# THE NEED FOR SYSTEMIC COMPATIBILITY IN MANAGEMENT APPROACHES:

## A BASIS FOR LONG TERM SUSTAINABLE PERFORMANCE IMPROVEMENT

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# DECLARATION

I the undersigned hereby declare that the work contained in this thesis is my own original work and has not previously in its entirety or in part been submitted at any university for a degree.

Signed by candidate Date: 22/02/1993

# ACKNOWLEDGEMENTS

I wish to thank the workers and staff of Puma Jersey for their support and cooperation, and in particular Craig Smith (Operations Executive, Puma Jersey) for his invaluable support and ideas. I would also like to thank my supervisor Tom Ryan (Associate Professor, School of Engineering Management) for his support and guidance.

# SYNOPSIS

The textile industry in South Africa is presently experiencing a severe recession. For a textile company to survive in the competitive market prevailing will require increased performance in the competitive variables. Puma Jersey is typically such a company and has realized the necessity of improving lead time and delivery performance to regain market share.

To attain long term sustainability of performance requires the systemic compatibility of approaches used to reduce lead times and late deliveries. Systems thinking methodology was used to evaluate the appropriateness and compatibility of the approaches used. Systems thinking as also used to develop and practical implement the suggested approaches.

Increased performance in lead time and delivery performance was attained by implementing appropriate performance measurements and then communicating these measurements with a technique called CEDAC. Synchronous manufacturing philosophy was implemented to reduce lead times. Systems dynamics was used as a complementary tool to assist the synchronous manufacturing principals. Systems dynamics was also used to determine the effectiveness of proposed systems to increase lead time and delivery performance.

A considerable improvement in lead times and delivery performance was attained at Puma Jersey by implementing these four systemicaly compatible approaches.

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# GLOSSARY OF TERMS

**BATCH** Pieces of the same quality and same shade that are dyed together. A batch may consist of more than one dye-lot and more than one order.

**CALLENDER** A machine that pads, stabilizes and drys tubular fabric.

**DYE-LOT** The pieces that are dyed together at the same time in the same machine. A dye-lot may consist of many orders.

**FINISHING** The processes undergone in the finishing department.

**GREIGE** The knitted fabric after it is knitted and before it is prepared.

**INSTRUCTION** An instruction is a document that travels with a dye-lot for a particular order from the grave yard till rolling. An instruction contains all the information relevant to all the departments about the dye-lot. The instruction specifies the route, shade, quality, weight, instruction number, piece numbers of the pieces in the dye-lot, order number, customer and delivery date.

**OPEN WIDTH** The tubular fabric that is slit to form a sheet of fabric.

**ORDER** A legal contract by the customer and Puma describing the details of the finished product required by a certain delivery date. A order may consist of several order lines.

**ORDER CONFIRMATION** When an order is approved by a customer and a contractual agreement has been formed.

**ORDER LINE** An order line is a specific product in an order. An order line is different if the shade or quality is different. An order can consist of many order lines. An order line may consist of several batches.

**ORDER REQUEST** When an order has no finalized delivery date and the customer has the right to cancel the order

**PADDING** When the fabric passes through a bath containing chemicals in a liquid solution and then passed between two rollers to force penetration of the liquid into the fabric and remove excess the liquid.

**PERCHING** Visual inspection of a batch undergone in the perching department.

**PFP** (Prepare for printing) The fabric that will be printed on.

**PIECE** A continuous roll of knitted fabric.

**PIECE DYED** Fabric that is dyed after it has been knitted. Piece dyed fabric generates about 70% of Puma Jerseys revenue.

**QUALITY** The design of the knit pattern.

**PREPARING** When the greige is unrolled and the separate pieces are sewn together to form a continuous rope of fabric.

**REPLACEMENT** When fabric has to be re-knitted due to it being faulty.

**REPROCESS** When a batch does not conform to specifications and has to undergo additional processes.

**RECIPE** The quantity of chemicals and dyes that are used to prepare and dye the fabric.

**SHADE** The colour of the dyed fabric.

**STENTER** A machine that pads, stabilizes and drys open width fabric.

**TUBULAR** A sock of fabric as it is knitted on a knitting machine.

# 1. INTRODUCTION

## 1.1 BACKGROUND TO THE PROBLEM

The state of the South African economy will be used as a introduction. Statistics obtained from various sources will be used as a forum to substantiate various claims made about the South African economy. The South African textile industry will then be discussed in the backdrop of the South African economy. Once the relevance of the textile industry in the present economy has been discussed, a textile manufacturing firm that was investigated for the purposes of this thesis, will be discussed in the context of the textile industry as a whole. The historical background of this textile firm will be discussed to give background to the present situation of the textile firm.

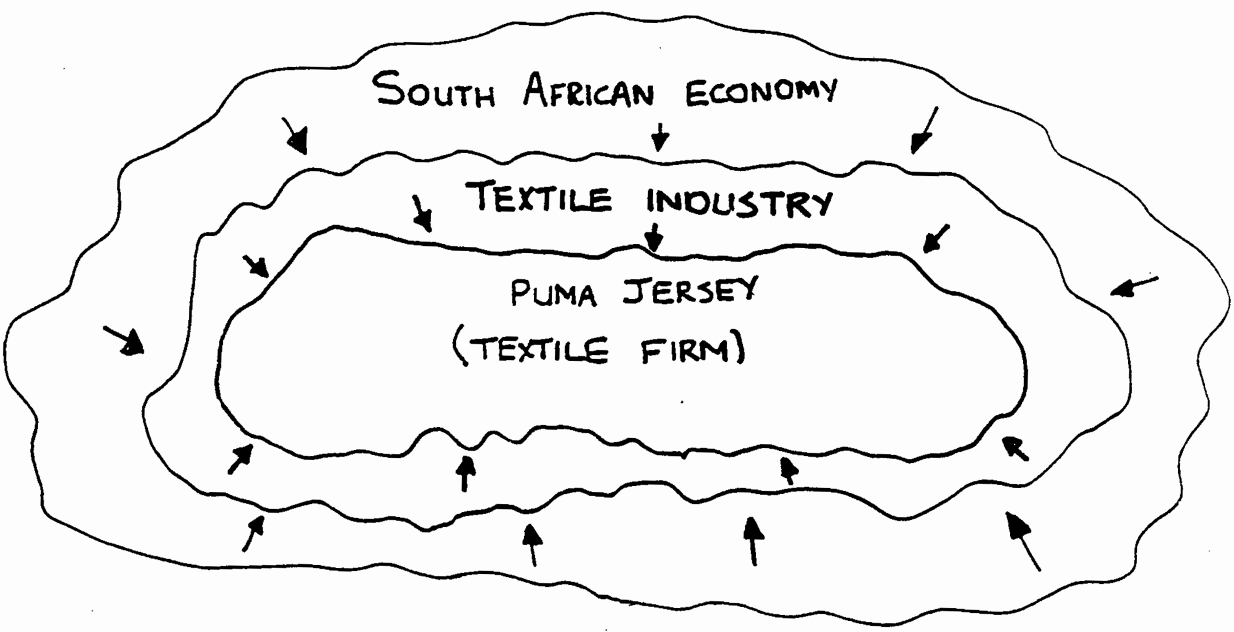
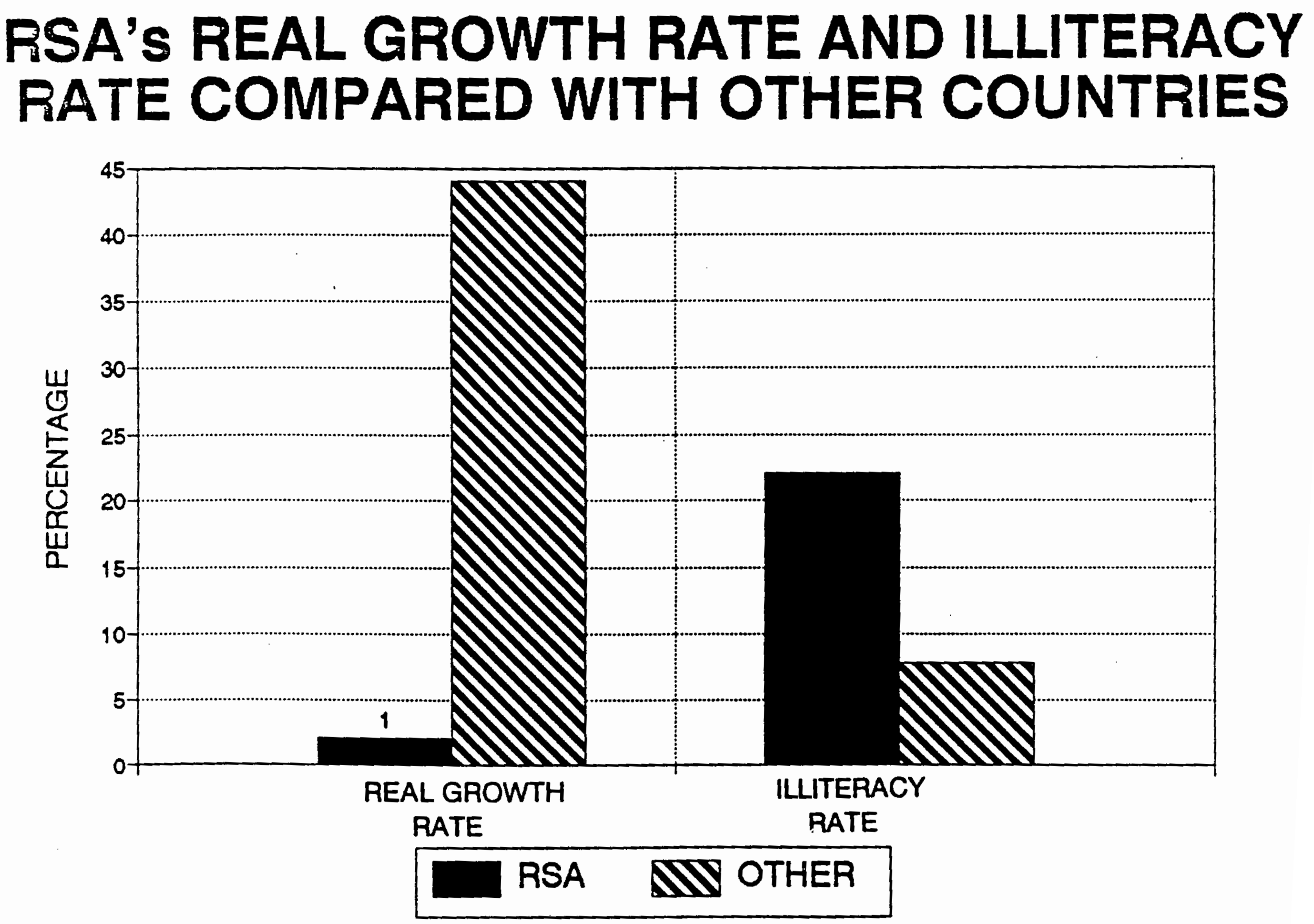



*DIAGRAM 1.1*

*APPROACH USED TO GAIN INSIGHT INTO THE BACKGROUND INTO THE PROBLEM*

### 1.1.1 THE SOUTH AFRICAN ECONOMY

The real growth in South Africa in industrial production since 1980 as only been 2%, which is comparative to third world countries like Brazil. In comparison to the 44% average real growth in industrial production of other countries compared, it can be seen that South Africa has a very low growth in industrial production (22). The real growth rate of South Africa compared to the average of a crosscut of 35 other countries is shown in *Graph 1.1*.



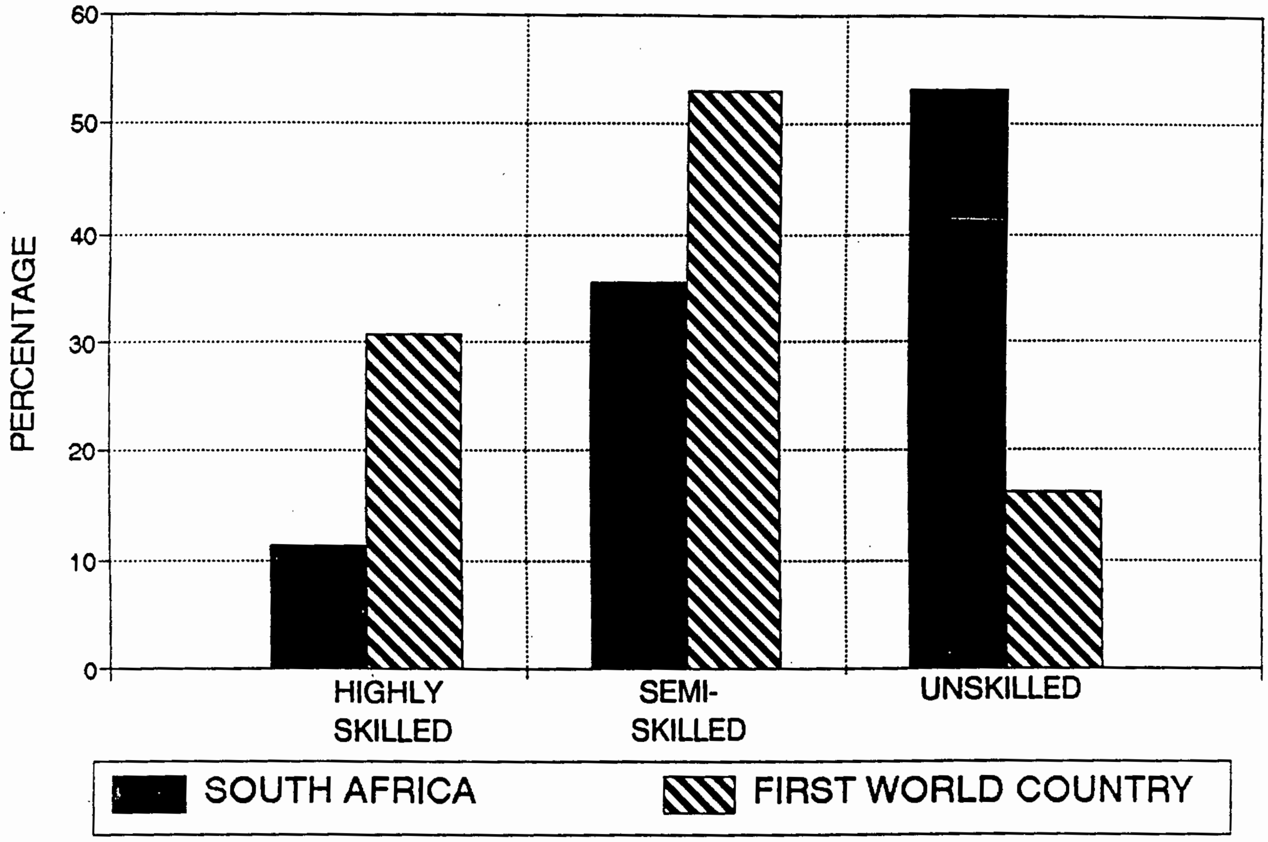

*GRAPH 1.1*

An important indicator to determine a countries ability to attain a healthy economic growth rate is the illiteracy level. The illiteracy level in South Africa is 22% which, compared to the average of 35 other countries, is far below average as shown in *Graph 1.1*. The illiteracy level is the third highest of the countries compared.

This high illiteracy level has been partly responsible for the growing unskilled work force in South Africa. 53% of South Africa's labour force is unskilled, compared to an average of 16% of first world countries. The unskilled labour force in first world countries is decreasing, while it is on the increase in South Africa. The occupational skill structure of the labour force for South Africa and first world countries is shown in *Graph 1.2* on the following page.

South Africa can increase its economic growth by gaining ground to foreign countries in the manufacturing sector to become internationally competitive in the international arena. South Africa has however a lot of "catching up" to do before this can be achieved. This is demonstrated by the international competitiveness indicators shown in *Appendix 1.1*. These indicators in *Appendix 1.1* also show that the manufacturing value added per worker in South Africa is $13,316 (US dollars), which is also far below the average of $26,484 of the countries compared (22). Coupled with the high illiteracy level it is clearly evident that South Africa is losing ground to foreign countries in the manufacturing sector (22).

## COMPARISON OF SKILL STRUCTURE OF RSA WITH THAT OF A FIRST WORLD COUNTRY



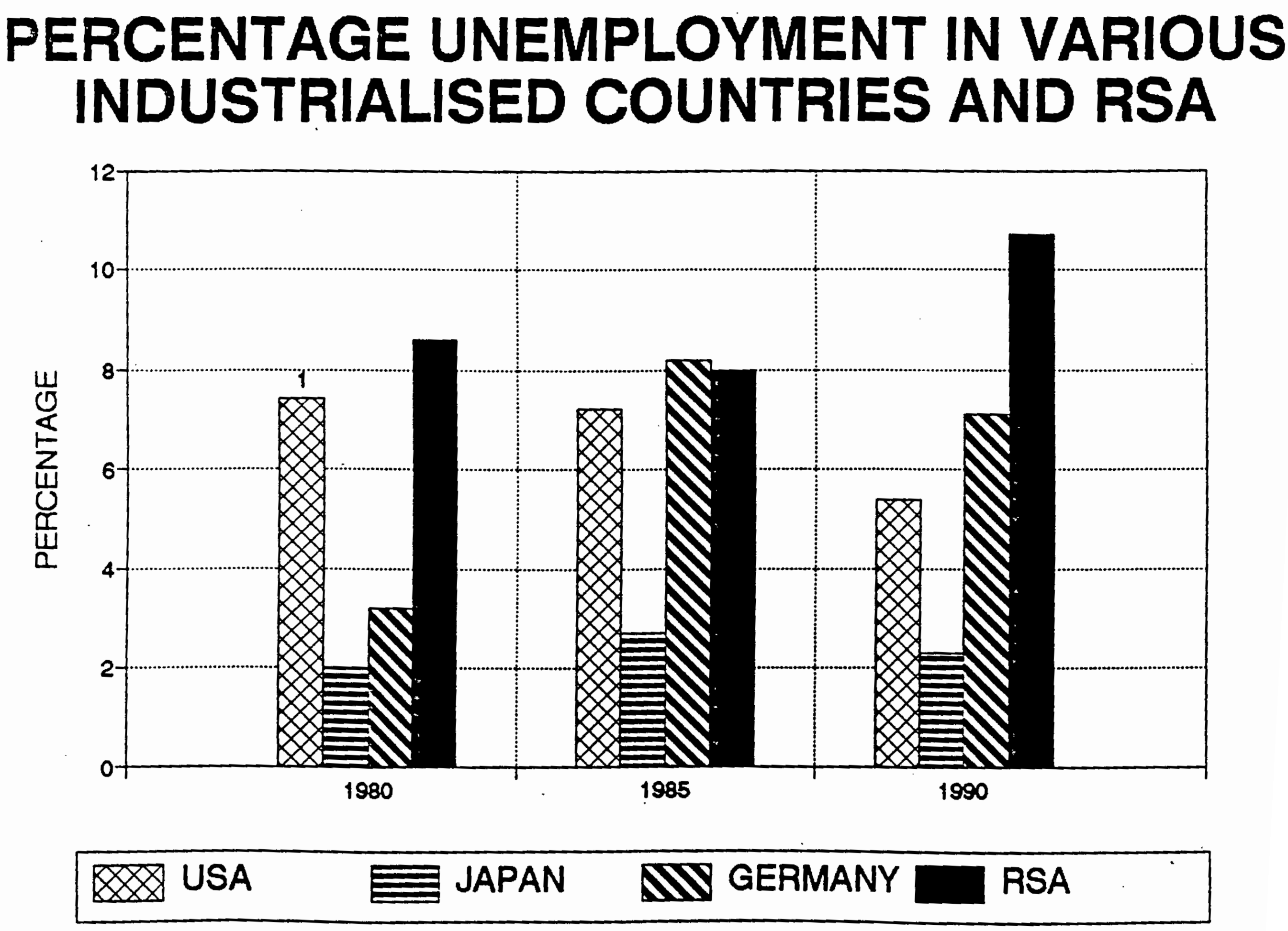

*GRAPH 1.2*

To increase the economic growth rate in South Africa by regaining industrial competitiveness in the international market will not be simply attained by educating the illiterate population sector, increasing labour productivity and by providing more capital to industry, because South Africa needs a sound economic structure to accommodate and sustain the growth required for increased competitiveness

(1). A solid economic structure is required to satisfy the investment opportunities in South Africa because foreign investors seek political stability before they will invest (21). However, no political stability can be achieved through "*a new political dispensation unless it is accompanied by a successful economic model. They have to go hand in hand as an integrated strategy. People will judge a new political system not only on its underlying moral fibre, but also on how much extra money it delivers into their pockets.*" (21)

Seen against the background of South Africa's economic performance over the last ten years, it now seems that South Africa has developed an inappropriate economic structure which has a "*limited basis for growth, depends on scarce skills and has a limited potential to offer employment to a large and rapidly growing unskilled or semi-skilled work force*" (1). The economy that has developed is geared more towards the wants and consumer demands of the developed section of the population which has a high propensity for imported consumer goods, or goods requiring capital intensive production methods and little absorption of unskilled labour (1). However, it is difficult for the South African economy to sustain the capital intensive requirements of the consumer demands because declining foreign investment and sanctions have placed limitations on the availability of capital.

It is evident that the South African economic structure can not accommodate the needs of the growing unskilled labour force because of the high unemployment experienced. South Africa's unemployment measured in 1990 is 10.7% of the economically active population, compared to an average of 5.3% of various other industrialized countries. The percentage unemployment in South Africa is still increasing rapidly in the last 2 years due to the severe local recession experienced presently. Unemployment will increase even further as the proportion of South African skills are becoming more unskilled. The percentage unemployment in various industrialized countries compared to South Africa's unemployment is shown in *Graph 1.3* below, and in *Appendix 2.1.* It is also evident from this graph that unemployment is on the increase in South Africa.




*GRAPH 1.3*

The South African economy which is largely determined by the pattern of consumer spending can not offer substantial employment opportunities to the unskilled work force. South African industry needs to generate employment opportunities to improve the economic growth rate. (21). As a short term objective the economic structure of South Africa should attempt to support a growing unskilled labour force because, large scale unemployment in unskilled labour is an immediate threat that South Africa is faced with (21). *Diagram 1.2* below gives insight into a complex situation for the present economic performance of South Africa.

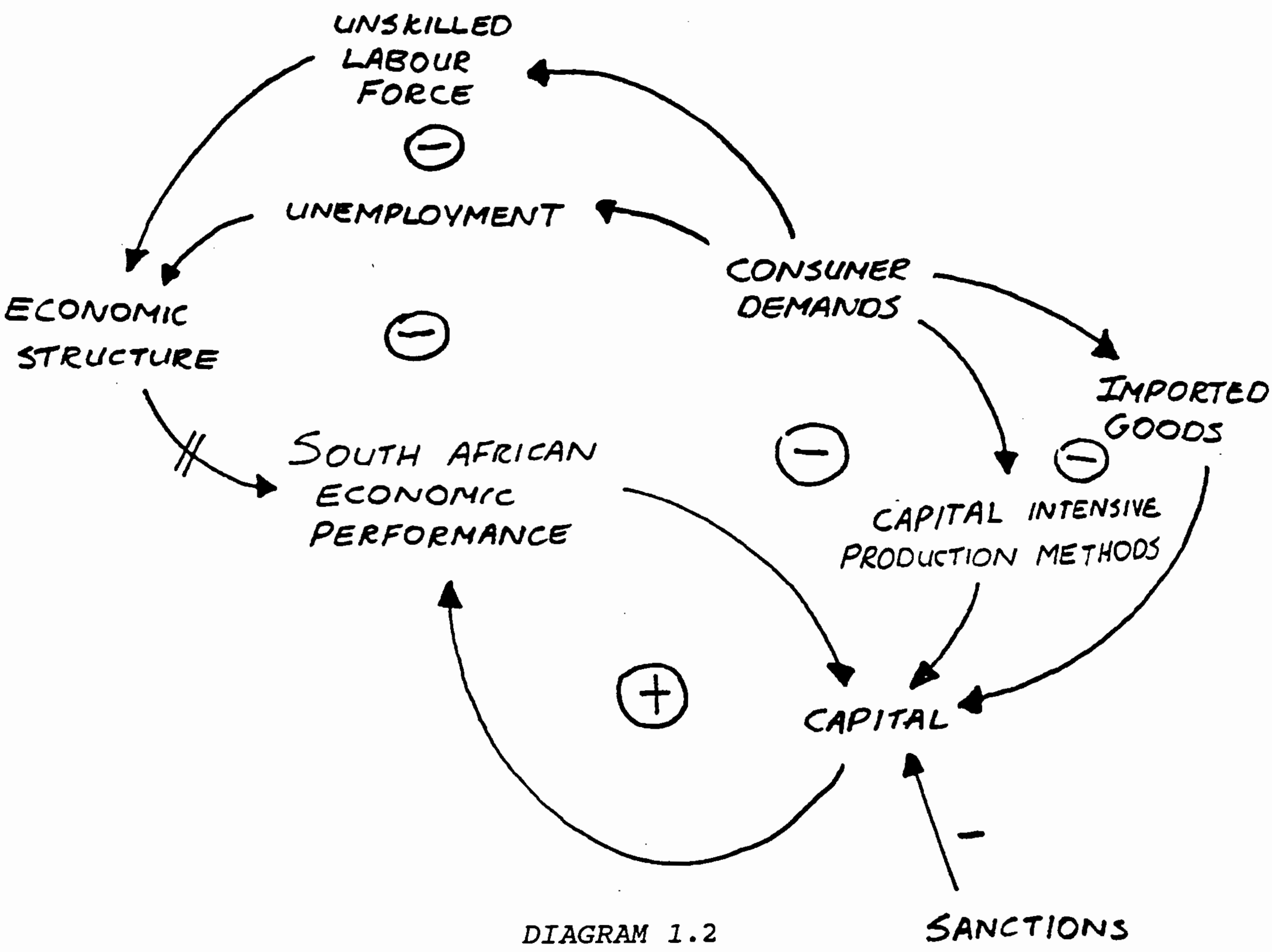



*DIAGRAM 1.2*

*INSIGHT INTO THE PRESENT ECONOMIC PERFORMANCE*

From this perspective it seems that economic decline in South Africa is inevitable. However, the informal sector and small business sector has the potential to provide employment to the skilled and unskilled labour force (21). Small businesses and informal sector activities have proved to be major factors in employment creation and growth in both highly developed and less developed nations. They have become key factors in a reorientation of growth and development objectives with the realization that large corporations and high technology production processes are not providing the necessary economic growth and employment opportunities. In the United States the informal manufacturing businesses with fewer than 20 employees were responsible for 56% of employment growth over the period 1976-1982 (1).

"*In South Africa bureaucratic restrictions, excessive regulation and policies supporting and protecting large industry through capital depreciation allowances, subsidies, tax and other concessions undermined the competitive position of the informal sector and small business*" (1). This is however changing with the introduction of the Small Business Development Corporation and government policy changes to promote the development of small businesses. The growth and development of small businesses and the informal sector will become much more evident within the next five years in South Africa (21).

The emergence of influential trade unions in South Africa has had a negative impact on the growth of the formal sector. The informal sector has no ties with trade unions, which makes it a lucrative option for entrepreneurs. This factor will also stimulate the growth of the informal sector (13). Given the current trends, it is not very likely that the formal economy will, or can, provide sufficient opportunities for economic growth (21). Self-help through the informal sector activity and small business entrepreneurship, can serve to provide a new basis for reconstruction in South Africa (1). The emergence of a successful self-help economy is likely to stimulate the formal economy and could result in a much higher growth rate of say 5% per year (1). If the economic growth rate of 2% or less, as experienced in South Africa in present years, persists, along with simultaneously decreasing employment intensity and increased population growth " *the country will not only become impoverished further, but absolute deprivation and political instability are bound to become endemic before the turn of the century*" (1).

It is therefore evident that growth in the informal self-help economy is inevitable. This will however have severe consequences on the formal economy. The effect that the informal and small business sector has had on the formal sector will be discussed in context of the textile industry in the section following.

*Diagram 1.3* below explains the interactions existing within the formal and informal sector and the causality associated with it. The government tends to place more restrictions on the economic variables in times of poor economic performance to stimulate the formal economy. This results in short term economic performance. However, this has counter intuitive implications because the informal and small business sector suffers as a result of this. The effect of a stunted informal sector growth is only experienced in the long term due the delayed reaction that economic structure has on economic performance. The informal and small business sector has a greater potential to improve the economic performance in South Africa than the formal economy (this is explained in *Diagram 1.4*). Therefore a debilitating loop arises that leads to poor economic performance. Restrictions have to be lifted to break this loop. This mental model shows a typical example of a high leverage point, namely bureaucratic restrictions, and the dangers of delays in causality.

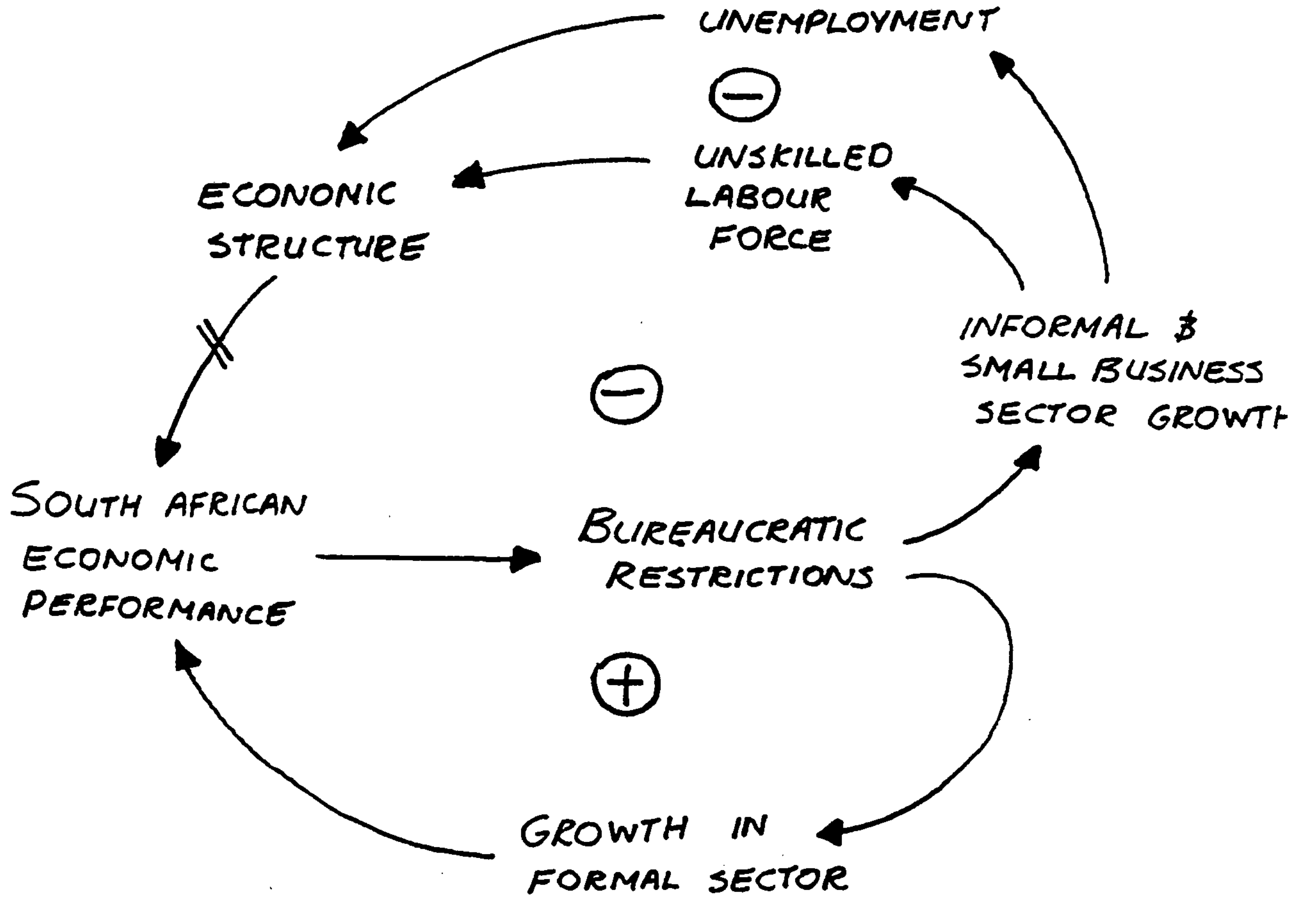



DIAGRAM 1.3

INTERACTIONS EXISTING WITHIN THE FORMAL AND INFORMAL SECTOR

### 1.1.2 TEXTILE INDUSTRY IN SOUTH AFRICA

The textile industry has recently experienced the introduction of the informal sector and the small businesses, which has had a profound influence on the formal textile industry. The emergence of the informal and small business sector has resulted in a decline in the formal sector due to better competitive advantages of small enterprises. This in turn has forced the larger textile manufacturers to become competitive with the informal sector in order to survive.

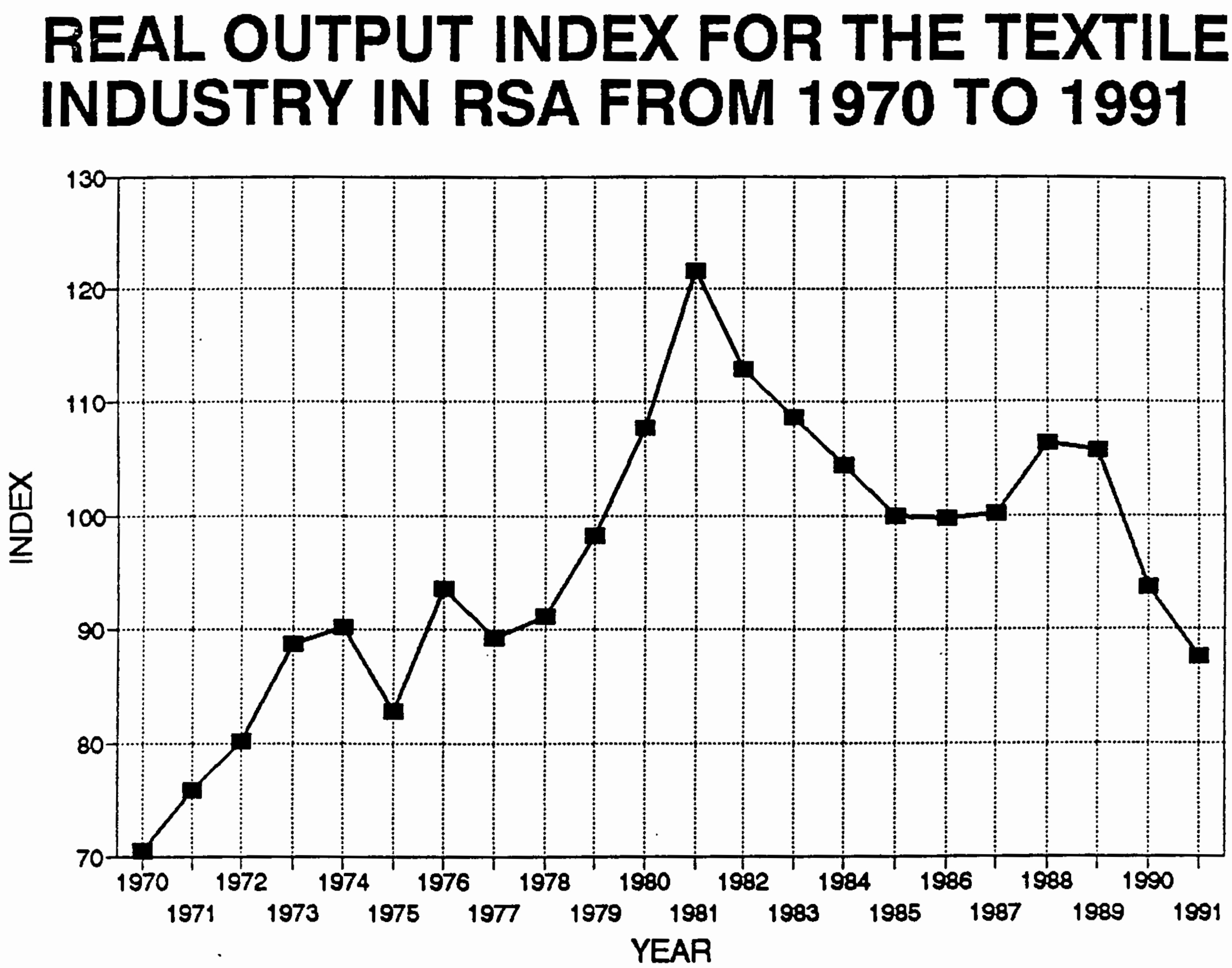
The reason that the informal sector and small businesses are more competitive are because they produce one or two product lines which require inexpensive machinery, low maintenance, little technological expertise to set-up the machines, and therefore operate at overheads much lower than that of a larger textile manufacturing firm, which in turn results in lower product prices.

In addition to lower product prices, the lead time and delivery performance of these small operations are also more competitive due to the simple nature of the operations. These small operations do not rely heavily on forecasts and complex scheduling, have little labour problems etc and can therefore can attain better delivery performances than the larger companies. The smaller textile operations, that only produce a limited number of product lines, also have less machinery set-ups and operate with flexible working hours (due to the small work force required) which results in shorter lead times than that of the larger companies.

In addition to the local threat of the informal sector to the growth and survival of the formal textile industry, there is also fierce competition from abroad. The recent decline in sanctions against South Africa has been coupled with increased competition of foreign manufacturers (18).

Many of the larger textile companies are producing at only 40% capacity and are struggling for survival. This has resulted in increased competition among the textile companies in local markets, says Allan Robinson, specialist consultant of the CSIR's division of textile technology (18).

The compounded effect of the growing informal and small business sector, aggressive foreign competition, and the severe local recession experienced in South Africa have resulted in the decline in the formal textile industry. This is demonstrated by the multifactor productivity indices for the Textile industry as shown in *Appendix 1.3*. The real output of the formal textile industry in South Africa has decreased by 20% in two years since 1989 as shown in *Appendix 1.3* and *Graph 1.4* below (22).




*GRAPH 1.4*

The textile industry is dependant on a large unskilled labour force (13). From this point it can be argued that the textile industry has a definite potential for improvement in the economy and employment in South Africa. Therefore there is a need to keep the formal textile industry healthy.

It is evident that there is a desperate need for increased competitiveness in the textile industry to regain market share from foreign competition, or more importantly, for survival from the local competition. For some time now, many have waited for an upswing in the South African economy to end the industrial decline, which has been blamed on labour unions, government regulations, sanctions and other various forces (1). But it is now becoming apparent that many companies wont survive this waiting period and the only way to regain the competitive position in the market place is by adopting new management techniques. Bad management practice has also been a culprit for the loss of competitive advantage in the market place.

*Diagram 1.4* below interprets the causality associated with the growth of the textile industry in South Africa. We are presently experiencing a decline in the textile industry due to the recent lifting of sanctions. However, the growth of the textile industry is dependant on the ability to remain competitive with foreign markets. But regaining competitiveness has a delay associated with it, and many textile companies can not survive this delay period due to the severe market conditions prevailing. Therefore the ability to steer the formal textile industry to competitiveness through proper management becomes self evident.

CAUSALITY OF THE GROWTH OF THE FORMAL AND INFORMAL SECTOR OF THE TEXTILE INDUSTRY

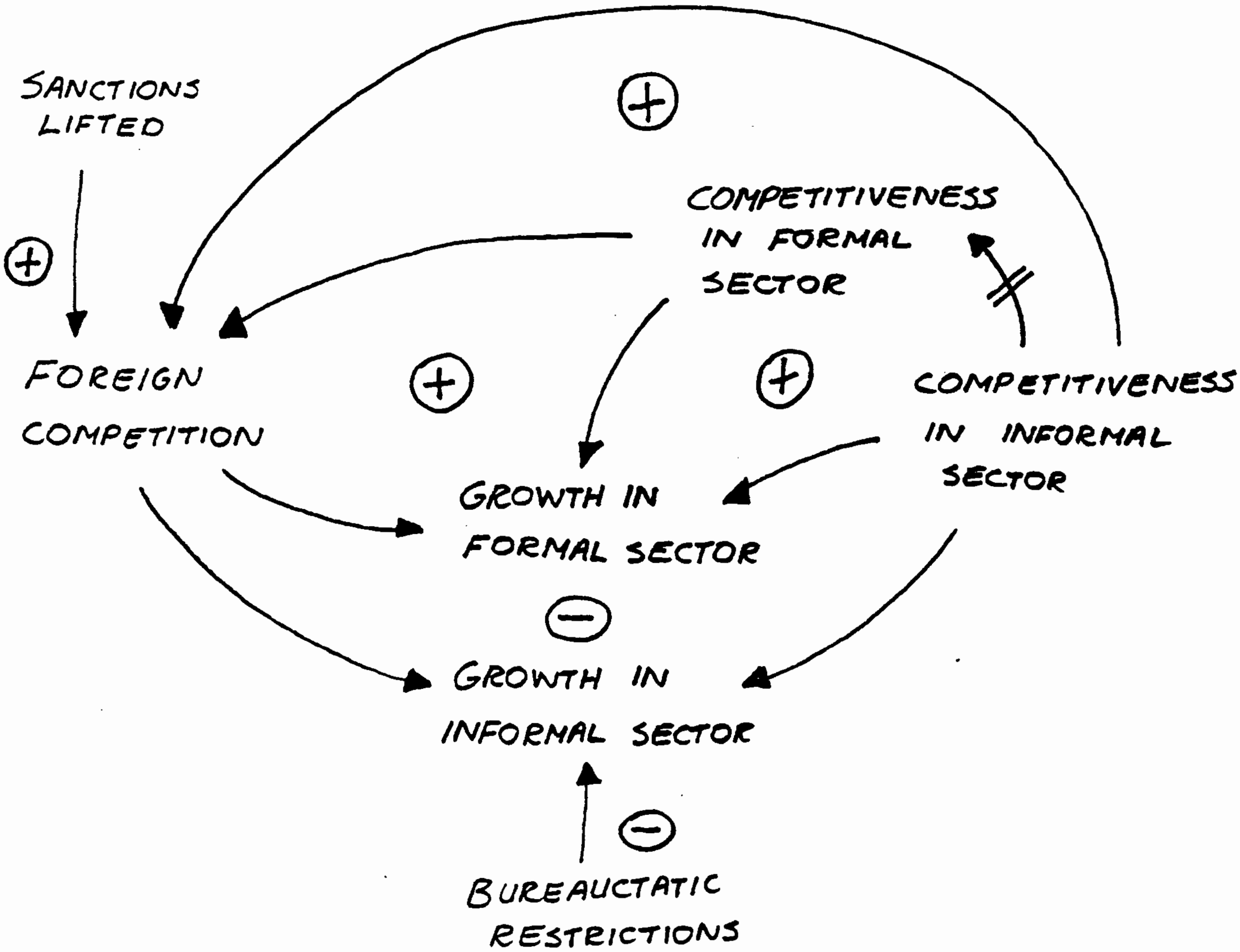



DIAGRAM 1.4

To regain the competitive edge, managers of manufacturing organizations must reexamine traditional managerial philosophies and systems. Managers must come to terms with, and understand the concept of competitive advantage, before this trump card can be used to conquer the present predicament of the textile industry. Like competition itself, competitive advantage is a constantly moving target. For any company in any industry, the key is not to get stuck with a single simple notion of its source of advantage. The best competitors, the most successful ones, know how to keep moving and always stay on the cutting edge.

Manufacturing firms continually struggle to obtain or maintain an advantage over their competitors. This is because competitive variables constantly change to accommodate the market demands. Competitive variables are not only dependant on market conditions, but are also dependant on the competitors ability to satisfy these market demands. It can therefore be recognized that there is no finish line in the endeavor to gaining competitive advantage. The target is a moving one. The process of continuous improvement is cardinal to obtain or maintain a moving competitive advantage.

Continuous improvements is a generic term used to describe the process of perpetually striving for excellence in incremental steps. This philosophy has become one of the cornerstones of the Japanese approach to operations, and is often contrasted with the more traditional Western approach of relying on major technological or theoretical innovations to achieve "big win" improvements (12). The success of continuous improvements results from the accumulation of relatively easily attainable small improvements on an ongoing basis.

### 1.1.3 PUMA JERSEY

Puma Jersey is a textile company situated in Athlone and forms part of the Anglovaal group. Puma Jersey employs approximately 850 people and belongs to the formal sector of the textile industry. Puma Jersey are producing at approximately 60% capacity and need to regain market share by increasing its competitiveness through customer satisfaction. Puma Jersey are experiencing the negative impact of the ever growing informal and small business sector, foreign competition and local recession. Puma Jersey have recognized the vital necessity of gaining competitive advantage to regain market share, and have commited themselves to increase competitiveness by shortening lead times and reducing late deliveries.

Puma Jersey have gained an unfavorable reputation in the local market for excessive lead times and exceptionally poor delivery performance. This can mainly be attributed to inappropriate management styles in the past. Puma Jersey has been managed by autocratic management styles typical in the traditional approach to management. Company wide employee dissatisfaction and demotivation was evident. Traditional management techniques was also evident due to the fixation of using quick fix and non-scientific approach to problematical situations.

Whenever there was pressure to attain increased performance management attempted to increase employees performance through fear driven means. Threats of firing employees and threats to annual bonuses were common, and employees were "often treated with disrespect". This autocratic top down management did however achieve increased performance in the short term, which reinforced this management style even further. But the long term effect was that employees became dissatisfied and demotivated, which lead to a gradual decrease in performance.

This autocratic non-participative management style also has the long term effect that employees are unable to participate and experience team learning. The employees ability to learn as an individual is also eroded as a result of this. These elements of learning are vital for increased performance and company growth (15). Due to the employees inability to learn, and therefore perform, management created a perception that the employees are incapable, which reinforced this autocratic non-participative management style even further.

*Diagram 1.5* illustrates the complex interactions emanating from bad management techniques. Managements fixation on events leads to a gradual decay in the long term of employee performance. This is a typical example of the danger of slow gradual processes (parable of the boiled frog). The delays result in events not being related in time or space, and are therefore not recognized by management that focuses on events. The high leverage point for this system is to adopt better management techniques, rather than to fight the symptoms as was done in the past. The symptom is the proverbial incompetent worker.

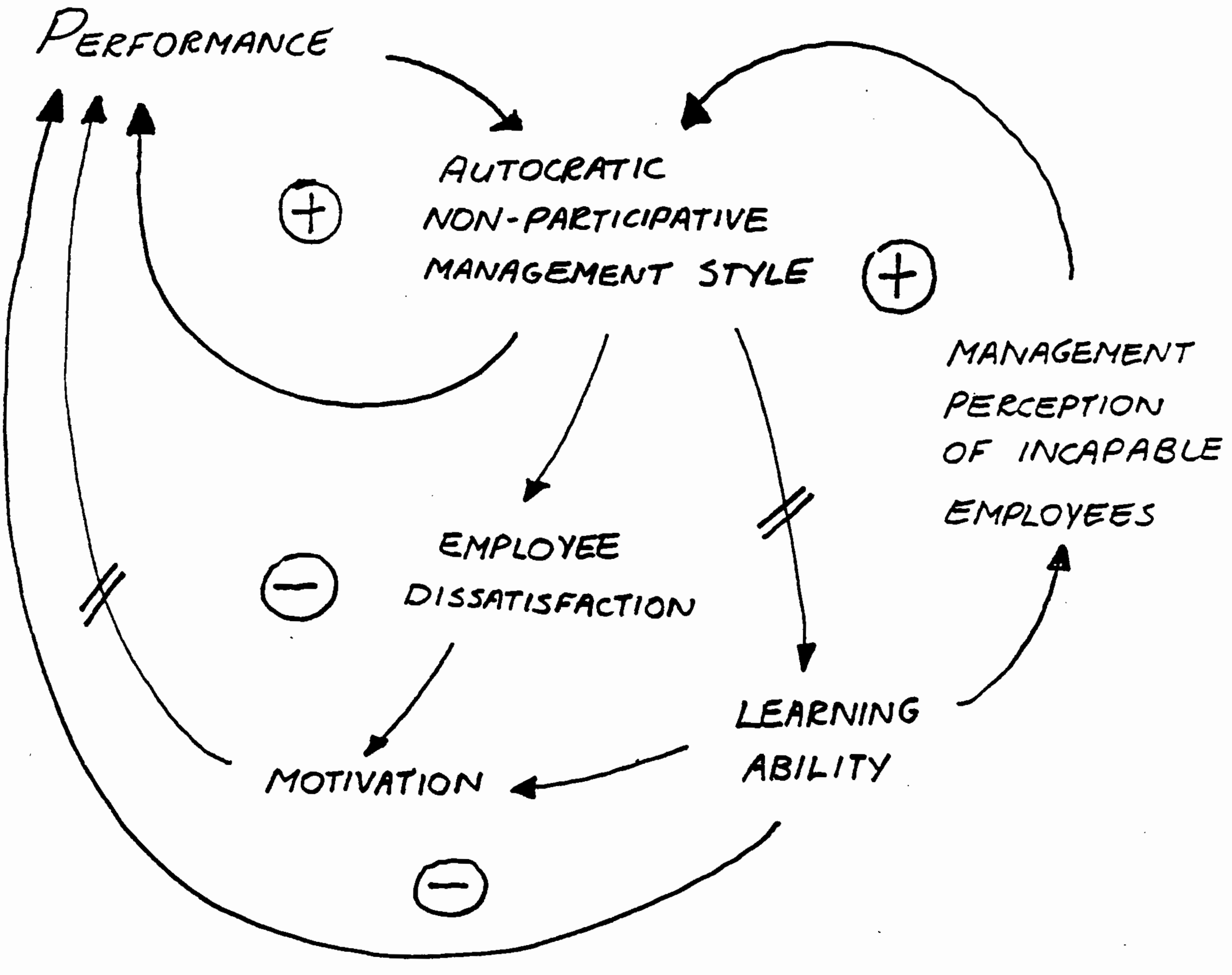



*DIAGRAM 1.5*
*INFERIOR PERFORMANCE AS A RESULT OF BAD MANAGEMENT TECHNIQUES*

Quick fix approach to problematical situations is widely evident at Puma Jersey because excessive exploitation of expediting and the non scientific approach to problematical situations are prevalent. The long term impact of this management style was not realized because a quick fix attitude fosters short term fixation on events. The behavioral patterns in the long term were ignored which resulted in treating problematical situations symptomaticaly, instead of treating the root cause. Therefore problems reoccurred at a later stage, or appeared in a different form which resulted in decreased performance in the long term. This phenomenon is explained in *Diagram 1.4*. A typical example describing the short-term and long-term consequences of quick fix solutions is expediting.

When an order is expedited it is pushed ahead of other orders to speed up the process. Therefore the order can be delivered on time, which reinforces this management style even further. This is the short-term consequence of expediting. The symptom has been treated but the root cause for the late delivery has still not been established, or addressed, and late deliveries will still occur in the future.

Expediting also results in other orders being delayed because they can not be processed according to schedule because the expedited order took their place, which leads to more late deliveries. These late deliveries will probably also be expedited. This is recognized as the long-term cause, and has a negative impact on delivery performance. The delayed effect of expediting makes it difficult for management to recognize the consequences. The causal interactions of quick fix solutions and expediting are shown in *Diagram 1.6* below.

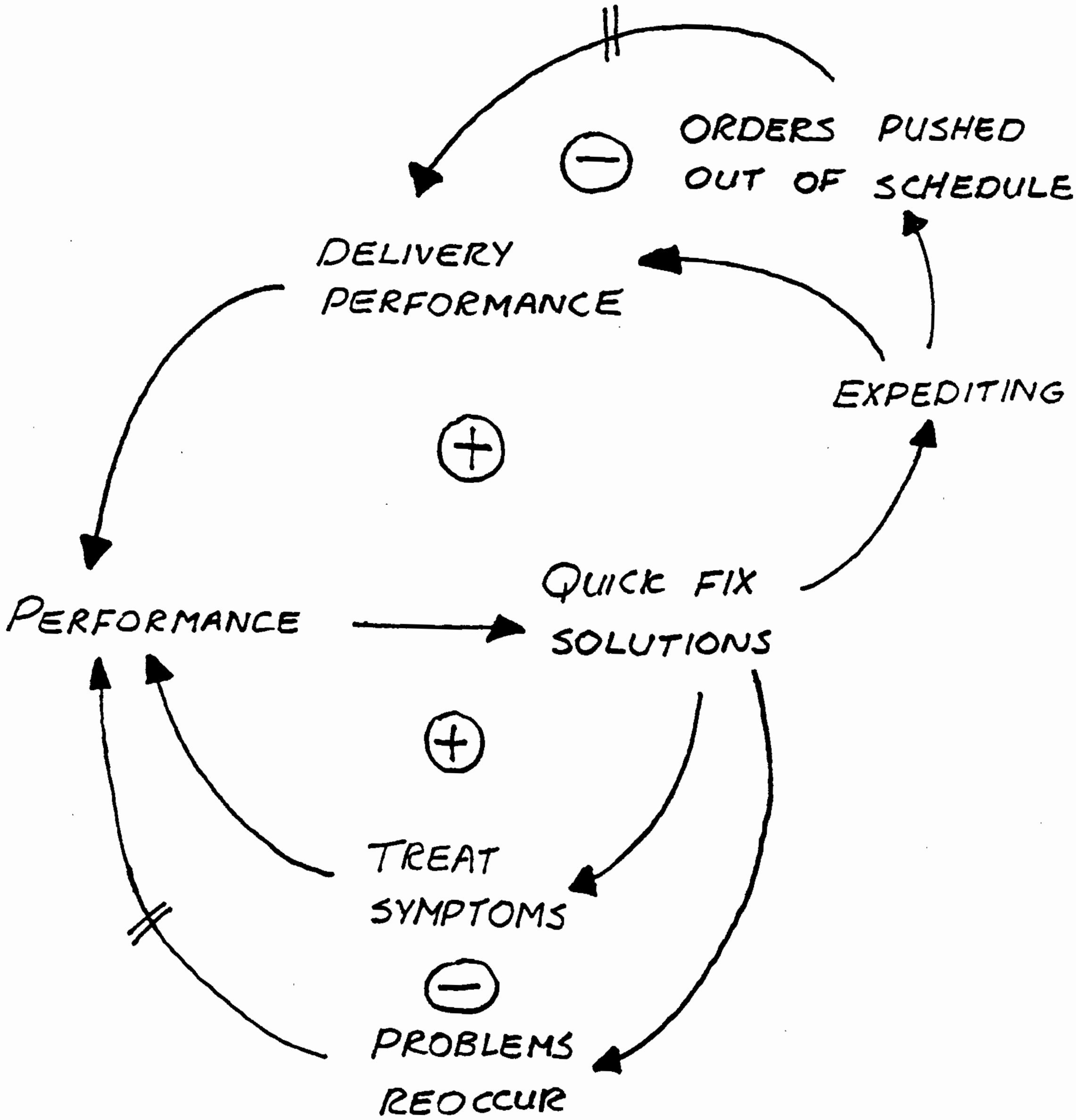



*DIAGRAM 1.6*
*RESULTS OF EXPEDITING AND OTHER QUICK FIX SOLUTIONS*

These inappropriate management techniques survived due to the healthy economic climate prevailing in South Africa in the early eighties. However, Puma Jersey has been on a steady decline in the recession and realized the necessity to adopt a different management approach.

Customized systems appropriate for the manufacturing and cultural environment at Puma Jersey had to be developed to reduce late deliveries and lead times. Four principals and approaches were found to be applicable and appropriate to the Puma Jerseys environment. The four techniques and tools used to develop systems to reduce lead times and late deliveries at Puma Jersey are:-

1. Performance measurements
2. CEDAC
3. Synchronous manufacturing
4. Systems dynamics

The underlying concept of systems thinking methodology is paramount to successfully apply these four tools to develop sustainable systems for continual improvement of delivery performance and lead times. The success of these four approaches hinges on their systemic compatibility. An explanation of the factory operations at Puma Jersey can be found in *Appendix 1.4*.

## 1.2 HYPOTHESIS OF THE INVESTIGATION

The hypothesis of the investigation is:-

**"THE LONG TERM SUSTAINABILITY OF PERFORMANCE REQUIRES THE SYSTEMIC COMPATIBILITY OF APPROACHES"**

In simpler terms it means that performance measurements, CEDAC, synchronous manufacturing and systems dynamics (the four techniques and approaches) have to be complementary and agreeable to each other in a systemic way to achieve decreased lead times and late deliveries.

## 1.3 PURPOSES OF THE INVESTIGATION

Shortening lead time and reducing late deliveries has the direct result of increasing customer satisfaction. This leads to increased competitiveness and a gain in market share. Increased lead time and delivery performance can be increased by developing management methodologies and using certain techniques and tools relevant to Puma Jerseys environment.

The purpose of the investigation is therefore to develop an approach to attain sustainable performance in lead time and delivery performance at Puma Jersey. Many companies are in a similar environment and predicament as Puma Jersey, and therefore this investigation can be relevant to other firms.

## 1.4 CONSTRAINTS OF THE STUDY

The scope of the thesis will be to develop an effective approach to reduce lead time and late deliveries for piece dyed knitted fabrics at Puma Jersey. The sales, marketing, research and development and finance departments will not form part of this investigation. Only the departments directly responsible to the operations manager will be investigated.

The study will only investigate the following approaches to reduce lead times and late deliveries:-

1. Cause and Effect analysis
2. Performance measurements
3. Synchronous manufacturing
4. Systems dynamics

## 1.5 METHOD OF INVESTIGATION

First a literature survey will be carried out on the following:-

1. Lead times
2. Delivery performance
3. Systems thinking

A literature review will be carried out on the following approaches and techniques that will assist in reducing lead times and late deliveries:-

4. CEDAC
5. Performance measurements
6. Synchronous Manufacturing
7. Systems Dynamics

The literature review will facilitate substantiative argument for the discussion following. The discussion will use systems thinking as a platform to motivate the applicability and necessity of the techniques and principals outlined in the literature review. The systemic compatibility of the techniques and principals will be proven in the discussion. The hypothesis will be proven in the sections following, which will describe the work carried out at Puma Jersey.

Before potential areas for improvement are recognized and systems are implemented, the lead time and delivery performance of Puma Jersey will be established. These performances will be compared to the competitors performance and the required performance to determine Puma Jerseys competitiveness before improvements are implemented.

Then methods, or tools, used to identify potential areas of lead time and delivery performance improvement at Puma Jersey will be described. The potential areas of improvement will also be established. Systems will then be implemented at these potential areas. Systems implemented to reduce lead time and late deliveries will be explained under the following techniques and approaches used:-

1. CEDAC
2. Performance measurements
3. Synchronous Manufacturing
4. Systems Dynamics

Lead time and delivery performance results obtained by implementing these techniques and approaches will then be discussed. Conclusions about the effectiveness of implementing these systems will then follow. Finally recommendations will be made.

# 2. LITERATURE REVIEW

The literature review serves as a forum for discussion and substatiative argument. The literature review will not attempt to analyze and prove the systemic compatibility of the approaches used to improve lead time and delivery performance, unless it is so stated in the literature researched. The approaches will therefore be discussed in isolation of each other. The literature review will research the following topics:-

1. Systems thinking
2. Lead times
3. Late deliveries
4. Performance measurements
5. CEDAC
6. Synchronous manufacturing
7. Systems Dynamics

## 2.1 SYSTEMS THINKING

The fundamental approach to attaining excellence in any manufacturing system is through the improved management of that system (14). Along this line, there is much that can be learned from the Japanese philosophy of manufacturing management and techniques to attaining excellence. A number of companies have copied and applied parts of the Japanese management philosophy and techniques to their own operations with some degree of success. But it is not reasonable to expect that the Japanese systems can be totally copied by firms that exist within other cultural, political, social and manufacturing environments (14).

"*Companies that try to emulate the Japanese may be able to improve their operation, but in the final analysis, the approach of trying to copy as much of the Japanese system as possible dooms the firm to long term inferiority to customized manufacturing management philosophies and techniques*" (10). It is through systems thinking that is inherent in all the Japanese management philosophies and techniques, that have enabled Japan to achieve global competitiveness (10).

Therefore management should attempt to copy the method of developing and implementing systems, rather than copying the systems and applying them to their own unique environment. The ability to successfully develop customized systems to increase competitiveness hinges on whether management can adopt a systemic approach to develop and implement systems that contain a mechanism for continual improvement (14).

Before a definition of systems thinking can be derived there must be an understanding of what constitutes a system. A system is defined as "*a set of objects together with* *relationships between the objects and between their attributes related to each other and to their environment so as to form a whole*".(15) In addition a system "*works together towards the accomplishment of a certain logical and purposeful end*" (3).

Systems thinking is defined as viewing a system in a holistic way, taking cognizance of the interaction of elements making up a system. Systems thinking possesses understanding of the interfaces between different areas affecting the system. Systems thinking is used as a vehicle for organized thought about problematical situations (3). Systems thinking is a conceptual framework, a body of knowledge and tools that have been developed to facilitate the understanding of systems structures and therefore systems behavior.

Systems thinking methodology contradicts the traditional mechanistic thinking approach which fosters a reductionism philosophy. Reductionism is the idea that a "*system is the sum of its parts*" (15). However reasonable this sounds, reductionism falls short of accurately describing reality because a system has synergy (3). Synergy exists due to organization and relationships existing between the parts of the system (15). Traditionally managers have practiced mechanistic thinking by focusing on snapshots of isolated parts of a system and disregarded the interrelated actions of the entire system.

Breaking real world into separate manageable elements and viewing these elements in isolation for easy understanding has been the trademark of historical thinking. "*From a very early age, we are taught to break apart problems, to fragment the world. This apparently makes complex tasks and subjects more manageable, but we pay a hidden enormous price. We can no longer see the consequences of our actions, we lose our intrinsic sense of connection to a larger world. We then try to "see the big picture", we try to reassemble the fragments in our minds, to list and organize the pieces. But the task is futile - similar to trying to reassemble the fragments of a broken mirror to see a true reflection*" (4).

The importance of systems thinking can be related to the manufacturing environment. In many manufacturing plants "walls" have been built for protection. These walls divide a company into easily manageable parts. These walls, both physical and non physical in nature, are intended to insulate individual departments and functional areas form uncertainty and the numerous disturbances that regularly occur within the manufacturing environment (15). They seemingly give each department or functional area a greater sense of independence, importance and security. However, these walls are dysfunctional because in reality the walls only act to divide the plant into small empires, which weakens the total system (15). These walls are inconsistent with the systems thinking methodology and concurrent engineering principals, also known as simultaneous engineering.

These walls also satisfy the production manager because an department is sealed off from outside disturbances so that one kind of product, all of one colour, with infinitely long production runs can be accomplished (10). A local optimum is achieved for the department which reflects favorably on the production manager. However, this local optimum is attained at the expense of lead time and delivery performance.

It is common practice in contemporary management culture to attain local optimization in subsystems of the total system in an attempt to achieve the desired result of global optimization of the entire system. This theory hinges on the premise that the sum of local optima is equal to the global optimum of a system. However, this theory fails because it supports a reductionist approach of treating subsystems in isolation. The systems thinking methodology clearly states that "*everything is connected to everything else. Real life is lived in a complex world system where all the subsystems overlap and effect each other. The common mistake is to deal with one subsystem in isolation, as if it did not connect with anything else. This mechanistic approach almost always backfires as other subsystems respond in unanticipated ways*" (15).

The local optima that might be achievable must be subservient to the global optimum of the total system. It must be remembered that the sum of local optima does not equal to the global optimum. If an operation is to be successful then all of the various departments and functions must be in harmony with the common goal of the entire system (5). This is consistent with systems thinking methodology.

Physical boundaries evident in independent functional departments are not the only "walls" existing in an organization. Non physical boundaries that have no concrete appearance also fosters an environment of local optimization. Vertical organizational hierarchies that form rigid authority and reporting structures create authority boundaries (10). Identity boundaries are created by inflexible job descriptions is another form of a psychological boundary that lends itself to local optimization. Identity and authority boundaries can create an "us versus them" approach in the work environment (10).

By making clear "who reports to whom" and "who is responsible for what", boundaries have been formed to determine individual behavior (10). The problem is that this traditional organizational map describes a world that no longer exists. New technologies, fast changing markets and global competition are revolutionizing business relationships. Companies have to blur their traditional boundaries to respond to this more fluid business environment (10). The roles people play at work and the tasks that they perform will become correspondingly blurred and ambiguous (10).

## 2.2 REDUCING LEAD TIME

The ways leading companies manage time represent the most powerful new resources of competitive advantage (18). Japanese companies best illustrate their success in pursuing these advantages. They regard time as the most critical yardstick for performance. However, traditional management almost never monitors the consumption of time as precisely as the consumption of sales and costs (18).

Companies are systems and therefore time connects all parts. The most powerful competitors understand this axiom and are reducing the consumption of time to gain a multitude of competitive advantages. By competing on time (ie developing and producing a product ahead of the competition) a firm enjoys first-mover advantages that include higher pricing, high market share, productivity improvement, and reduced risks (18). But by reducing the consumption of time in every aspect of the business, companies not only improve sales by staying close to their customers, but also reduce costs and improve quality (18). Reducing lead time also incurs savings due to extra interest earned. (*Appendix 2.1* shows the extra interest earned at Puma Jersey by reducing the lead time by 1 week.)

Traditional manufacturing requires long lead times to resolve conflicts between various jobs or activities that require the same resources. The long lead times, in turn, require sales forecasts and production schedules to guide planning. But forecasts are inevitably wrong because by definition they are guesses into the future, however informed. All forecasts carry an element of error because production schedules are flexible to accommodate unforeseen changes. Naturally as lead times lengthen the accuracy of the forecast declines (14). With more forecasting errors, inventories balloon and the need for safety stocks at all levels increases (14).

Errors in forecasting also mean more unscheduled jobs that have to be expedited, thereby crowding out scheduled jobs which in turn ultimately results in late deliveries. The need for longer lead times grows even greater and the planning loop expands even more, driving up costs, increasing delays and late deliveries, and creating system inefficiencies.

Managers who find themselves trapped in this planning loop often respond by asking for better forecasts and longer lead times. In other words, they treat the symptoms and worsen the problem. The only way to break the planning loop is to reduce the consumption of time throughout the system. That will in turn cut the need for lead time, estimates, safety stocks and reduce late deliveries (14). The most powerful competitors understand the systemic consequences of long lead times and are breaking the debilitating loop that strangles much of the traditional manufacturing planning.

Reduction in lead time also have a direct affect on quality improvement. This occurs because defective products are detected much sooner and do not have time to accumulate, resulting in less defective products in the system before detection. Fewer defective products in the system also reduces expediting because work flow will be according to schedule. The process of identifying the cause of the problem and finding ways to prevent the problem from reoccurring becomes considerably easier as lead times decrease. This is because the cause of the quality problem is closer in time from the point of detection, and the problem is not hidden in a sea of inventory.

The systemic causal loops of lead time is shown in *Diagram 1.2* below. This diagram shows the systemic behavior resulting from lead times. This systemic representation shows all the interactions occurring between the different elements of the system, and thus giving a holistic perspective on the systemic behavior relating to lead times.

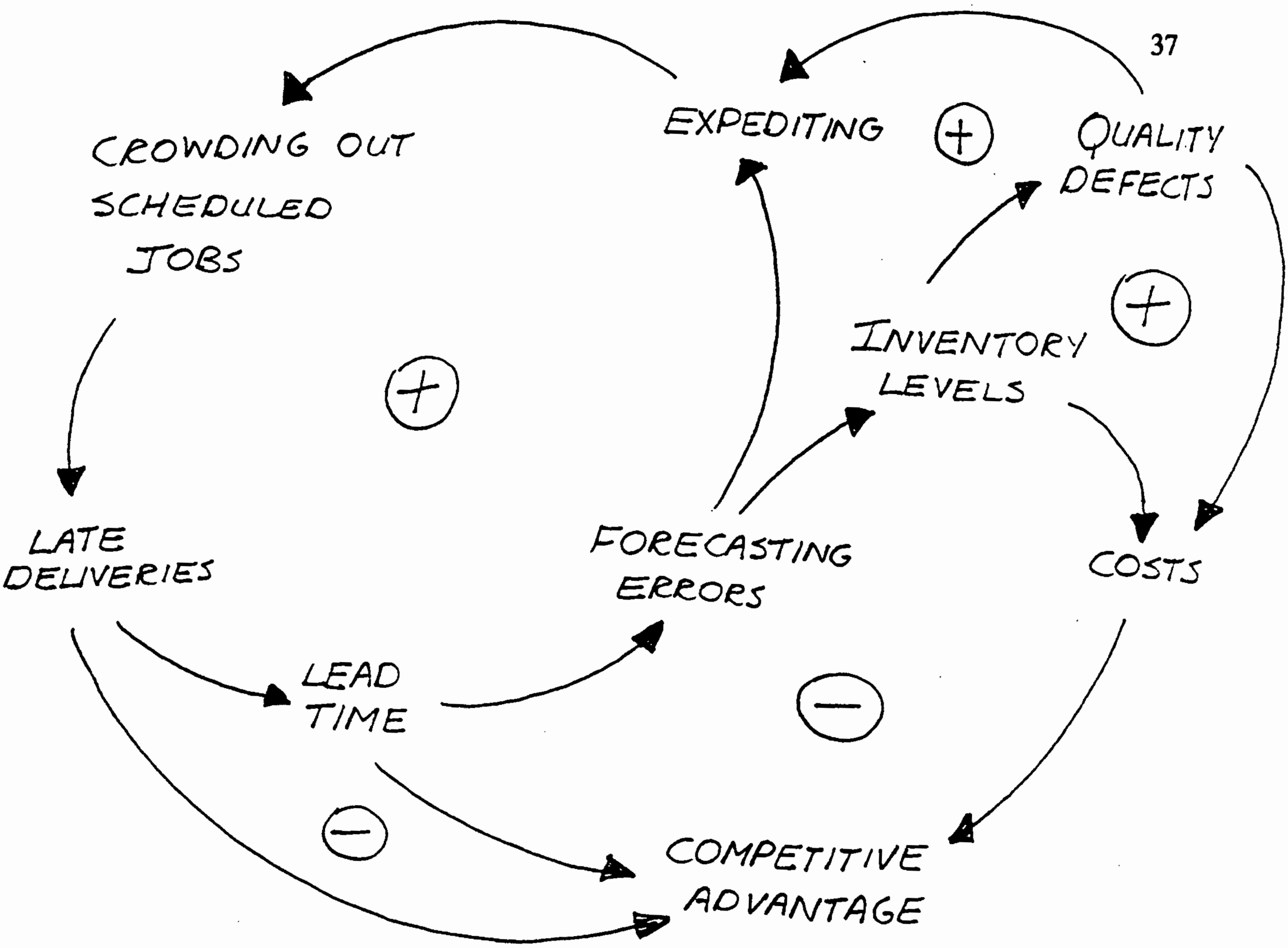



*DIAGRAM 2.1*
*SYSTEMIC CAUSAL LOOP FOR LEAD TIME*

It is evident from this diagram that lead time is the high leverage point to attaining competitive advantage. Time based competitors have recognized this relatively simple solution to increase competitiveness. Time based competition has a goal of eliminating wasted time from all activities in the value chain. Time reduction methods include overlapping product development activities, improving communication channels, simplifying complex processes, reducing set-up times, and smoothing production flow (12). The Japanese have excelled at these time reducing activities. They have redefined the factory mission as a service concept.

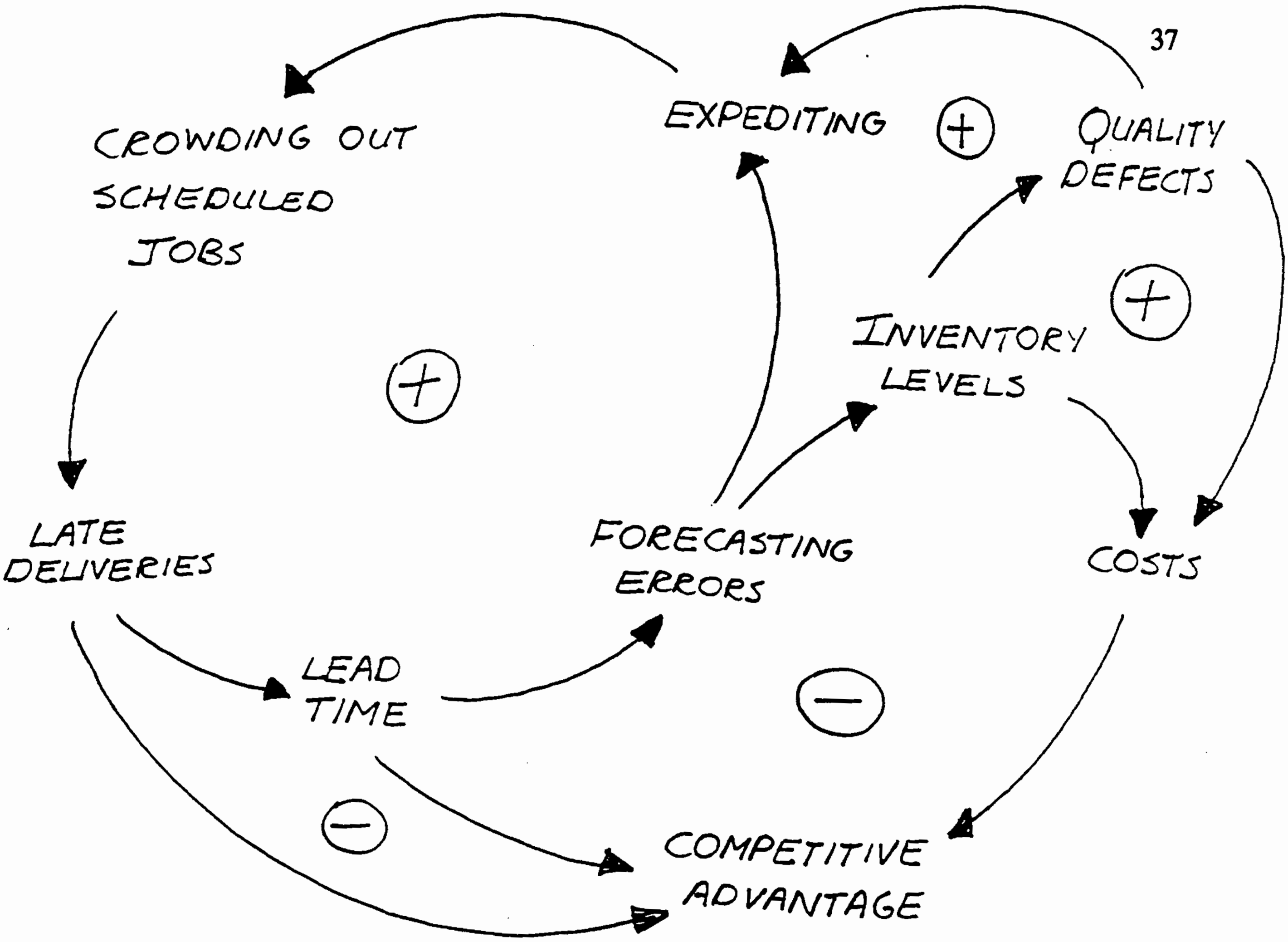



DIAGRAM 2.1
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Most contemporary manufacturers prominently feature a customer orientation in their mission statements. These statements tend to focus solely on product attributes such as functional capabilities and quality levels rather than the important elements of the service to be provided, like time (18).

## 2.2 INCREASING DELIVERY PERFORMANCE

Another important aspect of customer service is delivery performance. Customers of textile manufacturers are primarily demanding more reliable delivery performance. Timeous deliveries are crucial to the customer because a late delivery can have a severe impact on the customers production schedule, which effects the customers delivery performance. Late deliveries have a ripple effect of inconveniences which lead to customer frustration down the line. Late deliveries usually cause greater customer frustration and dissatisfaction than long quoted lead times (14).

Not surprisingly, a firms delivery performance is also a function of the manufacturing lead time. This is again attributable to a forecasts reliability degenerating as the lead time increases. Long lead times, and therefore unreliable forecasts results in variability in product flow due to expediting, quality problems and excessive work in progress. This uncontrolled variability in product flow hiding in a cushion of inventory and defective products is largely responsible for late deliveries.

A late delivery also has the implication that production has not gone according to schedule. Therefore a late delivery has a ripple effect of other implications. If an order is processed after the delivery date it means that it utilizes the production time of a scheduled job, thereby crowding out scheduled jobs which will result in further late deliveries. This systemic consequences of late deliveries and expediting are shown in *Diagram 2.1*. A systemic, and holistic perspective is taken on late deliveries because a single time frame is not viewed in isolation, but the ripple effect of consequences further down the line is taken into account.

The primary objective of increased delivery performance is to reduce customer dissatisfaction, which has the direct result of increased profits due to an increase in market share.
A secondary objective of timeous deliveries is to earn extra interest due to a decrease in the debtors payback period. *Appendix 2.2* shows the extra interest earned by timeous deliveries at Puma Jersey.

## 2.4 PERFORMANCE MEASUREMENTS

The standard cost system has been the measuring yardstick of performance for most South African manufacturing companies (14). These traditional cost accounting systems have provided the basis for most of the key decisions made in manufacturing firms (14). But this approach has some fundamental flaws. It focuses too much attention on direct labour and ignores the effects of interactions that exist in manufacturing organizations.

Traditional costing techniques harbors a non-systemic approach because responsibilities can be delineated. Each manager is responsible for controlling the cost of the operations that fall under his control. This has resulted in a highly localized managerial perspective that overemphasizes the reduction of direct labour (14). Furthermore, it is incorrectly assumed that calculated local cost savings represent savings for the whole plant, or stated in a broader terms that the sum of local optima does not equal to the global optimum. The typical result is a highly nonsynchronized flow of products through the plant that adversely effects the firms ability to compete (14).

