QUALITY IMPROVEMENT PROGRAMME AT AFROX LIMITED: GAS EQUIPMENT FACTORY

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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, 1988

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 other degree or examination in any other University.

(Signature of candidate)

28th day of October 198 8

ABSTRACT

This Project Report deals with the investigation of quality improvement at Afrox Limited: Gas Equipment Factory *(G.E.F), Germiston, South Africa, which employs* the Just-In-Time/Total Quality Control (JIT/TQC) manufacturing philosophy. The investigation was carried out to determine the underlying causes of inconsistent product quality, high scrap and reject rates, and excessive rework in the Regulator cell. The Project Report documents a Quality Improvement Programme aimed specifically at the improvement of the toolsetters' performance which was found to be largely responsible for poor quality. The programme is designed to organize the toolsetters' machine setup activities in the most efficient and regulated way possible in order to achieve maximum quality and productivity improvement. The design of the Quality Improvement Programme is presently under consideration for implementation.

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I thank especially:

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The employees of Afrox Limited: Gas Equipment Factory, in particular the Business Manager Brett Sachs, for their cooperation and assistance throughout the duration of this Project Report.

Most of all I wish to thank Tess for all her invaluable help and patient support during these past months.

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1.0 INTRODUCTION

Quality is of great importance to virtually all product businesses. Customers' expectations for product quality are constantly rising, partially as a result of their experience with Japanese products, and many businesses are working actively on quality improvement so that competitive pressures on quality are increasing (1).

All of the above factors point to the importance to a business not only of quality improvement but also of a high rate of improvement. Without improvement action the absolute level of quality of a business will deteriorate because of the natural tendency of everything to decay from order to chaos (Second Law of Thermodynamics).

A significant rate of introduction of specific quality improvement projects is therefore necessary to counteract this general process. To retain a constant relative status of product quality against the rising expectations of customers and the improvement activities of competitors, requires a higher improvement rate which for a business already having a superior level of product quality is the minimum necessary for it to retain its position. For a business with only an average level of quality to reap the mai strategic advantages which arise from superiority requires yet another increment in improvement rate (2).

The current status of a business's product quality is never good enough. A business whose current status is poor must improve rapidly if it is to survive, one whose status is superior must improve to retain the major advantages of that position, and one which is average must improve to prevent its status from becoming poor, and to make it superior.

The major challenge to a business's treatment of quality is to master the art of quality improvement, and to make this a continuing part of the total business philosophy. Simply to maintain an existing quality level, even a good one, is not enough (3).

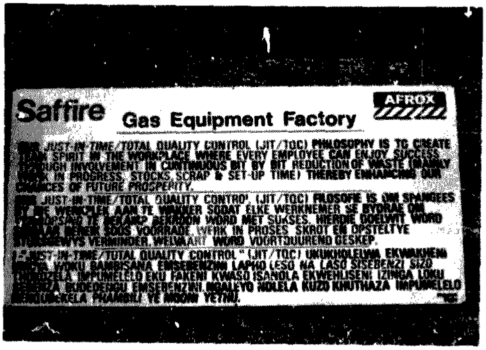
Quality improvement is probably the greatest single potential source to improve company performance in South Africa, as it is for many other countries. However, most company managers are pre-occupied with control and generally lack awareness of the need for improvement, the benefits or the techniques available (4).

It is impossible to over-emphasize the importance to the company of the quality of the products that it supplies or the processes that it undertakes or the services that it provides or the effectiveness with which it functions. Quality can be an asset or a liability. It can result in significant cost advantage or it can be appallingly expensive. It can build the image of the company or destroy it.

The costs of poor quality include the time and material costs associated with repeating or rectifying work, costs of lost output, cost of management time, penalty costs and warranty costs These are the measurable failure costs that can destroy profitability. There are also the immeasurable effects, such as loss of customer goodwill, loss of sales and the effects on staff of frustration and demotivation.

Thus the consequences of poor quality can have a detrimental effect not only on the "bottom line" of the company but also on the workforce and the image of the company.

One such company which is aware of the implications of poor quality is Afrox Limited : Gas Equipment Factory (G.E.F), Germiston. Early in 1986 Afrox G.E.F adopted the Just-In-Time/Total Quality Control (JIT/TQC) manufacturing philosophy. Their commitment to JIT/TQC is illustrated by the company philosophy shown in Photograph 1.1.



Photograph 1.1 The JIT/TQC philosophy of Afrox G.E.F.

Afrox G.E.F has been aware and is now becoming concerned about the high scrap and reject rates, inconsistent product quality and percentage of rework in the various machine shops for gas equipment cells namely, Regulator cell, Valve and Nozzle cell, and Torch cell. Management is also concerned about the percentage of customer complaints. Although these complaints are reflected to be relatively small, management believes an impeccable quality record and image to be of strategic importance in the future.

It is for these reasons that this study has been performed. The purpose of this report is to investigate the underlying causes of excessive rework, high scrap and reject rates, and inconsistent product quality in the Regulator cell at Afrox G.E.F. Having identified the nature and origin of the problems the main objectives of the project report are to propose suitable and practical solutions for the attainment of quality improvement.

The organization of this project report has been set out in such a way so as to make it easy for the reader to see at a glance the relationship between the various parts of the study.

The report is divided into three sections. Section one provides the necessary background information to the project. The Japanese manufacturing techniques of Just-In-Time (JIT) and Total Quality Control (TQC) are described in Chapter 2. Chapter 3 provides the reader with insight to Afrox G.E.F - the company, gas pressure ulators - the product, and problems facing the Regulator cell.

Section two introduces the techniques and methods employed for problem identification. In particular, Chapter 4 describes the process analysis tools used in tracing the source of problems. Chapter 5 presents the approach used to pin-point the fundamental cause of problems.

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Section three describes a suitable action plan for improvement. Chapter 6 presents a detailed Quality Improvement Programme designed specifically to address the exposed problems.

Finally, the concluding chapter, Chapter 7, presents a summary of the development of the project report together with recommendations for future improvement.

2.0 BACKGROUND INFORMATION TO THE PROJECT

2.1 INTRODUCTION

Reference is made to various concepts and principles throughout the discussion of the report. The aim of this chapter is to provide the reader with the necessary background information to these principles in order that he may grasp the basic understanding of them. In particular, the principles of the Japanese manufacturing techniques of Just-In-Time (JIT) and Total Quality Control (TQC) are explained since these two techniques form the basis upon which Afrox G.E.F's manufacturing strategy is based.

2.2 JUST-IN-TIME PRODUCTION WITH TOTAL QUALITY CONTROL

Western industry has amassed numerous prescriptions for catching up with the Japanese. Until recently, most prescription lists omitted Japanese Just-In-Time production management and Total Quality Control. According to Schonberger (5), Just-In-Time production is simple, requires little use of computers, and in some industries can provide far tighter controls on inventory than are attainable through the more sophisticated computer-based approaches. Furthermore, a JIT implementation leads to significantly higher quality and productivity by exposing hidden problems, and provides visibility for results so that worker responsibility and commitment are improved.

Schonberger (6) describes some of the benefits of TQC as:

- Fewer rework labour hours

- Less material waste

- Higher quality of finished goods

Total Quality Control, however, is a quality management system which is not merely concerned with the conventional function of quality control of production and its associated departments.

Schonberger (7) claims that higher quality of finished goods is not an effect of JIT. He puts forward the argument that equally high product quality could be attained by means of extensive final inspection plus rework lines and scrap bins. Therefore JIT will not necessarily improve product quality but it will certainly lower costs by improving the process quality. Total Quality Control, by contrast, certainly will improve product quality.

Thus there exists a direct relationship between the two techniques of JIT and TQC. In order to appreciate the concepts involved in these techniques let us examine first those of Just-In-Time, followed by Total Quality Control and finally the relationship between them.

2.2.1 INTRODUCTION TO JUST-IN-TIME (JIT)

Bicheno (8) defines manufacturing as: "An integrated system for the production of products which uses people to progressively solve problems which stand in the way of material related operations taking place economically at the last moment, with no wastage, exactly to customer requirements of performance and delivery." Just-In-Time is an important key to bringing about the efficiencies in the definition.

The name Just-In-Time emphasizes producing exactly what is needed and conveying it to where it is needed, precisely when required. Just-In-Time is a philosophy, a simplistic approach to production management which, when implemented, gives rise to a lean and efficient manufacturing operation (9).

JIT is not a technique, or even a set of techniques, rather it is an overall philosophy which embraces both old and new techniques. JIT has a provocative goal which may be stated as: "To produce instantaneously, with perfect quality and minimum waste" (10). JIT is therefore a waste elimination programme where waste is anything which adds no value to the product. Ohno (11) identifies the seven sources of waste as:

1. Waste of over-production

2. Waste of waiting

3. Waste of transportation

4. Waste of processing itself

5. Waste of stocks

6. Waste of motion

7. Waste of making defective products

The JIT goal will never be achieved but can be restated in more practical terms as: "To have all external materials required to produce a product arrive at only the correct time in the schedule when they are needed and in only the quantity required."

According to Crosby (12), until recently, JIT manufacturing has remained beyond the reach of manufacturers, except perhaps in isolated small shops. The reasons for this elusiveness are not hard to isolate. For JIT to work, two things must happen. First, all parts must arrive where they are needed, when they are needed, and in the exact quantity needed. Second, all parts that arrive must be usable parts.

Therefore Crosby (13) suggests that a Just-In-Time implementation should be carried out in two sequential stages. To solve the quantity problem first is difficult if the quality is in doubt. Thus Stage One is concerned with the quality of materials and Stage Two is concerned with the quantity of materials.

Bicheno (14) presents a similar framework for approaching the JIT goal and may also be presented as a two stage process, as shown in Figures 2.1 and 2.2, or referred to as the "Vehicle-Driver" model.

Stage One or the "Vehicle" stage prepares the facility and the product for:

- High quality

- Low cost

- Minimum lead-time

- High flexibility

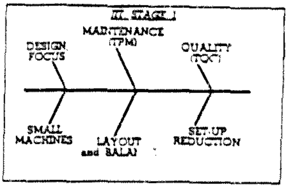


Figure 2.1 *JIT - Stage One.*

Stage Two or the "Driver" stage allows the product to be produced:

- Instantaneously

- To market rates

- With perfect quality

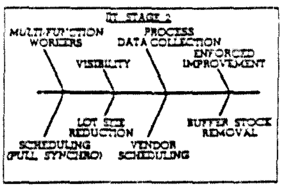
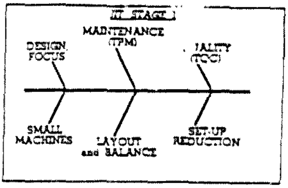


Figure 2.2 JIT - Stage Two.

Thus both *Crosby and Bicheno* identify quality as being of prime importance in a JIT manufacturing environment.

- High flexibility



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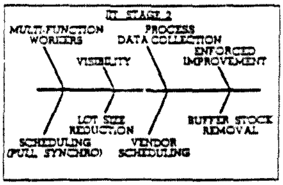

Figure 2.2 JIT - Stage Two.

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2.2.1.1 Benefits of JIT Techniques with Respect to Quality

Stage One and Stage Two, together, list fourteen JIT techniques. Each technique will be briefly discussed and its benefit with respect to quality explained. However, two techniques, namely, quality (TQC) and setup-time reduction will be discussed separately and in greater detail (see Section 2.2.2) whereafter the relationship between the two will be identified. The understanding of the relationship between quality and setup-time reduction is essential since the focus of this study hinges on this particular relationship.

Design and Focus

This is concerned with rationalising the product line, and then engineering and simplifying the chosen products for ease of manufacture. Under JIT, design cannot be a divorced activity, but must become integrated with manufacturing and marketing (15). Unless these three disciplines are totally integrated, production will be a turmoil of conflict and engineering change and as a result product quality will suffer.

Producibility is an oft-neglected aspect of product design (16). If products are designed with particular attention paid to producibility and manufactureability as well as to the statistical capabilities of processes, the possibility of constantly producing defect-free, quality products greatly increases.

Focus is related to the concept of the 'focused factory' as first proposed by Wickham Skinner of the Harvard Business School. This concerns identifying those few actions and characteristics that are crucial to success, and doing those very well even at the expense of others. For JIT this would imply thinking in terms of 'factories within a factory', each with its own specific requirements and concentrated expertise (17). As a result greater attention can be paid to product quality.

Small Machines

The small machine concept refers to the use of several small machines, possibly permanently set up, which are preferred to one large machine (18). The small machines may be located at the point of use, thereby improving flexibility, quality and reducing setup and lead times (19).

The small machine concept also extends to 'NAGARA' (self developed machines) and to 'POKAYOKE' (foolproof devices) (20,21). This is in-house manufacturing innovation that allows improved quality by the detection and prevention of defects.

Total Productive Maintenance (TPM)

Total Productive Maintenance (TPM) is the technique of using operators to perform simple preventative maintenance tasks. Multi-functional operators who perform these tasks, together with skilled maintenance people performing the more sophisticated preventative maintenance tasks, ensures maximum machine availability (22).

Preventative Maintenance (PM) is important to preserve the equipment and even more important to preserve quality (23). The real reason for preventative maintenance is to preserve the process capability of the equipment and tooling. If that is done, the equipment must also be preserved from excess wear and tear, and the standard of excellence to which each machine must be maintained will allow fail-safe production of quality output (24). Preventative maintenance applies to instruments and tooling as well as machines. A regular program to keep all instruments and gauges in calibration is one of the most important aspects of total quality (25).

Layout

Under JIT, layout is not a static concept, but rather a continuous drive towards shortening the manufacturing process length (26). As each category of waste is eliminated, the process length should be shortened - often, it is the principal way to eliminate or reduce wasteful movement (27).

Layout follows directly from Focus concepts. Here, the concepts of *Group Technology (GT) are most relevant.* GT seeks to group machines so as to produce families of products with similar manufacturing *characteristics* (28). The implementation of GT requires the relocation of machinery which results in reductions in materials handling, machine setup time (due to product/component families), lot sizes and thus a reduction in defective products (29). The advantage of GT is that it provides immediate feedback and visibility of total operations, thereby enhancing product quality.

A strong thread in the JIT/TQC tapestry is good housekeeping (30). Keep it clean, sharp, lubricated, calibrated, in an exact, nearby location, and ready to use. Good housekeeping provides an environment conducive to improved work habits, quality, and care of facilities (31).

Multi-function Workers

The concept of having workers capable of performing several tasks is consistent with the desire to make only what is required, when it is required (32). JIT demands that operators not only be moved from low to high demand areas, but that they are also responsible to a larger degree for conducting simple maintenance, setup and quality improvement procedures (33).

Visibility, Process Data Collection and Enforced Improvement

These are related issues of management style under JIT. The aim is continuous, enforced improvement by making problems visible and demanding quick response to solve them (34).

Problem solving and the desire to eliminate all waste requires extensive collection of data to determine "where we are and in what direction we are heading" (35). Quality control, mean- me between failures, total lead times, setup times, quality problems, etc. charts or graphs are commonly displayed in JIT plants. This not only tells all employees how they are progressing, but it also highlights problem areas by making them visible. The important aspect of these charts is that they are often completed in real time by the operators themselves and not by some remote department at the end of the week or month (36). This allows for improved problem solving by the operators and thus improved levels of quality.

Lot Size Reduction and Buffer Stock Removal

Excess inventory literally hides problems and prevents much improvement (37). Therefore inventory must be reduced in order to surface and thus solve these problems. By reducing lot sizes and buffer stocks, problems will be highlighted, e.g., setup reduction, machinery relocation,materials handling, insufficient capacity, rejects, etc.. Unfortunately for many managers, lot size reduction and buffer stock removal forces the company to "tread on thin ice", which they find uncomfortable (38). However, if top management truly believe in the JIT philosophy it becomes a management priority to get rid of inventory and thus ensure continuous improvement.

Schonberger (39) explains simply the reason why minimum lot sizes lead to lower scrap and better quality: If a worker makes only one of a given part and passes it onto the next worker immediately, the first worker will hear about it soon if the part does not fit at one of the next work stations. Thus defects are discovered quickly and their causes may be nipped in the bud so that production of large lots high in defects is avoided.

Scheduling

The cardinal sin in JIT is to overproduce, in other words, making anything, from components to finished goods, which cannot be sold in the very short term, must be avoided. JIT tries to achieve continuous flow which minimizes leadtime (40). In a JIT environment, the plant is scheduled to meet the market demand for the time interval while not overproducing. Regular schedules, comprising the complete product mix, should be repeated with increasing frequency. The prime requirement being to keep bottleneck operations busy, while non-bottleneck operations may be idle (41).

Under-capacity scheduling allows operators free time at the end of the shift to conduct planned maintenance, machine setups and discuss and implement quality improvements (42).

The "Pull System" is an important JIT tool for scheduling (43). When used with a level schedule (regular batch sizes), a pull system becomes a prime tool to control work-in-progress (WIP), prevent overproducing and to identify bottleneck operations. The pull system allows simplicity in scheduling, since only end-items need be scheduled with components simply being "pulled" as required. According to Hall (44), the quality incentive of a pull system is powerful. In fact, the next operation is the worker's customer and should be regarded that way. The objective is to always be figuring out how to serve the customer better.

Vendor Scheduling

Contrary to common belief about JIT, working with suppliers is not a prerequisite to implementing a JIT philosophy. JIT is a waste reduction strategy, not an inventory reduction programme (45).

The greatest benefits of JIT are achieved in-house, with only a small proportion coming from working with suppliers (46). Once the company is producing according to a level, regular schedule, materials will be consumed at a steady rate, and this is when buyers can begin to talk with vendors about long-term agreements and pull systems for purchased items. By working closely with suppliers the buying company will be able to ensure the delivery of small lots and with perfect quality. The buyer becomes a facilitator of communication, spending major amounts of time in suppliers' plants and with his own engineers for the purpose of improving the quality of procured materials.

For the supplier, the reward is that he can move towards JIT faster by levelling his production schedule, reducing his finished goods inventory and enjoying an increasingly secure market.

