which represented the quantities that would have been required if the schedules were fully levelled for the whole year. An example of the resultant output is given in Figure 5.4.

COMPONENT AVAILABILITY

FRAME	PLN	AVL	BAL
D90L	5	120	115
DX100LA		64	64
DX100/112	118	160	42
DZ100LA	140	80	- 60
DZ100/112	538	420	-118
D132MA	9	40	31
DX132	299	176	-123
DZ132MA	8	80	72
DZ132	158	260	102
C160M		20	20
C160L		20	20
DX160	55	96	41
D160SA	15	36	21
DZ160/180	32	88	56
D160LA	19	24	5
C180M		16	16
C180L	8	16	8
DX180	39	52	13
D200L	73	60	- 13
C200M	1	16	15
C200L	2	16	14
D200LA	60	53	- 7
D225	13	40	27
C225		8	8

Figure 5.4: Example of a component capacity check

Each kanban system was designed to 'easily' supply components at the daily EAD rate and thus kanban tags for components having a higher demand than this in a current time bucket could be expected to cycle faster than average during that period. This list was issued to the foremen of the component supplying sections. It warned them informally to respond more quickly during that particular two week time bucket to kanban tags demanding components belonging to any of the frame groups showing a negative figure in the 'Balance' column. This information proved very helpful to the foremen in deciding which job to work on first when they had several jobs of equal colour priority to chose from.

It must be stressed that this feature was not an MRP explosion. It was merely a broad summary of which groups of components might currently be demanded at a faster or slower than average rate. Component producing cells were only authorised to produce according to the demands of the kanban tags received and could not treat the above list as an authorisation to produce any parts ahead of the actual need.

The complete order processing procedure is shown as a flow diagram in Figure 5.5.

