The Kanban Control Board

A large wooden board was painted black and fixed to the wall facing the shaft line. A total of 37 cup hooks were then fastened to this board, and a label positioned above each hook. The description of one of the standard shafts was on each of the first 32 of these labels. The last five were labelled "In Hand".

Whenever a green bin in the store was emptied, the storeman would bring the empty bin's tag to the board and hang it on the demarcated hook for that shaft. When a second bin was emptied the yellow tag would be hung on the same hook, on top of the green. Likewise, the red tag would be hung on top of both of them if the third bin was emptied. When the foreman began a job he would take the tag, or tags, off their hook and hang them on one of the "In Hand" hooks. Once the batch was completed, the foreman would attach the tag, or tags, to the stillage and place it in a demarcated area on the floor; awaiting collection by the storeman.

In this manner, a quick glance at the kanban control board would tell the foreman, or any interested manager, the current status of the line. Up to date information was always visible regarding which shafts were needed, in what quantities, and how urgently; as well as which jobs were currently being worked on. The absence of red tags on the board signified that the assembly line was not being held up due to the lack of any shaft.

Drawings and CNC Programs

An unused filing cabinet was removed from an office and placed on the shop floor near to the kanban control board. Copies of the latest drawings and tapes of the CNC programs for each of the 32 standard shafts were obtained and kept in the cabinet for the use of the foreman and the setter. The drawings were reusable and were replaced only if they became tattered through continued use.

In the case of a design change, the foreman would be informed by means of a standard Engineering Change Note, which was circulated weekly to various departments. He would then be responsible for collecting a new drawing from the print room and a new CNC program from the Industrial Engineering department. When he had finished his first batch of the new shafts, he would personally supervise their delivery to the store. He would then ensure that any remaining shafts of the old design were moved to the green bin, so that they would be used before the new ones.

Raw Material Requirements

Using the billet diameter and length requirements compiled for the tags, as well as the bin quantities, it was possible to calculate 5 days' billet requirements. By comparing these results with the lengths of the billets from the supplier, the numbers of billets of eacn size needed in one 5 day week were found. These calculations are given in Appendix E. In order that the shaft kanban system could function effectively, it was essential that the required billets were always available. Since there was no formal system in use for controlling these billets, a simple reorder point system was quickly implemented. This will be refined at a later stage if necessary.

The reorder levels used were the calculated week's shafting requirements, even though the supplier's lead time was only 2-3 days. The reasoning behind this was as follows: in an average week, one bin (green) of each shaft should be required; but in practice the shaft line foreman would usually wait until he had a yellow tag before beginning a certain job. Thus there was the potential for up to two weeks' billets to be required during a single week. This would happen if all the shafts requiring a certain billet diameter were made on yellow tag 'orders' during a single week. Although such an extreme situation was not very likely, surges in demand for a particular billet size needed to be accommodated.

The system developed involved the weekly issue of a card to the shaft billet cutter. This card is shown in Figure E.1 on page 180. At the end of each day the operator checked his stocks of each billet size and entered the numbers of full-length billets in the appropriate blocks. He then briefly showed this card to the production controller, who immediately ordered billets of any size whose stock had fallen below he reorder level shown in the second column.

Sequencing of Setups

During the course of commissioning the system, the author noticed that only the foreman and the setter were capable of setting up the machines on the line. Consequently, there was a possibility that one of the bottleneck CNC machines might have to stand idle, awaiting a setup, if both these men were occupied elsewhere. Thus, the setups on all the machines were studied in detail to see if any immediate improvements could be made.

Setups on each machine were carefully observed and broken down into separate operations, some essential and the rest non-essential. Essential operations were those which had to be performed for every setup. The total time taken for these operations represented a theoretical minimum setup time (in the absence of any tooling modifications). Non-essential operations were those which had to be performed only if some particular dimension of the present shaft was different from that of the previous shaft. The total time taken for these operations thus represented time which could potentially be saved by careful sequencing of jobs. The total of essential and non-essential operation times clearly represented the longest possible setup time.

The thirteen most common shafts, covering the entire range of sizes, were then selected and drawings of each of them obtained. With the aid of the detailed setup study, it was possible to perform the following calculations: The D90L shaft was first assumed to be the current job. The time taken to changeover each machine to a D90LD was then calculated. The total setting time needed, for the whole line to changeover from a D90L shaft to a [illegible]0LD shaft, could then be found by adding the values for each of the machines together. The total line changeover times from a D90L to each other shaft in turn, were determi[illegible] the same way.

It was now possible to ascertain, given a current job of D90L shafts, which shaft should be selected for the next job, in order to minimise the total changeover tim[illegible] Thus the shaft giving the shortest total changeover time was assigned priority "1", the next priority "2", and so on.

The D90LD shaft was next assumed to be the current job. The total line changeover time to each other shaft was calculated and priorities for the subsequent job thus assigned. The process was repeated until each of the thirteen shafts had been treated as the current job.

Priority sheets were then compiled (see Appendix F) for the use of the shaft line foreman. These sheets were intended to be used only to decide between jobs whose coloured tag status was identical. In other words, the priority was always in the order red, yellow, green regardless of the setup times involved. However, if the foreman had a choice between, say, two yellow tags; he used the priority sheets. He located his current job at the top of one of the sheets and then consulted the column below it to see which of his two jobs had the higher changeover priority. The time given indicated the expected difference in total changeover time between a setup for that job and one for the job having priority "1". This served to indicate the relative importance of successive priorities. For example, with a current job of D90L, the difference between priorities "1" and "2" was 102 minutes, whereas between "3" and "4" it was only 2 minutes (see Appendix F).