2.2.2 INTRODUCTION TO TOTAL QUALITY CONTROL (TQC)

According to Feigenbaum (47), Total Quality Control *(TQC) may be defined as:* "*An effective system for* integrating the quality development, quality maintenance, and quality improvement efforts of the various groups in an organization so as to enable production and service at the most economical levels which allow for full customer satisfaction." In essence, Feigenbaum is proclaiming that all functions must unite in *building quality in rather than the* outmoded approach of inspecting quality in.

What is quality? Crosby (48) defines quality as, "conformance to requirements", and the following quotation from his book, 'Quality Is Free', gives his reasons: (49)

The first erroneous assumption is that quality means goodness, or luxury, or shininess, or weight. The word 'quality' is used to signify the relative worth of things in such phrases as 'good quality', 'bad quality', and that brave new statement 'quality of life'. 'Quality of life' is a cliche because each listener assumes that the speaker means exactly what he or she , the listener, means by the phrase. It is a situation in which individuals talk dreamily about something without ever bothering to define it. That is precisely the reason we must define quality as "conformance to requirements" if we are to manage it.

Quality means conformance to the requirements, and that is all it means. If you start confusing quality with elegance, brightness, dignity, love, or something else, you will find that everyone has different ideas. Don't talk about poor quality or high quality. Talk about conformance and nonconformance.

Juran (50) has a similarly terse definition of quality, "fitness for use". Both Crosby and Juran assert that their two definitions are not just different words expressing essentially the same idea: they state that their definitions of quality are fundamentally different. The following quotation from Juran's Quality Control Handbook summarizes his ideas: (51)

Of all concepts in the quality function, none is so far-reaching or vital as "fitness for use". Among these overall needs, the extent to which the product things in such phrases as 'good quality', 'bad quality', and that brave new statement 'quality of life'. 'Quality of life' is a cliche because each listener assumes that the speaker means exactly what he or she , the listener, means by the phrase. It is a situation in which individuals talk dreamily about something without ever bothering to define it. That is precisely the reason we must define quality as "conformance to requirements" if we are to manage it.

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Of all concepts in the quality function, none is so far-reaching or vital as "fitness for use". Among these overall needs, the extent to which the product successfully serves the purpose of the user, during usage, is called its "fitness for use". This concept of fitness for use, popularly called by such names as "quality", is a universal concept, applicable to all goods and services. Fitness for use is determined by those features of the product which the user can recognize as beneficial to him, e.g., fresh baked taste of bread, clear reception of radio programs .....

To the user, quality is fitness for use, not conformance to specification. The ultimate user seldom knows what is in the specifications. His evaluation of quality is based on whether the product is fit for use on delivery to him and whether it continues to be fit for use.

Traditionally, three factors have been taken to influence a customer's purchase of a product and his or her satisfaction with it: price, quality, and delivery. To this effect, Groocock (52) proposes the following definition of quality which encompasses the definitions of both Crosby and Juran:

"The quality of a product is the degree of conformance of all of the relevant features and characteristics of the product to all of the aspects of a customer's need, limited by the price and delivery he or she will accept".

Crosby (53) defines the five absolutes of quality as follows:

- Quality means conformance, not elegance.

- There is no such thing as a quality problem.

- There is no such thing as the economics of quality; it is always cheaper to do the job right the first time.

- The only performance measurement is the cost of quality.

- The only performance standard is Zero Defects.

Quality is measured by the cost of quality (COQ). A general definition of quality costs is "costs resulting from making defective products" (54). Quality cost is an unsatisfactory name for this definition and the commonly used "cost of quality" is even worse. The costs included in the definition are not the positive costs of achieving superior quality but rather the negative costs of doing things incorrectly. They are "unquality" costs. However, the name "quality cost" is so ubiquitous that it is not practicable to change it, but it is important to remember what it really means and not be misled by the apparent meaning (55).

Quality costs may be divided into three main categories namely, appraisal, failure, and prevention costs. Groocock (56) defines these costs as follows:

Appraisal costs are the costs of inspecting and testing purchased items and products during manufacturing because of the possibility of their failure.

e.g., Prototype inspection and test
Production specification conformance analysis
Supplier surveillance
Receiving inspection and test
Product acceptance
Process control acceptance

Failure costs are the costs resulting from the actual failure of products during manufacture or use.

e.g., Design errors/redesign
Corrective action costs
Rework
Scrap
Warranty replacements
Product liability

Prevention costs are the costs incurred in trying to reduce appraisal and failure costs.

e.g., Product qualification
Supplier evaluations
Process capability studies

Operation training

Quality audits

Preventative maintenance

Groocock (57) lists the purposes of quality cost measurement as follows:

1. To enable managers to know the size of their quality cost opportunity so that they can apply appropriate resources for its realization.

2. To show broadly where the opportunity is, for example, in inspection or in warranty, so that managers can concentrate effort effectively.

3. To enable managers to set targets for quality cost reduction and plan actions that meet the targets.

4. To enable progress towards meeting the targets to be measured.

Crosby (58) describes Zero Defects as the attitude of defect prevention. Zero Defects is a standard for management, a standard that management can convey to the employees to help them decide to "do the job right the first time" (59). The Zero Defects concept is based on the fact that mistakes are caused by two things: lack of knowledge and lack of attention.

Lack of knowledge can be measured and attacked by tried and true means. But lack of attention is a state of mind. It is an attitude problem that must be changed by the individual (60).

Over the years we have been taught that we can have high quality or low cost, but not both. The Japanese have shown that you cannot have low cost without high quality (61). They have adopted a Total Quality Control approach to locating and eliminating the root causes of problems. Just-In-Time cannot be successful without Total Quality Control.

We have been taught that it is the responsibility of the quality control department to ensure the products leaving the factory are of high quality. JIT proponents have shown that it is the responsibility of each individual to ensure their own quality (62). Thus we move from a quality control department to a quality audit department, and move from inspecting quality in to building quality in.

TQC is the technique which aims to eliminate the root causes of poor quality thereby ensuring defect free manufacture. Total Quality Control particularly emphasizes (63):

- A goal of continual quality improvement, project after project

- Assigning the primary responsibility for quality to the production people and removing it from the quality control department

- Quality control of every process, not reliance upon inspection of lots for only selected processes (defect prevention, not random detection)

- Measures of quality that are visible, visual, simple and understandable, even to the casual observer

- Automatic quality measurement devices (self-developed)

According to Schonberger (64) the goals of TQC are twofold and closely related. The operational goal is to sustain the habit of quality improvement, while the target is, simply, perfection or Zero Defects (ZD). The operational goal pursues the target.

The main incentives for employing Total Quality Control are that quality is a major force for productivity improvement as well as a major competitive weapon.

The most essential TQC concept is the organization of production responsibility. As has already been discussed, this means assigning the primary responsibility for quality to the production people and removing it from the quality control (QC) department.

The role of the QC department changes to being that of facilitator. The QC department should promote the removal of defect causes, keep track of quality accomplishments, monitor operations to ensure that standard procedures are followed, join with purchasing people to similarly monitor supplier plant procedures, and coordinate QC training (65).

The QC department may serve as teachers and disseminators of QC information, but this function should not be so extensive that QC people become the recognized quality experts. Production has the primary responsibility for quality, and production foremen should be the quality experts (66).

Schonberger (67) describes the seven basic principles of TQC as follows: process control, easy-to-see quality, insistence on compliance, line stop, correcting one's own errors, and project-by-project improvement.

Process Control

Process control means controlling the production process by checking the quality while the work is being done. Total Quality Control is dependent on total process control whereby every process is to be controlled by checking the quality during production. The only affordable way to control quality in all processes is for the workers to do it themselves (58). Thus every work station may be an inspection point.

Easy-to-See Quality

Display boards posted around the factory tell the workers, bosses, customers, and outside visitors what quality factors are measured, what the recent performance is, what the current quality improvement projects are, etc. TQC particularly demands visual, obvious indicators of quality at every process, and the indicators must be easy to understand, e.g., not a page of computer listings understandable only to a technician.

Insistence on Compliance

TQC principles condemn the poor manufacturing practice of passing parts and subassemblies that actually do not quite meet established quality standards. In order to rectify this disregard for compliance, top management merely needs to inform manufacturing that quality comes first and output second, and insist on it.

Line Stop

The line stop principle is based on giving each worker the authority to stop the entire production line in order to correct quality problems. Line stops are necessitated by direct quality problems, such as parts not fitting quite right, and the problem needs to be noted and immediately forwarded to the work centres that made the poorly fitting parts. The line stop assures that the assemblers will take enough time to make sure that they are not the cause of bad quality.

Correcting One's Own Errors

The principles of process control, easy-to-see quality, insistence on compliance, and line stop help to enforce the assignment of responsibility for quality to the production department. The fifth basic principle, correcting one's own errors, closes the loop (69). Primarily, the principle refers to rework: The worker or work group that made the bad parts performs the rework itself to correct the errors. Any rework that is necessary is considered to be well worth it in order to be assured that the workers have a full measure of responsibility for quality.

100 Percent Check

The principle, 100 percent check, means inspection of every item, not just a random sample. The principle is intended to apply rigidly to finished goods, and where feasible to component parts. The long-range goal is to make changes that will make it feasible to do a 100 percent check of component parts.

Project-by-Project Improvement

The discussion of easy-to-see quality referred to display boards which often mention the current quality improvement projects going on in the work area associated with the display. The displays may also list quality improvement projects that have been completed in the work area which is a type of quality improvement scoreboard. The essence of project-by-project improvement is having a continual succession of quality improvement projects in every work area, year after year.

Human beings will always make mistakes, but the work process can be designed to eliminate many of them (70). Thus, the idea of making the process somewhat foolproof has become prominent in TQC. Devices called "BAKAYOKE" may be attached to machines to automatically check for abnormality in a process. The monitoring mechanisms thus may check for causal factors like malfunction and tool wear, as well as measuring dimensions of produced parts and warning when tolerances are coming close to being exceeded. Foolproof devices to check every piece are especially suitable for production of component parts.

According to Ishikawa (71), TQC must be continued for as long as the company is in existence. One cannot turn the spigot on and off at will. Once begun, the movement must be continuously promoted and renewed.

The concept of Total Quality Control is available to all the industrial world to use. The tools and methods are well known, yet it is surprising that many companies are not even giving serious consideration to their use (72). In order to be a world class competitor, or even to survive in the ever increasing international arena companies must use every possible means to improve their productivity. TQC is the basic foundation for this survival (73).

2.2.2.1 Setup-Time Reduction

Setup-time reduction is often viewed as a fundamental leg of the JIT philosophy because without it, many of the other techniques leading towards continuous improvement and the JIT goal, are not possible.

Hall (74) defines setup time for any process as the elapsed downtime between the last production piece of component A and the first good production piece of component B. A setup is not complete if the process is still running scrap and trying to make production. Likewise, setup time is not the total labour time required for the setup.

Setup procedures are usually thought of as infinitely varied, depending on the type of operation and the type of equipment being used. According to Shingo (75) when these procedures are analysed from a different viewpoint, it can be seen that all setup operations comprise a sequence of basic steps. They are:

<u>Preparation, After-Process Adjustment, Checking of Materials, Tools, etc.</u> This step ensures that all parts and tools are where they should be and that they are functioning properly. Also included in this step is the period after processing when these items are removed and returned to storage, machinery is cleaned, etc.

<u>Mounting and Removing Blades, Tools, Parts, etc.</u> This includes the removal of parts and tools after completion of processing and the attachment of the parts and tools for the next lot.

Measurements, Settings and Calibrations. This step refers to all of the measurements and calibrations that must be made in order to perform a production operation, such as centring, dimensioning, etc.

Trial Runs and Adjustments. Adjustments are made after a test piece is machined. The greatest difficulties in a setup operation lie in adjusting the equipment correctly. The greater the accuracy of the measurements and calibrations in the preceding step, the easier these adjustments will be.

Shigeo Shingo developed the concept of "single-minute exchange of die" or SMED which is based on setups being performed in under ten minutes. SMED is a scientific approach to setup-time reduction that can be applied in any factory and to any machine (76).

Setup reduction requires a *detailed analysis of* existing setup procedures and a categorization of these procedures into "internal" (those activities that can only be done while the machine is stopped) and "external" (those preparatory activities that can be done while the machine is still running) setup.

The objective is to minimize the length of time required for internal setup and thus to maximize the time required for external setup. According to Shingo

(77) experience has shown that converting as much setup activity as possi. from internal setup to external setup reduces downtime by as much as 50 percent or more.

The core of a setup i e external elements (78). The exchange of the attachments must generally be done with the machine stopped. All the attachments, tools, and workers required should be in place and standing by with everything laid out as if they were surgical instruments on a tray. With thought, workers soon learn to define the exchange elements in the narrowest way, so that every move made with the machine stopped is essential. As a result, the internal setup should proceed without the slightest hesitation or confusion.

This requires organization of the external setup so that nothing is forgotten in preparation for the exchange process. It also stimulates the worker to mentally prepare for what he is about to do. However, standardizing the external setup work procedure on the same machine is also very helpful in causing workers to go through a setup by a routine which can be practised and refined until there are no mistakes.

Adjustment time is almost always a part of internal setup time, and sometimes a major part, so attention to it is vital. After displacing as much internal setup activity as possible to exte[illegible] experienced [illegible] estimate that on the aver[illegible] ut 50 per [illegible] residual internal setup ti[illegible] med b[illegible] or reducing adjustment t[illegible] el[illegible] the adjustment activity, any scrap that [illegible] well as the time required for adjustment [illegible].

Executing a setup well requires correct reactions, so practice is necessary when the procedure is new and periodically thereafter when it is revised or when new people must execute them.

2.2.2.2 Relationship Between Quality and Setup-Time Reduction

According to Hall (80) the reduction of process downtime (last piece to first good piece) results in increased production flexibility. Shingo (81) describes the benefits of reduced setup time as: reduced inventory levels, increased responsiveness, reduced lead time, improved quality, elimination of setup errors, simplified housekeeping, and lower skill level requirements.

Setup-time reduction provides the economical means for lot size reduction which eventually results in minimal inventory levels (82). Small-lot production leads to lower scrap and better quality since defects can be discovered quickly and therefore there can be fast feedback to the worker or work station responsible for producing defects. In this way, causes of problems are highlighted as they occur and can be solved immediately. Thus production of large lots high in defects is avoided.

Setup reduction requires setups to be performed in standard ways as a routine operation. Consider the difference between changing a tyre on a passenger car for the first time in five years and changing one in a pit stop during a grand prix race. A setup requires the same timing, organization, standardization of procedures, and practice as the changing of a tyre in a grand prix race pit stop.

In order for the internal setup to proceed without the slightest hesitation or confusion, the external setup must be organized to the finest detail so that nothing is forgotten in preparation for the change over. Standardizing the external setup procedure enables the workers to setup according to a routine that can be practised and refined until split second timing is achieved and there are no mistakes. Thus the quality of parts and components produced is improved since operating conditions are fully regulated in advance. Standardization reduces the number of tools required, and those that are still needed can be organized more functionally to permit fast, quality setups.

According to Juran (83) process variations, and hence quality defects, are traceable to the following two kinds of causes:

1. Random, i.e., due solely to chance.

2. Assignable, i.e., due to specific "findable" causes.

Table 2.1 summarizes the difference between random and assignable causes.

Table 2.1 Distinction Between Random and Assignable Causes.

RANDOM CAUSES	ASSIGNABLE CAUSES
Consists of many individual causes.	Consists of one or just a few individual causes.
Any one random cause results in a minute amount of variation (but many random causes act together to yield a substantial total).	Any one assignable cause can result in a large amount of variation.
Random variation cannot economically be eliminated from a process.	Assignable variation can be detected; action to eliminate the causes is economically justified.
When only random variation is present, the process is operating at its best; if defectives are still being produced, a basic process change must be made or the specifications revised in order to reduce the defectives.	If assignable variation is present, the process is not operating at its best.

A diagnostic chart (Figure 2.3) was developed which shows the breakdown of quality defects into random and assignable causes. Each of these is then further broken down into specific causes. Suitable action is then prescribed in order to eliminate the cause. This chart shows specifically that an incorrect setup can result in large variations and thus be responsible for the production of defects.

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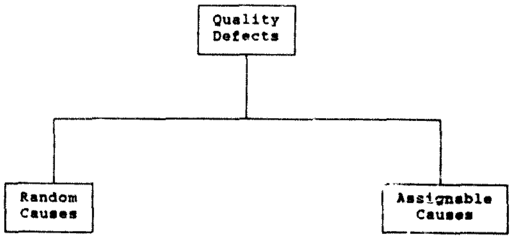


Figure 2.3 Diagnostic chart for quality defects.

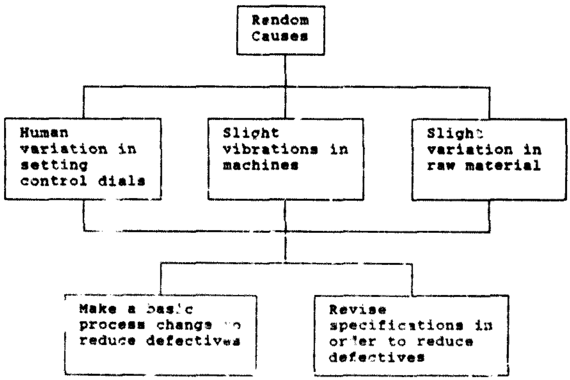


Figure 2.3 (continued).

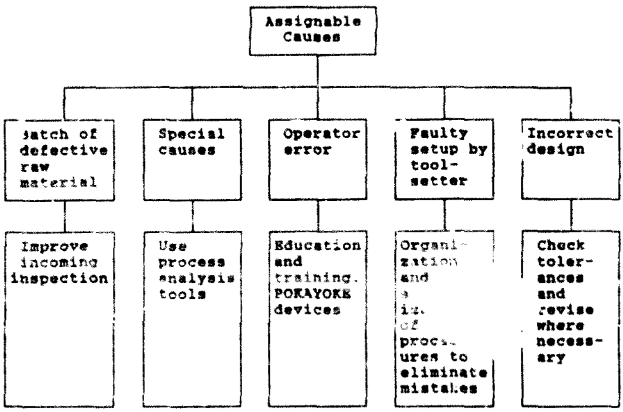


Figure 2.3 (continued).