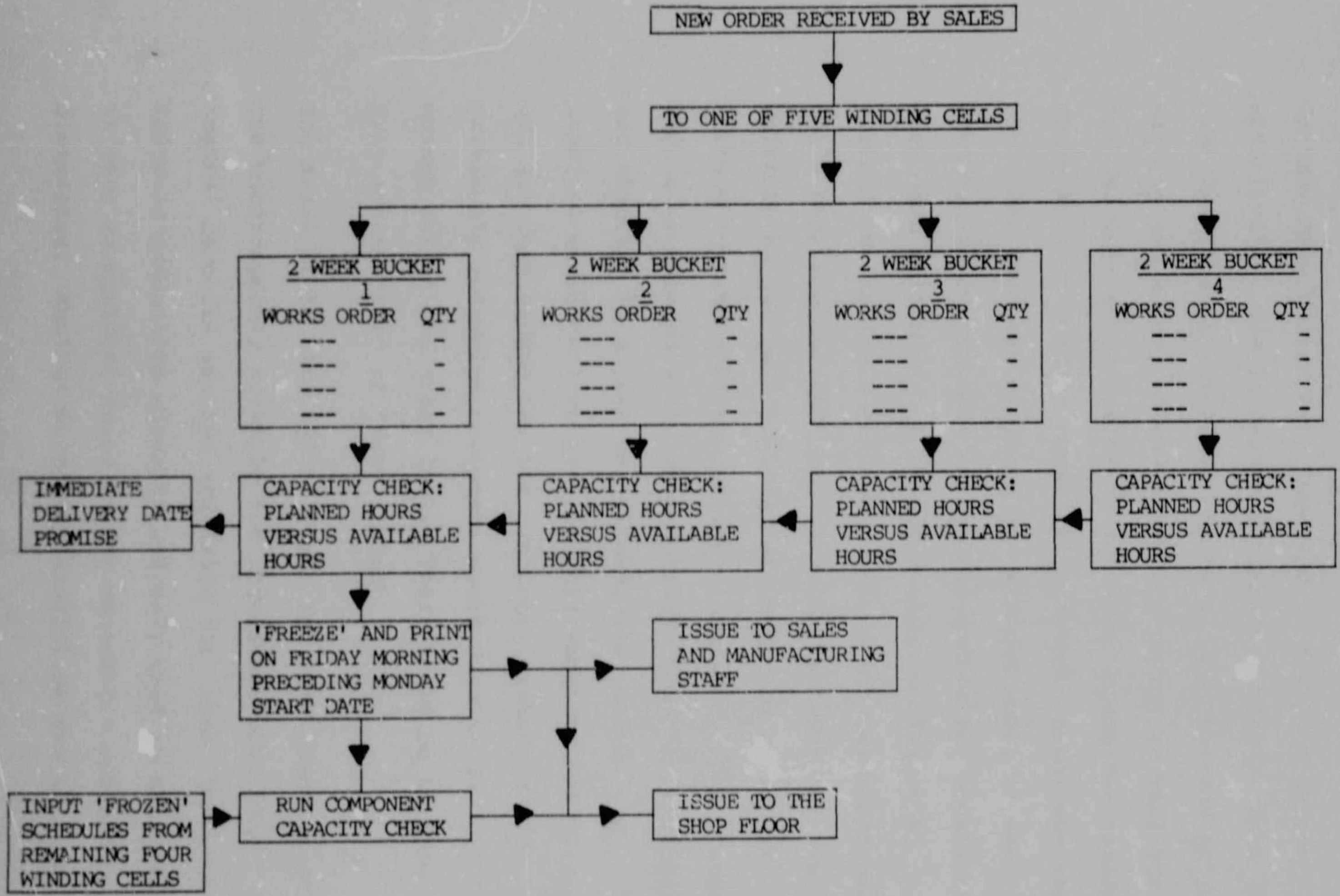

Figure 5.5 Flow Diagram of the Order Processing Procedure

5.2 The Disciplines Required

Certain disciplines were required to make the system work effectively. The marketing disciplines were perhaps the most difficult to instill. First of all, instead of just selling any motor, it was necessary to try to sell the mix and quantities stated in the EADs, since the factory was geared to produce these efficiently. Also, now that the order load was measured per winding cell, it was possible to concentrate on finding sufficient orders to keep each cell busy. A salesman could no longer be praised for taking a big order for an already overloaded cell, when another cell had no work. However, he was unlikely to get such an order since he was no longer allowed to make arbitary delivery promises. The customer had to be told honestly when delivery could be expected and clearly, if a cell was already overloaded, the leadtime would be lengthy. If this expected delivery was not good enough for the customer, exchanges with previously scheduled customers would have to be worked out or the order lost. There could be no more promises to "try" or "make a plan".

The sales staff also had to learn the real function of the undercapacity schedule and understand that the 'spare' capacity was not available for 'rush' jobs. Any leftover production capacity was only used in this manner in very exceptional cases at the Managing Director's discretion. Another essential discipline was that no changes could be made to a schedule already issued to the shop floor. This was accepted surprisingly quickly by the sales staff, perhaps because the schedule was only frozen for two weeks and was entirely flexible outside of that time frame.

Care had to be taken with purpose made orders to ensure that all engineering work was completed during the provisional scheduling phase since no order was allowed to be released to the shop, on the frozen schedule, if the engineering was incomplete. Potential errors in manufacturing were thereby avoided. Similar care had to be taken with orders which required special components to be bought in. In such cases the buyer had to be consulted, before the order could be released, to ensure that all the parts would be available in time for assembly.

Having obtained commitment to these disciplines from the Marketing and Sales departments, the Manufacturing function had to make an equally essential commitment to meet the schedule. No production problems would be considered as a valid excuse for not meeting the schedule. It was the responsibility of Manufacturing to monitor the progress of each winding cell, and of the assembly section, relative to the schedule in each time bucket. Monitoring of the component producing cells was easily achieved by checking the kanban control boards for red tags. If any section was falling behind, overtime had to be worked or some other action taken to catch up to schedule. In no case were the total number of units left incomplete at the end of a time bucket allowed to be significant enough to require revision of the schedule for the subsequent time bucket. If this had been allowed, the entire system would have been degraded and the disciplines built up in the Sales department would probably have been destroyed.

In summary then, the operation of the GEC Small Machines MPS system required strong disciplines and commitments from both the Marketing/Sales and the Manufacturing functions. In the author's view, the same is true of any effective MPS system.

