SETUP TIME REDUCTION IN A JUST-IN-TIME MANUFACTURING ENVIRONMENT

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DECLARATION

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

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24TH day of JUNE 1988.

ABSTRACT

Setup time reduction is an essential activity used to prepare the facility for just-in-time (JIT) manufacturing; the aim of which is to assist in meeting the desirable manufacturing requirements of delivering low cost quality products on time. (20) The Japanese have shown that setup reduction eliminates the need for setup skills and producing in large or "economic" lot sizes. (1) It is usually the case that preperation and adjustments, which usually account for 95% of the setup time, can be externalised or eliminated. (1)

The overall production process should be examined before setup times are reduced on existing equipment. (2) Considerations include group technology, setup sequencing, dedicated machines identifying bottlenecks (stated by OPT) and the 80/20 rule. A training programme should be initiated where setup reduction teams, consisting of production operators, setters, foremen line supervisors and production engineers, are educated in JIT manufacturing, the changing business environment and recording and analysis methods. (31)

A theoretical approach to setup reduction has been formulated by Shigeo Shingo. (1) During the preliminary stage internal and external setup are not distinguished, therefore this stage involves a work/time study of the existing setup and activity categorisation. From this, potential externalisation or elimination of setup operations can be determined. The first

stage of setup reduction involves seperating internal and external operations. During this stage tooling organisation and pre-preperation activities are converted to external operations. The second stage of setup reduction involves converting internal to external setup. A simple Pareto analysis is conducted to determine time consuming activities, which are then tackled first. This stage includes equipment modification, standardisation of procedures, parallel operations and elimination of adjustments. The third stage involves streamlining setup operations by improving operations and initiating setup practise sessions. All ideas should be documented and implemented immediately.

Setups should be kept in mind when buying new equipment, however it is usually more beneficial to modify existing equipment in-house. (4) Setup reduction costs are low at first for large time reductions, but costs become high yielding small returns during the final stages of the programme. (31) It may be beneficial to introduce an incentive scheme where members of setup teams receive recognition and a financial reward for implemented ideas. (34)

A setup reduction programme was implemented at Viro Locks, the aim of which was to illustrate the theoretical approach to setup reduction. Setups were reduced here on a transfer machine by 67%, 50% time savings being achieved at low/no cost. A survey was performed involving 16 leading JIT companies, where it was found that the majority (14 companies) have initiated a setup reduction programme. However many of these companies have only limited experience in setup reduction and, according to the survey, require 4-5 years to reach the final stages of setup reduction.

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DEFINITIONS

Setup - The physical changes a work centre experiences when changing from the manufacture of one product to another.

Setup time - Elapsed downtime between the last production piece of part A and the first good production piece of part B.

Internal Setup - Setup functions performed when the machine is stopped.

External Setup - Setup function performed when the machine is running.

Time to set up machine = Internal Setup + External Setup Time

≠ Setup Time

Attachments - All devices which may be detached or altered in configuration during setup but which, when running, are attached to the machine.

Tools - Devices used during setup for attaching, detaching or adjusting; but when the machine is running they are not attached to the mechanism that directly performs the function of the machine.

Tooling - A combination of attachments and tools.

Material - That which is operated on to go into the product being made; referred to as the workpiece.

Lead Time - Processing time + Queue time + Setup time + Move time (21)

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1. INTRODUCTION

A definition of manufacturing has been put forward by Bicheno as follows: " An integrated system for the production of products which uses people to progressively solve problems which stand in the way of all material related operations taking place economically at the last moment, with no wastage, exactly to customer requirements of performance and delivery". (25) In essence the desirable characteristics for manufacturing include :

- short lead times
- high or perfect quality
- producing to market rates of demand
- minimum wastage of materials
- elimination of all activities that do not add value

Although these are idealistic, the Just-in-time (JIT) manufacturing philosophy captures and integrates these characteristics. (25) Lee has suggested that the JIT philosophy demands that we make the minimum necessary units in the smallest possible quantities at the latest possible time. (31) Kelleher has stated that an examination of Japanese manufacturing has revealed more than just innovative approaches to production and inventory control. (2) Factors such as product design, process planning, quality assurance, preventative maintenance and management (to mention but a few) have all contributed to the Japanese success story. They have accomplished much more than excellence in these specific disciplines; they have succeeded in integrating them so they complement one another in the achievement of company objectives. (2)

Bicheno suggests that JIT manufacturing can be divided into two *subsystems: one concerned with creating* the structure in which JIT can operate (figure 1.1) and the second carrying out the actual processes (figure 1.2). (25) These two subsystems conceptually lie between the supplier and customer subsystems, and the whole collection makes up the "JIT Ecosystem". The components of each subset forms an interacting and mutually reinforcing set (figure 1.3). These components are the minimum necessary activities for the JIT manufacturing system to be complete.

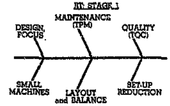


FIGURE 1.1 : Stage 1 of JIT Framework (20)

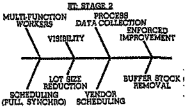


FIGURE 1.2 : Stage 2 of JIT Framework (20)

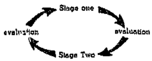


FIGURE 1.3 : Interrelationship Between Stages 1 & 2 (20)

Bicheno states that since JIT is an ongoing cycle of improvement, there are a large number of possible paths along the road of improvement. For example reducing setup times may allow lot size reduction which may allow improved quality allowing buffer stock removal, allowing improved layout allowing better "pull" type scheduling which exposes maintenance problems for improvement, which encourages the wider use of multifunctional workers and so on. (25)

Referring to figures 1.1 and 1.2, the following discusses how setup reduction affects and interacts with other important JIT activities.

(i) DESIGN AND FOCUS

Wickham Skinner has stated that each self contained focused factory should be internally consistent with regard to product volumes, quality requirements, flexibility, tooling, types of equipment and skill levels. (25) Under JIT, design must be undertaken so as to control or reduce parts proliferation and improve ease of manufacture. (25) Taking setups into account in the design stage encourages standardisation of setup activities and tooling. The activity of setting up appropriate product families (group technology) aids setup reduction by confining similar tooling and equipment within specific groups.

(ii) TOTAL QUALITY CONTROL (TQC)

Important principles include prevention rather than inspection, quality at the source, process control and operator involvement. (25) All these can be accomodated at the setup stage if trial and error is removed from the setup procedure, allowing the first-off component to be free of any defects. Furthermore, operators who set up their own machines can quickly identify causes of quality problems. (25)

(iii) PREVENTATIVE MAINTENANCE

The usual pattern is for plants to work two shifts with a two or three hour gap between them. (5) This gives time for both preventative maintenance and overtime work if they are needed to meet the schedule. Preventative maintenance can also be used as a means of checking the condition and availability and condition of tooling before each setup. (25) Operators can aid preventative maintenance by setting up their machines as much as possible. This gives him a better understanding of how the machine works, thus allowing him to pay some degree of attention to the machine while it is running. For example, he should be able to detect a change in noise or performance patterns, thus bringing attention to the problem early. (4)

(iv) SMALL MACHINES

This JIT principle states that the smallest possible machine consistent with quality requirements be chosen. (25) This makes setups considerably easier where operators may even set up their own machines (multifunctional workers). Furthermore, fewer setups are usually required on simple machines since these are designed to handle only a small group of specific parts. It may even be feasible to have smaller machines permanently set up, thus eliminating setups entirely.

(v) BALANCE

This is the concept of achieving a uniform plant load and producing a little each day to match market rates, rather than large lots periodically. Since the improved setup can be designed to have a standard time, regularity of events is more feasible and scheduling becomes easier. (25) It becomes possible to balance capacity by reducing setup times on bottleneck work centres.

(vi) LOT SIZE REDUCTION

Smaller lot sizes facilitate early identification of quality problems, improved layouts and less cash tied up in 'work-in-process inventory and storage space. (25) Lot size reduction is usually only achieved successfully after setup reduction since many more setups would be required for a similar production throughput. This activity can be used to build in compulsory improvement and includes the deliberate withdrawal of inventory in order to expose problems. (25) This aids setup reduction by exposing bottlenecks and thus allowing setup reduction to be implemented in the most beneficial areas.

The setup reduction programme can be divided into a hierarchy of activities as follows: (30)

(i) Procedural level, which includes setup reduction methods, tooling arrangements and maintenance, organisational methods and documentation. (section 4.3)

(ii) Structural level, which examines the production structure and includes layouts, part family groupings, sequencing and bottlenecks (section 4.1).

(iii) Technological level, which looks at product design methods, fixtures and new equipment (section 4.4).

The aims of this dissertation are as follows :

(a) To provide a setup reduction implementation guide (using a case study as an example).

(b) To show benefits of setup reduction as part of JIT manufacturing (with reference to a case study).

(c) To determine how advanced a representative group of South African companies (currently implementing JIT) are in the practice of setup reduction.

It should be noted here that the time factor was a limitation on this dissertation. Setup reduction may take many months or even years to develop through trial and error, considerably longer than the duration of this dissertation. Therefore in the case study example, implementation was in the initial stages and certain results had to be estimated. Although immediate benefits have been achieved, much work is required to further advance the setup reduction programme.

2. SETUP REDUCTION BY INDUSTRY TYPE

Classification of production by industry type is stated by Schonberger as shown in figure 2.1. (5)

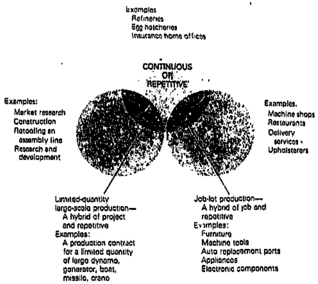


FIGURE 2.1 : Production by Industry Type (5)

In the history of production there has been a tendency to move toward more continuous or repetitive production; in other words to more streamlined operations. Discreet job-lot producers - even the service sector - also want the advantage of smooth flow operations; that is , they want high efficiency, low inventory, low labour cost, uniform quality, simple planning and control and few surprises. (5)

2.1. CONTINUOUS PRODUCTION

This segment usually consists of the process industries where raw materials enter as flows and end products emerge as units. If a plant is able to change its production line to run say *different blends or container sizes, short setup times and* rigorous maintenance are important since production will stop when the line stops. Using conventional methods, a production line changeover may take days, which may include completely cleaning out equipment. Therefore the company that can make changes fast has an edge. (5)

Some examples of relevant setup time reduction techniques are as follows: (1,5)

(i) In a paint production line it is almost certain that tanks must be cleaned when there is a colour change. To save time a buffer tank could be used where a clean tank can be quickly attached and the old tank removed and cleaned externally.

(ii) In a spaghetti factory the spaghetti must pass through a die to attain its shape. *Quick die changeovers would* apply (discussed in section 4.4)

(iii) In a chemical process industry part of the setup may involve changing pressures, temperatures, feedrates, valve mix settings and so on. If these are properly documented settings can be made with no after-adjustments necessary.

In the case of the process industry where it is likely that the entire production line will stop during a setup, it may be necessary to use a setup team to tackle each section of the line simultaneously. (5) By reducing setup times substantially smaller production runs could be made in a move towards JIT production.

2.2. REPETITIVE PRODUCTION

This is similar to the process industry with the distinction of production being measured in whole units. It is useful to think of repetitive in relative terms. Highly repetitive is the most similar to continuous flow processing; the product rarely stops moving since there is little storage and in-process inventory. In order to maintain a low in-process inventory in a highly repetitive environment it is necessary to produce in small lot sizes more frequently, thus lowering holding costs. (5) Subsequently setup times must be effectively reduced since the frequency of setups will increase with reduced lot sizes.

2.3. JOB SHOP / JOB-LOT PRODUCTION

In job shop or job-lot production there is a changing mix of jobs produced in moderate or small quantities. In such a production environment inventory plans are translated into scheduled manufacturing orders, where order priorities are kept current and progress data is collected and processed for control purposes. (5) Usually new setups for different operations occur at different work centres. Operations for various jobs are seperately planned, scheduled and controlled since: a special setup crew may need to be on hand, materials handling may be needed, inventory may build up before an operation, or there may be a choice of operations for different jobs queued at a given workcentre. (5)

If jobs are widely varied, setups will tend to be dissimilar and will depend largely on trial and error. However unwanted surprises can be removed from setups, such as locating missing tooling. Furthermore, setup time is an element of lead time and should be managed correctly in order to facilitate more accurate scheduling. (7) This approach has been taken by John Deere who produce in a job shop environment. They have reduced setup times by 30% throughout the factory merely by improving tooling organisation. (44)

2.4. PROJECT / LIMITED QUANTITY LARGE SCALE PRODUCTION

Project and limited large scale production are similar to job shop and job-lot production. They also require planning and sequencing, time estimating, scheduling and reporting and updating. The only difference is that path analysis is unique to project operations where PERT or CPM (critical path method) is used. (5)

In order to perform a critical path analysis on the system it is necessary to estimate the time required to complete each activity in the network. It is more difficult to estimate times for projects than for repetitive or job shop operations because of project uncertainty and task variability. Usually a technical estimate is obtained from those in charge of each activity. (5) Setup times are included in the lead time estimates and similar to the job shop environment, tooling organisation can eradicate unnecessary setup delays.

When the work structure is analysed it is not uncommon that certain tasks are similar for different projects. (5) For example manufacturing window frames or building floors may be repetitive. A house is considered a project, however building houses is so routine that it is more like repetitive than project production. (5) Therefore setup reduction techniques could be applied to common tasks throughout the duration of the project.

2.5. SURVEY OF SOUTH AFRICAN COMPANIES

The aim of this survey is to determine the extent of setup reduction implementation in South Africa. The survey included companies in South Africa which are known to be leaders in just-in-time manufacturing. A questionnaire was drawn up which investigates general aspects of respective setup reduction programmes. It was decided to conduct interviews with relevant managers and industrial engineers (with respect to the questionaire) over the telephone. This avoided confusion as to answers given as well as being able to gauge how much managers know about setup reduction. In addition it was possible to learn about aspects of setup reduction which did not appear on the questionaire.

2.5.1. THE QUESTIONAIRE

The questionaire is divided into three parts (appendix A1). Section A addresses the overall production process and classifies companies according to specific industry types.

Section B shows how the company approached setup reduction and how this was used to achieve just-in-time goals. The human factor is also addressed here with reference to involvement, education, attitudes and reporting systems. Finally it is shown what physical improvements have been made. From this it is possible to gauge how far the company is into the setup reduction programme. Section C applies to companies which have not yet implemented setup time reduction and investigates if setup reduction is still relevant in the future.

2.5.2. ANALYSIS OF RESULTS

Results of the setup reduction survey are summarised in table A.1. of appendix A2. The most important setup reduction activities were included in this table. Results were analysed and trends are shown in table A.2. Observations of tables A.1 and A.2 are further discussed in appendix A2.

2.5.3. CONCLUSIONS

It is evident that the majority of leading JIT companies in South Africa realise the importance of setup time reduction in order to achieve overall JIT objectives. A large percentage of these companies have chosen the correct implementation approach. However setup time reduction is apparently a fairly new activity in South Africa and most of these companies are not well advanced in this practice. Only two isolated cases are as yet in a position to extend the full advantages of setup reduction to benefit the company as a whole. Most managers interviewed foresee a time scale of 4-5 years before respective setup reduction programmes are well advanced.

3. CONVENTIONAL AND JIT SETUP STRATEGIES

3.1. CONVENTIONAL SETUP STEPS

Setup procedures are often thought of as infinitely varied, depending on the operation and type of equipment used. However even for vastly different machines, the setup procedure is basically the same and comprises of the following steps as shown in table 3.1.(1)

TABLE 3.1 : Times For Conventional Operations (1)

OPERATION	% OF TIME
- Preperation of materials, tools and attachments. (jigs, gauges, etc.)	30
- Mounting and removing attachments	5
- Measurement, settings and callibration	15
- Trial runs and adjustments	50

(i) PREPERATION

This ensures that all materials, tools and attachments are where they should be and are functioning correctly. Included here is the function of returning old tooling to stores, as well as cleaning the machine.

(ii) MOUNTING AND REMOVING ATTACHMENTS

This includes mounting of attachments (drills, dies, blades, etc) for the upcoming job and removal of attachments for the complete job.

(iii) MEASUREMENTS, SETTINGS AND CALIBRATIONS

This refers to all functions required to produce a production piece eg. centering, dimensioning, measuring, operating conditions, etc.

(iv) TRIAL RUNS AND ADJUSTMENTS

This refers to changes made after the test piece has been machined. The greater the accuracy of steps (ii) and (iii), the shorter the time for step (iv) will be. The frequency and length of test runs and corresponding adjustments depend largely on the skill of the setter.

It should be noted that steps (iii) and (iv) conventionally require a high level of skill. In this case the setter usually performs these tasks, while the operator is diverted to another job or remains idle. Furthermore it is during these two stages that errors or discrepencies in setups occur. Steps (iii) and (iv) *necessitate a great deal of trial and error,* leading to uncertainties (1). The aims of setup modification would be to move stages (i) and (iii) from internal to external operations and to eliminate as much of stage (iv) as possible.

3.2. CHANGING CONVENTIONAL THINKING TO SUIT JIT

Setup times are often treated as a given, (in most cases, inherently long activities) where upper managers, who have not come up through engineering and manufacturing, scrutinise large *obvious costs, like direct labour, tolerate a certain specified* level of scrap and rework, and neglect setup costs. (3) It is important to have the conviction that drastically shortened setups are possible. Drastic reductions can be made by starting out with the attitude that a tooling change, for example, is merely a matter of removing one die and attaching another. (1) With dedication to the task, it is possible to reduce setup times of common machine types by 80% in the course of a year, with plenty of potential left for further setup time reduction after that. (2) Those who have never before considered a programme to reduce setup times frequently look with disbelief at the setup times listed by companies well advanced in the practice. (2)

The optimal solution for setups using conventional management techniques is thought to lie in the following: (1)

(i) Setup skills are required to perform the job, therefore skilled setters must be hired.

(ii) Large-lots must be processed in order to maximise production time.

(iii) Large-lots of inventory must be controlled by taking economic lot sizes into account.

Analysis of these methods are shown below:

3.2.1. SETUP SKILLS

In a traditional setup highly skilled workers are often required. (1) The setter must have a good working knowledge of machines and related equipment (eg. tools, dies, jigs, etc) as well as having the skill to perform setup functions (eg. measuring, centering, adjusting, calibrating, etc). The setter's skills are often most needed when a machine is complex.

While the setter is working on the machine the operator assists the setter, operates another machine, cleans the machine, or simply waits. These activities generally do not effectively reduce the total setup time. (1)

Many companies have introduced policies designed to raise the skill level of operators, but very few have implemented strategies that lower the skill level required by the setup itself. (2) The setup should be simplified to such an extent that operators could set up the machine. Skilled operators usually demand high wages and therefore simplifying setups to an unskilled or semi-skilled level could decrease labour costs.

3.2.2. REDUCING LOT SIZES

For large orders the setup poses no problem since the setup time is small in comparison with production time. However it becomes a very real problem when orders are low volume diversified. The conventional solution is to combine several orders and produce in anticipation of demand, reducing the ratio of setup time to total production time. (1)

In effect a large number of setups are being combined into one, the immediate result being a substantial increase in work rates and production capacity. In fact this approach is viewed as time saved since a large number of setups have been eliminated. With traditional setup techniques, large-lot production seems the simplest way to reduce the undersirable effects of setups.

Advantages of large-lots are perceived as follows: (1)

- Man-hours required for a certain product are reduced.
- The proportion of man-hours spent on setup to total productivity is reduced.
- Load levelling can be achieved since inventory exists (not proportional to fluctuating demand).
- Inventory cushions the impact of problems (eg. machine breakdowns).
- Inventory is available for rush orders.

The disadvantages of large lots are as follows: (1)

- Capital turnover rates are decreased.
- Work-in-progress inventory does not produce added value, therefore it wastes physical space within the factory. Transportation and storage of stock requires extra man-

hours and material handling systems, which increase costs.

- Large-lots mean longer lead times which could lead to delayed orders and missed deadlines. Furthermore there may be discrepencies between actual and forecasted demands which leads to stockouts or large internal inventories.
- Model changes could leave large amounts of old stock, which must now be disposed of or sold at a large discount.
- Inventory quality decreases with time, eg. rust or dated stocks may diminish in value.

Quality problems take longer to detect in large lots.

One of the most important factors to address regarding large lot sizes is lead time. Using smaller lot sizes leads to a dramatically reduced processing time from the raw material stage through to the finished product. This means that lead times for orders placed can be reduced significantly. Following setup time improvements, a reduction in the total production time can be achieved through the elimination of waiting for processes, waiting for lots and producing in small lots. (1) These lead time reduction techniques may be used to reduce or eliminate queues as follows:

(a) LEAD TIME REDUCTION TECHNIQUES

(i) ELIMINATING WAITING FOR PROCESSES

If a production line is not balanced the production rate will be governed by the bottleneck workcentre. (16) It is evident that workcentres upstream and downstream of the bottleneck will be idle for a certain amount of time according to respective processing times relative to the bottleneck's processing time. The shorter the processing time of the workcentre, the longer the idle time of that workcentre. (21) According to Shingo, this idle time often accounts for 60% of the total production time, resulting in only 40% of the total time used for processing. (1)

Say a machine A is the first process and machine B is the second. Now in this hypothetical case machine A completes its task quicker per component than machine B. There will obviously be a line balancing problem here. A buffer should be set up before machine B. When there are a maximum of say 20 products in the buffer, machine A stops production. Due to labour costs being higher than machine idle-time costs, the worker must perform another task. When the buffer stock gets down to say 5 products, machine A resumes production. This can be organised effectively by having several machines waiting (planned) so that workers can change between machines in a set routine. This will improve labour utilisation but will not speed up the rate of production. Waiting for processes can be eliminated by balancing the line so that no bottlenecks exist. This can be achieved by reducing setup times on bottleneck workcentres.

