Other Kanban Variations

There are many variations of the kanban system. When the same parts are manufactured of[illegible], the detailed information on the cards may not be necessary. Pull signals can therefore be given by electronic messages, coloured golf balls transmitted through pneumatic tubes, coloured chips or washers, plastic markers, painted squares on the floor (kanban squares), and the containers themselves. The use of dedicated containers was considered impractical at GEC Small Machines, due to the physical constraints of the workplace. Containers often needed forklifts to move them, and the prospect of having to handle a specific container into place when its parts were being produced was not attractive. It would definitely have been easier just to ensure that standard containers were always available at the output end of a cell and then to attach the relevant card to the container once it was filled.

One kanban variation involves the use of a single triangular shaped marker which has the part number written on it. The marker is placed between boxes in a pile at the outbound stock point. When the box directly above the marker is removed for use, the marker is hung on a post which is visible to the workers and tells them which parts are running low. The number of boxes beneath the marker represents a reorder point and so the hung marker tells the workers that if they are not already running that part, they should do so urgently.

A lot of these variations, and to some extent single card kanban, appear similar to the old reorder point or two-bin systems. However, they are actually improvements in that they are employed as part of a JIT system and so include the following features:

i) They employ standard containers with exact quantities, which makes inventory counting and control considerably easier.

ii) The quantities in the containers are usually small, so that several containers per day are likely to be used up. This helps to keep the user area uncluttered, as only a few full containers are on hand at a time.

iii) The use of small lot sizes requires prior action at the supplying work centre to reduce set up times.

iv) Management is always pressing to have the inventory reduced and so a prompt response to the needs of the using work centre is required. Thus, a degree of alertness not present in ordinary reorder point systems, is expected of the people in the supplying work centre.

3.2.6 The Applicability of Kanban Systems to GEC Small Machines

Schonberger believes that kanban is feasible in just about any plant making goods in whole discrete units, that is, not process industries; but advises [59]:

"Kanban will work well only in the context of a just-in-time system in general and the setup time/lot size reduction feature of JIT in particular."

This was not seen as a problem for GEC Small Machines since the company was committed to the JIT philosophy. Although not much setup time reduction had yet been performed, it was definitely in the company's future plans. Moreover, the author believed that many lot size reductions were immediately possible in non-bottleneck resources, as discussed earlier. Also, the enhanced visibility to be provided by the new master scheduling system would eliminate much of the "just in case" element of the current lot sizes.

Schonberger also recommends that very expensive or large items should not be included in kanban since they are costly to store and carry. GEC Small Machines did not have any large items to be concerned about, but decided that the expensive copper wire used in stator winding should not be included in the kanban system, especially since its price was subject to constant fluctuation. Its ordering and delivery would instead be closely regulated by the buyer, as Schonberger suggests.

Lastly, he explains that the parts included in the kanban system should be used every day [60]:

"Kanban provides for at least one full container of a given part number to be on hand all the time, which is not much inventory idleness if the full container is used up the same day it is produced."

The intention at GEC Small Machines was to apply kanban to only the standard parts, most of which were in fairly constant high use. However, due to the structure of the MPS, not all the parts would be used every day. The extra inventories (when compared to an advanced JIT system) that this would imply, were considered acceptable in the short term as they were certain to be lower than under the present system. Any move towards smaller lot sizes would help the company to achieve some JIT benefits; and since these improvements would be ongoing, the ideal of daily parts usage was expected to be achieved eventually.

Vollmann, et al, state [61]:

".... the kanban card control system is only suited to very stable production schedules."

This refers to the need to evenly distribute the requirements for materials over time. Clearly, if the material requirements are steady (or levelled), the capacity requirements will be as well; but the reverse is not necessarily true. It is preferable to avoid sudden peaks and troughs in the demand for particular materials or components. Ohno [62] discusses this under his 'rules' for applying the dual-card system:

"... if the subsequent process [illegible] to withdraw materials evenly with regard to [illegible] ntity, the preceding process will require [illegible] sonnel and facilities to accommodate its requests. The end result is that the earlier the process stands in the total manufacturing process, the greater the need for excess capacity."

To illustrate these concepts, consider the example of a factory which produces four models; A, B, C and D. The total demand for a particular 20-day working month consists of 400 As, 400 Bs, 200 Cs and 200 Ds. A typical, non-level approach would be to produce them over the 20 day period in the sequence:

400 x A, 400 x B, 200 x C, 200 x D.

If each of the products uses components that are largely unique, the resulting loads on work centres and vendors supplying type A components will be large for the first seven days, and thereafter will fall to zero for the following thirteen days. Without having enormous excess capacity it would be impossible for the components to be supplied by a pull system. Instead, a schedule based push system would be used and work centres and vendors would stockpile the components in advance. This approach is clearly a negation of the JIT philosophy.

If the factory levels its schedule to some extent, by producing the same mix each day for 20 days, that is:

20 x A, 20 x B, 10 x C, 10 x D;

the resulting improvements will be vast. Each work centre or vendor will now have to stockpile no more that one day's inventory at a time. If this level of inventory is feasible between processes, a kanban system can now be used to control it. A further 50% reduction in pipeline stock can be achieved for type A and B components if the above daily sequence is changed to an even more level one such as:

10 x A, 10 x B, 10 x C, 10 x A, 10 x B, 10 x D.