5.3 Results

With the support of the kanban systems already in operation, the implementation of the MPS system produced the following results:

1. The previous continuous conflict between the Manufacturing and Sales departments was largely eliminated. The simplicity of the system made it easy to work with. Since the system was transparent to everyone, they could make well informed decisions. No one had to guess priorities, or could change

tags. If any section was falling behind, overtime had to be worked or some other action taken to catch up to schedule. In no case were the total number of units left incomplete at the end of a time bucket allowed to be significant enough to require revision of the schedule for the subsequent time bucket. If this had been allowed, the entire system would have been degraded and the disciplines built up in the Sales department would probably have been destroyed.

In summary then, the operation of the GEC Small Machines MPS system required strong disciplines and commitments from both the Marketing/Sales and the Manufacturing functions. In the author's view, the same is true of any effective MPS system.

5.3 Results

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1. The previous continuous conflict between the Manufacturing and Sales departments was largely eliminated. The simplicity of the system made it easy to work with. Since the system was transparent to everyone, they could make well informed decisions. No one had to guess priorities, or could change

instructions on work in process. This improved all working relationships and enhanced the attitude of working together to solve problems as they appeared.

2. The efficiency and output of the winding cells was increased by the better planning visibility and the use of less time for setups, due to the intelligent sequencing of work. The lack of system 'nervousness', previously present, contributed to the efficiency increase as well as to a more relaxed environment.

3. The accuracy of delivery lead times and promised delivery dates was vastly improved. Late orders were reduced by 50% in the first three months. This improvement in the credibility of promises to customers was expected to gradually increase the company's market share. It was also expected to change customer ordering patterns to smaller, more regular orders since they could have any type of motor every two weeks. The tendancy to exagerate the required dates was also likely to be reduced as customers began to trust the promised dates.

4. Due to the timely distribution of accurate information, telexes and telephone calls from branch managers and customers, chasing orders, were almost eliminated; therby saving the sales managers time

and expediting effort. Likewise, the expediting efforts of the manufacturing staff were greatly reduced.

5. Fourteen months after the investigation of the first kanban system, and three months after the MPS implementation, the following results were evident:

	Initially	14 Months Later	Improvement
Total Stockholding (months)	2,7	2,1	22,2%
Sales/Net Inventory (ratio)	5,2	8,0	53,8%
Cost of Sales/Net Inventory (ratio) (= Stock Turns)	4,3	6,0	39,5%

6.0 CONCLUSIONS

1. The new master production scheduling system has allowed GEC Small Machines to shorten lead times and make accurate delivery promises. This can be expected to lead to an increase in market share.

2. The MPS system has largely eliminated the ongoing conflict between the Manufacturing and Sales departments and has saved considerable staff expediting time in both these areas. This has allowed the company to move beyond an ongoing mode of crisis management and has thereby given managers more time to concentrate on real improvements.

3. The sensible sequencing of work has led to more efficient utilisation of available productive resources; as has the lack of system 'nervousness'. Results such as a more than 50% improvement in the sales to net inventory ratio have been achieved.

4. The MPS has been strongly supported by the company's three bin prioritised kanban system. This kanban system has proved to be a very low cost and extremely effective method of controlling both the production and the stockholding of internally produced components.

5. The principle advantage of the three bin prioritised kanban system are:

- it ensures the use of the smallest practically possible lot sizes and automatically adjusts these up or down to cope with short term fluctuations in the rate of demand relative to the rate of supply.

- it is capable of responding to non-levelled demand to a much greater extent than other kanban systems; especially when aided by the simple 'component capacity check' feature of the GEC Small Machines MPS system.

- it runs 'automatically' on the shop floor without any ongoing input from clerical or production planning staff.

- it [illegible] simple, highly visual system which is easily understood by uneducated shop floor personnel.

- it effectively results in a continuous, highly visible measurement of performance which strongly enhances the motivation of the workforce through pride.

- it can be used as a tool for enforced productivity improvement through problem identification and solution.

6. The principle limitations of the three bin prioritised kanban system are:

- it is not suitable for controlling the production of parts that are consumed by more than one work centre.

- it does not always detect a slowdown in the rate of supply as quickly as dual card kanban would.

