PRODUCTIVITY IMPROVEMENT IN A DYEHOUSE IN THE TEXTILES INDUSTRY

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I, Andrew Sean Craven, submit this dissertation for the Degree of Master of Engineering. I claim that it is my original work and that it has not been submitted in this, or in a similar form, for a degree at any university.

signature removed

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ABSTRACT

This dissertation describes the application of productivity improvement techniques in a dyehouse in order to reduce costs and to improve quality and delivery performance. It consists mainly of investigations into the high reject rate in the dyehouse and into the dyeing process itself. In these, the technique of Pareto analysis and the application of the principle that all processes contributing to product quality should be controlled, were applied. In addition, work study techniques were used to improve process flow, planning and batch sizes.

A number of conclusions and recommendations were made: there are no major obstacles to successful first-time dyeing; the proportion of rejects produced tends to increase with increasing workload; the overall ability of the dyehouse operators and supervisors needs to be improved; the dyeing process is very vulnerable to human error, and increased automation, such as the purchase of a more sophisticated machine control system, is recommended; investigation into the purchase of a colour matching computer is also recommended.

Although the effect of certain important initiatives has yet to be felt, real improvements in the reject rate have been achieved since the start of the Dyehouse Project. The percentage by mass of reject material produced is down to 7.9% in the second half of the year from 10.2% in the first half. The cost indicator 'Total costs per accepted kilogram' should yield useful information in 1993. It is recommended that the indicator 'cost of dye materials per kilogram for specific shade/ yarn qualities' be installed as soon as possible, as it will give valuable information about the success of the project.

Since the beginning of the Dyehouse Project, responsibility for the performance of the dyehouse has been shared by the project

team and the dyehouse management. The responsibility for sustaining the improved performance must eventually pass back to the dyehouse management. It is suggested that the effectiveness of the Dyehouse management be monitored carefully and the Dyehouse Manager be sent on a good quality management course.

GLOSSARY OF TERMS

Yarn	- Spun thread
Worsted	- Fine yarn or cloth spun from wool or a wool blend
Lot/ shot	- Batch
Tops	- Bundles of unspun fibres
Weighing/ colour kitchen	- Area where dyestuffs and chemicals are weighed and measured
Hank	- Sample of yarn taken from batch to be tested against the master shade
Dyepot/ pot	- Dye machine
Hydro	- Centrifugal dryer
RF dryer	- Radio frequency dryer
Carrier	- Aluminium base and frame onto which yarn is loaded so that the yarn can be lowered, and taken out of, the dyepot
Pin trolley	- Trolley for easy transport, loading and unloading of yarn
White yarn	- Yarn that has not yet been dyed
Spectrophotometer	- Instrument for measuring the colour of a sample
Conditioning	- The process where hot, moist yarn from the RF dryer is cooled to room temperature

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1. INTRODUCTION

1.1 The Textiles Industry in South Africa

In addition to the overall political uncertainty and the depressed economic climate in South Africa today, the textiles industry has found itself in a particularly difficult situation over the past few years.

In 1989, the government introduced a quota system which allowed manufacturers to import clothing and textiles duty-free, based on the value of goods which they had exported. This boosted clothing exports by some 300% but at the same time had a serious detrimental effect on the textiles sector which also had to contend with the 'dumping' of heavily-subsidised imports from overseas. In the knitwear and acrylic spinning sector, for instance, some 8000 jobs were lost.

Thus the clothing and textiles sectors have been in sharp disagreement in what seemed to be a no-win situation: the clothing industry needs low cost inputs to be competitive on both the local and the overseas markets whilst the textiles industry has difficulty in competing with often subsidised imports.

The latest agreement, effective from November 1992, provides for a simplified system of ad valorem tariffs on imports. These tariffs are quite substantial (maximums of 35%, 50% and 100% on yarn, fabrics and clothing respectively). The stated aims of the committee responsible for the agreement is to gradually reduce the tariffs over a period of years. The tariffs are, however, deemed to be necessary for the textile industry given the high cost of raw materials, the high wage rates, the <u>low productivity</u> and high taxation in South Africa[1] (see also **3. LITERATURE REVIEW**).

On the other hand, according to a visiting British consultant:

"There's this perception that you can't compete internationally because of labour problems. But your problems are management, not worker related...Instead of looking to exploit new export potential, they want to hide behind duties." (2)

1.2 SA Fine Worsteds (Pty) Ltd

SA Fine Worsteds was begun by a Greek immigrant in 1948 and initially produced a range of men's high quality worsted suiting material. It has since been acquired by the Anglovaal group of companies and has expanded to produce a range of cloth and yarn for men's and ladies' high quality outerwear, hosiery, sportswear, interlining, curtaining and upholstery. Some 5 - 10% of the 1500 tonnes of cloth manufactured is exported to overseas and regional markets.

The spinning and dyeing plant is situated in Atlantis, 50 kms north of Cape Town, whilst the weaving plant is in Maitland, in Cape Town itself. The Maitland plant is situated on old and crowded premises whilst the Atlantis plant is relatively new (1982) and boasts a spacious factory and modern equipment. Overall the company employs 700 people.

The company has been losing money since 1991 when the effects of the recession and the various difficulties facing the industry began to take their toll. At present the company is running at around 70% capacity.

It was into this environment that the new General Manager was appointed in April 1992. He clearly had a brief to turn the company around and an atmosphere of purposeful change has become evident in the company.

1.3 The Dyehouse, Atlantis Plant

The Atlantis dyehouse forms a critical part of SA Fine Worsteds. It dyes 'tops' for spinning (20% of total output), yarn for weaving (70%) and cloth pieces (10%). 50% of dyed material is sold direct to external customers whilst the balance is transported to the Maitland plant for weaving.

The average cost for dyeing is R8 per kilogram which represents a sizable portion of the R35 per kilogram of dyed yarn. Efficiency in the dyehouse has been relatively low, the reasons for which will be discussed in Section 2. Because of this the Dyehouse Project was initiated by the new General Manager in May 1992.

1.4 Circumstances surrounding this Dissertation

I was employed by SA Fine Worsteds as an industrial engineer on a small salary and on a nine month contract. Essentially the company wanted to get someone cheaply to help them improve their plants, whilst I needed a base from which to perform my dissertation.

Originally, the School of Engineering Management at the University was particularly keen on the application of systems thinking in industry. I was unable to find such a topic that I could 'sell' to the company. As a compromise solution, I and the company settled upon the productivity improvement topic described.

1.5 An Overview of the Dyeing Process

Undyed yarn, wound onto plastic cones in 'packages' of approximately 2.5 kilograms, is first pressed onto the spindles of a carrier before being loaded into a dyepot. The yarn needs to be pressed so that it is at the right density for the dyeing process. The particular process to be used for the dyeing is specified on the dye 'recipe'. This covers the type and quantities of dyestuffs to be used, as well the heating cycle through which the dye machine runs. The dye vessels are pressurised (between 2 and 4 bar) and are heated to 100 - 130 degrees C. The dyestuffs and chemicals are dissolved in water and this dye liquor is pumped into the dyepot. The dye liquor is pumped through the inside of the cones to the outside, and then the flow is reversed so the yarn is dyed evenly.

When the heating cycle is completed, a sample hank is taken from the dyed yarn. This is dried and compared to the 'master' shade. If the sample is not on shade, an 'addition' is usually made. This entails adding more dyestuffs to correct the shade and putting the yarn through another heating cycle. Unfortunately, final shade acceptance is made at the Maitland plant which means that frequently that yarn has 'to be put back into the pot' if the shade is not accepted. Other processes include: stripping - lightening the shade; and levelling - making a small addition to get the shade even. Yarn that cannot be corrected is usually overdyed to a darker colour. Once the dyeing is completed, the yarn is dried in a centrifugal dryer and then dried further in a high frequency dryer (like a huge microwave oven). It is then packed and dispatched to either an external customer or to the Maitland plant. Tops follow a similar route to yarn, whilst cloth pieces are not pressed initially and are finished differently to yarn.

1.6 Objective of this Dissertation

The purpose of this dissertation is to describe how various productivity improvement tools were selected and applied in order to improve the efficiency of the dyehouse and to draw conclusions from the results obtained.

1.7 Scope

The Dyehouse Project involved a very wide range of different activities. Only those activities that required the application of the productivity improvement techniques of quality improvement and work study are described in detail in this dissertation. It is, however, also necessary to describe the project as a whole, both to put these applications into context, and because all the different aspects of the project are intertwined in one way or another. In addition, the results of all these initiatives cannot be measured in isolation to each other because they all contribute to the common goal of improving the efficiency of the dyehouse. Thus the **Results** section describes the results to date of the Dyehouse Project as a whole.

This project begins with an investigation into the high reject rate in the dyehouse, followed by further investigations based on these initial findings. Work study improvements are then discussed and the other aspects of the project are described. The results of the project overall are then reviewed and, finally, conclusions are drawn and recommendations made.

2. DEFINITION OF THE PROBLEM

There were two main reasons why the Dyehouse Project was initiated :

- To reduce costs
- To improve quality and delivery performance

The total cost of dyeing the annual 800 or so tonnes of yarn, pieces and tops is currently in the region of seven million Rand. This cost has increased by 200% since 1984 due, mainly, to a 400% rise in the cost of dyestuffs during this period of time. Thus the cost of dyeing had become extremely expensive and there was an urgent need to make the process more efficient, particularly in the light of the high reject rate.

Yarn, pieces or tops that are 'rejected' are generally 'put back into the pot' in order to be corrected or are overdyed to a darker colour and a new batch of white yarn dyed to the required shade. The other problem with batches of yarn that need to be corrected or redyed is that it prevents the customer (whether it is the Maitland factory or an external customer) from receiving their order in time. In weaving this is especially critical because, if one component of the weave is not ready, the weaving process cannot begin.

Between January and September 1992, the average reject rate by lots was 11.2% and by kilograms 9.4%. This represents an estimated R370 000 pa cost for redyeing (see **Appendix 2**) in direct costs alone, and takes no account of the cost of delays and the loss of goodwill to customers. It was difficult to establish what was a 'good reject rate' for the dyehouse from outside sources. A 'good' dyehouse in Europe is said to have a reject rate of between 3 and 5%. A survey of nine South African dyehouses found a reject rate by kilograms of between 3.9% and 15.2%[17]. This was not very helpful as it was outdated and the dyehouses involved differed widely in the materials, machines and techniques they used. What was clear, however, was that there was a great deal that could be improved in the dyehouse and also that it had to improve for the economic good of the company. No specific quality objective was defined, but the feeling was that a reduction to a 5% reject rate was achievable.

The specific problems facing the dyehouse were many and varied. The problems as they appeared in May 1992 at the beginning of the Dyehouse Project were as follows (see also **Appendix 1**: Dyehouse Investigation Summary for a preliminary report that was made at that time):

- The layout of the dyehouse had changed considerably since production first started in 1984. New machines had been added and the dyehouse offices, the colour kitchen and the shopfloor had been rearranged and were consequently more crowded than they had been originally designed for. Working conditions were difficult and inefficiencies resulted.

- The machinery in the dyehouse had been neglected due to very tight budgets during the previous Managing Director's rule. Machine failures contributed significantly to the high reject rate.

- The operators were not properly trained or supervised.

- The laboratory supervisor did not have the necessary technical or supervisory skills.

- The shift supervisors lacked the technical and supervisory skills needed to do their jobs properly.

- The Dyehouse Manager appeared to be lacking in the management skills necessary for the effective running of the dyehouse.

- The dyehouse lacked modern equipment (such as a computer-based recipe system, automated dyestuffs weighing scales, and a computer-based spectrophotometer for shade matching).

- The range of yarn qualities and shades had grown to such an extent that there were some 2000 shade/ yarn quality combinations that were required to be dyed by the dyehouse.

As the investigation continued, further problems came to light. These and the above will be discussed in more detail later in the text.

3. LITERATURE SURVEY AND DISCUSSION OF RELEVANT THEORY

3.1 Introduction

This section introduces the concept of productivity and its importance, particularly in the South African context. It goes on to describe the productivity improvement techniques that were used and their origins and relevance. The Cielab colour assessment system is also described as this was used extensively in the process investigation.

3.2 Definitions of Productivity

Mundel[3] defines productivity as "a ratio of outputs produced per unit of resources consumed (input), compared to a similar ratio from some base period". Thus, when more output is produced from the same quantity of resources, productivity improvement is said to have taken place. The Pocket Oxford Dictionary gives a more concise but equally useful definition: productivity is the "effectiveness of productive effort".

All productivity systems revolve around 'what is made (or done)' compared to 'what it took to make (or do) the thing'. For instance, a certain number of labour hours, a certain machine and a certain mass of steel may be required to make a table-top. The quantity of resources consumed reflects on how efficiently the table-top was made and can be used for comparison with past or future table-top manufacture, or with manufacture in another country. However efficiently the table-top is made, it is no good if nobody wants to buy it and all the resources expended are wasted. Thus, productivity improvement is useless unless it is applied effectively. Mundel makes this point strongly to the extent that the title of his book is 'Improving Productivity and Effectiveness'. The level at which measurements of productivity are made is also essential, as this example illustrates.

Multifactor, or total productivity, indicators take into account all the resources used for a particular output. Partial productivity indicators, such as labour or capital productivity, describe the use of one particular resource. Although these are very useful, Liebenberg warns that they can be dangerous as they present only part of the picture(4). Examples of partial indicators include: the labour productivity index which is a measure of output in terms of labour hours, and capital productivity which generally measures output in terms of the cost of fixed capital assets such as buildings, plant and machinery.

3.3 The Need for Productivity

In economic theory the 'economic motive' describes man's striving to satisfy a wide variety of needs. Man is limited, however, by his abilities and the resources available to him. In terms of an economy as a whole, the issue of just how to obtain the maximum satisfaction of needs with limited resources is known as the economic principle(5). Thus the need for 'productivity improvement' stems from a most basic instinct in man to improve his lot. In terms of its effectiveness in satisfying this need, Fabricant(6) states that "Productivity is *the* factor accounting for per capita output differences across the earth" (see also **Figure 1**).

Kendrick(7) lists the benefits of improved productivity as being:

- The conservation or saving in the use of scarce resources per unit of output.
- It helps to mitigate inflation by offsetting rising wage rates and other input prices.
- It increases international competitiveness.

The first of these has become particularly important in the wake of the fuel crisis in the 80's and the environmental problem that is reaching crisis proportions in the 90's. The issue of inflation is also extremely important: if wage rates increase and there is no corresponding increase in productivity, inflation will tend to result because the cost of the product must rise as the cost of the inputs rise. International competitiveness, too, is clearly an issue of vital importance in the modern world where a country's success is very much dependent on its ability to manage its imports and exports. The NPI's Productivity Focus 1991(8) presents some statistics which show an alarming lack of, and need for, productivity improvement in South Africa today. In **Figure 1** the per capita GDP in South Africa can be seen to have actually decreased since 1975. This can be attributed to factors of both political and economic nature, one of the most important being a lack of productivity improvement in industry.

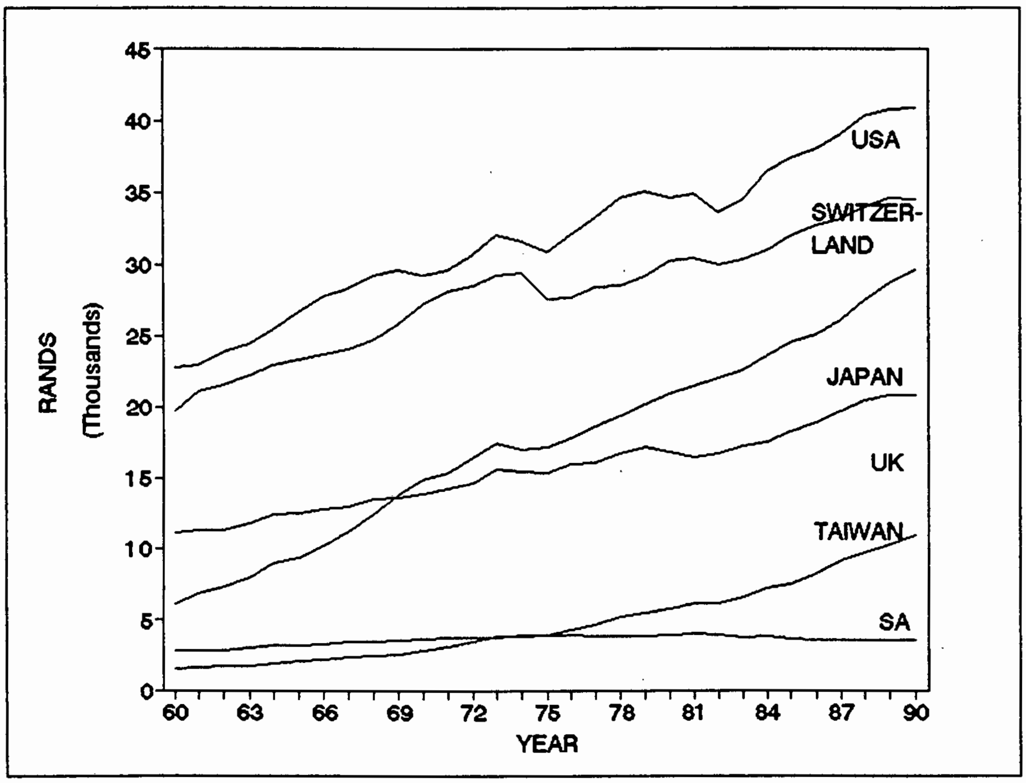

Figure 1: GDP per capita in 1985 prices and exchange rates

Figure 2 illustrates multifactor productivity in manufacturing. Once again the reasons for the trends in the curves are many and varied but what should be noted is that multifactor productivity actually declined between 1970 and 1990. The increase in the labour productivity index would appear to be due to the higher expenditure (as indicated by the drop in capital productivity) on capital. This increase does not offset the higher expenditure and, hence, the overall (multifactor) productivity factor has not improved.

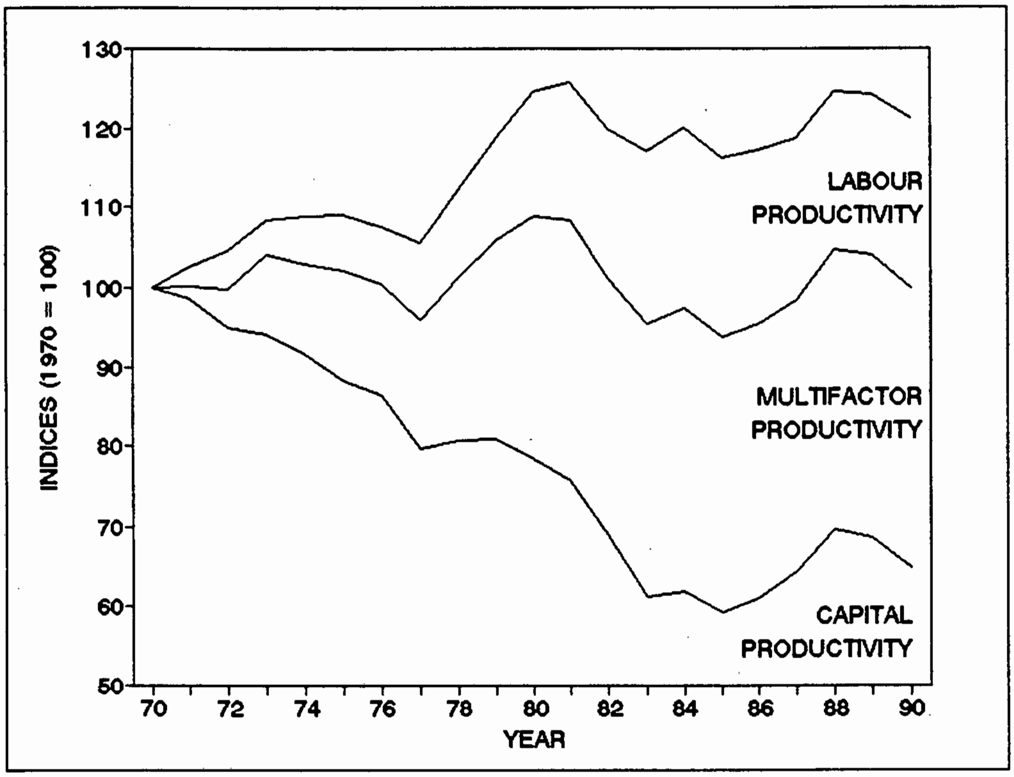

Figure 2: Multifactor productivity in manufacturing

Figure 3 shows labour productivity and earnings in the manufacturing sector in South Africa. Here can clearly be seen how real income has not increased despite soaring nominal earnings and inflation. Wage increases that are not accompanied by a corresponding increase in productivity ultimately will not result in improvement in real earnings in the long term.

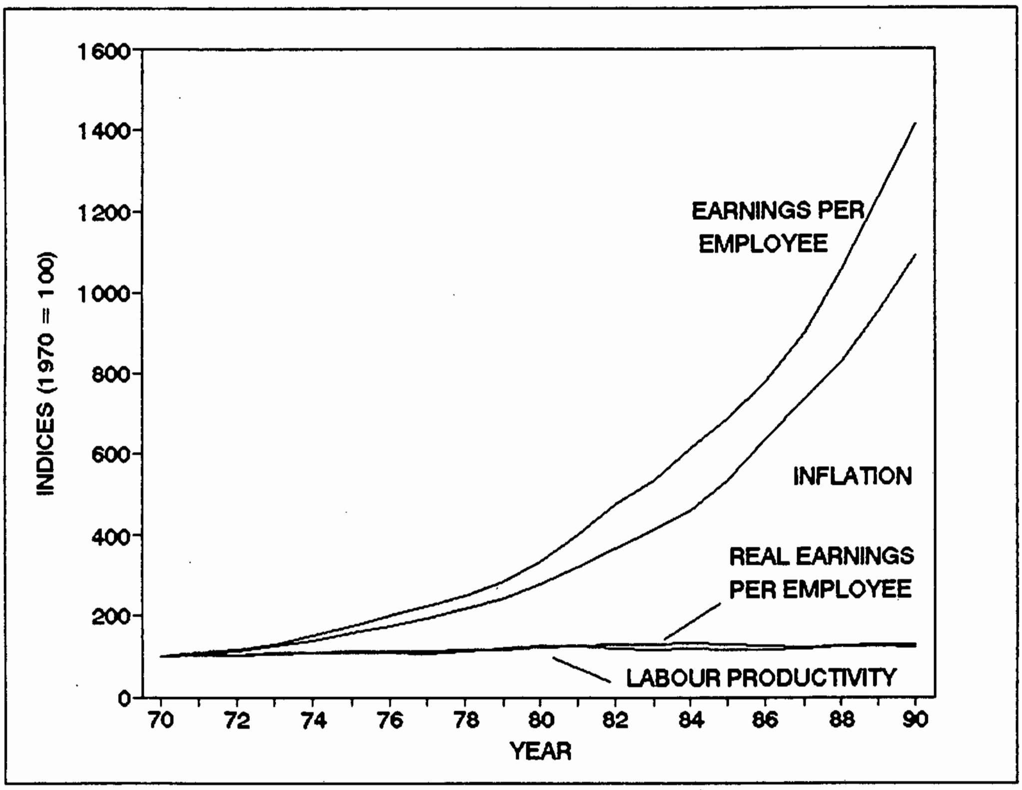

Figure 3: Labour productivity and earnings in manufacturing

The textiles industry has not fared as badly as the manufacturing sector as a whole. Between 1970 and 1989 overall annual increases in capital and labour productivity were registered, with the average annual multifactor productivity growth being 1.9% pa. During this period growth in real output in textiles was 1.8% pa and employment growth was -0.5%[8]. Thus output has been increasing to a small degree whilst employment has actually decreased. These figures indicate that the textiles industry has grown leaner but that the growth rate is still very low.

3.4 Quality as a Productivity Tool

In the 80's and 90's, the word quality has come to be treated almost with reverence, such has been the impact of the quality revolution in industry. The 'Quality Manifesto', for instance, has as its first declaration: " Quality is the key to pride, productivity and profitability. By addressing quality first, the others logically follow" [9].

Quality has very much supplanted Productivity as a buzzword in industry and business. But, in fact, quality improvement in all its guises is very much a form of productivity improvement. Deming [10] maintains that quality improvement is essential to productivity improvement and competitive advantage. Schonberger and Knod[15] support this by saying " Increasing quality does not mean that productivity will suffer...better quality is perhaps the best way to increase productivity!"

The Quality movement began after the Second World War. Its cause was spread by a small number of well known Quality 'Gurus' whose contribution will be briefly mentioned here. Deming can be considered to be the father of the quality movement and he began developing his ideas in the 50's. In his 14 points, he advocates: a commitment to constant improvement; the 'building in' of quality using statistical methods rather than 'inspecting it out'; putting the responsibility for quality back into the hands of management and workers and giving them the tools to do this; an emphasis on training and education; and an acknowledgement of the worker's right to pride of workmanship[10]. Juran identified that the majority of quality problems lie within the control of management. In order to resolve these problems he recommended to identify the critical issues and specific action based on this analysis. He defined quality management in terms of three phases: planning, control and improvement. Feigenbaum was the author of the concept of Total Quality Control. In this, he brought to prominence the notion that quality control revolves around the identification and satisfaction of the customer's requirements. Ishikawa promoted the use of advanced statistical control. Probably his most visible contribution to quality in the Western world was his assertion that there is not enough use of 'nonspecialists' in quality improvement. He coined the term Company Wide Quality Control to make this distinction between his ideas and those of TQC.

Finally, Crosby(16) is particularly well known for his contribution to the popular culture of quality with slogans such as "Do it right first time!" and "Zero defects".

Another area where quality has been in the limelight has been that of accreditatation to a particular standard. Examples of these standards include SABS 0157, BS 5750 and ISO 9000.
These systems are relatively quickly implemented and do not necessarily lead to productivity improvements. Beard(11) states that "It is important to note that SABS 0157 does not require the use of techniques which make quality a strategic weapon". The essential difference between a quality system for accreditation purposes and a system such as TQM/TQC is highlighted by Daniels(12): "BS 5750 is a procedurally-based approach; it is always easier to change procedures than to change the culture of an organisation".

Despite its limited use as a productivity improvement system SABS 0157/ ISO 9000(18) nevertheless advocates some important principles, one of which was used as the basis for the process investigation in Section 4.3 of this project. The code states that: " The supplier shall identify and plan the production...processes which directly affect quality and ensure that these processes are carried out under controlled conditions".

One of the Quality tools used in this report is Pareto analysis. It is a simple method of separating the important few (say, reasons for quality defects) from the unimportant many. For example, these reasons for quality defects would be identified; the frequency of defects attributable to each reason for a time period would be recorded; and a bar chart would be plotted with the most frequently found factor being plotted first and the second most frequent next, etc. From this a strategy of 'attack' could be developed with focus being on the most important factors. Such analysis usually leads to an investigation of causes and, often, further analysis.

3.5 Work Study as a Productivity Tool

The International Labour Office in its 'Introduction to Work Study'[13] says of work study: "It is one of the most penetrating tools of investigation available to management". That it is an important investigative tool still holds true today and most contemporary production and operations management texts acknowledge its value as a work improvement tool.

Work study evolved from the scientific management movement pioneered by Taylor and the Gilbreths at the beginning of this century. Scientific management is essentially the use of systematic procedures such as method study and graphic models such as process flow charts for improving manufacturing productivity.

Work study consists of two elements - method study and work measurement. Work measurement is concerned with standard times and will not be discussed as it has not been used in this project. Method study is defined as: "The systematic recording, analysis and critical examination of existing and proposed ways of doing work and the development and application of easier and more effective methods"[13]. The basic procedures of method study are to : define the problem; obtain all the relevant facts; examine the facts critically but impartially; consider the alternatives and decide which to follow; act on one of the alternatives and then follow up after the implementation.

