to sheep and cattle. The short, mild winters obviate the need for extensive housing of livestock as in Europe and North America and there is no need to grow large quantities of supplementary crops. Hay and silage are able to be used, these are cheaper because continuous cropping exhausts soil fertility and requires expensive nitrogenous fertilisers to replace it.
New Zealand soils receive nitrogen from clover and animal droppings.

Hence productivity of land is higher and costs are lower based on animal products, based on pasture. After 1920 there were a number of trends including decreased labour content, increased fixed capital in livestock, plant, buildings and fences, increased working capital especially fertiliser and the advent of a number of technological advances.

The current situation with regard to the advantages of various types of livestock farming is reflected in Table A5.1 which shows the estimated gross margins for the 1981-82 season in the Manawatu Region.

Farming pattern	Gross Margin[1] $/hectare
Town milk supply	815.00
Bull beef (dairy bulls)[2]	675.44
Factory milk supply	656.50
Breeding ewe - prime lamb	432.90
Breeding ewe - store lamb	363.22
Prime beef	331.86
Beef breeding	320.00

Table A5.1: Estimated Gross Margins[1] 1981-82 season Manawatu Region (Source: Ministry of Agriculture and Fisheries. Cropping and livestock gross margins 1981/82 Palmerston North. Ministry of Agriculture and Fisheries. September 1981)

A comparison of seasonal milk production with smoothed production

In New Zealand, the sector of the dairy industry which produces milk for liquid consumption by the local population is distinct from the manufacturing milk supply. On such farms, known as "Town Milk" suppliers, production is relatively constant throughout the year, the average farm producing 74% of its milk to meet a constant quota.[3] This type of farming represents about 10%of total milk production.

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1. Gross Margin is defined as the total income from a particular enterprise less the particular costs associated with that enterprise.
2. Although Bull Beef currently has a higher return than dairying, as do a number of cropping ventures, the return from such ventures is highly variable and it is considered that in the longer term, dairying is a source of higher income.(2).
3. In actual fact some milk in excess of the quota is paid at town milk prices, thus contributing to this 74% but this is limited to some producer companies and is limited in extent.

	Factory Supply[1]	Town Milk[2]
Administration	886	1170
Animal health	914	981
Breeding and herdtesting	501	550
Contractors	334	904
Dairy shed expenses	409	750
Electricity	654	1118
Feed and Grazing	1823	4191
Fertiliser and seed	2471	2927
Freight	234	471
General, weed and pest control	276	276
Vehicle expenses	2234	3678
Repairs and maintenance	2685	3655
Irrigation	-	140
Development expenditure	471	-
Insurance, accident compensation	433	697
Rates	659	1123
Labour	2268	8300
Interest	3345	5188
Rent	538	950
Depreciation	1819	4176
Total Expenditure	24100	41245

Table A5.2 : Expenditure on average town milk and factory supply farms for 1978-79 season

1. Source: New Zealand Dairy Board. An economic survey of factory supply dairy farms in New Zealand 1978-79 Wellington, New Zealand, 1980.
2. Source: Lincoln College. Agricultural Economics research unit. Research Report No.108 An economic survey of N.Z. town milk producers 1978-79. Canterbury, Lincoln College July 1980.

A comparison of costs in the two types of farming will give some indication of the expense at this part of the total system in smoothing milk supply to factories by this method.

Costs in each type of dairying are listed in Table A5.2 . Additional costs arise in town milk supply under the listed categories for the following reasons:

i. Administration. A more complicated method of farming is involved with a greater number and value of inputs. There are a greater number of stock transactions and the greater use of run-offs separate from the home farm.

ii. Contractors. Additional feed must be stored hence this includes greater hay making and silage making costs.

iii. Dairy shed expenses. The shed is running for the whole year and thus there is greater wear and tear on equipment such as rubberware, hoses and cleaning equipment.

iv. Electricity. The shed is running all year.

v. Feed and grazing. It is necessary to store more feed for use in winter, or buy it in and to use leased areas for rearing dry stock.

vi. Fertiliser and seed. It is necessary to use more fertilisers to ensure pasture growth when required.

vii. Freight. Stock must be freighted to and from the run-off which may be on poorer land at some distance. There are also additional stock purchases which tend to be in smaller numbers, more widely spread through the year than on Factory supply farms.

viii. Vehicle expenses. Vehicles are run all year round. There is additional feeding-out required, there are also additional vehicle expenses in visiting the run-off area.

ix. Repairs and maintenance. Fences, tracks and vehicles suffer extra wear and tear through continual use, especially tracks under use in poor weather conditions.

x. Insurance, accident compensation. There is greater capital employed on the town milk farm and also additional labour.

xi. Rates. Town milk farms are closer to towns and cities and so rates are higher.

xii. Labour and rations. The labour component is much greater on town milk farms because of all year milking, calves need rearing most of the year, feed supplements must be made and distributed and there are more groups of stock to control.

xiii. Rent. Town milk farms are more often involved in renting run-offs or grazing rights and their costs may be higher due to being closer to centres of population.

xiv. Interest and Depreciation. Capital is higher in town milk farms. It is more likely that the farmer will own equipment to harvest and distribute supplementary feed, also the farm's area is greater in town milk farms.