Finally, in advanced WCM companies the aim is to reduce changeover times so much that the schedule can be levelled on an hourly, rather than a daily basis. Thus, if the company works a ten-hour day, the schedule would call for:

A, B, C, A, B, D;

every hour. This is a truly levelled schedule which would require little more than an hour's worth of pipeline stock. This stock could be controlled extremely accurately by dual-card kanban. By contrasting this situation with the first schedule above, the benefits of a level schedule become clear.

Unfortunately, the use of properly levelled schedules at GEC Small Machines did not seem possible in the short term. This would have required accurate forecasting and a sales management discipline of attempting to make those forecasts (in mix as well as quantity) a reality. Instead, the existing sales practice was to sell as much as possible of anything at all, without regard for the resultant factory loads. Getting the sales team to accept the need for a fixed capacity scheduling approach to order promising, proved to be such a major educational project that the author decided to accept that level schedules would be impossible in the short to medium term.

Ohno [63] explains that where actual demands vary slightly from the levelled schedule:

"... Kanban can only respond to the need for fine tuning, but not to a major change."

Shingo [64] quantifies these variations as being about 10-30% from his experience, but notes that they depend on the character of the plant and can be decided from practical applications.

At GEC Small Machines the overall daily assembly rate could be expected to be fairly constant, even though the mix would not be. Fortunately, the nature of electric motor production is such that each motor, irrespective of the model, requires essentially the same components, although of different sizes. Examples include the need for one shaft, one frame and two endshields per motor. Consequently, the total quantity of a component family, for example shafts, demanded daily, could be expected to be fairly constant. Since these would all be produced in the same machining cell, its capacity requirements would be reasonably levelled. Naturally, a certain amount of excess capacity would be needed to respond to a possible high demand for a larger component with a longer cycle time. When the demand swung towards smaller components with shorter cycle times, this capacity would become idle.

Such capacity requirement variations due to the non-levelled schedule were not expected to be serious enough to render kanban impractical. As Hall [65] observes:

"In the fabrication operations that feed final assembly, if the same equipment is used to make all the parts for all models, it has a good chance of adjusting to mix changes if the overall rate does not change."

Shingo [66] suggests that:

"Simply adapting the kanban system for convenience could be a possible way."

He suggests starting with perhaps five times as many kanban cards and containers as the TPS would consider desirable and gradually reducing the stock levels by removing cards. "The following could then be expected:

- We would be able to find the limit of reducing the amount of stocks at the present control level.
- By further reducing the number of sheets (cards) of kanban, the bottleneck of the process could be manifested, so early improvements of the necked process could be performed.
- By utilising kanban system for 'visual control', we could prevent occurence of stocks exceeding the fixed number of sheets of kanban."

Ohno [67] describes an example of the use of kanban to control five types of balancing weights that are attached to a propeller shaft to prevent uneveness in rotation. The weights required vary from shaft to shaft and so the demands for the weights are highly irregular. He notes the benefits achieved in identifying the items, standardising the process and maintaining control over stock levels due to kanban. He describes this as an important example and states that, although stabilisation and equalisation of products are important, kanban can be used without stability in the quantity of parts withdrawn. He admits that such cases may require more materials or parts on hand than for those whose production quantities are stable, and offers the following advice:

"... it is important not to delay the relaying of information. Since the quantities are irregular and inconstant to begin with, if the information is delayed the existing distortion becomes even worse ... Even more important ... is eliminating the delay in processing and shortening the lead time."

The GEC Small Machines staff agreed that many kanban benefits could be gained by starting with high levels of kanban stock and reducing them; but the level required at the start gave cause for concern. Firstly, it was decided that a method had to be found of calculating Shingo's "lower limit of stock at the present control level"; instead of starting off fairly far above it. Early estimates showed that even such a level would need to be prohibitively high in order to cope with unexpected surges in demand for particular components; expecially with the fairly long setup times currently required.

For GEC Small Machines, the major problem with the dual card kanban system appeared to be the rule that production must take place in the order in which the P-kanban are received. With a non-levelled schedule, this could mean that a component manufacturing cell might begin work on a component of which only a relatively small usage had recently occured at the final assembly line. The assembly line might subsequently have started a longer run of use of a second component, whose cards would fall behind those of the first component in the P-kanban queue. However, the earlier demanded component might not actually be needed again in the short term, whilst those behind it in the queue might actually require urgent replenishment to cope with the ongoing final assembly production run.

In summary then; in view of the long setup times and non-levelled schedules at GEC Small Machines, dual card kanban, with its lack of priority information, could not have been used without impractically high stock levels. Single card kanban could have been used, but this would have required substantial scheduling effort for the component cells. Also, most of the inherent disadvantages of push systems, as discussed earlier, would have remained. Worst of all, the desired advantage of using the production and inventory control system to drive productivity improvements (as in dual card kanban) would have been lost.

Schonberger [68] notes that when the Kawasaki, Lincoln plant needed a 'quick fix', the simplicity of kanban was attractive when compared with the time and the cost required to fully implement MRP. GEC Small Machines was in a similar situation and thus appeared to need kanban right away. However, it seemed that further modifications to the kanban system than those suggested by Shingo and Ohno might be necessary to facilitate its use. Indeed, this has been the experience of other Western companies attempting to adopt certain JIT techniques. Coetzee [69] notes:

" ..... in something as Japanese as kanban, Harley Davidson has bent the technique to suit practical limitations.."

Cooper [70] believes:

"There is no fixed or right way of using kanbans. They lend themselves to various system designs."

Thus, GEC Small Machines decided to design a kanban system to suit its own needs. A little known system, described next, provided some useful ideas; out of which the concept of the GEC Small Machines kanban system grew.

