THE DESIGN AND INTRODUCTION OF A JUST IN TIME MANUFACTURING SYSTEM

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A project report submitted to the Faculty of Engineering, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Master of Science in Engineering.

Johannesburg, 1985.

DECLARATION

I declare that this project report is my own, unaided work. It is being submitted for the Degree of Master of Science in Engineering in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in any other University.

J Gobbs

16th day of January 1986

"Our Life is frittered away by detail ....
Simplify, simplify"

H D Thoreau

"Simplify and reduce, simplify and integrate,
simplify and expect results"

R J Schonberger

ABSTRACT

This paper presents the experiences gained in the implementation of the Just In Time (JIT) philosophy at a South African factory.

The initial chapters discuss the deteriorating productivity performance of the South African Manufacturing Industry against their major overseas trading competitors, and the hypothesis is given that the use of the JIT philosophy could be of major benefit in halting, and perhaps reversing this trend. The basic principles of the JIT philosophy are summarised and compared with the traditional approach.

The main portion of this paper describes the actual approach taken in a specific JIT implementation. This is done from the broad conceptual considerations, through the development of general criteria, to the detailed analysis of specific problems and eventual implementation.

A "before-and-after" evaluation of the results achieved is undertaken, and also compared with the "classical" JIT requirements as defined by some American authorities in this field.

ACKNOWLEDGEMENTS

I would like to thank the Directors of GEC for their encouragement to engage in the research for this project, and for their permission to submit it to the University.

I would also like to thank the Management and Staff of GEC Small Machines Company for their enthusiastic participation and involvement in this project, and particularly the following :

Tony Shepperson
Thys Potgieter
Jan Oosthuizen
Mo Ahmed
Cliff Jeffery
Chris van der Merwe
David Noko
Heinz Kohlpainter
Steve Heyman
David Cowlishaw

Further thanks should go to:

Eric Stockenstrom of GEC South Africa
and Professor John Bicheno at Wits

and of course
Carole Fischer who did all the typing

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1.0 INTRODUCTION

The writer of this report is the Director of Manufacturing, Planning and Development of GEC South Africa, and is a Director of all the operating subsidiaries of this Company.

Prior to his present position the writer was Managing Director of a Group of Companies within GEC South Africa, namely Transformers, Medium Voltage Switchgear, Low Voltage Distribution, Cables, Measurements and Projects

During the first half of 1984 it was recognised by the Board of GEC South Africa that a number of strategic moves would have to take place in the organisation in order to offset the very difficult times manufacturers were having and to be able to plan for future potential and growth.

Amongst other aspects the following were decided upon:

Management restructuring of the Group of Companies within GEC South Africa would include the appointment of a Director of Manufacturing who would be given the responsibility of ensuring that the strengths of the various manufacturing operations would be enhanced. This was of prime importance as it was recognised that more and more of GEC's manufacturing operations were coming under severe threat from importers. The writer was appointed to this position.

It was further decided that the writer, in the first instance, would concentrate his efforts at GEC Small Machines, a manufacturing subsidiary of GEC South Africa.

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2.0 PRODUCTIVITY IN SOUTH AFRICA

2.1 General Discussion

South Africa's improvement in productivity has fallen way behind that of its major trading competitors.

TABLE A1 shows that not only is South Africa's output per capita very low in comparison to its major competitors, but the average annual rate of growth in output per capita in the South African economy is also way behind.

As dismal as is the labour productivity figures, what is as alarming is the reduction in improvement in Fixed Capital productivity. Table A2 shows the rate of improvement in Labour Productivity in the non agricultural sectors of the economy. Improvements here in the period 1972 - 1982 is some 1,2% per annum. Equivalent figures for Capital Productivity show a decrease in productivity rates of some 2,3% per annum

Table A3 gives comparable figures for the manufacturing industry, and labour productivity improvements amount to some 2,4% per annum, whilst Capital Productivity has fallen by 2,1% per annum; this despite the fact that plant capacity utilization percentages showed no significant change in the years 1972 and 1982 (87,5% and 87,6% respectively.)

The above has in no small way contributed to the very high rates of inflation inherent in the country. There are many structural reasons for this, but Industrialists are not blameless. The net result is that high inflation, coupled with low productivity is increasingly affecting the South African manufacturer's ability to compete with international manufacturers in South Africa, never mind in exports. These trends, coupled with high birth rates, are a recipe for disaster.

The current recession has certainly brought this home to South African manufacturers, and those who do not respond to the challenge are likely to go out of business in the next couple of years.

2.2 Areas of Concern

Areas of particular concern in South African manufacturing are:

- Indifferent service
- Indifferent delivery service
- Indifferent quality
- Slow reaction to changing circumstances
- High prices
- Expectation of inflation
- Monopolistic and oligopolistic base material suppliers
- Lack of adequate skills at all levels
- Lack of adequate education at all levels
- Small volume production
- High variety

These are not new features, and indeed there have been improvements over the years. However, the world is getting smaller and we are no longer being judged on South African terms, but against international standards and some of these are very high indeed.

Previously the company that performed better than its local competitor in the above factors, was the more successful one. However, very few South African manufacturers compare favourably with overseas manufacturers - and the gap in our performance versus the overseas manufacturers widens, increasingly to our detriment.

2.3 Productivity Improvement Projects

In general, South African managers are aware of these problems and trends and most, if not all, are actively pursuing various cost reduction and productivity improvement projects. Typical of these could be the following:

- work/method study
- value engineering
- more economical batch sizing
- better labour/machine utilisation
- more inspectors
- Q.A. systems
- factory layouts
- better handling
- more productive capital equipment, and so on.
- computerisation
- incentive schemes
- commission schemes

Unfortunately, priorities are difficult to assess. In South African factories there are normally more projects than competent and trained people. In any event, day to day fire fighting always takes precedence over long term planning. Furthermore, so many projects are carried out in isolation to others that optimum benefit is seldom realised.

In the view of the writer the Japanese developed philosophy of Just- In-Time zero inventory, is the most effective way yet developed of assisting in the cost reduction drive.

3.0 MANUFACTURING APPROACH

In general, the typical South African approach to manufacturing varies markedly from that of the Japanese. For the purpose of discussion this chapter itemises the typical (perhaps extreme?) view for each two countries. These listings have no scientific basis, but are gleaned from, in the case of the South *African approach, the writer's own experience in the* manufacturing industry, and in the case of the Japanese, from general impressions gained in readings (particularly references 3, 4 and 5).

No doubt there are South African manufacturers who would be more fairly described as a typical Japanese manufacturer, and some Japanese manufacturers who should really be in the South African listing.

Be that as it may, the view given by the writer is subjective and emotive without apology and is merely an attempt to indicate that the emphasis on approach between South African and Japanese is significantly different.

3.1 Typical South African Approach

The South African approach could perhaps be described as follows (reference 13).

1. Keep machine tools working - amortisation costs are high.
2. Keep direct labour working, it is a crime to have idle direct labour.
3. Maintain machines only when necessary, preventative maintenance is too expensive.
4. Set up costs are not very high - why waste good Industrial Engineering time and effort on what is really only a small percentage of

total costs when the same effort could reduce direct labour substantially

5. Keep defective and re-work costs down. Employ hosts of inspectors to ensure this, but also make sure extra stocks are available to cater for disaster.

6. South African labour is bad - so the jobs are broken down to the smallest elements, and the labour kept doing the same job day in and day out. In any event take people on when they are needed and lay them off when they are not

7. This also saves in training costs for the untrainable.

8. South African foremen are not competent - employ them as progress chasers.

9. South African suppliers are the worlds worst - in delivery performance as well as quality; therefore have high raw material stocks, plenty of progress chasers, and goods inwards inspectors

10. Buy for price - feel no compunction about changing suppliers if a better deal can be obtained elsewhere. Treat suppliers as adversaries, do not develop good working relationships with them, they will only take advantage.

11. Delivery promises are honoured more in the breach than in the observance.'

12 Quality is indifferent - customers are not willing to pay extra for good quality.

13 Organise work shops in job-shop format. It is too expensive to have dedicated lines, or too complicated to look at Group Technology.

14. Layout workshops with wide gang ways and plenty of room between machines for Work in Progress queues

3.2 Typical Japanese

The Japanese approach is somewhat different.

1. They keep machines and *labour working, but* consider that there is no point in doing so purely for good utilisation - all one is doing is making inventory, and if it is not for immediate sale, why do it?
2. Preventative maintenance is obligatory - operatives are also utilised for routine maintenance and service.
3. Set up costs are a prime cause of high inventory - time and effort spent here will pay handsomely in reduced inventory and improved flexibility.
4. Defects and re-work costs should be zero - in any event calculated in parts per million, not parts per hundred.
5. Quality is the responsibility of the shop supervision and the operatives. The Quality Control personnel are there to assist in this regard; carry out audits; do trouble shooting and so on.
6. Labour and supervision are only as good as their management. Training and education are excellent investments.
7. Suppliers are only as good as their customers. Long term relationships are developed with suppliers, encouragement and assistance are given to them to develop Just-In-Time schemes; carry out proper Quality Control procedures; gain mutual loyalty and interdependence.
8. Shops are laid out in Group Technology format - cells are U shape formation, and all to be used to complete a full component or sub-assembly.

9. Cheap, hand made dedicated machine tools are used extensively in these Group Technology cells.

10. Machines are placed as close together as possible. Little space is allowed for Work in Progress. Components are unloaded from one machine, and loaded directly into the next.

11. Delivery promises are sacrosant.

12. It is cheaper to produce good quality goods than indifferent quality goods.

Many Japanese factories have formalised this approach into the Just-in-Time philosophy.

3.3 Typical American Approach (Compared with Japanese)

Walt Goddard (Reference 2) compares the Toyota's Kanban (sic) philosophy with that of a typical United States Company.

Table 3.1 gives Toyota's principles, in terms of various factors.

Table 3.2 gives the typical American philosophy against these factors.

Factors	Toyota's Kanban
Inventory	A liability. Every effort must be extended to do away with it.
Lot Sizes	Immediate needs only. A minimum replenishment quantity is desired for both manufactured and purchased parts.
Set Ups	Make them insignificant. This requires either extremely rapid changeover to minimise the impact on production, or the availability of extra machines already set up. Fast changeover permits small lot sizes to be practical, and allows a wide variety of parts to be made frequently.
Queues	Eliminate them. When problems occur, identify the causes and correct them. The correction process is aided when queues are small. If the queues are small, it surfaces the need to identify and fix the cause.
Vendors	Co-Workers. They're part of the team. Multiple deliveries for all active items are expected daily. The vendor takes care of the needs of the customer, and the customer treats the vendor as an extension of his factory.
Quality	Zero defects. If quality is not 100% production is in jeopardy.
Equipment Maintenance	Constant and effective. Machine breakdowns must be minimal.
Lead Times	Keep them short. This simplifies the job of marketing, purchasing and manufacturing as it reduces the need for expediting.
Workers	Management by consensus. Changes are not made until consensus is reached, whether or not a bit of arm twisting is involved. The vital ingredient of "ownership" is achieved.

TABLE 3.1
TOYOTA'S KANBAN PHILOSOPHY

Factors	American Philosophy
Inventory	An asset. It protects against forecast errors, machine problems, late vendor deliveries. More inventory is "safer".
Lot Sizes	Formulas. We're always revising the optimum lot size with some formula based on the trade-off between the cost of inventories and the cost of set up.
Queues	Necessary investment. Queues permit succeeding operations to continue in the event of a problem with the feeding operation. Also, by providing a selection of jobs, the factory management has a great opportunity to match up varying operator skills and machine capabilities, combine set ups and thus contribute to the efficiency of the operation.
Vendors	Adversaries. Multiple sources are the rule, and it's typical to play them off against each other.
Quality	Tolerate some scrap. We usually track what the actual scrap has been and develop formulas for predicting it.
Equipment Maintenance	As required. But not critical because we have queues available.
Lead Times	The longer the better. Most foremen and purchasing agents want more lead times, not less.
Workers	Management by edict. New systems are installed in spite of the workers, not thanks to the workers. Then we concentrate on measurements to determine whether or not they're doing it.

TABLE 3.2

AMERICAN PHILOSOPHY

4.0 JUST-IN-TIME PHILOSOPHY

4.1 General Definition

In essence, it is the writer's view that the philosophy provides the *hypothesis that* "*in order* to improve productivity, waste must be eliminated, that the main cause of waste is idle inventory; therefore to reduce waste and thus improve productivity the total elimination of idle inventory must be striven for". The traditional manufacturing hypothesis is the converse of this. Perhaps it can be stated in the following way "inventory is *required in order to* minimise the effects of uncontrollable events in the manufacturing environment such as machine breakdowns, absenteeism, reject work, fluctuating deliveries, late suppliers, queues, uneconomic small batches and so on".

Robert Hall (refer 3) describes the ideal of stockless production as :

"Eliminating waste of time. Nothing sits.
Eliminating waste of energy. Operate equipment only for a productive purpose.
Eliminating waste of material. Convert all of it to a product.
Eliminating waste of errors. No rework."
and this is achieved by:
"Producing exactly what is needed and conveying it to *where it is needed precisely* when it is required.

Yasuhiro Monden (Reference 4) describes the Toyota production system as :

"to maintain a continuous flow of products in factories in order to flexibly adapt to demand changes. The realisation of such production flow is called Just-in-Time production at Toyota, which means producing only necessary items in a necessary quantity at a necessary time. As a result, the excess inventories and the excess work force will be naturally diminished, thereby achieving the purposes of increased productivity and cost reduction".

Richard J Schonberger (Refer 5) describes the Japanese approach as:

"the Japanese cut the wasted hours and wasted materials by not allowing large lots of defectives to be produced. "The main force that drives Japanese quality and productivity is Just-in-Time inventory control".

Compare this with the following quotation from Schonberger (reference 5):

"The typical Western way, by contrast, is to make parts in large lots - a whole forklift truck load - two weeks worth, maybe. The second worker might find 10 per cent to be defective, but he doesn't care. He just tosses a defective part into a scrap or rework bin and grabs another. There are enough good ones to keep him busy, so why complain about defectives?"

Implicit in the J.I.T. philosophy is the further hypothesis that (Reference 6) "there are only two types of activities or events that can take place in any environment:

- those that add value
- those that add cost

and that it therefore follows that all cost adding activities (or events) must be entirely eliminated."

5.0 INVENTORIES

5.1 Inventories Main Cause of Waste

But why should inventory be blamed for being the major cause of waste?

The traditional hypothesis, as discussed in Chapter 3 and 4 largely answers this question. Inventory is supposed to assist in the orderly management process - this it does, but in the meantime it not only *causes* major costs, but certainly disguises or hides other major costs.

What costs does inventory cause or directly contribute to?

- cost of capital (interest)
- excessive floor space
- *excessive warehousing, plus allied costs*
- damage - the more the inventory lying around, the greater the risk of damage
- handling, inventory must be fetched and carried
- housekeeping
- obsolescence
- slow reaction to engineering changes
- stock deterioration
- etc.

What costs does inventory disguise or hide?

- rejects and rework
- inventory control
- lack of control

- shortages
- inaccurate forecasting
- etc.

These various aspects will all be covered in detail later.

5.2 Types of Inventory

Generally speaking there are four levels or types of inventory holding in most manufacturing activities:

- Raw materials and bought outs
- W.I.P.
- Modified components and sub assemblies
- Finished goods.

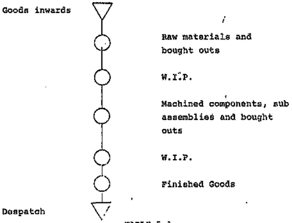

TABLE 5.1
MATERIAL FLOW

5.3 Manufacturing Lead Times

Manufacturing lead times can be defined as the time required from goods inwards to despatch - many costly decisions are made on this lead time, which is frequently considered to be fixed or given.

Warwick Johnson (Reference 7) gives a pictorial description of what he refers to as the "real components of lead time", and compares the traditional concept of lead time with that of the J.I.T. concept. Figure 5.1 shows this

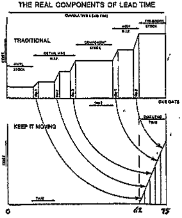

FIGURE 5.1

THE REAL COMPONENTS OF LEAD TIME

This example shows that in the traditional production systems, 13 added value units are produced during 75 time units.

The ideal J.I.T. production system gives 13 added value units during 13 time units.

If the J.I.T. hypothesis is correct - "that inventory adds cost" - and that the amount of inventory is a function of manufacturing lead time, it can safely be said that the costs due to inventory are as 13:75 in favour of the J.I.T. system (for this example).

5.4 Warehousing Costs

Obviously warehousing is required for the material, component and finished goods stock. Costs associated with warehousing are:

1. Floor space and associated costs - lighting, heating
2. Security
3. Racking
4. Mechanical handling - in and out plus delivery to point of use
5. Controls - includes record keeping, stock checks, requisitions, delivery notes
6. Storemen
7. Risk or redundancy or obsolescence
8. Risk of damage or deterioration
9. Access
10. Location

5.5 Work in Progress Costs

For work in progress inventory, costs associated are:

1. Floor space between operations to hold Work in Progress
2. Gangways to move Work in Progress from operation to operation in the batch mode
3. Mechanical handling
4. Risks or redundancy
5. Risks of damage
6. Time lost by operator fetching components for next operation, and then taking it to subsequent one
7. Inaccessibility of components
8. Increased risk or reject or rework, particularly serious the later down the chain of operations the reject is effected or discovered
9. Cost of lights, heating
10. Control costs - paperwork etc

5.6 Other Inventory Costs

Other costs are:

1. Cost of financing the idle inventory - particularly pertinent in South Africa today.
2. Lack of flexibility.
3. General slackness - if lead times are long and buffer stocks high, attention to detail is blurred.

6.0 QUALITY

It would be as well to consider in a little more detail the quality costs inherent in the traditional manufacturing operation versus the J.I.T. approach.

6.1 Quality Costs - Traditional View

Too often, costs of quality are considered in a very rigid and prescribed way, and this can invariably lead to an incorrect appreciation of the real costs of bad quality - invariably understated.

Costs of quality are usually calculated as (if indeed they are calculated at all).

a). Costs of the quality control department
- inspectors
- testers
- Q.A. personnel.

b). Direct costs of actual defective work and replacement or rework.
- material
- direct labour
- and perhaps some of the overhead costs associated with these.

However, it is now commonly accepted that these costs as calculated are perhaps only the tip of the iceberg.

6.2 Quality Management Grid

Philip Crosby (see referance 8) in his Quality Management Maturity Grid attempts to define Quality Management Maturity. His grid takes the form of a questionnaire, and on completion, the respondee should be in a position to establish the approximate stage of Quality Awareness (or maturity) in his Organisation. Crosby defines 5 stages of maturity, from uncertainty, through awakening, to enlightenment, wisdom and ultimately certainty. He also hazards a guess as to the actual costs of quality (C-O-Q) in an organisation (depending on their level of maturity) and compares this with what they believe their costs of quality are. The differences are startling. Table 6.1 summarises his views.

Stage	Description	Reported C.O.Q	Actual C.O.Q.
i	Uncertainty	Unknown	20%
ii	Awakening	3%	15%
iii	Enlightenment	8%	11%
iv	Wisdom	6,5%	8%
v	Certainty	2,5%	2,5%

TABLE 6.1
COSTS OF QUALITY COMPARED WITH
QUALITY MANAGEMENT MATURITY

6.3 South African Position

A typical South African factory would probably classify its manufacturing/production maturity somewhere between stage ii and stage iii; i.e. waking itself up and wishing to be enlightened.

This company would have a Quality Assurance Department, with reasonable status, and would believe that it calculates its costs of detection and rework correctly and accurately.

Certainly it knows its Quality Department's costs, and it will measure the direct costs of defect work reasonably accurately - materials and direct labour (plus some overheads, normally those directly associated with the direct labour involved in making the defect, or those doing the rework) - Total C.O.Q. then as calculated is 6%.

However, according to Crosby (and doing a bit of extrapolation) actual cost of Quality is probably closer to 15% of sales. Why the discrepancy?

In order to establish this, one must look at the costs <u>not</u> included in the C.O.Q. calculation - and these can be substantial - according to Crosby as high as 9% of sales more than is thought - or 2.1/2 times as much as is believed!

6.4 Quality Costs - Realistic View

The probable reason why Quality Costs are not accurately calculated is largely due to the difficulty of accurately and with reasonable integrity attaching numbers to the real costs of bad quality. Unfortunately these costs form the major element of Total Costs of Quality. The following lists items of quality costs which are seldom, if ever, included in the evaluation of quality. (The writer's view).

a). Obsolescence. The annual provisions put aside for possible redundancy (and invariably exceeded). These are very definitely costs of quality.

b). Slow moving stock - the special offers made to customers to get rid of excess finished goods. Not to mention the storage space required or costs due to upsets in stable pricing arrangements.

c). It is part of traditional thinking to assume that some defective work will always be made, so batch sizes are increased to cope with any shortfall in an order completed due to rejects. The costs given earlier in this regard to surplus inventory are definitely costs of quality in this regard.

d). Disruption caused in the manufacturing system when a batch is found faulty, or made faulty at a very late stage of completion. Such as just prior to assembly, when it has taken many weeks to get the batch there, and now in order to meet commitment, it will have to be hurried through re-work, to the detriment of all other jobs in process; some perhaps with equally high priority.

e). The amount of time and effort spent by all supervisors, management and support staff in handling crises caused by reject work. These people could be better employed in using their time to <u>make</u> money for the company, not attempting to <u>minimise</u> the costs of rejects. Alternatively, if defective work is non existent, the number of the above categories of personnel could be substantially reduced.

f). Loss of sales (in cancellations or future business:
- due to inability to deliver on time
- due to low quality
- inability to change quickly in changing conditions
- reluctance to modify against established standards.

g). Penalty payments - due to late delivery, or incorrect specification. These costs are seldom, if ever charged to cost of quality.

h). Extra inventory due to late delivery - never charged to C.O.Q.

i). Lost production or disruption caused by machine breakdowns due to lack of preventative maintenance.

j). Costs caused by accidents.