Therefore other performance measures are necessary to help managers develop a more effective global perspective for decisions effecting the firms operation. The operational measures of throughput, inventory and operating expense are recognized by the synchronous manufacturing philosophy to describe an effective global perspective for management decisions. (14,17). Focusing on these measures will help managers evaluate the impact of specific manufacturing actions and decisions on overall system performance. This in turn will enhance the quality of decision making throughout the organization and improve both the competitive position and profitability of the firm.

To compound to the problem of applying inappropriate variables to measure performance, management traditionally have not utilized performance measurements to their full capacity to achieve the desired objectives. In other words, performance measurements are not used as a technique to improve the performance that is being measured. This technique is heavily reliant on feedback of these measurements to the relevant people that effect the variable being measured. Feedback of performance measurements gives a sense of purpose to a task. Feedback enables workers to justify a sense of existence and importance in doing their jobs because they can see that they perform an integral part in achieving the final product.

However, there is a general unawareness of the importance of feedback of performance measurements. The vital element of feedback to encourage performance is explained by the "Human Performance System" shown in *Diagram 2.2* below (22).

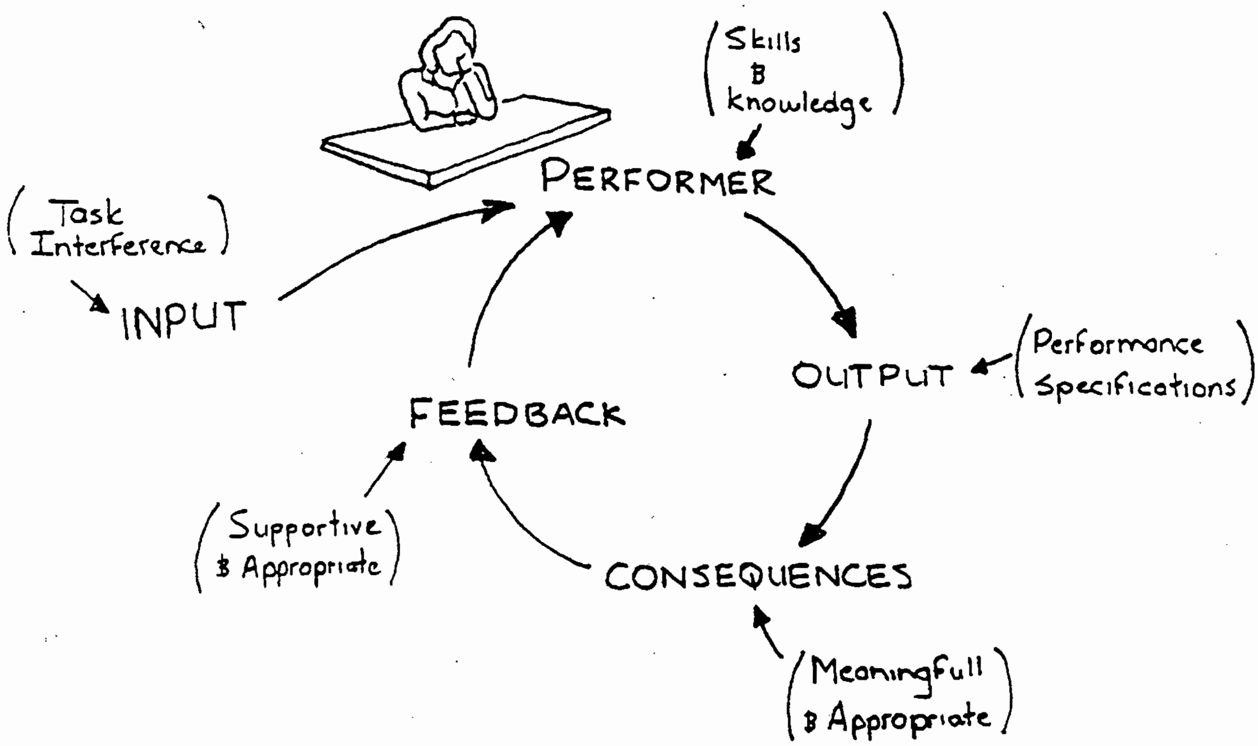



*DIAGRAM 2.2*
*HUMAN PERFORMANCE SYSTEM*

Performance is throttled by one of these five factors. Managers have traditionally concentrated too much on the performers skills and knowledge. Measuring meaningful and appropriate performance variables enables the performer to be measured. The feedback of these measurements completes the human performance loop. The necessity of appropriate performance measures, and the feedback of these measurements have been neglected by most managers in the past.

contribution. Although these two philosophies are based on quality improvement, it is still relevant to the situation of reducing lead times and late deliveries because the same motivational behavioral science principals apply. (Quality gurus to the likes of Garvin and Crosby define "delivery performance as a dimension of quality" (24), and even go to the extent to say that "*quality is buying from the same place twice*" (24), so strictly speaking, lead time and delivery performance is a quality issue.)

The Zero Defect and Quality Circle philosophies both advocate top management commitment to shop floor participation. These philosophies stipulate that shop floor suggestions should be respected and trusted because shop floor personnel often have a much better understanding of problems associated with their jobs because they are so familiar with it. Shop floor participation should also be done on a voluntary basis, and those that do not participate should not be discriminated against but should be motivated to participate. Suggested solutions should be implemented with quick response.

The CEDAC system is found to encapsulate the requirements of the Zero defect and Quality Circle approach to shop floor participation. CEDAC is a system that communicates performance measurements, sets clear measurable performance targets and involves the shop floor in a simple yet effective technique. The communication and feedback of performance measurements in an appropriate manner forms an integral part in the "Human Performance System". CEDAC is now considered as the "*most effective tool for managing improvement within a company*" (8). The inventor was awarded the prestigious Deming Literature Prize for his contributions to the science of productivity and quality improvement with his CEDAC system.

CEDAC is a modification of the cause and effect diagram (or also known as the fishbone or Ishikawa diagram). CEDAC stands for "Cause and Effect diagram with the Addition of Cards". However, it is not simply a diagram but a "whole system".

CEDAC works in the following way:-

1. A problem area is identified
2. The variable representing the problem is plotted on a control chart. A target value may also be plotted on the chart to set an objective.
3. The causes for the problem are identified by managers, foremen, operators or any one else.
4. Each cause is written on an individual card.
5. Causes for the problem are grouped into similar categories as in the Ishikawa diagram and attached to the CEDAC diagram.
6. Solutions to the causes are attached to the relevant cause with a different colored card. Solutions can be suggested by anyone involved.

An example of a CEDAC diagram is shown below in *Diagram 2.3*.

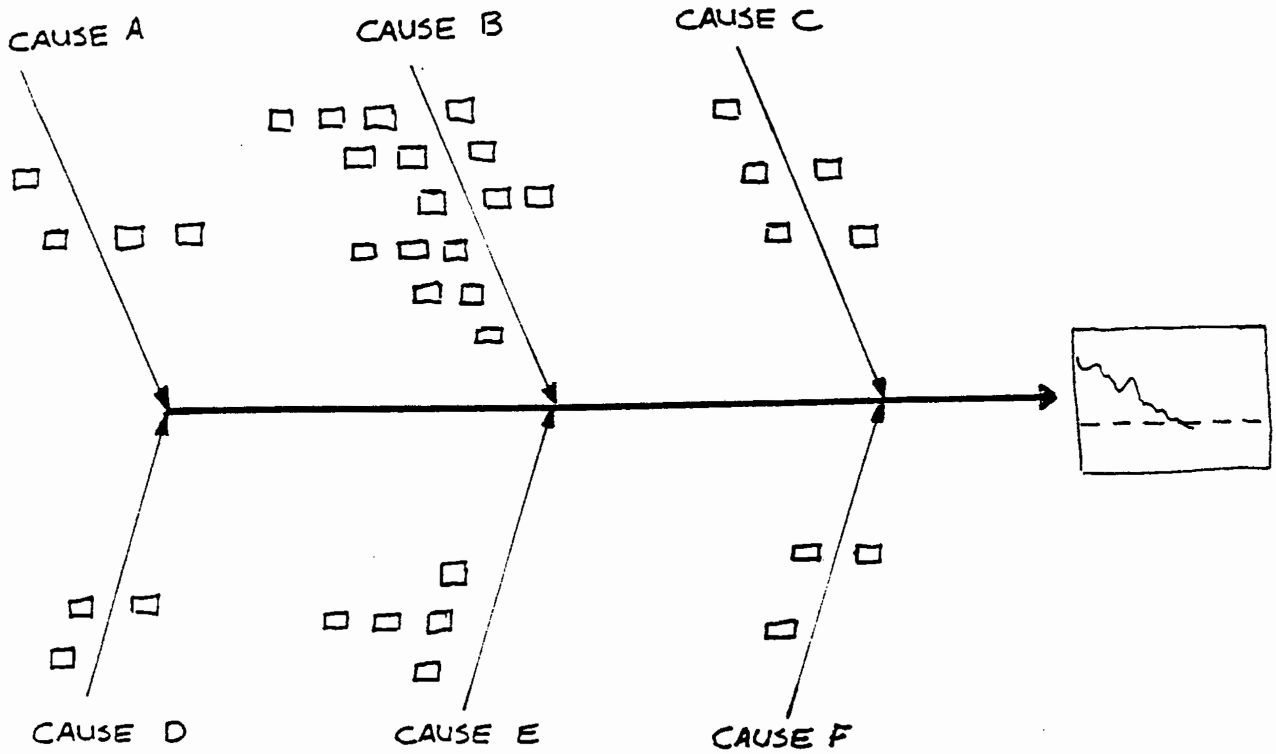



*DIAGRAM 2.3*
*EXAMPLE OF A CEDAC*

CEDAC is a communication tool for managers and the shop floor. It communicates what the firm is trying to achieve, and how the shop floor plays an integral part in achieving these objectives (8). It monitors all the variables effecting the variable plotted on the control chart. The effect that an implemented solution has on the variable being measured is also monitored. Progresses are constantly visible to everybody.

As a managerial tool CEDAC also helps the process of policy deployment and assures coherence of improvement themes with business objectives (8). As a working tool it gives participants more freedom, since it does not require frequent meetings, and at the same time avoids bureaucracy, because written reports, minutes and paper work are no longer necessary (8).

## 2.6 SYNCHRONOUS MANUFACTURING

Constraints exist in every organization and effectively limit the ability of the firm to improve their productivity and make more money. Constraints may appear in many forms. The market may be a major limitation on what the firm can achieve. Material and capacity constraints place physical limitations on what the firm can produce. Logistical, managerial and behavioral constraints introduce inefficiencies into the organization.

Synchronous manufacturing directly addresses the capacity constraints of a system. Synchronous Manufacturing recognizes these constraints as capacity constrained resources (CCRs). CCRs are those resources which if not properly scheduled and managed, are likely to cause significant problems in the planned product flow throughout the plant (14). CCRs must be a focal point of managerial attention and may be either bottleneck or non-bottleneck resources. The identification and management of CCRs are a major consideration in the implementation of synchronous manufacturing in a plant.

A five step approach developed by Goldratt is paramount to synchronous manufacturing and the resulting ability for improved company performance. The recommended approach includes the following steps (17):-

1. Identify the constraints of the system
2. Determine how to exploit the constraints to improve the performance of the system
3. Subordinate all parts of the system to the support of step 2
4. Carry out the steps necessary to improve the performance of the system
5. If in the previous step, a constraint has been broken or a new constraint develops, go back to step 1

Synchronous manufacturing recognizes that the interactions that exist between resources lead to the conclusion that there is a distinct difference between activation and utilization. In many cases, it is possible to activate a resource, especially a non-bottleneck, beyond what is useful or productive for the system. But according to the synchronous manufacturing philosophy, resources must only be utilized and not simply activated (14). By utilization is meant activation to contribute positively to company performance.

Synchronous manufacturing directly addresses the issues of managing bottlenecks and synchronizing work flow to decrease inventory levels, and therefore lead time. Implementing the synchronous manufacturing philosophy to synchronize work flow is very effective in situations where large work in progress levels are evident (14). These situations where large levels of work in progress are experienced are traditionally synonymous with assembly and batch processing production environments (12). The large levels of work in progress are not usually accountable to value added process time, but accountable to the time wasted in the process when no value is added (14). Process time is defined as the time taken for work to be processed. The following various kinds of time make up the non value added times in production (12).

1. Set-up time - the time a machine requires for setting up.
2. Queue time - the time work waits to be processed while the resource is busy with something else.
3. Wait time - the time that work does not wait for a resource, but for another part to be assembled.
4. Idle time - unused time (ie none of the above).

Synchronous Manufacturing directly addresses reducing queue time, idle time and wait time by synchronizing the flow of products (12). Set-up time and process times are usually technological issues that often require engineering techniques for solutions.

Synchronous manufacturing has been described here in its most elementary and simplistic concepts which forms the backbone and basis of synchronous manufacturing. These concepts are much in line with the theory of constraints principals. The more complex and detailed concepts like time buffers, drum-buffer rope system, transfer batches etc, have not been described because it bears no relevance to this thesis.

Synchronous manufacturing recognizes that the standard cost system has severe limitations as a fundamental decision making technique (14). Therefore a new set of operational measures have been established to properly evaluate the effect of manufacturing actions on the productivity and profitability of the entire firm. These measures also play a key role in the development of procedures that result in good operating decisions. These measures accurately describe the key activities that govern a plants performance (12). These three operational measures used in synchronous manufacturing are:-

1. Throughput
2. Inventory
3. Operating expense

Synchronous Manufacturing can simply be summarized as a method of improving work flow by identifying capacity constrained resources, and controlling these resources to efficiently attain the global goal of the system. As a result synchronous manufacturing has identified a new set of operational measures that directly relates to the work flow of the system. Synchronous manufacturing hinges on the simple concepts of theory of constraints.

However, applying Synchronous Manufacturing techniques to a real world system is not as simple. Due to the myriad of interactions occurring between the resources in a system and the dynamic nature of the work flow in a system a complementary tool is necessary to assist the understanding and analysis of the dynamic complexity of a system. Systems Dynamics is an appropriate complementary tool to assist in applying the simple Synchronous Manufacturing concepts to a real world system.

## 2.7 SYSTEMS DYNAMICS

System Dynamics means exactly what its name implies. It is concerned with creating models or representations of real world systems of all kinds and studying their dynamics and behavior. The word "system" is used to denote "*any combination of real world elements which together have a purpose and which form a set which is of interest to the inquirer*" (25).

The purpose of applying Systems Dynamics is to facilitate understanding of the relationship between "*behavior of a system over time and its underlying structure*" (25). It is a methodological means to approaching complex real world systems in a holistic manner to improve and/or control problematic system behavior.

Management, without the knowledge of systems dynamics, can only manage by events. Events are incidents that occur on a day to day basis due to the natural variations occurring in a system. This fixation on focusing on events as a primary vehicle for management decisions is doomed for underperformance because "*primary threats of survival do not come from sudden events but from slow gradual processes - parable of the boiled frog*" (4). Systems dynamics focuses on patterns of behavior and an explanation for causes of these patterns of behavior.

Relationships between components are more important than the components themselves (4). The backbone of systems dynamics is the dynamic relationships between components of a system. Viewing separate components as having linear causal affect relationships predominates in the contemporary management culture. This can result in misplaced solutions to problems because "*cause and effect are not closely related in time or space*" (4). An effect of an intuitive decision based on experience may have far reaching consequences that may only surface some time after the decision is made. This delayed "ripple effect" may seem to have no correlation to its original cause due to the complex interrelationships existing in a system and the delayed reaction. The human mind is unable to predict and understand patterns of systems behavior due to the complexity of component relationships making systems dynamics an insidious decision making aid.

Systems dynamics comes into its own when trying to identify high leverage points. A high leverage point is an area in a system where "*a small change produces big results*" (4). These areas are usually least obvious and counter intuitive.

Systems dynamics strives to reveal the fundamental causes of system behavior "*so that the root treatment can be applied, rather than just treating the leaves - the symptoms*" (17). A symptom is the means that a problem expresses itself and may not necessarily be the problem. It is the symptom that is recognized by management. Opting for symptomatic solutions is enticing and often the wrong solution. If the fundamental cause is not treated the symptom will re-surface at a later stage, and sometimes even i n a different form. Symptomatic solutions may give short term benefits but long term dis-benefit. This phenomena occurs frequently because behavior grows better before it grows worse due to the effect of delay in feedback response (4). It is due to the effect of feedback and delay that systemic problems are difficult to recognize and even more difficult to solve without the aid of systems dynamics.

Systems dynamics is centered on the use of diagrams as a medium of transmitting mental models. Diagrams are an invaluable communication tool for systems dynamics because they are a less ambiguous and more condensed form of communication than a written description. There are two types of diagrams that can accurately represent all the relationships and activities within a system, namely process flow diagrams and information flow diagrams also known as causal loop diagrams.

The use of systems dynamics diagrams to structure and analyze ill defined situations can be considered as a "*free standing methodology, having much in common with the soft system methodologies recently developed as an alternative to science-based approaches (Checkland 1987, Ackoff 1978, Rosenhead 1989, Keys 1988)*" (25). It is evident that the correctness of the diagrams structure is essential for the systems analysis.

Process flow diagrams show the flow and change in level of a resource. The word resource is used in the widest possible sense and includes any tangible entity that can be measured to have an accumulated quantity in resource units. The rate at which these resources accumulate is determined by rate variables. Rate variables control flows into and out of stocks. The process flow structure of systems, as represented by resource flows made up of levels and rates, has to be directly relevant to the purpose of the model. A process flow diagram is shown below in *Diagram 2.4*.

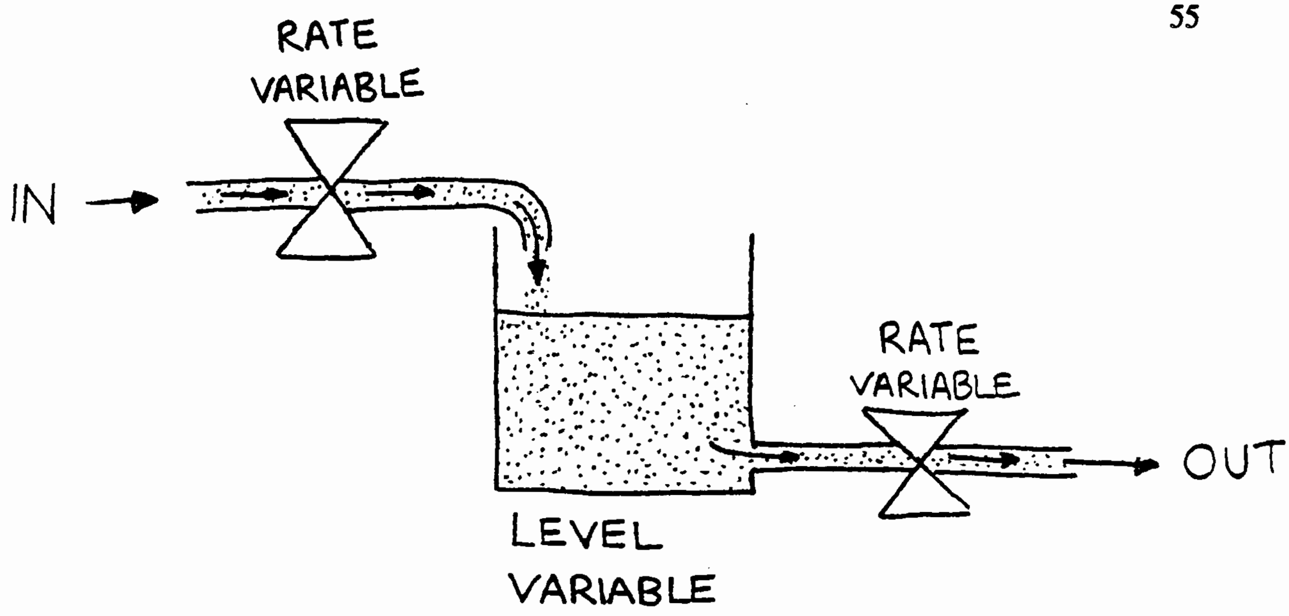



*DIAGRAM 2.4*
*PROCESS FLOW DIAGRAM*

The rate variables can be related directly to the concepts of synchronous manufacturing as capacity constrained resources. The queues behind the resources are represented as levels in Systems Dynamics. Systems Dynamics has an additional feature of including information flow that controls the work flow.

Information flow diagrams creates information structure to the model by representing the flow of information. Information flow will convert the open loop process flow diagrams into closed loop models. This occurs because causality is specified to the rate variables. Explained in simpler terms it means that rate variables need information to control the flow of resources into and out of levels. The information needed to control the rates can only depend on the level of a resource. The rate of inflow and outflow of any resource in the system can be determined by any function of any level variable in the system. By implication, two central characteristics of systems dynamics emanate, namely feedback and delay.

It is an underlying premise of the subject of Systems Dynamics that the feedback structure of a system is a "*direct determinant of its behavior over time*" (25). It is due to feedback and delay that systems are difficult to predict and understand mentally. Delay can be described as the time lapse in information flow or resource flow. Feedback can be described as the return of output of a system, which will therefore control that system by its results or effects.

The creation of computer simulations of dynamic models has always been a significant factor in improving systemic understanding. This is because there is a "*severe limit in the cognitive ability of the human brain to process multi-variate problems without the help of computers*" (25). The computer simulation package that will be used for simulation in this investigation is DYNAMO PLUS.

# 3. DISCUSSION

Systems thinking will be used as a backdrop for discussion of the applicability and reasons for using the approaches and techniques discussed in the literature review. The systemic compatibility of the approaches and techniques reviewed in the previous section will be explained in the discussion.

## 3.1 PERFORMANCE MEASUREMENTS

Performance measurements is probably the most fundamental approach for assistance in decision making. The choice of performance measurements is therefore critical because inappropriate performance measurements results in sub-optimal decisions. The importance of what to measure cannot be overemphasized. One of the major reasons of the downfall of many companies has been the inability to correctly identify what to measure (14). Eli Goldratt stresses the importance of measuring the appropriate variables by simply stating: "*Tell me how you will measure me, and I will tell you how I will behave. If you measure me in a illogical way then do not complain about illogical behavior*" (6).

A systems thinking perspective has to be adopted to determine appropriate variables that need to be measured, because the system being measured is ultimately attempting to achieve global optimization. Therefore the performance measurements should facilitate in attaining this global optimal performance.

Therefore the first step is to determine the global objective of the company, before it is possible to determine what to measure. It was previously stated in the introduction that the focus is on increasing timeous deliveries and reducing lead times to increase competitiveness and thus market share. In simpler terms it may be stated the goal is to maximize profits or "*to make more money*" (5). This is seen to be the goal for all companies according to E.M. Goldratt in his book "The Goal". Therefore the objective, or global goal, of the company is to "make more money" by increasing timeous deliveries and reducing lead time.

The second step is to determine the constraining factors to maximizing profits. A system constraint can be defined as "*anything that limits a system from achieving higher performance versus its goal*" (17). These constraints are constraints of the total system, and not departmental constraints isolating a part of the system. This systemic approach is necessary to achieve a global optimum and not local optima as is done with traditional costing performance measurements (14). These constraints have been recognized by synchronous manufacturing (12,14) and Goldratt (5,6,17) to be:-

1. Throughput
2. Inventory
3. Operating expense

These constraints are seen to be the three fundamental operational measurements. The definition of throughput considers only sales, and not units produced because finished goods inventory is a money consuming entity. Throughput is considered the most important factor to achieving financial performance (6). It is necessary to break throughput into different elements controlling it because throughput as an is controlled by many factors. Therefore the third step is to determine the global constraints of throughput.

Throughput can only be constrained by market demand or production capacity (14,17). All manufacturing organizations can be classified in one of two categories, namely production constrained and market constrained. Production constrained firms are those organizations that cannot currently produce as much as they can sell. Market constrained firms are those companies that can currently produce more products that they can sell. Puma Jersey is clearly a market constrained company in the prevailing market conditions. Therefore market demand is a constraint to the throughput, and therefore the financial performance for Puma Jersey.

The fourth step is to establish constraints to increasing market share, and therefore the throughput. These constraints are:-

1. Product cost
2. Product quality
3. Lead time
4. Delivery performance

These measurements should be the fundamental performance measurements that a company can effectively measure to have the biggest impact on financial performance for a market constrained company. These measurements are a far cry from traditional cost measurements used by many companies today. Traditionally too much emphasis has been placed on measuring operating expense (6).

The constraints of throughput, inventory and operating expense are recognized as the set of operational measures that will properly evaluate the effect of manufacturing actions on the profitability of the entire firm. It has been established that throughput is the most important measurement. It must be noted that this includes the operational measurement of inventory because lead time, a measurement of throughput, is directly related to inventory of semi finished goods. It can be seen that the performance measurements are consistent with synchronous manufacturing principals, and systems thinking. Operating expense and raw material inventory are considered as a secondary measurements (6).

The four performance measurements established are measurements that will increase the global performance of a system because they measure the global constraints of the system. The systemic nature of the necessity of performance measurement, feedback, and nature of performance measurement is shown in *Diagram 3.1*. If the performance measurements do not measure a global performance that will lead to increased profits, a strong negative feedback loop will exist that can lead to a decrease in performance. However, if performance measurements are measured that will result in increased profits, a positive feedback loop will exist that will reinforce increased performance.

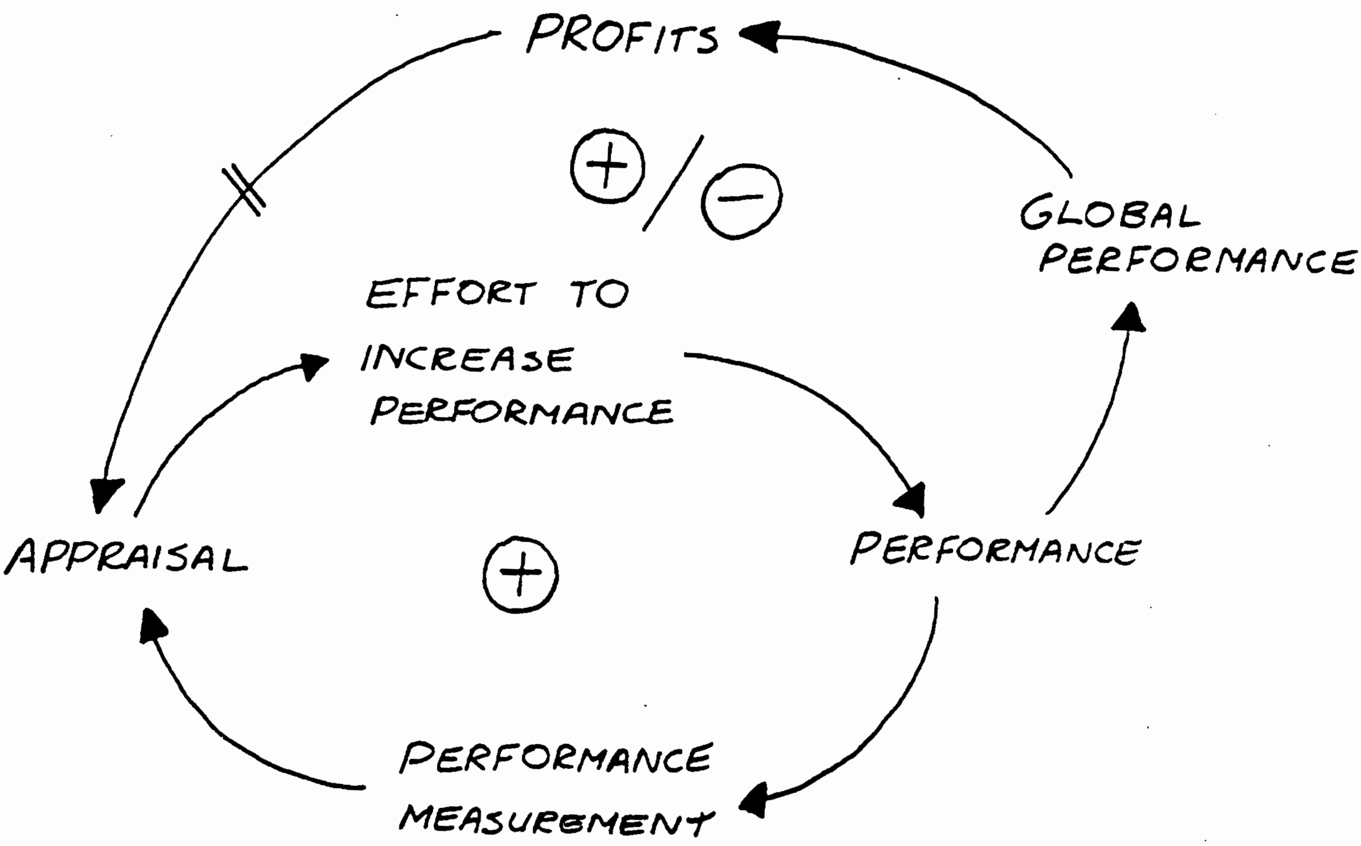



*DIAGRAM 3.1*
*NECESSITY FOR PERFORMANCE MEASUREMENTS*

The concept of performance measurements to continuously monitor performance is an absolutely vital element to achieving goals. With measurements one can manage by facts, and not by perception as is done in many companies presently. Management is unable to detect trends and deviations of performance without performance measurements, and can therefore not react in a way to manage the situation.

Performance measurements are also of vital importance as a motivator, because it is only through these measurements that the relevant people can be appraised and judged. The human performance system discussed in the literature review is a systemic method of viewing human behavioral science principals because it considers all the variables necessary for motivation, and therefore performance. CEDAC is a technique used to satisfy the requirements of the human performance system. Traditional management has singled out skills and knowledge in isolation as the cause for employee under performance. But the root cause lies within their own inability to view the human performance system in a holistic perspective, and from that perspective to evaluate the constraining factor to increased performance. This illustrates how traditional management is held captive by the confines of mechanistic thinking (ie non-systems thinking).

## 3.2 <u>CEDAC</u>

Once the correct performance measurements have been identified, the measurements must be structured and organized in such a way as to communicate the reality of a situation to the decision maker. Although the performance measurements may be correct, a considerable amount of information can be lost in the communication process which can lead to sub-optimal decision making. CEDAC is a technique used to communicate performance measurements in an intelligible systemic way to aid the decision making process. CEDAC is a systemic method of communicating performance measurements because the measurements are not viewed in isolation of each other, but are viewed as a complete system, in time and space, with interacting components.

CEDAC facilitates the learning process required in a organization. The most powerful learning comes from direct experience. "*We learnt eating, walking, communicating through direct trial and error - through taking an action and seeing the consequences of our actions, and then taking a new and different action. But what happens when we no longer observe the consequences of our actions ? What happens if the primary consequences of our actions are in the distant future or in a distant part of a larger system within which we operate ? We each have a "learning horizon", a breadth of vision in time and space within which we measure our effectiveness*" (4).

When our actions have consequences beyond our learning horizon, it becomes impossible to learn from direct experience. Herein lies the core dilemma that confronts an organizations ability to learn (4). CEDAC has the ability to broaden the learning horizon of individuals and the organization as a whole because system wide consequences not related in time or space can be monitored using CEDAC. CEDAC does not isolate the performance measurements of a selected time frame, but takes a holistic time perspective by displaying performance measurements for any time range required. Therefore it can be seen that CEDAC is consistent with systems thinking principals.

CEDAC is also a technique that will address the basic behavioral science motivation principals to facilitate the improvement process because CEDAC closes the loop in the Human Performance System, sets clear measurable targets and facilitates shop floor participation. CEDAC closes the human performance loop because it functions as a feedback mechanism of performance measurements.

The CEDAC system was chosen for the following reasons:-

1. Holistic view to making decisions because system is not viewed in isolation of other important factors.
2. Monitor impact of decisions because any behavior can be related back to the implemented solution.
3. Global view of objectives.
4. Clear measurable targets displayed.

5. Communicates performance measurements to everyone involved.
6. Clear feedback to shop floor.
7. Recognition of involvement and improvement.
8. Breaks departmental barriers because everyone is aiming to achieve the same objective.
9. Facilitates a team approach to solving problems because all people are involved in decision making and problem solving.
10. Eliminates manager - operator barriers because everyone is striving towards the same goal.
11. System that is flexible to change.
12. System that is simple and can be understood by everyone involved.

Although CEDAC was originally developed for quality improvement, it also has applicability to lead time and delivery performance improvements. CEDAC was found to particularly suitable for the environment at Puma Jersey because Puma Jersey has historically had no shop floor involvement to problem solving and decision making. No feedback on performance has been given in the past to the shop floor operators and foremen, because no performance measurements were available. No clear performance objectives were defined to shop floor employees previously at Puma Jersey. The worker dissatisfaction and resulting underperformance can mainly be attributed to the non existence of these three basic behavioral science motivation principals, namely shop floor involvement, performance feedback and setting performance objectives. These motivation factors are also mentioned in the Deming 14 point plan.

## 3.3 SYNCHRONOUS MANUFACTURING

Once the correct performance measurements have been identified and these performance measurements have been communicated in an effective way, an increase in performance will result. However only a limited increase in performance can be expected from these techniques. To attain further improvements an approach must be implemented that will physically improve the process. This approach has to be consistent with the set of systemic performance measurements discussed in *Section 3.1.*

The Synchronous manufacturing philosophy was found to fulfil these requirements and be compatible with the performance measurements discussed. Synchronous manufacturing is a philosophy that will improve performance relating to time by physically improving the process. Synchronous manufacturing is an all-encompassing management philosophy that includes a consistent set of operational measurements, and techniques where every action is evaluated in terms of the common global goal of the system. It helps management focus on the critical issues that impact on the common global goal.

Synchronous manufacturing is consistent with the systems thinking methodology to reduce lead times because it recognizes the fact that the entire system works together toward the accomplishment of a common global goal and concentrates on the elements in the system that effect the global goal. Synchronous Manufacturing also realizes the importance of appropriate operational performance measures as a prerequisite for increased performance and is aware that traditional costing performance measurements are ineffective.

Synchronous manufacturing also looks for high leverage points which is typical of systemic thinking. There are weak spots in any system that control the systems behavior and determine its response to change. Synchronous manufacturing philosophy recognizes these points as bottlenecks. These bottlenecks are focal points for managerial attention because it effects the entire systems behavior.

Systems thinking is also evident in synchronous manufacturing in that it is realized that the parts in the system are interconnected. The immediate effect of an action will have other consequences that will ripple through the system. As one bottleneck is relieved another bottleneck is created elsewhere in the system therefore realizing that every solution creates new problems, so there are no final answers (15).

Synchronous manufacturing recognizes that he manufacturing lead time for any order is highly dependant upon a number of variables. But the critical ingredient that establishes a general level of manufacturing lead time within any operation is the "*degree to which the material flows are synchronized. In general the greater the level of synchronization, the lower the level of work in progress inventory, and as a result the shorter the manufacturing lead time*" (14).

Synchronous manufacturing was found to be applicable to the production environment at Puma Jersey because excessive levels of work in progress are evident in the typically batch type operation. 85% of the lead time at Puma Jersey can be accounted to queue time (see *Section 5.1*). Synchronous manufacturing directly addresses reducing queue time and wait time by synchronizing the flow of products. Set-up time and process time only account for 15% of the total time utilized at Puma Jersey. Therefore the greatest benefits will be gained in reducing WIP levels, and therefore lead time, by reducing queue time and wait time. Reducing these times requires a management philosophy that does not require capital expenditure while reducing set-up times and process times are technological issues and are usually very costly to reduce.

From this point of view it can be seen that Synchronous manufacturing is in line with the objective of reducing lead time through continuous improvement using systems thinking as a vehicle to achieve this. Reducing lead times will automatically enhance delivery performance because the forecasting period will be reduced and thereby reducing variability, the main culprit for late deliveries. However, the nature of work flow at Puma Jersey is of a complex nature and can not be analyzed manually and therefore requires a complementary tool. Systems dynamics is a complementary tool that is compatible with synchronous manufacturing.

## 3.4 SYSTEMS DYNAMICS

Unfortunately many companies do not meet performance expectations because the tools and methods used to achieve these goals are inadequate for our present day environment of complexity and rapid change. Increased performance often boils down to setting goals arbitrarily and then taking actions based on intuition and experience to achieve these goals (17). All our inventions, decisions and convictions are only based on intuition and the communication of this to ourselves and others is based on logic (17). Increasing performance by means of intuition and experience, however, yields variable results. Some companies are very successful while the performance of others is mediocre or poor. Company performance changes over time in response to changes in the business environment so a successful plan in one environment becomes unsuccessful in another.

Such variable performance is a consequence of complex systems. The myriad of interactions among functional areas within a company, and between a company and its environment prevent effective performance based solely on intuition. The human mind is incapable of evaluating the implications of more than a few such interactions.(25) Systems dynamics is a tool that enables all these complex interactions to be evaluated. Systems dynamics facilitates gaining insight into a systems structure because an understanding is developed into the forces driving the system.

The use of systems dynamics as a decision making aid does not necessarily imply that absolute solutions are derived from analyzing structures, but insight and understanding of the system, and problems relating to it, is acquired. This structural understanding aids the decision making process.

The cornerstone of systems dynamics is the systems thinking methodology. This stems from the fact that all the subsystems of the system in question, and the relationships between the subsystems forms the framework that systems dynamics functions on. Systems thinking is congruent with the systems dynamic approach because parts of a system are not viewed in isolation of each other, neither in time or space. Systems dynamics is simply a vehicle to facilitate the implementation of systems thinking.

Systems dynamics is compatible with synchronous manufacturing because it models and simulates the complex behavior of work flow through a system. It is not always easy to identify bottlenecks in a rapidly changing dynamic work flow environment where scores of interactions are occurring simultaneously. Systems dynamics enables bottlenecks and leverage points to be identified with relative ease. horizon.

However, systems dynamics can be a dangerous tool if used incorrectly. If inappropriate variables are used to measure the effectiveness or behavior of a system sub-optimal decisions will result. Therefore the importance of appropriate performance variables is evident again. Systems dynamics displays many properties that the CEDAC system displays. They both view the behavior of a system resulting from the components of the system. Systems dynamics and CEDAC also both realize the importance of viewing systems behavior over a time horizon. Therefore it can be seen that systems dynamics is a complementary tool to CEDAC that requires the proper performance measurements to be monitored.

# 4. ESTABLISHING PUMA JERSEYS COMPETITIVENESS

It is useful to first establish Puma Jerseys competitiveness before any improvements in lead times and delivery performance are attempted. To determine the competitiveness of Puma Jersey the following three variables must be established:-

1. Puma Jersey's performance before improvements are implemented.
2. The competitors performance.
3. The performance required by the customers.

Performance is used here in a generic sense to describe lead time and delivery performance. It is necessary to establish these three variables in order to determine how competitive Puma Jersey is before any improvements are implemented. The concept of attaining a competitive advantage hinges on the premise that the competitive variables are superior to those of the competitors. Therefore it is necessary to acquire knowledge about the competitors performance to ascertain the extent of performance improvements necessary to gain a competitive advantage. There is no purpose in attaining competitive variables that surpass the customers needs and eclipse that of rivaling competition. The implementation of expensive systems to attain these overly superior competitive variables may be counter productive.

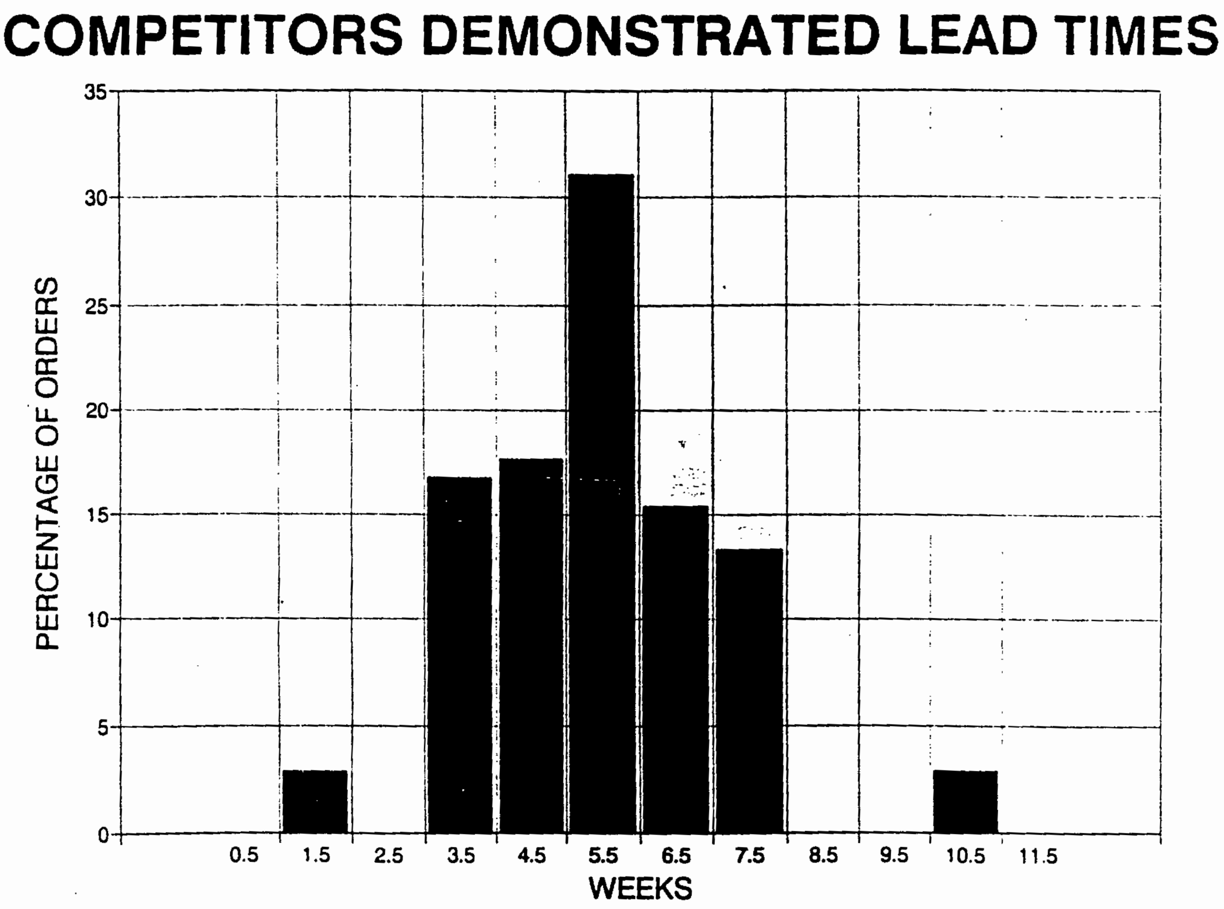
Determining the competitors competitive variables is commonly known as "benchmarking", and is used extensively by Japanese companies. Determining the competitors lead time and delivery performance, and the markets required lead time and delivery performance for the local textile industry has not been established before. Therefore no historical data could be used and a survey had to be conducted on the demands and perceptions of textile manufacturers lead times and delivery performance.

Because this survey acts as a benchmarker for the required performance at Puma Jersey, only the customers and potential customers of Puma Jersey were approached for the survey. The 32 largest customers of the knitted fabric textile industry were approached to participate in the survey. The companies that were approached are responsible for approximately 98% of the sales volume at Puma Jersey. The customers only consisted of clothing manufacturers. A response rate of 70% was achieved for this survey.

The questionnaire for this survey was validated to be statistically and psychologically correct by the University of Cape Town. A copy of the survey may be found in *Appendix 4.1*. The results of the survey can be found in *Appendix 4.2*. The results were obtained by weighting the respondents results according to the average monthly demand of knitted fabric, and then accumulating these respective results to give an average. The results are displayed graphically and are explained in the sections following.

## 4.1 LEAD TIME COMPETITIVENESS

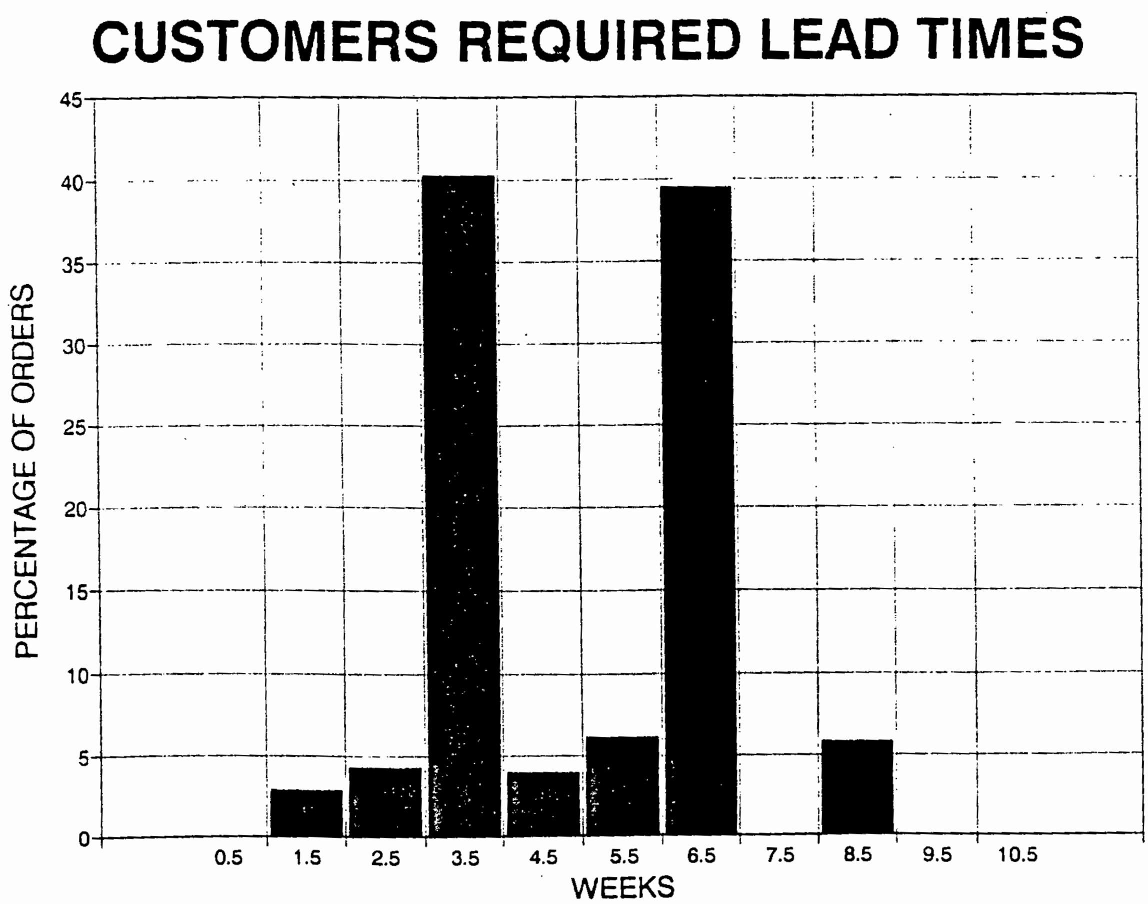
The lead times demonstrated by the manufacturers of piece dyed knitted fabric is shown in *Graph 4.1*. Lead time is considered as the time taken from order conception to complete delivery of the order. The competitors demonstrate an average lead time of 5.4 weeks.




*GRAPH 4.1*

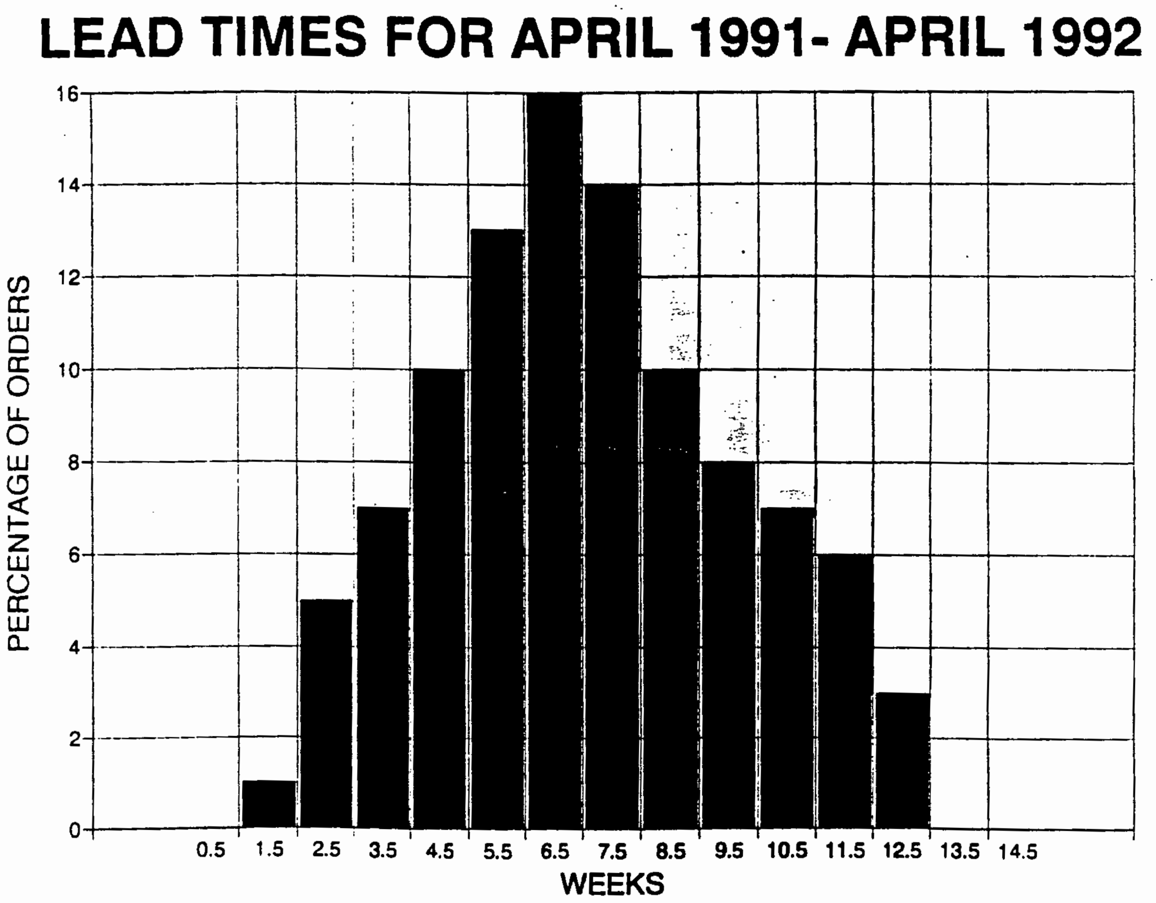
The best local suppliers demonstrate lead times of 3 to 4 weeks. The average textile manufacturer delivers within 6 to 7 weeks, while the worst local suppliers have lead times of 7 to 8 weeks (see *Appendix 4.2 question A2*). Compared to overseas suppliers, with the best lead times from 8 to 10 weeks, the local market is under no visible immediate threat of losing competitive advantage in lead times from foreign suppliers (see *Appendix 4.2 question A3*).

The lead times required by the clothing manufacturers, ie the customers, are shown in *Graph 4.2*. The average lead time required by the market is 5.0 weeks.



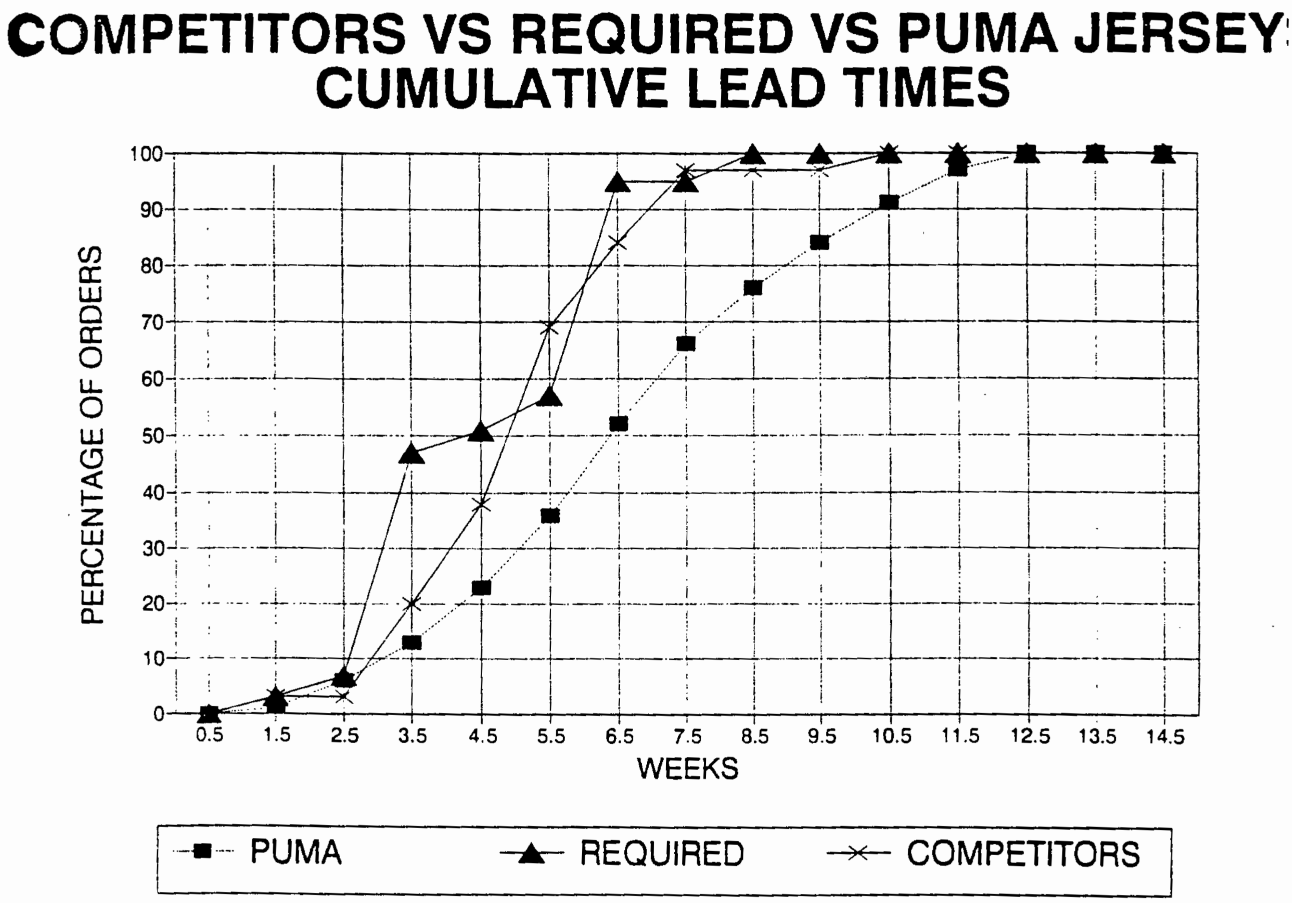

*GRAPH 4.2*

A sample of 160 orders was taken to establish the lead times at Puma Jersey. The lead times demonstrated by Puma Jersey from April 1991 to April 1992 is shown in *Graph 4.3*. It is necessary to sample from a years population to omit the seasonal fluctuations. The average lead time demonstrated by Puma Jersey is 7.0 weeks, which is far greater than the average competitors demonstrated lead time and the customers required lead time. This excessively large lead time places Puma Jersey in the category of average to worst performers of lead times in the local market.



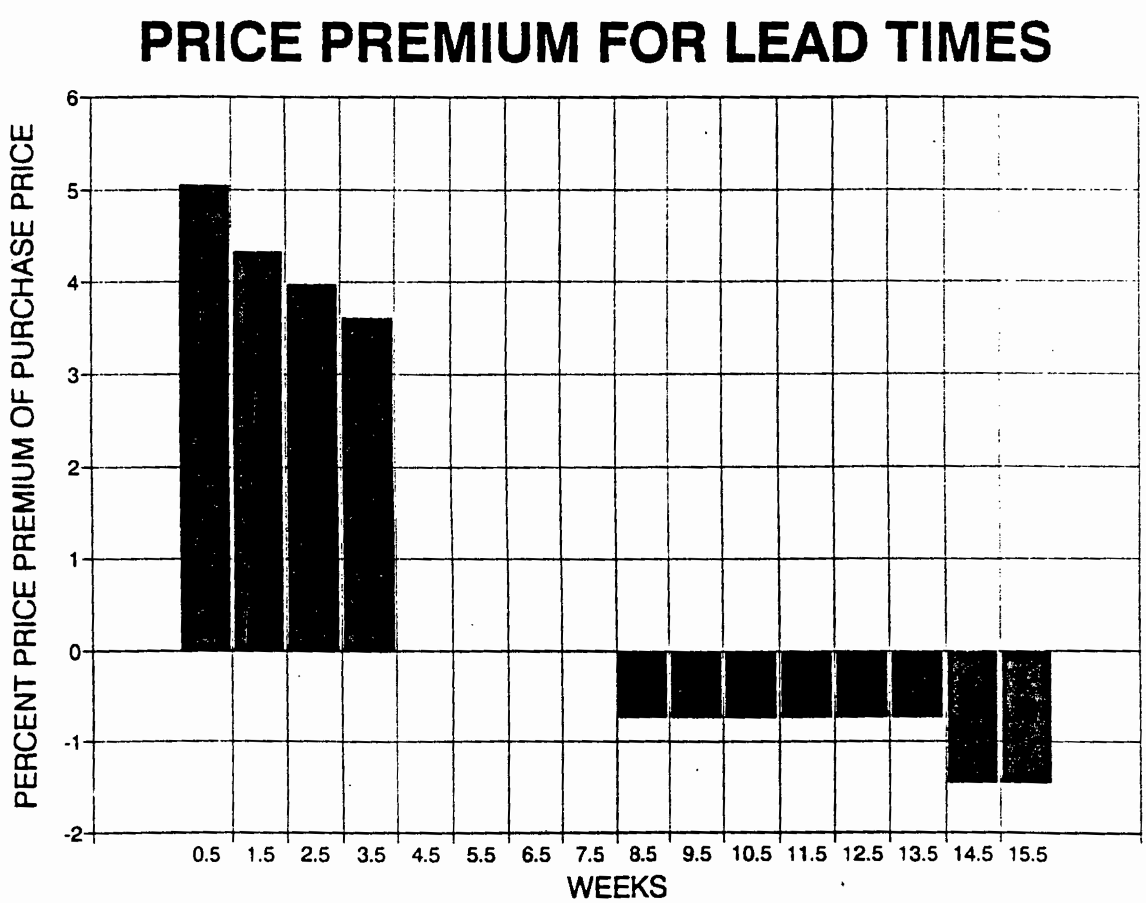

*GRAPH 4.3*

It is difficult to compare and give comment on these separate statistics when viewed in isolation of each other. *Graph 4.4* shows the accumulated percentage of orders delivered within the indicated lead times demonstrated by the competitors, by Puma Jersey from April 1991 to April 1992, and the customers required lead time. A cumulative percentage indicates the total percent of orders delivered before a specified lead time.




*GRAPH 4.4*

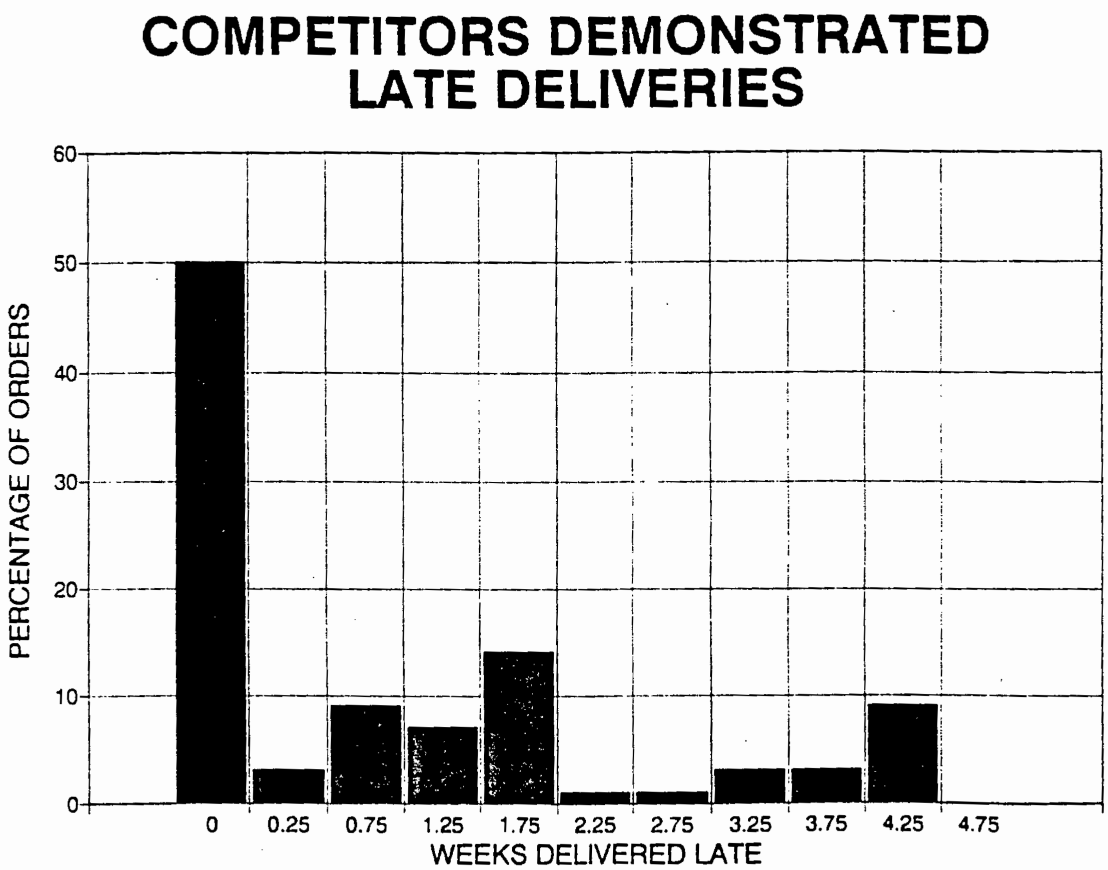
It is evident from this graph that Puma Jerseys performance is inferior to that of its rivaling competitors. It can also be seen that the competitors are performing below the customers required performance. Therefore the necessity for improved lead times at Puma Jersey to gain a competitive advantage over the competitors and to increase customer satisfaction is self evident. *Graph 4.5* below shows the price premium in percentage increase on the present purchase price that the customers are willing to pay for the lead times. With this statistic the customers have quantified the importance of short lead times. This result is significant because it illustrates the direct profitability that can be achieved by reducing lead times.




*GRAPH 4.5*

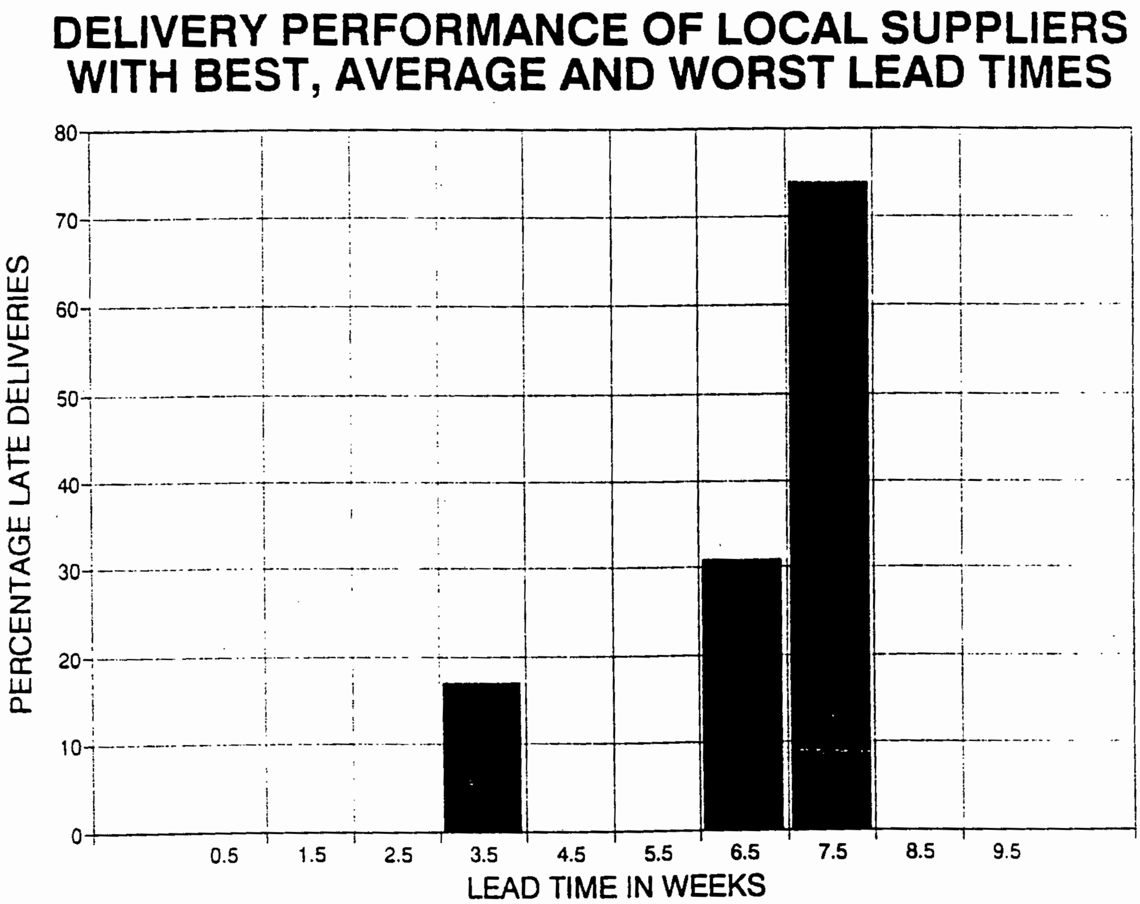
## 4.2 DELIVERY PERFORMANCE

The delivery performance demonstrated by the manufacturers of piece dyed knitted fabric is shown in *Graph 4.6*. A late delivery occurs when the finished goods are reieved by the customer after the established delivery date. The competitors of Puma Jersey have an average of 50% on time deliveries, and the late deliveries are delivered late by an average of 2.1 weeks.



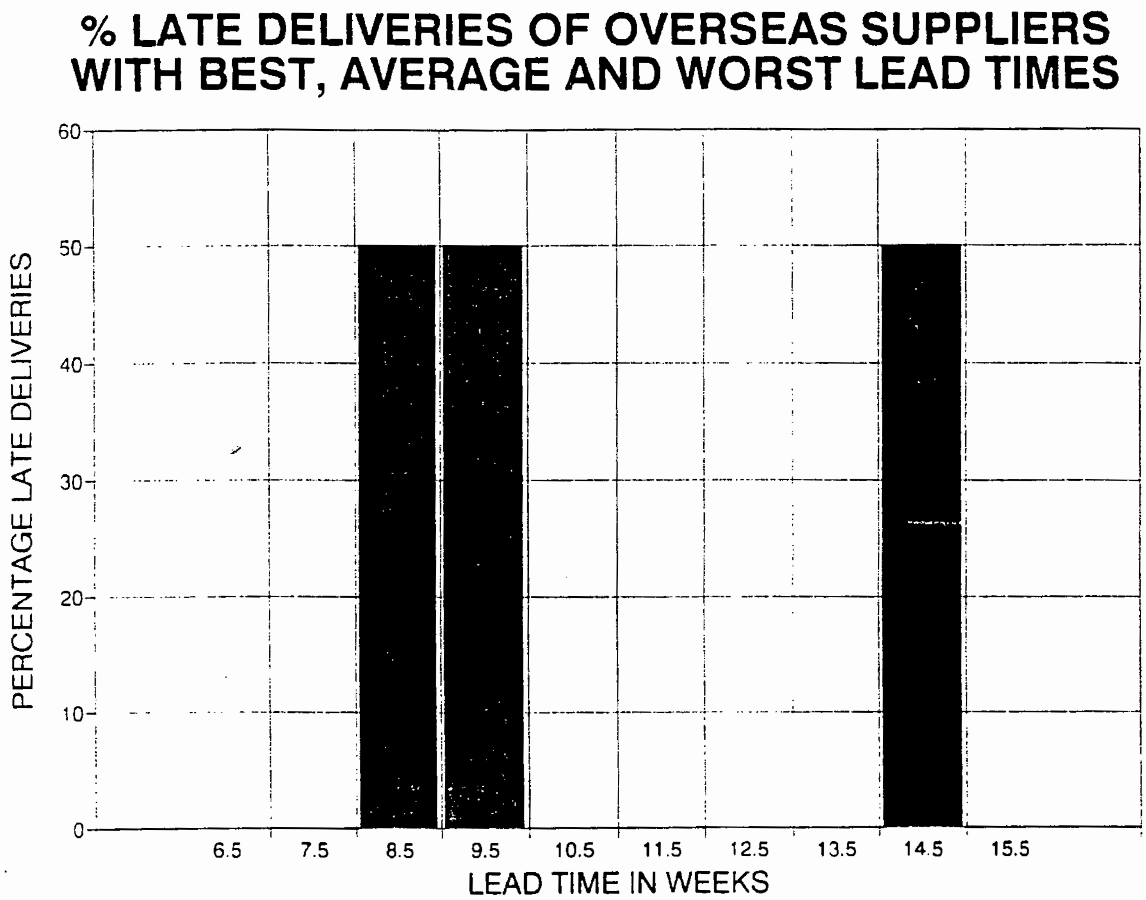

*GRAPH 4.6*

The local competitors with the best lead times demonstrate the best delivery performance of 17% late deliveries, whilst the suppliers with the longest lead times have the poorest delivery performance of 74% late deliveries. This trend is shown in *Graph 4.7* below and substantiates the causal effect relationships explained in *Diagram 2.1.*



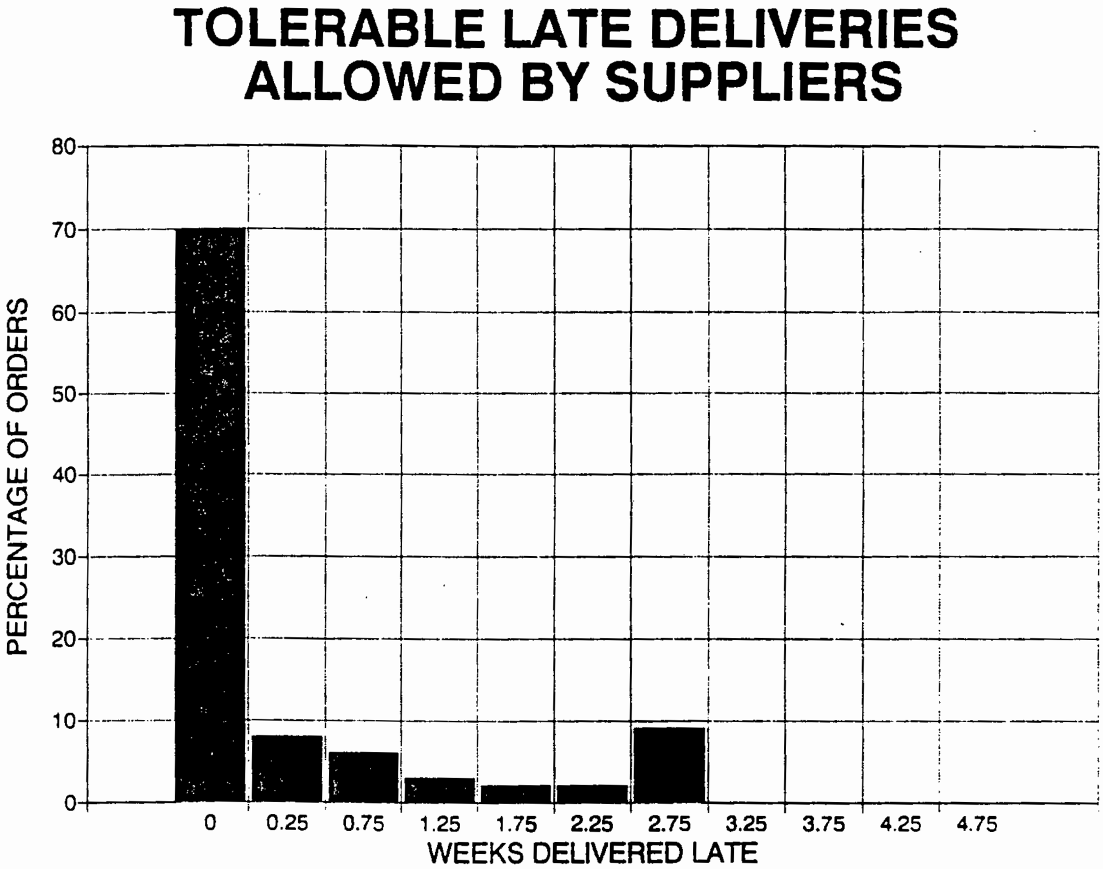

*GRAPH 4.7*

However, lead times do not effect the delivery performance of overseas suppliers because the delivery performance and lead times are dependant on transportation. The average delivery performance of overseas suppliers experienced in South Africa is 50% on time deliveries. This is shown in *Graph 4.8* below.



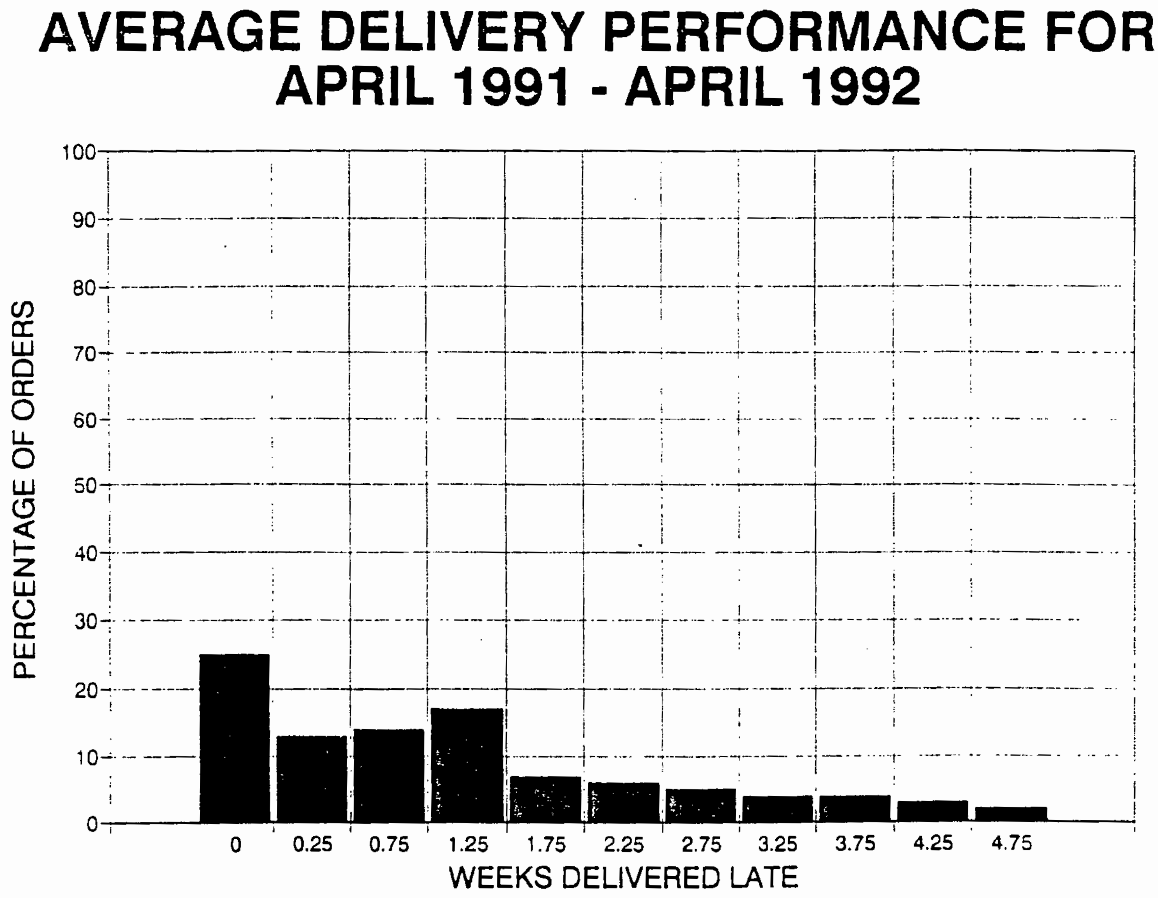

*GRAPH 4.8*

The tolerable late deliveries allowed by the customers is shown in *Graph 4.9*. This graph shows that the customers require 70% on time deliveries and that an acceptable late delivery may be on average 1.2 weeks late.