The gross income, representing total payout, on a factory supply farm was $37,384, whereas the town milk supply farm gross income was $60,788. There are 113 cows per town milk supply farm as opposed to 117 on a factory supply farm. Ignoring differences in cow breed and any differences in milk production due to the relative time of the year the lactation cycle occurred, then the gross income of a town milk farm must be multiplied by 117/113 to obtain the payout necessary to achieve a smoothed milk flow to manufacturing. This results in the payout needing to be of the order of 1.7 times the present value.[1]

This is obviously a crude estimate because if only this level of return was necessary then all farmers now involved in factory supply would be trying to move into town milk supply. There must be a greater return than this to make such a change feasible. Additionally such factors as the increased management skill required to operate a town milk farm have been ignored.

1. Correcting for the number of cows by a factor of 117/113, the town milk gross income would have to be 60788 x 117/113 = 62939.
This gross income is 62939/37384 = 1.68 times that of the factory supply farm.

<u>Pressures causing a higher peak milk supply</u>

The normal lactation period for New Zealand dairy cows has in the past lasted for up to ten months from the date of calving. It has been considered that farmers cannot afford to dry off any cows at all during March, or even April, because this production represents the farmer's profit.

However, Campbell et al, (4) in a paper assessing the reasons for the higher milk production on Ruakura Research Centre farms than the average South Auckland dairy farm, suggest that this reasoning is fallacious. They suggest that cows should be dried off earlier if necessary in order to be in good condition and correct live weight at calving in order to produce better afterwards. They suggest that gains through such improved production early in lactation will more than offset the loss at the end of the season. In addition, by feeding more spring grass to produce this milk at this time, it is not necessary to make as much hay or silage to try to recoup poor cow condition, resulting from late drying off, during the winter.

Ruakura No. 2 dairy farm cows are dried off progressively from the end of February onwards with the aim of drying off cows in the condition they should be immediately after calving. Such flexibility in drying off date would be particularly important in seasons or areas where a dry summer was experienced. Hooper (5) cited an example of a farm with herd production up 27% by January 31 and per cow production increased by 22% for the same period. The effects of the ensuing drought were largely avoided by increased stocking rate, flexible drying off and with the additional benefit of reduced necessity to harvest supplementary feed.

It was suggested by Hutton (6) that "attainment of a high peak yield for the herd is considered of more importance to achieving a high total lactational output than the length of lactation." However Davis et al (7) stated that "No direct experimental data are available on the effect of drying off on current and future production".

Nevertheless, high rates of production have been achieved under Campbell's management system. This system of management must have appeal to farmers even if only for the reasons of reduced silage and hay making requirement and reduced time spent milking. These will become increasingly important as stocking rates are increased.

An additional feature of milk production which may affect the pattern of milk supply is the advantages offered to the farmer of a more concentrated calving period. In addition to giving each cow a good lactation length, particularly if early drying off may be required, Campbell (4) suggests there are several other advantages including:

i. The chore of calf rearing is compressed.

ii. It allows the better selection of replacement stock in that more calves will be by AB sires and more emphasis can thus be placed on the dam when selecting herd replacements.

iii. Mating management of the yearling progeny is simplified because they are of similar age and likely to be of similar weight at mating.

iv. Simplified early spring grazing management is brought about because the mob of drys is eliminated more quickly.

In a survey of farms with the highest producers of milkfat per hectare in the Dairy Board's economic survey, Hutton (6) found that most regarded concentrated calving as important. Pearce and Taufa (8) in a comparison of concentrated calving herd with a normal calving herd reported that the "concentrated herd built up a production advantage in early lactation and this 11-12 kg advantage was maintained through the season".

These measures both lead to modifications in the seasonal pattern of production whereby the peak milk flow is increased by:

i. Increasing the peak output of cows;

ii. Intensifying the occurrence of the peaks.