Furthermore, there are also vast areas of defective costs that no one makes an attempt to get to - those in the administration areas.

As mentioned previously, implicit in the JIT philosophy is the hypothesis that there are only two events or activities that can take place:

- those that add value
- those that add costs.

If this hypothesis was tested throughout the organisation, and not only in the manufacturing environment, it will be easy to arrive at other major areas of avoidable costs:

- credit notes passed
- use of long distance telephones instead of telex or letter
- memos typed instead of handwritten
- correction of incorrect drawings
- attending to irate customers, instead of selling to willing buyers.

6.5 Conclusion

There is no doubt that a single minded approach to the adoption of the JIT philosophy by South African manufacturers can put them into a very strong position regarding good quality and the minimization of quality costs.

7.0 SOUTH AFRICAN MANUFACTURERS VERSUS IMPORTERS

7.1 Introduction

Perhaps it is as well to summarise the preceding chapters, and attempt to establish a strategy to be adopted by South African manufacturers facing import competition. For clarification, local manufacturer versus importer, is used purely for comparative purposes. The lessons learnt could be equally valid for internal competitors or for export of manufactured goods.

Chapter 2 discusses the general state of productivity and productivity improvement within the South African economy. Some comparison is also carried out regarding overseas trade competitors. The general conclusion is that South African productivity rates of improvement are increasing at a lower rate than major trading partners, and that this is compounded by the fact that they are off lower bases.

Chapter 3 compares the typical South African manufacturing approach to that of the Japanese, to the detriment of the South African. The chapter's conclusion is that the philosophy of production known as Just-in-Time, used in part, or substantially by many Japanese manufacturers, could be a reason for the differences.

Chapter 4 attempts to define the Just-in-Time philosophy in general terms and reaches the conclusion that high inventory is the main cause of low productivity and that in order for productivity to be improved, inventory must be reduced.

The chapter concludes further that quality and productivity are significantly one and the same thing.

Chapter 5 lists the areas of waste inherent in inventory holding.

Chapter 6 discusses the costs of quality, and arrives at the conclusion that the typical South African manufacturers quality costs could be 2 - 3 times what it is thought to be.

7.2 Competitive Strategy

According to Michael Porter (Reference 9), there are three general strategic paths that a company can take to out perform other firms in that Industry:

- overall cost leadership
- differentiation
- focus.

He maintains that sometimes, but rarely, can a firm pursue more than one of these approaches as its primary target.

7.3 Overall Cost Leadership

Table 7.1 shows (according to Porter) the implications of the Cost Leadership strategic thrust:

Commonly Required Skills & Resources	Common Organisational Requirements
- Sustained capital investment and access to capital	- Tight cost control
- Process engineering skills intense supervision of labour	- Frequent detailed control reports
- Products designed for ease in manufacture	- Structured organisation and responsibility
- Low cost distribution system	- Incentives based on meeting strict quantity targets.

TABLE 7.1
ELEMENTS OF COST LEADERSHIP STRATEGY

7.4 Differentiation

Table 7.2 shows (Porter) the implications of the Differentiation Strategic Thrust.

Commonly Required Skills & Resources	Common Organisational Requirements
- Strong marketing ability	- Strong co-ordination amongst functions in R & D., product development, and marketing.
- Product Engineering	
- Creative flow.	
- Strong capability in basic research	- Subjective measure ment and incentives instead of quantitive measuring
- Corporate reputation for quality or technological leadership.	- Amenities to attract highly skilled labour, scientists or creative people
- Strong co-operation from channels.	

TABLE 7.2
ELEMENTS OF THE DIFFERENTIATION STRATEGY

7.5 Focus

The focussed strategy is any one of the above policies, but directed at a particular strategic market.

7.6 *Required Strategy*

For the purposes of this report, it will be assumed that the hypothetical company under investigatiion will be concentrating on the focussed strategy in the cost leadership mode. This means that this Company will focus on the South African market, but will be competing, not only with local manufacturers, but also importers. Furthermore, this chapter will attempt, in a subjective way, to demonstrate that the judicious *use of the Just-In-Time philosophy* will assist in the profitable realisation of the chosen strategy.

7.7 Comparison - Local versus Importers

Overseas manufacturers have major advantages over South Africans - many of these advantages are assailable, some are not. However South African manufacturers have advantages over imports - some of which cannot be attacked by importers - or if so, with *difficulty. The following paragraphs* discuss the apparent disability of the South African versus the Importer, but most of these disabilities can be overcome by the judicious use of JIT philosophy for the total company.

Table 7.3 gives a hypothetical comparison between the financial performance of an overseas manufacturer importing to South Africa against a South African manufacturer servicing the South African market.

	I Importer	S.A. Manu-facture	Difference S.A. on I Actual	%
Material Costs	33,1	39,0	5,9	
Direct Labour	5,1	12,5	7,4	
Overheads	11,8	29,5	17,7	
Costs ex Factory	50,0	81,0	31,0	62%

These costs can be restated as follows

Material costs	33,0	36,0	3,0	
Direct Labour	5,0	10,0	5,0	
Overheads	9,5	20,0	10,5	
Quality	2,5	15,0	12,5	
Cost ex factory	50,0	81,0	31,0	62%
Duty	15,0	-	(15,0)	
Transport	7,5	2,5	(5,0)	
Landed Cost	72,5	83,5	11,0	15,2%
Selling Costs	13,0	13,0		
Interest on Finished goods stock	3,5	3,5	11,0	12,4%
TOTAL COST	89,0	100,0	11,0	12,4%

TABLE 7.3

FINANCIAL PERFORMANCE SOUTH AFRICAN VERSUS IMPORTER

From this table it can be seen that the Importer's costs, with the exception of Import Duty and Transport, are always the equal or better than the South African. It can also be seen that if Import Duty was not payable, the South African total costs would be 15 units worse than represented above. This would give a total cost penalty to the South African of 26 units or 25% worse than the Importer.

7.7.1 Raw Material Costs

These are of great advantage to the Importer and can be considered to be of two types:

(a) Access to world producers and the competitive edge thus gained by the purchaser. South African manufacturers are subjected to greater monopolistic and oligopolistic raw material producers. Indeed very often South Africans directly subsidise exports of raw materials by paying export levies. At the very best purchases are at so called International Market levels (London Metal Exchange), but gain no benefit for transport costs, for locally mined minerals. (Copper is a specific case in this regard).

(b) Volume purchasing should always give cost benefits. The larger the purchase the lower the price.

However there are two ways in which better material costs can be obtained, and both are JIT related:

1. There is no reason to believe that the local raw material suppliers quality costs are any better than the machinist and assembler. If all manufacturing in South Africa were able to reduce scrap rates to those of overseas manufacturers, there is no doubt that raw material prices could benefit.

2. Closer contact with a supplier can bring mutual benefit. This is one of the side benefits of JIT - see Table 3.1.

7.7.2 Direct Labour

Labour productivity in the Industrialised nations is far greater than South Africas'. Table A1 indicates this quite clearly. In the writer's view these are in large part due to :

a) Better methods;
b) Better training;
c) Greater education amongst workers;
d) Better motivation;
e) More mechanical and automatic assistance.

However, none of these advantages are unassailable. Indeed there is one major South African advantage, and that is comparably low pay levels - and this for all classes of labour; unskilled to highly skilled. The other advantage is that improvement from a very low base is almost inevitable.

Table 7.4 shows comparible hourly wage rates for steel workers in various countries (Reference 10).

United States	$23,99	R48,00
West Germany	$13,45	R26,90
France	$12,37	R24,74
Japan	$11,08	R55,0
Britain	$ 9,32	R18,64
South Korea	$ 2,39	R 4,78

TABLE 7.4
HOURLY EMPLOYMENT COSTS (INCLUDING BENEFITS)
FOR THE STEEL INDUSTRY 1982 FIRST 9 MONTHS

However, American steel workers are abnormally highly paid, and it would appear that the average wage rates for all U.S. manufacturers was 60% of the above figure, namely some R29,00 per hour (extrapolated from reference 10.).

South African wage rates are substantially lower than these. Hourly rates as at August 1985 (including benefits) are as in Table 7.5 (source GEC South Africa).

R2,89 - Lowest paid production workers
R9,60 - Average Artisan
R4,83 - Average of all grades

TABLE 7.5
AVERAGE EMPLOYMENT COSTS INCLUDING BENEFITS FOR THE SOUTH AFRICAN ELECTRICAL MANUFACTURERS INDUSTRY- AUGUST 1985

7.7.3 Overhead Costs

The overseas advantages here are numerous, and the following is felt, by the writer, to be the most important.

(a) Actual South African costs here are generally excessive:

- people productivity is low (Table A1)
- costs of fixed capital high, due largely to lowering productivity of capital (Table A3)
- control costs are generally high, with low returns. It is the writer's view that South African industry attempts to replace general factory productivity by excessive control, and does not succeed.

The net effect is that costs increase with negative benefit factors.

(b) Overhead absorption due to volume is a difficult advantage to counter. However, Elwood Buffa (Reference 10) demonstrates quite clearly that economies of scale change in step functions, and that the secret is to operate at close to capacity as possible. An organisation is at its most vulnerable just after a quantum capacity upgrading.

7.7.4 Quality Costs

Overseas advantages here are vast, and the difference in costs between a South African manufacturer and its import competition could be as much as 10 - 20% of selling price.

Philip Crosby (Reference 8) states that total costs of quality vary from a low of 2.5% to greater than 20% (of sales), depending on the Quality Management Maturity of a firm. The writer believes that it could be reasonably safe to assume that large scale importers are on the lower end of the scale, whereas the average South African manufacturer tends towards the upper.

Crosby maintains that "Quality is Free". He further states "No other action a manager can take will generate improved operations, increased profits, and reduced costs so quickly with so little effort".

The main benefit of Just-In-Time is the elimination of waste through inventory reduction.

If Quality costs are considered to be waste, (and they are), a reduction of Quality costs from 15% to 2,5% of sales is enough to change a struggling company into a powerful one. It can be seen from the hypothetical model (see Table 7.3) that a reduction of quality costs of this nature, will place the local manufacturer costs some 1,5 units lower than the importer.

A further factor to bear in mind is that many overseas manufacturers are calculating reject rates in parts per million, not parts per hundred as is the case in South Africa (Reference 5). The psychological impact of this approach is unbelievable. The fraction one millionth is 10 000 times smaller than the fraction one hundredth. To be able to plot meaningful information using both scales would not be possible on a linear graph (unless it was some 1 000 metres long!)

7.7.5 Import Duty

Most goods manufactured in South Africa are protected by duty. The authorities have always been, and still are sympathetic to local manufacturing; however their patience has "worn thin". Up until recently duty protection has largely been translated into corporate profits - very little of it into sowing for future harvesting, particularly high level education and training. The fact is duty is there, and the normal rates of between 20% and 30% on F.O.B. value should be sufficient to protect most manufacturers against the one single item outside of the local manufacturers immediate control - namely volume. Paragraph 7.7.10 discusses this statement more fully.

7.7.6 Transport Costs

This (and duty) is the one disadvantage that an Importer suffers in relation to the South African manufacturer. Shipping costs are expensive, not only in the movement of the goods, but also the paperwork, the packing, identification and so on.

7.7.7 Selling Costs

Superficially there does not appear to be any basic advantage or disadvantage for a local or an Importer. However, frequently the local manufacturer has the advantage of market share (in South African markets) and he should be able to take advantage of it. Economy of scale apply equally to selling costs as they do to manufacturing costs.

7.7.8 Finished Goods Stock

South Africa should have the advantage here, given that all investment in South Africa is subject to similar rates of interest. The South Africans' greatest advantage should, of course, be the shorter or smaller pipeline from factory to customer. To ship from Johannesburg to Durban should be many weeks less than from Tokyo to Johannesburg, (followed by further redistribution throughout the country). This should mean that the South African manufacturers should be able to hold much greater variety of stocks, with significantly less stock holdings than the Importer. Not only will this give lower interest payments, but will assist markedly in the selling and marketing effort.

7.7.9 Overall Cost Reduction

Based on the previous sections (7.7.1 to 7.7.8) perhaps it would be instructive to estimate some cost reductions that could be achieved, via JIT, and compare them with the costs as listed in Table 7.3. Table 7.6 summarises the results:

	South African Manufacturing Costs		Remarks
	Table 7.3	Improved	
Material Costs	36,0	35,0	+/-3% improvement
Direct labour	10,0	9,0	10% improv.
Overheads	20,0	18,0	10% "
Quality	15,0	2,5	
Cost ex factory	81,0	64,5	
Duty		-	-
Transport	2,5	2,5	
Landed Cost	83,5	67,0	
Selling costs	13,0	12,0	7.1/2% improvement.
Interest on finished goods stock	3,5	1,0	Inventory reduced by +/-70%
		100,0	80,0
Imported Cost (Table 7.3)	89,0		89,0

TABLE 7.6

FINANCIAL PERFORMANCE SOUTH AFRICAN MANUFACTURERS

In affect, not only has the overall cost chain been reduced by some 20%, but the improved cost is some 10% lower than the Importers.

The effect of this cost differential between the local and the Importer is significant. By judicious pricing, the Importer could now be tempted to leave the market. Table 7.7 shows the effect of pricing.

	Importer	South African	
		Table 7.3	Table 7.6
Selling Price	100	100	100
Cost	89	100	80
Profit	11	0	20
Profit %	11%	0%	20%
Selling Price	90	90	90
Cost	89	100	80
Profit	1	(10)	10
Profit %	1.1%	(11.1%)	11,1%

TABLE 7.7

EFFECT ON SELLING PRICE AND COST ON PROFITABILITY

It must be born in mind that with the previous cost situation, the Importer, due to his cost leadership could, if he so desired, exert price leadership. With the new, or improved costing, the local manufacturer would exert price leadership.

It is interesting to note that one of the elements in competitive strategy is a factor referred to as cost of exit (reference 9,10 and 11), or exit barriers. The cost of exit for an established manufacturer is great.

These costs would include retrenchment pay, loss on resale of capital equipment, run down costs, and so on. These costs could be so great as to cause the manufacturer to continue trading long after it was viable to do so. On the other hand, costs of exit to a trader are far less, and he would exit a market far quicker than a manufacturer would.

7.7.10 Learning Curves

It would be interesting to test whether, in terms of learning (or experience) curves, the improvements postulated are contradicted by theory.

Abel & Hammond (Reference 11) give a formula for the experience curve.

$$Cq = Cn[q/n]^{-b} \qquad \text{Formula A}$$

where q = cumulative production to date
n = cumulative production at an earlier date
Cq = the cost of unit q (deflated)
Cn = the cost of unit n (deflated)
b = a constant that depends on the learning rate (see Table 7.8)

From the above formula A, the following is derived:

$$(q/n) = (Cn/Cq)^{1/b} \qquad \text{Formula B}$$

Assume now the following:
q = cummulative production of an Importer
n = cumulative production of local manufacturer

Cq = cost of unit a = 50 (Table 7.3)
Cn = cost of unit n = 64.5 (Table 7.6).

The following table uses formula B, and calculates various values of (q/n) for varying learning rates, and for (Cn/Cq) = 64,5/50,0 = 1,29

Learning Rate	95%	90%	85%	80%	75%
b	0,074	0,152	0,235	0,322	0,415
(q/n)	31,22	5,34	2,96	2,21	1,85

TABLE 7.8
COMPARISON OF LEARNING RATES
WITH PRODUCTION DIFFERENCES

The interpretation of this table is as follows:
If learning rate for the hypothetical product and industry is 90% say, then it is possible (in terms of learning curve theory) to achieve the cost difference of 64,5 for the local manufacture, against 50 for the Importer (ex factory costs) if the cumulative production of the Importer's principal is not greater than 5,34 times the local manufacturers.

It seems unlikely that many South African manufacturers have cumulative production rates comparable with overseas production rates to the extent shown in Table 7.8, at experience rates less than 95%. However, many local manufacturers derive their technology from overseas principals, and then it is entirely possible in these cases that the cumulative production of the local manufacturer (plus his principal) is within these limits proposed in Table 7.8.

In effect this means that the local manufacturer can have two points on a learning curve; one low down the cost curve, due to his principals extensive production experience; and two, high up the curve due to his lesser experience. The net result will then be a compound type formula. (Which is beyond the scope of this report.)

7.7.11 Summary

To summarise the above:

The only structural advantage the overseas manufacturer should have is that of volume. This is a great disadvantage for local manufacturers. However, it is the belief of the writer that the structural advantages of the local manufacturer should offset this:

Import duty
Transport costs
Stockholding
Variety of stockholding
Closer contact with customers
Better service
Patriotism
Adaptation to local needs and requirements
Lower wage and salary levels

and, perhaps as important as all these, potentially cheap materials -but this will require an integrated economic policy for the country as a whole.

7.7.12 Conclusion

Although South African manufacturers face certain disadvantages compared to overseas manufacturers, there are enough local advantages to outweigh this fact

However, the South African manufacturer will have to get his house in order - and fast.

The philosophy of JIT can be of tremendous benefit in this regard.The writer postulates the hypothesis that inventory is waste and the adoption of this philosophy by a manufacturer forces him in a controlled, logical and focussed manner to reduce his inventory, thus reducing and eventually eliminating all areas of waste, and therefore maximising his productivity within the parameters he wishes to operate.

8.0 GEC SMALL MACHINES COMPANY - DESCRIPTION

8.1 Ownership

GEC Small Machines Company is a division of the GEC Electric Motor Manufacturers Co (Pty)Limited, which in turn is a wholly owned subsidiary of GEC S.A. (Pty) Limited. GEC South Africa (Pty) Ltd. in turn is 50% owned by Reunerts Limited (a quoted South African Company and 50% by GEC plc. (a quoted United Kingdom Company). Reunert Limited is controlled by Barlow Rand Limited (a quoted South African Company).

Figure 8.1 shows the above relationship. It also gives an indication of various other GEC South Africa companies.

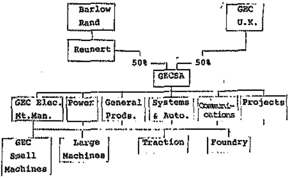

FIGURE 8.1
GEC SMALL MACHINES COMPANY-RELATIONSHIPS

8.2 Management Structure

GECSA has a management philosophy of decentralisation into Strategic Business Units (SBU), of which the Small Machines Company is one of some 27 in South Africa. Each SBU is treated as an autonomous profit centre and is permitted to have the resources and facilities required to effect the optimisation of profits and growth.

The present Management structure of Small Machines is as follows:

- General Manager
  - Manufacturing Manager
  - Industrial Engineering Manager
  - Chief Engineer
  - Sales Manager
  - Finance Manager
    - Quality Control Manager
    - Systems Manager

Figure 8.2
MANAGEMENT STRUCTURE
SMALL MACHINES COMPANY

8.3 Scope of Activity

Total complement in this Strategic Business Unit (SBU) is approximately 430 people.

Manufacturing takes place at the Small Machines' factory in Benoni, Transvaal and stocking and selling outlets exist throughout the country:

Benoni, Pretoria, Durban, Port Elizabeth, Cape Town, Welkom, and Bloemfontein. These branch offices are the direct rersponsibility of the Small Machines Company, but share office and storage facilities with other GEC Companies at all Banches, except Benoni.

Areas other than those mentioned above are covered by appointed Agents (independents); other GEC Companies; and other Reunert Companies.

Furthermore, Small Machines Company also manufactures motors for other major manufacturers in the South Africa as well as under proprietary brand names for Oganisations such as VETSAK, who in turn sell through Agricultural Co-ops.

8.4 Product Range

The Company manufactures Low Voltage motors in the IEC range 71-225. Essentially these motors are standard dimensioned motors, and comply with various local South African Bureau of Standard specifications, as well as International.

However the company also sells and markets motors that can be considered near standard or variations on standard - i.e. motors that are manufactured to customers requirements, but are closely related to the standard range.

The theoretical maximum number of individual type motors could be in excess of 3 000, with perhaps 1 000 actually in current manufacture.

8.4.1 Frame Size

Varieties of standard motors are as follows. The major designation is frame size, which is essentially the shaft height off the ground in mm., and further described in terms of short frame (s), medium frame (m) and long frame (l).

viz: 71;80s; 90s;90l;100;112m;132s;132m;160m;160l;180m;180l;200m; 200l;225s;225m.

8.4.2 Enclosures

Essentially there are two types of enclosures, IP44 which is TEFC (Totally Enclosed Fan Cooled), and normally designated D frame; and a IP22 enclosure - referred to as Drip Proof, and normally designated C frame.

8.4.3 Outputs

Outputs are in the following kilowatt steps:
0,25; 0,37; 0,55; 0,.75; L,L; L,5; 2,2; 3,0; 4,0; 5,5; 7,5; 11,0; 15,0; 18,5; 22; 30; 37; 45; 55; 75.

8.4.4 Speeds

Standard speeds per kilowatt output are normally designated in poles, which gives a particular synchronous speed at 50Hz, and an operating speed somewhat less than this due to slip.

Poles	Synchronous speed r/min.	Operating speed r/min
2	3 000	2 820-2 965
4	1 500	1 410-1 475
6	1 000	920- 980
8	750	700- 730

TABLE 8.3
MOTOR SPEEDS

8.4.5 Phases

Single and three phase motors are manufactured, although single phase above frame size D100L are not produced.

8.4.6 *Voltages*

Single phase	220 volt nominal
Three phase	380, 433, 522 volt nominal

8.4.7 Mountings

Three basic mountings are manufactured, foot; flange; pad mounted (or rod).

8.4.8 Materials

For the TEFC range of motors, the envelope (frame and end shields) could be either aluminium, or steel or cast iron. Essentially the aluminium range of motors are cost reduced, but are not suitable for all applications due to prevailing atmospheric conditions or robustness required. Smaller motors have a steel frame, whereas larger motors have a cast iron frame. This is purely manufacturers choice.

8.4.9 Insulation

The standard insulation system is Class F (60°C permitted temperature rise over an ambient of 40°C), but actual maximum temperature rise of the motor is restricted to class B (40°C rise over an ambient of 40°C).

8.4.10 Variety

The above variations give a total number of some 900 models as per GEC's stock and price list.