2.2.3 JUST-IN-TIME/TOTAL QUALITY CONTROL (JIT/TQC) INTERLINK

Having described the techniques of Just-In-Time and Total Quality Control it is now possible to identify the relationship that exists between them. The first goal of quality improvement is satisfying the customer whereas the first benefit of JIT is fast response to the customer (84).

Thus it is evident that the relationship that exists between JIT and TQC is due to the fact that both techniques cater for the requirements of the customer.

Schonberger (85) explains the JIT and TQC interlink in the following manner: Someone asked me once what the connection is between quality and JIT. I said, "Two peas in a pod." It was a dumb thing to say. I should have said one pea in a pod. Schonberger (86) summarizes the connection between quality and JIT as follows:

1. How quality enhances JIT

Fact	JIT/Quality Effect
Variability in quality is major reason for buffer stock.	Control variability to justify buffer stock cuts.

2. How JIT cuts cost of quality

Fact	JIT/Quality Effect
Scrap/rework/damage costs of quality linearly related to raw and in-process (RIP) stock.	RIP reduction cuts scrap/rework/damage costs to same extent.

3. How JIT improves quality

Fact	JIT/Quality Effect
Time destroys evidence of causes of variability.	Effective process analysis requires fresh evidence in period of limited changes - provided by vigorous JIT.

Thus JIT techniques help to slash lead times which creates a permanent early warning system (87) i.e., by keeping evidence fresh it facilitates the production people in solving quality problems. Large cost reductions are possible using JIT techniques since by removing any idle inventory the potential for scrap and rework is minimized. By reducing lead times JIT does not result in flexibility, but it does demand flexibility: flexible labour and flexible equipment (88).

TQC fans the flames: It greatly accelerates quality improvement, which lowers scrap, rework, warranty and liability costs. TQC takes out some of the rework loops as well, which aids in cutting lead times (89).

2.3 CONCLUSION

The techniques of Just-In-Time and Total Quality Control provide the means to improve manufacturing performance and hence competitiveness in the marketplace since both techniques are equally important for ensuring improved productivity and product quality. This chapter has provided the necessary background information to these two techniques as well as outlining the *numerous benefits from such an* implementation.

The JIT/TQC system is an imperative to continually improve (90) and thus a sure way of achieving manufacturing excellence. However, it should be borne in mind that JIT/TQC is a people programme whose success is embedded in total employee involvement.

3.0 INSIGHT TO THE COMPANY

3.1 INTRODUCTION

Having explained the manufacturing philosophy of JIT/TQC adopted by Afrox G.E.F it is now necessary to describe other aspects of the company in order to put the project in its correct perspective. The purpose of this chapter is to provide the reader with sufficient background information to the company in order that he may appreciate the unique organization of the factory, the product being manufactured and the nature and extent of problems facing the company.

3.2 AFROX G.E.F - THE COMPANY

In December 1962, African Oxygen Limited (Afrox) opened the Gas Equipment Factory (G.E.F) in Germiston, South Africa. The G.E.F was to manufacture gas welding equipment which had, until then, been imported from the parent company, British Oxygen (B.O.C). Numerous variations of the following four products were to be manufactured: (91)

- Gas pressure regulators

- Gas cutti... elding torches

- Gas cutting/welding nozzles

- High- and low-pressure gas cylinder valves

By 1982, the G.E.F had captured the major share of the South African market, the balance being made up by imported equipment (92).

With the emergence, in the early 1970s, of high quality, cheap products from Europe and above all, the Far East, pressure was brought to bear on Afrox by B.O.C to reduce costs at the G.E.F. In 1979, a material requirements planning (MRP) system was installed in the G.E.F. The system was gradually upgraded with the implementation of more software packages, so that by 1984 the MRP system had grown into a successful manufacturing resources planning (MRPII) system (93).

Due to the initial failure of the MRP system, Afrox Management was forced to consider alternative methods of cost reduction. The availability of group technology knowledge and experience within the B.O.C group resulted, at the end of 1981, in the decision to implem... group technology (GT) as a means of reducing manufacturing costs (94).

In April 1983 GT was implemented which resulted in the establishment of four cells:

- Regulator cell, for the manufacture of all gas pressure regulators

- Torch cell, for the manufacture of gas cutting/welding torches

- Valve and Nozzle cell, for the manufacture of high- and low-pressure gas cylinder valves and gas cutting/welding nozzles

- Central Workshops cell, for the manufacture of special purpose products on a quotation basis

Each cell was established as an independent profit centre and, as such, 'four factories within a factory' were established (95).

The organizational structure of the G.E.F may be represented by Figure 3.1 where particular attention is paid to the infrastructure of the Regulator cell. However, the infrastructure within the other cells is identical.

The Quality Control department was dissolved during the GT implementation in 1983 and the operators were made responsible for product quality. The present

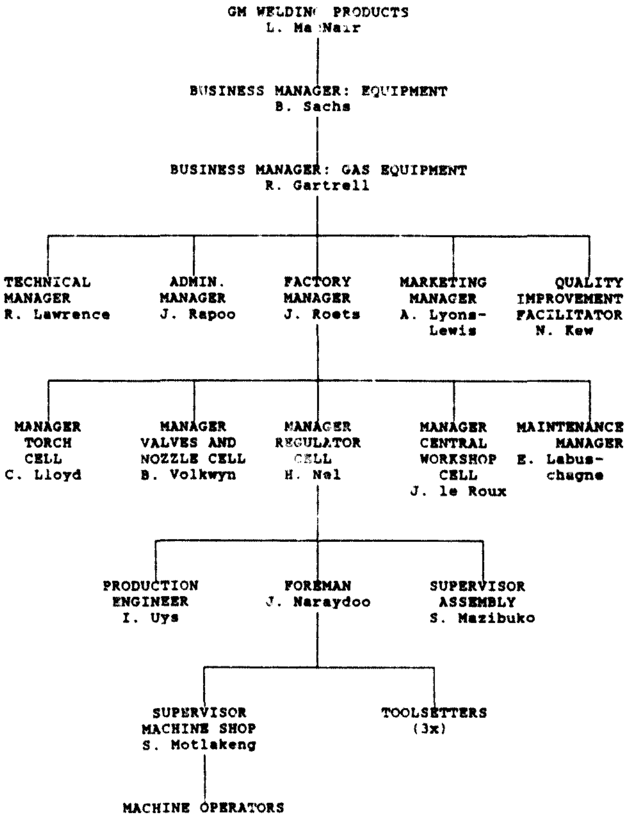


Figure 3.1 The G.E.F organizational structure, June 1988.

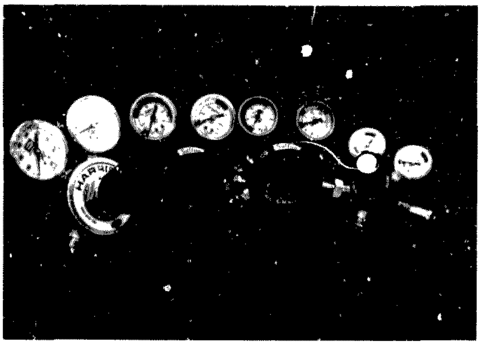
organizational structure shows a Quality Improvement Facilitator (QIF) who has been appointed head of the newly set up Quality Assurance (QA) department. The QA department is not responsible for the conventional function of quality control of production and its associated departments. However, their responsibility involves the education and training of the production people in formal quality techniques.

Many JIT principles (96,97) are in fact GT principles (98). Thus since the implementation of GT in 1982/1983, the G.E.F has unknowingly been moving down the JIT road. Early in 1986, JIT/TQC formally became the manufacturing philosophy of the G.E.F which would build upon the success of the GT system and further reduce manufacturing costs (99).

The investigation of quality improvement was confined to the Regulator cell, which is responsible for the manufacture of all gas pressure regulators, since this cell generates approximately 50% of the factory's turnover and is therefore the area where the greatest cost reductions could be attained.

3.3 GAS PRESSURE THE PRODUCT

The Regulator c..il . tures approximately twenty-five end products which consist of single-stage and multi-stage (two stages) regulators. Examples of regulators are shown in Photograph 3.1.



Photograph 3.1 Gas pressure regulators manufactured in the Regulator cell.

The breakdown of components of a typical multi-stage regulator is shown in Photograph 3.2.

3.3 GAS PRESSURE REGULATORS - THE PRODUCT

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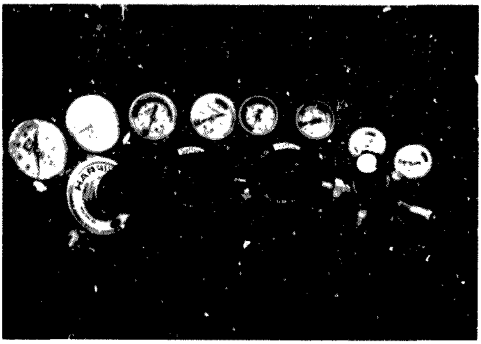

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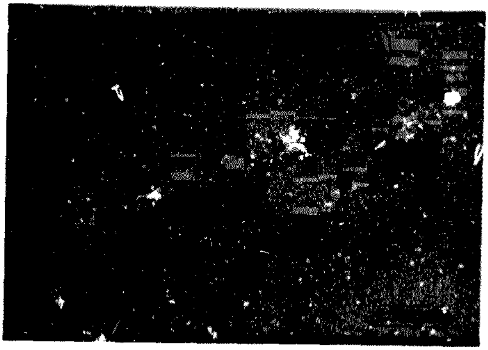

Photograph 3.2 Breakdown of components of a multi-stage regulator.

The manufacture of regulators is not a flow-line manufacturing process. The Regulator cell is essentially divided into two areas: The machine shop and the assembly area. The machine shop supplies components to the sub-assembly and final assembly operations and the sub-assembly operations in turn feed the final assembly stations.

A large percentage of regulator components are machined in the machine shop in one operation on automatic machines that are dedicated to the manufacture of a single component or group of components. However, a few small families of components are machined in mini-cells which consist of between three and five machine tools run by one or two operators. The remainder of components are bought-out items or subcontracted out.

Simple low cost automatic devices are used as an aid in the assembly of regulators, thereby eliminating many skilled, manual assembly operations. The use f low cost automation in the assembly area results in the reduction of the amount skill required to perform a particular task. These automatic devices reduce the margin for error during assembly operations (e.g., the motors used for screwing the bonnets onto the regulator body have a pre-set torque) and thereby improve the quality of the finished product.

3.4 PROBLEMS FACING THE REGULATOR CELL

The direct and indirect effects of poor quality, in particular, 8.5% scrap and 20% rework, were taking their toll on management and workers alike in the Regulator cell. The poor quality that had permeated through the cell was seriously hampering any progress to the attainment of the JIT/TQC philosophy adopted by the company.

The present organization of the machine shop is partly responsible for the poor quality prevalent in the Regulator cell. At present there is dual accountability for both quality and output which results in the toolsetters blaming one another for the production of defects and allows them to neglect their responsibilities. The management of the toolsetters' activities is a difficult task since their responsibilities are not clearly defined. Each toolsetter does not have his own group of machines and components for which he is responsible and accountable. Due to the lack of control of the tool cabinets no one toolsetter can be held responsible for the condition of a particular cabinet.

The quality philosophy of the company (Appendix A) states: "Quality improvement is the gas equipment business's most important objective. This is everyone's job." Unfortunately the production people appeared to overlook this objective which resulted in product quality being adversely affected.

The consequences of having allowed poor quality to persist in the cell were inconsistent product quality, high scrap and reject rates (8.5%), and a high percentage of rework (20%). All of these consequences are elements of waste which were threatening the future prosperity of the Regulator cell. Crosby (100) argues that "Quality is free. It's not a gift, but it is free. What costs money are the non-quality actions - all the actions that involve not doing jobs right the first time."

The measurable failure costs of the cell's poor quality include the time and material costs associated with repeating or rectifying work, cost of lost production output, cost of management time, penalty and warranty costs. However, there are also the immeasurable effects such as loss of customer goodwill, loss of sales and the effects on staff of frustration and demotivation (101). During an interview with the former cell manager, Kobie Jacobs, he expressed the following sentiments on the effects of poor quality, "The workers and I are pressurized to meet the daily schedule. We are always fire-fighting and the workers are frustrated having to work under these conditions".

The quality philosophy of the company also state "If it comes to a trade off, quality is more important n cost or output." On numerous occasions this prin ie was violated possibly because management was not fu y committed to the idea of placing quality before output This resulted in a bad example being set for the workforce who began to disregard quality in order to meet production quotas.

During the implementation of group technology in the factory in 1983 the Quality Control department was dissolved and the operators, not roving inspectors, made accountable for product quality. Observations revealed that the operators and machine tool setters tended to abdicate from their quality responsibilities since they were failing to detect defectives that were passed onto the assembly operations, let alone prevent defectives from occurring.

The TQC technique used for quality control is "N = 2" where the first and last pieces are inspected. Some of the more common gauges used for component inspection are: standard plug gauge, limit plug gauge, plate gauge, adjustable caliper gauge, limit caliper gauge, adjustable diameter, adjustable screw, ring and ring screw. The majority of these gauges are "go/no-go" type gauges. Using the "N = 2" approach, if the first and last pieces are good it assumed that the process has remained stable (r no tool wear or out-of-adjustment conditions have arisen) and therefore all parts are good

Systems that had been developed to record measure of quality such as scrap rate have been comple disregarded by the operators and machine tool set These systems revealed a scrap rate ranging fror to 3.0% (see Table 3.1), the validity of wh questionable. One such system is the three coloured tray (3-tray) system (Appendix B). As a result of this lack of discipline a high percentage of scrap that was produced in the machine shop was going unnoticed. It was convenient for the operators and machine tool setters to turn a blind eye to the scrap produced or even at times attempt to conceal it. This is because the scrap rate is one of five factors used in their appraisal system and thus an excessive scrap rate would be detrimental to their *performance record*.

Thus the little information that is recorded does not give an accurate reflection of the true to life situation. This is evident in the recorded scrap rates for the machine shop for the first six months of 1987 shown below in Table 3.1.

Table 3.1 Monthly Scrap Rates For Regulator Cell (AFROX,1987)

	JAN	FEB	MAR	APR	MAY	JUN
Machine shop scrap rate in Regulator cell.	3.0%	2.4%	1.2%	1.7%	1.6%	1.3%

Unfortunately these figures are *extremely* misleading and not only do the workers and management begin to believe them but the danger arises when they convince themselves and others that they don't have a quality problem. Scrap rate figures were recorded for the months of September and October which revealed a more accurate measure of the order of 8.5%. This figure is based on the collection of data shown in Section 4.2.2.2.

This *defect rate of 8.5%* may be categorized in the following manner:

65% of defects are due to the *production process*.

20% of defects are due to vendor supplies.

15% of defects are due to design error.

The production process is responsible for the majority of defects and thus this study was targeted to improve it in order to realize the greatest impact.

The main cause of quality problems can be attributed to the lack of management commitment and involvement, whereas the production people are only the symptomatic cause of problems. The management problem is presently being addressed by the use of an external quality consultant in order to establish the foundation for the long term solution. However, the problems identified in the production process are being addressed by the proposed Quality Improvement Programme and serves as the short term solution.

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Inconsistent quality of machined components seriously hampered the performance of the final assemblers. The percentage of rework at times reached alarming proportions of about 20%. This resulted in frustrated, dissatisfied and demotivated workers because poor quality components thwarted their efforts to meet production schedules.

"The development of trusting and mutually beneficial relationships between the customer, ourselves and our suppliers, as well as between employees and management, is the key strategy aimed at improving our quality." So states the quality philosophy of Afrox G.E.F. However, due to the existing troublesome situation in the cell, management blamed the workers and vice versa. Unfortunately this resulted in the workers adopting a "Them versus Us" attitude which only further complicated matters in the already strife torn Regulator cell.

3.5 CONCLUSION

The discussion of this chapter attempted to give the reader greater insight to the company. Afrox G.E.F has a unique factory organization whereby 'four factories within a factory' have been established and each 'factory' operates as an independent profit centre. The Regulator cell is one of the four autonomous 'factories' within the factory which is dedicated to the manufacture of all gas pressure regulators.

The problems identified in the Regulator cell are a result of workers and management alike losing sight of the company's most important objective, that of quality improvement. For this very reason the cell lapsed into a state of disorder where inconsistent product quality was allowed to persist.

Checking through effects to find exceptions or something unusual does not in itself serve the interests of the company (102). The cause factors for these exceptions must be found and appropriate actions taken. When considering corrective action it is important to take measures to prevent recurrence of these exceptions. However, making adjustments to the cause factors involved will not be enough. One must endeavour to remove the cause factors which have been responsible for the exceptions. In removing the causes for exceptions, one must establish the fundamental cause of the problem in order to take appropriate action to prevent recurrence. In the following chapters this is the approach adopted to change the status quo of the Regulator cell and thus achieve an improved level of quality.

4.0 PROBLEM IDENTIFICATION

4.1 INTRODUCTION

Problem identification and gaining control over the process is founded on measurement and study (103). Problems exposed are candidates for investigation and analysis. This chapter deals with the basic principles and tools used to monitor the process, whereby not only were the areas of improvement highlighted but also investigated and analysed. In particular, the problem identification was directed at the underlying causes of inconsistent product quality, high scrap and reject rates, and excessive rework. The methodical process of measurement and data analysis provides the means to establish the sources of these problems.

4.2 PROCESS ANALYSIS TOOLS

Problem identification is greatly facilitated by means of easy-to-use process analysis tools. A process analysis may be as simple as using a gauge, however, Ishikawa (104) and Schonberger (105) suggest that a more complete study may employ the following five primary tools of process analysis:

1. **Process flow chart**: Track the flow of the product through all steps and stages.