Quality Control

The quality control department was concerned that they would lose both data collection and control of quality due to the implementation of the new system. The reason for this was that the loading sheet, previously issued with each job, had incorporated an inspection report and an operations checklist (see Appendix F).

The operations checklist had been signed by the inspector after he had checked the first-off of a new batch. This had been done after each machine setup. The inspection report had been completed only when the whole job was finished and checked.

The quality control department still required a signature of an inspector after each setup and subsequent first-off check. This was to compel the setter to get the inspector to perform this check, before allowing the operator to proceed with the job. It was also to facilitate the tracking down of the causes of any defects that should surface at a later stage.

Patrol sheets had previously been developed for the purpose of random checks by the inspector, and were supposed to be available on clipboards attached to each machine. However, this system was not being used in practice. Thus it was decided to use this patrol sheet for checking the first-off after a setup, thereby removing the need for a separate operations checklist to follow each particular job down the line.

In place of the inspection report, it was agreed that the inspector would record the information in his own book. He was then able to use the existing system, of a small disposable green card attached to the stillage, to signify that the shafts had passed final inspection.

The presence of both this green card and the kanban tags taken from the "In Hand" hook, authorised the storeman to remove the batch and replenish his bins.

4.3.5 Results

The shaft line settled into the new system of control reasonably easily and within a month it was running extremely smoothly. By this time, the f lowing results were evident:

1. The line ran 'automatically' with no need for any planning, paperwork or clerical effort by any member of staff (except in the case of occasional orders for special shafts).

2. The system cycled primarily around yellow tags, as planned. The batch sizes calculated were fairly accurate since the line hardly ever found itself in the position of having only green tags to work on. Likewise, red tags only appeared in the case of a serious breakdown, or if there was a really unusual surge in demand for a particular shaft. (The latter problem was later taken care of by a refinement arising out of the new MPS system).

3. The overall shaft stock level had only dropped by about 10%. This was not surprising since the kanban system had been designed around the existing production constraints, without making any significant changes to setup times or capacity. However, the mix represented within the shaft stock level had vastly improved; to the extent that the previously common stockouts had been virtually eliminated. On the other hand, the overstocking of

certain shafts, observed in the past, was now prevented by the kanban system.

4. A significant improvement in the motivation of all the shaft line employees was noted. The line won the company's monthly housekeeping competition for the first time and continued to do so for several subsequent months, until other sections of the plant achieved similar motivation levels. This particular result of the kanban system had not been anticipated by the author. The most likely reason was that the performance of the line was now highly visible to management, visitors, etc., by means of the kanban control board. All the people on the line had been trained in the kanban system and they appeared to take great pride in having no red tags on the board. This increase in pride proved very valuable when new quality assurance systems were introduced to the line, soon after the kanban system.

Thus, the power of the kanban system was strongly demonstrated by the pilot project in that tight control was achieved over production, with certain spin-off benefits, and without the staff effort previously expended ineffectively. Consequently, the author was encouraged to extend the system to other areas of the plant without delay.

4.4 Variations on the GEC Small Machines Kanban System

The same basic kanban system used on the shaft line was applied to component production throughout the plant. However, in a few cases certain variations were used to deal with unique problems.

4.4.1 Multi-Cell Kanban Control

In one machining area, a certain foreman was in charge of six separate small GT cells. Not all of these cells could be manned at all times and it was the foreman's responsibility to allocate the men under his control to various cells as required. The normal approach would have been to erect a kanban control board at each of these cells with a hook for each of the products produced in that cell only. To assist the foreman with his manning problem, it was decided instead to erect one large board on a nearby wall. This board was divided into groups of hooks pertaining to particular cells, by means of white lines. Each group of hooks included one "In Hand" hook to show what was in progress in that particular cell.. In this way, the foreman could consider the relative workloads of all the cells under his control simultaneously and could be sure to allocate his men intelligently.

4.4.2 The Blue Tag System

The D90L stator frame required a very long setup when being machined. The reason for this was that one of the machines in the relevant cell was not in fact capable of accommodating such a small frame. Since there was no other machine which was suitable for the job, the method used was to fabricate a special brass bush on the machine as part of the setup. This had to be done on the machine in question to ensure that it was centred correctly. Thus, the bush could not be made in advance and unfortunately, it could not be removed without damage and so a new one had to be made as part of each setup. There were plans to try to find suitable tooling to modify the machine; but in the short to medium term, this problem could not be overcome.

It was therefore agreed that the D90L frame should be made only a few times a year, in large batches. This was not suitable for the three bin kanban system since a large production batch (green plus yellow) would imply a large amount of dead stock in the red bin. A simple reorder point system, with a large reorder quantity, appeared to be the most appropriate system but it was preferable that this could operate in parallel with the kanban system used for all the other components produced by the cell. This was achieved by painting a single tag blue and writing the normal kanban system information on it; except that the quantity shown was the large batch reorder quantity. Also shown was a reorder level which was set as low as possible to provide for assembly whilst the large batch was being setup and machined.

This blue tag was then attached to the reorder quantity of frames, whilst the rest of the stock did not have any kanban tags. This unmarked stock was used first. When the blue tag was finally reached, it was detached and taken to the kanban control board. The board had one allocated hook for this particular frame, as for the others on the normal kanban system. The foreman was instructed to treat the blue tag with a higher priority than an ordinary yellow tag, but not as high a priority as a red one. Due to the lengthy setup and long production run involved, the fo[illegible] always run at full capacity (i.e. two shifts [illegible]me) when working on the blue tag. In this way [illegible] could accommodate the occasional blue tag without serious disruption of his ordinary kanban workload.