(ii) ELIMINATING WAITING FOR LOTS

Much time is lost when work-in-progress must wait for processing of an entire lot between work stations. The ideal situation is to have only one item being transported between all stations. (1) In this way each item moves directly to the next process as soon as it has undergone processing. All intervals between processes will now take the time needed to process one item. Therefore, for 10 processes, the overall lot processing time will be cut to 10% of its original time. The only problem with this is that transportation operations will increase tenfold. Thus the necessity to improve plant layout and simplify transportation techniques between stations. (eg. simple conveyers between closely grouped machines).

(iii) PRODUCING IN SMALL LOTS

Smaller lot sizes must be produced per production run in order to facilitate a more flexible production mix. (1) This is where the importance of setups arises. The frequency of setups will increase but due to the drastic reductions in setup times, more changeovers can be performed without any losses in production times. In essence, the degree to which setup times have been reduced will determine how many more changeovers can be permitted, and in turn will determine the lot sizes.

For example, let us say that the setup time is one-tenth of what it originally was. This means that ten setups can be performed for every original one without any losses in production time. Consequently the lot sizes can also be reduced by a factor of ten, which will result in a 90% cut in processing time of any particular item.

(b) EFFECTS OF QUEUE ELIMINATION

Referring to table 3.2, waiting for processing can be reduced to say 40% of the original time (discussed before). The time spent waiting for lots can be reduced to 10% of the original value for say 10 processes. Furthermore the time taken can be reduced to 10% of original value by reducing lot sizes by a factor of say 10. This results in a time saving of 99,6% in moving a particular product through the production process. It should be noted that the time saving effects are multiplicative rather than additive.

TABLE 3.2.: Effects of Queue Elimination (1)

STRATEGY	% OF PREVIOUS TIME
Waiting for processes	40%
Waiting for lots	10%
Producing in small lots	10%
Total productivity time	0,4%

The implications of table 3.2 are that lead times can be cut down dramatically resulting in an improvement in customer satisfaction. Furthermore costs are not only saved in a reduction in work-in-progress, but also from the ability to make-to-order rather than make-to-stock. Production can now take place after orders have been placed rather than before and rush orders can be dealt with promptly. Furthermore delivery dates are easy to meet.

3.2.3. ECONOMIC-LOT SIZE METHOD

The right quantity to produce is that which best balances the costs related to the number of production runs (setup costs), against the costs related to the lot size (holding costs). When these costs have been properly balanced the total cost is minimised. The resulting production quantity is the economic lot size or economic order quantity (EOQ). (21)

$$Q = \sqrt{\frac{2*D*S}{I*C}} \quad (21)$$

Where Q = EOQ
D = Demand
S = Setup Cost
IC = Carrying Cost

The application of this formula is illustrated in figure 3.1 below. The EOQ is essentially where the total cost is minimised.

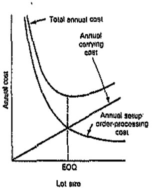


FIGURE 3.1 : The EOQ Cost Graph (5)

The EOQ graph can now be modified as shown in figure 3.2 where the EOQ can be made to approximately equal one in theory or a very small lot size in practice. On the graph it is shown that setup costs are cut dramatically using setup reduction techniques. This leads to the feasibility of producing in small lots which in turn reduces carrying costs. The graph clearly implies that setup reduction is a catalyst for achieving small lot production at minimum cost.

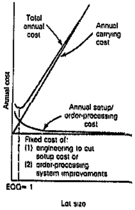


FIGURE 3.2 : Effects of Setup Reduction on EOQ (5)

3.3 BENEFITS OF REDUCING SETUP TIMES

- A larger proportion of setup errors are eliminated due to the standardisation and simplification of setups.

- Operating conditions are fully regulated in advance ie. a quality item can be produced on the first run. This leads to the elimination of trial runs and therefore fewer defects are produced. By using dead stops and making adjustments during external setup, Viro Locks has almost eliminated the trial and error process required to achieve a quality workpiece, thus eliminating approximately 40% of setup time.

- Simplification of setups leads to an increase in safety levels. Promex have reduced the risks of handling heavy dies by adopting suitable materials handling equipment. (26)

- Housekeeping is simplified since many tools are standardised as well as unstandardised tools more functionally organised. Afrox have placed tooling cupboards on the shop floor at the GT cell for which the respective tooling is used. (40)

- The cost of standardising setup operations and tooling is relatively low when compared to the benefits received from productivity increases. Viro Locks has achieved a 67%

reduction of setup times on bottleneck machines, and have subsequently increased productivity by 10% at a cost of approximately R6760.00

- Tooling changes are quick, therefore workers have no reason to avoid them. At Rowen Engineering many setups have been simplified and reduced by over 90%, allowing operators to perform many of the setups themselves. (45)

- Lower skilled workers can be adopted for simple tool changes. Furthermore workers can stay with one machine for a reasonable amount of time rather than being moved around when a setup is required. This leads to workers feeling a sense of responsibility for their particular machine. At Viro Locks specific operators have been selected to assist with setups and have been included in the setup teams. Therefore they feel part of the programme and know more about setup reduction in the changing JIT environment.

- When setups are short it is less likely for interruptions to take place eg. lunch breaks, telephone calls, other urgent tasks, etc. At Viro Locks idle time has effectively been eliminated since setups are now short enough to be performed between breaks.

- Setup procedures are standardised, therefore known setup times facilitate better production planning. Rowen

Engineering know their setup times to within 5% and can therefore plan production more accurately. (45)

- Simplified materials handling avoids lifting of heavy objects. Promex have adopted methods for lifting and positioning of heavy dies (as shown in figure 4.9). (26)

- Job security is increased since setup teams are responsible for reducing setup times, and will perform advanced setups more frequently when lot sizes are reduced. Note that the setter's job is not at risk since his job role will be diverted to other activities, such as training of operators, reducing setups, tooling organisation, etc. At Viro Locks the time saved on setups is diverted to these activities, resulting in a shift of job definition.

- Scrap is reduced since setup reduction techniques eliminate trial runs and adjustments. Also quality is improved since setups are standardised and no longer depend on individual setup skills. At Rowen Engineering the scrap level has been reduced to less than 1% due to setup reduction and preventative maintenance techniques. (45)

4. SETUP REDUCTION IMPLEMENTATION

Hall says that a programme to reduce setup times is much like any other programme of industrial engineering methods study. (2) Since much of the work of changing the setup on any equipment is a matter of making mechanical changes and revising the layout of material and items around it, much can be done to reduce setup times without resorting to advanced engineering. (2) There are no "hard and fast" rules for setup reduction, however any changes made to the production process with respect to setups should be simple, with changes restricted to equipment which is available and easy to understand. If the whole production process is to be altered in the future, it is advisable to get a basic idea of what the eventual system will consist of and select operations which are least likely to be disturbed by these changes. Management cannot escape the fact that future development cannot be entirely foreseen, and that revisions may have to be made. (2) The setup programme can only proceed by "doing"; failing this it is doubtful whether setup reduction will ever be implemented. (2)

A summary of the setup reduction implementation programme discussed in this section is shown in table 4.1 with other considerations for implementation summarised in table 4.2.

TABLE 4.1: Summary of Setup Reduction Implementation Programme

Implementation Steps		Description
1. Examine overall production	Group technology	- Grouping of machines according to component families simplifies tooling organisation and allows improved control over setup sequencing.
	Setup sequencing	- Grouping a family of parts into a specific order such that the change from one component in the sequence to the next is small and requires minor changes.
	Dedicated machines	- *Dedicating smaller, simple machines run in parallel may eliminate* setups.
	The OPT principle	- Reducing setup times on bottleneck workcentres increases overall throughput and may be used as a line balancing technique.
	The 80/20 rule	- *Criteria* such as machines generating largest turnover, highest throughput, etc may be used to determine which machines take priority for setup reduction.
2. Training	Training programme	- Study activities include the JIT concept, JIT manufacturing, JIT in the changing business environment, recording and analysis methods and setup demonstrations.
	Setup teams	- Consists of 2-3 setters and operators who are supported by technical people, management and controlled by a programme facilitator.
3. *Approach to* setup reduction	Distinguish between internal & external setup	- A work/time study is recorded using a time-lapse video camera for which a simple process ch rt describing setup activities and associated times is devised.
	Seperating internal & external setup	- *Involves obvious changes where operations can be performed externally* simply by making organisational changes, rescheduling and tooling simplification. Examples include tooling grouping, standardisation, prepreparation, tooling transportation and warning systems.
	Converting internal to external setup	- A simple pareto analysis is conducted on remaining operations to rank in highest order the time consuming internal operations, thus determining which setup operations take priority. Modifications include setup procedure standardisation, parallel operations, functional clamps, die centering techniques, functional standardisation, intermediary jigs and mechanisation. Adjustments are eliminated during internal setup by making fixed settings or adjusting during external setup.
	Streamlining setup operations	- Involves further improvements to both internal and external setup. Undercapacity scheduling allows setup practise time for building skills, trying out new ideas and debugging new setup procedures.

TABLE 4.2: Summary of Other Considerations Required for Setup Reduction

Considerations	Comments
1. Study/action approach	- It is preferable to take action immediately when an idea is generated than to plan continuously and not make any physical progress.
2. Changeovers during a production run	- These changeovers should be treated as setups where all tooling is prepared in advance during external setup time.
3. Documentation	- All information concerning the setup must be documented for others to follow and to act as a basis for further improvement.
4. Machine selection	- Use smaller, less expensive machines with emphasis on reliability, ease of maintenance, ease of setup, suitability to overall production process and ease of operation. By upgrading existing machines in-house, equipment can be modified to incorporate quick setups.
5. Cost	- During initial stages of setup reduction, simple modifications and tooling organisation yield large time savings at low cost. During the final stages, small improvements require large expenditure (diminishing returns). A budget may be allocated for minor cost changes and further capital expediture justified before funds are approved.
6. Worker motivation	- Economic incentives include profit sharing schemes, wage and salary systems, promotion practices, merit evaluation and perquisites. Non-economic incentives include job redesign, job rotation and non-financial recognition. It is recommended that group rather than individual rewards are given to avoid setup team members competing against one another.

4.1. EXAMINING OVERALL PRODUCTION

Reducing machine setup time should not be the first step of a setup reduction programme. Effort spent reducing setup time on existing equipment can be wasted without first looking at the overall production process. (2) The company may change, redesign or drop certain products for which setup time reduction has been implemented. Alternatively the company may be planning on buying new machines, thus negating all efforts made on older machines. Therefore it is up to management to look at the future of the production process in order to avoid unnecessary setup reduction implementation. (2)

4.1.1. GROUP TECHNOLOGY (GT)

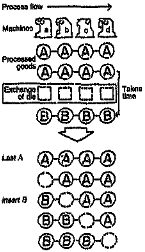
According to Schonberger, the concept of GT is a key to achieving JIT results where item variety is high. (5) GT is a way of grouping machines and work centres based on parts that require the same technology. According to Burbidge, the original concept of GT was devised to reduce setup time. (12) Therefore a family of components should be created with this in mind. A GT cell may be set up for several parts that follow the same manufacturing process. In effect jobs are selected requiring similar technology to be run through a machine sequence as a group. The machines may be positioned close enough together so that as each unit is completed on one machine, it may be loaded into the next. This creates a small production line consisting of an irregular mix of parts with little or no idle inventory between stages. (5)

Toyota have developed U-shaped GT cells containing a maximum of five manned work stations. (5) When the cell is operating at less than full capacity, fewer than five operators may be assigned, with each operator running more than one machine. At the limit a single worker could handle all five machines. (5)

Schonberger says that setup time may be an obstacle to GT since all different parts in the GT cell would require its own machine settings, tool changes, and so forth. (5) However parts following the same flow path are likely to have similar setup characteristics so that a quick-setup idea adopted for one of the parts may work on all the others as well. (5)

The GT approach to setup time reduction is more a question of good planning and organisation than of new investment. The task of finding tooling families can be facilitated by using a classification and coding system where common tools are used for various components. (12) GT simplifies setup reduction since tooling organisation is simplified and setup sequencing (see section 4.1.2.) is easier to control.

A GT setup technique suitable for die changeovers has been adopted at Toyota. (6) The setup procedure is illustrated in figure 4.1 where parts A and B are processed in sequence on four machines. The idea is not to process the last part A on all four machines and then set up all four machines for part B, since this would take too much time. Processed parts flow one by one with each cycle time. Therefore the setup proceeds sequentially on each machine within one cycle time. This results in a loss of one production piece only. In any GT cell, providing the setup time on each machine is equal to or less than the cycle time, this approach can be adopted. Note that this cycle time may be for one component, one lot of components, *etc*, depending on the relationship between setup and cycle times.



KEY: (A) - Production of component A

(B) - Production of component B

( ) - Setup procedure

FIGURE 4.1 : Setup in a GT Cell (6)

4.1.2. SETUP SEQUENCING

This involves grouping a family of parts into a specific order such that the change from one component in the sequence to the next is small. Therefore between any two consecutive items in the family only a minor setup change is required. (12,27) The main disadvantage of this technique is the lack of flexibility. At this stage it is important to note that violating the required sequence should be avoided at all costs. Not only do setup times rise sharply, but managers could be inclined to feel that they can get away with bad planning. Before long there would be no sequence at all due to "emergency" orders constantly taking preference. A solution to maintain flexibility (to a certain extent) would be to keep the sequence but alter the lot sizes to meet demand changes.

An example of setup sequencing has been documented for GEC Small Machines' rotor shop. (29) Each rotor has been classified according to specific common parameters, in this case diameter, end ring thickness and shaft hole diameter. In this case study an attempt was made (using the rotor classification data) to determine the most beneficial sequencing schedule. This was arrived at by discussion with shop supervision and production engineering, and was based largely on intuition. A production run was simulated (using the deduced sequencing rules), namely the first approximation. The sequence was examined and changes were tested against a second simulated production run (the second approximation). A third simulation was run but yielded no real benefits, and therefore the second approximation was adopted. Machine *utilisation for one* week's *production* rose from less than 50% to 92%.

According to Carstens, sequencing can be *adopted before setup* times are reduced. In this way a halfway stage can be devised by scheduling which reduces the negative effects of long setups immediately and allows JIT to be introduced immediately *with degrees of compromise* and sub-optimisation. Scheduling should be sufficiently flexible so that as setting problems are solved with time, development into "pure" JIT would be simple. (29)

4.1.3. DEDICATED MACHINES

Many Japanese companies buy simple equipment with lower capacity, in order that they may dedicate these and thus eliminate setups. (5) Smaller machines are run in parallel which *has* the *added advantage* of production able to continue (although not at full capacity) in the event of a breakdown. It should be noted that the possibility of GT and sequencing should be examined first since these may *eliminate the need* for dedicated machines. Companies which have old, depreciated equipment not in use should also dedicate these machines as LCA (low cost automation). Even if they cannot handle the *required capacity* they can still run in conjunction with newer equipment and reduce the number of setups to be performed. (5)

If dedicated machines are not feasible an alternative could be to adopt semi-dedicated machines. Then the number of setups would be limited on each machine, *encouraging the possibility* of operators setting up their own machines. Semi-dedicated machines have been adopted at Mono Pumps. Four identical milling machines exist to process a number of components. One of the objectives of setup reduction was to have dedicated tooling for each job, however for 20 different jobs, 80 sets of tooling would be required for each job per machine. This would have been too costly. therefore the jobs were divided up and dedicated to certain machines. In other words, in the case of 20 jobs, each machine would process 5 specific components. Although flexibility was decreased, only 20 sets of tooling were required. The setup has been considerably shortened since tools are efficiently organised and flexibility losses have been compensated for by adopting suitable scheduling techniques. (42)

4.1.4. THE OPT (OPTIMISED PRODUCTION TECHNOLOGY) PRINCIPLE

Benefits from setup time savings are dependent on the type of resource involved. The available time at a bottleneck resource is split between processing time and setup time. If we save an hour of setup, we gain an hour of processing time. Furthermore, an hour saved at a bottleneck operation is more important than just the increased hour of production at the bottleneck. It is equivalent to an increased hour of throughput for the total system. On non-bottleneck operations, we have three elements of time - processing, setup and idle time. Here if we save an hour of setup, we gain an additional hour of idle time. Consequently, an hour saveu at a non bottleneck is worth nothing. (21)

Therefore it is evident that *setup reduction on a non-bottleneck work centre will fail to improve throughput levels.* After the bottleneck setup time has been reduced the line may still be unbalanced. If setup time on the bottleneck was a significant factor, drastic reductions may shift the bottleneck to another work centre up- or downstream of the original bottleneck. Each bottleneck can then be tackled consecutively using setup reduction techniques until the line is approximately balanced.

4.1.5. THE 80/20 RULE

This usually applies to most activities within a factory. For example, a few operations produce most of the scrap, a few items hold up most of the backorders, a few products account for the bulk of production, etc. (7)

GEC Small Machines *have reduced setup times on two machines* which generate a large proportion of turnover. This approach was taken in order that the bulk of production may be streamlined and the low turnover special items tackled at a later stage. (39)

At Viro Locks most of the changeovers occur for special items which account for a small proportion of turnover. It was decided to reduce setup times for these products since machines for large turnover items have been semi-dedicated and require few changeovers. Furthermore, machines for both high volume and special items are similar, therefore common principles can be applied to both.

4.2. TRAINING REQUIREMENTS AND SETUP TEAMS

Setup reduction does not happen on its own. It takes a team of people who aggressively pursue the problem to make short changeovers a reality. (40,45) Hall says that: "The job of management is to enable the direct-action people to perform better. That job is coaching, and coaching is development of others while developing yourself. Coaches teach, make correction, blend talent as a team, develop individual and collective skill and motivate, but coaches do not play themselves. That is reserved for the players." (10) This suggests that setters and operators should ultimately be trained to make setup changes themselves.

4.2.1. THE TRAINING PROGRAMME

To get into the spirit of workplace organisation, worker training and involvement must begin, else basic problem solving is not sufficiently transferred to the workers and supervisors themselves. (10) This applies to setup reduction, where the basic nature of the setup reduction process (trial and error) compels education through involvement.

A training approach adopted by "Cummins Engine Company" has been documented. (31) The training programme should involve all relevant production operators, setters and immediate support staff. From these attendees, setup reduction teams are formed who would then spearhead the improvement programme. (31)

(a) STUDY ACTIVITIES

Each manufacturing work team, along with supervisory, technical and other direct support staff would initially spend time learning about the following:

(i) THE JIT CONCEPT

This would include a general overview of its origins, benefits and the state of implementation in Japan and the West.

(ii) JIT MANUFACTURING

This would involve learning the basic JIT principles such as uniform plant load, line balancing, plant layout, kanban systems and implications of JIT manufacturing.

(iii) THE CHANGING BUSINESS ENVIRONMENT

This includes what JIT means for the plant and the changes that people would see going on around them. This portion of training would lead up to a recognition of the need to reduce setup times. *It should be clearly shown where setup reduction* fits in and how it benefits the factory.

(iv) RECORDING AND ANALYSIS METHODS

Not all the people making setup analyses may have a good background in industrial engineering method studies. Therefore it may be advisable to give a format to work by and some basic instruction in methods studies. (2)

(b) COURSE SUMMARY

The course should show setup teams how to go about setup reduction by showing attendees physical illustrative examples. It is essential that those examples have been taylored by the team facilitator to suite the equipment in that particular factory. (40) Giving setters generalised examples which do not apply to their machines is meaningless. *Relevant examples* should generate some ideas at a later stage since in many instances workers will have seen these techniques before on other machines, however in the past they may not have related to them as setup reduction techniques. (2)

At "Cummins Engine Company" each attendee received a certificate validating his successful completion of the training programme. They also received a comprehensive reference manual containing a copy of all course material, as well as analysis and improvement guide notes. (J1)

(c) SETUP DEMONSTRATIONS

The aim of physical demonstration is to let setters see setup reduction techniques in action. (37 - 45) This can be achieved by running a pilot project where before each demonstration setup, plant managers, section leaders, department heads and related personnel observe actual setup operations in the shop, look for problem areas and work towards solutions. (2) The author suggests that demonstrations begin on simpler equipment where large setup reductions can easily be attained and progress to compl-x machines at a later stage.

4.2.2. SETUP TEAMS

According to Lee, the team should consist of 2 - 3 operators and setters who are regularly involved in the setup of the machine in focus. They are supported by technical people - such as line process engineers and tool control supervisors. A maintenance operator may need to be added if maintenance is poor. The role of the facilitator is usually filled by an industrial (work study) engineer whose basic functions are to call meetings, issue minutes and chair brainstorming sessions, etc. (31)

During the initial stages of the setup reduction programme the person training the team (usually a manager) should act as a guide. (31) His role is to allow the teams to gain recognition by introducing the team to the new way of thinking and giving setup examples. This should generate some ideas at a later stage since in many instances operators will have seen these techniques before on other machines. (2)

Lee recommends that line supervisors should not be core members of the setup team since his commitments already usually take up most of his time and there is a risk that the supervisor would become the person who finishes up with the majority of team work assignments, owing to his demonstrated skills in getting things done. This would overload him eventually and could cause the team to become a "study" group who delegate work to other (already stretched) resources. (31) It is recommended however that line supervisors be regularly updated on the team's activities by means of minutes, occasional invitations to team meetings and by constant updating by the team facilitator.

Afrox has structured its setup teams differently. (40) According to Karle it was found that by only including setters in setup reduction teams, foremen and line supervisors felt threatened. Therefore it was decided that teams would consist of a cell manager (who was the team leader), the cell production engineer, the cell foreman and 2 - 3 setters for a particular cell. Since Afrox had 3 high volume cells, 3 setup teams were formed. A monthly evaluation is made of implemented suggestions and a monthly reward is equally divided between members of the setup reduction team.

In the author's experience it is desirable that the setup team:

(i) Has a thorough knowledge of the machines involved to that he knows when an idea will work, or can give reasons why it will not work.

(ii) Has some engineering skills in order to avoid machine attachments which are either impossible or too costly to make. *This includes hardening, welding, etc.*

(iii) Has draughting skills in order to produce working drawings if required by subcontractors.

(iv) Is well connected with outside companies if parts are to be made by subcontractors, and should be able to co-ordinate the manufacture of these parts.