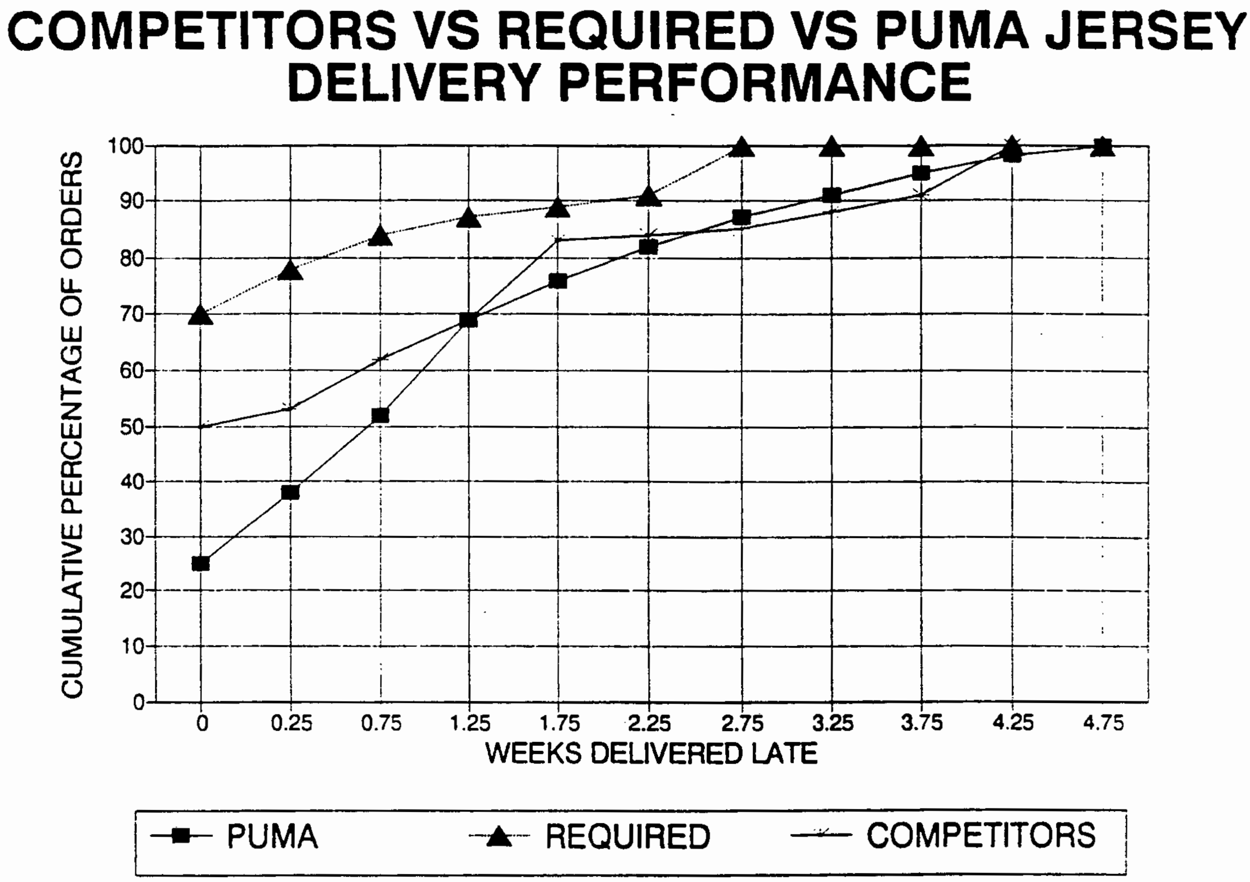

*GRAPH 4.9*

A sample of 160 orders was taken to establish the delivery performance at Puma Jersey. The delivery performance demonstrated by Puma Jersey from April 1991 to April 1992 is shown in *Graph 4.10*. It is necessary to sample from a years population to omit the seasonal fluctuations. The late deliveries were on average 1.5 weeks late, and an average of 25% on time deliveries were attained in this time period.




*GRAPH 4.10*

These separate statistics are compared against each other by plotting the accumulated percentage of late deliveries together. *Graph 4.11* shows the accumulated percentage of the competitors demonstrated delivery performance, the customers tolerable late deliveries allowed and Puma Jersey's delivery performance as explained in the previous graphs.




*GRAPH 4.11*

It is evident from this graph that Puma Jerseys performance is inferior to that of its rivaling competitors. Both Puma Jersey and its competitors are performing at below the acceptable delivery performance the customers require. The performance in the 0.75 to 4.75 range is however the most critical because it causes a considerable inconvenience and is unacceptable to the customer, as can be seen from questions *B4* and *B5* in *Appendix 4.2*. It is of vital importance to attain increased performance in the 0.75 to 4.75 week range.

# 5. DETERMINING AREAS FOR IMPROVEMENT AT PUMA JERSEY

This section will discuss the methods used to determine areas for improvement in lead times and delivery performance. It must be noted that all the areas in a manufacturing system are areas for potential improvement, and an endeavor must be made to continuously improve all areas. No matter how small the improvement is, the accumulation of these small improvements are vital in attaining the ultimate global goal of achieving excellence. However, only the areas that will attain the biggest and most significant improvements, and that are the easiest to implement will be discussed due to the time constraint of the thesis.

## 5.1 METHODS USED TO IDENTIFY AREAS OF IMPROVEMENT IN LEAD TIMES

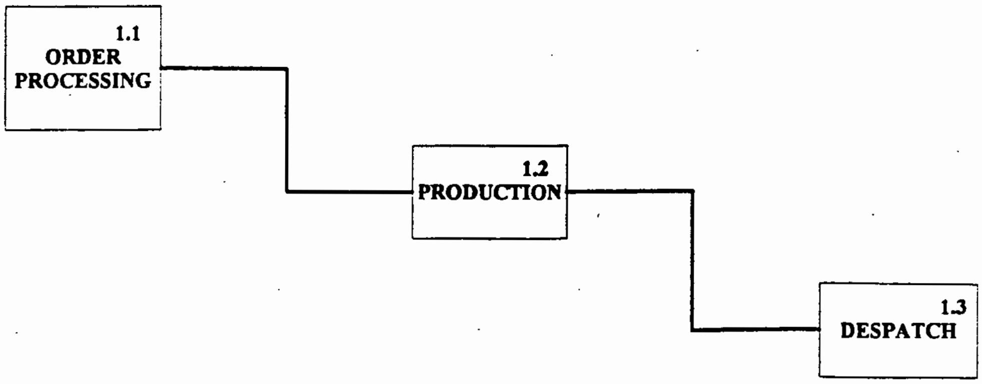
Three methods were used to identify areas for improvement in lead time. The results of these methods were attained by performing comprehensive time-motion studies. These methods had not been used at Puma Jersey before.

### 5.1.1 PROCESS FLOW ANALYSIS

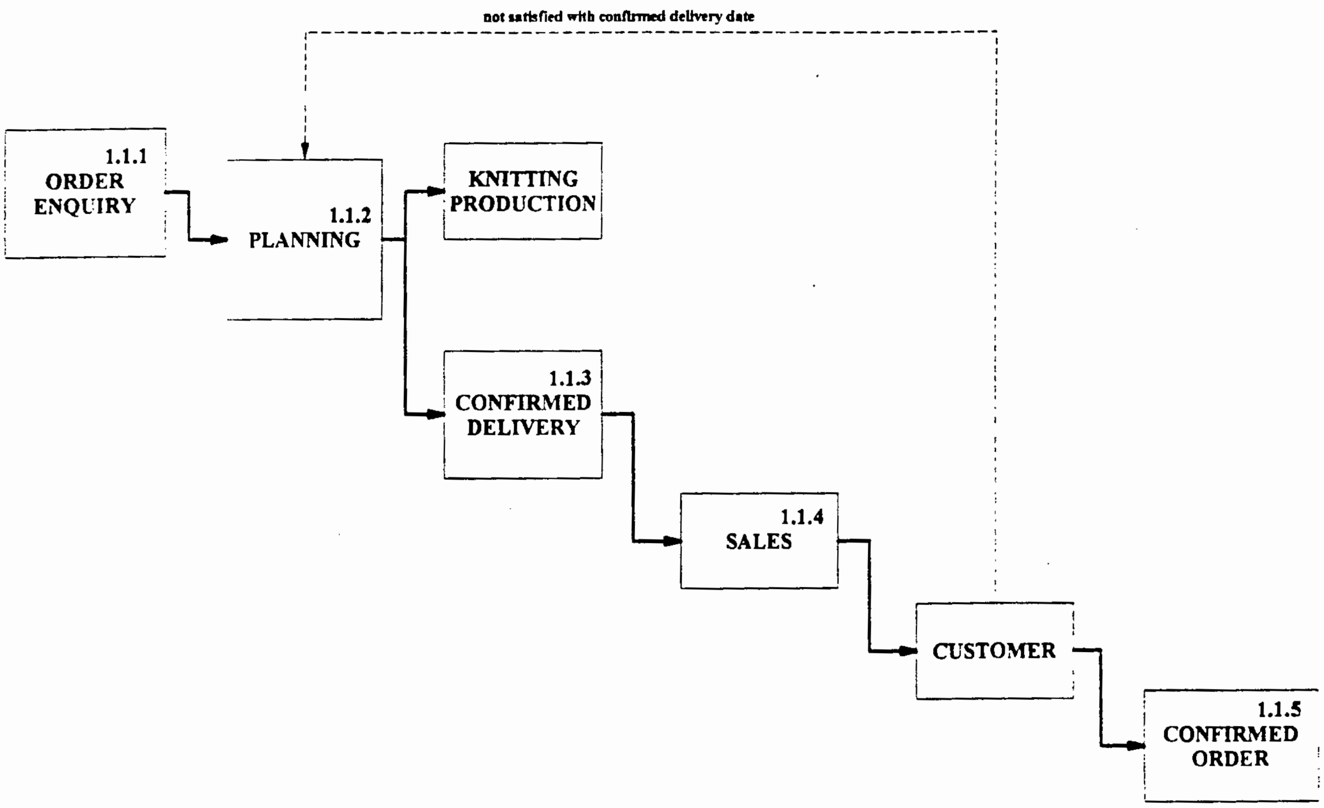
The process flow analysis is probably the most familiar recording procedures in method study. The process flow analysis only shows the main parts of the process. It is a simple record of important constructive and essential steps in a process, omitting all the ancillary steps in the process that only occur by exception. The process flow analysis can identify processes that are duplicated, unnecessary, processes that run in parallel and processes that can be combined.

The process flow analysis done for the production of piece dyed knitted fabric at Puma Jersey from order conception to order delivery are shown in the *Diagram 5.1* below.

*1. BULK PIECE DYES*



<u>*1.1 ORDER PROCESSING FOR BULK PIECE DYES*</u>




<u>*1.2 BULK PRODUCTION FOR PIECE DYES*</u>

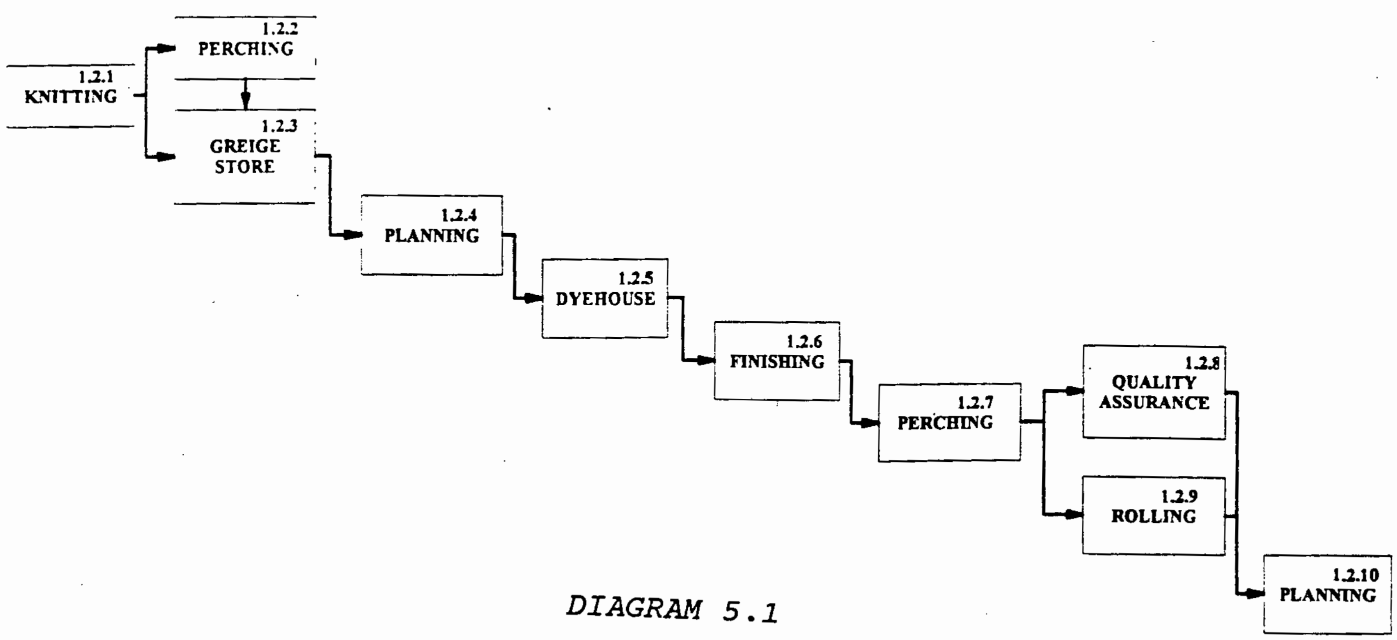



DIAGRAM 5.1

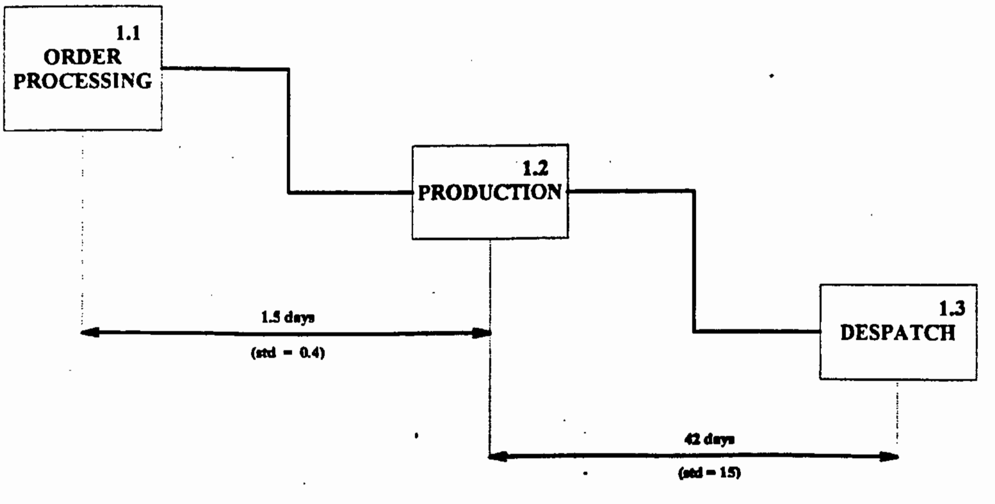
<u>PROCESS FLOW ANALYSIS FOR PUMA JERSEY</u>

## 5.1.2 CYCLE TIMES

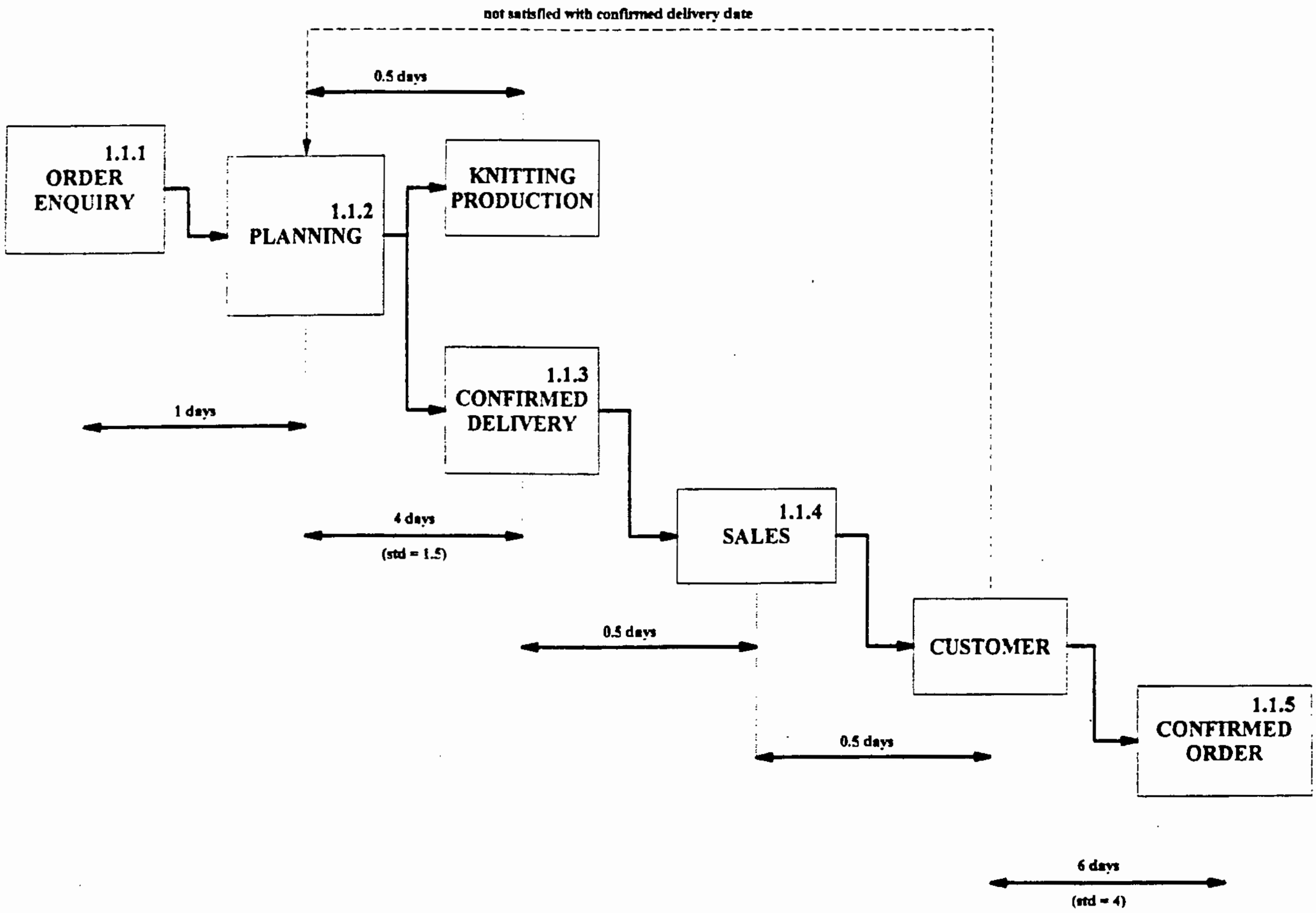
The next important step is to establish the time taken for each of the processes described in the process flow analysis. Cycle times can identify the most critical processes necessary for improvement of lead times. Establishing cycle times is a time consuming exercise because it requires the person doing the investigation to physically time a relative large sample for reliable results. The study for the purposes of this investigation used a sample size of 120 to attain an accuracy of 96%.

The findings discussed below are the findings of the time motion study before any improvements were implemented. The average lead time for order enquiry to complete delivery of the finished goods is 7 weeks and is shown in *Diagram 5.2* below. The average cycle times for all the operations involved in producing piece dyed finished goods is shown in *Diagram 5.2*. The standard deviation for the cycle times are indicated in brackets.

***1. BULK PIECE DYES***



## 1.1 ORDER PROCESSING FOR BULK PIECE DYES




## 1.2 BULK PRODUCTION FOR PIECE DYES

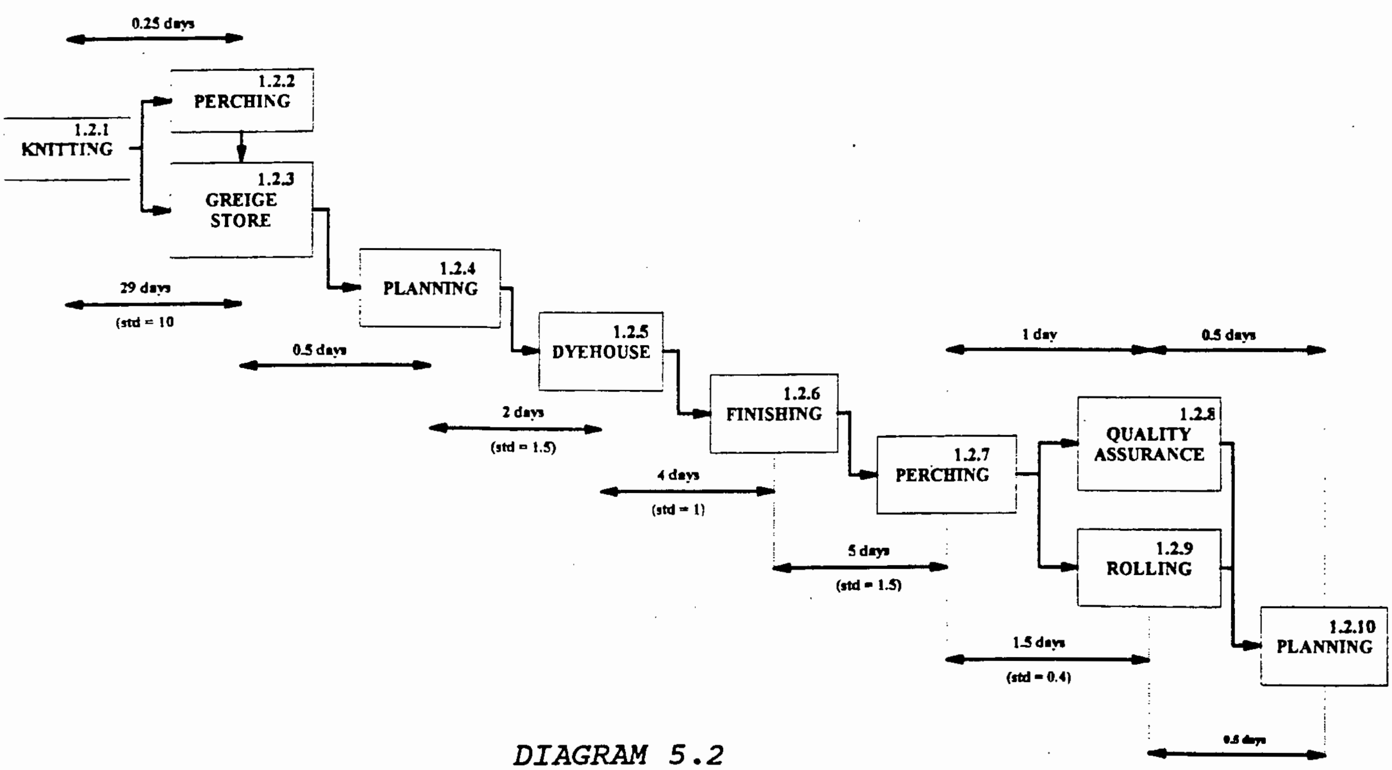



DIAGRAM 5.2

CYCLE TIMES FOR OPERATIONS AT PUMA JERSEY

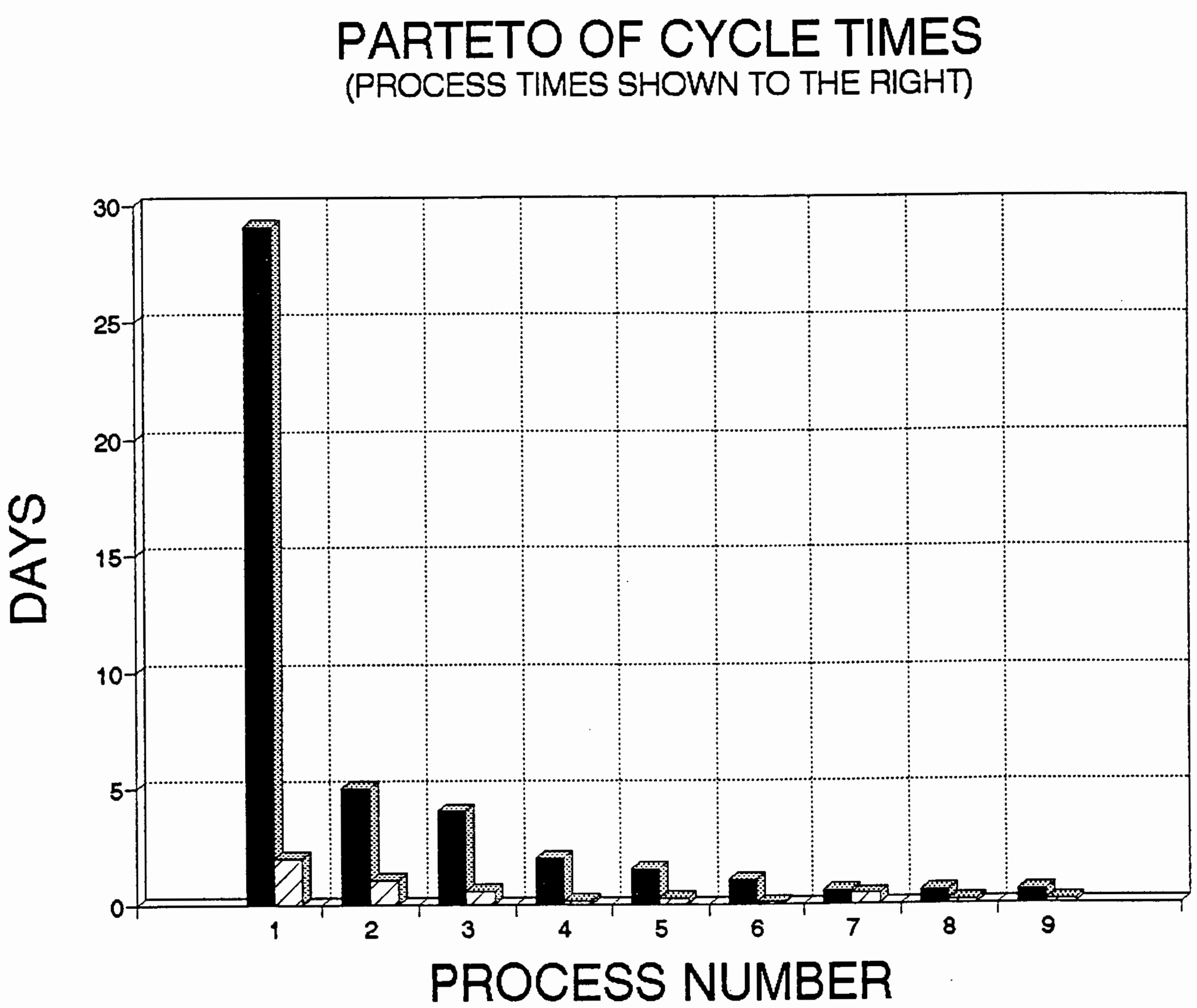
### 5.1.3 QUEUE TIME

Queue time is the time that work waits before it can be processed. Queue time and percentage queue time are simply calculated as follows:-

*QUEUE TIME = CYCLE TIME - PROCESSING TIME*

*PERCENTAGE QUEUE TIME = (QUEUE TIME / CYCLE TIME) * 100*

Percentage queue time indicates the time that work in progress has no value added to it. Percentage queue time is an important measurement because it indicates areas where relatively easily implemented improvements can be made to reduce cycle times. Queue time can be reduced by implementing simple work flow optimizing systems to reduce the work in progress, and does not require expensive technical changes to machinery. A Pareto chart of cycle times with the demonstrated queue time for each production process is shown in *Diagram 5.3*. The table shows the percentage queue times for each production process.




| PROCESS NUMBER | PROCESS DESCRIP'N | CYCLE TIME | PROCES TIME | QUEUE TIME | % QUEUE TIME |
|---|---|---|---|---|---|
| 1 | KNITTING | 29 | 4 | 25 | 86 |
| 2 | FINISHING | 5 | 1 | 4 | 80 |
| 3 | DYEING | 4 | 0.5 | 3.5 | 88 |
| 4 | PLANNING | 2 | 0.1 | 1.9 | 95 |
| 5 | PERCHING | 1.5 | 0.2 | 1.3 | 87 |
| 6 | ORD ENQ | 1 | 0.05 | 0.95 | 95 |
| 7 | QUALITY | 0.5 | 0.4 | 0.1 | 20 |
| 8 | ROLLING | 0.5 | 0.1 | 0.4 | 80 |
| 9 | PLANNING | 0.5 | 0.1 | 0.4 | 80 |
| | TOTAL | 44 | 6.45 | 37.55 | 85 |

*DIAGRAM 5.3*

*PARETO OF CYCLE TIMES WITH CORRESPONDING QUEUE TIME*

## 5.2 METHODS USED TO IDENTIFY AREAS OF IMPROVEMENT IN LATE DELIVERIES

Before areas for improvement can be determined it must first be established what a late delivery is, and what will constitute a late delivery. Late deliveries are finished goods that are received by the customer after the confirmed delivery date due to reasons accountable to Puma Jersey. The method used to determine areas for improvement in delivery performance is a simple cause and effect analysis, and a pareto of the frequency of these causes established in the cause and effect analysis. These methods have not been applied before at Puma Jersey.

### 5.2.1 CAUSE AND EFFECT ANALYSIS

There were many theories for why late deliveries occurred but no scientific or methodological procedure has been used to establish the exact causes. The cause and effect analysis was seen to be the most suitable method to determine the causes. All the relevant people were asked to participate in determining the reasons for late deliveries. After this brainstorming session the reasons were listed in a cause and effect diagram, where the effect is a late delivery. The basic cause and effect, or Ishikawa, diagram without the detail is shown below in *Diagram 5.4*.

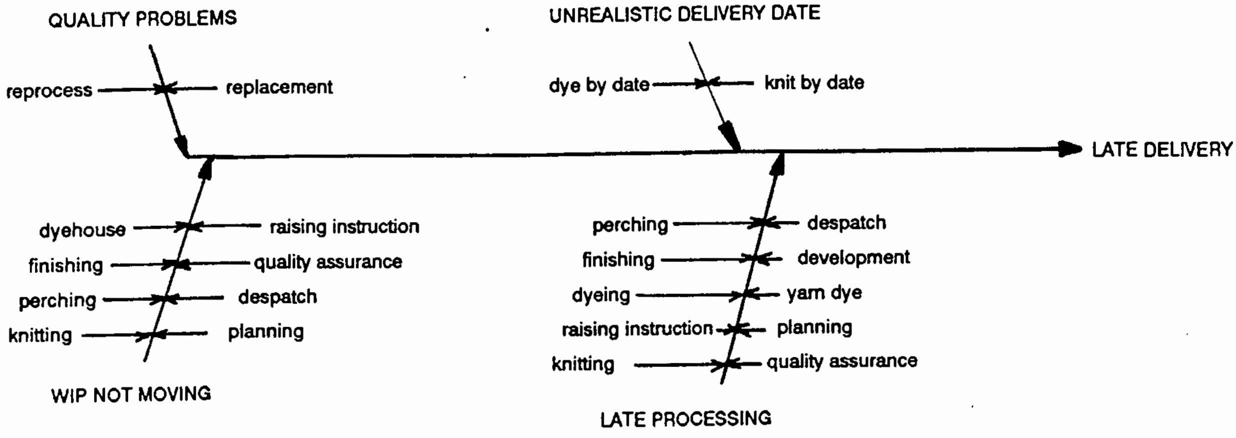


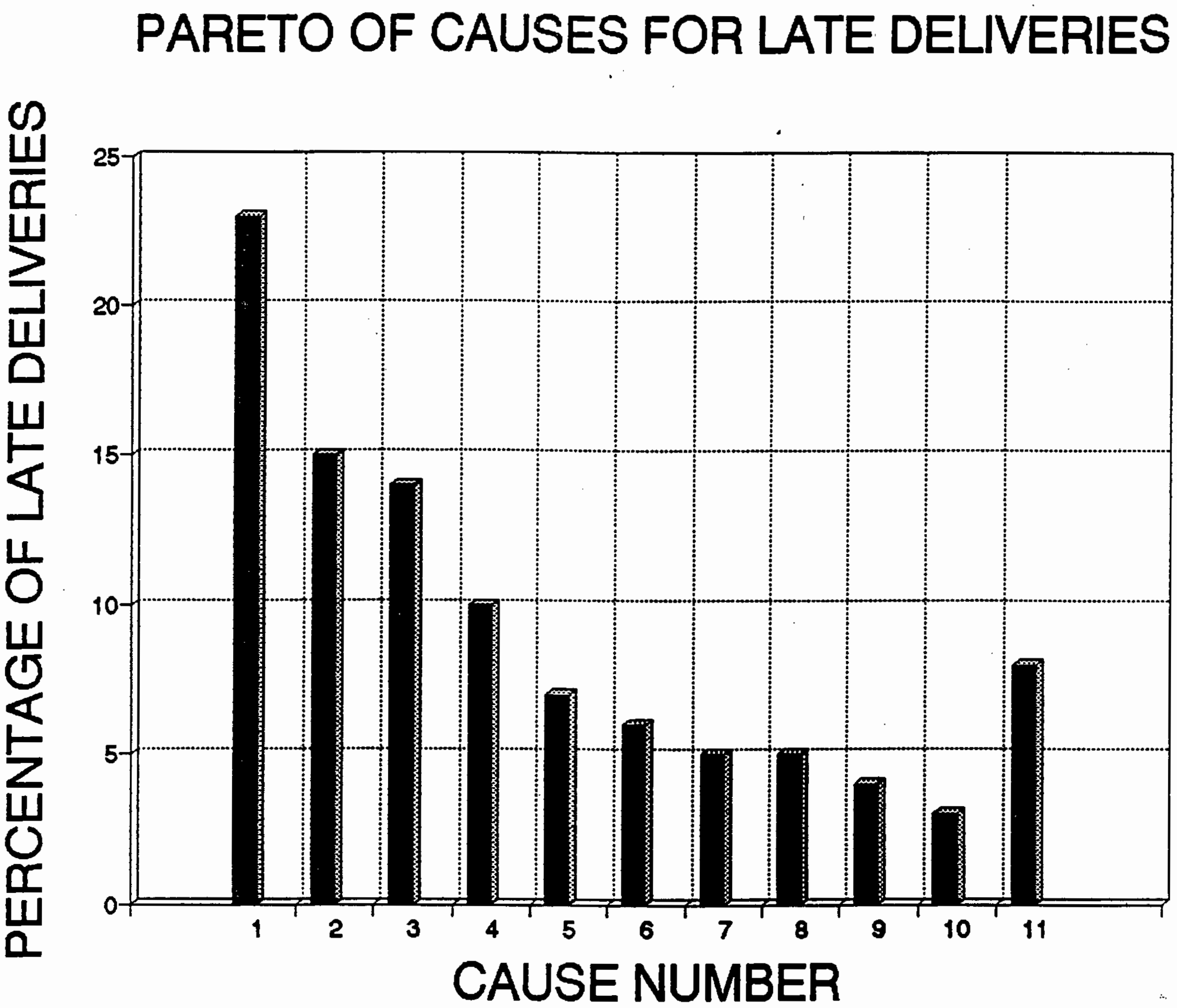

*DIAGRAM 5.4*
*CAUSE AND EFFECT ANALYSIS FOR LATE DELIVERIES*

Late deliveries occur due to four reasons, namely:-

1. Unrealistic delivery dates
2. Quality problems
3. WIP not moving
4. Late processing

**5.2.2 PARETO OF FREQUENCY OF CAUSES**

A study over a period of 4 months was done to determine the frequency that the causes ,established in the previous section, resulted in a late delivery. The frequency, expressed as a percentage of total late deliveries ,was then plotted on a Pareto chart to indicate the problems that should be addressed first. The Pareto analysis is shown in *Diagram 5.5*.




| CAUSE NUMBER | DESCRIPTION OF CAUSE | FREQUENCY (% OF TOTAL |
|---|---|---|
| 1 | LATE DYEING | 23 |
| 2 | REPROCESS | 15 |
| 3 | WIP NOT MOVING IN FINISHING | 14 |
| 4 | WIP NOT MOVING IN DYEHOUSE | 10 |
| 5 | REPLACEMENT | 7 |
| 6 | LATE FINISHING | 6 |
| 7 | WIP NOT MOVING IN PERCHING | 5 |
| 8 | UNREALISTIC KNIT BY DATE | 5 |
| 9 | LATE PLANNING | 4 |
| 10 | LATE QUALITY ASSURANCE | 3 |
| 11 | OTHER | 8 |

*DIAGRAM 5.5*

*PARETO ANALYSIS OF CAUSES FOR LATE DELIVERIES*

# 6. SYSTEMS IMPLEMENTED AT PUMA JERSEY

Only the systems implemented will be discussed in this section. Systems that were proposed, but not implemented, will not be included because there effectiveness can not be determined in order to validate the hypothesis. The systems implemented attempts to address the critical areas for improvement that was established in *Section 5*. Only the final solution to the implemented system will be described due to the time constraint of the thesis.

The systems implemented are explained in context with the relevant techniques discussed in the *Literature Review* and *Discussion*. Systems that were implemented that are not relevant to these techniques are explained in *Appendix 6.1*. Although these systems discussed in *Appendix 6.1* may not be directly relevant to the techniques discussed, they have been vital in assisting in the implementation of the relevant techniques.

## 6.1 <u>PERFORMANCE MEASUREMENTS IMPLEMENTED</u>

Performance measurements relating to lead time and delivery performance can be divided into two categories, namely external and internal performance measurements.

### 6.1.1 EXTERNAL PERFORMANCE MEASUREMENTS

External performance measurements are the most important because these measurements are a direct measure of customer satisfaction. These are measurements that the customer judges Puma Jersey with. The following external performance measurements were implemented to monitor customer satisfaction:-

1. Percentage of orders delivered on time.
2. Percentage of orders delivered late by 1,2 and 3 weeks.
3. Percentage of dye lots delivered on time.
4. Average lead time.
5. Difference in customers requested delivery date and confirmed delivery date.
6. Cycle time from order enquiry to delivery confirmation.

The external performance measurements are monitored on a weekly basis. Monitoring and submitting feedback on a weekly basis will assist in eliminating the "month end syndrome". The month end syndrome predominates at Puma Jersey because the managers are appraised and judged by the monthly sales and cost reports which are submitted and evaluated at the end of each month.

### 6.1.2 INTERNAL PERFORMANCE MEASUREMENTS

Internal performance measurements do not directly relate to customer satisfaction, but directly measure the operations occurring within the company. Internal performance measurements allow processes to be measured individually and therefore critical areas can be identified when the external performance measurements deviate from the desired target.

It is the internal performance measurements that management has to control to achieve the desired external performance. The following internal performance measurements were implemented:-

1. Percentage of dye lots instructed within 2 weeks of confirmed delivery date.
2. Percentage of orders instructed within 2 weeks of confirmed delivery date.
3. Percentage of orders delivered late that were instructed less than 2 weeks before the confirmed delivery date.
4. Average lead time for orders delivered late.
5. Average time from when first instruction raised for an order to last instruction raised for an order.
6. The following cycle times:-
   - Order enquiry to instruction raised
   - Knitting cycle time
   - Instruction raised to despatch
   - Dye house cycle time
   - Finishing cycle time

- Rolling to final quality assurance cycle time

These internal performance measurements are monitored on a weekly basis. It must be noted that these internal measurements do not foster an environment conducive to achieving local optimization because these measurements are subservient to the global common goal of the external measurements.

The following performance measurements are monitored on a daily basis because these measurements are used as a daily control by management. These measurements are seen to be extremely important measurements, because if these measurements can be controlled, then management can effectively manage lead time and late deliveries. These measurements directly control lead time and late deliveries. These measurements are:-

7. Number of dye lots that need to be delivered in the present week.
8. Number of dye lots that are late.
9. Queue length in hours behind every machine.
10. List of the dye lots that have been stationary in a department for longer than 4 days.
11. Machine utilization - Machine utilization is calculated as :-

$$UTILIZATION = \frac{TIME\ WITH\ WORK}{AVAILABLE\ TIME}$$

12. Machine efficiency - Machine efficiency is calculated

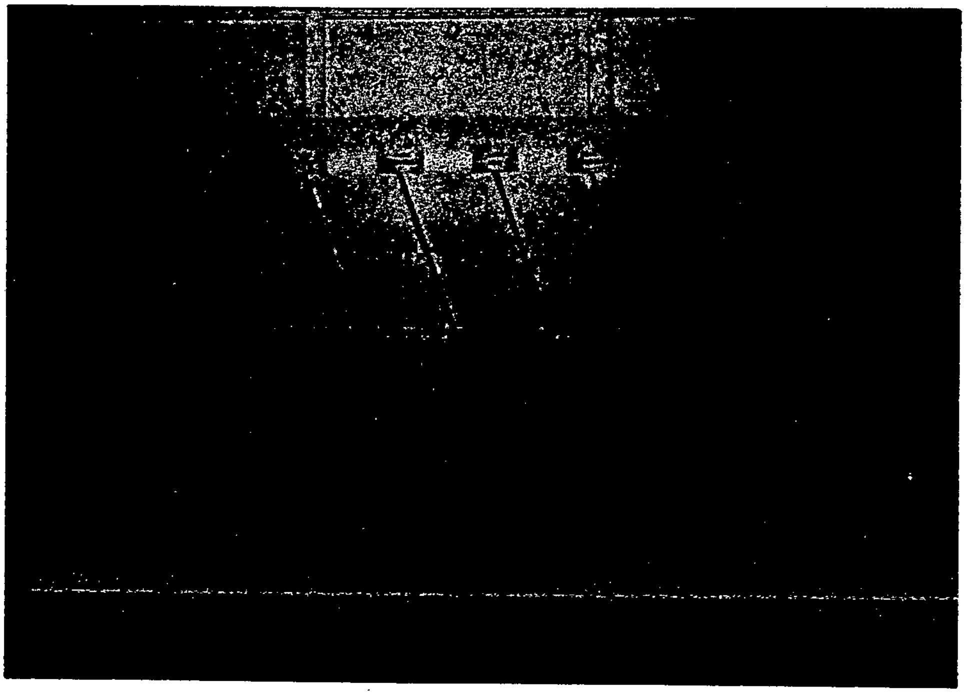
as :- $$EFFICIENCY = \frac{MACHINE\ RUNNING\ TIME * 100}{AVAILABLE\ TIME*UTILIZATION}$$

**6.1.3 METHOD OF MEASURING PERFORMANCE MEASUREMENTS**

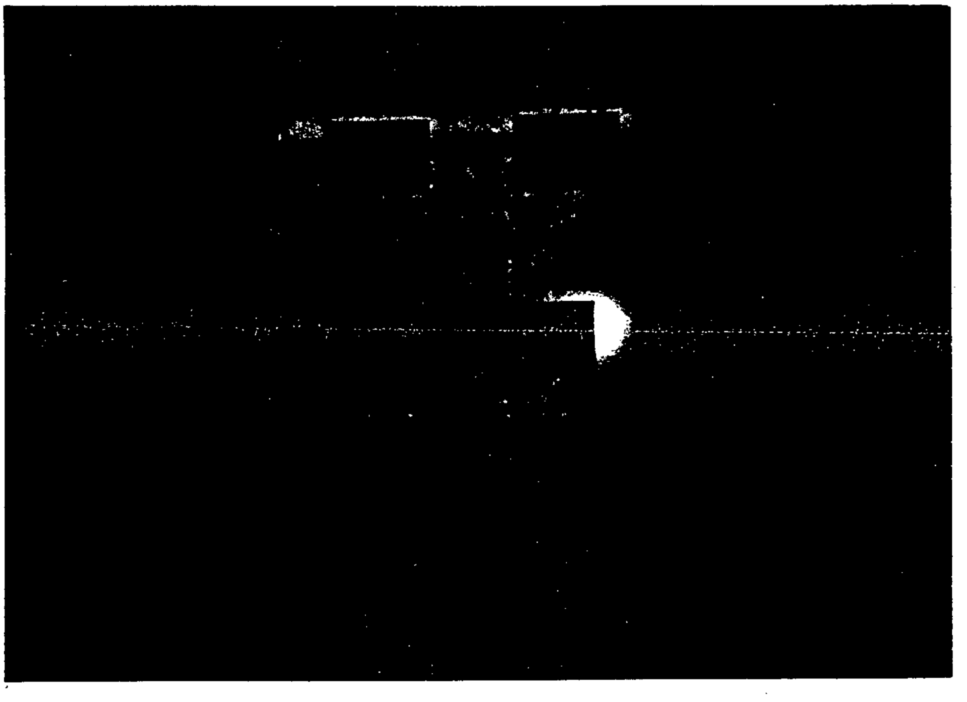
A suitable method had to be developed to attain these performance measurements. The method entails a system that monitors the physical flow of the work through the factory. This system is explained in *Appendix 6.2*. This WIP monitoring system is vital to the implementation of monitoring the performance measurements discussed in this section.

## 6.2 IMPLEMENTING CEDAC

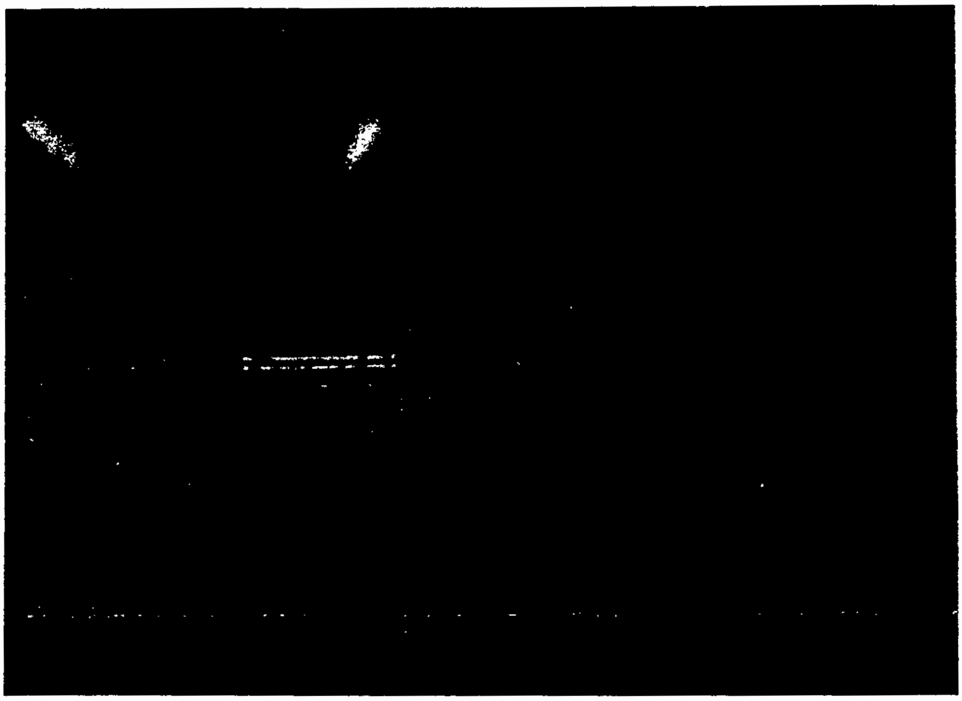
A CEDAC communication office was constructed in a central location in the factory. This room is accessible and central to all the departments. The 6m X 4m office has 35 square meters of wipe-off writing surface. This multi-purpose office is used to communicate performance measurements and involve shop floor involvement through the use of CEDAC. CEDAC's were developed and implemented for late deliveries, lead times and quality control. This office will serve as a central location for all the measurements in the factory. Therefore management has easy and up-to-date access to information necessary for decision making. The pictures below are pictures taken of the lead time and late delivery CEDAC.



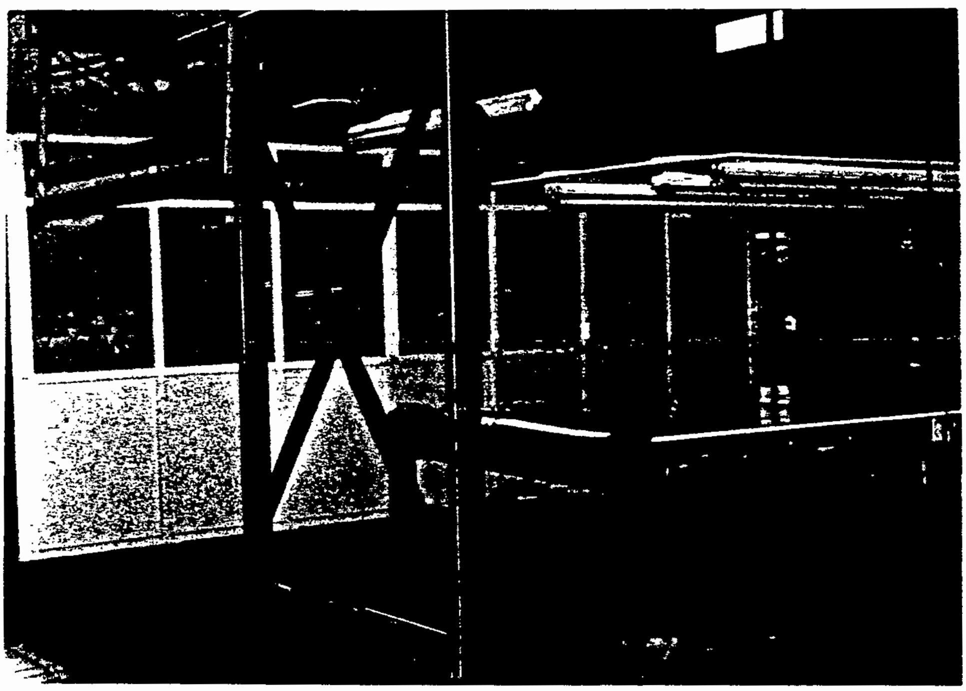
CEDAC for late deliveries



CEDAC for lead times



CEDAC for quality



CEDAC office situated on the shop floor

Management were initially approached to participate on a voluntary basis. Once confidence was gained in this system all of the production departments had to communicate there performance measurements in the CEDAC office. Management are presently obligated to use CEDAC as a communication medium. Management first have to become completely confident and familiar with this system before a formal introduction to the shop floor personnel is attempted. However, shop floor personnel are participating with the CEDAC on a voluntary basis. The use of CEDAC will not be enforced on any shop floor personnel ,which is much in line with the Zero Defect and Quality Circle philosophies.

## 6.3 IMPLEMENTING SYNCHRONOUS MANUFACTURING PRINCIPALS

The implementation strategy adopted to implement the concepts of Synchronouse Manufacturing is congruent with the 5 step approach developed by Goldratt, as described in the *Literature Review*. The basic principals of Synchronous Manufacturing will be applied first, before attempting the more complex concepts such as the "drum-buffer-rope system"

### 6.3.1 IDENTIFYING THE CONSTRAINTS OF THE SYSTEM

This is the first step to the 5 step approach to theory of constraints. The systems constraints can be determined by using one of two methods:-

1. Determining the queues behind all the processes involved in producing piece dyed knitted fabric.
2. Calculating capacities of all the processes involved in producing piece dyed knitted fabric.

Identifying the systems constraints by determining the queues behind every machine is a useful "hands-on" management tool, but lends itself to reactive management because the constraint has already formed. Management can however prevent the queue from increasing. To pro-actively forecast bottlenecks will require the capacity of each machine to be calculated.

The difficulty in determining the constraints, or bottlenecks, of the system by calculating the machine capacities, is that the capacities are dependant on the product mix. The product mix changes continuously on a daily basis, so therefore the machine capacities, and in turn bottlenecks, change on a daily basis. The capacities calculated for different product mixes for each department are shown in *Appendix 6.3* to illustrate the effect that the product mix has on the capacities.

To complicate the matter even more, the different products undergo different processes. The different processes, or routes, are shown in *Appendix 6.3*. Due to the dynamic nature of the product mix and the complicated nature of product flow it is necessary to use System Dynamics to determine the system constraints (see *Section 6.4.6.1*).

Bottlenecks are undesirable for the following reasons:-

1. Non bottleneck resources are under utilized.
2. WIP level increases.
3. Throughput decreases.
4. Quality problems increases because the WIP has increased. Quality problems will accumulate in the WIP as explained in *Section 2.1* and *Section 2.2*.

Considering all the above factors it can be concluded that bottlenecks are undesirable because they incur a cost factor, decrease quality, increase lead times and decrease delivery performance. Therefore the ability to forecast and then control bottlenecks is vital to achieving the global goal of increasing profits. There is little use if a bottleneck can be forecasted but nothing can be done about it. Therefore a bottleneck should be controlled.

### 6.3.2 DETERMINE HOW TO EXPLOIT THE CONSTRAINTS TO IMPROVE THE PERFORMANCE OF THE SYSTEM

This is the second step to the 5 step approach to theory of constraints. In simpler terms step 2 in the 5 step approach determines how to control bottlenecks in order to increase the throughput at this bottleneck. There are 3 ways to control bottlenecks at Puma Jersey, namely;-

1. Introduce overtime at the bottleneck resource.
2. Control the product mix.
3. Increase efficiency at the bottleneck resource.

Introducing overtime at a bottleneck resource is costly and impractical. It is costly because overtime rates are high. Overtime is also impractical because bottlenecks move on a daily basis, and it would be difficult to acquire the extra labour resources at such short notice. Therefore the most viable option is to control the product mix. The product mix effects the location of a bottleneck because different products follow different routes and utilize different machines. An explanation of the main products that have to be controlled to prevent bottleneck have been identified in *Appendix 6.3*.

The efficiencies can also be increased at a bottleneck resource in conjunction with controlling the product mix. Efficiencies can be increased by:-

1. Increasing the batch size to reduce set-up times.
2. Utilizing an extra machine operator from a non-constrained resource to assist in set-up.
3. Working through lunch breaks and tea breaks.

## 6.4 IMPLEMENTING SYSTEMS DYNAMICS

Systems dynamics is used to determine the effectiveness of implementing systems to reduce lead times and late deliveries. However, it is difficult to measure the effectiveness of a system by isolating the measurement that the system was intended to improve, because of the myriad of relationships that this system can have with other important variables. It has been previously established in *Section 3.1* that the global objective of the company is to maximize profits. Therefore the effectiveness of a proposed system will be measured by the quantity of money produced and the ability to sustain such financial performance.

The first step to reaching this objective is to develop a model of Puma Jersey's factory operations, and its environment before the systems for improvements are implemented. This is necessary to verify the model. The model is verified by comparing the systems dynamics model behavior with the actual behavior. Only once the model has been verified can various scenarios be analyzed to determine the systems behavior under certain conditions. The following conditions were applied to the model to determine how the system would behave under certain conditions:-

1. Step change in demand
2. Pulse change in demand

The behavior to these conditions facilitates the understanding of the underlying forces that determine the systems behavior. The following systems were then applied to the model to determine the effectiveness of the proposed systems performance:-

3. Increasing dye house capacity
4. Decreasing dyeing to finished goods cycle time
5. Reducing quoted cycle time from dyeing to finished goods
6. Carrying greige inventory

Systems dynamics also assisted in developing and designing these systems to obtain an optimum solution.

**6.4.1 EXPLANATION OF THE DYNAMO MODEL**

Before a model can be developed it is necessary to first determine the constraints to reaching the objective of the systems analysis. The ultimate objective of the systems analysis is to determine the sustainable profitability of implementing systems to reduce lead times and late deliveries. A system constraint can be defined as "*anything that limits a system from achieving higher performance versus its goal*" (17). These constraints have been established in *Section 3.1* to be :-

1) Throughput
2) Inventory level
3) Operating expense

The quantity of money produced or the rate of sales is determined by the throughput, which in turn is directly controlled by the rate of production, better known as demonstrated production capacity. There has to be an input of orders into the system for a production capacity to exist. The rate that orders, or money, enters the system is determined by the market demand.

The rate of production is constrained either by the achievable production capacity of the system, or the market demand depending on the market conditions prevailing. When the market demand is below the achievable production capacity (ie, the system can produce more products than it can sell) then the constraining factor to making money is the market demand. If the market demand exceeds the achievable production capacity (ie, the system can not produce more products than it can sell) then the constraint is production capacity. It has been established in *Section 3.1* that market demand is the constraint to throughput at Puma Jersey because Puma Jersey can produce more products than they can sell.

Inventory is a constraint to increasing profits because inventory forfeits opportunity costs. Invested money yields higher returns than inventory on the shop floor. *Appendix 2.1* shows the opportunity costs that can be achieved by reducing lead time and therefore WIP inventory. Operating expense is a direct money consuming entity and is clearly an obstacle to achieving the goal of maximizing profits.

The constraints that have been analyzed will largely determine the basic structure of the model. The choice of basic structure of the model is explained in *Appendix 6.4*. The basic structure of the DYNAMO model is shown in *Diagram 6.1*.

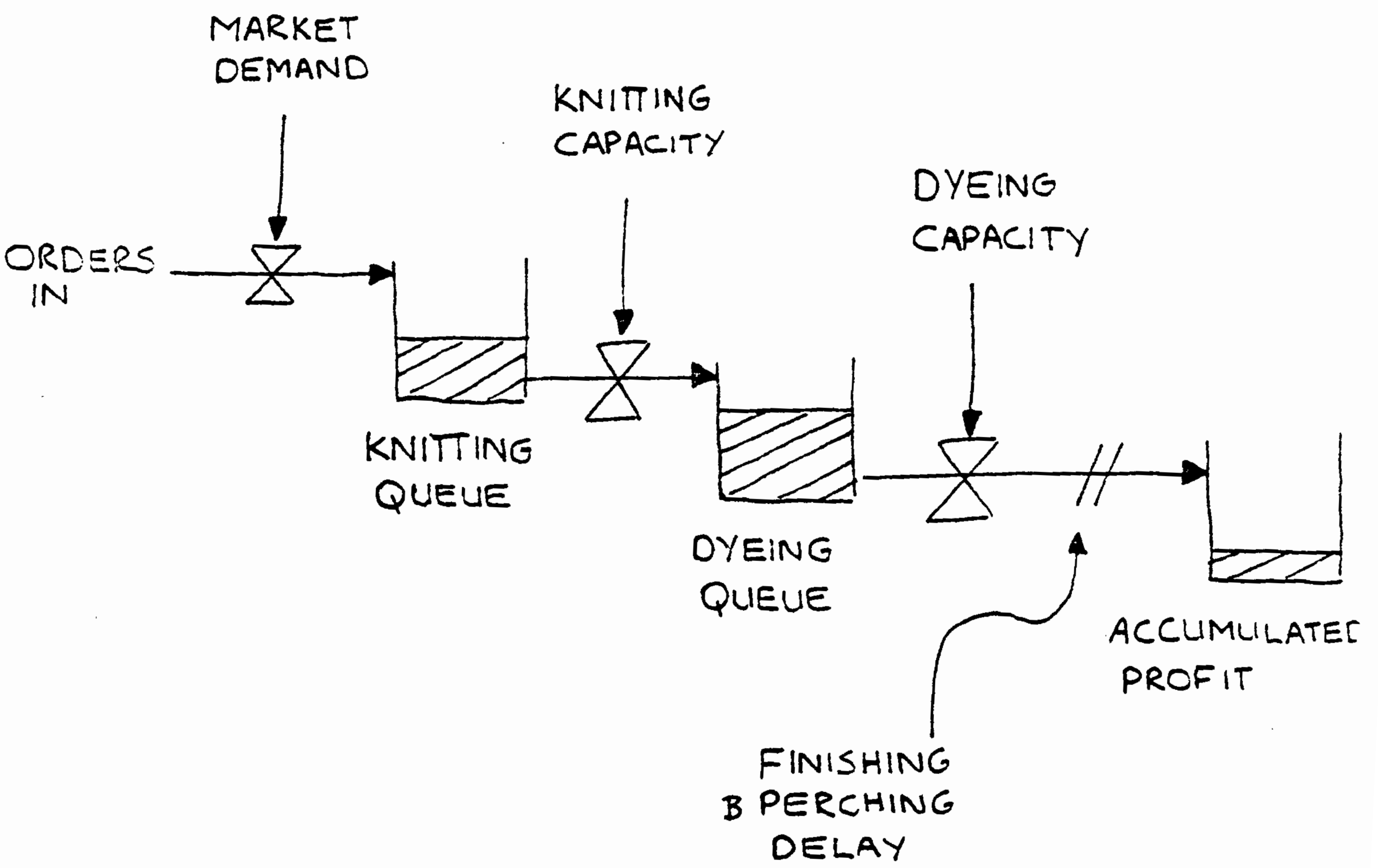



*DIAGRAM 6.1*

*BASIC STRUCTURE OF THE DYNAMO MODEL*

The final model is explained with the use of three loops. These loops attempt to directly address the constraints of the system. Even though these loops are discussed separately, they are dependant on each other because they form inter-woven relationships with each other.

The dynamics created by market demand is represented by the "sales loop". The dynamics created by production capacity is represented by the "production loop". Production capacity is directly responsible for inventory levels, therefore the dynamics created by inventory level is also discussed in the "production loop". The third loop that will be discussed is the "profit loop" and will show the dynamics in created in profit generated by the operations at Puma Jersey. This loop will include the dynamics created by operating expense. These three loops will discussed separately and then combined to form the foundation of the system to be analyzed. The combined behavior of the three loops will simulate the present behavior at Puma Jersey.

#### 6.4.1.1 Sales loop

The first feedback loop that will be discussed is the so-called "sales loop". The sales loop is shown in *Diagram 6.2*. The sales loop explains dynamics caused by market demand. Market demand controls the throughput and is therefore one of the constraints to reaching the final objective of increasing profits. The sales loop explains the dynamics of throughput of Puma Jersey.

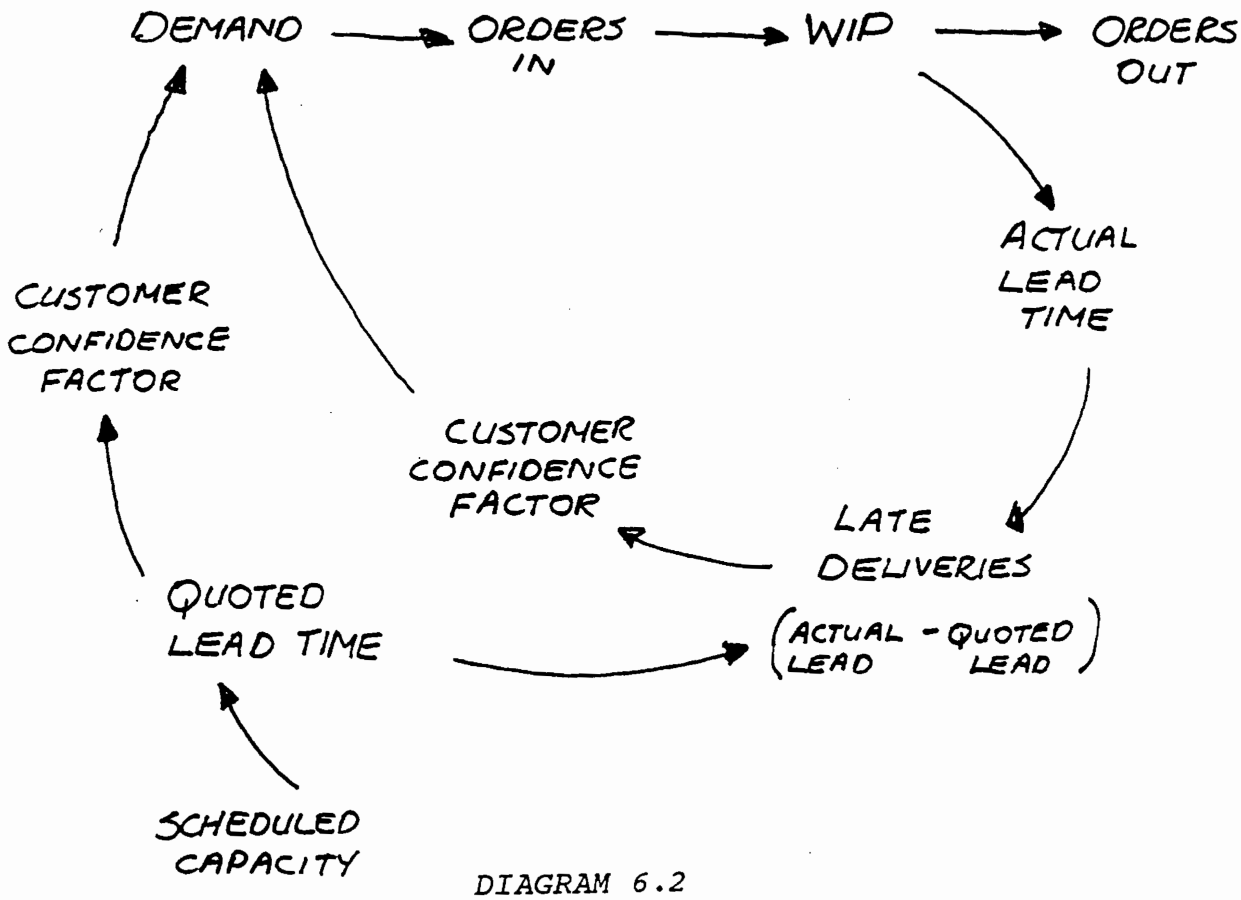
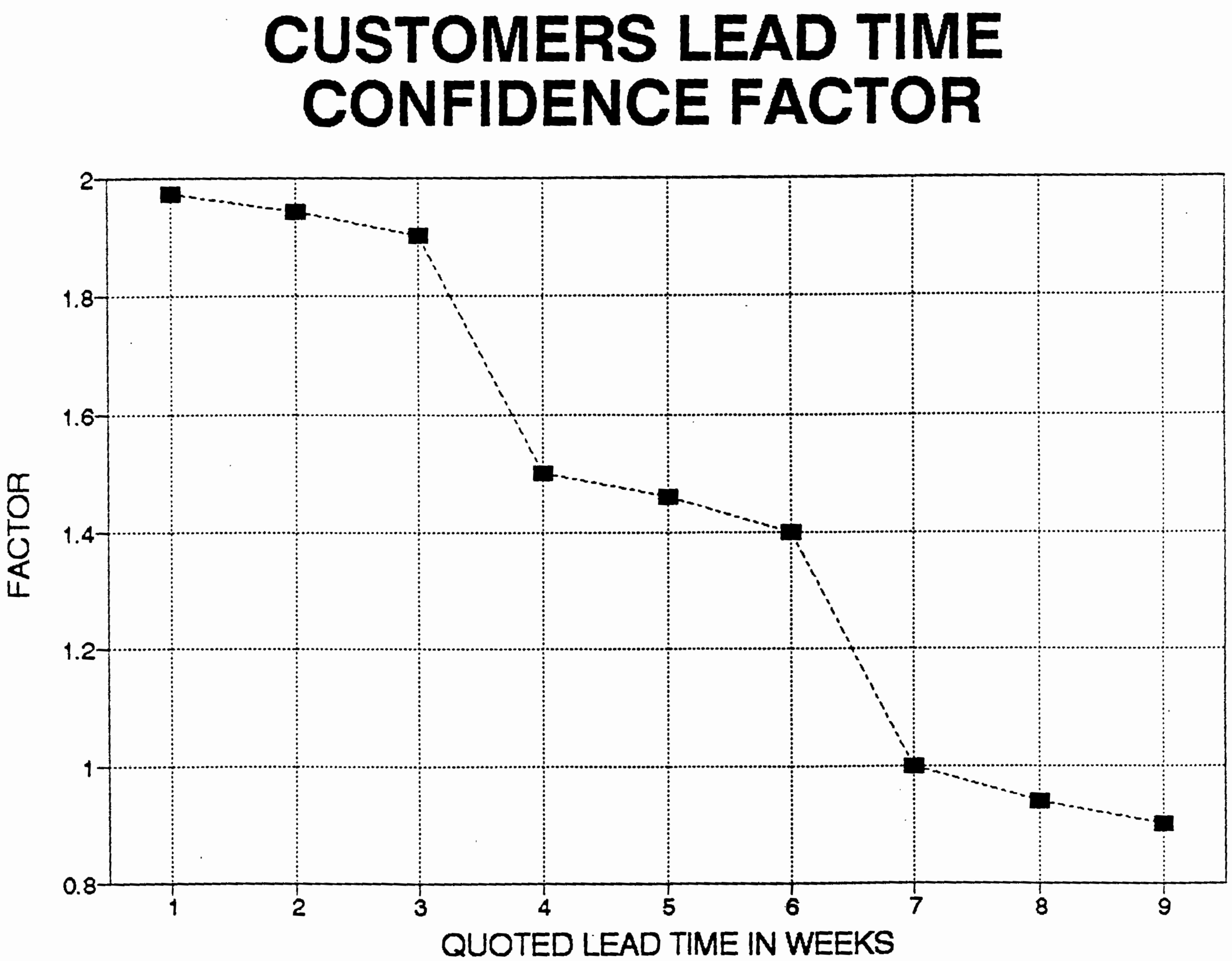



DIAGRAM 6.2

SALES LOOP

Because the variables successively determine one another, the description of the loop can be started at any point. The first variable that will be described is the number of orders into the system. The number of orders into the system is controlled by the market conditions prevailing and the level of customer satisfaction achieved. Customer satisfaction is dependant on a number of variables but only the quoted lead time and the occurrence of late deliveries will be considered for this purposes of the systems dynamics model.

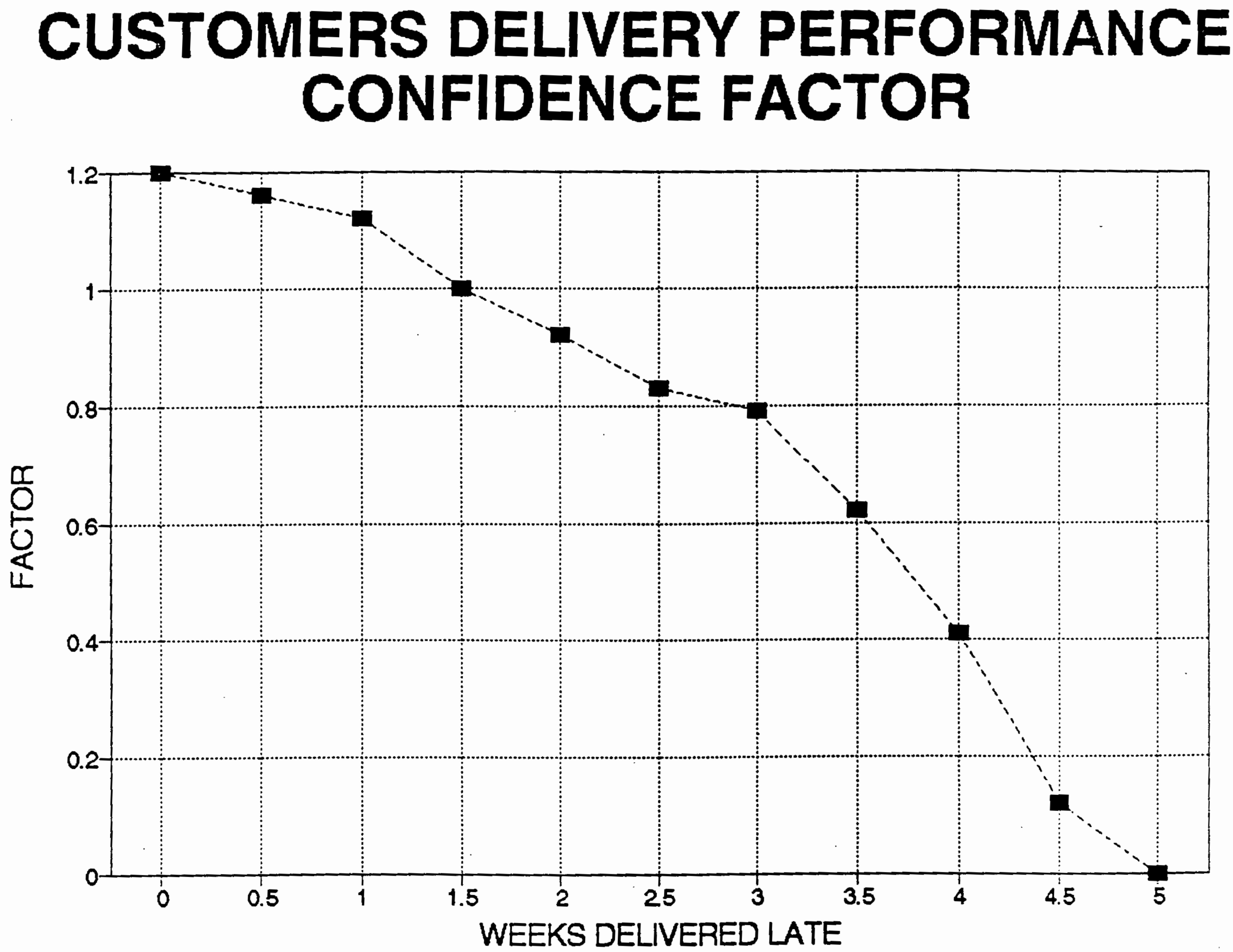
If the quoted lead time is satisfactory to the customer, then the customer will place the order, and the order is termed a successful confirmed order. The relationship between quoted lead time and the number of successful orders is an important relationship because it is critical to the behavior of the system. The relationship between quoted lead time and the customer confidence, or satisfaction, factor is shown in *Graph 6.1*.




*GRAPH 6.1*

This relationship is derived from the survey on customer perceptions on lead time and late deliveries as discussed in *Section 4*. It can be seen that the quoted lead time experienced before systems were implemented is used as a reference point, and is given a customer confidence factor of one. The quoted lead time is determined by the scheduled production capacity and WIP levels for the time period in question. In other words the quoted lead time is determined by the Master Production Schedule.

If late deliveries occur, then the rate of orders into the system will decrease due to the customers dissatisfaction. This behavior has a delayed effect due to the customer only taking action if a late delivery occurs several times, before a change in supplier will be considered. The relationship between late deliveries and the number of successful orders is also an important relationship because it is vital in determining the systems dynamic behavior. The relationship between late deliveries and the customer satisfaction factor is shown in *Graph 6.2* below. This relationship, and the derivation of the delay period, is also derived from the survey on customer perceptions on late deliveries and lead times in Section 4.




*GRAPH 6.2*

A late delivery is calculated from the equation:-

*LATE DELIVERY = ACTUAL LEAD TIME - QUOTED LEAD TIME*

Where the actual lead time of an order is directly dependant on the level of WIP in the system. The actual lead time is calculated as:-

$$\textit{ACTUAL LEAD TIME} = \frac{\underline{\textit{NUMBER OF ORDERS IN SYSTEM}}}{\textit{PRODUCTION CAPACITY}}$$

The number of orders in the system is equal to the level of WIP in the system. The level of WIP will be explained in the production loop.

#### 6.4.1.2 Production loop

Production and inventory are inter-related and are therefore explained simultaneously. The "production loop" is shown in *Diagram 6.3* and explains dynamic behavior caused by the demonstrated production capacity and inventory levels. Production capacity determines the rate that orders exit the system and generate revenue. The rate that orders exit the system is the throughput of the system, a constraint to increasing profits. Inventory is also recognized as a constraint to reaching the objective. Therefore the production loop describes the dynamics of two constraints to increasing profits.