2. **Pareto analysis** (The principle of the 'vital few and trivial many): Plot disturbances, for example defects, at every point in the process flow. Select the worst case (longest bar on the Pareto chart) for further study.

3. **Fishbone chart** (Ishikawa diagram or Cause and Effect diagram): Make the 'worst case' the spine of a Fishbone chart. Secondary causes become secondary bones connected to the spine. Tertiary causes connect to secondary causes. Begin experiments on extremity 'bones'.

4. **Histograms**: Sometimes it is useful to measure a process characteristic - perhaps one of the extremity bones - and plot the measurement data on a histogram. The shape provides clues to causes.

5. **Run diagrams and Control charts**: In many cases it is valuable to plot measured process data for critical characteristics on Run diagrams and Statistical Process Control (SPC) charts.

These tools are mostly not for design engineers and quality engineers. Design engineers may have a need for higher-order statistical analysis, particularly design-of-experiment methodologies. Quality engineers may need to use multiple regression techniques to investigate complex causal patterns. However, these process analysis tools are best suited for use by production employees such as line operators and assemblers since they are responsible for the taking of measurements and collection of data.

During the course of the investigation it was found unnecessary to utilize all five tools in order to pin-point the source of problems. However, in the discussion that follows each tool used will be briefly explained and then shown how it contributed to the homing-in of the fundamental cause of the problem.

4.2.1 PROCESS FLOW CHART

A process flow chart identifies the operations in a production process and how they are sequenced. For complex products it is useful to prepare a flow chart depicting how the streams of materials move and converge during the processing stages. Such a flow chart makes it easier for all concerned to understand the system design (106).

preparation of a flow diagram, showing the ɔgression of operations from raw material to the nished product, is a useful aid in determining the ɔcation of control stations. By monitoring these tations it is possible to identify the areas of reatest disturbance to the manufacturing process.

As mentioned previously, the manufacture of regulators is not a flow-line manufacturing process and thus to depict a detailed sequence of operations in the form of a flow diagram would be prohibitive. For the purposes of the study, a simplified process flow chart (Figure 4.1) has been prepared showing the general sequence of operations from raw material to the machine shop to final assembly.

4.2.1.1 Control Mechanisms

The process flow chart in Figure 4.1 was used to determine the location of suitable control stations. The machine shop and the assembly area were identified as the main areas where controls should be instituted. In order to devise suitable control mechanisms it required a period of familiarization with the various operations and processes in the machine shop, sub-assembly and assembly areas.

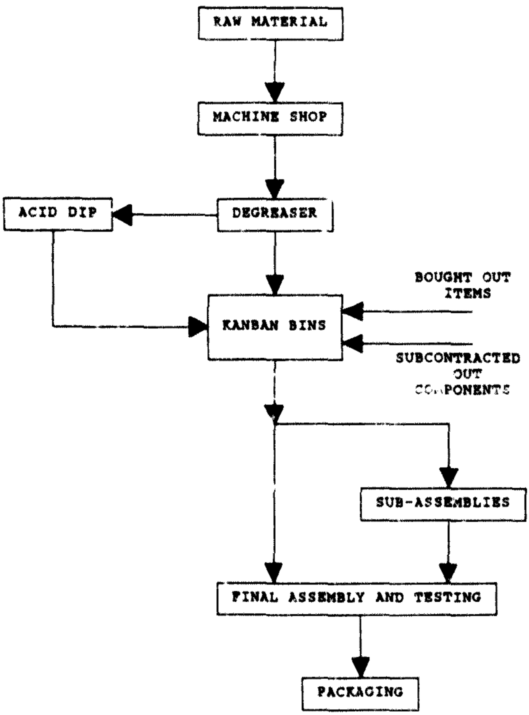

Figure 4.1 Process flow chart for the manufacture of regulators.

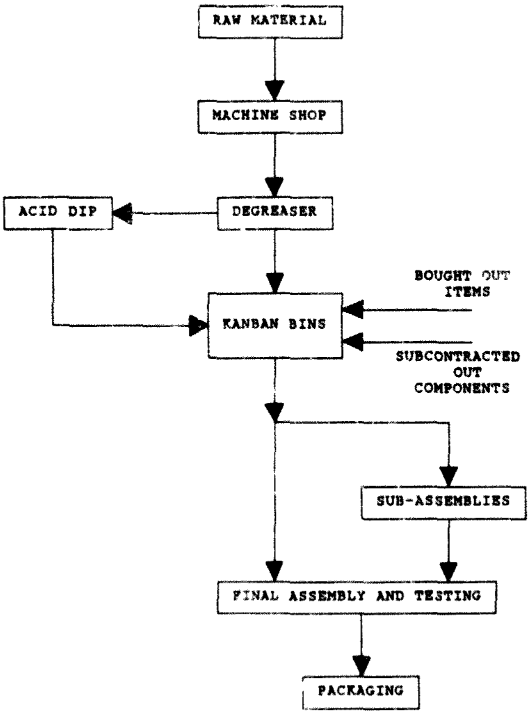

Figure 4.1 Process flow chart for the manufacture of regulators.

Two separate checklists were developed (Appendix C), one for the machine shop and one for the assembly area, in order to record the possible causes of inconsistent product quality and defective components.

The checklist for the machine shop (*Figure C1*) lists eleven possible causes of defects. The toolsetter or machine operator was required to record the defects, using the clipboard and pen provided, on a separate sheet for every batch of each component machined. Unfortunately this recording system failed despite constant efforts to explain the purpose and stress the importance of it to the toolsetters and operators. The failure can be attributed to the toolsetters' and machine operators' lack of discipline, lack of understanding, lack of co-operation and fear, although unjustified, of revealing the truth.

The checklist for the assembly area (Figure C2) lists thirteen possible causes of defects. A clipboard and pen was set up at the workstation of each assembler to enable them to record the nature of the defect and the frequency with which it occurs in the simplest possible way. Since the machine shop system failed it resulted in employing the strategy of monitoring activities downstream i.e., in the assembly area and working back upstream to determine the possible causes of assignable defects

During the initiation of this defect recording system the purpose and importance of capturing this data was explained to the assemblers in conjunction with the supervisor who is able to converse in the workers' language. In order for this system to be successful it was found necessary to reinforce these ideas each week. The assemblers, however, were found to be far more responsive and co-operative than the toolsetters and machine operators. The purpose of this system was not only to record the nature and frequency of defects but also to create a heightened awareness of the need for quality improvement.

The information recorded on these defect lists is valid although not entirely accurate. The accuracy of the data is questionable because occasionally one or two of the eight assemblers had a slightly different spread of problems compared to the rest of the assemblers. There could be a number of reasons for this behaviour:

(i) The assembler concerned might think that the occurring defect is not serious and thus does not warrant attention.

(ii) The assembler might pick up a defect but is unsure of the cause of the defect. As a result he might think that it is better to leave it out than to mark an incorrect cause.

(iii) The assembler could be afraid that if he records too many defects he will be reprimanded and thus to avoid such a situation defects might not be recorded. By obtaining management support for the system and encouraging management to assure the assemblers that their performance record would not be affected it was possible to allay the unjustified fears of the assemblers.

4.2.2 PARETO ANALYSIS

4.2.2.1 The Pareto Principle

The principle of the 'vital few and the trivial many' is known as 'the Pareto principle' (107). A vital few members of the assortment account for most of the total effect. The bulk of the members (the trivial many) account for very little of the total effect.

A major use of the Pareto principle is in the design of quality improvement programmes. Here the principle has so wide an application that no intelligent approach to quality improvement is possible without it. Improvement can be justified only for the vital few projects. It is these projects which contain the bulk of the opportunity for improvement in failure rates, quality costs, etc..

The vital few projects are identified through a 'Pareto analysis'. In its most basic form, this consists of a listing of the contributions to the problem in the order of their importance.

4.2.2.2 Discussion of Pareto Analysis

The data recorded on the defect lists in the assembly area was collected and analysed on a weekly basis. A Pareto analysis was performed each week (Figure 4.2 - Figure 4.9) to determine the most frequently occurring defects in the manufacture of regulators. In this way, it was hoped to identify a common recurring pattern of defects which could be further investigated.

Close examination of the weekly Pareto charts revealed that there was no recognizable pattern when the top 20% of categories of defects (which generally accounted for about 80% of the defects) of each chart were compared with one another. The various defects appeared to occur in a fairly random fashion and thus was difficult to isolate a group of common recurring defects. Therefore further analysis using Ishikawa diagrams would have

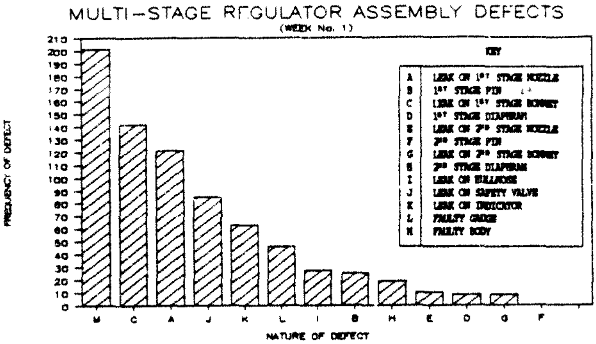

Figure 4.2 Pareto analysis of assembly defects (Week 1).

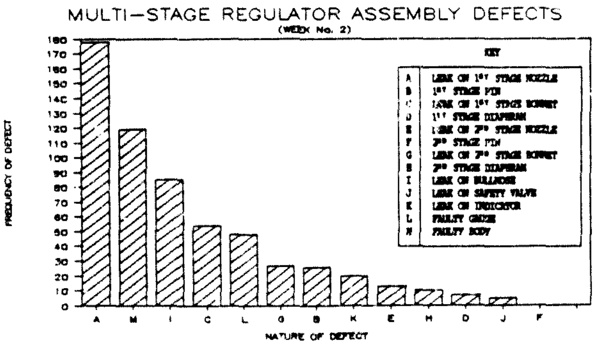

Figure 4.3 Pareto analysis of assembly defects (week 2).

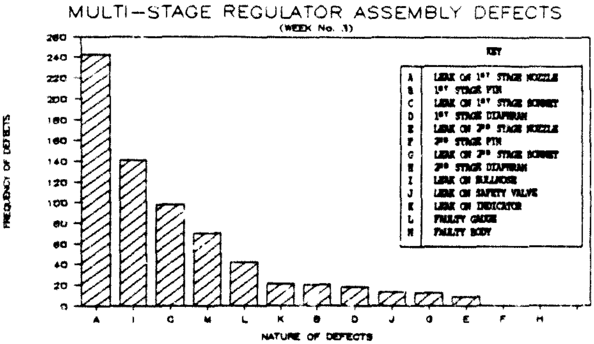

Figure 4.4 Pareto analysis of assembly defects (Week 3).

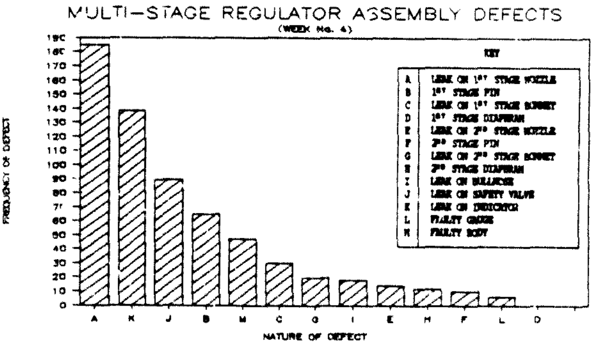

Figure 4.5 Pareto analysis of assembly defects (Week 4).

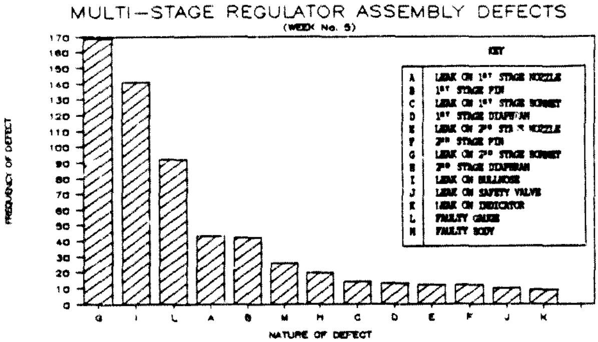

Figure 4.6 Pareto analysis of assembly defects (Week 5).

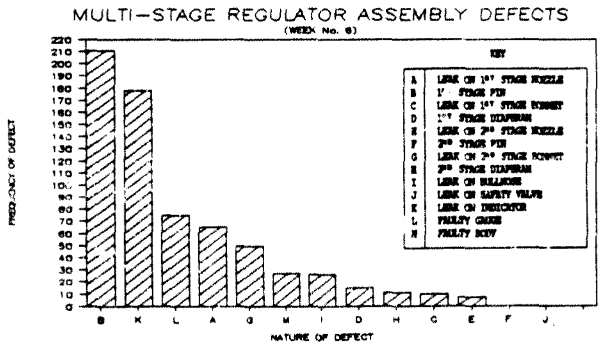

Figure 4.7 Pareto analysis of assembly defects (Week 6).

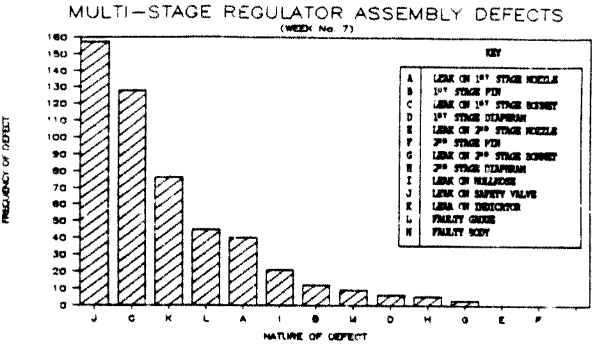

Figure 4.8 Pareto analysis of assembly defects (Week 7).

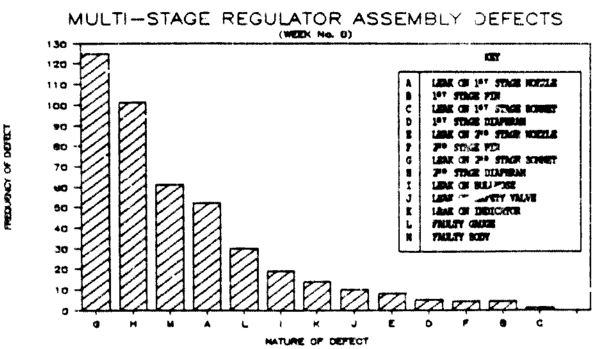

Figure 4.9 Pareto analysis of assembly defects (Week 8).

required a fairly lengthy period of investigation and measurement.

Due to the random nature of the defects there appeared to be a common denominator responsible for the inconsistent product quality and excessive defect rate.

Detailed inspection of the recorded defects revealed an interesting result. The majority of defects (65%) were found to originate from the machine shop. Since the toolsetters and machine operators have been assigned the responsibility for product quality both were suspected of abdicating their responsibilities. The toolsetters were chosen to be investigated first because they are assigned the responsibility of setting up the machines according to drawing specifications. Initial suspicions of lack of discipline and lack of co-operation further justified the decision to investigate their activities.

4.3 CONCLUSION

The process analysis tools employed provided valuable information necessary to narrow down the fundamental cause of the problem to a few specific areas.

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4.3 CONCLUSION

The process analysis tools employed provided valuable information necessary to narrow down the fundamental cause of the problem to a few specific areas.

Additional techniques and measurements are now required to further investigate these possible sources of poor quality (nonconformance to requirements) and ultimately pin-point the root cause.

5.0 THE 'BREAKTHROUGH'

5.1 INTRODUCTION

Quality improvement activities are concerned with both sporadic and chronic quality problems. A sporadic problem is a sudden adverse change in the status quo, requiring a remedy through restoring the status quo. A chronic problem is a long-standing adverse situation, requiring a remedy through changing the status quo (108). Sporadic problems are dramatic and receive immediate attention. Chronic problems are not dramatic because they have been occurring for a long time, are often difficult to solve and are accepted as inevitable. The danger is that the fire-fighting on sporadic problems may take continuing priority over effort where larger savings are possible i.e., on chronic problems (109).

The chronic problems facing the Regulator cell required a change in the status quo. In order to change the status quo, Juran (110) advocates that a breakthrough is needed in order to achieve an improved level of quality.

5.2 EVALUATION OF TOOLSETTERS

The toolsetters are largely responsible for product quality in the machine shop and thus an in-depth investigation into their activities was necessary either to confirm or remove suspicions regarding their performance.

5.2.1 WORK-SAMPLING ANALYSIS

Work-sampling is like the before flow chart. It shows what is happening at present (111). The work-sampling study yields data on percentage of idle or delay time. The purpose of conducting a work-sampling analysis was not to determine utilization rates but rather to establish the manner in which the toolsetter allocates his available time to the various activities of setting a machine.

In order to avoid bias, the work-sampling study was performed in a period of time representative of average conditions. Other types of bias that were guarded against are as follows:

- The study was conducted over a number of weeks so that the results were not biased by a single unusual day.

- 'Instantaneous' observations were made so that the toolsetters did not "glide" into another activity, leaving the author a choice of which one to record.

- Observations were made at random intervals so that the toolsetters did not "prepare for" the observations at set intervals.

- The toolsetters were informed about the nature of the study in order to prevent hostility and deliberate attempts to foul it up.

- When in doubt, the toolsetter was asked what the observed activity is in order to avoid judgemental bias.

- A sample size of 300 observations was taken which, for the purposes of the study, was considered a large enough sample to yield convincing results.