8.4.11 Near Standard or Stock Modifications

In addition to the above, variations on these standards can be manufactured. Whether or not orders are taken for these motors is subject to price achievable, volume, designs available, customer, etc.

Variations possible are either of a mechanical, electrical or cosmetic nature (paint finishes).

8.4.12 Mechanical

The following is a brief list of various mechanical motors are cost reduced, but are not suitable for all applications due to prevailing atmospheric conditions or robustness required. Smaller motors have a steel frame, whereas larger motors have a cast iron frame. This is purely manufacturers choice.

8.4.9 Insulation

The standard insulation system is Class F (60°C permitted temperature rise over an ambient of 40°C), but actual maximum temperature rise of the motor is restricted to class B (40°C rise over an ambient of 40°C).

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Variations possible are either of a mechanical, electrical or cosmetic nature (paint finishes).

8.4.12 Mechanical

The following is a brief list of various mechanical features available:

- Non standard shafts (materials or extensions)
- Improved enclosures for spark proof; dust ignition proof;hose proof; carbon black proof and particular finishes for chemical works etc.
- Glands and non standard cable or terminal boxes
- Combination mountings-foot and flange
- Special flange end shields, frequently gear box manufacturers requirements
- Special rod mountings
- Heaters fitted
- Burn out protected
- Etc.

8.4.13 Electrical

- Multi speed motors
- Slow speed (less than 8 pole)
- High starting torque
- Class of insulation
- etc.

8.4.14 Motor Mass

Motors here have masses from 1[illegible]kg to 310kg.

8.4.15 Motor Price

Subject to all normal marketing considerations, but retail list price varies from R107 to R3 033 (as at July 1985).

8.4.16 Mechanical Configuration

Electric motors have basically the same configuration, but components obviously vary in size -the following lists the major components in a motor.

Description	Particulars
Stator frame	A
Feet	A
End Shields	A
Bearings	B
Shafts	B
Rotor cores	C
Stator cores	C
Terminal boxes	B
Terminal lids	B
Terminal bases	B
Capacitors	D
Winding Wire	E
Insulation	F
Fasteners	B
Cowls	B
Fans	B

A Varies per frame size; material; enclosure; mounting.

B Varies per frame size

C Varies per frame size; speed; kw

D For types of single phase starting characteristics

E Varies pe[illegible]ical design

F Same r[illegible], regardless of most motor specifica[illegible] but cut to specific size requirements.

TABLE 8.4

MOTOR COMPONENTS

8.5 Manufacturing Systems

In essence, the bulk of motors are sold on an ex stock basis from all branch offices. All motor ranges are manufactured every 5 weeks and non-stock or non-standard motor deliveries are manufactured in line with the stock range of motors applicable. To elaborate, 100 frame size motors say are manufactured every 5 weeks. During this production cycle, all 100 frame motors are manufactured, including non stock and non standard motors. This allows for the optimum use of the synergy existing between all motors in the 100 frame size range.

Agents, other manufacturers and branches all order in line with the cycle as laid down.

This system has been in operation, with minimal changes, for some 15 years.

8.6 Proposed System Changes

The present manufacturing system has been reasonably effective over the years, but suffers from the inabilities of all systems not JIT based.

Furthermore, this company (the largest electric motor manufacturer in South Africa) was suffering from the same problems as discussed in previous chapters (particularly Import competition).

The GECSA Board perceived this, and it was decided that a JIT based system should be introduced with all despatch.

The writer, as Director of Manufacturing, Planning and Development for GECSA was seconded to the Small Machines Company to oversee the analysis, design and implementation of a JIT system with the Small Machines Company.

It was also recognised by the Board that there was no point in investigating other systems - such as MRP II, but that JIT would be the system and that other possibilities would be incorporated with JIT, rather than the other way around.

9.0 JIT REQUIREMENTS (establishmennt of criteria)

9.1 General Approach

The first task was to assess JIT requirements - namely those aspects that would be essential for a JIT type of philosophy to be viable.

JIT could be said to be : (see section 4,0 through 6,0)

"Elimination of waste through inventory reduction"

JIT could also be said to be:

"Not an inventory reduction philosophy, but a total Quality Assurance Programme".

It was decided to use the first definition as the motto - and guiding light. We did not think we could go wrong - if inventory is a major cause of waste - reducing inventory is reducing waste - the two being synonomous.

"Inventory is waste".

9.2 Inventory Reduction

The problem was tackled as an inventory reduction exercise - knowing full well that in order to reduce inventory - those waste elements that prevented or hampered inventory reduction or elimination would be highlighted, and highlighted soon - thus giving priorities to concentrate on.

However, it was also realised that reduction of quality costs would give major benefits - and those reasonably quickly.

9.3 Quality

It was also very soon realised that probably a major stumbling block in achieving JIT was not only Quality costs, but the disruption caused by rejects, rework and time spent on inspection, test and so on.

9.4 Resource Restraints

Skilled manpower resources within the company, like the majority of South African organisations, is severely limited, so it had to be made quite sure that where resources were committed, payback had to be quick and measurable.

So viewing the organisation as a whole, where is the starting point? - keeping two major requirements in mind :

- inventory reduction
- quality cost reduction

and realising

- low qualified manpower resources
- quick pay back
- essential to gain confidence
- essential to impart this confidence to the workforce.

Furthermore, it was important to tackle those areas where there was internal control - or alternatively lack of control was due to internal faults or inadequacies. There would be no point in saying

"If only our suppliers would play ball".

"if only our shareholders would give us R2m to solve this set up problem".

"if only our customers would give us better lead times - or alternatively accurate forecasting".

9.5 Management Attitudes

Additionally it became very quickly apparent that the writer was in a minority of one. He was, at the onset, the only person (in the SBU) totally dedicated to the premise that JIT was viable in South Africa. The senior management of the company thought "it was a good idea; that it would be fabulous if it worked; but given the terrible problems facing S.A. manufacturing - labour, quality, suppliers, set ups, batches, it was unlikely".

So really the very first thing that was required was to install some motivation into the management. Three approaches would be taken :

- the possible gains from JIT would be so great that any costs, problems, etc. would be well worth incurring.
- in any event, if JIT was not adopted, or could not achieve the benefits desired, the company had no real future.

- to mitigate against uncontrolled disaster, a pilot scheme would be commenced in a smallish self contained product line, within the company, but not so small as to be a laboratory type experiment, but not so large as to put the overall SBU at risk.

9.6 Summary

Summarising then, the first criteria for JIT implementation required the following:

- inventory reduction
- quality improvement
- quick pay back and measurable
- if this could happen confidence would be gained by all levels of employees, operators up to senior management
- solutions to problems had to be within internal control
- significant capital investment would not be acceptable
- start small, develop confidence, and expand later
- keep it simple

10.0 ANALYSIS OF CRITERIA

Five categories of inventory are carried in this organisation:

- raw materials
- component Work in Progress
- machined components plus bought out completes
- sub assembly and final assembly Work in Progress (W.I.P.)
- finished goods

All these categories were carrying substantial inventory and each was investigated in turn against the criteria established above (Section 9.6).

10.1 Raw Materials

Inventory was excessive due largely to buffer stocks required for so-called unforeseen happenings.

- late deliveries by suppliers
- rejects discovered late in the day in the stores due to bad quality from supplier
- requirements for manufacturing rejects or rework
- inadequate or unreliable forecasting (particularly slow moving items)
- items not yet required by the factory, due to lateness by the factory

- accumulation of components, over time, so that a full batch could be on hand, before delivery to the factory

Some of these points were, in the short term, outside of the company's control being supplier related.

Some were within internal control, but solutions would take time - forecasting being one.

Some were within internal control, and solution would be related to success within the manufacturing environment, (defect reduction, batch sizes etc.)

Cost reduction can be categorised into a number of sub-areas:

<u>Immediate</u> - if [illegible] rejects are made, less rework engaged in, costs will be less; also less stock holding, less financing costs.

<u>Medium</u> - if suppliers are prone to defective deliveries, the purchaser actually pays for these rejects. By the supplier improving his quality his costs will reduce, and some of those benefits will come the purchaser's way.

<u>Long term</u> - reductions due to smaller warehouses and related costs will take time. Given no expansion and no possibility of sub leasing, the manufacturer could be saddled with the surplus space.

It was then decided to concentrate on those areas which would be improved by factory improvements, and leave supplier and forecasting related problems for later.

In other words, some inventory reduction would be achieved due to the improvement in some of the internal inadequacies, as JIT mode was introduced in the factory. Namely :

- no buffers for rejects
- no accumulation of large batches, but allow piece batch deliveries into the workshops.

However, contact was made with three major suppliers. They were given notice of what was intended in regard to JIT, and they were also lectured on the philosophy and principals of JIT.

10.2 Component W.I.P.

Inventory here is largely made up of queues.

- components waiting for next operation.
- components waiting due to priority scheduling as a result of reject and remanufacture, rework, late scheduled work, or un-scheduled work.

It could be said that all factors influencing high inventories here are within internal control, and that the proper approach to JIT here will have major influence on inventory holding, quality costs, etc.

10.3 Machined Components and Bought-outs

Similar factors apply here as apply in raw material stocks. However, inventory holdings are further aggravated by greater variety of components held - for instance - one type of rotor lamination could be die cast into six different rotors. However, the machined components are put into stores because they are placed there, by the company (or its system or employees).

The following conclusion was arrived at:

- bought outs - suffer same problems as raw material stock, and will be treated initially in the same way. However, cost penalties of not reducing inventory here to JIT mode are not exceptionally great as the majority of these items are of a relatively cheap nature - fasteners for instance.

- machined components - if the factory could go into JIT mode, lead times could reduce, flexibility could be improved; reaction time would be minimised and hence, these levels of inventory could be substantially reduced in the short term and probably eliminated in the long.

10.4 Sub Assembly and Assembly W.I.P.

Excess inventory here is largely due to similar reasons as for component W.I.P., but further aggravated by the fact that to make a sub assembly or final assembly many components and operations need to be matched. For instance, if the chances of a stock out are 5% for one item - i.e. service level is 95%, the service level for two items is $(0,95)^2 = 90\%$ i.e. 10% chance of a stock out. If 10 items are required for a sub assembly, service level is 60%, i.e. 40% chance of a stock out.

However, with the exception of bought-out components, all other problems encountered here can be said to lie within internal control.

10.5 Finished Goods

Excess inventory is largely due to the following reasons :

- inaccurate forecasting
- independent forecasting and stocking, branch by branch
- lead time from factory into bins
- lead time from receipt of order, to time of despatch
- the making up of economic container loads for despatch to branches or customers
- buffer stock required due to length of manufacturing cycle

10.6 Summary

It was decided, based on the above analysis, to concentrate on W.I.P. reduction. In doing so various of the parameters as laid down would be complied with:

- inventory reduction would result but additionally some aspects of excess inventory in raw materials, machined component stocks and F.G. would also result, these being related to excess or low control on W.I.P.

- quality cost reduction. The factory is a major source of quality costs. By concentrating on W.I.P. those areas of high quality cost would have to be tackled and eliminated. Furthermore improved quality in the factory could have impact on areas of quality cost in the other areas.

- problems and solutions here lay largely in the company's hands

- improvements here could be considerable. Assessment of reduction in W.I.P., throughput time, manufacturing costs etc., would not be difficult.

10.7 Conclusion

It was still needed to establish the area in which to start the exercise.

Frame size designation, rather than kilowatt gives better comparison for the physical attributes of motors.

The motor range was viewed and the conclusion was reached that sub-division into a number of motor ranges was possible, and that these could be handled reasonably independantly.

frame	size	71, 80, 90 (mini motors)
"	"	100 - 112
"	"	132
"	"	160 - 180
"	"	200 - 225

Each of these group of motors had similar characteristics *and used similar manufacturing* facilities; or could be re-planned to use similar facilities

Certainly this was true of the first three categories above, and less so of the last two.

Furthermore, the size of each of these product ranges (in manufacturing cost terms) were approximately similar. The least was 16% of total, with the largest 24% of total.

The mini motor category had the most independence, as it had previously been a stand-alone manufacturing operation in Kwa Zulu and had been moved up to Benoni the previous year.

The other ranges were fairly well integrated, and in order to comply with the statements made above, a fair amount of replanning would have to take place.

The move of the mini motor range from Kwa Zulu had been a shambles and it was suffering very serious production problems - quality, output, new labour (most of the Kwa Zulu labour force remained in Kwa Zulu), backlogs, machine tool breakdowns, lost tooling, breakages etc. Furthermore the production control system was non existent.

Due to these reasons the general management decided that as the mini motor range required a great deal of urgent and priority attention, it would be as well to start the JIT implementation there. If this was not to be the case, insufficient resources would be available for satisfactory implementation elsewhere.

All of the prime criteria had now been complied with and there was no doubt, that due to the abysmal state of the mini motor production line, that pay back here would be quick - and that confidence would be gained for subsequent implementation.

These investigations and analysis took about 6 weeks - July and August 1984.

At the beginning of September 1984 it was decided to commence with the mini motor programme.

11.0 MINI MOTORS - PRELIMINARY INVESTIGATION

The general state of the mini motor product group could only be described as abysmal. It is not the purpose of this paper to establish the reasons for this state of affairs, suffice to say that control had all but been lost and all aspects of the business were in disarray.

The production control system was haphazard, factory output well below requirement, rejects very high, general quality not up to requirement, overdues very high, labour untrained and ignorant; similarly for most of the supervision; plant and equipment in a bad state of repair; factory layout unsatisfactory, stocks and W.I.P. very high, but shortages rampant. The following summarises the various aspects of the business at that time.

11.1 Production System

The production system was more than haphazard and it serves no purpose to give any detailed attention to it. Essentially, raw materials were purchased for stock against E.A.D's (estimated annual demands). Similarly, these raw materials were further processed for stock, into finished components ready for further sub or final assembly on requirement.

Orders for motors were than placed on the factory at intermittent intervals, for customer orders and stock replenishment at the Benoni and Branch stores.

Overdues were rampant, and no formal system was *available* for rescheduling or establishing priorities. Priorities were continually changing, and were established purely by the rank of the company *officer* chasing the overdue, the power of the customer, the convenience of the factory or frequently the availability of parts.

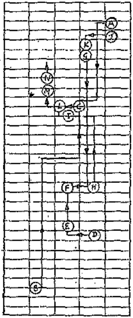
(a) Even if the system was operating correctly inventory levels would have been high, due to the systematic use of raw material stores, component work in progress, component stores, assembly and subsequently work in progress, finished goods stores.

(b) The inventory levels were further aggravated by a large motor delivery backlog, and no attempt had been made at rescheduling the manufacturing lines.

(c) The batch mode was used for the entire process. In essence the ordinary rule was that all batch sizes, from raw materials ordering to finished motors, would be of 5 weeks requirements suitably modified to accept allowances for rejects, long lead times for some items, low confidence in suppliers delivery *promises* and so on.

11.2 Factory Layout

Essentially, with *some exceptions*, *the* various manufacturing departments had been integrated on a functional basis, with similar work shops for the other *product groups*. *Shafts* with shafts, core building with core building, die casting with die casting, etc. Figure 11.1 shows where the major *departments were* situated in the factory.



A- Rotor die cast
B- Shaft machining
C- Rotor assembly
D- Stator Core Build
E- Wind
F- Connect
G- Shell Manufacture
H- Impregnation
I- Stator Machining
J- End Shield Casting
K- End Shield Machining
L- Motor Assembly
M- Final Test
N- Spray Paint

SCALE 1 mm = 1m.

Figure 11.1
Mini-Motor Production Areas
Pre-relayout

As the batch mode was the order of the day, there was plenty of room between machines and processes to allow for queuing between operations, awaiting inspection or test, and so on. Distances travelled were long, and control was continually being lost, due to these distances, as well as Work in Progress pile ups.

For instance the winding shop foreman's duties were to wind stators. Once a particular order was completed, his obligations were over. However, large piles of wound stators were situated at many places throughout the factory and it was not uncommon for stators to be lost, and more often than not they were remanufactured rather than being looked for. The lost stators were of course then ignored, never re-located, but still physically in the company's premises, and financially still on the company's books as a so-called asset.

Generally the layout was further aggravated by the accepted situation that the mini motor line had the status of a step child and was subordinate to the other product groups. Mini motors had to fit where there was room available, and do the best they could.

11.3 Supervision

Supervision had the most unenviable task trying to manage a system out of control, an inadequate factory layout,"green" labour, high backlogs, high reject rates, masses of W.I.P. inventory and so on. They "spent their lives" putting out fires, chasing shortages, changing priorities, being hammered by their management, and having no success - only failures. Obviously there was no time available to put things right. When defectives were made, and this was a chronic condition, the only action a foreman had time to do was carrying out the paper work required to remanufacture. He certainly had no time to establish the cause of the reject and ensure that it did not happen again. They did not even work through the rejects to establish if there was any salvage, or if they could be repaired, or whatever. The rejects were either dumped, or left to rot on the shop floor.

11.4 Labour

Most of the labour employed on this product group were green. When the group was transferred to Benoni from Kwa Zulu none of the operatives were transferred with the line. This fact due entirely to Government Policy regarding re-deployment of black labour from so called homelands to urban areas. Hence all labour required for this production facility at Benoni had to be newly engaged, or surplus labour transferred from other departments at the Benoni site. Most of these employees were new to the type of work they were expected to carry out. This is not necessarily a bad thing if proper induction, education and training is carried out, and the employment of people conducted in an orderly and planned fashion, and within the scope of the organisation to handle such an influx. None of this was the case. Training was purely "sit by Nelly (or rather Andries)" and invariably training was imparted by the undertrained. Errors, ignorance, misunderstanding and the like were all passed on as gospel, and obviously perpetuated.

The foremen certainly had no time to train them, and their positive contribution was *minimal, whereas* negative contribution was great - namely screaming and shouting at errors, *taking disciplinary actions* and similar acts after the event.

11.5 Quality

It comes as no great surprise, that given the scenario painted above, reject and defective generation was vast. Fortunately, the one area of supervision and operatives that had not been weakened, but rather strengthened, was the Inspection and Test Departments.

Fortunate, purely for the reason that at least reject and defective work was *kept within the* confines of the factory, and that the quality of motors being sold was not *totally unacceptable* to some customers.

However, the Inspection and Test departments viewed their responsibility purely as Inspection and Test, and that if they successfully found sub-standard work and rejected it, their obligation was at an end. They certainly did not view their jobs as being involved in the quality process, but rather in the *rejecting* business. Of course, to be fair, some of the Quality Control staff saw their jobs as *being wider than* pure detection, but they certainly had little time to investigate, *analyse and prevent* future similar occurrences. In any event, the very nature of batch *manufacture, compounded* by long process lead times did not assist in this regard. It is almost impossible to *adequately* analyse the cause of sub standard work when that work has been carried out some six weeks previously, by an anonymous operative, subject to the supervision of any one of a number of setters and on any one of a number of machines, and according to a drawing which can no longer be found.

Furthermore, the cause of defective work was not always due to an operative or a setter. A major cause of reject work was undoubtedly damage or deterioration caused by high inventory, especially Work in Progress. The copper overhangs of a stator are particularly susceptible to damage, and any handling, stacking or movement aggravates the dangers. This is also of course true of most precision engineered products. Other causes were engineering changes, not picked up in time or ignored, or too late for incorporation.

Order cancellations due to non adherence of delivery dates, sometimes resulted in obsolescence of specially engineered customer requirements.

11.6 Statistics

In order to reduce the subjectivity of some of the statements made in the preceding paragraphs, and obviously to give a base for measurement and comparison of future performance, a number of significant indicators were compiled. The indicators were also subject to certain restrictions or parameters:

- they had to be meaningful, not only to the management and supervision, but also to the operatives;
- they had to be measurable, within a reasonable degree of accuracy;

- should not be subject to misunderstanding due to conventions, possible *"noise" from* the other product groups, or accounting conventions;
- had to be able to be produced regularly and *promptly;*
- preferably produced by the mini motor management and supervision themselves;
- had to be such that past history was available for their compilation, or estimates made had to be beyond carping or quibbling.

The following table shows the major *indicators* established and the 'state of play' as at the end of September 1984. i.e. the weekly *average* of the indicators since the beginning of April 1984. Figures Nos. 11.2 to 11.7 *show the* weekly movement of these indicators. Stator Work in Progress shown is that for *the mid July*, 1984 stock takes.

FIGURE NO	INDICATOR	UNIT	WEEKLY AVERAGE 30.3.84-28.9.84
11.2	Motors passed final test	Motors	416
11.3	Motors rejected final test	%	34,8%
11.4	Stator winding rejects	%	13,0%
11.5	Stators requiring rewind	%	6,2%
11.6	Hours per motor passed final test	Hours	7,49hrs.
11.7	Wages & Salaries per motor produced	Rands	R22,63
	Stator Work in Progress	Days	31,5days

TABLE 11.1

LIST OF INDICATORS MINI MOTOR PRODUCTION

The following gives more exact descriptions of the various indicators.

Motors passed final test - two curves are given here, a weekly output curve (adjusted for number of days in the week) and a 5 week moving average.

Motors rejected final test - these are given as a percentage of motors passed final test, and the two curves are for weekly performance, as well as 5 week moving average. Rejects here are defined as all defects whether of a minor nature, requiring a couple of minutes rectification, or of a major nature, requiring a possible rewind or even the scrapping of a complete motor.

Stator winding rejects - these are given as a percentage of stators passed as satisfactory at the intermediate stator test station. Curves are for weekly performance as well as 5 week moving average. Rejects here are defined as all defects whether of a minor or major nature.

Stators requiring rewind - these are given as a percentage of motors passed final test. Rejects requiring rewind are obviously those where the defect is serious and expensive. Curves once again are for weekly performance and 5 week moving averages.

Total Hours Per Motor Passed Final Test - this curve is the ratio of total hours booked by all hourly paid employees involved with mini motor manufacture, to the number of motors passed final test. This includes direct, indirect, inspectors, storemen, supervision, etc. The only curve given is a 5 week moving average.

Salaries and Wages Per Motor Produced - this curve is the ratio of total wages and salaries paid to all employees involved in mini motor production, including management, production control staff, production engineers, as a ratio of motors passed final test. Only a 5 week moving average is given.