A process flow chart sets out a sequence of the flow of work or of a product through a factory or department by recording all the events in the sequence using the operation, transport, delay, inspection and storage symbols. Starr[14] commends the use of process flow diagrams for optimising plant layout by saying: "... resolution of the plant layout problem is considerably expedited by the use of flow process layout diagrams".

3.6 The Cielab Colour Assessment System

This section describes the theory for the Cielab Colour Assessment System which is applied in Section 4.5.4.

The system is used for measuring the colour of a yarn sample relative to that of a master. It consists of a spectrophotometer and a computer with the appropriate software. The spectrophotometer is used to measure certain properties associated with the colour of the test items. The computer then translates these into the Cielab values of Da, Db and Dl. The master is assigned Da, Db and Dl values of zero. Thus Da represents the redness/ greenness of the sample compared to the master; Db the yellowness/ blueness; and Dl the lightness/ darkness. The overall value DE gives the magnitude of the Cielab colour difference between the master and the sample. It is related to the Da, Db and Dl components in the following way:

$$DE = (Da^2 + Db^2 + Dl^2)^{1/2}$$

It should be noted that the DE value is a scaler quantity and does not fully describe the colour difference being assessed: the components of DE also need to be examined.

A DE value of 0,8 corresponds to a 4 - 5 difference on the grey scale. These difference ratings are generally regarded as the limits within which shades are considered to be the same (although different customers may have different requirements).

4. USING QUALITY AS A PRODUCTIVITY TOOL

4.1 Introduction

Before taking action on the causes of the 10% or so rejects in the dyehouse it was first necessary to establish what exactly were the causes and which were the most important. To this end an assessment of documented reject data was made, the data was analysed and the results were presented in the form of statistics and Pareto Charts. In addition, the dyeing process was investigated according to the principle that all operations directly affecting quality must be carried out under controlled conditions. From these investigations certain conclusions and recommendations were made. As a result of these, further process investigations were performed and these are described.

4.2 Investigation of Historical Data

4.2.1 Analysis of Reject Data by Machine

In the Dyehouse there are ten dyemachines with capacities ranging from 10 kilograms to 1050 kilograms. The smaller machines tend to be less sophisticated and receive less attention than the big machines. The failure rate per machine was assessed from historical data in order to:

- Identify any trends or patterns that might be occurring in terms of the workload and success rate of the different dye machines.
- Identify which machines were responsible for the most problems and in which area the most attention should be focused.

Appendix 4 (Analysis of reject data by machine) contains the graphs from this analysis. It is sufficient here to summarise the findings:

- On average the small machines (S1, S2, 1, 2 and 4) were 45% busier than the other machines.
- The large machines (5, 6, 7, 8) were responsible for 82% of the total kilograms rejected.
- The average reject rate by kilograms was 15.2% for the small machines and 9.3% for the large machines.

It can be seen that, although the larger machines tend to perform better, they are still responsible for the bulk of the reject kilograms. The reasons why the reject rate was higher on the small machines were found to be:

- More care and attention was taken by production personnel when dyeing with the larger machines.
- The dyehouse management tended to take more risks when submitting for shade acceptance on the smaller batches produced by the smaller machines.
- The smaller machines were less automated and in poorer conditions than the big machines.

4.2.2 The Basis for the Pareto Analysis
(see also **Figures 4** and **5**)

A Pareto analysis was performed to investigate the causes of reject yarn. The analysis was based on data from the Reject Yarn Control records for the period for the year September 1991 - August 1992 (see **Appendix 3**) . These only record rejects and the reasons for the rejects when new yarn has to be ordered for redyeing (frequently yarn that has been rejected is overdyed to a dark shade). Unfortunately there was no historical data which recorded the cause of rejects for every rejected batch. I do believe that it is a fairly representative sample of reject yarn. There are, nevertheless, a number of things to note:

- The cause of the reject yarn is based on what was reported by the Dyehouse Manager. Frequently they were educated guesses (eg 'looks like a machine fault') and there is very likely to be some unintentional bias in these reports. The VALUE column in **Appendix 3** gives an indication of the degree of certainty of each investigation. The overall degree of certainty as to causes was found to be 79%. In other words, for 21% of the time it is not known what the problem is. **Figure 4** (Pareto Chart: % Reject Kilograms by Problem) is more accurate in that it classifies rejects by what was **observed**, as opposed to what was **interpreted as being the cause** (**Figure 5**: Pareto Chart: % Reject Kilograms by Cause).

- 8.9% of the reject kilograms in the analysis were due to 'difficult shades'. These were all light shades. When an error is made on a light shade there is less chance of it being 'fixed': the spoiled yarn is generally overdyed and new yarn called for. Thus this value of 8.9% will be higher in the analysis than in reality.

- This Reject Yarn Control data is by kilogram and not by lot because frequently it is not the whole lot that is rejected but only a few cones. If the analysis could have been made with reject lots as the basis the figures would have been slightly different, particularly on the smaller percentages. For instance, dissolving errors account for 5.1% of the reject kilograms analysed but these kilograms represent only two reject lots (1.2% of the total lots recorded).

4.2.3 Discussion of Figure 4: % Reject kgs by Problem

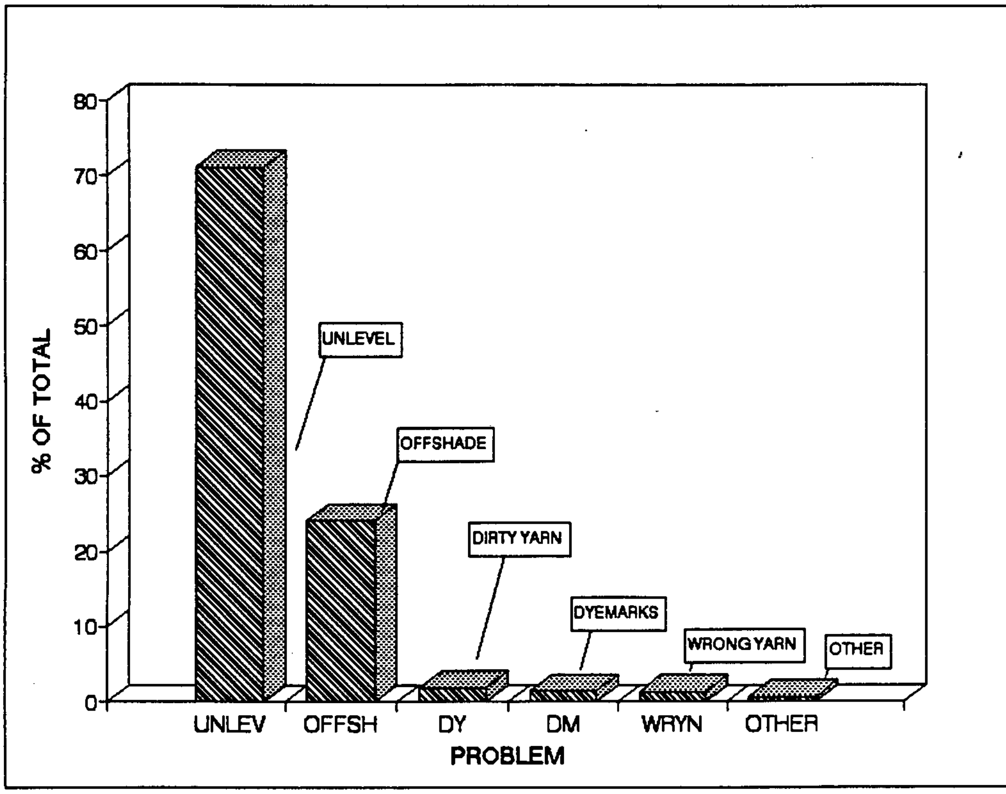

Figure 4: Pareto chart (% reject kgs by problem)

Unlevel: 71.1%

The causes of unlevelness were mainly problems which occur during the actual dyeing process and tended to be due to dye liquor flow, yarn and machine faults (examples include 'cones not properly pressed' and 'machine pump stopped' - perusal of the individual cases reported in **Appendix** 3 gives a clearer idea of this).

There is far less certainty about the causes of unlevelness (75% certainty according the VALUE column in **Appendix** 3) than about the causes of offshade (90% certainty). This finding tends to support the recommendation in Section 4.3 for the installation of temperature recording machines, because there is clearly a need to know more about what happens in the dyepot during dyeing.

Offshade: 24.0%
These are generally related to the use of dyestuffs (colour weighing errors, light shades and bad recipes).

Dirty yarn: 1.7%
These are generally due to dirt on the yarn from processes previous to the dyehouse.

Dyemarks: 1.3%
These are due to bad handling and unclean equipment.

Wrong yarn: 1.2%
This is wrong quality yarn or mixed yarn as supplied from the yarn store.

Figure 5 below classifies the Reject Yarn Control data according to what was interpreted by dyehouse personnel as being the cause of the reject.

4.2.4 Discussion of Figure 5: % Reject Kilograms by Cause

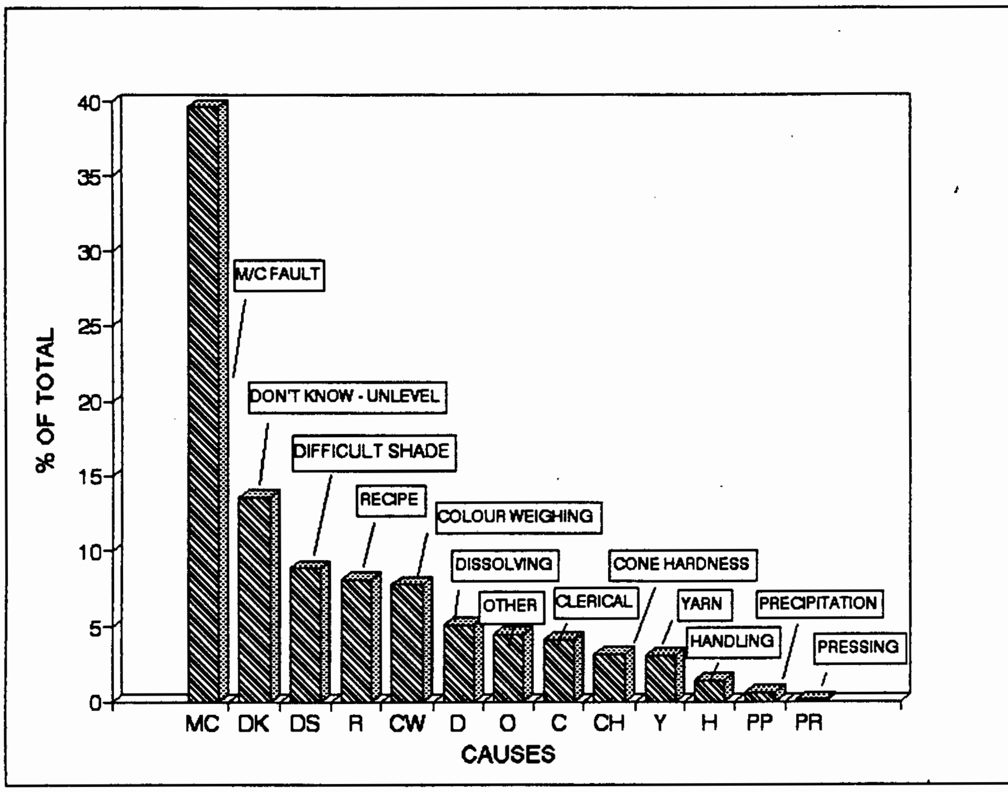

Figure 5: Pareto chart (% reject kilograms by cause)

Machine fault: 39.6%

A frequency chart of these machine faults is shown in **Figure 6** (Reject Lots due to Machine Breakdown). Although this figure of 39.6% is very high it can be seen from **Figure 6** that the position improved markedly during the year. This is due to the major improvement in machine maintenance that took place over this period (see Section 6.10 Machine Maintenance Improvement). This percentage is also high because it contains a high proportion of big (up to 1000 kilogram) lots. This is because the Dyehouse personnel tend to be more careful with the bigger lots. If they get the ingredients right, one of the most likely things that can go wrong is machine breakdown during the dyeing process.

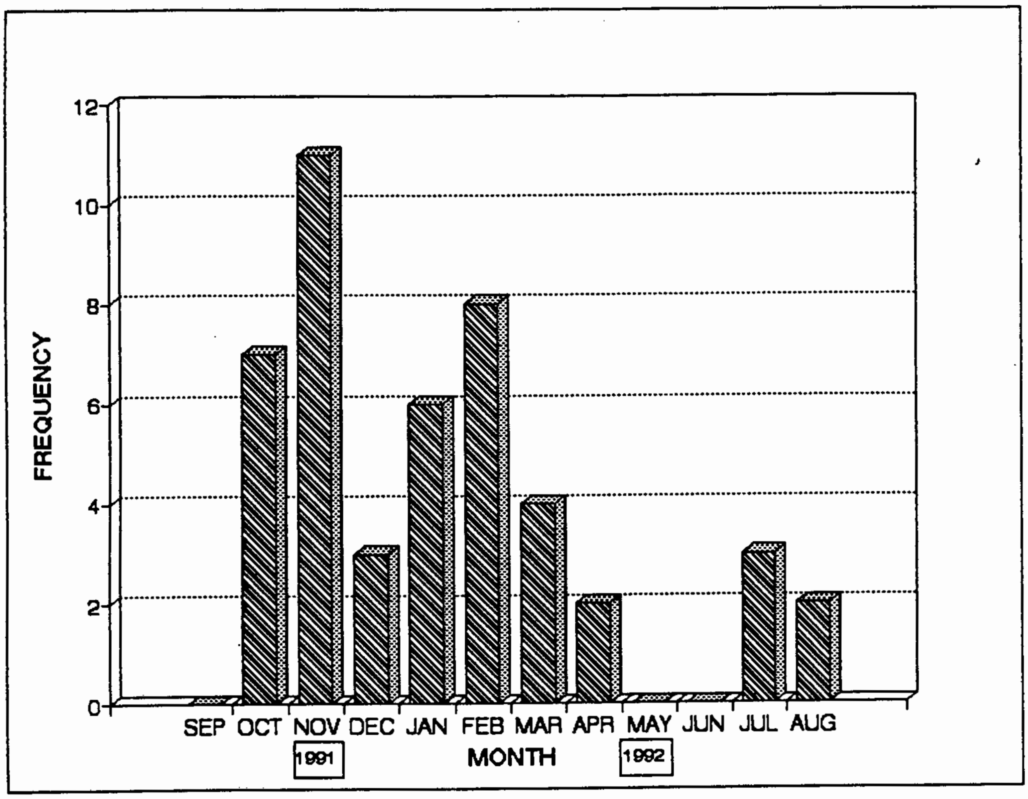

Figure 6: Reject lots due to machine breakdown

Don't know - unlevel: 13.6%
This is very significant because unlevelness tends to be a problem with what actually happens in the dyepot such as temperature or flow or the way the yarn is pressed. When yarn comes out unlevel and no immediate reason for this is apparent, it is often supposed that the fault is to do with the machine. Such uncertainty should not be acceptable in such an expensive operation as the dyehouse.

Difficult shade: 8.9%
As stated previously this percentage is probably disproportionately high because yarn is often required when redyeing light shades. These shades are amongst the hardest to

dye because they are extremely susceptible to contamination and are not easily corrected by additions. The dyeing of light shades can only really improve under tighter process control conditions.

Recipe: 8.1%

These are bad recipes where the recipe is not correct and needs to be sent either the dyehouse lab or the dyestuff supplier for correction.

Colour weighing: 7.8%

Colour weighing errors are surprising low considering the disorganised conditions, the lack of supervision and the opportunities for human error in the colour kitchen.

Dissolving errors: 5.1%

This percentage is probably disproportionately high because it is due to only two lots, one being of 1088 kilograms. Once again, successful dissolving depends very much on the diligence of the colour weigher. He must ensure that the dissolving water is at the right temperature and that the liquor is only released into the dyepot when all the dyestuffs are dissolved.

Other: 4.5%

These are generally due to human error and are not easily categorised elsewhere. They include: ' loose spindles', 'pot was only half full' ,' shade planned wrong' , 'operator put in only half the yarn', 'Maitland did not specify the requirements clearly', etc.

Clerical: 4.2%

These result from recipes which are either inaccurately written or are mis-read.

Yarn: 3.1%

These errors include 'wrong yarn from yarn store', ' twisted by error', 'mixed, dirty yarn'. These are faults external to the dyehouse but which have slipped through the yarnstore and dyehouse receiving inspection procedures.

Handling:1.4%
This is generally dyespots and dyemarks due to bad handling and unclean equipment. It is directly related to good housekeeping practice.

4.3 Preliminary Investigation of the Process

4.3.1 Introduction

The reject figures that have been discussed up till now are for yarn that is not accepted by the Maitland plant ('% reject lots or kilograms'). Before the yarn or samples are sent to Maitland the yarn may well have been corrected by the dyehouse. Records exist of the redyes and relevels made by the dyehouse before submission to Maitland (see Section 7.2.4). The indicator '% reject, redyed, and relevelled lots' totals all the lots where yarn is taken out of the dyepot and is found to be not correct. It is then either redyed to correct it or it is overdyed and a new batch of yarn is dyed in its place. It is thus a more basic measure of the success of the dyeing process than '% reject lots or kilograms'. The average % reject, redyed, and relevelled lots was 21.5% for the first half of 1992 (see also Section 7.2.4).

This high figure, in combination with the results of the Pareto analysis (particularly the 71.1% unlevelness factor), led to my belief that improvements in the process were absolutely critical to the reduction of the reject rate. In addition, the attitude in the dyehouse towards dyeing was that it was an 'art' and that one could not necessarily control what came out of the dyepots. I felt that this attitude was fundamentally incorrect and was not conducive to the process of ongoing improvement required to change such a situation.

Successful dyeing depends on the control of the variables that make up the dyeing process. If all of these could be completely controlled, I believed that there would be no or negligible rejects or additions. In practice this would be very difficult to achieve but considerable improvements could be made by tightening up this control.

For these reasons it was decided to perform an investigation into the variables that affect the dyeing process.

4.3.2 Investigation

Appendix 5 contains the details of the investigation. What is described in this section are the variables that were investigated, the recommendations made and the actions taken on the recommendations.

Water quality

It was recommended that: acceptable water hardness levels be defined; water hardness levels be displayed daily; water samples be sent for lab analysis on a regular basis; the water softener problems be investigated and resolved. All these recommendations were carried out. The water softeners, in particular, were not in good condition: the one had to be repaired, the other two serviced and a flow meter replaced.

Dyestuffs and chemical quality

It was recommended that: 20 samples of commonly used dyestuffs and 10 samples of commonly used chemicals from opened containers be sent back to their manufacturers for analysis. 10 dyestuff samples were sent off to be tested for strength and purity. They were all found to be in satisfactory condition.

pH

It was recommended that the pH meter be calibrated at regular intervals. This now done on a daily basis.

The dyepot operator's procedures

It was recommended that the operators be trained on the basic aspects of their machines, what can go wrong with them and what the symptoms of these faults are. A four hour course for machine operators on how their machines work and what can go wrong with them was developed and run as a result of this.

The dyepot pressure

It was questioned whether the wide variations in dyepot pressures during dyeing would affect the quality of the product. However, Dr F Barkhuizen of the South African Wool and Textiles Research Institute indicated that this was not the case: the main function of pressure in the dyepot was to enable the dyepot temperature to rise above 100 degrees C.

The temperature cycle for the lot

It was recommended that temperature cycle recording charts be purchased for each dye machine. These were used on the machines in the past but had since fallen into disrepair. These would serve to:

- Provide an historical record of the exact temperature cycle that took place. This could be checked for correctness.
- Indicate that other machine faults such as flow or pressure problems have taken place. These could be seen as discontinuities (squiggles) on the graphs as the controller is forced to compensate for changing conditions.
- Reduce the area of uncertainty concerning the causes of unsatisfactory dyeing.
- Provide a record of machine performance in order to pick up indications of future machine problems.

In response to this the Atlantis factory management undertook to refurbish and re-install the old temperature recording charts that had fallen into disrepair.

Machine variability

One machine may be different (eg different size, different design) to another resulting in different dyeing characteristics. It was recommended that documented trials be performed using the same yarn, recipe etc, but on different machines in order to establish the nature of the variations that occur on each. Initially tests should be performed on sister machines to ensure that the same result occurs on each. If they did not then the reasons why not would be investigated.

The liquor ratio for the lot

This is the ratio of yarn to liquor in the dyepot. Sometimes a lot is dyed with a pot that is less than full of yarn and sometimes with the pot full. It was suggested that documented trials be performed using the same machine, yarn type, recipe etc, but with different ratios of yarn to liquor in order to establish the nature of the variations that occur. From this it could be established what was an acceptable or not acceptable liquor ratio and what compensations could be made. The very least that it could serve would be to put some focus on an area that was receiving very little attention.

4.4 Conclusions and Recommendations from the Preliminary Investigations

The overall **conclusions** submitted to management were as follows:

- The reasons for reject lots are neither well enough understood nor carefully enough recorded. This can be attributed to:
  - Lack of a system to formally investigate and record each reject lot.
  - Lack of process monitoring equipment.
  - Lack of information on and control of the critical process variables.

It was recommended that the system for investigating and recording each reject lot be maintained. It was not, but it is now apparently being revived under the new TQM drive. As mentioned, a commitment to install temperature control charts was made.

- The indicator '% Reject, redyed and relevelled lots' is a more important indicator of how successful the process is than '% Reject lots'.

It was recommended that this should be watched very closely. It was graphed and monitored and is discussed in the Results Section 7.2.4.

- There are clear signs (**Figure 6:** Reject Lots due to Machine Breakdown) that attention given to improving the maintenance of the dyehouse machines is paying off. This should make a significant contribution to reducing the reject rate in the long term.

- The one aspect of the dyehouse that is critical to the reject rate but which has not received as much attention as it deserves is the process itself. Work is required to tighten up the control of process variables such as water hardness, dyestuff contamination and absorbtion etc, machine temperature pressure and flow, variations from machine to machine, liquor ratio and pH meter calibration.

These problems were addressed as discussed in the previous section.

- The focus in the dyehouse tends to be on CORRECTION rather than on GETTING THE PROCESS RIGHT in the first place. There is a perception that dyeing is an 'art' and that the product of dyeing is not necessarily a direct result of the process.

This conclusion is addressed in the next section.

4.5 Further Investigation of the Process

4.5.1 Objectives

As a result of the preliminary investigation described in Section 4.3 and the recommendations made in Section 4.4, it was found necessary to further investigate the dyeing process. The objectives were as follows:

- To perform a detailed and systematic investigation of the dyeing process in terms of process and quality control.
- To perform dyeing trials to prove that successful dyeing depends on the control of process variables such as: yarn weighing, pressing and moisture content, recipe calculation, dyestuff and chemical dissolving, pH, water hardness, machine and machine operator performance, and testing sample hanks against the master.
- To investigate the effects of dyeing with the dyepots only partially (one third and two thirds full) in order to test the variations of shade with liquor ratio.
- To investigate the possibility that different dyeing machines have different dyeing characteristics.
- To put focus on, and stimulate some interest in, the control of the dyeing process.
- To dispel the perception in the dyehouse that dyeing is an 'art' and that the product of dyeing is not necessarily a direct result of the process.

4.5.2 Experimental Procedure

It was envisaged that five sets of trials be performed. Each set would involve dyeing a trial shot in Machine 1 and also in Machine 2. These would be performed at the same time in order that certain variables such as water hardness, boiler steam availability, machine speed, the machine operator and colour weigher would be the same. These are sister machines and are nearly identical. The first three sets would be to prove repeatability both from shot to shot and from machine to machine with the same number of cones (24), the same recipe and the same yarn type. Two more trial sets would be performed in order to investigate the problem of shade variations with liquor ratio. One set would be with the dyepots two thirds full (16 cones) and the second with the dyepots one third (8 cones) full.

In each case 47/1 Trevira/Wool yarn would be dyed to khaki shade 1519. 47/1 Trevira/Wool yarn is the most common yarn type and recipe 1519 is a common recipe. This is definitely a limitation of this experiment in that only one yarn type and one recipe was tested. However, this was the only practical approach and the trials certainly do represent very typical dyelots.

An important aspect of the trials was that each stage of the process would be scrutinised. The preliminary investigation discussed in Section 4.3 had involved checking the main process variables. It had not involved observing each stage of the dyeing operation. In this investigation, each stage of each trial was observed both to ensure that the stages were performed correctly and to identify any actions or processes that might affect the quality of the product.

4.5.3 Work Performed

What actually took place was not as planned. The following trials were performed:

TRIAL SET	DATE	MACHINE 1	MACHINE 2
1	10/11/92	TRIAL 1 (24 CONES)	TRIAL 2 (24 CONES)
2	24/11/92	TRIAL 3 (24 CONES)	TRIAL 4 (24 CONES)
3	30/11/92	TRIAL 5 (24 CONES)	
4	14/12/92	TRIAL 6 (16 CONES)	
5	14/12/92	TRIAL 7 (8 CONES)	

Unfortunately, the P30 temperature controller on Machine 2 was removed for servicing over the shutdown before all tests were completed and they were unable to be completed at a later date. Thus Trial Sets 3,4 and 5 were performed on Machine 1 only.

Appendix 6 contains the written observations and **Appendix 7** the tabled observations for this investigation.

4.5.4 Results

The sample hanks produced from the dyeing trials were analysed on a colour matching computer according to the Cielab system for D65 lighting.

Unfortunately Trial 7 had not been completed when the colour matching was performed and this was not possible to do at a later date because of the Christmas shutdown. It can be reported that the Trial 7 hank was much lighter than the other samples - by some 30% compared to the Trial 2 'standard' according to the estimate of the Dyehouse Manager.

Figure 7 plots the relative colour difference between the different trial samples (Da and Db); **Figure 8** plots the relative lightness (Dl); and **Figure 9** plots the overall colour and light difference (DE).

4.5.5 Discussion

Discussion of Results:

Figure 7: colour difference test results (Da and Db)
If the trials had gone perfectly **Figure 7** should have been as follows:

- Trials 1 to 5 should all have been grouped together. This is because they were the same sized batches under identical conditions as far as possible.
- Trial 6 would probably be different: the dyestuff concentration would be lower (same water volume, less dyestuff); and the dye liquor flow characteristics in the dyepot would be different because one of the three spindles would be blanked off allowing dye liquor to flow through only two of the spindles. Thus the flow rate would be higher but the concentration lower.
- The master itself should have been grouped right in the centre of Trials 1 to 5. If it was not, it would mean either that the master was not the correct shade or that the recipe used to dye the master was not the same as that used for the samples.

It can be seen that Trials 1 to 5 were grouped together within an area of not more than 0,3 on the Cielab difference scale. (although, of course, the lightness component of Delta E has not yet been taken into account).

Trial 6 can be seen to be to be much greener-bluer whilst the master was much redder-bluer. It is possible, too, that the computer read the master differently because it was wound on a cone whereas the hanks were loosely hanging and their strands were more parallel than those on the cones.