(v) Knows what standard "off the shelf" items are available, which may be used instead of specially manufactured parts.

4.3. A THEORETICAL APPROACH TO SETUP REDUCTION

The theory of setup time reduction was developed in Japan by Shigeo Shingo, author of "A Revolution in Manufacturing: The SMED System". (1) This was developed through years of experience where a number of setup steps have been laid down as follows: (1)

(i) Preliminary stage : Internal and external setup not distinguished
(ii) Stage 1 : Seperating internal and external setup
(iii) Stage 2 : Converting internal to external setup
(iv) Stage 3 : Streamlining setup operations

A graphic representation of these stages is shown in figure 4.2 and illustrates the effect of each stage on overall setup time. A detailed discussion of each setup stage follows.

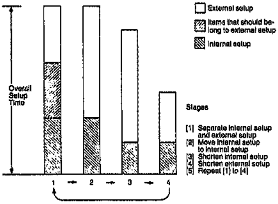


FIGURE 4.2 : Stages of Setup Time Reduction (1)

4.3.1 PRELIMINARY STAGE - INTERNAL & EXTERNAL SETUP NOT DISTINGUISHED

In the conventional setup all operations are usually performed internally causing unnecessary delays. (1) This stage involves analysing the existing setup and distinguishing which setup operations could be external instead of internal.

(a) WORK/TIME STUDY

In order to implement any form of improvement a time/method study analysis should be made of the existing setup. According to Lee, no better method exists than the use of a time lapse video camera to record what actually happens during a setup. The video tape becomes a "living" record, very much superior to either the written or spoken word which often tends to suggest what ought, rather than did occur. (31)

Lee suggests that the recording be done openly and becomes the property of the setup team. This ensures that the video cannot be misused and builds up an environment of trust. Also it should be stressed that the setup be filmed like it is, where setters do not violate normal setup practice for the sake of the camera. Furthermore the camera should not be stopped when something goes wrong (tight threads, jammed wheels, etc). (31)

(b) ACTIVITY CLASSIFICATION

Soon after the video is made, the first setup team meeting should take place. The video is reviewed and an analysis sheet is filled out. (31) It is the author's view that complicated work study tables are not necessary at this stage of the programme, since the exact setup procedure has not yet been standardised. All that is required is a simple process chart describing each worker's activities, and the associated times taken (see appendix B1).

In order to distinguish between internal and external setup operations each work element should be classified. (31) One approach has been documented for "Cummins Engine Company" where activities are classified according to the following work categories (31) :

Clamp (C), Adjustment (A), Other (O), Unclamp (UC), Cleandown (CD), and Problem (P).

From these categories it is evident that "Adjustment", "Cleandown" and "Problem" categories can possibly be made external operations. (31) Furthermore a checklist for each category has been drawn up stating what can be done to improve operations.

Another approach has been documented for "GEC Small Machines" where setup activities are classified according to "transportation", "operation" and "delay" functions. (28) The reasoning here is that there is great potential to externalise "transportation" and "delay" activities. (28)

An alternative method (used by the author in the case study) is to classify each work element according to broad work categories with associated times (appendix B2). The aims of this classification are to:

(i) Determine which activities can possibly be made external or eliminated.
(ii) Identify activities which are easily made external.
(iii) Identify which operations account for the longest times during the setup.

4.3.2. STAGE 1 - SEPERATING INTERNAL AND EXTERNAL SETUP

The most logical areas to attack setup times are those where changes are so obvious, there is no need to delay. (2) Most of the time, people familiar with the particular setup can look at the list of categories and immediately spot potential ways to make operations external. At this stage it may be a good idea to predict which operations must remain internal, which can be made completely external, which can be made partly external, and which can be eliminated. Obviously predictions cannot be entirely accurate, however this does give a guide as to which operations must be tackled first. Moving operations to external setup lessens the number of internal operations and makes the analysis easier later on. An example of seperating internal and external operations is illustrated in appendix B3.

Since the aim of making operations external is to prepare operating conditions in advance, all the attachments, tools and workers required should be in place and standing by with everything laid out. Then as the machine stops they are ready to perform the setup without having to go through unnecessary internal operations.

In order to make tooling organisation an external operation, it is usually necessary to revise the factory's tooling layout. With regard to setup reduction, the aim of layout is to group all tooling and equipment required for setups as close to the work station as possible. (Preferably in tool cupboards at the machine). If this is not possible due to large heavy equipment, a tooling store may have to be used. However it is recommended that this store be layed out in such a way that:

(i) All attachments are grouped accordingly for specific job setups.

(ii) All attachments are easily accossable at a moments notice. For example, if dies are piled on top of each other it is difficult and time consuming to locate the die at the bottom of the pile. (13)

(iii) Attachments must be easily transportable to the machine. The best and cheapest method is usually a trolley. Each set of tooling may be stored in its own dedicated trolley or stored in trays which can easily be loaded onto a trolley. (2)

In the case of tools it may be the case that these cannot always be dedicated for each job. In such a case a list must be made up of each tool and where in the setup it is used. An example is shown in appendix C. This allows setters to prepare tools beforehand and avoids having to search for tools during the setup.

Some useful hints for improving tooling organisation are as follows: (2)

(i) Reduce the variety of tools (if possible), make screws uniform and standardise tools even if screws are of different sizes.

(ii) If there is no obstacle to the operation, secure wrenches or handles to screws to eliminate having to pick up and put down tools; or use devices which can be tightened by hand, eg. wingnuts.

(iii) Keep tools nearby and arranged neatly. Label tool hooks or keep tools together on boards.

Immediately after a setup, when old attachments have just come off the machine, the setter must see to it that all these attachments are prepared for the next setup of that particular job. A tooling board allows for the setter to check that all attachments are available, however he cannot tell if relevant functional checks have been performed. Therefore attachments to be sharpened or checked should not be packed away until the setter has done so. As setup times become shorter and batch sizes are reduced, the number of setups increase. Subsequently setups become more frequent and it becomes increasingly more important for the setter to organise old attachments immediately after a setup. If there are a sufficient number of intermediary jigs to be dedicated to each job (this is not always the case), then adjustments must be made at this stage so that attachments are preset when put away.

This ensures that before a setup, all that is required is to transfer tooling boards to the machine. When tools cannot be dedicated to each job, the setter (who should have a list of tools for each job) must lay these out at the machine before the setup commences. Gauges to check workpieces must also be ready at the machine. If general intermediary jigs are used for all jobs, adjustments are made on external gauges during this time.

Pre-preparation also includes a warning system to inform setters precisely when the next setup will be. Usually the supervisor is given a production schedule to work from, therefore he knows approximately when a setup will take place. (2) Every morning the supervisor can give the setters a list of setups for the day. This allows the setter to mentally prepare for each setup. (2) This would not be necessary if a fixed schedule or job sequencing techniques are used.

Other common operations which can be moved to external setup include preheating of dies, cleaning operations and maintenance (which can be scheduled out of normal working hours).

4.3.3. STAGE 2 - CONVERTING INTERNAL TO EXTERNAL SETUP

Once stage 1 has been completed the setup becomes shorter and more simple, and it becomes easier to concentrate on internal operations. The main aim here is to modify equipment and procedures in order to eliminate unnecessary internal operations; thereby reducing internal setup time to a minimum.

(a) PARETO ANALYSIS

It is logical that the next area to reduce setup times are those operations which take up the most time. (2) The Pareto chart is used to classify categories by placing the longest operation first and so on until the shortest operation is reached. This draws the attention of idea generation to the longest operations first. These are usually the areas where the most impressive setup time reductions can be made in a relatively short period of time.

Hall demonstrates setup improvements by means of Pareto Analysis. (2) An example is illustrated in figure 4.3. Broad categories are analysed first on level 1. These are broken down into operations and analysed on level 2. Operations can be broken down further into activities and analysed on level 3. The number of levels is not limited and depends on the complexity of the setup and the desired detail of analysis. Note from the example that procedures which have already been eliminated or moved to external setup are discluded from further analysis.

The example shows how categories of the setup are analysed. Categories 2 and 4 are made external and category 5 eliminated. These decisions have been made on level 1 and only categories 1 and 3 need be further analysed. Categories 1 and 3 are subdivided into operations. These represent the existing operational times before any improvements take place. Also shown here are operations which can be (fully or partially) externalised or eliminated. After implementation, the remaining internal operations on level 2 are further analysed. The internal portion of operation 3 is then subdivided into existing activities. Ideas for improvement are generated on level 3 and activities are again (fully or partly) externalised or eliminated. The analyst continues until the desired number of levels (determined by the setup team) have been analysed.

In practice all that is required is a simple Pareto analysis conducted to rank in highest order the time consuming operations. (31) An example of Pareto analysis involving two levels has been documented. (28) Broad setup categories have been listed, making up level 1. These have then been broken down into operations, making up level 2. The time taken for each operation on level 2 have been added to give the total time of each level 1 category. Another example of Pareto analysis is shown in appendix B4.

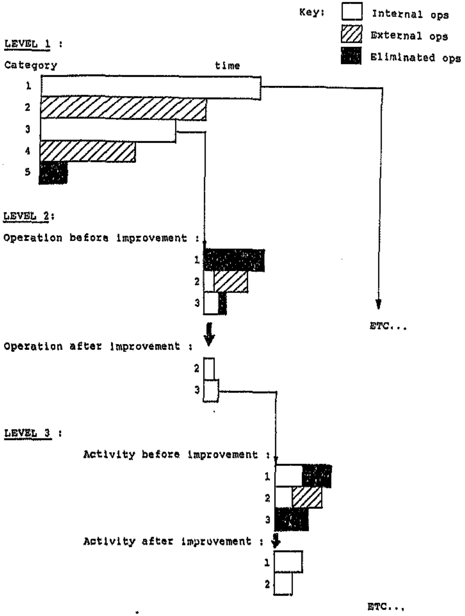


FIGURE 4.3 : Pareto Analysis

(b) MODIFICATIONS FOR INTERNAL SETUP

Examples of equipment modifications include the use of functional clamps, die centering, functional standardisation, intermediary jigs and mechanisation (refer to section 4.4.3).

Much of the idle time encountered during a setup is due to a non standard setup procedure. A set procedure allows each worker to go in and do his job without having to think of what to do next. The procedure must be written out in a simple form so that workers involved in the setup can mentally prepare before the machine stops. It may be a good idea for the setup team to post up a procedure at the machine (just before the setup) for the operator or setter to follow. This will probably only be necessary until setters are familiar with their respective tasks.

Parallel operations, when properly devised, can more than halve setup times due to economy of movement. (1) This is particularly relevant to larger equipment, such as a die casting machine, where setup is required on both sides of the machine. The setter then does not have to walk back and forth between either side of the machine.

When devising parallel operations it is important that there is no unnecessary waiting by any worker performing setup operations. The setup procedure must therefore be devised so that workers' actions complement each other. A problem exists when equipment modifications for improvement have just been made. At this stage the new procedure has not been carried out and therefore the operational times are unknown. Therefore it is necessary to estimate these times and draw up a rough procedure. Then when the setup takes place, discrepencies can be noted and the procedure duly modified. It may take a few setups and subsequent modifications before the procedure is perfected. This process must be carried out every time a modification takes place; however this becomes easier as the setup is simplified.

An important factor to be considered in parallel operations is safety. If two workers for instance are performing tasks on opposite sides of the machine, they must communicate by means of hand signals, shouting, whistles or buzzers. (1) This avoids the first worker indexing a tool post for example, while the other worker's hand is still in the machine. Since this system is not foolproof it may be useful to adopt safety devices; eg. an immobalising switch may be activated by one worker so that the other worker cannot index the tool post while the first worker's hands are in the machine.

(c) <u>ELIMINATING ADJUSTMENTS</u>

Adjustments usually account for the largest percentage of setup time. (1) The aim here is to make fixed settings so that no adjustments is necessary during internal setup. This may involve making adjustments off the machine as an external operation prior to the setup. Eliminating adjustment involves positioning attachments on the m^chine in precisely the same location for the same setup.

Techniques include intermediary jigs, function standardisation and die centering (see section 4.4.3). Adjustments can also be eliminated by simply documenting fixed numerical settings, eg. temperatures, feedrates, etc. Once settings have been calibrated, they can then be set at the same value each time. Furthermore two different setters will obtain the same readings for their respective setups. Adjustments are made by trial and error, and as long as settings are made on the basis of intuition, there is no way to avoid trial runs. (2)

Techniques also depend greatly on the accuracy required for the workpiece. Making settings often relies on moving attachments against a dead stop, or screwing a bolt up against a machine face. Whether such an attachment is pushed up against the stop hard or gently may make a difference of a few microns. If a large degree of accuracy is required, this method is not acceptable and may have to be tested and revised.

Determining preset values for future setup is no easy task. The only basis available from which to work is the conventional setup. In other words, the machine must be set up first using the conventional methods of trial and error. This is an important setup since all subsequent setups are dependant on its accuracy. The point to be made here is that this "model" setup must be as accurate as possible (according to machine capability) in order that future setups remain accurate.

The setter is now in a position to take measurements off the machine for preset values. This will involve delaying the setup somewhat, however the time lost is small in comparison with future benefits which will be achieved. Furthermore this delay will only occur during one setup (for that particular job). Bearing in mind that these dimensional values are crucial for future setup presettings, the setter must be allowed to take his time taking measurements and should double-check all readings. An example of such measurements and its transferance to respective attachments is illustrated in Appendix E.

4.3.4. STAGE 3 - STREAMLINING SETUP OPERATIONS

This involves further improvements to both internal and external operations. Lee states that, when the setup team believes that the duration of the setup has been reduced in compliance with the goals set, another video should be made of the new method. (31) This serves as a "springboard" for further improvements. It has been suggested that if the new method is allowed to mature and become the "norm" for several months, then further improvements of significant magnitude can be made by a new or reconvened team. (31)

In order to standardise setup times and procedures, it is important for setup people to be thoroughly familiar with all setups concerned. Executing a setup well requires correct reactions, so practise is necessary when the procedure is new, and periodically thereafter when it is revised or when new people must execute them. In the case of complex setups, teams may be required. Members of the team must practise setup procedures so that activities complement one another. (2)

If undercapacity scheduling is implemented it may be a good idea to reserve some time after a shift for practising setups. Since setup times have been drastically reduced, there is usually enough time to practise as well as set up the machine for the next shift. This practise time should be used constructively, enabling setup people to build their skills, try out new ideas and debug new setup procedures.

4.3.5. OTHER CONSIDERATIONS

(a) THE STUDY/ACTION APPROACH

The setup improvements achieved depend very much on the approach taken. Discussed below are two possibilities: (2)

(i) Study the entire setup in detail and implement changes only when all possible ideas for improvement have been generated.

(ii) Study the setup, starting roughly and gradually make refinements, while constantly implementing these ideas.

Studying the entire setup in detail makes the analysis more complicated. Using this approach, no physical improvements have been made, therefore all operations need to be examined.

On the other hand, a study-action approach may be implemented. The setup is studied broadly first and any ideas generated are immediately implemented. If no developments result from this a more detailed analysis is made and subsequent ideas are again put into practice. This second approach involves far less work since the setup is being physically shortened on a continuous basis.

It is better to take action immediately when an idea (which has been proven in theory) is generated than to plan continuously and not make any physical progress. Setup people may lose interest in the setup reduction programme if no implementation is carried out. Furthermore implementation gives the programme momentum for further idea generation. (2) Shigeo Shingo has stated; "If you cannot figure out how to do something, talk it over with your machines." (1) The point being made here is that it is better to make modifications in small progressive stages and see how they work physically, than to make major changes which are untested. If a small modification does not work, it can be redesigned and altered at a relatively low cost.

(b) CHANGEOVERS DURING A PRODUCTION RUN

It is usually the case that a machine requires attachment changeovers during a production run. These attachments may include blades, drills, or cutting tips which become blunt after a certain amount of time. This type of changeover is treated in exactly the same manner as a setup.

All operating conditions must be prepared in advance when changing blunt attachments. All the benefits of setup reduction are negated if adjustments are required for this changeover. The method used here can be duplicated from the actual setup in order to eliminate trial runs and adjustments. Intermediary jigs play an important role and an example of changing lathe tool tips is illustrated in section 4.4.3.

(c) DOCUMENTATION

All information related to the setup reduction programme should be documented at meetings by the programme facilitator. The reasons for this formality are, *firstly if a person who is* instrumental in the setup reduction programme leaves the company, *his successor* can carry on with the programme from where it was left off. Secondly, documented information can be used as a basis for further improvement. From the author's experience it is suggested that this include the following:

(i) A progress chart which moniters the rate of improvement as illustrated in figure 4.4. This allows management to see if enough time is being devoted to the programme.

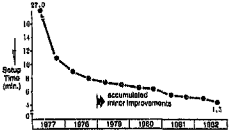


FIGURE 4.4. : Setup Improvements Progress Chart (1)

(ii) The existing setup procedure. This merely involves filing the work/time study tables.

(iii) A simple Pareto analysis to show time consuming activities.

(iv) Ideas which have or have not been implemented. Reasons for non-implemented ideas must be given, since circumstances may change to make these ideas acceptable. The most effective way to illustrate ideas is by a series of sketches.

(v) Delegation of responsibilities, indicating who performs specific activities for making improvements.

(vi) The revised setup procedure must be made available to setup people in order that there is no confusion regarding procedures. This must include both internal and external operations.

(vii) New policies; eg. who has access to tooling cupboards, etc.

(viii) Recordings of actual setup times. This moniters the degree to which the setup has been standardised and may call for further idea implementation or setup practise sessions.

(ix) Goals for the future. Realistic goals must be set so that setup people know what they are working towards. For example, "Cummins Engine Company" initially set a target figure of 75% reduction within 12 months. (31)

4.4. MACHINE SELECTION AND MODIFICATION

It is essential that management and workers know the capabilities and limitations of their machines. Failing this, setup reductions cannot be fully effective, in fact overlooking relevant factors when changing the configuration of the machine may lead to machine damage.

4.4.1. MACHINE CARE

A typical Japanese company looks after its machines by means of management practices. (4) For example, by implementing undercapacity scheduling and load levelling the machines are not excessively used and in fact run well below capacity. (4) Furthermore, lower operating speeds not only reduce the possibility of jams and breakdowns but also reduce wear on machine parts and dies. The combination of regular preventative maintenance, constant cleaning and adjustment and reduced rates of work leads to machines lasting longer. (4)

How is all this related to setups? Firstly it is often the time saved by quicker setups that allows for undercapacity scheduling, preventative maintenance, etc. Secondly it is feared that by performing setups often, equipment damage will occur. In fact just the opposite seems to happen; the setup is so short and simple and has been practised so often that it is inevitable that it will be done right first time. (2) Lastly it is a well known fact that in order to make settings and not adjustments on a machine, operating conditions must remain constant. (1) If a machine is excessively worn operating conditions will vary, the machine will not be able to hold tolerance, and pre-setup will not be possible. One American manager, when asked what the principle difference was between Japanese and American machines answered; "They use their machines, we abuse ours." (4)

Many Japanese companies have experienced the use of elaborate equipment monitering and early warning systems. These devices moniter the process flow and signal when jams occur, measure dimensions and other characteristics of finished parts, indicate when these characteristics approach tolerance limits, keep track of the usage of dies or fixtures, and signal when it is time to adjust or regrind them. A result of this extensive monitoring is that the Japanese worker can see a problem and take corrective action immediately before any damage occurs to the machine, tools or the workpiece. (4)

4.4.2. <u>BUYING EQUIPMENT - WHAT TO LOOK FOR</u>

If a company does not have the tooling capacity or manpower for physical setup changes it should consider purchasing of equipment carefully by looking for the following basic points:

(1) The Japanese tend to use smaller, less expensive machines and place higher importance on reliability and ease of maintenance than on throughput rate. (4) By having smaller,

lower capacity machines running in parallel, a breakdown would not be as serious as one large, high capacity machine stopping production. Furthermore simpler machines are easier to set up and setups can very often be performed by operators. (2)

(ii) *It is important to keep setups in mind when purchasing a* machine. One should look for ease of making physical changes. Look for any problems which may arise during the production cycle, including setups. Make sure the machine is suited to the specific job.

(iii) When purchasing machines it is best to stay with one type. For example, if all drilling machines perform more or less the same task, purchase identical drilling machines. With mixtures of equipment brands, developing setup time-saving modifications is more costly. (3)

(iv) The company concerned should not base their decision to buy a machine on the lowest bid. (3) Other considerations include suitability for the overall production process, ease of operation and ease of setup.

(v) Before *buying a new machine, one should first look at* existing machines. It may be the case that one part of a machine needs to be reground or replaced in order to run another 10 years. Also production routings may be altered in order that older machines can be dedicated and utilised.

In many Japanese firms most of the capital investment is devoted to upgrading of existing equipment and processes. (4) This can be achieved by introducing materials handling and other process rationalisation measures, rebuilding and improving equipment, adding monitering devices and reducing the number of workers through automation. United States companies, and it is believed most of the Western World, have made "capital investment" synonymous with "capacity expansion". (4)

4.4.3. MACHINE AND ATTACHMENT MODIFICATIONS

Setup reduction often requires machine modification which in some cases could be fairly extensive if the full benefits of setup reduction are to be achieved. In some companies there may exist a misconception that one should not tamper with machine tools designed by experts. Furthermore, some believe that the resale value of such general-purpose equipment could be reduced if it is modified for special jobs. (3)

Much of Western industry relies too much on independent equipment suppliers. Very often they cannot design and produce their own production equipment, or even carry out major repairs or modifications on the equipment they purchase. Subsequently they do not have the ability to compete on the basis of unique process technology, something which is not available "off-the-shelf". (4)

In Japanese industry we find there is a large amount of equipment and machinery which has been designed and built "in-house" for specific production purposes. (3) Their machine shops are well-staffed and active, a place where many of the new process technologies are developed, and therefore unavailable to competitors. (4) By modifying, or even better, manufacturing, equipment can be designed so that fast setup hardware techniques are incorporated. Furthermore problems arising during actual production can be eliminated; something an external supplier could not foresee. (2) The Japanese in some cases cut their setup times essentially to zero since the machine is designed for just one job; all attachments and fixtures may be built so that no settings or adjustments are necessary. (3)

Modifications involve changes to machines where part of a machine may be redesigned or modified for quick changeovers. Also additional attachments may be added for simplar setups. This includes tooling changes where drills, dies, blades, jigs, etc. are standardised for easy attachment during a setup.