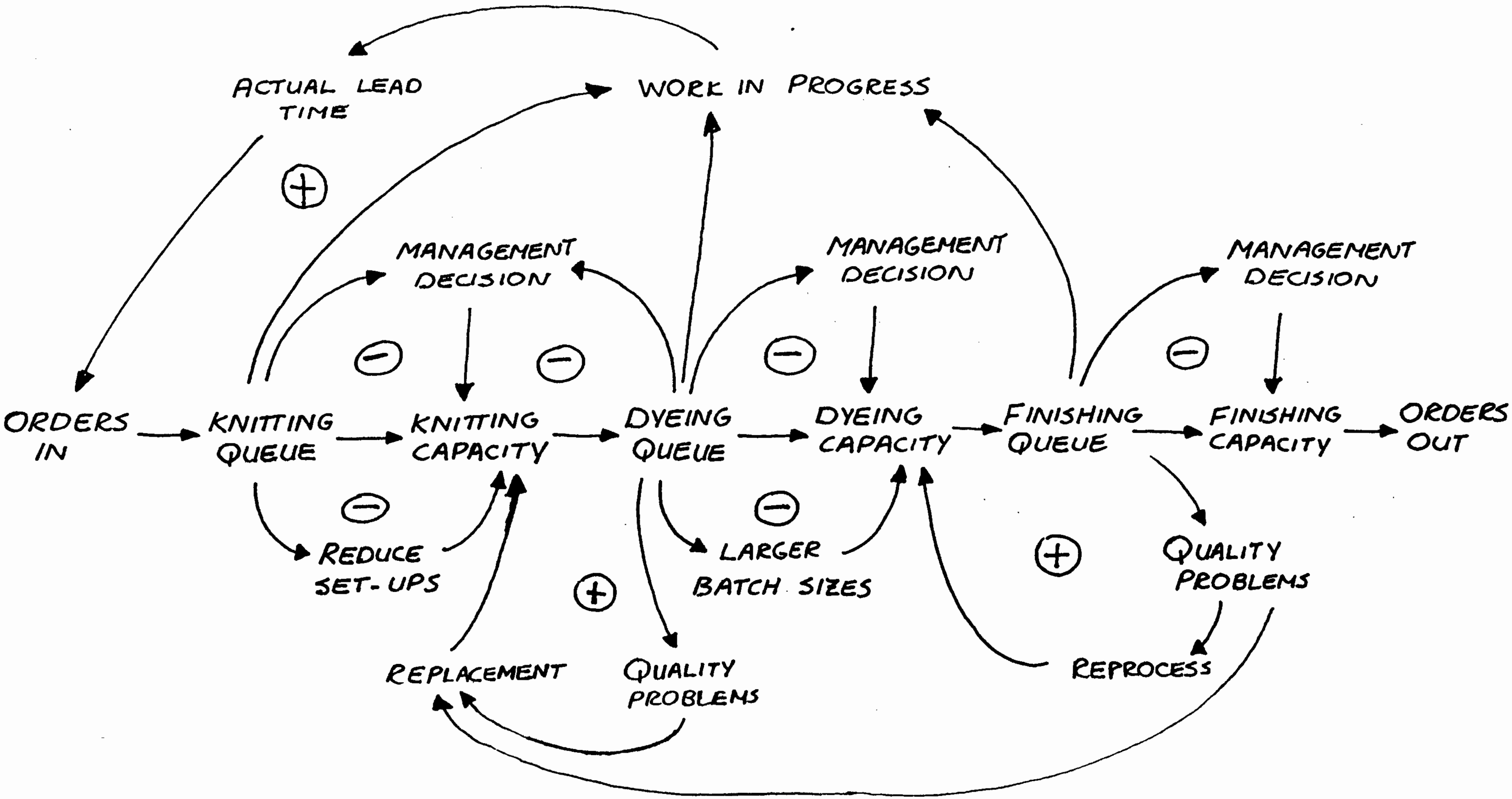



DIAGRAM 6.3

<u>PRODUCTION</u> <u>LOOP</u>

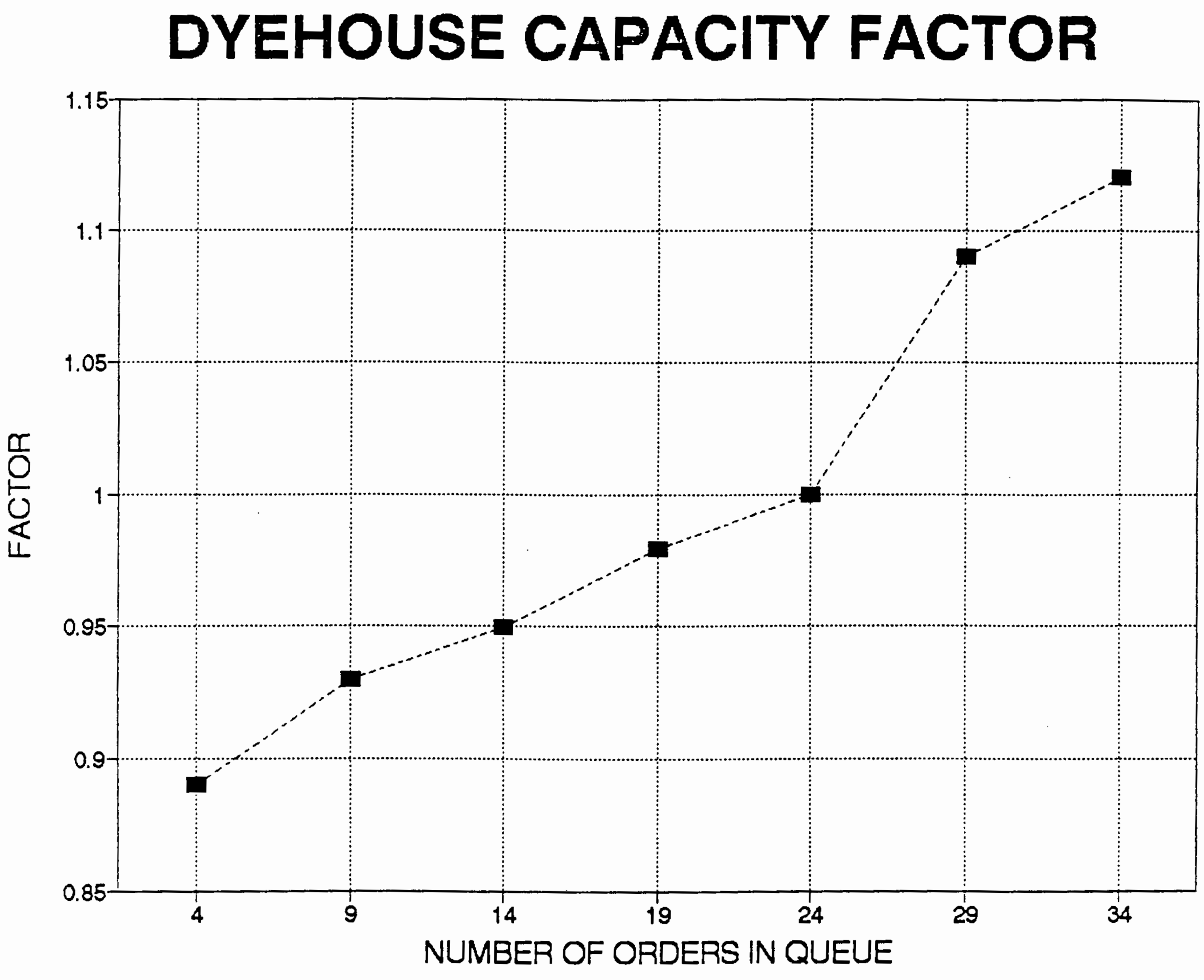
Revenue leaves the system (ie the factory) in the form of finished goods or completed orders. The rate that these completed orders leaves Puma Jersey is directly proportional to the rate that orders can be completed. It is company policy to allow for 2 weeks for an order to be completed after it has been dyed, and the quoted lead time is based on this assumption. This policy was determined by management as the average cycle time for the processes following the dyeing operation. The processes following the dyeing operation have a greater design capacity than the dye house. Therefore the dye house capacity determines the rate of finished orders out of the system because it is the global bottleneck.

The dye house demonstrated capacity is the amount of orders that can be dyed in the dye house in a specific week. Management determines this dyeing capacity by implementing overtime or short-time, depending on the orders that have to be delivered, and the amount of available work (ie dye house WIP). The time that it takes for management to decide and implement overtime or short-time is approximately 3 to 4 days, therefore a delay exists.

The dye house WIP, or dyeing queue, is the work in progress of orders that have been knitted and are ready to be dyed. It physically exists as knitted greige that waits in the graveyard and greige store. The dyeing queue is expressed as a level variable. The actual knitting capacity controls the inflow of greige into the queue, and the actual dyeing capacity controls the outflow of greige out of the queue. It is management policy to have a dye queue that can supply the dye house with approximately 3 to 4 days work. The dye house capacity is determined from the dyeing queue in the following way:-

1) If the WIP at the dye house (ie greige inventory) becomes greater than 4 days work, then the dye house increases its capacity.
2) If the WIP at the dye house becomes too small for all the machines too be utilized, then the dye house will decrease its capacity in an attempt to avoid low efficiencies. (The WIP queue must usually be less than 1.5 days before the machines become inefficient.)
3) If potential late deliveries exist then the dye house will increase its capacity. A potential late delivery is regarded when an order has not been dyed one week before the delivery date. Management will only consider overtime if more than 3 orders will be potentially late.

A dye house capacity factor is derived from the WIP at the dye house, also called the dyeing queue. The capacity factor was obtained from historical data and is shown in *Graph 6.3*. The actual demonstrated dye house capacity is the product of the dye house scheduled capacity and the dye house capacity factor.




*GRAPH 6.3*

As the dye house WIP accumulates the quality problems caused by the knitting also accumulate. This phenomenon was explained in *Section 2.1*. Therefore an increase in the dye house WIP will increase the occurrence of quality problems, which in turn will increase the amount of rework in the dye house and knitting. Therefore a large dye house WIP will decrease the dye house capacity. However, an increase in dye house WIP leads to an increase in capacity because the dye house has a bigger time frame to batch similar product lines together, and then dye these different orders in the same dye lot which increases the capacity. The dynamic complexity of dye house capacity can be realized due to the positive and negative feedback loop created.

As the dye house capacity increases the WIP in the finishing and perching departments also increases. The large levels of inventory carry quality problems that have to be replaced and reprocessed in the knitting and dye house respectively. The level of WIP in the finishing department directly determines the difficulty to monitor the location and movement of orders, which contributes to late deliveries.

The demonstrated knitting capacity is the amount of orders that are knitted by the knitting department in a particular week. Management determines this knitting capacity by implementing overtime or short-time. The delay for this decision making process is 3 to 4 days.

The required knitting capacity is determined by the amount of dye-lots that exist in the dye house WIP, or dyeing queue. The dying queue is the amount of available dye-lots that have been knitted and are ready to be dyed. It is management policy to have a dye queue of approximately 3 to 4 days work. The knitting capacity is also determined from the dyeing queue in the following way:-

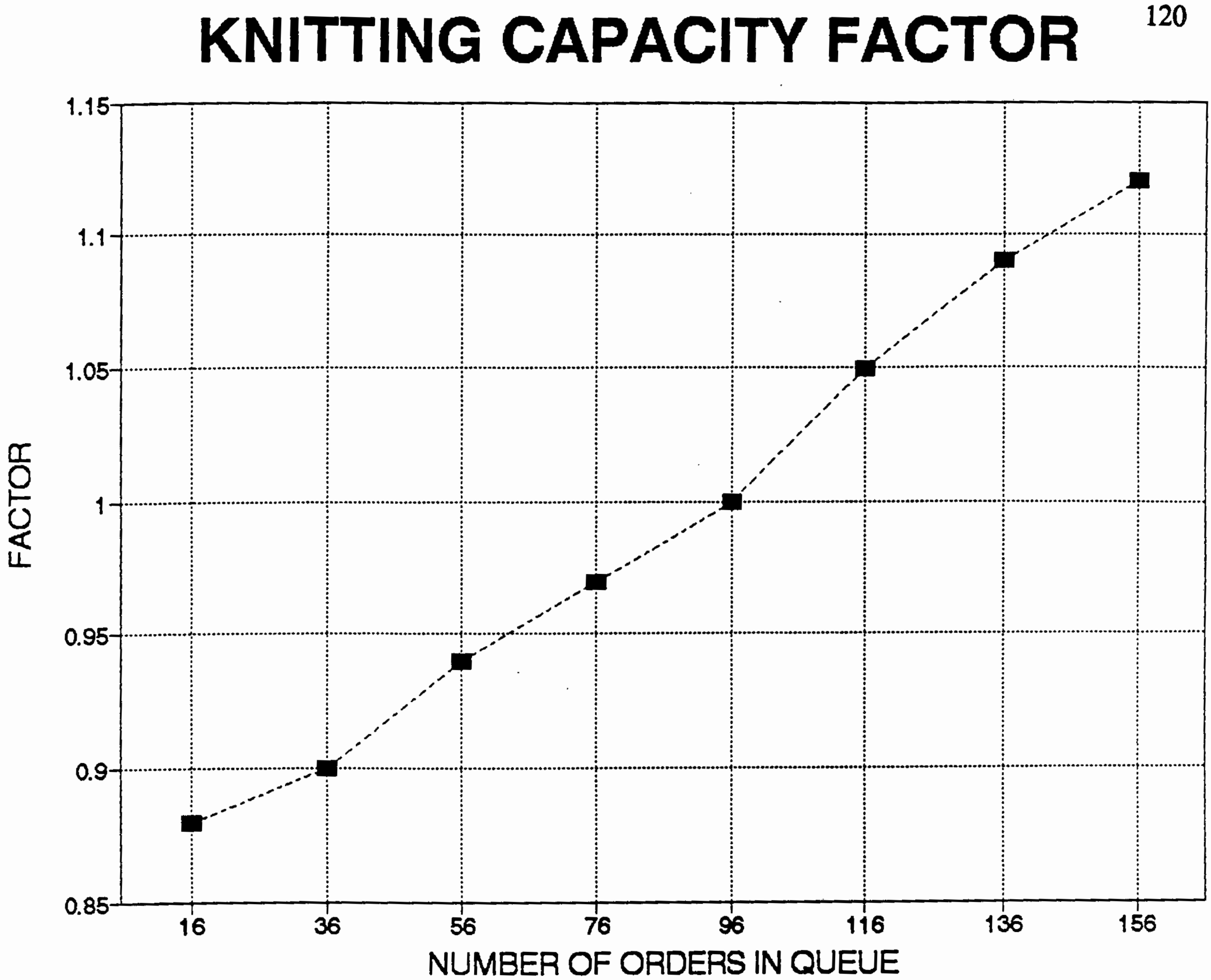
1) If the dyeing queue becomes less than 3 days then the

knitting department will increase its capacity, and therefore the dyeing queue.

2) If the dyeing queue becomes more than approximately 6-7 days, then the knitting will decrease its capacity in an attempt to reduce the dyeing queue.

3) If potential late deliveries exist then the knitting department will increase its capacity. A potential late delivery is regarded when an order has not been knitted two weeks before the delivery date. Management will only consider overtime if more than 3 orders will be potentially late.

The knitting capacity and the dyeing capacity are both determined by the dyeing queue because the dye house is considered as the global bottleneck of the system. A knitting capacity factor is derived from the dyeing queue. The capacity factor was obtained from historical data and is shown in *Graph 6.4*. The actual demonstrated knitting capacity is the product of the knitting scheduled capacity and the knitting capacity factor.




*GRAPH 6.4*

The knitting queue is the work in progress of orders that have not been knitted. It physically consists of orders waiting to be knitted, and orders that are being knitted. An order only leaves the knitting queue if the complete order has been knitted. The rate of confirmed orders generated controls the inflow of orders into the queue, and the actual knitting capacity controls the outflow of orders out of the knitting queue. If the knitting queue becomes large the knitting efficiency increases because set-up times can be reduced. Therefore the knitting capacity increases with an increase in orders into the system.

**6.4.1.3 Profit loop**

The "profit loop" will describe the dynamic behavior of the "sales loop" and the "production loop" in monetary units. Profit made is the paramount variable for all management decisions. Profit can be measured in two ways, namely:-

a) Rate of profit made
b) Cumulative profit made over a time period.

The rate that profit is made is an useful measurement because it gives insight into the behavior of a systems ability to generate profit in response to a management decision. The rate of profit made is a measure of the immediate benefits of an implemented system.

Cumulative profit is the fundamental measurement because it measures the primary goal, "to make more money, now and in the future" (hay). The accumulated profit measures the overall long term benefits of an implemented system once the system has reached a steady state. Therefore the rate of profit made is a subservient measurement to accumulated profit because accumulated profit describes a global perspective on a systems sustainable effectiveness to generate money. The profit loop is shown in *Diagram 6.4* below.

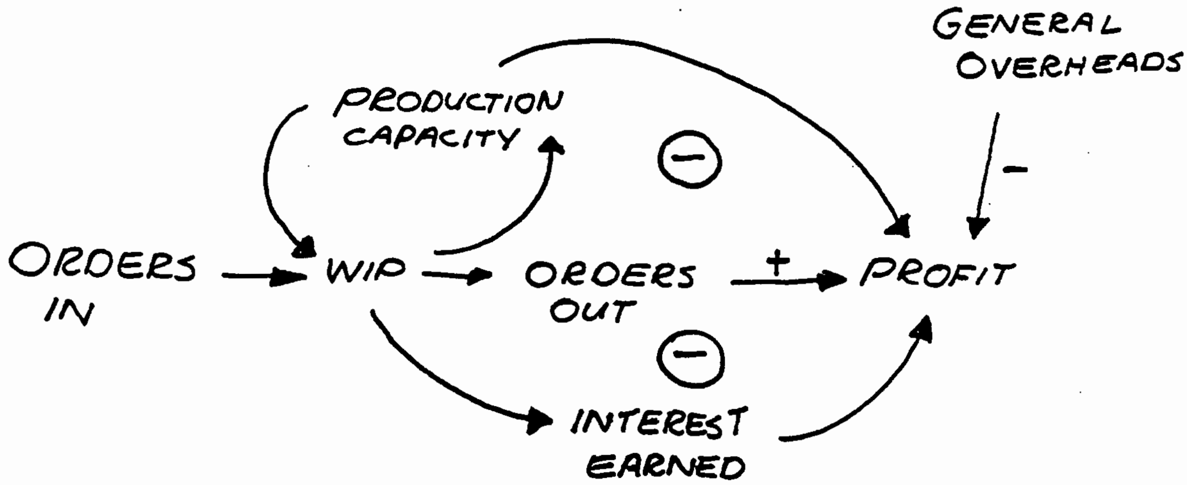



*DIAGRAM 6.4*

*PROFIT LOOP*

The rate of orders out of the system generates profits. The costs incurred in generating this revenue occurs due to operating expense as a result of production capacity. Material costs, general overheads, and interest lost due to holding WIP also incurs costs on the system. Therefore to calculate profit the following variables need to be known:-

1) Average price per order
2) Average raw material cost per order
3) Average general overhead expense per week
4) Average variable cost per day for the dye house
5) Average variable cost per day for the finishing, perching and despatch.
6) Average variable cost per day for the knitting
7) Average fixed cost per week for the dye house
8) Average fixed cost per week for the finishing, perching and despatch.
9) Average fixed cost per week for the knitting

These variables were established by taking a 6 month period sample. Once these variables were established the following relationship could be derived be derived:-

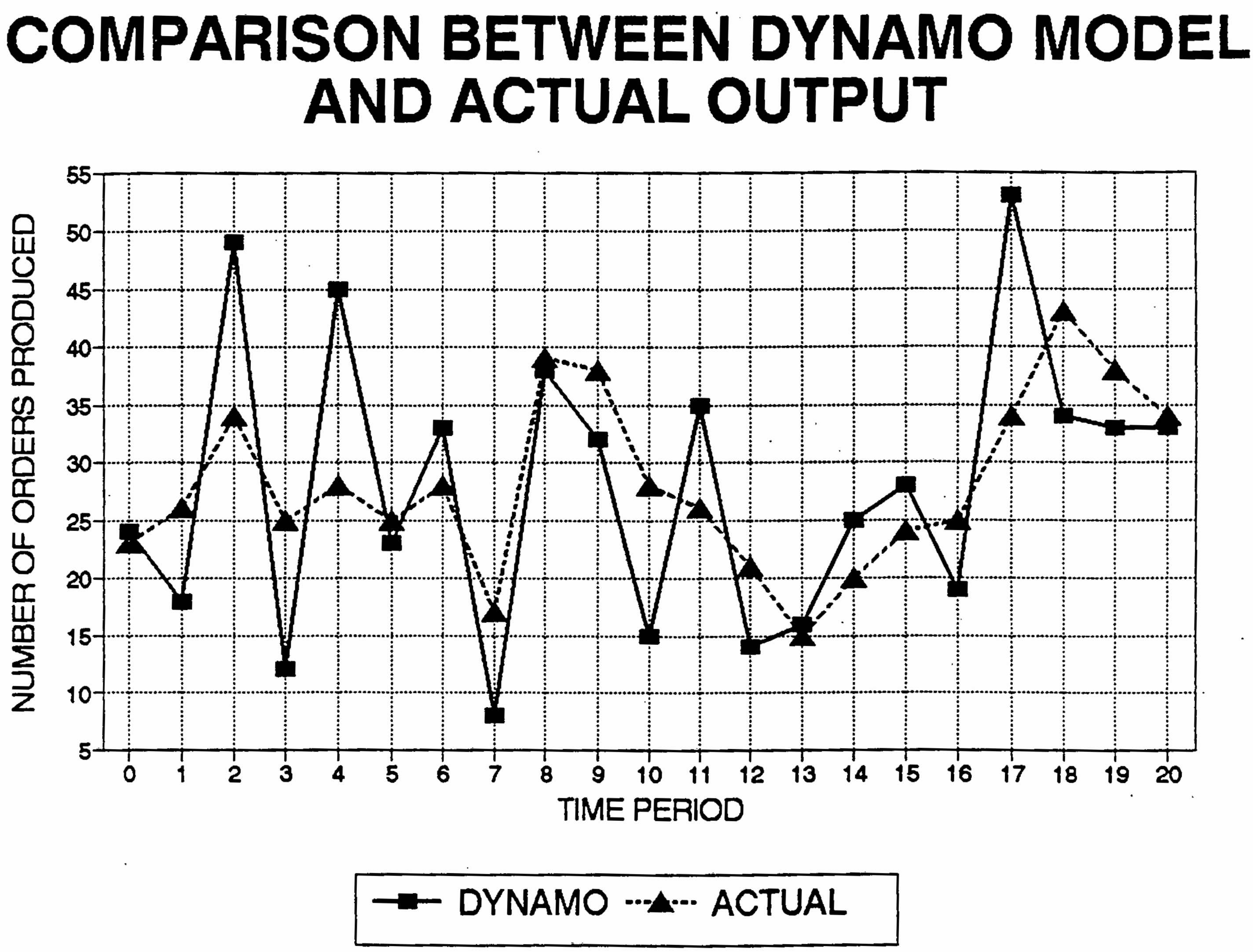
PROFIT = (PROFIT PER ORDER * ORDERS IN)
- (OPERATING EXPENSE PER DEPARTMENT)
- (GENERAL OVERHEADS)
- (WIP COSTS)

The profit per order is calculated by subtracting the raw material costs from the selling price of the order. The operating expenses in this equation describes the weekly costs accountable to variable costs of the relevant departments. This is calculated by multiplying the daily variable costs by the number of working days in each department. The fixed costs for each department are accumulated in the general overhead cost. The WIP cost is calculated by accumulating the opportunity cost of interest lost per order. Money invested in Anglovaal earns on average 18.5% interest, and therefore WIP incurs a considerable cost to Puma Jersey and has to be included in the equation.

The DYNAMO model used to simulate the "sales loop", "production loop", and the "profit loop" simultaneously is shown in *Appendix 6.5*. The computer program shown in the appendix was used to verify the model.

### 6.4.2 VERIFYING THE MODEL

The DYNAMO model was verified by corresponding the rate of orders into the system with the actual weekly orders into the system from June to August. The resulting production output from the model and the actual output is shown in *Graph 6.5*.




*GRAPH 6.5*

The correlation is satisfactory for the purposes of this investigation. The model can now be used to analyze different scenarios.

to June 1992. The lead time and late deliveries experienced was 7 weeks and 2.1 weeks late respectively. This relates closely to the simulated model shown in *Diagram 6.5* below.

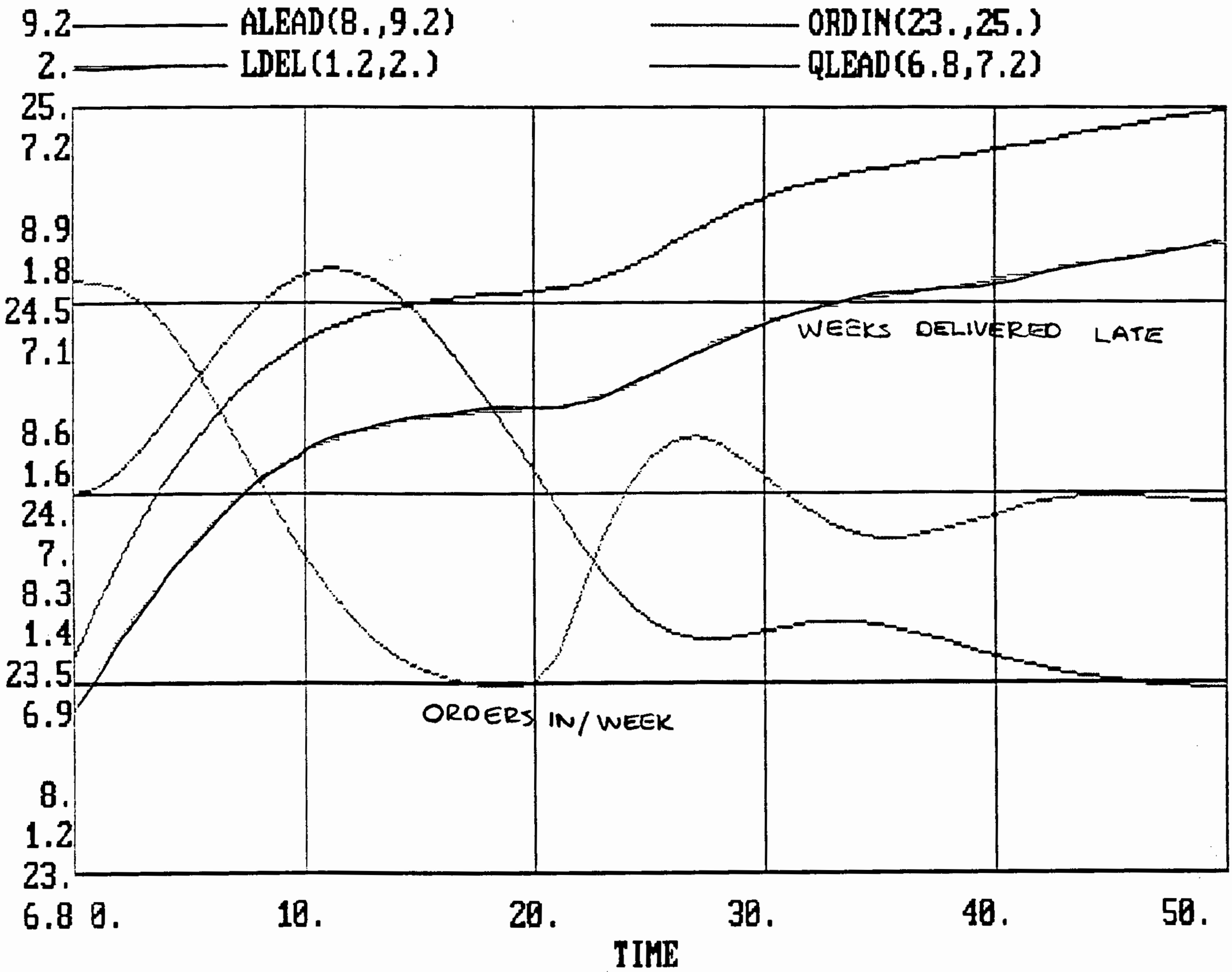



*DIAGRAM 6.5*
*DYNAMO OUTPUT WITH 0% STEP INCREASE IN DEMAND*

It is evident from *Table 6.1* that the average time of a late delivery decreases as the lead time decreases. This su$bstantiates the discussion in *Section 2.1* and *Section 2.2*. The transition from working 4 days per week to 5 days per week should be made at a 15% increase in demand to maximize profits. When the demand exceeds a 40% increase, which is equivalent to 33.6 orders per week, the production capacity must be increased by increasing from 5 working days per week to 6 working days per week.

The accumulated profits after 50 weeks, as shown in *Table 6.1*, are used as the criterion to determine the transition in working days. Accumulated profit takes a global perspective on long term benefits and disregards the short term benefits. The profit generated in the short term can be a misleading measurement as shown in *Diagram 6.6* below, which shows the profits made per week for a 0% and 20% step change in demand with 4 working days. From 0 to 8 weeks the 0% step change generates greater profits per week than the 20% step change. However the accumulated profits show the opposite as shown in *Table 6.1*.

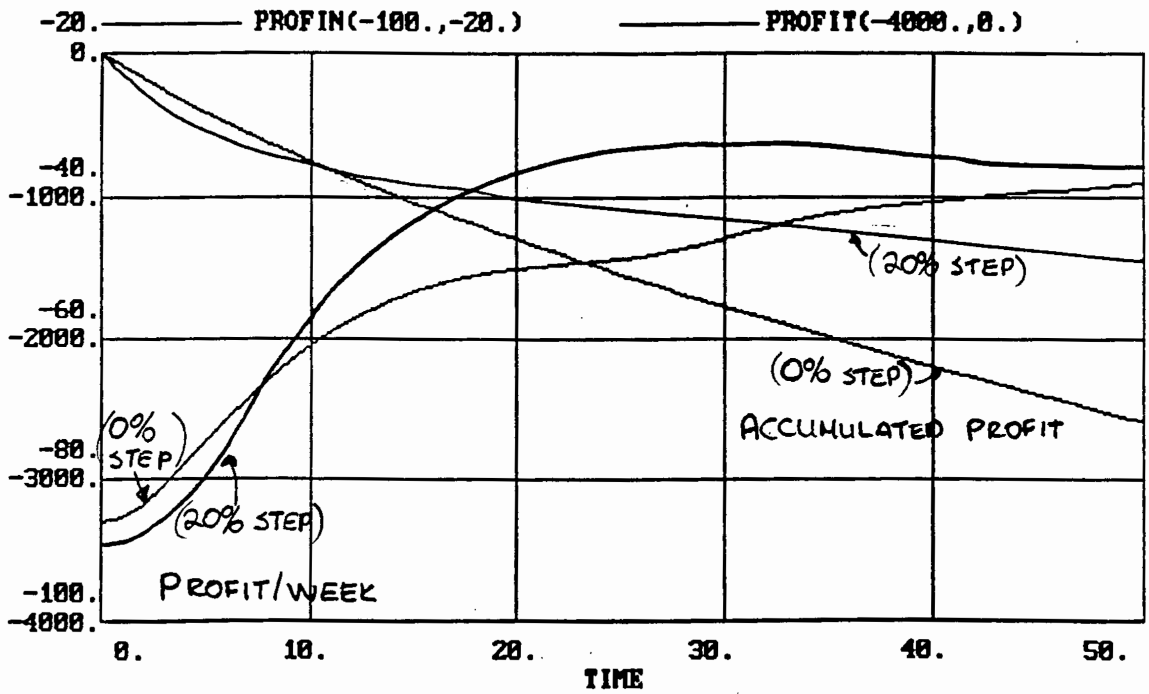



*DIAGRAM 6.6*
*DYNAMO OUTPUT OF PROFIT GENERATED WITH 0% AND 20% STEP INCREASE IN DEMAND*

### 6.4.4 PULSE CHANGE IN DEMAND

A pulse change in demand is applied to the model to determine the resulting behavior of a single large change in order demand experienced in an individual week. For this model no overtime to the scheduled capacity is implemented to determine the systems behavior without capacity compensation. The equilibrium state reached after 50 weeks for the different scenarios are shown below in *Table 6.2*. The systems output is described in *Appendix 6.7*.

| ORDERS PER WEEK AT TIME 2 | PERCENT INCREASE IN PULSE | WORKING DAYS PER WEEK | QUOTED LEAD TIME AT TIME 50 | MAXIMUM QUOTED LEAD TIME | TIME OF LATE DELIVERY AT TIME 50 | ORDERS PER WEEK AT TIME 50 | PROFIT x R1000 AT TIME 50 |
|---|---|---|---|---|---|---|---|
| 25.2 | 5 | 4 | 6.9 | 7.15 | 1.84 | 24 | -2450 |
| 26.4 | 10 | 4 | 6.9 | 7.19 | 1.84 | 24 | -2470 |
| 27.6 | 15 | 4 | 6.9 | 7.22 | 1.84 | 24 | -2490 |
| 28.8 | 20 | 4 | 6.9 | 7.27 | 1.83 | 24 | -2510 |
| 25 | 30 | 4 | 6.9 | 7.34 | 1.83 | 24 | -2530 |
| 33.6 | 40 | 4 | 6.9 | 7.42 | 1.83 | 24 | -2540 |
| 36 | 50 | 4 | 6.9 | 7.5 | 1.83 | 24 | -2550 |

*TABLE 6.2*
*DYNAMO MODEL OUTPUT OF PULSE CHANGE IN DEMAND*

It is evident from this table that the larger the increase in orders the less the accumulated profit increases. The quoted lead time is not effected proportionally to the pulse increase in orders. A 45% increase in orders only results in a 5% increase in the maximum quoted lead time. *Appendix 6.7* shows that a pulse increase in orders will be followed by an increase in late deliveries almost immediately, with a gradual increase in the quoted lead time that reaches a maximum value 8 weeks after the pulse increase. Quoted lead time increases after an increase in order intake to compensate for the WIP. This in turn reduces the rate of orders into the system which reduces the quoted lead time. A decrease in orders will follow immediately after a pulse increase in orders. The rate of orders into the system will stabilize after approximately 25 weeks.

### 6.4.5 INCREASING DYE HOUSE CAPACITY

The dye house capacity can be increased by 5% by implementing the system described in *Appendix 6.8*. The effect of increasing the dye house capacity on the overall performance is determined by simulating the behavior. The model simulated is based on the market and production conditions at the time of implementation. The market conditions were 24 orders per week and Puma Jersey produced at 4 working days per week.

The dye house is the global bottleneck of the system because the dye house has an inferior design capacity to all the other processes in the system. The knitting capacity will also increase to accommodate for the increase in dyeing capacity without introducing overtime. The output of the simulation is shown in *Diagram 6.7* below.

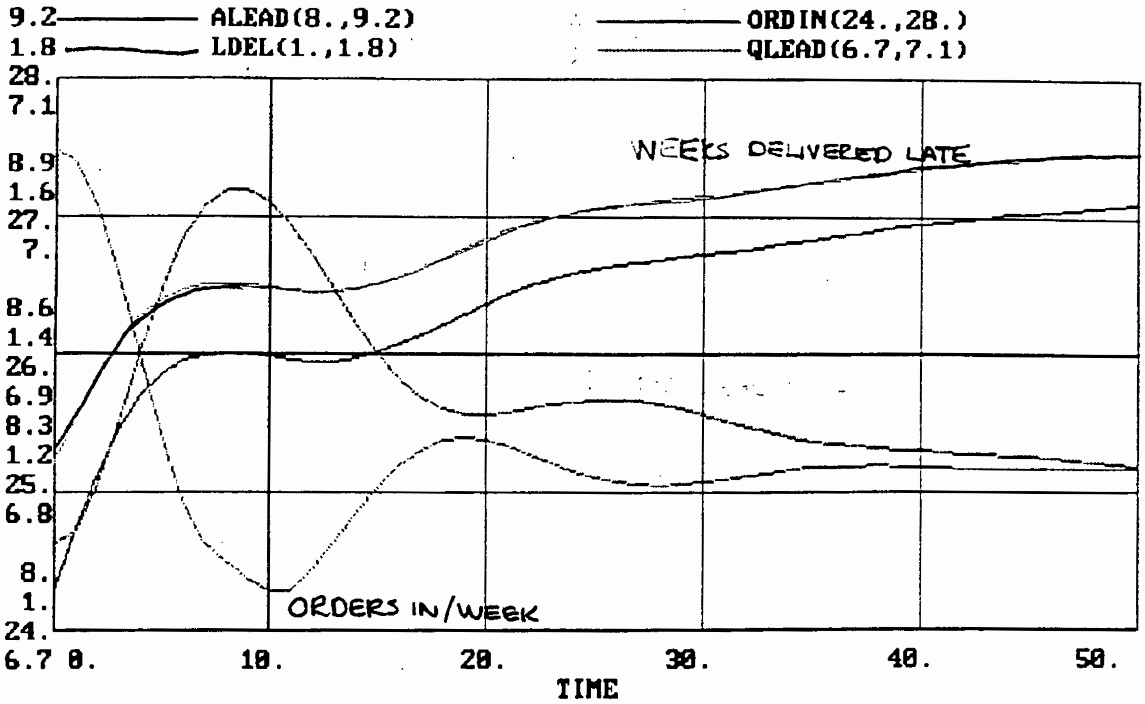



*DIAGRAM 6.7*
*DYNAMO OUTPUT WITH A 5% INCREASE IN DYE HOUSE CAPACITY*

A sudden increase in orders will be followed by a gradual decrease in orders that will stabilize at 25 orders per week, which is a 4% increase in orders. The quoted lead time will increase for 20 weeks and will then reach an equilibrium point of 6.8 weeks. The late deliveries will reduce by 9% as a result of an increase in dye house capacity. It is therefore evident that late deliveries are sensitive to the dye house capacity. The accumulated profit made will increase by 5% as a result of an 5% increase in dye house capacity.

### 6.4.6 REDUCING CYCLE TIME FROM DYEING TO FINISHED GOODS

Systems dynamics was used to reduce the cycle time from dyeing to finished goods, and systems dynamics was also used to analyze the effect that this would have on the entire system developed in *Section 6.4.1*. Both analyses were carried out with the 5% extra dye house capacity discussed in *Section 6.4.5*.

#### 6.4.6.1 Reducing the cycle time from dyeing to finished goods using systems dynamics

*Section 6.3* discussed the necessity of using systems dynamics to implement synchronous manufacturing techniques to reduce the cycle time from dyeing to finished goods, because the nature of work flow makes it too complex to manually forecast bottlenecks. The flow of products through the dye house, finishing, perching and rolling functions are analyzed using a separate *DYNAMO* model from the model developed in *Section 6.4.1* in order to accommodate the flow of product type.

The model described in *Section 6.4.1* analyzes the flow of orders through the system and disregards the type of products in the order. The flow of product type is analyzed because the machines demonstrate different capacities for different product types, and different product types follow different routes. A route is the machine processes and the sequence that these processes are performed for a particular product type from dyeing to perching. The different routes followed by the different product types is shown in *Appendix 6.3* .

*Appendix 6.3* also shows the effect that product mix has on the dye house and finishing capacities. Therefore the product mix largely determines the cycle time form dye house to despatch.

Simulating the flow of products through the dye house, finishing and perching is necessary to identify bottlenecks in advance. Once possible bottlenecks have been identified in advance, the bottlenecks can be eliminated or alleviated by:-

1. Controlling the product flow
2. Implementing overtime
3. Increasing machine capacities

The systems dynamic model works in a similar way to queueing theory. Rate variables represent the machine capacities and level variables represent the queues behind the machines. The capacity for each individual machine is calculated as follows:-

$$\sum_{i=n}^{i=1} \frac{\text{MACHINE CAPACITY FOR PRODUCT } i}{(\text{HOURS OF PRODUCT } i \text{ IN QUEUE}) * (\text{TOTAL HOURS IN QUEUE})}$$

The queue behind a particular machine is calculated as follows:-

$$\sum_{i=n}^{i=1} \textit{MACHINE CAPACITY FOR PRODUCT } i)*(\text{METERS } \textit{OF PRODUCT } i)$$

Different product types undergo different routes, therefore a complex network of product flows results. The *DYNAMO* model for the simulation of product flow is shown in *Appendix 6.9*. Output from this model is also shown in *Appendix 6.9*. This model is used daily on the shop floor and has been verified to be more than 90% accurate. The reason for the 10% inaccuracy is due to the sequencing of jobs (ie product types) in the queue. The jobs are not processed according to FIFO, but are processed randomly

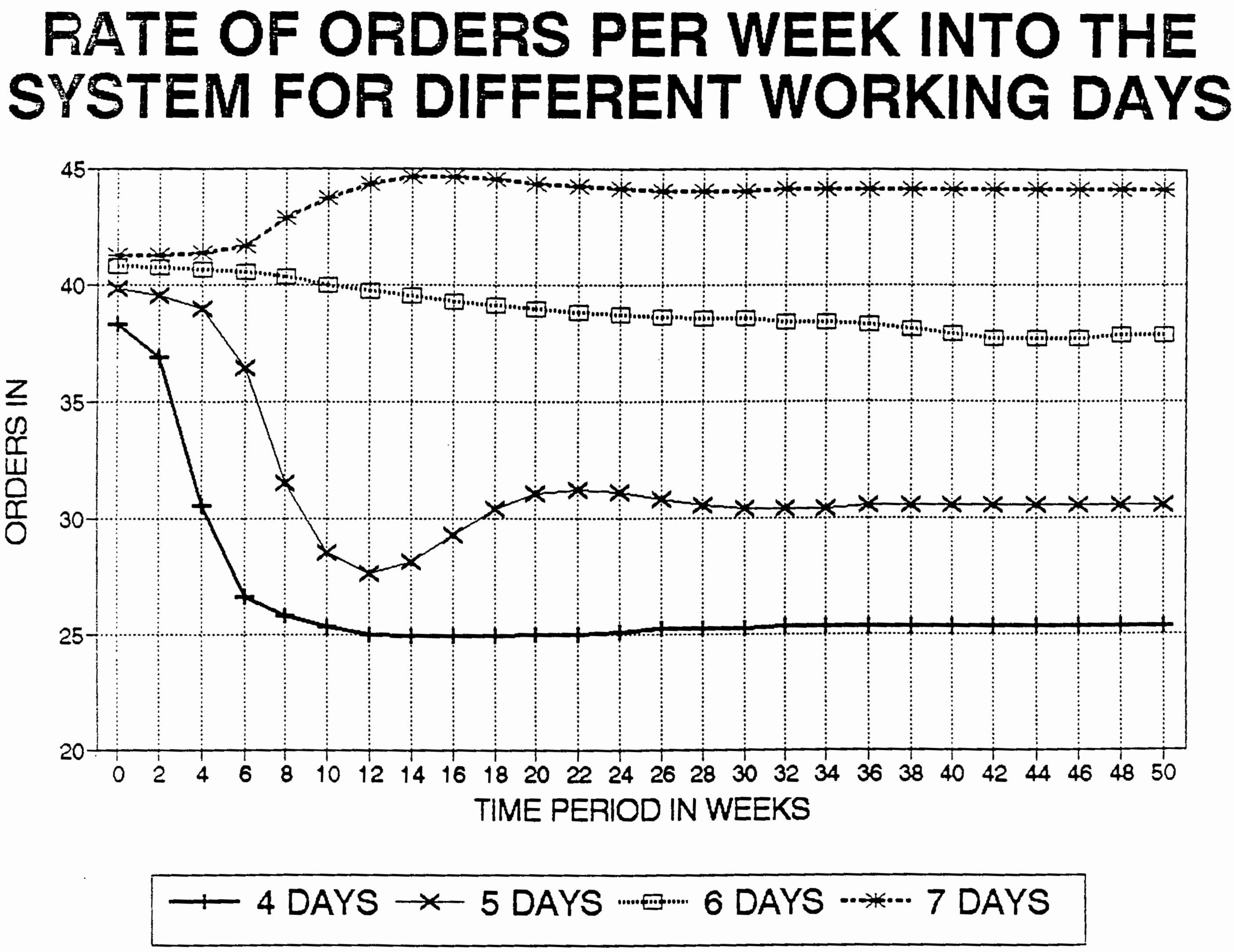
#### 6.4.6.2 Global effect of reduced dyeing to finished goods cycle times

The cycle time from dyeing till the finished goods is on average 3.1 weeks. This cycle time was reduced to 1.8 weeks. The model simulated includes the 5% increase in the dye house capacity and was run for a 4, 5, 6 and 7 day working week. The effect that this reduction in cycle time has on the entire system is summarized in *Table 6.3* below. The output of the simulation can be found in *Appendix 6.10*.

| WORKING DAYS | ORDERS IN AT TIME 50 | QUOTED LEAD TIME AT TIME 50 | LATE DELIVERIES AT TIME 50 | ACCUMULATED PROFIT x R1000 AT TIME 50 |
|---|---|---|---|---|
| 4 | 25 | 7.8 | 0.7 | 650 |
| 5 | 30 | 6.7 | 0.37 | 8640 |
| 6 | 38 | 6 | 0.13 | 10350 |
| 7 | 44 | 3.8 | 0 | 8130 |

*TABLE 6.3*
*DYNAMO MODEL OUTPUT OF REDUCTION IN CYCLE TIME FROM DYEING TO FINISHED GOODS*

The optimum number of working days that will lead to the greatest accumulated profit after 50 weeks is 6 working days per week. Puma Jersey is also presently operating at 6 days per week. Puma Jersey determines the number of working days by determining the demand on the system. The initial demand resulting from the increased dye house capacity and reduced cycle times is 40 orders per week. *Graph 6.6* shows that this demand can be maintained at 6 working days per week. Therefore the system is self regulating in that the demand will determine the required capacity, and therefore the number of working days required for optimal performance. Reducing lead times by implementing excess production capacity is counter productive because the accumulated profit decreases.




*GRAPH 6.6*

The corresponding lead time and delivery performance resulting from the decreased cycle time will be 6 weeks and 0.13 weeks respectively with a 6 day working week. These are approximately the present lead times and late deliveries experienced by Puma Jersey.

### 6.4.7 REDUCING THE QUOTED CYCLE TIME FROM DYEING TO FINISHED GOODS

The quoted lead time of an order is determined by 3 variables, namely:-

1) Time taken to knit the entire order
2) Time taken to dye the entire order
3) Time taken from dyeing till completion of the order

The policy is to quote 2 weeks for the time taken from dyeing to completion as explained in the "production loop". The systems dynamic model was used to determine an optimal quoted cycle time. A DYNAMO model with the 5% increase in dye house capacity and average cycle time of 1.8 weeks from dyeing to finished goods was used to determine the quoted cycle time that would generate the most profits in the long term. The results of the simulation are shown in *Table 6.4* below.

| QUOTED CYCLE TIME | ORDERS PER WEEK AT TIME 50 | QUOTED LEAD TIME AT TIME 50 | LATE DELIVERIES AT TIME 50 | ACCUMULATED PROFIT x R1000 AT TIME 50 |
|---|---|---|---|---|
| 2 | 38 | 6 | 0.13 | 10350 |
| 1.5 | 39.1 | 5.6 | 0.54 | 12540 |
| 1 | 37.8 | 5.1 | 1.86 | 9360 |

*TABLE 6.4*
*DYNAMO MODEL OUTPUT OF REDUCTION IN QUOTED CYCLE TIME FROM DYEING TO FINISHED GOODS*

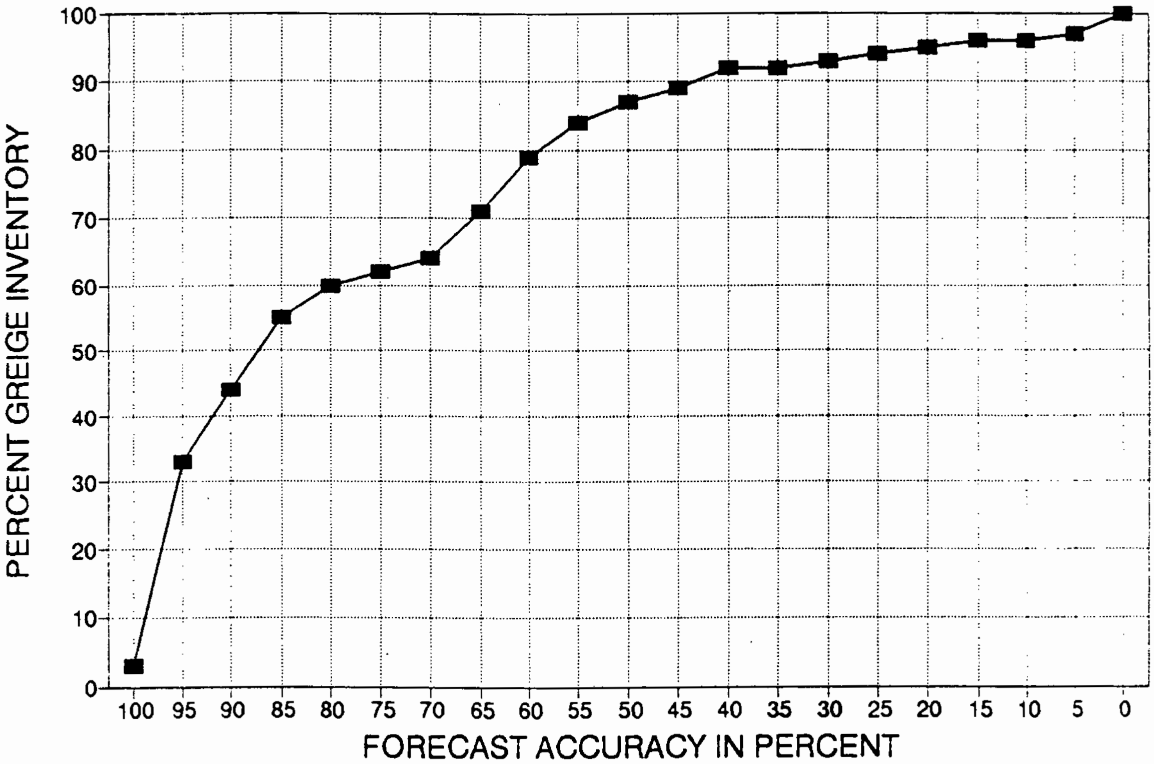
It can be seen that quoting a 1.5 week cycle time from dyeing to completion of the order is the optimum cycle time.

### 6.4.8 CARRYING GREIGE INVENTORY

If Puma Jersey knits greige to stock, and not to order as was done in the past, then the lead time for an order would be equal to the cycle time from dyeing to finished goods. A lead time of less than 3 weeks would make Puma Jersey more competitive than all the local competitors. In addition to the reduced lead time, the knitting department will increase its capacity by approximately 11% because fewer set-ups will have to be carried out. However, it is not possible to carry inventory of all the qualities of greige because some qualities are ordered very seldom. Systems dynamics will be used to determine the level of greige inventory that must be carried to optimize profitability.

An analysis was done on all the qualities of greige produced by Puma Jersey in 1991 and 1992. The monthly demand for these 313 qualities was obtained from historical data. A seasonal forecasting algorithm was applied to all these qualities to determine if a trend existed in the monthly demand of these qualities. *Appendix 6.11* shows the percentage of greige production that showed a correlation between the forecasted demand and actual demand for different weighting functions in the forecasting algorithm. This correlation is determined after a 4 month period. *Graph 6.7* shows the maximum percentage of greige that can be carried in stock with the corresponding forecasting accuracy associated with this inventory level.

# PERCENT GREIGE INVENTORY CARRIED WITH CORRESPONDING FORECASTING ACCURACY




GRAPH *6.7*

A DYNAMO model with the 5% increase in dye house capacity and average cycle time of 1.8 weeks from dyeing to finished goods was used to determine the level of greige inventory and production capacity required to maximize the accumulated profit generated. The output of the simulation can be found in *Appendix 6.12*. The results of the simulation are summarized in *Table 6.5* below.

| PERCENT GREIGE INVENTORY | WORKING DAYS PER WEEK | ORDERS PER WEEK AT TIME 50 | QUOTED LEAD TIME AT TIME 50 | LATE DELIVERIES AT TIME 50 | ACCUMULATED PROFIT x R1000 AT TIME 50 |
|---|---|---|---|---|---|
| 0 | 6 | 37.4 | 6 | 0.13 | 10350 |
| 33 | 6 | 37.3 | 5.8 | 0.13 | 15670 |
| 44 | 6 | 37.8 | 5.7 | 0.13 | 14230 |
| 55 | 6 | 37.5 | 5.1 | 0.13 | 8750 |
| 0 | 7 | 43.2 | 3.8 | 0 | 8130 |
| 33 | 7 | 43.6 | 3.73 | 0.14 | 13290 |
| 44 | 7 | 43.6 | 3.68 | 0.14 | 17110 |
| 55 | 7 | 43.8 | 3.6 | 0.14 | 18730 |
| 60 | 7 | 43.7 | 3.5 | 0.14 | 12560 |

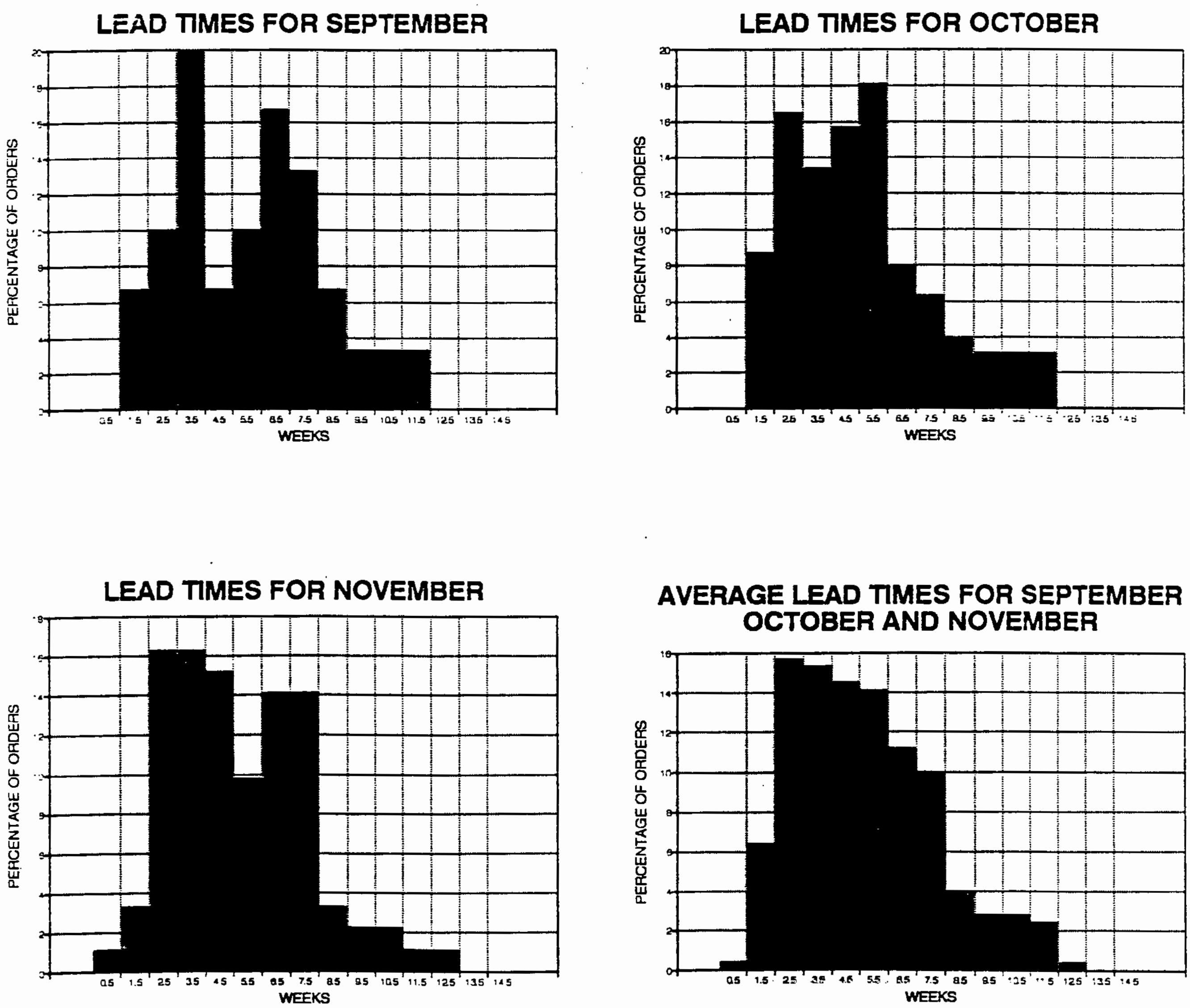
*TABLE 6.5*
*DYNAMO MODEL OUTPUT OF CARRYING GREIGE INVENTORY*

It is evident from the simulation that it is profitable to carry greige inventory because the accumulated profit is greater when greige is held in stock compared to when greige is knitted to order. The maximum profits will be gained if Puma Jersey knits 44% of its greige to stock with production working 7 days per week. If Puma Jersey works a 6 day week the average quoted lead time will increase gradually from approximately 4.3 weeks because the production capacity is too low to accommodate for the increase in orders resulting from the decreased lead times. The greige stock will be depleted gradually as a result of the increase in orders. Late deliveries are not effected by carrying greige inventory.

# 7. RESULTS

The results of implementing performance measurements, CEDAC, synchronous manufacturing and systems dynamics, with the aid of systems thinking, is analyzed in this section. The results directly relate to improvements in lead time and delivery performance.

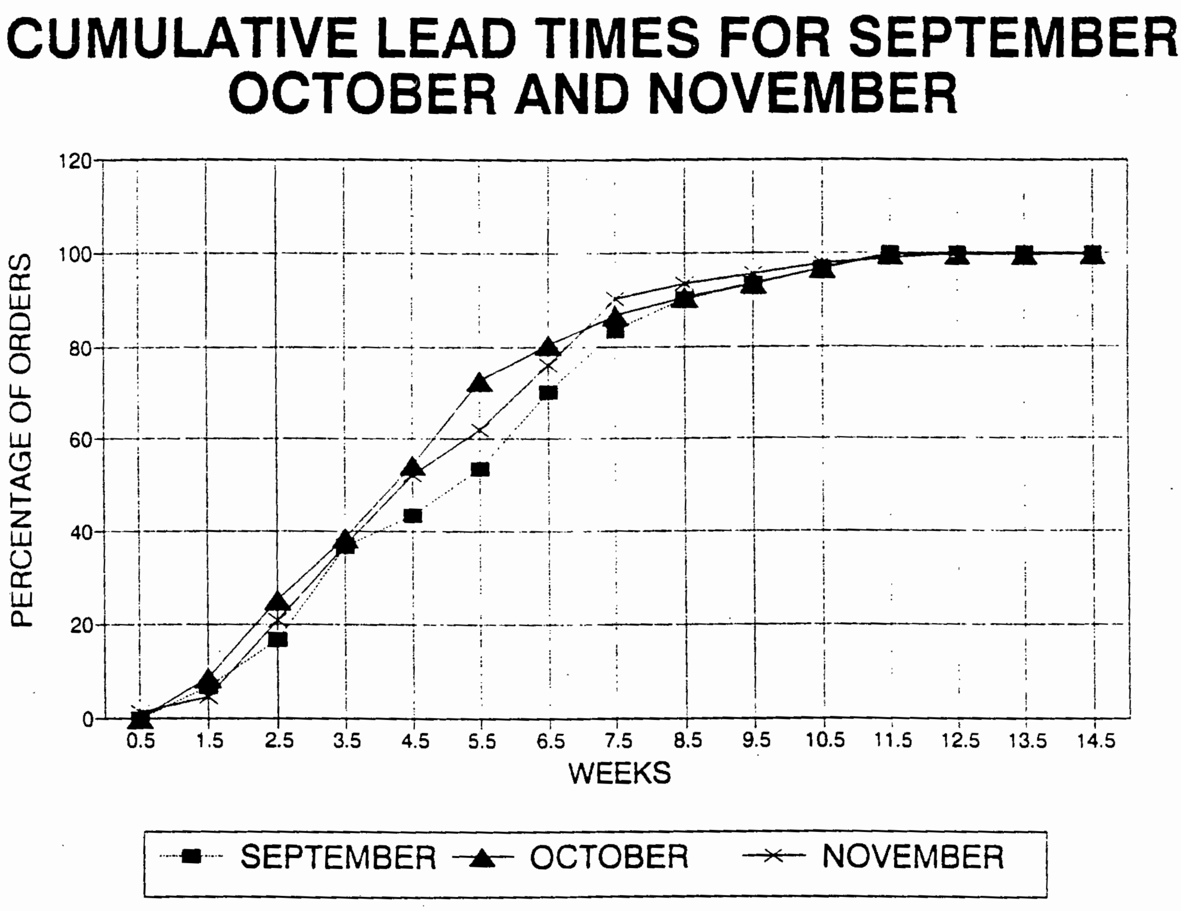
## 7.1 LEAD TIMES




*GRAPH 7.1*

The lead time performance for the period from September to November are shown in *Graph 7.1*. The average lead time experienced from September to November is 5.1 weeks.

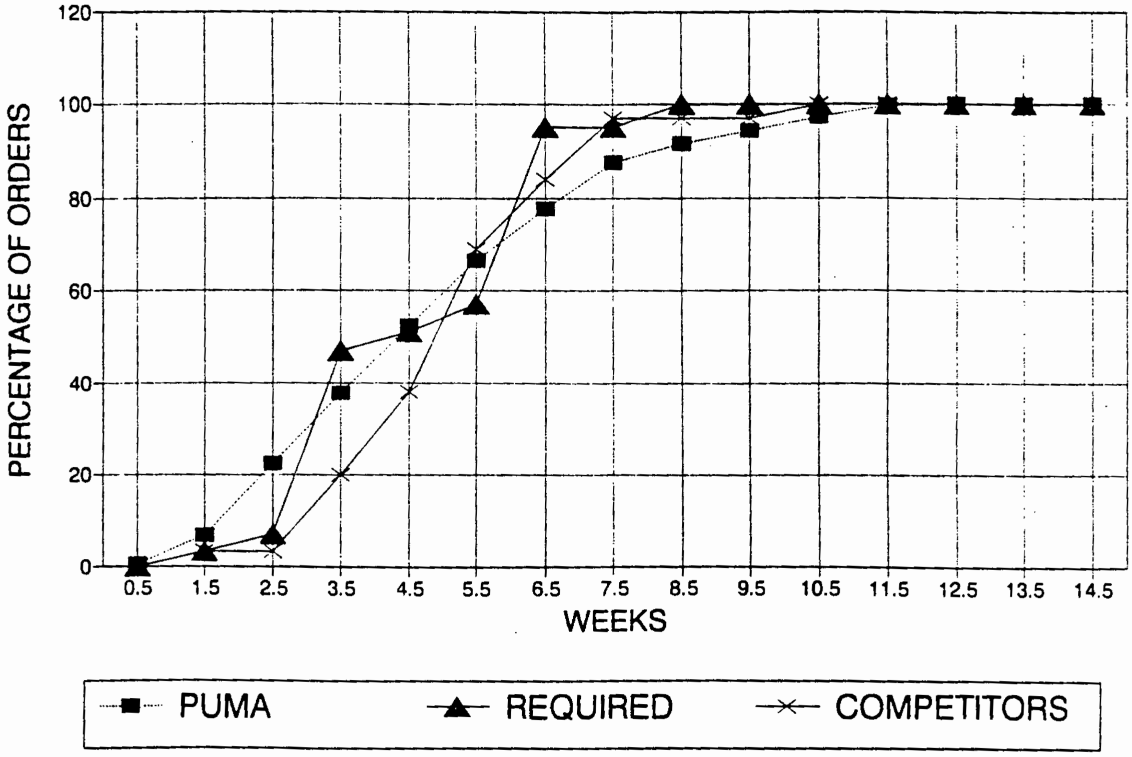
The performances are difficult to compare in isolation, therefore *Graph 7.2* shows the cumulative percentage of orders delivered before the indicated lead times for September, October and November. It is evident from this graph that the lead times are still improving.




*GRAPH 7.2*

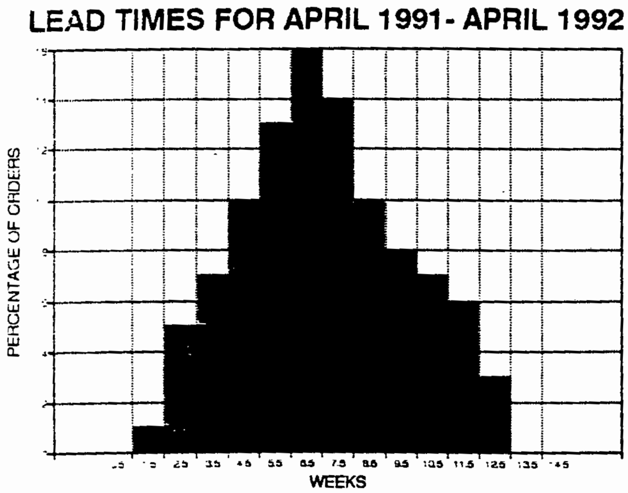
Graph 7.3 shows the percentages of orders delivered before the indicated lead times for the competitors, the customers required lead time and Puma Jerseys average lead time from September to November. This graph is similar to *Graph 4.4* except that Puma Jerseys performance after the improvements were implemented is shown. It is evident from this graph that Puma Jersey is performing marginally better than its competitors and the customer required performance. However, further reduction in lead times are still necessary to gain a substantial competitive advantage, especially in the 6.5+ week range. The competitors average lead time of 5.4 weeks is larger than that of Puma Jersey, but the average customer required lead time of 5 weeks is less than Puma Jerseys average demonstrated lead time of 5.1 weeks.

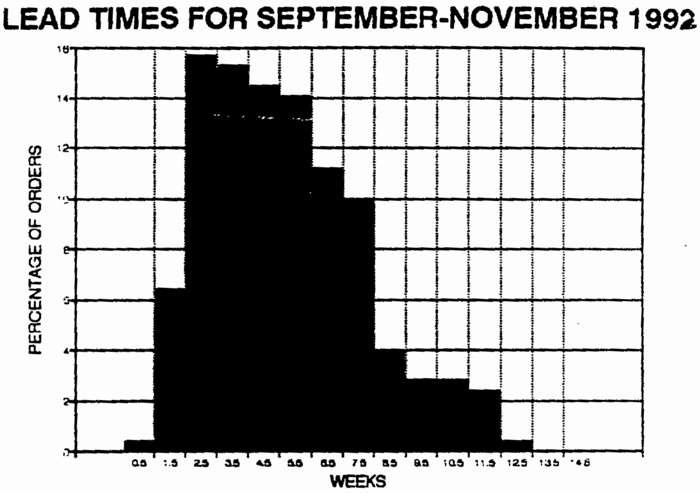
**COMPETITORS VS REQUIRED VS PUMA JERSEYS CUMULATIVE LEAD TIMES**

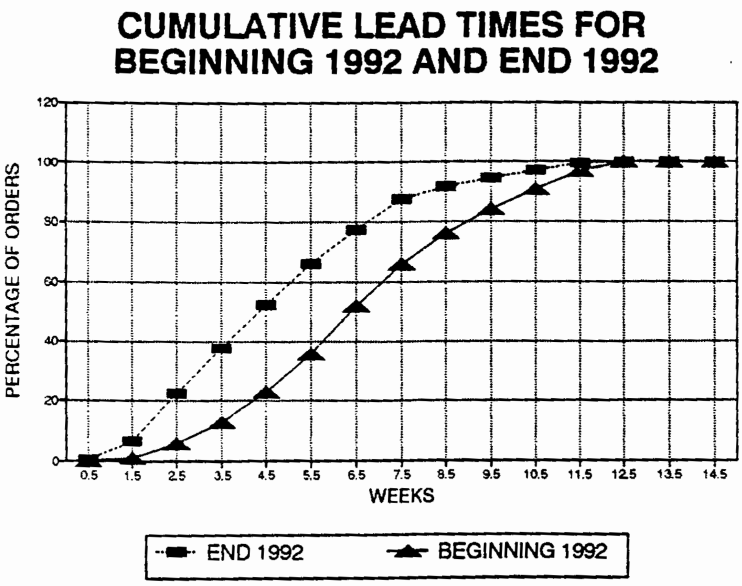



*GRAPH 7.3*

*Graph 7.4* shows the improvements in lead times attained in the period from April to September. A comparison of cumulative orders delivered before the indicated lead times is also shown. The average lead time improved by an average of 30% from 7.1 weeks to 5.1 weeks.



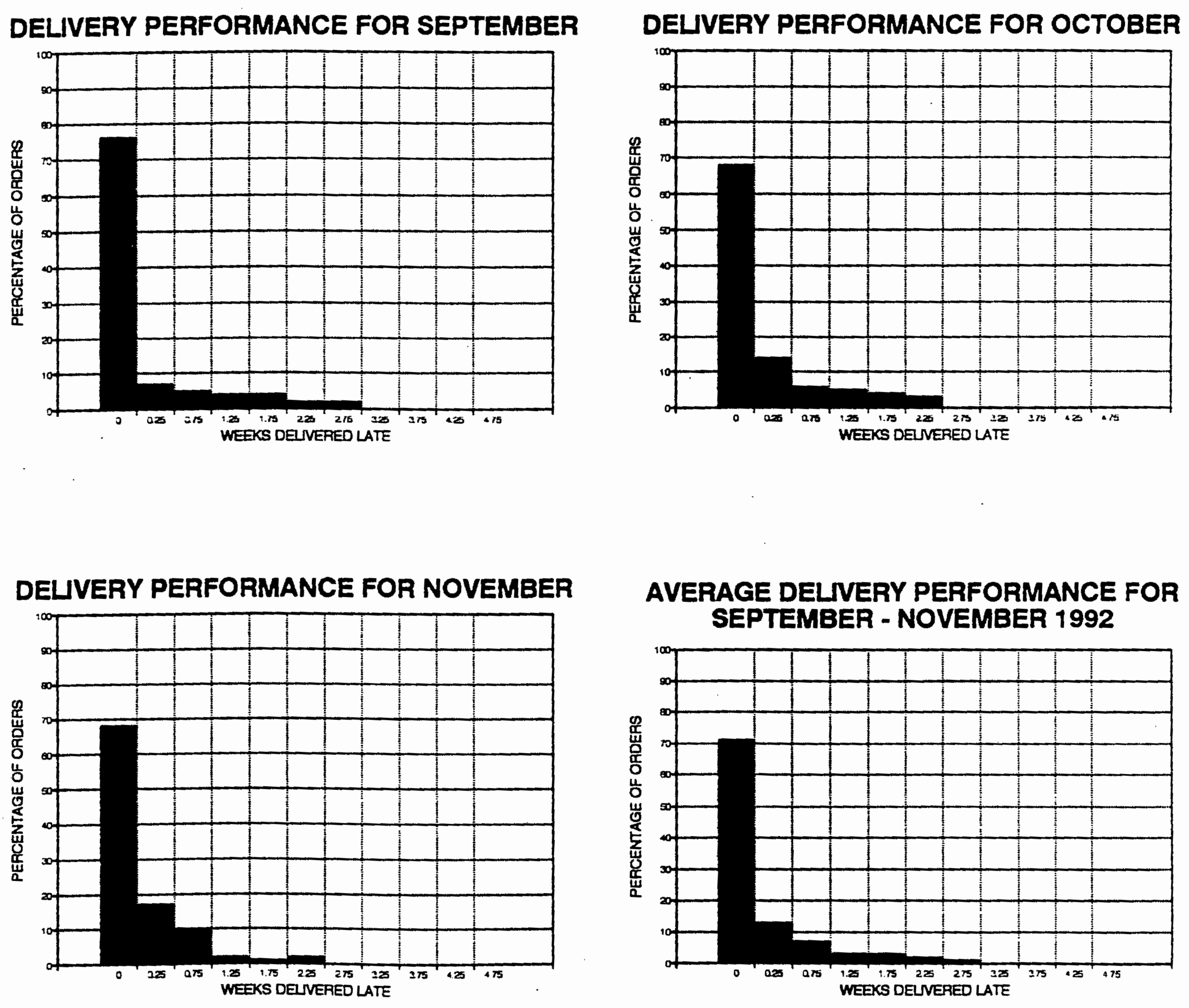




*GRAPH 7.4*

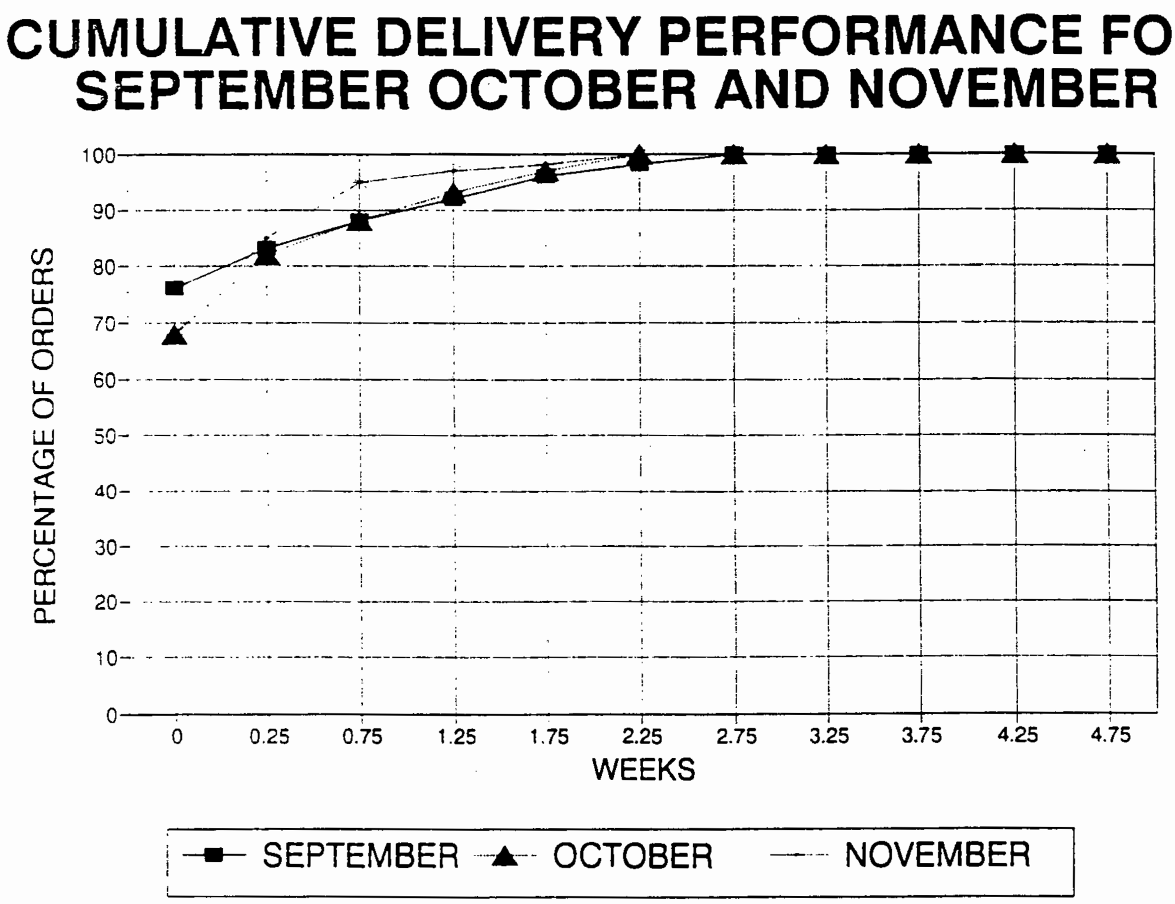
## 7.2 DELIVERY PERFORMANCE

The delivery performance for the period from September to November are shown in *Graph 7.5*. Puma Jersey delivered on average 70% of its orders on time. The late deliveries from September to November were delivered on average 0.8 weeks late.



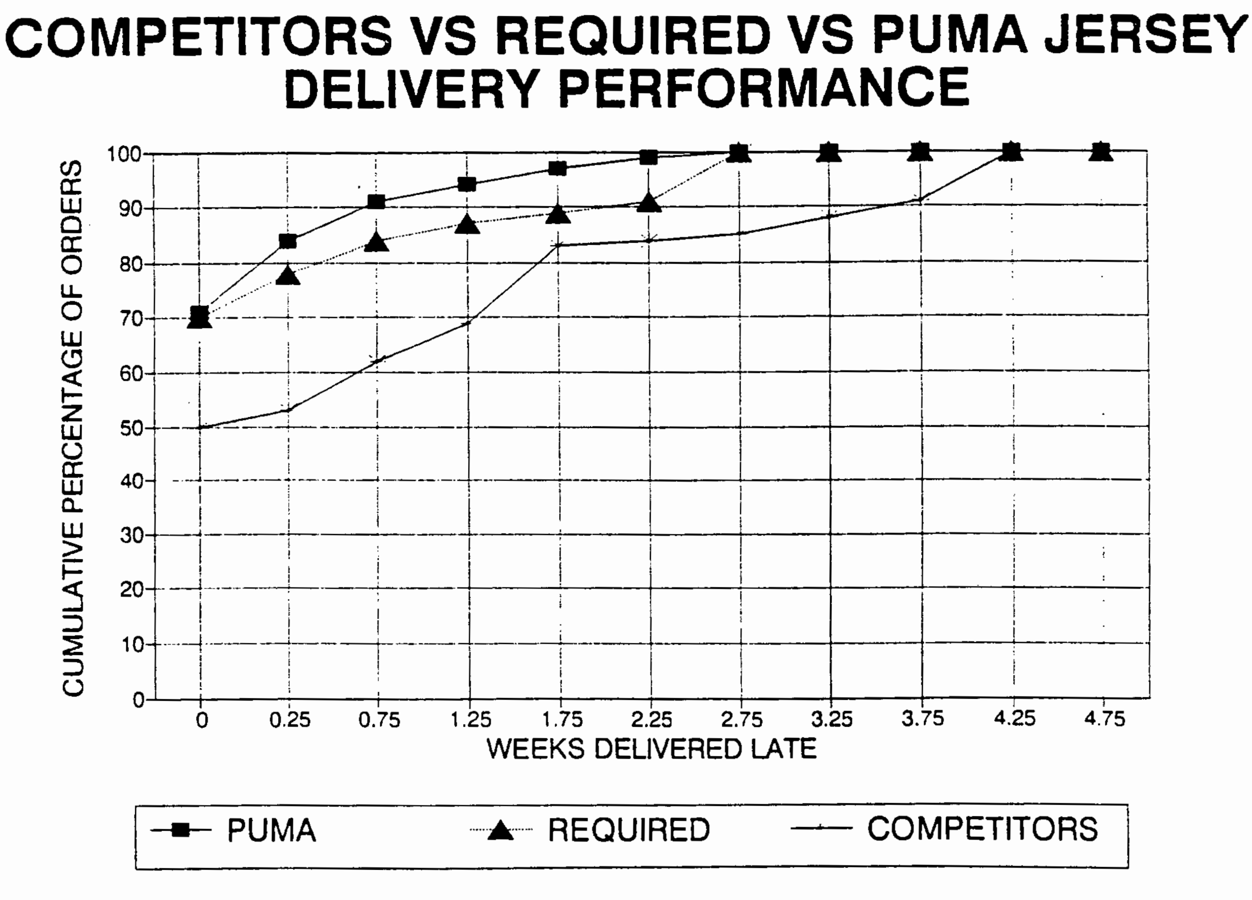

*GRAPH 7.5*

The performances are difficult to compare in isolation, therefore *Graph 7.6* shows the cumulative percentage of orders delivered before the indicated times after the confirmed delivery date for September, October and November. It is evident from this graph that there is not much variability in the monthly performances.



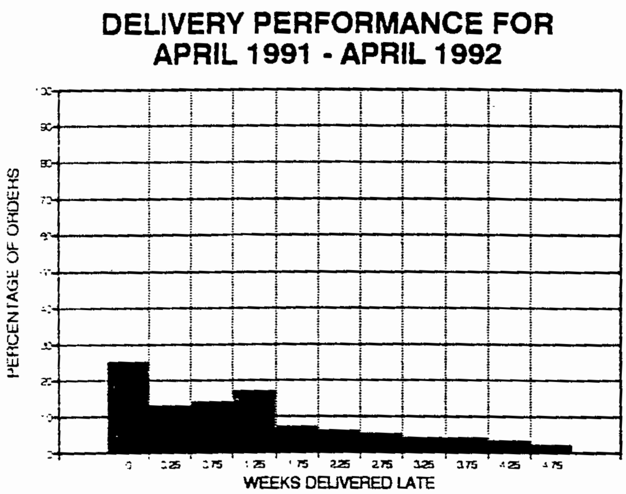

*GRAPH 7.6*

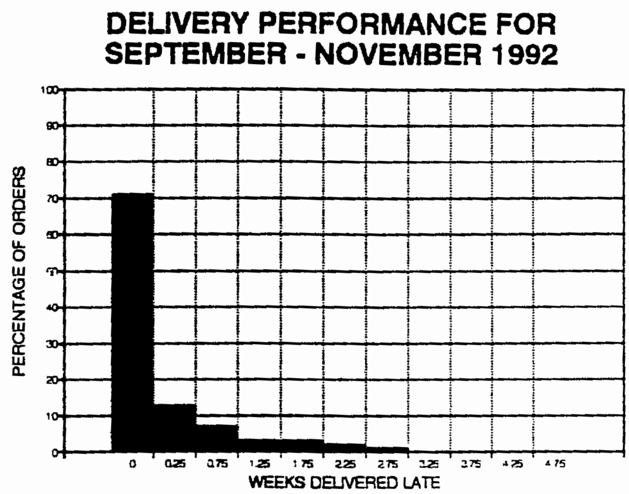
Graph 7.7 shows the cumulative percentage of orders delivered before the indicated times after the confirmed delivery by the competitors, and that required by the customers, and Puma Jerseys average delivery performance from September to November. This graph is similar to *Graph 4.11* except that Puma Jerseys performance after the improvements were implemented is shown. It is evident from this graph that Puma Jersey is performing substantially better than its competitors and the customer required performance. However, a further reduction in late deliveries is still necessary because any order delivered later than 0.75 weeks causes a considerable inconvenience to the customer.