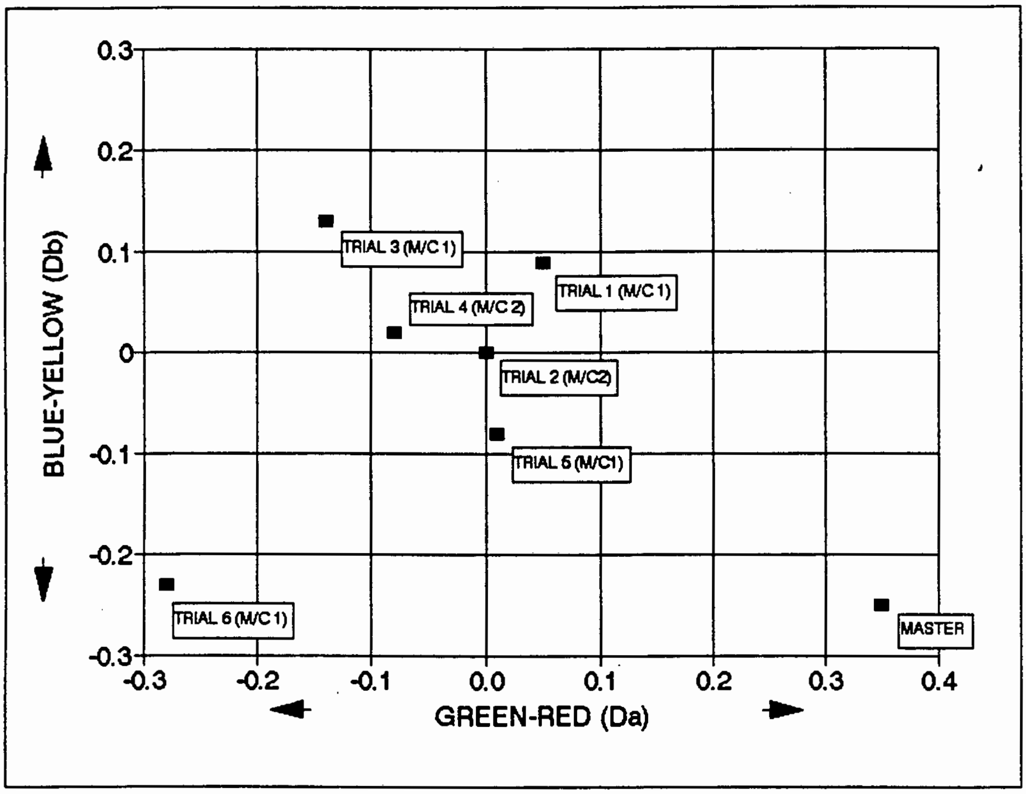

Figure 7: colour difference test results (Da and Db)

Figure 8: colour difference test results (Dl)

Ideally on this graph the Trials 1 to 5 would be very similar in lightness and Trial 6 (the partial load trial) would probably be lighter. If anything, the master would be lighter because it is older and possibly somewhat faded.

As it turned out Trial 1 was a lot darker than the others. I have no explanation for this. All of the other values lie within a Cielab range of 0,7 which is a fairly close grouping.

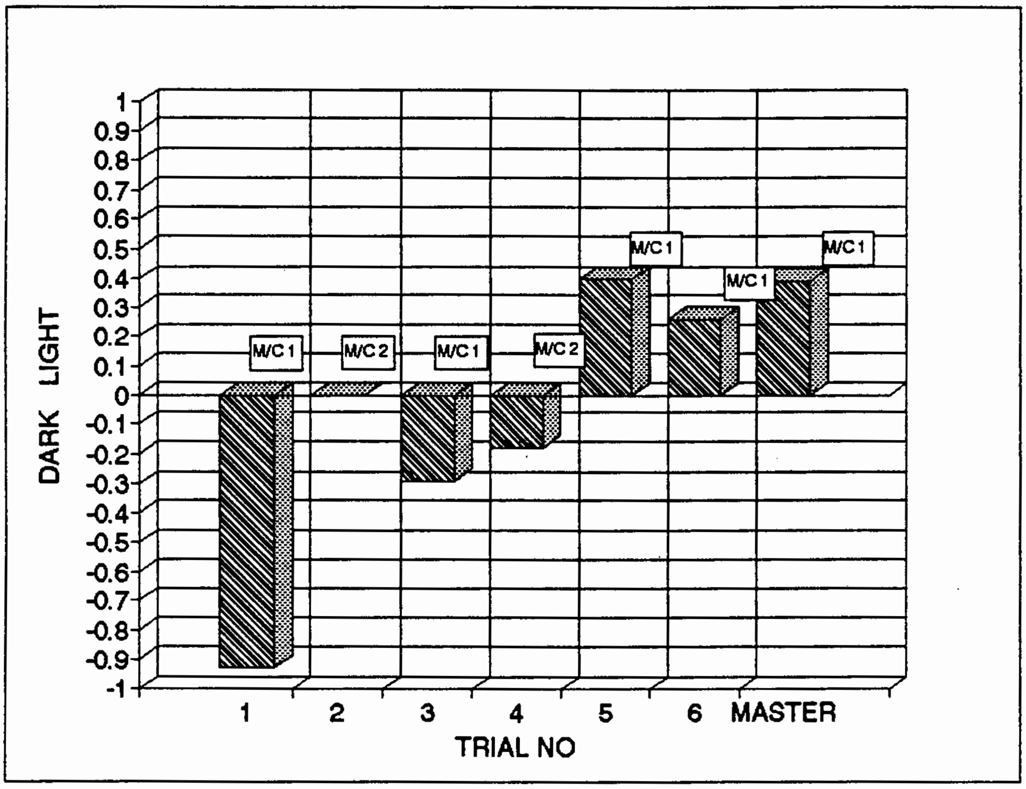

Figure 8: colour difference test results (Dl)

Figure 9: colour difference test results (De)
Ideally the values for Trials 1 - 5 would be similar and close to the ideal of zero. If the master was perfect it would also have a value of zero. The trial 6 value would be different, the extent of the difference being what is under investigation.

In fact all the values lie within a Delta E range of 0,9 which is slightly more than the acceptable 4 - 5 difference on the grey scale. The values for Machine 2 (Trials 2 and 4) seem to be lower than for the equivalent trials on Machine 1 (Trials 1, 3 and 5). The difference between the two (0,5 on average) is small enough to say that, practically speaking, there is no difference in the dyeing characteristics of the two machines.

Figure 9 does not prove that dyeing partially loaded machines affects the shade of the product. However, **Figure 7** indicates that this is the case and the Trial 7 result (30% lighter - see Section 4.5.4) certainly confirms this.

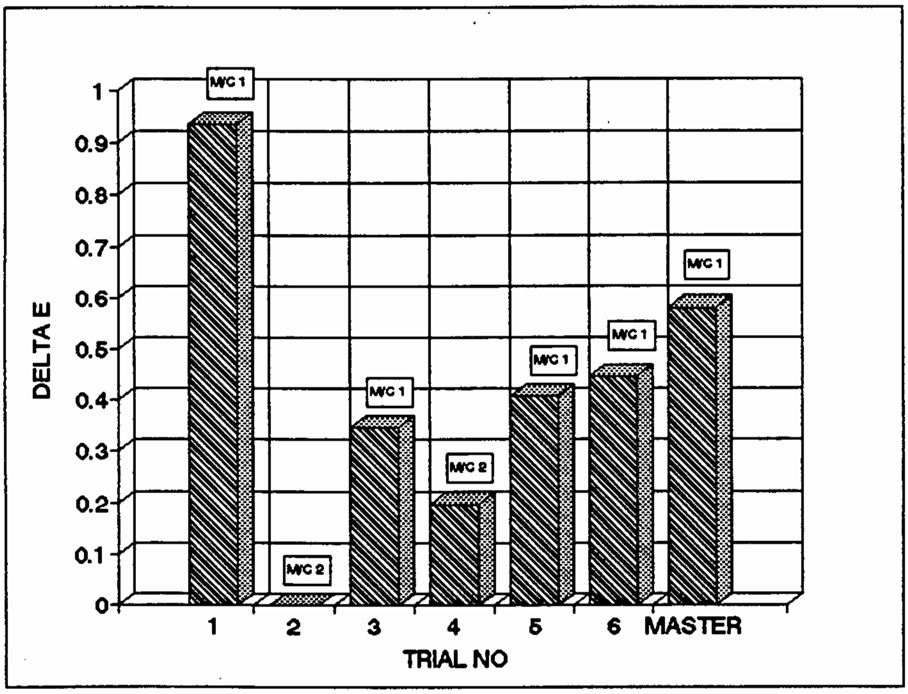

Figure 9: colour difference test results (De)

Errors that are 'Built Into' the Dyeing Procedure

These are detailed in **Appendix 6** but will be briefly reviewed here. These are not mistakes but are the small measurement and operational errors that appear as part of the everyday procedure. The errors given in the table are estimates based on what was calculated from the trials and also from the 'error potential' of the measuring system.

PROCEDURE	**MAX ERROR(%)**
YARN WEIGHING	1,5
YARN MOISTURE CONTENT	1,5
RECIPE CALC ROUNDING ERROR	1,0
DYESTUFF WEIGHING ERROR	0,2
TOTAL	4,2%

This maximum error of some 4% is very small when one takes into account the fact that redyes, etc are so common. These are associated with recipe strength and would only affect lightness. This area should not be ignored but is not the most important of the dyehouse's quality problem.

Things that can go Wrong in the Process

This list is based on the observations made during the trials which are discussed in detail in **Appendix 6** but will be summarised here for the purpose of this discussion:

a) The Yarnstore Supervisor can calculate the wrong yarn weight and the Production Coordinator does not check this.

b) The machine operator can press the yarn to the wrong height.

c) The machine operator can fail to get the pH right.

d) Various people can read and write recipe details incorrectly.

e) Packets of weighed dyestuffs and chemicals can get mixed up.

f) Operators can fail to check that the flow reversal or machine speeds are correct.

g) Colour weighers can use the wrong chemicals or even omit chemicals that are not in stock.

h) Colour weighers can weigh masses instead of measure volumes.

i) Sample hanks can be rinsed or not, affecting the matching with the master.

j) Operators can fail to notice or report machine problems during dyeing.

It should be mentioned that items d) and h) should be mostly resolved by the new recipe/ weighing system (see Section 6.5).

Errors and what Can be done about Them

The two areas where improvements can be made are those of equipment and people.

In terms of equipment, an integrated machine, planning, monitoring, controlling and fault diagnosing system could automate the process considerably and eliminate a number of potential operator errors as well as vastly improve fault diagnosis and detection. This option is a logical one but will require considerable capital outlay.

In the meantime, it is necessary to organise the workforce so that they can best monitor and control the process. From the discussion above, it can be seen that correct dyeing depends very much on the discretion of the machine operators and the colour weighers. It also must be borne in mind that the operational errors witnessed occurred when the operators were 'on their best behaviour', both because they were being watched, and because they had recently passed through a major training program and were anxious to show what they had learnt.

What needs to be improved is the sense of responsibility of the workers and their ability to understand the processes and importance of the things for which they are responsible. A number of machine operators have an educational standard of only Standard 6. This is somewhat low given these needs and the sophistication of the dyehouse operation. Because of this, a system has been put into place which will raise the education level of machine operators to Standard 8, colour weighers to Standard 10 and supervisors to Standard 10. This will only take effect when new personnel are recruited and is thus a medium to long term measure. Job descriptions have also been specified for all dyehouse personnel so that roles are clearly defined, and that the correct match can be made when recruiting new personnel.

The shift supervisors currently employed in the dyehouse are of mediocre quality in terms of reliability, supervisory skills and decision-making ability. However, good dyehouse shift supervisors are difficult to find. In order to fill this need, the Training and Development Manager has specified a plan to develop good supervisors from operator level.

The performance of the Dyehouse Manager and Assistant Manager must also come under scrutiny. The Assistant Manager is considered barely satisfactory for his job and has been warned that he will be replaced if his performance does not improve. The Dyehouse Manager himself is very competent technically but appears to lack management ability in motivating, organising and controlling his department. Part of the problem is that his job is a difficult one and he spends much of his time on technical matters. His job is being made easier by the improvement in the conditions and systems in the dyehouse (for example, the appointment of the new Lab Manager - see also Section 6). It remains to be seen how effectively he will perform under these new conditions. He has already been sent on a good management course. Given that management training is a developmental process, it is suggested that he also be sent on a good quality management course to educate him on the need for preventative, as opposed to, corrective action.

Benefits can also be gained from reorganising/ motivating the dyehouse personnel. The TQM management system is already being introduced into the company. If it is successfully implemented it should significantly increase the participation and involvement of the dyehouse personnel.

4.5.6 Conclusions from the Further Investigations

- Shade variations for the five trials where repeatability was being tested were very small indicating that:
  - this shade can be repeatably dyed to the same shade.
  - it is machine faults and human error that give rise to inconsistencies and not 'Gremlins inside the machines'.

Although this conclusion is drawn for only one shade/ yarn type it is applicable to the majority of cases because the most common yarn type and a typical recipe were used.

- Shade variations for these five trials between Machine 1 and Machine 2 were very small indicating that there is very little difference in the dyeing characteristics of these two machines. Whether or not this would apply to all of the dye machines needs to be investigated further.

- The shade variation on the 1/3 loaded dyepot was substantial (estimated at 30%) and small but significant on the 2/3 loaded dyepot. More trials would have been desirable but it can still be concluded that dyeing with partly loaded dyepots should be avoided as far as possible.

- Although the dyeing process is a complicated one, there are **no major obstacles to successful first-time dyeing and dyeing is not an 'art'**. What is required is methodical, responsible monitoring and control of the numerous process variables and a commitment to eliminating causes of defects. The systems in place for monitoring and control are adequate but rely very much on the human factor. The commitment to eliminating causes of defects is still lacking.

- A necessary improvement in the overall ability of the dyehouse operators and supervisors should take place in the medium term as the effect of a new employment policy is felt. This policy demands higher minimum education levels and includes a plan to develop good supervisors from operator level.

- The dyehouse manager is good technically but appears to lack management ability in a position which requires strong management skills. His position should be made easier by improvements in the conditions and systems in the dyehouse. It remains to be seen how effectively he will perform under these new conditions.

- The dyeing process should be automated as far as possible to minimise the chances of human error. Integrated monitoring, controlling and fault diagnosing systems for the dye machines are available but are costly. Such systems will become a necessity in the long term with increasing demands for manufacturing efficiency and they should be considered with this in mind.

- The use of a colour matching computer produces relatively objective results in a way that visual matching can never do. It provides an unambiguous basis from which decisions and improvements can be made. Given the enormous expenditure on dyestuffs and the high proportion of time spent on shade matching and recipe prediction, the purchase of a colour matching computer would be an important investment. The existing computer performs shade matching but not recipe prediction.

4.5.7 Recommendations from the Further Investigations

The following recommendations were submitted to management:

- The yarn pressing height system should be revamped so that the different yarns can be pressed to the correct height. Acetic acid and Ammonia should be 'on tap' in the dyehouse so that operators can properly perform their job of adjusting the pH.

- Whether chemicals are measured by volume, by weight or by both should be made clear to the colour weighers. This should be resolved, too, for the new computerised weighing system which can only measure weights.

- Further dyeing trials, using the same yarn and recipe, should be performed on the other dyemachines in order to identify whether or not they have substantially different dyeing characteristics.

- The quality focus of the dyehouse management **must** shift from **correction** to **prevention.** To send the Dyehouse Manager on a good quality management course would be an important start.

- The purchase of an integrated monitoring, control and fault diagnosing system for the dye machines should be considered.

- A feasibility study should be made to estimate the payback period on the purchase of a (or upgrade of the existing) shade-matching computer.

4.5.8 Actions Taken

Unfortunately the results of this investigation were submitted to management at the end of my contract with SA Fine Worsted and so nothing has yet been done as a result of these recommendations.

5. USING WORK STUDY AS A PRODUCTIVITY TOOL

5.1 Introduction

Conditions in the dyehouse, especially when busy, tended to be crowded and chaotic. Significant changes in the office and shopfloor layout improved this situation by making more space available and easing the flow of work in progress. Further changes still to be implemented are: changes in the process to reduce lead time and planning and batch size changes to reduce workload and cut costs. This section describes these changes and the techniques that were used to create them.

5.2 Office and Shopfloor Layout

Figure 10 (Original dyehouse layout) and **Figure 11** (Revised dyehouse layout) illustrate the changes that were made to the dyehouse office and shopfloor. The most important change was to remove the old hydro and RF dryer. These were used as a standby for the new hydro and dryer but took up precious space and were temperamental. The old hydro has since been scrapped and the old dryer is in the process of being set up in the nearby storage/ finishing room to be used as a standby. The basis for this decision was simple logic: the old equipment served only a backup function but took up a great deal of space and interrupted the flow of work between dyeing and hydro-ing. On a similar basis, the offices were rearranged and refurbished to provide more space and better working conditions for the staff.

5.3 Process Flow

Figure 12 (original process flow (busy conditions)) and **Figure 13** (revised process flow) show the improved and more orderly flow conditions after the old RF dryer had been removed. One

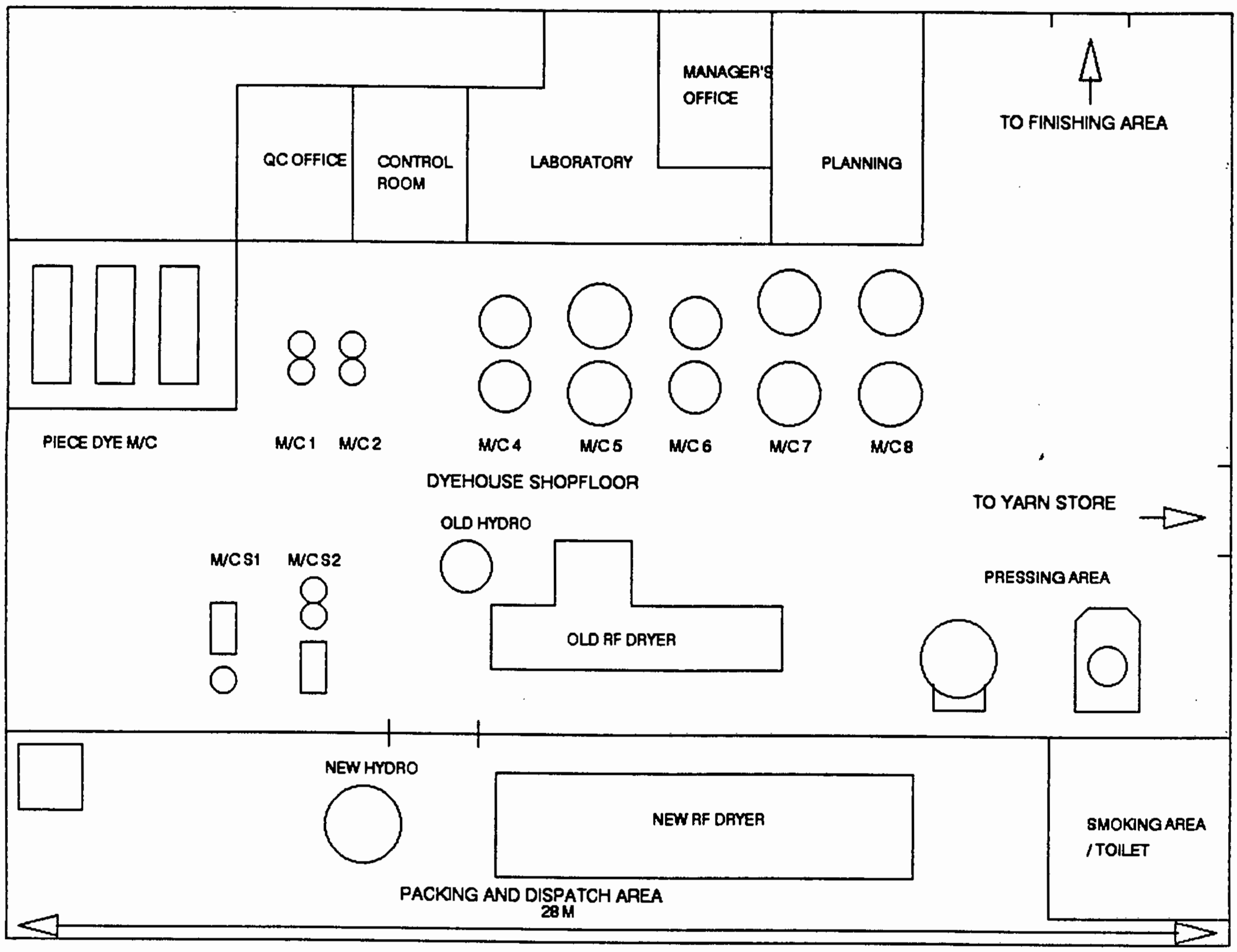

Figure 10: Original dyehouse layout

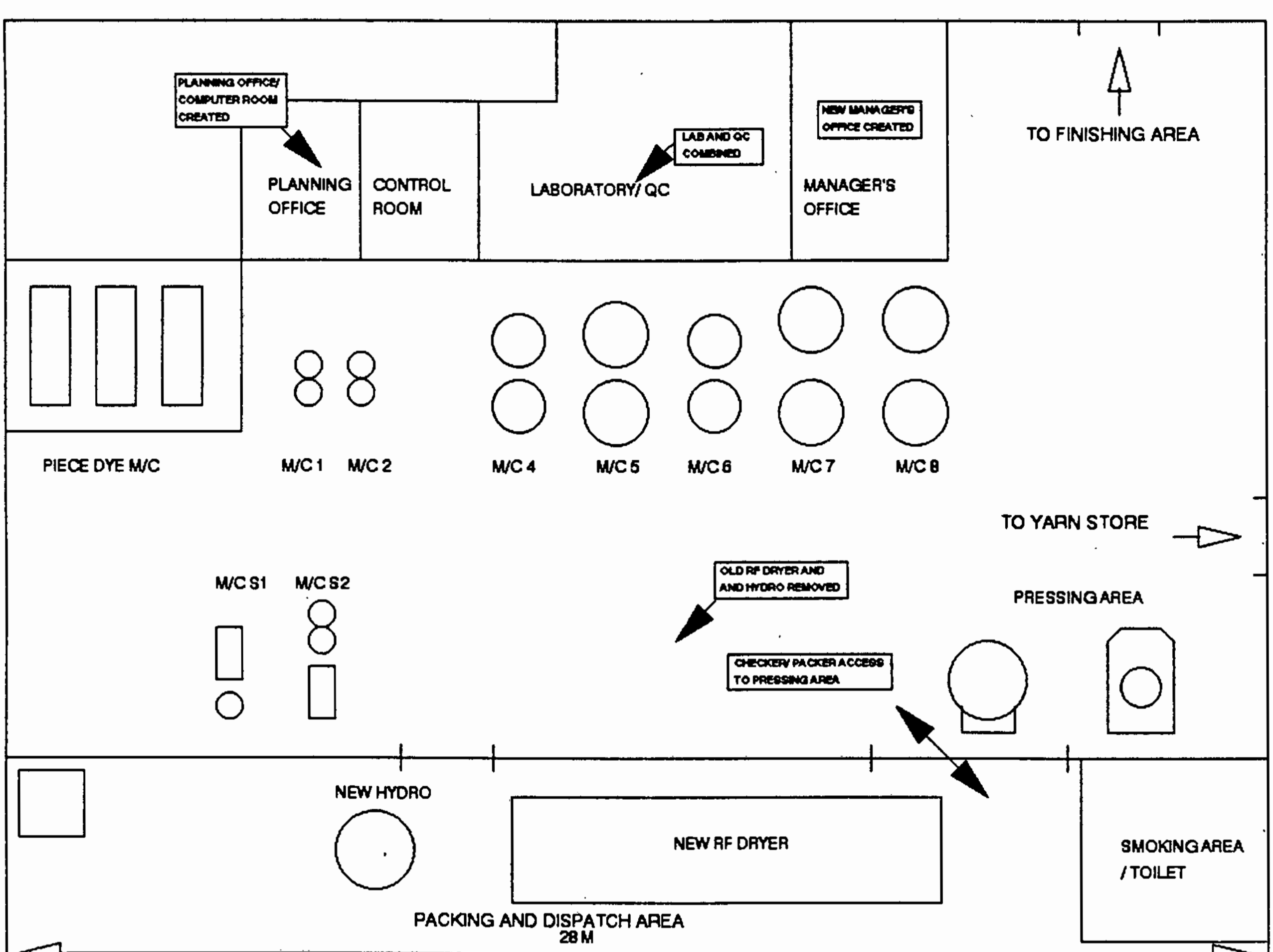

Figure 11: Revised dyehouse layout

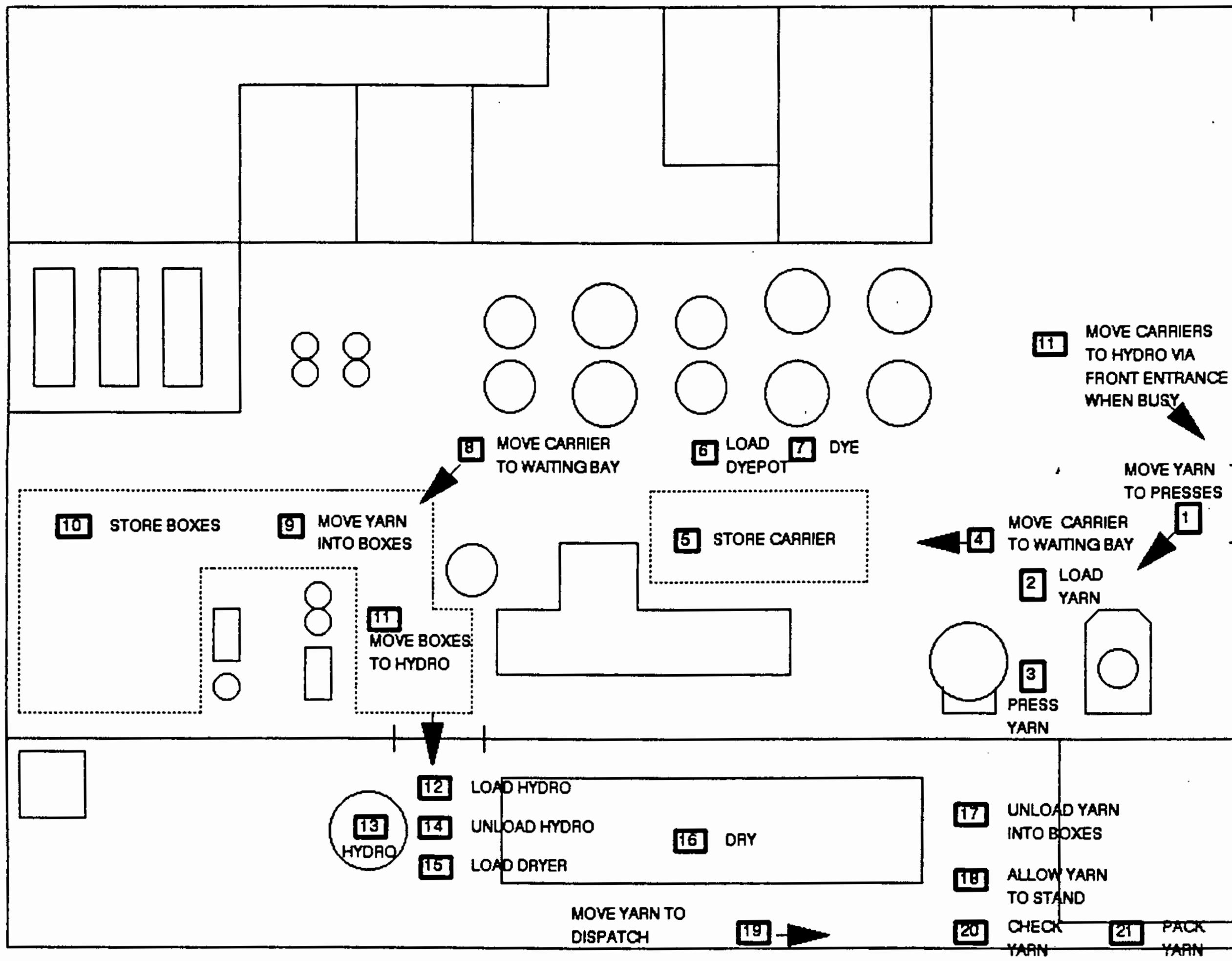

Figure 12: Original process flow (busy conditions)