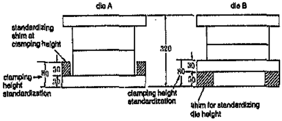
Applications of setup time reduction have been extensively documented (1,2). Therefore this section will merely summarise various examples for common setup problems. For more detailed explanations refer to the prescribed literature.

(a) <u>DIE CHANGEOVERS</u>

This type of setup is commonly found to take a long period of time and may cause bottlenecks. Whether the equipment involved is a metal press or a plastic forming machine, general setup reduction principles are similar with respect to related hardware. The following examples show general changes for machines, tooling, attachments and materials handling equipment.

(i) <u>STANDARDISED DIE HEIGHT AND CLAMPING POINTS</u>

Shut height adjustment wastes time and requires considerable skill. These shut height adjustments are only necessary because die and clamping heights differ. This problem can be solved by attaching shims or blocks of appropriate thickness to standardise these heights (figure 4.5).



<u>FIGURE 4.5 : Die and Clamping Height Standardisation (1)</u>

(ii) <u>DIE CENTERING</u>

Precise die centering is necessary and must be carried out with caution since the die could be destroyed if the ram is not correctly alligned. Therefore this operation is time-consuming and difficult. The setup can be improved by making use of a centering jig made up of two plates as shown in figure 4.6; one side is attached to the machine and the other side to the die. The V-shaped projection between the plates allows for automatic centering in both X and Y planes.

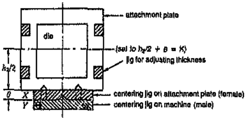


FIGURE 4.6 : Centering Jigs (1)

(iii) SIMPLIFIED DIE EXCHANGE

The conventional method often involves an overhead crane which lifts the old die out of the machine, places it alongside, picks up the new die and places it in the machine. The first alternative is to use roller conveyors on medium-sized dies. Figure 4.7 shows a progression of steps for simplification by means of the roller conveyor method. For this method the conveyor height is standardised to conform to the die height position in the machine (figure 4.8). This method is preferred when human effort is required since any lifting operations are eliminated.

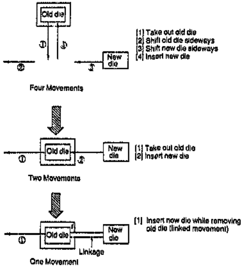


FIGURE 4.7 : Simplifying Die Exchange (1)

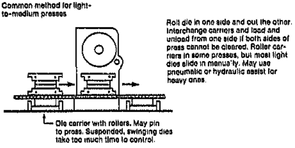


FIGURE 4.8 : The Roller Conveyor Method (2)

An alternative method can be used when the machine does not allow for the roller conveyor method. Figure 4.9 shows the correct method for hoisting dies. The new die is prepared in advance just before the changeover (stage 1), by suspending it just high enough to allow for lateral movement, using the first hoist. The other hoist is then used to lift the old die out of the machine (stage 2). The hoists are then moved along a rail and the new die is lowered into the machine (stage 3).

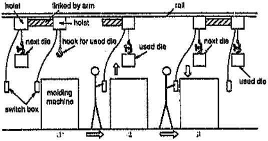


FIGURE 4.9 : The Hoist Method (1)

(iv) COOLANT LINE CONNECTIONS

Most injection moulding machines have a series of supply and drainage lines attached to the die for coolant purposes. In the conventional method each of these lines is attached seperately. Figure 4.10 shows how connections can be simplifie' by means of using manifolds.

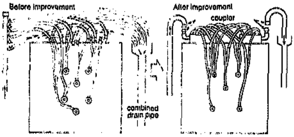


FIGURE 4.10 : Improved Coolant Line Connections (1)

(v) DIE PREHEATING

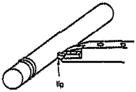
In the conventional setup a number of scrap parts are made until the die has heated up. (1) Therefore the new die must be preheated to eliminate this scrap. Methods include steam generators and electrical heaters.

(vi) ELECTRICAL CONNECTIONS

A considerable amount of time can be saved by grouping individual wires and sockets to form one *plug and socket*.

(b) *INTERMEDIARY JIGS*

Intermediary jigs are used in order to eliminate adjustments during a setup. When blades are changed for example, holders, referred to as intermediary jigs, should be used instead of mounting blades directly onto the head. Dimensions can then be set during external setup and holders merely have to be switched during internal setup. Intermediary jigs may be designed in such a way so as to eliminate all adjustment (internal and external). (1) This is illustrated in figure 4.6 where the die is automatically centred in the machine by means *of a sub-plate or* intermediary *jig.* This can also be applied to changing of lathe tips. Conventially tips are changed inside the machine, after which fine adjustments are required. For quick changeover the entire *tool holder (which* serves as the intermediary jig) is removed from the lathe and tips are changed outside the machine on a gauge during external setup (figure 4.11).



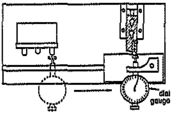


FIGURE 4.11 : *Changing Lathe Tips Outside of Machine (1)*

(c) FUNCTION STANDARDISATION

This involves leaving the mechanism alone and modifying only the function. In effect, one multi-purpose mechanism is designed in order to eliminate physically changing attachments. Therefore only a minor adjustment is required for a setup. The following examples serve to illustrate this point.

(i) ROTATING TOOL POST

The setup here merely requires rotating the tool post. Then tooling for the next setup can be inserted behind the machine as external setup (figure 4.12).

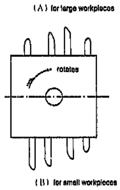


FIGURE 4.12 : Rotating Toolpost (1)

(ii) EXCHANGING PROFILE TEMPLATES

By sinking linear templates into a shaft one can obtain the required copying function by merely rotating the shaft (figure 4.13).

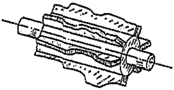


FIGURE 4.13 : Rotating Profile T.mplate (1)

(d) FUNCTIONAL CLAMPS

A functional clamp is an attachment device serving to hold objects in place. This involves fixing attachments to the machine and usually takes the form of nuts and bolts. A bolt is passed through a hole in the attachment and fixed into a nut on the machine. The bolt must be turned a large number of times into the nut before the attachment is tightly secured onto the machine. However, it is only the last turn that tightens the bolt and the first turn that loosens it. The time required for the remaining turns are wasted. Figure 4.14 illustrates some of the one-turn or quick release attachments.

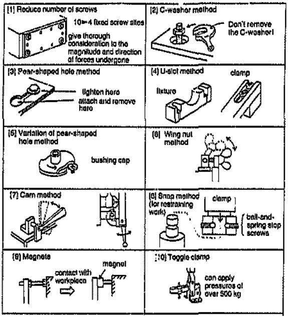


FIGURE 4.14 : Examples of Screw Improvement (1)

(e) MECHANISATION

Mechanisation should preferably be the last stage of the setup reduction programme. Mechanising an inefficient setup operation will only achieve limited time reductions, and will do little to remedy the basic faults of a poorly designed setup process. (2) It is much more effective to mechanise setups that have already been streamlined. It should also be noted that mechanisation can involve a large capital layout, therefore it is advisable to investigate if this small improvement is cost effective.

4.5 COST CONSIDERATIONS

It is recommended that the same costing approach be adopted as has been done by Cummins Engine Company. (31) They have adopted a "no cost/low cost" approach with limited expense budgets available. Capital expenditure if required later, would need to be fully justified via the normal capital approval process for the particular company. (31)

4.5.1 COST/SETUP TIME RELATIONSHIP

During the initial stages of the setup reduction programme simple machine or attachment modifications and tooling organisational changes can be made yielding large time savings at low cost and in a relatively short period of time. (1) After that things get tougher in compliance with the law of diminishing returns - big money for small improvements. (31)

The 80/20 rule could be used to roughly approximate the relationship between setup time and improvement costs, demonstrated by figure 4.18. As shown, 70 - 80% setup time improvement is acnieved with 20 - 30% of the potential modification costs. This is accomplished via stages 1 and 2 of the setup reduction programme which involves tooling organisation improvements, procedural changes and simple low cost tooling modifications (refer to sections 4.3.2 and 4.3.3). In order to cut down the remaining 20 - 30% setup time it would be necessary to invest another 70 - 80% of the potential modification costs. This represents stage 3 of the setup reduction programme where setup operations are streamlined via further tooling and machine modifications (refer to section 4.3.4). It should be noted that the curve shown if figure 4.15 may vary marginally, depending on the setup.

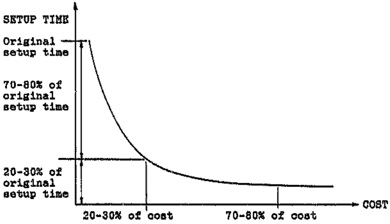


FIGURE 4.15: Cost/Setup Time Relationship

4.5.2 SETUP COST ANALYSIS

As was previously stated, capital expenditure for setup reduction may have to be justified before funds are approved. Therefore it is usually necessary to calculate if setup reduction is cost effective.

According to Goldratt the company concerned should determine how idle machines affect real cash flows and accounting costs should not be considered. (13) Therefore machine depreciation costs have not been included in the analysis since this is an accounting figure (usually used for tax purposes). Salaries of setters have also not been included since it is usually the case that if setups are drastically reduced, the company will still employ the setter full time. His expertise will merely be used elsewhere in the company. Therefore setters' salaries do not effectively change. Salaries may only be included in the analysis if setters are dismissed. Overheads have also not been included since these are fixed costs regardless of setup time.

The setup cost analysis proved to be a diffucult process since certain relevant factors are not easily quantifiable and interact with other relevant activities. However a rough costing procedure has been devised by the author as follows:

Real Costs of machine downtime:

A = loss of sales/hr. related to lead times.

B = holding costs/hr. determined by lot sizes and overall work-in-progress.

C = scrap costs/hr. due to unsuitable preventative maintenance or setup techniques. Note that adjustments will almost always produce scrap.

Note that scrap costs are related to lot sizes, since the smaller the lot size, the quicker quality problems are detected and therefore the lower the scrap.

C(t) = Total cost/hr. due to the above factors
= A + B + C

Setup Times:

Present setup time = T(1)

NOTE: All times associated with the operation being examined must be included; eg. related adjustment time and trial run times.

Estimated improved time (using pareto analysis) = T(s)

Cost of Implementation:

Cost of tooling for setup activity = D
Cost of subcontracted labour for implementation = E
Total implementation cost = C(I)

Break-even Analysis:

Cost of present setup $C(p) = C(t) \times T(1)$
Cost of improved setup $C(n) = \dfrac{C(t) \times T(s)}{x^*}$

Number of setups to be performed to cover implementation costs $N = \dfrac{C(I)}{C(p) - C(n)}$

It is now possible to look at the production schedule and determine over what period of time N setups will be performed. From this it can be determined if implementation of an idea is cost effective or a short, medium or long term basis.

* Setup time reduction also reduces setup costs indirectly by allowing smaller lot sizes to be economical - thus reducing holding costs, and improving quality - thus reducing scrap costs. Therefore a weighting factor x has been introduced in calculating the cost of the improved setup. The larger the holding cost and scrap savings, the higher the weighting factor. It is the author's opinion that this weighting factor would range between 1,0 and 2,0.

4.6 WORKER MOTIVATION

The general aim of motivation is to appeal to the *psychological* process to get individuals to willingly pursue organisational objectives. (32) If possible, a manager should "match" organisational objectives with an individual's personal objectives through selected work assignments. (32)

Fein says that unless managers believe that workers can help raise productivity and are willing to involve them, a programme should not be started. Half-hearted management support indicates to workers that management does not believe they can help; the programme is doomed. Requirements for a successful programme are trust and credibility between employees and management. (34)

4.6.1. *MOTIVATION TECHNIQUES*

According to Shell, Scuder and Damachi, it has been found that the top five factors to motivate *technical employees* are achievement, recognition, advancement, the work itself and the possibility of growth. (32) These are incentives which tend to motivate by linking rewards to performance.

Rewards will only assist in performance if the following occur : (32)

(i) The employee believes that productive effort will lead to reward.

(ii) The criteria that will be used as bases for rewards are clearly communicated and understood.

(iii) Rewards are perceived as fair and equitable.

(iv) Managers understand the potential impact of rewards on other subordinates.

(v) The organisation attempts to involve its people in decisions affecting their work lives; eg. pay, benefits, job security, alternate work schedules and participation.

According to Sink, motivational techniques can be classified under money, goal setting, participation and job enrichment. (33) He makes reference to a study which showed that financial incentives are relatively more effective than any of the other techniques. (33) Contrary to these findings, Schonberger (11) and Hall (10) both agree that incentive pay systems are disadvantageous to the long term goals of the company. Individual incentive pay systems make a company's shop floor into an every-worker-for-himself-affair, which is disasterous if they must work as a team (which is usually the case for setup reduction). (10)

This convincingly backs up the fact that not all people need the same rewards, and the same individual may need different things at different times. (32) According to Schonberger, one of the problems with incentive schemes is that managers are not sure which performance measures to base the incentive system on. (10) The company must think carefully before inplementing an incentive pay system, since once implemented it is difficult to abandon. (11)

4.6.2. INCENTIVE SCHEMES

According to Sink, incentive systems can be divided into economic and non-economic incentives. (33)

(a) ECONOMIC INCENTIVES

Direct financial plans include cost savings sharing and profit sharing schemes. (33) According to Fein, an important element in the success of productivity sharing plans is that employees share directly in productivity gains and all employees are involved. They see the fruits of their efforts in their pay cheques. Since productivity losses affect them, employees participate actively in raising output (34).

Indirect financial plans include wage and salary systems, benefits, promotion practices, merit evaluation and perquisites (33). With regard to setup reduction, it may be the case that any of these plans applied to individuals are indeed not beneficial, as stated by Schonberger and Hall (discussed before). Therefore it is recommended by the author that group rather than individual financial incentive schemes are adopted. This would encourage competition between setup teams and would at the same time encourage members of the team to actively participate.

(b) NON-ECONOMIC INCENTIVES

This mainly consists of job redesign, job rotation and non-financial recognition. (33) Sink refers to a job redesign model which identifies five core job dimensions - skill variety, task identity, task significance, autonomy and feedback. (33)

With regard to setup reduction, skill variety is satisfied since the setter's job is effectively transformed from performing long setups to identification of setup improvements. Task identity and task significance can be related to the training programme where setters are educated in "the JIT concept", "JIT manufacturing" and "the changing business environment". (31) In effect setters have been made aware of why their task is important and how it fits into the company's manufacturing and business strategy. Autonomy is satisfied since setup teams are free to implement no cost/low cost changes when necessary. (31) Feedback is then accomplished since setters can visually see how modifications improve setup times.

Job redesign takes place in an attempt to increase the degree to which a given job satisfies the five core job dimensions. (34) Improvement of the job dimensions will theoretically improve or enhance critical psychological states or how the individual feels about the job, which will in turn have a beneficial effect on behaviour and work-related outcomes. (34)

Non-financial recognition involves publicising the achievements of setup teams. Improvements should be displayed either at the machine or on a notice-board for all to see. (2)

5. SETUP TIME REDUCTION AT VIRO LOCKS - A CASE STUDY

A setup reduction programme was implemented at Viro Locks (Pty) Ltd, where modifications were made on a bottleneck machine. This section will discuss the production process of the company, the product, the approach to the setup programme, what modifications were made on bottleneck machines, and what still has to be done. The changes shown here were devised over a 2 month period with the author acting as a full time setup reduction programme co-ordinator.

5.1. THE COMPANY

Viro Locks are market leaders in the production of brass padlocks, and have been so for a number of years. Over the past year (1986 - 1987) the company has become extremely interested in just-in-time production and some major improvements have already been made.

The factory layout is shown in figure 5.1 where the process moves from incoming raw materials through to component manufacture and on to final assembly and despatch. The assembly side of the factory has experienced some major changes where lot sizes, and therefore work-in-progress, has been reduced dramatically. Assembly has been streamlined where short assembly lines have been set up for each product. In fact assembly never has more than one or two days work-in-progress at any one time.

The problems lie on the component manufacturing side of the factory. A batch system is still being used where large lots are being processed. Very often the criteria used to change to another job is when raw material is all used up. Raw material is ordered according to forecasted demand, therefore components are also being manufactured according to this demand. If actual demand is less than that forecasted, the company is manufacturing components in anticipation of firm orders. Conversely if actual demand is higher than that forecasted, stockouts will occur. Essentially the company uses a push system for component manufacture and a pull system for assembly. After manufacturing, components are kept in the stores and drawn by assembly when needed (figure 5.1).

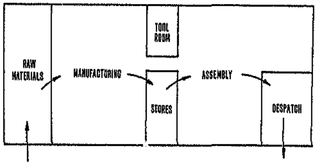


FIGURE 5.1 : Factory Layout

Viro Locks manufactures a range of brass padlocks with hardened shackles as well as security locks and night-latches. Since padlocks account for the majority of production only these will be further discussed. Plate 5.1 illustrates the basic components making up the padlock assembly.

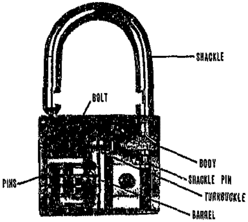


PLATE 5.1 : Padlock Assembly

A range of standard locks are produced which are "bread and butter" lines and account for most of the company's turnover. Orders for standards are fairly consistant every month, therefore forecasts are fairly accurate. The company continuously produces the required number of products, for each model type, to meet the forcasted demand. Assembly assembles these items soon after the components have been manufactured (in predetermined batch sizes) in order to avoid excess work-in-progress. Unfortunately only one model type can be assembled at any particular time. In essence standard items are made-to-stock due to the large time gaps between model changeovers. Therefore a buffer stock of finished goods is built up in an attempt to avoid stockouts of any particular model.

A small percentage of turnover is generated by approximately 12 special items. Orders are erratic and therefore it is almost impossible to forecast demand for these items accurately. Smaller lots of lock bodies (2 days - 2 weeks production) are manufactured on one machine, (for all 12 body types) since demand is lower. Since the changeover takes 1 - 2 days it is evident that setup times take up a large proportion of production time.

The company is able to deliver special items with short lead times. This is achieved by manufacturing components according to a monthly forecast (usually a very inaccurate one) and moving them to stores when completed. When a fixed order is placed, the company can draw components from stores and assemble the desired numbers in a short period of time. Therefore special items are make-to-stock, assemble-to-order.

5.2. EXAMINING OVERALL PRODUCTION

(a) GROUP TECHNOLOGY

Machines have not been grouped into product families because manufacturing and assembly have been laid out seperately in the factory. Therefore a finished product could not emerge from a GT cell. Furthermore shackles are sent out for hardening which causes a significant time delay. Combining manufacturing and assembly has been previously reviewed (35) but was discarded due to problems in noise levels and high costs. GT cells would not benefit special items since finished articles are made-to-stock, assemble-to-order. If manufacturing and setup lead times were reduced, specials could be made to order. However a suitable stock of shackles would have to be kept since these experience a significant lead time when sent to a subcontractor for hardening.

(b) SETUP SEQUENCING

Setup sequencing has been implemented for standard items since demand for these items is fairly constant and a production sequence has been calculated accordingly. Machines for these items have fairly long runs with few setup changes, therefore in this case setup sequencing is not a priority. However when setups become shorter and more regular, more effort will be spent on sequencing. For special items orders are not consistant. A buffer for special items has been created by making-to-stock, assembling-to-order; however there are still material shortages, emergency orders, breakdowns and at this stage the long setup time (1-2 days) on the transfer machine. This requires a large degree of flexibility for special items, thus limiting the advantages of setup sequencing.

(c) DEDICATED MACHINES

Machines producing parts for standard items have been semi-dedicated, where two or three similar parts have been assigned to one machine. For example, four standard lock bodies are processed by two machines. In this case tooling organisation has been simplified since only two sets of tooling are required at each machine. In the case of special items, certain machines have been dedicated to these items. This ensures that standard item production is kept constant and is not affected by special item market changes. Unfortunately small machines running in parallel have not been implemented (especially in the case of transfer machines producing lock bodies - a bottleneck in the system) effectively resulting in production stoppages in the event of a breakdown.

(d) THE OPT PRINCIPLE

It was determined by management that a bottleneck existed at the transfer machines producing lock bodies. (36) This was largely due to setups taking 1 - 2 days to complete. At present assembly must often wait for lock bodies to be completed and inventry always exists before transfer machines. Since transfer machines for standard items have been semi-dedicated, the setup reduction programme was concentrated on transfer machines producing special item lock bodies. Since all transfer machines are similar, changes which are made on one machine can eventually be made on all transfer machines.

(e) THE 80/20 RULE

The value of the lock body was also used as a criteria for machine selection for setup reduction. The lock body accounts for approximately 75% of the value of the completed padlock (36), resulting in a large amount of cash being tied up in inventory. It would be desirable to have as little inventory of this component as possible. Therefore the need to minimise setup times, resulting in smaller batches and thus less inventory.

5.3. PRODUCTION PROCESS AND MACHINING

Since setup reduction was initially only performed on bottleneck workcentres (transfer machines), only these will be further discussed.

Raw material arrives at the factory as long strips of brass, extruded in the shape of the specific lock body profile. Bodies are then cut to size on a manual cut-off machine and the name of the lock stamped. Up to this point there are no bottlenecks.

In order to make up the assembly (plate 5.1), a number of holes must be drilled in the body into which other components fit. Drilling and reaming operations are performed by transfer machines.

The company has not used its old transfer machine for dedicated manufacture. The newer machines are semi-dedicated and produce standard bodies while the older machine is used to process specials. The reason for this is that newer machines have twice the capacity of the older one, which are needed to keep up with the high demand of standard products.