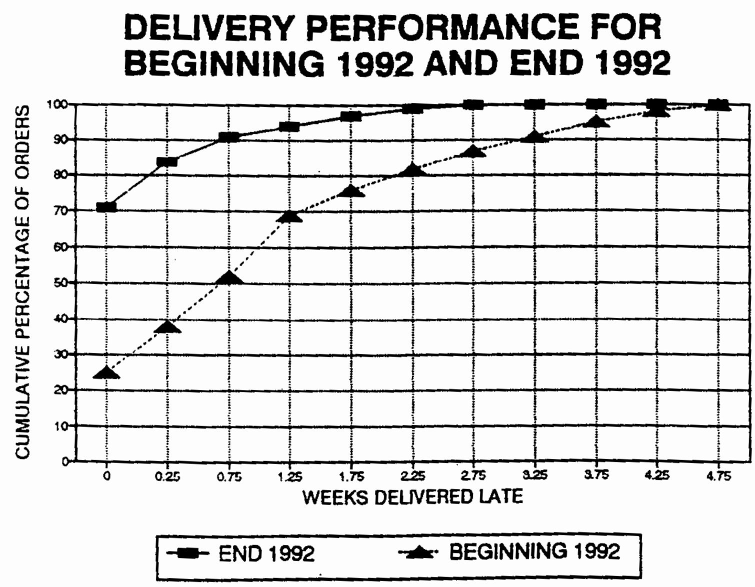



*GRAPH 7.7*

*Graph 7.8* shows the improvements in delivery performance attained in the period from April to September. A comparison of cumulative orders delivered within the indicated times after the confirmed delivery is also shown. On-time deliveries improved by 55%, and the average time for a late delivery improved by an average of 50% from 1.6 weeks to 0.8 weeks.




*GRAPH 7.8*

# 8. CONCLUSIONS

Performance measurements, CEDAC, synchronous manufacturing and systems dynamics are effective in attaining sustainable increases in lead time and delivery performance at Puma Jersey.

Performance measurements, CEDAC, synchronous manufacturing and systems dynamics are systemically compatible approaches.

Systems thinking is the single most important methodology used to develop compatibility between performance measurements, CEDAC, synchronous manufacturing and systems dynamics.

Systems thinking methodology is vital in developing and implementing performance measurements, CEDAC, synchronous manufacturing and systems dynamics.

## 8.1 PERFORMANCE MEASUREMENTS

Performance measurements has been the single most necessary tool in achieving the improved lead time and delivery performance.

Determining the global objective is paramount in developing appropriate performance measurements.

The most important performance measurements are those controlling throughput, namely lead time, delivery performance, quality and price.

## 8.2 CEDAC

CEDAC requires absolute consistency and compatibility with the performance measurements that management appraises and judges performance with.

Shop floor participation with CEDAC requires total management commitment and complete understanding of the CEDAC system. Therefore CEDAC requires time to be utilized to its full potential.

CEDAC's implementation is relatively quick with positive response from management as a management tool to display performance measurements in an intelligible way.

CEDAC is an effective technique to communicate performance measurements and set performance targets.

It is possible to determine systems behavior with the aid of CEDAC.

## 8.3 SYNCHRONOUS MANUFACTURING

Synchronous manufacturing has to be compatible and consistent with the performance measurements monitored for successful application.

Theory of constraints principals have considerable potential for improvement in lead times in a batch processing environment where typical of textile manufacturing firms.

The effectiveness of theory of constraints decreases as the percentage processing time of the total lead time increases.

The drum-buffer-rope system has limited application in a textile manufacturing environment where bottlenecks are changing daily.

Synchronous manufacturing is a disciplined approach to understanding work flow.

## 8.4 SYSTEMS DYNAMICS

The successful application of systems dynamics requires compatibility with performance measurements. Systems dynamics substantiates the necessity of global performance measurements as a vehicle for decision making.

Systems dynamics demonstrated the importance of sustainable improvement. Systems dynamics showed that a systems behavior that is inferior in the short term can lead to superior performance in the long term.

Systems dynamics was found to be an insidious tool to understand the underlying reasons for systems behavior. Systems dynamics does not necessarily give any final answers or solutions but gives insight into problematical situations and assists in creative problem solving.

In the model building phase systems dynamics was a disciplined method of systematically analyzing the variables controlling the plant performance. It forced an understanding and analysis of policies and systems that determines the production plants behavior.

Systems dynamics is useful for identifying high leverage points. The knitting operation was identified as a high leverage point for decreasing lead times. Dyeing, finishing and perching operations is the high leverage point for improving delivery performance.

Systems dynamics was useful to identify areas where synchronous manufacturing principals could be applied.

Systems dynamics is an ideal tool to model queueing theory which is necessary for implementing the synchronous manufacturing approach. Systems dynamics is a useful tool to analyze the effectiveness of increasing machine capacities and changing work flows.

# 9. RECOMMENDATIONS

Lead times must be decreased to 4 weeks. More accurate forecasting of greige demand should be implemented to reduce lead times.

Orders delivered late by more than 5 days should be avoided. This can be achieved by implementing a quick response system for potential late deliveries.

Not necessary to improve process and set up times in the dye house and finishing departments. The large queue and wait times indicate that there is potential for scheduling techniques to reduce the lead times.

Opportunity to become a JIT supplier if a delivery performance of 95% can be attained. This will hold potential benefits because the lead time to the clothing retail store can be improved by up to 40%.

A person in a management position should be able to develop systems dynamics models to analyze the effectiveness of policy deployment and decisions.

Shop floor training is required to further increase delivery and lead time performance. This will also lead to increased involvement and participation in the CEDAC technique.

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# APPENDIX 1.1

# INTERNATIONAL COMPETITIVENESS INDICATORS

## *COMPETITIVENESS INDICATORS*

| COUNTRIES | REAL GROWTH IN INDUSTRIAL PRODUCTION IN 1990: 1980=100 | REAL GROWTH IN SERVICES 1980-1989 % | REAL GROWTH IN RETAIL SALES 1985-1990 % | AGRICULTURAL PRODUCTIVITY IN 1989: US$ | GROWTH IN FOOD PRODUCTION (1979-81=100) % CHANGE 1987-89 | MANUFACTURING VALUE ADDED PER WORKER IN US$ |
|---|---|---|---|---|---|---|
| AUSTRALIA | 136.5 | 3.6 | 1.2 | 25 621 | 95.1 | 34 206 |
| AUSTRIA | 133.0 | 2.0 | -2.4 | 15 224 | 105.1 | 38 602 |
| BELGIUM | 123.0 | 1.6 | 1.9 | 29 552 | 118.6 | 48 254 |
| BRAZIL | 100.0 | 3.2 | 6.2 | 1 957 | 104.7 | 10 981 |
| CANADA | 122.0 | 3.2 | 3.8 | 25 153 | 114.6 | 44 474 |
| DENMARK | 131.0 | 1.7 | -1.0 | 26 635 | 138.4 | 31 950 |
| FINLAND | 130.0 | 3.3 | 7.6 | 26 642 | 113.7 | 49 533 |
| FRANCE | 133.0 | 2.7 | 2.7 | 23 058 | 98.8 | 46 620 |
| GERMANY | 123.0 | 3.0 | 3.8 | 18 126 | 110.5 | 42 513 |
| GREECE | 110.0 | 2.5 | 2.5 | 8 854 | 96.0 | 10 149 |
| HONG KONG | N/A | N/A | 2.2 | 5 974 | 61.0 | 12 879 |
| HUNGARY | 102.0 | 2.2 | -3.1 | 4 251 | 106.8 | 4 804 |
| INDONESIA | N/A | 6.6 | N/A | 536 | 131.6 | 2 540 |
| IRELAND | 184.0 | 3.4 | 0.4 | 20 263 | 113.6 | 4 932 |
| ITALY | 114.0 | 2.8 | 2.7 | 15 714 | 93.5 | 40 839 |
| JAPAN | 149.0 | 3.2 | 1.6 | 15 718 | 95.4 | 54 651 |
| KOREA | 302.0 | 9.1 | 12.8 | 6 338 | 88.9 | 11 616 |
| MALAYSIA | 231.0 | 3.9 | -0.8 | N/A | 158.5 | N/A |
| MEXICO | 120.0 | 2.7 | N/A | 482 | 97.3 | 15 344 |
| NETHERLANDS | 116.0 | 1.6 | 2.6 | 32 010 | 118.8 | 39 194 |
| NEW ZEALAND | N/A | 2.0 | -2.5 | 21 362 | 98.5 | 25 996 |
| NORWAY | 171.0 | 3.0 | -2.4 | 20 886 | 99.7 | 42 160 |
| PAKISTAN | N/A | 7.1 | N/A | 633 | 104.6 | 1 552 |
| PORTUGAL | 161.0 | 1.3 | 3.6 | 3 593 | 120.8 | N/A |
| SINGAPORE | N/A | 7.0 | 6.9 | 16 724 | 93.9 | 20 980 |
| SOUTH AFRICA | 102.0 | 2.5 | 2.6 | 6 149 | 84.8 | 13 316 |
| SPAIN | 120.0 | 2.1 | 8.2 | 11 364 | 114.2 | 38 738 |
| SWEDEN | 114.0 | 1.0 | 1.6 | 30 686 | 103.5 | 41 393 |
| SWITZERLAND | 122.0 | 2.3 | 0.9 | 23 437 | 103.4 | 43 387 |
| TAIWAN | 179.3 | 12.5 | 9.6 | 6 741 | 124.7 | 18 647 |
| THAILAND | N/A | 7.4 | 2.7 | 500 | 104.5 | 6 005 |
| TURKEY | 212.0 | 5.0 | 0.1 | 1 412 | 97.6 | 7 701 |
| UK | 118.0 | 4.8 | 2.2 | 18 972 | 108.5 | 26 098 |
| USA | 130.0 | 3.3 | 2.5 | 29 544 | 95.7 | 40 601 |
| VENEZUELA | N/A | 0.4 | N/A | 3 268 | 91.9 | N/A |

## *COMPETITIVENESS INDICATORS*

| COUNTRIES | GOVERNMENT EMPLOYMENT AS A % OF TOTAL EMPLOYMENT IN 1989 | MILITARY EXPENDITURE AS % OF GDP 1990 | TOTAL EXPENDITURE ON R&D AS % OF GDP 1990 | WORKING DAYS LOST PER 1 000 INHABITANTS PER YEAR IN 1990 | % OF HOUSEHOLD INCOMES GOING TO HIGHEST 20% OF HOUSEHOLDS 1988 | ILLITERACY RATE: % OF POPULATION 1990 |
|---|---|---|---|---|---|---|
| AUSTRALIA | 22.9 | 2.3 | 1.3 | 99.2 | 42.2 | 0.0 |
| AUSTRIA | 20.7 | 1.0 | 1.4 | 0.6 | N/A | 0.0 |
| BELGIUM | 31.3 | 2.4 | 1.6 | N/A | 36.0 | 0.0 |
| BRAZIL | 4.5 | 0.5 | 0.4 | 416.8 | 62.6 | 13.9 |
| CANADA | 19.4 | 2.0 | 1.4 | 131.0 | 40.2 | 0.0 |
| DENMARK | 29.8 | 2.0 | 1.5 | 18.8 | 38.6 | 0.0 |
| FINLAND | 21.9 | 1.8 | 1.9 | 36.3 | 37.6 | 0.0 |
| FRANCE | 22.8 | 3.6 | 2.4 | 9.2 | 40.8 | 0.0 |
| GERMANY | 15.5 | 2.9 | 2.8 | 0.7 | 38.7 | 0.0 |
| GREECE | N/A | 5.7 | 0.5 | 126.7 | N/A | 6.8 |
| HONG KONG | 6.8 | 0.4 | N/A | 0.4 | 47.0 | 11.9 |
| HUNGARY | 21.4 | 2.1 | 1.9 | N/A | 32.4 | 0.7 |
| INDONESIA | N/A | 1.6 | 0.2 | 3.4 | 41.3 | 23.0 |
| IRELAND | 15.0 | 1.4 | 0.8 | 74.7 | 39.4 | 0.0 |
| ITALY | 15.6 | 2.3 | 1.4 | 562.3 | 41.0 | 2.9 |
| JAPAN | 6.1 | 0.7 | 3.0 | 2.1 | 37.5 | 0.0 |
| KOREA | 4.2 | 3.9 | 1.8 | 128.7 | 45.3 | 3.7 |
| MALAYSIA | N/A | 4.6 | 0.1 | 0.7 | 51.2 | 21.6 |
| MEXICO | 6.4 | 0.3 | 0.2 | 25.3 | 57.7 | 12.7 |
| NETHERLANDS | 15.1 | 2.7 | 2.2 | 0.6 | 38.3 | 0.0 |
| NEW ZEALAND | 18.1 | 1.9 | 0.9 | 111.7 | 44.7 | 1.5 |
| NORWAY | 26.9 | 3.4 | 1.9 | 19.8 | 36.7 | 0.0 |
| PAKISTAN | N/A | 7.1 | 1.0 | 1.9 | 45.6 | 65.2 |
| PORTUGAL | 12.8 | 2.9 | 0.5 | 27.1 | 49.1 | 15.0 |
| SINGAPORE | 6.1 | 4.9 | 0.9 | 72.1 | 48.9 | 13.9 |
| SOUTH AFRICA | 29.1 | 3.8 | 0.8 | 176.5 | 59.3 | 21.8 |
| SPAIN | 13.9 | 1.9 | 0.9 | 305.1 | 40.0 | 5.0 |
| SWEDEN | 31.8 | 2.4 | 2.8 | 94.5 | 36.9 | 0.0 |
| SWITZERLAND | 10.3 | 1.6 | 2.9 | 0.1 | 44.6 | 0.0 |
| TAIWAN | 17.6 | 4.8 | 1.4 | N/A | 37.7 | 6.8 |
| THAILAND | 4.1 | 3.2 | 0.2 | 0.7 | 49.8 | 7.0 |
| TURKEY | N/A | 4.6 | 0.1 | 3.9 | 56.5 | 19.3 |
| UK | 19.9 | 4.0 | 2.3 | 64.9 | 39.5 | 0.0 |
| USA | 14.4 | 5.5 | 2.8 | 17.9 | 41.9 | 0.0 |
| VENEZUELA | N/A | 2.0 | 0.3 | 25.5 | 50.6 | 11.9 |

# APPENDIX 1.2

# UNEMPLOYMENT STATISTICS

# LABOUR PRODUCTIVITY INDICES

## TEXTILES

| YEAR | OUTPUT PVP INDEX | EMPLOY-MENT NUMBER | LABOUR PRODUC-TIVITY INDEX | EARNINGS PER EMPL R /p.a. | EARNINGS PER EMPL INDEX | REAL EARNINGS PER EMPL INDEX | UNIT LABOUR COST INDEX | SALES PER EMPL R /p.a. | REAL SALES PER EMPLOYEE |
|---|---|---|---|---|---|---|---|---|---|
| 1970 | 70.5 | 97 993 | 68.3 | 884 | 13.5 | 72.3 | 19.8 | 0 | 0 |
| 1971 | 75.8 | 100 148 | 71.9 | 973 | 14.9 | 74.8 | 20.7 | 0 | 0 |
| 1972 | 80.2 | 101 831 | 74.8 | 1 055 | 16.1 | 76.2 | 21.6 | 0 | 0 |
| 1973 | 88.8 | 106 358 | 79.3 | 1 190 | 18.2 | 78.5 | 23.0 | 0 | 0 |
| 1974 | 90.2 | 109 450 | 78.2 | 1 395 | 21.3 | 82.4 | 27.3 | 0 | 0 |
| 1975 | 82.8 | 109 700 | 71.7 | 1 597 | 24.4 | 83.1 | 34.1 | 8 425 | 22 112 |
| 1976 | 93.7 | 112 754 | 78.9 | 1 843 | 28.2 | 86.2 | 35.7 | 10 456 | 25 135 |
| 1977 | 89.2 | 109 025 | 77.7 | 1 991 | 30.5 | 83.9 | 39.2 | 10 951 | 23 350 |
| 1978 | 91.2 | 107 217 | 80.8 | 2 245 | 34.4 | 85.2 | 42.5 | 12 686 | 25 733 |
| 1979 | 98.3 | 108 069 | 86.4 | 2 553 | 39.1 | 85.7 | 45.2 | 15 075 | 28 336 |
| 1980 | 107.7 | 111 125 | 92.0 | 3 054 | 46.7 | 90.0 | 50.8 | 18 632 | 31 314 |
| 1981 | 121.6 | 113 342 | 101.9 | 3 675 | 56.2 | 94.0 | 55.2 | 21 801 | 33 232 |
| 1982 | 113.0 | 111 597 | 96.1 | 4 474 | 68.5 | 99.8 | 71.2 | 21 338 | 29 110 |
| 1983 | 108.7 | 102 442 | 100.7 | 4 984 | 76.3 | 98.9 | 75.7 | 24 355 | 30 751 |
| 1984 | 104.4 | 98 625 | 100.5 | 5 771 | 88.3 | 102.7 | 87.9 | 28 953 | 34 063 |
| 1985 | 100.0 | 94 948 | 100.0 | 6 535 | 100.0 | 100.0 | 100.0 | 32 910 | 32 910 |
| 1986 | 99.7 | 94 767 | 99.9 | 7 747 | 118.5 | 100.0 | 118.7 | 40 502 | 33 752 |
| 1987 | 100.2 | 95 333 | 99.8 | 9 192 | 140.7 | 102.2 | 141.0 | 45 303 | 31 747 |
| 1988 | 106.3 | 95 700 | 105.5 | 10 611 | 162.4 | 104.5 | 154.0 | 52 711 | 31 320 |
| 1989 | 105.7 | 97 500 | 102.9 | 12 488 | 191.1 | 107.2 | 185.6 | 61 089 | 29 741 |
| 1990 | 93.8 | 97 242 | 91.6 | 14 174 | 216.9 | 106.4 | 236.8 | 62 093 | 26 277 |
| 1991 | 87.5 | 93 150 | 89.2 | 16 521 | 252.8 | 107.6 | 283.5 | 68 197 | 26 311 |

AVERAGE ANNUAL PERCENTAGE CHANGE

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1970-91 | 1.3 | -0.5 | 1.8 | 15.4 | 15.4 | 1.9 | 13.3 | 0 | 0 |
| 1973-79 | 1.4 | 0.0 | 1.4 | 13.2 | 13.2 | 1.2 | 11.6 | 0 | 0 |
| 1979-89 | -0.5 | -1.8 | 1.3 | 16.8 | 16.8 | 1.8 | 15.2 | 14.5 | 0.4 |
| 1989-90 | -11.3 | -0.3 | -11.0 | 13.5 | 13.5 | -0.8 | 27.6 | 1.6 | -11.6 |
| 1990-91 | -6.7 | -4.2 | -2.6 | 16.6 | 16.6 | 1.1 | 19.7 | 9.8 | 0.1 |

TABLE 3.30.2: **PERCENTAGE UNEMPLOYMENT IN VARIOUS INDUSTRIALISED COUNTRIES, 1960-1990, AND SOUTH AFRICA, 1980-1990**

| YEAR | UNITED STATES | UNITED KINGDOM | GERMANY | JAPAN | SOUTH AFRICA[1] CPS | SOUTH AFRICA[1] BF '90 |
|---|---|---|---|---|---|---|
| 1960 | 6,6 | 1,4 | 2,2 | 1,2 | | |
| 1965 | 4,5 | 1,3 | 0,6 | 0,8 | | |
| 1970 | 4,4 | 2,2 | 0,9 | 1,2 | | |
| 1975 | 8,5 | 4,6 | 4,0 | 1,9 | | |
| 1980 | 7,4 | 7,0 | 3,2 | 2,0 | 8,6 | 31 |
| 1985 | 7,2 | 11,8 | 8,2 | 2,7 | 8,0 | 37 |
| 1990 | 5,4 | 6,6 | 7,1 | 2,3 | 10,7 | 43 |

Note: 1) Unemployment is not readily measurable or unambiguously definable for South Africa because, especially among the black population, many are involved in traditional rural economic activities, are underemployed, or are involved at a low level of activity in informal, subsistence and other peripheral occupations. Statistics of the registered unemployed published by the Department of Manpower (SA Labour Statistics, 1989, Table 2.7) indicate unemployment levels of less than one percent of the economically active population. In an attempt to obtain a more realistic picture of levels of unemployment, a 'Current Population Survey (CPS)' was instituted by South Africa's Central Statistical Services (CSS) but this gives numbers which decline strongly over time for an unchanged population sample and is based on First World definitions of unemployment. For example, a black unemployment rate of 8,0 percent in 1986 shot up to 19,9 percent when a new population sample was taken. By January 1990 the unemployment level registered for this same sample had worn down to 10,7 percent. Probably the best indication of effective employment levels are given in *Business Futures 1990* (BF '90) Table 3.32.4. This indicates that, in 1988, 41 percent of the economically active population was not involved in the formal economy. This cannot be interpreted, however, as a 41 percent unemployment rate.

Sources: OECD. Department of Economics and Statistics. *Quarterly Labour Force Statistics* (various issues).

Table 3.32.4.

TABLE 3.31.2: **OCCUPATIONAL SKILL STRUCTURE OF THE LABOUR FORCE FOR SOUTH AFRICA AND A FIRST WORLD COUNTRY, 1940 TO 2000**

| | **FIRST WORLD COUNTRY[1]** | | | | **SOUTH AFRICA** | |
|---|---|---|---|---|---|---|
| | **PERCENTAGE DISTRIBUTION** | | | | | |
| | **1940[2]** | **1960[2]** | **1985** | **2000** | **1985** | **2000** |
| Professional and executive | 17,4 | 24,6 | 30,8 | 31,4 | 11,3 | 9,3 |
| Less skilled | 47,6 | 54,3 | 53,0 | 52,0 | 35,5 | 33,9 |
| Unskilled | 35,0 | 21,1 | 16,2 | 16,6 | 53,2 | 56,8 |

| | **RATIO RELATIVE TO PROFESSIONAL AND EXECUTIVE** | | | |
|---|---|---|---|---|
| | **1985** | **2000** | **1985** | **2000** |
| Professional and executive | 1 | 1 | 1 | 1 |
| Less skilled | 1,72 | 1,66 | 3,14 | 3,65 |
| Unskilled | 0,53 | 0,53 | 4,71 | 6,11 |
| Less skilled and unskilled | 2,25 | 2,19 | 7,85 | 9,76 |

Note: 1) Sadie used Canada as a reference country with typical First World characteristics. He also differentiates between executive and professional classes and assumes that the executive class alone provides the entrepreneurial spirit and driving force for economic growth.

2) For the years 1940-1960 US Office of Technology Assessment data were adjusted to match the structure of Canadian data.

Sources: Sadie, JL. 1988. The human resources of South Africa. *SA Journal of Science*, 83(5): 289-294.

United States of America. Office of Technology and the American transition. 1988. *Technology and the American transition*. Washington DC: US Government Printing Office.

# APPENDIX 1.3

# MULTIFACTOR PRODUCTIVITY INDICES FOR THE TEXTILE INDUSTRY

## *TEXTILES*

| YEAR | REAL OUTPUT | LABOUR INPUT | FIXED CAPITAL INPUT | MULTI-FACTOR INPUT | MULTI-FACTOR PRODUC-TIVITY | LABOUR PRODUC-TIVITY | FIXED CAPITAL PRODUC-TIVITY | CAPITAL LABOUR RATIO |
|---|---|---|---|---|---|---|---|---|
| 1970 | 70.5 | 103.2 | 86.2 | 93.7 | 75.2 | 68.3 | 81.8 | 83.6 |
| 1971 | 75.8 | 105.5 | 89.5 | 96.8 | 78.3 | 71.9 | 84.6 | 84.9 |
| 1972 | 80.2 | 107.2 | 92.1 | 99.2 | 80.8 | 74.8 | 87.1 | 85.9 |
| 1973 | 88.8 | 112.0 | 92.7 | 101.3 | 87.7 | 79.3 | 95.8 | 82.8 |
| 1974 | 90.2 | 115.3 | 93.4 | 103.4 | 87.2 | 78.2 | 96.5 | 81.0 |
| 1975 | 82.8 | 115.5 | 94.8 | 104.3 | 79.4 | 71.7 | 87.3 | 82.1 |
| 1976 | 93.7 | 118.8 | 95.1 | 106.4 | 88.1 | 78.9 | 98.5 | 80.1 |
| 1977 | 89.2 | 114.8 | 94.1 | 106.9 | 83.4 | 77.7 | 94.7 | 82.0 |
| 1978 | 91.2 | 112.9 | 90.5 | 103.4 | 88.2 | 80.8 | 100.7 | 80.2 |
| 1979 | 98.3 | 113.8 | 90.3 | 103.2 | 95.2 | 86.4 | 108.8 | 79.4 |
| 1980 | 107.7 | 117.0 | 98.4 | 108.7 | 99.1 | 92.0 | 109.4 | 84.1 |
| 1981 | 121.6 | 119.4 | 101.4 | 111.5 | 109.1 | 101.9 | 119.9 | 84.9 |
| 1982 | 113.0 | 117.5 | 103.3 | 112.6 | 100.3 | 96.1 | 109.4 | 87.9 |
| 1983 | 108.7 | 107.9 | 100.7 | 105.8 | 102.8 | 100.7 | 108.0 | 93.3 |
| 1984 | 104.4 | 103.9 | 102.7 | 103.5 | 100.9 | 100.5 | 101.6 | 98.9 |
| 1985 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| 1986 | 99.7 | 99.8 | 93.3 | 97.6 | 102.2 | 99.9 | 106.8 | 93.5 |
| 1987 | 100.2 | 100.4 | 92.2 | 97.2 | 103.0 | 99.8 | 108.7 | 91.8 |
| 1988 | 106.3 | 100.8 | 99.7 | 100.4 | 105.9 | 105.5 | 106.7 | 98.9 |
| 1989 | 105.7 | 102.7 | 106.5 | 104.0 | 101.6 | 102.9 | 99.2 | 103.7 |
| 1990 | 93.8 | 102.4 | 110.0 | 104.3 | 90.0 | 91.6 | 85.3 | 107.4 |
| 1991 | 87.5 | 98.1 | N/A | N/A | N/A | 89.2 | N/A | N/A |

AVERAGE ANNUAL PERCENTAGE CHANGE

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1970-90 | 1.6 | -0.5 | 0.7 | 0.1 | 1.5 | 2.1 | 0.8 | 1.2 |
| 1973-79 | 1.4 | 0.0 | -0.5 | 0.3 | 1.1 | 1.4 | 2.0 | -0.5 |
| 1979-89 | -0.5 | -1.8 | 0.3 | -0.9 | 0.4 | 1.3 | -0.9 | 2.2 |
| 1989-90 | -11.3 | -0.3 | 3.3 | 0.2 | -11.5 | -11.0 | -14.1 | 3.5 |
| 1990-91 | -6.7 | -4.2 | N/A | N/A | N/A | -2.6 | N/A | N/A |

# APPENDIX 1.4

# EXPLANATION OF FACTORY OPERATIONS

## EXPLANATION OF THE FACTORY OPERATIONS

Puma Jersey operates on a strictly make to order basis. The inputs and outputs of the system are shown in the figure below.

| INPUTS | | OUTPUTS |
|---|---|---|
| Yarn | | Dyed knitted fabric |
| Paper | → TRANSFORMATION → | Printed knitted fabric |
| Chemicals | | Printed paper |
| Dyes | | |

Nine basic operations exist to transform yarn to the finished product. A simple flow analysis is used to show the logical sequence of operations. These operations are discused under the relevant sections below.

Yarn store
↓
Planning
↓
Knitting
↓
Greige store
↓
Dyeing
↓
Finishing
↓
Perching
↓
Quality assurance
↓
Despatch

## 1 YARN STORE

Yarn inventory is stored in the yarn store. The three types of yarn used by Puma Jersey are cotton, poly-cotton and polyester. The function of the yarn store is to check if all the incoming yarn delivered is as specified by the order form. The yarn is weighed, to determine if the correct quantity has been delivered, and visually inspected to determine if the correct type of yarn has been delivered. A predetermined number of random samples are selected from the delivered quantity and submitted to the quality assurance department for further tests, to determine if the yarn will pass Puma's quality standards.

After the random samples have been selected the yarn is stored in pallets, and the exact location is documented. The yarn store now supplies the knitting department with the yarn when it is needed.

## 2. PLANNING

The planning departments major function is to develop a schedule so that the product requested by the customer can be delivered on time and according to specification. The planning department also facilitates the flow of information by instructing other departments of the work to be carried out. The basic operation of the planning department is as follows:-

1. Planning receives an order request from the sales department and then determines when the greige can be knitted by (this is called the knit-by date), and when the fabric can be dyed by and schedules for this accordingly. Planning can now determine a delivery date for an order. This confirmed delivery date is given to the sales department. The sales department will communicate the confirmed delivery date to the customer. If the customer gives consent to proceed with the order, if he/she is satisfied with the confirmed delivery, then an order confirmation is drawn up. A customer may not cancel an order once the order confirmation has been drawn up.
2. Planning determines if the specified yarn is available in the yarn store. If the yarn is unavailable or the inventory is below the required level, then planning will order yarn. Yarn is ordered to stock.
3. Planning now instructs the knitting department to knit the specified quality and quantity of greige. Planning also allocates the machine that will knit the greige. It is company policy to proceed with the knitting before a confirmed delivery date is determined.
4. Planning receives the piece ticket from each individual piece that has been knitted and determines when all the greige is available to make up a dye-lot.
5. Planning now instructs a dye lot to be dyed by means of an instruction sheet.

6. The instruction sheet with all the relevant information regarding the particular dye-lot is produced by the planning department and submitted to the dye-house. The instruction sheet stays with the dye-lot until it gets rolled. Despatch is given a copy of the instruction sheet so that they can deliver all the pieces belonging to a particular dye-lot to the dye house.
7. Planning also determines what processes must be undergone in the dyehouse, finishing and perching departments and in what sequence the processes must proceed. This is known as the route. Different routes result in different end products.
8. After the pieces have been rolled, the finished product's piece tickets are submitted to planning. When an order has been completed the planning department instructs despatch to pack the pieces belonging to that specific order and to deliver the order.

## 3 KNITTING

The fabric is knitted in this department. The knitted fabric is called greige. There are 59 knitting machines that knit the greige at a mean rate of 12 rolls per day. This roll is called a piece. A piece is either 60 or 120 meters long and weighs approximately 25 kilograms. The knitting machines are capable of knitting any specified design. This knit design is called a knit quality. The same machines however usually knit the same qualities because it can take up to 2 days to set up a machine for a different quality.

The machines also generally knit the same yarn type (ie cotton, poly-cotton and polyester) because yarn residue or "fluff" builds up on the machine. If another yarn is knitted then this fluff is picked up in the greige. This is undesirable because different yarns react differently to dyeing. If the yarn type has to be changed on a certain machine then the machine has to be cleaned to prevent the residue fibres from mixing with the new yarn.

After the knitting department has received instructions from the planning department, the knitting department orders the yarn from the yarn store. The greige is then knitted and a piece ticket is attached to the piece. The piece ticket contains information about the piece. The finished pieces are then transported to the greige store where it is stored. Samples of the greige are also inspected in the knitting department. The policy is to inspect one piece per machine per day.

**4 GREIGE STORE**

The greige store is situated in the same place as despatch. After the pieces have been knitted and inspected the pieces are stacked outside the knitting department. From here the pieces are transported to the greige store and stored. The location of the pieces in the greige store is documented. Planning is informed by the greige store that the piece has been knitted by receiving a copy of the piece ticket.

The greige store is also notified by the planning department what pieces make up a batch. When the dye-house instructs the greige store to deliver a particular batch to them, the greige store transports the pieces contained in that particular batch to the graveyard.

## 5 DYEING

The greige is dyed in the dye house. Firstly the dye-house receives instructions from the planning department to proceed with dyeing a batch. A batch consists of pieces of fabric that will be dyed the same colour. A colour is referred to as a shade. The dye-house then orders the pieces of greige from the greige store. The pieces making up the batch are delivered to the graveyard. The graveyard is a holding area next to the dye house where the greige is stored for up to 4 days before it is dyed. The pieces making up a dye lot are unrolled and sewn the together to form a rope before it is loaded into the dyeing machine. This procedure is known as preparing.

The batch is now loaded into a dyeing machine. Different machines dye different yarn types and different shades. Polyester is dyed at high pressure and high temperatures.

Cottons are dyed at moderate temperatures. Before a batch can be dyed it first has to be cleaned and bleached. The dyes are then added to the machine. This is all done semi-automatically. The batch is now unloaded out of the dyeing machine and the excess water is removed by the hydro machine. The hydro spins the fabric in a rotating drum much like a washing machine. The fabric is now sent to the finishing department.

The chemicals and their respective quantities used to make up a shade is called a dye recipe. The dye recipes are developed in the dye-house laboratory. Existing shades are recorded to avoid repetition. This recipe is made up in the dye kitchen.

## 6 FINISHING

The finishing department receives fabric from the dye-house after the excess water has been removed by the hydro. The fabric is still in its tubular form. The fabric can be slitted along a needle line on a slitting machine if the customer so requires. This slitted fabric is now called open width fabric.

The fabric can now follow a number of routes in the finishing department depending on the type of yarn, quality of fabric and customer requirements. The different routes that can be followed are explained in Table ?. The different machines involved in finishing will be explained.

The dryers simply dry the fabric by using heat. The fabric can also be padded before it goes into the dryer. ( Padding occurs when the fabric passes through a bath containing chemicals in a liquid solution and then passed between two rollers to force penetration of the liquid into the fabric and remove excess the liquid.)

The stenter is only used for open width fabric. The stenter pads the fabric and then stretches or compresses the fabric length-ways and breadth-ways to produce the required width dimension and weight per square meter. The stenter also stabilizes the fabric.

Tubular fabric passes through a calender. A calender performs the same function as a stenter

If the customer requires a fleece fabric, then the fabric is passed through brushing machines. The fabric can also pass through a cropping machine after the brushing machine if cropped fabric is desired.

**7 PERCHING**

After the fabric comes off the stenter or the calender the fabric is inspected visually for flaws and allowances are made. An allowance is the length of fabric that can not be used due to a flaw. The customer does not pay for this allowance. If a fault occurs due to a dyeing error, then the entire batch is usually rejected and the batch has to be reprocessed.

After the batch has been perched the individual open width pieces are rolled and packed in plastic bags. Tubular pieces are lap folded and packed in cardboard and plastic. These pieces are now transported to despatch. Planning receives information from despatch that the pieces have been rolled and are ready for delivery.

**8 QUALITY ASSURANCE**

The quality assurance department inspects and tests the yarn from all the suppliers before the greige is knitted. The quality assurance department also inspects and tests all the finished goods after perching. If the finished goods do not pass the quality tests the quality assurance department instructs the fabric to be replaced or reprocessed.

Fabric is replaced if the fabric has to be re-knitted because the dye house or finishing department can not remedy the fabric. Fabric is reprocessed if the fault can be corrected by the dye house or finishing departments.

## 9 DESPATCH

Despatch receives the rolled pieces from the perching department and documents its location. When the customers order is complete the planning writes out an packing instruction for despatch. The packing instruction contains information about all the pieces that need to be packed for the order, and where the order should be sent to. Despatch packs the pieces into trucks and transports the finished goods to the customer.

# APPENDIX 2.1

# OPPORTUNITY COSTS GAINED BY REDUCING LEAD TIME

## OPPORTUNITY COSTS GAINED BY REDUCING LEAD TIME

This calculation determines the saving that will be made per month by reducing the lead time at Puma Jersey by 1 week. Insurance costs are disregarded in this calculation. Only savings incurred by the extra time that interest is earned in the bank is considered. This is calculated the following way:-

| | |
|---|---|
| Average Anglo-Vaal overdraft rate | = 18% nominal |
| Average sales per month | = R5700 000 |
| Savings per month | = (0.18*7/365)*5700000 |
| | = **R19 700** |

**INTEREST EARNED BY REDUCING LEAD TIME BY 1 WEEK = R20 000**

# APPENDIX 2.2

## OPPORTUNITY COSTS GAINED BY TIMEOUS DELIVERIES

## SAVING INCURRED WITH TIMEOUS DELIVERIES

If the goods are delivered in the proceeding month agreed upon by the confirmed delivery, then the debtors collection period is increased by 30 days. For example, if the confirmed delivery date is 29/05/92 and the goods are only recieved by the customer on the 02/06/92, then the goods are only delivered three days, but the debtors collection period has extended by 30 days.

A sample of 158 orders were taken and it was found that the percentage of orders delivered late and that resulted in an increase in the debtors payback period is 35% of the total orders. The savings due to this are calculated as follows:-

Savings per month = (0.18/12)*0.35*5700000

= **R30 000**

**SAVINGS INCURED WITH TIMEOUS DELIVERIES = R30 000**

NOTE:- A discount is of 2.5% of the total value of the order is offered due to timeous payment of the account. It can not be determined how a reduction in collection period will effect customer payments. This cost is significant but can not be calculated.

# APPENDIX 4.1

# QUESTIONNAIRE FOR THE SURVEY ON CUSTOMER PERCEPTIONS ON LEAD TIMES AND DELIVERY PERFORMANCE

## QUESTIONNAIRE

This questionnaire is divided into two sections.

Section A is a survey of your companies perceptions on the **lead times** of piece dyed knitted fabric from your suppliers. Lead time is defined as the time taken from when the order is fully specified to the delivery of the finished goods.

Section B is a survey of your companies perceptions on the **late deliveries** of piece dyed knitted fabric from your suppliers. A late delivery occurs when the Finished goods are received after the suppliers promised date of delivery.

**Please answer the following questions:**

Name of Company ______________________________

Average monthly demand of knitted piece dyed fabric in metres ______________________________

## SECTION A

A1 Estimate the percentage of knitted fabric delivered in the lead times indicated below

| LEAD TIME IN WEEKS | 0-1 WK | 1-2 WKS | 2-3 WKS | 3-4 WKS | 4-5 WKS | 5-6 WKS | 6-7 WKS | 7-8 WKS | 8-10 WKS | 10-12 WKS | 12-14 WKS | 14-16 WKS | 16+ WKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % OF FABRIC DELIVERED | | | | | | | | | | | | | |

A2 Mark the appropriate box with an "X" for the best, average and worst lead times from **local** suppliers

| LEAD TIME IN WEEKS | 0-1 WKS | 1-2 WKS | 2-3 WKS | 3-4 WKS | 4-5 WKS | 5-6 WKS | 6-7 WKS | 7-8 WKS | 8-10 WKS | 10-12 WKS | 12-14 WKS | 14-16 WKS | 16+ WKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BEST | | | | | | | | | | | | | |
| AVERAGE | | | | | | | | | | | | | |
| WORST | | | | | | | | | | | | | |

A3 Mark the appropriate box with an "X" for the best, average and worst lead times from **overseas** suppliers

| LEAD TIME IN WEEKS | 0-1 WKS | 1-2 WKS | 2-3 WKS | 3-4 WKS | 4-5 WKS | 5-6 WKS | 6-7 WKS | 7-8 WKS | 8-10 WKS | 10-12 WKS | 12-14 WKS | 14-16 WKS | 16+ WKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BEST | | | | | | | | | | | | | |
| AVERAGE | | | | | | | | | | | | | |
| WORST | | | | | | | | | | | | | |

.........

A4 Estimate the percentage of knitted fabric your company would ideally require from your supplier to be delivered within the indicated lead times

| LEAD TIME IN WEEKS | 0-1 WK | 1-2 WKS | 2-3 WKS | 3-4 WKS | 4-5 WKS | 5-6 WKS | 6-7 WKS | 7-8 WKS | 8-10 WKS | 10-12 WKS | 12-14 WKS | 14-16 WKS | 16+ WKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % OF FABRIC DELIVERED | | | | | | | | | | | | | |

A5 Estimate the price premium in percentage increase on present purchase price your company is willing to pay for the lead times indicated below

| LEAD TIME IN WEEKS | 0-1 WK | 1-2 WKS | 2-3 WKS | 3-4 WKS | 4-5 WKS | 5-6 WKS | 6-7 WKS | 7-8 WKS | 8-10 WKS | 10-12 WKS | 12-14 WKS | 14-16 WKS | 16+ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % INCR ON PRESENT PURCHASE PRICE | | | | | | | | | | | | | |

## SECTION B

B1 Estimate the percentage of your knitted fabric that gets delivered late by the time period indicated

| DAYS DELIVERED LATE | 0-1 DAYS | 1-2 DAYS | 2-3 DAYS | 3-4 DAYS | 4-6 DAYS | 6-8 DAYS | 8-11 DAYS | 11-14 DAYS | 14-21 DAYS | 21-28 DAYS | 28+ DAYS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| % OF FABRIC | | | | | | | | | | | |

B2 Estimate the average percentage late deliveries of **local** suppliers offering the best, average and worst lead times

| | BEST | AVERAGE | WORST |
|---|---|---|---|
| % OF LATE DELIVERIES | | | |

B3 Estimate the average percentage late deliveries of **overseas** suppliers offering the best, average and worst lead times

| | BEST | AVERAGE | WORST |
|---|---|---|---|
| % OF LATE DELIVERIES | | | |

B4 Describe on a scale of 1 to 4, the inconvenience caused to your company by late deliveries from your suppliers

1 = no inconvenience
2 = minor inconvenience
3 = minor rescheduling, but a considerable inconvenience
4 = unacceptable

| DAYS DELIVERED LATE | 0-1 DAYS | 1-2 DAYS | 2-3 DAYS | 3-4 DAYS | 4-6 DAYS | 6-8 DAYS | 8-11 DAYS | 11-14 DAYS | 14-21 DAYS | 21-28 DAYS | 28+ DAYS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| INCONVENIENCE FACTOR | | | | | | | | | | | |

B5 Estimate the number of times a supplier must consecutively deliver late by the time period indicated before a change in supplier will be considered

| DAYS DELIVERED LATE | 0-1 DAYS | 1-2 DAYS | 2-3 DAYS | 3-4 DAYS | 4-6 DAYS | 6-8 DAYS | 8-11 DAYS | 11-14 DAYS | 14-21 DAYS | 21-28 DAYS | 28+ DAYS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NUMBER OF TIMES | | | | | | | | | | | |

B6 Estimate the tolerable percentage of late deliveries delivered late by the time period indicated

| DAYS DELIVERED LATE | 0-1 DAYS | 1-2 DAYS | 2-3 DAYS | 3-4 DAYS | 4-6 DAYS | 6-8 DAYS | 8-11 DAYS | 11-14 DAYS | 14-21 DAYS | 21-28 DAYS | 28+ DAYS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NUMBER OF TIMES | | | | | | | | | | | |

# APPENDIX 4.2

## RESULTS OF THE SURVEY ON CUSTOMER PERCEPTIONS ON LEAD TIMES AND DELIVERY PERFORMANCE

## SECTION A

A1 Estimate the percentage of knitted fabric delivered in the lead times indicated below

| LEAD TIME IN WEEKS | 0-1 WK | 1-2 WKS | 2-3 WKS | 3-4 WKS | 4-5 WKS | 5-6 WKS | 6-7 WKS | 7-8 WKS | 8-10 WKS | 10-12 WKS | 12-14 WKS | 14-16 WKS | 16+ WKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % OF FABRIC DELIVERED | 0 | 3 | 0 | 17 | 18 | 31 | 15 | 13 | 0 | 3 | 0 | 0 | 0 |

A2 Mark the appropriate box with an "X" for the best, average and worst lead times from **local** suppliers

| LEAD TIME IN WEEKS | 0-1 WKS | 1-2 WKS | 2-3 WKS | 3-4 WKS | 4-5 WKS | 5-6 WKS | 6-7 WKS | 7-8 WKS | 8-10 WKS | 10-12 WKS | 12-14 WKS | 14-16 WKS | 16+ WKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BEST | | | | X | | | | | | | | | |
| AVERAGE | | | | | | | X | | | | | | |
| WORST | | | | | | | | X | | | | | |

A3 Mark the appropriate box with an "X" for the best, average and worst lead times from **overseas** suppliers

| LEAD TIME IN WEEKS | 0-1 WKS | 1-2 WKS | 2-3 WKS | 3-4 WKS | 4-5 WKS | 5-6 WKS | 6-7 WKS | 7-8 WKS | 8-10 WKS | 10-12 WKS | 12-14 WKS | 14-16 WKS | 16+ WKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BEST | | | | | | | | | X | | | | |
| AVERAGE | | | | | | | | | X | | | | |
| WORST | | | | | | | | | | X | | | |

A4 Estimate the percentage of knitted fabric your company would ideally require from your supplier to be delivered within the indicated lead times

| LEAD TIME IN WEEKS | 0-1 WK | 1-2 WKS | 2-3 WKS | 3-4 WKS | 4-5 WKS | 5-6 WKS | 6-7 WKS | 7-8 WKS | 8-10 WKS | 10-12 WKS | 12-14 WKS | 14-16 WKS | 16+ WKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % OF FABRIC DELIVERED | 0 | 3 | 4 | 40 | 4 | 6 | 39 | 0 | 6 | 0 | 0 | 0 | 0 |

A5 Estimate the price premium in percentage increase on present purchase price your company is willing to pay for the lead times indicated below

| LEAD TIME IN WEEKS | 0-1 WK | 1-2 WKS | 2-3 WKS | 3-4 WKS | 4-5 WKS | 5-6 WKS | 6-7 WKS | 7-8 WKS | 8-10 WKS | 10-12 WKS | 12-14 WKS | 14-16 WKS | 16+ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % INCR ON PRESENT PURCHASE PRICE | 5 | 4 | 4 | 4 | 0 | 0 | 0 | 0 | -1 | -1 | -2 | -2 | -2 |

## SECTION B



B1 Estimate the percentage of your knitted fabric that gets delivered late by the time period indicated

| DAYS DELIVERED LATE | 0-1 DAYS | 1-2 DAYS | 2-3 DAYS | 3-4 DAYS | 4-6 DAYS | 6-8 DAYS | 8-11 DAYS | 11-14 DAYS | 14-21 DAYS | 21-28 DAYS | 28+ DAYS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| % OF FABRIC | 3 | 0 | 0 | 8 | 1 | 7 | 0 | 14 | 2 | 7 | 9 |

B2 Estimate the average percentage late deliveries of **local** suppliers offering the best, average and worst lead times

| | BEST | AVERAGE | WORST |
|---|---|---|---|
| % OF LATE DELIVERIES | 17 | 31 | 74 |

B3 Estimate the average percentage late deliveries of **overseas** suppliers offering the best, average and worst lead times

| | BEST | AVERAGE | WORST |
|---|---|---|---|
| % OF LATE DELIVERIES | 50 | 50 | 50 |

B4 Describe on a scale of 1 to 4, the inconvenience caused to your company by late deliveries from your suppliers

1 = no inconvenience
2 = minor inconvenience
3 = minor rescheduling, but a considerable inconvenience
4 = unacceptable

| DAYS DELIVERED LATE | 0-1 DAYS | 1-2 DAYS | 2-3 DAYS | 3-4 DAYS | 4-6 DAYS | 6-8 DAYS | 8-11 DAYS | 11-14 DAYS | 14-21 DAYS | 21-28 DAYS | 28+ DAYS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| INCONVENIENCE FACTOR | 1 | 1 | 1 | 1 | 2 | 3 | 3 | 3 | 3 | 4 | 4 |

B5 Estimate the number of times a supplier must consecutively deliver late by the time period indicated before a change in supplier will be considered

| DAYS DELIVERED LATE | 0-1 DAYS | 1-2 DAYS | 2-3 DAYS | 3-4 DAYS | 4-6 DAYS | 6-8 DAYS | 8-11 DAYS | 11-14 DAYS | 14-21 DAYS | 21-28 DAYS | 28+ DAYS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NUMBER OF TIMES | N/A | N/A | N/A | N/A | N/A | 10 | 8 | 4 | 3 | 2 | 1 |

B6 Estimate the tolerable percentage of late deliveries delivered late by the time period indicated

| DAYS DELIVERED LATE | 0-1 DAYS | 1-2 DAYS | 2-3 DAYS | 3-4 DAYS | 4-6 DAYS | 6-8 DAYS | 8-11 DAYS | 11-14 DAYS | 14-21 DAYS | 21-28 DAYS | 28+ DAYS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NUMBER OF TIMES | 32 | 30 | 29 | 27 | 18 | 16 | 16 | 12 | 10 | 0 | 0 |

# APPENDIX 6.1

# SUPPLEMENTARY SYSTEMS IMPLEMENTED

# SUPPLEMENTARY SYSTEMS IMPLEMENTED

## 1. SCHEDULING WORK IN PROGRESS

### 1.1 Choice of scheduling technique

Many scheduling techniques offer optimum solutions to sequencing problems, but a question that should be asked is whether or not optimum solutions are necessary or even desirable. If a solution to a problem can be obtained only after excessive computation or through over simplification then there is little to recommend it (12).

It would be difficult to optimally schedule the WIP on the factory floor due to the complexity and dynamic nature of the problem. This complex scheduling technique would require computer assistance, due to the complexity of the problem, and continual updating due to the dynamic nature of the WIP flow. When a dynamic problem arises then there is no practical and general method of ensuring an optimum solution, and then it is reasonable to consider such problems in simpler dispatching terms (12). Dispatching considers the immediate priority of jobs on one facility, rather than attempting explicitly to consider several facilities at once.

### 1.2 Description of scheduling technique used

The principal method of job dispatching is by means of priority rules. The use of priority rule dispatching is an attempt to formalize the decisions of the experienced human dispatcher (12). The following rules have been allocated to a dye lot in order of priority:-

- First process jobs that are late (ie where the present date is after the delivery date).
- Then process jobs to reduce operating expense. This rule will only apply to the stenters and dyeing machines
- Then process jobs that need to be delivered for that week.
- Then process jobs to reduce set-up times. This rule will only be applicable to the stenters and the dyeing machines again.
- Then process jobs that are delaying the entire order.

### 1.3 Identifying dye lots to assist scheduling

It is explained in *Appendix 6.2* that it is difficult to monitor the location of WIP. The system discussed in *Appendix 6.2* to monitor the location of WIP has solved this problem to some extent, but it is still tedious for the shop floor operators to determine which jobs, or dye lots, need to be processed first according to the priority rules. The priority rules are dependant on delivery dates, and it would be time consuming for the machine operators to determine the delivery dates for all the dye lots existing in the queue for that particular machine. A single machine may have up to 30 different jobs in a queue at any one time.

A planning board will not be a feasible solution for the same reasons as explained in *Appendix 6.2*. A colour coded flagging system was found to be the most viable solution. It consists of physically marking trolleys with a colored flag on a length of pipe. Different colored flags are used to distinguish between jobs that are late, jobs that have to be delivered the same week and jobs that are delaying the entire order. Advantages of this system are the follows:-

- Not labour intensive or time consuming.
- No capital expenditure is required.
- Direct visual impact for machine operators to easily and quickly apply the dispatching priority rules.
- Direct visual impact for supervisors and management to easily and quickly determine bottlenecks, late deliveries and WIP not moving.
- A system that everyone can understand.
- A flexible system because different colour flags can be used to represent different status of WIP (eg A certain customer may be allocated a colored flag).

The flag system has proven to be the most useful shop floor visual management technique to control delivery performance.

## 2 REVISING KNITTING PRODUCTION STANDARDS

A knitting production standard is the theoretical time that a group of similar machines can knit a piece of a particular quality. The knitting production standards need to be revised on a continual basis so that accurate knit-by dates can be determined. The knitting production standards change with time for the following reasons:-

1. Different knitting machines have different knitting capacities.
2. Operator capability is different for each individual operator.
3. Different yarns knit at different rates. Yarns change seasonally.
4. Operator efficiencies change seasonally.
5. Machine efficiency is reliant on the work force available in the knitting department.

A continuous record of daily production capacities for each machine is presently recorded daily. Statistical process control can be used to monitor and control the production standards for each knitting machine. Exponentially weighted moving average (EWMA) is found to be the most applicable method to control production standards. It is simply weights the most recent production standards exponentially ie the most recent standard has the biggest weighting.

These daily production standards should be monitored daily by exception. When the EWMA of daily production standards exceeds the control limits an exception report showing all the details should be printed out. The control limits are set at +8% and -10% from the existing production standard. This process can be completely automated with the use of the existing computer system.

**3. SCHEDULING PLANNED MAINTENANCE**

Scheduled maintenance is not taken account of in the Master production schedule. The planning department should take account of scheduled maintenance for each knitting machine. This information should simply be communicated to the knitting master production schedule.

**4. EXPEDITING ORDER LINE DELAYING AN ENTIRE ORDER**

A sample of 82 orders was taken and the following findings were made :-

(a) An average order consists of an average of 7 order lines.
(b) 20% of the order lines delay an order by an average of 5 days.

It is difficult determine which order line is delaying an entire order because the exact location of a batch or order line is tedious and time consuming to determine manually. The computerized WIP monitoring system is used to establish the order line holding up an entire order. Establishing the order lines delaying an entire order holds definite advantages because :-

(a) If 20% of the order lines are expedited then the lead time can be cut down by 5 days or 11%.

(b) If 20% of the order lines are expedited then late deliveries can be reduced by 30%

# APPENDIX 6.2

# SYSTEM IMPLEMENTED TO MEASURE PERFORMANCE MEASUREMENTS

**SYSTEM IMPLEMENTED TO MEASURE PERFORMANCE MEASUREMENTS**

A system that will measure performance measurements must be able to monitor the movement of the WIP on the shop floor. Therefore this system needs to monitor the physical location of the WIP. If the physical location of all the WIP existing on the shop floor can be determined then the following systems can also be implemented to reduce lead time and more importantly, reduce late deliveries :-

1. Control throughput of the part of the order delaying the entire order.
2. Scheduling machines to ensure efficient throughput in terms of cost and time.
3. Forecast orders that could be delivered late.
4. Determine the work load for a particular week.

1 DIFFICULTY IN MONITORING WIP

A common problem on the shop floor is the inability to physically determine the location of an order, or part of an order due to the following reasons:-

1. An average of approximately 100 orders exists on the shop floor at any one time.
2. This work in progress is relatively fast moving. (ie some

work in progress can undergo up to 8 different operations in one day).

3. An average of 300 trolleys are moved around the factory floor daily. Fabric that is dyed in the same dye lot moves around the factory floor in a trolley. This dye lot will not be separated at any stage of the process because the entire dye lot will undergo the same operations. A single trolley may contain fabric belonging to several orders.
4. Order lines making up an entire order are dyed, finished, perched etc at different times and undergo different operations. Therefore a complete order does not move together in time or space.

## 2 PROPOSED SYSTEMS TO MONITOR WIP

Two systems were proposed to monitor the WIP on the shop floor between the greige store and the finished goods store. These systems are discussed below.

### 2.1 Planning board.

A large central planning board displaying the movement and location of all the dye lots on the shop floor is the first proposal. This planning board would have to show the location and movement of dye lots through all departments on the same board. To operate and update such a board would be a time consuming and labour intensive operation due to large numbers of dye lots continuously moving through the shop floor at a considerably rapid rate. It will also be impossible to locate the planning board in a physical position where it is easily accessible to all departments. A planning board also loses its visual impact when large amounts of information has to be communicated, and the complicated nature of the problem at hand, will give rise to confusing visuals.

It can be seen from this discussion that a planning board is not a viable solution to monitor WIP because it is not a self sustaining solution and nor will it communicate information in an appropriate manner. However, a significant advantage of a planning board is that it involves all the shop floor workers and managers from all the departments. This will reform the contemporary "over the wall" attitude that prevails inter-departmentaly and foster a team approach to solving problems.

**2.2 Computerized WIP monitoring system.**

The second alternative will be to strategically position computer terminals on the shop floor to monitor dye lots that pass through that particular point. The advantages of this system are:-

- Not labour intensive or time consuming to operate.

- Ability to process data in the required format.
- Flexible system because monitoring points can be moved to monitor temporary bottlenecks, additional monitoring points can be added, ..etc.
- Computer can generate forecasts for bottlenecks.
- Other systems can be linked to this computer program.
- Performance measures relating to time can be calculated from the WIP monitoring data.
- Functions as a permanent running document and therefore time consuming paper documentation can be reduced.

A computerized WIP monitoring system was implemented and is used daily at Puma Jersey. This system has proven to be an extremely useful management tool to decrease late deliveries and control work flow. It has aided to make production meetings redundant because all the information is available to everyone. An example of the computer print-out of the WIP monitoring system is shown below.

fmr060 PUMA JERSERY DIVISION Date : 10/08/92

Time : 15:42:20

OPTIONS WIP STATUS OF ORDERS BY PLANNED DELIVERY DATE Page : 1

From: 10/07/92 To: 15/07/92

| Delivery Date | Order Number | Line | Customer Name | Quality | Specifications | Dye Batch | Dye Lot | Instruction | Process Date | Process Time | Last Proce |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 10/07/92 | 4877/99 | 1 | MANHATTAN MANUFACTURERS | 2825 P | 19737 D GREEN | 4909 | 001 | D 166241 | 17/07/92 | 08:16 | PERCHING |
| 15/07/92 | 4609/99 | 1 | PASTEL CLOTHING DIVISION | 2812 Y | 1119 50 | 4645 | 003 | D 167324 | 21/07/92 | 10:27 | PERCHING |
| 15/07/92 | 4609/99 | 3 | PASTEL CLOTHING DIVISION | 2812 Y | 1120 52 | 4647 | 001 | D 167040 | 10/07/92 | 10:59 | PERCHING |
| 15/07/92 | 4609/99 | 4 | PASTEL CLOTHING DIVISION | 2812 Y | 1120 53 | 4648 | 002 | D 167172 | 14/07/92 | 10:33 | FINISHING |
| 15/07/92 | 4609/99 | 6 | PASTEL CLOTHING DIVISION | 2812 Y | 1121 55 | 4650 | 001 | D 167865 | 10/08/92 | 15:30 | ROLLING |
| 15/07/92 | 4609/99 | 6 | PASTEL CLOTHING DIVISION | 2812 Y | 1121 55 | 4650 | 002 | D 167912 | 10/08/92 | 08:18 | DYE OUT |
| 15/07/92 | 4610/99 | 2 | PASTEL CLOTHING DIVISION | 2071 Y | 877 A99 | 4643 | 001 | D 167382 | 20/07/92 | 13:53 | FINISHING |
| 15/07/92 | 4611/99 | 2 | PASTEL CLOTHING DIVISION | 2071 Y | 877 A94 | 4634 | 001 | D 166909 | 08/07/92 | 09:18 | PLANNING |
| 15/07/92 | 4611/99 | 3 | PASTEL CLOTHING DIVISION | 2071 Y | 877 A96 | 4635 | 001 | D 166911 | 08/07/92 | 09:20 | PLANNING |
| 15/07/92 | 4611/99 | 4 | PASTEL CLOTHING DIVISION | 2071 Y | 877 A99 | 4636 | 001 | D 167390 | 21/07/92 | 20:22 | FINISHING |
| 15/07/92 | 4611/99 | 5 | PASTEL CLOTHING DIVISION | 2071 Y | 877 C23 | 4637 | 001 | D 167444 | 21/07/92 | 20:24 | FINISHING |
| 15/07/92 | 4611/99 | 6 | PASTEL CLOTHING DIVISION | 2071 Y | 1116 D90 | 4638 | 001 | D 166839 | 07/07/92 | 08:12 | DYE OUT |
| 15/07/92 | 4611/99 | 7 | PASTEL CLOTHING DIVISION | 2071 Y | 1116 D91 | 4639 | 002 | D 166860 | 08/07/92 | 16:40 | PERCHING |
| 15/07/92 | 4612/99 | 4 | PASTEL CLOTHING DIVISION | 2071 Y | 1056 D88 | 4654 | 001 | D 166908 | 16/07/92 | 13:33 | PERCHING |
| 15/07/92 | 4763/99 | 4 | PASTEL CLOTHING DIVISION | 2780 P | 35034 XD BURGUNDY | 4624 | 003 | D 166526 | 30/06/92 | 16:59 | FINISHING |

# APPENDIX 6.3

# DYE HOUSE AND FINISHING CAPACITIES FOR DIFFERENT PRODUCT MIXES

## DYE HOUSE AND FINISHING CAPACITIES FOR DIFFERENT PRODUCT MIXES

Different scenarios for the dye house capacities are calculated by considering the following variables:-

1. Daily and seasonal fabric weight fluctuations. (see graph)
2. Daily shade fluctuations which are categorized as light, medium and dark.
3. Daily change in product mix

Different scenarios for the finishing capacities are determined by the daily changes in product mixes. Only the product mix effects the finishing capacities.

# DYE HOUSE CAPACITIES

## 1000'S OF METERS PRODUCED AT 240 GPM

## SEASON : SUMMER
## SHADE : DARK

| | POLYES | POLY/C | COTTON |
|---|---|---|---|
| White | 5.0 | 15.0 | 25.0 |
| Light & medium | 20.0 | 20.0 | 10.0 |
| Dark & Xdark | 75.0 | 65.0 | 65.0 |
| DYEING TIME | 5.5 | 13.9 | 9.2 |

| | POLYES | POLY/C | COTTON |
|---|---|---|---|
| Reprocess (%) | 2.0 | 5.0 | 5.0 |
| Rejects (%) | 0.4 | 2.0 | 2.0 |

METERS PER DAY

| POLYES | POLY/C | COTTON |
|---|---|---|
| 2.0 | 1.3 | 22.6 |
| 2.0 | 3.1 | 19.9 |
| 2.0 | 4.8 | 17.2 |
| 2.0 | 6.6 | 14.5 |
| 2.0 | 8.4 | 11.9 |
| 3.4 | 1.3 | 21.8 |
| 3.4 | 3.1 | 19.1 |
| 3.4 | 4.8 | 16.4 |
| 3.4 | 6.6 | 13.7 |
| 3.4 | 8.4 | 11.0 |
| 8.1 | 1.3 | 19.1 |
| 8.1 | 3.1 | 16.4 |
| 8.1 | 4.8 | 13.7 |
| 8.1 | 6.6 | 11.0 |
| 12.8 | 1.3 | 16.4 |
| 12.8 | 3.1 | 13.7 |
| 12.8 | 4.8 | 11.0 |
| 17.4 | 1.3 | 13.7 |
| 17.4 | 3.1 | 11.0 |
| 22.1 | 1.3 | 11.0 |

METERS PER 5 DAYS

| POLYES | POLY/C | COTTON |
|---|---|---|
| 10.0 | 6.5 | 113.0 |
| 10.0 | 15.3 | 99.6 |
| 10.0 | 24.2 | 86.1 |
| 10.0 | 33.1 | 72.7 |
| 10.0 | 42.0 | 59.3 |
| 17.0 | 6.5 | 109.0 |
| 17.0 | 15.3 | 95.5 |
| 17.0 | 24.2 | 82.1 |
| 17.0 | 33.1 | 68.7 |
| 17.0 | 42.0 | 55.2 |
| 40.4 | 6.5 | 95.5 |
| 40.4 | 15.3 | 82.1 |
| 40.4 | 24.2 | 68.7 |
| 40.4 | 33.1 | 55.2 |
| 63.8 | 6.5 | 82.1 |
| 63.8 | 15.3 | 68.7 |
| 63.8 | 24.2 | 55.2 |
| 87.2 | 6.5 | 68.7 |
| 87.2 | 15.3 | 55.2 |
| 110.6 | 6.5 | 55.2 |

METERS PER 6 DAYS

| POLYES | POLY/C | COTTON |
|---|---|---|
| 12.0 | 7.7 | 135.6 |
| 12.0 | 18.4 | 119.5 |
| 12.0 | 29.1 | 103.4 |
| 12.0 | 39.7 | 87.2 |
| 12.0 | 50.4 | 71.1 |
| 20.4 | 7.7 | 130.8 |
| 20.4 | 18.4 | 114.6 |
| 20.4 | 29.1 | 98.5 |
| 20.4 | 39.7 | 82.4 |
| 20.4 | 50.4 | 66.3 |
| 48.5 | 7.7 | 114.6 |
| 48.5 | 18.4 | 98.5 |
| 48.5 | 29.1 | 82.4 |
| 48.5 | 39.7 | 66.3 |
| 76.6 | 7.7 | 98.5 |
| 76.6 | 18.4 | 82.4 |
| 76.6 | 29.1 | 66.3 |
| 104.7 | 7.7 | 82.4 |
| 104.7 | 18.4 | 66.3 |
| 132.8 | 7.7 | 66.3 |

METERS PER 7 DAYS

| POLYES | POLY/C | COTTON |
|---|---|---|
| 14.0 | 9.0 | 158.2 |
| 14.0 | 21.5 | 139.4 |
| 14.0 | 33.9 | 120.6 |
| 14.0 | 46.3 | 101.8 |
| 14.0 | 58.8 | 83.0 |
| 23.8 | 9.0 | 152.6 |
| 23.8 | 21.5 | 133.8 |
| 23.8 | 33.9 | 115.0 |
| 23.8 | 46.3 | 96.1 |
| 23.8 | 58.8 | 77.3 |
| 56.6 | 9.0 | 133.8 |
| 56.6 | 21.5 | 115.0 |
| 56.6 | 33.9 | 96.1 |
| 56.6 | 46.3 | 77.3 |
| 89.3 | 9.0 | 115.0 |
| 89.3 | 21.5 | 96.1 |
| 89.3 | 33.9 | 77.3 |
| 122.1 | 9.0 | 96.1 |
| 122.1 | 21.5 | 77.3 |
| 154.9 | 9.0 | 77.3 |

METERS PER 17 DAYS

| POLYES | POLY/C | COTTON |
|---|---|---|
| 33.9 | 21.9 | 384.2 |
| 33.9 | 52.1 | 338.5 |
| 33.9 | 82.3 | 292.9 |
| 33.9 | 112.5 | 247.2 |
| 33.9 | 142.7 | 201.5 |
| 57.8 | 21.9 | 370.5 |
| 57.8 | 52.1 | 324.8 |
| 57.8 | 82.3 | 279.2 |
| 57.8 | 112.5 | 233.5 |
| 57.8 | 142.7 | 187.8 |
| 137.4 | 21.9 | 324.8 |
| 137.4 | 52.1 | 279.2 |
| 137.4 | 82.3 | 233.5 |
| 137.4 | 112.5 | 187.8 |
| 216.9 | 21.9 | 279.2 |
| 216.9 | 52.1 | 233.5 |
| 216.9 | 82.3 | 187.8 |
| 296.6 | 21.9 | 233.5 |
| 296.6 | 52.1 | 187.8 |
| 376.2 | 21.9 | 187.8 |

METERS PER 22 DAYS

| POLYES | POLY/C | COTTON |
|---|---|---|
| 43.9 | 28.4 | 497.2 |
| 43.9 | 67.4 | 438.1 |
| 43.9 | 106.6 | 379.0 |
| 43.9 | 145.6 | 319.9 |
| 43.9 | 184.7 | 260.8 |
| 74.8 | 28.4 | 479.4 |
| 74.8 | 67.4 | 420.4 |
| 74.8 | 106.6 | 361.3 |
| 74.8 | 145.6 | 302.1 |
| 74.8 | 184.7 | 243.0 |
| 177.8 | 28.4 | 420.4 |
| 177.8 | 67.4 | 361.3 |
| 177.8 | 106.6 | 302.1 |
| 177.8 | 145.6 | 243.0 |
| 280.7 | 28.4 | 361.3 |
| 280.7 | 67.4 | 302.1 |
| 280.7 | 106.6 | 243.0 |
| 383.8 | 28.4 | 302.1 |
| 383.8 | 67.4 | 243.0 |
| 486.8 | 28.4 | 243.0 |

METERS PER 26 DAYS

| POLYES | POLY/C | COTTON |
|---|---|---|
| 49.9 | 32.3 | 565.0 |
| 49.9 | 78.8 | 497.8 |
| 49.9 | 121.1 | 430.7 |
| 49.9 | 165.5 | 363.5 |
| 49.9 | 209.8 | 296.3 |
| 85.0 | 32.3 | 544.8 |
| 85.0 | 76.6 | 477.7 |
| 85.0 | 121.1 | 410.6 |
| 85.0 | 165.5 | 343.3 |
| 85.0 | 209.8 | 276.2 |
| 202.0 | 32.3 | 477.7 |
| 202.0 | 76.6 | 410.6 |
| 202.0 | 121.1 | 343.3 |
| 202.0 | 165.5 | 276.2 |
| 319.0 | 32.3 | 410.6 |
| 319.0 | 76.6 | 343.3 |
| 319.0 | 121.1 | 276.2 |
| 436.2 | 32.3 | 343.3 |
| 436.2 | 76.6 | 276.2 |
| 553.2 | 32.3 | 276.2 |

METERS PER 30 DAYS

| POLYES | POLY/C | COTTON |
|---|---|---|
| 59.9 | 38.7 | 678.0 |
| 59.9 | 92.0 | 597.4 |
| 59.9 | 145.3 | 516.8 |
| 59.9 | 198.6 | 436.2 |
| 59.9 | 251.8 | 355.6 |
| 102.0 | 38.7 | 653.8 |
| 102.0 | 92.0 | 573.2 |
| 102.0 | 145.3 | 492.7 |
| 102.0 | 198.6 | 412.0 |
| 102.0 | 251.8 | 331.4 |
| 242.4 | 38.7 | 573.2 |
| 242.4 | 92.0 | 492.7 |
| 242.4 | 145.3 | 412.0 |
| 242.4 | 198.6 | 331.4 |
| 382.8 | 38.7 | 492.7 |
| 382.8 | 92.0 | 412.0 |
| 382.8 | 145.3 | 331.4 |
| 523.4 | 38.7 | 412.0 |
| 523.4 | 92.0 | 331.4 |
| 663.8 | 38.7 | 331.4 |

# DYE HOUSE CAPACITIES

## SEASON : SUMMER
## SHADE : LIGHT

# 1000'S OF METERS PRODUCED AT 240 GPM

| | POLYES | POLY/C | COTTON |
|---|---|---|---|
| White | 30.0 | 75.0 | 40.0 |
| Light & medium | 20.0 | 10.0 | 15.0 |
| Dark & Xdark | 50.0 | 15.0 | 45.0 |
| DYEING TIME | 4.7 | 7.2 | 8.1 |

| | POLYES | POLY/C | COTTON |
|---|---|---|---|
| Reprocess (%) | 2.0 | 5.0 | 5.0 |
| Rejects (%) | 0.4 | 2.0 | 2.0 |

METERS PER DAY

| POLYES | POLY/C | COTTON |
|---|---|---|
| 2.4 | 2.5 | 25.6 |
| 2.4 | 5.9 | 22.6 |
| 2.4 | 9.4 | 19.5 |
| 2.4 | 12.8 | 16.5 |
| 2.4 | 16.2 | 13.4 |
| 4.0 | 2.5 | 24.7 |
| 4.0 | 5.9 | 21.6 |
| 4.0 | 9.4 | 18.6 |
| 4.0 | 12.8 | 15.6 |
| 4.0 | 16.2 | 12.5 |
| 9.6 | 2.5 | 21.6 |
| 9.6 | 5.9 | 18.6 |
| 9.6 | 9.4 | 15.6 |
| 9.6 | 12.8 | 12.5 |
| 15.2 | 2.5 | 18.6 |
| 15.2 | 5.9 | 15.6 |
| 15.2 | 9.4 | 12.5 |
| 20.7 | 2.5 | 15.6 |
| 20.7 | 5.9 | 12.5 |
| 26.3 | 2.5 | 12.5 |

METERS PER 5 DAYS

| POLYES | POLY/C | COTTON |
|---|---|---|
| 11.9 | 12.5 | 128.0 |
| 11.9 | 29.6 | 112.8 |
| 11.9 | 46.8 | 97.6 |
| 11.9 | 64.0 | 82.3 |
| 11.9 | 81.2 | 67.1 |
| 20.2 | 12.5 | 123.4 |
| 20.2 | 29.6 | 108.2 |
| 20.2 | 46.8 | 93.0 |
| 20.2 | 64.0 | 77.8 |
| 20.2 | 81.2 | 62.6 |
| 48.0 | 12.5 | 108.2 |
| 48.0 | 29.6 | 93.0 |
| 48.0 | 46.8 | 77.8 |
| 48.0 | 64.0 | 62.6 |
| 75.8 | 12.5 | 93.0 |
| 75.8 | 29.6 | 77.8 |
| 75.8 | 46.8 | 62.6 |
| 103.6 | 12.5 | 77.8 |
| 103.6 | 29.6 | 62.6 |
| 131.5 | 12.5 | 62.6 |

METERS PER 6 DAYS

| POLYES | POLY/C | COTTON |
|---|---|---|
| 14.2 | 15.0 | 153.6 |
| 14.2 | 35.6 | 135.3 |
| 14.2 | 56.2 | 117.1 |
| 14.2 | 76.8 | 98.8 |
| 14.2 | 97.4 | 80.6 |
| 24.3 | 15.0 | 148.1 |
| 24.3 | 35.6 | 129.9 |
| 24.3 | 56.2 | 111.6 |
| 24.3 | 76.8 | 93.3 |
| 24.3 | 97.4 | 75.1 |
| 57.6 | 15.0 | 129.9 |
| 57.6 | 35.6 | 111.6 |
| 57.6 | 56.2 | 93.3 |
| 57.6 | 76.8 | 75.1 |
| 91.0 | 15.0 | 111.6 |
| 91.0 | 35.6 | 93.3 |
| 91.0 | 56.2 | 75.1 |
| 124.4 | 15.0 | 93.3 |
| 124.4 | 35.6 | 75.1 |
| 157.7 | 15.0 | 75.1 |

METERS PER 7 DAYS

| POLYES | POLY/C | COTTON |
|---|---|---|
| 16.6 | 17.5 | 179.2 |
| 16.6 | 41.5 | 157.9 |
| 16.6 | 65.6 | 136.6 |
| 16.6 | 89.6 | 115.3 |
| 16.6 | 113.7 | 94.0 |
| 28.3 | 17.5 | 172.8 |
| 28.3 | 41.5 | 151.5 |
| 28.3 | 65.6 | 130.2 |
| 28.3 | 89.6 | 108.9 |
| 28.3 | 113.7 | 87.6 |
| 67.2 | 17.5 | 151.5 |
| 67.2 | 41.5 | 130.2 |
| 67.2 | 65.6 | 108.9 |
| 67.2 | 89.6 | 87.6 |
| 106.2 | 17.5 | 130.2 |
| 106.2 | 41.5 | 108.9 |
| 106.2 | 65.6 | 87.6 |
| 145.1 | 17.5 | 108.9 |
| 145.1 | 41.5 | 87.6 |
| 184.0 | 17.5 | 87.6 |

METERS PER 17 DAYS

| POLYES | POLY/C | COTTON |
|---|---|---|
| 40.3 | 42.4 | 435.2 |
| 40.3 | 100.8 | 383.5 |
| 40.3 | 159.2 | 331.7 |
| 40.3 | 217.6 | 280.0 |
| 40.3 | 276.0 | 228.3 |
| 68.7 | 42.4 | 419.6 |
| 68.7 | 100.8 | 367.9 |
| 68.7 | 159.2 | 316.2 |
| 68.7 | 217.8 | 264.5 |
| 68.7 | 276.0 | 212.8 |
| 163.2 | 42.4 | 367.9 |
| 163.2 | 100.8 | 316.2 |
| 163.2 | 159.2 | 264.5 |
| 163.2 | 217.6 | 212.8 |
| 257.8 | 42.4 | 316.2 |
| 257.8 | 100.8 | 264.5 |
| 257.8 | 159.2 | 212.8 |
| 352.4 | 42.4 | 264.5 |
| 352.4 | 100.8 | 212.8 |
| 446.9 | 42.4 | 212.8 |

METERS PER 22 DAYS

| POLYES | POLY/C | COTTON |
|---|---|---|
| 52.2 | 54.9 | 563.2 |
| 52.2 | 130.4 | 496.2 |
| 52.2 | 206.0 | 429.3 |
| 52.2 | 281.6 | 362.3 |
| 52.2 | 357.2 | 295.4 |
| 88.9 | 54.9 | 543.0 |
| 88.9 | 130.4 | 476.1 |
| 88.9 | 206.0 | 409.2 |
| 88.9 | 281.6 | 342.3 |
| 88.9 | 357.2 | 275.4 |
| 211.2 | 54.9 | 476.1 |
| 211.2 | 130.4 | 409.2 |
| 211.2 | 206.0 | 342.3 |
| 211.2 | 281.6 | 275.4 |
| 333.6 | 54.9 | 409.2 |
| 333.6 | 130.4 | 342.3 |
| 333.6 | 206.0 | 275.4 |
| 456.0 | 54.9 | 342.3 |
| 456.0 | 130.4 | 275.4 |
| 578.4 | 54.9 | 275.4 |