3.2.7 The Kippo System

This is basically a kanban-type pull system which employs a prioritising feature. It is in operation at the John Deere tractor plant at Getafe. The only available information on the system was contained in [71] which the author obtained from the Managing Director of GEC Small Machines, who had previously been employed by John Deere. Full details of the system are not given in this reference and so certain aspects of it are not entirely clear.

"Three different shapes and three different colours are used and every Kippo, depending on shape and colour, acts as a signal that a procurement, production or movement of a given part is required (or will be required in the near future)."

The Kippos are essentially metal kanban tags in the form of circles, triangles or rectangles and they are painted green, yellow or red. Only one container of each part number is kept at the point of consumption and is tagged with a green circular metal disc.

"The round green Kippo is basically a movement order. It instructs the user of the part to remove the green disc from the parts container when a given number of parts is left in the container. This movement order is then placed in a box next to the aisle and becomes an instruction to the forklift driver or other material handler to go to a given part supermarket and fetch a container with a fixed number of the required parts in it."

The green kippo lists the part number, the 'supermarket' (store) position where replenishment containers can be found, the point of consumption, and the quantity per container. In these respects it is similar to a

C-kanban under the dual card system. However, the green kippo also gives a reorder point which is calculated as in a traditional reorder point system. That is, it represents the expected demand for the part during the replenishment lead time, plus a certain safety factor. Clearly, this reorder point quantity is much smaller than would normally be the case in a traditional reorder point system, since the replenishment lead time consists only of the time taken to fetch another container from a store.

The containers in the store have triangular kippos on them which are either yellow or red.

"A yellow triangle is an <u>optional</u> instruction to manufacture a given quantity of a part and a red triangle is a <u>mandatory</u> instruction to do so."

Although there is only one round green kippo for each part number, there may be any number of containers and triangular kippos in the store for a given part number. The triangular kippos list the part number, the department in which it is manufactured, the quantity of parts in a container and the number of kippos (e.g. 1 of 4, 2 of 4, etc.).

When the material handler arrives at the store with a round green kippo he goes to the correct address for the part number and selects the container with the lowest numbered triangular kippo. He removes this triangular kippo and attaches the round green one to the container. The container is then taken to the point of consumption to replenish the stock. The triangular kippo is taken to the production foreman's office at the specified department and placed in a holder against the office wall.

Thus, the triangular kippos are essentially the same as P-kanban cards except for the yellow and red colour coding. Also, the red triangular kippo acts as a mandatory instruction to produce not just its own quantity of parts, but those of all previously received yellow kippos for that part number too. Under the dual card kanban system a supplying work centre may decide to work on one or more of the cards it has for a particular part number, depending on which quantity is most convenient at the time. This added flexibility allows a work centre driven by dual card kanban to choose not to produce a long batch run of a particular part, whenever there is a danger that this might render it incapable of meeting demands for other parts timeously. The kippo system is at a disadvantage in this respect.

The procedure for determining how many containers and triangular kippos to use for a particular part number is not described, but presumably it would be similar to that used by the dual card kanban system to determine the number of containers and P-kanbans. However, the question of where to use red or yellow triangular kippos is not at all clear. It is evident that the first triangular kippo (1 of n) is always yellow but also that a red triangular kippo can be followed by further yellow ones. Unfortunately, no further information is given regarding how many of the total number of triangular kippos should be painted red or yellow, nor in which sequence they should follow the first, yellow one.

For the parts in the store that are supplied by an outside vendor, rectangular yellow and red kippos are used. When released by consumption, these are taken to the receiving store where the purchasing department is informed of the purchasing need. The yellow rectangular kippos are optional purchasing orders and the red ones are mandatory. In only one instance were these kippos being used to directly trigger vendor deliveries without a purchasing department action, but there were plans to expand this when possible.

Thus, the kippo system is similar in many respects to dual card kanban, but from the point of view of GEC Small Machines, its most powerful advantage lay in its use of a prioritising system driven by colour coding. Clearly, if a yellow triangular kippo for part A arrives at a work centre, followed by a yellow one for part B and then a red one for part B; part B will be produced first. This is in spite of the fact that a demand for part A was noted first. Part B is able to 'jump the queue' because there has been a sudden surge in its demand, whereas the demand for part A has slowed down. Although the exact use of the yellow and red colours in the kippo system was not known, it was decided that some use should be made of colour coding to solve the prioritising problem and develop a kanban system suitable for GEC Small Machines.

3.1.8 Theoretical Model of the Component and Raw Material Supply System

The discussion up to this point highlights the following constraints on the design of a component and raw material supply system for GEC Small Machines:

1. It must be a pull system.
2. It must be simple enough to be understood and used by a largely uneducated workforce.
3. It must retain the productivity improvement feature of a pure pull system in that buffer stocks must be tightly controlled and capable of being reduced in increments to expose problems.
4. It must employ a prioritising feature to help alleviate the problem of non-levelled schedules.

The need to use both conveyance and production kanbans was examined critically since it was felt that the two separate sets of cards might confuse some members of the workforce. There was no one component which would need to be produced in more than one cell. Likewise, no no internally manufactured component was used by more than one work centre or cell. Thus, there was no need to separate the conveyance and the production funtion of a kanban card. Each card would serve both functions and so would act as an instruction to a supplying work centre to produce a certain quantity of a particular part and to deliver it to a specified user. To allow the system to work in this way, all buffer stocks would be kept as close as possible to the point of use and there would be no outbound stock point at the supplying work centre.