The work-sampling form (Figure D1) drawn up for the study lists ten of the toolsetters' activities most likely to be encountered. The results of the study may be summarized as follows (Table 5.1):

Table 5.1 **Results of Work-Sampling Study**

ACTIVITY	PERCENTAGE OF TOTAL OBSERVATIONS
1. Sharpening tools	13.67%
2. Gauging components	11.33%
3. Marking off	0%
4. External machine setup	3.67%
5. Internal machine setup	15.00%
6. Recalled to machine	27.00%
7. Aiding another toolsetter	2.33%
8. Stripping down machine	12.00%
9. Functional test	2.67%
10. Other	11.00%

An analysis of the results revealed that the toolsetters spent approximately 30% of their time being recalled to a machine. This is not only an indication of their lack of education and training that limits their machine tool setting abilities but also of their disregard with respect to their product quality responsibilities. As a result the quality of machined components was inconsistent, components were not machined according to the schedule dictated by the Kanban board (approximately 35% of all components had to be expedited), and a large amount of scrap (8.5%) was produced which was not formally recorded and thus went unnoticed.

The percentage of time recorded for external machine setup activities was approximately 4% which is abnormally low. Shingo (112) suggests that the proportion of time spent on external machine setup activities should be at least 50% of the total machine setup time. This is a clear indication that there was barely any planning or organization prior to a machine setup. This resulted in the adverse situation of unnecessarily long setup times which severely hampered the cell's JIT strategy of producing in small lots. This lack of preparation probably also accounts for the high percentage of machine recalls.

The purpose of the functional test is not only to determine that the component conforms to drawing specifications and thus allows for trouble-free assembly, but also to ensure that the component performs its desired function. The low percentage of time spent by the toolsetters is evidence of the fact that insufficient measures were taken by them in order to ensure defect free components.

5.2.2 ATTITUDE OF TOOLSETTERS

Having observed the activities of the toolsetters and highlighted many of their shortcomings it was an interesting exercise to draw up a questionnaire for the toolsetters in order to ascertain their perceptions regarding their performance. The questionnaire for the toolsetters (*Appendix E*) is based on the Toyota Production Systems *Waste Questionnaire.*

The general impression gained from the questionnaire was that there were large discrepancies and numerous contradictions between the observations of the author and the perceptions of the toolsetters. The toolsetters gave the overall impression that they were performing to the best of their ability and facing up to their designated responsibilities.

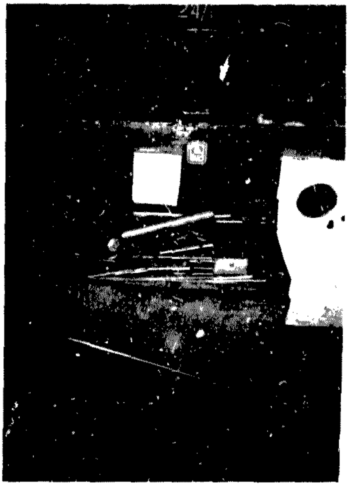
The machine shop is highly dependent on the skills of the toolsetters in order to get the machines set up and producing quality components. Unfortunately the toolsetters appeared to have taken advantage of this situation which has been to the detriment of the cell.

The present performance appraisal system of the toolsetters (Appendix F) has unfortunately, through certain loopholes, been partly responsible for allowing the toolsetters to adopt an attitude of superiority. The toolsetters have a rating of five which is the highest possible rating. The validity of this rating is questionable due to the findings of the poor performance of the toolsetters. As a result of their rating they have reached a plateau with regards to their performance appraisal and thus appear to have lost their incentive and motivation to attaining any further goals.

It is apparent that revised standards are necessary to overcome this situation and prevent a future recurrence. Mike Karle, the JIT manufacturing consultant for Afrox G.E.F, has proposed new performance appraisal standards for the toolsetters (Appendix F) which outlines objective standards to measure and give recognition to the performance of the toolsetters.

Quality control is perhaps the chief reason for good housekeeping but safety and pride undoubtedly are important related factors. One may expect that sloppy housekeeping habits encourage sloppy work habits, which lead to personal injury and injury to products and equipment (113). Conversely, good housekeeping should provide an environment conducive to improved work habits, quality, and care of facilities. Inasmuch as good housekeeping is considered a contributor to good quality, housekeeping responsibility must reside with those who have quality responsibility, namely, the foreman and the workers (114).

The toolsetters' attitude towards quality and lack of pride in their work may be depicted in their untidy housekeeping *habits* which is evident from their poorly maintained tool trolleys (Photograph 5.1). However, the real cause for the toolsetters' lack of motivation can once again be attributed to management. Management should give the toolsetters the *recognition* they deserve and encourage and reward any innovative and creative ideas.



Photograph 5.1 Example of a toolsetter's disorganized tool trolley

A clean and tidy workplace makes the *unspoken* statement that quality is expected (115). Thus the slovenly housekeeping habits of the toolsetters were merely a confirmation of the previous findings of the toolsetters' poor performance with regard to product quality.

5.3 CONCLUSION

Traceability is the ability to identify the individual parts of any component, and that could mean people, tools, materials, and any other particulars that pin-point the origination of quality problems. One of the most difficult aspects of solving quality problems is identifying where and when the problem the originated. Without that information, the ability to solve problems decreases inordinately. If one does not know what caused the problem, it is only reasonable to expect that the problem will not be solved (116).

The extensive investigation into the toolsetters' activities provided the much sought after breakthrough that the toolsetters were responsible for the poor quality (8.5% scrap - 65% of these defects were due primarily to incorrect setup procedures, 20% rework) of machined components in the machine shop.

The design of a suitable quality improvement programme would provide the necessary means to achieve an improved level of quality. However, for the successful implementation of the quality programme it is essential to secure the correct management commitment and support. Management commitment must be coupled with total management involvement. Thus unless management faces up to its responsibilities to achieve quality no quality programme, irrespective of how good it is, will be able to solve their problems (117).

6.0 DESIGN OF THE QUALITY IMPROVEMENT PROGRAMME

6.1 INTRODUCTION

The achievement of quality improvement ultimately leads to the attainment of unprecedented levels of performance. Without a disciplined and planned approach one is limited to the troubleshooting and fire-fighting role, responsibilities will remain undefined and efforts to achieve improvement will be dissipated and wasted (118). This chapter deals with the design of a detailed Quality Improvement Programme intended for the specific purpose of improving the toolsetters' performance. This programme will enable the toolsetters' efforts and energies to be channelled in the right direction in order to achieve maximum quality and productivity improvement.

The human factors that may be involved in the introduction of remedial changes are essential to consider. These human factors may very well result in resistance to change because of social consequences and the need for altered patterns of behaviour or learning.

Two of the most important factors necessary for the successful implementation of a programme are that full training be provided for those who will be required to operate and manage it and the proper definition and delegation of responsibilities (119). However, motivation for workers is equally important since it consists of discovering and applying the stimuli needed to induce employees to meet their responsibilities with respect to quality.

6.2 USE OF BOLT/UNBOLT OPERATORS

The toolsetters are required to perform all the menial and skilled tasks necessary to complete a machine setup. The toolsetters are the most skilled workers in the machine shop and thus the design of the Quality Improvement Programme attempts to harness their full potential. An investigation into the toolsetters' activities revealed that a large percentage of them may be considered as menial tasks. Thus in order to assist the toolsetters it was decided to introduce the concept of a bolt/unbolt operator.

The toolsetters are classified as artisans or Grade "A" whereas the bolt/unbolt operators are graded as "D" operators (semi-skilled workers) according to the SEIFSA (Steel Engineering Industries Federation of South Africa) Grading System. According to their job description there are numerous tasks which they can perform in order to alleviate the toolsetters of the burden of the menial tasks. The following list covers the most general tasks:

- Changing the collet size on a machine

- Changing the feed-finger on a machine

- Removing tool holders and tools from the turret

- Inserting tool holders and tools in the turret in the correct sequence according to the tool layout

- Stripping down the machine

- After stripping down the machine the bolt/unbolt operator can take the tools that require sharpening to the toolroom and get the tool-grinder to sharpen them

- Once the tools have been re-sharpened the operator can replace them in the tool cabinets in their correct position

- The operator can remove a cam set from a machine

- The operator can fit a cam set onto a machine

- The operator can assist in external setup procedures namely, preparing all the necessary tools, cam sets, collet size etc. for setting up a machine

- Maintaining the tool cabinets in an orderly manner

- Ensuring that the correct size of material is available at the machine

- Ensuring that the correct drawing is available at the machine during a setup

- Removing tools from the slides

- Placing tools in the slides in the correct sequence according to the tool layout

- Organizing that the correct gauges are available at the machine for use by the machine operator

- Replacing the gauges in their respective positions in the tool cabinets

Thus it appears from the above list that the work load of the toolsetters will decrease enormously. However, with the introduction of the bolt/unbolt operators the toolsetters will be expected to concentrate their efforts on the more skilled activities of a setup as well as being required to accept a change of roles. The toolsetters will be encouraged to utilize their available time for developing improved methods for improving the quality of components and reducing lot sizes in order to reduce the stock of components.

6.3 REORGANIZATION OF THE MACHINE SHOP

The reorganization of the machine shop was necessary in order to facilitate with the management of both the toolsetters' and the bolt/unbolt operators' activities. At present in the machine shop there is dual accountability for both quality and output which unfortunately results in finger-pointing amongst the toolsetters and shirking off of their responsibility.

The machine shop will be divided into three separate groups (Figure 6.1). Each toolsetter in the machine shop will have his own group of machines and components for which he is responsible and accountable. Each toolsetter will be assigned his own bolt/unbolt operator who reports to him. There will be three separate tool cabinets in the machine shop, each housing the tools and gauges for its respective group of machines, where each toolsetter will be responsible for his own tool cabinet.

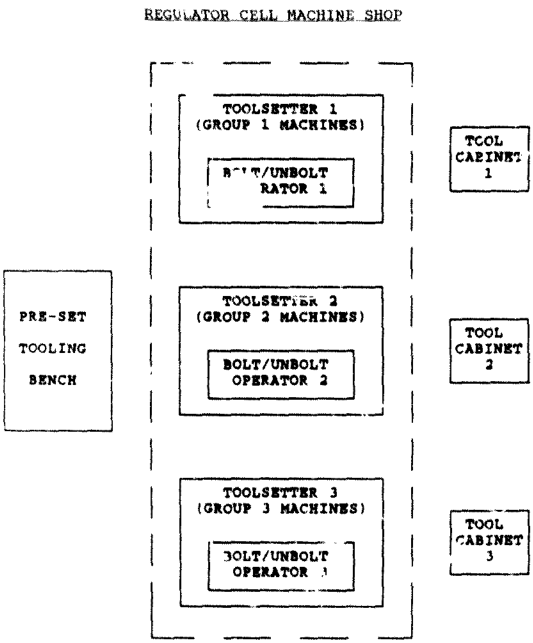


Figure 6.1 The reorganization of the machine shop.

The inclusion of a pre-set tooling bench should provide the necessary incentive to engage in the development of pre-set tooling which should be the responsibility of both the toolsetters and the production engineer.

An added advantage of organ[illegible] the machine [illegible] this manner is that job rota[illegible] be intr[illegible] both the toolsetters and [illegible] nbolt[illegible] This job rotation schem[illegible] ure [illegible] each toolsetter and his respective bol /un[illegible] will become equally competent on all th[illegible] in the machine shop and thus provide gr[illegible]ter [illegible]ction.

The cost effect of employing three bolt/unbolt operators (Grade "D") can be calculated as follows:

For a Grade "D" operator the annual cost is:

(R4.52/hr) X (45 hrs/week) X (52 weeks) X 1.333

= R14 100

where: R4.52 is the SEIFSA minimum wage rate for a Grade "D" operator (effective from 20 July '88)

The 1.333 factor ac[illegible]nts for pension, medical benefits, sick leave, canteen subsidies, UIF, etc.

Thus the total annual cost for three bolt/unbolt operators = 3 X R14 100

= R42 300

Production costs can be approximated and broken down into three main areas:

Material	60%
Overheads	30%
Direct Labour	10%

Thus the additional annual direct labour cost seems insignificant when compared to the average monthly inventory holding costs of about R1 000 000 (AFROX, '88). The benefits of improved quality and minimization of lost production output further justify this additional cost.

6.3.1 TOOL CABINETS

Each toolsetter and his bolt/unbolt operator is responsible for organizing and maintaining their tool cabinet in an orderly manner. The tools and gauges for each component must be arranged, for example by component number as well as use made of colour coding, for ease of identification. This will also enable visual inspections to be carried out for missing gauges and broken tools.

The investment of back-up tooling is suggested in order to prevent tool breakages from causing disruptions and stoppages to production. Although the cost of tooling is expensive, the cost of loss of production output and poor quality of machined components must be weighed up against the cost of this investment.

6.3.2 TOOLROOM FACILITIES

There is a centralized toolroom which provides a tool-grinding service to all four cells within the G.E.F. Previously the toolroom was manned by three tool-grinders but at present the workforce has been reduced by two-thirds and is now manned by a single tool-grinder.

As a result of the present tool-grinding capacity the response time, which is the time elapsed between handing a tool in and the tool being returned, of the toolroom has deteriorated since it cannot cope with the existing demand. The average response time was found to be approximately a week and a half.

The production services department provided the following breakdown of toolroom hours amongst the various cells (Table 6.1):

Table 6.1 Breakdown of Toolroom Hours For Cells (AFROX, '88)

	AVE. '86/'87	OCT. '87	NOV. '87	DEC. '87	JAN. '88	AVE. % OF TOTAL TOOL-ROOM HOURS.
Regulator cell	50	89	92	30	35	32.96%
Central workshops cell	23	34	54	18	18	16.62%
Torch cell	67	68	83	30	25	30.06%
Valve and Nozzle cell	43	19	27	30	18	17.48%
Other	13	17	1	-	-	2.90%
	196	227	257	108	96	100.02%

The Regulator cell has the highest average percentage of toolroom utilization. Thus with the investment of back-up tooling there will be an increasing demand on the toolroom. Therefore it is suggested that management at G.E.F recruit another trained tool-grinder in order to provide additional tool-grinding capacity.

The expected benefits from employing a second tool-grinder are as follows:

- Improved toolroom response time

- Workload in toolroom will be evenly spread

- The toolroom will be able to cope with the increasing demand more efficiently

- Reduced overtime costs

- Less stoppages in production due to broken tools

- In the event of one tool-grinder being absent due to illness then the second tool-grinder provides the necessary backup

The cost of employing another trained tool-grinder (artisan) can be calculated as follows:

For an artisan the annual cost is:

(R6.53/hr) X (45 hrs/week) X (52 weeks) X 1.333

= R20 400

where: R6.53 is the *SEIFSA* minimum wage rate for an artisan (effective from 20 July '88)

The 1.333 factor accounts for pension, medical benefits, sick leave, canteen subsidies, UIF, etc.

Thus the cost of employing a second tool-grinder should be easily off-set by the above expected benefits, some of which are immeasurable in terms of cost savings.

6.4 MACHINE SETUP PROCESS FLOW CHART

The investigation into the toolsetters' activities showed that a large percentage of their time was spent on being recalled to a previously set machine. This indicated that they were not sufficiently prepared in order to set up the machine correctly the first time within the allotted time.

Another result of the investigation showed that although they did not spend an abnormal amount of time re-sharpening tools they persistently performed this activity at the wrong time i.e., during a machine setup.

Thus the output of components from the machine shop was being severely affected by the poor performance of the toolsetters and unfortunately quality was being sacrificed for the sake of output. It is for the above and previously discussed reasons that a machine setup process flow chart was designed. A graphical representation of the process flow chart is shown on the following pages (*Figure 6.2*).

The process is designed on the *following* basis:

- The process must be as practical as possible for those involved in its implementation

- The process must be easily controlled by management of the cell

A key factor in the development of this process was the constant meetings and discussions held with the different parties concerned. The involvement of the people at the planning stage of the process was important in order to ensure the success of its eventual implementation.

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MACHINE SETUP PROCESS FLOW CHART

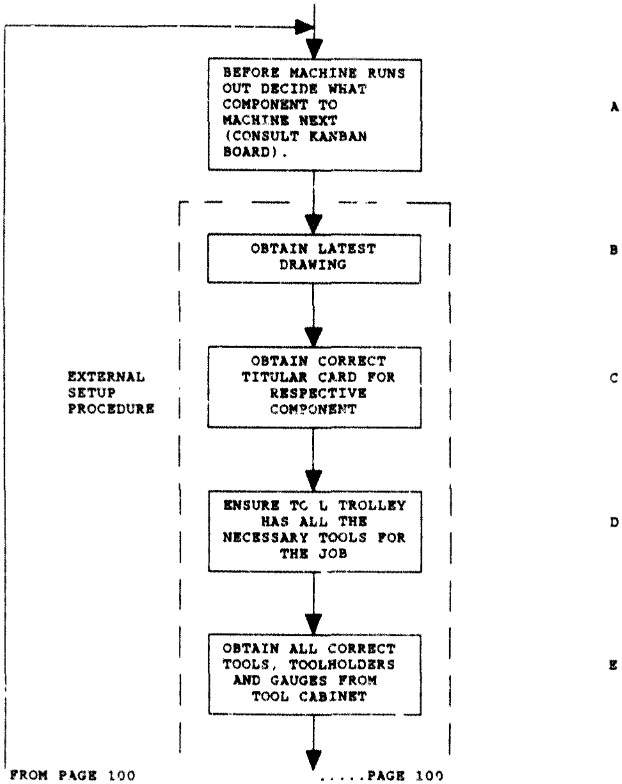


Figure 6.2 Machine setup process flow chart.