The tails of the distribution are reduced by drying off of cows and by concentrating calving. This trend has not so far been evident in the national milk production statistics but may in any case be more confined in its effects to individual factories. Because a factory is supplied from a limited geographical area it is likely that both calving date and drying off will be governed by similar climatic factors in a large proportion of the factory's supplying herd, thus causing a sharp peak. The effects may not be so evident in the national statistics because such dates will vary from area to area depending on local conditions, thus forming a smoothed aggregate.

The New Zealand Co-operative Dairy Company has indicated that it considers the sharpening peak to be a serious problem. It was estimated that the peak milk could increase by 3% annually. Rangitaiki Plains Dairy Company has an incentive scheme to encourage a balanced seasonal intake. It was said to be an important consideration in the merger of Taranaki and Kiwi Dairy Companies that calving pattern among Kiwi suppliers is earlier than Taranaki's by as much as four weeks. Thus the merger will spread the peak of milk intake and allow more economic utilisation of manufacturing plant. (9) Thus dairy companies are seriously affected by the trends discussed above by the need to provide processing plant to handle the peak milk flow.

The market for milk powders

Prior to 1890 and the introduction of refrigeration practically all of New Zealand's limited dairy exports went to Australia, this country having the only market close enough for the delivery of a relatively perishable product. From 1890 on, the direction of dairy export changed to Britain where it substantially remained. During the two World Wars New Zealand and British Governments established agreements whereby almost all New Zealand dairy products were bought by Britain. It was not until 1954 that New Zealand was free to compete on the World Market. The dependence of New Zealand on the British market is illustrated in Table A5.3.

	Butter	Cheese	Milk (Dried, Condensed etc)
1930	82.4	100	83.5
1940	98.5	100	73.6
1950	96.0	89.5	78.7
1960	90.1	93.1	52.6

Table A5.3 Percentage of New Zealand Dairy Products by weight sold in United Kingdom

(Derived from N.Z. Official Year Books 1933, 1943, 1953, 1963)

Changes in the market

During the past twenty years there have been a number of important changes in the market for milk powders. These are illustrated by reference to tables A5.4, A5.5.

i. Change in Main Market.

As can be seen from Table A5.4, the main market for milk powders has changed from the United Kingdom, which took 52.6% of the total in 1960 to Malaysia and the Philippines. No milk powder is now marketed in the United Kingdom.

ii. Expansion in Total Market

The total market for milk powders has grown from 70,000 tons in 1960 to 200,000 tonnes in 1979, a three-fold increase. Maximum sales occurred in 1978 when 242,000 tonnes were sold.

iii. Diversification in Market Destinations

From the situation where there was one major market in 1960 there have grown to be a number of markets of a similar size including Japan, Malaysia and the Philippines. Principal market areas are now South East Asia, Japan, Central and South America. Markets have both increased in size and number. Whereas in 1960 the principal market accounted for 52.6% of the produce, in 1979 it accounted for onlt 15.2%. Whereas in 1960, the next nine most sizeable markets accounted for onlt 20,300 tons, they accounted for 122,800 tonnes in 1979. In 1960 there were only eight markets of more than 1000 tonnes per annum, in 1979 there were 19.

1960*		1965		1970		1975		1979	
United Kingdom	37.1	United Kingdom	43.1	Japan	33.7	Peru	27.0	Malaysia	30.5
Philippines	5.0	Philippines	10.7	U.K.	29.5	Malaysia	23.8	Philippines	29.1
India	4.4	Malaysia	7.3	Malaysia	25.4	Philippines	22.5	Indonesia	24.9
Jamaica	3.4	Peru	5.5	Philippines	19.1	Japan	13.3	Peru	16.5
Malaya	1.8	India	3.9	Peru	11.8	Thailand	7.4	Japan	15.3
Singapore	1.6	Japan	3.5	Thailand	10.9	Chile	6.0	Taiwan	9.5
Peru	1.5	Jamaica	3.2	Singapore	9.2	Indonesia	5.8	Thailand	7.9
Trinidad & Tobago	1.3	Trinidad & Tobago	2.0	Pakistan	8.2	Singapore	5.3	Venezuela	7.4
Ceylon	0.8	Netherlands	0.95	India	5.9	Ghana	5.1	Singapore	6.5
Fiji	0.5	South Africa	0.81	Ceylon	4.6	Jamaica	2.9	Sri Lanka	5.7
Others	13.1	Others	5.8	Others	23.1	Others	40.8	Others	47.1
Total	70.4	Total	86.7	Total	181.4	Total	159.9	Total	200.5

* Note: Data in thousands of tons 1960-70, thousands of tonnes 1975,1979.