The transfer machine used for this task has been designed almost like a group technology work- cell. Seven stations containing nine heads are situated around the perimeter of the machine facing inwards, sideways or downwards. At the centre of the machine is a rotating table containing eight sets of pneumatic jaws, into which eight bodies are placed.

The drilling cycle works as follows:
The operator puts a body into the set of jaws facing him. Note that there are seven drilling stations and eight sets of jaws. This is so that the operator can load the machine while the drilling heads are working. When the automatic cycle mode is engaged, the indexing table is actuated by the pneumatic system which closes the jaws on the body. Then when the heads have

all completed drilling, the table indexes automatically such that each body advances by one station. The operator removes the completed body and inserts the next one, thus repeating the process. In this way seven bodies are all operated on simultaneously and advance between stations until all holes are completed.

Plate 5.2 shows how the bodies are located in the jaws. Figure 5.2 illustrates the lock body, showing which holes must be drilled in this operation. Next to each hole the number in brackets signifies which machine head or unit was used for drilling or reaming. Figure 5.3 illustrates the basic layout of the machine showing the seven stations and where the nine drilling units are located. An "H" on the diagram signifies that that particular unit traverses horizontally. A "V" means vertical traverse. Furthermore each unit is labelled with a "D" or an "R". A "D" signifies that a drill is used in this unit and an "R" corresponds to a reamer. Therefore if a hole has been machined by two units (figure 5.2), then that hole has been drilled and reamed.

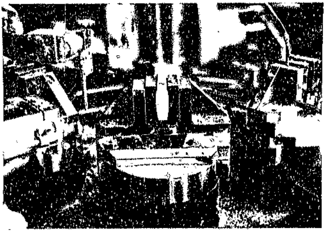


PLATE 5.2 : Body Orientation in Jaws

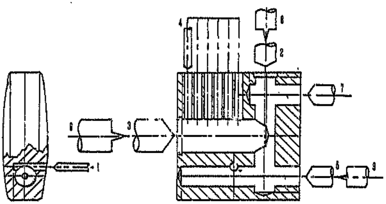


PLATE 5.2 : Drilled Body

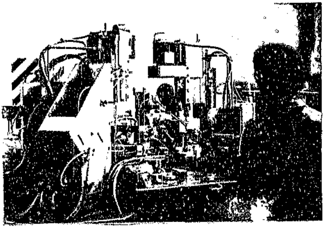


PLATE 5.3 : Transfer Machine

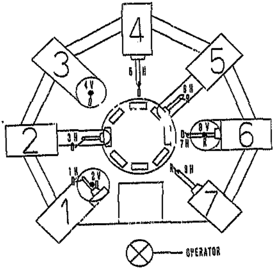


FIGURE 5.3 : Transfer Machine - Plan View

5.4. TRAINING OF THE SETUP TEAMS

At the start of the setup reduction programme top management (specifically the technical director) decided that it would not play an active role, but merely coach the people directly involved with the programme, ie. setters, operators, line supervisors, etc. This ensured that ideas had to come from people on the shop floor.

The training programme was initiated by the author and included the two primary setters in the company and two operators involved with transfer machines. This group essentially made up the setup team with the author acting as programme coordinator. The production manager was also involved since he had a sound knowledge of the machines involved and could recommend or reject proposed modifications.

The setup team was shown how setup reduction would benefit the company as a whole by giving them an overview of the JIT concept and JIT manufacturing, as well as how setup reduction would change their position in the company (see section 4.2 on training for setup teams). Setters were shown how their jobs would change from long tedious setups to short, simple setups with more time available for idea generation and building of modifications.

The author introduced he team to the new way of thinking by giving generalised examples and showing how these could be used on the transfer machine. This immediately triggered ideas from setters who had seen similar techniques on other machines but had never related these to setup reduction.

Since setup reduction was new in the company the team could not learn via setup demonstrations. However this team was used to generate a demonstration setup on an existing transfer machine in order to train other personnel.

It was established by the author that the desirable qualities of the setup team and associated management personnel consisted of the following:

(i) The setters, production manager and technical director had a good knowledge of the machines.

(ii) The production manager had engineering skills in order to control machine modifications and knew which off-the-shelf items were available.

(iii) The production manager and technical director were well connected with outside companies for subcontracting purposes.

5.5. APPROACH TO SETUP REDUCTION

5.5.1 PRELIMINARY STAGE: INTERNAL AND EXTERNAL SETUP NOT DISTINGUISHED

(a) WORK/TIME STUDY

It was found that the existing setup had no set procedure and all setup operations were performed randomly. Similar operations for a specific job took varying amounts of time, depending on the setter's performance on that particular day. For these reasons more than one setup was observed and average times calculated. Different problems arose for different jobs (these were random problems which had little to do with the specific job being set up). Therefore a number of different setups were observed to expose as many setup problems as possible.

A time lapse video was used to film the setups as well as an analyst (the author) who simultaneously recorded activities and respective times on a work sheet for each setup. Worksheet examples for the case study are shown in appendix B1.

(b) ACTIVITY CLASSIFICATION

It was observed that since there was no setup procedure, certain activities were interupted and resumed later. For example, the operation could be changing jaws and the setter would require assistance with height adjustment. The operator would then leave the jaw attachment operation and assist with height adjustment. For this reason it was necessary for the analyst to decide on broad categories first and then fit activities from the worksheet to these categories. Using this method overall times for each category were determined by adding times o. eac.. relevant activity.

Setup categories for the case study are shown in appendix B2 with approximate times for each category. Setups 1 and 2 are similar setups, therefore the time discrepencies between these illustrate how unpredictable setup times can be. It should be noted here that the addition of the times for each category does not equal the total time for the setup since setters and operators may work on different operations simultaneously. Therefore times should be calculated as follows. If setup people are performing different tasks simultaneously, their times fall into different categories and will be added. If they are performing the same task together, their times fall into one category and only the actual time (which is the time for one worker's activities) is taken into account.

5.5.2 STAGE 1 - SEPERATING INTERNAL AND EXTERNAL SETUP

By studying the worksheet, a rough estimate was made of which setup categories could be externalised or eliminated (appendix B3). Referring to the table in appendix B3 it was immediately evident for example that tooling organisation was internal due to bad planning and subsequently had to be rearranged. Inspection time could be considerably shortened by making an inspection gauge available at the machine, shimming of jaws could be eliminated by setting predetermined jaw heights and maintenance could be eliminated from the setup by scheduling a periodic maintenance inspection outside of setup time. Furthermore it was realised that no presettings were made; everything had to be adjusted afterwards.

All activities which could be made external or eliminated were tackled first in order to achieve maximum benefit with minimum effort.

5.5.3 STAGE 2 - CONVERTING INTERNAL TO EXTERNAL SETUP

(a) PARETO ANALYSIS

For the case study a Pareto chart of each category (listed in appendix B4), for setups 1 and 2, was drawn up and is illustrated in appendix F. Note however that tooling organisation and maintenance have not been included, since these have already been moved to external operations and do not require further analysis. Furthermore, adjustment time has also been omitted from Pareto analysis since:

(i) Adjustments are dependant on changes made to other operations. For example, the extent of adjustment is directly dependent on setting drill depths, mechanical stops and electrical stops; shimming jaws; and height settings. It was realised that by presetting all of these, much of the adjustment and trial run time could be eliminated.

(ii) Adjustments vary between setups. It would be pointless to analyse this category of operations since the adjustment time required for different setups is completely random. For example, on one setup the required setting may be achieved first time without any adjustment necessary. On the other hand the setter could be unlucky on another day, and may have to make say eight adjustments before the desired setting is reached. This illustrates how the operation of making adjustments cannot be fixed in a set procedure.

Since much implementation still has to take place, these charts show what the new setup time is percieved to be. Each operation was examined, and using the relevant idea an estimate can be made of which operational segments could be made external, eliminated, or reduced.

Besides looking at times, it was important to observe how well operations were carried out. Although the setup showed cleaning time to be low, it was found that the machine was not adequately cleaned. It was estimated that to clean the machine properly using existing methods would take approximately 4 hours. Therefore this cleaning operation time has been added in the pareto analysis in order to receive the proper attention required (appendix B4).

(b) MODIFICATIONS FOR INTERNAL SETUP

Modifications to attachments and machine are discussed in section 5.6. The problem of not adopting fixed setup procedures in the conventional setup was effectively illustrated. The operator was usually not aware of what to do next and waited for instructions from the setter. Unfortunately the setter also did not know what was to come next, and decided as he went along. In the end the operator assisted the setter in operations where two people were needed; performed operations which should be external, eg. looking for tools, gauges, etc; or merely remained idle waiting for his next instruction.

The categorised setup operations (appendix B2) show idle times for setups 1 and 2. However this only illustrates the times for which both workers were simultaneously idle. If the time study worksheets are examined (Appendix B1), it is evident that the times for which each worker is idle are considerably longer.

For example, setup 1 shows an idle time of 45 minutes, which is accounted for by one lunch break of 30 minutes and one tea break of 15 minutes. When analysing the work/time study sheet it is apparent that the setter was idle for the above 45 minutes. H[illegible] the operator (who was assisting) was idle for a total of 5 hours and 30 minutes, plus the above 45 minutes. This idle time for the operator does not include time spent on activities which could be eliminated or made external. These times made up an additional 50 minutes, totalling almost 8 hours. This means that for a 10 hour setup, the operator was effectively utilised for approximately 20% of the setup.

After some modifications were made to the setup, a rough procedure was drawn up (appendix D), where an attempt was made to synchronise operations performed by the setter and operator, as well as minimise idle time. This procedure will be tested and modified accordingly. It is not impossible for time estimates to be so inaccurate that the procedure must be totally revised. This illustrates how setup time reduction can only progress by doing and seeing.

(c) <u>ELIMINATING ADJUSTMENTS</u>

This was achieved mainly by dedicating attachments of fixed dimensions to specific jobs. For example; instead of adjusting the length of a threaded rod for a depth stop, a bolt of predetermined length was inserted for each respective job. The workpiece then had correct hole depths on the first run, eliminating any further adjustments. (Discussed further in section 5.6)

5.5.4 STAGE 3 - STREAMLINING SETUP OPERATIONS

Since the setup reduction programme is still in the initial stages, this stage has not yet been reached.

5.5.5 OTHER CONSIDERATIONS

(a) STUDY/ACTION APPROACH

Putting ideas into practice is an ongoing activity at Viro Locks. Modifications are tried out immediately providing they fall within the budget of R3000.

(b) CHANGEOVERS DURING A PRODUCTION RUN

During production it was necessary to change small drills every 3 hours and large drills once daily. The conventional method involved replacing drills in approximately the correct positions and adjusting mechanical and electrical depth stops. This was a fairly lengthy procedure since trial runs had to be made and test pieces checked with gauges. It was discovered that this was a job that operators avoided, and the necessary changes were not made periodically as specified. This led to a higher scrap level since blunt drills were "wandering" on the face of workpieces.

This activity was improved by using the same procedure for setting drill depths as was adopted in the setup (see section 5.5.6.). Blunt drills were resharpened and lengths preset when they came off the machine in order to be ready for the next drill changeover. This activity was shortened to a few minutes, thus giving the operator no reason to avoid it, as well as reducing trial run scrap pieces.

(c) DOCUMENTATION

The following have been documented at Viro Locks by the facilitator (the author):

(i) The existing setup procedure for job numbers 430/530/010 and 302 (appendix B1).
(ii) Pareto analyses of these jobs (appendices B4 & F).
(iii) Implemented ideas and rejected proposals (section 5.6).
(iv) A proposed, revised setup procedure (appendix D).
(v) New policies (section 5.6.1).

In addition the setter has documented which tools are required for these specific jobs (appendix C).

(d) SUBCONTRACTING

From observations by the author it was usually the case that the toolroom was too busy attending to everyday requirements to worry about setup reduction attachments. Therefore the company had to turn to a subcontractor. It was noted that subcontracting caused delays in the setup reduction programme since toolmakers had a backlog of jobs.

(35,36)

Subcontractors had the added disadvantage of not being able to identify with the actual machine. Therefore the company had to provide the subcontractor with a detailed set of working drawings, a time consuming activity. Furthermore subcontracting was expensive without any guarantees that parts would be accurate.

5.6. MACHINE MODIFICATIONS

The following are hardware changes which were made on the transfer machine used for manufacturing special items. Since all transfer machines in the company are similar, the ideas adopted here can be extended to other areas in the factory.

This section will take each broard category in the setup (appendix B2) and discuss each in turn, illustrating what originally existed and respective modifications.

(a) TOOLING ORGANISATION

Tooling was originally pre-sharpened and organised at the machine before the setup begins (externally). Therefore the time for this function should essentially be zero. However certain problems could arise due to inadequate tooling organisation which would make tooling organisation internal. These included the following:

(i) Problem 1:
Although tooling was brought to the machine it was not organised logically. Therefore time was wasted in looking for which tool fits into a particular unit. (Operator especially could not readily identify tooling).

Solution 1:

Organise tooling into tooling boards where all tooling for each station is easily identifiable. ie. group tooling for each station or unit of the machine together and label each tool (plate 5.4). Tooling must be arranged on the boards in a pattern approximately corresponding to the setup procedure, ie. the order in which the setter uses the tooling. The boards fit onto trays which can be placed on the perimeter of the machine (plate 5.5).

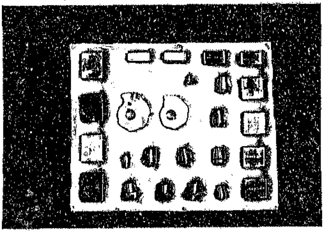


PLATE 5.4 : Attachments Arranged on Boards

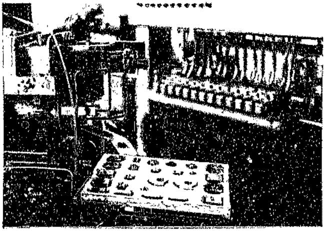


PLATE 5.5 : Trays Located on Machine During Setup

(ii) Problem 2:

Tools were left on tool trolley, on machine or any ledge, or settur and operator both needed the same tool at once. Therefore setter and operator were walking back and forth looking for tools during the setup.

Solution 2:

Tools required for a certain job must be itemised and placed in a seperate tool board near to the machine (plate 5.6). When each tool has been used it must be replaced on the tool board.

If the setup procedure requires that a particular tool is used by setter and operator simultaneously, a duplicate of that tool must be made available during the setup.

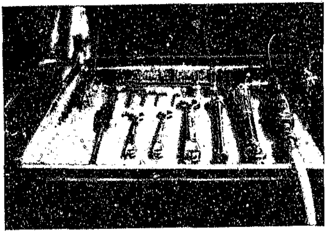


PLATE 5.6 : Tools Organisation During Setup

(iii) Problem 3:

When old tooling was taken off a machine it was placed next to new tooling and blunt tooling could get mixed up with sharp tooling.

Solution 3:

Plastic bin/s must be provided into which all old tooling is placed. Operator or setter must not clean or sharpen any of this tooling until setup is complete.

(iv) Problem 4:

The job originally scheduled for setup 1 was job no. 430. All the tooling, etc, was presharpened and prepared for the setup. As the machine went down it was decided to change to job no. 802. No tools were pre-sharpened, hence the additional time required for tooling organisation. Furthermore drills, reamers, collets and bushes had to be located from stores - a lengthy procedure.

Solution 4:

Tooling organisation must fall into the post- rather than pre-preparation category, ie. all old tooling must be sharpened and cleaned immediately after the setup is complete. In this way all tooling can be available at a moments notice before the setup. Two policies need to be adopted as follows:

Policy 1 : Each job will have its own complete set of tooling. If any tooling breaks it must be replaced from stores and not borrowed from another job's tooling. Setup tooling must be kept in a locked cupboard on the shop floor (near to the machine) to which only the setter has a key. In this way the setter can be held responsible for missing tooling.

Policy 2 : No tooling may be replaced in the tooling boards until all drills, etc, have been sharpened and all required distances on other setup equipment have been checked. It may be a good idea to actually drill and ream all holes in a piece of scrap brass and check hole diameters (using plug gauges) for burrs or other inaccuracies. (burrs are sometimes found on a test body and time is wasted changing and re-adjusting the drill during the setup).

(v) Problem 5:

Tooling organisation in the tooling cupboards was poor and the setter had to search for tooling (plate 6.7). The only identification was the job number stamped onto the jaws and seats. Other tooling was found in stores by using a drawing of the body.

Solution 5:

All tooling must be colour coded where the tooling and tooling boards have matching colours according to a specific job. The setter can then tell at a glance if any tooling is incorrect or missing and make the necessary replacements before the setup begins. If a set of tooling can be used for two jobs (eg 430 and 530), the tooling board and tooling must contain both colours. For specific tooling which is required for two different jobs (eg. seat inserts which are expensive to make for every job), keep all seat inserts on a specific board labelled "seat inserts" (which is colour coded) and transfer tooling from the "seat insert" board to the job tooling board just before the setup begins. As a backup to the colour coding system, all tooling and tooling boards should be stamped with the relevant job number.

PLATE 5.7 : Tooling Cupboards Before Improvements

(vi) Conclusions:

With efficient tooling organisation, this activity can essentially be converted to an external operation. ie. tooling organisation time is cut down to zero during the setup. Furthermore this external function can be streamlined and the time for this reduced, resulting in higher flexibility when dealing with extraordinary conditions.

(b) REMOVING OLD AND REFITTING NEW JAWS

Present procedure for each vice is as follows:

- Remove jaws
- Remove left-hand vice
- Remove seat
- Clean left-hand vices (off machine)
- Clean vices (on machine)
- Fit new seats
- Replace left-hand vice
- Fit new jaws

The left hand vice must be removed in order to reach the bolts, holding the seat, with an allen key. (figure 5.4)

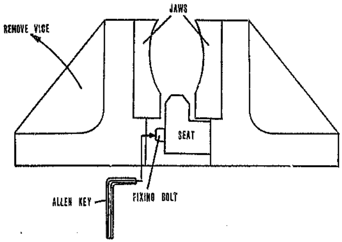


FIGURE 5.4 : Seat Attachment Before Improvement

Proposals for improvement:

(i) A second set of vices could be made where the jaws and seats are fitted off the machine, and the old vice assembly is replaced by the new. A major advantage is that inaccurate jaws could be shimmed off the machine. The proposal was discarded however due to (1) the enormous cost involved, (2) the time scale required for delivery, (3) it was doubtful that a local subcontractor could successfully manufacture such an item and (4) four bolts are used to fix each vice whereas only two are used to hold each jaw.

(ii) The jaws and vices could be remade to incorporate a dovetail or T-slot arrangement as shown in figure 5.5. This was also discarded as a short term solution for the same reasons as proposal (i). However this was recommended as a long term solution.

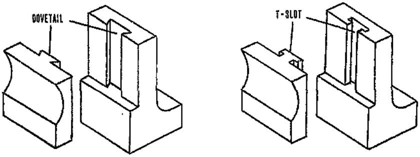


FIGURE 5.5 : Quick Attachment/Removal of Jaws

(iii) A pneumatic tool is already available therefore as a short term solution it was decided to mount the jaws onto the vice as is currently being done, but with the mechanical aid. The function of taking off the left hand vice in order to detach the seats is an unnecessary time consuming activity. Therefore it was decided to design and manufacture a new set of seats with different size seat inserts corresponding to different lock sizes. (plate 5.8)

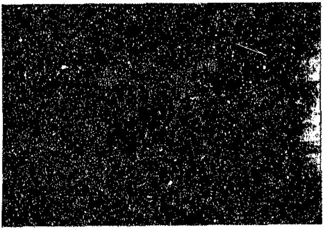


PLATE 5.8 : Seat Inserts

Another solution to streamline the operation may be to use the split thread method to fix the jaws to the vice so that only one turn is required per bolt (figure 5.6). The seat insert only needs one turn since the pear shaped hole method of

(iii) A pneumatic tool is already available therefore as a short term solution it was decided to mount the jaws onto the vice as is currently being done, but with the mechanical aid. The function of taking off the left hand vice in order to detach the seats is an unnecessary time consuming activity. Therefore it was decided to design and manufacture a new set of seats with different size seat inserts corresponding to different lock sizes. (plate 5.8)

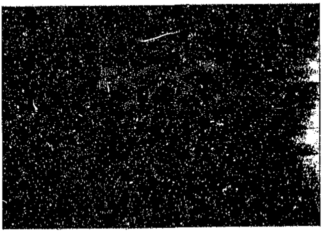


PLATE 5.8 : Seat Inserts

Another solution to streamline the operation may be to use the split thread method to fix the jaws to the vice so that only one turn is required per bolt (figure 5.8). The seat insert only needs one turn since the pear shaped hole method of fixation has been incorporated. Furthermore the bolts length which fixes the seat insert has been standardised, therefore the bolt need never be removed.

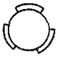


FIGURE 5.6 : Split Screw Thread

(c) REMOVING OLD TOOLING

This takes up a very small percentage of the total setup time and therefore the present methods have been deemed acceptable for the short term. The time for this will improve slightly since preset (quick release) tool holders have been fitted to units 8 and 9. (plate 5.9) Unit 2 is also suitable for a preset tool holder but this will cause problems with the bush through which the respective drill passes.

For the long term a completely new arrangement would be required for holding drills and reamers and for fixing bushes. This would involve major modifications to the machine and must therefore be analysed for cost effectiveness. A proposal is illustrated in figure 5.7 where a special quick release tool holder must be designed (similar to existing ones). Then all drills and reamers can be mounted into tool holders off the machine and adjustments made externally. Standard tool holders (plate 5.9) cannot be used since length L is long and most heads are not designed for them. Notice in figure 5.7 the pear shaped holes for attachment bolts in order that bolts need only be loosened one turn in order to remove drills.