4.4.3 Two Bin Prioritised Kanban

One of the component production lines, producing mini-motor shafts, was situated such that it fed shafts directly into a rack. On the other side of this rack was the user; the mini-motor final assembly line. From a JIT point of view this layout was ideal, but the rack was not being used intelligently. Finished shafts were placed anywhere on the rack as there were no demarcations specifying which shafts should be placed where. Consequently, stockouts and resultant production delays were common in spite of the physical proximity of the two sections.

The use of a kanban system in this area was investigated and unfortunately, the existing rack was not physically suited to a three bin system. The rack could have been modified or replaced but only with a fairly lengthy delay. This rack was, however, capable of accommodating a two bin system for the number of standard shafts required. It was reasoned that, in view of the visibility of the actual stock levels to the mini-motor shaft line itself, the 'advance warning' of the green kanban tag was perhaps not as important as it had been in the previously implemented systems.

As a result, a two bin system using only the yellow and red kanban tags was implemented. The system worked fairly well due to the visibility of the bins to the line foreman. However, it was certainly not as successful as the three bin systems employed elsewhere in the plant and its frequency of stockouts was considerably higher.

Paradoxically, these stockouts occur in spite of the fact that the two bin kanban system carries more stock, on average, than an equivalent three bin kanban system. In designing either system, it is necessary to consider the existing production constraints together with the market demand. This is achieved by means of Formulas (i) and (ii) in Appendix A. The resulting range of values of x_i will be the same, regardless of the system being considered. Since x_i is the required production batch size, the three bin system uses $x_i/2$ in each bin. The two bin system however, requires x_i in each bin, since a batch must be produced on receiving the yellow tag. This means that the maximum stock carried by the two bin system is $2x_i$, whilst for the three bin system it is only $3x_i/2$.

In both cases, the average stock carried is dependant on the speed of response to the yellow kanban tag. This varies according to the line's current workload; but regardless of this response time, the average stock carried by the two bin system will always be $x_i/2$ greater than that of the three bin system. The reason for this is that when the yellow tag arrives on the kanban board, the current stockholding of the two bin system is always x_i whereas that of the three bin system is only $x_i/2$.

4.5 Vendor Kanban Systems

4.5.1 Complete Vendor Kanban Systems

The first vendor kanban systems were implemented between GEC Small Machines and two of its major suppliers, both of whom were GEC companies. The companies were GEC Foundries, located in Springs; and GEC Large Machines, located on the same Benoni site as GEC Small Machines. The delivery performance of both these companies tended to be very poor, since they appeared to regard GEC Small Machines as a captive market; rather than as an important customer.

The top management of the two companies were invited to an 'open day' at GEC Small Machines during which they were shown the internal kanban systems in operation. The GEC Small Machines Managing Director explained the advantages of the kanban system and why he wanted to extend it to vendors. Copies of a general specification for vendor kanban systems (see Appendix G) were then handed out and the visitors were asked to study it.

After this, the author received fairly good cooperation from the representatives of the two companies and was able to proceed with system implementation. The major issue for discussion was the kanban quantities. As GEC Small Machines was not the only customer of these two vendors, a procedure like that in Appendix A was of little value. It could have been used if a vendor was prepared to dedicate a certain fixed percentage of capacity to GEC Small Machines' work. Unfortunately, both companies were reluctant or unable to do so.

The procedure adopted was to issue the vendor with a list of the company's average daily requirements for all the components generally purchased from him. The vendor was then asked to submit a proposal of his minimum production batch size for each component. Many of these batch sizes were unacceptably large from the point of view of GEC Small Machines and the reasoning behind them was challenged. In some cases, the vendor agreed to smaller quantities, but in others it was clear that reductions would be difficult. An example of this problem was that certain of the small components that were purchased from GEC Large Machines were punched out of large sheets of steel. Once punching had begun, it was difficult to punch less than a full sheet.

Although certain large quantities were accepted, none of them were any larger than those that had previously been purchased. In many cases, significant reductions in batch sizes were achieved, since every reason for a large batch was vigourously challenged. It was not surprising then, that the implementation of these kanban systems led to reduced stockholdings at GEC Small Machines.

Once the full list of batch sizes had been agreed upon, the bin quantities were set at half of these figures (since the normal production batch would be yellow plus green). The number of days' worth of stock - from GEC Small Machines' point of view - represented by one bin quantity was then calculated for each component; using its average demand rate. This information was conveyed to the vendor company, which then committed itself to a maximum response time for a yellow kanban tag, which was in each case identical to the stock days represented by the red bin.

The raw casting yard at GEC Small Machines was reorganised to accommodate the kanban system. Green, yellow and red storage areas of suitable sizes were painted on the floor for each component. When the last casting from one of these 'bins' was removed by the factory, the storeman took the kanban tag to the buyers' office, where it was hung on a board. The GEC Foundry delivered castings at least every second day. Their driver would hand the kanban tags pertaining to his delivery to the storeman; who would then offload the castings into the correct bins and attach the tags to them. Before leaving, the Foundry's driver would go to the buyer's office to collect the latest tags from the board.

The buyer employed a small pinboard which had a list of all the Foundry components down the left hand side. Next to each component label were three spaces which could accommodate a green, a yellow and a red pin. As the driver removed the latest kanban tags, the buyer would place coloured pins in the relevant spaces. Likewise, based on the delivery note for the latest delivery, he would remove the relevant pins from his board. In this way, the buyer's board would tell him at any time what kanban tags had been sent to the vendor so that he could audit the system to ensure that no kanban tags had been lost. This board was also used for expediting purposes as the buyer would notice if a particular red tag was not being responded to quickly enough. Similar systems were used for GEC Large Machines, except that kanban tags were taken there daily, since they were on the same site.

Due to existing accounting and computer systems, an order number was required to allow the vendor to invoice GEC Small Machines, and for payment to be made to him. One 'order' was thus placed for each vendor kanban system which listed all the relevant components and specified quantities sufficient to cover at least a year's demand. This one order number was then written on the back of each kanban tag for convenience.