METERS PER 28 DAYS

| POLYES | POLY/C | COTTON |
|---|---|---|
| 59.3 | 62.4 | 640.0 |
| 59.3 | 148.2 | 563.9 |
| 59.3 | 234.1 | 487.9 |
| 59.3 | 320.0 | 411.7 |
| 59.3 | 405.9 | 335.7 |
| 101.1 | 62.4 | 617.1 |
| 101.1 | 148.2 | 541.0 |
| 101.1 | 234.1 | 465.0 |
| 101.1 | 320.0 | 389.0 |
| 101.1 | 405.9 | 312.9 |
| 240.0 | 62.4 | 541.0 |
| 240.0 | 148.2 | 465.0 |
| 240.0 | 234.1 | 389.0 |
| 240.0 | 320.0 | 312.9 |
| 379.1 | 62.4 | 465.0 |
| 379.1 | 148.2 | 389.0 |
| 379.1 | 234.1 | 312.9 |
| 518.2 | 62.4 | 389.0 |
| 518.2 | 148.2 | 312.9 |
| 657.3 | 62.4 | 312.9 |

METERS PER 30 DAYS

| POLYES | POLY/C | COTTON |
|---|---|---|
| 71.1 | 74.9 | 767.9 |
| 71.1 | 177.9 | 676.7 |
| 71.1 | 281.0 | 585.4 |
| 71.1 | 384.0 | 494.1 |
| 71.1 | 487.1 | 402.8 |
| 121.3 | 74.9 | 740.5 |
| 121.3 | 177.9 | 649.3 |
| 121.3 | 281.0 | 558.0 |
| 121.3 | 384.0 | 466.7 |
| 121.3 | 487.1 | 375.5 |
| 288.0 | 74.9 | 649.3 |
| 288.0 | 177.9 | 558.0 |
| 288.0 | 281.0 | 466.7 |
| 288.0 | 384.0 | 375.5 |
| 454.9 | 74.9 | 558.0 |
| 454.9 | 177.9 | 466.7 |
| 454.9 | 281.0 | 375.5 |
| 621.8 | 74.9 | 466.7 |
| 621.8 | 177.9 | 375.5 |
| 788.7 | 74.9 | 375.5 |

# DYE HOUSE CAPACITIES

## SEASON : WINTER
## SHADE : DARK

# 1000'S OF METERS PRODUCED AT 300 GPM

| | POLYES | POLY/C | COTTON |
|---|---|---|---|
| White | 5.0 | 15.0 | 25.0 |
| Light & medium | 20.0 | 20.0 | 10.0 |
| Dark & Xdark | 75.0 | 65.0 | 65.0 |
| DYEING TIME | 5.5 | 13.9 | 9.2 |

| | POLYES | POLY/C | COTTON |
|---|---|---|---|
| Reprocess (%) | 2.0 | 5.0 | 5.0 |
| Rejects (%) | 0.4 | 2.0 | 2.0 |

METERS PER DAY

| POLYES | POLY/C | COTTON |
|---|---|---|
| 1.6 | 1.0 | 18.1 |
| 1.6 | 2.5 | 15.9 |
| 1.6 | 3.9 | 13.8 |
| 1.6 | 5.3 | 11.6 |
| 1.6 | 6.7 | 9.5 |
| 2.7 | 1.0 | 17.4 |
| 2.7 | 2.5 | 15.3 |
| 2.7 | 3.9 | 13.1 |
| 2.7 | 5.3 | 11.0 |
| 2.7 | 6.7 | 8.8 |
| 6.5 | 1.0 | 15.3 |
| 6.5 | 2.5 | 13.1 |
| 6.5 | 3.9 | 11.0 |
| 6.5 | 5.3 | 8.8 |
| 10.2 | 1.0 | 13.1 |
| 10.2 | 2.5 | 11.0 |
| 10.2 | 3.9 | 8.8 |
| 14.0 | 1.0 | 11.0 |
| 14.0 | 2.5 | 8.8 |
| 17.7 | 1.0 | 8.8 |

METERS PER 5 DAYS

| POLYES | POLY/C | COTTON |
|---|---|---|
| 8.0 | 5.2 | 90.4 |
| 8.0 | 12.3 | 79.7 |
| 8.0 | 19.4 | 68.9 |
| 8.0 | 26.5 | 58.2 |
| 8.0 | 33.6 | 47.4 |
| 13.6 | 5.2 | 87.2 |
| 13.6 | 12.3 | 76.4 |
| 13.6 | 19.4 | 65.7 |
| 13.6 | 26.5 | 54.9 |
| 13.6 | 33.6 | 44.2 |
| 32.3 | 5.2 | 76.4 |
| 32.3 | 12.3 | 65.7 |
| 32.3 | 19.4 | 54.9 |
| 32.3 | 26.5 | 44.2 |
| 51.0 | 5.2 | 65.7 |
| 51.0 | 12.3 | 54.9 |
| 51.0 | 19.4 | 44.2 |
| 69.8 | 5.2 | 54.9 |
| 69.8 | 12.3 | 44.2 |
| 88.5 | 5.2 | 44.2 |

METERS PER 6 DAYS

| POLYES | POLY/C | COTTON |
|---|---|---|
| 9.6 | 6.2 | 108.5 |
| 9.6 | 14.7 | 95.6 |
| 9.6 | 23.3 | 82.7 |
| 9.6 | 31.8 | 69.8 |
| 9.6 | 40.3 | 56.9 |
| 16.3 | 6.2 | 104.6 |
| 16.3 | 14.7 | 91.7 |
| 16.3 | 23.3 | 78.8 |
| 16.3 | 31.8 | 65.9 |
| 16.3 | 40.3 | 53.0 |
| 38.8 | 6.2 | 91.7 |
| 38.8 | 14.7 | 78.8 |
| 38.8 | 23.3 | 65.9 |
| 38.8 | 31.8 | 53.0 |
| 61.3 | 6.2 | 78.8 |
| 61.3 | 14.7 | 65.9 |
| 61.3 | 23.3 | 53.0 |
| 83.7 | 6.2 | 65.9 |
| 83.7 | 14.7 | 53.0 |
| 106.2 | 6.2 | 53.0 |

METERS PER 7 DAYS

| POLYES | POLY/C | COTTON |
|---|---|---|
| 11.2 | 7.2 | 126.6 |
| 11.2 | 17.2 | 111.5 |
| 11.2 | 27.1 | 96.5 |
| 11.2 | 37.1 | 81.4 |
| 11.2 | 47.0 | 66.4 |
| 19.0 | 7.2 | 122.0 |
| 19.0 | 17.2 | 107.0 |
| 19.0 | 27.1 | 92.0 |
| 19.0 | 37.1 | 76.9 |
| 19.0 | 47.0 | 61.9 |
| 45.3 | 7.2 | 107.0 |
| 45.3 | 17.2 | 92.0 |
| 45.3 | 27.1 | 76.9 |
| 45.3 | 37.1 | 61.9 |
| 71.5 | 7.2 | 92.0 |
| 71.5 | 17.2 | 76.9 |
| 71.5 | 27.1 | 61.9 |
| 97.7 | 7.2 | 76.9 |
| 97.7 | 17.2 | 61.9 |
| 123.9 | 7.2 | 61.9 |

METERS PER 17 DAYS

| POLYES | POLY/C | COTTON |
|---|---|---|
| 27.2 | 17.5 | 307.3 |
| 27.2 | 41.7 | 270.8 |
| 27.2 | 65.9 | 234.3 |
| 27.2 | 90.0 | 197.7 |
| 27.2 | 114.1 | 161.2 |
| 46.2 | 17.5 | 296.4 |
| 46.2 | 41.7 | 259.9 |
| 46.2 | 65.9 | 223.3 |
| 46.2 | 90.0 | 186.8 |
| 46.2 | 114.1 | 150.2 |
| 109.9 | 17.5 | 259.9 |
| 109.9 | 41.7 | 223.3 |
| 109.9 | 65.9 | 186.8 |
| 109.9 | 90.0 | 150.2 |
| 173.6 | 17.5 | 223.3 |
| 173.6 | 41.7 | 186.8 |
| 173.6 | 65.9 | 150.2 |
| 237.3 | 17.5 | 186.8 |
| 237.3 | 41.7 | 150.2 |
| 300.9 | 17.5 | 150.2 |

METERS PER 22 DAYS

| POLYES | POLY/C | COTTON |
|---|---|---|
| 35.1 | 22.7 | 397.7 |
| 35.1 | 53.9 | 350.5 |
| 35.1 | 85.3 | 303.2 |
| 35.1 | 116.5 | 255.9 |
| 35.1 | 147.7 | 208.6 |
| 59.8 | 22.7 | 383.6 |
| 59.8 | 53.9 | 336.3 |
| 59.8 | 85.3 | 289.0 |
| 59.8 | 116.5 | 241.7 |
| 59.8 | 147.7 | 194.4 |
| 142.2 | 22.7 | 336.3 |
| 142.2 | 53.9 | 289.0 |
| 142.2 | 85.3 | 241.7 |
| 142.2 | 116.5 | 194.4 |
| 224.6 | 22.7 | 289.0 |
| 224.6 | 53.9 | 241.7 |
| 224.6 | 85.3 | 194.4 |
| 307.0 | 22.7 | 241.7 |
| 307.0 | 53.9 | 194.4 |
| 389.4 | 22.7 | 194.4 |

METERS PER 26 DAYS

| POLYES | POLY/C | COTTON |
|---|---|---|
| 39.9 | 25.8 | 452.0 |
| 39.9 | 61.3 | 398.3 |
| 39.9 | 96.9 | 344.6 |
| 39.9 | 132.4 | 290.8 |
| 39.9 | 167.9 | 237.1 |
| 68.0 | 25.8 | 435.9 |
| 68.0 | 61.3 | 382.2 |
| 68.0 | 96.9 | 328.4 |
| 68.0 | 132.4 | 274.7 |
| 68.0 | 167.9 | 221.0 |
| 161.6 | 25.8 | 382.2 |
| 161.6 | 61.3 | 328.4 |
| 161.6 | 96.9 | 274.7 |
| 161.6 | 132.4 | 221.0 |
| 255.2 | 25.8 | 328.4 |
| 255.2 | 61.3 | 274.7 |
| 255.2 | 96.9 | 221.0 |
| 348.9 | 25.8 | 274.7 |
| 348.9 | 61.3 | 221.0 |
| 442.5 | 25.8 | 221.0 |

METERS PER 30 DAYS

| POLYES | POLY/C | COTTON |
|---|---|---|
| 47.9 | 31.0 | 542.4 |
| 47.9 | 73.6 | 477.9 |
| 47.9 | 116.3 | 413.5 |
| 47.9 | 158.8 | 348.9 |
| 47.9 | 201.4 | 284.5 |
| 81.6 | 31.0 | 523.0 |
| 81.6 | 73.6 | 458.6 |
| 81.6 | 116.3 | 394.1 |
| 81.6 | 158.8 | 329.6 |
| 81.6 | 201.4 | 265.1 |
| 193.9 | 31.0 | 458.6 |
| 193.9 | 73.6 | 394.1 |
| 193.9 | 116.3 | 329.6 |
| 193.9 | 158.8 | 265.1 |
| 306.3 | 31.0 | 394.1 |
| 306.3 | 73.6 | 329.6 |
| 306.3 | 116.3 | 265.1 |
| 418.7 | 31.0 | 329.6 |
| 418.7 | 73.6 | 265.1 |
| 531.0 | 31.0 | 265.1 |

# DYE HOUSE CAPACITIES

## SEASON : WINTER
## SHADE : MEDIUM

## 1000'S OF METERS PRODUCED AT 300 GPM

| | POLYES | POLY/C | COTTON |
|---|---|---|---|
| White | 20.0 | 70.0 | 30.0 |
| Light & medium | 20.0 | 5.0 | 10.0 |
| Dark & Xdark | 60.0 | 25.0 | 60.0 |
| DYEING TIME | 5.0 | 7.9 | 8.9 |

| | POLYES | POLY/C | COTTON |
|---|---|---|---|
| Reprocess (%) | 2.0 | 5.0 | 5.0 |
| Rejects (%) | 0.4 | 2.0 | 2.0 |

METERS PER DAY

| POLYES | POLY/C | COTTON |
|---|---|---|
| 1.8 | 1.8 | 18.7 |
| 1.8 | 4.3 | 16.5 |
| 1.8 | 6.8 | 14.3 |
| 1.8 | 9.4 | 12.1 |
| 1.8 | 11.9 | 9.8 |
| 3.0 | 1.8 | 18.1 |
| 3.0 | 4.3 | 15.8 |
| 3.0 | 6.8 | 13.6 |
| 3.0 | 9.4 | 11.4 |
| 3.0 | 11.9 | 9.2 |
| 7.1 | 1.8 | 15.8 |
| 7.1 | 4.3 | 13.6 |
| 7.1 | 6.8 | 11.4 |
| 7.1 | 9.4 | 9.2 |
| 11.3 | 1.8 | 13.6 |
| 11.3 | 4.3 | 11.4 |
| 11.3 | 6.8 | 9.2 |
| 15.4 | 1.8 | 11.4 |
| 15.4 | 4.3 | 9.2 |
| 19.6 | 1.8 | 9.2 |

METERS PER 5 DAYS

| POLYES | POLY/C | COTTON |
|---|---|---|
| 8.8 | 9.1 | 93.7 |
| 8.8 | 21.7 | 82.6 |
| 8.8 | 34.2 | 71.4 |
| 8.8 | 46.8 | 60.3 |
| 8.8 | 59.3 | 49.2 |
| 15.0 | 9.1 | 90.4 |
| 15.0 | 21.7 | 79.2 |
| 15.0 | 34.2 | 68.1 |
| 15.0 | 46.8 | 57.0 |
| 15.0 | 59.3 | 45.8 |
| 35.7 | 9.1 | 79.2 |
| 35.7 | 21.7 | 68.1 |
| 35.7 | 34.2 | 57.0 |
| 35.7 | 46.8 | 45.8 |
| 56.4 | 9.1 | 68.1 |
| 56.4 | 21.7 | 57.0 |
| 56.4 | 34.2 | 45.8 |
| 77.1 | 9.1 | 57.0 |
| 77.1 | 21.7 | 45.8 |
| 97.8 | 9.1 | 45.8 |

METERS PER 6 DAYS

| POLYES | POLY/C | COTTON |
|---|---|---|
| 10.6 | 11.0 | 112.5 |
| 10.6 | 26.0 | 99.1 |
| 10.6 | 41.1 | 85.7 |
| 10.6 | 56.2 | 72.4 |
| 10.6 | 71.2 | 59.0 |
| 18.0 | 11.0 | 108.5 |
| 18.0 | 26.0 | 95.1 |
| 18.0 | 41.1 | 81.7 |
| 18.0 | 56.2 | 68.4 |
| 18.0 | 71.2 | 55.0 |
| 42.9 | 11.0 | 95.1 |
| 42.9 | 26.0 | 81.7 |
| 42.9 | 41.1 | 68.4 |
| 42.9 | 56.2 | 55.0 |
| 67.7 | 11.0 | 81.7 |
| 67.7 | 26.0 | 68.4 |
| 67.7 | 41.1 | 55.0 |
| 92.5 | 11.0 | 68.4 |
| 92.5 | 26.0 | 55.0 |
| 117.4 | 11.0 | 55.0 |

METERS PER 7 DAYS

| POLYES | POLY/C | COTTON |
|---|---|---|
| 12.3 | 12.8 | 131.2 |
| 12.3 | 30.4 | 115.6 |
| 12.3 | 47.9 | 100.0 |
| 12.3 | 65.5 | 84.4 |
| 12.3 | 83.1 | 68.8 |
| 21.0 | 12.8 | 126.5 |
| 21.0 | 30.4 | 110.9 |
| 21.0 | 47.9 | 95.3 |
| 21.0 | 65.5 | 79.7 |
| 21.0 | 83.1 | 64.1 |
| 50.0 | 12.8 | 110.9 |
| 50.0 | 30.4 | 95.3 |
| 50.0 | 47.9 | 79.7 |
| 50.0 | 65.5 | 64.1 |
| 79.0 | 12.8 | 95.3 |
| 79.0 | 30.4 | 79.7 |
| 79.0 | 47.9 | 64.1 |
| 107.9 | 12.8 | 79.7 |
| 107.9 | 30.4 | 64.1 |
| 136.9 | 12.8 | 64.1 |

METERS PER 17 DAYS

| POLYES | POLY/C | COTTON |
|---|---|---|
| 30.0 | 31.0 | 318.6 |
| 30.0 | 73.7 | 280.7 |
| 30.0 | 116.4 | 242.9 |
| 30.0 | 159.1 | 205.0 |
| 30.0 | 201.8 | 167.2 |
| 51.1 | 31.0 | 307.3 |
| 51.1 | 73.7 | 269.4 |
| 51.1 | 116.4 | 231.5 |
| 51.1 | 159.1 | 193.7 |
| 51.1 | 201.8 | 155.8 |
| 121.5 | 31.0 | 269.4 |
| 121.5 | 73.7 | 231.5 |
| 121.5 | 116.4 | 193.7 |
| 121.5 | 159.1 | 155.8 |
| 191.8 | 31.0 | 231.5 |
| 191.8 | 73.7 | 193.7 |
| 191.8 | 116.4 | 155.8 |
| 262.2 | 31.0 | 193.7 |
| 262.2 | 73.7 | 155.8 |
| 332.5 | 31.0 | 155.8 |

METERS PER 22 DAYS

| POLYES | POLY/C | COTTON |
|---|---|---|
| 38.8 | 40.2 | 412.3 |
| 38.8 | 95.4 | 363.3 |
| 38.8 | 150.7 | 314.3 |
| 38.8 | 205.9 | 265.3 |
| 38.8 | 261.1 | 216.3 |
| 66.1 | 40.2 | 397.7 |
| 66.1 | 95.4 | 348.6 |
| 66.1 | 150.7 | 299.6 |
| 66.1 | 205.9 | 250.6 |
| 66.1 | 261.1 | 201.6 |
| 157.2 | 40.2 | 348.6 |
| 157.2 | 95.4 | 299.6 |
| 157.2 | 150.7 | 250.6 |
| 157.2 | 205.9 | 201.6 |
| 248.2 | 40.2 | 299.6 |
| 248.2 | 95.4 | 250.6 |
| 248.2 | 150.7 | 201.6 |
| 339.3 | 40.2 | 250.6 |
| 339.3 | 95.4 | 201.6 |
| 430.3 | 40.2 | 201.6 |

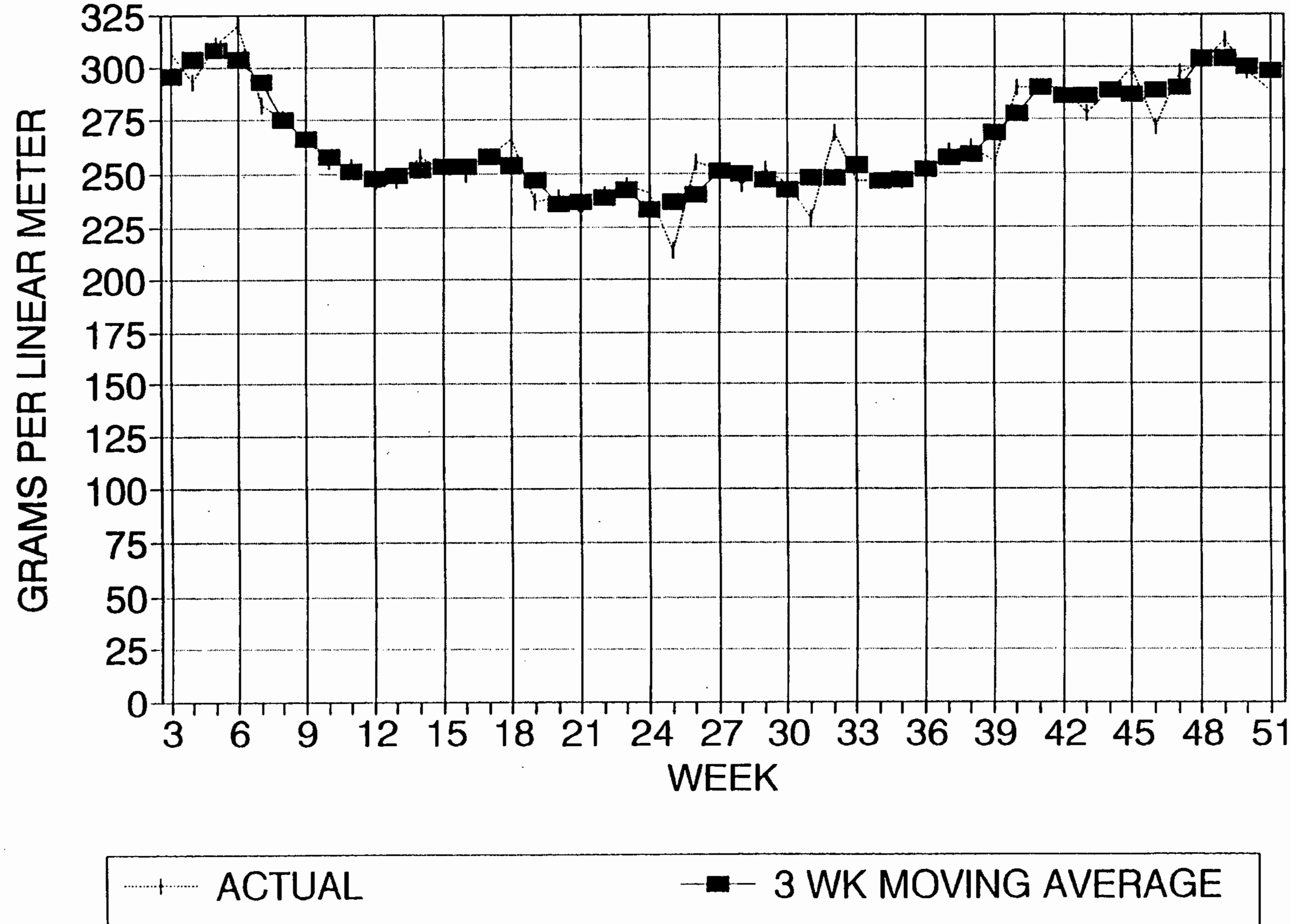
METERS PER 26 DAYS

| POLYES | POLY/C | COTTON |
|---|---|---|
| 44.1 | 45.6 | 468.6 |
| 44.1 | 108.4 | 412.8 |
| 44.1 | 171.2 | 357.2 |
| 44.1 | 234.0 | 301.5 |
| 44.1 | 296.7 | 245.8 |
| 75.2 | 45.6 | 451.9 |
| 75.2 | 108.4 | 396.2 |
| 75.2 | 171.2 | 340.5 |
| 75.2 | 234.0 | 284.8 |
| 75.2 | 296.7 | 229.1 |
| 178.6 | 45.6 | 396.2 |
| 178.6 | 108.4 | 340.5 |
| 178.6 | 171.2 | 284.8 |
| 178.6 | 234.0 | 229.1 |
| 282.1 | 45.6 | 340.5 |
| 282.1 | 108.4 | 284.8 |
| 282.1 | 171.2 | 229.1 |
| 385.5 | 45.6 | 284.8 |
| 385.5 | 108.4 | 229.1 |
| 489.0 | 45.6 | 229.1 |

METERS PER 30 DAYS

| POLYES | POLY/C | COTTON |
|---|---|---|
| 52.9 | 54.8 | 562.3 |
| 52.9 | 130.1 | 495.4 |
| 52.9 | 205.4 | 428.6 |
| 52.9 | 280.8 | 361.8 |
| 52.9 | 356.1 | 295.0 |
| 90.2 | 54.8 | 542.3 |
| 90.2 | 130.1 | 475.4 |
| 90.2 | 205.4 | 408.5 |
| 90.2 | 280.8 | 341.8 |
| 90.2 | 356.1 | 274.9 |
| 214.3 | 54.8 | 475.4 |
| 214.3 | 130.1 | 408.5 |
| 214.3 | 205.4 | 341.8 |
| 214.3 | 280.8 | 274.9 |
| 338.5 | 54.8 | 408.5 |
| 338.5 | 130.1 | 341.8 |
| 338.5 | 205.4 | 274.9 |
| 462.6 | 54.8 | 341.8 |
| 462.6 | 130.1 | 274.9 |
| 586.8 | 54.8 | 274.9 |

# SEASONAL FABRIC WEIGHT FOR 1992



ASSUMPTIONS MADE TO CALCULATE DYEHOUSE CAPACITIES

| MACHINE | COTTON | POLY/C | POLYES | DEMONSTRATED CAPACITY PER LOT |
|---|---|---|---|---|
| SCHOLL1 | * | * | * | 350 |
| SCHOLL2 | * | * | * | 310 |
| SCHOLL3 | * | * | * | 365 |
| SCHOLL4 | * | * | * | 210 |
| SCHOLL6 | * | * | * | 90 |
| ATTIC1 | | * | * | 30 |
| ATTIC2 | | * | * | 90 |
| THIES1 | * | | | 120 |
| THIES2 | * | | | 150 |
| ECOSOFT | * | | | 370 |
| SUBTILO | * | | | 350 |
| BRAZZOLI | * | | | 100 |

GASTON CAPACITY NOT INCLUDED
(Capacity = 3 tons PFP per day)

PERCENTAGE PRODUCT MIX FOR
POLYESTER AND POLY/COTTON
COTTON UTILIZES EXCESS CAPACITY

| POLYES | POLY/C |
|---|---|
| 4 | 10 |
| 4 | 30 |
| 4 | 50 |
| 4 | 70 |
| 4 | 90 |
| 10 | 10 |
| 10 | 30 |
| 10 | 50 |
| 10 | 70 |
| 10 | 90 |
| 30 | 10 |
| 30 | 30 |
| 30 | 50 |
| 30 | 70 |
| 50 | 10 |
| 50 | 30 |
| 50 | 50 |
| 70 | 10 |
| 70 | 30 |
| 90 | 10 |

# FINISHING CAPACITIES (3 SHIFTS PER DAY)

| | STENTER CAPACITY | | | | ALEA & | ESSICO | SLIT | BRUSH | CALEND |
|---|---|---|---|---|---|---|---|---|---|
| | BRUSHED | COTTON | P/C&P'EST | PFP | BRUCK | | | | |
| METERS / MINUTE | 18 | 21 | 34 | 40 | 12 | 10 | 30 | 20 | 10 |
| EFFICIENCY (%) | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 55 | 90 |
| METERS PER SHIFT | 7231 | 16873 | 28841 | 34560 | 4519 | 3766 | 11299 | 4603 | 3766 |

| | PERCENT REPLACEMENT & REPROCESS | | | |
|---|---|---|---|---|
| | BRUSHED FABRIC | COTTON | POLYES & POLY/C | PFP |
| REPROC' | 5 | 5 | 2 | 0.3 |
| REPLAC' | 2 | 2 | 0.5 | 0 |

1000 OF METERS
PER DAY (24hrs)

| BRUSHED FABRIC | COTTON | POLYES & POLY/C | PFP |
|---|---|---|---|
| 0 | 15.2 | 24.9 | 25.9 |
| 0 | 25.3 | 21.5 | 25.9 |
| 0 | 25.3 | 24.9 | 15.6 |
| 0 | 25.3 | 24.9 | 5.2 |
| 0 | 35.4 | 4.3 | 25.9 |
| 0 | 35.4 | 12.9 | 15.6 |
| 0 | 35.4 | 21.5 | 5.2 |
| 1.1 | 15.2 | 24.9 | 25.9 |
| 1.1 | 25.3 | 17.2 | 25.9 |
| 1.1 | 25.3 | 24.9 | 15.6 |
| 1.1 | 25.3 | 24.9 | 5.2 |
| 1.1 | 35.4 | 8.6 | 15.6 |
| 1.1 | 35.4 | 17.2 | 5.2 |
| 2.2 | 15.2 | 24.9 | 25.9 |
| 2.2 | 15.2 | 24.9 | 15.6 |
| 2.2 | 15.2 | 24.9 | 5.2 |
| 2.2 | 25.3 | 12.9 | 25.9 |
| 2.2 | 25.3 | 21.5 | 15.6 |
| 2.2 | 25.3 | 24.9 | 5.2 |
| 2.2 | 35.4 | 4.3 | 15.6 |
| 2.2 | 35.4 | 12.9 | 5.2 |
| 6.5 | 5.1 | 24.9 | 25.9 |
| 6.5 | 5.1 | 24.9 | 15.6 |
| 6.5 | 5.1 | 24.9 | 5.2 |
| 6.5 | 15.2 | 12.9 | 25.9 |
| 6.5 | 15.2 | 21.5 | 15.6 |
| 6.5 | 15.2 | 24.9 | 5.2 |
| 6.5 | 25.3 | 4.3 | 15.6 |
| 6.5 | 25.3 | 12.9 | 5.2 |
| 10.8 | 5.1 | 12.9 | 25.9 |
| 10.8 | 5.1 | 21.5 | 15.6 |
| 10.8 | 5.1 | 24.9 | 5.2 |
| 10.8 | 15.2 | 4.3 | 15.6 |
| 10.8 | 15.2 | 12.9 | 5.2 |
| 13.8 | 5.1 | 4.3 | 15.6 |
| 13.8 | 5.1 | 12.9 | 5.2 |

1000 OF METERS
PER 5 DAYS (24hrs)

| BRUSHED FABRIC | COTTON | POLYES & POLY/C | PFP |
|---|---|---|---|
| 0 | 76 | 124.5 | 129.5 |
| 0 | 126.5 | 107.5 | 129.5 |
| 0 | 126.5 | 124.5 | 78 |
| 0 | 126.5 | 124.5 | 26 |
| 0 | 177 | 21.5 | 129.5 |
| 0 | 177 | 64.5 | 78 |
| 0 | 177 | 107.5 | 26 |
| 5.5 | 76 | 124.5 | 129.5 |
| 5.5 | 126.5 | 86 | 129.5 |
| 5.5 | 126.5 | 124.5 | 78 |
| 5.5 | 126.5 | 124.5 | 26 |
| 5.5 | 177 | 43 | 78 |
| 5.5 | 177 | 86 | 26 |
| 11 | 76 | 124.5 | 129.5 |
| 11 | 76 | 124.5 | 78 |
| 11 | 76 | 124.5 | 26 |
| 11 | 126.5 | 64.5 | 129.5 |
| 11 | 126.5 | 107.5 | 78 |
| 11 | 126.5 | 124.5 | 26 |
| 11 | 177 | 21.5 | 78 |
| 11 | 177 | 64.5 | 26 |
| 32.5 | 25.5 | 124.5 | 129.5 |
| 32.5 | 25.5 | 124.5 | 78 |
| 32.5 | 25.5 | 124.5 | 26 |
| 32.5 | 76 | 64.5 | 129.5 |
| 32.5 | 76 | 107.5 | 78 |
| 32.5 | 76 | 124.5 | 26 |
| 32.5 | 126.5 | 21.5 | 78 |
| 32.5 | 126.5 | 64.5 | 26 |
| 54 | 25.5 | 64.5 | 129.5 |
| 54 | 25.5 | 107.5 | 78 |
| 54 | 25.5 | 124.5 | 26 |
| 54 | 76 | 21.5 | 78 |
| 54 | 76 | 64.5 | 26 |
| 69 | 25.5 | 21.5 | 78 |
| 69 | 25.5 | 64.5 | 26 |

1000 OF METERS
PER 6 DAYS (24hrs)

| BRUSHED FABRIC | COTTON | POLYES & POLY/C | PFP |
|---|---|---|---|
| 0 | 91.2 | 149.4 | 155.4 |
| 0 | 151.8 | 129 | 155.4 |
| 0 | 151.8 | 149.4 | 93.6 |
| 0 | 151.8 | 149.4 | 31.2 |
| 0 | 212.4 | 25.8 | 155.4 |
| 0 | 212.4 | 77.4 | 93.6 |
| 0 | 212.4 | 129 | 31.2 |
| 6.6 | 91.2 | 149.4 | 155.4 |
| 6.6 | 151.8 | 103.2 | 155.4 |
| 6.6 | 151.8 | 149.4 | 93.6 |
| 6.6 | 151.8 | 149.4 | 31.2 |
| 6.6 | 212.4 | 51.6 | 93.6 |
| 6.6 | 212.4 | 103.2 | 31.2 |
| 13.2 | 91.2 | 149.4 | 155.4 |
| 13.2 | 91.2 | 149.4 | 93.6 |
| 13.2 | 91.2 | 149.4 | 31.2 |
| 13.2 | 151.8 | 77.4 | 155.4 |
| 13.2 | 151.8 | 129 | 93.6 |
| 13.2 | 151.8 | 149.4 | 31.2 |
| 13.2 | 212.4 | 25.8 | 93.6 |
| 13.2 | 212.4 | 77.4 | 31.2 |
| 39 | 30.6 | 149.4 | 155.4 |
| 39 | 30.6 | 149.4 | 93.6 |
| 39 | 30.6 | 149.4 | 31.2 |
| 39 | 91.2 | 77.4 | 155.4 |
| 39 | 91.2 | 129 | 93.6 |
| 39 | 91.2 | 149.4 | 31.2 |
| 39 | 151.8 | 25.8 | 93.6 |
| 39 | 151.8 | 77.4 | 31.2 |
| 64.8 | 30.6 | 77.4 | 155.4 |
| 64.8 | 30.6 | 129 | 93.6 |
| 64.8 | 30.6 | 149.4 | 31.2 |
| 64.8 | 91.2 | 25.8 | 93.6 |
| 64.8 | 91.2 | 77.4 | 31.2 |
| 82.8 | 30.6 | 25.8 | 93.6 |
| 82.8 | 30.6 | 77.4 | 31.2 |

1000 OF METERS
PER 7 DAYS (24hrs)

| BRUSHED FABRIC | COTTON | POLYES & POLY/C | PFP |
|---|---|---|---|
| 0 | 106.4 | 174.3 | 181.3 |
| 0 | 177.1 | 150.5 | 181.3 |
| 0 | 177.1 | 174.3 | 109.2 |
| 0 | 177.1 | 174.3 | 36.4 |
| 0 | 247.8 | 30.1 | 181.3 |
| 0 | 247.8 | 90.3 | 109.2 |
| 0 | 247.8 | 150.5 | 36.4 |
| 7.7 | 106.4 | 174.3 | 181.3 |
| 7.7 | 177.1 | 120.4 | 181.3 |
| 7.7 | 177.1 | 174.3 | 109.2 |
| 7.7 | 177.1 | 174.3 | 36.4 |
| 7.7 | 247.8 | 60.2 | 109.2 |
| 7.7 | 247.8 | 120.4 | 36.4 |
| 15.4 | 106.4 | 174.3 | 181.3 |
| 15.4 | 106.4 | 174.3 | 109.2 |
| 15.4 | 106.4 | 174.3 | 36.4 |
| 15.4 | 177.1 | 90.3 | 181.3 |
| 15.4 | 177.1 | 150.5 | 109.2 |
| 15.4 | 177.1 | 174.3 | 36.4 |
| 15.4 | 247.8 | 30.1 | 109.2 |
| 15.4 | 247.8 | 90.3 | 36.4 |
| 45.5 | 35.7 | 174.3 | 181.3 |
| 45.5 | 35.7 | 174.3 | 109.2 |
| 45.5 | 35.7 | 174.3 | 36.4 |
| 45.5 | 106.4 | 90.3 | 181.3 |
| 45.5 | 106.4 | 150.5 | 109.2 |
| 45.5 | 106.4 | 174.3 | 36.4 |
| 45.5 | 177.1 | 30.1 | 109.2 |
| 45.5 | 177.1 | 90.3 | 36.4 |
| 75.6 | 35.7 | 90.3 | 181.3 |
| 75.6 | 35.7 | 150.5 | 109.2 |
| 75.6 | 35.7 | 174.3 | 36.4 |
| 75.6 | 106.4 | 30.1 | 109.2 |
| 75.6 | 106.4 | 90.3 | 36.4 |
| 96.6 | 35.7 | 30.1 | 109.2 |
| 96.6 | 35.7 | 90.3 | 36.4 |

1000 OF METERS
PER 17 DAYS (24hrs)

| BRUSHED FABRIC | COTTON | POLYES & POLY/C | PFP |
|---|---|---|---|
| 0 | 258.4 | 423.3 | 440.3 |
| 0 | 430.1 | 365.5 | 440.3 |
| 0 | 430.1 | 423.3 | 265.2 |
| 0 | 430.1 | 423.3 | 88.4 |
| 0 | 601.8 | 73.1 | 440.3 |
| 0 | 601.8 | 219.3 | 265.2 |
| 0 | 601.8 | 365.5 | 88.4 |
| 18.7 | 258.4 | 423.3 | 440.3 |
| 18.7 | 430.1 | 292.4 | 440.3 |
| 18.7 | 430.1 | 423.3 | 265.2 |
| 18.7 | 430.1 | 423.3 | 88.4 |
| 18.7 | 601.8 | 146.2 | 265.2 |
| 18.7 | 601.8 | 292.4 | 88.4 |
| 37.4 | 258.4 | 423.3 | 440.3 |
| 37.4 | 258.4 | 423.3 | 265.2 |
| 37.4 | 258.4 | 423.3 | 88.4 |
| 37.4 | 430.1 | 219.3 | 440.3 |
| 37.4 | 430.1 | 365.5 | 265.2 |
| 37.4 | 430.1 | 423.3 | 88.4 |
| 37.4 | 601.8 | 73.1 | 265.2 |
| 37.4 | 601.8 | 219.3 | 88.4 |
| 110.5 | 86.7 | 423.3 | 440.3 |
| 110.5 | 86.7 | 423.3 | 265.2 |
| 110.5 | 86.7 | 423.3 | 88.4 |
| 110.5 | 258.4 | 219.3 | 440.3 |
| 110.5 | 258.4 | 365.5 | 265.2 |
| 110.5 | 258.4 | 423.3 | 88.4 |
| 110.5 | 430.1 | 73.1 | 265.2 |
| 110.5 | 430.1 | 219.3 | 88.4 |
| 183.6 | 86.7 | 219.3 | 440.3 |
| 183.6 | 86.7 | 365.5 | 265.2 |
| 183.6 | 86.7 | 423.3 | 88.4 |
| 183.6 | 258.4 | 73.1 | 265.2 |
| 183.6 | 258.4 | 219.3 | 88.4 |
| 234.6 | 86.7 | 73.1 | 265.2 |
| 234.6 | 86.7 | 219.3 | 88.4 |

1000 OF METERS
PER 22 DAYS (24hrs)

| BRUSHED FABRIC | COTTON | POLYES & POLY/C | PFP |
|---|---|---|---|
| 0 | 334.4 | 547.8 | 569.8 |
| 0 | 556.6 | 473 | 569.8 |
| 0 | 556.6 | 547.8 | 343.2 |
| 0 | 556.6 | 547.8 | 114.4 |
| 0 | 778.8 | 94.6 | 569.8 |
| 0 | 778.8 | 283.8 | 343.2 |
| 0 | 778.8 | 473 | 114.4 |
| 24.2 | 334.4 | 547.8 | 569.8 |
| 24.2 | 556.6 | 378.4 | 569.8 |
| 24.2 | 556.6 | 547.8 | 343.2 |
| 24.2 | 556.6 | 547.8 | 114.4 |
| 24.2 | 778.8 | 189.2 | 343.2 |
| 24.2 | 778.8 | 378.4 | 114.4 |
| 48.4 | 334.4 | 547.8 | 569.8 |
| 48.4 | 334.4 | 547.8 | 343.2 |
| 48.4 | 334.4 | 547.8 | 114.4 |
| 48.4 | 556.6 | 283.8 | 569.8 |
| 48.4 | 556.6 | 473 | 343.2 |
| 48.4 | 556.6 | 547.8 | 114.4 |
| 48.4 | 778.8 | 94.6 | 343.2 |
| 48.4 | 778.8 | 283.8 | 114.4 |
| 143 | 112.2 | 547.8 | 569.8 |
| 143 | 112.2 | 547.8 | 343.2 |
| 143 | 112.2 | 547.8 | 114.4 |
| 143 | 334.4 | 283.8 | 569.8 |
| 143 | 334.4 | 473 | 343.2 |
| 143 | 334.4 | 547.8 | 114.4 |
| 143 | 556.6 | 94.6 | 343.2 |
| 143 | 556.6 | 283.8 | 114.4 |
| 237.6 | 112.2 | 283.8 | 569.8 |
| 237.6 | 112.2 | 473 | 343.2 |
| 237.6 | 112.2 | 547.8 | 114.4 |
| 237.6 | 334.4 | 94.6 | 343.2 |
| 237.6 | 334.4 | 283.8 | 114.4 |
| 303.6 | 112.2 | 94.6 | 343.2 |
| 303.6 | 112.2 | 283.8 | 114.4 |

1000 OF METERS
PER 28 DAYS (24hrs)

| BRUSHED FABRIC | COTTON | POLYES & POLY/C | PFP |
|---|---|---|---|
| 0 | 395.2 | 647.4 | 673.4 |
| 0 | 657.8 | 559 | 673.4 |
| 0 | 657.8 | 647.4 | 405.6 |
| 0 | 657.8 | 647.4 | 136.2 |
| 0 | 920.4 | 111.8 | 673.4 |
| 0 | 920.4 | 335.4 | 405.6 |
| 0 | 920.4 | 559 | 136.2 |
| 28.6 | 395.2 | 647.4 | 673.4 |
| 28.6 | 657.8 | 447.2 | 673.4 |
| 28.6 | 657.8 | 647.4 | 405.6 |
| 28.6 | 657.8 | 647.4 | 136.2 |
| 28.6 | 920.4 | 223.6 | 405.6 |
| 28.6 | 920.4 | 447.2 | 136.2 |
| 57.2 | 395.2 | 647.4 | 673.4 |
| 57.2 | 395.2 | 647.4 | 405.6 |
| 57.2 | 395.2 | 647.4 | 136.2 |
| 57.2 | 657.8 | 335.4 | 673.4 |
| 57.2 | 657.8 | 559 | 405.6 |
| 57.2 | 657.8 | 647.4 | 136.2 |
| 57.2 | 920.4 | 111.8 | 405.6 |
| 57.2 | 920.4 | 335.4 | 136.2 |
| 169 | 132.6 | 647.4 | 673.4 |
| 169 | 132.6 | 647.4 | 405.6 |
| 169 | 132.6 | 647.4 | 136.2 |
| 169 | 395.2 | 335.4 | 673.4 |
| 169 | 395.2 | 559 | 405.6 |
| 169 | 395.2 | 647.4 | 136.2 |
| 169 | 657.8 | 111.8 | 405.6 |
| 169 | 657.8 | 335.4 | 136.2 |
| 280.8 | 132.6 | 335.4 | 673.4 |
| 280.8 | 132.6 | 559 | 405.6 |
| 280.8 | 132.6 | 647.4 | 136.2 |
| 280.8 | 395.2 | 111.8 | 405.6 |
| 280.8 | 395.2 | 335.4 | 136.2 |
| 358.8 | 132.6 | 111.8 | 405.6 |
| 358.8 | 132.6 | 335.4 | 136.2 |

1000 OF METERS
PER 30 DAYS (24hrs)

| BRUSHED FABRIC | COTTON | POLYES & POLY/C | PFP |
|---|---|---|---|
| 0 | 456 | 747 | 777 |
| 0 | 759 | 645 | 777 |
| 0 | 759 | 747 | 468 |
| 0 | 759 | 747 | 156 |
| 0 | 1062 | 129 | 777 |
| 0 | 1062 | 387 | 468 |
| 0 | 1062 | 645 | 156 |
| 33 | 456 | 747 | 777 |
| 33 | 759 | 516 | 777 |
| 33 | 759 | 747 | 468 |
| 33 | 759 | 747 | 156 |
| 33 | 1062 | 258 | 468 |
| 33 | 1062 | 516 | 156 |
| 66 | 456 | 747 | 777 |
| 66 | 456 | 747 | 468 |
| 66 | 456 | 747 | 156 |
| 66 | 759 | 387 | 777 |
| 66 | 759 | 645 | 468 |
| 66 | 759 | 747 | 156 |
| 66 | 1062 | 129 | 468 |
| 66 | 1062 | 387 | 156 |
| 195 | 153 | 747 | 777 |
| 195 | 153 | 747 | 468 |
| 195 | 153 | 747 | 156 |
| 195 | 456 | 387 | 777 |
| 195 | 456 | 645 | 468 |
| 195 | 456 | 747 | 156 |
| 195 | 759 | 129 | 468 |
| 195 | 759 | 387 | 156 |
| 324 | 153 | 387 | 777 |
| 324 | 153 | 645 | 468 |
| 324 | 153 | 747 | 156 |
| 324 | 456 | 129 | 468 |
| 324 | 456 | 387 | 156 |
| 414 | 153 | 129 | 468 |
| 414 | 153 | 387 | 156 |

# ASSUMPTIONS

PROPORTION OF TIME SPENT ON STENTERS

| BRUSHE FABRIC | COTTON | POLYES POLY/C | PFP |
|---|---|---|---|
| 0 | 30 | 45 | 25 |
| 0 | 50 | 25 | 25 |
| 0 | 50 | 35 | 15 |
| 0 | 50 | 45 | 5 |
| 0 | 70 | 5 | 25 |
| 0 | 70 | 15 | 15 |
| 0 | 70 | 25 | 5 |
| 5 | 30 | 40 | 25 |
| 5 | 50 | 20 | 25 |
| 5 | 50 | 30 | 15 |
| 5 | 50 | 40 | 5 |
| 5 | 70 | 10 | 15 |
| 5 | 70 | 20 | 5 |
| 10 | 30 | 35 | 25 |
| 10 | 30 | 45 | 15 |
| 10 | 30 | 55 | 5 |
| 10 | 50 | 15 | 25 |
| 10 | 50 | 25 | 15 |
| 10 | 50 | 35 | 5 |
| 10 | 70 | 5 | 15 |
| 10 | 70 | 15 | 5 |
| 30 | 10 | 35 | 25 |
| 30 | 10 | 45 | 15 |
| 30 | 10 | 55 | 5 |
| 30 | 30 | 15 | 25 |
| 30 | 30 | 25 | 15 |
| 30 | 30 | 35 | 5 |
| 30 | 50 | 5 | 15 |
| 30 | 50 | 15 | 5 |
| 50 | 10 | 15 | 25 |
| 50 | 10 | 25 | 15 |
| 50 | 10 | 35 | 5 |
| 50 | 30 | 5 | 15 |
| 50 | 30 | 15 | 5 |
| 70 | 10 | 5 | 15 |
| 70 | 10 | 15 | 5 |

TUBULAR FABRIC

TUBULAR FABRIC NOT INCLUDED
BECAUSE INDEPENDANT ON OPEN WIDTH

TUBULAR CAPACITY (2 SHIFTS/DAY) = 8000 METERS
TUBULAR CAPACITY (3 SHIFTS/DAY) = 12000 METERS

METHOD OF CALCULATING CAPACITIES

OPEN WIDTH CAPACITIES IS CALCULATED USING THE STENTER AVAILABLE CAPACITY AS A BASIS.
IF THE STENTER CAPACITY EXCEEDS THE BRUSHING, DRYING OR SLITTING CAPACITY THEN THIS WILL BECOME THE CONSTRAINT. tHE EXCESS AVAILABLE CAPACITY GENERATED BY THIS CONSTRAINT WILL BE LOADED ON THE STENTER EQUALY AMONG THE NON CONSTRAINED FABRIC GROUPS

3RD STENTER CAPACITY NOT INCLUDED

3RD STENTER CAN ONLY STENTER PFP
AND POLYESTER

CAPACITY (2 SHIFTS/DAY) = 30 000 METERS
CAPACITY (3 SHIFTS/DAY) = 46 000 METERS

# APPENDIX 6.4

# DEVELOPING THE BASIC STRUCTURE OF THE DYNAMO MODEL

## DEVELOPING THE BASIC STRUCTURE OF THE DYNAMO MODEL

Before the basic structure of the model can be developed it is necessary to first determine the constraints to reaching the objective of the systems analysis. The ultimate objective of the systems analysis is to determine the viability of implementing systems to reduce lead times and late deliveries. The viability is measured by the quantity of money produced and the ability to sustain such a performance.

Therefore constraining factors to maximizing profits must be determined. A system constraint can be defined as "*anything that limits a system from achieving higher performance versus its goal*" (17). These constraints are :-

1) Throughput
2) Inventory level
3) Operating expense

The quantity of money produced or the rate that orders are produced by the system is determined by throughput, which in turn is directly controlled by the rate of production, better known as production capacity. There has to be an input of orders into the system for a production capacity to exist. The rate that orders, or money, enters the system is determined by the market demand.

The rate of production is constrained either by the maximum production capacity of the system, or the market demand depending on the market conditions prevailing. When production is below the maximum production capacity level then the constraining factor to making money is the market demand. If the market demand exceeds the maximum production capacity then the constraint is production capacity. Inventory and operating expense are money consuming entities and are clearly obstacles to achieving the goal.

Now that the constraints have been analyzed the basic structure of the model can be determined. Once the basic structure of the model as been chosen, the model can be developed in more detail.

The fundamental level equation largely determines the structure of the model. A level equation measures the level of a variable by calculating the rate that the variable enters and leaves the system. The three basic structures that can exist are determined by the following level variables:-

1) Level of money in the system
2) Level of physical goods in the system
3) Level of orders in the system

These structures will be discussed under the relevant headings below, and the choice of structure that will be used for the computer simulation is discussed.

1. **LEVEL OF MONEY**

The level of money in the system at any given time is calculated as explained in *Diagram 1* below.

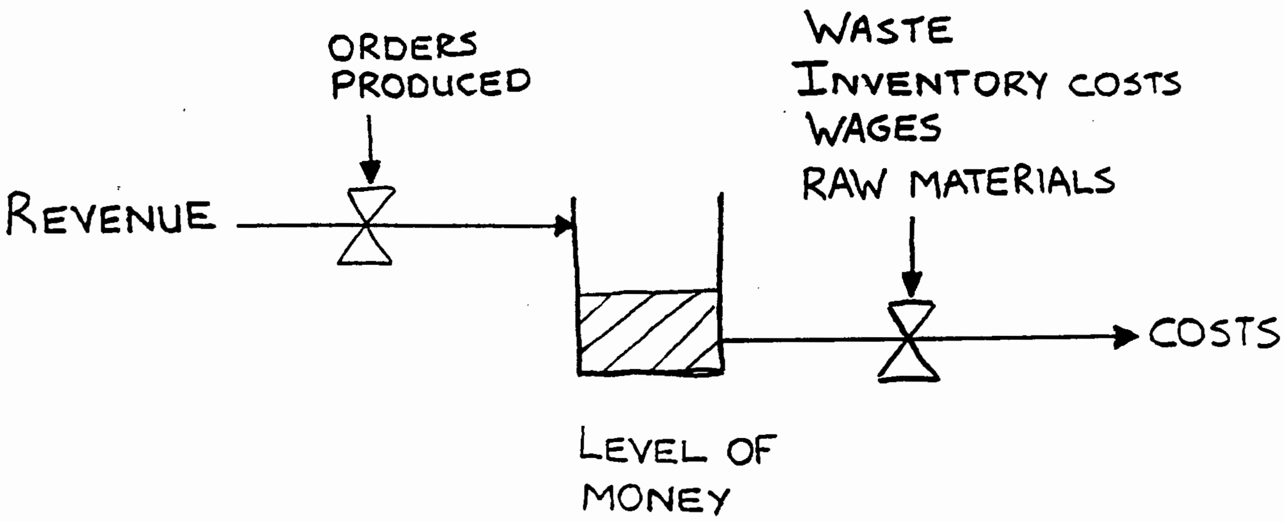



*DIAGRAM 1*

The rate that money goes into the system is equivalent to the rate that orders are produced by the system, which is controlled by production capacity. The rate that money leaves the system is determined by the following factors:-

- Raw materials purchased
- Salaries and wages
- Cost of holding inventory
- Waste
- Capital expenditure on equipment, buildings, etc

The cost of raw materials is not pertinent to the problem at hand because the objective of the systems analysis is to make more money by reducing lead times and late deliveries. The inclusion of raw materials cost into the equation will unnecessarily complicate the problem and cloud the solutions with variables that are not relevant to lead times and late deliveries.

The solution will be clouded because the purchasing of raw materials has a pronounced affect on the level of money in the system. Lead times and timeous deliveries do not affect the purchasing of raw materials. Stock outs and shortages seldom occur at Puma and therefore do not affect lead times.

The level of money in the system however is important to the systems analysis because it measures what the company is trying to achieve - making more money.

**2. LEVEL OF PHYSICAL GOODS**

Physical goods consist of raw materials, work in progress, waste and finished goods. The level of physical goods in the system at any time is calculated as shown in *Diagram 2* below.

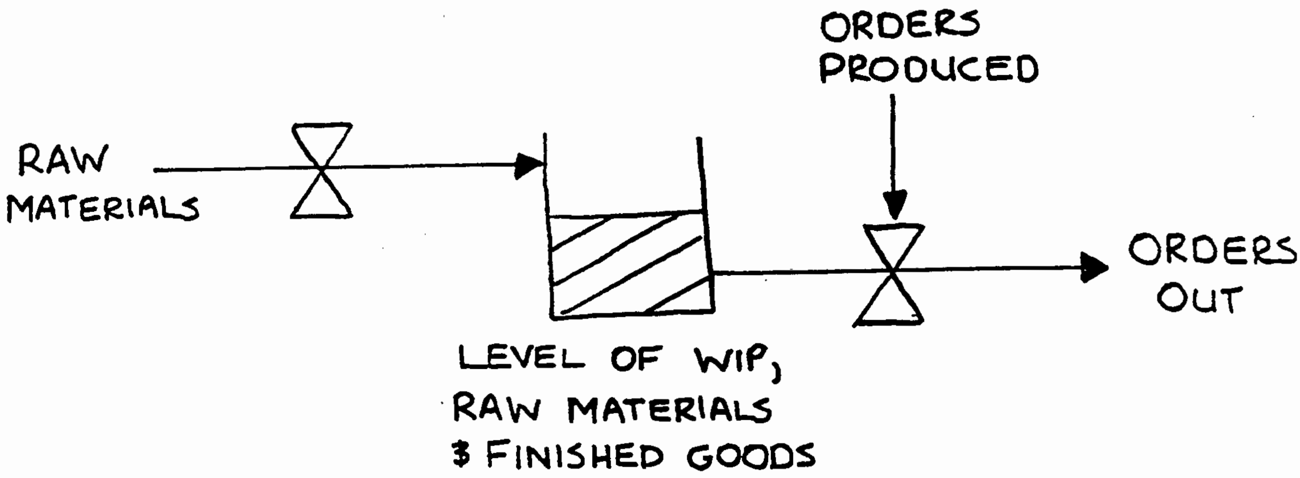



*DIAGRAM 2*

The same argument holds for this structure as for the previous structure because the rate that raw materials enter the system is of paramount importance to this structure.

**3. LEVEL OF ORDERS**

The level of orders in the system at any time is calculated as shown in *Diagram 3* below.

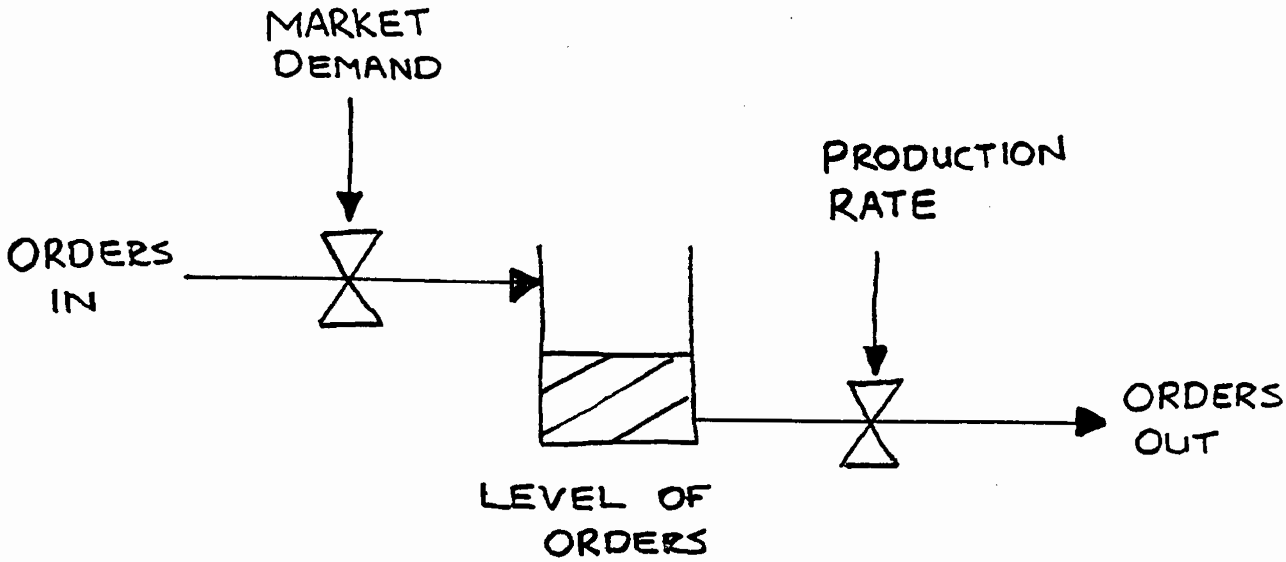



*DIAGRAM 3*

The amount of orders in the system is a measure of the work in progress (WIP) inventory. The amount of orders in the system is controlled by the rate of orders into the system and the rate of orders out of the system. The rate of orders into the system is in turn controlled by market demand, and the rate of orders out of the system is controlled by production capacity. So the level of orders in the system is controlled by the constraining factors to maximizing profits.

To achieve the desired objective of "making more money", the goal is to increase the rate of orders out of the system. This can be done by increasing production capacity. To increase production capacity there has to be sufficient market demand. In the present economic climate, where Puma only works a 4 day week, it is evident that there is not sufficient market demand to enable Puma to produce at maximum production capacity. Therefore the constraint is the prevailing market conditions, so by implication the goal is to increase market demand. Timeous deliveries and a reduction in lead time increase competitiveness and therefore market demand.

Another approach to maximizing profits is to reduce money consuming entities such as inventory. The level of inventory is represented by the level of orders in the system. Therefore the goal is also to reduce the level of orders in the system. Reducing lead time directly influences the reduction of work in progress because there will be less orders in the system. There will be less orders in the system because the throughput of orders through the system is increased, and orders therefore spend less time in the system.

It can be seen that the level of orders in the system best describes the problem at hand and will be used to simulate the behavior of the system. The level of orders in the system can be broken down into two more level equations because two distinct operations occur at Puma. These two operations are knitting and dyeing. Knitting and dyeing are also the two major bottlenecks in production.

Another level equation must be introduced to measure the amount of money generated by the system. This is necessary to determine the effectiveness of decisions on the final objective. The final basic structure of the DYNAMO model is shown in *Diagram 4* below.

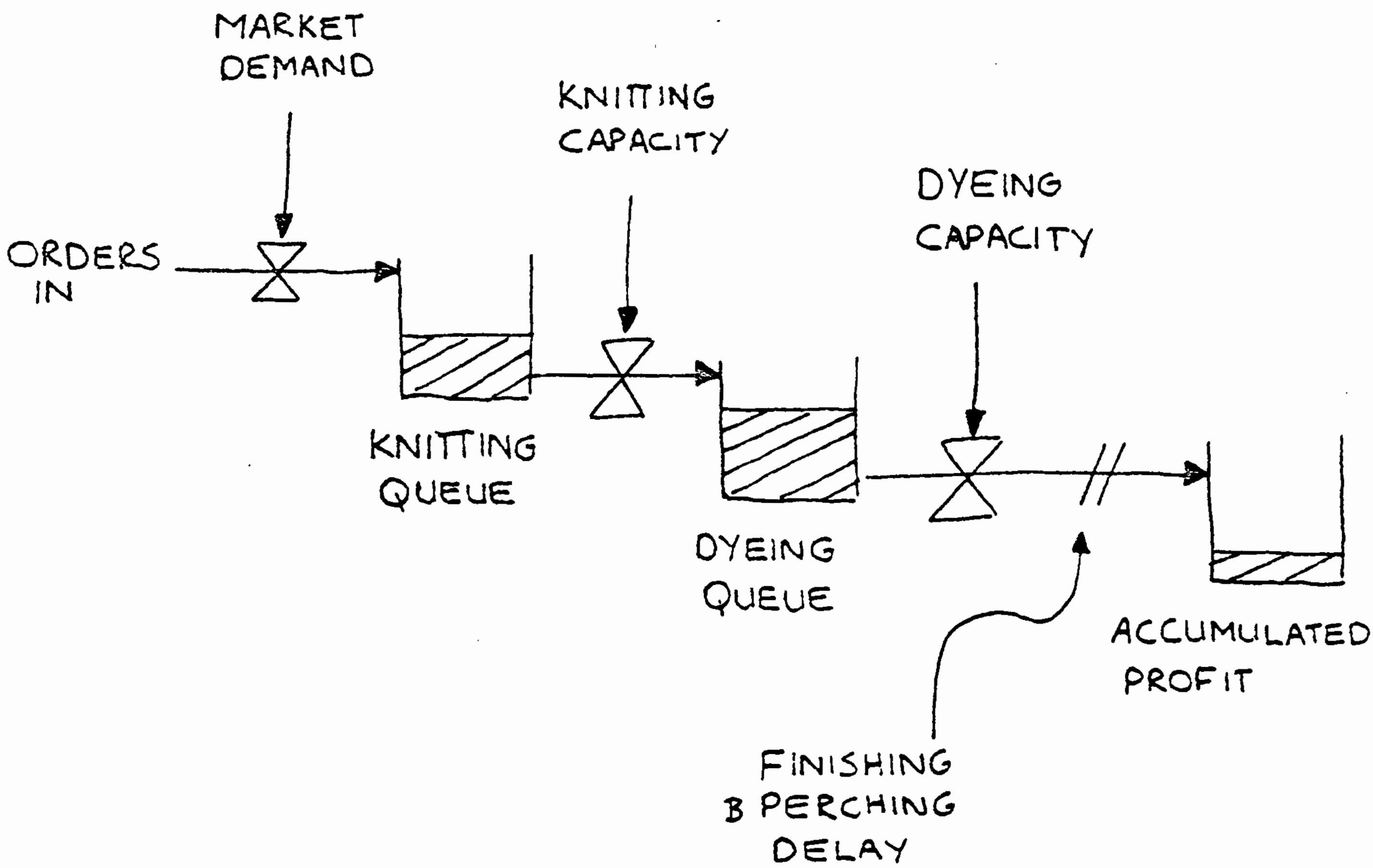



*DIAGRAM 4*

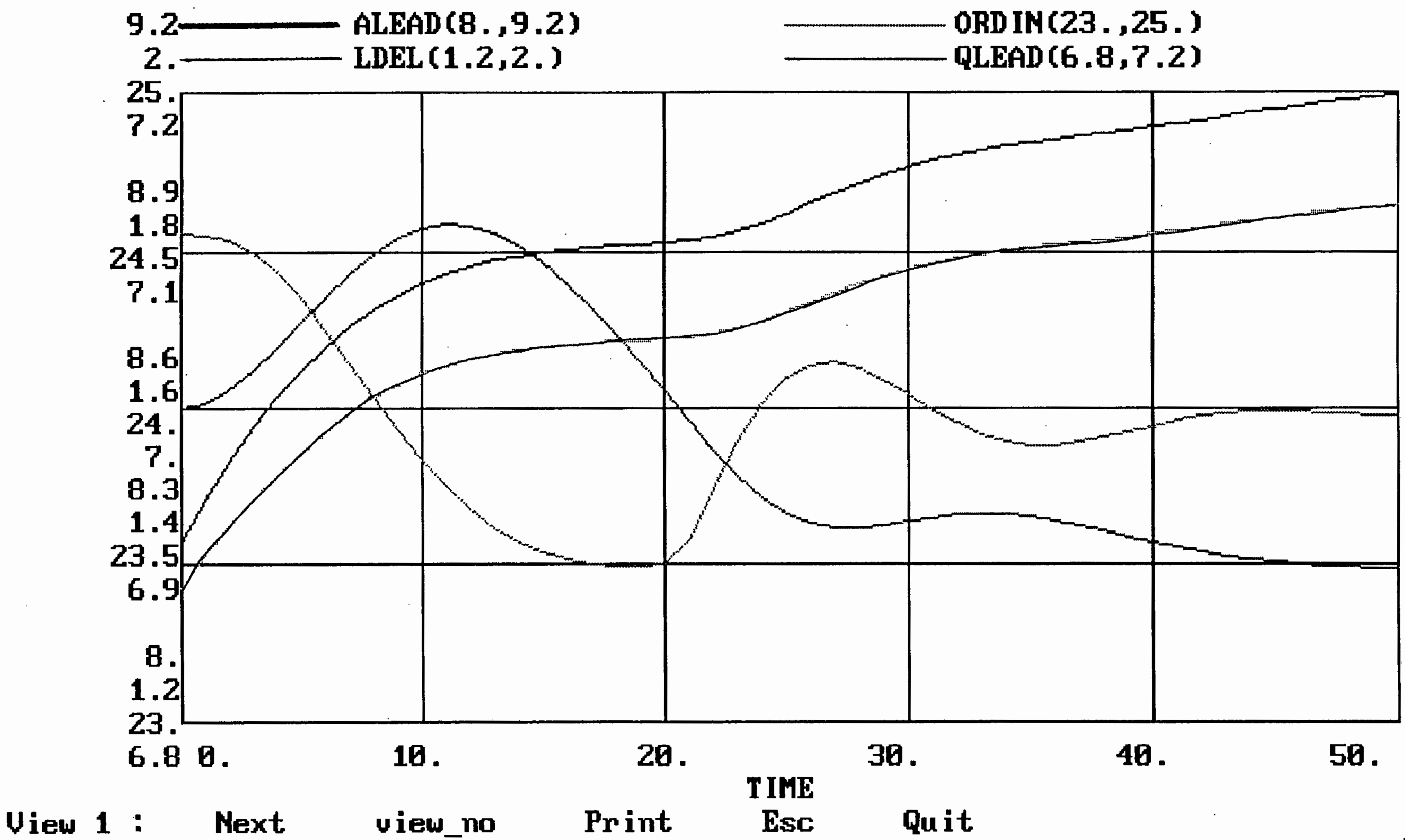
# APPENDIX 6.5

# COMPUTER PROGRAM OF THE DYNAMO MODEL USED TO SIMULATE THE GLOBAL PERFORMANCE

```
NOTE LATE DELIVERIES = 75%
NOTE AVERAGE LATE DELIVERIES = 1.5 WEEKS
NOTE QUOTED LEAD TIME = 7 WEEKS
NOTE ORDERS PER WEEK = 22.5
NOTE
NOTE
NOTE
NOTE   SALES LOOP
NOTE
C WORKD=4
L ORDER.K=ORDER.J+DT*(ORDIN.JK-ORDOUT.JK)
N ORDER=168
R ORDIN.KL=(DEMAND.K*POTORD.K*DCDFLD.K*LATED)+DEMAND.K*POTORD.K*(1
A DEMAND.K=24
A POTORD.K=TABLE(TPOTORD,QLEAD.K,1,9,1)
T TPOTORD=1.97,1.94,1.9,1.5,1.46,1.4,1,0.94,0.9
NOTE
C LATED=0.75          Percentage late deliveries
C AALDEL=1.5
A QQLEAD.K=KNITT.K+DYET.K+2     Quoted lead time (weeks)
A QLEAD.K=DELAY1(QQLEAD.K,3)
L KNITQ.K=KNITQ.J+DT*(ORDIN.JK-KNITC)      Knitting queue (orders)
A KNITT.K=KNITQ.K/KNITC        Time taken for knitting
L DYEQ.K=DYEQ.J+DT*(KNITC-DYEC)       Dyeing queue (orders)
A DYET.K=DYEQ.K/DYEC       Time taken for dyeing
N KNITQ=100
N DYEQ=28
C KNITC=25.2     Scheduled knitting capacity  (orders/week)
C DYEC=25.2    Scheduled dyeing capacity (orders/week)
NOTE
NOTE     PRODUCTION LOOP
NOTE
R ORDOUT.KL=DELAY1(ADYEC.KL,ACTFD)
C ACTFD=1.8    Average cycle time from finishing to despatch
NOTE
NOTE  Dyeing operation
C REPRO=0.02
R ADYEC.KL=DYEC*(1-REPRO)*DCF.K
R DDYEC.KL=DELAY1(ADYEC.KL,0.5)      Delayed dyeing capacity manag
L ADYEQ.K=ADYEQ.J+DT*(AKNITC.JK-DDYEC.JK)      Actual dyeing queue
N ADYEQ=28
A ADYET.K=ADYEQ.K/DDYEC.KL         Actual dyeing time
A DCF.K=TABLE(TDCF,ADYEQ.K,4,34,5)    Dyeing capacity factor
T TDCF=0.89,0.93,0.95,0.98,1,1.09,1.12
NOTE
NOTE  Knitting operation
N REPLA=0.005
R AKNITC.KL=KNITC*(1-REPLA)*KCF.K    Actual knitting capacity
A KCF.K=TABLE(TKCF,AKNITQ.K,16,156,20)    Knitting capacity factor
T TKCF=0.88,0.9,0.94,0.97,1,1.05,1.09,1.12
A AKNITT.K=AKNITQ.K/AKNITC.KL       Actual knitting time
L AKNITQ.K=AKNITQ.J+DT*(ORDIN.JK-AKNITC.JK)      Actual knitting q
N AKNITQ=100
A ALEAD.K=AKNITT.K+ADYET.K+ACTFD
A LDEL.K=TABLE(TLEDEL,ALEAD.K,4.6,10.6,1)
T TLEDEL=0,0.25,0.6,1,1.5,2.1,2.7
A CDFLD.K=TABLE(TCDFLD,LDEL.K,0,5,0.5)  Customer disatisfaction fa
T TCDFLD=1.2,1.16,1.12,1,0.92,0.83,0.79,0.62,0.41,0.12,0
A DCDFLD.K=DLINF3(CDFLD.K,6)   Delayed customer disatisfaction fac
Note
R PROFIN.KL=ORDOUT.KL*30-663.5-WORKD*10.7-WORKD*5.7-WIPCOST.K
A WIPCOST.K=ORDER.K*0.115
L PROFIT.K=PROFIT.J+DT*(PROFIN.JK)
N PROFIT=0
R ORDPROF.KL=ORDOUT.KL*30-WIPCOST.K
CONTROL STATEMENT
```

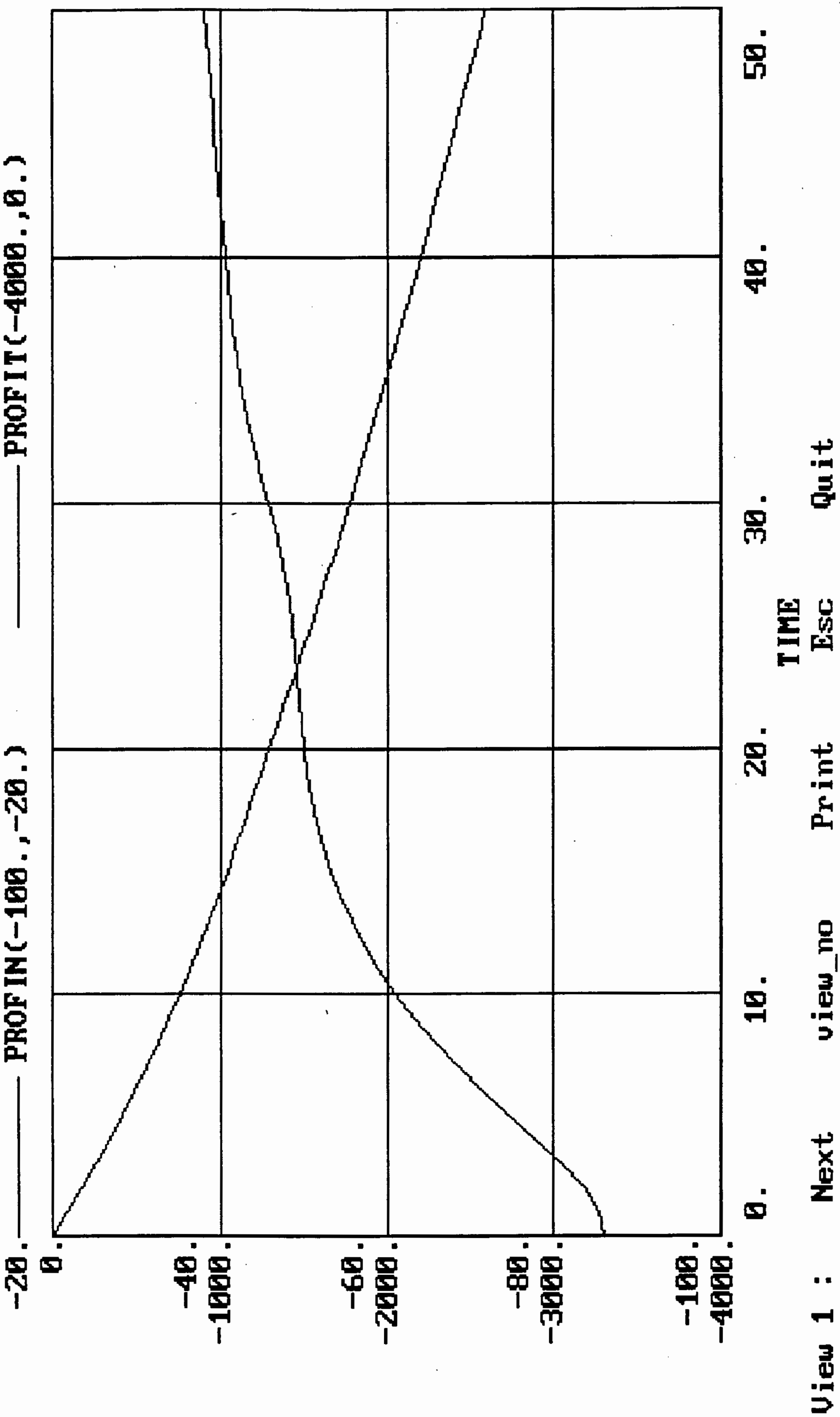
# APPENDIX 6.6

# DYNAMO SIMULATION OUTPUT OF STEP CHANGE IN DEMAND

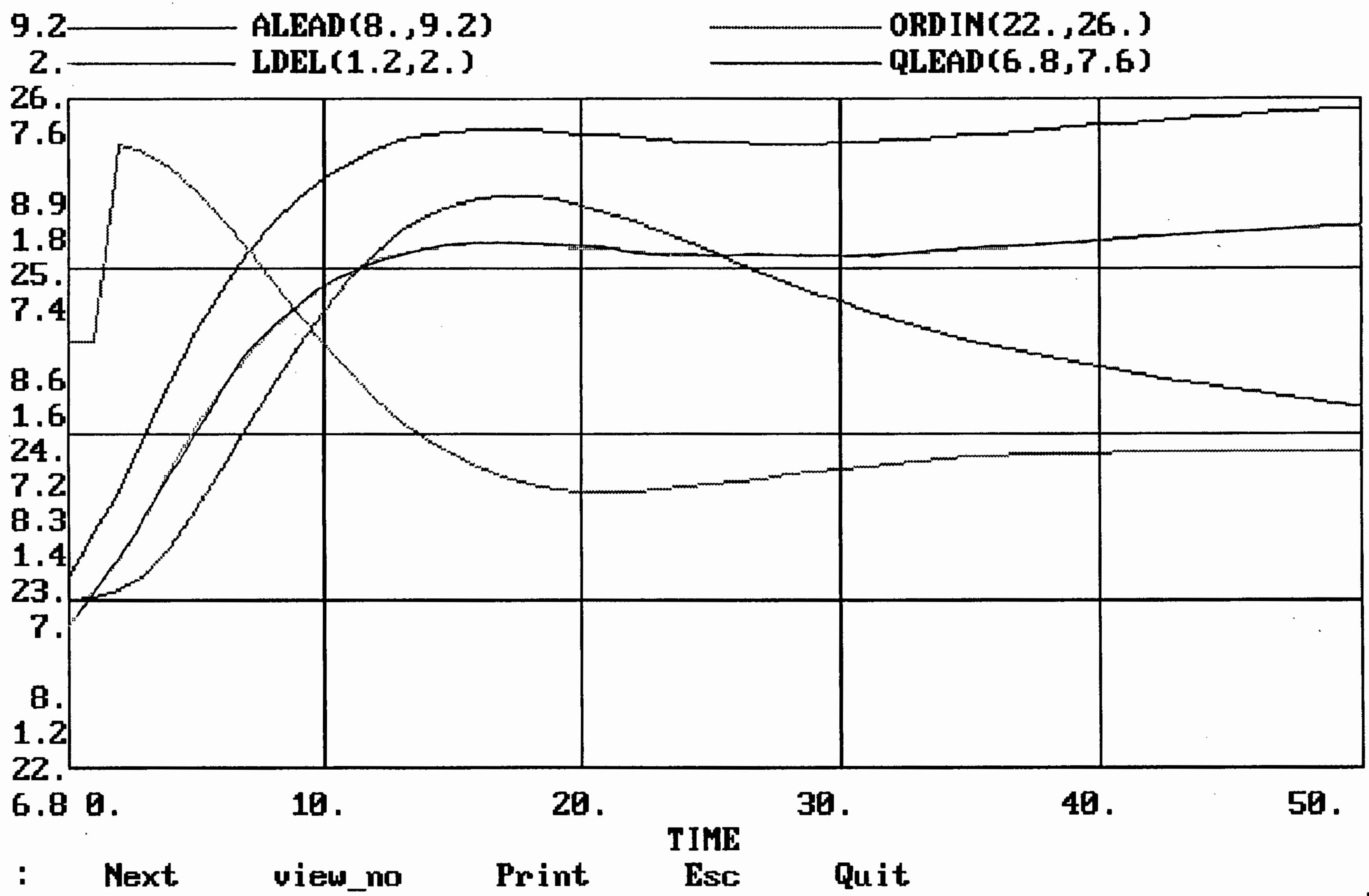



0% STEP CHANGE

4 DAYS / WEEK

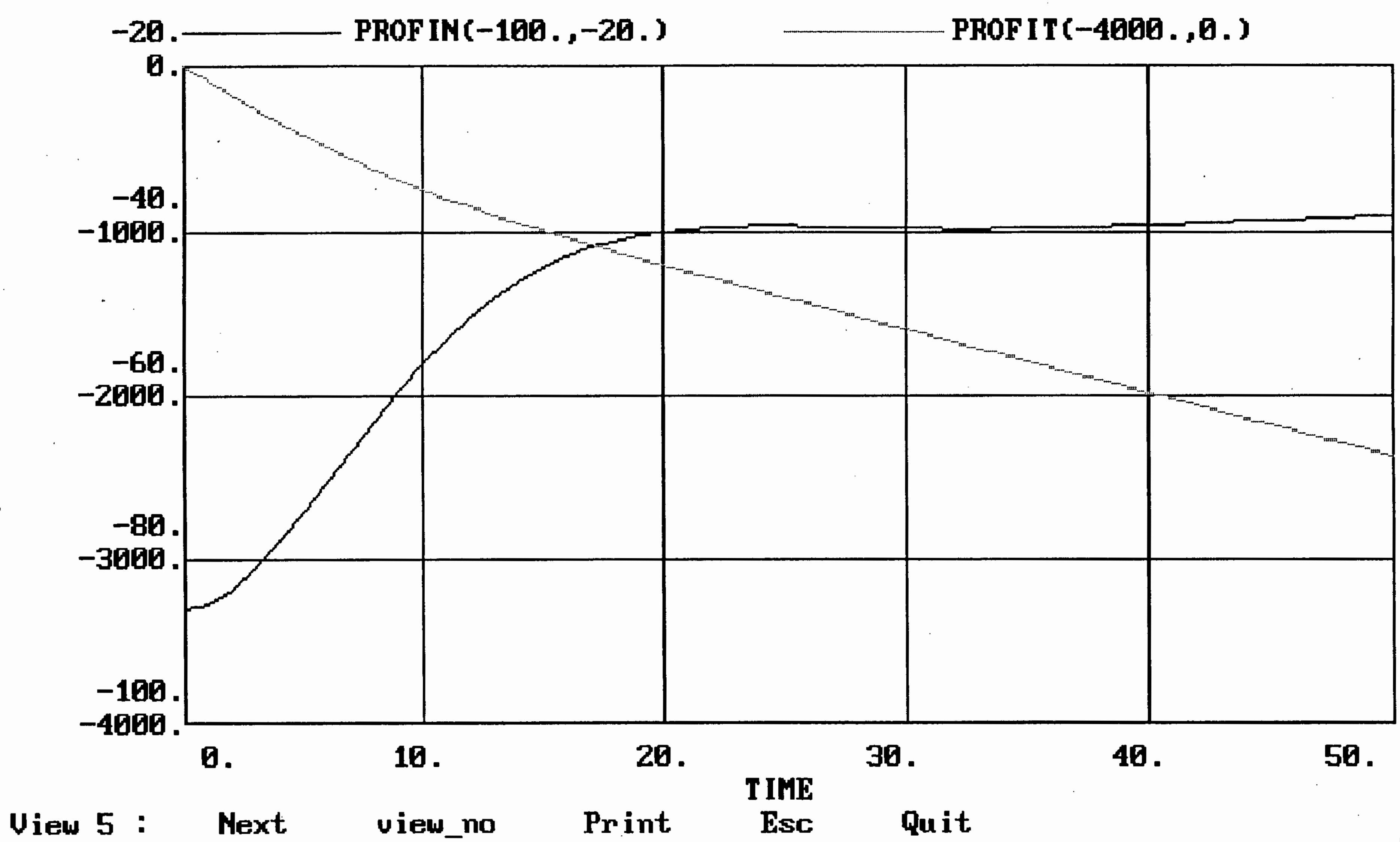


PROFIN(-100.,-20.)
PROFIT(-4000.,0.)
-20.
0.
-40.
-1000.
-60.
-2000.
-80.
-3000.
-100.
-4000.
0.
10.
20.
30.
40.
50.
TIME
View 1 :
Next
view_no
Print
Esc
Quit