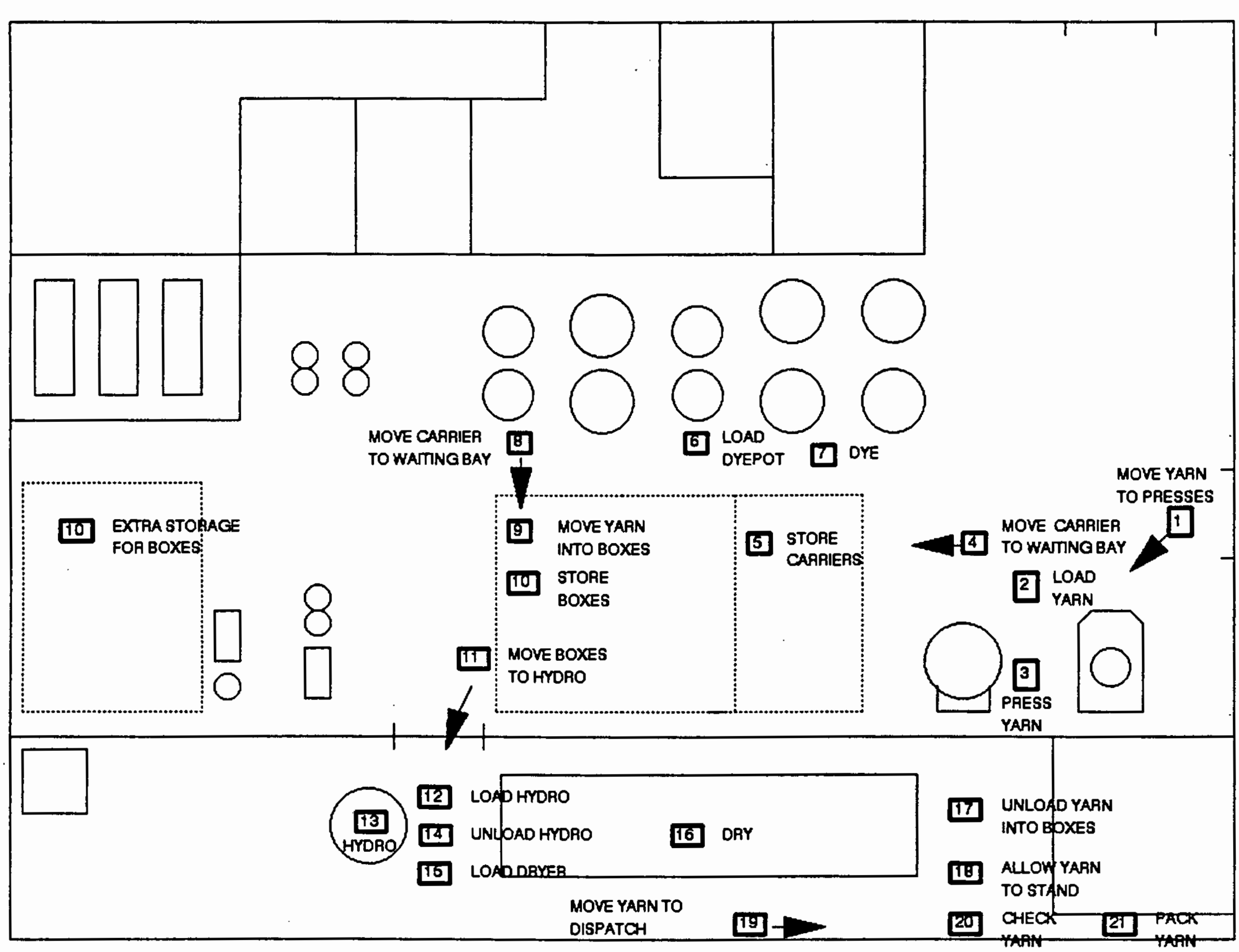

Figure 13: Revised process flow

problem that this eliminated was the need, under busy conditions, to transport yarn via the front entrance of the dyehouse (see operation 11 on the right hand side of **Figure 12**) to the hydro. It also reduced the movement of carriers and boxes that were waiting to be hydro-ed. The boxes can now, for the most part, be stored centrally (see 9 and 10 on **Figure 13**) and moved directly to the hydro. Previously (see 9 and 10 on **Figure 12**) the boxes were loaded and stored on the left hand side of the dyehouse and wherever else there was space. This reduction in the movement of boxes is important because the boxes are transported by hand trolley and can weigh up to 400 kilograms.

The technique of method study was used to generate the process flow chart in **Figure 14**. From this, three areas were identified where improvements should be made:

Work in Progress in General

There is a problem with large amounts of work in progress (as can be seen from **Figures 15** and **16**) in the dyehouse and this stems from two main reasons:

- The workload in the dyehouse swings regularly from over to under capacity. This leads to an attitude in the dyehouse of 'dye as much as you can whilst you can' which tends to lead to a bottleneck situation at the hydro and dryer. This can be relieved as will be discussed under **Dryer/ Checking/ Packing.**
- The time to dye a batch of yarn varies considerably, both because different recipes require different times, and because so much time is spent making corrections on yarn that has been dyed. Thus it is difficult to plan the movement of yarn through the dyehouse.

No immediate solution was found for this problem although it should improve in the medium term with a new centralised planning system, more careful planning of batch sizes and a

FIGURE 14: PROCESS FLOW CHART

MATERIALS PROCESS FLOW CHART

SUBJECT: DYEHOUSE YARN PROCESS FLOW

CHARTED BY: AS CRAVEN

KEY:
O - OPERATION
> - TRANSPORT
D - DELAY
[] - INSPECTION
V - STORAGE

NO	DESCRIPTION	DISTANCE (M)	TIME (MIN)	SYMBOL O	>	D	[]	V	REMARKS
1	MOVE YARN TO PRESS	10	10		O				BOX ON TROLLEY
2	LOAD YARN ON SPINDLES		15		O				MANUALLY
3	PRESS YARN		15	O					MANUALLY/ PRESSING MACHINE
4	MOVE CARRIER TO WAITING BAY	7	10		O				CRANE
5	STORE CARRIER		-			O			
6	LOAD DYEPOT	4	10		O				CRANE
7	DYE YARN		120	O					
8	MOVE CARRIER TO WAITING BAY	8	10		O				CRANE
9	MOVE YARN INTO BOXES		15		O				MANUALLY
10	STORE BOXES		-			O			
11	MOVE BOXES TO HYDRO	7	15		O				BOX ON TROLLEY
12	LOAD HYDRO		15		O				MANUALLY
13	HYDRO YARN		25	O					
14	UNLOAD HYDRO		10		O				MANUALLY
15	LOAD DRYER		10		O				MANUALLY
16	DRY YARN		120	O					
17	UNLOAD YARN INTO BOXES		15		O				YARN FALLS OFF DRYER
18	ALLOW YARN TO STAND		120			O			
19	MOVE YARN TO DISPATCH	8	5		O				CRATE ON TROLLEY
20	CHECK YARN		-				O		
21	PACK YARN		15						MANUALLY

reduction in the number of corrections made on dyed yarn.

From Carrier to Hydro

When a carrier is taken out of a dyepot the yarn is usually unloaded by hand into boxes. It stands in the queue with other boxes of yarn until the boxes are put on a hand trolley, moved to the hydro and loaded manually into the hydro. The obvious way to improve this situation would be to unload direct from the carrier into the hydro. This would eliminate transport problems (the carriers are lifted by overhead crane) and a complete loading and unloading cycle. Unfortunately this is not possible because if the carriers stand waiting to be unloaded then they cannot be reloaded for another lot. The cost of extra carriers is prohibitive (approximately R70 000 for a double (1050 kilogram) carrier).

A pin trolley was purchased to evaluate its usefulness compared to boxes for storing and transporting yarn mainly between the carriers and the hydro. It was concluded that, although functionally it performed better than the boxes, the high cost for the 10 required (R17 000) was not justified (see **Appendix 9**).

Dryer/ Checking/ Packing

After yarn has been hydro-ed it is loaded onto the RF dryer conveyor belt. It passes through the dryer and falls from the conveyor belt into boxes. Because it is allowed to fall naturally, the cones of yarn pack themselves loosely in the slatted boxes. The cones are hot and moist at this stage and are left to 'condition' - to cool to room temperature by natural air circulation. This conditioning process also allows any excess moisture to evaporate from the cones. A problem can arise if the cones are packed directly as they come off the RF dryer: they tend to retain moisture in a way which can disrupt the weaving process. This conditioning process means that the yarn stands loosely packed for anything from 2 to 16 hours depending on the type of yarn and which shift it is. It also requires that the yarn be repacked correctly which takes more labour and subjects the yarn to yet another stage of manhandling. It was thus proposed that the conditioning stage be eliminated by using some form of forced cooling.

Another major advantage of doing this is related to labour and the hydro/ dryer bottleneck. Under average conditions one shift operator can cope with the three jobs of: loading the hydro, loading the dryer and ensuring that there are boxes available for the yarn to fall into at the back end of the dryer. When the dyehouse is busy he cannot cope but this fact has not been considered critical enough until now to warrant an extra shift worker (ie 3 new employees). However, by putting the normally day-working packers on shift this provides the extra person.

In order to get some idea of the time benefits of making these and certain other changes, a model was created (see **Appendix 12**). Because of the nature of the model the results are more useful for comparative purposes than for absolute purposes. The average lead times from the dyeing of the yarn to its dispatch to Maitland or to a customer were found to be as follows:

a) Maitland approval, natural conditioning - 37.4 hours
b) Atlantis approval, natural conditioning - 24.9 hours
c) Atlantis approval, natural conditioning, shift checker-packer - 22.3 hours
d) Atlantis approval, forced conditioning, shift checker-packer - 18.7 hours

From these results it was concluded that the introduction of forced conditioning and a shift checker-packer would significantly reduce lead time (by 6.2 hours). The decision has been made to introduce a shift checker-packer and to this end an opening was made into the dyehouse area from the back end of the new RF dryer (see **Figure 11**). This is so that the shift checker-packer can help with yarn pressing when he is not busy checking dried yarn. What has not yet been resolved is the best way to force-condition the yarn and whether it can be done successfully and practically. The QC Manager is currently working on this problem.

The moving of shade approval to Atlantis (12.5 hours time reduction) was also seen to be extremely important. This result provided strong justification for the decision to make shade approval the responsibility of the Atlantis plant (see Section 6.6).

5.4 Planning and Batch Sizes

A major difficulty that faced the dyehouse was that it essentially dyed to order. Batches were ordered according the needs of the client or of the Maitland weaving department. This meant that often batches of the same shade and yarn quality would be ordered frequently although not necessarily regularly. Because the size of the orders and the size of the dyemachines varied so much (the smallest dyemachine has 10 kilograms capacity whilst the largest has 1050 kilograms capacity), it meant that often it would make sense to dye to stock using the bigger machines and to draw from this stock as orders came through. The advantages of this would be: quicker delivery time as orders would be supplied from stock much of the time; more consistent shades because different orders would be supplied from the same batch; less rejects as the yarn would tend to be dyed in the bigger machines which have lower reject rates (see Section 4.2.1); reduced workload and operating costs because less shots are dyed; better utilisation of the machines by putting more work on the bigger machines and less work on the smaller machines. The disadvantages of this would be those associated with carrying stock: space, cost and the need to manage the stock.

Method study was used to investigate this problem. The technique used was as follows (see **Appendix 13**):

- All the weaving yarn orders that were placed on the dyehouse between July and November 1992 were recorded according to yarn quality and shade type. This represented several hundred shade/ qualities.
- These were cut down to a more manageable number by selecting according to frequency: shade/ qualities that appeared less than five times (ie once per month) were not considered.
- The order histories of the shade/ qualities selected were investigated back to January 1992 to ensure that the high frequency was not just seasonal.
- An optimal batch size was calculated for each shade/ quality on the basis of savings in operating costs versus the lost opportunity costs due to holding stock.

Using this optimum batch size model it was estimated that 231 fewer batches (5.3 % of 1992 production) could be dyed and R201 000 in operating costs saved if larger batches are dyed for the most frequent shade/ qualities.

This model was well received by management and will be implemented in conjunction with the shade rationalisation program (see Section 6.9).

6. OTHER ASPECTS OF THE DYEHOUSE PROJECT

6.1. Introduction

Although this dissertation is concerned mainly with the work described in Sections 4 and 5, it is also necessary to consider the other aspects of the Dyehouse Project to put this work into perspective. Also, as will be seen in Section 7, all the elements of the project made and are making a contribution to the same goal - productivity improvement in the dyehouse. They share the same indicators of success or failure because the effectiveness of each component cannot be isolated (see also **Appendix 10**: Assessment of the major solutions implemented). Thus this section briefly describes these other aspects.

6.2 Rebuilding the Dyekitchen

The dyekitchen is a large room above the dyehouse offices. It contains storage space for dyestuffs and chemicals, the weighing scales for weighing out the recipes and also the dissolving tanks for dissolving the chemicals before they are drawn into the dyepots. Dyestuffs were stored in cardboard boxes on rickety wooden shelves under very crowded conditions.

The dyekitchen has since been enlarged by extending it over the finishing area. New steel racks have been built to accommodate new storage bins for the dyestuffs. This storage area has become a dry area away from the dissolving tanks.

6.3 Training

A major training program was carried out to improve the knowledge and performance of the dyehouse personnel. The Training and Development Manager was assigned full time to the dyehouse for a period of nine months. He was involved not only in theoretical and on-the-job training but also in troubleshooting, housekeeping on the shopfloor and the development of work instructions and job descriptions. Internal training was aimed mainly at operator and supervisor levels and included courses on topics such as basic technical knowledge, quality, production flow and housekeeping.

The Dyehouse Manager was sent on an external management training course whilst the QA Manager was sent on a course to improve his understanding of shade matching and approval. It was intended that the QA Manager would ultimately become responsible for final shade approval (see also Section 6.6: Atlantis shade approval).

6.4 Appointment of a New Lab Manager

The dyehouse needed a laboratory manager with strong technical knowledge in dyeing in order to supervise the development of new recipes, fix difficult redyes etc. Until a new lab manager was appointed, the Dyehouse Manager himself spent a great deal of time in the lab supervising because he was the only person in the dyehouse with the necessary knowledge. An experienced person was recruited from one of the dyestuff suppliers and he appears to be making an important contribution to the improvement of the dyehouse.

6.5 Weighing Computer and Recipe Database

Dyestuff weighing errors are fairly frequent in the dyehouse (see **Appendix 3**). These are usually due to either the colour weigher weighing the wrong chemical, weighing the wrong amount, or omitting an item altogether. A new set of computerised weighing scales is to be installed in the dyekitchen which will control the weighing operation to some extent. It will prompt the weigher for the right chemical and will only let him carry on to the next ingredient if he puts the right quantity on the scale. This will not eliminate weighing errors but it will certainly improve the situation.

The recipes themselves will be stored on a computer database instead of on cards in a filing cabinet. This is significant when one considers that there are some 2000 recipes. Not only will clerical errors be reduced but also some calculation errors will be eliminated as the computer will perform certain basic calculations previously done by hand.

6.6 Atlantis Shade Approval

Generally when the dyehouse consider that a batch of yarn has been successfully dyed it sends a sample hank to Maitland for final shade approval. If Maitland rejects the shade the batch will either have to be redyed or a new batch of white yarn will be dyed. It can take up to 24 hours from the time a hank leaves Atlantis to the time that the dyehouse hears whether the shade has been approved or not. Not only is this a terrible waste of precious delivery time but there also tremendous communications problems involved. The hank is dyed against a master shade and it is passed or failed against a master shade. However, the masters in Maitland do not always match those in Atlantis! Similarly the shades are matched by eye and even trained people's opinions under controlled conditions can be different.

It was thus identified as a priority that final approval be moved to Atlantis. This will take place early in 1993 and will be the responsibility of the Atlantis QA Manager.

6.7 Shade-Matching Computer

As mentioned above, when shade matching is done by eye different people can have different opinions, and abilities in this can vary widely. A computer and spectrophotometer was used in the dyehouse when it first started operations. It fell into disuse because the previous managing director apparently did not trust its readings.

This has been refurbished and will be reused for the purpose of helping dyehouse personnel (particularly the less able shift supervisors) make objective shade-matching decisions.

6.9 Rationalisation of the Shade Range

The 2000 recipes used by the dyehouse make consistent dyeing of each shade enormously difficult because there is a learning curve for each recipe (just as a cook would tend to be more successful if he baked cakes to only 40 recipes instead of 2000!).

A major drive is under way to rationalise the shade range and reduce the number of recipes being used.

6.10 Machine Maintenance Improvement

Well before the Dyehouse Project was started a commitment was made to improve the condition of the dyemachines and associated machinery. To this end the dyehouse maintenance budget was increased and an electro/ mechanical technician was appointed early in 1992 to work specifically on the dyehouse machines. A definite improvement in the number of lots rejected due to machine breakdowns has taken place as can be seen in **Figure 6**. The technician from the dyemachine agents described the improvement in the conditions in the machines as being like 'night and day'.

7. RESULTS

7.1 An overview of Sections 4, 5, and 6

In Sections 4 and 5 it was found that:

- The major causes of reject yarn were machine breakdowns and problems associated with the dyeing process itself which caused unlevelness (**Figures 4** and **5**) although there are clear signs that rejects due to machine breakdowns (**Figure 6**) are decreasing.
- The reasons for reject lots are neither well enough understood nor carefully enough recorded and commitment to the elimination of problems causing defects is lacking.
- The indicator '% Reject, redyed and relevelled lots'(**Figure 21**) is a more important indicator of how successful the process is than '% Reject Lots' (also **Figure 21**).
- Yarn can be dyed right first time if all the process parameters are carefully controlled.
- The focus in the dyehouse tends to be on correction rather than on prevention.
- Significant shade variations occur when yarn is dyed in only partially loaded dyepots.
- A necessary improvement in the overall ability of the dyehouse operators and supervisors should take place in the medium term as the effect of a new employment policy is felt.
- The dyehouse manager is good technically but appears to lack management ability. His position should be made easier by improvements in the conditions and systems in the dyehouse.
- There is a need to automate the dyeing process as much as possible in order to minimise the chances of human error.

What has been suggested to improve this situation is:

- Closer monitoring of dyemachine performance, most specifically the reinstallation of temperature recording charts.
- Dyehouse personnel should use the system for investigating and recording each reject lot.
- The development of a basic training course to increase the operator's understanding of how their machine's work and what can go wrong with them.
- The implementation of a program for the understanding of and the tightening up of the control of the process variables.

All of the above recommendations were or will be implemented. Further investigation recommended that:

- Further dyeing trials be performed on the dyemachines other than numbers 1 and 2 to identify whether or not they have different dyeing characteristics.
- The dyehouse manager be sent on a good quality management course.
- An integrated monitoring, control and fault diagnosing system for the dyemachines be considered.
- A feasibility study should be made to estimate the payback period on the purchase of (or upgrade of the existing) shade-matching computer.

These recommendations were made at the end of my time with the company and they have yet to be discussed and acted upon.

Along with this mainly investigation-based work, several major initiatives were carried out, or are in the process of being carried out, in the dyehouse. These are:

The rebuilding of the dyekitchen, the re-arranging and refurbishing the dyehouse offices, the improvement of the shopfloor layout and process, a major training program, the upgrading the dyehouse machine maintenance and the appointment of a new lab manager.

Very important projects which have not yet been implemented are: the installation of a computerised recipe weighing system and shade-matching computer, the moving of shade approval to Atlantis, and the rationalisation of the shade range.

7.2 Discussion of Results

7.2.1 Introduction

The Dyehouse Project began in earnest in June 1993. When considering the results of this project, it must be borne in mind that the project is not yet complete and that the actions that are complete tend to be more preparatory in nature - establishment of the sources of problems, establishment of a working environment conducive to efficiency and the training of personnel. It must also be considered that the project is an ongoing one and will continue until satisfactory results are achieved.

What then are the goals of the project? Unfortunately these were not clearly defined at the start of the project but they are basically to improve the cost per kilogram of dyed yarn and also to improve the reliability of the delivery of this yarn. The reject rate was targeted as the most important point of attack because it was high (in the region of 10%), cost a lot of money (estimated at R370 000pa in direct costs alone (see **Appendix 2**)), and was the cause of much of the late delivery problem. It was also an indicator that was very visible, easy to understand, easy to measure and there were historical figures against which to compare. As will be seen it is probably the best measure available at present.

7.2.2 Total cost productivity

What the management of SA Fine Worsted need from the Dyehouse Project is bottom-line Rands improvement. The total cost productivity indicator, total Rands cost per successfully-dyed kilogram of yarn (**Figure 15**), must be the indicator of this. In **Figure 15** it is plotted by month for 1992. It fluctuates considerably because: the cost of the dyestuffs consumed (50% of total costs) varies from month to month depending on the type of dyestuffs that are being used and also production varies considerably from month to month depending on demand (see **Figure 17**). The bump in the second half of the year can be attributed to extra expenses from the Dyehouse Project although capital expenses are not included in this. The figures for November and December were not yet available.

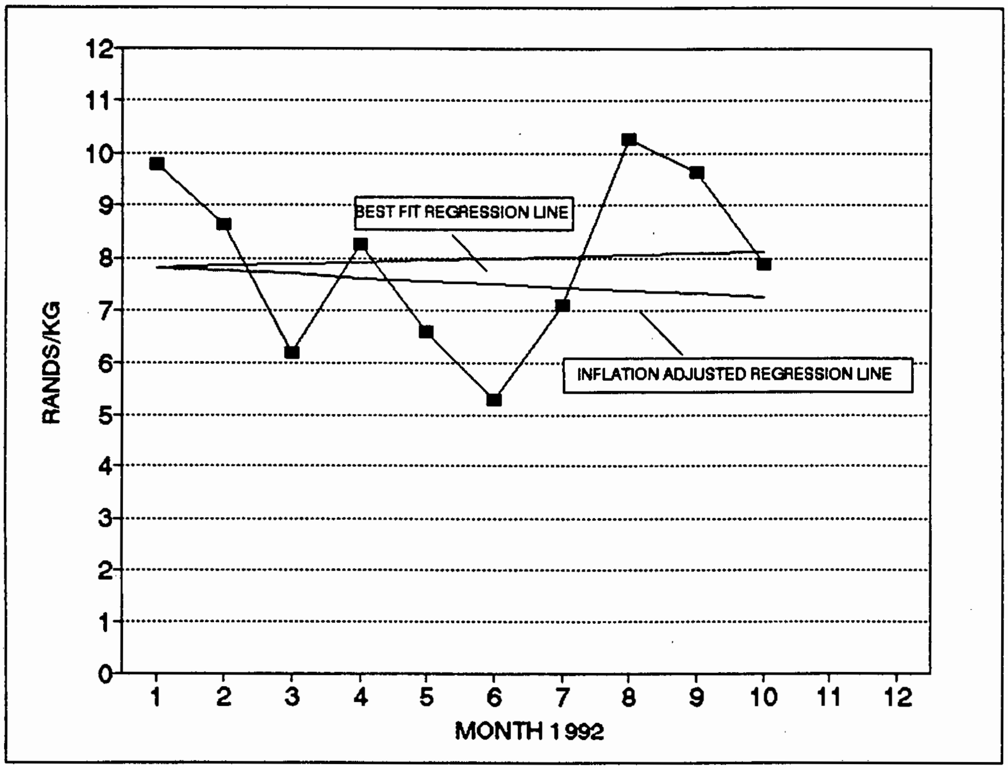

Figure 15: Total dyecosts per accepted kilogram

Regression analysis produces a best-fit straight line indicating a slight increase in total cost per kilogram over the year. When then this line is corrected for 15% annual inflation it shows a slight decrease in total cost per kilogram which is encouraging but not conclusive.

Thus this total Rands per kilogram curve does not present useful information for 1992. It will prove more useful in 1993 when project costs will be minimal and the effect of all the project initiatives is felt.

There remains a need for more specific cost-based indicators which can be used for control purposes. It is, at present, not possible to identify what is, and what is not, responding to the changes due to the Dyehouse Project.

The installation of the weighing computer and recipe database system will make an important contribution in this area. The exact quantity of dyestuffs and chemicals used for each lot will be calculated by the weighing computer from its recipe data. Thus the materials component of the dyeing costs for each lot and, consequently, each shade/ yarn quality combination will be accessible. Since the weighing computer system is to interface with the company's mainframe computer, this data can easily be made available in report form.

The indicator 'cost of dye materials per kilogram for specific shade/ yarn qualities' will give very valuable information about the success of the Dyehouse Project. It can be more easily adjusted for inflation by using standard costs of materials. A full activity-based costing system yielding total costs per specific shade/ yarn quality would be ideal, and this is being investigated, but this is likely to be a long term project.

7.2.3 Labour productivity

The labour productivity indicator (**Figure 16**: Man-minutes per accepted kilogram) has the advantage that it is not inflation linked. It is an important measure of efficiency in the dyehouse and should reflect improvements due to training, improved maintenance and machine upgrade etc.

This graph should show an improvement in performance in the second half of the year but it does not. This can be attributed to the fact that July, August, September was the time when the major training effort was taking place and the workers spent a lot of time in the classroom.

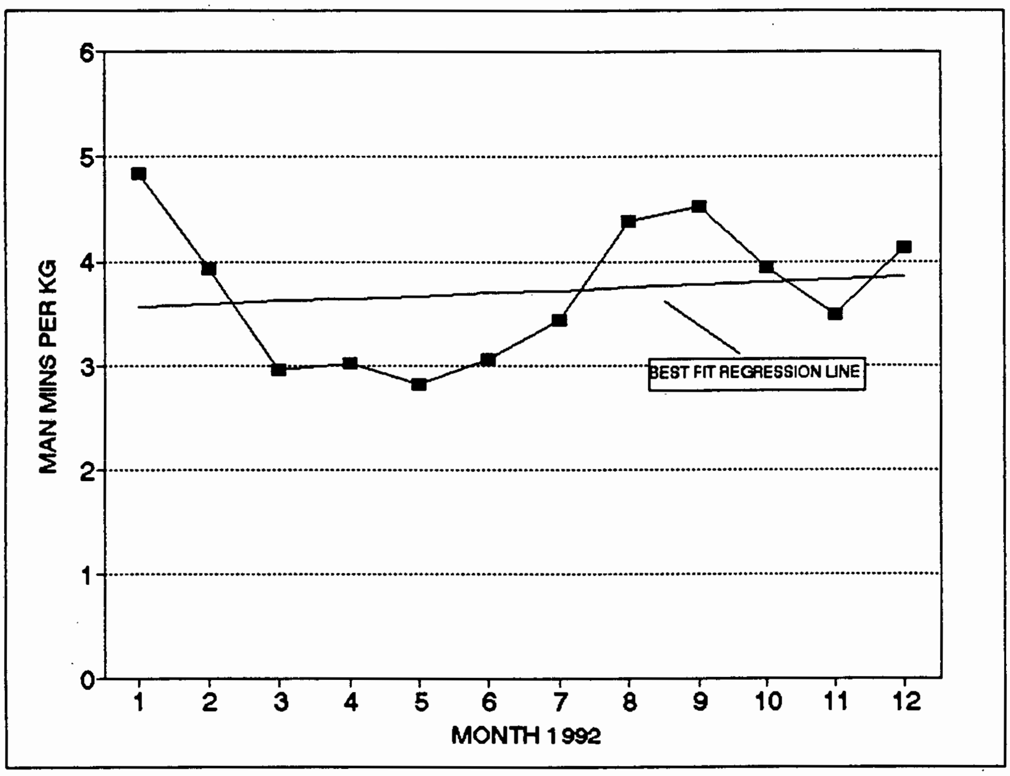

Figure 16: Man-minutes per accepted kilogram

This graph will be a useful performance indicator in 1993 when the movements of dyehouse personnel become more stable.