The information written on the front of each kanban tag was exactly the same as for in-house systems, except that the heading specified the two companies involved. Various production information, as requested by the vendor company, was written on the back of the kanban tag. In the case of the Foundry system, problems were experienced with the information gradually fading in the rain as the tags stood outside in the casting yard. Attempts to find a truely waterproof marker pen were unsuccessful and eventually each kanban tag, once written out, was encased in thin adhesive plastic; which solved the problem.

For ease of identification, it was decided that vendor kanban tags should be square. The advantage of this was that any factory employee, when releasing a kanban tag by drawing parts, knew that if the tag was square it had to go to the buyer's office. If, on the other hand, it was round, he had to locate the correct board in the factory to hang it on. The resultant kanban tag and material flows are shown in Figure 4.5.

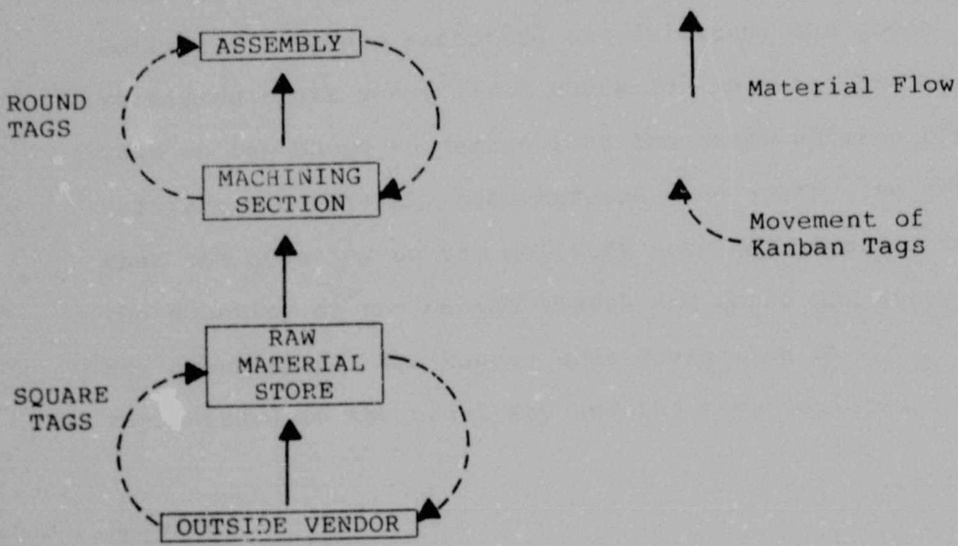

Figure 4.5: Kanban Tag and Material Flows

4.5.2 Interim Vendor Kanban

In some cases vendors were not yet confortable with the idea of actually receiving a kanban tag in place of an official order. It was nevertheless felt that the three bin system would be useful from the point of view of GEC Small Machines' stock control for some of these items. An interim vendor kanban system was thus developed which employed two kanban control boards.

The stock was kept in three bins in the usual way, but when a bin was emptied, its tag was taken to a board in the buyer's office headed 'To Be Ordered'. Once the buyer had ordered the components called for by the tags, he would take the tags to another kanban board in the goods receiving area headed 'On Order - Awaiting Delivery'. Before accepting any delivery, the goods receiving clerk would first check for matching kanban tags on the board to ensure that the items offered for delivery had actually been ordered. He would also check that the quantity on the delivery note corresponded to the quantity on the kanban tag(s) and would not accept any oversupply. The kanban bins would then be replenished in the usual way and the tags replaced.

4.5.3 Results

The interim vendor kanban systems improved the availability of certain purchased components due to the tidy, organised stores layouts and the accurate placing of orders. However, the due date performance of certain suppliers was still poor and thus the improvements noted were directly attributable to the removal of errors from the GEC Small Machines end of the buying process.

Unfortunately, this control over stockholding and reordering at the company was also the major contributor to the total improvement brought about by the complete vendor kanban systems. The continued incidence of stockouts of components supplied by the GEC Foundry and GEC Large Machines was not due to any fault of the systems themselves. It was, instead, a result of the continued lack of commitment, on the part of these two goods receiving area headed 'On Order - Awaiting Delivery'. Before accepting any delivery, the goods receiving clerk would first check for matching kanban tags on the board to ensure that the items offered for delivery had actually been ordered. He would also check that the quantity on the delivery note corresponded to the quantity on the kanban tag(s) and would not accept any oversupply. The kanban bins would then be replenished in the usual way and the tags replaced.

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4.6 Discussion

4.6.1 Special Features of the GEC Small Machines Kanban Systems

The following features, which proved very effective, gave the GEC Small Machines kanban system an advantage over many other systems of production and inventory control:

1. The calculation method in Appendix A ensures that all available cell capacity is used productively. Components are made at no more than the required rate and the balance of the capacity is all used for setups. This ensures that the smallest practically possible lot sizes (allowed by the current production and setup times) are always used. Whenever an improvement in a setup time or production method is made, the kanban quantities are recalculated.

2. The theoretically correct lot sizes mentioned above represent the sum of the green and yellow kanban quantities. However, the system automatically adjusts these lot sizes up or down to compensate for the performance of the cell relative to that of the consuming operation. If the cell is running late it will receive red kanbans and will thus produce larger batches and use less time for setups.

Likewise, if the cell has been producing faster than the rate of consumption, it will eventually have only green kanbans to work on. The cell will therefore produce smaller batches and use more time for setups, until a state of balance is achieved again.