Table A5.4 The ten principal milk powder markets for selected years since 1960

(Source: New Zealand Official Year Book 1962, 1966, 1971, 1977, 1980)

iv. Growth in Market for fat-bearing milk powders.

While total milk powder sales have increased three-fold, it can be seen from Table A5.5 that the market for fat-bearing powders has increased more than nine-fold from 1960 to 1979.

	1960	1965	1970	1975	1979	1980
SMP	45.7	66.0	147.6	113.6	120.3	172.1
WMP	7.1	8.6	14.6	23.8	64.8	61.4
BMP	8.0	10.6	15.5	12.5	10.9	21.2
Total	60.8	85.2	177.7	149.9	196.0	254.7

* Note: Figures in thousand tons 1960-70, thousand tonnes 1975-80.

Table A5.5 Market Sales of Powders for selected years since 1960 [1]

v. Increase in the variety of specifications

From days when Britain comprised practically the whole market and large volumes of similar produce could be manufactured to suit that one market, the situation has changed. The Board now offers 40 specifications of skim milk powder. In the 1977/78 season 85% of all skim milk powder produced in New Zealand was of the non-standard types. There are some 30 specifications for baby foods and special fat-bearing powders, and 18 specifications for wholemilk powder. (10) The Dairy Board sends over 1000 samples a year to overseas buyers and 20% of these are new or modified products. (11)

Reasons for changes in the market

i. Britain's entry of the E.E.C.

Britain's entry of the E.E.C., first proposed publicly by the British Prime Minister, Harold Macmillan in July 1961, brought an end to New Zealand's free access to the British Market, with the advent of the "Common Agricultural Policy" and the end of Britain's "Cheap Food"

1. Source: New Zealand Dairy Board Annual Report 1960, 1965, 1970, 1979, 1980. Please note that the Tables do not agree because the Year Book refers to calendar years, while the Dairy Board figures refer to 12 months prior to June of the year given.

policy. Although Britain did not actually enter the E.E.C. until 1973 the writing was on the wall. The days of colonial interdependence were at an end. New Zealand was forced to find new markets for its dairy products, both the milk powders and the fat products, cheese and butter. The necessity to sell milk fat on other markets has coincided with developments in the production and marketing of wholemilk powders which have assisted in finding new markets for this milk fat but even today no alternative market has been found for large volumes of butter.

At a meeting of the old European Community and Britain in Luxembourg during June 1971, and agreement was reached whereby New Zealand was permitted to continue to sell butter and cheese on the British Market.

New Zealand considered such an agreement necessary because it was estimated that if the E.E.C's Common Agricultural Policy was applied to the British market an immediate loss of $150 million a year in export earnings for butter and cheese would have occurred. This would have been catastrophic for the New Zealand economy, bringing about a balance of payments crisis leading to extensive unemployment and a rapid emigration as well as painful re-adjustments to the New Zealand Dairy Industry. (12)

The quantities of product guaranteed access to the British market are given in Table A5.6. There was to be a complete halt to the selling of New Zealand milk powders on the British market with entry to thr E.E.C. in 1973.

Year	Butter percent	Butter tons	Cheese percent	Cheese tons	Milk equiv. percent
1973	96	163200	90	67500	95
1974	92	156400	80	60000	90
1975	88	149600	60	54000	83
1976	84	142800	40	30000	77
1977	80	136000	20	15000	71

Table A5.6 Quantities of dairy products given access to the U.K. market during the transitional period.

(Source: N.Z. Official Year Book, 1972 p 537)

There was no quantitative guarantee laid down for cheese from 1978 onwards but the butter situation would be reviewed in the light of the supply and demand situation and trends in the major producing and consuming countries in the world, particularly the E.E.C. and New Zealand.[1]

Additionally, the E.E.C. agreed to make every effort to promote an international agreement on dairy products marketing and also not to frustrate New Zealand's efforts of diversification by indiscriminate dumping of E.E.C. dairy surpluses.

Thus the New Zealand Dairy Industry was faced with four major alternatives:

i. To find alternatives to the British market.

ii. To develop alternatives to the traditional dairy products.

iii. To divert farm production to alternative types, for example, beet, cropping or horticulture.

iv. To find alternative income to farming.

In fact developments occurred in all four of these areas (13) but in this section only the former two alternatives will be discussed.

ii. Growth in the Recombining Industry

The United States Army pioneered recombining of milk during the Second World War. It involves the reconstitution of milk by adding water to skim milk powder, buttermilk powder and fat, usually in the form of Anhydrous Milk Fat, but vegetable oils are used in some cases. The product of this process is canned evaporated milk, sweetened condensed milk, or liquid milk ready for immediate consumption.