7.2.4 % Reject Kilograms and % Reject, Redyed and Relevelled Lots

It is first necessary to explain the meaning of these different terms. % reject kilograms (**Figure 17**) is the ratio of kilograms rejected (ie those kilograms of yarn, pieces and tops that will have to be overdyed to a dark colour and a new batch started or will have to be corrected by redyeing) to total kilograms dyed. Also plotted on **Figure 17** is the monthly production in tonnes. This is plotted on the same graph because there is a fair correlation (Pearson correlation coefficient of 0.73 - see **Appendix 11**) between total kilograms dyed and % reject kilograms ie the busier the dyehouse becomes, the higher the proportion of rejects that are produced. This is due to the fact that, under busier conditions, more physical labour is required, the shopfloor becomes crowded with work-in-progress and the dyehouse personnel at all levels become more pressurised.

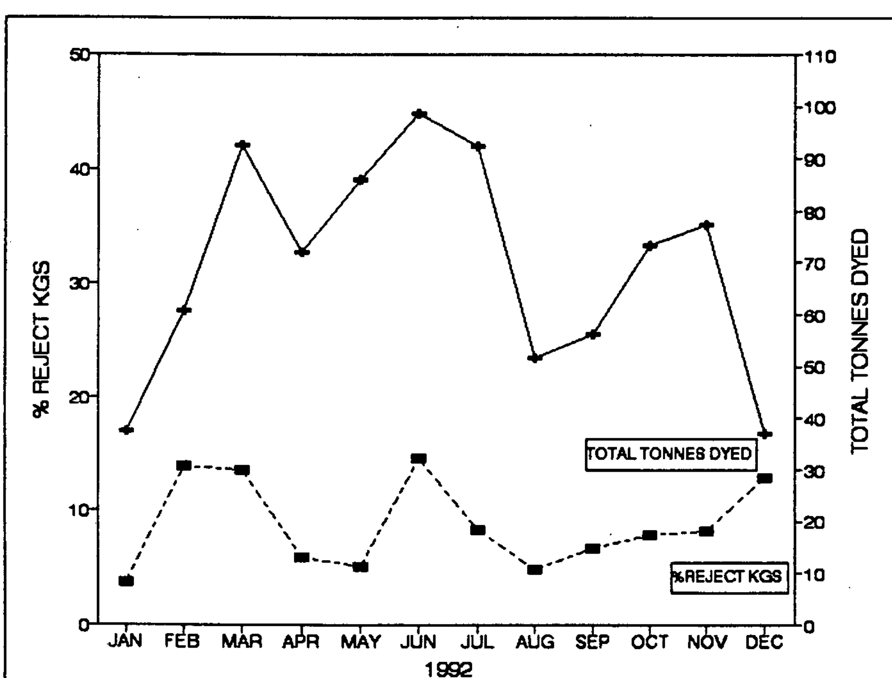

Figure 17: % reject kilograms

Figure 18 has three lines plotted: % reject lots; % reject, redyed and relevelled lots (these have been discussed in Section 4.3.1); and total lots dyed. In this case, the correlation coefficient between total lots dyed and % reject lots was found to be lower at 0.42.

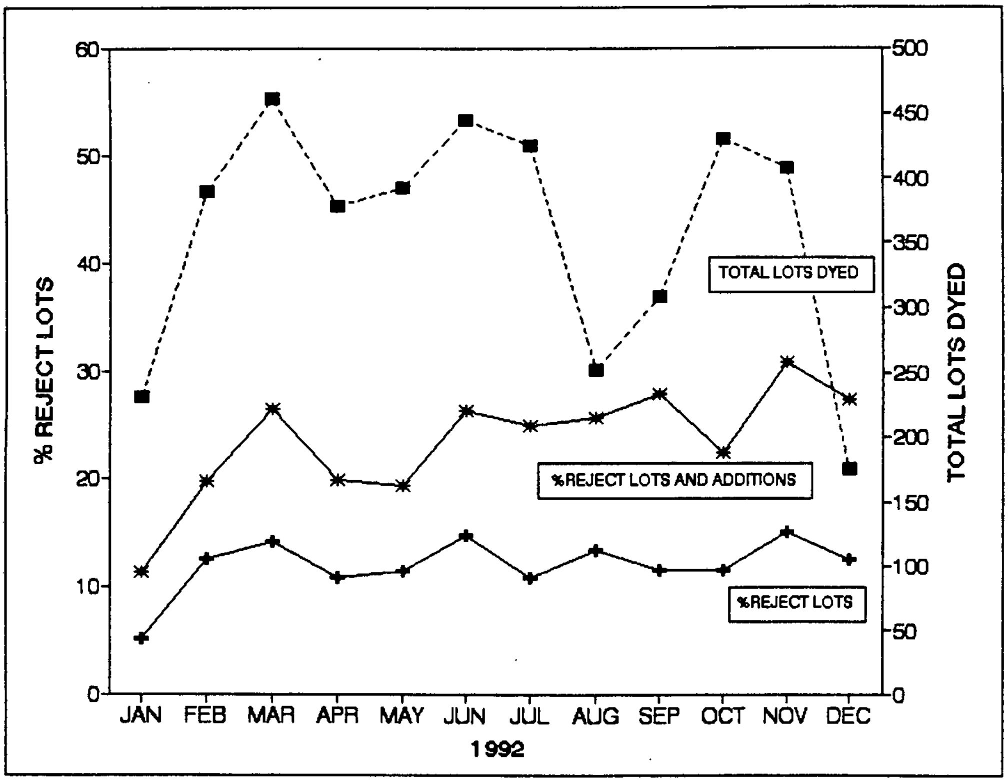

Figure 18: % reject lots

The table below gives a useful comparison of the overall trends in these two graphs between the first half and the second half of 1992.

PORTION 1992	**FIRST HALF**	**SECOND HALF**
PROPORTION OF TOTAL LOTS FOR YEAR (%)	53.4	46.6
% REJECT LOTS	12.2	12.5
% REJECT, REDYE, RELEVEL LOTS	21.5	26.4
PROPORTION OF TOTAL KILOGRAMS FOR YEAR (%)	53.6	46.4
% REJECT KILOGRAMS	10.2	7.9

There are a number of points to note. The percentage reject kilograms figure is 23% lower in the second half of the year. This is due mainly to an improvement in machine maintenance (see **Figure 6**), and a heightened awareness of the importance of reducing the reject rate. The fact that % reject kilograms has come down and % reject lots has stayed more or less the same shows that the improvement has taken place on the larger lots.

The increase in the % reject, relevel and redye lots from 21.5% to 26.4 % is worrying. It implies that the dyehouse personnel are trying very hard to bring down the reject rate but are doing so by increasing their efforts to correct lots before they are submitted for shade approval. This may produce a lower reject rate in the short term but does not attack the cause of the problem which is one of process control. The problem is that, when the initial impetus of the Dyehouse Project dies down, the enthusiasm for keeping the reject rate low is likely to diminish.

It must also be mentioned that, over the period approximately

July to October, the Training and Development Manager spent much of his time basically working as an extra manager in the dyehouse. This brought visible improvements in areas such as housekeeping, morale and commitment to improvement in the dyehouse. In this way I believe it also contributed to the improvement in reject kilograms. What is worrying is what happens when the Training and Development Manager leaves the dyehouse alone? Such interventions can create dependencies which do not always help in the long term(19).

7.2.5 The Sustainability of Improved Performance in the Dyehouse

Real improvements need to be achieved and sustained in the dyehouse. The Atlantis Factory Manager has stated, as one of his objectives for 1993, that the reject rate in the dyehouse should be reduced to 5% by June 1993.

Since the start of the project, there have been weekly project meetings with the Managing Director attending these every second week. During this time, responsibility for the performance of the dyehouse has been shared by the project team and the dyehouse management. When all the 'external improvements' have been established, this responsibility must pass back to the dyehouse management. Sustained performance will depend on them. Whether they can achieve this is questionable as discussed in Section 4.5.6 and 7.2.4 above.

8. OVERALL CONCLUSIONS

1. Although the dyeing process is a complicated one, there are **no major obstacles to successful first-time dyeing and dyeing is not an 'art'**. What is required is methodical, responsible monitoring and control of the numerous process variables and a commitment to eliminating causes of defects.

2. There remains a need in the dyehouse for:
   - an improvement in the overall ability of the dyehouse operators and supervisors. This should take place in the medium term because job requirements have been defined which include increased minimum education level requirements and a plan for supervisor development.
   - increased automation, such as more sophisticated machine monitoring, control and fault diagnosing system, because the dyeing process is very vulnerable to problems associated with human error.

3. The use of a colour matching computer provides an unambiguous basis from which decisions and improvements can be made. Given the high expenditure on dyestuffs and the amount of time spent on shade matching and recipe prediction, the purchase of a colour matching computer would be an important investment.

4. The Dyehouse Project began in June 1992 and is not yet complete. The actions that are complete tend to be more preparatory in nature - establishment of the sources of problems, establishment of a working environment conducive to efficiency and the training of personnel. The effect of important initiatives

such as the shade rationalisation program, Atlantis shade approval and computerised weighing and shade matching have yet to be felt.

5. The productivity indicators 'Total cost per accepted kilogram' and 'Man-minutes per accepted kilogram' do not give any meaningful information about the progress of the Dyehouse Project but they should do so in 1993. The indicator '% reject kilograms' shows a significant improvement in the reject rate, being down to 7.9% in the second half of the year from 10.2% in the first half.

6. There are signs that these improvements may not be sustained in the long term. The intervention of the Training and Development Manager as a 'manager' in the dyehouse in the latter part of 1992 and the significant rise of the factor '% reject, redyed and relevelled lots' suggest this.

7. The indicator 'cost of dye materials per kilogram for specific shade/ yarn qualities' will give very valuable information about the success of the Dyehouse Project. Data for this will become available when the weighing-computer system is installed.

8. There is a fair correlation (Pearson correlation coefficient of 0.73) between total kilograms dyed and % reject kilograms ie the busier the dyehouse becomes, the higher the proportion of rejects that are produced. This is due mainly to the fact that the dyehouse personnel make more mistakes under the busier, more crowded and more pressurised conditions.

9. Whilst the Dyehouse Project has been under way, responsibility for the performance of the dyehouse has been shared by the project team and the dyehouse management. When all the 'external improvements' are complete, responsibility for sustaining the improved performance must pass back to the dyehouse management. Whether they can achieve this is questionable.

9. OVERALL RECOMMENDATIONS

1. The Dyehouse Manager should be sent on a good quality management course.

2. The purchase of an integrated monitoring, control and fault diagnosing system for the dye machines should be considered.

3. A feasibility study should be made to estimate the payback period on the purchase of a (or upgrade of the existing) shade-matching computer.

4. The indicators 'Total cost per accepted kilogram', 'Man-minutes per accepted kilogram', '% reject kilograms', '% reject lots' and '% reject, relevelled and redyed lots' should be monitored carefully in 1993.

5. The indicator 'cost of dye materials per kilogram for specific shade/ yarn qualities' should be set up as soon as possible. It is likely to be the best indicator of improvements in dyeing efficiency.

6. The effectiveness of the dyehouse management, in maintaining the improved performance of the dyehouse in the future, must be monitored carefully as there indications that they will not be able to sustain this on their own.

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APPENDICES

APPENDIX 1: DYEHOUSE INVESTIGATION SUMMARY

DYEHOUSE INVESTIGATION SUMMARY

DATE: 25/05/1992

1. PRESENT POSITION: DYEHOUSE PRODUCTIVITY:

In the last year the average reject rate in Kgs has been 8,2%. If this was reduced to an acceptable level of 4% the direct savings using an average dye cost of R4.00/kg could be +-R137000

PROBLEMS IN THE DYEHOUSE:

2.1 Dyehouse weighing/ dissolving/office area poorly laid out and overcrowed.
2.2 Kgs has increased by approximately 70% since 1984 (see figure 2).
2.3 Range of dyes and material types to be dyed has increased considerably since this time.
2.4 Dyehouse maintenance has been badly neglected (see figure 3).
2.5 Dyehouse equipment is inadequate.
2.6 Overall dyehouse management need attention.
2.7 Shift supervisors lack technical and supervisory skills.
2.8 Lab supervisor lacks technical and supervisory skills.
2.9 Operators not properly trained or supervised.

3. PROPOSED SOLUTIONS:

3.1 Train operators and supervisors. Make replacements where necessary and possible.
3.2 Rearrange weighing/dissolving/office area depending on budget and envisaged future production needs.
3.3 Improve machine maintenance and critical spares level.
3.4 Increase QA manager's involvement in dyehouse quickly. Train him in QA principles get him involved in process control.
3.5 Increase information feedback from dyehouse and apply increased control to dyehouse manager.
3.6 Purchase process monitoring and recording equipment. Purchase computerised colour weighing equipment. Upgrade existing shade matching machine.

APPENDIX 2: THE COST OF REDYEING

1. Kgs yarn,pieces, tops from dyehouse for year Sept 91 - Aug 92 (source Dyehouse Production Stats 91/92 by EM).

Total rejects kgs: 72035 kgs

2. New yarn/pieces/tops requested when redyeing is not possible (source: Internal Dye Order, Reject Yarn Control Sept'91 - Aug 92 by AC)

New Yarn: 21546 kgs

3. Cost of Dyeing
(source Dyehouse Production Stats 91/92 by EM)
Dyes, chemicals: R3.48/kg
Labour, overheads etc: R3.87/kg

4. Cost of Redyeing
(ie yarn that is rejected and then dyed again)
Dyecosts = 10% of R3.48/kg = R0.35/kg
Other costs = 100% of R3.87/kg = R3.87/kg
Total = R4.22/kg

(Based on estimated percentage of dyecosts when redyeing from Dyehouse Manager)
Therefore annual cost of redyeing:
= (total reject - new yarn) * 4.22
= (72035 - 21546) * 4.22 = R2130635.

Cost of dyeing new yarn:
= (new yarn) * (total cost) = 21546 * 7.35
= R158363

Thus **TOTAL ANNUAL COST FOR REDYEING YARN**

= R213063 + R158363
= R371426

APPENDIX 3: ASSESSMENT OF REJECT YARN CONTROL DATA

REQ NO	DATE	SHADE	NM	KGS	BAL?	M/C NO	PROBLEM / OBSERVATION	REASON	OBS CODE	REASN CODE	VALUE (1 - 5)
1427	4-3-92	8128	44/1	37		1	UNLEVEL	DIFFERENT SIZED CONES	WRON	YARN	5
1426	1-3-92	7013	30/1	20			WRONG YARN	WRONG YARN FROM YARN STORE	WRON	YARN	5
1415	4-12-91	7820	30/1	100			TWISTED YARN	TWISTED BY ERROR	WRON	YARN	5
1428	10-3-92	7013	30/1	10			OFFSHADE	WRONG YARN FROM YARN STORE	WRON	YARN	5
1401	24-10-91	865	47/1	10	Y		WRONG YARN	YARN STORE MIXED YARN	WRON	YARN	5
1419	27-1-91	7961	30/1	10			TWISTED YARN	STORES MISTAKE	WRON	YARN	5
1401	24-10-91	130	47/1	25	Y			YARN STORE MIXED YARN	WRON	YARN	5
1419	27-1-91	7040	30/1	50			MIXED YARN	STORES MISTAKE	WRON	YARN	5
1401	24-10-91	2416	28/1	5	Y			YARN STORE MIXED YARN	WRON	YARN	5
1430	23-3-92	925	47/1	1081		7	UNLEVEL	M/C FAULT PUMP CUT OUT	UNLEV	MC	5
1402	28-10-91	530	44/1	24	Y	S2	UNLEVEL,RINGS	CONES DIRTY FROM BASEPLATE	UNLEV	HH	5
1412	26-11-91	7973	28/1	20		S2	UNLEVEL	RECIPE	UNLEV	BR	3
1432	1-4-92	967	60/1	1122		7	UNLEVEL	M/C PUMP CUT OUT	UNLEV	MC	5
1429	19-3-92	2290	60/1	65		1	UNLEVEL	M/C LOSING LIQUOR	UNLEV	MC	5
1452	18-8-92	965	60/1	257		6	UNLEVEL	M/C FAULT FLOW CONVERTOR STUCK	UNLEV	MC	5
1450	23-7-92	9302	40/2	30		1	UNLEVEL	RECIPE	UNLEV	BR	4
1598	16-10-91	8122	44/1	218		6	RINGS	RECIPE - SUBSEQUENTLY CHANGED	UNLEV	BR	5
1450	23-7-92	9302	25/2	66		2	UNLEVEL	RECIPE	UNLEV	BR	4
1595	8-10-91	865	47/1	30			UNLEV,RINGS ON CENTRE	DON'T KNOW	UNLEV	DUNNO	5
1403	31-10-91	8124	60/1	336		8	UNLEVEL	RECIPE	UNLEV	BR	4
1451	13-8-92	2750	44/1	10		S1	UNLEVEL	BAYER RECIPE PROBLEM	UNLEV	BR	5
1598	16-10-91	8013	44/1	389		8	RINGS	RECIPE - SUBSEQUENTLY CHANGED	UNLEV	BR	5
1416	11-12-91	515	60/1	40		2	UNLEVEL	M/C,FAULTY FLOW CONVERTOR	UNLEV	MC	5
1411	21-11-91	15	60/1	577		8	UNLEVEL,TOO YELLOW	"LOOKS LIKE A HEATING PROBLEM"	UNLEV	MC	3
1416	11-12-91	544	60/1	40		2	UNLEVEL	M/C,FAULTY FLOW CONVERTOR	UNLEV	MC	5
1416	11-12-91	4136	43/1	52		2	UNLEVEL	M/C,FAULTY FLOW CONVERTOR	UNLEV	MC	5
1418	23-1-92	8854	60/1	20		S2	UNLEVEL	M/C FAULT,FLOW CONVERTOR	UNLEV	MC	5
1418	23-1-92	8978	47/1	18		S2	UNLEVEL	M/C FAULT,FLOW CONVERTOR	UNLEV	MC	5
1433	6-4-92	3460	60/1	251		8	UNLEVEL	M/C SEAL	UNLEV	MC	5
1421	6-2-92	535	60/1	39		1	UNLEVEL	M/C FLOW PROBLEM	UNLEV	MC	5
1446	6-7-92	8233	87/2	10		1	UNLEVEL	M/C PUMP STOPPED	UNLEV	MC	5
1430	23-3-92	1810	43/1	639		5	UNLEVEL	M/C FAULT PUMP CUT OUT	UNLEV	MC	5
1446	6-7-92	8233	44/1	10		1	UNLEVEL	M/C PUMP STOPPED	UNLEV	MC	5
1452	18-8-92	967	60/1	230		8	UNLEVEL	M/C FAULT FLOW CONVERTOR STUCK	UNLEV	MC	5
1446	6-7-92	8233	86/2	10		1	UNLEVEL	M/C PUMP STOPPED	UNLEV	MC	5
1434	16-4-92	7227	34/1	465			YELLOW RINGS	DON'T KNOW	UNLEV	DUNNO	5
1410	19-11-91	925	47/1	1088		5	UNLEVEL	AGGLOMERATION, DISSOLVING PROBLEM	UNLEV	DP	5
1402	28-10-91	8940	68/2	59		4	UNLEVEL	CONES SHRINK, BECOME HARD	UNLEV	CH	4
1598	16-10-91	8713	28/1	160		6	UNLEVEL	COLOUR WEIGHER PUT WRONG CHEMICAL	UNLEV	CWE	5
1446	6-7-92	4456	60/1	57		2	UNLEVEL,3 ADDITIONS	UNLEVEL, PALE BLUE COLOUR	UNLEV	DS	5
1431	27-3-92	7973	28/1	200		8	UNLEVEL,BAD ADDITIONS	RECIPE,PALE BEIGE	UNLEV	DS	5
1420	31-1-92	7966	27/1	55		1	UNLEVEL,OFFSHADE	DIFFICULT SHADE	UNLEV	DS	3
1596	9-10-91	8940	68/2	89		4	OFFSHADE	HARD CONES ?	UNLEV	CH	4
1596	9-10-91	6939	66/2	87		4	UNLEVEL	HARD CONES ?	UNLEV	CH	4
1441	3-6-92	7561	30/1	20		S1	UNLEVEL	CONES TOO SOFT	UNLEV	CH	5
1402	28-10-91	8964	68/2	11		S2	UNLEVEL	CONES SHRINK, BECOME HARD	UNLEV	CH	4
1402	28-10-91	8967	68/2	171		6	UNLEVEL	CONES SHRINK, BECOME HARD	UNLEV	CH	4
1593	25-9-91	8713	28/1	160		6	UNLEVEL	SOFT CONES	UNLEV	CH	3
1596	9-10-91	8711	28/1	74		4	UNLEVEL	HARD CONES ?,RECIPE	UNLEV	CH	4
1592	24-9-91	8037	47/1	1012		7	UNLEVEL	DON'T KNOW	UNLEV	DUNNO	5
1440	20-5-92	8207	87/2	104			UNLEVEL	DON'T KNOW	UNLEV	DUNNO	5
1407	7-11-91	130	47/1	26		S2	UNLEVEL	"LOOKS LIKE A DYEING PROBLEM"	UNLEV	DUNNO	5
1589	10-9-91	8097	47/1	930		5	UNLEVEL	DON'T KNOW	UNLEV	DUNNO	5
1410	19-11-91	530	44/1	40		2	UNLEVEL,RING ON OUTSI	DON'T KNOW	UNLEV	DUNNO	5
1423	18-2-92	8128	44/2	38		1	UNLEVEL,RING	DON'T KNOW	UNLEV	DUNNO	5
1410	19-11-91	505	44/1	22		S2	UNLEVEL,RING ON OUTSI	DON'T KNOW	UNLEV	DUNNO	5
1598	16-10-91	8485	60/1	97		6	YELLOW STAINS,SPOTS	LIGHT BEIGE COLOUR	UNLEV	DS	5
1450	23-7-92	8960	47/1	108		8	UNLEVEL,BAD ADDITIONS	PALE BEIGE	UNLEV	DS	5
1405	5-11-91	8978	47/1	89		4	DIRTY RINGS	PALE BEIGE COLOUR	UNLEV	DS	5
1407	7-11-91	15	60/1	77		4	UNLEVEL	"LOOKS LIKE A DYEING PROBLEM"	UNLEV	DUNNO	2
1594	3-10-91	175	44/1	15	Y		UNLEV,RINGS ON OUTSID	DON'T KNOW	UNLEV	DUNNO	5
1410	19-11-91	505	44/1	40		2	UNLEVEL,RING ON OUTSI	DON'T KNOW	UNLEV	DUNNO	5
1417	17-1-92	9303	8/2	10		S2	UNLEVEL	M/C REPAIR FAULT	UNLEV	MC	5
1599	18-10-91	2635	44/1	25		S2	UNLEVEL	"LOOKS LIKE FLOW PROBLEM"	UNLEV	MC	3
1407	7-11-91	7995	26/1	10		S1	UNLEVEL	"LOOKS LIKE A M/C FAULT PROBLEM"	UNLEV	MC	5
1423	18-2-92	515	60/1	50		2	UNLEVEL	M/C FAULT	UNLEV	MC	5
1421	6-2-92	660	47/1	177		8	UNLEVEL	M/C FLOW PROBLEM	UNLEV	MC	5
1408	11-11-91	7205	34/1	1100		5	UNLEVEL	PUMP STOPPED	UNLEV	MC	5
1421	6-2-92	544	60/1	42		1	UNLEVEL	M/C FLOW PROBLEM	UNLEV	MC	5
1427	4-3-92	505	47/1	89		4	UNLEVEL	M/C FAULT LEAKING SEAL	UNLEV	MC	5
1419	27-1-91	8989	43/1	191		8	UNLEVEL	M/C FAILURE	UNLEV	MC	5
1421	6-2-92	925	60/1	196		8	UNLEVEL	M/C FLOW PROBLEM	UNLEV	MC	5
1423	16-2-92	8045	44/2	670		7	RUINED	M/C ELECTRICAL FAULT	UNLEV	MC	5
1417	17-1-92	729	47/1	40		1	UNLEVEL	PRECIPITATION OF DYESTUFFS	UNLEV	PPT	5
1412	26-11-91	8166	86/2	5		S2	UNLEVEL	NOT PROPERLY PRESSED	UNLEV	PP	4
1445	20-7-92	7059	30/1	50			UNLEVEL	RECIPE TRANSCRIPTION ERROR	UNLEV	TE	5
1421	6-2-92	8989	43/1	50	Y	6	DYE RINGS, PRECIPITATIO	HARDNESS PROBLEM	UNLEV	PPT	2
1412	26-11-91	8166	44/1	5		S2	UNLEVEL	NOT PROPERLY PRESSED	UNLEV	PP	4
1589	10-9-91	7948	27/1	200		6	UNLEVEL	LOOSE SPINDLES	UNLEV	OTHER	3
1428	10-3-92	8092	44/1	135		8	UNLEVEL	POT WAS ONLY HALF FULL	UNLEV	OTHER	5
1412	26-11-91	8166	55/128	5		S2	UNLEVEL	NOT PROPERLY PRESSED	UNLEV	PP	4
1437	27-4-92	8077	87/2	5		S1	UNLEVEL	NOT PRESSED CORRECTLY	UNLEV	PP	4
1410	19-11-91	1680	78/2	24		2	UNLEVEL	M/C FAULT	UNLEV	MC	5
1409	11-11-91	4456	60/1	16		S2	UNLEVEL	M/C FAULT	UNLEV	MC	5
1599	18-10-91	925	55/1	60		1	UNLEVEL	M/C LEAKING, LOSING PRESSURE	UNLEV	MC	5
1410	19-11-91	8962	47/1	69		2	UNLEVEL	M/C FAULT	UNLEV	MC	5
1406	6-11-91	530	44/1	24		S2	UNLEVEL	CONTROLLER TEMP GUAGE READING WRON	UNLEV	MC	5