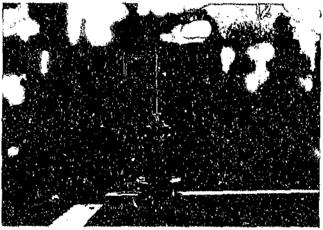


PLATE 5.9 : Existing Quick Release Tool Holder

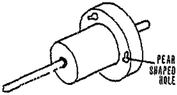


FIGURE 5.7 : New Quick Release Tool Holder

(d) HEIGHT ADJUSTMENT

At present height adjustment time is deceiving. Looking at setups 1 and 2 it appears that this function takes a relatively short time. In fact the current method used is totally inadequate and leads to highly inaccurate machining. Height blocks are used to position the heights of each station as shown in plate 5.10. Once height is determined (using height blocks as a feeler gauge in gap) bolts holding units are retightened.

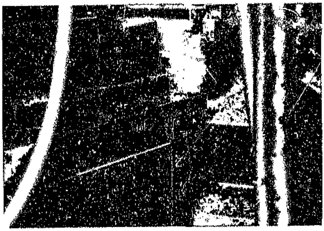


PLATE 5.10 : Height Setting Blocks

Reasons for inaccuracies:

(i) When loosening bolts (which hold unit) the sliding portion of the unit tends to move away from the fixture leaving a gap as shown in figure 5.8.

Therefore even if a clock gauge were to be used on the unit to adjust heights it would not give the same reading as the actual movement of the tool, since the tool is no longer horizontal.

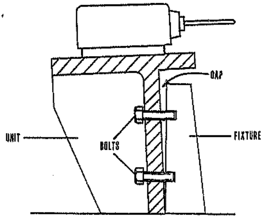


FIGURE 5.8 : Undesirable Gap on Unit

(ii) When the height blocks are placed in the gap (plate 6.10), either the fit of the blocks will be different from one setup to another or the fit will be different on either side of the head. On some heads, which were eventually set correctly, the height blocks would not fit into the required gap.

(iii) When the bolts holding the head are retightened the whole head tends to move due to friction.

(iv) When a clock gauge is mounted onto the base of the unit to change height, inaccuracies occur due to internal stresses on the unit.

<u>Solution:</u>

It was decided to eliminate height adjustments by using dead stops. Existing height blocks were accurately machined and respective heads reston height blocks when the machine is in operation. This solved problems (ii) and (iv).

Problems (i) and (iii) were resolved as follows. On each bolt used to tighten the head a new arrangement was adopted as shown in figure 5.9.

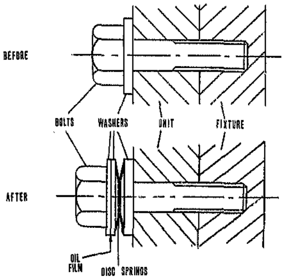


FIGURE 5.9 : Tightening Bolts for Height Adjustment

The oil film between two washers prevent the head from moving when tightoning bolts. During the setup the bolts are loosened and retightened to a very low torque. This allows the head to move up and down but the disc springs prevent the head from moving away from the machine.

(e) FITTING NEW TOOLING

Short of re-designing and manufacturing new heads, the method of attachment must essentially remain the same. As was mentioned before units 8 and 9 are of the quick release type and the tool protrusion from the tool holder can be preset. There is a gauge for this purpose currently used for two other machines (plate 5.11). The proposed tool holder for quick attachment is discussed in section (c).

(f) <u>SETTING DRILL DEPTHS</u>

At present the protrusion of drills from respective heads is estimated by the setter. This means that mechanical stops need to be adjusted accordingly (discussed later). Since the aim is to make settings rather than adjustments, each tool must protrude the *same amount for* a specific job for every setup.

<u>Proposals</u>:

(i) A collar (which fits over the tool) or gauge block of predetermined size could locate from the tool tip to the head of the unit (collet face) as shown in figure 5.10. The gauge block is held against the collet face and the tool pulled out until it touches the end of the gauge block.

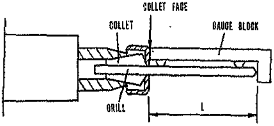


FIGURE 5.10 : Gauge for Presetting Drill Length

This was discarded because a different gauge block would have to be made for every tool for every job - a large task which would slow progress. Also a problem would exist with drills which operate through bushes. A gauge block would not be suitable since the tip of the drill is located within the bush in the head's retracted position (figure 5.11).

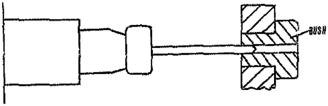


FIGURE 5.11 : Status of Drill in Retracted Position

(ii) It was originally decided to locate the tool in the back of the head (figure 5.12). The backs of the tools would be drilled and tapped and a bolt with a lock nut inserted. This bolt would be used to bring the tool to a predetermined length. Even after the tool is shortened by sharpening, the bolt would be used to bring the overall length back to the original overall dimension. This idea was discarded since the back of the tooling is hardened and therefore could not be tapped.

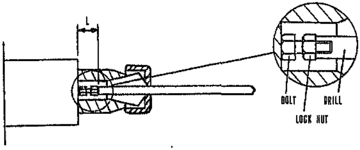


FIGURE 5.12 : Predetermining Drill Length

(iii) It was decided to use drill collars where the length of each drill is set externally using an external gauge (plate 5.11). The collar is fixed onto the drill via a grub screw and locates against the collet face (figure 5.13). This location acts as a dead stop requiring no adjustment during internal setup.

PLATE 5.11 : External Gauge for Presetting Tool Length

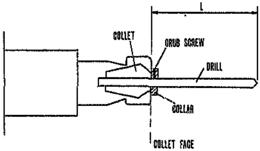


FIGURE 5.13 : Setting Drill Lengths

(g) ADJUSTING DEPTH STOPS

(i) FAST FORWARD STOPS

For the shortest possible cycle time the tool must traverse rapidly until it almost touches the job. Thereafter the predetermined feedrate is engaged by means of a steel block depressing a limit switch. The position of this block (ie. where the transition between fast and slow traverse occurs) must be predetermined in order to eliminate adjustments. At present the block is mounted on a slide so that its position can be adjusted for different jobs. The mechanism is shown in figure 5.14.

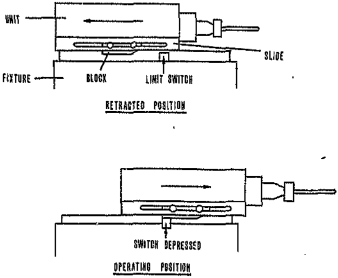


FIGURE 5.14 : Fast Forward Mechanism

Proposals:

(1) It was proposed that an extra set of slides be made with corresponding blocks. Then the position of the block on the slide could be preset before the setup and replaced during the setup. This involved extra time on the external setup and was therefore discarded.

(2) A simpler solution was adopted where a gauge block was placed between block mounting bolt and back of slide as shown in figure 5.15. The gauge block could not locate onto the block itself because the block is situated behind the slide and is therefore inaccessable unless the whole slide is removed. This method is acceptable since the preset distance need not be completely accurate.

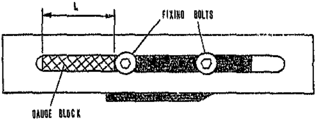


FIGURE 5.15 : Fast Forward Setting Gauge

(ii) MECHANICAL STOPS

Mechanical stops determine the stroke of the head, ie. the depth of each hole in the lock body. The back stop will determine the positional limit of the unit in its retracted position which must be sufficient for the vices to clear the tools when the table is rotated. The forward stop determines how deep the tool will drill into the body. Forward and back stops are shown in plate 5.12.

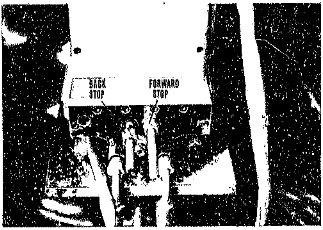


PLATE 5.12 : Forward and Back Mechanical Stops

One of the problems with the current method is that the lock nuts get damaged due to excessive adjustment. Furthermore when a drill change occurs during a particular run the mechanical stops are constantly adjusted. This could be avoided if the tool length was preset (discussed in Section (f)).

The back stop was redesigned by manufacturing a collar (partly threaded) which fits over and locates against the back of the respective threaded rod. The forward stop threaded rod was replaced by a partly threaded bolt of predetermined length. These are now fixed and cannot be tampered with by supervisors or operators (figure 5.16).

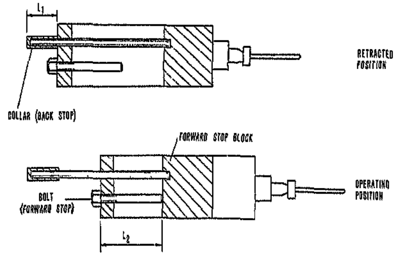


FIGURE 5.16 : Mechanical Stops After Modification

(iii) ELECTRICAL STOPS

These consist of slides along which adjustable blocks are mounted. When the mechanical stops are set the blocks are moved until the limit switch is activated. This may have to be adjusted if the mechanical stop positions are changed.

Other problems encounted are that the slides are becoming distorted due to wear and as a result the blocks are not locating squarely on the slide (plate 5.13). If these stops are to be preset, the present system is totally unacceptable.

PLATE 5.13 : Existing Electrical Stop Slides

<u>Proposals</u>:

(1) It was suggested that, like the fast forward stops, a spare set of slides be made up on which the stop blocks could be preset before the setup. This was however discarded for the same reasons as the fast-forward stop.

(2) A simple system was developed for preseting this function. An assembly as shown in figure 5.17 was made up where a rod was used as a stop. This stop can be adjusted if the limit switch needs to be replaced, since not all limit switches have identical positional stops. As can be seen lengths x1 and x2 are preset and the collar locates against the block face. A pair of rods (of preset length) would be kept in the tooling tray for each unit for every job. During the setup the setter simply replaces the old rods with the new.

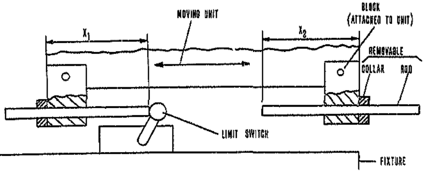


FIGURE 5.17 : Proposed Solution for Electrical Stops

(h) FINAL ADJUSTMENT AND INSPECTION

As can be seen from setups 1 and 2 this constitutes a rather large proportion of the setup and for this reason it was evident that most of the setup problems lay here. On analysis it was discovered that heights, mechanical stops and electrical stops had to be adjusted up to eight times! Then two sets of eight bodies (one per jaw) were checked and sent for inspection.

The reasons for adjustments are as follows:

(i) The hole depths are only approximated in the first instance, therefore it is obvious that adjustments need to be made. The present procedure is to approximate the hole depth, machine a test body, check if the hole is too deep or too shallow and adjust. This is repeated constantly until the setter is satisfied with the finished lock body.

(ii) Height adjustment method which affects distances between holes is inadequate. The solution to this is discussed previously under section (d).

(iii) The setter is not using an adequate sampling size to check bodies. Each dimension has a tolerance band and for the setup the setter should work as close to the mean of this band as possible. The discussion below illustrates the problem.

The present system works as follows. The setter machines a test body and checks distances between holes on a profile projector. He then calculates the difference between the distance measured and the tolerance mean on the drawing. The height of the station is then altered accordingly (using the old inaccurate system as discussed in section (d). Another test body is machined and it was found that the distance was still not correct. The reason for this is illustrated in figure 5.18. The setter adjusts from his measured piece the difference to the drawing dimension. For example if he has measured say 9,78mm and the drawing dimension is 10mm, he will move the machine head correspondingly by 0,22mm.

The problem is that he does not know where the machine mean is (the machine head also moves within a certain tolerance). In effect he is using a sample size of one to determine the machine mean and this is why the machine head is not moving according to the amount which was adjusted for.

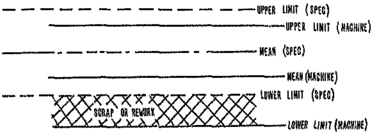


FIGURE 5.18 : Relationship between Tolerance Bands

By using a sample size of one, the specification mean is not matching up with the machine mean. Therefore a larger sample size (of say 2 sets of 8 bodies) should be taken and the mean calculated. Then the machine unit height can be adjusted according to this mean. This approach was tested and was found to be accurate to within 0,02mm.

It should be noted here that this sampling need only take place when the presettings for the heights of the units are being calculated. It is imperative at this stage that these presettings correspond to the drawing mean of the respective dimension. In other words the machine and drawing means must correspond closely, since all future setups are based on these presettings. Once these presettings are accurate, adjustments need never be made in future setups.

(iv) Once the setter is satisfied with the test pieces they are sent to inspection which takes an extra 45 minutes to check the pieces. It is imperitive that either this time be cut down or the setter measures the pieces and is responsible for quality control.

(v) The setter has to walk approximately 25 metres and up a flight of steps in order to check distances on the profile projector. This is fatigueing to the setter and wastes time.

There are two possible solutions. The profile projector could be moved onto the shop floor, however checking bodies on the profile projector is still a lengthy procedure. Alternatively a gauge could be used to check the distances between holes on the body. These gauges already exist (plate 5.14) but the method of measurement would have to be checked for accuracy. Since these gauges are small they can be situated at the machine as part of the prepared tooling.

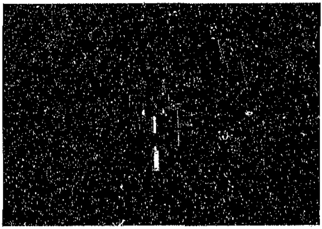


PLATE 5.14 : Gauge for Checking Hole Positions

(vi) Time is wasted checking hole depths, diameters and recesses since gauges cannot always be located. Gauges are shared between machines, and therefore the operator is usually required to locate these during the setup. Furthermore gauges were thrown loosely into a plastic bin, making it necessary to search for specific gauges.

This problem was solved by purchasing a set of gauges which was dedicated to this particular machine. Since hole diameters and depths have been standardised for different size locks, only four sets of gauges were required for the entire range of specials. These were set out logically on gauge boards in such a way that an inexperienced person could locate the required gauges for specific holes. An example is shown below in figure 5.19.

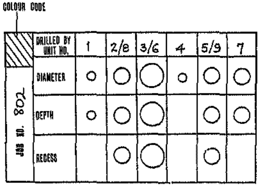


FIGURE 5.19 : Gauge Organisation on Boards

(vii) Conclusions:

Although adjustment accounts for a majority of the setup time it can be cut down dramatically by presetting all operating conditions in advance. This includes drill lengths, mechanical, electrical and fast forward stops. Height adjustments can be eliminated by setting heights to a dead stop and inspection time can be reduced by using gauges placed at the machine.

(i) SHIMMING JAWS

The operation must be performed when jaws are located at different heights with respect to a fixed reference point. The drill which machines the shackle pin hole (figure 5.2) passes through a bush which is located in the jaw (plate 5.15). The jaw locates on the vice as shown in plate 5.16 on plane A. If the distance Y between the bush centre and the locating face of the jaws is not consistant, shimming blocks may be required to lift certain jaws fractionally off the vice (figure 5.20). If the jaw is situated too low the clearance between the shackle pin hole and the long-shackle hole is undersize, and that specific jaw must be shimmed up. Alternatively, if the jaw is situated too high the clearance is oversize and the jaw must be shimmed down. Unfortunately shimming down is not possible therefore such a set of jaws was producing scrap bodies.

PLATE 5.15 : Bush Situated in Jaw

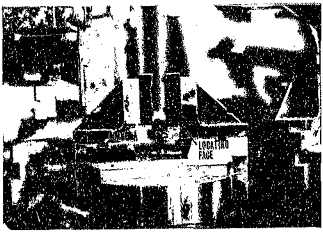


PLATE 5.16 : Location of Jaws on Vice

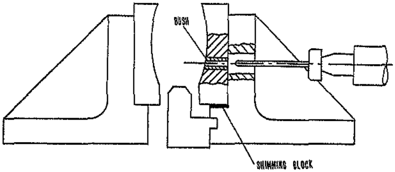


FIGURE 5.20 : Shimming Block for Correct Bush Height

On inspection, distance Y of all jaws were accurate to within 0.03mm. The heights of the vices where the jaws locate were also compared, and were found to vary by 0.05mm.This meant that jaws could be as much as 0.08mm too high or too low. Although each set of vices are numbered the jaws are not. Therefore a random set of jaws fit onto each vice.

The problem was solved by matching each vice with a certain set of jaws. For example if the location step on a particular vice was lower than average, a set of jaws with a larger than average distance Y was matched with this vice. In other words the higher jaw compensated the lower location plane on the vice. The same was true for a situation that was visa versa. (refer to figure 5.21).

This matching of jaws and vices was not performed by taking measurements. The jaws were fixed onto vices at random and eight test bodies (one per set of jaws) were machined and checked. The gauges are of the go, no-go type and operate such that one can feel approximately by how much the clearance in under - or oversize. Therefore, for clearances which were acceptable, the respective jaws were left alone. The jaws for the most over - and undersize bodies were swopped. Next the second-most over - and undersize jaws for respective bodies were swopped and so on. Bushes (situated in jaws) were then all situated at the same height. Each set of jaws was marked according to the vice number so that it could be fixed to the same vice for subsequent setups. In this way shimming was eliminated completely.

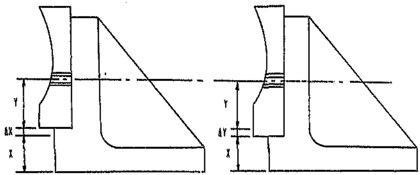


FIGURE 5.21: Matching Jaws for Height Compensation

(j) MAINTENANCE

As was discussed in section 5.5.2, maintenance was not included during internal setup time.

(k) IDLE TIME

This has been discussed in section 5.5.3.

(l) CLEANING MACHINE

Before any improvements were made, cleaning the machine could take anything up to a full day to complete. The machine is fairly complicated and therefore difficult to clean since some places are not easily accessable. During operation a large amount of brass swarf is built up and is distributed over the entire machine. The bulk of the swarf falls to the bottom of the machine where it can be removed via a door which faces the operator (plate 5.17). It is imperitive to clean the machine before a changeover since swarf on locating faces will cause setup inaccuracies. Also it is uncomfortable for the setter to work if he must constantly pull out brass splinters.

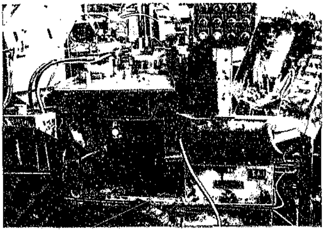


PLATE 5.17 : Machine Access Point

The machine was originally cleaned with a brush, however this was found to be slow and ineffective. Management had already identified the problem and had adopted a *vacuum cleaning* system to suck swarf from the machine. The cleaner would start cleaning the machine approximately 15 minutes before the changeover. During this time much of the swarf would be removed from the indexing table and the work-station units. However it was found that this system was not fully effective for the following reasons:

(i) The machine is too intricate, therefore the vacuum pipe cannot access all areas.

(ii) No warning system existed for the cleaner, resulting in having to sometimes wait for cleaning to commence after the machine had stopped.

(iii) The cleaner had not been instructed how to clean the machine and therefore was unaware as to which areas had to be spotless for attachment location purposes. (A cleaning procedure has been laid out in Appendix D).

The cleaning operation time was substantially reduced as follows. A warning system was adopted where the supervisor would summon the cleaner 15 minutes before the setup. The bulk of the swarf around the machine was still removed by vaccuuming during this time. The setup procedure was devised such that when the machine stops, the setter and operator are performing operations away from the operating position. This gives the cleaner a chance to open the door under the machine and remove the bulk of the swarf.

Supply and drainage tanks were designed and built (plates 5.18 and 5.19 respectively) and were used for washing away swarf by means of spraying a cleaning fluid onto the machine. The cleaner was shown to start near the top of the machine and work his way down until all swarf was removed. He was then shown which areas to wipe dry afterwards (these are the attachment location areas).

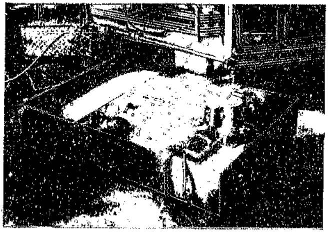


PLATE 5.18 : Feeder Cleaning Tank

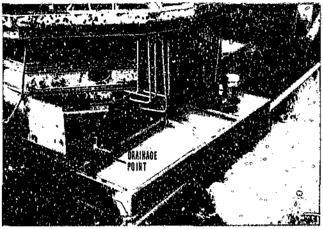


PLATE 5.19 : Drainage Tank

5.7. COST CONSIDERATIONS

It was decided by management that a low cost approach would be adopted. A budget of R3000.00 was allowed for initial changes with more costly modifications requiring justification (via the analysis discussed later in this section).

The following changes were made at almost no cost:

(i) Organisation of tools which involved rearranging tooling, colour coding and organising tool cupboards.
(ii) Using existing quick release tool holders.
(iii) Height blocks were made in-house by setters and tightening bolt assemblies for height adjustment were bought at low cost (approx. R60.00).
(iv) Collars for setting drill depths were made in-house and the gauge for presetting tool length already existed.
(v) Mechanical, electrical and fast forward stops were made in-house from scrap material.
(vi) The gauge to be used for final inspection already existed.
(vii) Boards for plug gauge organisation was made by setters.
(viii) Elimination of jaws shimming was achieved at no cost.

The following changes were made at low cost:

(i) Manufacture of 12 tooling trays (approx. R1200).
(ii) Feeder cleaning tank and drainage tank (approx. cost

R1000.00).

The following changes exceeded the allowed budget:

(i) Manufacture of new seats (approx. R4500.^0).
(ii) Dovetail or T-slot on jaws for quick attachment and removal (in excess of R10 000.00 per set of jaws).

It is evident from the above that most setup benefits can be obtained at no or low cost. An example of an analysis for cost justification is discussed below. Since replacement of seats and jaws are performed simultaneously, they will be analysed together.