The growth of the Recombining Industry has occurred as there has been an increasing awareness of the benefits of improved nutrition in terms of public health, educational progress and increasing the length of working life in developing countries. Thus milk in schools programmes have been instituted in a number of countries. (14) There had

1. New Zealand was subsequently granted continued access till 1980 and again from 1980 onwards with diminishing volumes permitted.

also been improvements in the standard of living in countries such as Malaysia and the Philippines leading to a change in food patterns involving greater use of dairy products. Soaring oil revenues in Middle East countries had resulted in nutritional projects being implemented there (15) thus leading to increased milk consumption.

Trade in the developing countries was considered to be more secure than other countries because governments were more positively involved. They could not risk a stoppage which would affect peoples' food, jobs and public health programmes, and sometimes the development of the local dairy industry as well. (16)

Recombining industries rested on the advantage of low cost milk production and manufacture into concentrated forms for shipment and storage. In many South East Asian countries recombining plants received a degree of protection while dairy products in their final consumer pack form were penalised by high rates of duty. (17)

The New Zealand Government was able to play an important role in establishing access to the new markets through their trade commissioners. (18) Additionally the Dairy Board received help from government and trading banks in providing credits to facilitate a "full flow of trade", in the example cited, with South America. (19)

New Zealand developed its dairy trade in these new areas initially through the use of local agents. It was considered advantageous to use such people because they live and work in the market and know the ways of the customers, speak the language and understand the local idiosyncracies and customs. The loyalty of the agents was won by providing the goods and service required. Such agents were considered to give the New Zealand Dairy Industry status in the market and they also supplied information on shifting demands, new competition and long term market prospects. (20)

New Zealand was involved in a number of joint ventures in setting up recombining plants, providing technical advice and assistance to many clients. The New Zealand Dairy Industry was in a strong marketing position because of its single selling organisation, its high product quality, the uniformity of product and by being in a position to guarantee supply. Additionally New Zealand was not in a disadvantageous position with regard to shipping distance to the South East Asian market.

The support of technical staff and the Dairy Research Institute in dealing with problems of diversification and development has been a vital factor in obtaining the new markets. Increasingly the Dairy Industry had to be capable of manufacturing products to a wide variety of specifications, competitive status depending on the ability to meet such specifications more accurately than anyone else. (21) Milk powders had to be suited to individual customers, for instance in Thailand and Malaysia a more viscous sweetened condensed milk is required because in the past, imported condensed milk from Europe had usually developed viscosity by the time it reached these areas. However, in Vietnam a thin product has always been preferred. Various vegetable oils used in "filled" products meant that skim milk powder properties had to be varied to suit the particular oil.(22) As one of the Dairy Board's agents said "I sell a taste in the mouth and I have to provide it". Each market has its specialised tastes. Thus the Dairy Board discusses with the customer the specific type of each product they want and the taste they are looking for in that product and sets out to meet the customer's specialised needs. (23)

iii. Growth in Market for Whole Milk Powders

Paralleling the growth in the recombining trade as New Zealand sought new markets for dairy products, was a slow growth in the consumption of whole milk powders. They were used as an alternative to condensed milk in some countries such as Trinidad and Venezuela. (24) Whole milk powders were also "built" to form a wide range of therapeutic drink compounds and infant milk foods. They found some outlets in nutrition programmes, for example in Brazil where they were provided at cost or gratis to nursing mothers and young children. (25)

More recently there has been a shift away from condensed and evaporated milk as products of the recombining plant to the production of liquid milk which is then U.H.T. treated to maintain its condition for an extended period, without refrigeration. Additionally there has been a growth in the sale of whole milk powder in consumer packs. With the development of instant whole milk powder many consumers were considered to be moving their interest from condensed and evaporated milks to this more sophisticated product. (26) Instant wholemilk powder and U.H.T. milk were considered especially important in reducing refrigeration costs as energy prices increased. Additionally there was growth in the use of whole milk powder in the recombining plants as opposed to the use of skim milk powder and A.M.F. (27)

New Zealand was considered to have an advantage in the developing market because of the good reputation built up in the recombining trade and the technical back-up which the Dairy Board was able to provide. (28).

The Chairman of the New Zealand Dairy Board, Mr A.L. Friis considered that although in the production of milk powders the "standards of purity and the complexity of specifications make exacting demands on the companies..." that "This is undoubtedly one of the most promising growth sectors". (29)

iv. <u>Competition in the International Market</u>

<u>The extent of the International Market</u>

It has been estimated that total world milk production is about 400 million tonnes per annum. Of this it was estimated that about 3% or 10 to 12 million tonnes was involved in International trade. This represents about 1.26 million tonnes of milk solids comprising 370,000 tonnes of milk fat and 890,000 tonnes of solids not fat. (30)

A 1% variation in world production would thus represent one third of the International market. Similarly the E.E.C. produces 95 million tonnes of milk per annum, so a 4% variation in E.E.C. production represents a third of the International market volume.