7. The vendor kanban systems implemented with the company's two most important suppliers decreased stockouts to some extent. Unfortunately, this improvement was mostly due to the increased accuracy of stockholding and ordering at GEC Small Machines itself. The continued poor delivery performance of these vendor companies, both members of the GEC Electric Motor Manufacturers division, led to a considerable number of stockouts of key components. This sometimes severely disrupted the MPS and was detrimental to the performance of the entire GEC Small Machines operation.

The responsibility for solving this problem lay directly with the Managing Director of GEC Electric Motor Manufacturers. Once the vendor kanban systems were operational, the Managing Director of GEC Small Machines could clearly demonstrate that his stockouts were not due to any fault of his own company with respect to ordering the correct parts at the correct time. The Managing Director of GEC Electric Motor Manufacturers, however, did not appreciate the magnitude of the problem and/or was unable to effectively motivate his subordinates (the management of GEC Large Machines and GEC Foundries) to improve their customer service to GEC Small Machines.

This demonstrates the need for top management commitment when implementing the WCM approach. It also demonstrates the typically Western problem, noted by the Japanese, of top management who are so far removed from the manufacturing environment that they have little understanding of the value of manufacturing excellence to the company as a whole.

7.0 RECOMMENDATIONS

7.1 Recommendations for GEC Small Machines Company

The new systems at GEC Small Machines should not be regarded as the ultimate solution, but rather as a framework within which to make further continuous improvements towards WCM. These systems should therefore remain flexible and should be adapted as and when it becomes expedient to do so. The following specific recommendations are made in this regard:

1. A continuous effort should be made to induce the two major vendors to improve their delivery performance so that GEC Small Machines can realise its full productive potential.

2. A program should be developed on the existing microcomputer to carry out kanban level calculations by the method detailed in Appendix A. This should then be linked to series of databases containing the list of setup times, standard production times and EADs pertaining to each existing kanban system. All kanban levels could then be easily recalculated when the next set of EADs is issued. Also, whenever an improvement in a production method or a setup time is implemented, the kanban levels for the relevant cell could be immediately revised.

3. As the new assembly section layout is implemented, it is recommended that, where possible, kanban bins be moved to their positions of use next to the assembly lines. This will eliminate a considerable amount of material handling, especially by forklifts.

4. A preventive maintenance program should be introduced, especially in the winding cells. This will gradually allow tighter scheduling of these cells, using closer to 100% of standard capacity. A successful reduction in final test rejects would also facilitate tighter scheduling. However, it is recommended that some degree of undercapacity scheduling should always be maintained, as this will allow some time for work on improvement projects.

5. Setup reductions should be aggressively pursued in the winding cells. This will allow the two week loading cycle to be gradually reduced to one week, and eventually to one day. Thus, the factory will become more and more responsive to customer demand and the sales force will have an extra competitive edge.

7.2 General Recommendations

All aspects of WCM are recommended by the author to any manufacturing company, but the points particularly emphasised by the experience of this project are:

1. There are no absolute prerequisites for implementing WCM techniques; and small pilot projects started by a few committed individuals are often the best way to gain wider support. However, it is recommended that the earliest possible effort should be made to enlist top management support, in order to ensure that WCM can realise its full potential.

2. The GEC Small Machines MPS system is not widely applicable. Each company should tailor the structure of its MPS to suit its own situation, but the basic principle of a finite capacity schedule which recognises bottlenecks, is strongly recommended.

3. The three bin prioritised kanban system could work well in numerous other businesses, but each company should examine its own requirements very carefully before deciding what kind of kanban system, if any, would be most suitable. However, some kind of pull system is strongly recommended as a component of any WCM effort and companies are encouraged, if necessary, to develop new pull systems.

APPENDIX A: DERIVATION OF KANBAN LEVEL FORMULAE

Consider a cell which produces n different components. It is necessary to determine the length L (in days) of a processing cycle which will allow the cell to be setup for each component once per cycle and then to have sufficient time remaining to produce all the components required over the period L. The demand for each component, although irregular in practice, is derived as a daily average using the estimated annual demands (EADs) for final products, as determined by the Marketing/Sales department.

let: t = available work time in a day

d_i = the daily demand for the i th component (derived from the EADs)

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

S_i = the setup time at the bottleneck operation for the i th component (assuming that S_i is independant of the sequence of components processed - where it is not, the 'worst case' time is used).