The minimum total cost for this modification is R10 000.00 per set of jaws x 5 sets required + R4500.00 = R54 500.00

For this transfer machine and taking the average cost for a padlock at R3.00 (including labour) and the cost of a lock body at R1.00:

For a bottleneck machine (where extra output = extra sales):

A = *loss of sales/hr*	= R3/lock x 200 bodies/hr	= R600/hr
B = holding costs/hr	= R0.25/body x 200 bodies/hr	= R 50/hr*
C = scrap costs/hr	= R1/body x 20 bodies/hr	= R20/hr
C(t) = total cost/hr		= *R670/hr*

* Holding cost is approximately 25% of value of lock body. (35)

For replacing seats and jaws:

Present setup time = T(1) = 2h50 (Appendix B)

Estimated improved time = T(s) = 0h50 (Appendix D)

Implementation cost = C(I) = R4500.00

Cost of present setup = C(p) = R670/hr x 2h50 = R1898.33

$$\text{Cost of improved setup} = C(n) = \frac{\text{R670/hr} \times \text{0h05}}{1.5^{**}} = \text{R37.22}$$

** It was decided by the author to use a weighting factor of 1.5 due to the added potential of smaller lot sizes, reduced holding costs and improved quality.

Number of setups to cover implementation costs

$$N = \frac{\text{R54 500}}{\text{R1898.33 - R37.22}} = 29.28$$

Therefore 30 setups are required to cover implementation costs. Since one setup is conducted approximately every 2 weeks on this machine it would take 60 weeks for this modification to pay off, ie. a long term modification.

Management has decided that this capital outlay is too large, therefore the seat modification for R4500.00 was examined seperately as follows:

Total cost = R670/hr

Present setup time =2h50

Estimated improved setup time = 1h00

Implementation cost = R4500.00

Cost of present setup = R1898.33

$$\text{Cost of improved setup} = \frac{\text{R670/hr} \times \text{1hr}}{1.3^*} = \text{R515.39}$$

* Note that this weighting factor has been reduced since the potential benefits of smaller lot sizes has been decreased.

$$N = \frac{\text{R4500}}{\text{R1898.33} - \text{R515.39}} = 3.25$$

Therefore 4 setups (approximately 8 weeks) are required to pay for this modification, ie. a short term modification.

5.8. WORKER MOTIVATION

Management at Viro Locks demonstrated that they wanted full involvement in the setup reduction programme. This showed setters and operators that management was interested in their potential for carrying out a successful programme. Implemented ideas initiated by setters have given them a sense of achievement. Successful changes are recognised by management and results are displayed. Setters have advanced in their jobs since the work emphasis has shifted from lengthy setups to setup reduction implementation.

Management has decided that pay incentives would not be beneficial for competative reasons. It was preferred to use non-economic incentives where setters' jobs have been redesigned to make their jobs easier by eliminating tedious setups and encouraging them to think of new setup methods. Job redesign has encouraged setters to vary their skills, has given them task identity and allows them to communicate with management via feedback channels.

Setters also receive non-economic recognition since they will be invited to perform a setup for top management when it has been improved according to the setup reduction potential (Appendix D).

5.9. SUMMARY OF BENEFITS

For implemented setup improvements (using short term modifications):

Original setup time	= approx 10 hours (Appendix B)
Setup time after improvements	= 3,3 hours
Time savings	= 67%
Low cost/no cost improvements	= 50% of time savings
Implementation costs	= R6760.00
Productivity improvement	= 10% (Appendix G)
Mixed model frequency increase	= 3 times (Appendix G)

Potential setup improvements (using long term modifications):

Potential setup time	= 2,3 hours
Time savings	= 77%
Implementation costs	= R54500.00

Setters and operators receive more job satisfaction since tedious and lengthy setups on the transfer machine have been eliminated. Furthermore they are given the opportunity to generate new ideas and be rewarded for it.

Setup time reduction on transfer machines (and other machines at a later stage) will affect the production of standard and special items in different ways. Setup time reductions for standards will allow for a better model mix since smaller batches will be economical. Less inventory is required for finished goods since the mixed models will decrease the chance of stockouts. Since demand is known, the company can run a level schedule which meets these customer requirements.

For special items, setup reduction will have different implications. Production runs are already fairly short (2 days - 2 weeks), therefore setup reduction will increase work rates substantially. When setup times are sufficiently reduced the company may decide to reduce batch sizes further (to say 1 day). Eventually component stocks (which are kept in stores) could be eliminated, with assembly "pulling" components directly from manufacturing. If an emergency order was to come in, it would not take long to change over to that job.

6. SUMMARY AND CONCLUSIONS

In order to satisfy the aims of this dissertation the following has been concluded and summarised:

(a) SETUP REDUCTION IMPLEMENTATION GUIDE SUMMARY

(i) EXAMINING OVERALL PRODUCTION

- Examine the overall production process before making any detailed setup reduction modifications, taking into account future product changes and purchasing of new equipment.
- Examine the possibility of implementing GT, setup sequencing or dedicated machines as means of reducing setups.
- Use the OPT principle (tackling bottlenecks first) and/or the 80/20 rule to determine where in the plant the programme should be started.

(ii) TRAINING

- Develop a training programme where all relevant production operators, setters, line supervisors, foremen, production engineers and immediate support staff are involved.
- The training programme should include the abovementioned staff learning about the following:

  - the overall JIT concept.
  - basic JIT principles in manufacturing, eg. kanban,

balancing, etc.

- how JIT and setup reduction will change the factory environment and potential benefits.
- recording and analysis methods.

- Devise setup teams, consisting of a team leader, process engineer or line supervisor, foreman and 2 - 3 setters or operators.
- Train team members in setup reduction methods by means of relevant examples and physical demonstrations

(iii) APPROACH TO SETUP REDUCTION

- It is advisable to implement ideas immediately. This simplifies setup analysis since the setup is being physically shortened on a continuous basis and momentum is given to the programme.
- Tooling changes during a production run must be treated in the same manner as a setup.
- Document all details of the programme for future reference.

PRELIMINARY STAGE - DISTINGUISHING BETWEEN INTERNAL AND EXTERNAL OPERATIONS

Examine existing setup/s by means of work/time study methods. A time lapse camera may be used. Analyse the setup and determine which activities could be made external. A useful aid is to first group operations into broad work categories eg.

transportation, operation, delay, etc.

STAGE 1 - SEPERATING INTERNAL AND EXTERNAL SETUP

Start with obvious changes which are simple. This includes preparing, tooling and operating conditions in advance, improved tooling organisation and setup warning systems (indicating the time of the next setup). Other common operations include preheating of dies and externalising cleaning and maintenance operations.

STAGE 2 - CONVERTING INTERNAL TO EXTERNAL SETUP

Use a simple pareto analysis (usually 1 - 2 levels) to determine which operations are time consuming and must therefore receive priority. Techniques include devising a standard procedure in order to eliminate idle time; using parallel operations (economy of movement); and eliminating adjustments, where fixed settings are made or adjustments are made off the machine during external setup. Equipment modifications include the use of functional clamps, functional standardisation, intermediary jigs and mechanisation. At this stage all presettings are determined from an accurate "model" setup.

STAGE 3 - STREAMLINING SETUP OPERATIONS

This involves further improvements to internal and external operations. Practise setup procedures to develop correct reactions and therefore achieve standard setup times. Adopt undercapacity scheduling in order to practise setups, build setup skills, try out new ideas and debug new setup procedures.

(iv) COSTING

- Adopt a no cost/low cost approach with limited expense budgets available and large capital expenditure requiring full justification.
- Setup reduction follows the law of diminishing returns - large benefits for low cost initially, progressing to small benefits for high cost.

(v) MOTIVATION

- Suitable motivational techniques should be used to encourage teams to participate.
- A financial reward divided equally amongst members of the setup team for implemented ideas with some form of recognition is recommended.

(b) SETUP REDUCTION IN SOUTH AFRICA

- Setup reduction is a fairly new activity in South Africa where setup improvements range from 0 - 90%.
- The setup reduction programme is perceived to be a lengthy procedure of trial and error which (according to the survey)

would take 4 - 5 years to implement successfully.

- The main areas of concern for setup reduction include a lack of priority given to setup reduction, lack of training and no monitering or documentation.

(c) BENEFITS OF SETUP REDUCTION AT VIRO LOCKS

- Setup time on a bottleneck transfer machine has been reduced from 10 hours to 3,3 hours, a 67% reduction.
- The setup time can be further reduced by one hour if long term modifications are made, resulting in a potential time saving of 77%.
- ROI is high with a 10% increase in productivity due to setup time reduction at a cost of approximately R6760.00.
- Setters' and operators' jobs are more rewarding due to ideas being implemented and elimination of tedious setups.
- Setup reduction has potentially allowed the frequency of mixed models to increase threefold, resulting in a decrease in inventory levels.
- Emergency orders can be dealt with promptly due to short changeovers.
- Operating conditions are regulated in advance by making adjustments during external setup, thus eliminating trial and error procedures accounting for approximately 40% of setup time.
- Idle time has been eliminated by shortening setups and organisation of setup procedures.
- Job definition has been changed to setup reduction

activities resulting in an increase in job security.

- Scrap levels are reduced since setups are performed more accurately and no longer depend on individual skills.

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40. Mike Karle and Ivan Schoneveld of Afrox.

41. Dave Carstens of TEK Corporation.

42. Alex Feher of Mono Pumps.

43. Tony Hope of Promex.

44. Paul Plant of John Deere.

45. Benny Massotti of Rowen Engineering.

46. Mr. Germishuis of Mitco Tools.

47. B. Donnerly of Wilson Rowntree.

48. Jurgen Tietz of AECI.

49. Mr. Hopkins of GUD Filters.

50. Gert Jacobs of Tosa.

51. Norman Mindell of Barlows Manufacturing.

52. Martinus Odendaal of Lasher Tools.

53. Frank Scullion of MSN.

APPENDIX A1 : SETUP REDUCTION QUESTIONAIRE

COMPANY : ______________________________

SECTION A :

1. How would you classify production? (delete what is not applicable)

   A. Many / Few product types

   B. Job shop / Repetitive

   C. Make to order / Make to stock

   D. High / Low components to finished goods ratio

   E. Unit / Volume type production

   F. Tight / Loose tolerances

   G. High / Low skill levels

   H. Capital / Labour intensive production

2. What priority was setup reduction given as part of the JIT programme?

   LOW MEDIUM HIGH

3. Which of the following have been adopted?

Dedicated Machines	Y / N
Parts Standardisation	Y / N
Group Technology	Y / N
Setup Sequencing	Y / N

SECTION B : Only complete if you have implemented SUR

1. How did you approach SUR? ______________________________

____

____

____

____

2. Was SUR translated into other actions? Y / N

If yes - What others? ______________________

____

If no - Why not? ______________________

____

____

3. Who did SUR? (State all people involved) ______________________

____

4. Who has received training on SUR? ______________________

____

5. What are attitudes towards SUR? ______________________

____

6. Has a SUR reporting system been established? Y / N

If so - How does it work? ______________________

____

____

7. What improvements have been achieved? __________%

8. What proportion of the plant has experienced SUR? ______%

SECTION C : Only complete if SUR has not been implemented.

1. Why has SUR not been implemented? ______________________

____

____

____

____

____

____

2. When are you planning to implement it in the future?

____

APPENDIX A3 : SURVEY RESULTS AND ANALYSIS

TABLE A1 : Results Analysis

COMPANY	ACGI	AEROX	BARLOWS	BOSCH	FEDMECH	GEC (SMALL M/C'S)	GUD FILTERS	JOHN DEERE	LASHER TOOLS	M&H	MITCO TOOLS	MONO PUMPS	PROMEX	ROWEN	TEK CORP.	TOSA	VIRO LOCKS	WILSON ROWNTREE
SUR initiated	x	x		x	x	x	x	x			x	x	x	x	x		x	x
Rep. & make-to-order	x	x		x			x	x	x	x			x	x		x	x	
Priority of SUR	L	H	H	H	H	L	H	H	L	L	M	M	M	H	M	H	M	H
Dedicated machines	x	x		x	x	x	x	x	x	x	x	x		x	x		x	
Parts standardization	x	x		x	x	x	x	x	x	x	x	x		x	x		x	
Group technology		x			x	x		x	x	x	x	x		x	x	x	x	x
Setup sequencing		x		x		x					x			x	x	x		
Bottlenecks studied 1st		x	x		x	x	x				x	x	x	x	x		x	
Work/time study used				x	x	x	x	x			x		x	x	x		x	x
Formal analysis				x	x		x	x			x			x			x	
Easy changes made 1st			x	x			x	x				x	x	x	x	x		
Lot sizes reduced	x	x		x		x	x	x			x		x	x	x		x	x
QC problems exposed							x				x			x	x		x	x
Flexibility increased				x										x			x	
Management involvement	x	x		x	x	x	x	x			x		x	x	x		x	x
Worker involvement		x		x		x		x			x		x	x			x	x
Worker training		x		x		x		x			x		x	x			x	x
Positive attitudes		x			x	x	x				x	x	x	x				x
SUR reporting system					x		x	x			x			x			x	
Reductions achieved (%)	99	75	0	75	80	0	0	30	0	0	60	80	85	90	60	0	80	85
Extent of programme (%)	1	35	0	20	5	5	0	75	0	0	30	20	10	100	10	0	5	15

TABLE A2 : Setup Reduction Trends

ASPECT OF SETUP REDUCTION	% PARTICIPATION (all companies)
Setup reduction initiated	78%
Repetitive and make to order	61%
High priority given	50%
Dedicated machines	89%
Parts standardisation	78%
Group technology	72%
Setup sequencing	39%
	(only companies which have implemented setup reduction)
Bottlenecks examined first	79%
Work/time study used	79%
Formal operational analysis	50%
Easy changes made first	64%
Lot sizes reduced	86%
Quality problems exposed	43%
Flexibility increased	21%
Management involvement	93%
Complete worker involvement	64%
Worker training	21%
Positive attitudes	57%
Setup reduction reporting system	43%

Note that the top part of table A.2 takes all 18 companies into account. The figures on the bottom part of the table are calculated with respect to the companies who have started implementation (14 companies).

Referring to table A.1 it is evident that of the 18 companies interviewed, 14 have made some attempt at setup reduction (78%). Rowen Engineering is the furtherest advanced in the practice of setup time reduction and have achieved an average of 90% improvement throughout their entire plant. As can be seen, they have implemented all the necessary activities listed in table A.1, as well as giving their programme a high priority. Afrox is also fairly well advanced with an average of 75% improvement in 35% of the factory.

Eight of the companies listed have implemented setup reduction rigourously, achieving 60-98% improvement: however they have only looked at a very small portion of the factory (below 20%). In essence they have actually initiated a pilot setup reduction programme where the general aim is to prove to workers that substantial setup time improvements can be achieved.

Out of the six companies who have not achieved any physical improvements yet, five of them have just started or are about to start setup reduction (in the next 3-6 months). Only one company, MSN Electronics, believed that setup reduction was not relevant to their company, and that current setup methods were optimal.

GEC Small Machines have adopted an interesting policy. They have purposely reduced inventory (before implementing setup reduction) in order to expose bottlenecks as well as to show workers that it is a real need and not just an exercise. John Deere have also adopted a different approach. Instead of concentrated efforts in one specific area, they have looked at 75% of the factory, but have only achieved 30% improvement (moving internal to external operations).

Referring to table A.2, there appears to be some areas of concern. Only 50% of the 18 companies have given setup reduction a high priority. The main reason given was that managers have so many other tasks that they can only spend less than 5% of their time on setup reduction. Most managers agreed that improvements would occur much faster if someone in the company was dedicated to setup reduction. Only 39% of the companies have implemented setup sequencing. Although this activity was not relevant to some companies, other managers were not aware of sequencing benefits.

It seems that most companies are on the right track towards setup reduction. 79% have adopted the correct method of examining bottlenecks first and implementing a work/time study. Unfortunately 50% have adopted an informal approach and 38% have not taken advantage of making simple changes first at relatively low cost. The main benefit achieved was lot size reduction which 86% of the companies adopted. Only small percentages found quality problems or made use of increased flexibility.

Management involvement is high at 93%, however complete worker involvement (including operators) at 64% could be improved. Some companies are still in the analysis stage, the reason given for not including all workers yet. These companies do intend involving all workers when the programme is further advanced.

Training of workers in setup reduction techniques is low at 21%, and much of this is informal. Rowen has trained workers as the programme progressed by involving them in the implementation, ie. "hands-on" training. Afrox has built a training cell of machines no longer in use, where workers are trained in JIT/TQC methods. Training is also not extensive due to the companies still being in the early stages of implementation.

Only 57% of the companies have positive attitudes amongst both management and workers. It seems that workers are sceptical until they actually see physical improvements. Therefore this figure will most likely improve as companies progress.

Only 43% of the companies have reporting systems where progress is monitored, and many of these systems are informal. This is related to the low percentage of companies who have adopted a formal approach.

A P P E N D I X   B1

WORK / TIME STUDY TABLES

B1

SETUP 1 JOB NO. 802

	SETTER	OPERATOR	COMMENTS
0h00	Organise tooling		Tooling organization should be
0h40	Strip safety covers & check belt tensions	Remove jaws & clean relevant surfaces.	post-preperation, organise on tooling boards
		Remove left hand vices to attach seats	
0h54	Cam replacement - head 4 ; organise tooling at station		
0h56	Remove old cams		
0h58	Clean & replace new cams		
1h01	Remove bit, collet, holder & bush - head 5		
1h04	Remove bit, etc - head 3		
1h10	Remove bits & bush - heads 1 & 2		
1h16	Loosen height bolts at all stations		
1h21	Removn drill, etc - head 9	Idle	
1h22	Clean slides		
1h24	Set height - station 1		
1h26	Set height - station 2		
1h27	Set height - station 3		
1h28	Set height - station 4		
1h31	Set height - station 5		
1h32	Set height - station 6		
1h35	Waiting for cleaner		Eliminate waiting

1h39	Fitting seats, vices & jaws		
		Fit bush - head 5	
1h55		Fit bush - head 8	
2h02		Fit bush - head 2	
2h05		Fit reamer - head 9	Organise drills in collets externally
2h10		Fit reamer - head 8	
2h31	Sharpen drills	Fit reamer - head 6	
	END OF DAY		
	START OF DAY		
2h35	Tooling organization		
2h45	Sharpen drills	Replace jaws, etc	Jaw replacement takes approx 14,5 mins / station
3h03	Fit jaws	Fetch drills	Bad organization therefore operator not sure of matching drill & collet sizes
3h04		Fit drill - head 7	
3h06	Stop to allow operator access	Fit drill - head 2	
3h12		Fit drill - head 5	
3h13		Fit drill - head 1	
3h16		Fit drill - head 3	
3h20	Looking for drills	Looking for drills	
3h24	Sharpening drills	Replacing last jaw	Jaws were not finished since block was missing
3h32	Set drill depth - head 1	Idle	
3h36	Set drill depth - head 2		
3h39	Set drill depth - head 4		
3h41	Set drill depth - head 5		

3h45	Set drill depth - head 6	Idle	
3h46	Set drill depth - head 7		
3h52	Set drill depth - head 9		
3h54	Replace last jaw		Block found on floor - block should be attached to jaw but pin broke off. Tool-room has been asked to make another block.
4h05	TEA BREAK		
4h26	Take off jaw & measure		Tool-room wants measurement for block
4h27	Replace jaw		
4h29	Start test piece (drill all except head 4)	Looking for missing gauges	
4h34	Check holes & approximate correct depths		
4h36	1st adjustments	Helping to machine test bodies & index table	Drill depth & station height adjustment Height blocks are not accurate
4h40	Recheck holes on body		
4h46	Machine test piece & check all holes		
4h56	2nd adjustments		
5h04	1st adjustment for head 4		
5h13	LUNCH		
5h45	Check holes for fine adjustment	Idle	
6h01	Check body on profile projector		
6h07	Make adjustments		
6h25	Check body on profile projector		

6h39	Make adjustments	Idle	
6h55	Check body on profile projector		
7h09	Make adjustments		
7h22	Check body on profile projector		
7h28	Make adjustments		
7h34	Check body on profile projector		
7h45	Make adjustments		
7h51	Check body on profile projector		
7h57	Make adjustments		Test piece acceptable
8h15	Change drill		Drill causing a burr
8h20	Shim jaws		
8h50	Final inspection & further adjustments		
10h00	END		

SETUP 2 JOB NO. 430/538/010

	SETTER	OPERATOR	COMMENTS
0h00	Idle	Idle	Cleaner cleaning machine (up to 1h30)
0h55		Remove jaws & left hand vices at all stations	Machine is not clean in relevant places
1h20	Remove drill - head 2		
1h22	Remove drill - head 3		
1h23	Remove drill - head 5		
1h24	Remove drill - head 8		
1h25	Remove drill - head 7		
1h26	Remove reamer - head 6		Setter is checking if old reamer can be used for new job (it can't)
1h29	Remove bush - head 2		
1h30	Clean rings (which must be replaced)		
1h33	Fit bush - head 2		2 more bushes would normally have to be replaced but was excluded due to sequencing of jobs
1h34	Fit drill - head 3	Assisting setter - head 2	
1h36	Fit bush - head 5	Cleaning vices on machine	
1h37		Cleaning vices off machine	Seats would normally have to be replaced but was excluded due to sequencing of jobs - add 15 minutes for this operation Fixing screw for bush missing - head 5
1h38	Looking for head 5 bush bolt		
1h43	Fit bush screw - head 5		

1h44	Fit drill - head 4		
1h45	TEA BREAK		
2h04	Waiting for air supply for cleaning	Idle	Maintenance replacing air supply tank
2h05	Fit bush screws - head 7	Cleaning vices off machine	
2h06	Waiting for air supply		New air source located (cannot reach everywhere on machine)
2h07	Fit reamer - head 7		
2h11	Remove reamer - head 9		
2h14	Fit reamer - head 9		
2h19		Cleaning vices on machine	
2h21	Fit reamer - head 6		
2h23	Fit drill - head 7	Remove drill - head 3	
2h25	Remove bush - head 4	Resume cleaning vices	Operator is cleaning vice faces while indexing table. Setter is cleaning heads & dirtying vices.
2h27	Fit bush - head 4		
2h29	Looking for drill - head 4	Looking for drill - head 4	
2h30	Having difficulty with replacing drill - head 4	Resume cleaning vices	
2h31	Fit drill - head 1	Replace drill - head 4	
2h33		Idle	Setter standing in way of operator
2h34	Get tooling	Resume cleaning vices	
2h35	Loosen height bolts - station 1		
2h36	- station 2		
2h37	- station 4		