Although this could be described as a single card system, it is very different from the common single card kanban described earlier, in which only C-kanban are used and production schedules are issued to each supplying work centre. The GEC Small Machines kanban system uses no such push system features and hence satisfies the very important constraint (3) above.

The use of colour coding, similar to the kippo system, was seen as the easiest method of employing a prioritising feature. The traffic light sequence - green, yellow, red - used in the kippo system was considered suitable due to the common association of green with the absence of a problem, yellow with 'caution' and red with 'danger'. The kippo system was simplified by having only three cards (one of each colour) for each component.

The maximum total buffer stock of each component would be divided into three equal quantities, or three bins. The word 'bin' is used here in the sense of its use in the term 'two-bin system' and hence a bin could consist of one or more containers or pallet loads, or simply a marked space on a shelf. Thus, the GEC Small Machines kanban system became known as a 'three-bin kanban system'. The green kanban card would be attached to the first bin of components, the yellow kanban to the second bin and the red kanban to the third.

When the first bin was emptied, the green kanban would be returned to the supplying work centre; followed by the yellow and then the red kanbans as their respective bins were emptied. The foreman at this work centre would be faced with demands, via the kanban cards, for each of the standard components produced. The colours of the cards would inform him of the relative priorities of the components required. A green kanban would not be an urgent job because the using work centre would still have the yellow and red bins to use. A yellow kanban would signal the need to begin production of a component soon, since only the red bin would be available to the user.

A red kanban would be an urgent signal to produce parts immediately, since it would indicate a stockout.

When the components had been produced, they would be sent to the storage point at the using work centre, together with the relevant kanbans. The bins would then be replenished in the reverse order of consumption, that is: red, yellow, green. If, for example, two bins worth of components were being delivered to the storage point with their yellow and green kanbans, the red bin might, by this time, be half empty. The replenishment would thus result in full red and yellow bins, and a half empty green bin. This could be accomplished by physically moving the components, or by simply swopping over the kanbans; depending on the particular application. Thus, when a further half bin quantity had been consumed, the green kanban would be returned to the supplying work centre once again. Clearly, the average stockholding of any component would be somewhat less than the three-bin maximum.

The reason for this replenishment discipline is simply to keep the priorities, according to colour coding, correct at all times. If this discipline was not followed in the above example, then the next time the foreman at the supplying work centre received the yellow kanban, the red bin would be only half full; but he would be unaware of this. Thus, he would tend to estimate his actual available lead time to replenish as being twice as much as it really was; and so the chance of a stockout would be far greater.

It was envisaged that the system could be designed in such a way tha when it was running smoothly, most components would be produced according to the signal of a yellow kanban. Components would only be produced on a green kanban signal if there was a certain amount of excess capacity at the supplying work centre, due to a downstream stoppage. Red kanbans were not expected to appear at the supplying work centre unless there was a very sudden large surge in demand for a particular component, or if the supplying work centre was having difficulties in keeping up. Thus, red kanbans were expected to be useful in highlighting problems, especially those exposed by reductions in buffer stock.

The above framework was used to design various kanban systems for controlling the flow of components within the GEC Small Machines factory and also the ordering of components and raw materials from certain external vendors. Methods of calculating the required bin quantities for each component were developed during the first system implementation and then expanded into a general method which was used in implementing further systems.

Conceptually, it has been suitable to consider the theoretical development of the master production scheduling system before that of the component and raw material supply system which supports it. However, in practice, several kanban systems were designed and implemented prior to the implementation of the master scheduling system. Hence, the implementation of kanban systems will be discussed first; followed by the implementation of the master scheduling system. From this it will be clear that certain issues arising out of kanban implementation led to the addition of extra features to the design of the master production scheduling system.

4 IMPLEMENTATION OF THE GEC SMALL MACHINES KANBAN SYSTEM

4.1 Theory of Kanban Levels

Prior to any implementation of the three-bin kanban system, a method had to be developed for determining how much stock of each part number would need to be carried. Since it was intended that most production should take place according to the signal of a yellow kanban, the red kanban level could be considered as a reorder point.

A reorder point is normally defined as the demand during the lead time to resupply; plus some safety stock. However, at GEC Small Machines the demand for a particular component could be highly variable over the lead time and so a very large safety stock would appear to be needed. Also, in the case of an in-house component cell driven by kanban, the lead time to resupply would be highly variable as it would depend on the current queue of kanbans and their priority colours. Thus, consideration of the red kanban level as a reorder point was of little value in designing an in-house kanban system.

On the other hand, the green and yellow kanban levels together could be considered as an 'order quantity'. The economic order quantity (EOQ) formula was occasionally used at GEC Small Machines and so it was decided to examine it further. The formula is usually given as:

$$EOQ = \sqrt{\frac{2DS}{H}}$$

where: D = demand per time period

S = setup cost

H = holding cost per time period

At GEC Small Machines the holding cost was determined by the interest rate on borrowings and did not take account of the many other handling and storage costs. Also, the demand per time period was not easy to estimate and so the formula was difficult to apply accurately. In any case, it is doubtful whether this formula is valid, especially in a JIT environment, because as Schonberger [72] points out:

"The EOQ formula fails to account for several benefits of smaller lot sizes, including scrap/quality improvement; less rework; and fast feedback on errors, which leads to problem awareness and solution."

He then notes a further problem, which is even more strongly stated by Shingo [73]:

"..... there is an important blind spot in the concept of economic lot size: the assumption that drastic reductions in setup times are impossible. The economic lot size lost its entire reason for being when the SMED (Single Minute Exchange of Dies) system was developed."