In each cycle of L days, the total working time needed is equal to the sum of the setup times for each component type and the processing times for the required quantities of each component; that is:

$$\sum_{i=1}^{n} S_i + \sum_{i=1}^{n} p_i d_i L$$

The total working time available over L days is tL. If the processing cycle length L is chosen correctly then this will be identical to the above expression:

$$tL = \sum_{i=1}^{n} S_i + \sum_{i=1}^{n} p_i d_i L$$

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

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

The lot size x_i required for each product will be equal to its demand over a period of L days, since it will be run only once during that period:

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

In the case of the GEC Small Machines kanban system the lot size x_i would represent both the green and the yellow kanbans, since it is normal to produce on receiving a yellow kanban. Thus the kanban bin quantities would be $x_i/2$ in each of the green, yellow and red bins.

In cases where production occurs on only the green kanban, a quantity of $x_i/2$ would be produced. This can only occur if there are no yellow kanbans to work on and hence the cell is 'ahead of schedule' and can thus afford smaller batch sizes and more setups than is usual.

Likewise, when a cell produces on the red kanban it will produce a quantity of $3x_i/2$. The red kanban implies that the cell is 'behind schedule' and so it must run larger batches and use less time for setups. In this way the GEC Small Machines kanban system automatically 'adjusts' the batch size up or down from the theoretically correct x_i to compensate for the performance of the cell relative to that of the consuming operation.

APPENDIX B: LOADING SHEET FOR EXISTING SYSTEM

SMALL INDUSTRIAL MOTORS-JIT

SECTION	19	COMPONENT	SHAFTS.	MACHINE	–	WEEK ENDING	21/2/86

RAW BIN	SHAFT STL. DIA.	DRAWING NUMBER	FINISHED BIN	SHAFT LENGTH IN MM	FRAME SIZE	NET REQ'D		MNF QTY	PRIORITY
2-1-55	35	2·71·01·0002	44·1·16	314	D90L	6	✓	30	
	·	2·71·01·0003	44·1·44	335	D90LD	-2			
2-1-57	40	6601·2·47·1·4	47·1·4	361	DX·DZ 100·112 STD	912	✓✓	951	
	·	2·72·01·0008	NO BIN	357	DX 100·112LA	-36			
	·	2·72·01·0006	72·01·0006	357	DA100LA	33	✓✓	50	2
	·	6601·2·47·1·3	47·1·3	316	DZ (STD) 100·112LA	130	✓✓	130	
	·	6601·2·47·1·19	47·1·19	409	DZ100LDB	-29			
	·	2·49·01·0002	47·1·20	409	DZ112MDB	[illegible]			
2-1-62	55	2·74·01·0001	74·01·0001	478	DX132S·M	652	✓✓	652	
	·	2·74·01·0012	74·01·0012	429	D132MA	-54			
	·	2·74·01·0006	74·01·0006	429	DA132MA	-			
	·	7001·2·47·1·5	47·1·5	440	DZ132S·M	774	✓✓	800	
	·	35 7015 1122·1	47·1·6	391	DZ132MA	4	✓✓	50	
	·	35 7015 1243	47·1·21	473	DZ132SDB	-25			
2-1-63	60	2·59·01·0002	45·1·15	573	C160M	20	✓✓	30	5
	·	2·59·01·0001	45·1·16	619	C160L	-13			
	·	2·75·01·0006	75·01·0006	586	DX160M·L	147	✓✓	160	6
	·	2·75·01·0021	75·01·0021	558	D160SA	-6			
	·	2·75·01·0013	75·01·0013	558	DA160SA	-			
	·	2·75·01·0022	75·01·0022	661	D160LA	61	✓✓	40	
	·	2·75·01·0014	75·01·0014	661	DA160LA	-8			
	·	35 701 3 1089·1	47·1·8	673	DZ160M·L	147	✓	160	
	·	35 701 3 1253	47·1·22	682	DZ160MDB	11	✓✓	20	1
2-1-66	70	2·60·01·0001	45·1·17	646	C180M	-1			
	·	2·60·01·0002	45·1·18	684	C180L	4	✓	20	
	·	35 7015 1090·1	47·1·9	673	DX·DZ 180M·L	74	✓✓	100	3
2-1-63	60	2·32·01·0001	32·01·0001	683	DZ180MDB	18	✓✓	50	
2-1-69	80	2·61·01·0003	45·1·19	726	C200M	1	✓	10	
	·	2·61·01·0002	45·1·20	765	C200L	2	✓	10	
	·	2·77·01·0003	44·1·25	726	D200L	64	✓✓	80	4
	·	2·77·01·0011	77·01·0011	781	D200LA	26	✓✓	40	
	·	2·77·01·0007	77·01·0007	781	DA200LA				
2-1-69	80	2·62·01·0002	45·1·57	841	C225M-2P	-8			
	·	2·62·01·0003	44·1·118	861	C225M-4P	[illegible]			
	·	2·78·01·0003	44·1·116	828	D225-2P	[illegible]	1		
	·	2·78·01·0002	44·1·117	858	D225-4P	31	✓✓	50	