The principal countries involved in exports to the International Market were the E.E.C. and New Zealand, accounting for about one third each and followed by Australia, Canada, U.S.A. and Poland.

New Zealand must compete on the International Market with about 80% of its total production against countries that are exporting only a small percentage, often under 5%. Thus the quality of New Zealand's total production must be uniformly high whereas others can select the small quantities of high quality product for export. (31)

The major markets for dairy produce can be split into two groups, the developed and the developing nations. The former include Japan, North America and Europe while the latter include South East Asia, Central and South America, Africa and the Middle East.

The Features of International Milk Products Trade

The principal problems in the international marketing of dairy products have been that the wealthy, developed nations who have been able to purchase dairy products have erected trade barriers to support their domestic dairy industries and countries of the under-developed and developing world, with great need for dairy products, have not been able to purchase them through a lack of foreign exchange.

The United Kingdom, which used to be the largest single free market for dairy products is now virtually closed to exporters outside the E.E.C. as a result of the Common Agricultural Policy. New Zealand has negotiated continued access for butter but with continually diminishing volumes and as yet there is no other market which could absorb this volume of milk fat. There has been some relief of pressure on New Zealand and Australia, in that as they were forced out of the British market, the Dutch and French were busily learning to make cheddar cheese to supplant them there, whereas Australia and New Zealand were making Dutch varieties for Japan. (32)

In the developed countries there are a complex range of social, regional and environmental objectives which all take precedence over technical efficiency, comparative advantage or the real costs of supply. For instance, because food is such a basic need, there is a deep instinctive urge within any independent state to be self sufficient. Many countries have been involved in recent wars and know what it is to be hungry. Thus they have been prepared to pay a high price to achieve that self sufficiency. It should be realised that in the industrialised and more affluent countries, it is industrial activity which generates income and provides the wherewithal to meet social and income needs. In New Zealand it is the income and overseas exchange earnings of the agricultural sector which have largely determined income levels for the rest of the community. Any country has the right and ability to decide for itself how it wishes to distribute and redistribute income and resources, the reasons are not necessarily economic. (33)

The result of such subsidised dairy industries has often been surpluses in certain commodities caused by the failure of the price mechanism to control production levels. This has led to subsidised dumping of excess product on the International Market, with its attendent problems for New Zealand which is heavily dependent on this market.

Even where a food-producing country is not self sufficient in production of a commodity, there is invariably a vocal and politically powerful group of farmers watching vigilantly to ensure that imports of their type of product are prevented from undercutting their prices. The range of protective devices includes food and drug regulations and strict hygeine requirements which can be called on to prevent or frustrate trade.

The demand for reciprocal trade, common in the communist bloc, may also limit or eliminate an export market, and finally vagaries of climate may create shortages or surpluses with the attendent fluctuations in price causing loss of markets or poor incomes.

The Methods used to compete

As a result of these problems, the competition on the International Market is extremely fierce.

The principal method of avoiding barriers to trade is the development of trade agreements. New Zealand has been involved in a number including Protocol 18, permitting continued access for butter to Britain, voluntary agreements on quotas to the U.S.A., New Zealand-Australia Free Trade Agreement, NAFTA, which enables us to send 2000 tonnes of cheese to Australia, GATT, OECD and UNCTAD which although of no direct influence, help in preventing additional trade barriers and promote understanding.(34)

In the face of subsidised dumping and strong competition on the International Market, New Zealand's comparative advantage in the creation of dairy products has ceased to be a decisive factor in selling product. The need has been:

i. To ensure that for existing markets New Zealand is making a better product in terms of quality, packing and presentation than other producers.

ii. To formulate products to specific buyer and market requirements, thereby establishing New Zealand in particular sectors of the milk powder trade where standard, run of the milk powders cannot compete.

iii. To add as much value as possible to the product while it is in New Zealand. This has meant a shift from being a bulk seller of anonymous powders to being a bulk seller of special specification powders. Also, there has been a move to consumer packing of any brand of powder and development of markets for consumer packs for specific New Zealand brands of powders and baby foods.

iv. To use milk powder as a vehicle to sell milk fat by giving particular emphasis to milk powder for recombining plants or producing more directly fat-bearing powders such as whole milk powders and baby foods. (35)

The New Zealand Dairy Board's effect on short runs.