Hall [74] notes that if S were reduced to zero the EOQ would be zero. Thus, in practice, the JIT approach of lot sizes of one would be the most economical; once setup times had been reduced to almost nothing. However, the current problem was whether or not to use the EOQ whilst working towards negligible setup times. Hall [75] believes it should not be used:

"The intent of stockless production is to shift setup costs into fixed cost without increasing fixed cost or, in other words, to lose no necessary production time and incur no extra cost due to setup. If that is done, the setup cost is no longer something to consider in the old way."

Thus, the best approach for GEC Small Machines would be to determine how much of the available time in a period would be required to run the parts demanded by assembly over that period, and then to allocate the balance of the available time to setups. The following formulae were thus derived (see Appendix A):

$$L = \frac{\sum_{i=1}^{n} S_i}{(t - \sum_{i=1}^{n} p_i d_i)} \qquad \text{(i)}$$

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$$L = \frac{\sum_{i=1}^{n} s_i}{\left(t - \sum_{i=1}^{n} p_i d_i\right)} \qquad \text{(i)}$$

where: L = the length (in days) of a period during which one batch of each component could be made if desired.

S_i = the setup time at the bottleneck operation for the i th component.

t = available work time in a day.

p_i = the processing time at the bottleneck operation per unit of the i th component.

d_i = the daily demand for the i th component - derived from the sales EAD (estimated annual demand) figures.

Once a suitable period length, L, has been determined, the lot size to run, x_i, is then given by:

$$x_i = Ld_i \quad \text{(ii)}$$

This lot size x_i represents both the green and the yellow kanbans, since the system is expected to trigger production mostly on yellow kanbans. Hence, each of the three bins (green, yellow and red) contains a quantity of $\frac{x_i}{2}$ components.

4.1 The Choice of a Pilot Project

For a pilot project in kanban implementation, the component manufacturing line or cell had to be complicated enough to be representative of all the different kinds of problems that would be faced in other areas of the plant. In this way it was expected to demonstrate the power of the system to the remainder of the plant and generate support and enthusiasm. The pilot project was also expected to serve as an experimentation and learning centre where all the detailed problems of implementation could be faced and ways found to overcome them. For this reason it was desirable to have enthusiastic and positive people working there, since they would be required to maintain a positive attitude and contribute to solving many more implementation problems than the other areas of the plant might later have to face.

The industrial motor shaft manufacturing line appeared to have all these characteristics; including a positive thinking, hardworking and enthusiastic foreman with a strong character. Working under him was a toolsetter who had exactly the opposite outlook - he was negative, unenthusiastic and always complaining. Thus the line was selected with the understanding that the foreman would assist the implementation effort, whilst the toolsetter would not. However, it was believed that if this toolsetter could be convinced that the system was effective, his support would help to convert other doubters.

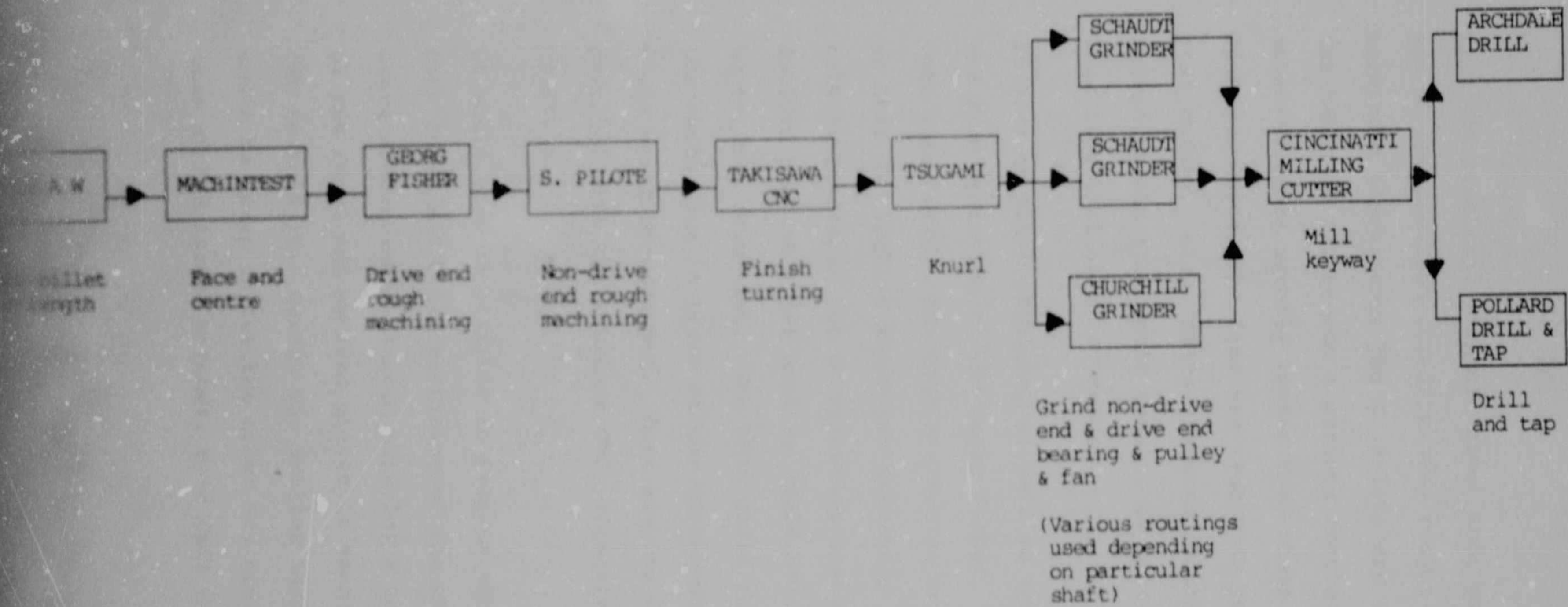
4.3 The Industrial Motor Shaft Line Kanban System