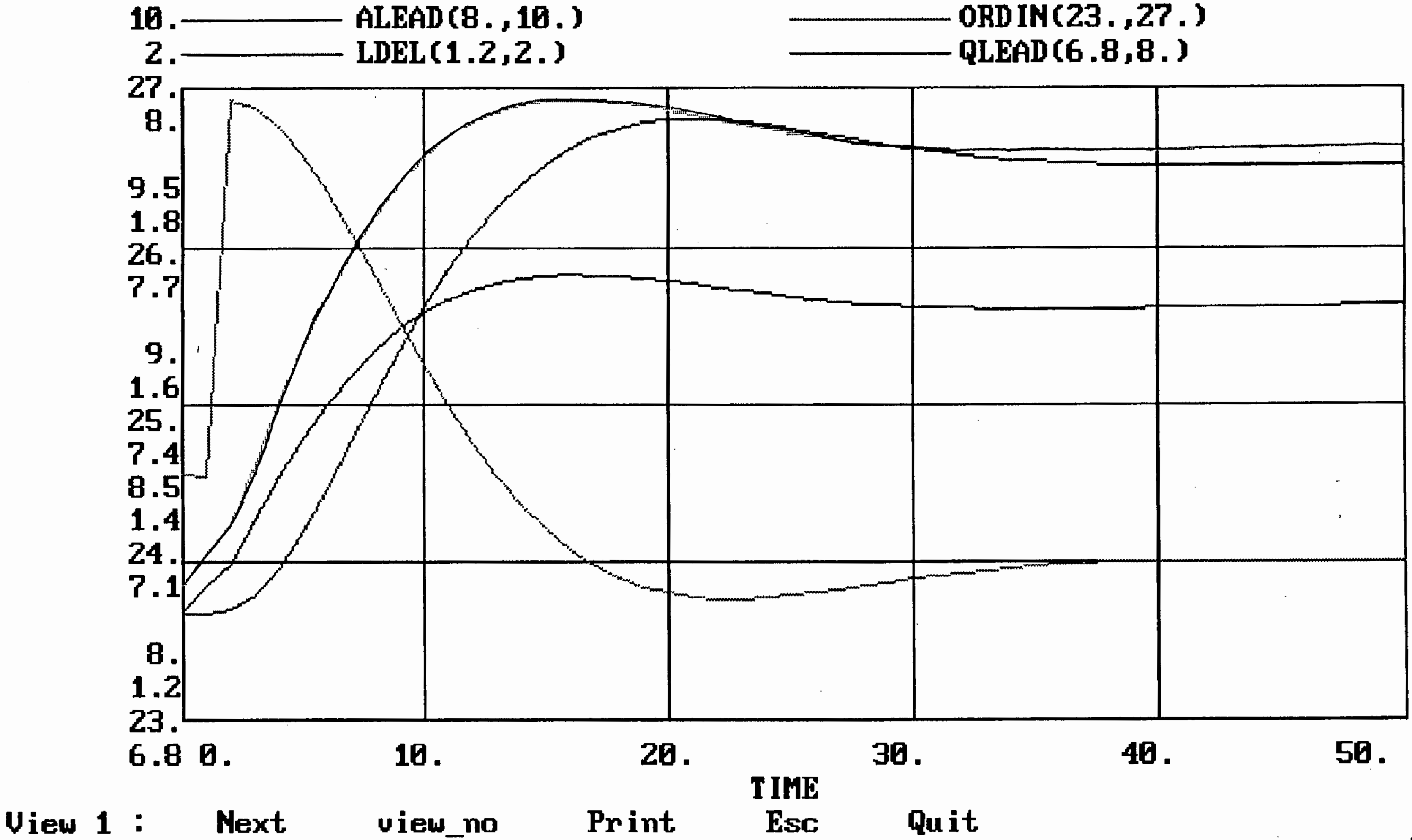



5% STEP CHANGE

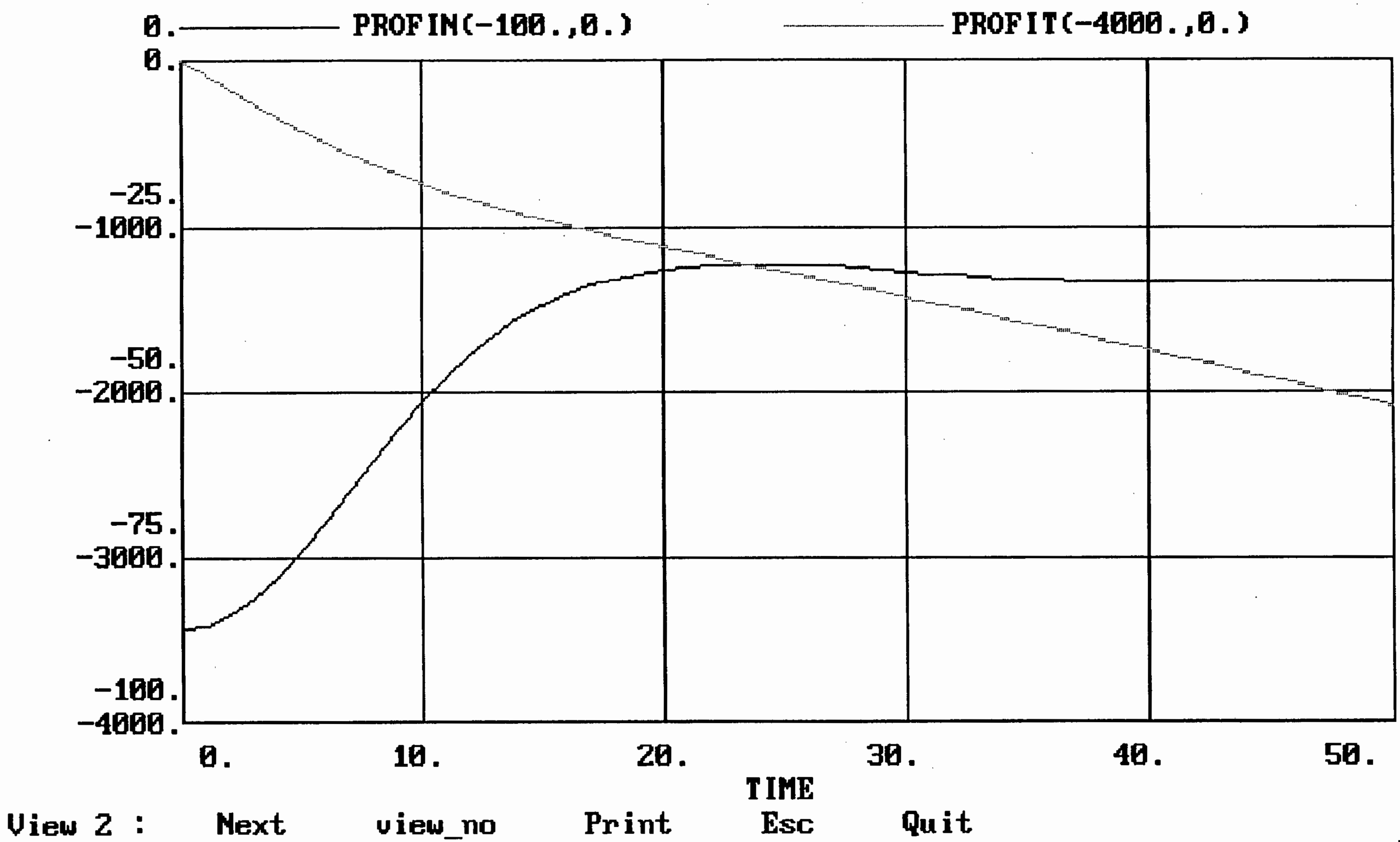
4 DAYS / WEEK



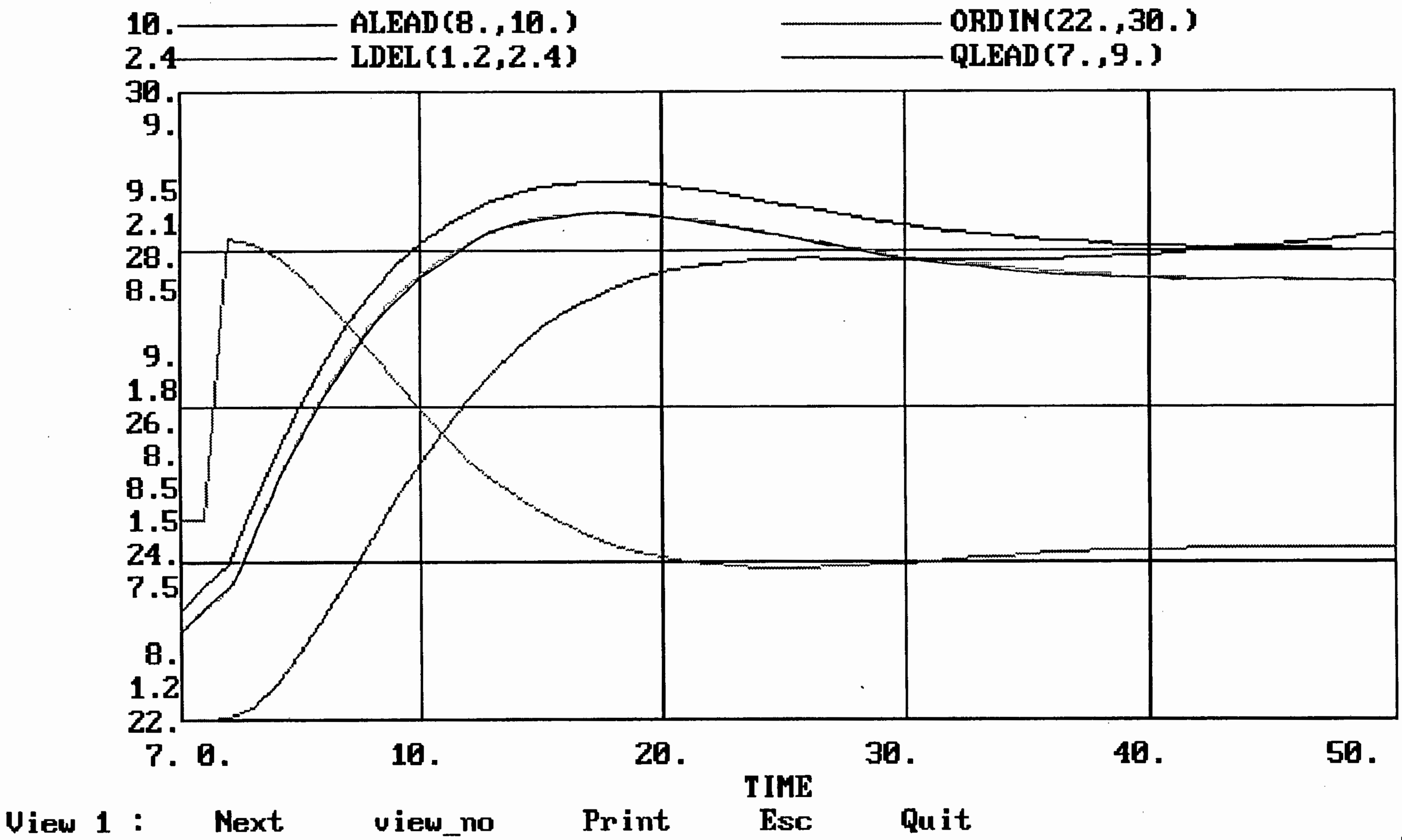
-20. PROFIN(-100.,-20.)
PROFIT(-4000.,0.)
0.
-40.
-1000.
-60.
-2000.
-80.
-3000.
-100.
-4000.
0.
10.
20.
30.
40.
50.
TIME
View 5 :
Next
view_no
Print
Esc
Quit




10% STEP CHANGE
4 DAYS / WEEK

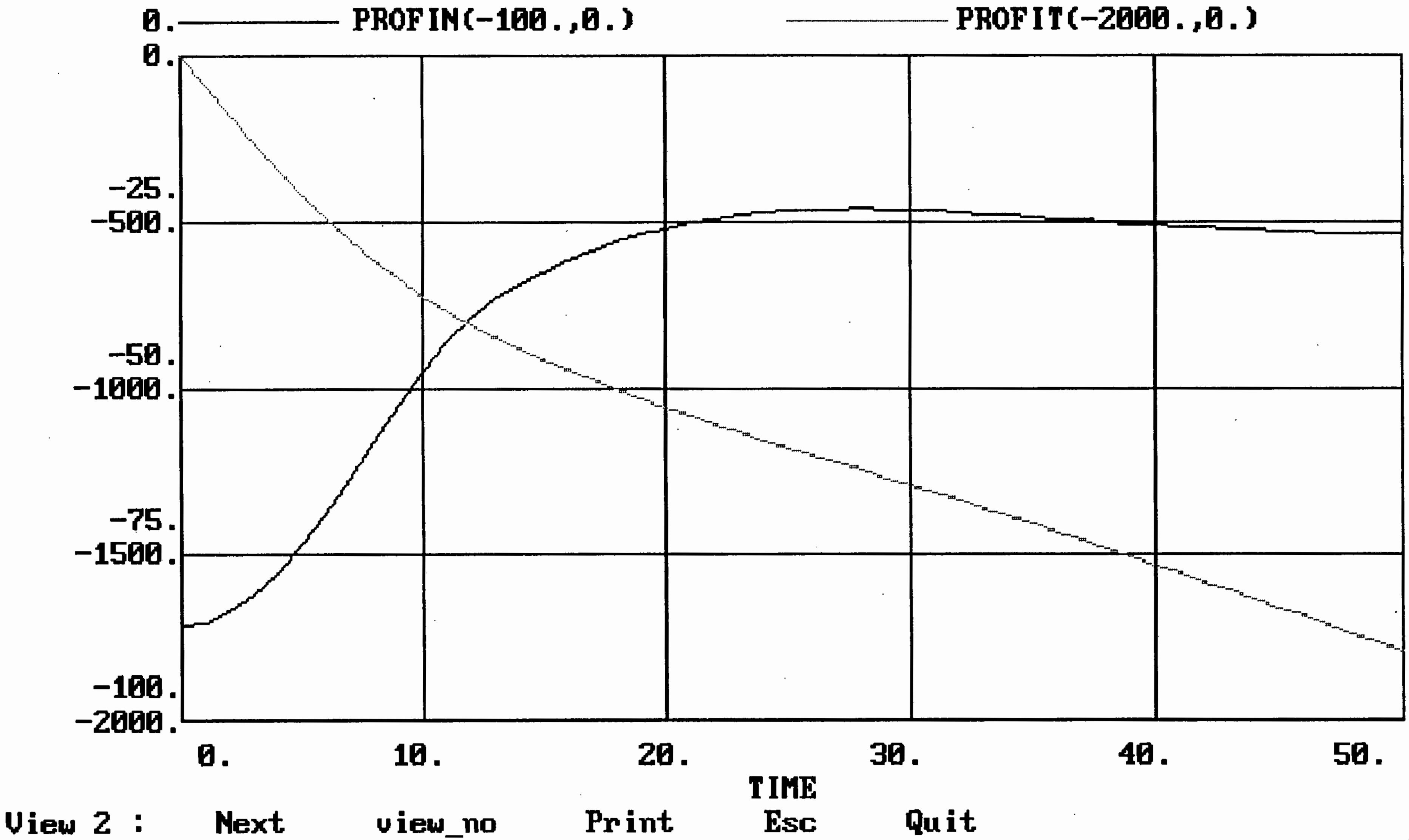


0. PROFIN(-100.,0.)
PROFIT(-4000.,0.)
0.
-25.
-1000.
-50.
-2000.
-75.
-3000.
-100.
-4000.
0.
10.
20.
30.
40.
50.
TIME
View 2 : Next view_no Print Esc Quit

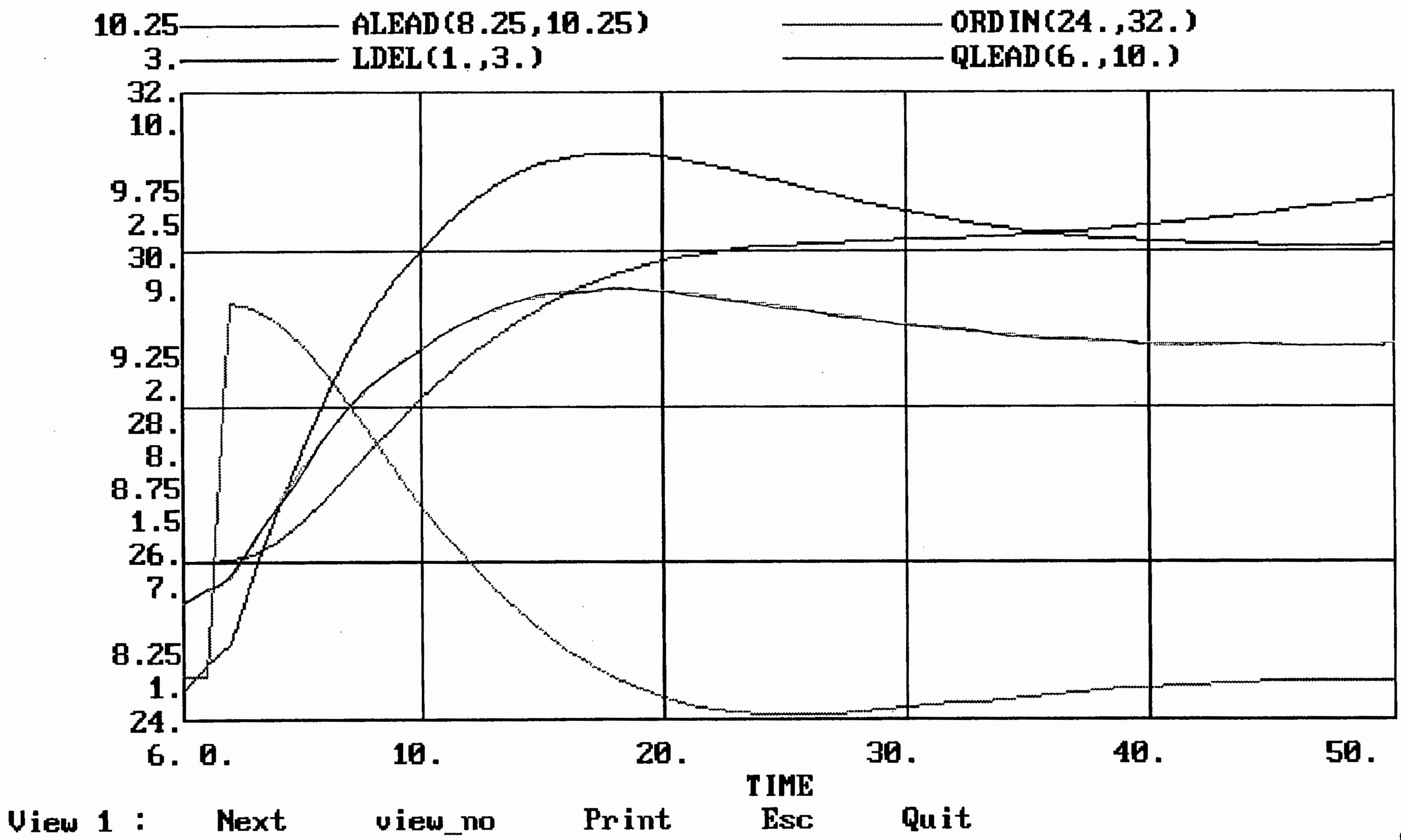



15% STEP CHANGE

4 DAYS / WEEK

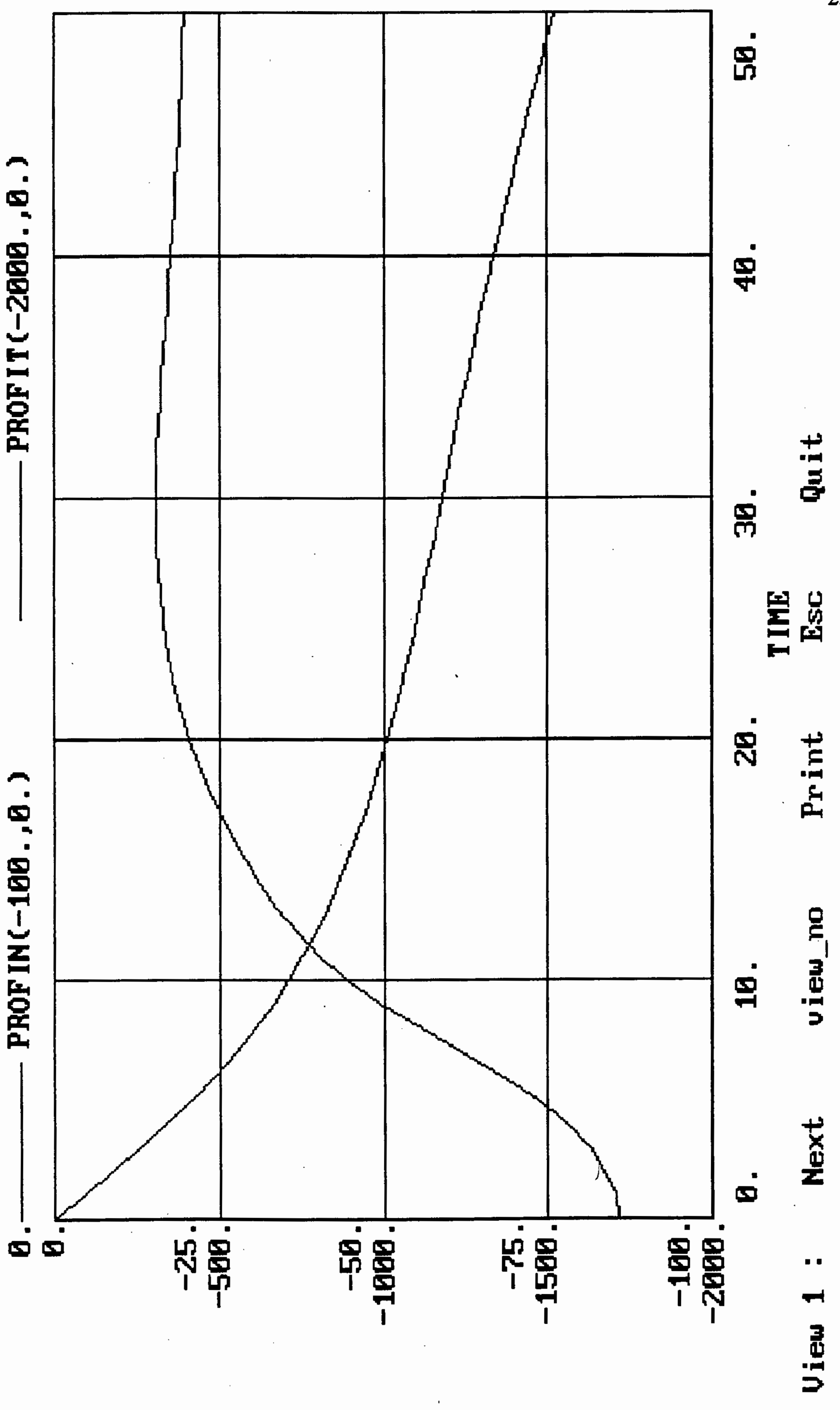


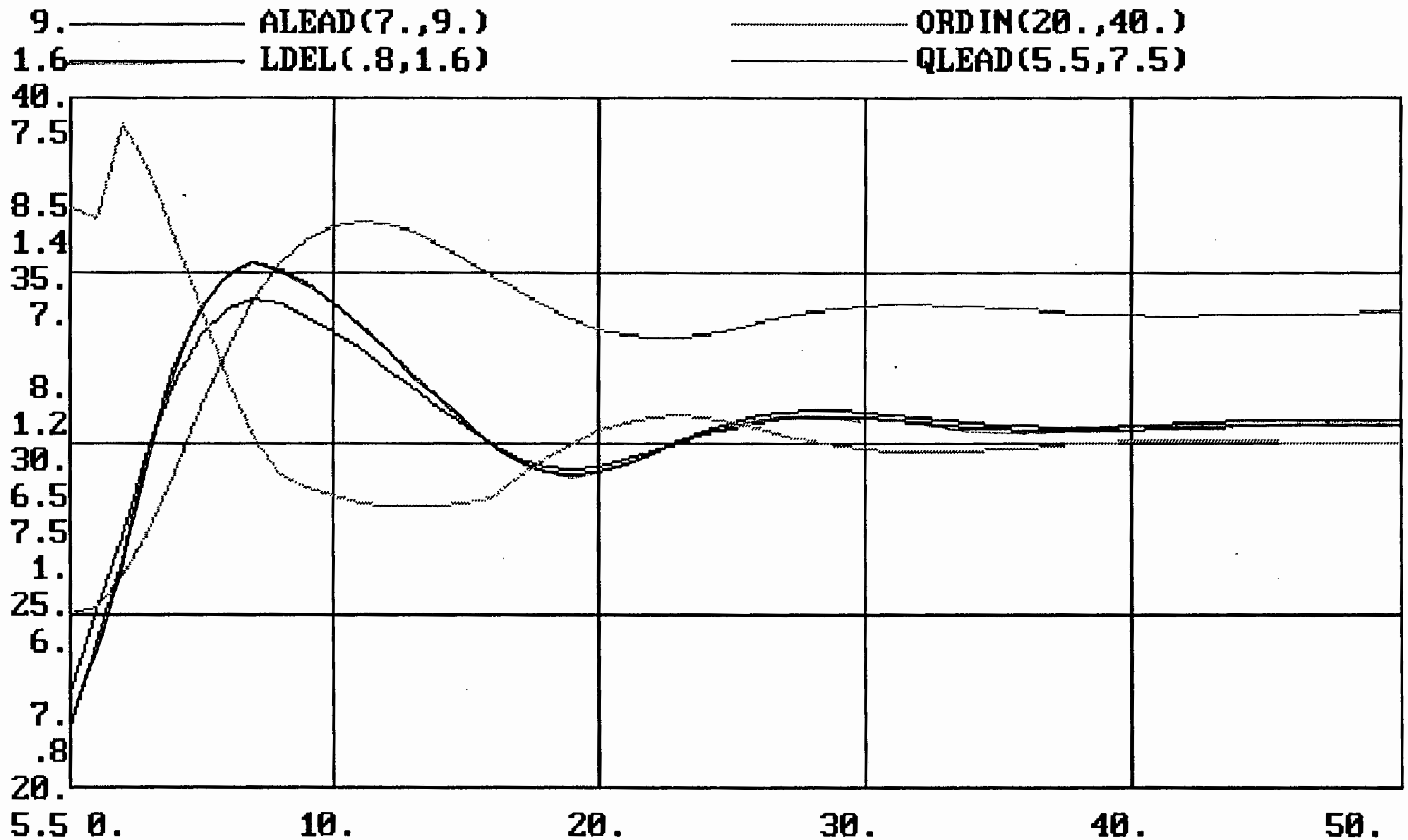
0. PROFIN(-100.,0.)
PROFIT(-2000.,0.)
0.
0.
-25.
-500.
-50.
-1000.
-75.
-1500.
-100.
-2000.
0.
10.
20.
30.
40.
50.
TIME
View 2 : Next view_no Print Esc Quit




20% STEP CHANGE

4 DAYS / WEEK

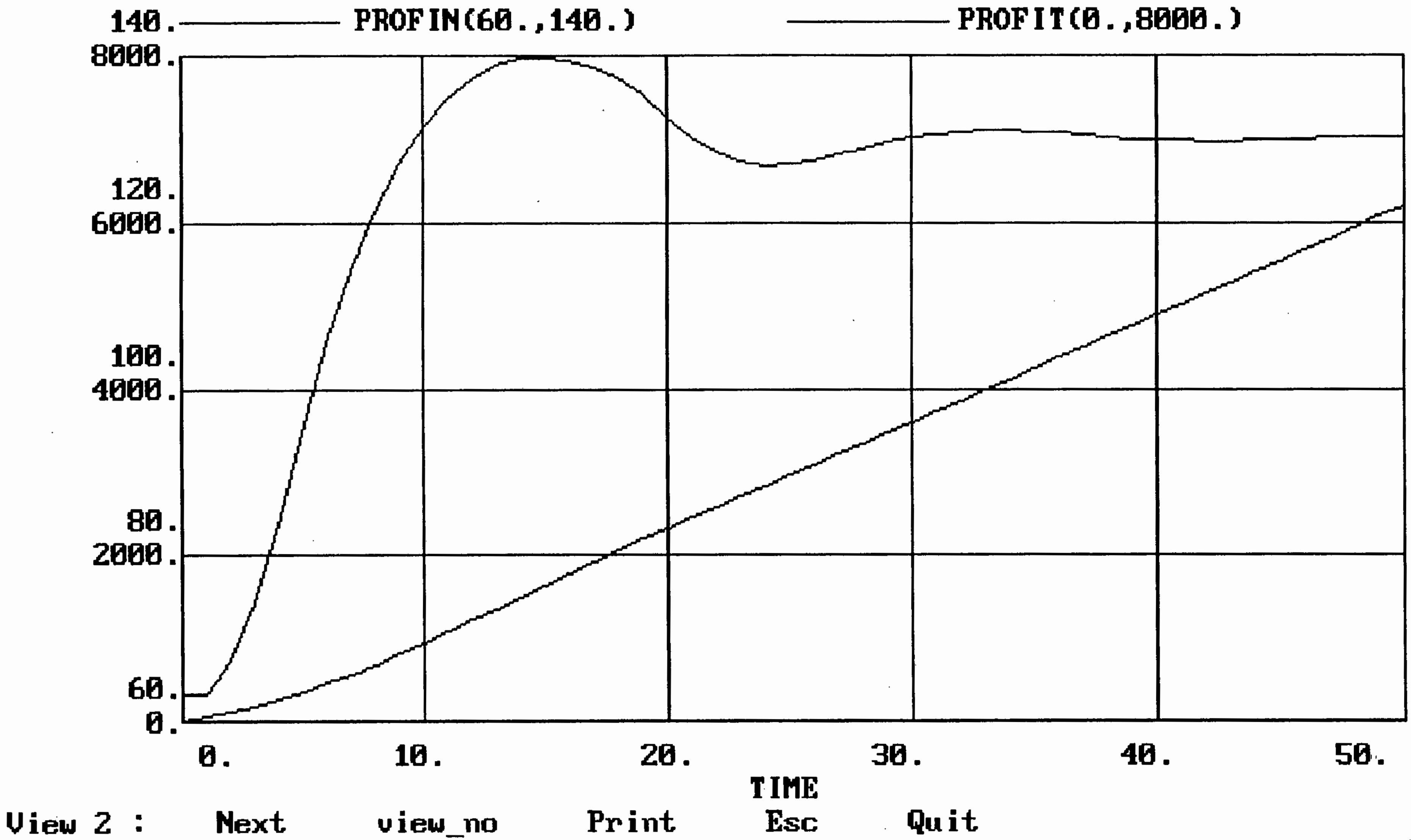

PROFIN(-100.,0.)
PROFIT(-2000.,0.)
0.
0.
-25.
-500.
-50.
-1000.
-75.
-1500.
-100.
-2000.
0.
10.
20.
30.
40.
50.
TIME
View 1 :
Next
view_no
Print
Esc
Quit

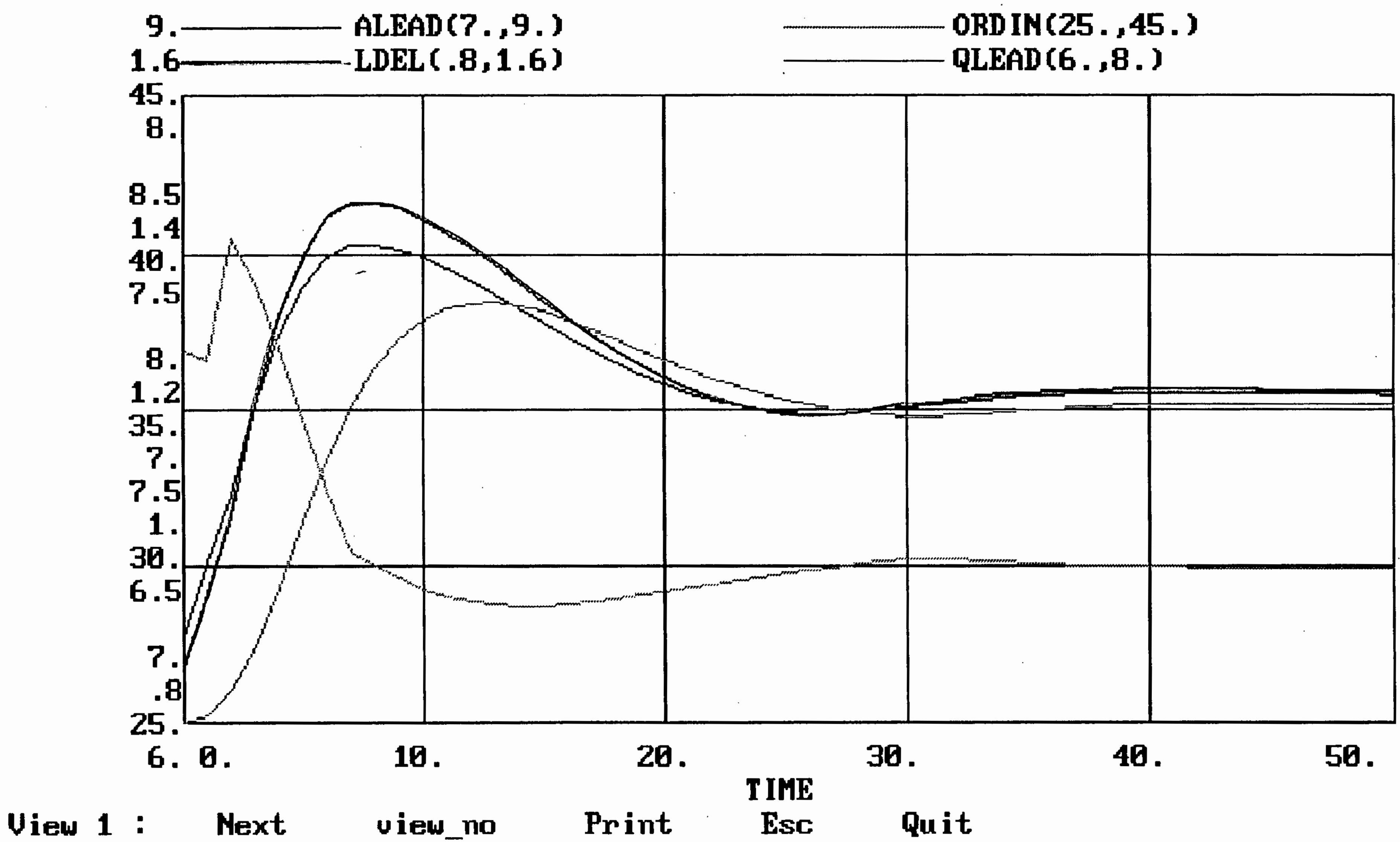



View 1 : Next view_no Print Esc Quit

15% STEP CHANGE

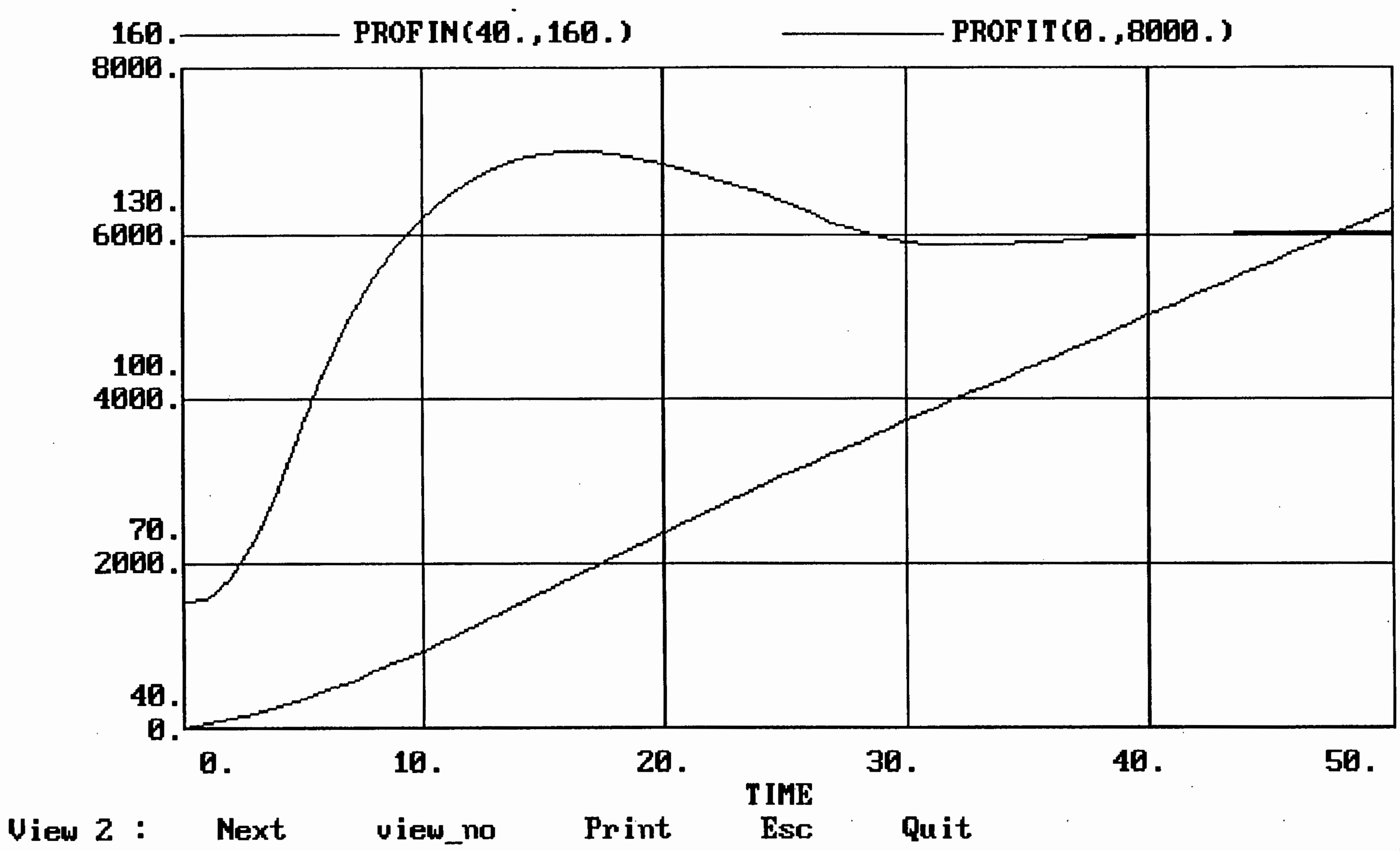
5 DAYS / WEEK


140.
PROFIN(60.,140.)
PROFIT(0.,8000.)
8000.
120.
6000.
100.
4000.
80.
2000.
60.
0.
0.
10.
20.
30.
40.
50.
TIME
View 2 :
Next
view_no
Print
Esc
Quit




20% STEP CHANGE

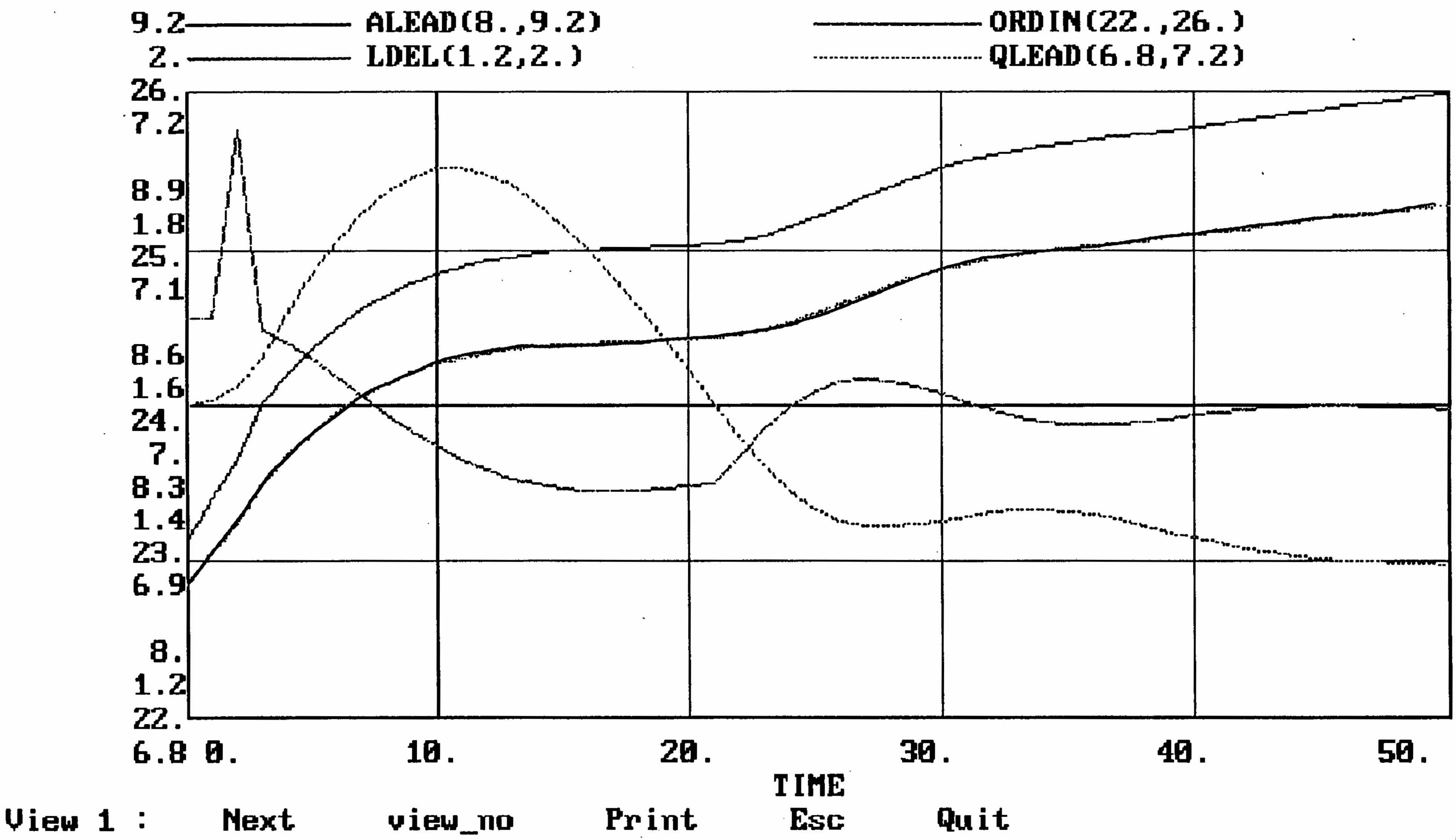
5 DAYS / WEEK



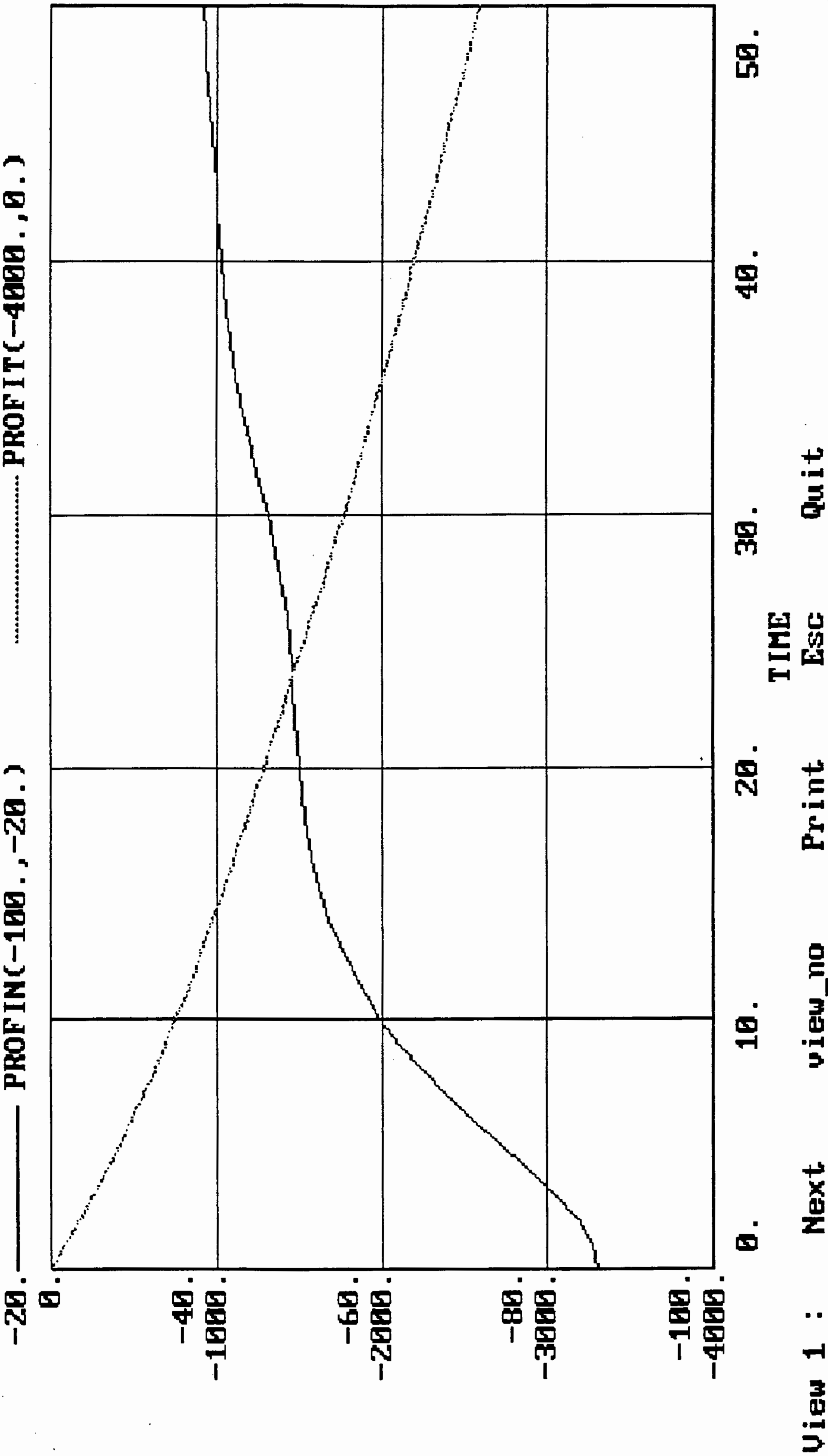
160.
PROFIN(40.,160.)
PROFIT(0.,8000.)
8000.
130.
6000.
100.
4000.
70.
2000.
40.
0.
0.
10.
20.
30.
40.
50.
TIME
View 2 : Next view_no Print Esc Quit

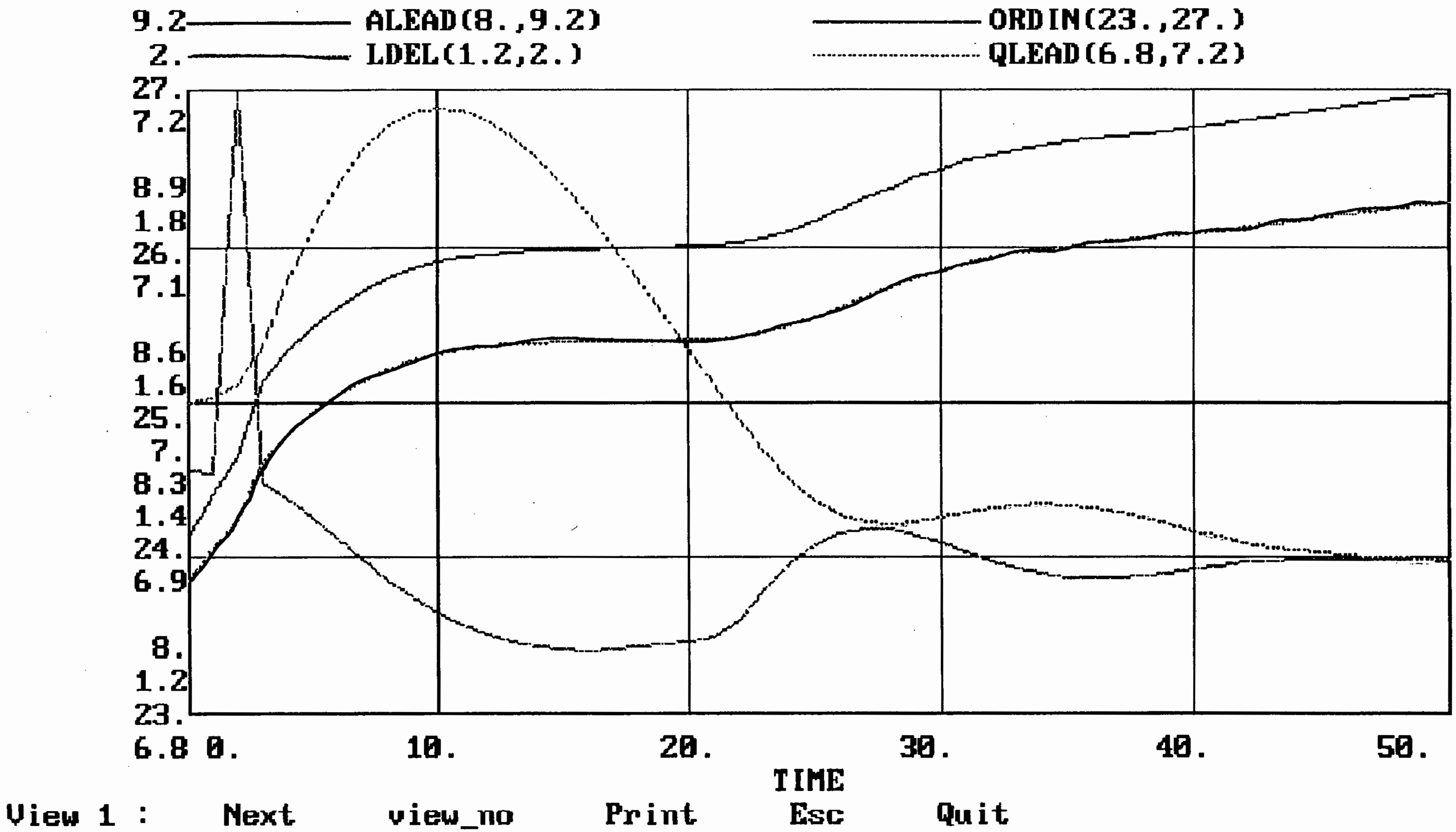
# APPENDIX 6.7

# DYNAMO SIMULATION OUTPUT OF PULSE CHANGE IN DEMAND

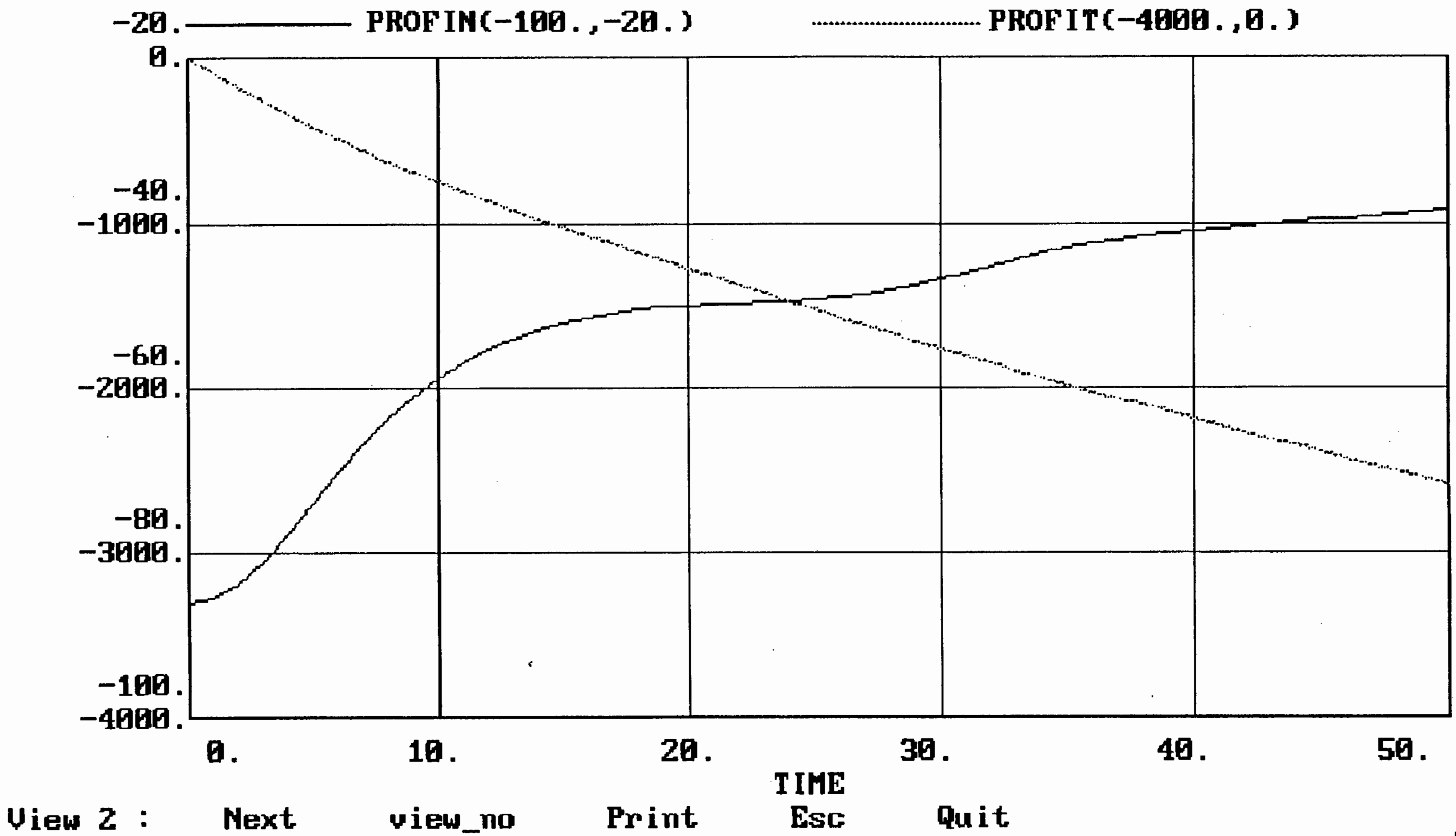



5% PULSE CHANGE

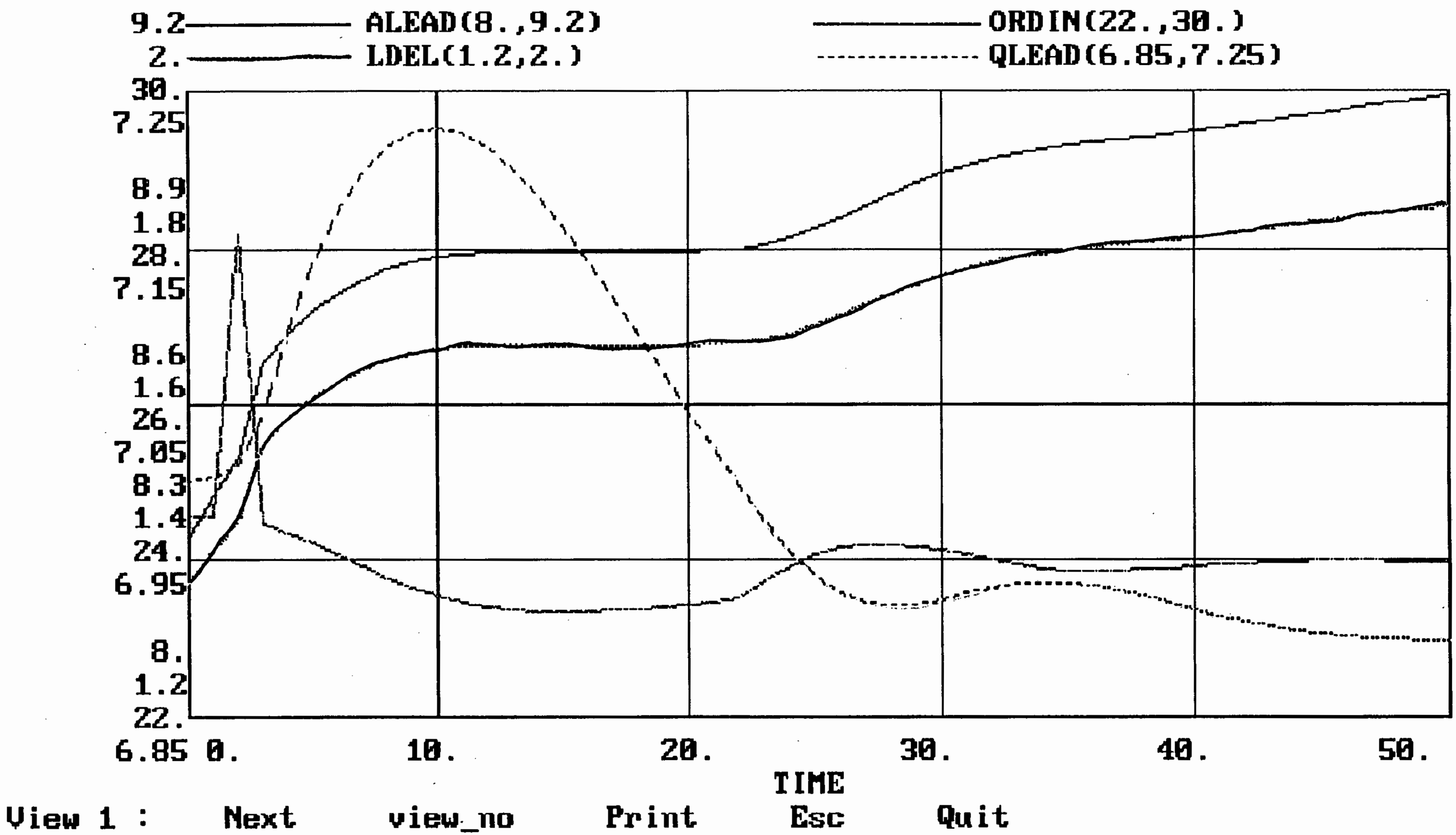

PROFIN(-100.,-20.)
PROFIT(-4000.,0.)
-20.
0.
-40.
-1000.
-60.
-2000.
-80.
-3000.
-100.
-4000.
0.
10.
20.
30.
40.
50.
TIME
View 1 :
Next
view_no
Print
Esc
Quit



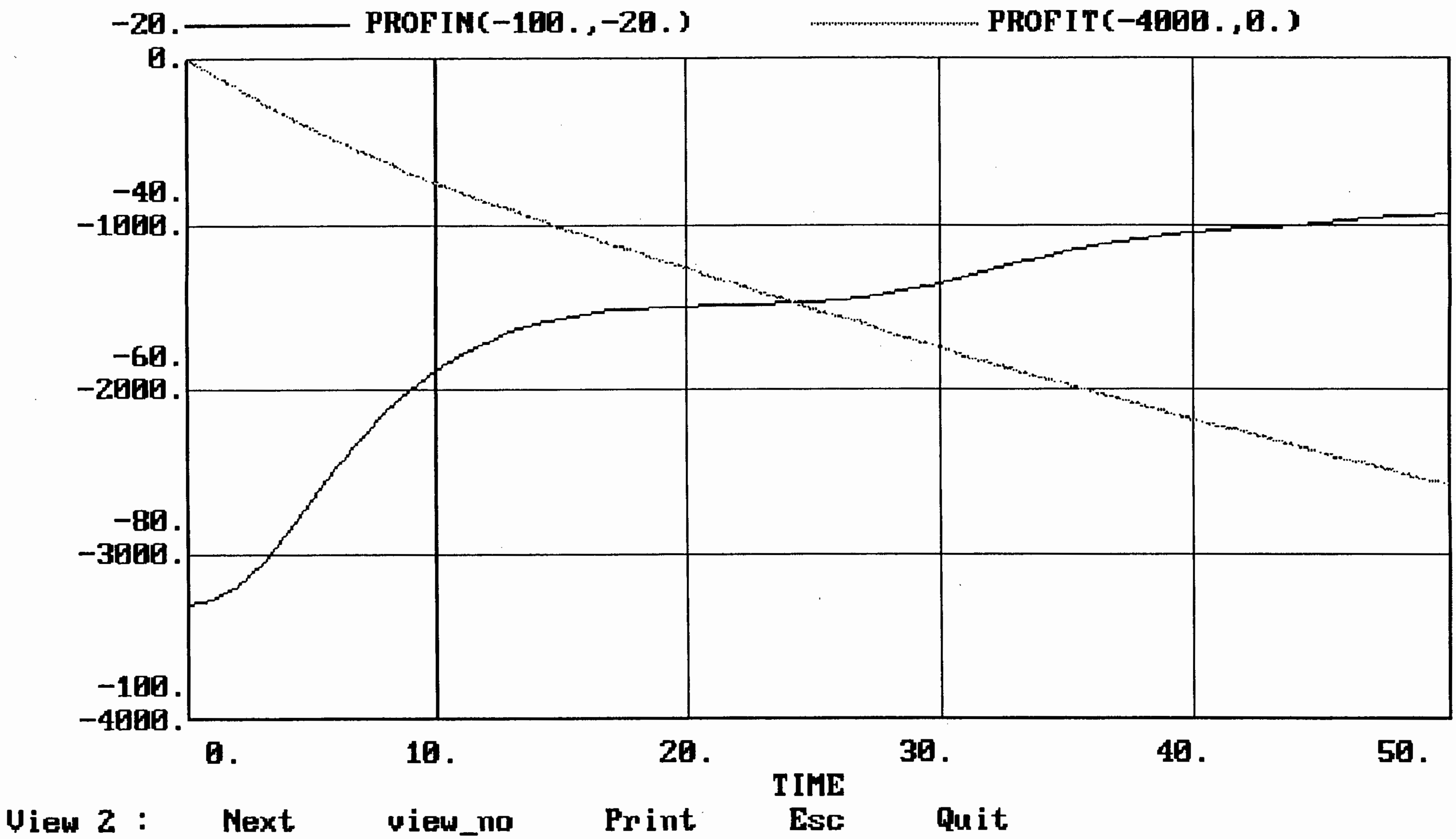

10% PULSE CHANGE

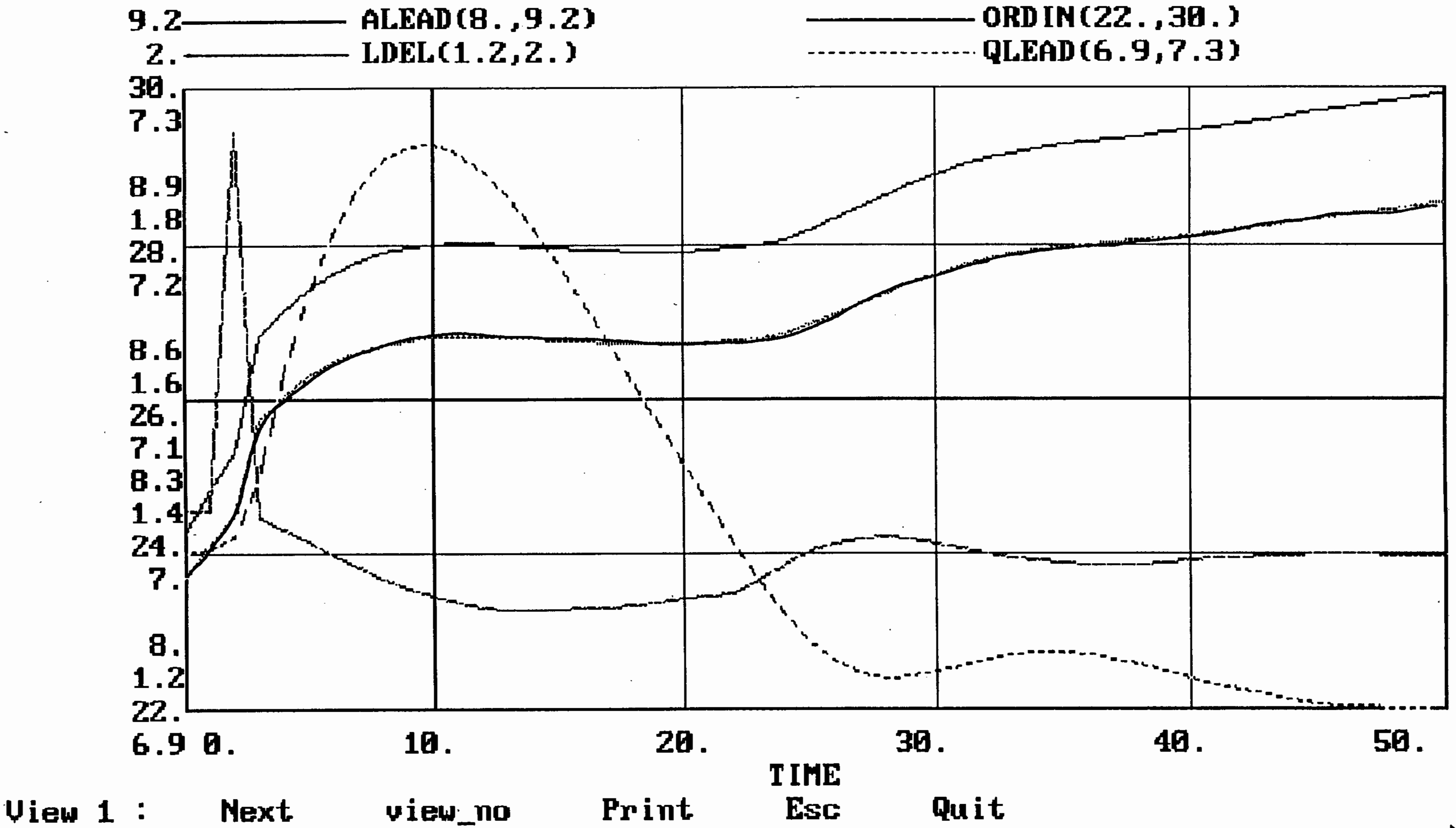


-20. PROFIN(-100.,-20.)
PROFIT(-4000.,0.)
0.
-40.
-1000.
-60.
-2000.
-80.
-3000.
-100.
-4000.
0.
10.
20.
30.
40.
50.
TIME
View 2 : Next view_no Print Esc Quit

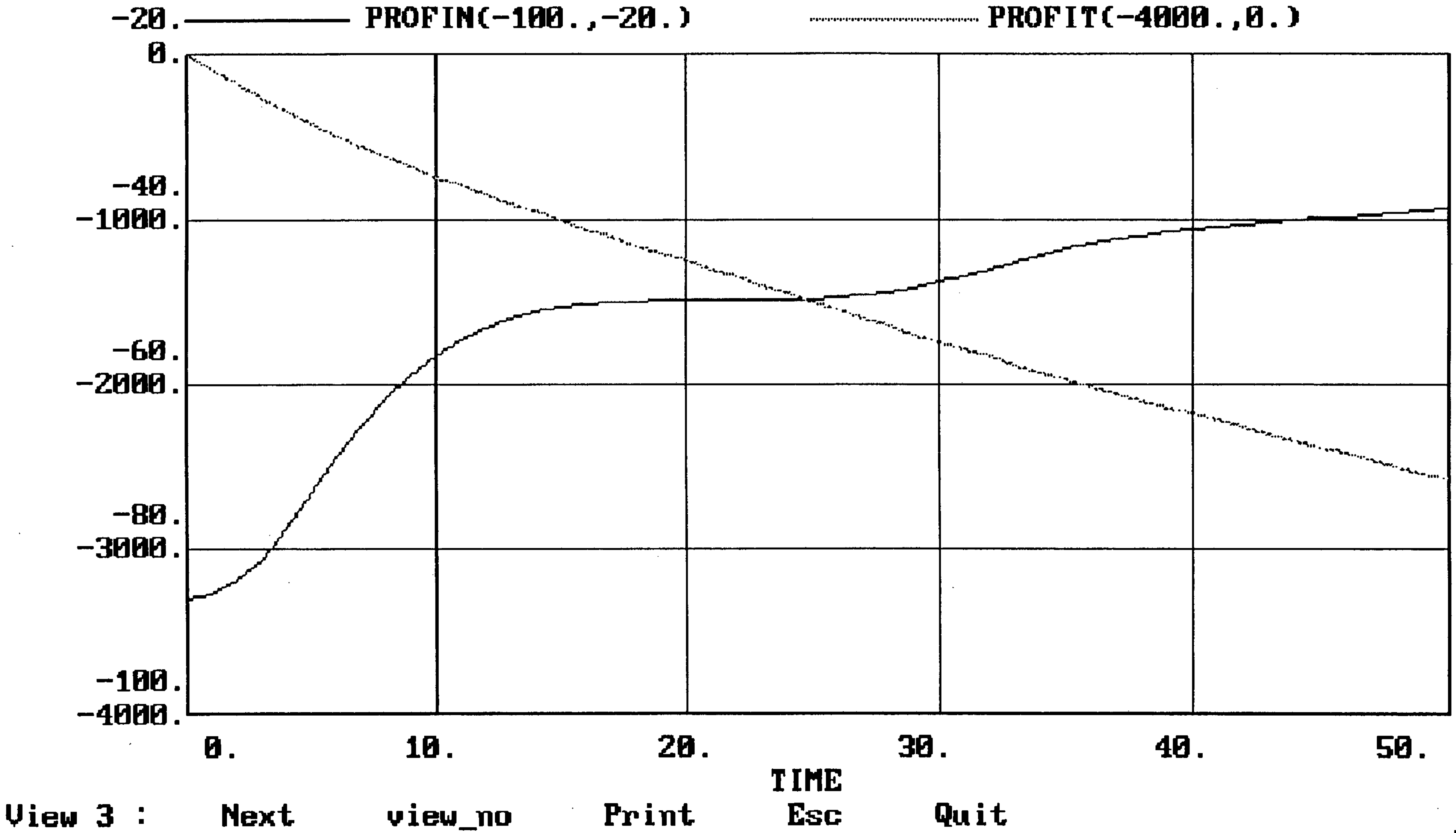


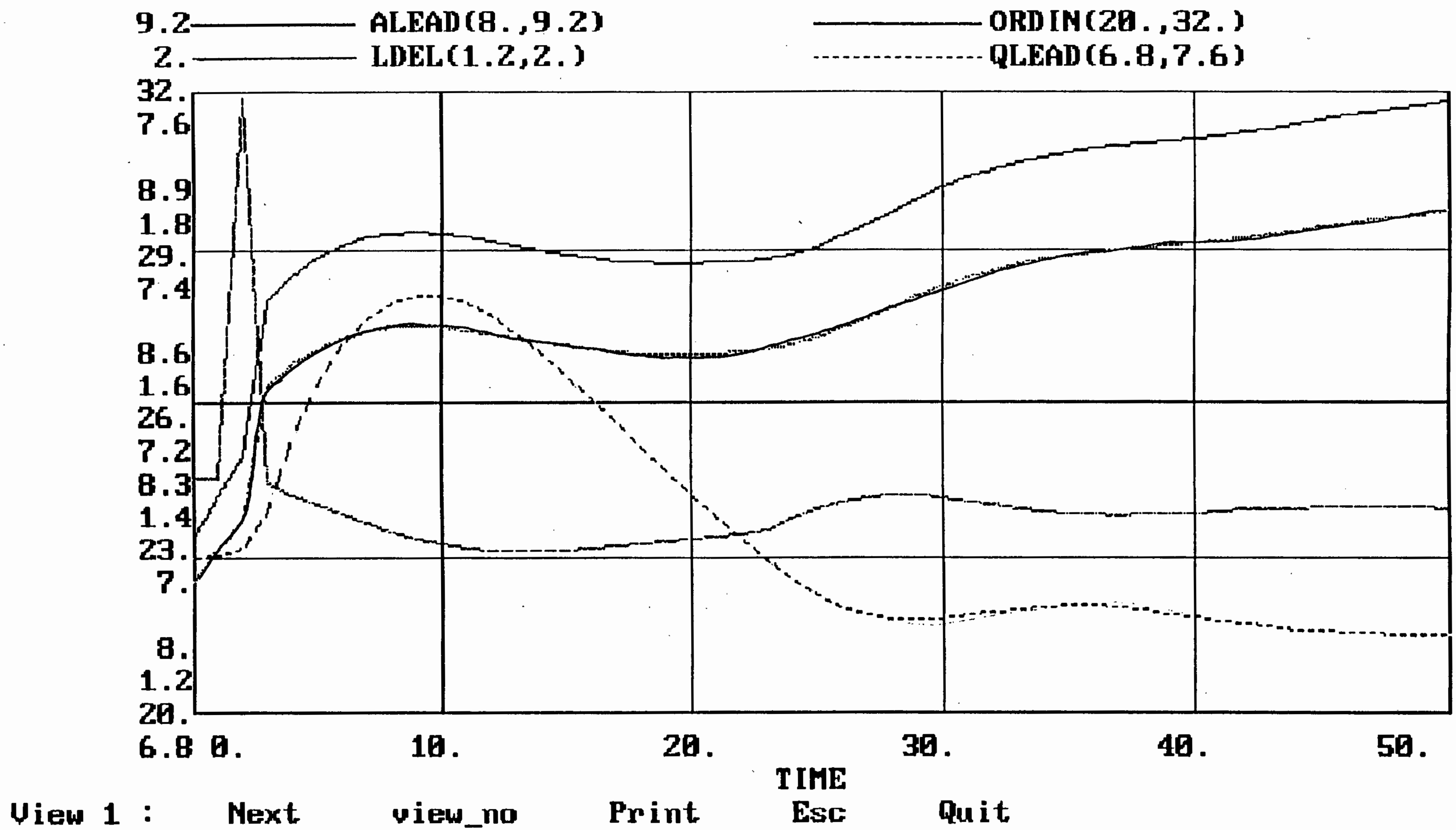

15% PULSE CHANGE


-20. PROFIN(-100.,-20.)
PROFIT(-4000.,0.)
0.
-40.
-1000.
-60.
-2000.
-80.
-3000.
-100.
-4000.
0.
10.
20.
30.
40.
50.
TIME
View 2 : Next view_no Print Esc Quit