Stators W.I.P. - figures given here are the number of stators throughout the department, from the commencement of winding to motors not yet passed final test, as a ratio of the daily rate of final motor production on a daily basis.

11.7 Conclusions

The state of the mini motor product group was such that a major overhaul of virtually all aspects of the manufacturing operation would have to be undertaken. The opinion was that the implementation of JIT in the operation would be no more radical than any new approach to solve this product units problems, and that inherently JIT would have many of the answers and solutions.

Figure 11.2

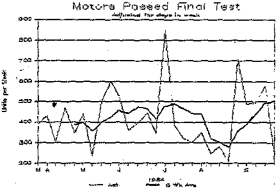


Figure 11.3

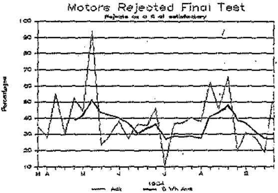


Figure 11.4

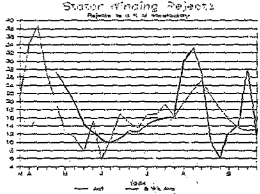


Figure 11.5

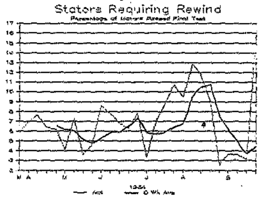


Figure 11.6

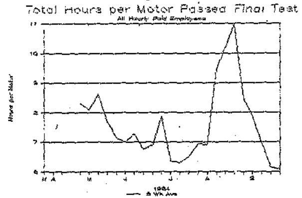
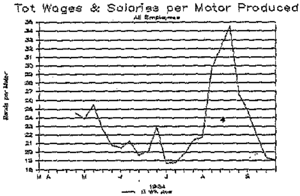


Figure 11.7



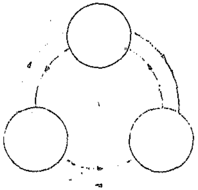
12.0 MINI MOTOR - SYSTEM DEFINITION

12.1 Introduction

The problem with facing a situation as described is where to start, as all the problems are integrated. Briefly the steps taken were as follows:

(a) A flow process chart was constructed for the major components and sub assemblies;
(b) Factory layouts were looked at;
(c) A formal system was investigated.

These three items cannot really be solved in isolation so modifications were continuously being effected.



In due course the following ideal criteria were arrived at:

12.2 Factory Layout

(a) As many of the operations and processes involved in mini motors would have to be contained in one geographical area in the factory as was possible (refer to figure 11.1 for previous layout).

(b) The factory would be laid out in such a way that there could be visual communication between the various shops.

(c) Manufacturing lines would be such that actual component movement for each line would be a minimum and that the finished component or sub assembly would be at its next point of requirement immediately following the subsequent process.

(d) Machines and equipment were to be as close as possible subject to safety and maintenance requirements.

(e) None or very little room was to be allowed for inter operational queuing or accumulation of inter-departmental work in progress. No component or work in progress, or finished component stores would be permitted. The only official stores, in the first instance, would be - a raw material and bought out component store and a finished motor store.

(f) The U shape approach to manufacturing cells would be adopted where practicable.

(g) Manufacturing incentives would be such that operatives could with ease move from job to job or carry out dis-similar functions.

(h) The initial layout would be such that modification could be easily achievable. In other words, machine tools would not be grouted in, and that the overhead busbar system of power supply would be used, and that as few permanent features as possible would be permitted in the initial stages.

(i) Space would have to be made available for the current very high levels of work in progress. Open floor areas would be kept alongside the production lines for all this work in progress to be marshalled and controlled.

Figure 12.1 shows the layout eventually arrived at. Figure 12.2 shows the mini motor manufacturing departments in relationship to the small motor factory. (This should be compared with Figure 11.1).

12.3 System

(a) Whatever system was introduced had to be simple and easily understood by all.

(b) It would have to cater for the major elements of the JIT philosophy but the more advanced aspects of control, such as Kanban would be left for the future.

(c) There would probably be more formal structuring required in the short term than perhaps would be desirable, but as long as the structure of the system designed was such that it was capable of modification in the long run, this was not seen to be a problem.

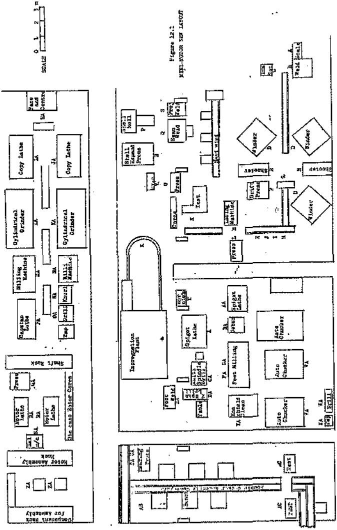
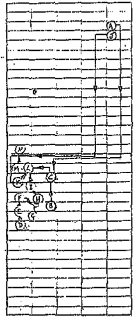


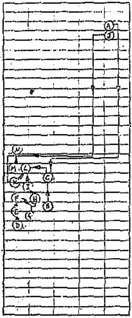
Figure 12.1
MINI-MOTOR NEW LAYOUT



A - Rotor Die Cast
B - Shaft Machining
C - Rotor Assembly
D - Stator Core Build
E - Wind
F - Connect
G - Shell Manufacture
H - Impregnation
I - Stator Machining
J - End Shield Casting
K - End Shield Machining
L - Motor Assembly
M - Final Test
N - Spray Paint

SCALE 1 cm = 1 m.

Figure 12.2
Mini-Motor Production Areas
Post relayout



A - Rotor Die Cast

B - Shaft Machining

C - Rotor Assembly

D - Stator Core Build

E - Wind

F - Connect

G - Shell Manufacture

H - Impregnation

I - Stator Machining

J - End Shield Casting

K - End Shield Machining

L - Motor Assembly

M - Final Test

N - Spray Paint

SCALE 1 mm = 1 m.

Figure 12.2
Mini-Meter Production Area
Post relayout

(d) Due to assumed "culture shock" the system as such would be rather *simplistic* and *acceptable* to folk used to working in batch mode, with long lead times i.e. lead times in new system would not be so short that factory personnel *could not accept* them as reasonable and realistic. However, the system must be such that it would be easy to reduce lead times as confidence and acceptability increased.

12.4 Process Specifications

Figure 12.3 shows the process procedures eventually arrived at. The process chart shown is for a typical *single phase motor. Figure* A1 *gives* an exploded view of such a motor. Figure A2 shows an exploded view of a three phase motor.

Generally speaking, a single phase motor is more complicated to manufacture than a three phase motor due to more components being required. For instance, most single phase motors will have a capacitor, a stator switch (mounted on the non drive end endshield), a rotor switch (mounted on the non-drive end of the rotor shaft), and more complex terminations. Other differences are not significant.

12.5 Statement of Problems

In essence what was being attempted was a continuous flow of materials being *modified* at various work stations; accepting other components into further sub assemblies (these components themselves previously subjected to modification and adaption); until a completed motor was available, tested, painted, boxed and ready for despatch.

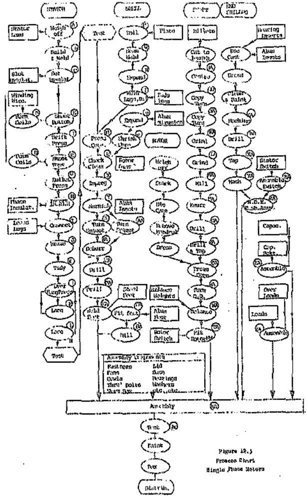


Figure 12.1
Process Chart
Single Phase Motors

Furthermore, there was to be no waiting time between operations and the only inventory acceptable would be components or sub assemblies currently being modified or added to. Furthermore, only motors required for immediate sale would be manufactured.

It was very soon realised that major stumbling blocks were in the way of achieving this ideal solution. The significant ones being:

(a) The range of motors being manufactured was large (some 150 possible variations); and whereas the components being used were similar, quite great variations are found;

(b) Whereas it was known that set ups could and would be reduced, the ideal solution required zero set ups;

(c) Lines would have to be balanced and flexible;

(d) "Culture shock" could be great.

12.6 Generalised Solution

A generalised solution was then arrived at.

* The full range of motors would be manufactured every week.
* Sequence of manufacture would be the same every week.
* Whereas a degree of idle inventory might be acceptable (in the first instance) as one component or sub assembly waited for others to be added to it, this would be kept to a minimum.
* This same tolerance would not be permitted within manufacturing cells.

By adopting the above approach (in the first instance), the following benefits would be achieved:

(a) Proper sequencing would assist greatly in the minimisation of set ups.

(b) Having the same sequencing, week after week, would develop habit and familiarity.

(c) Sequencing cycles could be shortened with time. That is five days could be reduced to four, to three, to two and ultimately to one.

(d) Change in work habits would not be traumatically drastic.

(e) Scheduling delivery determination would be simpler.

(f) Vendors could be relatively easily slotted into this sequencing discipline, with perhaps similar benefits to themselves as this company would achieve.

(g) Customers could also be similarly beneficially treated.

(h) Flexibility would not necessarily be reduced, as it would be no great problem to slip in a small batch of motors, in its proper sequence, at short notice.

(i) Similarly, cancellations or modifications to orders could be handled reasonably well, with little upset.

13.0 DETAILED INVESTIGATION

In essence the heart of an electric motor consists of two elements –

- the stator
- the rotor

all other components are there merely to ensure the proper operation or the mechanical tying together of the heart.

A stator lamination and rotor lamination start life together, being punched from the same steel strip; part company as they get further processed; and eventually return to be assembled into the same motor.

The rotor assembly process is relatively simple compared to that of the stator, but set up times in rotor die casting are large, and mitigate against small batches.

13.1 Rotor Manufacture

13.1.1 Process

The rotor process follows the following operation sequence:

(a) Laminations are received from the supplier in bundles of 100mm (each lamination is 0,5mm thick);

(b) The laminations are weighed off against requirement on a simple scale balance;

(c) These laminations are then stacked on a keyed mandrel, to the given length and according to the skew required for the rotor;

(d) These core stacks are then placed into a 400 tonne *horizontal die casting* press, and molten aluminium introduced into the assembly;

(e) The cast rotor is then removed from the die cast press and the mandrel pressed out of the core;

(f) Rotors are then fettled and transported to the rotor assembly area;

(g) The mandrels are then re-used *for further rotor* die casting;

(h) Two rotors are cast at a time;

Three problems were viewed here:

(a) Physical location of die cast shop in relation to the mini motor line;

(b) Cell style of manufacture;

(c) Set up times.

13.1.2 Location of Die Cast Shop

The *Small Machines* Company has a general die cast shop which manufactures all aluminium die cast components and rotors for the full range of motors.

The question posed was whether it would be beneficial to remove a press from this die cast area and positioned in such a manner that it would be closer to the mini motor production area. A number of advantages would be gained by doing this:

(a) Transport distance of cast cores would be considerably lessened

(b) Rotor core manufacturing, an important element in a motor, could become the direct responsibility of the mini motor management;

(c) Flexibility could perhaps be improved, largely due to item (b).

However, a number of disadvantages would also arise:

(a) Die casting is a specialist manufacturing procedure, not yet far removed from a black art. If the die cast shop was split, specialist setters, operatives and management would have to be duplicated. With the limited resources at the company's disposal, such duplication was not really viable.

(b) Available in the general die cast shop were other presses which could be utilised in the event of a breakdown, or during routine maintenance.

(c) Die casting is a dangerous process, and is thus normally subject to much higher safety conditions than normal.

(d) Die casting areas are hot and smelly. Introducing such extra elements into an open factory area could present problems.

On *balance* it was decided that the die casting equipment would remain where it was, and that control of this area would not be subverted by dual management responsibility. However, whatever system was devised for mini-motor manufacture would have to be whole heartedly accepted and worked to by the die cast people.

Further they would assist in the solution of problems, develop and maintain flexibility, and claim some ownership in the overall system. In other words, they would be part of the solution, not the problem.

13.1.3 Cell Manufacture

This was not a problem, as the traditional die casting process largely took place in a cell. Mandrels are normally limited to about six and hence batch sizes, between building and casting could not exceed this. However, it could happen that fettling or dressing of the cast rotor could be carried out in the batch mode. i.e. no dressing would take place until the whole batch was cast. But this would be no problem to modify.

13.1.4 Set Up Times

This was by far the biggest problem to be solved in this area. Rotors can vary in a number of ways. Diameter, length, slot configuration, shaft hole, skew angle of rotor bars, type of aluminium and end ring dimensions.

For the purpose of [illegible] casting only the following variations are material (see figure 13.1).

- *Diameter* of rotor (D). For mini motors only two diameters are required - 2 pole and 4/6 pole.
- End ring *thickness* (T). *For* 2 pole rotors two are required, for 4/6 pole only one. (Other thickness sometimes required, but rarely).
- Shaft hole diameter (d). For each diameter/end ring thickness, two shaft hole configurations *are available*.

The above *combinations give six basic* configurations of rotor, before length considerations are taken into account (although only *five configurations are* normally required)

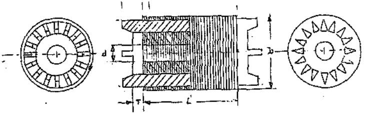
Length (L) - core lengths vary in steps of 5mm. from a minimum of 41 mm to a maximum of 121mm. This gives a possible 17 core *lengths for* each basic rotor configuration: a possible 85 rotor sizes. However, steps could theoretically be less than 5mm and *lengths* range could exceed the minimum and maximum currently required. It so happens however that 45 *configurations* of rotor cores are in current production

Present set ups follow generally the following times:

(a) To set up a particular diameter/end ring configuration - 2 hours.

(b) To change this configuration from one shaft hole to another -15 *minutes*.

(c) To change further to a different core length/*skew* configuration - 0 minutes. All set-up requirements are external.



KEY

D Core Diameter

L Core Length

T Endring Thickness

d Shaft hole diameter

Figure 13.1
Aluminium Die-Cast Rotor

If with present set up times, and with random order requirements from the die cast shop, and assuming all 45 rotor configurations were *required per week*, total set up time would be 2 hours x 45 set ups = 90 hours, a full double shift! This does not leave much time for production!

Of course, the *above* is absolute maximums, as the chances of a complete two hour set up for every subsequent order would be rare.

On the other hand, assuming that all core length *configurations* were sequenced so that minimum overall set up time was achieved, the following picture would be arrived at:

Three diameter/end ring/hole *configurations* - 3 x 2 hours = 6 hours Three further hole configurations - 2 x 15 mins = 30 mins.

Total set up - 6 hours 30 minutes.

Set up times *per week* would perhaps average out to 1/2 (90 hours + 6 hours 30 minutes) = some 48.1/4. hours per week.

Even if major set ups were reduced to say 30 minutes and *minor* to 5 minutes, similar arithmetic to the above would give average set-up down-times per week of some *12 hours*.

Superficial examination of the *set* up problem indicated that quick and cheap solutions to solving this die cast problem would not be forthcoming for the *following* reasons:

(a) Handling hot *dies in and* out of large presses is not easy and would require specialised handling equipment;

(b) Pre-heating of dies, prior to set up would require specialised equipment;

(c) Existing die design did not lend itself particularly well to *ease of set up*. Furthermore, dies are expensive commodities.

(d) Reluctance of die cast personnel to stretch their minds to solve the problems. A condition frequently found in the foundry industry.

In any event, some quick solutions were required, even if not generally within the total spirit of JIT.

The general solution was as follows:

(a) Sequence rotor casting in such a way that set ups are minimised.

(b) Work would continue on reduction of set ups, but urgency would largely be removed by acceptance of (a) above.

However, a sequencing pattern would have to be evolved that did not conflict with the overall requirements of the remainder of the mini motor lines.

Section 13.3 discusses in detail the solution to this sequence problem.

Figure 13.3 *shows* the sequencing arrangement finally arrived at for the rotor die casting.

Given that a full range of cores are die cast every week, in the sequence established, total down time per week due to set up would be 6 hours 30 minutes, calculated in the following manner (refer to figure 13.3).

Route A	- 2 hours
Route B	- 2 hours
Route C	- 15 minutes.
Route D	- 2 hours
Route E	15 minutes
	6 hours 30 minutes

For a 45 hour working week, this would give a machine utilisation of some 85%. For a 90 hour double shift, utilisation would improve to 92%. Given the present and medium term potential of requirement, these utilisation figures are more than adequate.

13.2 Wound Stator Core Manufacture

13.2.1 Process

The stator process follows the following process sequence.

(a) Laminations are received from the supplier in bundles of 100 mm.each (each lamination is 0,5 mm thick);

(b) Laminations are weighed off on a simple scale and stacked onto a mandrel, forming part of a seam welding machine;

(c) Core packs are pressed together, and seams welded in slots.

(d) Welded core pack is then loaded onto a slot insulating machine where the insulation is cut, formed and set into stator slots.

(e) Cores are then placed on a coil shooter, where copper coils, formed on a winding machine, are transported over and 'shot' into stator slots.

(f) Core is then placed in a drift press where coils in slots are pushed back.

(g) Core then replaced in [illegible]oter where a second set of coils are shot into the co[illegible]

(h) Some stators with three coil configurations will repeat (f) and (g).

(i) Core and windings are then placed on a bullet press where overhangs are pushed back.

(j) Phase insulation is then inserted between windings on overhang (for some configurations this process is carried out between shooting sequences).

(k) The series of coils placed in the core are then connected together to specification, together with cable leads.

(l) Connections are brazed.

(m) Stator core is placed in an overhang press where the overhangs are shaped and properly spaced.

(n) Core then placed in a lacing machine, where overhang is laced together to form a compact whole. and danger of loose wires negated.

(o) Operations (m) and (n) repeated for other side.

(p) Wound stators are then tested for electrical and mechanical integrity.

Table 13.1 indicates the operation sequences for the various types of wound stator cores. (Capital letters refer to machines as designated in figure 12.1).

13.2.2 General

The wound stator core line is the most important of all the production lines. The importance of this line is due to:

- the wound stator core represents some 55% of the cost of a mini motor.
- the windings are probably the most vulnerable part of a motor particularly prior to dip and bake.

Tooling for the various operations are complex, expensive and specialised. Furthermore, original design of equipment and tooling was based on large batches and infrequent set ups. In JIT this is no longer acceptable.

MACHINES

A	Build & Weld Core
B	Slot Insulation
C,D or E.	Form 1st set
F or G	Shoot 1st set
H	Drift Press
F or G	phase
C,D or E.	Form 2nd Set
F or G	Shoot 2nd set
H	Drift Press
C,D or E.	Form 3rd Set
F or G	Shoot 3rd Set
I	Bullet Press
Manual)	Phase, connect,
}	braze and tidy
J	Overhand Press
K	Lace
J	Overhand Press
K	Lace
L	Test

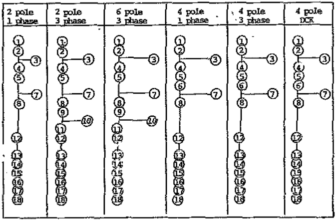


TABLE 13.1

OPERATION SEQUENCES FOR THE VARIOUS TYPES OF STATOR CORES (REFER TO FIG. 12.1)

13.2.3 Tooling

Build and Weld Stator Core

The building mandrel varies as the diameter of the core bore thus two mandrels are required (a) 2 pole
(b) 4/6 pole

Slot Insulation Machine

The forming tooling here varies against the stator slot configuration thus three sets are required

(a) 2 pole
(b) 6 pole and 4 pole, 1 phase
(c) 4 pole 3 phase, 4 pole DCZK

Winding Formers

The tooling configurations here are somewhat complex.

In general, 1 phase winders use the same former for first and second sets, but they are set to different configurations.

In general, 3 phase winding use the same formers for the first, second and third sets (where required) and set to the same configurations.

The following former sets are thus available :

(a) 2 pole 1 and 3 phase
(b) 4 pole 1 and 3 phase
(c) 6 pole 1 and 3 phase

Coil Shooters

Tools here vary by slot configuration. Where slots are the same, but core lengths differ, same tool is used, but adjusted to suit the length.

Three tools are required:

(a) 2 pole 1 phase; 2 pole 3 phase (2 pole lamination)
(b) 6 pole 3 phase; 4 pole 1 phase (domestic lamination)
c) 4 pole 3 phase; 4 pole DCZK (industrial lamination)

Drift Press

Tools here vary by slot configuration. No extra adjustment is required for the core length variation.

Three tools are required

(a) 2 pole 1 phase, 2 pole 3 phase;
(b) 6 pole 3 phase, 4 pole 1 phase;
(c) 4 pole 3 phase, 4 pole DCZK

Bullet Press

Two bullet presses are required

(1) all 2 pole
(c) all 4 and 6 pole

Overhang Press

Two tools are required here, but adjustments are required for core length:

(a) all 2 pole
(b) all 4 and 6 pole

Lacing Machine

Two tools *are required here:*

(a) all 2 pole
(b) all 4 and 6 pole

However, adjustments are required for length *changes*, and indexing adjustments are required between 1 phase and 3 phase, *as well as 4 pole* and 6 pole.

Set up Times

Table 13.2 gives the present set up times for the above equipment.

	Present Set Up Times	
	Major	Minor
Build & Weld A	15 mins. lamination to lamination	
Slot Insulator B	30 mins. lamination to lamination	10 mins. length to length
Winder C,D,E	30 mins. former to former	10 mins. winding type to winding type
Shooter F,G	90 mins. lamination to lamination	30 mins. length to length
Drift Press H	20 mins. lamination to lamination	
Bullet Press I	Nil	Nil
Overhang Press J	30 mins. lamination to lamination	5 mins. length to length
Lace K .	20 mins. lamination to lamination	10 mins. length to length
Test L	10 mins. winding specification to winding spec.	

TABLE 13.2
PRESENT SET UP TIMES - STATORS

13.2.4 Coil Shooting

The heart of the problem here lies in the coil shooting operation. Set up times are long - 90 minutes to change from tool to tool, and 30 minutes length to length.

Two machines are available for coil shooting. Both are identical, and have a full set of tooling each.