4.3.1 The Production Line

The layout and operation sequence of the existing shaft line was as shown in Figure 4.1. Standard times for each of the operations on this line were available for various shafts. It was clear that the rough machining operations of the Georg Fisher and the S. Pilote were the bottleneck in the line. In the case of the Anglo American specification shafts (prefix "A"), the final drilling and tapping was the longest operation, but the Georg Fisher and S. Pilote were still bottlenecks earlier in the line.

Both these machines had technically exceeded their useful life and various worn out parts appeared to be responsible for certain quality defects. It was not uncommon for two shafts from a batch to be scrapped in the process of setting up either of these machines.

During the course of the investigations the S. Pilote's chuck failed. Attempts to find a replacement within RSA were unsuccessful due to the age of the machine. As an interim measure, programs were written which would allow the Takisawa CNC lathe to perform the non-drive end rough machining, as well as the finish machining of the whole shaft. There was some added efficiency in this, in



4.1: Existing Production Line for Industrial Motor Shafts that the resultant standard times were not as high as the sum of the previous non-drive end rough, and finish machining times; when the S. Pilote was in use. However, the Takisawa did become a serious bottleneck, with standard times usually longer than those of the Georg Fisher. Hence, the line was even more poorly balanced than before. Also, there was some concern as to the kanban levels that would result, as there was now even less time available for setups.

In view of these problems, as well as the unreliability and slow operation of the Georg Fisher, other options were considered. The most attractive of these involved an AX30 CNC machine which was currently in use for the relatively simple job of spigoting stator frames. It was decided that an older machine could be cheaply overhauled to perform this task. The AX30 could then be moved into the shaft line in place of the broken-down S. Pilote, which would be scrapped. This machine would operate in parallel with the Takisawa CNC, effectively doubling its capacity.

It would then be possible to program the CNCs to perform both rough and final machining of the whole shaft. The Georg Fisher would be used only for a halo cut on one end of the faced and centred billet to enable the jaws on the CNC to hold it. During the smaller batch runs, one CNC would be setup whilst the other was operating. In the case of the larger batches, both CNCs could be used

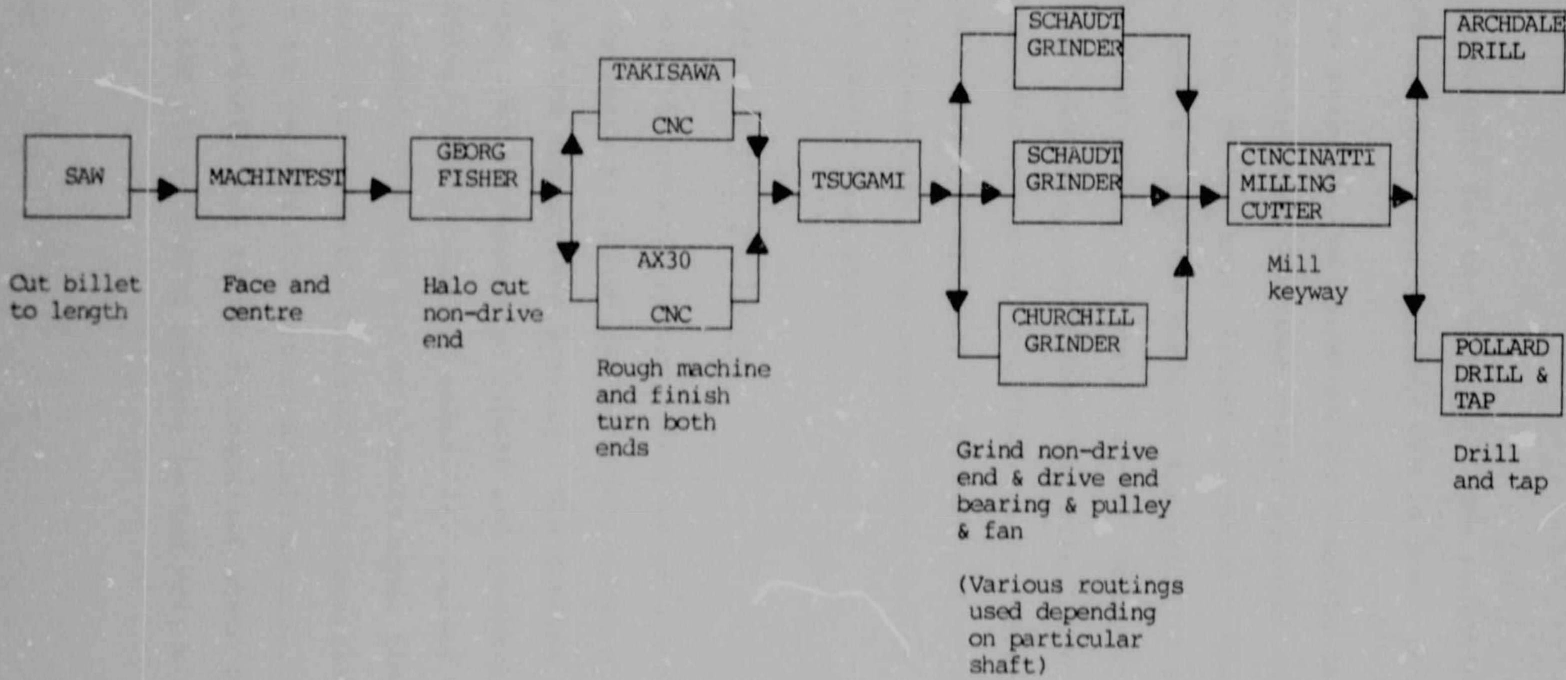


Fig. 4.2: Revised Production Line for Industrial Motor Shafts

simultaneously for the same job. The resulting new line layout and operation sequence was as shown in Figure 4.2.