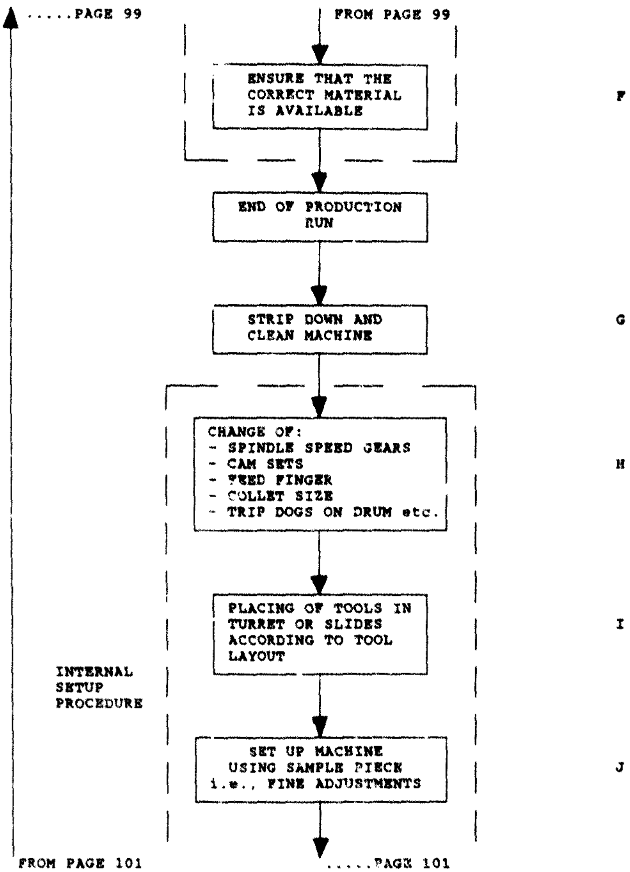
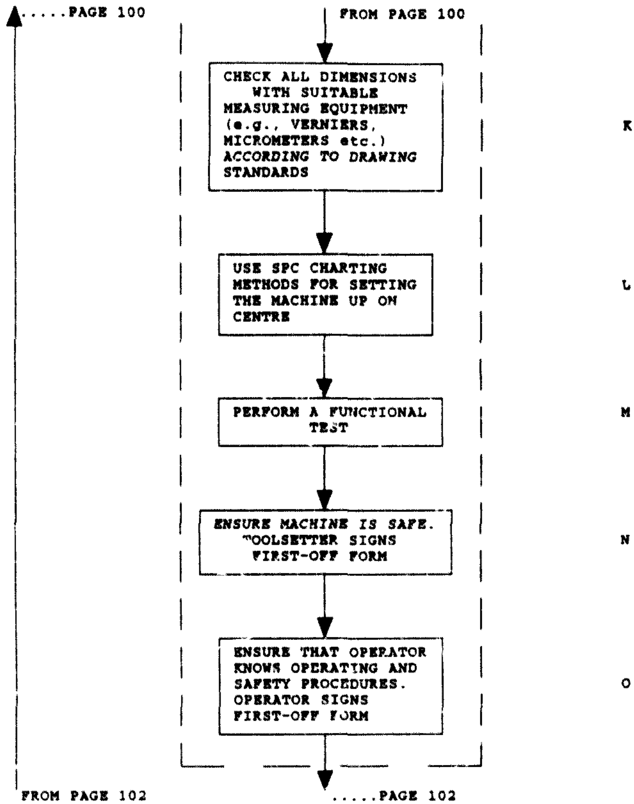


Figure 6.2 (continued).



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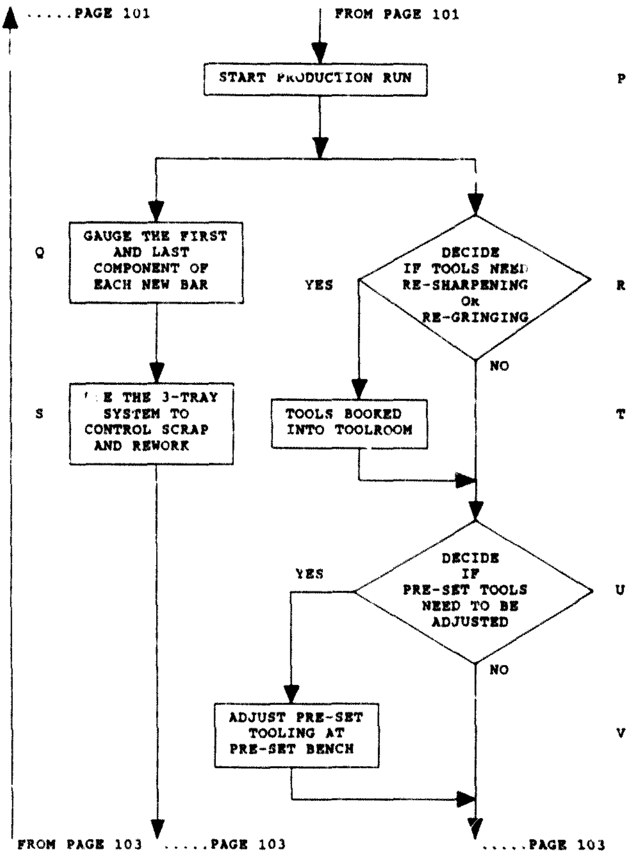


Figure 6.2 (continued).

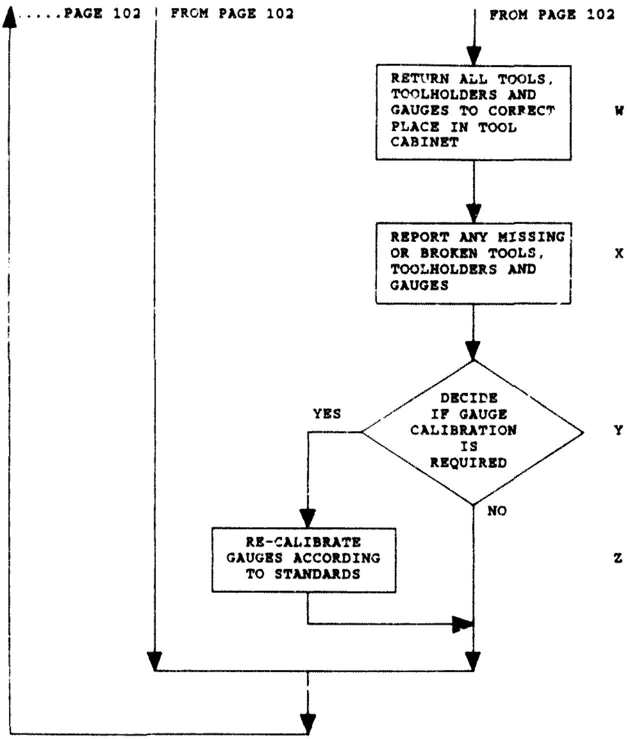


Figure 6.2 (continued).

GUIDE TO THE DELEGATION OF ACTIVITIES FOR MACHINE SETUP PROCESS

ACTIVITY	PERSON RESPONSIBLE FOR ACTIVITY
A	Foreman
B	Bolt/Unbolt operator
C	Bolt/Unbolt operator
D	Bolt/Unbolt operator
E	Bolt/Unbolt operator
F	Bolt/Unbolt operator
G	Bolt/Unbolt operator and cleaner
H	Bolt/Unbolt operator
I	Bolt/Unbolt operator
J	Toolsetter
K	Toolsetter
L	Toolsetter
M	Toolsetter
N	Toolsetter
O	Machine operator
P	Toolsetter
Q	Machine operator
R	Toolsetter
S	Machine operator and supervisor
T	Bolt/Unbolt operator
U	Toolsetter
V	Toolsetter
W	Bolt/Unbolt operator
X	Toolsetter
Y	Toolsetter
Z	Quality Improvement Facilitator

6.4.1 DISCUSSION OF FLOW CHART

The flow chart describes the logical sequence of events or activities necessary to perform a quality machine setup. Each activity is clearly defined so that the delegation of responsibility for each activity is easily accomplished. In this way, every person involved in the process will be accountable for his assigned activities. It will also facilitate the cell management in controlling the process.

On analysis of the flow chart it is evident that the toolsetters' activities occupy between 10% and 15% of the total machine setup time whereas the bolt/unbolt operators' activities occupy between 85% and 90% of the total machine setup time.

The allocation of time was based on the fact that a large percentage of activities involved in a setup may be considered as menial tasks. Thus with the introduction of the bolt/unbolt operators it would be possible for the toolsetters to be alleviated of the burden of having to perform all the menial tasks themselves. In this way, the toolsetters would be able to concentrate more on the advanced activities of a setup and thereby creating a means of ensuring consistent quality setups.

The intension of [illegible] the toolsetters of such a large percentage of [illegible] resent activities is to allow them the opportunity [illegible] become more actively involved in setup time reduction techniques. Thus the changing role of the toolsetters is important for their job security which is discussed in detail in Section 6.5.

At present the toolsetters' imagination and innovation are stifled by their mundane daily routine. Setup-time reduction is a key factor in the achievement of quality machine setups since the less time consuming a setup is, the less time the toolsetter has to concentrate on the task and thus the margin for error is reduced. Also, setup-time reduction techniques tend to simplify and regulate the tasks involved and thereby again reducing the margin for error. Setup-time reduction requires the organization and standardization of procedures so that operations can be performed in a routine manner. Thus an important reason for setup-time reduction is the quality improvements possible since operating conditions are fully regulated in advance.

Crosby (120) suggests that "Quality is ballet, not hockey." Thus a quality machine setup is achieved using a planned, organized and deliberately designed approach like ballet as opposed to hockey which is a game of haphazard actions and ever-changing situations.

The machine setup process clearly identifies the external setup procedure and the internal setup procedure. *This distinction helps to optimize the time* utilization of both the toolsetters and the bolt/unbolt operators.

The inefficiency of the machine shop at present is a result of the following three factors:

- Lack of organization

- Lack of discipline

- Lack of accountability

The objective of the machine setup process is to provide those people who are responsible for the manufacture of parts and components a framework to work within. This process is a means of instilling some form of discipline and hence organization in their work environment.

A detailed discussion of the various activities follows where suggestions for improvement and implementation are discussed.

ACTIVITY A

The Kanban board is a visual display which is used as an aid in scheduling the machining of components. The foreman is responsible for the smooth running of the machine shop and the decision as to which component to machine next is based on the Kanban display.

In the ideal Kanban system there should be no necessity to expedite any job. However, since the present system is not ideal the foreman must assume responsibility for the co-ordinating and scheduling of components. As the system progresses the foreman should place more emphasis on becoming a facilitator to the toolsetters and training them to operate the system efficiently.

EXTERNAL SETUP PROCEDURE (ACTIVITY B TO F)

External setup procedure is defined as those activities which may be performed while a machine is in operation.

All the activities of the external setup procedure have been assigned to the bolt/unbolt operators since none of the activities really requires the skill of the toolsetter. Although the toolsetter will not be directly responsible for these activities he will act as a mentor to the bolt/unbolt operator and assist him where necessary.

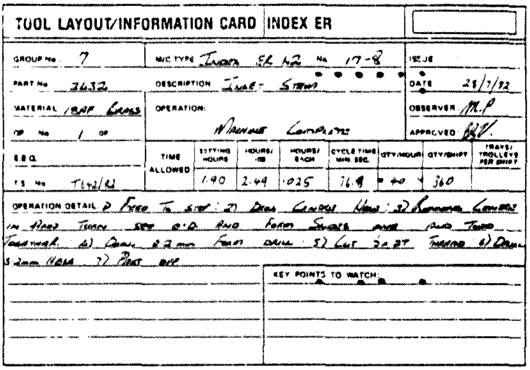
ACTIVITY B

It is imperative that the most up to date revised drawings be stored in the filing cabinet on the shop floor. Tight controls must be introduced to ensure that the most recent revisions prepared in the drawing office are also found on the shop floor. The drawing must always be available at the machine to facilitate the toolsetter in setting up a job according to drawing specifications.

ACTIVITY C

The Titular card (Figures 6.3 and 6.4) is an important aid to the external setup procedure. It contains the following information:

- Component number
- Cycle time
- Machine setup time
- Machine number
- Tools required
- Tool layout


TOOL LAYOUT/INFORMATION CARD | INDEX ER

GROUP No 7 | M/C TYPE | No 17-8 | ISSUE
PART No | DESCRIPTION | DATE 28/7/92
MATERIAL | OPERATION: | OBSERVER M.P
OP No 1 OF | | APPROVED
E.B.Q. | TIME ALLOWED | SETTING HOURS 1.90 | HOURS/100 2.49 | HOURS/EACH .025 | CYCLE TIME MIN. SEC. | QTY/HOUR 40 | QTY/SHIFT 360 | TRAYS/TROLLEYS PER SHIFT
T.S. No

OPERATION DETAIL:

KEY POINTS TO WATCH:

Figure 6.3 Front side of the Titular card.

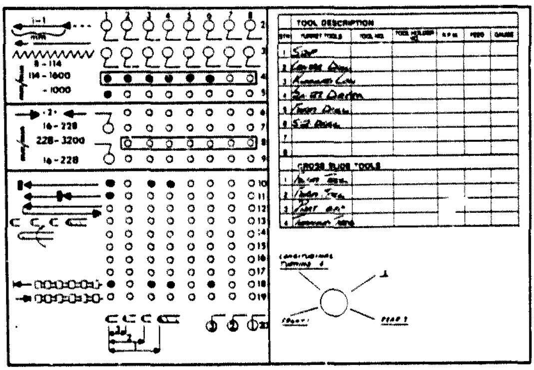


Figure 6.4 Reverse side of the Titular card.

ACTIVITY D

The bolt/unbolt operator must ensure that his tool trolley has all the necessary tools to strip down and set up a machine without having to walk away from it.

If for some reason he walks away from the machine in order to find a particular tool then it is a sign of insufficient preparation and results in unnecessarily longer setup times.

ACTIVITY E

The bolt/unbolt operator should have little trouble or none at all in obtaining the correct tools, toolholders and gauges from the tool cabinet provided the cabinet is arranged in an orderly manner i.e., according to component number.

At present a large amount of emphasis is being placed on the organization of the tool cabinets. There should be no instances of missing gauges and broken or unsharpened tools left lying in the cabinets once the new system is implemented.

ACTIVITY F

The bolt/unbolt operator must ensure that the correct size, type and quantity of material is available at the machine. It is important to ensure that no excess of material is kept at the machine since it could hide potential scrap being produced.

ACTIVITY G

Once the machine has stopped production the bolt/unbolt operator must strip down the machine. All the tools removed from the machine must be put to one side for the toolsetter to inspect and decide, only after the next setup is complete, whether they can be replaced to the cabinet or must be booked into the toolroom.

The cleaner must remove all the accumulated swarf and clean the machine so that the bolt/unbolt operator and the toolsetter can work unhindered. A clean machine also helps to c a a better working environment as well as maint the machine in better working condition.

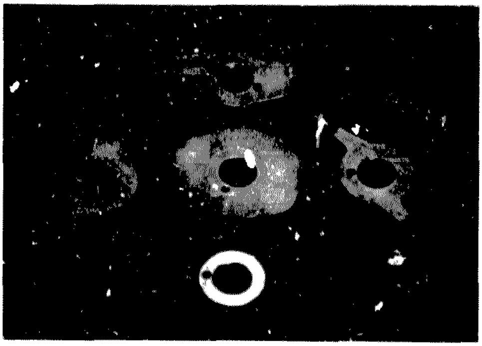
INTERNAL SETUP PROCEDURE (ACTIVITY H TO O)

Internal setup procedure is defined as those vities which may be performed only when a machine is ..oped.

ACTIVITY H

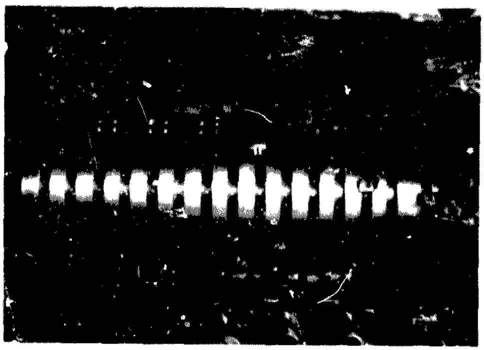
The bolt/unbolt operator should be able to accomplish these tasks easily with initial guidance from the toolsetter. Certain tasks in this activity may be improved upon or even removed in order to reduce the setup time. There are two possible improvements:

(i) By developing a common cam set for a group of components it will completely eliminate the necessity of changing cam sets (Photograph 6.1) and could reduce the setup time for each component by about 15 to 20 minutes.



Photograph 6.1 Example of a typical cam set.

(ii) A spare cylindrical drum (*Photograph 6.2*) was purchased for the hydraulic machines but is never used. By setting the trip dogs on the spare drum while the machine is in operation the setup times on these machines could be reduced. Thus this operation could be converted from the internal setup procedure to the external setup procedure.



Photograph 6.2 A cylindrical drum showing typical trip dog settings.

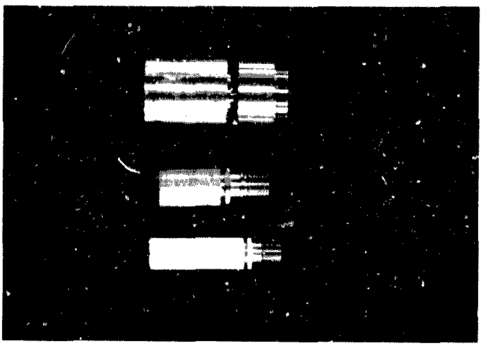
ACTIVITY I

The 'Titular car' provides the bolt/unbolt operator with the tool layout which is essential for the correct placing of tools in the turret or slides.

At this stage of the setup process the bolt/unbolt operator's activities come to a halt since he has a "D" grading and is not permitted to set a machine for another operator. Thus while the toolsetter takes over and completes the setup the bolt/unbolt operator may begin to prepare for another setup.

ACTIVITY J

Where possible the toolsetter should use a sample piece (Photograph 6.3), where the component is still part of the bar of raw material, when setting up a machine. This method provides the toolsetter with a fast reliable means of making fine adjustments.



Photograph 6.3 Sample pieces used for making fine adjustments.

ACTIVITY K

The toolsetter must accurately check all dimensions with analogue measuring equipment such as verniers, micrometers and depth gauges according to drawing specifications. Thus it is vital that the most recent revised drawing be available at the machine. This can be accomplished by removing all previous drawing revisions from the filing cabinet on the machine shop floor and ensuring that only the latest revision prepared by the drawing office is available for use.