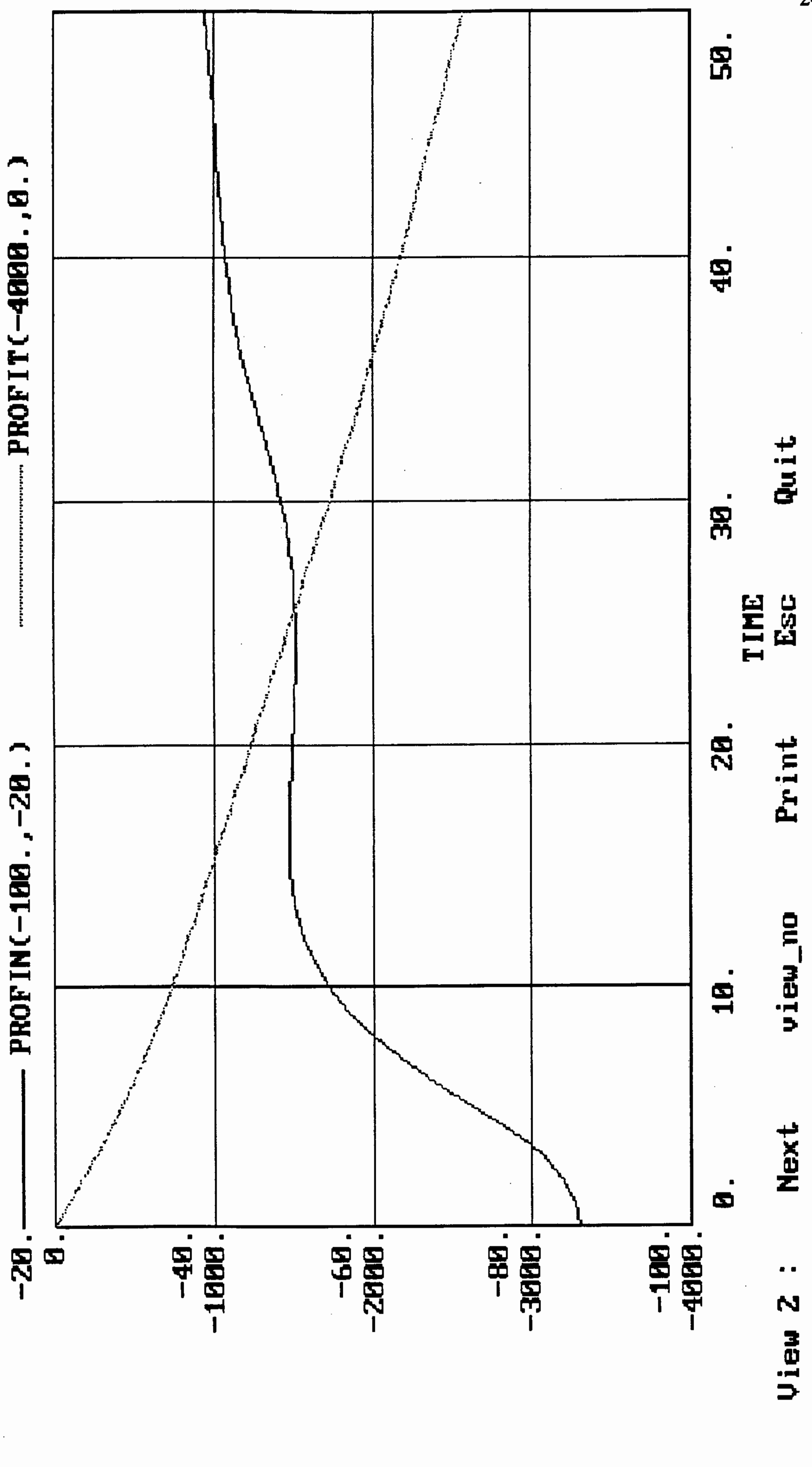


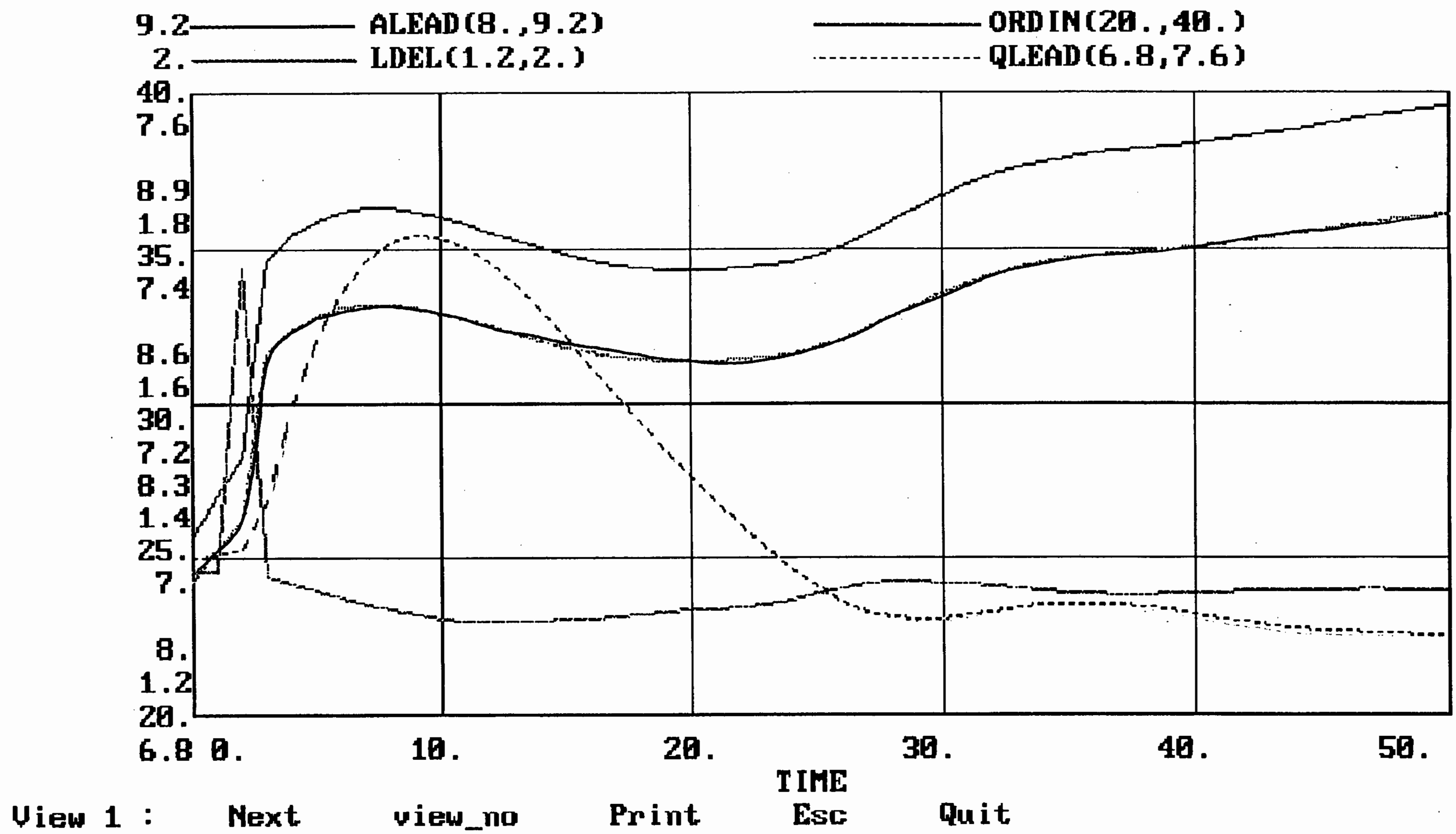

20% PULSE CHANGE


-20. PROFIN(-100.,-20.)
PROFIT(-4000.,0.)
0.
-40.
-1000.
-60.
-2000.
-80.
-3000.
-100.
-4000.
0.
10.
20.
30.
40.
50.
TIME
View 3 : Next view_no Print Esc Quit

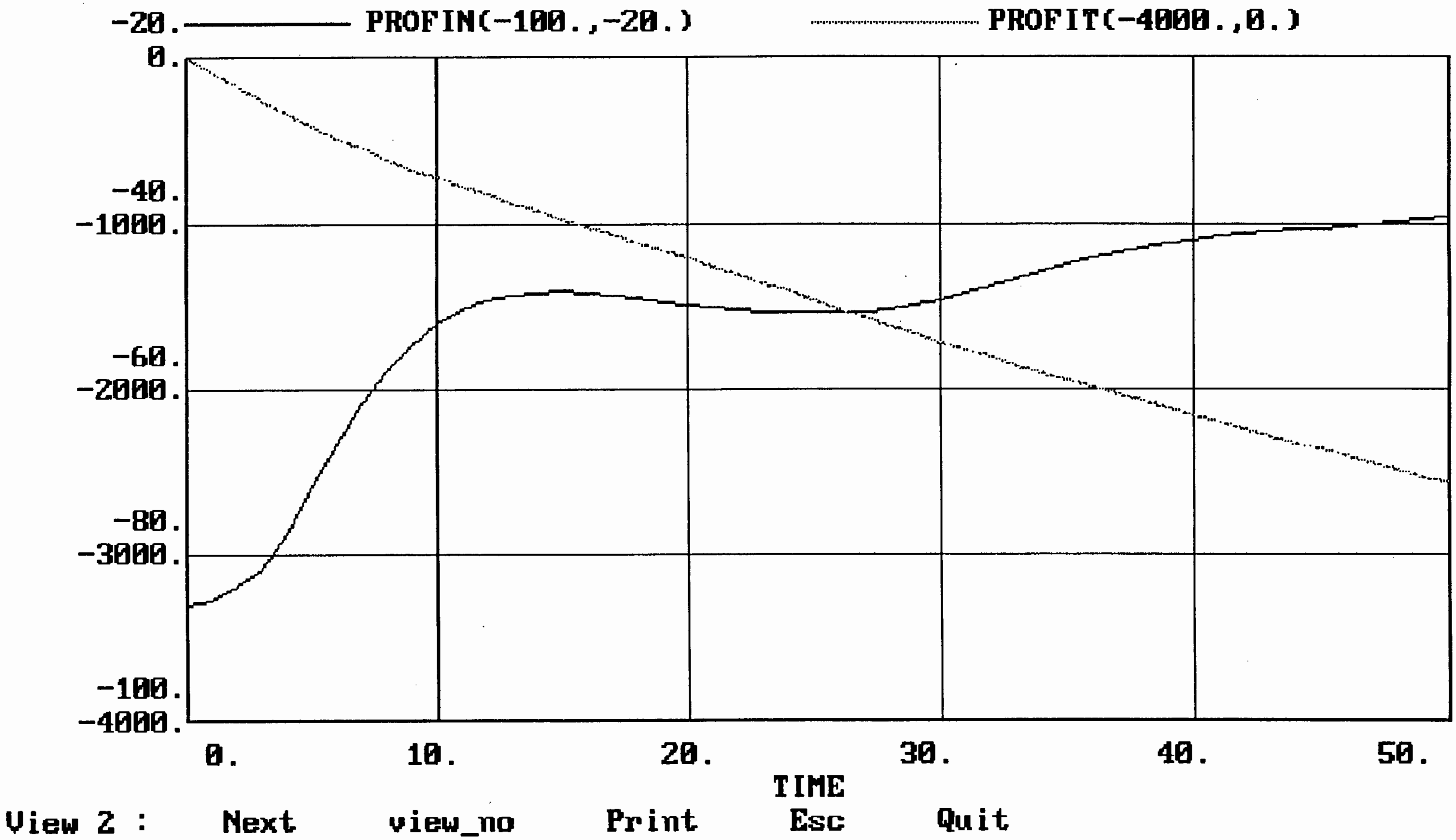


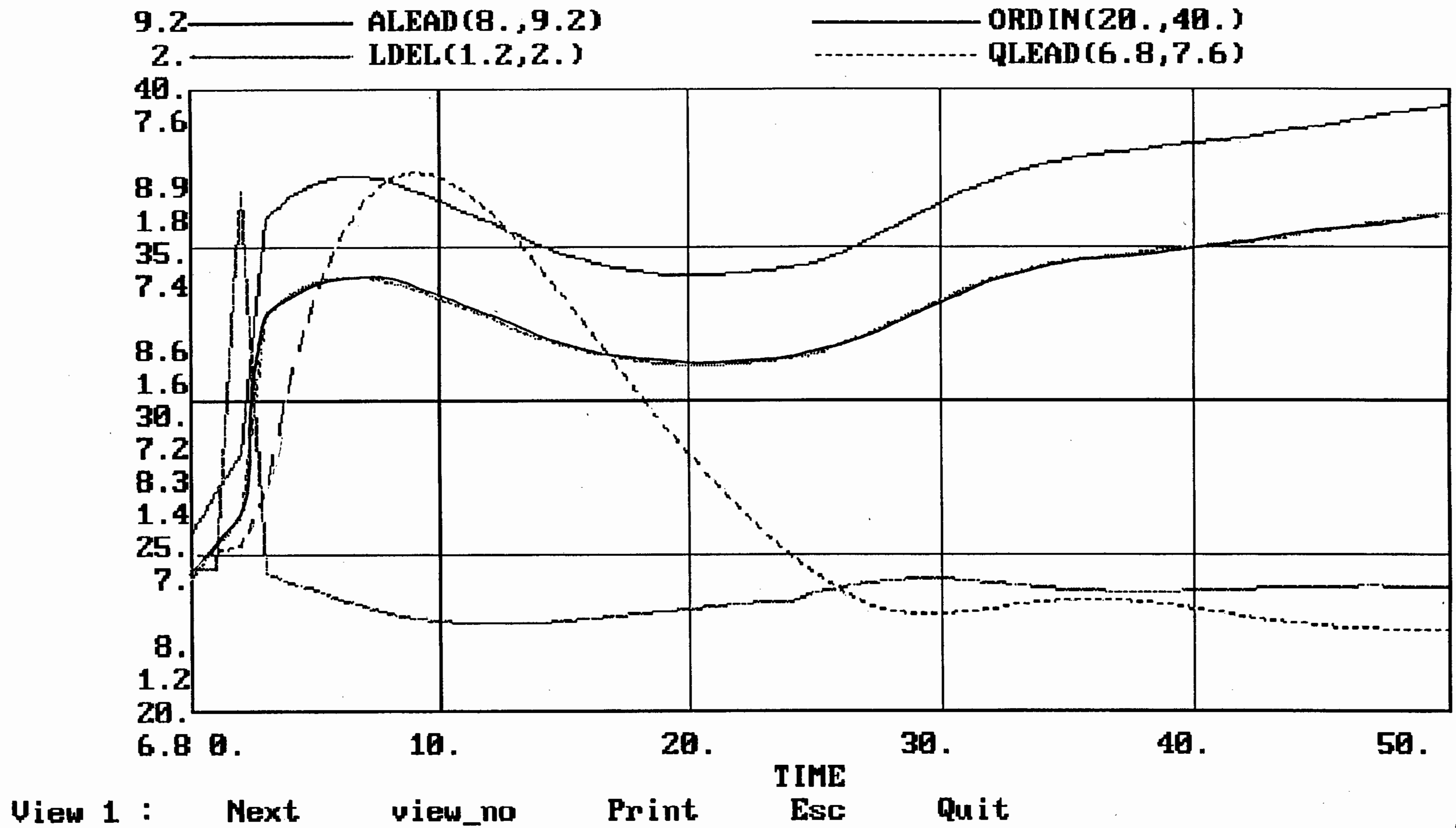

30% PULSE CHANGE


PROFIN(-100.,-20.)
PROFIT(-4000.,0.)
-20.
0.
-40.
-1000.
-60.
-2000.
-80.
-3000.
-100.
-4000.
0.
10.
20.
30.
40.
50.
TIME
View 2 :
Next
view_no
Print
Esc
Quit

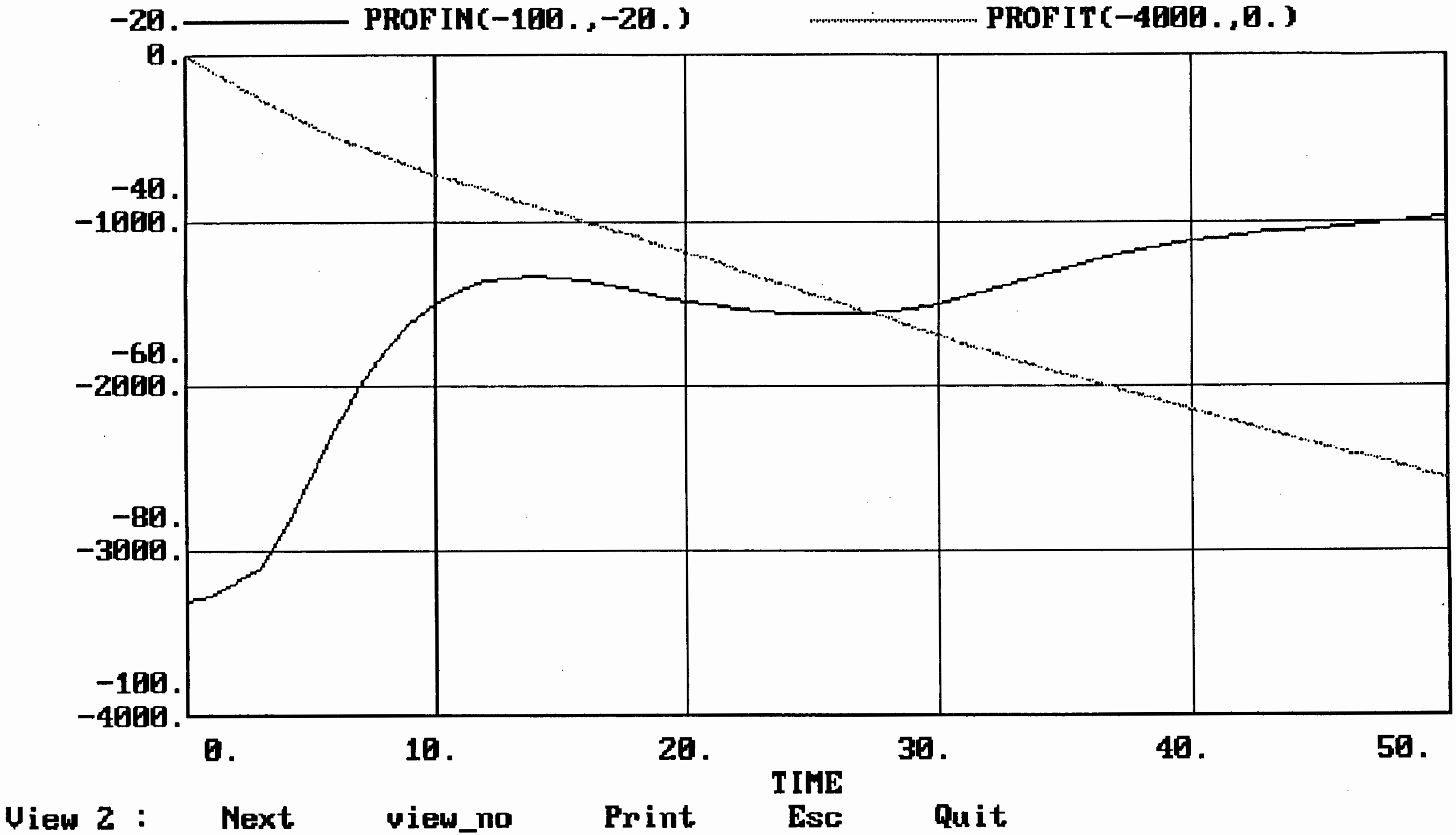



40% PULSE CHANGE


PROFIN(-100.,-20.)
PROFIT(-4000.,0.)
-20.
0.
-40.
-1000.
-60.
-2000.
-80.
-3000.
-100.
-4000.
0.
10.
20.
30.
40.
50.
TIME
View 2 : Next view_no Print Esc Quit




50% PULSE CHANGE



-20. PROFIN(-100.,-20.)
PROFIT(-4000.,0.)
0.
-40.
-1000.
-60.
-2000.
-80.
-3000.
-100.
-4000.
0.
10.
20.
30.
40.
50.
TIME
View 2 : Next view_no Print Esc Quit

# APPENDIX 6.8

# SYSTEM IMPLEMENTED TO INCREASE THE DYE HOUSE CAPACITY

## INCREASING DYE HOUSE CAPACITY

The dye house capacity can be increased by increasing the batch size. The batch size can be increased by dyeing orders together with similar shades. Operating costs will also decrease by increasing the batch size.

The reason that the dye machines are not scheduled efficiently by dyeing similar shades together and therefore increasing the batch size, is because it is difficult to determine different orders that contain identical shades manually, as was done previously. A computer terminal was set up in the dye house and planning departments to determine the orders that have similar shades. The program allowed the user to enter the shade number and the output is a list of all the order numbers, customers and the delivery dates for all the orders that have to be delivered within the following 4 weeks. These order lines are then grouped together, without affecting the delivery performance, to produce a full dye load for the dyeing machines.

A study over a period of 8 weeks was done and an average of 5 dye-lots per week with identical shades were dyed separately that could have been dyed together. This costs the dye house R11 200 per month and utilizes 5% of the dye house capacity. These calculations are shown below.

**1. EXTRA CAPACITY BY DYEING IDENTICAL SHADES TOGETHER**

AVERAGE TIME TAKEN TO DYE A BATCH

| | |
|---|---|
| Average amount of cotton dyed per year | = 653 tons |
| Average amount of polyester dyed per year | = 193 tons |
| Average amount of poly-cotton dyed per year | = 429 tons |
| Total dyed per year | = 1275 tons |

| | |
|---|---|
| Average dyeing time for cotton | = 11 hours |
| Average dyeing time for polyester | = 4 hrs |
| Average dyeing time for poly-cotton | = 14 hrs |

Average time taken = 11*653/1275 + 4*193/1275 + 14*429/1275

= **11 hours**

AVERAGE PERCENTAGE TIME TAKEN TO DYE IDENTICAL SHADES

| | |
|---|---|
| Average number of dye-lots with identical shades not dyed together per week | = 5 /week |
| Average time saved | = 5*11 = 55 hours |
| Average dye machine working hours per week | = 1400 hours |
| Average percentage time saved | = 55*100/1400 |
| | = **5%** |

**<u>Conclusion</u>**

AVERAGE INCREASE IN CAPACITY = **5%**

**2. COST OF RE-DYING IDENTICAL SHADES**

The cost of dying a shade that could have been dyed with another batch uses an approximate method. The costs of dyes are not included in the calculation because extra dye will need to be added for the extra weight dyed.

AVERAGE COST OF CHEMICALS PER BATCH

| | |
|---|---|
| Average number of batches dyed per month | = 694 |
| Average cost of chemicals per month | = R147000 |
| Average cost of chemicals per batch | = 147000/694 |

AVERAGE OPERATING COSTS PER BATCH

| | |
|---|---|
| Average amount of cotton dyed per year | = 653 tons |
| Average amount of polyester dyed per year | = 193 tons |
| Average amount of poly-cotton dyed per year | = 429 tons |
| Total dyed per year | = 1275 tons |

| | |
|---|---|
| Average dyeing time for cotton | = 11 hours |
| Average dyeing time for polyester | = 4 hrs |
| Average dyeing time for poly-cotton | = 14 hrs |

Average machine operating costs per hour = R28 (see below)

Average operating costs per batch

= 28.44 { (11*653/1275) + (4*193/1275) + (14*429/1275) }

= **R311**

**Conclusion**

AVERAGE COST OF RE-DYING A SHADE = 212 +311 = **R523**

**3. DYE MACHINE OPERATING COSTS**

The dye machine operating costs per hour are calculated using two different methods. Two methods are used to determine the validity of the results. The nature of the problem does not require the results to be 100% accurate. A reasonable estimation is obtained by using these methods.

Depreciation costs and the cost of operating the boiler are not considered because the purposes of this calculation are to determine practical costs and not costs for accounting purposes. Depreciation will still occur if the machine is not operative and the boiler will still operate at the same capacity if a machine stands idle.

**Method 1**

This method determines the machine operating costs per hour by using the average costs incurred by all the machines in the dye-house per month. Results were obtained for 12 months and the averages are tabulated below.

A reasonable assumption is made that only 11 machines of the 13 incurred these costs because on average there are two machines that stand idle per day. The average number of working days for the dye-house is calculated to be 25. The results below are in rands.

| COST INCURRED BY | MONTHLY | DAILY | HOURLY | PER MACHINE |
|---|---|---|---|---|
| Electricity | 10700 | 428 | 18 | 1.64 |
| Water & Effluent | 39700 | 1588 | 66 | 6.00 |
| Repairs & Maintenance | 86000 | 3440 | 143 | 13.01 |
| Wages | 52000 | 2080 | 86 | 7.82 |
| TOTAL | R188400 | R7536 | R313 | **R28.46** |

**Method 2**

This method calculates machine operating costs per hour by determining the costs incurred to one machine directly.

ELECTRICITY COST :- Electricity cost = 15.23 c/KW

Average machine power = 25 KW

Cost per hour = 15.23 * 25

= **R3.81** /hour

WATER COST :- Water cost = 0.129 c/liter

Average machine volume = 3400 liters

Average baths per hour = 1

| | | |
|---|---|---|
| | Cost per hour | = 1*3400*0.129 |
| | | = **R4.39** /hour |
| EFFLUENT COST :- | Effluent cost | = 0.0667 c/liter |
| | % water to effluent | = 85% |
| | Cost per hour | = 0.85*3400*0.0667 |
| | | = **R1.94** /hour |
| LABOUR COST :- | Average operator cost | = **R5.26** /hour |

REPAIRS & MAINTENANCE :- There is no documentation or history to determine an individual machines costs due to repairs and maintenance. The mechanics that repair these machines spend approximately equal time on all machines so an accurate assumption can be made that the machines share the monthly repairs and maintenance costs evenly as in method 1.

Average cost = **R13.01** /hour

| | | |
|---|---|---|
| TOTAL COST :- | Electricity cost | = R3.81 |
| | Water cost | R4.39 |
| | Effluent cost | R1.94 |
| | Labour cost | R5.26 |
| | Repairs & Maintenance | R13.01 |
| | | ------ |
| | TOTAL | **R28.41** |

**Conclusion**

AVERAGE DYE MACHINE OPERATING COSTS PER HOUR = **R28.44**

# APPENDIX 6.9

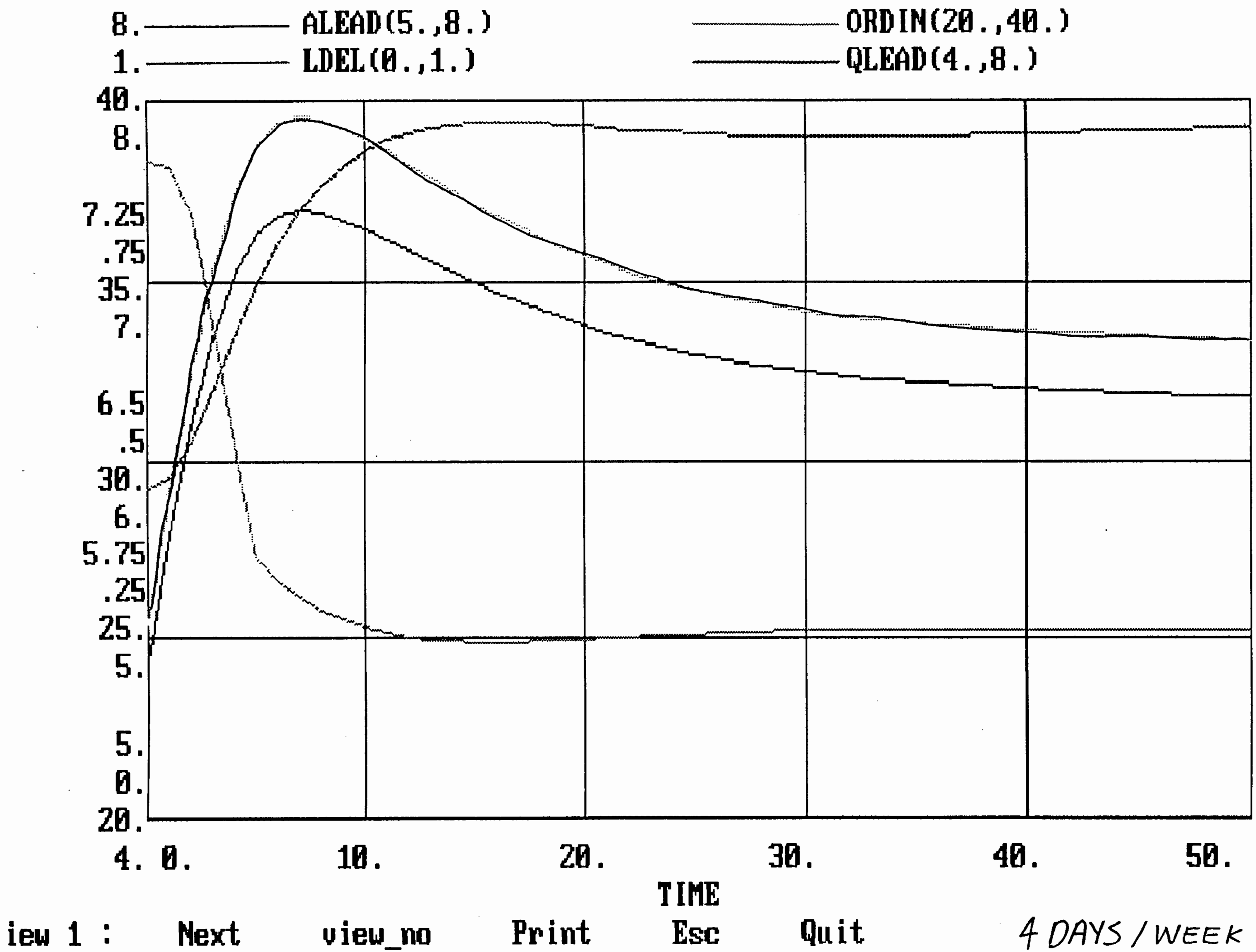
# COMPUTER PROGRAM OF THE DYNAMO MODEL USED TO FORECAST BOTTLENECKS

```
NOTE *************************************************************
NOTE                          PRODUCTION MIX
NOTE *************************************************************
NOTE          POLY-COTTON
C APOLC=3000
C BPOLC=2500
C CPOLC=210
NOTE          POLYESTER
C APOLES=230
C BPOLES=3400
C CPOLES=1900
NOTE          COTTON OPEN WIDTH
C ACOTOW=4500
C BCOTOW=2340
C CCOTOW=2100
NOTE          COTTON TUBULAR
C ACOTUB=3600
C BCOTUB=4560
C CCOTUB=1270
NOTE          BRUSHING
C ABRUSH=6000
C BBRUSH=10000
C CBRUSH=3000
NOTE          PFP
C APFP=0
C BPFP=0
C CPFP=1000
NOTE          PFP WOVEN
C APFPW=0
C BPFPW=0
C CPFPW=0
NOTE *************************************************************
NOTE                           INITIAL QUEUES
NOTE *************************************************************
NOTE          STENTER I
N QSTENT=10
NOTE          STENTER II
N QSTENTII=100
NOTE          ALEA & BRUCKNER
N QALEA=1000
NOTE          ESSICO
N QESSICO=800
NOTE          CALENDER
N QCALEN=100
NOTE          BRUSHING
N QBRUSH=5000
NOTE          CROPPING
N QCROP=900
NOTE          PERCHING
N QPERCH=15000
NOTE *************************************************************
NOTE                         MACHINE CAPACITIES
NOTE *************************************************************
NOTE          STENTER I
C STICAP=5000
NOTE          STENTER II
C STIICAP=6000
NOTE          ALEA & BRUCKNER
C ALEACAP=3000
NOTE          ESSICO
C ESSICAP=3500
NOTE          CALENDER
C CALCAP=10000
NOTE          BRUSHING
C BRCAP=7000
NOTE          CROPPING
```

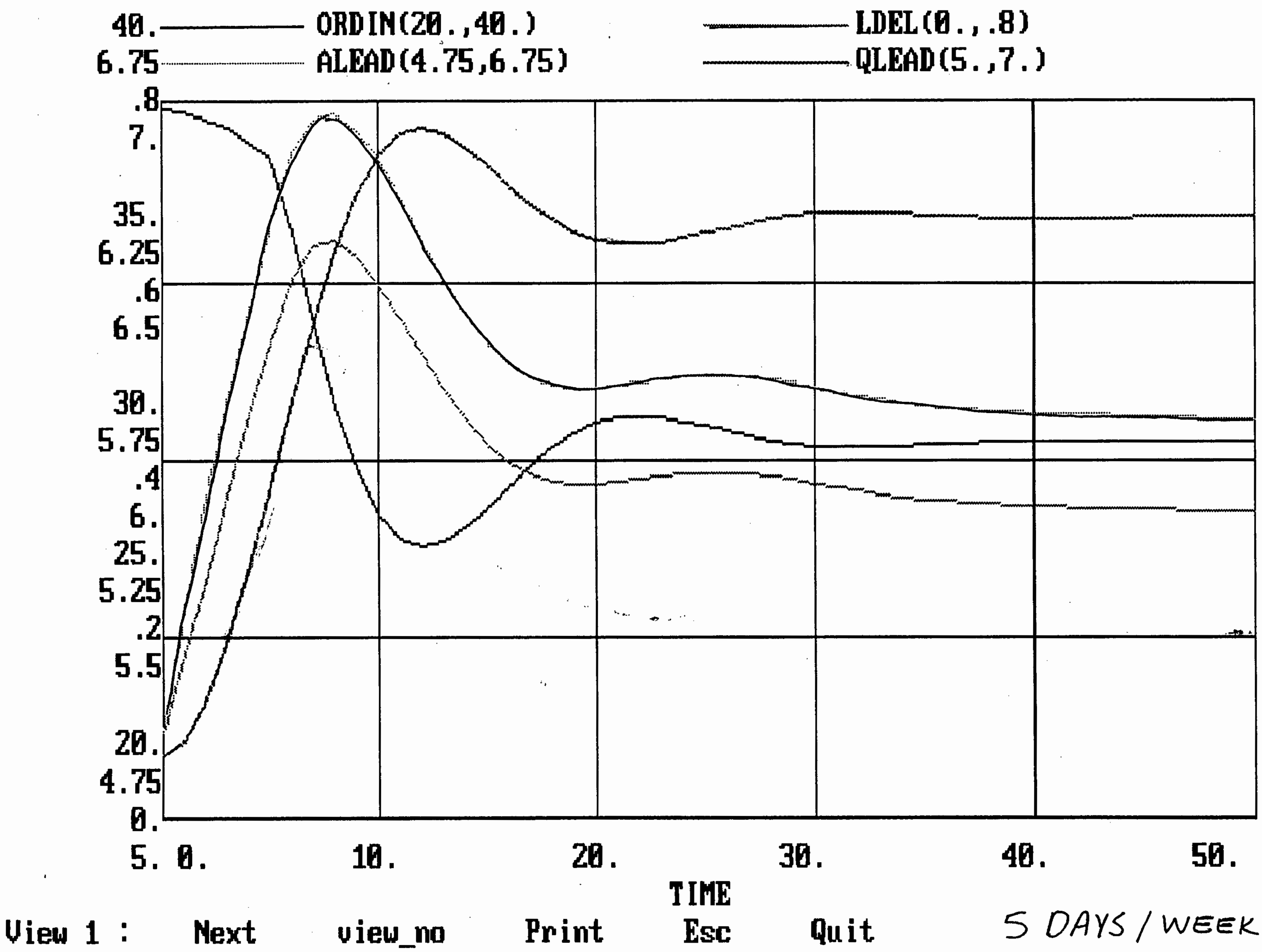
```
C CRCAP=9000
NOTE          PERCHING
C PERCAP=15000
NOTE *************************************************************
NOTE                   CYCLE TIMES IN DAYS FROM DYEING
NOTE *************************************************************
NOTE          DRYING
C TDRY=0.5
NOTE          STENTERING
C TSTENT=1
NOTE          BRUSHING
C TBRUSH=2.5
NOTE          CALENDERING
C TCALEN=2
NOTE *************************************************************
NOTE                                     CALCULATIONS
NOTE *************************************************************
NOTE           STENTER
L QSTENT.K=QSTENT.J+DT*(RINST.JK-ROTST.JK)
R ROTST.KL=CLIP(STICAP+STIICAP,0,QSTENT.K,0)
R RINST.KL=ARINST.K+STEP(BRINST.K-ARINST.K,1)
A ARINST.K=STEP(APOLC+ACOTOW+ABRUSH+APFP+APFPW,TSTENT)
A BRINST.K=STEP(BPOLC+BCOTOW+BBRUSH+BPFP+BPFPW,TSTENT)
NOTE           BRUSHING
L QBRUSH.K=QBRUSH.J+DT*(RINBR.JK-ROTBR.JK)
R ROTBR.KL=CLIP(BRCAP,0,QBRUSH.K,0)
R RINBR.KL=ARINBR.K+STEP(BRINBR.K-ARINBR.K,1)
A ARINBR.K=DELAY3(ABRUSH,TBRUSH)
A BRINBR.K=DELAY3(BBRUSH,TBRUSH)
NOTE           CALENDERING
L QCALEN.K=QCALEN.J+DT*(RINCL.JK-ROTCL.JK)
R ROTBR.KL=CLIP(CALCAP,0,QCALEN.K,0)
R RINBR.KL=ARINBCL.K+STEP(BRINCL.K-ARINCL.K,1)
A ARINBR.K=DELAY3(ACOTUB,TCALEN)
A BRINBR.K=DELAY3(BCOTUB,TCALEN)
NOTE           DRYING
A QDRY.K=QALEAA.K+QESSICO.K
A DRYCAP.K=ALEACAP.K+ESSICAP.K
L QDRY.K=QDRY.J+DT*(RINDRY.JK-ROTDRY.JK)
R ROTDRY.KL=CLIP(DRYCAP,0,QDRY.K,0)
R RINDRY.KL=ARINDRY.K+STEP(BRINDRY.K-ARINDRY.K,1)
A ARINDRY.K=STEP(APOLC+ACOTOW+ABRUSH,TDRY)
A BRINDRY.K=STEP(BPOLC+BCOTOW+BBRUSH,TDRY)
NOTE *************************************************************
NOTE                               CONTROL STATEMENTS
NOTE *************************************************************
SAVE QBRUSH,QSTENT,QCALEN,QDRY
SPEC DT=0.2/LENGTH=5/SAVPER=0.2
```

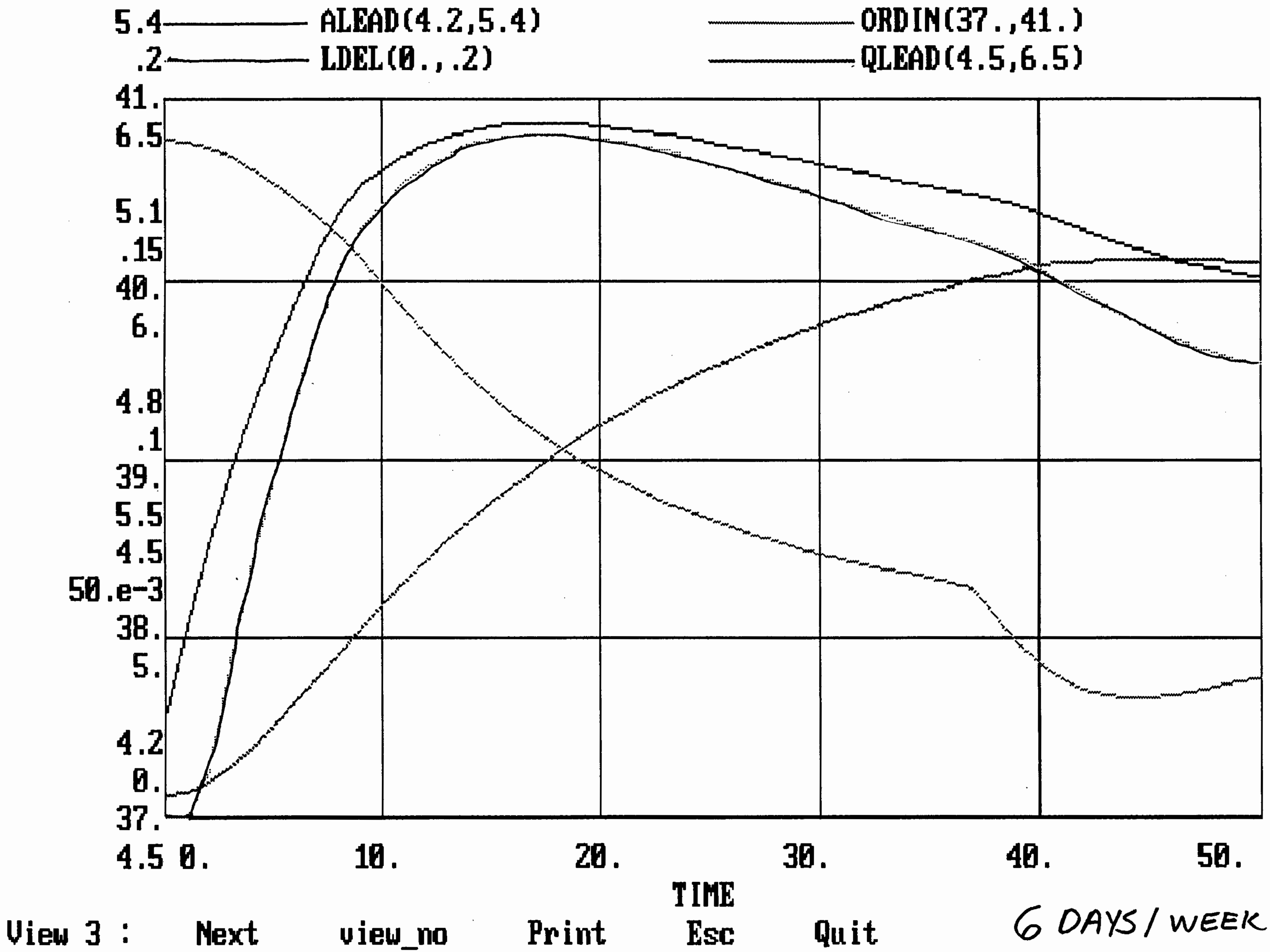
# APPENDIX 6.10

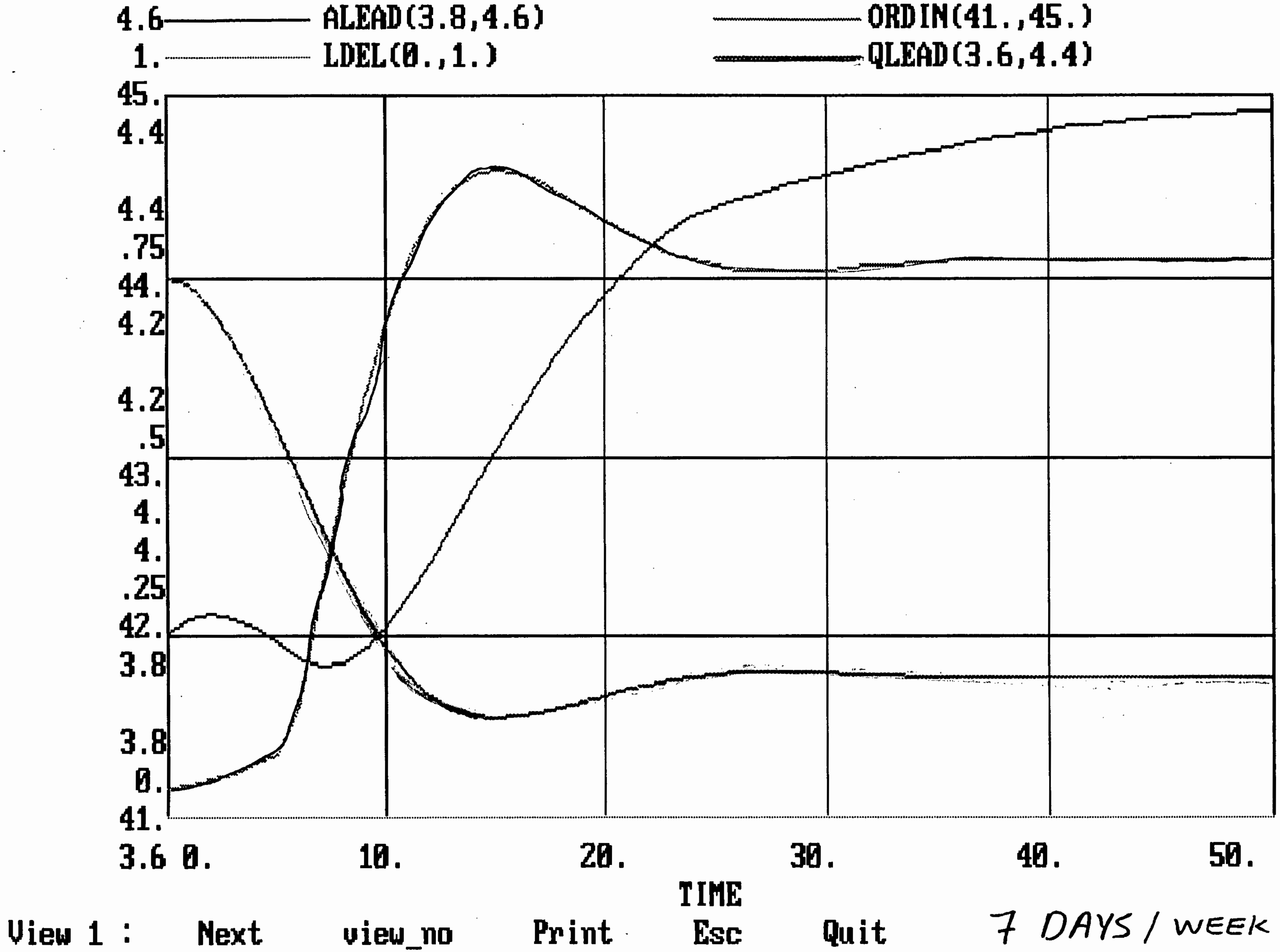
# DYNAMO SIMULATION OUTPUT OF REDUCING DYEING TO FINISHED GOODS CYCLE TIME



8. ALEAD(5.,8.)
1. LDEL(0.,1.)
ORDIN(20.,40.)
QLEAD(4.,8.)
40.
8.
7.25
.75
35.
7.
6.5
.5
30.
6.
5.75
.25
25.
5.
5.
0.
20.
4.
0.
10.
20.
30.
40.
50.
TIME
iew 1 :
Next
view_no
Print
Esc
Quit
4 DAYS / WEEK


40. ORDIN(20.,40.)
6.75 ALEAD(4.75,6.75)
LDEL(0.,.8)
QLEAD(5.,7.)
.8
7.
35.
6.25
.6
6.5
30.
5.75
.4
6.
25.
5.25
.2
5.5
20.
4.75
0.
5.
0.
10.
20.
30.
40.
50.
TIME
View 1 : Next view_no Print Esc Quit
5 DAYS / WEEK


5.4 ALEAD(4.2,5.4)
.2 LDEL(0.,.2)
ORDIN(37.,41.)
QLEAD(4.5,6.5)
41.
6.5
5.1
.15
40.
6.
4.8
.1
39.
5.5
4.5
50.e-3
38.
5.
4.2
0.
37.
4.5
0.
10.
20.
30.
40.
50.
TIME
View 3 : Next view_no Print Esc Quit
6 DAYS / WEEK


4.6 ALEAD(3.8,4.6)
1. LDEL(0.,1.)
ORDIN(41.,45.)
QLEAD(3.6,4.4)
45.
4.4
4.4
.75
44.
4.2
4.2
.5
43.
4.
4.
.25
42.
3.8
3.8
0.
41.
3.6
0.
10.
20.
30.
40.
50.
TIME
View 1 : Next view_no Print Esc Quit
7 DAYS / WEEK

# APPENDIX 6.11

## CORRELATION OBTAINED FOR FORECASTING GREIGE PRODUCTION WITH DIFFERENT FORCASTING WEIGHTING FACTORS

## CORRELATION OBTAINED FOR FORECASTING GREIGE PRODUCTION WITH DIFFERENT FORECASTING WEIGHTING FACTORS

The results below show the percentage of greige that can be carried in stock with the corresponding forecasting accuracy for different weighting factors in the forecasting algorithm. The forecasting accuracy is calculated as the percentage difference in actual and forecasted greige usage after a 3 month period.

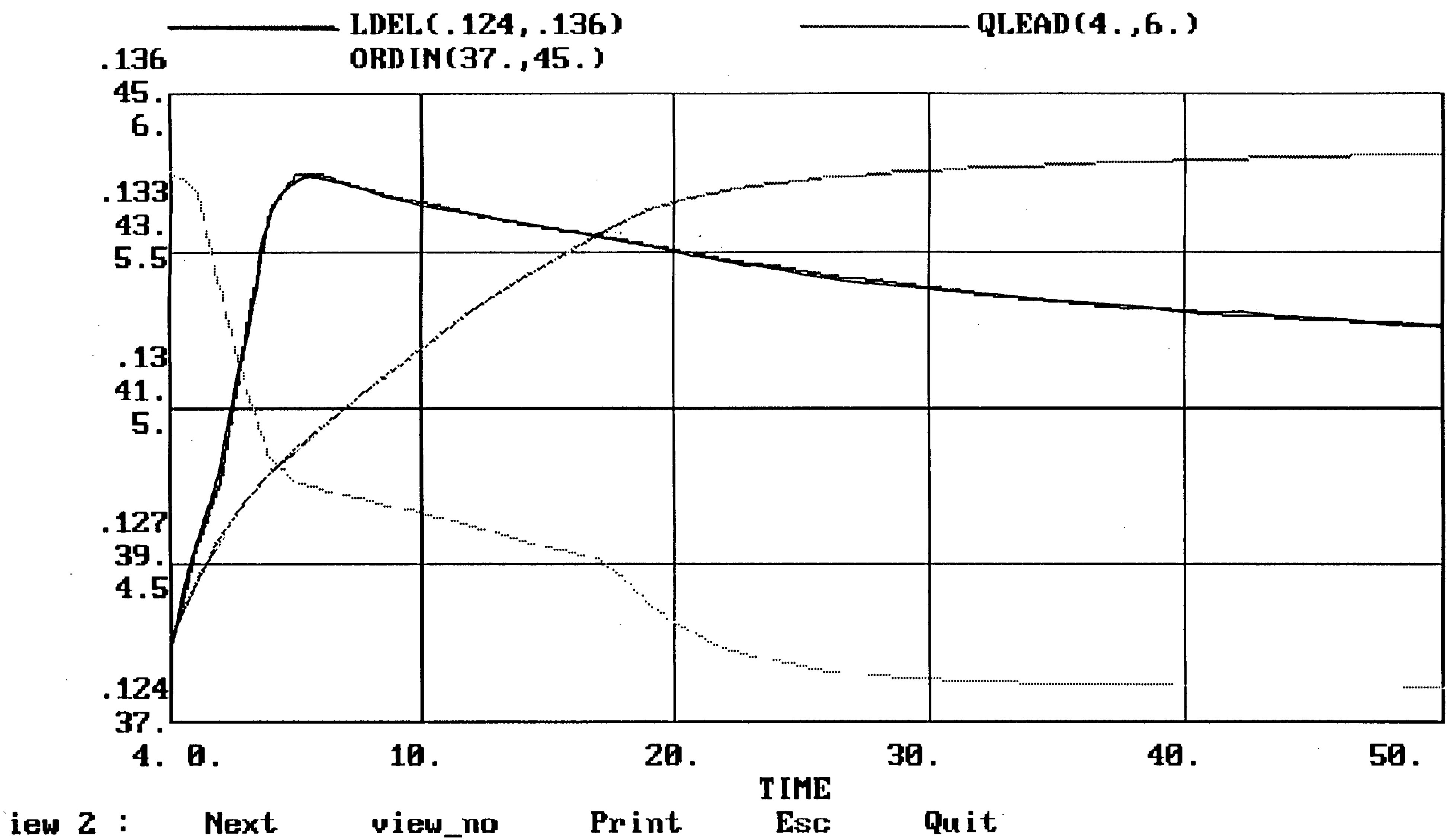
| WEIGHTING FACTOR | CORRELATION COEFFICIENT | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0.95 | 0.9 | 0.85 | 0.8 | 0.75 | 0.7 | 0.65 | 0.6 |
| 0.1 | 8.1 | 29.6 | 38.6 | 43.9 | 51 | 56.7 | 67.5 | 75.3 |
| 0.2 | 9.8 | 31.4 | 43.8 | 49.4 | 55.1 | 62.1 | 70.7 | 78.9 |
| 0.3 | 19.6 | 34.8 | 44.7 | 51 | 58.5 | 64.4 | 68.3 | 72.4 |
| 0.4 | 21.4 | 38.2 | 49.2 | 55.4 | 61.9 | 62.3 | 64.3 | 73.4 |
| 0.5 | 26.1 | 39.5 | 51.1 | 59.6 | 61.1 | 61.5 | 63.3 | 73.2 |
| 0.6 | 25.6 | 41.7 | 54.9 | 56.9 | 59.8 | 61.4 | 62.2 | 70.1 |
| 0.7 | 31 | 44.2 | 50.3 | 52.7 | 55.6 | 57.4 | 59.6 | 66.9 |
| 0.8 | 32.5 | 42.3 | 43.9 | 48.5 | 49.8 | 54 | 56.8 | 65.3 |
| 0.9 | 31.4 | 40.1 | 42.1 | 47.1 | 48.3 | 49.4 | 55.5 | 65.3 |

The optimum percentage of stock that can be held for a particular forecasting accuracy is summarized in the table below.

| FORECAST ACCURACY | WEIGHT FACTOR | PERCENT GREIGE INVENTORY |
|---|---|---|
| 95 | 0.8 | 33 |
| 90 | 0.7 | 44 |
| 85 | 0.6 | 55 |
| 80 | 0.5 | 60 |
| 75 | 0.4 | 62 |
| 70 | 0.3 | 64 |
| 65 | 0.2 | 71 |
| 60 | 0.2 | 79 |

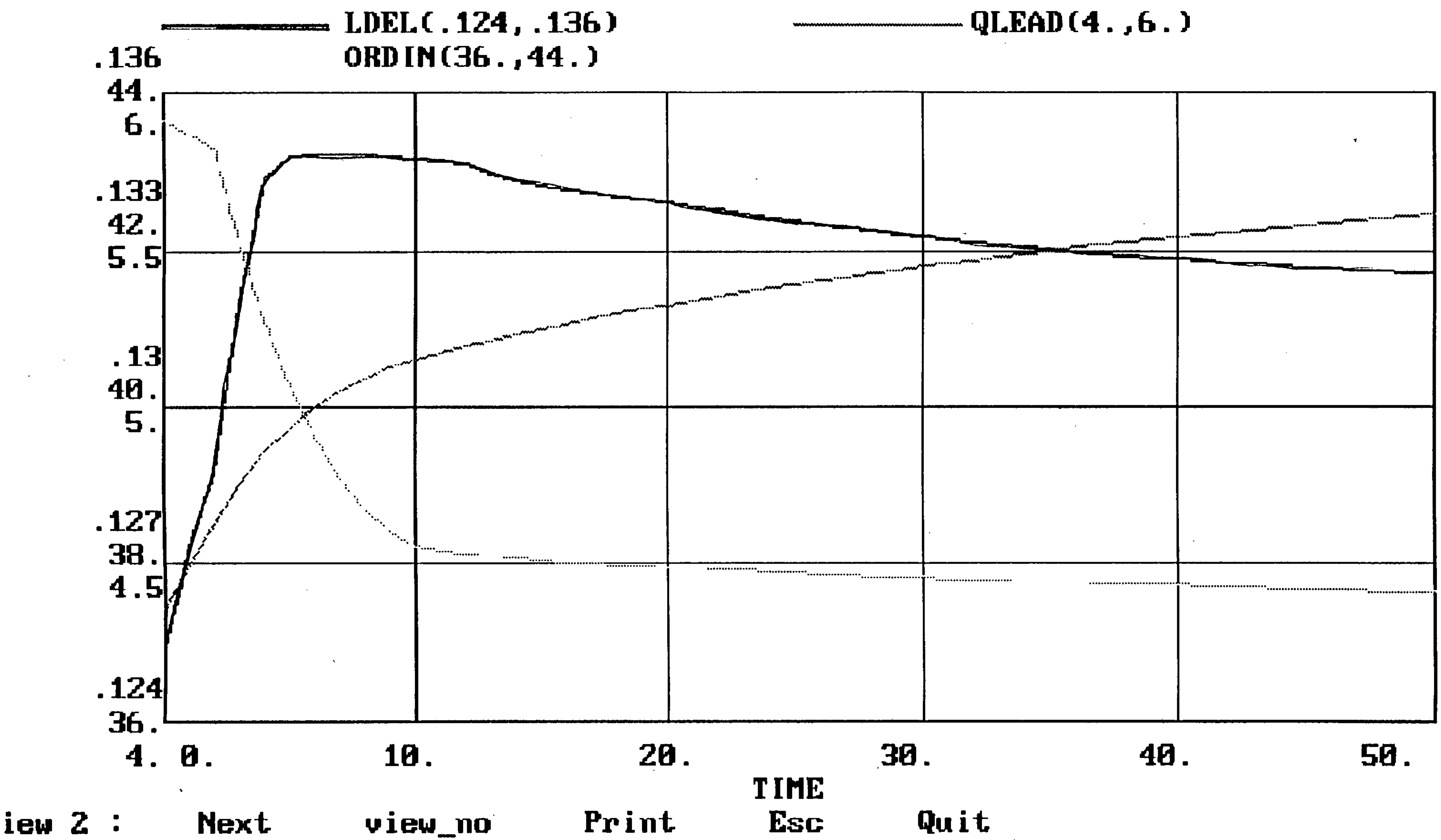
# APPENDIX 6.12

# DYNAMO SIMULATION OUTPUT OF CARRYING DIFFERENT LEVELS OF GREIGE INVENTORY

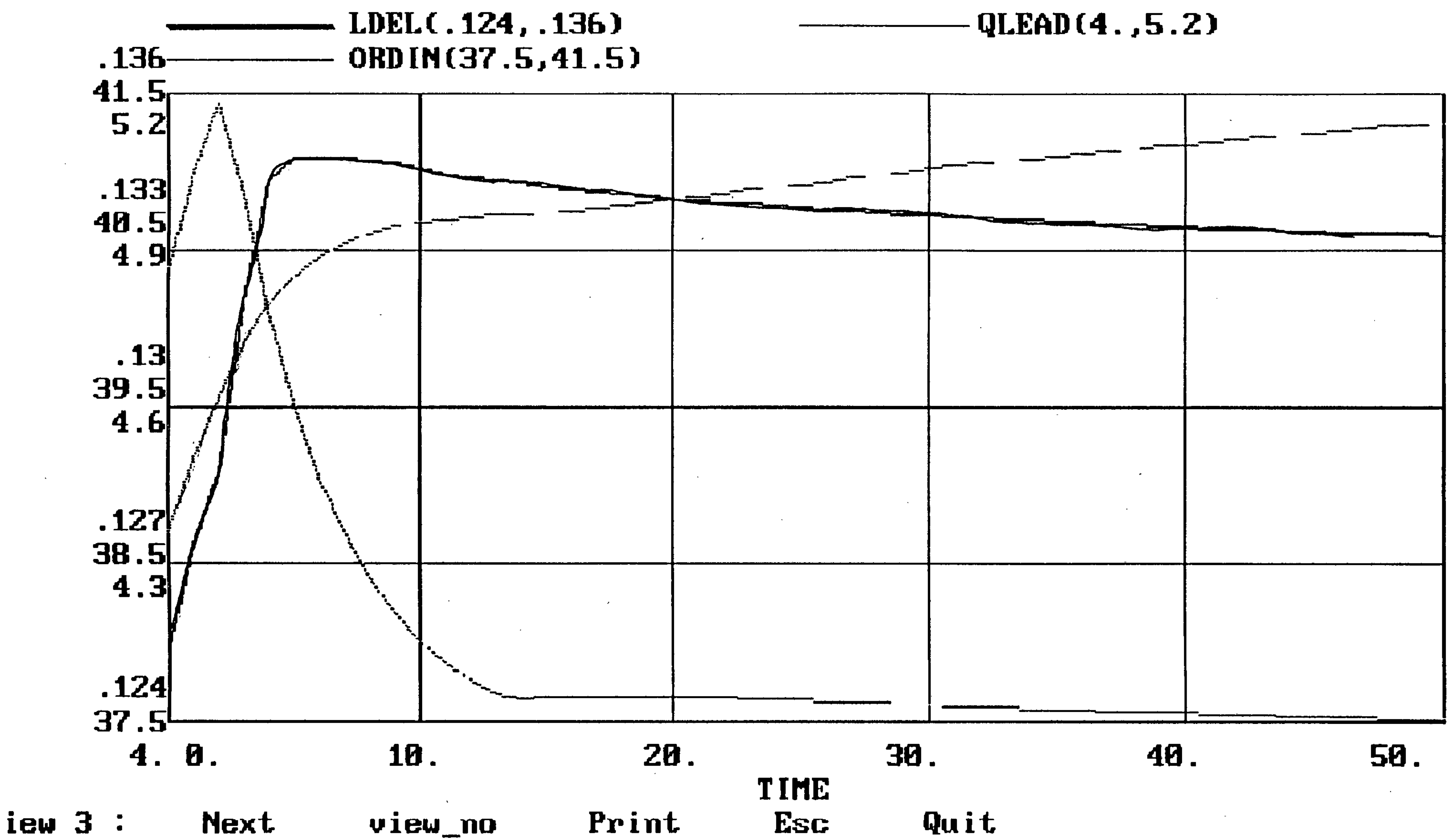



33% GREIGE STOCK

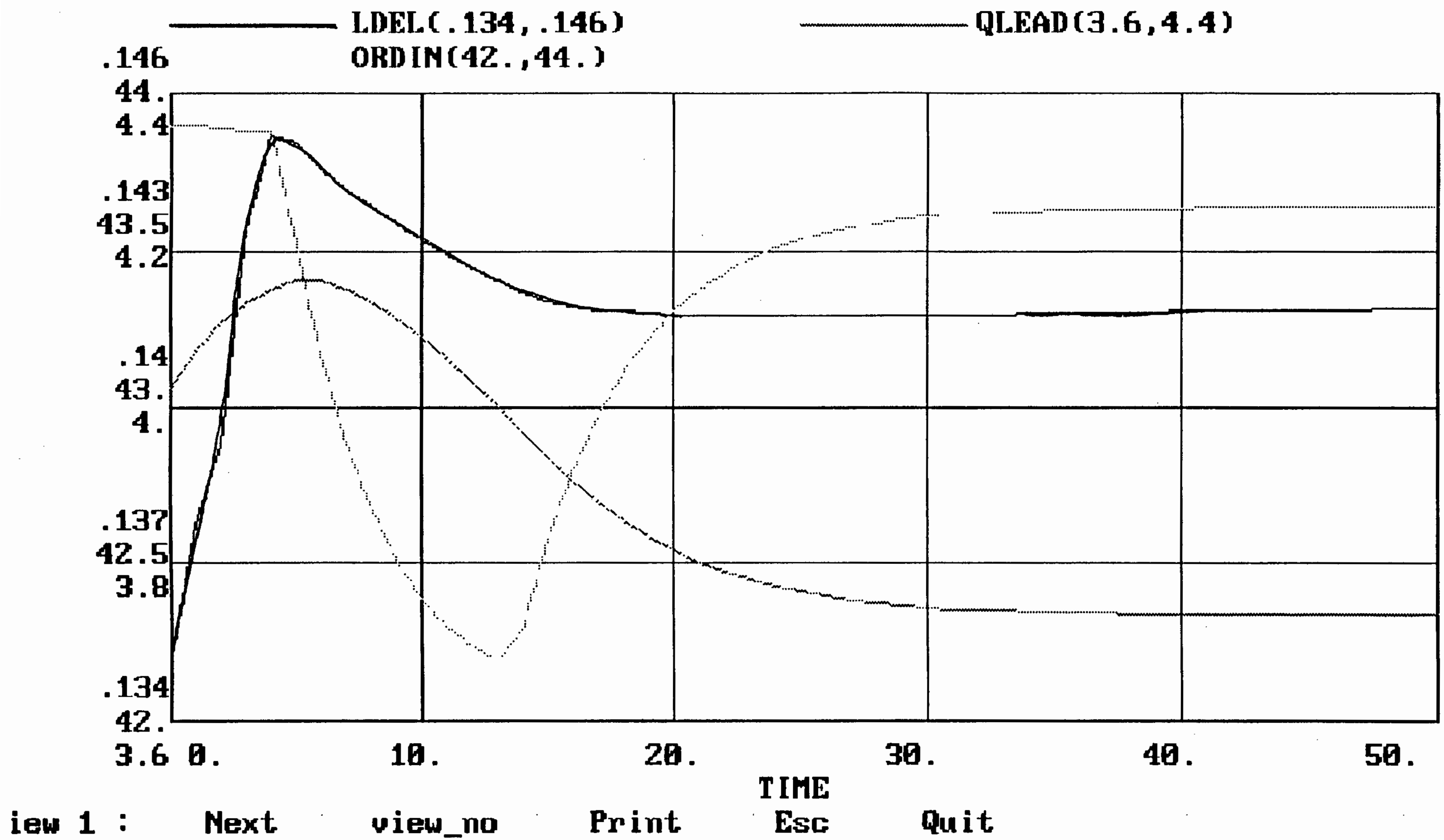
6 DAYS / WEEK




44% GREIGE STOCK
6 DAYS / WEEK

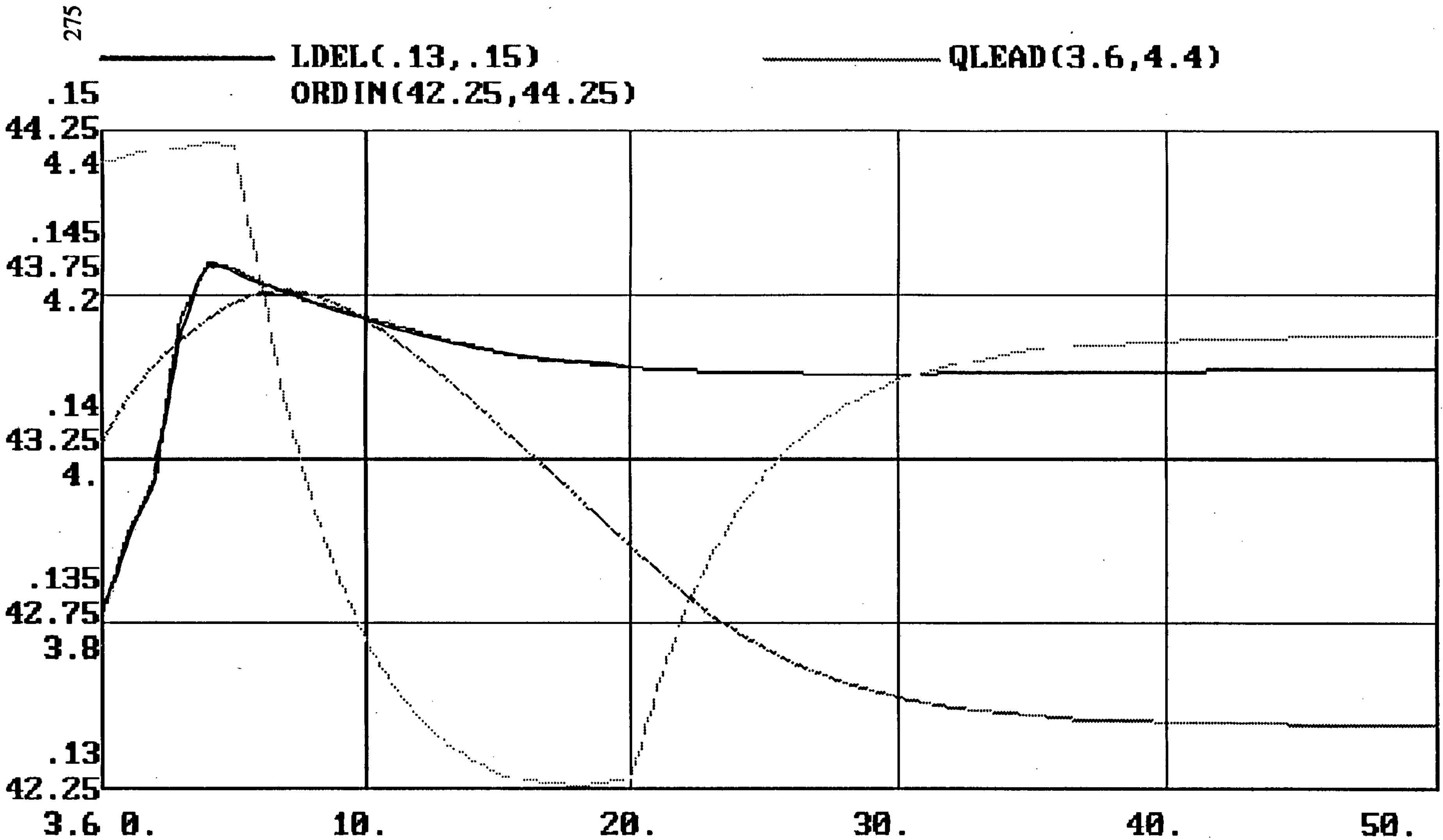



55% GREIGE STOCK
6 DAYS / WEEK



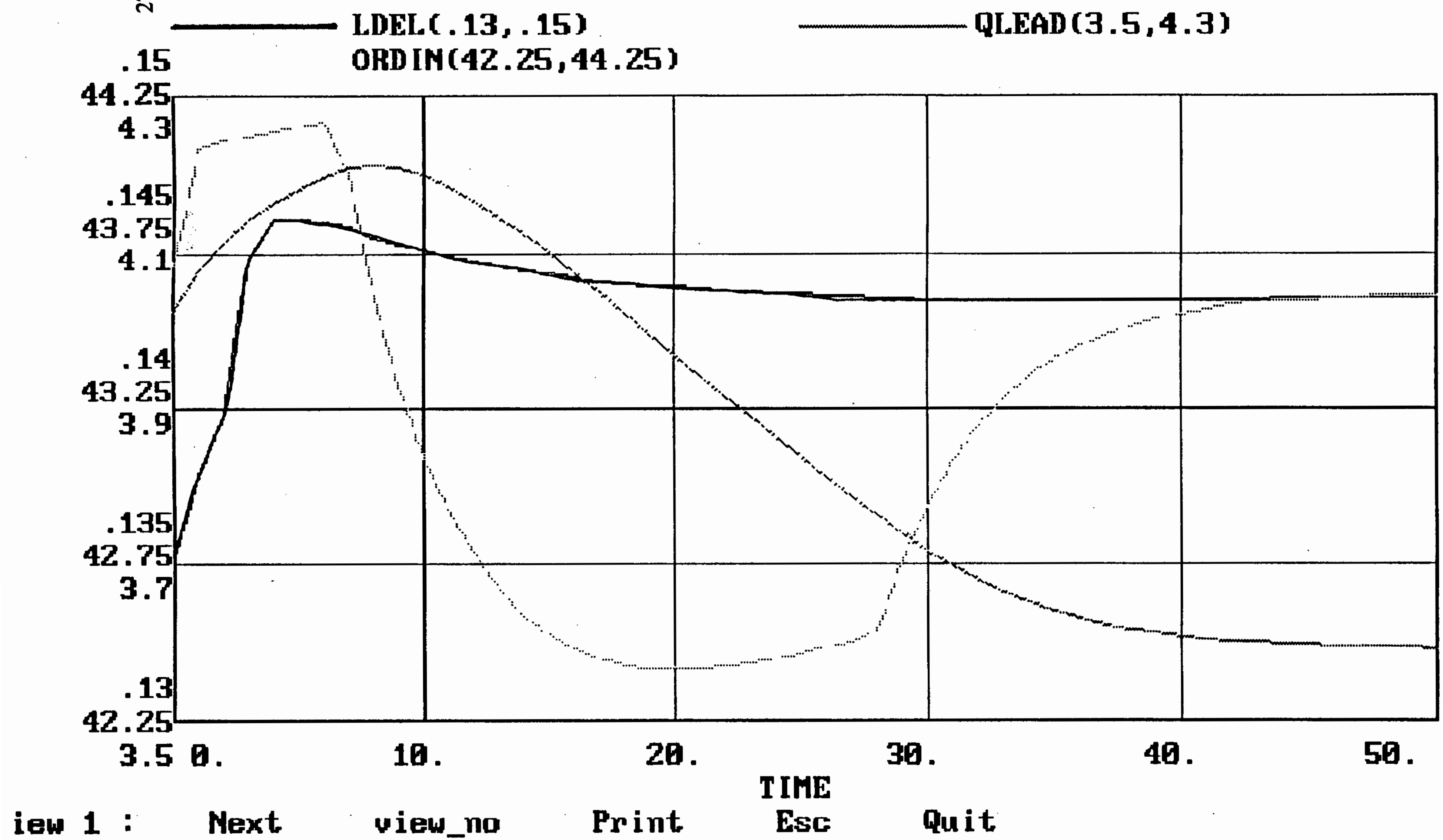

33% GREIGE STOCK

7 DAYS / WEEK



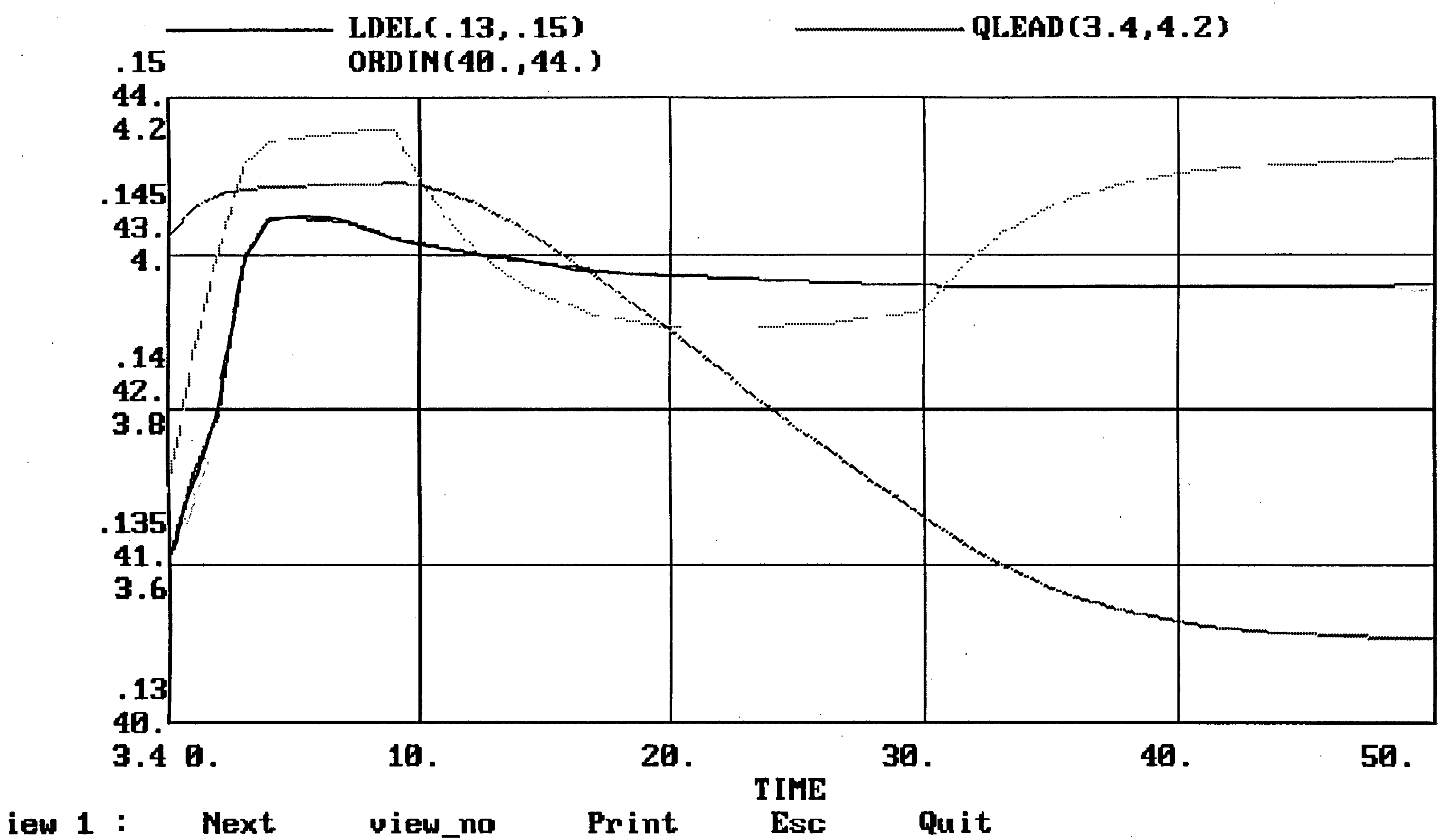

iew 3 : Next view_no Print Esc Quit

44% GREIGE STOCK
7 DAYS / WEEK




55% GREIGE STOCK

7 DAYS/WEEK




60% GREIGE STOCK

7 DAYS / WEEK