OPERATIONS:-

CUT		GRIND	
FACE & CENTRE		KEYWAY	
MACHINE		DRILL	
KNURL			

AUTH.	[signature]	DATE.	21/2/86

INSPECTION REPORT

OPERATION TYPE	GAUGE CHECK	DATE	COST CENTRE	QTY PASS'D	REJECT REPORT	QTY REJECT	SIGN.

APPENDIX B: LOADING SHEET FOR EXISTING SYSTEM

SMALL INDUSTRIAL MOTORS-J.I.T.

SECTION	19	COMPONENT	SHAFTS.	MACHINE	—	WEEK ENDING	21 [illegible]

RAW BIN	SHAFT STL. DIA.	MCSS	DRAWING NUMBER	FINISHED BIN	SHAFT LENGTH IN MM	FRAME SIZE	NET REQ'D		MNF QTY	PRIORITY
2-1-55	35		2-71-01-0002	44-1-16	314	D90L	-3	✓	20	
	.		2-71-01-0003	44-1-344	335	D90LD	-2			
2-1-57	40		6601-2-47-1-4	47-1-4	361	DX-DZ 100-112 STD	912	✓✓	950	
	.		2-72-01-0008	NO BIN	351	DX 100-112LA	-36			
	.		2-72-01-0006	72-01-0006	351	DA100LA	77	✓✓	50	2
	.		6601-2-47-1-3	47-1-3	316	DZ (STD) 100-112LA	190	✓✓	220	
	.		6601-2-47-1-19	47-1-19	405	DZ100LDB	-29			
	.		2-49-01-0002	47-1-20	405	DZ112MDB	-17			
2-1-62	55		2-74-01-0001	74-01-0001	478	DX132S-M	652	✓✓	652	
	.		2-74-01-0012	74-01-0012	429	D132MA	-54			
	.		2-74-01-0006	74-01-0006	429	DA132MA	-			
	.		7001-2-47-1-5	47-1-5	440	DZ132S-M	774	✓✓	800	
	.		JS 7013 1122-1	47-1-6	391	DZ132MA	4	✓✓	50	
	.		JS 7013 1243	47-1-21	473	DZ132SDB	-25			
2-1-63	60		2-59-01-0002	45-1-15	573	C160M	20	✓✓	50	5
	.		2-59-01-0001	45-1-16	619	C160L	-18			
	.		2-75-01-0006	75-01-0006	586	DX160M-L	147	✓✓	160	6
	.		2-75-01-0021	75-01-0021	558	D160SA	-16			
	.		2-75-01-0013	75-01-0013	558	DA160SA	-			
	.		2-75-01-0022	75-01-0022	661	D160LA	61	✓✓	40	
	.		2-75-01-0014	75-01-0014	661	DA160LA	-8			
	.		JS 701 3 1089-1	47-1-8	673	DZ160M-L	147	✓	160	
	.		JS 701.3 1253	47-1-22	682	DZ160MDB	11	✓✓	20	1
2-1-66	70		2-60-01-0001	45-1-17	646	C180M	-1			
	.		2-60-01-0002	45-1-18	684	C180L	4	✓	20	
	.		JS 7013 1090-1	47-1-9	673	DX-DZ 180M-L	71	✓✓	110	3
2-1-63	60		2-52-01-0001	62-01-0001	685	DZ180MDB	18	✓✓✓	50	
2-1-69	80		2-61-01-0003	45-1-19	726	C200M	1	✓	10	
	.		2-61-01-0002	45-1-20	765	C200L	2	✓	10	
	.		2-77-01-0003	44-1-25	726	D200L	64	✓✓	80	4
	.		2-77-01-0011	77-01-0011	781	D200LA	20	✓✓	40	
	.		2-77-01-0007	77-01-0007	781	DA200LA				
2-1-69	80		2-62-01-0002	45-1-57	861	C225M-2P	-8			
	.		2-62-01-0003	44-1-118	861	C225M-4P	-22			
	.		2-78-01-0003	44-1-116	828	D225-2P	[illegible]	1		
	.		2-78-01-0002	44-1-117	858	D225-4P	31	✓✓	50	