Initially the shooters operated in parallel. The one shooter working on 2 pole stators, with the other operating on 4 pole or 6 pole.

This arrangement gives the best utilisation of the shooters, as they both can then operate to their full available capacity (after set up times) if demand so requires.

However, due to long set up times, and the need for both machines to operate alongside of each other, plus the 5 week batch sizes, queuing and WIP was large, for the following reasons:

- stator core manufacture took place in the batch mode. Batches would be alternated to keep both shooters fed as each unique core came through the welder and insulation setting machine, queues would accumulate awaiting shooting.

- coil forming presented no major problems as three winding machines were available. Some stator configurations would require identical coils for first, second and third sets, whereas others would have the first and second sets different. All that was required was that for the two jobs running, the requirement was not more than three winders between them. This could be accomplished by having a 2 pole 1 phase run on the two winders (coils here are different), whilst the remaining winding machine formed coils for a stator that required identical coils (4 pole 3 phase say).

- drift pressing presented problems, due to 20 minute set ups required (lamination to lamination) so queuing resulted.

- phasing, connecting, brazing and tidying was no problem as all the operations were manually orientated.
- however further queuing took place at the overhang press, lashing machine and tester.

The problem faced was how to flow the work, with minimum queuing and WIP, still given the large set ups presently inherent in the wound stator core process.

It so happens that current demand for mini motors is such that one shooter is sufficient to produce the current requirements (given no set ups).

Based on this fact, it was decided that the shooting would take place on one machine only, whilst the other machine was being set up for the next job. Figure 13.2 gives a simulated run of this arrangement on the shooters, at present demand (refer also to table 13.5 for sequencing order (discussed in section 13.3)

From this simulation run, it can be seen that the hourly rate of output off the shooter is reasonably constant, given this sequencing arrangement.

In any event, this problem is by no means solved, and committed dedicated investigation will be required to establish a reasonable JIT arrangement. A prime requirement is the significant reduction in set up times.

All that has been achieved in this area so far is to develop a framework around which the JIT philosophy can be implemented. Of course, batch sizes have been reduced as well: in general from 5 weeks to 1 week requirement per motor.

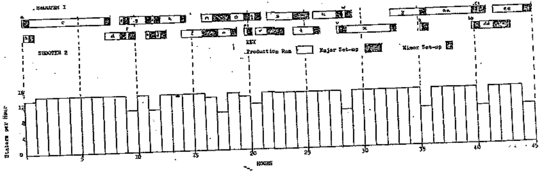


Figure 13.2
Core Shooting Simulation

13.3 Stator Rotor Sequences

13.3.1 Summary

Quick set up times could be considered a corner stone of JIT. If set ups are significantly large, flexibility is reduced, queues will develop, line balancing becomes extremely complex, and the tendency to *batch* in bigger and bigger lots by the shop supervision and controllers will increase with time.

As mentioned previously, there is no doubt that application and *rational* thought will assist in reduction of set ups considerably. However this can take time, money and the *dedication of* competent supervision, operators, setters and production engineers. All these resources are *invariably scarce*, in South Africa particularly so.

The quandary the company faced was:

- should all our set up problems be solved before the JIT philosophy was implemented - or
- could a half way stage be devised which by careful *scheduling* could reduce the negative effect of long set ups and result in the following advantages:
  - (a) JIT philosophy could be immediately *introduced, albeit* with degrees of compromise and sub optimisation;
  - (b) Scheduling *should be sufficiently* flexible so that as setting problems were solved with

time, development into "pure" JIT would be simple and automatic;

(c) Scheduling rules would be simple and understood by all. Further their *rules* would not be subject to constant revision and up dating depending on mix,

(d) Scheduling rules would have to be such that both stator and rotor manufacture would benefit;

(e) Ideally, once supplier JIT was tackled, advantages to the vendor would be reasonable.

A *schedule* sequence has been devised which, by and large, satisfies the above parameters.

13.3.2 *Investigation*

The investigation to *determine* the optimum sequencing of the stator and rotor lines was carried out in the following fashion:

- firstly, an attempt was made to *determine what* would be the most beneficial sequencing for wound stator core manufacture. This was arrived *at by* discussion with shop supervision and production engineering, and largely based on intuition

- secondly, a similar exercise was carried out to determine the most beneficial sequencing for rotor die casting.

- a production run was simulated (using the deduced *sequencing rules*) to determine where the stator and rotor sequencing could possibly conflict. (This *is called the first* approximation).

- from this exercise it was quite easily noticed that simple changes in some of the *rules*, on both stator and rotor lines, would improve the flow.

- the new rules were then again tested against a simulated production run. (second approximation).

- improvement was obviously gained, but further modifications were once again undertaken. (Third approximation)

- a simulation against this set of rules showed no *real* improvement and the second approximation was finally settled on.

13.3.3 First Approximation

The rules established at the initial stages were :
(a) stator sequence would be in the following order:

- 2 pole single phase;
- 2 pole three phase;
- 6 pole three phase;
- 4 pole single phase;
- 4 pole three phase;
- 4 pole single phase plus models DCZK.

TABLE 13.3

STATOR SEQUENCE - FIRST APPROXIMATION

(b) Each category of stator would commence with the *shortest* core, and proceed in steps to the longest. No differentiation would be made for cores with holes as opposed to cores without holes.

(c) Rotor

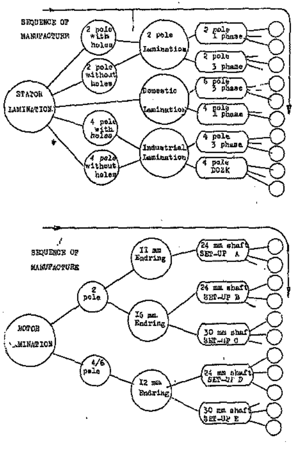
Sequence would be in the following order:

- 2 pole laminations, 11 mm endrings, 24 mm diameter shaft hole
- 2 pole laminations, 16 mm endrings, 24 mm diameter shaft hole
- 2 pole laminations, 16 mm endrings, 30 mm diameter shaft hole
- 4/6 pole laminations, 12 mm endrings, 24 mm diameter shaft hole
- 4/6 pole laminations, 12 mm endrings, 30 mm diameter shaft hole

each category would commence with shortest core and continue to the longest.

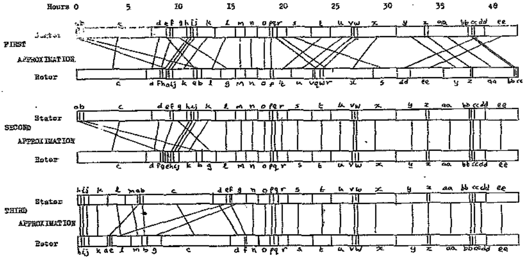
The following figure (13.3) shows the sequences in diagramatic form.

Table 13.4. gives the simulation details, using estimated weekly quantities of the various models, in the planned first approximation sequence. Figure 13.4 gives the simulation run in bar chart forms. For convenience and comparison, the three simulations are plotted together. (Approximations 1, 2 and 3.)



STATOR AND ROTOR SEQUENCING

FIGURE 13.3



STATOR AND ROTOR SIMULATIONS.

FIGURE 13.4

Motor	Designation Code	Frame Size	Frame Material	Estimated Weekly Output	Sequence Priority Stat.	Rot.	Rotor Set up No.
2pole	a	KDC71	Steel	2	1	5	B
1ph	b	DZCK90S	Alum.	7	2	10	C
	c	KDK560D	Steel	100	3	1	A
	d	KCK565	Steel	20	4	2	A
	e	KDC80	Steel	5	5	9	B
	f	KDK570D	Steel	3	6	3	A
	g	DZCK90L	Alum.	21	7	12	C
2pole	h	KDY71	Steel	5	8	4	B
3ph	i	KDY80A	Steel	4	9	6	B
	j	KDY565	Steel	6	10	7	B
	k	KDY80	Steel	27	11	8	B
	l	DZ90S	Alum.	29	12	11	C
	m	DZ90L	Alum.	15	13	13	C
6pole	n	KDY80	Steel	17	14	14	D
3ph	o	KDY80A	Steel	18	15	15	D
4pole	p	KDC71	Steel	4	16	16	D
1ph	q	KD..80A	Steel	7	17	20	D
	r	KCC565	Steel	15	18	22	D
	s	KDC80	Steel	35	19	24	D
4pole	t	KDY71	Steel	27	20	17	D
3ph	u	KDY80A	Steel	31	21	18	D
	v	DZ71DB	Alum.	3	22	19	D
	w	DZ80DB	Alum.	4	23	21	D
	x	KDY80	Steel	59	24	23	D
	y	DZ90S	Alum.	40	25	27	E
	z	DZ90SDB	Alum.	2	26	28	E
	aa	DZ90L	Alum.	60	27	29	C
	bb	DZ901DB	Alum.	3	28	30	E
	cc	KDY90A	Steel	3	29	31	E
4pole	dd	DZCK90S	Alum.	17	30	25	E
DZCR	ee	DZCK90L	Alum.	48	31	26	E

TABLE 13.4

STATOR AND ROTOR SIMULATION

FIRST APPROXIMATION (REFER FIG.13.3)

Referring to the bar chart simulations, the following becomes immediately apparent.

- given that the stator and rotor lines run in tandem, queues will invariably form. Sometimes rotors awaiting stators (15 occurrences) and sometimes stators awaiting rotors (11 occurrences), and on 5 occasions no waiting occurs.

13.3.4 Second Approximation

The second set of rules established were as follows:

(a) For the second approximation it was decided to leave the stator sequencing alone (same as first approximation), and test the manipulation of the rotor sequence. It was noted that in the rotor die cast area, no internal set up time is required for changing for core length, given the same lamination end-ring/shaft hole configuration. The second approximation then followed the following rules.

Stator - the same rules as first approximation
Rotor - the same rules as first approximation except that core length considerations would be ignored.

Figure 13.3 for the first approximation, is valid for a schematic representation of the second approximation.

Table 13.5 gives the details for the second approximation simulation run.

Figure 13.4 gives this simulation run in bar chart forms.

Motor	Designation Code	Frame Size	Frame Material	Estimated Weekly Output	Sequence Priorities Stator	Rotor	Rotor Set up No.
2pole	a	KDC71	Steel	2	1	4	B
1ph	b	DZCK90S	Alum.	7	2	10	C
	c	KDK560D	Steel	100	3	1	A
	d	KCK565	Steel	20	4	2	A
	e	KDC80	Steel	5	5	5	B
	f	KDK570D	Steel	3	6	3	A
	g	DZCK90L	Alum.	21	7	11	C
2pole	h	KDY71	Steel	5	8	6	B
3ph	i	KDY80A	Steel	4	9	7	B
	j	KDY565	Steel	6	10	8	B
	k	KDY80	Steel	27	11	9	B
	l	DZ90S	Alum.	28	12	12	C
	m	DZ90L	Alum.	15	13	13	C
6pole	n	KDY 80	Steel	17	14	14	D
3ph	o	KDY80A	Steel	18	15	15	D
4pole	p	KDC71	Steel	4	16	16	D
1ph	q	KDK80A	Steel	7	17	17	D
	r	KCC565	Steel	15	18	18	D
	s	KDC80	Steel	35	19	19	D
4pole	t	KDY71	Steel	27	20	20	D
	u	KDY80A	Steel	31	21	21	D
	v	DZ71DB	Alum.	3	22	22	D
	w	DZ80DB	Alum.	4	23	23	D
	x	KDY80	Steel	59	24	24	D
	y	DZ90S	Alum.	40	25	25	D
	z	DZ90SDB	Alum.	2	26	26	E
	aa	DZ90L	Alum.	60	27	27	E
	bb	DZ90LDB	Alum.	3	28	28	E
	cc	KDY90A	Steel	3	29	29	E
4pole	dd	DZCK90S	Alum.	17	30	30	E
DZCK	ee	DZCK90L	Alum.	48	31	31	E

TABLE 13.5

STATOR AND ROTOR SIMULATION SECOND APPROXIMATION

Referring to the bar chart simulation, the following becomes immediately apparent.

- stators await rotors on 3 occasions, rotors await stators on 7 occasions, and on 21 occasions no waiting occurs.

- 6 pole and 4 pole stator and rotor lines run completely in tandem, with no waiting.

- 2 pole lines still have waiting, albeit less than in first approximation.

13.3.5 Third Approximation

For the third approximation it was decided to alter the stator sequences, but without breaking any of the cardinal rules.

A simple change was decided on, namely the transposing of the 2 pole single and three phase categories. Stators would still however be produced in core lengths order. (From shortest to longest). Rotors would, within their set up category number, have no core length priority restraints.

Table 13.6 gives the simulation details and Figure 13.4 gives the simulation run in bar chart form.

Referring to the bar chart simulation, the following becomes apparent:

- stators await rotors on 6 occasions
- rotors await rotors on 3 occasions
- no waiting on 22 occasions.

Motor	Designation Code	Frame Size	Frame Material	Estimated Weekly Output	Sequence Priorities Stator	Sequence Priorities Rotor	Rotor Set Up No.
2pole 3ph	h	KDY71	Steel	5	1	4	B
	i	KDY80A	Steel	4	2	2	B
	j	KDY565	Steel	6	3	3	B
	k	KDY80	Steel	27	4	4	B
	l	DZ90S	Alum.	28	5	7	C
	m	DZ90L	Alum.	15	6	8	C
2pole 1ph	a	KDC7L	Steel	2	7	5	B
	b	DZCK90S	Alum.	7	8	9	C
	c	KDK560D	Steel	100	9	11	A
	d	KCK565	Steel	20	10	12	A
	e	KDC80	Steel	5	11	6	B
	f	KDK570D	Steel	3	12	13	A
	g	DZCK90L	Alum.	21	13	10	C
6pole 3ph	n	KDY80	Steel	17	14	14	D
	o	KDY80A	Steel	18	15	15	D
4pole 1ph	p	KDC71	Steel	4	16	16	D
	q	KDK80A	Steel	7	17	17	D
	r	KCC565	Steel	15	18	18	D
	s	KDC80	Steel	35	19	19	D
4pole 3ph	t	KDY71	Steel	27	20	20	D
	u	KDY80A	Steel	31	21	21	D
	v	DZ71DB	Alum.	3	22	22	D
	w	DZ80DB	Alum.	4	23	23	D
	x	KDY80	Steel	59	24	24	D
	y	DZ90S	Alum.	40	25	25	E
	z	DZ90SDB	Alum.	2	26	26	E
	aa	DZ90L	Alum.	60	27	27	E
	bb	DZ90LDB	Alum.	3	28	28	E
	cc	KDY90A	Steel	3	29	29	E
4pole DZCK	dd	DZCK90S	Alum.	17	30	30	E
	ee	DZCK90L	Alum.	48	31	31	E

TABLE 13.6

STATOR AND ROTOR SIMULATION-THIRD APPROXIMATION

This is perhaps marginally better than the second approximation, although if stators awaiting rotors is considered a worse state than rotors awaiting stators, second approximation must be better.

13.3.6 Conclusion

The second approximation was to be the system finally adopted.

13.4 *Shell Manufacture*

Shell manufacture presented no major problems.

Two basic types of shell are used:

- *aluminium extrusion*
- rolled steel shell

13.4.1 Aluminium Extrusion

There are six basic types of extrusion, and these in fact can be cut to particular lengths. Furthermore, *depending on* motor configuration, variations on drilling and tapping for various hole requirements are catered for after impregnation (see paragraph 13.5)

The manufacturing process is as follows:

(a) lengths of extrusion are received from supplier;
(b) *on request from* shell shop, the long lengths are then cut to required lengths and delivered to the shell shop.
(c) in shell shop, the shells are expanded to a given roundness on a press and are now ready for stator assembly.

13.4.2 Rolled Steel Shell

There are 14 basic configurations of steel shell. Further variations in some drilling and tapping are catered for after impregnation. (See section 13.5)

The manufacturing process is as follows:

(a) Flat steel plate cropped to size, and containing various punched holes, are received from supplier;
(b) Shells are then rolled to form a cylinder;
(c) Seam is then welded on a specially designed seam welder;
(d) Shell is then expanded to given roundness. This operation also confirms the integrity of the weld.
(e) Various lugs and pads then welded onto shell for certain configurations, such as airstream or lawn mower motor types.

13.4.3 Manufacturing Procedure

All machines required for both aluminium and steel shell are laid out in a cell, and one operative carries out all operations. Theoretically the same wound stator core can be pressed into either a steel or aluminium shell. Certainly, wound stator cores arriving could be coming in mixed lots, requiring either aluminium or steel shells.

When the foreman loads the stator core welding section, he loads the shell section with the required shells in the order that the wound cores will be coming off the wound stator core tester.

Currently there is probably not more than a couple of hours worth of shells awaiting wound cores. This should be compared with the previous situation where shells were made in batches for stock, and subsequently drawn for requirement.

13.5 Stator Assembly

13.5.1 Process

This section describes the process from pressing up until just prior to motor assembly:

(a) Wound stator core is pressed into steel shell - aluminium shell is heated on what is colloquially called a 'braai' and the stator core shrunk into the shell.
(b) Framed core assembly now goes through an impregnation process. Basically, on a moving overhead conveyor, the framed core is pre heated, dipped in an epoxy varnish, and baked.
(c) Impregnated framed core then arrives back at similar point on track where initially loaded.
(d) Assembly is stacked alongside impregnation plant for an hour or so until cooled to ambient temperatures.
(e) Bore of core is then burnished to remove surplus varnish adhering to bore.
(f) Core assembly is then loaded in a lathe on a mandrel where spigots are machined to size and concentric to the bore.
(g) Spigots are then deburred.
(h) Various drilling and tapping operations then take place dependent on motor configuration.
(i) For steel shells, pressed steel feet are then welded onto the shell. Framed core assembly is now ready for final assembly.
(j) Aluminium shells have extruded aluminium feet fitted, and feet assembly is then milled to size.
(k) The assembly is now ready for final assembly.

13.5.2 Solutions

All equipment for the above operation was laid out in a U type cell. Particular problems encountered and solved were:

(a) Previously impregnation was carried out in the main impregnation plant used for all other stator cores. This was impractical as distances travelled, loss of control, danger of damage and queuing at the other plant all mitigated against proper JIT philosophy. There was available an oven in the 'second hand yard' which had previously been used at Kwa Zulu, and to this was added tracks (overhead conveyor line) and incorporated into the flow line and dedicated purely for mini motors.

(b) Spigotting presented problems, as machining aluminium and steel on the same machine and at random, presents certain problems in cutting speeds, cleaning of machine, reclaiming of swarf, and so on. Previously core assemblies were batched, and set ups changed at frequent intervals. Furthermore, changeovers from 2 pole to 4 pole and 4 pole to 6 pole necessitated quite long set ups. This was solved by pulling out of the scrap yard an old lathe, due to be junked, and refurbishing it and adapting it for spigot turning. On the line now are two spigot lathes, each one dedicated either to aluminium or steel. Figure 13.5 shows the loading for both spigotting machines. The problem is not entirely solved as there is insufficient time to change over from 4 pole to 2 pole on the aluminium machine.(Figure 13.5). However both sizes suffering queuing as a result will be so small, that overall objective will be gained.

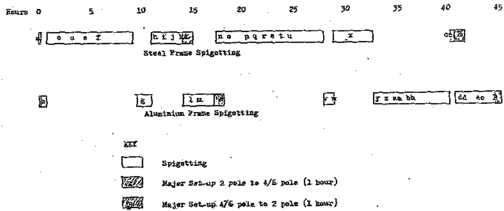


Figure 13.5

Spigotting Simulation

(c) Drilling also presented certain problems, as a variety of hole sizes and configurations are required. Furthermore drilling jigs were used in conjunction with single spindle drills. This was never satisfactory as operations were carried out in the batch mode, queues developed between operations and the danger was always present that drawings would be misread, incorrect drilling jigs used and generally resulting in high scrap. This problem was solved by designing and manufacturing a special purpose drilling rig.

Figure 13.6 shows the construction details of this rig. Advantages of this rig are that:

(a) Whereas the rig is special purpose and custom designed, the drills and mountings are not. If drilling configuration changes it would not be difficult to alter placement of drills. In the event of this range becoming obsolete, drills can always be used for other components.

(b) Setting up is very quick and easy. The controller consists of a number of switches attached to air valves which actuate the drills. Setting instructions are then limited to which switches will be in ON position and which in OFF.

(c) Special drilling requirements ca also be catered for, as each drill can take a variety of drill bits, and depths can be adjusted. All of this quite easily, but obviously set up time would be greater than norrally desirable.

(d) Alongside of this multi drill is a bank of single spindle drills and tappers. These are used for holes than cannot be catered for on the multi drill.

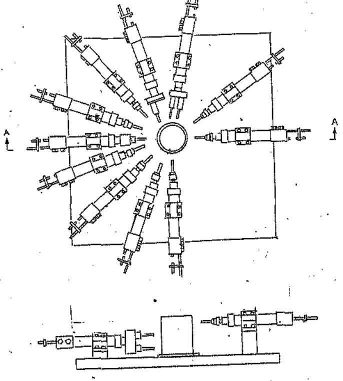


Figure 13.6
Stator Drilling Rig

13.6 Shafts

13.6.1 Process

Operation sequence in shaft manufacture is as follows:

(a) Billet is received from supplier in raw material stores and cut to length on instruction.
(b) Billet is faced and centred.
(c) Passed to copy lathe where one end is turned to requirement.
(d) Goes to second copy lathe, for second side turning operation.
(e) Cylindrical grinding on two machines then takes place.
(f) Shaft then passes on to keyway milling if required.
(g) Core diameter is then knurled for further press fit requirements for rotor assembly.
(h) Fan hole drilled.
(i) Shaft extension hole drilled and tapped.
(j) Shaft extension threads rolled, if required.

13.6.2 Solutions

Problems encountered on this line are not yet adequately solved, although the arrangement is a vast improvement on previous.

Previously batch sizes were large, and manufactured for stock; and subsequently drawn out from stock. Queues between the operations were also large, and total throughput time could be greater than a week.