The new standard time obtained for complete machining on a CNC machine was, for each shaft, somewhat greater than twice that of the next slowest operation. However, as there were now two CNC machines operating in parallel, these times were effectively halved. Thus, whilst the CNC machining was a bottleneck operation, the line was in considerably better balance than before. Also, the CNC machines could be reliably programmed and setup so that the previous problem of scrap produced during setting up was virtually eliminated.

4.3.2 The Existing Control System

The existing control system consisted of a loading sheet (see Appendix B) issued for each job, along with a new copy of the appropriate drawing. The loading sheet incorporated an inspection report and operations checklist. The production controller decided what shafts were needed, with the aid of a works order list. He then compared this with the finished shafts available in the store and decided what shafts should be made. Unfortunately, due to the disorganised state of this store and its recording system, he had only a rough idea of the quantities in stock. Thus, to be on the safe side, as well as to replenish the store, he tended to load large batches; which lead to excessive WIP.

The print room issued a new drawing for each job, which was destroyed after that job. The reason for this was to ensure that obsolete shafts would not be made in the event of a design change. Considerable time, trouble and cost was involved in ensuring that the correct drawing was printed and issued with each job.

The production controller was also responsible for ensuring that he had in stock, or had on order, sufficient raw steel billets to make whatever shafts he was loading. The steel supplier's lead time was 2-3 days.

4.3.3 Determination of Kanban System Parameters

The EAD figures for finished motors were obtained from the Sales department and translated into an annual demand for each of the standard shafts. The expected demand for each of the Anglo American specification shafts was added to that of the corresponding standard shaft, since the only difference is the addition of two tapped holes. The demand for Anglo shafts was highly irregular and so they could not be specifically included in the kanban system.

It was planned, instead, to draw shafts from the standard bins and add the tapped holes whenever there was a demand for these shafts. Several 'near standard' types of shafts were accommodated by the system in this way. The demand for completely special shafts was low and it was decided that these would be loaded specifically by production control as required, using the old system.

The EADs for the 32 standard shafts were converted to a daily demand (d_i) by dividing by the number of working days in a year (235). These figures are listed in Appendix C, together with the bottleneck standard times (p_i); which are the times required on the CNC machines to perform complete machining, under the revised line layout. These bottleneck standard times are multiplied by the daily demands and the results summed for the 32 shafts to obtain $\sum_{i=1}^{32} p_i d_i$. The total available working time per day on each machine is 8,5 hours, and so the CNC machining operation has 17 hours available (t). The standard setup time (S_i) for either of the CNC machines was measured as 0,42 hours.

The above information was then used in formula .i) to obtain a suitable period length L. This was rounded upwards to the nearest day and was equal to 10 days. The value of x_i for each shaft was then calculated using

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The above information was then used in formula (i) to obtain a suitable period length, L. This was rounded upwards to the nearest day and was equal to 10 days. The value of x_i for each shaft was then calculated using formula (ii). Half of x_i was used as the recommended quantity to be kept in each of the three bins. These figures were rounded, usually upwards, to the nearest 5 shafts. In nine cases, the figure obtained for $x_i/2$ was substantially less than 5 shafts. For these slower moving shafts, rounding upwards to 5 shafts per bin meant that substantially more than 10 days' stock would be produced at a time. However, this was seen as necessary since the demand for such shafts tended to occur in irregular surges. For example, the average 10-day demand for a C200M shaft was 1,79, but this would manifest itself as say, a sudden demand for 9 shafts at one time after a period of 50 days of zero demand.

This rounding up of the calculated bin quantities for slow moving shafts, meant that these nine shaft types would not be demanded as often as once every 10 days. As a result, a certain amount of setup time was saved in each 10 day 'cycle'. The rounding up of the period length, L, to 10 days also had a similar effect. The result was some degree of undercapacity planning in the design of the kanban system. It was envisaged that the extra time available would allow the shaft line to produce occasional special shafts loaded specifically by production control, without delaying their normal kanban work.

4.3.4 Commissioning

Kanban Tags (Cards)

Paper was not a suitable material for the kanban cards. The nature of the factory environment was such that they were not durable enough and needed constant replacement. An alternative material was sought which would be suitable for painting or otherwise colouring, as well as for having information permanently written on it. The problem was solved by using steel scrap at no cost. The GEC Large Machines Company operates on the same site as the Small Machines Company and cuts laminations out of sheet steel. The piece punched out of the centre of one of the larger size laminations is a 120mm diameter disc with a small protruding lug. Hundreds of these parts were freely available in scrap bins. Once in use, they became known at GEC Small Machines as kanban "tags" as the word "card" seemed inappropriate.