3. The occurence of problems in a cell is highlighted by the strong visual signal of a red kanban tag appearing on its kanban control board. This signal is highly visible and ensures that the necessary people get involved in solving the problems urgently. On the other hand, the absence of any red tags on a cell's kanban control board signifies that the cell is definitely not delaying production elsewhere in the plant. This continuous measurement of performance generates a considerable amount of pride in the employees in the cell, which tends to enhance productivity, quality assurance and housekeeping.

4. The system can also be used as a means to force productivity improvements. The quantities on the kanban tags can be temporarily reduced by means of covering the tag quantities with small white stickers having lower quantities written on them. The operation of the cell is then observed closely as it comes under the increasing pressure of more and and more yellow tags until finally, it receives red tags. In this way, many inefficiencies are exposed

and can be eliminated. Once some improvements have been made, the kanban quantities are recalculated and the figures on the tags are more permanently adjusted.

5. As outlined earlier, the prioritising feature of the different coloured tags automatically rearranges the 'queue' of work at a cell to match the current consumption trend. In this way, non-levelled final assembly schedules can be accommodated much more effectively than is the case with simplistic first in, first out systems.

4.6.2 Comparison With Toyota's Dual Card Kanban System

1. The Toyota system uses two sets of cards, the conveyance and the production kanban. A GEC Small Machines kanban tag is actually a conveyance and a production kanban in one. It effectively instructs the receiver to produce a specified quantity of a specified part number and deliver it to the point of use. It also conveys a priority, which neither a C- nor a P-kanban can do.

   The major disadvantage of having only one set of kanbans is that they pool the inefficiency allowance of the source work centre, the using work centre, and the material handlers. This makes it a little more difficult to isolate the sources of problems and compress the variance in production.

A limitation of the GEC Small Machines system is that if there were more than one point of use of a particular part number, it would be necessary to produce parts for each user separately. This situation did not in fact arise at GEC Small Machines but it would be handled in a superior way by the dual card system. One set of P-kanbans would cycle between the cell and its outbound stockpoint whilst different users, each with their own set of C-kanbans, could all draw from this stockpoint.

2. A red tag on a kanban control board can signify a stoppage of a production line at GEC Small Machines, unless the line has already moved on to other products. Dual card kanban is superior in that it can detect a slowdown in the rate of supply earlier than this and corrective action might then be taken in time to prevent a line stop. This occurs when a C-kanban is taken to fetch parts from the outbound stockpoint of the supplying work centre and such parts are found to be unavailable. In this case, the work centre will stop its other work to produce the required parts immediately. This can occur whilst the using work centre still has one or more containers of parts left. Hence, it may be possible

for the parts to be supplied in time to prevent a line stoppage.

3. The C-kanban in the dual card system draws inventory which is kept at the point of manufacture, but the GEC Small Machines kanban system keeps all inventory at the point of use, or as nearby as possible. It does not reorder, however, until a bin has been fully consumed; whereas in dual card kanban, the C-kanban is detached as soon as consumption of the bin begins. The reason for this is that companies using dual card kanban, such as Toyota, usually have a sufficiently levelled schedule to be confident that the bin will continue to be used. Therefore the bin will probably be empty by the time its replacement arrives. At GEC Small Machines, on the other hand, the schedule is not levelled and so consumption of a bin may begin and subsequently be halted for a considerable period of time. The convention of releasing a kanban tag only when the bin has been fully consumed ensures that no overproduction can occur.

4. Although dual card kanban usually leads to some motivation improvement through low level responsibility, it cannot be expected to achieve the same dramatic motivation improvements brought about by the GEC Small Machines kanban system. By means of the colour coding, this system achieves a

continuous, highly visible measurement of performance which motivates the workforce through pride; as they strive to avoid the appearance of red tags on their kanban boards.

5.0 IMPLEMENTATION OF THE MASTER PRODUCTION SCHEDULING SYSTEM

As mentioned in Chapter 3, the system consists of four separate MPSs; one for each of the four winding cells. All of these schedules are structured in a similar way and thus only the most complex one will be discussed here. The cell in question winds all motors of the 132 and 160 frame sizes and is limited by a winding and shooting machine called the "Industra II".

5.1 The Industra II MPS

5.1.1 The Structure of the Schedule

A full list of all the motors that could be made in this cell was first obtained. The list also gave the standard winding times for each of these motors. The methods of setting up the Industra II machine were then studied and it was soon apparent that each setup could be classified into one of three levels of difficulty. The resultant setup 'hierarchy' was as follows:

1. A pole change - There were four complete sets of tooling, one for each of the following: 132 2 pole,

132 4 pole, 160 2 pole and 160 4 pole. To change from any one of these sets of tooling to any other took an average of 2,0 hours.