Introduction

The Dairy Board is the administrative head and export marketing agency of the manufacturing dairy industry[1] which is totally co-operative.

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1. The New Zealand Milk Board, a separate body, controls the production and distribution of liquid milk for domestic consumption in New Zealand and this sector accounts for 10-12% of total annual milk production.

The Board is a statutory body formed under the Dairy Board Act 1961. It has power to acquire all dairy export products from manufacturing companies which are to be marketed overseas. The proceeds of sales are returned to the co-operative manufacturing companies, less marketing costs, who in turn pass on the proceeds to the farmers, less processing costs.

The suppliers of the co-operative companies elect their company's board of directors who control the operation of the company. The Dairy Board comprises two members appointed by the Government and eleven producer members, elected by wards, which are geographical groups of companies. The wards also elect delegates to an annual conference whose decisions are considered binding on the Dairy Board. Thus co-operative dairy companies control the Board through their ability to elect members and the annual conference.

The industry has long provided for fluctuating international price levels by paying fixed prices which can be altered by small percentages from year to year. The price paid is based principally on the volume of milk fat supplied. Thus dairy farmers' incomes are stabilised.

The purchase price system is used to create financial incentives to influence the industry's pattern of manufacture in the products made. A large number of dairy companies have several alternative processes that could be used to manufacture. They represent about 70% of the industry's milk output. The Board also has the ability to divert milk from company to company if the processes available at the usual factory are not in fitting with the needs of the market. This occurs particularly with transfers in and out of cheese for the reason that most cheese manufacture is undertaken by single process companies.

System of receipt of orders

There are two main methods of purchase of spray-dried products from the Dairy Board.

The Dairy Board allocates tonnages to the companies by taking into consideration such factors as the company's past performance, its technical capability, its previous proportion of non-standard products, the need to spread expertise and risks and of course the demand and expected demand for the various specifications.

The Dairy Board then gives the individual companies a schedule of tonnages of each specification required each month for the season and as the season progresses this schedule may be updated depending on milk production, any manufacturing problems that may arise, and other factors discussed below.

Manufacture

Individual companies manufacture to meet the Dairy Board requirements. Scheduling of production within each monthly period is under the control of company management, although shipping deadlines must be met.

After manufacture the product may be stored in the dairy company's store or sent immediately to grade stores where it is graded. This takes six to eight weeks. Loading onto the ship takes up to two weeks.

Causes of short production runs

Complications arise through problems experienced by both customer and manufacturer. The Dairy Board plays the intermediary role in smoothing such disturbances.

Customer: As a result of the length of time between initial order and manufacture, it may occur that the customer's requirements change. This would be due to changing economic circumstances, results of marketing effort or changing competitive prices. Thus the size of the order may be reduced or increased. Reducing the order may result in Short Production Runs due to the smallness of the order. Increased requirements could result in complicated scheduling causing short runs or if it is near the end of the season, short daily running times.

Customers often specify preferential manufacturers, from whom they have received satisfactory product in the past. This places restrictions on allocation.

i. Bulk Purchases

This type of agreement is known as an "Evergreen" contract and mainly concerns dealings with milk recombiners. Seventy-five percent of SMP and BMP are sold this way. The product is used in the manufacture of sweetened condensed milk, evaporated milk, milk, "enriched milk" and UHT milk.

The Dairy Board sets prices six months in advance of the commence of two six month periods (price may differ in the two periods). The recombiners then decide how much they want, in light of the prices of other suppliers, and make orders for the first six month period, on a tonnage per shipment basis. Thus for that period the Dairy Board knows exactly what is required at what date.

The Dairy Board makes estimates of what they expect to be required in the second six month period and thus can allocate required tonnages to factories on a monthly basis for the whole season.

ii. Contract

The remaining spray-dried products are sold on a one year contract basis. There are two ways these may arise. Tenders for supply are invited, for which the Dairy Board competes on the International Market. Alternatively, a multi-national company asks for the Dairy Board to supply a particular geographical area with the multi-national brand of product. This is usually in cans.

System of allocation of orders

Having received the orders the Dairy Board is able to allocate tonnages to the various companies. The companies submit to the Dairy Board a plan of what they would like to produce, firstly in terms of standard products and secondly including non-standard products. The companies base their decision on product differentials, set each season by the Dairy Board to encourage the required product mix. For example, in the 1980-81 season casein was in demand so it received an additional 5c per kilogram of milk fat above base, cheese received 2c per kilogram and skim milk received only base price.