1599	18-10-91	8298	44/1	185		6	UNLEV,RINGS ON OUTSID	M/C FAULT	UNLEV	MC	3
1596	9-10-91	130	60/1	192		6	RINGS	M/C FAULT DURING DYEING	UNLEV	MC	5
1417	17-1-92	9073	8/1	10		S2	UNLEVEL	M/C REPAIR FAULT	UNLEV	MC	5
1411	21-11-91	1680	78/2	25		2	UNLEVEL	M/C FAULT	UNLEV	MC	5
1420	31-1-92	7965	27/1	200		6	UNLEVEL	M/C FAULT	UNLEV	MC	3
1402	28-10-91	8962	47/1	69		2	UNLEVEL	M/C FAULT,PUMP STOPPED	UNLEV	MC	3
1599	18-10-91	734	55/1	61		1	UNLEVEL	M/C LEAKING, LOSING PRESSURE	UNLEV	MC	5
1401	24-10-91	505	44/1	40		2	UNLEVEL	M/C FAULT	UNLEV	MC	5
1402	28-10-91	3205	47/1	15		S2	UNLEVEL	M/C FAULT,FLOW PROBLEM	UNLEV.	MC	3
1406	6-11-91	175	44/1	16		S2	UNLEVEL	CONTROLLER TEMP GUAGE READING WRON	UNLEV	MC	5
1424	19-2-92	7382	32/2	200		6	UNLEVEL	M/C FLOW PROBLEM	UNLEV	MC	5
1421	6-2-92	1535	60/1	181		6	UNLEVEL	M/C FLOW PROBLEM	UNLEV	MC	5
1443	11-6-92	3724	43/1	10		S1	OFFSHADE	COLOUR WEIGHING ERROR	OFFSH	CWE	5
1592	24-9-91	8005	44/1	208		6	OFFSHADE	COLOUR WEIGHING ERROR	OFFSH	CWE	5
1446	6-7-92	7085	30/1	245		6	OFFSHADE	RECIPE TRANSCRIPTION ERROR	OFFSH	TE	5
1422	10-2-92	925	28/1	115		4	OFFSHADE	COLOUR WEIGHING ERROR	OFFSH	CWE	5
1431	27-3-92	85	43/1	228		8	OFFSHADE	COLOUR WEIGHING ERROR	OFFSH	CWE	5
1422	10-2-92	85	47/1	48		1	OFFSHADE	COLOUR WEIGHING ERROR	OFFSH	CWE	5
1414	2-12-91	8964	68/2	476		8	OFFSHADE	PROBABLY WEIGHING ERROR	OFFSH	CWE	3
1410	19-11-91	2715	47/1	5		S1	OFFSHADE,TOO DULL	LIGHT SHADE	OFFSH	DS	5
1450	23-7-92	8420	60/1	10		S1	OFFSHADE,BAD ADDITION	PALE OLIVE	OFFSH	DS	5
1410	19-11-91	8064	87/2	5		S1	OFFSHADE,TOO DARK	LIGHT SHADE	OFFSH	DS	5
1409	11-11-91	85	43/1	364		8	OFFSHADE AFTER ADDNS	LIGHT GRAY COLOUR	OFFSH	DS	5
1406	6-11-91	9063	8/2	7		S1	OFFSHADE,ADDNS WRON	LAB TRANSCRIPTION ERROR	OFFSH	TE	5
1449	23-7-92	7013	30/1	100		4	OFFSHADE,BAD ADDITION	RECIPE TRANSCRIPTION ERROR IN LAB	OFFSH	TE	5
1441	3-6-92	8074	87/2	5		S1	OFFSHADE	RECIPE,PALE BEIGE COLOUR	OFFSH	DS	5
1442	9-6-92	8068	86/2	122		6	TOO DARK AND YELLOW	RECIPE,LIGHT TURQUOISE	OFFSH	BR	5
1409	11-11-91	1520	47/1	58		1	OFFSHADE	M/C FAULT	OFFSH	MC	5
1588	5-9-91	8039	47/1	495		8	OFFSHADE	RECIPE TRANSCRIPTION ERROR	OFFSH	TE	5
1407	7-11-91	9300	40/1	10		S1	OFFSHADE	RECIPE	OFFSH	BR	2
1447	10-7-92	965	86/2	22			OFFSHADE	WRONG WEIGHT ON REQUISITION	OFFSH	YARN	5
1439	20-5-92	9071	8/1	5		S1	OFFSHADE,BAD ADDITION	RECIPE	OFFSH	BR	3
1425	25-2-92	9313	8/1	12		1	OFFSHADE	RECIPE	OFFSH	BR	5
1421	6-2-92	9305	25/1	10		S1	OFFSHADE	COLOUR WEIGHING ERROR	OFFSH	CWE	5
1592	24-9-91	8065	88/2	10		S2	OFFSHADE	COLOUR WEIGHING ERROR	OFFSH	CWE	5
1438	6-5-92	734	47/1	155		8	OFFSHADE	COLOUR WEIGHING ERROR	OFFSH	CWE	5
1437	27-4-92	9312	8/1	5		S1	OFFSHADE	COLOUR WEIGHING ERROR	OFFSH	CWE	5
1589	10-9-91	9069	8/1	10		S2	OFFSHADE	COLOUR WEIGHER OMITTED CHEMICAL	OFFSH	CWE	5
1437	27-4-92	515	43/1	41			OFFSHADE	COLOUR WEIGHING ERROR PROBABLY	OFFSH	CWE	3
1441	3-6-92	1519	60/1	212		6	OFFSHADE	COLOUR WEIGHING ERROR	OFFSH	CWE	5
1419	27-1-91	9305	25/2	10		S1	OFFSHADE	PALE BLUE COLOUR	OFFSH	DS	5
1452	18-8-92	8238	60/1	109		4	OFFSHADE	WRONG RECIPE WAS USED	OFFSH	OTHER	5
1401	24-10-91	2730	47/1	286		8	OFFSHADE	LAB MATCHED TO WOOL STANDARD	OFFSH	OTHER	5
1446	6-7-92	890	78/2	25		2	OFFSHADE	200% BLUE WEIGHED FOR 400% BLUE	OFFSH	OTHER	5
1423	18-2-92	9306	40/1	10		S1	OFFSHADE	RECIPE	OFFSH	BR	5
1427	4-3-92	1519	47/1	131		4	OFFSHADE	DON'T KNOW	OFFSH	DUNNO	5
1446	6-7-92	2465	55/1	13		S2	OFFSHADE	BAD RECIPE	OFFSH	BR	5
1425	25-2-92	8166	44/2	7		S1	OFFSHADE	RECIPE,PALE YELLOW	OFFSH	BR	5
1426	1-3-92	729	47/1	40			OFFSHADE	RECIPE	OFFSH	BR	5
1426	1-3-92	9072	8/1	10		S2	OFFSHADE, BAD ADDITIO	RECIPE	OFFSH	BR	5
1407	7-11-91	8962	47/1	68		1	OFFSHADE	"LOOKS LIKE A M/C FAULT PROBLEM"	OFFSH	MC	2
1436	22-4-92	4728	43/1	308		8	OFFSHADE	RECIPE	OFFSH	BR	3
1439	20-5-92	25	28/1	23			OFFSHADE	CONTAMINATION(SHADE PLANNED WRONG)	OFFSH	OTHER	5
1419	27-1-91	1730	60/1	69		1	OFFSHADE	OPERATOR PUT IN ONLY HALF THE YARN	OFFSH	OTHER	5
1410	19-11-91	8030	44/1	21		S2	OFFSHADE	RECIPE BAD	OFFSH	BR	5
1596	9-10-91	8913	47/1	50		2	OFFSHADE AFTER ADDNS	LIGHT BLUE	OFFSH	DS	5
1418	23-1-92	660	47/1	118		4	OFFSHADE	PALE BLUE COLOUR	OFFSH	DS	5
1450	23-7-92	2465	55/1	13		S2	OFFSHADE,BAD ADDITION	PALE BEIGE COLOUR	OFFSH	DS	5
1589	10-9-91	9182	10/1	10		S1	OFFSHADE	LIGHT BLUE COLOUR	OFFSH	DS	5
1444	25-6-92	8960	47/1	316			UNLEVEL,BAD ADDITION	LIGHT BEIGE COLOUR	OFFSH	DS	5
1401	24-10-91	8485	60/1	257		6	OFFSHADE,UNLEVEL	RECIPE, PALE BEIGE COLOUR	OFFSH	DS	3
1587	3-9-91	2415	47/1	80		4	OFFSHADE	PALE PINK COLOUR	OFFSH	DS	5
1422	10-2-92	8166	44/2	6		S1	OFFSHADE	RECIPE	OFFSH	BR	5
1443	11-6-92	2481	43/1	10		S1	OFFSHADE	BAD RECIPE FROM HOECHST	OFFSH	BR	5
1598	16-10-91	2750	44/1	91		4	OFFSHADE	RECIPE?	OFFSH	BR	3
1425	25-2-92	9313	8/2	8		1	OFFSHADE	RECIPE, PALE BEIGE	OFFSH	BR	5
1451	13-8-92	8578	47/1	59		1	OFFSHADE,BAD ADDITION	PALE BLUE	OFFSH	DS	5
1410	19-11-91	729	47/1	12		S2	OFFSHADE	CONTAMINATION FROM PREVIOUS SHOT	OFFSH	HH	5
1444	25-6-92	890	78/2	25			OFFSHADE	CONTAMINATIN FROM PREVIOUS DYESHOT	OFFSH	HH	5
1411	21-11-91	9202	10/1	15		S2	DYEMARKS	HANDLING AT DRYER	DM	HH	5
1598	16-10-91	1410	44/1	51		1	DYEMARKS	BAD HANDLING	DM	HH	5
1438	6-5-92	705	60/1	5	Y	S1	DIRTY YARN	BAD HANDLING	DM	HH	5
1401	24-10-91	9087	8/2	3	Y		DYEMARKS	BAD HANDLING	DM	HH	5
1401	24-10-91	9063	8/2	7	Y		DYEMARKS	BAD HANDLING	DM	HH	5
1422	10-2-92	729	47/1	41		1	DYEMARKS,RINGS	PRECIPITATE ON TOP,BOTTOM CONES	DM	PPT	5
1426	1-3-92	2715	47/1	13	Y		DYEMARKS,SPOTS	BAD HANDLING,CARELESSNESS	DM	HH	5
1596	9-10-91	2605	60/1	25		S2	DIRTY,DYESPOTS	BAD HANDLING	DM	HH	5
1426	1-3-92	2713	47/1	3	Y		DYEMARKS,SPOTS	BAD HANDLING,CARELESSNESS	DM	HH	5
1447	10-7-92	4003	60/1	10	Y	S1	DYESPOTS	DIRTY CONES	DM	HH	5
1438	6-5-92	4625	47/1	33	Y	1	DIRTY YARN	BAD HANDLING	DM	HH	5
1591	17-9-91	2353	47/1	13	Y	S2	DYEMARKS	UNDISSOLVED DYESTUFFS	DM	DP	4
1426	1-3-92	8126	47/1	23	Y		DYEMARKS,SPOTS	BAD HANDLING,CARELESSNESS	DM	HH	5
1425	25-2-92	9307	25/2	10		S1	STAINMARKS OF DIRTY C	CONES NOT BOILED OUT	DM	HH	5
1426	1-3-92	2715	44/1	7	Y		DYEMARKS,SPOTS	BAD HANDLING,CARELESSNESS	DM	HH	5
1426	1-3-92	8148	47/1	8	Y		DYEMARKS,SPOTS	BAD HANDLING,CARELESSNESS	DM	HH	5
1435	16-4-92	2602	28/1	27		1	BLUE DYEMARKS	PROBABLY M/C NOT BOILED OUT PROPERLY	DM	HH	3
1443	11-6-92	8181	50/1	21		S2	DIRTY YARN	DIRTY YARN	DIRTY	YARN	5
1413	28-11-91	7011	27/1	120			DIRTY RINGS	DIRTY YARN	DIRTY	YARN	3
1413	28-11-91	7009	27/1	200			DIRTY RINGS	DIRTY YARN	DIRTY	YARN	3
1446	13-7-92	7925	30/1	30		1	MIXED,DIRTY YARN	MIXED,DIRTY YARN	DIRTY	YARN	5
1404	5-11-91	7827	30/1	100		4	WRONG SHADE PLANNED	HUMAN ERROR		OTHER	5
1598	?????	7793	28/1	20		2	WRONG RECIPE	MAITLAND DID NOT CLARIFY REQUIREMENT		OTHER	5

APPENDIX 4: ANALYSIS OF REJECT DATA BY MACHINE

Daily production records for the period January to August 1992 were assessed in terms of reject lots and reject kilograms by dyemachine. The capacities for each machine are as follows:

Machine 1 : 65kgs
Machine 2 : 65 kgs
Machine 4 : 115 kgs
Machine 5 : 1050 kgs
Machine 6 : 250 kgs
Machine 7 : 1050 kgs
Machine 8 : 550 kgs
Machine S1: 10 kgs
Machine S2: 25 kgs
Jet : Piece dyeing

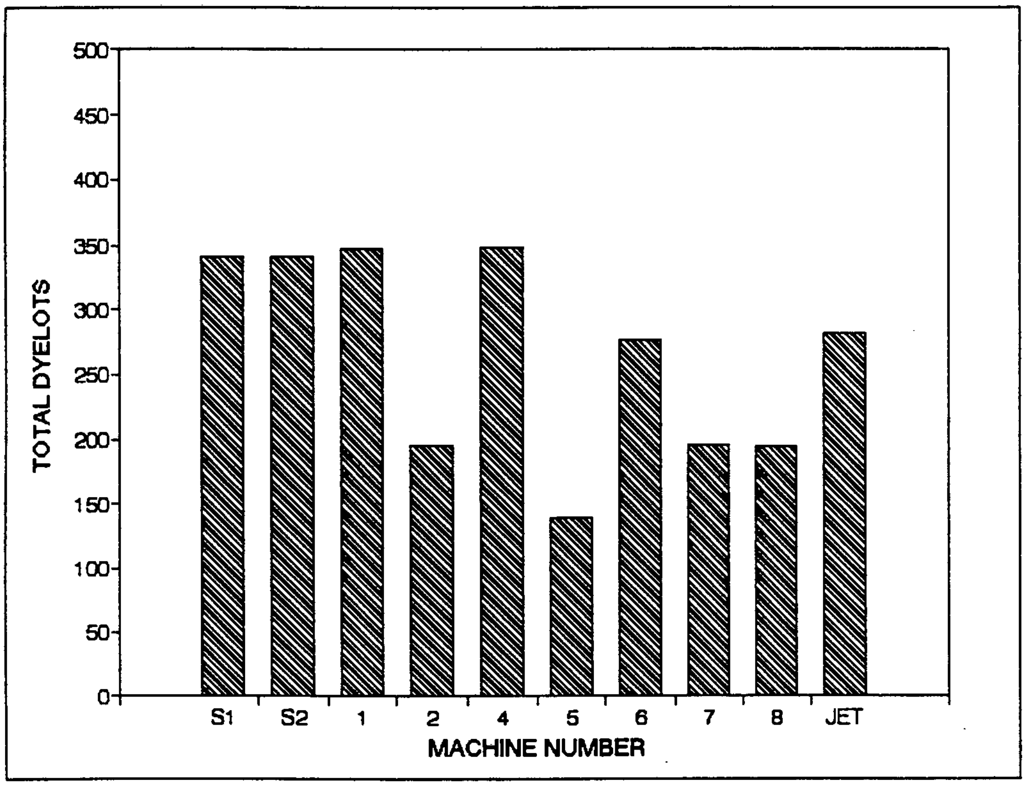

Figure A1: Total lots per machine (Sept '91 - Aug '92)

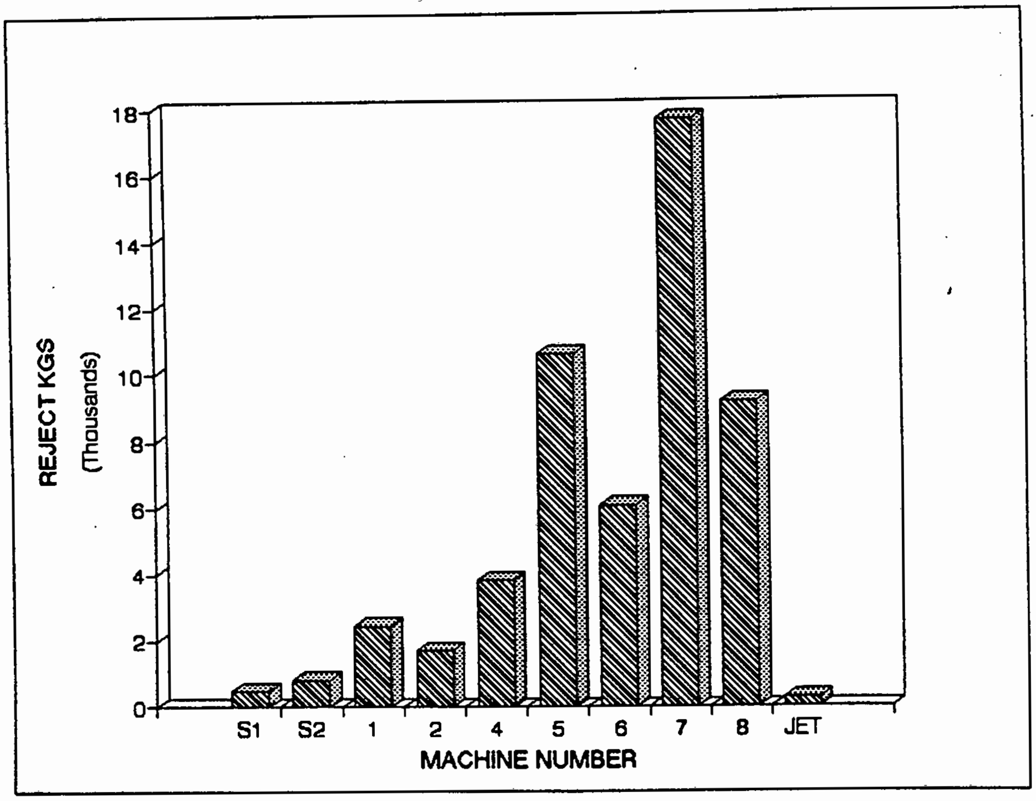

Figure A2: Reject kgs per machine (Sept '91 - Aug '92)

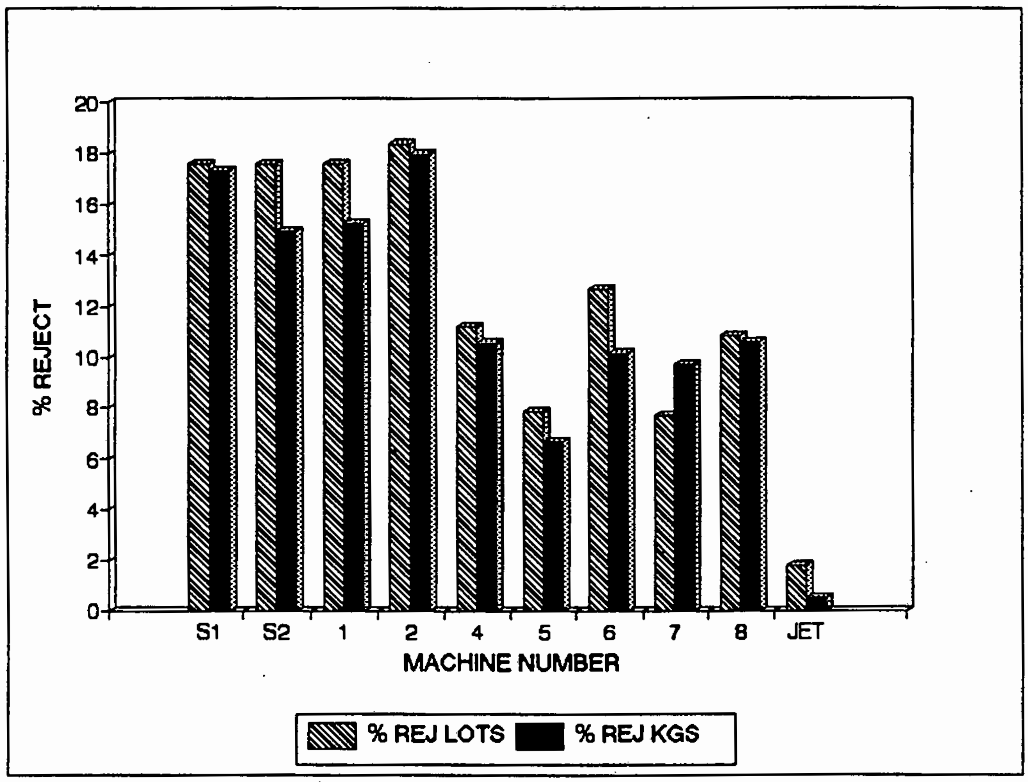

Figure A3: % Reject per machine (Sept '91 - Aug '92)

APPENDIX 5: RESULTS AND RECOMMENDATIONS OF A PRELIMINARY PROCESS INVESTIGATION

Water

Water hardness is usually (although for two months it was not) displayed on a board in the foreman's office in the dyehouse. There does not seem to be any specific action to be taken if the water hardness is too high or too low. One of the softeners is not working and, according to the plant engineer's calculations, up to 85% of the dyehouse's water is not softened. This alarming figure may be as a result of a faulty flow meter and the engineer is checking this.

Recommendations

- Define acceptable water hardness levels and specify appropriate actions if this is exceeded
- Display water hardness levels
- Send water samples for lab analysis on a regular basis
- Investigate the water softener problem

Dyestuffs and chemical quality

Dyestuff manufacturers, in particular, work to very high quality standards. However, once the dyestuffs are delivered to SA Fine Worsteds, they could be contaminated by reaction with water, absorbtion of water or contamination by other dyestuffs or chemicals.

Recommendations

- Send 20 samples of commonly used dyestuffs and 10 samples of commonly used chemicals from opened containers back to their manufacturers for analysis.

pH

The correct pH level in the dyepot is controlled completely by the dyepot operator. The operators are, however, well trained in ensuring that the correct pH is reached. One quality problem is that the pH meter is not regularly calibrated and it is a machine that can go out of control fairly easily.

Recommendations

- Calibrate and record pH on a regular basis.

Dyepot and colour weigher's operating procedures

Operators are thoroughly trained in operating their machines although they do not always understand how these work. One of the problems is that they do not have 'ownership' of their process. In order to do this, they must be involved and understand what is their contribution to the success of the product. At the moment what comes out of the pot after the dyeing is not really meaningful to them. The extent of their responsibility in the process can be clearly specified, but it cannot really be monitored except by the vigilance of the dyehouse supervisors/ management. The recommendations for this are thus more medium to long term.

Recommendations

- Train operators on the basic aspects of their machines, what can go wrong with them and what the symptoms of these faults are.
- Install process monitoring equipment such as temperature recording charts in order to ensure that the operator takes responsibility for monitoring his machine.

Dyepot pressure

No automatic feedback system exists for controlling the pressure in the dyepots. Pressures vary considerably from time to time and from machine to machine. The working limits for dyepot pressure are accepted to be between 2 and 4 bar whilst the optimum limits are 2.5 - 3 bar, according to the Dyehouse Manager. Pressure is a function of temperature, pump speed and the size of the orifices through which the dye liquor flows. No simple (cheap!) solution exists for this problem as yet.

Recommendation

- to be investigation further.

The temperature cycle for the lot

The temperature cycle for each recipe is programmed into the machine controllers by the Assistant Dyehouse Manager or the Shift Supervisor. The sample machines are manually programmed by the individual operators. Temperature variations are critical.

Recommendation

- That temperature cycle recording charts be purchased for each machine. These used to be used on the machines but have since fallen into disrepair. These would serve to:

    - Provide an historical record of the exact temperature cycle that took place. This can be checked for correctness.
    - Indicate that other machine faults such as flow or pressure problems have taken place. These could be seen as discontinuities (squiggles) on the graphs

as the controller is forced to compensate for changing conditions.

- Eliminate an enormous area of uncertainty concerning the cause of unsatisfactory dyeing and enable the focus of these causes to be in the right place.
- Provide a record of machine performance in order to pick up indications of future machine problems.

Liquor ratio

Liquor ratio does apparently have a significant effect on the result of the dyeing process.

Recommendations

- Perform documented trials using the same machine, yarn type, recipe etc, but with different ratios of yarn to liquor in order to establish the nature of the variations that occur. From this it may be established what is an acceptable or not acceptable liquor ratio and what compensations can be made. The very least that it could serve is to put some focus on an area that is not being addressed currently.

Variations from machine to machine

Variations in dyeing characteristics may well occur from machine to machine because of different sizes, different liquor flows etc.

Recommendation

- Perform documented trials using the same yarn, recipe etc but on different machines in order to establish the nature of the variations that occur on each. Initially tests should be performed on sister machines to ensure that the same result occurs on each. If they do not then it would be clear that the controlled variables are not under control.

APPENDIX 6: WRITTEN OBSERVATIONS FROM FURTHER PROCESS INVESTIGATIONS

Yarn Weighing

Yarn weighing and mass calculation is performed by the Yarn Store Supervisor on the Avery floorscale. This scale reads to the nearest 1/2 kilogram, eg any weight between 1.76kg and 2.24kg will be recorded as 2.0kg. The yarn is weighed in a crate and the Yarn Store Supervisor subtracts the estimated crate mass and the yarn cone mass from the floor scale total. The yarn for Trial 1 was checked on the Masskot Dye Kitchen scale (accurate to 1g) and there was found to be a weighing error of 1.2%. Similarly the error for Trials 6 and 7 were found to be only 0.1%. The approximate mass of the yarn is checked by the production coordinator who counts the number of cones and from this estimates the total mass.

Yarn Pressing

Yarn cones are pressed onto the dyepot carrier spindles according to the height indicated on a set of measuring sticks. There is some apathy/ confusion as to the height to which a spindle of cones should be pressed. In the case of the 6" AVA 47/1 cones being pressed, the marking stick indicated a level that was higher than the actual spindles themselves. Some of the operators proclaimed that the measuring sticks were all wrong and pressed the yarn tight so that the spindles could be locked whilst one head operator found spindle extensions and pressed the yarn to the height indicated on the measuring stick. Extensions were used on Trials 3, 4, 5 and 6. I was unfortunately not present to witness the pressing of Trial 7.

Yarn Moisture Content

The moisture content of all the yarn batches was checked before they were weighed and were found in each case to be 7.1%. According to the QA Manager, the moisture content of Trevira/ Wool yarn usually between 7% and 9%. This can depend on a number of factors , the most important of which being relative humidity. Relative humidity in the mill varies considerably with the weather. For example, records for October indicate that the RH in the Winding Department reached a peak on 23/10/92 of 71,0 and a low on 30/10/92 of 44,7.

Recipe Calculation

For each shade a standard recipe exists. The recipe quantities are scaled according to the size of the dye machine and the mass of the yarn being dyed. Chemicals are generally calculated in terms of grams or cc per litre volume of the dyepot. Dyestuffs are generally calculated in terms of grams per kilogram of yarn. These calculations are performed by calculator. The result is checked by a Shift Supervisor or the Assistant Dyehouse Manager. For the seven trials performed the percentage rounding error was found to be between 0.2% and 0.5% (see **Appendix** 7). Reading and writing errors are easy to make as everybody associated with the recipes are aware. In Trial 5, the colour weigher had some difficulty in deciding whether the quantity of Eganol PS was 320cc/litre or 370cc/litre.

The units describing the dyestuff and chemical quantities are not only critical for the recipe calculation but also for the colour weigher who is weighing the recipe. This is clearly a problem which I only realised on the last trial. The colour weigher would generally WEIGH the quantity of Eganol PS or Remol NTG on the weighing scale when in fact the recipe was calling for a VOLUME of Eganol PS and a WEIGHT of Remol NTG(In Trial 6 and 7 the colour weigher used a measuring flask to measure **both** the Remol and the Eganol!). Thus an assumption is made that the density of Eganol PS and Remol NTG is that of water ie 1g/cc (my quick experiment indicated that the density of Eganol PS and Remol NTG is 1,0g/cc and that of Remol NTG is 1,2g/cc).

Recipe Weighing

In Trials 1 and 2 the accuracy of the Dye Kitchen dyestuff weights was checked against the lab scale (accurate to +- 10mg) and were found to be in error by 0.1% and 0.2% respectively (See **Appendix** 7).

When the dyestuffs and chemicals were reweighed for Trial 7 it happened to be a windy day. It was observed that this could affect the weight reading on the scale by 2 or 3 grams. This could represent a 7% error in the weight of , say, Remacen Red BBS in Trial 1.

One particular event is worth recording. The dyestuffs and chemicals for Trial 7 were weighed several days before the trial actually took place because of a delay in getting time on Machine 1. The dyestuffs and chemicals were each stored in plastic bags in the colour kitchen over the next few days. The dyestuffs' overall mass was found to be correct but the bag supposedly containing 480g of Sodium Acetate and Versene weighed 747g! This packet was discarded and the chemicals reweighed.