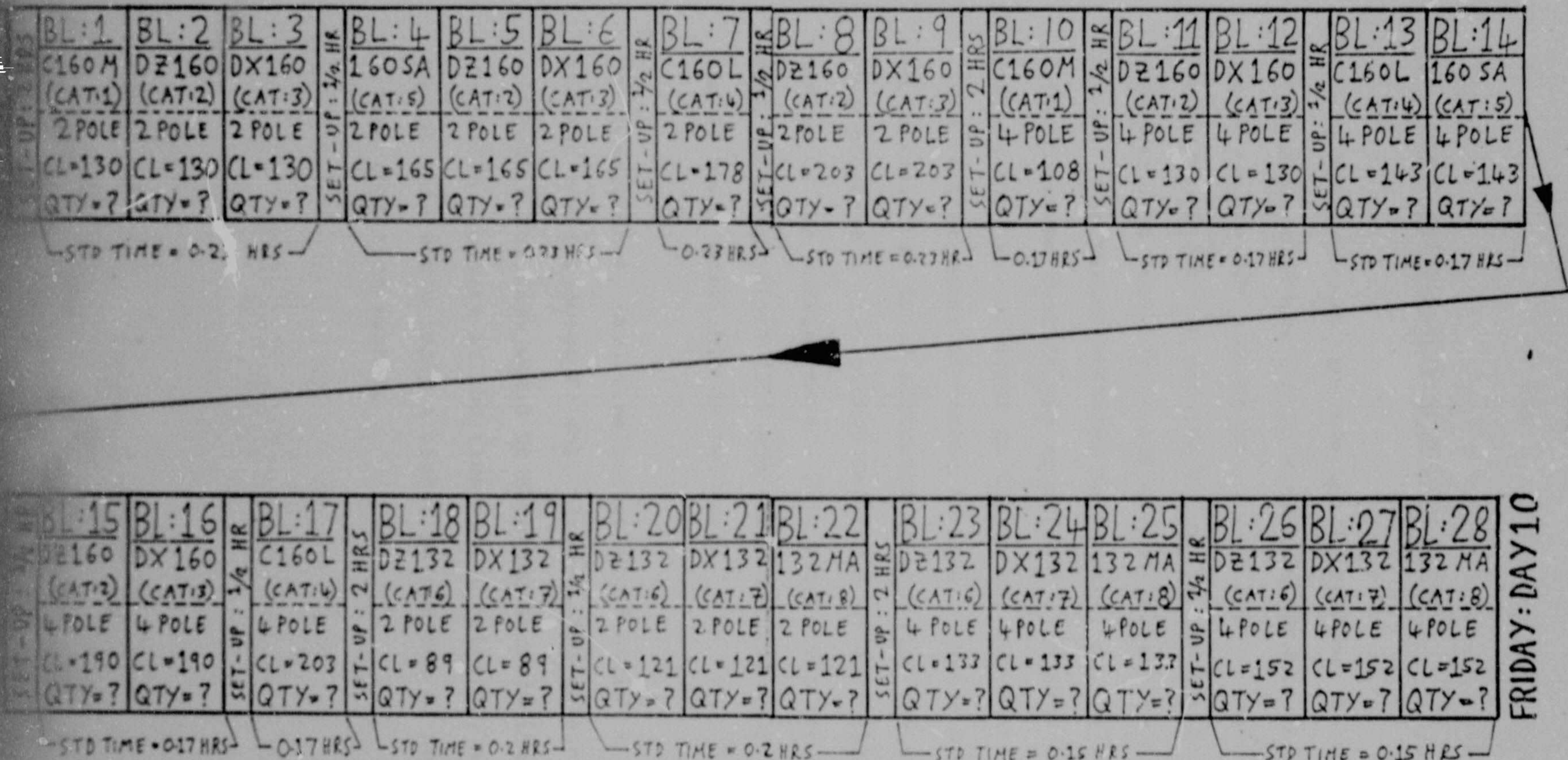
2. <u>A core length change</u> - Many different lengths of stator cores were wound. When changing from one core length to another, the complete set of tooling did not have to be removed; providing that both the motors in question belonged to the same pole group. Extensive adjustment of the machine was required, however, and the complete core length change took an average of 0,5 hours.

3. <u>A voltage change</u> - Within the same pole group and core length, it was possible to wind motors with different voltage ratings. This was achieved by using different gauges of copper wire. Various different wire rolls were always available next to the machine and the process of removing one and loading another took a maximum of 0,1 hours.

An optimal winding sequence was required which would allow each different type of motor to be produced, using the minimum of setup time. Clearly, it would be best to setup for each pole group only once during the sequence and then to make all the motors required from that pole group. Within each pole group it would be best to complete all the motors of one core length before changing to the next core length. Finally, once setup for a particular core length, it would be best to complete all the motors of one voltage before changing to the next voltage.

Thus it was decided to produce the motors in the sequence: 160 2 pole, 160 4 pole, 132 2 pole, 132 4 pole; and to run through the different core lengths, from the shortest to the longest, in ascending order in each case. The resultant schedule structure is given in Figure 5.1, which also shows the standard winding time for each motor type (The significance of the Block and Catagory numbers is explained later under section 5.1.5).

Figure 5.1 shows the major setups (pole and core length changes) and these total 12,5 hours for the complete sequence. However, not all of the core length changes would always be needed, since it was unlikely that all possible motors would be required in a particular time bucket. It was initially estimated that the time saved here would easily provide for the voltage changes required. The figure of 12,5 hours was therefore used as an initial estimate of the setup time required to run through the entire production sequence.



Key:

BL = Block

CAT = Category

Figure 5.1 Industra II Master Production Schedule for 160 and 132 Windings

5.1.2 The Length and Capacity of a Time Bucket

It was decided that the Industra II machine, being a bottleneck, should not stop during tea breaks and would therefore run for 9 hours per day on normal time. From the point of view of Manufacturing, it was not desirable to spend more than 10% to 15% of available time on setups. The Marketing/Sales department, on the other hand, believed that it was essential to be able to deliver any type of motor to their best customers within three to four weeks of taking an order. Since one of those weeks had to be allocated to assembly and shipping, they proposed a time bucket length of no more than two weeks, or ten working days. This figure was accepted by Manufacturing since 12,5 hours represented only 13,9% of the 90 hours available in two weeks.

For convenience, each time bucket would begin on a Monday and end the following Friday. It was also agreed that any public holidays would be absorbed by reducing the available capacity in the time bucket affected; even though this would imply a higher percentage of setup time during that time bucket.

The question of undercapacity scheduling was then discussed and it was felt to be advantageous for the reasons outlined in Chapter 3. Since there was currently no preventive maintenance program, a fairly high figure of 15% undercapacity scheduling was decided upon. This meant that the capacity of the Industra II would be assumed to be 85% of the 90 available clock hours, that is, 76,5 hours per two week time bucket.