ACTIVITY L

It is essential that the toolsetters set up the machine around the mean of the tolerance band. On a number of occasions the toolsetters would set up the machine on the lower limit hoping to compensate for tool wear. However, they were unaware of the natural variation of the machine and as a result a fair amount of scrap would be produced. Thus to ensure that the machine has been set up correctly it is suggested that the toolsetters take a sample of say five components and record the results on pre-prepared charts using verniers and micrometers.

ACTIVITY M

Prior to the start of a production run the toolsetter must perform a functional test on the component. This is to ensure that it can be easily assembled, performs the required function and to ensure the safety of the product.

ACTIVITY N

The toolsetter is responsible for ensuring that the machine is safe to operate. He must check that all tools are correctly tightened, there are plastic guards on the macnine and the bar feeding mechanism is properly secured.

When the toolsetter signs the first-off form (Figure G1) he is committing himself to the following statement: I confirm that component number, say, 18720 conforms to all specified parameters on the drawing and that I have confirmed that the operation is safe.

ACTIVITY O

The machine operator must sign the first-off form only once he has demonstrated to the toolsetter how to operate the machine properly, an understanding of safety instructions and an understanding of correct quality inspection procedures.

ACTIVITY P

Once the component conforms to specifications and the machine is safe to operate the toolsetter starts the production run and allows the machine operator to assume his duty.

ACTIVITY Q

At present the machine operator is expected to gauge the first and last component of each new bar in an attempt to control the quality of machined components. Although this is not the most reliable means of control it will suffice until such time that the operators have been sufficiently trained in Statistical Process Control (SPC) charting methods.

Statistical Process Control is an unnatural process for an operator. It is not natural, hour after hour, day after day, week after week, to measure the pieces, plot the points, perform the arithmetic, and constrain all personal actions by the results. Some operators will have difficulty with arithmetic. Many will feel a reluctance to plot points that show the process is out of control and to seek assistance in solving problems. Others will be disinclined to put written accounts of problems and actions on the charts. Statistical Process Capability and Control apply similar constraints to the natural behaviour of first line supervisors (e.g., by requiring them to stop a process and lose output while a special cause is investigated). Thus the introduction of process capability and control is a major challenge to management because of the psychological factors, technical difficulties, and financial constraints (121).

Groocock (122) suggests a list of some of the actions that have to be planned, scheduled, provided with resources, and implemented so that a company can complete a programme of Statistical Process Capability and Control (Appendix H). The list indicates the complexity and difficulty involved in successfully implementing such a programme.

ACTIVITY R

The toolsetter is responsible for making decisions as to whether tools need re-sharpening or re-grinding. These decisions should be based on standards and specifications. This decision process should preferably take place during production runs in order to optimize his time utilization.

ACTIVITY S

The three tray system should be used to control the amount of scrap and rework. It is an effective system when used since scrap and rework are clearly visible to everyone on the shop floor and can be used as a motivator for improvement. However, the tendency is usually to try and hide or remove any evidence of non-conforming components. Thus to the unsuspecting observer the scrap rate may appear to be of the order of 1% or 2%.

In order for this system to yield valid results and to be effective the machine shop supervisor must empty the trays at the end of each day and record the results on the first-off form. Using these results an approximate scrap rate may be calculated and reasonable goals for improvement may be set.

ACTIVITY T

Once the toolsetter has decided which tools need re-sharpening or re-grinding the bolt/unbolt operator can book them into the toolroom.

ACTIVITY U

At present, pre-set tooling does not exist. However, this is one area in which the toolsetters should be able to make progress in order to further reduce setup times.

The reason why the idea of pre-set tooling was included was to show these activities in the context of the setup process in the event of this tooling being developed or possibly purchased.

The toolsetter should decide if the pre-set tools need to be adjusted but those that were re-sharpened or re-ground should automatically be sent for adjusting.

ACTIVITY V

A pre-set tooling bench will be required so that the tooling can be correctly adjusted by the toolsetter for the next setup.

ACTIVITY W

Once the tools have been re-ground, re-sharpened and adjusted they can be replaced to their correct place in the tool cabinet together with all the other tools, toolholders and gauges. In this way, the tools and gauges will always be available for dispatch for the next setup.

ACTIVITY X

The toolsetter should frequently inspect the cabinets and report any missing or broken tools, toolholders and gauges. If any of these are critical to an operation and are not reported it could lead to unnecessary stoppages in production and possibly have a detrimental cascading effect on product assembly.

However, if each toolsetter were allocated a budget to cover the costs of replacing or purchasing additional tools, toolholders and gauges then their responsibility for the tool cabinets would increase. Insodoing, the expected benefits would be:

(i) Well maintained tool cabinets to permit fast setups and machining of quality components.

(ii) The toolsetters would be provided with the necessary resources for developing innovative ideas.

ACTIVITY Y

The decision as to whether re-calibration of gauges is necessary can be based on a simple time period system as follows: At the beginning of a time period a colour sticker can be placed on each gauge. At the end of the time period all the gauges can be re-calibrated and a new colour sticker can be used to indicate the beginning of a new time period.

ACTIVITY 7

The gauges must be re-calibrated by the head of the newly set up Quality Assurance department, namely, the Quality Improvement Facilitator according to pre-defined standards.

6.5 CHANGING ROLE OF THE TOOLSETTERS

A company intending to increase productivity and quality has a serious credibility problem obtaining participation from a workforce who believes that their reward will be an early place in the unemployment line. Suspicion of management motives is the biggest reason employees, whether unionized or not, fear participating in workplace improvement. *Narrow job descriptions are* seen as a lifeboat that will see them to retirement without realizing that the lifeboat has a leak (123).

The introduction of the bolt/unbolt operators results in a change in the toolsetters' role and thus a restructuring of their jobs. This changing role is important for the job security of the toolsetters. It is essential for the toolsetters to realize that they will not be made redundant with the introduction of the bolt/unbolt operators but rather a form of job enrichment will result from their recruitment. This will provide the toolsetters with the opportunity for growth and achievement. In order to assure the toolsetters that they will not become redundant and face possible dismissal, management must openly declare in a written statement or policy that workers will not be dismissed as a result of JIT or quality improvements. This formalized policy is essential for the toolsetters' job security.

The bolt/unbolt operators will alleviate the toolsetters of many of their existing menial tasks in order to enable the toolsetters to concentrate their efforts on the actual skilled task of setting a machine. Thus the toolsetters will be expected to perform consistent quality setups which will result in an improved level of quality of machined components.

The toolsetters must see some sort of advancement for themselves possibly in the form of a higher position and more money. This is vital if they are to accept this system. However, the workers must be sufficiently motivated in order for them to strive towards the accomplishment of their tasks.

The toolsetters' new role requires them to become involved in the development of improved setting and machining methods. This will enable the Regulator cell to improve quali'' but will also increase the self esteem of the tools. ers.

The toolsetters may *combine* their skills and form a group or an "A-team" of problem solvers and eliminators. The synergistic effect of this team could provide the means for continuous and rapid quality improvements within the ce'l.

6.5.1 MOTIVATION

Motivation may be defined as the process of stimulating employees to work towards goals that they consider will satisfy their needs (124). Applied to quality, motivation consists of discovering and *applying* the stimuli needed to induce employees to meet their responsibilities with respect to quality (125).

Many managers deplore what they regard as a loss in pride of *workmanship* or a decline in the spirit of 'craftsmanship' which once prevailed among workers. The implication is that workers were once self-motivating with respect to quality and that this self-motivation has been lost (126). McGregor (127) *proposed* two alternatives regarding the worker: Is the change in the worker or in the work ? These two alternatives have been given names - Theory X and Theory Y, respectively.

Under Theory X, the modern worker has become lazy, uncooperative, will not accept responsibility, etc. Hence managers must combat this decline in worker motivation through skilful use of incentives and penalties. Under Theory Y there has been no change in human nature. What has changed is the way in which work is organized. Hence the solution is to create new job conditions which permit the normal human drives to assert themselves. Managers are not unanimous in adhering to one or the other of these theories. However, there seems to be no conclusive evidence that either can outperform the other in economic terms.

When considering motivational strategies it is essential to know what motivates workers. Herzberg (128) suggests that the most important sources of motivation for employees are those factors that are intrinsic or directly related to the job itself. The growth or motivator factors that are intrinsic to the job are: achievement, recognition for achievement, the work itself, responsibility, and growth or advancement.

According to Herzberg (129) the absence of factors that are extrinsic to the job such as: company policy and administration, supervision, interpersonal relationships, working conditions, salary, status, and security can make a worker dissatisfied but their presence will not motivate him to work harder.

The only way to motivate employees is to give them challenging work in which they can assume responsibility (130). However, monetary rewards based on merit and achievement have a high degree of motivational value as opposed to general salary increases which have little, or no, long-term motivational value. Thus the changing role of the toolsetters provides them with jobs that should meet their needs for growth, recognition, achievement, and responsibility.

6.6 CONCLUSION

The identification of problems is necessary but insufficient in order to achieve an improved level of quality. The exposure of problems alone is ineffective unless accomparied by a suitable action plan for improvement.

The design of the Quality Improvement Programme attempts to address those specific elements found responsible for poor quality. In particular, a reorganization of the machine shop was proposed whereby each toolsetter would be responsible and accountable for his own group of machines and components. The concept of a bolt/unbolt operator was proposed in order to alleviate the toolsetter of menial tasks and thus enable him to concentrate his efforts on performing consistent quality setups. The introduction of bolt/unbolt operators resulted in a change of roles for the toolsetters who would become actively involved in the development of improved methods for reducing setup times. Finally, a twenty-six step machine setup process was developed, where responsibilities are clearly defined, in order to regulate the toolsetters' and the bolt/unbolt operators' activities for maximum quality and productivity improvement.

7.0 CONCLUSION

It is difficult to visualize a scenario in which the importance of quality to consumers declines. Depression or prosperity, quality will make gains for two basic reasons (131).

First, consumers expect more today, and their increasing knowledge and sophistication will be a continuing force behind that impetus. Companies supplying products and services will need to upgrade their quality systems and programmes continually to reach and satisfy more demanding customers. That trend will be accentuated as prosperity continues because consumers will be making free choices for goods and services among increasing numbers of competitive products (132).

Second, quality is the last accessible frontier for cost reduction. Although company forms and functions may change drastically in the future, those changes are essentially evolutionary. The pressures for impacting return-on-investment (ROI) with workable cost reduction efforts are intense right now and quality costs are the last costs to be addressed under known management techniques. More and more companies will be turning to quality professionals to help them with those efforts (133).

The development of the Project Report is set out in a logical fashion in order to enable the reader to appreciate the nature of the study performed and may be summarized as follows: Chapter 2 describes the manufacturing philosophy of Just-In-Time production with Total Quality Control adopted by Afrox G.E.F. The company, the product, and the problems facing the Regulator cell are outlined in Chapter 3. Chapters 4 and 5 present the techniques used to identify, highlight, and analyse the source of problems. Chapter 6 documents a detailed Quality Improvement Programme tailored to suit the needs of the toolsetters.

The study revealed that the toolsetters, who are *assigned the responsibility for* product quality, were the major contributing factor to quality problems. The Quality Improvement Programme is designed to provide the toolsetters with the necessary resources, in particular the concept of a bolt/unbolt operator was proposed, in order to enable them to reach their full potential. The twenty-six step machine setup process developed was designed to regulate the machine setup activities for maximum quality and productivity improvement. Although some of the activities are specific to the machine shop of the Regulator cell the general process may be modified and adapted to suit other industries.

The programme emphasizes the necessity for making each toolsetter responsible and accountable for his assigned group of machines and components. In this way, each toolsetter will be solely responsible for his quality and output and thereby facilitate management with the future control of the cell. This delegation of responsibility will create an awareness amongst the toolsetters that defective work can be traced back to them and therefore they will be likely to take more care and pride in their work.

The introduction of bolt/unbolt operators requires the toolsetters to become more actively involved in setup time reduction techniques. The development of improved methods will create the opportunity for further reducing lot sizes as well as the buffer stock of components between the machine shop and the assembly area.

The action plan for quality improvement has been clearly defined and the foundation for an improved level of quality has been established. However, the necessary education and training must be provided in order to reap the full benefit of such a programme.

APPENDIX A

QUALITY PHILOSOPHY OF AFROX G.E.F

AFROX

Quality Philosophy

Quality is much bigger and broader than just physical product quality. Quality improvement is about meeting the needs of all people we are involved with in such a manner that we "enhance their experience of product ownershi nd association" with our products and organisation.

The existence of delegated product quality staff does not allow anybody to abdicate from their quality responsibilities.
Quality improvement is the gas equipment business's most important objective. This is everybody's job.

The customers needs must always reign supreme for without them we have no business at all. Therefore, "the customer is king is our guiding motto.

If it comes to a trade off, quality is more important than cost or output.

However, just as charity should start at home, so should service – we must be dedicated to provide high quality service to each other, our employees and other departments and divisions within Afrox.

Quality improvement must start with an attitude of mind that refuses to accept any unsatisfactory experiences as unavoidable or inevitable and commitment to the ideals of service and perfection, through the elimination of problems at their source.

The development of trusting and mutually beneficial relationships between the customer, ourselves and our suppliers, as well as between employees and management, is the key strategy aimed at improving our quality.

Finally – the degree of excellence in quality can only be judged by the recipient of the product or service – not the provider.

"Quality is whatever the customer perceives it to be".

BRETT SACHS
Business Manager, Gas Equipment

APPENDIX B

EXPLANATION OF 3-TRAY SYSTEM

THE 3-TRAY SYSTEM

The 3-tray system (Photograph B1), which is intended to control the elements of waste of scrap and rework, operates on the following basis:

- Each machine is fitted with a stop and a run sign and an indicator which indicates how frequently a component needs inspection

- All machined components are placed into a dark green tray

- When the indicated quantity for gauging is reached, the last component machined is then inspected with the gauges supplied

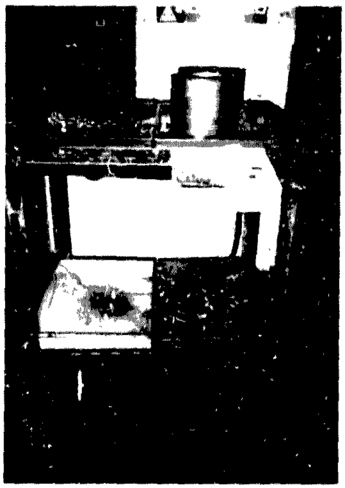
- Should the component be found defective , all the machined components in the dark green tray are transferred into a light green tray and submitted for 100% inspection

- The machine is stopped, the stop sign is displayed and the machine tool setter and supervisor are notified

- Only after the necessary adjustments to the machine have been made by the toolsetter may the stop sign be removed and the machine set in motion again

- Should the last component of the indicated quantity for gauging be found to be correct, all the machined components in the dark green tray can then be transferred to an ordinary tray ready for the next operation

- The red tray is for scrap components. Only components that have been thoroughly inspected and cannot be rectified are placed in this tray



Photograph B1 The 3-tray system.

APPENDIX C

REGULATOR DEFECT CHECKLISTS

MACHINE NO.: ____________ TOOLSETTER: ________________

COMPONENT NO.: ____________ DATE: ________________

BATCH SIZE : ______________________

MACHINED COMPENENTS DEFECTIVE LIST (PER BATCH SIZE)

1. Overall length	TOO LONG	TOO SHORT
2. Outer Diameter (OD)	TOO BIG	TOO SMALL
3. Inner Diameter (ID)	TOO BIG	TOO SMALL
4. Thread	TOO BIG	TOO SMALL
5. Thread	TOO DEEP	TOO SHALLOW
6. Hole Depth	TOO DEEP	TOO SHALLOW
7. Seating Face	TOO ROUGH	CHATTER MARKS
8. Holes not breaking through		
9. Drill bits breaking		
10. Concen-tricity		
11. Burrs		

NOTE: 1. Toolsetter must perform functional test before production run
2. Operator must sample 1st and last component of each bar.

Figure C1 Defect list for machined components.

NAME: FRANCIS
DATE: ______________

WEEKLY ASSEMBLY PRODUCTION DEFECTS (Multi-stage Regs)

1. Leak on 1st Stage nozzle												
2. 1st Stage Pin												
3. Leak on 1st Stage Bonnet												
4. 1st Stage Diaphragm												
5. Leak on 2nd Stage [illegible]												
6. 2nd Stage Pin												
7. Leak on 2nd Stage Bonnet												
8. 2nd Stage Diaphragm												
9. Leak on Bull Nose												
10. Leak on Safety Valve												
11. Leak on Indicator												
12. Faulty Gauges												
13. Faulty Body												

Figure C2 Defect list for assembled components.

APPENDIX D

WORK-SAMPLING FORM

WORK-SAMPLING FORM			
CATEGORY OF ACTIVITY	OBSERVATIONS	PERCENTAGES	COMMENTS
1. Sharpening tools			
2. Gauging components			
3. Marking off			
4. External machine setup			
5. Internal machine setup			
6. Recalled to a machine			
7. Aiding another toolsetter			
8. Stripping down machine			
9. Functional test			
10. Other			

Figure D1 Work-sampling form.

APPENDIX E

QUESTIONNAIRE FOR TOOLSETTERS

QUESTIONNAIRE FOR TOOLSETTERS

When answering the question, cross the appropriate block. If [?] is crossed, the situation you have uncovered must be considered as an item of waste and investigated.

Does the toolsetter:

1. Have the proper tools for a setup ? YES [ ] NO [?]
2. Have easy access to his tools ? YES [ ] NO [?]
3. Have to share tools ? YES [?] NO [ ]
4. Maintain the tool and gauge cabinets in an orderly manner ? YES [ ] NO [?]
5. Spend a lot of time searching for the correct gauges ? YES [?] NO [ ]
6. Spend a lot of time doing bolting and unbolting operations ? YES [?] NO [ ]
7. Have to be recalled to machines often ? YES [?] NO [ ]
8. Report common occurring problems ? YES [ ] NO [?]
9. Facilitate with maintenance of machines ? YES [ ] NO [?]
10. Report missing tools, gauges etc. ? YES [ ] NO [?]
11. Have to walk unnecessarily to fetch tools ? YES [?] NO [ ]
12. Use the right tool for the right job ? YES [ ] NO [?]