The arrangement now is that shafts are only made against a weekly requirement, during the week of that requirement. Hence batch sizes are much smaller, similarly with queues, and finished shafts awaiting rotor assembly are never normally in excess of a couple of days requirement.

However the setting problem is not solved and movement through shop is erratic and stop and start. Quality has improved, but this is due largely to batch sizes being smaller, and hence danger of a large batch being scrapped after 1st operation is reduced.

Overall layout will lend itself to future improvement in continuous flow.

13.7 Rotor Assembly

13.7.1 Process

No real problems were encountered in this area. The Manufacturing process is as follows:

(a) Shaft is pressed into rotor core.
(b) Outside diameter of rotor then turned to size, and concentric with bearing journals on shaft.
(c) Assembly then dynamically balanced.
(d) Assembly now available for final motor assembly.

Department is laid out in a U cell, and all operations carried out by two operatives. There is no queuing between operations.

13.8 Endshields

13.8.1 Process

The majority of endshields used in mini motors are die cast from aluminium. There are five basic aluminium endshields, which in turn are machined into 28 different configurations.

Manufacturing process is as follows:

(a) Endshield is die cast in pairs, on a 400 tonne horizontal die casting machine. Integral with the die casting process is the insertion of rolled steel bearing liners.

(b) Endshields are then transferred to the endshield shop where machining and drilling is carried out.

(c) For single phase end shields, the non drive endshield has a stator switch assembled to it.

13.8.2 Solutions

Obstacles on the road to full implementation of JIT of these components are not yet overcome.

- set up times on the die cast machines are very high, and batch sizes still too large.

The problem is this. There are two basic endshield dies, and inserts within the dies can be replaced according to bearing configurations. The dies are as follows:

"Round" endshield	-	35 mm. bearing insert
	-	47 mm. bearing insert

"lugged" endshield	-	35 mm. bearing insert
	-	47 mm. bearing insert
	-	52 mm. bearing insert

The "round" endshield is the endshield used for steel frame motors which incorporates through holes in the stator core.

The "lugged" endshield is used for aluminium extruded frames which do not have a through belt in the stator core, but have the bolts going over the outside of the frame.

Figure 13.7 should make this clear.

Set up times are as follows:

"Round" set up - 3 hours
change of insert 30 minutes
"lugged" set up - 3 hours
change of insert 3 hours

The reason for this is that the "lugged" die is very badly designed, and the inserts cannot be changed whilst the die is in the machine.
The die has to be removed, stripped down and inserts changed. Die is then loaded into the machine.

If all endshields are to be cast weekly, set up times can be as follows:

Set up "round" + 35 mm. insert	- 3 hours
change to 47 mm.	30 mins.
Set up "lugged" + 35 mm. insert	- 3 hours
change to 47 mm. insert	- 3 hours
change to 52 mm. insert	- 3 hours
Total set up time per week	12hrs30.

On a 45 hour week, machine utilisation will thus have to be a maximum of 72%.

However, *development* work is currently underway to utilise only through both type stator cores, and thus only round endshields will be required.

For endshields, this will result in the following significant benefits.

Unmachined aluminium castings will reduce from 5 *basic* types to 3.

Set up times will reduce in the following manner:

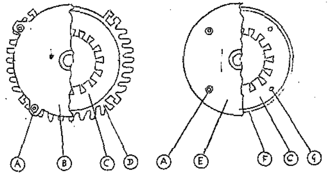
Set up round	+ 35 mins. insert	- 3 hours
change to 42 mins.insert		- 30 mins
change to 52 mins insert		- 30 mins
	Total set up per week	4hrs.00.

This results in a set up reduction of some 8.1/2 hours per week, and an improvement in maximum machine utilisation, at single shift, from 72% to 91%.

Batch sizes for machining have been reduced. Previously *endshields were machined* for stock, and subsequently drawn for assembly.

Now quantities are produced adequate for a weeks requirement.

Whereas machining section has been set out in a U type cell, queues still exist between some operations, but not as great as previous.



KEY

A Through bolts
B Lugged Endshield
C Stator Core
D Extruded Frame
E Round Endshield
F Steel Shell
G Through bolt Holes

Figure 13.7
Endshield Details

The machining section used to be part of the general aluminium component machine shop, somewhat remote from the mini motor assembly line. It is now physically in the mini motor department, and subject to their control

It was decided not to move the die casting machine from the aluminium foundry to the mini motor line for the same reasons as for the rotor die cast (see section 13.1.2).

13.9 Motor Assembly

13.9.1 General

The assembly department assembles the full motor from all the various sub assemblies and components manufactured previously, or bought out complete.

Figure A2 gives an exploded view of a typical foot mounted three phase totally enclosed fan cooled motor (steel shell type).

Figure A1 gives an exploded view of a typical foot flange single phase totally enclosed fan cooled motor (steel shell type).

Other configurations could include capacitors, thermal overload units, or exclude the fan and cowl or the feet.

Major decisions that had to be made here were:

(a) Nature of layout
(b) Form that marshalling of components would take
(c) Operations expected from operatives.

These three decisions are totally interdependant and need to be considered together.

Three basic forms that the assembly process could take were considered:

(a) A flow type of operation where each operative would concentrate on a particular operation/s
(b) An integral type of operation where each operative would assemble a complete motor
(c) A mixture of the above.

The following gives the consideration given to all three types of assembly procedure.

13.9.2 Flow assembly

In essence, the sequence of operations could be as follows:

Operative A could receive the stator assembly and assemble to it the terminal base and box arrangement.
Operative B, in parallel with operative A, could be assembling the bearings to the rotor.
Operative C could then thread the rotor assembly into the stator assembly.
Operative D would assemble the endshields to the motor.
Operative E would fit the fan and cowl.

Given this operation sequence, there could be two ways of feeding the sub assemblies to the operatives:

- the components and stator assembly would be fed down the conveyor line and each operative would be fed, independantly, the components required for these operations.

- all the assemblies could be marshalled into a tray, and this tray fed down the conveyor line. Each operative would then take from this tray their components and carry out their operations.

13.9.3 Integrated Assembly

Here each operative would be fed all the components required to assemble the complete motor.

Each operative could either be fed independantly with component and sub assemblies, or full sets of components could be marshalled and conveyed to them

13.9.4 Analysis

The flow assembly method has the following advantages:

- each operative would become extremely proficient and skilled in his limited operations.

- training of labour for limited operations would be comparatively simple.

- a moving belt conveyor concept could possibly be installed.

The disadvantages are more numerous:

- line balancing would become a problem. Variety of assemblies required are very great and difference in assembly times are quite high. For instance single phase motor assembly time is much greater than three phase due to the addition of capacitors.

Similarly end shield assembly is greater due to connection of the stator switch to terminations, whereas fan and cowl assembly, rotor and rotor threading would be the same. A further example is for air stream motors which could be single or three phase, but require no feet or cowl.

- increasing or decreasing capacity requirements would be a problem. To decrease or increase the output of 5 operatives doing different work is no easy matter. There are fairly small finite limits to this extension or reduction, namely slack due to additions or subtraction of overtime.

- absenteeism would affect the line balance. One operative off sick is not a labour reduction of say 20%, but is a 100% labour reduction in one whole operation.

- operator morale could be a problem due to low skills required
- labour flexibility and increase of general skills would not be easily accomplished.

The integral assembly method advantages would be the converse of the above with certain other advantages.

- pinpointing of operative causing rejects or damage would be easy. Each motor assembly would be almost the total responsibility of one individual.

- queuing of semi completed motors between operations would not apply. Queues would be limited to components awaiting assembly, or motors assembled awaiting test. By limiting possible areas of queuing, queuing can be more easily reduced or eliminated.

So on balance, the integral assembly approach was opted for with some modifications due to machine capacity restrictions (the bearing press).

13.9.5 Component Marshalling

There were two alternatives considered here:

(a) independant feeding of components to assembly i.e. each operative would have his own private 'stock' of components for assembly;

(b) general marshalling of components and despatch to all operatives, who would take a marshalled set of components as required, from the common pool.

Alternative (a) had no real advantages that could be seen, but had a number of serious disadvantages.

- each operative having his own private pool of components awaiting his use seemed to be against the spirit of JIT.

- the organisation required to split individual requirements would require quite expensive and detailed control.
- the possibility of inventory levels being large was quite high.
- what would have to be done if operative was absent?
- how would reduction or increase in output requirements be managed?
- floor space requirements would be high as independent marshalling areas would require more space.

The second alternative had a number of advantages and no real disadvantages:

- operatives would take from a communal pool of components as and when they required them.

This seemed to have the capability of keeping Work In Progress at a minimum. If output required was, say, 10 an hour, marshalling could take place at the same rate.

- differences in skill and speed levels of individual operatives would not cause hold ups or stock build ups.
- only one skilled marshaller would be required. If components were correctly marshalled against specification and assembly requirements, chances of incorrect assembly would be minimised.

The second alternative was then chosen, with some modification. In other words, major and some minor components and sub assemblies would be marshalled in a central area, and despatched to operatives, but common cheap components would be kept at the assembly work bench. These components, would be mostly common fasteners required for most motor models.

A marshalling tray was devised for the marshalling of the major sub assemblies and components (see Figure 13.8). This tray was designed in such a way that it could take batches of three wound stator cores plus the rotor assemblies, endshields, terminal boxes, capacitors, fans, cowls etc.

13.9.6 Layout

It was decided that roller conveyors would be utilised for transportation to the operatives. A motorised conveyor was not given real consideration but is a possibility for the future.

A number of problems needed resolving before the layout solution was arrived at.

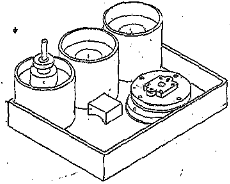


Figure 13.8
Assembly Tray

Feeding marshalling trays as well as complete motors down a single conveyor track could present waiting problems. i.e. if material flow was not fast and balanced, an operative at the end of the line could be in a position of waiting some considerable time before a marshalled tray became available to him. This problem would be further aggravated if assembly benches were on both sides of the central conveyor line.

Similar problems would be encountered if two parallel conveyors were to be used, although to a lesser extent. The theory being that one conveyor line would be used for marshalling trays, and the other for assembled motors. However, the result could still be jamming on the line.

The present layout was then arrived at which works satisfactorily. This consists of a double decker arrangement of conveyors. The top deck taking only marshalling trays, and the bottom deck taking only finished assembled motors. Jamming does not occur here, and floor area is saved. Normally vertical space is "free" whereas horizontal space is not. (See Figure 13.9).

Previously the motor test was centralised in a "test area", with the various motor assembly lines arranged around this test area. This was done for three basic reasons:

- testing is a specialist job, requiring certain high level skills. Having all the test beds and personnel in a common area would give flexibility in this area, in both equipment and personnel and make supervision easier.

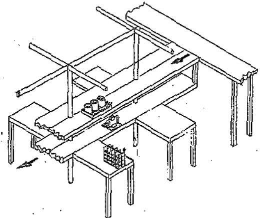


Figure 13.9
Assembly Conveyor System

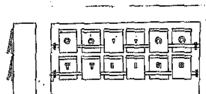


Figure 13.10
O Component Bins

- testing was considered a Quality Control procedure and in the old style thinking, had to be separate from production.

- electrical testing is a dangerous procedure, and isolation plus restricted entry would help alleviate dangers to personnel. The first and third factors are valid, but the second, in JIT philosophy, is not.

The above arrangement suffered a number of serious disadvantages, the three major ones being:

- separation of "Quality" from "Production" develops and maintains a "Them" and "Us" mentality. "I make them, You reject them".

- queues of finished motors awaiting test is inherent in this arrangement. Queues, of course, cause a number of adverse consequences: high inventory, increased floor area, large physical and psychological separation between operations and people, and perhaps most important, high defect rates.

- reject rates are inherent in this type of layout. Any errors built into a motor will be perpetuated until the error is detected and corrective action taken. If days elapse between assembly and test, corrective action is expensive and frustrating. The longer the time delay, the greater will be the number of motors incurring a defect and the more difficult it will be to establish the person or action or event responsible for such defect, and thus more difficult to rectify for long term benefit.

With all the above in mind, the obvious solution was to put the test beds right on the assembly line. This was done.

The assembly line also had to be placed in such a way that the major sub assemblies - such as wound stator frame and rotor assembly, would be completed at the start of the assembly line.

However, other components that could not be completed at the point of the start of assembly needed to be held in a marshalling stock area. These components would almost entirely be bought out items such as fans, cowls, terminal boxes, through bolts, rotor switches, capacitors and the like. This would be necessary as it was not the intention yet to have fully operational vendor JIT. Furthermore, so called C items (namely items purchased on a two bin system) needed to be held in this marshalling area. These components would be fed onto the assembly lines either by being included in the marshalling trays or by filling up the small racks held by each assembler.

Figure 13.10 shows the form of the bins designed for these C components. The principle behind these racks are as follows:

Each component is housed in two bins, alongside of each other. One locked, and one is used. A sample component is affixed to the outside of each bin lid. The locked bin contains sufficient components to last out the purchase lead time of that component plus buffer. Placed inside, on top of the components is a completed order form. As the bin in use is exhausted, the other bin is unlocked, the purchase order immediately placed on the supplier, and the bin put into use. When new replenishment stock is delivered, this will be placed in the other bin, with an order form, and locked.

This system is crude, but effective and holds out the promise of being able to be converted to a KANBAN control system in the future.

13.9.7 Assembly System

The basic form of the assembly procedure is as follows. The wound stator frame arrives from its final operation and is placed on a marshalling tray, on the transverse conveyors on the assembly line.

The rotor is obtained from the rotor assembly section, the bearings pressed onto the shaft (alongside the marshalling conveyor) and placed inside the stator core (see Figure 13.8). Various components are then obtained from the marshalling area, and counted off against a Bill of Materials, into the marshalling trays.

The tray with 1 to 3 motor component sets is then pushed down the upper assembly conveyor. The assemblers remove these trays from the conveyor line and onto their work benches as needed. Components not available from the marshalling trays, are obtained from the small component racks attached to each assembly bench. The supervisor, on request from each assembler will replenish these from the two bin racks, as required.

On completion each assembled motor is sent down the bottom level conveyor to the test benches.

Queues between assembly and test, are kept at a minimum. If necessary the supervisor will assist the tester to ensure this.

If a reject or defective is detected at test, or on the line during assembly, the supervisor is immediately notified and the assembly line stopped. This is done by word of mouth. The intention here is eventually to place visible and audible signals at each bench, and at test, to signify a problem.

The cause of the defective is immediately determined, corrective action taken, and the line allowed to recommence work.

The foreman and senior Quality technician are always involved, and it is their duty and responsibility to ensure that this fault does not occur again.

After test the motor is immediately conveyed to the painting area, where it is painted to the desired specification and boxed, ready for despatch.

14.0 *RESULTS ACHIEVED*

14.1 Summary

In *section* 9.0, the criteria for JIT implementation was given, and they are repeated here.

- inventory reduction
- quality improvement
- quick pay back and measurable
- solutions to problems had to be within internal control
- significant capital investment *would not be* acceptable
- start small, develop confidence and expand later
- keep it simple

the *first part of this* section will test the results achieved against these criteria.

However, the real criteria for JIT is somewhat different

- zero inventory
- zero defects

and the second part of this section will deal with how close the realisation of this dream is.

14.2 Inventory Reduction

The critical path of mini motor manufacture is the manufacture of the wound stator frame.

-from stator laminations to stator core pack, wound and connected stator core, wound stator frame, machined wound stator frame and assembled motor.

The comparisons given here are for the corepack from winding to final motor test.

The July 20 1984 a stock take gave a figure of 2 974 cores in Work in Progress. The five week moving average motors passed test at that date was 470 motors per week. This gave an average stock holding of some 32 days. In other words, it was taking some 32 days from commencement of stator manufacture to when that stator was finally included in an electric motor, tested and available for sale.

The July 19 1985 stock take, almost exactly 12 months later, gave a stator inventory figure of 448 cores in Work in Progress. The five week moving average motors passed final test at that date was 493 per week. This gave an average stock holding of some 4,5 days.

	WIP Inventory	No of Days
July 20, 1984	2 974	31,6
Dec.14, 1984	2 350	22,9
Mar. 1, 1985	940	7,5
April 27, 1985	457	4,2
July 25, 1985	448	4,5

TABLE 14.1
STATOR WORK IN PROGRESS

It thus took 20 weeks to reduce inventory from 2 974 to 2 350 cores, an improvement of some 21%.

It took a further 7 weeks to reduce inventory to 940 cores, an improvement of some 60%.

It took another 8 *weeks to reduce* to 457 cores, an incremental improvement of 51%. The next 13 weeks showed only a slight improvement of 2%.

Calculating these improvements in numbers of days indicates slightly different percentages.

INCREMENTAL CHANGES

	Production Weeks Elapsed	Inventory Expressed as Units	*Inventory* Expressed as No.of Days
July 20,1984			
Dec.14, 1984	20	21%	28%
March 1, *1985*	7	60%	67%
April 27,1985	8	51%	44%
July 25, 1985	13	2%	(7%)
July 20 1984 to July 26 1985	48	85%	86%

TABLE 14.2
CHANGE IN WORK IN PROGRESS

Figure 14.1 shows the above movement in graphical form. It can *safely be said* that an inventory reduction has been achieved. However, what is disturbing is that there has been no improvement in the last *13 weeks*. This will be dealt with later.

Having said this, at least this *product unit* has *learnt* to operate with Work In Progress inventory very much lower than normal.

14.3 Quality Improvement

Once again, the *stator was taken* as the yardstick of measurement.

Figure 14.1

STATOR WORK IN PROGRESS

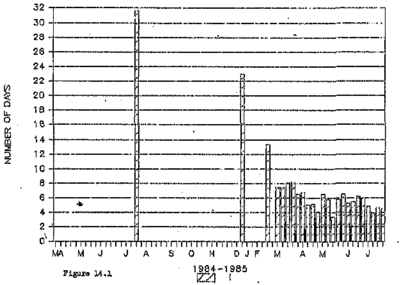


Figure 14.1

There are two major testing points in the production cycle of an electric motor.

The first point is an intermediate test just after lashing at which stage various electrical tests are carried out on the wound stator core.

The second point is after final assembly where the complete motor is fully tested.

14.3.1 Intermediate Test

Wound stators here can be rejected for a variety of reasons

- inter turn shorts
- wrong connections
- down to earth
- hot joints
- appearance
- incorrect resistance
- out of balance between phases
- etc.

some rejects can be repaired within minutes, but some will require rewinds, an expensive business.

It was decided very early on that whereas the various reasons for the defect should be logged and action taken for general control, interest in the total reject level was important. If one is embarking on a campaign of zero defects it can be argued that one defect is as bad as another. It is the writer's view that if a differentiation between "cheap" defectives, and "expensive" defects is made, the attitude of mind prevalent in the business - "it didn't cost much to fix up, so it is unimportant" would be continued. This attitude was to be broken down and a frame of mind developed that could not accept any sub standard work, regardless of the cost implications.

Figure 14.2

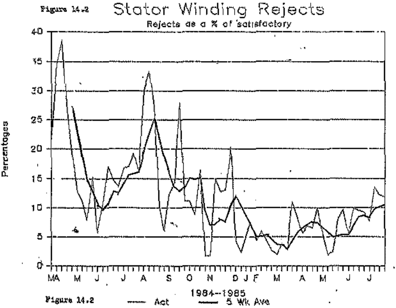


Figure 14.2

Figure 14.3 STATOR REJECTS VERSUS STATOR WIP

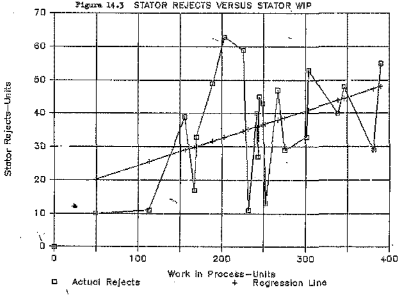


Figure 14.2 shows the movement of stator rejects graphically.

14.3.2 Final Assembly

Here the quality improvement has been more gratifying. Assembled motors can be rejected for a very large number of reasons:

- down to earth
- short between phases
- noisy bearings
- wrong name plate
- incorrect connections
- wrong direction of rotation
- stator unbalance
- rotor unbalance
- appearance
- incorrect works order number
- incorrect speed
- and so on.

Once again, rectification costs vary enormously. However, the comments made in 14.3.1 apply here as well regarding definitions of "cheap" and "expensive" rejects.

Rejects for the period March 30 to September 28 1984 amounted to some 35% of motors passed test. Within this period, rejects fluctuated considerably, from highs of 94% to lows of 11%.

Once the quality improvement programme was embarked on, reject rates almost immediately started reducing.

Average percentage reject rates as measured on a five week moving average basis, reduced from 26,9% at the end of September 1984, to a low of 1,7% in the middle of May 1985. Since then reject rates have increased to 4,0% as at the end of July 1985.

Figure 14.4 shows this graphically.

14.3.3 Rewinds

Despite the comments made earlier regarding the non differentiation between cheap and expensive defectives, statistics have been kept showing the amount of stators that required re-winding - definitely an expensive reject. Under this heading "rewind", it should be noted that some stator rejects, *especially after dip and bake,* are not actually rewound, but scrapped. This is certainly an extremely expensive exercise.

During the period March 30 1984 to September 28 1984, the average rate of rejects was 6,3%. Five week average rate of rejects at this point was some 4,5%. With the commencement of the campaign at the beginning of October 1984, the 5 week moving rate increased to a high of 9,2% by the end of October. This was caused, not by increased rewind generation, but by stators already in the system (in Work in Progress) not yet tested and therefore not yet identified as a rewind. So modifying the base period, from end March 1984 to mid November 1984 an average rewind rate during that period of some 6,7% is obtained. In any event, based on 5 week moving averages, the rewind rate fell from a high *of 9,2% at the end of October 1984,* to a low of 0,2% at the end of May 1985. Since then the rate has increased to 0,6% at the end of July 1985.