Dyestuff and Chemical Dissolving

This was found to be performed satisfactorily and according to procedure.

Testing the pH of the Chemicals in the Dyepot

This is performed by the machine operator before the dyestuffs are added to the pot. The pH meter was unfortunately being repaired for all but the last of the tests and pH paper was used instead. This method is almost adequate for the job in that it is accurate to approximately +- 0,2 pH. For this particular recipe the Dyehouse Manager stated that the pH accuracy of around +- 0,3 would be adequate.

If the pH is not satisfactory the operator will adjust it by adding either acetic acid or ammonia. I think that is unlikely that too many additions of ammonia are made because the operator has to go outside and tip the 200l ammonia container to get his 50cc or 100 cc sample!

Water Hardness

In none of these trials did the water hardness exceed the 10.0 limit.

Machine Performance/ Operator Procedures
(see **Appendix** 7)

Dyepot temperature, pressure and flow convertor change times were recorded at 10 minute intervals for all the trials. The machines followed the temperature required by the program closely although there tended to be a temperature lag of about 5 minutes when the program switched from a constant temperature of 106 degrees to cooling at 5 degrees C per minute. This is understandable as it will take some time for the cooling water to start having an effect on the dyepot temperature.

Dyepot pressure is recommended to be between 2,5 bar and 4 bar by the Dyehouse Manager. The pressure in Machine 1 was, however, mostly around 2 bar. Discussion with Dr F Barkhuizen of South African Wool and Textile Research Institute indicates that the function of pressure is principally to enable the dye liquor to reach temperature and its exact control is therefore not critical. Pressure also serves a secondary function of promoting penetrating of the yarn by the dye liquor.

Flow convertor change times were satisfactory except in Trials 3 and 4 when the operator did not notice that the flow convertor change timers were not working until I pointed this out to him.

There is a tendency for operators not to make sure that all the dyestuffs and chemicals are flushed through the piping from the dissolving tank. This is because it requires a lot of flushing to thoroughly clean out the pipes. The proportion of dyestuffs not flushed into the dyepot is small, probably in the order of 1%.

Machine Speed

The circulating pump for Machine 1 runs at a fixed speed of 1150 RPM. For the purpose of the trial the variable speed drive for machine 2 was set to the same speed (as far as practically possible using a hand tacho and parallel shaft measurement). The knob for adjusting Machine 2's circulating pump speed is small and unmarked. The speed indicator is on the wall some 1.5 metres above the operator's head. It is impossible to read even fairly accurately without a step ladder. It is thus unlikely that the operators ever consider the pump speed on Machine 2. This pump speed is usually indicated on the recipe although in this particular case it was not.

Testing the Sample Hank against the Master

It is worth noting that for Trials 1 and 2 The Assistant Dyehouse Manager rinsed the sample hanks and that this made a significant difference to the shade of the hanks. Unfortunately the pre-rinsed hanks were not tested on the colour-matching computer. This detail is significant in that it seems to have affected the results of the trials as will be seen in Section 4.5.4.

The master itself was not in very good condition (dated 26/05/92) and appeared to be slightly faded. This, too, can be seen in Section 4.5.4.

In none of the trials was there found to be problems of unlevelness in the yarn that was dyed.

APPENDIX 7: TABLED OBSERVATIONS FROM FURTHER PROCESS INVESTIGATIONS

WEIGHING

	1	2	3	4	5	6	7
DATE	10/11/92	10/11/92	24/11/92	24/11/92	30/11/92	07/12/92	09/12/92
MACHINE NO	1	2	1	2	1	1	1
MACHINE VOLUME (L)	317	317	317	317	317	317	317
YARN:							
WEIGHT, YARNSTORE (KG)	59.1	60.6	59.6	59.1	60.1	40.4	20.7
WEIGHT, ACTUAL (KG)	58.4		-	-	-	40.46	20.72
% ERROR	1.2					0.1	0.1
% MOISTURE CONTENT	7.1	7.1	7.1	7.1	7.1	7.1	7.1
DYESTUFFS & CHEMICALS:							
(COLOUR KITCHEN SCALE)							
VERSENE (0.5G/L)	158	158	158	158	160	160	160
EGANOL PS (1ML/L)	317	317	317	317	320	320	320
REMOL NTG (2% KG/KG)	1182	1204	1192	1182	1200	800	400
SODIUM ACETATE (2G/L)	634	634	634	634	630	630	320
REMACEN YELLOW RMS (0.29% KG/KG)	171	175	173	171	174	117	60
REMACEN RED BBS (0.07% KG/KG)	41	42	42	41	42	28	14
REMACEN BLACK BMS (0.63 % KG/KG)	372	382	375	372	379	255	130
% ROUNDING ERROR (ON CALCULATING RECIPE QUANTITIES)	0.2	0.2	0.0	0.2	-0.0	-0.0	0.5
DYESTUFFS AND CHEMICALS:							
(LAB SCALE)							
REMACEN YELLOW RMS (0.29% KG/KG)	170.59	175.1					
REMACEN RED BBS (0.07% KG/KG)	40.43	41.48					
REMACEN BLACK BMS (0.63 % KG/KG)	372.21	381.3					
% DIFF (LAB & COLOUR KITCHEN SCALES)	-0.1	-0.2					

NOTES:

MOISTURE CONTENT FOR TREVIRA WOOL YARN OF THIS TYPE VARIES FROM 6 - 8 %
WHEN LEFT TO STAND DEPENDING ON ATMOSPHERIC HUMIDITY

OBSERVATIONS:

TRIAL NO: 1&2

DATE: 10/11/92

TEMPERATURE, PRESSURE AND FLOW REVERSAL OBSERVATIONS:

	MACHINE 1				MACHINE 2			
	DYEPOT TEMP	DYEPOT PRESS	FLOW CONVERTER TIMES		DYEPOT TEMP	DYEPOT PRESS	FLOW CONVERTER TIMES	
TIME	TEMP (C)	PRESS (BAR)	I/O (MIN)	O/I (MIN)	TEMP (C)	PRESS (BAR)	I/O (MIN)	O/I (MIN)
11.30 AM	47	3.8			38	3.5		
11.40 AM	56	4.0	8.0	3.0	48	3.7	8.0	2.0
11.50 AM	66	3.9	8.0	2.5	59	3.8	8.0	2.0
12.00 AM	76	3.8	1.5	3.0	68	3.5	1.0	3.0
12.10 AM	85	3.8	3.5	3.0	78	3.4	3.0	3.0
12.20 AM	95	3.8	5.0	3.0	88	3.6	4.0	3.0
12.30 AM	106	4.0	6.0	3.0	99	3.8	5.0	3.0
12.40 AM	106	4.0	7.0	3.0	106	3.4	5.5	3.0
12.50 AM	106	4.1	8.0	1.0	106	3.6	7.0	3.0
1.00 PM	106	3.9	0.0	0.0	106	3.8	8.0	1.0
1.10 PM	82	3.8	8.0	2.0	105	3.4	8.0	3.0
1.20 PM	FINISH				69	3.6	8.0	1.0
					FINISH			
COMMENT	SEE BELOW	OK	OK	OK	SEE BELOW	OK	OK	OK

NOTES:

M/C 1 - TOOK 10 MINUTES TO COOL FROM 106 C TO 82 C INSTEAD OF 5 MIN (RECIPE COOLING RATE 5 C / MIN)

M/C 2 - TOOK 13 MINUTES TO COOL FROM 106 C TO 69 C INSTEAD OF 8 MIN (RECIPE COOLING RATE 5 C / MIN)

PH - APPROX 5.5(TESTED USING PH PAPER). RECIPE REQUIRES THAT PH = 5.5. HOWEVER PH METER OUT OF ORDER

WATER HARDNESS - 7.7

WHEN C ROSS RINSED THE SAMPLE HANK IN WATER IT LOST A 'LOT OF GREEN'. THIS AFFECTED THE MATCHING OF THE SAMPLE AGAINST THE MASTER.

OBSERVATIONS

TRIAL NO: 3&4

DATE: 24/11/92

TEMPERATURE, PRESSURE AND FLOW REVERSAL OBSERVATIONS:

	MACHINE 1				MACHINE 2			
	DYEPOT TEMP	DYEPOT PRESS	FLOW CONVERTER TIMES		DYEPOT TEMP	DYEPOT PRESS	FLOW CONVERTER TIMES	
TIME	TEMP (C)	PRESS (BAR)	I/O (MIN)	O/I (MIN)	TEMP (C)	PRESS (BAR)	I/O (MIN)	O/I (MIN)
10.28 AM	40	1.8	NOT WOR	NOT WOR	42	3.6		
10.41 AM	53	1.9	NOT WOR	NOT WOR	55	3.4	8.0	3.0
10.51 AM	63	1.9	NOT WOR	NOT WOR	65	3.4	6.0	3.0
11.00 AM	73	1.9	8.0	1.0	75	3.4	8.0	3.0
11.11 AM	84	1.9	8.0	3.0	85	3.5	8.0	3.0
11.20 AM	93	1.8	3.0	3.0	94	3.3	7.0	3.0
11.34 AM	106	2.0	8.0	2.0	106	3.8	8.0	2.0
11.40 AM	106	2.0	3.0	3.0	106	3.5	8.0	2.0
11.50 AM	106	2.0	4.0	3.0	106	3.5	2.0	3.0
12.04 AM	106	2.0	1.0	3.0	107	3.4	3.0	3.0
12.10 AM	96	1.8	1.0	3.0	78	3.4	7.0	3.0
12.13 AM	90	1.7	8.0	2.0	72	3.6	1.0	3.0
12.15 AM	83	1.6	5.0	3.0	67	3.4	0.0	0.0
12.17 AM	75	1.8	4.0	3.0	69	FINISH	7.0	3.0
12.21 AM	67	FINISH			FINISH			
COMMENT	SEE BELOW	OK	SEE BELOW	SEE BELOW	SEE BELOW	OK	OK	OK

NOTES:

M/C 1 - TOOK 17 MINUTES TO COOL FROM 106 C TO 67 C INSTEAD OF 8 MIN (RECIPE COOLING RATE 5 C / MIN)

M/C 2 - TOOK 14 MINUTES TO COOL FROM 106 C TO 69 C INSTEAD OF 8 MIN (RECIPE COOLING RATE 5 C / MIN)

M/C 1 FLOW REVERSAL NOT WORKING UNTIL I POINTED IT OUT TO THE OPERATOR

PH - APPROX 5.2 ON BOTH MACHINES (TESTED USING PH PAPER). RECIPE REQUIRES THAT PH = 5.5. HOWEVER PH METER OUT OF ORDER

ACETIC ACID, THEN AMMONIA, THEN ACETIC ACID AGAIN WERE ADDED TO GET THE PH CLOSE TO THE CORRECT VALUE

WATER HARDNESS - 9.9 (8 AM), 8.8 (12 AM)

M/C 1 DYEPOT TO POCKET TANK PIPES STILL CONTAINED LIQUOR FROM PREVIOUS DYEING.

OBSERVATIONS

TRIAL NO: 5

DATE: 30/11/92

TEMPERATURE, PRESSURE AND FLOW REVERSAL OBSERVATIONS:

	MACHINE 1				MACHINE 2			
	DYEPOT TEMP	DYEPOT PRESS	FLOW CONVERTER TIMES		DYEPOT TEMP	DYEPOT PRESS	FLOW CONVERTER TIMES	
TIME	TEMP (C)	PRESS (BAR)	I/O (MIN)	O/I (MIN)	TEMP (C)	PRESS (BAR)	I/O (MIN)	O/I (MIN)
1.06 PM	38	2.0	6.0	3.0				
1.16 PM	48	2.0	8.0	0.0				
1.26 PM	58	2.0	8.0	2.0				
1.35 PM	66	2.0	0.0	3.0				
1.46 PM	78	2.0	8.0	3.0				
1.56 PM	88	2.0	1.0	3.0				
2.09 PM	101	2.0	8.0	2.0	M/C 2 OUT OF ORDER BECAUSE TEMPERATURE CONTROLLER REMOVED FOR REPAIR			
2.15 PM	106	2.0	5.0	3.0				
2.35 PM	106	2.0	5.0	3.0				
2.35 PM	106	2.2	5.0	0.0				
2.45 PM	106	2.1	8.0	3.0				
2.50 PM	85	1.8	2.0	3.0				
2.55 PM	66	1.8	8.0	3.0				
COMMENT	OK	OK	OK	OK				

NOTES:

PH - APPROX 5.5(TESTED USING PH PAPER). RECIPE REQUIRES THAT PH = 5.5. HOWEVER PH METER OUT OF ORDER

WATER HARDNESS - 7.7 (8AM), 8.8 (12 PM)

OBSERVATIONS

TRIAL NO: 6

DATE: 07/12/92

TEMPERATURE, PRESSURE AND FLOW REVERSAL OBSERVATIONS:

	MACHINE 1				MACHINE 2			
	DYEPOT TEMP	DYEPOT PRESS	FLOW CONVERTER TIMES		DYEPOT TEMP	DYEPOT PRESS	FLOW CONVERTER TIMES	
TIME	TEMP (C)	PRESS (BAR)	I/O (MIN)	O/I (MIN)	TEMP (C)	PRESS (BAR)	I/O (MIN)	O/I (MIN)
1.20 PM	41	1.8	8.0	3.0				
1.30 PM	52	1.8	6.0	3.0				
1.40 PM	61	1.9	8.0	1.0				
1.52 PM	73	1.8	8.0	0.0				
2.00 PM	81	1.8	8.0	3.0				
2.12 PM	92	1.8	8.0	3.0	M/C 2 OUT OF ORDER BECAUSE TEMPERATURE CONTROLLER REMOVED FOR REPAIR			
2.26 PM	106	2.0	8.0	0.0				
2.36 PM	106	2.0	8.0	2.0				
2.46 PM	106	1.9	8.0	3.0				
2.56 PM	106	1.9	1.0	3.0				
3.00 PM	83	1.8	2.0	0.0				
3.06 PM	66	1.7	8.0	3.0				
COMMENT	OK	SEE BELOW	OK	OK				

NOTES:

PH - APPROX 5.2 (TESTED USING PH PAPER). RECIPE REQUIRES THAT PH = 5.5. HOWEVER PH METER OUT OF ORDER

ACETIC ACID FOLLOWED BY AMMONIA WAS USED TO CORRECT THE PH

WATER HARDNESS - 7.7 (8AM), 8.8 (12 PM)

RECOMMENDED OPERATING PRESSURE IS 2.5 - 4.0 BAR

THE EXPERIMENT WAS DELAYED FOR SEVERAL HOURS BECAUSE THE PNEUMATIC VALVE ACTUATOR ON THE DISSOLVING TANK/ ADDITION TANK WAS FAULTY

BECAUSE THE COLOUR WEIGHER WAS ABSENT, THE HEAD OPERATOR WEIGHED THE DYESTUFFS

OBSERVATIONS

TRIAL NO: 7

DATE: 14/12/92

TEMPERATURE, PRESSURE AND FLOW REVERSAL OBSERVATIONS:

	MACHINE 1				MACHINE 2			
	DYEPOT TEMP	DYEPOT PRESS	FLOW CONVERTER TIMES		DYEPOT TEMP	DYEPOT PRESS	FLOW CONVERTER TIMES	
TIME	TEMP (C)	PRESS (BAR)	I/O (MIN)	O/I (MIN)	TEMP (C)	PRESS (BAR)	I/O (MIN)	O/I (MIN)
1.48 PM	40	2.0	6.0	3.0				
2.00 PM	52	2.0	6.0	3.0				
2.11 PM	63	2.0	6.0	0.0				
2.20 PM	72	2.0	8.0	0.0				
2.31 PM	83	1.9	8.0	0.0				
2.41 PM	92	2.0	8.0	2.0	M/C 2 OUT OF ORDER BECAUSE TEMPERATURE CONTROLLER REMOVED FOR REPAIR			
2.55 PM	106	2.0	6.0	3.0				
3.05 PM	106	2.0	8.0	0.0				
3.15 PM	106	2.0	8.0	1.0				
3.25 PM	106	2.0	8.0	3.0				
3.30 PM	80	1.8	2.0	3.0				
3.36 PM	68	1.8	8.0	3.0				
COMMENT	OK	SEE BELOW	OK	OK				

NOTES:

PH - 5.1 (TESTED USING THE NEWLY RECEIVED PH METER).

ACETIC ACID FOLLOWED BY AMMONIA WAS USED TO CORRECT THE PH

WATER HARDNESS - 9.9 (8AM), 8.8 (12 PM)

RECOMMENDED OPERATING PRESSURE IS 2.5 - 4.0 BAR

THE EXPERIMENT WAS DELAYED FOR SEVERAL HOURS BECAUSE THE PNEUMATIC VALVE ACTUATOR ON THE DISSOLVING TANK/ ADDITION TANK WAS FAULTY

BECAUSE THE COLOUR WEIGHER WAS ABSENT, THE HEAD OPERATOR WEIGHED THE DYESTUFFS

APPENDIX 8: CIELAB D65 COLOUR DIFFERENCE DATA

COMPUTER GENERATED CIELAB D65 COLOUR DIFFERENCE DATA

TRIAL NO	Da X - AXIS GREEN/RED	Db Y - AXIS BLUE/YELL	Dl Z - AXIS BLCK/WHITE	DELTA E OVERALL
1	0.05	0.09	-0.93	0.94
2	0.00	0.00	0.00	0.00
3	-0.14	0.13	-0.29	0.35
4	0.01	-0.08	-0.18	0.20
5	-0.08	0.02	0.40	0.41
6	-0.28	-0.23	0.26	0.45
MASTER	0.35	-0.25	0.39	0.58

DELTA E = SQ. ROOT (Da*Da+Db*Db+Dl*Dl)

APPENDIX 9: PIN TROLLEY EVALUATION

'BALL PARK FIGURE' ESTIMATE OF COST OF YARN AND FLOOR DAMAGE

A) ESTIMATED ANNUAL COST OF YARN DAMAGED

ESTIMATE LENGTH OF YARN ON 1 OFF 47/1 2.5 KG CONE AT COST R35
= 47/1000*2500*1000 = 117 500M
ASSUME 1 THREAD (1 OUTSIDE 'CIRCLE') OF YARN IS DAMAGED PER CONE
ASSUME 600 TONNES OF YARN ARE DYED PER YEAR
THEN COST OF DAMAGED YARN PER YEAR :
600 000/2.5 * 3.14 * .25 = 188 400M DAMAGED YARN PER YEAR
= 188 400 / 117 500 * R35

= R56,12 PER YEAR
(NB IF 10 THREADS PER CONE WERE DAMAGED COST WOULD BE R561,20)

B) ESTIMATED ANNUAL COST OF FLOOR DAMAGE

10 YEARS DAMAGED COST R22 000 TO FIX
THE TROLLEYS WILL BE EFFECTIVE IN REDUCING FLOOR DAMAGE BY ABOUT 25 %
BECAUSE THE REMAINING CRATES AND THE CARRIERS WILL STILL BE RESPONSIBLE
FOR DAMAGE OVER LARGE AREAS OF THE FLOOR
THUS COST PER ANNUM FOR FLOOR DAMAGE:
= R22 000 * 25 / 100 /10

R550 PER YEAR

C) ESTIMATED ANNUAL COST OF 10 CRATES
ASSUME 3 YEAR LIFE CYCLE
= 10 * R130 / 3

= R433 PER YEAR

D) ESTIMATED ANNUAL COST OF 10 TROLLEYS
ASSUME 3 YEAR LIFE CYCLE
=10*R1731/3

=R5770 PER YEAR

E) OVERALL ANNUAL COST OF TROLLEYS TAKING TO ACCOUNT SAVINGS FROM NON DAMAGED FL
= R5770 - R56,12 - R550

= =R5164 PER YEAR COMPARED TO R433 PER YEAR FOR CRATES

CONCLUSION

EVEN TAKING INTO ACCOUNT LARGE VARIATIONS OF THE ACCURACY OF THIS ESTIMATE
THE PURCHASE OF PIN TROLLEYS CANNOT BE JUSTIFIED FINANCIALLY

DECISION TABLE FOR CRATES IN THE DYEHOUSE

FACTOR	CONTRIB %	PARAMETER	CONTRIB %	CRATE	RATING 1 - 4	CONTRIB * RATE	PIN TROLLEY	RATING 1 - 4	CONTRIB * RATE
STORAGE ABILITY	15	FLOORSPACE	5	1.2 M^2	4	20	1.68 M^2	2	10
		CAPACITY	5	80/100 CONES	3	15	84 CONES	2	10
		STACKABILITY	5	VERY GOOD	4	20	NIL	0	0
YARN DAMAGE	15	YARN DAMAGE	15	POOR	1	15	VERY GOOD	4	60
FLOOR DAMAGE	15	FLOOR DAMAGE	15	POOR	1	15	VERY GOOD	4	60
TRANSPORTABILITY	15	TRANSPORTABILITY	15	POOR	1	15	VERY GOOD	4	60
UN/LOADING EASE	5	UN/LOADING EASE	5	POOR	1	5	FAIR	2	10
COST	35	INITIAL COST	20	R130 EA	4	80	R1731 EA	1	20
		MAINT/REPLACE	15	CHEAP	4	60	EXPENSIVE	1	15
TOTAL	100					245			245
TOTAL (EXCL COST)	65					105			210

NOTES

- APPLICATION OF TROLLEYS IS LIMITED TO DYEPOT/ HYDRO AND HYDRO/ DRYER

- APPROX 10 TROLLEYS WOULD BE NECESSARY AT A COST OF R17 310

CONCLUSIONS

- FUNCTIONALLY THE PIN TROLLEYS MAKE MORE SENSE, PARTICULARLY IN THE LIMITED APPLICATION MENTIONED ABOVE WHERE STORAGE SPACE IS NOT CRITICAL

- THE COST PENALTY FOR PIN TROLLEYS IS HIGH, BUT THIS WOULD BE OFFSET TO SOME EXTENT IN THE LONG TERM BY REDUCED YARN AND FLOOR DAMAGE

APPENDIX 10: ASSESSMENT OF THE MAJOR SOLUTIONS IMPLEMENTED

Listed below are the major actions that have been taken or are being taken in terms of the objective of reducing the reject rate in the dyehouse. A standard set of questions has been applied to each action.

ACTION: REBUILD DYE KITCHEN

APPROX DIRECT 'EXTERNAL' COST: R73000

DATE WHEN ACTION EFFECTIVE: END NOVEMBER 1992

WHICH CAUSES IDENTIFIED IN THE PARETO ANALYSIS DOES IT ADDRESS: 'Colour weighing' and 'Difficult shade' - 16.7% of total causes

HOW EFFECTIVE IS IT IN ADDRESSING THESE CAUSES? It cannot really affect the weighing process at all. It should reduce the chances of dyestuff contamination and also identification problems because the colour kitchen will be more organised (contamination is a particularly serious problem with the light shades). It should reduce the chance of a colour weigher omitting an ingredient because he has run out of stock and is too lazy to go downstairs and get more stock.

CONCLUSION - The dyekitchen rebuild is an important 'Long term environmental factor' but can only contribute in a small way to reducing the reject rate.

ACTION: REARRANGE/ REFURBISH THE DOWNSTAIRS OFFICES

APPROX DIRECT 'EXTERNAL' COST: R22000

DATE WHEN SOLUTION EFFECTIVE: END SEPTEMBER, 1992

WHICH CAUSES IDENTIFIED IN THE PARETO ANALYSIS DOES IT ADDRESS: 'Clerical' - 4.2% of total causes

HOW EFFECTIVE IS IT IN ADDRESSING THESE CAUSES? The improved working environment can only reduce the number of clerical errors and increase staff productivity. One possible disadvantage is that it may tend to encourage dyehouse management to stay in the quiet, cool offices rather than on the shopfloor where the process is taking place.

CONCLUSION - The office rearrangement is again an important 'Long term environmental factor' and should contribute marginally to improving the reject rate.

ACTION: INTERNAL TRAINING, WORKING INSTRUCTIONS, JOB DESCRIPTIONS

APPROX DIRECT 'EXTERNAL' COST : NEGLIGABLE

DATE WHEN SOLUTION EFFECTIVE: SEPTEMBER 1992

WHICH CAUSES IDENTIFIED IN THE PARETO ANAYSIS DOES IT ADDRESS: It identifies all the causes identified in the analysis either directly or indirectly.

HOW EFFECTIVE IS IT IN ADDRESSING THESE CAUSES? All causes identified in the Pareto Analysis will be affected by the focus on operator and supervisor training. There is a marked improvement in awareness and job knowledge of these people. A small improvement in the reject rate can be expected from this training. Of more importance is that the well trained people have more potential to perform properly provided they have the right direction. Thus training can be seen as a neccessary prerequisite for improved performance. The question of sustainability of training also arises. The benefits of training will 'wear off' if not properly maintained. This will be discussed in the overall discussion.

CONCLUSION: Internal training addresses all aspects of the Pareto Analysis and will contribute a small but noticeable improvement in the reject rate. This improvement will diminish with time if not maintained.

ACTION: EXTERNAL TRAINING - QC MANAGER - TECHNICAL TRAINING, DYEHOUSE MANAGER - MANAGERIAL TRAINING

APPROX DIRECT 'EXTERNAL' COST: R8000

DATE WHEN ACTION EFFECTIVE: END SEPTEMBER, 1992

WHICH CAUSES IDENTIFIED IN THE PARETO ANALYSIS DOES IT ADDRESS: The QC Manager went on a technical course related to shade acceptance. This area is not covered by the Pareto Analysis but is nevertheless extremely important and will be discussed later in this section. The Dyehouse Manager went on a management course. This may or may not prove to be a worthwhile investment. Certainly the dyehouse can be considered the single most important factor in terms of influencing the Pareto causes.

CONCLUSION: Given that the Dyehouse Manager is the most important factor in the dyehouse it makes a great deal of sense to invest in developing his abilities as a manager. However a single management training course can only be considered a first step towards developing the Dyehouse Manager's management potential.

ACTION: APPOINTMENT OF A NEW LAB MANAGER

APPROX DIRECT EXTERNAL COST: R28000 PA more than the dyehouse staff budget before the start of the dyehouse project.

DATE WHEN ACTION EFFECTIVE: The benefits of this appointment are unlikely to be felt until early next year.

WHICH CAUSES IN THE PARETO ANALYSIS DOES IT DIRECTLY ADDRESS: -
Precipitation, recipe, difficult shade - 17.6% of total

causes. This action should also have important implications on shade acceptance.

HOW EFFECTIVE IS IT IN ADDRESSING THESE CAUSES: We can expect a marked improvement in these areas as it is placing expertise at the recipe source.

CONCLUSION

The new Lab Manager should contribute to a noticeable improvement in the reject rate.

ACTION: THE INSTALLATION OF THE DYESTUFF WEIGHING COMPUTER, STOCK SYSTEM,AND RECIPE DATABASE.

APPROX DIRECT 'EXTERNAL' COST: R30000

DATE EFFECTIVE: It is hoped that the system will be installed by the end of 1992. The real benefits should start to be felt early next year once the installation and teething troubles have been overcome.

WHICH OF THESE CAUSES IDENTIFIED IN THE PARETO ANALYSIS DOES IT ADDRESS: 'Colour weighing and clerical errors' - 12% of total causes.

HOW EFFECTIVE IS IT IN ADDRESSING THESE CAUSES: This action directly addresses the problems of stock control, colour weighing and clerical errors. There still remains problems of dyestuff identification, 'tricking the computer' etc but the large proportion of errors can be expected to be eliminated.

CONCLUSION: The major proportion of the 12% of total rejects can be expected to be eliminated by the implementation of these systems.