5.1.3 Development of the Computer Program

The development of a suitable computer program for preparing the schedules was investigated next. It was desired, if possible, to avoid capital expenditure by developing the program in-house to run on an available microcomputer. The correct sequencing of jobs, as well as the allocation of capacity to them from a data file of standard winding times, could easily be performed within the available "Focus" package. Unfortunately, the calculation of the exact setup times required within a time bucket due to the particular jobs loaded, was considered to be too complex a program for these existing resources to handle.

Since the 'optional' setups in question were short when compared to the 76,5 hours available, it was decided that such a degree of accuracy would not be necessary.

Instead, the current mix of motors, according to the EADs, was examined with the help of the sales managers. It was clear that motors from all of the four pole groups would almost certainly be demanded in each time bucket. This implied that 8 hours (4 x 2 hours) would always be needed for the major setups. However, not all of the available core lengths pertained to popular motors and it was estimated that no more than seven of the nine possible core length changes would be used in a single time bucket. Hence only 3,5 hours (7 x 0,5 hours) were reserved for these setups. Finally, most motors of a particular pole group and core length were commonly required with only one standard voltage rating. It was agreed that an allowance for four voltage changes (of 0,1 hours each) would be sufficient for each time bucket.

A total of 11,9 hours for setups was therefore deducted from the available 76,5 hours and the scheduling program was designed to load 64,6 hours of work per time bucket, ignoring setups. It was further reasoned that if the loading of particular time bucket required more than 11,9 hours of setup time, this would simply result in slightly less than 15% undercapacity scheduling; and vice versa.

A microcomputer program was therefore developed to arrange jobs into the correct production sequence per time bucket as they were input and also to calculate how much capacity the jobs in each time bucket would require. On entering each customer order, the operator was required to specify which time bucket the job should be loaded into. This was done by means of a priority number. Priority one referred to the next upcoming time bucket; that is, the schedule which would next be issued to the shop floor. Priorities from two upwards referred to the subsequent time buckets. Customer orders already loaded onto the shop floor were in the current time bucket, called priority zero, which could not be altered.

5.1.4 Using The System

An onscreen capacity check by time bucket could be carried out at any time. An example of this is given in Figure 5.2.

The total numbers of 160 and 132 frame size motors loaded in each bucket are given first. Underneath this, the hours of work loaded are compared with the available 64,6 hours and the unscheduled time in that bucket is thus calculated. Where this available balance is negative, it is converted to an overtime figure at 85% efficiency. The overtime figure thus represents the clocked hours of overtime that should be arranged for that time bucket if the planned schedule is accepted for production in its present format.

One nightshift crew was available and could be allocated to any chosen winding cell for a particular time bucket.

This had the effect of adding 76,5 hours of capacity to that cell for the time bucket in question. If the loading profile in Figure 5.2 was composed of customer requirements which could not be delayed, the nightshift would have to be allocated to the Industra II cell during the upcoming two week time bucket (PR1). On the other hand, the extra capacity needed in the following two time buckets could be provided by scheduling the overtime suggested and so the nightshift crew could be allocated to another winding cell. The fourth time bucket is almost empty in this example and thus any customer who currently placed an order could have it allocated into this time bucket. This represented the current lead time for motors of the 132 and 160 frame sizes, which was communicated to all the sales people on a regular basis.

INDUSTRA II WINDING LOAD CAPACITY- 132 - 160 Frame Sizes (2-4P)

PR 1	2	3	4
160 PN QTY 292	160 PN QTY 65	160 PN QTY 217	160 PN QTY 0
132 PN QTY 509	132 PN QTY 383	132 PN QTY 289	132 PN QTY 2
TOTAL QTY 801	TOTAL QTY 448	TOTAL QTY 506	TOTAL QTY 2
PLAND HR 137,05	PLAND HR 79,70	PLAND HR 86,66	PLAND HR 0,30
AVAIL HR 64,60	AVAIL HR 64,60	AVAIL HR 64,60	AVAIL HR 64,6
BALAN HR -72,45	BALAN HR 15,10	BALAN HR-22,06	BALAN HR 64,3
OVERTIME 85,24	OVERTIME 17,76	OVERTIME 26,96	OVERTIME 00

Figure 5.2 Example of a capacity check for a winding cell. The priority numbers (PR1-4) refer to the loading buckets (1-4)

The schedule loading remained flexible as late as possible, and sales managers had complete freedom to shift orders from one bucket to another, within the capacity constraints. They quoted delivery dates depending on the time bucket in which a customer's order had been scheduled. Every second Friday morning, the winding bucket due to commence the following Monday was finally frozen, and a printed schedule like that in Figure 5.3 was obtained for each winding cell.

The printed schedules were then issued to the managers and to the shop floor, where they were displayed prominently at each winding cell. The headed columns on the right hand side of the schedule were used to track the progress of orders through the various manufacturing steps. A mark was placed in the appropriate block as each operation was completed. Any salesman or manager who was concerned about a particular order could simply consult the schedule to see how it was progressing. As the windings came out of the resin dip into the assembly, they pulled components from kanban systems, and were assembled, tested, painted and shipped.