Figure 14.4

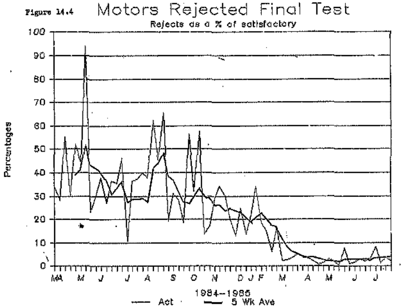

Motors Rejected Final Test
Rejects as a % of satisfactory
100
90
80
70
60
50
40
30
20
10
0
Percentages
MA M J J A S O N D J F M A M J J
1984–1985
Act
5 Wk Ave

Figure 14.5

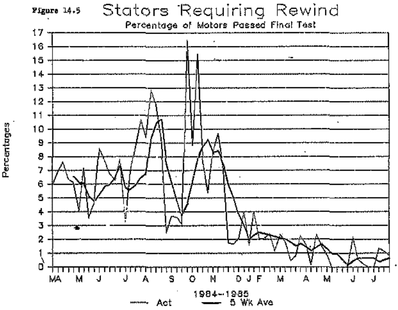

Stators Requiring Rewind
Percentage of Motors Passed Final Test
Percentages
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
MA M J J A S O N D J F M A M J J
1984–1985
Act
5 Wk Ave

Figure 14.5 shows this graphically.

It should also be added that during the period up to the end of February 1985, some further 1 500 stators were written off and scrapped. Statistics are vague in this area, and there is no knowledge as to when these stators were actually made. However, there is no doubt that some were manufactured during the period under review. Thus there is little doubt that the apparent improvement of reject rates shown in this write up is actually very conservative. True improvement is much better than shown.

14.4 Quick Pay Back and Measurable

14.4.1 Summary

There is no doubt that this objective was achieved. Pay back came quickly and this was definitely measurable. The timetable was as follows:

Investigation into JIT in Small Machines Company took place during July/ August 1984.

Detailed mini motor investigation - September and October 1984 (including factory relayout plans).

The winding, connecting, shell manufacturing and assembly lines were moved during October 1984.

Modified the assembly line during February 1985.

Moved the shaft line during April 1985.

At the beginning of the mini motor programme, it seemed reasonable that at least 6 months was needed to prove, beyond any doubt, that JIT was the way to go.

It is interesting to note that a schedule for implementing stockless production given in Hall's "Zero Inventory" (Reference 3) shows that 6 months is hardly sufficient for the initial study period, and commencement of strategic development and training.

Six months from the beginning of September takes us to the end of February 1985. A further 5 months takes us to the end of July and puts the issue beyond question.

The following sections will dis[illegible] the amounts of improvements achieved, and uses as base points the end of September 1985; the end of February 1985; and the end of July 1985.

14.4.2 Quality Payback

The previous section (14.3) discussed the various quality improvements achieved. These are summarised in Table 14.3.

	A	B	C	Percentage Improvement	
	Average Mar.30-Sept.28 1984	5 Week Average 1 Mar. 1985	5 Week Average 26 July 1985	B on A.	C on A
Stators rejected	17,0%	4,7%	10,6%	72%	38%
Motors rejected final test	34,7%	16,7%	4,0%	52%	88%
Stators req.rewind	6,3%	2,2%	0,6%	65%	90%

TABLE 14.3

IMPROVEMENT IN REJECTS

- ALL DEFECTIVE WORK IS WASTE AND IS TO BE ELIMINATED.

Defective work generation in the area preceding the intermediate test certainly improved, but disappointingly is once again on the increase.

Rejects for the period March 30 1984 to September 28 1984 amounted to some 17% of stators passed test. Within this period the level of rejects fluctuated considerably from highs of 39% per week, to lows of 6%.

The recent upward movement in rejects is worrying, but it is interesting to note that there is a distinct correlation between Work in Progress and reject rate at the intermediate test.

Figure 14.3 shows the number of rejects at the intermediate test plotted against the number of stators in progress from commencement of windings to just prior to intermediate test. On this graph is plotted a line of regression, and visually it can be seen that there is a definite correlation between Work in Progress and rejects. The calculated co-efficient of correlation is $r = 0{,}42$.

The lesson is quite clear, reduce Work in Progress, and the rejects will reduce accordingly.

Once the programme of aggressive quality improvement was embarked on, reject rates fell considerably and the average percentage rejects, *as measured on a five* week moving average, reduced from 13,4% at the end of September 1984, to a low of 3,1% during the middle of March 1985. Since then the defective rate (5 week basis) has increased to 10.6% at 26 July 1985.

Reviewing *these figures* and reading them in conjunction with Figures 14.2, 14.4, and 14.5, significant improvements are indicated from both base points compared to the reference period. The one jarring factor is the reversing trend in stator rejects.

14.4.3 *Inventory Payback*

A previous section (14.2) discussed the inventory improvements achieved. These are summarised in Table 14.4.

	A as at July 20 1984	B as at 1 Mar. 1985	C as at 26 July 1985	Percentage Improvement B on A	 C on A
stators, no. of days	31,6	7,5	4,5	76%	86%
stator, no. of units	2 974	940	448	68%	85%

TABLE 14.4
IMPROVEMENT IN WORK IN PROGRESS

These figurers certainly indicate significant improvements especially if read in conjunction with Figure 14.1.

14.4.4 Improved Output Payback

During the whole of 1984, demand for mini motors outstripped what could be supplied, so obviously if more motors could be produced, available for sale, payback could be impressive.

This in effect was achieved.

Figure 14.6 shows the trends in improvement in manufacturing output performance, and Table 14.5 gives the indicators at the various base points, previously discussed.

Unfortunately once the production back-logs had been cleared, and branches and agents restocked, demand fell (due to the hardening recession) and the manufacturing rate had to be cut back. However, it is highly probable that improvement in output could have been continued, albeit at a slower rate.

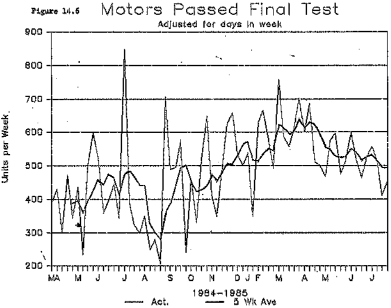
The improvement in output was particularly gratifying during a period of inventory reduction, quality improvement and cost reduction.

However, the one jarring note about this performance is the week by week fluctuations in output.

	A	B	C	Percentage	
	Av.Mar. 30-Sept. 28.'84	Five Week Av.1 Mar. 1985	Five Wk. Av.26/7. 1985	Improvement B/A	A/C
Motors passed test	416	625	493	50,2%	18,5%

TABLE 14.5
IMPROVEMENT IN OUTPUT

Figure 14.6


Motors Passed Final Test
Adjusted for days in week
Units per Week
900
800
700
600
500
400
300
200
MA M J J A S O N D J F M A M J J
1984-1985
Act.
5 Wk Ave

14.4.5 Labour Productivity Payback

Of course, improved output and quality could all have been gained at a price. However, actual costs of manufacture in people terms were reduced simultaneously with the other improvements.

Two separate indicators were chosen to give a view on labour productivity improvements. One in money terms, and one in input hours.

The indicators chosen were:

- total hours clocked per motor produced. The hours in *this case were for the hourly paid workers in* the mini motor section, and included all such people, regardless of job (viz Direct workers, storemen, inspectors, labourers, setters and supervision).

- total wages and salaries per motor produced. This ratio is similar to the one above, but included all staff people involved in mini motor manufacture viz production controllers, clerks and foremen.

Purposely assessment of productivity gains in so called direct labour was not carried out. It is the writer's view that the Western preoccupation with *direct* labour *sometimes* to the exclusion of other costs, is one of the reasons for their rate of improvement in productivity falling behind the Japanese.

Table 14.6 gives the comparable figures:

	A	B	C	Percentage Improvement	
	Av.Mar. 30-Sep. 28.	5 Week Av.1/3 1985	5 Week .Av.26/7 1986	B on A	C on A
Total hours per motor produced	7,47	4,30	4,78	42,4%	36,0%
Total wages & salaries per motor produced.	R22,64	R14,59	R16,72	35,6%	26,1%

TABLE 14.6
IMPROVEMENT IN LABOUR HOURS AND COSTS

Figure 14.7 and 14.8 show the above graphically.

The above needs commenting on.

- the hour index shows greater improvement than the money indicators. The reason for this is that hours are inflation free, whereas money is not. Hourly paid people receive wage awards during July, and salaried people during October of each year.
- the data required for Column A is an estimate. Prior to October 1984 many of the mini motor people were integrated with the rest of the Small Motor Company.

Figure 14.7

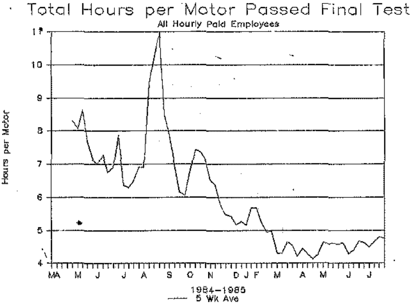
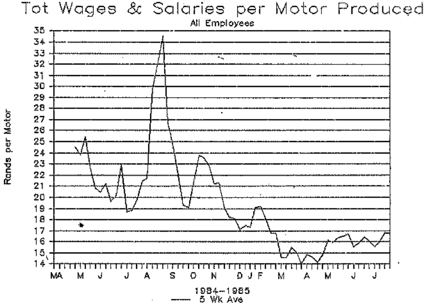

Total Hours per Motor Passed Final Test
All Hourly Paid Employees
Hours per Motor
11
10
9
8
7
6
5
4
MA
M
J
J
A
S
O
N
D
J
F
M
A
M
J
J
1984—1985
5 Wk Ave

Figure 14.8



Tot Wages & Salaries per Motor Produced
All Employees
Rands per Motor
35
34
33
32
31
30
29
28
27
26
25
24
23
22
21
20
19
18
17
16
15
14
MA
M
J
J
A
S
O
N
D
J
F
M
A
M
J
J
1984—1985
5 Wk Ave

However it is believed that any errors in the calculated index are not greater than *plus or minus* 5%.

- the reason for the fall off in productivity, as measured by these indices in the last couple of months is purely volume related. At this stage (beginning of August 1985) the Mini Motor product line is manufacturing *in parallel with orders and* no further increased output is required. There is obviously, in these figures, elements of fixed and variable people costs. Action could be taken to reduce people costs in light of fall off in demand, namely retrench some of the people. This has been decided not to be done. It is the writer's view that, if there is any *suspicion that JIT reduces jobs,* then motivational problems could arise in the future.

It has been demonstrated above that a reasonable pay back has been achieved, quickly and demonstrably.

The reasons for the above production improvements are *not hard to find.* However, estimating the effect of the various reasons is difficult and will not be attempted. They include:

- the "Hawthorne effect"
- making it right first time
- closer cohesion of the unit, and thus easier supervision
- improved training
- greater interest and morale
- less component shortages
- better material control and flow

- improved labour flexibility

14.5 Solutions to Problems

The criterion is "Has to be within internal control."

This was definitely achieved for the simple reason no facility or resource was used that was not already available within the company.

- Consultants were not used
- New skills were not employed, specifically for JIT implementation
- Outside assistance was not sought.

This is not to say that this will not be done in the future. As a matter of fact, currently there are three final year mechanical engineering students carrying out research and design investigations on JIT methods for their final year reports, at the Small Machines factory.

14.6 Capital Investment

Money spent on this project was small. It can actually be said that no money at all was spent on the JIT implementation. All money spent, and it was small, would have been spent anyway.

- Extra coil shooting tooling purchased was required for strategic reasons
- Spigot machine refurbishment was on the cards
- Multi spindle pneumatic drilling rig was justified and accepted prior to commencement of the JIT exercise

- The factory needed relaying out. In any event, it was carried out by people in the mini motor department themselves with assistance from the maintenance department. The actual spend was such that it was carried out on the normal maintenance overhead number.

14.7 Start Small

The criterion is "Develop confidence and expand later."

This has been done. Starting on the mini motor line was in effect a small start, as it only represented some 15% of the total small motor business. Confidence has certainly been developed. There is no doubt that any fears that people had prior to the commencement of the exercise, have now been significantly allayed. To quote an example, the superintendent of the mini motor line was very concerned about the JIT introduction. Amongst other problems he envisaged, he told the writer that he would not have time to get involved. He at that time had something like 240 open orders currently in production, and this took up all his time - as a matter of fact, he did not have sufficient time to satisfactorily service all those orders - loading the jobs, chasing shortages, re-arranging priorities, unjamming bottlenecks, and so on. He was asked that if the number of open orders were reduced significantly, would he then have the time. He answered in the affirmative, but was sceptical when he was told that JIT would reduce them for him. He now handles an average of 20-40 open orders, and his confidence has increased tremendously.

As far as expanding later is concerned, later is already here. Based as the perceived success of the JIT implementation the following has occurred.

- the manufacturing management and supervision of the other product groups within the Small Machines company commenced in an informal and unstructured manner to implement JIT principles. This they did on an ad hoc basis, without any relayouts or expenditure. Their successes have been good. *Certainly Work in Progress* has reduced by some 25% and their control over production has improved.

- in any event formal planning and detailed analysis was commenced during May 1985 to introduce JIT throughout the rest of the Small Machines Company. By end July much work had been done, and the factory relayout had commenced.

14.8 Keep it Simple

Inherently JIT is simple. Perhaps two anecdotes will illustrate this point.

- In early 1985 an overseas director of GEC visited South Africa. He is not an engineer, but an accountant by profession, and his response to the writer's detailed and enthusiastic explanation of the JIT philosophy and the company's involvement in it was - "I don't know why you are so excited, sounds and looks like ordinary common sense to me - rather simplistic in fact".

- the second anecdote refers to an operator in the mini motor section asking recently - "when are we going to get into this JIT thing then?".

14.9 Conclusion

Based on the above analysis, the writer believes that it can be safely said that the original criteria as laid down have been substantially achieved.

However, whether the company is actually in a JIT mode remains to be seen. The next section discusses this more fully.

15.0 'IDEAL' JIT A-LA- ROBERT HALL

15.1 Summary

Chapter 14.0 discusses the results achieved and compares them with the criteria originally laid down as the first step in the implementation of JIT. This chapter will attempt to compare the actual results achieved with that of the "Ideal JIT" solution. It goes on to then discuss the implementation techniques used, against those which form part of the so called classical JIT techniques.

15.2 JIT Philosophy

Robert Hall, in his book "Zero Inventories" (reference 3) defines the philosophy of JIT as follows:

" 1. Produce products the customer wants
2. Produce products only at the rate customers want them
3. Produce with perfect quality
4. Produce instantly - zero unnecessary lead times
5. Produce with no waste of labour, material or equipment - every move with a purpose so there is no zero idle inventory
6. Produce by methods which allow for the development of people".

Perhaps the above can be paraphrased into the following three statements:

1. Achieve zero idle inventory
2. Achieve perfect quality, with zero costs of quality achievement
3. *Develop people to the extent of their abilities.*

These three corner stones of JIT will be compared with the results currently achieved.

15.3 Zero Idle Inventory

Idle inventory is that inventory that is not having value added to it at a given point in time. Therefore, according to the definition, only material currently being worked on, or modified, in a value adding fashion, is acceptable inventory.

This means that the ideal level of inventory - from raw materials and bought out components, through work in process and onto finished goods awaiting sale or delivery to customer - is the sum total of the material being worked on at *an instant in time*. Therefore, if the sum of the standard times, for all the operations (in a particular flow) is x hours, then the ideal inventory must not exceed x hours worth. A "success" factor against ideal achievement could perhaps be referred to as the sum of operations at standard time divided by total throughput time.

Paragraph 5.3. in Chapter 5 should clarify this. In that example, total JIT inventory (or ideal inventory) should be equivalent to 13 time units, against the traditional inventory of 75 time units equivalent.

It could be said that the success factor for this example is:

$$\frac{\text{sum of operations at standard time}}{\text{total throughput time}} = \frac{6}{27} = 0.22$$

an alternative definition of this success factor could be ..

$$\frac{\text{theoretical minimum lead time}}{\text{actual lead time}}$$

Unfortunately, real life is not so simple, and in an operation such as the mini motor production line, where standard times per motor type can vary considerably, the above definition of success would be impractical to measure.

However, like the JIT concept in totality, simplicity is the order of the day, and the writer believes that the following approach to the defining of success, is for all practical purposes sufficient.

Figure 12.3 (In Chapter 12) gives the process procedure for a single phase mini motor. If it is assumed that all machine operations are of a similar time duration, and that at any given time all machines are occupied with adding value, a theoretical minimum amount of work in process can be calculated. Of course, not all operations have similar process times, and suitable modifications can be made to arrive at a more exact answer.

Taking the stator line, from weighing off of the lamination, right through to awaiting final motor test, it can be seen that some 28 operations are involved in the conversion process.

However, some 5 people are involved in concurrent final motor assembly, and the process time through the impregnation plant is some 4 hours. These factors need to be taken into account in our calculations.

Table 14.5 in 14.0 shows that the five week average throughput rate of motors was 493 (at 20 July, 1985), thereafter it can be estimated that the number of stators in the impregnation plant is equivalent to 4 hours worth, in 45 hours of throughput,

viz 4/45 x 493	=	44 stators
thus the number of stators		
in hand	=	28
extra for final assembly	=	5
extra for impregnation	=	44
		77 stators

Actual work in process for week ending 26 July was 444, therefore it can be said that the success factor achieved so far is 77/444 = 0,17. Still very far from the ideal of unity. An estimated ideal work in process figure of 77 stators, at a throughput rate of 493 stators per week is equivalent to 0,78 days worth of inventory.

Perhaps the above treatment of the so-called success factor is somewhat pseudo-*scientific*. What can be safely assumed however, is that work in progress *should be able to* be reduced to not greater than 1 days work, against the current 4.1/2 days worth. In other words, the overall ideal lead time is 1 day, against the present 4,5 days, compared with previous lead time of 31,5 days (at July 20th 1984).

What this of course means is that although work in progress has been reduced by a factor of 7 *times*, it still needs to be reduced by a further 4,5 times.

15.4 Zero Defects

Zero defects means exactly that, zero defects. However, this is an ideal situation, and how far is the mini motor product line from this?

To be more pragmatic, one could say that in order to be close to the dream of zero defects, reject rates need to be measured in terms of parts per million defects, rather than parts per hundred, as is currently done. What really does this mean? Currently, final test rejects are running at 4%. This mean 4 rejects per hundred good. If this measurement were carried out in terms of parts per million, then current defective rate would be 40 000 parts per million. Of course, final test defective rates have been reduced from 347 000 motors per million to 40 000 motors per million, but the current reject rates are still ridiculous measured in this way. Unverified information from European and Japanese manufacturers indicate that reject rates of less then 0,1% are achievable in electric motor manufacturing operations.

If this is so, then these rates are equivalent to one thousand motors rejected per million. So whichever way it is perceived, reject rate reduction has still got a long way to go.

15.5 People Development

In order to discuss the development of people, we need perhaps to establish what developmental needs means in the South African Industrial situation:

Abraham Maslow (Reference 12) defines the needs of people in a hierarchical fashion. From the most basic need to the most advanced. He maintains that for the higher level needs to become important requirements for an individual the lower level needs need to have been substantially fulfilled. His hierarchy of needs is as follows:

1. Physiological needs: these needs are the most basic, food, warmth, shelter and so on.
2. Safety needs : these are the security needs, the need to maintain the fulfillment of the physio logical needs at a secure level.
3. Belongingness needs: these are the needs of a person to belong to a group or society - a wife, a family, a tribe, a work unit etc.
4. Esteem needs: those are the needs to be valued, respected, appreciated; to have self respect as well as the respect and recognition of others.
5. Self Actualisation: this is the need for self fulfillment; the desire to be competent, skilled, famous and so on.

Maslow maintains that if a lower level need is not reasonably fulfilled then the higher level needs are less important requirements. A hungry cold man will have an all consuming passion to relieve his hunger, obtain shelter and so on. Once he obtains food and water and warmth he will probably set about securing a continuous or stable supply of the very basic needs. A starving man could kill or harm his nearest and dearest in order to survive. Certainly he would not have too much compunction in doing so to neighbours or acquaintances. In due course, once the dedicated need for security is fulfilled, the individual will develop a need for belongingness.

Once an individual has gone up the hierarchy and gone through the belongingness need, he would have the desire to have the respect or love of his family, workmates and so on. He would certainly want to maintain and develop his own self respect. Given that these esteem needs are reasonably fulfilled, the individual will then require to have self fulfillment. "Do his own thing".

Obviously the above are generalisations for society as a whole, and various individuals will behave in different and contradicting ways. Some people, in order to fulfill the highest level need - self actualisation - could seriously harm their lower level needs. An unknown artist starving in a garret is perhaps an extreme case of an individual anomaly or aberration.

Most societies will have groups of individuals at various levels of this hierarchy of needs. Third world countries in particular find extremes within their own society.

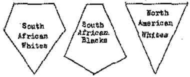
From individuals roaming the drought stricken land scavenging, stealing and plundering, with no care for anyone other than themselves, to small groups banded together for protection, through larger tribes etc. Within that same society there are' people who are concerned about the respect of their peer groups, their families love and going on to individuals who have achieved the pinnacle of self actualisation - authors, musicians, scientists etc.

South Africa in general is somewhat like this. Industrial South Africa, similar but perhaps not so extreme.

Of course, what *complicates South African society* is the fact that race is a major factor in the level at *which an individual* has fulfilled his lower level needs. Certainly there are more blacks, still struggling to fulfill the lower level needs than whites, whereas there are probably more whites pre-occupied with self actualisation than blacks.

Perhaps the following figures indicate the people distribution, at the various *levels of need* fulfillness better.

Self Actualisation
Esteem
Belongingness
Safety
Physiological



Individuals with[illegible] different societies or cultures will act in [illegible]ent ways in their progressive fulfillment of [illegible] *Japanese society* places a very high premium on [illegible]oup belongingness. The Japanese *seeking self actualisation* will probably attempt to do so without compromising their position within their group, be it the nation, the firm, or their family. North Americans place a higher premium on the individual. The"self made man" carries very high caste.