ACTION: RATIONALISATION OF SHADE RANGE

APPROX DIRECT 'EXTERNAL' COST: Negligable

DATE WHEN ACTION EFFECTIVE: Not clear

WHICH OF THE CAUSES IDENTIFIED IN THE PARETO ANALYSIS DOES IT ADDRESS: 'Difficult shade, recipe' - 17.0% of total causes.

HOW EFFECTIVE IS IT IN ADDRESSING THESE CAUSES: Currently there some 2000 recipes in the dyehouse filing system. A major reduction in the number of recipes will mean that the recipes used will become more familiar more quickly to the dyehouse personnel. Also the recipes can be expected to be 'perfected' more quickly as they receive more frequent and expert attention. It should reduce dyehouse staff workload in the long run. The benefits of a shade rationalisation will tend to be felt more in the medium term than in the short term.

CONCLUSION: A noticeable medium term improvement in problems associated with recipe, offshade problems.

ACTION: MOVE SHADE APPROVAL TO ATLANTIS, INSTALL SHADE MATCHING MACHINE IN ATLANTIS

APPROX DIRECT 'EXTERNAL' COST: R6500

DATE WHEN ACTION EFFECTIVE: The shade matching machine should be effectively running in Atlantis in September, 1992. It is not clear when the shade matching approval system will be moved to Atlantis.

WHICH OF THE CAUSES IDENTIFIED IN THE PARETO ANALYSIS DOES IT DIRECTLY ADDRESS: Shade approval is an area which falls outside the area of the Pareto Analysis. It will, however, have an important effect on reducing the reject rate as it is the standard against which the shade is accepted or rejected. Focus on this area can be expected to yield significant reductions in the reject rate. The shade matching machine itself will help to take some of the subjectivity out of the shade matching process and will also tend to improve the case of the dyehouse when they submit shades for shade approval.

CONCLUSION: These actions will tend to cause a reduction in the reject rate by 'changing the goalposts' by which shades are approved (or, possibly, by defining them more clearly).

APPENDIX 11: PEARSON CORRELATION COEFFICIENT CALCULATION

PEARSON CORRELATION COEFFICIENT FOR % REJECT LOTS (Y1) AND TOTAL LOTS DYED (Y2)FOR JAN - DEC 1992

Y1(% REJLOTS)	Y2(PRODUCTION(LOTS))	Y1-Y1AVE	(Y1-Y1AVE)^2	Y2-Y2AVE	(Y2-Y2AVE)^2	(Y1-Y1AVE)*(Y2-Y2AVE)
5.2	230.0	-6.8	46.8	-127.7	1.63E+04	873.8
12.6	389.0	0.5	0.3	31.3	9.80E+02	16.8
14.3	461.0	2.3	5.1	103.3	1.07E+04	233.1
10.9	377.0	-1.2	1.4	19.3	3.72E+02	-22.9
11.5	392.0	-0.6	0.3	34.3	1.18E+03	-19.9
14.9	444.0	2.8	7.9	86.3	7.45E+03	242.0
10.8	425.0	-1.2	1.5	67.3	4.53E+03	-83.2
13.5	252.0	1.4	2.1	-105.7	1.12E+04	-151.3
11.7	308.0	-0.4	0.1	-49.7	2.47E+03	18.5
11.6	431.0	-0.5	0.2	73.3	5.37E+03	-33.7
15.2	408.0	3.1	9.8	50.3	2.53E+03	157.7
12.6	175.0	0.5	0.3	-182.7	3.34E+04	-93.4
12.1	357.7	0.0	75.8	-0.4	9.64E+04	1137.5
12.1						

S((Y1-YA1)*(Y S((Y1-YA1)*(Y2-YA2))/S((Y2-YA2)^2*S(Y1-YA1)^2) = 0.42

PEARSON CORRELATION COEFFICIENT FOR % REJECT KGS (Y1) AND TOTAL TONNES DYED (Y2) FOR JAN - DEC 1992

Y1(% REJECT KGS)	Y2(PRODUCTION(TONNES)	Y1-YAVE	(Y1-Y1AVE)^2	Y2-Y2AVE	(Y2-Y2AVE)^2	(Y1-Y1AVE)*(Y2-Y2AVE)
1428.0	37483.0	-4937.5	24378906.3	-32085.9	1.03E+09	1.58E+08
8476.0	60809.0	2110.5	4454210.3	-8759.9	7.67E+07	-1.8E+07
12596.0	92406.0	6230.5	38819130.3	22837.1	5.22E+08	1.42E+08
4256.0	72093.0	-2109.5	4449990.3	2524.1	6.37E+06	-5.3E+06
4414.0	85800.0	-1951.5	3808352.3	16231.1	2.63E+08	-3.2E+07
14474.0	98603.0	8108.5	65747772.3	29034.1	8.43E+08	2.35E+08
7652.0	92236.0	1286.5	1655082.3	22667.1	5.14E+08	2.92E+07
2499.0	51681.0	-3866.5	14949822.3	-17887.9	3.20E+08	6.92E+07
3751.0	56242.0	-2614.5	6835610.3	-13326.9	1.78E+08	3.48E+07
5800.0	73384.0	-565.5	319790.3	3815.1	1.46E+07	-2.2E+06
6292.0	77233.0	-73.5	5402.3	7664.1	5.87E+07	-5.6E+05
4748.0	36857.0	-1617.5	2616306.3	-32711.9	1.07E+09	5.29E+07
6365.5	69568.9	0.0	168040375.0	0.2	4.90E+09	6.64E+08

S((Y1-YA1)*(Y2-YA2))/((S(Y2-YA2)^2)*(S(Y1-YA1)^2)) = 0.73

APPENDIX 12: LEAD TIME ESTIMATES (DYEING TO DISPATCH)

Objectives

The objectives of this exercise are to model the lead time from the time yarn is dyed to the time it is dispatched:

- To gain some understanding of the effect on this of various factors such as: sending the sample hank to Maitland, sample approval, truck departure times etc. This is complicated by the fact that production works on a three shift basis but many operations only take place during office hours for instance shade approval and QC testing.
- To compare this lead time for four different scenarios.

How it has been done

Each day is divided into three shifts and these into three segments of 2.67 hours each. Using the assumptions below, lead times are calculated for each segment and the average of the nine is calculated to get the lead time for the different scenarios.

Assumptions

- Hydro time - 2.67 hrs.
- Drying time - 2.67 hrs.
- Conditioning time - min 2.67 hrs. The time the yarn is conditioned depends on which shift it is because the packers only work on the day shift.
- Trucks depart from Atlantis only at the beginning of the first and second shifts.
- Hanks are sent to Maitland once a day at the beginning of the first shift
- QC inspection only takes place after shade approval is obtained.

- Production volume is constant throughout each of the nine time segments.

Results

Maitland approval, natural conditioning - ave time - 37.4 hrs.
Atlantis approval, natural conditioning - ave time - 24.9 hrs.
Atlantis approval, natural conditioning, shift checker packer - 22,3 hrs.
Atlantis approval, forced conditioning, shift checker packer - 18.7 hrs.

PAGE 1

DYEHOUSE LEAD TIME ESTIMATE (FROM DYEING TO DISPATCH)
PROCEDURE 1:MAITLAND APPROVAL, NATURAL CONDITIONING

DAY					1									2									3					TIME(HRS)
SHIFT		1			2			3			1			2			3			1			2			3		
BEG/MIDDLE/END	B	M	E	B	M	E	B	M	E	B	M	E	B	M	E	B	M	E	B	M	E	B	M	E	B	M	E	
TRUCK DEPART INTERVALS	X			X						X			X						X			X						
SEND HANK	X																											26.7
HYDRO	■																											
DRY		■																										
CONDITION			■	■																								
PACK					■																							
APPROVE				X																								
QC					X																							
DISPATCH										■																		
SEND HANK										X																		48.06
HYDRO		■																										
DRY			■																									
CONDITION				■	■	■	■	■	■																			
PACK										■																		
APPROVE													X															
QC														X														
DISPATCH																			■									
SEND HANK										X																		45.34
HYDRO			■																									
DRY				■																								
CONDITION					■	■	■	■	■																			
PACK										■																		
APPROVE													X															
QC														X														
DISPATCH																			■									
SEND HANK										X																		42.72
HYDRO				■																								
DRY					■																							
CONDITION						■	■	■	■																			
PACK										■																		
APPROVE													X															
QC														X														
DISPATCH																			■									
SEND HANK										X																		40.05
HYDRO					■																							
DRY						■																						
CONDITION							■	■	■																			
PACK										■																		
APPROVE													X															
QC														X														
DISPATCH																			■									
SEND HANK										X																		37.38
HYDRO						■																						
DRY							■																					
CONDITION								■	■																			
PACK										■																		
APPROVE													X															
QC														X														
DISPATCH																			■									

DYEHOUSE LEAD TIME ESTIMATE (FROM DYEING TO DISPATCH)
PROCEDURE 1:MAITLAND APPROVAL, NATURAL CONDITIONING (CONTD)

DAY					1									2									3					TIME(HRS)
SHIFT		1			2			3			1			2			3			1			2			3		
BEG/MIDDLE/END	B	M	E	B	M	E	B	M	E	B	M	E	B	M	E	B	M	E	B	M	E	B	M	E	B	M	E	
TRUCK DEPART INTERVALS	X			X						X			X						X			X						
SEND HANK										X																		34.71
HYDRO							■																					
DRY								■																				
CONDITION									■	■																		
PACK											■																	
APPROVE													X															
QC														X														
DISPATCH																			■									
SEND HANK										X																		32.04
HYDRO								■																				
DRY									■																			
CONDITION										■	■																	
PACK												■																
APPROVE													X															
QC														X														
DISPATCH																			■									
SEND HANK										X																		29.37
HYDRO									■																			
DRY										■																		
CONDITION											■	■																
PACK													■															
APPROVE													X															
QC														X														
DISPATCH																			■									
SEND HANK																												
HYDRO																												
DRY																												
CONDITION																												
PACK																												
APPROVE																												
QC																												
DISPATCH																												
SEND HANK																												
HYDRO																												
DRY																												
CONDITION																												
PACK																												
APPROVE																												
QC																												
DISPATCH																												
SEND HANK																												
HYDRO																												
DRY																												
CONDITION																												
PACK																												
APPROVE																												
QC																												
DISPATCH																												

AVERAGE TIME(HOURS 37.37

DYEHOUSE LEAD TIME ESTIMATE (FROM DYEING TO DISPATCH)
PROCEDURE 2:ATLANTIS APPROVAL, NATURAL CONDITIONING

DAY	1									2									3									TIME(HRS)
SHIFT	1			2			3			1			2			3			1			2			3			
BEG/MIDDLE/END	B	M	E	B	M	E	B	M	E	B	M	E	B	M	E	B	M	E	B	M	E	B	M	E	B	M	E	
TRUCK DEPART INTERVALS	X			X						X			X						X			X						
SEND HANK	N																											26.7
HYDRO	■																											
DRY		■																										
CONDITION			■	■																								
PACK					■																							
APPROVE	X																											
QC		X																										
DISPATCH										■																		
SEND HANK	N																											32.04
HYDRO		■																										
DRY			■																									
CONDITION				■	■	■	■	■	■																			
PACK										■																		
APPROVE		X																										
QC			X																									
DISPATCH													■															
SEND HANK	N																											29.37
HYDRO			■																									
DRY				■																								
CONDITION					■	■	■	■	■																			
PACK										■																		
APPROVE			X																									
QC				X																								
DISPATCH													■															
SEND HANK	N																											26.7
HYDRO				■																								
DRY					■																							
CONDITION						■	■	■	■	■																		
PACK											■																	
APPROVE				X																								
QC					X																							
DISPATCH													■															
SEND HANK	N																											24.03
HYDRO					■																							
DRY						■																						
CONDITION							■	■	■																			
PACK										■																		
APPROVE					X																							
QC										X																		
DISPATCH													■															
SEND HANK	N																											21.36
HYDRO						■																						
DRY							■																					
CONDITION								■	■																			
PACK										■																		
APPROVE										X																		
QC											X																	
DISPATCH													■															

DYEHOUSE LEAD TIME ESTIMATE (FROM DYEING TO DISPATCH)
PROCEDURE 2:ATLANTIS APPROVAL, NATURAL CONDITIONING (CONTD)

DAY					1									2									3					TIME(HRS)
SHIFT		1			2			3			1			2			3			1			2			3		
BEG/MIDDLE/END	B	M	E	B	M	E	B	M	E	B	M	E	B	M	E	B	M	E	B	M	E	B	M	E	B	M	E	
TRUCK DEPART	X			X						X			X						X			X						
INTERVALS																												
SEND HANK	N																											18.7
HYDRO							■																					
DRY								■																				
CONDITION									■	■																		
PACK											■																	
APPROVE										X																		
QC											X																	
DISPATCH													■															
SEND HANK	N																											16.02
HYDRO								■																				
DRY									■																			
CONDITION										■	■																	
PACK												■																
APPROVE										X																		
QC											X																	
DISPATCH													■															
SEND HANK	N																											29.37
HYDRO									■																			
DRY										■																		
CONDITION											■	■																
PACK													■															
APPROVE										X																		
QC											X																	
DISPATCH																			■									
SEND HANK																												
HYDRO																												
DRY																												
CONDITION																												
PACK																												
APPROVE																												
QC																												
DISPATCH																												
SEND HANK																												
HYDRO																												
DRY																												
CONDITION																												
PACK																												
APPROVE																												
QC																												
DISPATCH																												
SEND HANK																												
HYDRO																												
DRY																												
CONDITION																												
PACK																												
APPROVE																												
QC																												
DISPATCH																												

AVERAGE TIME(HOURS 24.92

DYEHOUSE LEAD TIME ESTIMATE (FROM DYEING TO DISPATCH)
PROCEDURE 3:ATLANTIS APPROVAL, NATURAL CONDITIONING, SHIFT CHECKER PACKER

DAY					1										2										3					TIME(HRS)
SHIFT		1			2			3			1			2			3			1			2			3		
BEG/MIDDLE/END	B	M	E	B	M	E	B	M	E	B	M	E	B	M	E	B	M	E	B	M	E	B	M	E	B	M	E	
TRUCK DEPART INTERVALS	X			X						X			X						X			X						
SEND HANK	N																											26.7
HYDRO	■																											
DRY		■																										
CONDITION			■	■																								
PACK					■																							
APPROVE	X																											
QC		X																										
DISPATCH										■																		
SEND HANK	N																											24.03
HYDRO		■																										
DRY			■																									
CONDITION				■	■																							
PACK						■																						
APPROVE		X																										
QC			X																									
DISPATCH										■																		
SEND HANK	N																											21.36
HYDRO			■																									
DRY				■																								
CONDITION					■	■																						
PACK							■																					
APPROVE			X																									
QC				X																								
DISPATCH										■																		
SEND HANK	N																											18.69
HYDRO				■																								
DRY					■																							
CONDITION						■	■																					
PACK								■																				
APPROVE				X																								
QC					X																							
DISPATCH										■																		
SEND HANK	N																											24.03
HYDRO					■																							
DRY						■																						
CONDITION							■	■																				
PACK									■																			
APPROVE					X																							
QC										X																		
DISPATCH													■															
SEND HANK	N																											21.36
HYDRO						■																						
DRY							■																					
CONDITION								■	■																			
PACK										■																		
APPROVE										X																		
QC											X																	
DISPATCH													■															

DYEHOUSE LEAD TIME ESTIMATE (FROM DYEING TO DISPATCH)
PROCEDURE 3:ATLANTIS APPROVAL, NATURAL CONDITIONING, SHIFT CHECKER PACKER (CONT)

DAY					1									2									3					TIME(HRS)
SHIFT		1			2			3			1			2			3			1			2			3		
BEG/MIDDLE/END	B	M	E	B	M	E	B	M	E	B	M	E	B	M	E	B	M	E	B	M	E	B	M	E	B	M	E	
TRUCK DEPART INTERVALS	X			X						X			X						X			X						
SEND HANK	N																											18.69
HYDRO							■																					
DRY								■																				
CONDITION									■	■																		
PACK											■																	
APPROVE										X																		
QC											X																	
DISPATCH													■															
SEND HANK	N																											16.02
HYDRO								■																				
DRY									■																			
CONDITION										■	■																	
PACK												■																
APPROVE										X																		
QC											X																	
DISPATCH													■															
SEND HANK	N																											29.37
HYDRO									■																			
DRY										■																		
CONDITION											■	■																
PACK													■															
APPROVE										X																		
QC											X																	
DISPATCH																			■									
SEND HANK																												
HYDRO																												
DRY																												
CONDITION																												
PACK																												
APPROVE																												
QC																												
DISPATCH																												
SEND HANK																												
HYDRO																												
DRY																												
CONDITION																												
PACK																												
APPROVE																												
QC																												
DISPATCH																												
SEND HANK																												
HYDRO																												
DRY																												
CONDITION																												
PACK																												
APPROVE																												
QC																												
DISPATCH																												

AVERAGE TIME(HOURS 22.25

DYEHOUSE LEAD TIME ESTIMATE (FROM DYEING TO DISPATCH)
PROCEDURE 4: MAITLAND APPROVAL, FORCED CONDITIONING, SHIFT CHECKER-PACKER

DAY	1									2									3									TIME(HRS)
SHIFT	1			2			3			1			2			3			1			2			3			
BEG/MIDDLE/END	B	M	E	B	M	E	B	M	E	B	M	E	B	M	E	B	M	E	B	M	E	B	M	E	B	M	E	
TRUCK DEPART INTERVALS	X			X						X			X						X			X						
SEND HANK	N																											10.68
HYDRO	■																											
DRY		■																										
CONDITION	N																											
PACK			■																									
APPROVE	X																											
QC		X																										
DISPATCH				■																								
SEND HANK	N																											24.03
HYDRO		■																										
DRY			■																									
CONDITION	N																											
PACK				■																								
APPROVE		X																										
QC			X							■																		
DISPATCH																												
SEND HANK	N																											21.36
HYDRO			■																									
DRY				■																								
CONDITION	N																											
PACK					■																							
APPROVE			X																									
QC				X																								
DISPATCH										■																		
SEND HANK	N																											18.69
HYDRO				■																								
DRY					■																							
CONDITION	N																											
PACK						■																						
APPROVE				X																								
QC					X																							
DISPATCH										■																		
SEND HANK	N																											24.03
HYDRO					■																							
DRY						■																						
CONDITION	N																											
PACK							■																					
APPROVE					X																							
QC										X																		
DISPATCH													■															
SEND HANK	N																											21.36
HYDRO						■																						
DRY							■																					
CONDITION	N																											
PACK								■																				
APPROVE										X																		
QC											X																	
DISPATCH													■															

DYEHOUSE LEAD TIME ESTIMATE (FROM DYEING TO DISPATCH)
PROCEDURE 4: MAITLAND APPROVAL, FORCED CONDITIONING, SHIFT CHECKER-PACKER (CONT)

DAY	1									2									3									TIME(HRS)
SHIFT	1			2			3			1			2			3			1			2			3			
BEG/MIDDLE/END	B	M	E	B	M	E	B	M	E	B	M	E	B	M	E	B	M	E	B	M	E	B	M	E	B	M	E	
TRUCK DEPART INTERVALS	X			X						X			X						X			X						
SEND HANK	N																											18.69
HYDRO							■																					
DRY								■																				
CONDITION	N																											
PACK									■																			
APPROVE										X																		
QC											X																	
DISPATCH													■															
SEND HANK	N																											16.02
HYDRO								■																				
DRY									■																			
CONDITION	N																											
PACK										■																		
APPROVE										X																		
QC											X																	
DISPATCH													■															
SEND HANK	N																											13.35
HYDRO									■																			
DRY										■																		
CONDITION	N																											
PACK											■																	
APPROVE										X																		
QC											X																	
DISPATCH													■															
SEND HANK																												
HYDRO																												
DRY																												
CONDITION																												
PACK																												
APPROVE																												
QC																												
DISPATCH																												
SEND HANK																												
HYDRO																												
DRY																												
CONDITION																												
PACK																												
APPROVE																												
QC																												
DISPATCH																												
SEND HANK																												
HYDRO																												
DRY																												
CONDITION																												
PACK																												
APPROVE																												
QC																												
DISPATCH																												

AVERAGE TIME(HOURS 18.69

APPENDIX 13: PLANNING/ BATCH SIZE STUDY

WEEKLY WEAVING YARN ORDERS (KGS) 1992

MONTH		JANUARY				FEBRUARY					MARCH					APRIL				MAY				JUNE			
YARN	SHADE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
431221	0990			158			159	150					2100				1050				1050				460		118
431221	4514			70				41					373								10				266		
441001	0201				250				550			250	250												1074		
471201	0085			47							121		53				156				23				115		
471201	0130			130				33			20		374				275				170				54		
471201	0175							261			12	250	1050				334				281		36				289
471201	0203			1050				550			230		1050		1050		1600				1050						
471201	0532												37				39				47						
471201	0535			115				211					97				62				46				18		
471201	0544			85							250		291				310				550						
471201	0734			10		17		357				115	77				154										
471201	0925			1600		173		4200		1100	42		1050				1050				3150				4313		3238
471201	0965				92			375		550	67		175				250				1050						1075
471201	0990			20									1050				1050				550				80		
471201	1413							73					85				220				102						
471201	1519										130		396				145				300				70		
471201	1730			80									128				53			150	65				93		
471201	2495							75					122								141						
471201	3535												21				58	65									174
471201	3555									175															117		
471201	3724		30										116	266			195				30				42		
601201	0203			1050				1050			550		2100				1050			550	1050				571		
601201	0515							29					171				157				52				22		
601201	0535							75					102				153				64						
601201	0965			413				445					1050				550				615				575		
601201	0967							550			92		1300	372			1050				615				1365		
601201	0990			63	200			550			250		1050				1050				550				579		
601201	1413							38					173				286				10				34		
862020	0201			365	126			113				51					18								630		
862020	0965			63				90		60							680				118				22		
862020	8052																										
862020	8053							45				34						15							22		
862020	8054									32																	10
862020	8058																18										
862020	8064																								112		
862020	8065									32								40							35		
862020	8073																								32		
872020	0201																										30

WEEKLY WEAVING YARN ORDERS (KGS) 1992

MONTH		JULY					AUGUST				SEPTEMBER					OCTOBER				NOVEMBER		
YARN	SHADE	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47
431221	0990											1050		1050		301	257				500	
431221	4514			65								404		246							541	
441001	0201											1237		232		565	1091				1125	
471201	0085			73					69							100					68	
471201	0130	103		132								16		70					66		120	35
471201	0175			290				93	225			122		27		230					560	
471201	0203	1088		1090	1081				2189			203		1073		561	552				1114	
471201	0532			87	88			86	175												42	
471201	0535				18				70			70		85		88	30		10		301	
471201	0544			274										31		41	56		72			120
471201	0734				127				137					28		19	145				226	
471201	0925	1082	1132		2218				1089			4410					138				1110	
471201	0965								51			45		940		203	195				19	
471201	0990											155		533		110	94				675	12
471201	1413							47				124		66		33					58	
471201	1519			205				50						26				15	72			
471201	1730				149				270					103		115	132				315	
471201	2495	66		246	23							25							66		6	
471201	3535			563													115		1350	10		
471201	3555			116				175		175											76	
471201	3724				18				70					61		83					129	
601201	0203								1109			1107		1101		2484	571				1132	
601201	0515			128										57			143			10		
601201	0535			62	40			43				42				26	92				38	
601201	0965			1385					2215			65										
601201	0967			230					1128			226		576		254	230				316	37
601201	0990								73			408		255		225	110	10			111	
601201	1413				41			38				64		54		42					68	
862020	0201	122				179		98	299		60	46		590		400	2400				160	34
862020	0965			14	122	22		505				80		995		922	620				115	
862020	8052				64			135						56		20	193					17
862020	8053				160			84	68					35		155						
862020	8054				10			280								170	310				35	
862020	8058				200			2	81			160				35	108					
862020	8064				45			60				28				100	38					
862020	8065				65			165	140		16			45		35	490					
862020	8073				64				80					236			115				44	
872020	0201							10				90	10		25						35	

				CALCULATED STOCK LEVEL			OPTIMISED STOCK HOLDING MODEL					
M O N T H		NO OF ORDERS	TOTAL KGS	KGS/ WEEK	AVE KGS /ORDER	STD DEV ORDERS	ORDER QTY (KGS)	STOCK TURNS	SHOTS SAVED	SAVED COSTS(R)	COST PA STOCK(R)	OVERALL SAVING
YARN	SHADE											
431221	0990	14	8403	179	600	418	1050	8.5	5	12348	3675	8673
431221	4514	9	2016	43	224	189	550	3.9	5	3997	1925	2072
441001	0201	11	6624	141	602	422	1050	6.7	4	9152	3675	5477
471201	0085	10	825	18	83	40	250	3.5	6	1936	875	1061
471201	0130	14	1598	34	114	102	550	3.1	11	4744	1925	2819
471201	0175	15	4060	86	271	258	1050	4.1	11	11292	3675	7617
471201	0203	17	15531	330	914	458	1050	15.7	1	4546	3675	871
471201	0532	8	601	13	75	46	250	2.6	5	1422	875	547
471201	0535	14	1221	26	87	80	250	5.2	9	2914	875	2039
471201	0544	11	2080	44	189	161	550	4.0	7	4841	1925	2916
471201	0734	12	1412	30	118	101	550	2.7	9	4085	1925	2160
471201	0925	33	31095	662	942	308	1050	31.5	3	9255	3675	5580
471201	0965	14	5087	108	363	385	1050	5.2	9	12200	3675	8525
471201	0990	11	4329	92	394	399	1050	4.4	6	9522	3675	5847
471201	1413	9	808	17	90	56	250	3.4	5	1762	875	887
471201	1519	10	1409	30	141	125	550	2.7	7	3735	1925	1810
471201	1730	12	1653	35	138	79	550	3.2	9	4534	1925	2609
471201	2495	9	770	16	86	75	250	3.3	5	1733	875	858
471201	3535	8	2356	50	295	462	1050	2.4	5	5767	3675	2092
471201	3555	6	834	18	139	42	250	3.5	2	952	875	77
471201	3724	11	1040	22	95	77	250	4.4	6	2273	875	1398
601201	0203	17	15475	329	910	284	1050	15.7	1	4729	3675	1054
601201	0515	8	769	16	96	64	250	3.3	4	1553	875	678
601201	0535	11	737	16	67	37	250	3.1	8	1945	875	1070
601201	0965	12	7313	156	609	399	1050	7.4	4	10124	3675	6449
601201	0967	18	8341	177	463	374	1050	8.5	10	17277	3675	13602
601201	0990	15	5484	117	366	334	1050	5.6	9	13211	3675	9536
601201	1413	11	848	18	77	81	250	3.6	7	2097	875	1222
862020	0201	20	5691	121	285	315	1050	5.8	14	15909	3675	12234
862020	0965	15	4428	94	295	348	1050	4.5	10	11890	3675	8215
862020	8052	6	485	10	81	70	250	2.1	3	1018	875	143
862020	8053	10	618	13	62	54	250	2.6	7	1661	875	786
862020	8054	8	847	18	106	125	250	3.6	4	1574	875	699
862020	8058	8	604	13	76	75	250	2.6	5	1425	875	550
862020	8064	6	383	8	64	34	115	3.5	2	439	402.5	36
862020	8065	11	1063	23	97	136	250	4.5	6	2287	875	1412
862020	8073	6	571	12	95	75	250	2.4	3	1064	875	189
872020	0201	8	200	4	25	27	115	1.9	6	541	402.5	139
								TOTAL=	231	201756	77805	123951