Holes were drilled in the protruding lug for the purpose of hanging the tags and all sharp edges were rounded. A third of these tags were then painted red by means of a dipping process already in use for motor components such as cowls. There were no available painting processes for green and yellow (except chemical yellow, which is expensive), so the remaining tags were cleaned with thinners and then spray-painted by hand using aerosol paint.

It was decided that each tag should have a heading "SM SHAFTS" in order to avoid confusion when similar tags were introduced in other areas of the factory. This was written on each tag using a waterproof permanent ink marker and was followed by the bin number (stock code), the frame type in larger letters, and then the drawing number. At the bottom was the bin quantity (as calculated in Appendix C) in larger letters. Thus, all the essential information was displayed on the front of the tag.

By consulting each of the drawings, the diameter of the raw billet and its cut length were obtained for each shaft type. This information was written on the back of each tag so that, if necessary, the foreman could begin a job immediately on receiving a tag; and would only later need to consult the drawing. An example of one of the completed tags is shown in Appendix D. Three tags; red, yellow and green, with identical informtion written on them, were made for each of the 32 standard shafts.

Shaft Storage

The existing shaft store consisted of steel racks of four wooden shelves (as shown in Figure 4.3), upon which shafts were packed at random.

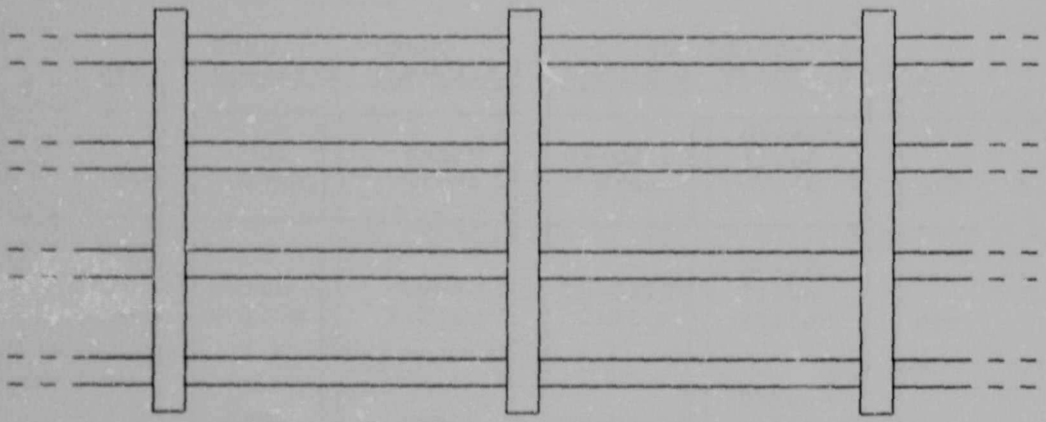

Figure 4.3: Existing Shaft Store

The shelves were labelled such that the three bins required for each shaft were vertically in line. In order to accommodate all the shafts in this manner, a carpenter was asked to partition the shelves as shown Figure 4.4.

The spaces for the green, yellow and red bins were then allocated as shown. The top shelf was used for storage of specials derived from the same basic shaft as those in the three bins below. In the long run, no space for specials would be needed, since they would not be kept in stock but would be loaded by production control only as required by assembly. However, there were many specials already in the store and so they were accommodated in this manner.

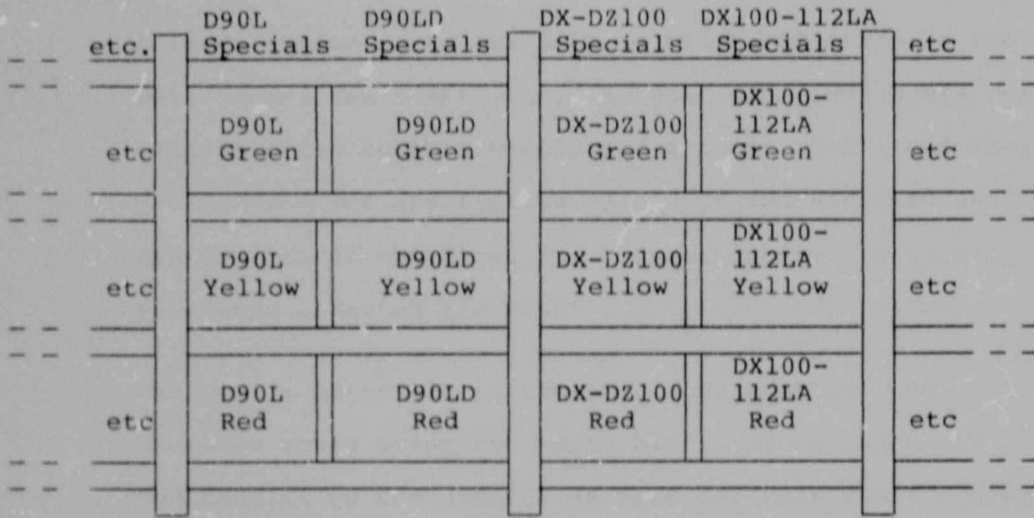

Figure 4.4: New Shaft Storage System

A brass square hook was fastened into each of the partitioned shelves, or bins, so that a tag could be hung on it. A permanent identification tag was also fixed to each set of three bins, so that the fixed location of a particular shaft could not be forgotten; even if the red tag was removed.

By partitioning the shelves, 28 of the standard shafts were accommodated. The remaining four, all of the largest (225) size, were each placed in a set of three dedicated stillages. The green, yellow and red stillages were placed on top of one another, to give the same layout as the shelves. The tags were fixed to these using copper wire, which was always readily available from the winding sections's scrap bins.