South African industrial society *faces the dichotomy* of different peoples in the factories, not only at different *phsycological need* levels, but premiums placed on different socially acceptable behaviour. *The* whites tending towards the North American cult of the individual and the Blacks maintaining strict requirements regarding family and tribal affiliations (depending, of course, on the degree and extent of urbanisation, further complicated by the repressive and oppressive legal/political conditions under which Blacks have to live and work).

So what does development mean? Particularly when we are referring to a heterogeneous industrial population.

It is the author's view that the JIT manufacturing philosophy can cater for the development and advancement of needs through Maslow's hierarchy up to whatever level an individual requires or is capable of. The author further believes it can actually cope with the ultimate desires of people to be either totally involved within group participation, well being and fulfillment, as well as for the people who wish to have self fulfillment on an individual basis.

At its most basic, JIT fulfills the need of the two lower level needs. Any system or philosophy of improving productivity must cater for these. Obviously improved productivity improves the viability of a manufacturing concern, and hence its chances of survival in the first instance are enhanced, and in due course growth and prosperity. This must reflect on the employees. The more secure a company is, the more secure the individuals within that company are.

Generally speaking any reasonably managed organisation can assist in the fulfillment of some of the belongingness needs. However, JIT takes this a number of steps further. For JIT to work and work well, peoples activities are far better integrated and group orientated than the traditional manufacturing systems. For instance, traditionally, peoples jobs are broken down into small elements. The buyers job is to purchase materials, the inspectors job is to ensure that only acceptable components are permitted for further modification, the storemans job is to receive and deliver, the machinists job is to manufacture components and so on.

Each of these individuals tasks are not really perceived as being part of the whole. We actually re-inforce this attitude - hence the proliferation of inventory. It can be said that inventory is the overt sign of mistrust by the Organisation in an individuals performance abilities. If the buyer is trusted to do a good job, why have buffer stocks in the stores? If the machinist was trusted, why inspect his work? and so on. JIT can only operate if each individual within an organisation realises that his role, within that organisation, is important to the whole. He begins to realise that if he does not achieve his job requirement, then others in the organisation will not be able to achieve theirs. In turn, there is pressure from upstream - the assembler cannot do his job if the machinist has not done his. Traditionally inventories buffer this requirement - much to the detriment, not only of the company but also of the individual. Further then, the whole company becomes an identifiable group. However, within the major company group, JIT requires the establishment of smaller sub groups - cells. The folk within these cells have to work together and will develop comradeship and unity. Individualism at this level cannot really be tolerated by JIT - individual piecework systems are not viable within JIT, but group systems can be.

This then takes us to the next level of needs in the hierarchy - esteem and respect, from others, but also self. JIT assists remarkably in this. Not only do operators know what is expected of them, but they are also expected to achieve these expectations. In other words, they know that they have achieved, they also know that their colleagues know, as well as their superiors. This can lead them into greater feelings of self worth, as well as respect from others, no matter how menial their task really is.

Despite the above, self actualisation can become a reality. Assisting in work flow, helping reduce set ups, or other bottlenecks, designing new and more effective tools, and so on can all be paths to self fulfillment, regardless of how low the level of actual self actualisation might be.

All of which brings us to people development in the mini motor JIT introduction.

Initially, the JIT concept was seen as a threat to many individuals in the section. The perceived threat being totally counter to the needs of individuals.

Intuitively individuals abhor change - change is danger. Any individual, regardless of where he fits into the needs hierarchy fears that he will be dislodged from that level.

The following are examples of how this threat was perceived and how attempts were made to eliminate these threats, and alter them to become major opportunities.

Safety needs - change always brings insecurity. Our basic need is to ensure survival, and once that is fulfilled, the maintenance of survival is required. In South Africa, work is survival. No work - no food. Social benefits such as unemployment pay are virtually non existent, or at the best, inadequate. So any change that affects security of employment will be severely resisted - particularly in times of high unemployment. Now unfortunately, South Africa is going through a major recession, of almost unprecedented duration.

Productivity improvements in a stable or reducing demand environment is bound to produce surplus labour, and if this surplus labour remains on the payroll, much of the productivity gains can be negated. To counter this, the following was decided and implemented.

1. Overtime was reduced virtually to nil. This action, of course, reduces peoples remuneration, but a 20% pay cut is more palatable than retrenchment.

2. New engagements were banned, as was replacement of leavers. This action had a number of effects.

- payroll reduced with time, by natural attrition
- supervisors were compelled to upgrade and train lower level employees into higher level jobs. Previously it was easier to engage workers of the required skills, now the required skills had to be given by the employer to the existing employees.

3. Retrenchments were not an option. Short time working was. In the event during the extent of this investigation, four days were lost by short time.

Belongingness needs - previously, the mini motor line was scattered throughout the factory. By giving a large degree of territorial integrity, in bringing the mini motor operation together, belongingness needs are given a chance to develop, or be re-inforced. Furthermore, by having equipment and work stations much closer together than the traditional method, workers are in closer physical and psychological contact. For instance, if the assembly line is stopped due to lack of machined endshields, this fact can be seen by the operatives in the endshield work centre - they are in no doubt as to who caused the stoppage and will attempt to redress this situation as soon as possible.

Esteem needs - self respect and respect from others is very largely, in the factories, dependent on the level of skills an individual has acquired and is permitted to utilise. Through the introduction of JIT, and the resultant concentration on manufacturing cells and work centres, operatives are now expected to be able to carry out more than one task. Supervisors are expected to train where necessary (re-inforced by current engagement policy). This has resulted in the acquisition of greater skills, job satisfaction and, in some instances, wage increases (due, at this time, to upgrading in the various job pay grades, as laid down in the Industrial Agreement).

Interestingly, as operatives are upgraded, and no re-employment permitted, people to fill the lower level jobs such as sweeper, cleaner and general labourer, *are becoming increasingly scarce.* This has resulted in the requirement that all employees, regardless of skill status, must assist in these jobs. All people are now required to clean their own work places and equipment. Previously artisans and most white operatives in general, had labourers doing this for them. The net result of this is that housekeeping has improved considerably, and so called menial jobs upgraded in status.

Self actualisation - the trend in South African industry in the past has been to break jobs down to the lowest possible skill and work content. This has resulted in people carrying out the most mind bendingly boring jobs; very often in total isolation to their colleagues. Often the rationale given is that this is all that most operatives are capable of. This is probably true - as a consequence of this employment practice!

Any human being, given what is laughingly referred to as an education, no training, and then 20 years of doing the same job (which took about two minutes to learn) has certainly had his potential for development severely curtailed. JIT is assisting in redressing this situation. JIT caters for all manner of self actualisation needs - the natural leader emerges; innovation is encouraged; problem solving ability becomes important and recognised; supervisors are now given the opportunity and time to manage (in all its ramifications); production engineers are now expected to widen their concept of what is considered good workshop practice; and many other examples are forthcoming.

The company has thus developed the framework for people development to take place; and this has happened, albeit still to a very small degree. However, the South African condition of racial mistrust and contempt still applies. The existence of these barriers remains the single largest factor mitigating against real productivity progress in the firm. JIT will only be able to go so far, before the people factor becomes of overriding importance.

16.0 LESSONS A-LA-RICHARD J SCHONBERGER

16.1 Introduction

Richard Schonberger, in his book "Japanese Manufacturing Techniques" (refer 5) discusses the philosophy, techniques and methods for JIT manufacturing systems. This book, in conjunction with Robert Halls "Zero Inventories" (refer 3), is the bible or the gospel for the JIT philosophy and it is actually written in a proselytizing style. He attempts to convert the American Industrial Manager into adopting the JIT philosophy by persuading him that JIT is not an exclusive Japanese philosophy, but is equally effective and "native" to the American *Industrial ethos*.

He believes that there are 9 basic lessons to be learnt from the Japanese approach, and that each of these lessons are universal, and not peculiar to a culture or a country.

His lessons are:

"Lesson 1	Management technology is a highly transportable commodity
Lesson 2	Just-in-Time production exposes problems otherwise hidden by excess inventories or staff
Lesson 3	Quality begins with production, and requires a company-wide "habit of improvement"
Lesson 4	Culture is no obstacle, techniques can change behaviour

Lesson 5	Simplify, and goods will flow like water
Lesson 6	Flexibility opens doors
Lesson 7	Travel light and make numerous trips - like the water beetle
Lesson 8	More self improvement, fewer programs, less specialist intervention
Lesson 9	Simplicity is the natural state".

In this chapter, an attempt is made to consider the applicability of the above lessons to the South African Industrial scene with particular reference to examples gleaned from thu introduction of JIT in the mini motor production line.

16.2 Lesson One

Management technology is a highly transportable commodity.

The writer believes the above statement is axiomatic. Managers in South Africa are probably as qualified and competent as their overseas counterparts, and certainly as motivated. However, due to the socio-political development of the country, middle managers are in short supply and stretched to a much greater extent than their colleagues in the Industrial Nations. This has had a number of effects on the development of the manager - good and bad. The good aspects are that South African managers are, in general, very versatile and are expected to have a wider range of skills and attributes than is expected abroad. Conversely, not enough time is available for the manager to manage in depth, and this results in poor follow through and completion.

JIT can be considered to be a war on waste. South Africa is short of managers; little or no attempt is made to involve all levels of employees in the management or problem solving process; the manager will do it all himself. What waste! Waste of the manager's time and competence, waste of human potential and development. JIT can only work totally satisfactorily if all are involved.

16.3 Lesson Two

Just in time production exposes problems otherwise hidden by excess inventories and staff.

This lesson has certainly been brought home to this company. Problems of high defective work; inadequate tooling; under trained and underutilised operatives; low expectations; damage; bad forecasting; inferior machine maintenance; bad factory layouts; excessive handling; little flexibility; pseudo control, by paperwork; high overhead costs and so on; have all been exposed, by the systematic reduction of inventory. The bulk of this paper indicates some of the successes achieved.

16.4 Lesson Three

Quality begins with production, and requires a company wide habit of improvement.

The traditional approach to quality maintenance and improvement in this company has been by means of increasing inspection and testing. Too frequently, when a defective was found, it was too late to do anything about it other than reject it.

The actual fault was probably caused weeks or months previously and investigation invariably foundered due to this time lag. The obvious solution was therefore to ensure, at source, that work met specifications. This traditionally meant more inspectors. Quality was improved this way, but quality costs not. There has been an attempt to replace the inspection of work by so called "unbiased inspectors" and put it where it *should be - with the operative.* He is responsible for his own work. Just as important, quality is expected from all people involved in the company; and JIT exposed the lack of quality in some non production area, which in time affect the ability of production to produce quality goods. Instances here are - inadequate drawings, incorrect Bills of Material, sub standard forecasting, misunderstood customer specification, long lead times of pre-shop paperwork, and so on.

16.5 Lesson 4

Culture is no obstacle, techniques can change behaviour.
What really is the culture of the Japanese supposed to be in the industrial environment?

- *abhorrence of waste*
- yearning for education and training
- self improvement
- homogeneous population
- repression of self for the benefit of the group
- lifetime employment
- promotion by age, not ability
- respect for humans
- industriousness
- hard working

  and so on

What is the South African cultural environment supposed to be?

- wasteful. In a land of plenty, everything is disposable
- intellectual level of majority of workers is such that education and training is wasteful
- heterogeneous population
- cult of the individual for some, faceless masses for others
- job and social insecurity
- *promotion by race*, not ability
- no respect for humans
- idleness

and so on.

In effect, most of the so called South African cultural norms are nonsense. Perhaps the only *significant* cultural difference (if indeed it is cultural) is expectation.

People will respond to expectation, and if given the opportunity to rise to that *expectation*, will invariably do so.

If the expectation is that 10% reject rates are acceptable, and that training and motivation of people to *achieve better* than that is a waste of time and money, then reject rates will be high. If an operative is severely *disciplined* for bad quality workmanship, for which he has been inadequately trained, and only has a vague appreciation of, he will not be able to improve his workmanship, but will certainly improve his capability for hiding the error, in the hope he will not be discovered.

If an operative takes the view that his security of employment is enhanced by stretching out his job to fill the time "available", instead of being motivated to reduce the time expended, (in the understanding that this is where real security lies) then expectation of the Company, and expectation of the worker differs markedly!

16.6 Lesson 5

Simplify and goods will flow like water.

Certainly it is being shown that simplification makes management and supervisory tasks easier. The reduction of artificial complexities in the manufacturing process has improved control and increased flexibility. Output increased at a reasonable rate until market forces inhibited this growth of output and actually caused a cut back.

Regarding flowing like water - well previously the manufacturing operation could have been likened to a large stagnant cesspit of bottomless depths and evil obstacles. Now - well maybe a reasonably flowing stream, interrupted in places by small cataracts and the odd stagnant pool.

16.7 Lesson 6

Flexibility opens doors.

There is no doubt that this lesson is fact and the improvement in flexibility in the product line has improved opportunity. Two examples of this are as follows:

Previously, even in recessionary periods, when work was desperately required for the factory, response time was slow. With the best *will in the world*, unexpected order opportunities could still only be translated *into delivery promises* of some 6 weeks lead time. Now, and this is happening frequently, business *is* won and achieved on very short delivery times, sometimes a week or less. This, in the majority of cases presents no problems.

It is being found that motor customers are interested in going on to JIT themselves. In some *instances* assistance has been given to them in developing the JIT approach, and *perhaps more significantly* this company has promised to become their first JIT *vendor*. *This* approach has already won new business, and will be increasingly used as a marketing tool.

16.8 Lesson 7

Travel light and make numerous trips - like the water beetle.

This *is an interesting analogy*. Perhaps a similar analogy for the traditional manufacturing approach *could* be likened to the dung beetle or miskryer, gamely battling uphill, gathering more and more dung, and seeming to be achieving nothing!

16.9 Lesson 8

More *self improvement*, *fewer programmes*, less specialist intervention.

This is certainly occurring. The JIT bug is biting mainly at the foremen level and above. Informal and formal study and experimentation is taking place, and this is being encouraged by the management.

Supervisors are beginning to realise that they no longer have to be victims, that they have actually a responsibility as well as the opportunity to pro-act, rather than react, as has been the traditional situation on the shop floor for many years now. Previously also, supervisors were inundated and pressured into carrying out many different objectives, some apparently conflicting :

- reduce inventory by a%
- increase output by b%
- reduce overheads by c%
- improve quality by d%

  and so on.

all in the budget year and with little regard for the interactive effect of these requirements.

Approach now is simple

- reduce idle inventory to zero

all priorities now flow from this requirement in a structured and non conflicting manner.

Previously also, staff people were used to assist in this regard. Production engineers would be called upon to solve a problem or establish a system, and they depart, very often, leaving the supervisor to pick up the pieces. Now the foreman has responsibility for the implementation. He calls on assistance, subject to his involvement. When the specialist departs, the supervisor, having assisted closely with the solution, analysis and implementation can maintain and perhaps even improve on what has been established.

16.10 Lesson 9

Simplicity is the natural state.

There is no doubt that any manufacturing organisation is or should be dynamic. Unfortunately, dynamism has been confused with complexity. *In other words*, solutions for dynamic problems have been solved in complex ways. It is the writer's belief, and the basis of JIT, that *simple analysis and approach* to dynamic problem solving can be successful. This can be taken further. In order to develop simple *solutions*, any problem has to be viewed in a simplistic light. In order to do this, the problem needs to be stripped down to its basic elements. The "cloud" has to be removed, complexities have to be unravelled. It can perhaps be said that "simplicity breeds simplicity", whereas the converse is also true "complexity breeds complexity".

17.0 SUMMARY

This paper presents the experiences gained in the design and implementation of the Just in Time Manufacturing philosophy at a South African factory.

This section summarises the development of the paper from the general to the specific.

Chapter 1 briefly describes the corporate decisions that resulted in the research required for this paper.

Chapter 2 discusses the general state of productivity and productivity improvement within the South African economy. Some comparison is also carried out regarding overseas trade competitors. The general conclusion is that South African productivity rates of improvement are increasing at a lower rate than major trading partners, and that this is compounded by the fact that they are off lower bases.

Chapter 3 compares the typical South African manufacturing approach to that of the Japanese, to the detriment of the South African. The chapter's conclusion is that the philosophy of production known as Just-in-Time, used in part, or substantially by many Japanese manufacturers, could be a reason for the differences.

Chapter 4 attempts to define the Just-in-Time philosophy in general terms and reaches the conclusion that high inventory is the main cause of low productivity and that in order for productivity to be improved, inventory must be reduced.

The chapter concludes further that quality and productivity are *significantly one and the same thing.*

Chapter 5 lists the areas of waste inherent in inventory holding.

Chapter 6 discusses the costs of quality, and arrives at the conclusion that the typical South *African* manufacturers quality costs could be 2 - 3 times what it is thought to be.

Chapter 7 discusses competitive manufacturing strategy, and shows a hypothetical comparative model of costs between a typical South African manufacturer and an Importer. The chapter then discusses, in more detail, the various cost components, and concludes that a South African manufacturer should have sufficient local advantages to offset Import *competition*, particularly if a whole hearted adoption of the JIT philosophy is undertaken.

Chapter 8 and 9 briefly describes the Small Machines Company, particularly its product range, and an attempt is made to establish the initial criteria for JIT implementation.

Chapter 10 analyses the inventory within the company; and the decision to concentrate on *Work in Progress* reduction (in the first instance), as well as quality improvement, is motivated. The chapter concludes with the further decision to use the mini-motor product unit as the pilot project.

Chapter 11 analyses the various aspects of the mini-motor product unit; particularly systems, factory layout, supervision, labour and quality performance.

A series of statistical indicators are derived, which will be the base for future comparison.

Chapter 12 analyses the above aspects (Chapter 11) in more detail, and a generalised solution to the problem is arrived at.

Chapter 13 discusses in detail the various major manufacturing processes, and describes how specific problems are solved.

Chapter 14 analyses the results achieved, as a result of the JIT implementation, and compares them with the original criteria as laid down (Chapter 9). The conclusion is that these criteria have been substantially achieved: inventory has reduced, rejects and defective work have diminished, payback was quick and measurable, no external assistance was needed, low capital investment was made, confidence was developed, and the above achieved in a relatively simple manner.

Chapter 15 does a general comparison of the results achieved against the "ideal" JIT solution as propounded by Robert Hall (Reference 3). This chapter shows that whereas significant improvement has been made, the ideals of zero inventory, zero defects and total people development and involvement are still far from realisation.

Chapter 16 compares the results with the "Lessons of Japanese Manufacturing Techniques" as deduced by Richard Schonberger (Reference 5). The conclusion is that these lessons are applicable in the South African manufacturing environment, and that the Small Machines Company is in the process of incorporating them.

APPENDIX A-PRODUCTIVITY INDICES

The information in these tables was obtained from the publication "Focus" (reference 1) - unless *specified* otherwise.

Country	Gross domestic product per capita at constant *1975 prices* and exchange rates in Rands		Average annual growth rate %
	1972	1982	
U.S.A.	5 199	5 816	1,44
Japan	3 123	4 210	3,03
Portugal	1 131	1 438	2,37
Switzerland	6 489	6 743	0,49
U.K.	2 941	3 257	1,06
S.Africa	1 000	1 060	0,55
Rep.ofChina	622	1 092	6,30
Israel	2 224	2 432	0,88
Italy		1 936	2,32
Germany		5 890	2.24
Sweden		6 840	1,52

The information for Italy, Germany and Sweden was obtained *from G J Geyser - Director of* the National Productivity Institute paper presented to the South African Institute for Production Engineering seminar *in June 1985.*

TABLE A1
GROSS DOMESTIC PRODUCT PER CAPITA
VARIOUS COUNTRIES

	Labour Productivity Index	Capital Productivity Index	Multi input Productivity Index
1972	101,7	92,9	97,9
1973	101,8	91,7	97,7
1974	102,3	90,1	97,2
1975	103,7	86,4	96,6
1976	103,3	82,4	93,7
1977	102,7	77,4	90,8
1978	105,0	76,3	90,9
1979	107,9	77,0	92,2
1980	112,5	78,7	94,3
1981	115,4	78,2	96,2
1982	114,5	73,6	93,7
%change per annum	1,2%	(2,3%)	(0,4%)

TABLE A2

PRODUCTIVITY TRENDS IN THE NON AGRICULTURAL SECTORS OF THE SOUTH AFRICAN ECONOMY

	Labour productivity Index	Capital productivity Index	Multi input productivity Index	Plant capacity utilization %
1972	145,6	97,5	124,6	87,5
1973	151,1	96,6	127,6	88,9
1974	151,5	94,3	126,4	89,3
1975	152,4	90,8	125,3	87,6
1976	152,6	89,3	124,6	86,1
1977	150,3	82,9	120,4	83,0
1978	160,0	84,6	126,6	84,2
1979	171,5	87,5	133,1	85,8
1980	182,9	88,6	138,0	88,5
1981	188,1	85,9	138,3	89,9
1982	184,8	78,8	134,5	87,6
%change p/annum	2,4%	(2,1%)	(0,8%)	

TABLE A3

PRODUCTIVITY TRENDS IN THE MANUFACTURING SECTOR OF THE SOUTH AFRICAN ECONOMY

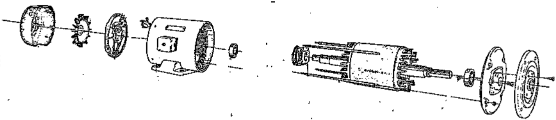
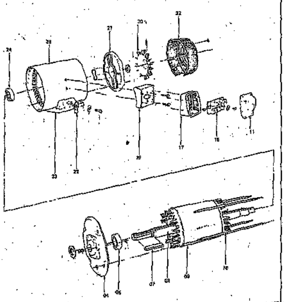


Figure A1
Exploded View
Foot Flange Single Phase Motor



A4

KEY

04 Drive end Endshield	19 Terminal Block
05 " " Bearing	22 Earthing Terminal
07 Shaft Key	23 Foot
08 Shaft	24 Non drive end Bearing
09 Rotor Core	25 Wound Stator Frame
10 Through bolt	27 Non drive end Endshield
11 Terminal Cover	30 Fan.
15 " Base	32 Cowl
17 " Box	

Figure A2
Exploded View-Foot Mounted
Three Phase Motor

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