In order to determine an expected delivery schedule, a uniform assembly lead time of one week was used. A planned relayout of the assembly section into seperate cells per frame size will allow shorter and more accurate assembly lead times to be used in future. The current

SMALL MACHINE INDUSTRIAL INDUTRA II WINDING LOADING 13/7- 21/7

WORKS ORDER	MOTOR_TYPE	KWATT	POLE	VOLT	C_LEN	QTY O/S	CUSTOMER	WIND	CONN	DIP	TEST
D9358	DZ160M	15.00	02	380	165.0	42	CO.STOCK				
D9364	DZ160L	18.50	02	380	203.0	27	CO.STOCK				
D9188	DZ160MDB	11.00	04	380	130.0	2	GEAREDMOTORS250				
D9203	DZ160MQ	11.00	04	380	130.0	5	LDC				
D9210	DZ160M	11.00	04	380	130.0	2	ELECT SALS-MAL				
D6289	DX160M	11.00	04	380	130.0	[illegible]	DAVEY S.A				
D5371	DX160M	11.00	04	380	130.0	1	REY'N LENFERNA				
D9274	DZ160MQ	11.00	04	380	130.0	5	ASEA ELEC				
D5481	DX160MQ	11.00	04	380	130.0	8	COMPAIR				
D5485	DX160MQ	11.00	04	380	130.0	3	COMPAIR				
D9168	DZ160L	15.00	04	380	190.0	10	CO.STOCK				
D9211	DZ160L	15.00	04	380	190.0	3	ELECT SALS-MAL				
D5229	DX160L	15.00	04	380	190.0	10	DONKIN				
D5291	DX160L	15.00	04	380	190.0	5	DAVEY S.A				
D9275	DZ160LQ	15.00	04	380	190.0	10	ASEA ELEC				
D9327	DZ160LQ	15.00	04	380	190.0	5	LDC				
D6716	DX160LD	15.00	04	525	190.0	6	HOWDEN SAFANCO				
D9229	DZ132S	05.50	02	380	89.0	58	CO.STOCK				
D9230	DZ132S	05.50	02	525	89.0	4	CO.STOCK				
D5008	DX132S	07.50	02	380	121.0	35	CO.STOCK				
D5307	DX132SD	07.50	02	380	121.0	2	CO.STOCK				
D9232	DZ132S	07.50	02	380	121.0	11	CO.STOCK				
D5188	DX132SQ	07.50	02	525	121.0	5	K.S.B PUMPS				
D5315	DX132S	07.50	02	525	121.0	23	CO.STOCK				
D5184	DX132SQ	05.50	04	380	133.4	2	HYTEC				
D9209	DZ132S	05.50	04	380	133.4	1	ELECT SALS-MAL				
D5306	DX132SD	05.50	04	380	133.4	3	CO.STOCK				
D5313	DX132S	05.50	04	525	133.4	12	CO.STOCK				
W6355	DX132MD	07.50	04	380	152.4	2	HANSEN TRANS				
D5236	DX132MDQ	07.50	04	380	152.4	3	GEC PRETORIA				
D5302	DX132MD	07.50	04	380	152.4	15	CO.STOCK				
D9238	DZ132S	07.50	04	380	152.4	13	CO.STOCK				
D5028	DX132M	07.50	04	525	152.4	100	CO.STOCK				
D5305	DX132M	07.50	04	525	152.4	42	CO.STOCK				

Figure 5.3: Example of the Frozen Schedule Issued to the Shop Floor

frozen, and provisional future, two week winding schedules were issued to the sales branches around the country as firm and provisional despatch schedules. The only difference was that the expected winding dates were adjusted by the assembly lead time to give despatch dates.

Most of the motors which were rejected at final test could be repaired in time to meet their expected despatch dates, but a few required complete rewinding. These motors were rewound immediately if the winding cell was still setup for the same type of motor. If not, they were easily accommodated in the next winding bucket due to the undercapacity scheduling employed. However, because of the fixed winding sequence, they could be delayed by up to two weeks, and the customers were advised of this immediately. If, from the customer's point of view, a motor had to be rewound sooner, a joint decision could be made by the Sales and Manufacturing managers to use some extra overtime to rewind it. This could only be done on the condition that after setting up the machine and winding the motor, the machine could be reset to its original condition in time for normal production to resume as planned. In other words, no rewind could be permitted to disrupt the current winding schedule.

In the author's view, the apparent disadvantage of such a rigid short term master schedule is only an illusion. The high cost of performing a special setup, rewind and re-setup on overtime only serves to clarify the true cost of a rejected motor. This cost was traditionally 'hidden' by performing the rewind during normal hours and not taking into account the resultant schedule disruption which lead to broken promises to other customers; not to mention lost productive capacity. Serving one customer only, at the expense of several others, is unacceptable in a WCM environment and applying a high penalty to a reject serves to remind all concerned of the importance of proper quality assurance.

5.1.5 The Component Capacity Check

In order to assist the in-house cells operating on kanban and to ensure that they would not disrupt the assembly schedule with stockouts, a further feature was added to the MPS system. The total requirements for major components in each two week time bucket were calculated according to motor frame type. In order to illustrate the operation of the computer program in this regard, the reader is referred again to Figure 5.1 (p.145)

The Industra II schedule was divided into 28 loading 'blocks' which pertain specifically to motor frame types.

There was not necessarily a winding machine setup between successive blocks. Consider, for example, blocks 1, 2 and 3. All of the windings concerned are 160 2 poles with a core length of 130 cm. Some of the motors loaded in each block may have been 380V and others 525V. In such a case, all the 380V motors would appear on the winding schedule before the 525V ones, regardless of which of the three blocks they belonged to. However, each of these three blocks of orders would require components of either type C, DZ or DX; each of which is unique.

There were a total of eight different categories (Cat) of components represented on the Industra II schedule. In calculating the component requirements for DZ160 (category 2), for example, the computer would add up the total numbers of motors loaded into blocks 2, 5, 8, 11 and 15. It would also check the other winding schedules for the same time bucket, for category 2 component requirements. There might, for example, have been a special 8 pole handwound motor requiring the same components.

Thus, the computer calculated the total requirements in a time bucket for each of the frame categories; of which there were a total of 24 that could possibly be required across the four different winding cells' schedules. It then compared these results with the two week EAD values,