2h38	Loosen height bolts - station 5	Attach seats, left hand vices & jaws	Each station takes approx 8,5 mins
2h39	- station 6		
2h40	- station 7		
2h41	Cleaning areas for fitting height blocks		
2h47	Set height - station 1		
2h55	- station 2		
2h59	- station 4		
3h03	- station 5		
3h05	- station 6		
3h09	- station 7		
3h11	Leaves machine		
3h19	Fit cams & adjust		
3h29	Set drill depth - head 4		
3h30	Set mechanical stop - head 2		
3h31	Waiting for operator		Operator finishing jaws
3h40	Fast forward, mechanical stops & electrical stops adjustments	Indexing table & traversing heads for setter	
	Head 2		
3h45	Head 3		
3h48	Head 5		
3h52	Head 6		
3h53	Head 7		
3h54	Head 8		
3h55	Head 9		
3h59	Machine a test body		
4h01		Check test body	
4h02	Adjust drill depth - head 4	Idle	

4h03	Change drill - head 3 (find drill first)	Idle	Drill leaving a burr
4h04	Sharpen drill	Check drill depth - head 3	
4h05	LUNCH		
4h35	Fit drill - head 3	Idle	
4h37	Adjust cam distance		
4h40	Check test body with gauges		
4h41	Re-machine test body	Assisting setter	
4h43	Adjust height - head 5		
4h45	Machine test body	Cleaning height bolts area	
4h48	Check with gauges		
4h51	Adjust height - head 9	Assisting setter	
4h53	Pull unit 7 back on slides		
4h55	Re-machine test body	Cleaning height bolts area	
4h58	Check with gauges		
4h59	Pack tools away		Setter fears that tools may be removed in his absence
5h00	Check body on profile projector	Idle	
5h15	Adjust height - head 3		
5h18		Assisting setter	
5h22	Adjust height - head 6		
5h26	Adjust height - head 7		
5h29	Adjust drill depth - head 2		
5h30	Adjust fast forward - head 3		
5h32	Re-machine test body		
5h33	Check with gauges	Clearing old jaws	Move to external setup
5h34	Adj drill depths - heads 6 & 9		
5h35	Adjust drill depth - head 2		

5h36	Re-machine test body	Cleaning old jaws	
5h37	Check with gauges	Idle	
5h38	Re-machine test piece		
5h40	Check body on profile projector		It takes approx 1,5 mins for every return journey to profile projector
5h54	Adjust height - station 2	Assisting setter	
5h56	- station 4		
5h59	- station 5		
6h02	- station 6		
6h04	- station 7		
6h06	Machine test body		
6h08	Check with gauges		
6h09	Check body on profile projector	Idle	
6h14	Re-adjust mech & elec stops -	Assisting setter	
6h15	head 3		
6h18	Re-machine test body	Idle	
	Idle		Setter & operator waiting for material to machine 8 test bodies - bad planning
	END OF DAY		
	START OF DAY		
7h45	Check body on profile projector		
7h50	Machine test body		
8h15	Machine 8 test bodies		
8h30			Inspection checking bodies. Only gauges are being used, therefore add 45 mins for full

			check on bodies (holes & distances between holes)
9h08	Fine adjustments - head 4		
9h13	Idle	Machine 8 test bodies	
9h20	Check 8 test bodies	Idle	Check made on adjustments only
9h40	Waiting for QC check		QC inspection not complete
9h49	Converse with QC		QC complete
9h54	Make adjustments & machine 2 test bodies		
9h56	Check with gauges		Drill oversize - head 3
10h07	Idle	Remove oversize drill - head 2	
10h10	Sharpen new drill	Idle	
10h12	Idle	Replace drill - head 2	
10h15		Machine test body (oversize hole only)	
10h17	Adjust drill depth - head 2	Idle	
10h19	Idle	Machine test body (bolt hole)	
10h20	Check drilled hole	Idle	
10h21	Leaves machine to remove brass splinter in eye		Workers should possibly wear safety glasses during setup
10h24	Idle	Machine 8 test bodies	
10h29		Check body with gauges	
10h33		Machine test body	
10h34	Waiting for QC inspection	Idle	
10h48	Idle		
10h51		Fetch tray of bodies to machine	
10h58		Remove tools & prepare	
11h05	END		

APPENDIX B2: SETUP OPERATIONS CATEGORISATION

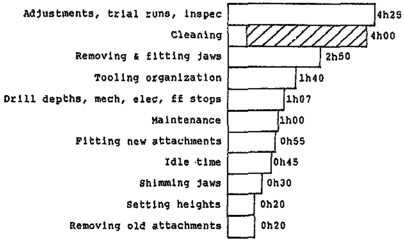
Setup Function	Time	
	Setup 1	Setup 2
1. Tooling organization	1h40	0
2. Removing old & refitting new jaws	2h50	2h20
3. Removing old attachments (drills, reamers, bushes, etc)	0h20	0h15
4. Height adjustment	0h20	0h35
5. Fitting new attachments	0h55	0h55
6. Setting drill depths by adjusting mech, elec & fast forward stops	1h07	0h15
7. Final adjustment, trial runs & inspection	4h25	5h35
8. Shimming jaws	0h30	0
9. Maintenance	1h00	0
Auxiliary Functions		
10. Idle time	0h45	3h55
11. Cleaning machine	0	0h55
Total setup time (ie. machine down-time)	10h00	11h05

APPENDIX B3 : SEPERATING INTERNAL AND EXTERNAL SETUP

Setup Operation	Status
1. Tooling Organisation	External
2. Removing old and refitting new jaws	Internal
3. Removing old attachments	Internal
4. Height adjustment	Internal
5. Fitting new tooling	Internal
6. Setting drill depths, adjusting mech, elec & fast forward stops	Internal/External
7. Final adjustment, trial runs & inspection	Internal/Eliminate
8. Shimming jaws	Eliminate
9. Maintenance	External
10. Idle time	Eliminate
11. Cleaning machine	External

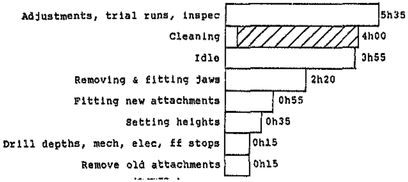
APPENDIX B4: PARETO ANALYSIS OF EXISTING SETUPS

Operational Category



Pareto Chart of Setup 1

Operational Category



Pareto Chart of Setup 2

APPENDIX C : LIST OF TOOLS AND ATTACHMENTS

REQUIRED TOOLS FOR JOB NO. 430/530/010

Fitting and removing attachments

STATION	ATTACHMENT	TOOLS
1	2 drills	chuck key; hook spanner; 27/30 spanner
	bush	4mm allen key; vice grip; soft hammer
2	drill	27/30 spanner; hook spanner
3	drill	19 spanner; small hook spanner
	bush	3mm allen key; 2mm allen key
4	drill	27/30 spanner; hook spanner
	bush	4mm allen key
5	reamer	27/30 spanner; hook spanner
6	drill &	
	reamer	27/30 spanner; hook spanner
	bush	4mm allen key
7	reamer	27/30 spanner; hook spanner

Adjusting station heights

torque wrench with long extension; 22mm socket

Setting mech & elec stops

2* 19 spanners; 3mm allen key

Setting fast-forward feed

3mm allen key; 2,5mm allen key

C2

REQUIRED ATTACHMENTS FOR JOB NO. 430/530/010

UNIT	DRILLS	COLLETS	BUSHES	CAMS	REAMERS	DIN
1	2,5mm					340
2	5,1mm	25*5/6	5,1mm			340
3	9,8mm	25*9/10				338
4	3,0mm	20*3	3,0mm	5 FORI*		340
				3,25 PASSO		
5	5,1mm	20*5/6	5,1mm			340
6		25*10/11			barrel	
7	5,3mm	20*5/6	5,3mm			340
8		25*6/7			bolt	
9		25*6/7			long	
					shackle	

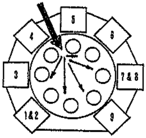
APPENDIX D1 : PROPOSED SETUP PROCEDURE

	SETTER	OPERATOR	CLEANER
-0h15	Prepare tooling taken to machine		Remove bulk of swarf
0h00	STOP MACHINE		Spray vices with liquid cleaner
0h02	Remove jaws & seats		Wipe gaps for height blocks
	Stand at operator position	Stand between stations 4 & 5	
0h09			Spray entire m/c according to procedure
0h17	Remove reamers & cams	Remove drills & bushes	Close drainage tank & remove feeder tank
0h26	Loosen height bolts	Wipe vice location surfaces	
0h29		Replace jaws & seats	Wipe relevant areas on external part of machine
0h32	Set rough heights using height blocks		
0h41:30	Tighten bolts to 8 Nm		
0h47:30	Set fast forward stops		
0h50:30	Set mech stops		

1h00:30	Set elec stops	Fit blocks into jaws	
1h01	Replace cams, drills, bushes (pump off)	Replace reamers (pump off)	Remove bulk of swarf from bottom of machine
1h36	Set heights		
2h11	Trial run (1 piece)		
2h13	Inspect (holes & hole positions)		
2h23	BEGIN PRODUCTION		

APPENDIX D2 : PROPOSED CLEANING PROCEDURE

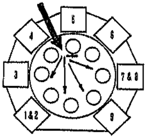
1. Spray jaws with solvent and remove large swarf particles. Access point is shown below. Cleaner is required to stand on edge of machine and clean all jaws from this position.



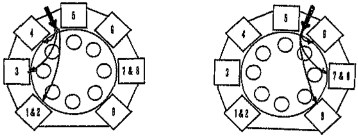
2. Wipe faces for height block settings, proceeding from station 1 through to 7.
3. Wipe mechanical stop heads and fast forward bolts (use in conjunction with air jet for cleaning), proceeding from station 1 to 7.
4. Clean heads and stations starting from a plane just below motors and work down to base of station. Access points are shown below.

APPENDIX D2 : PROPOSED CLEANING PROCEDURE

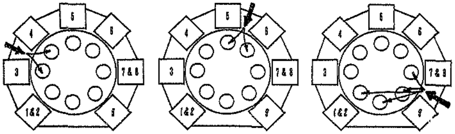
1. Spray jaws with solvent and remove large swarf particles. Access point is shown below. Cleaner is required to stand on edge of machine and clean all jaws from this position.



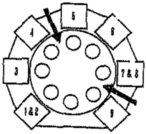
2. Wipe faces for height block settings, proceeding from station 1 through to 7.
3. Wipe mechanical stop heads and fast forward bolts (use in conjunction with air jet for cleaning), proceeding from station 1 to 7.
4. Clean heads and stations starting from a plane just below motors and work down to base of station. Access points are shown below.



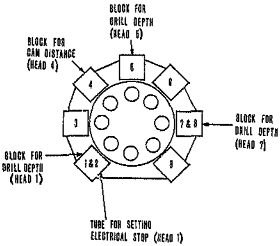
5. Clean vices (jaws have been removed at this stage) making sure that all fine brass particles are removed. Access points are shown below. Note that setter or operator must help cleaner by moving supply tank around to access points.



6. Clean indexing table and all areas in centre of machine using access points shown below.



7. Clean underneath each workstation, especially bolt heads and slides.
8. Close drainage tank lid and remove feeder tank from machine.
9. Continue wiping (or use air jet) areas on exterior of machine ie. mechanical, electrical, fast forward stops; areas where spacer blocks are used for setting. (this is done while setter and operator are performing respective tasks). Units using spacer blocks for setting are shown below.



10. Open door at bottom of machine and remove bulk of swarf (when jaws have been replaced).

APPENDIX B : ATTACHMENTS FOR SETUP REDUCTION

PRESETTING OF ATTACHMENTS FOR JOB NO. 430/530/010

UNIT 1 :

Maximum drill length	80mm
Forward stop (bolt)	35mm
Mechanical stop (block)	55,5mm (x30x10)
Electrical stop (1/2 tube)	55,5mm (12 ID)

UNIT 2:

Mechanical stop - depth stroke (bolt)	71,54mm (12 OD)
- back stroke (collar)	43,86mm (12 ID)
Fast forward (block)	96mm (x15x4)

UNIT 3 :

Mechanical stop - depth stroke (collar)	80mm (12 ID)
- back stroke (bolt)	30,3mm (12 OD)
Fast forward (block)	128mm (x15x4)

UNIT 4 :

Cam depth setting (block)	15,7mm (x17x25)

UNIT 5 :

Depth setting (block)	47mm (x20x25)
Drill depth (set nut & bolt)	21,5mm

UNIT 6 :

Mechanical stop - depth stroke (collar)	81,2mm (12 ID)

- back stroke (bolt)	32mm (12 OD)
Fast forward (block)	127mm (x15x4)

<u>UNIT 7</u> :

Depth setting (block)	27,4mm (x20x25)
Drill depth (plate)	0,0mm

<u>UNIT 8</u> :

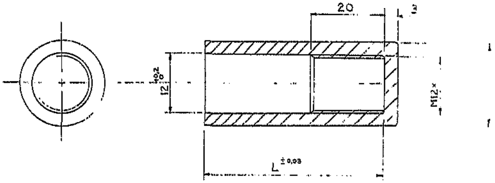
Mechanical stop - depth stop (bolt)	74,25mm (12 OD)
- back stop (collar)	65mm (12 ID)
Fast forward (block)	75mm (x15x4)

<u>UNIT 9</u> :

Mechanical stop - depth stop (bolt)	71,9mm (12 OD)
- back stop (collar)	37,6mm (12 ID)
Fast forward (block)	100mm (x15x4)

<u>Note</u> :

All electrical stops are adjusted to required settings during first setup for that particular job.

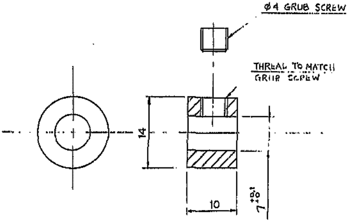


83

MECHANICAL STOP COLLAR

UNIT	2	3	6	8	9
L =	43,86	80	81,2	65	37,6

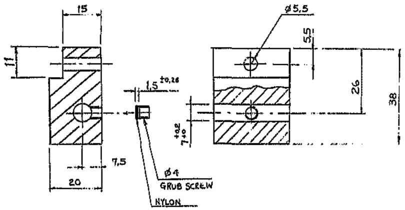
SCALE [illegible]
TOLERANCE [illegible],25



ELECTRICAL STOP COLLAR

MAKE 10 OF

SCALE 2:1
TOLERANCE ±0,25



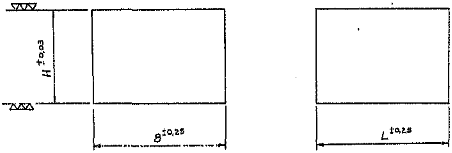
ELEC STOP FIXTURE

MAKE 10 OF

SCALE 1:1

TOLERAN. ±0,1

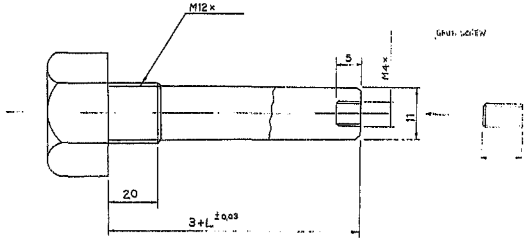
B5



SETTING BLOCKS

UNIT	1	4	5	7
H	55,5	15,7	47	27,4
B	10	17	21	21
L	25	25	25	25

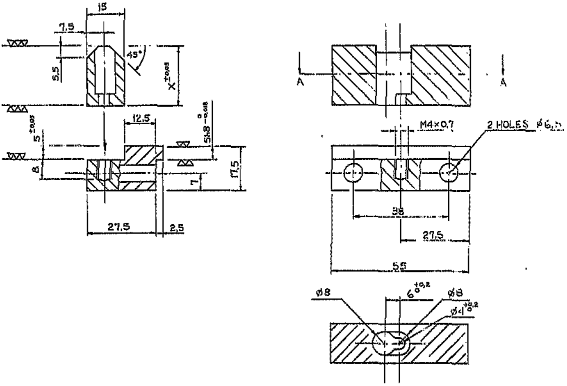
E6



MECH STOP BOLT

UNIT	1	2	3	6	8	9
L =	35	71,54	30,3	32	74,25	71,9

SCALE [illegible]
TOLERANCE [illegible]



SECTION A-A

VIRO LOCKS (PTY) LTD			X	
SCALE	1:1	SEAT(SA1)	8,5	21,0
DATE	04/87		13,5	23,5
TOLERANCE	±0,1		18,5	33,5

A P P E N D I X F

PARETO ANALYSIS

☐ Internal time

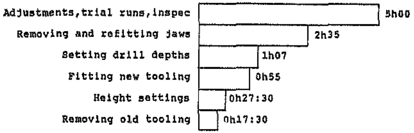
▨ External time

■ Eliminated time

After Improvements (from appendix B4)

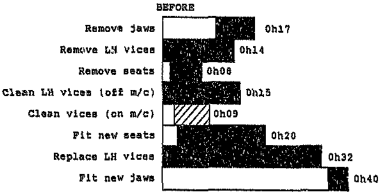
NOTE: The average time between setups 1 and 2 are used in this analysis

LEVEL 1:



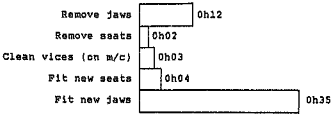
LEVEL 2:

(a) Removing and refitting jaws



Total time = 2h35

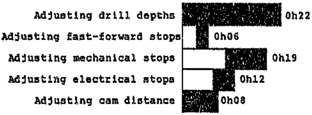
AFTER



Total time = 0h56

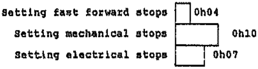
(b) <u>Setting drill depths, adjusting mechanical, electrical and fast forward stops</u>

BEFORE



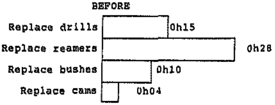
Total time = 1h07

AFTER

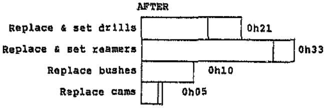


Total time = 0h21

(c) Fitting new tooling

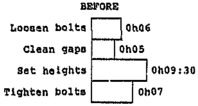


Total time = 0h55

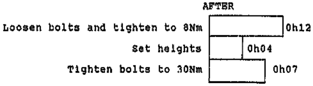


Total time = 1h09

(d) Height settings

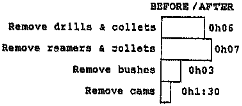


Total time = 0h27:30



Total time = 0h23

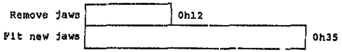
(e) <u>Remove tooling</u>



Total time = 0h17:30

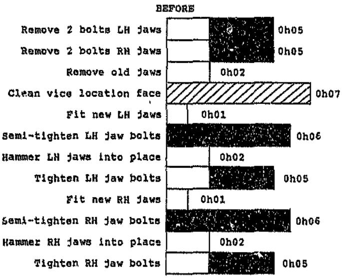
The operations "remove jaws" and "fit new jaws" are taken from level 2 and further broken down as follows:

LEVEL 2:



For convenience these operations will be combined into one operation - "<u>removing old and fitting new jaws</u>".

LEVEL 3:



Total time = 0h47

After implementation of the long term solution for attaching jaws (section 11.6.2) the setup procedure will be as follows:

AFTER

Loosen 1 bolt (1 turn) LH jaws	0h02
Loosen 1 bolt (1 turn) RH jaws	0h02
Remove old jaws	0h02
Fit new LH jaws	0h01
Hammer LH jaws into place	0h01
Tighten 1 bolt (1 turn) LH jaws	0h02
Fit new RH jaws	0h01
Hammer RH jaws into place	0h01
Tighten 1 bolt (1 turn) RH jaws	0h02

Total time = 0h14

Setup procedure for changing jaws on level 2 would then be as follows:

LEVEL 2:

Remove jaws	0h06
Remove seats	0h02
Clean vices	0h03
Fit new seats	0h04
Fit new jaws	0h08

Total time = 0h23 (Originally 2h35)

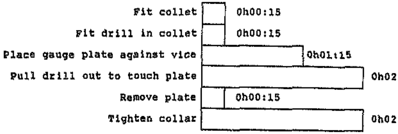
The operations "replace drills and reamers" are taken from level 2 and subdivided as follows:

LEVEL 2:

LEVEL 3:

(i) Replacing drills and reamers with no bush (time/head)

BEFORE

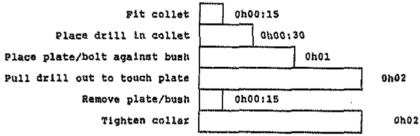


Total time = 0h06

Total time for 5 heads = 0h30

(ii) Replacing drills with bush (time/head)

BEFORE



Total time = 0h06

Total time for 4 heads = 0h24

APPENDIX G: PRODUCTIVITY INCREASE CALCULATION

Average production time between changeovers is 2,778 days = 66,67 hours. (36)

Present setup time = approx 10 hours

ratio of setup time to production time = $\frac{10}{66,67}$ = 15%

New setup time = 3,3 hours

Ratio of setup time to production time = $\frac{3,3}{66,67}$ = 5%

Productivity increase = 15 - 5 = 10%

If 3 setups were performed instead of one during the time between changeovers, setup time would increase to 10 hours for 3 setups or 15% of production time (same as for original setup). Therefore the frequency of mixed models could be increased 3 times without affecting productivity.

APPENDIX G: PRODUCTIVITY INCREASE CALCULATION

Average production time between changeovers is 2,778 days = 66,67 hours. (36)

Present setup time = approx 10 hours

ratio of setup time to production time = $\frac{10}{66,67}$ = 15%

New setup time = 3,3 hours

Ratio of setup time to production time = $\frac{3,3}{66,67}$ = 5%

Productivity increase = 15 - 5 = 10%

If 3 setups were performed instead of one during the time between changeovers, setup time would increase to 10 hours for 3 setups or 15% of production time (same as for original setup). Therefore the frequency of mixed models could be increased 3 times without affecting productivity.