13. Know what safety aids must be used ? YES [ ] NO [?]

14. Set up machines according to drawing specifications ? YES [ ] NO [?]

15. Perform setups in the manner that he does because he has always done it that way ? YES [?] NO [ ]

16. Spend unnecessary time sharpening tools during a setup ? YES [?] NO [ ]

17. Check the first and last components of each new bar ? YES [ ] NO [?]

18. Use gauging equipment like verniers and micrometers to check tolerances on components ? YES [ ] NO [?]

19. Aid another toolsetter frequently ? YES [?] NO [ ]

20. Encounter many machine breakdowns ? YES [?] NO [ ]

21. Perform a lot of rework operations ? YES [?] NO [ ]

22. Perform unnecessary setups ? YES [?] NO [ ]

23. Encounter a lot of drill bits and tools breaking off ? YES [?] NO [ ]

24. Follow the setup procedure specified below:

Before machine runs out (External procedure):

- Determine next component to be machined ? YES [ ] NO [?]

- Obtain latest drawing ? YES [ ] NO [?]

- Check that all the correct tooling and equipment that is required for a setup is available without having to walk away from the machine ? YES [ ] NO [?]

- Check that all drills and machine tools are sharpened ? YES [ ] NO [?]

- Check that all the necessary gauges and correct materials are available ? YES [ ] NO [?]

After machine runs out (Internal procedure):

- Strip down and clean machine ? YES [ ] NO [?]

- Set up machine using sample piece ? YES [ ] NO [?]

- Perform a functional test on the component before the start of the production run ? YES [ ] NO [?]

- Check all dimensions with suitable measuring equipment ? YES [ ] NO [?]

- Ensure machine is safe ? YES [ ] NO [?]

- Ensure that operator knows the correct operating and safety procedures ? YES [ ] NO [?]

25. Regrind and sharpen all tools during a production run that are in need of grinding and sharpening and store them in their respective cupboards ? YES [ ] NO [?]

26. Have available time at the end of the day to work on setup time reduction techniques ? YES [ ] NO [?]

27. Realize the importance of quality improvement ? YES [ ] NO [?]

28. Have an understanding of the cost of non-quality ? YES [ ] NO [?]

29. Have daily records of scrap produced ? YES [ ] NO [?]

30. Set reasonable goals for quality improvement ? YES [ ] NO [?]

APPENDIX F

PRESENT AND PROPOSED PERFORMANCE APPRAISAL STANDARDS FOR TOOLSETTERS

PRESENT PERFORMANCE APPRAISAL STANDARDS
FOR TOOLSETTERS

GRADE/RATE : ....

GAS EQUIPMENT FACTORY PERFORMANCE APPRAISALS

DEPT: ....

NAME: ....

CO.NO: ....

TOOLSETTER

PERFORMANCE AREAS	RELATIVE WEIGHT	PERFORMANCE RANKING 1	2	3	4	5	6	7	REMARKS
OUTPUT/DESPATCH	35	77-80	81-84	85-88	89-92	93-96	97-99	100	
SCRAP/QUALITY	25	> 3,1	2,6-3	2,1-2,5	1,6-2	1,1-1,5	0,6-1	0-0,5	
CONTRIBUTION	25	1	1	2	2	2	3	3 >	
ABSENTEEISM (DAYS)	10	> 10	9-10	7-8	5-6	3-4	1-2	0	
HOUSEKEEPING	5	U/A	POOR	B/AV	AVE	GOOD	V/GOOD	EXCL.	

NOTE ON CONTRIBUTION

CONTRIBUTION IS APPRAISED AGAINST THE FOLLOWING

1. METHOD IMPROVEMENT RECOMMENDATIONS TO REDUCE STANDARD TIME.
2. QUALITY IMPROVEMENT RECOMMENDATIONS TO REDUCE REJECT PERCENTAGE
3. COST SAVING RECOMMENDATIONS
4. SAFETY IMPROVEMENT RECOMMENDATIONS

A MEASUREABLE RESULT MUST BE OBTAINED ON ANY OF THE RECOMMENDATIONS

* ABBREVIATIONS
- U/A = UNACCEPTABLE
- P = POOR
- B/AV = BELOW AVERAGE
- A = AVERAGE
- G = GOOD
- V/G = VERY GOOD

DEPT. HEAD : ....

SUPERVISOR : ....

EMPLOYEE : ....

DEPT: ....

TOOLSETTER

		REL. WEIGHT	1	2	3	4	5	6	[illegible]	
PERF. AREAS	1.	35	35	70	105	140	175	210	245	1ST APPRAI
" "	2.	25	25	50	75	100	125	150	175	
" "	3.	25	25	50	75	100	125	150	175	
" "	4.	10	10	20	30	40	50	60	70	
" "	5.	5	5	10	15	20	25	30	35	

			1	2	3	4	5	6	7	
PERF. AREAS	1.	35	35	70	105	140	175	210	245	2ND APPRAI
"	2.	25	25	50	75	100	125	150	175	
" "		25	25	50	75	100	125	150	175	
" "		10	10	20	30	40	[illegible]	60	70	
" "	5.	5	5	10	15	20	25	30	35	

			1	2	3	4	5	6	7	
PERF. AREAS	1.	35	35	70	105	140	175	210	245	3RD APPRAI
" "	2.	25	25	50	75	100	125	150	175	
" "	3.	25	25	50	75	100	125	150	175	
" "	4.	10	10	20	30	40	50	60	70	
" "	5.	5	5	10	15	20	25	30	35	

			1	2	3	4	5	6	7	
PERF. AREAS	1.	35	35	70	105	140	175	210	245	4TH APPRAIS
" "	2.	25	25	50	75	100	125	150	175	
" "	3.	25	25	50	75	100	125	150	175	
" "	4.	10	10	20	30	40	50	60	70	
" "	5.	5	5	10	15	20	25	30	35	

2	3	4	5
270/350	355/440	445/595	600/700
39/50%	51/63%	64/85%	> /86%

	1st Appraisal		2nd Appraisal		3rd Appraisal		4th Appraisal		GRAND T	
	TOTAL	RATING	TOTAL	RATING	TOTAL	RATING	TOTAL	RATING	TOTAL	RA
TOTAL OBTAINED										
DEPT. HEAD										
SUPERVISOR										
EMPLOYEE										
DATE										

PROPOSED PERFORMANCE APPRAISAL STANDAR[illegible]

FOR T[illegible]ERS

PERFORMANCE APPRAISAL STANDARDS FOR TOOLSETTERS

Objective. Develop objective standards which will be used by cells to measure and give recognition to the performance of the toolsetters.

Requirements

a) What does Management require from the Toolsetters?

Management require the setters to ensure that the assembly area is supplied with quality machined parts (no scrap) with a minimum (ideally zero) stock of components.

b) What do the setters require from Management?

The setters require Management to give them due recognition for their achievements and to reward them with a good pay packet.

In order to meet the above two requirements, Management must

- develop objective standards to measure the setters performance and give them the recognition they deserve;
- reduce lot sizes ↄ encourage and reward setters for developing improved method: ich will enable the G.E.F. to improve quality and reduce stock of componen:s while increasing the self esteem of the setters.

Proposal

In order to try and meet the above requirements, the following two-part proposal has been developed.

- A formal appraisal will be used to measure the setters performance in the areas of
  - Quality
  - Output
  - Work related contributions
  - Absenteeism
- A Cell Setup Reduction Team (SRT) will be formed, where the team members will receive monetary compensation for improvements which they have implemented.

Each of the ab .e two parts will now be discussed in detail.

/1. Formal Appraisal...

I. FORMAL APPRAISAL

The proposed formal appraisal is designed for a JIT environment with the following requirements:

- Every setter in a cell has his own group of machines and components for which he is responsible and accountable. This means that there is no dual accountability for quality and output as is presently the case in certain cells.

- A pull system and associated Kanban board exists for manufactured components. The Kanban board must be divided to show which setter is responsible and accountable for which machines and therefore components, tool cupboards, gauges and cooling layout sheets/boards.

a) Quality and output Measurement

As was stated initially, the prime requirement of Management is that the setters keep the assembly areas supplied with quality parts, while the stocks of components is kept at a minimum. This means that, as an output standard, the setter is accountable only if the assembly area come to a standstill due to

(i) poor quality of machined parts
(ii) no parts due to inefficient setting procedures (not lack of raw material, etc.)

Line-Stoppage Measurement

To provide an objective measurement, assembly stoppages must be recorded against the particular setters name. In order to simplify what could be a very complicated procedure, I recommend that only the number of daily stoppages (as opposed to the actual stoppage time) be recorded by the foreman. This can be done in the form of a graph which will be displayed in the foremans' office (see example). This will result in fewer disputes and will ensure that the graph is visible to all. Obviously, only stoppages for which the setter can be held accountable must be recorded.

Definition. A line-stoppage is when the assembly area comes to a standstill due to a lack of parts (i.e. none in the bins or on the machine) or due to poor quality (scrap) parts.

Quality Problems

As we believe that "quality" is our most important objective, the following should be implemented.

/....

If a quality problem occurs in a cell, irrespective of how big or small it may be, it should be treated like an injury due to an accident in the factory. This means that the Cell Manager, Foreman, Production Engineer, Q.C. Foreman and the Setter must be called together immediately to determine the root cause of the problem and to implement changes to ensure that the same problem can never re-occur. The Q.C. Foreman will keep minutes of the Quality Incident meetings in book form and, as for accidents, each incident must result in minuted and delegated action plans. These minutes must not be dropped until the action is completed and signed off by the Q.C. Foreman.

It is important to note that the Setter is SOLELY accountable for the quality of components where quality is defined as "conformance to requirements (specifications)". If non-conformance components are discovered in assembly (or via the complaints system) the Setter who set the machine, is accountable and will be penalised in his appraisal. This obviously requires setting traceability, which can be achieved by having setters accountable for a specific group of machines and also by having serial numbered products.

Due to the importance of quality and output, this measurement should have a weighting factor of 60% in the Setters appraisal.

b) Work Related Contributions

As is the case presently, Setters will receive recognition for contributions when their performance appraisal is done. However,

(i) Recognition will only be given for suggestions implemented by the Setter.

(ii) Only work related suggestions will be accepted e.g. setup reduction, quality, machine reliability/maintenance, design change suggestions, lot size reduction, etc.

As Setters are members of the SRT, the improvement which the SRT has implemented will count as contribution on each of the Setters performance appraisals.

Work related contributions should have a weighting factor of 30% in the appraisal.

c) Absenteeism

This measurement will not change, except that its weighting factor will be 10%.

DUE DATES FOR APPRAISALS

Appraisals MUST be completed by the following dates each year and the results submitted (in summary form) to the Factory Manager.

31 January
31 May
30 June

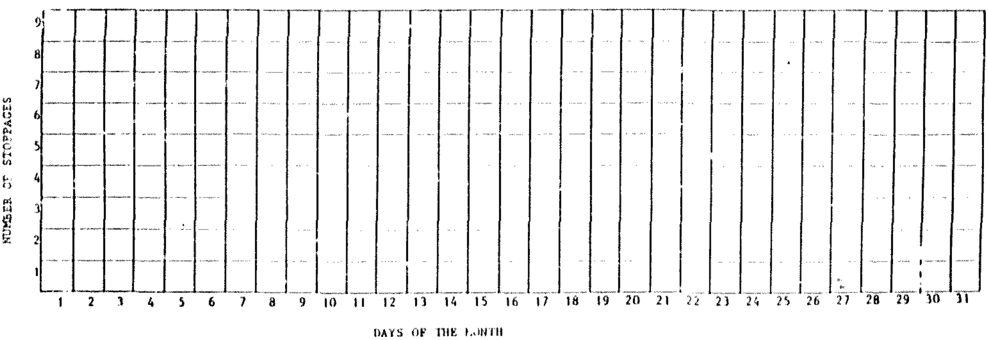
A S S E M B L Y - L I N E   S T O P P A G E S

MONTH.................

CELL..................

SETTER................

TOTAL STOPPAGES FOR THE MONTH.........



TOOLSETTERS PERFORMANCE APPRAISALS

Grade : .... Cell : ....

Name : .... Employee No. : ....

Setter : .... Date : ....

Foreman : .... Final Ranking : ....

Performance Area	Measurement	Relative Weight (%)	Performance Ranking & Point Value			
			2	3	4	5
Output/ quality	Total number of line stoppages per appraisal period (4 months)	60	45+	30-44	15-29	0-14
			120	180	240	300
Contribution	Total number of suggestions implemented	30	0-2	3	4	5+
			60	90	120	150
Absenteeism	Total number of days absent	10	6+	4-5	2-3	0-1
			20	30	40	50

Total number of Points: ....

Final Ranking of Setter

2	3	4	5
<250	251-349	350-439	440-500

Setter : .... Date : ....

Foreman : .... Final Ranking : ....

Performance Area	Measurement	Relative Weight (%)	Performance Ranking & Point Value			
			2	3	4	5
Output/ quality	Total number of line stoppages per appraisal period (4 months)	60	45+	30-44	15-29	0-14
			120	180	240	300
Contribution	Total number of suggestions implemented	30	0-2	3	4	5+
			60	90	120	150
Absenteeism	Total number of days absent	10	6+	4-5	2-3	0-1
			20	30	40	50

Total number of Points: ....

Final Ranking of Setter

2	3	4	5
<250	25 -349	350-439	440-500

Setter : .... Date : ....

Foreman : .... Final Ranking : ....

Performance Area	Measurement	Relative Weight (%)	Performance Ranking & Point Value			
			2	3	4	5
Output/ quality	Total number of line stoppages per appraisal period (4 months)	60	45+	30-44	15-[illegible]	0-14
			120	180	240	300
Contribution	Total number of suggestions implemented	30	0-2	3	4	5+
			60	90	120	150
Absenteeism	Total number of days absent	10	6+	4-5	2-3	0-1
			20	30	40	50

Total number of Points: ....

Final Ranking of Setter

2	3	4	5
<250	251-349	350-439	440-500

APPENDIX

FIRST-OFF FORM

SANFIRE GAS EQUIPMENT FACTORY

DAILY QUALITY / SAFETY / PRODUCTION REPORT

DATE: ....

TITLE: ....

MACHINE NO.: ....

CYCLE TIME: ....

DRAWING NO.: ....

M. NO.: ....

OPERATION: ....

ORDER QTY: ....

OPERATOR: ....

SET UP COMPLETED: ....

QUALITY APPROVED BY: ....

OPERATOR DEMONSTRATED UNDERSTANDING OF CORRECT QUALITY INSPECTION PROCEDURES

....

OPERATOR'S DEMONSTRATED UNDERSTANDING OF SAFETY INSTRUCTIONS WITNESSED BY:

....

SAFETY CHECKLIST ACTIVITIES SUCCESSFULLY COMPLETED BY

....

DATE	QUANTITY PRODUCED	SCRAP	ACHIEVED HOURS	SHIFT HOURS	EFF. %	REMARKS

Figure G1 First-off form.

APPENDIX H

ACTIVITIES FOR IMPLEMENTING A STATISTICAL PROCESS CAPABILITY AND CONTROL PROGRAMME

(Source: Groocock, J.M., The Chain of Quality: Market Dominance Through Product Superiority, John Wiley and Sons, 1986, pp 244-245)

Table H1 Activities for Implementing a Statistical Process Capability and Control Programme

Responsibility	Activity
Division manager	Decide to implement programme.
Division manager	Convince department heads he is serious.
Division manager	Establish multifunctional implementation committee and appoint programme manager.
Programme manager	Prepare initial implementation schedule.
Functional managers	Agree schedule and assess resources required.
Division manager	Agree schedule and resources.
Human relations manager	Get support of supervisors.
Consultants or internal trainers	Determine numbers of managers, engineers, supervisors, operators and inspectors who require training. Conduct training, taking account of education level of trainees.
Quality and manufacturing engineering	Identify all existing processes. Determine: which have had capability measured; which are incapable; which are under statistical process control; which require capability measured; and which require statistical control.
Purchasing and quality engineering	Communicate to suppliers of materials and components the desirability of instituting statistical process capability and control.
Quality and manufacturing engineering	Conduct process capability studies on all designated processes.
Manufacturing and quality engineering	Provide necessary additional and better gauges.

Responsibility	Activity
Manufacturing and quality engineering	Determine special causes of variation. Improve processes. Remeasure capability.
Manufacturing engineering	Revise process specifications.
Product engineering and marketing	Examine tolerances of design, which are beyond the capability of processes, and widen when possible. Conduct necessary negotiations with customers.
Manufacturing engineering	Establish statistical process capability requirements with vendors of machines.
Purchasing	Convince machine vendors of seriousness of this requirement.
Manufacturing engineering	Provide new machines and processes as required.
Manufacturing and quality engineering	Perform acceptance capability tests of new machines.
Quality and manufacturing engineering	Provide statistical process control methods for machine operators. Change time standards as necessary.
Manufacturing supervisors	Institute start of statistical process control and continually evaluate application.
Machine operators	Change from traditional to statistical methods of process control.
Supervisors, manufacturing and quality engineering	Respond rapidly and effectively to operator problems.
Manufacturing engineering	Determine need for and institute: improved machine maintenance, tool change, cycle time, etc.
Quality engineering	Monitor defect levels from the original and modified processes of items, and of the outgoing product.

Responsibility	Activity
Quality engineering	Modify inspection and test plans.
Inspection supervisor	Implement modified inspection and test plans.
Quality manager	Each month report progress of the implementation versus the scheduled milestones to the to the division and plant managers.
Marketing and quality managers	Inform customers about progress made in implementing the programme and the resulting improved product quality.
Division and plant managers	Follow progress of programme and continually communicate to all levels - managers, engineers, supervisors, operators, and inspectors - the importance of the programme.

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