Often customers specify that WMP must be less than three months old when delivered. This places great pressure on the system, especially if some product is found to be out of specification when graded. This can result in complicated scheduling and short runs to make up the balance of the order. Because of the need to reach the market so soon after manufacture, product cannot be manufactured in a long run and stored until next required. Thus short runs result.

Most recombining customers require powder of their own specification. This results in multiplication of product specifications and thus relatively small volumes of each specification. Thus short runs result.

Manufacturer: An additional complication to manufacturing of many products is that they must be canned. Thus their production schedule must fit with that of the canning plant, NZ Dairy Packers in Hamilton. This is especially important in the case of baby foods which must be canned as soon as possible after manufacture. Off specification product introduces the necessity for short runs to make up the shortfall and causes further complications in the packing plant, which may affect the manner in which other products are scheduled for production.

Some companies are willing to produce some products at certain times of the year because of the higher yields in that period due to the seasonal variation in milk supply.

Some spray-dried products have a much slower rate of throughput than others and therefore it is advantageous to produce them at the ends of the season when total milk flow is lower, thus utilising available capacity to best advantage. This further restricts the time of year when some companies are prepared to produce some products.

Some products, e.g. Heat Stable SMP, can only be produced at certain times of the year due to the seasonal variation in milk quality.

The above factors, combined with any problems with out-of-specification product can result in scheduling problems and thus short production runs.

Other problems

Under Dairy Board rules, companies could produce unlimited quantities of specification 600 skim milk powder, the standard specification. Thus they would avoid ever having to change specification. Companies do not do so because they believe they obtain a greater net return by producing non-standard products to specifications set by the buyer through the Dairy Board. For these they obtain a premium payment in addition to that which they would obtain for manufacturing the standard product.[1]

Tnis premium payment, in their view, should recompense them in two ways:

i. It should pay for any extra costs incurred in meeting this specification;

ii. It should provide some incentive to make the effort to produce a special product, when they could have made Spec.600.

Because of the difficulties in determining what a product costs, item "i" is open to abuse. Item "ii" is open to debate as to its extent and whether it should be paid at all. Implicit in the argument that it should be paid is the assumption that all milk powder could be sold if it were Spec.600. It assumes that marketing the product is not the companies' problem.

At present companies are paid on the above basis, although the Dairy Board does not officially recognise item "ii". Costs are paid based on the average for the industry or the companies who are asked to tender for the manufacture of the product. In general companies make the decision as to what they would like to produce based on what they believe their costs are relative to the average and what alternative products they could make.

However, there has arisen a certain problem in that companies who have the ability to, and succeed in obtaining NSPO's for products in which they are relatively efficient,

1. Although Spec.800 is the standard whole milk powder and premiums apply above this for other whole milk specs, any manufacture of whole milk powder, including spec.800 is subject to Non-standard purchase orders.

are able to pay a higher return to their suppliers, and thereby attract suppliers away from companies with lower payouts. Ultimately this could result in one company having lower costs and higher throughput through attracting suppliers away from companies, which then have under-utilised equipment, and the spiral could continue to the point where a company was no longer economic.

Thus the lower paying companies desire to increase their payout relative to the companies that compete with them for suppliers. They can do this in a number of ways including conversion of capital into payout, becoming more efficient, or by obtaining orders for non-standard products. Thus companies compete to be allowed to produce non-standard products with the highest premiums. If they succeed in this they win on two counts. Firstly, they obtain the premiums, and secondly they prevent their competitors from obtaining the premiums.

Hence the production process may not be the most efficient possible. The products with the highest premiums are those that require the most sophisticated plant to produce and meet the stringent requirements of a relatively small market. Thus such products are difficult to produce to specification and they are required in small volumes. Additionally, companies may be more willing to produce short runs than would normally be warranted on economic grounds, because they wish to be seen by the Dairy Board as being a suitable company to produce high premium, non-standard products.

Conclusion

It has been shown that the pressures to produce short production runs in spray-drying factories arise from both the market and the milk producer. The economics of dairy farming demand the seasonal pattern of production in order to bring about the greatest return in terms of the difference between income and expenditure.

The relegation of comparative advantage to the role of a spectator in the face of competition from subsidised products has meant a drive toward other means of securing markets. These have principally involved the increasing specialisation of production in an effort to differentiate New Zealand's product from the opposition and thereby maintain and develop markets by best satisfying the consumer.

In both these areas, short production runs are the result in the factory. Because the factory is under the influence of the supplier due to its co-operative nature it may be that the interaction between farmer and factory in producing short runs could be modified if it was found to be beneficial to the farmer. The market is largely beyond the producer's control and so the factory manager is faced with accepting short production runs and making efforts to deal with them in the best way possible.

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