OPERATIONS→

CUT		GRIND	
FACE & CENTRE		KEYWAY	
MACHINE		DRILL	
KNURL			

AUTH.	[signature]	DATE.	21/2/86

INSPECTION REPORT

OPERATION TYPE	GAUGE CHECK	DATE	COST CENTRE	QTY. PASS'D.	REJECT REPORT	QTY. REJECT	SIGN.

APPENDIX C: CALCULATION OF SHAFT KANBAN LEVELS

Table C1: Calculation of Shaft Kanban Levels

i	Shaft Type	EAD (235 days)	Daily Demand (d_i)	Bottleneck (CNC) Time (p_i) [Hrs]	$d_i \times p_i$	Ld_i ($=x_i$)	Kanban Bin Qty chosen ($\approx x_i/2$)
1	D90L	1192	5.072	0.065	0.3297	50,72	25
2	D90LD	569	2.421	0.065	0.1574	24.[illegible]	15
3	DX-DZ100/112	5371	22.855	0.075	1.7141	228.[illegible]	115
4	DX 100/112 LA	851	3.621	0.075	0.2716	36.21	20
5	DZ 100/112 LA	2744	11.677	0.075	0.8758	116.77	60
6	DZ 100 LDB	935	3.979	0.075	0.2984	39.79	20
7	DZ 112 MDB	466	1.983	0.075	0.1487	19.83	10
8	DX 132 S-M	4981	21.196	0.093	1.9712	211.96	110
9	D132MA	238	1.013	0.093	0.0942	10.13	5
10	DZ132S-M	5899	25.102	0.092	2.3094	251.02	130
11	DZ132MA	1495	6.361	0.092	0.5852	63.61	35
12	DZ132SDB	705	3.000	0.092	0.2760	30.00	15
13	C160M	75	0.319	0.105	0.0335	3.19	5
14	C160L	98	0.417	0.108	0.0450	4.17	5
15	DX160M-L	2392	10.179	0.120	1.2215	101.79	50
16	D160SA	442	1.881	0.108	0.2031	18.81	10
17	D160LA	165	0.702	0.108	0.0758	7.02	5
18	DZ160M-L	1761	7.494	0.120	0.8993	74.94	40
19	DZ160MDB	235	1.000	0.120	0.1200	10.00	5
20	C180M	53	0.226	0.114	0.0258	2.26	5
21	C180L	58	0.247	0.117	0.0289	2.47	5
22	DX-DZ180M-L	1580	6.723	0.120	0.8068	67.23	35
23	DZ180MDB	228	0.970	0.120	0.1164	9.70	5
24	C200M	42	0.179	0.154	0.0276	1.79	5
25	C200L	28	0.119	0.164	0.0195	1.19	5
26	D200L	857	3.647	0.151	0.5507	36.47	20
27	D200LA	183	0.779	0.157	0.1223	7.79	5
28	Howden D200LA	1642	6.987	0.157	1.0970	69.87	35
29	C225M-2P	13	0.055	0.266	0.0146	0.55	5
30	C225M-4P	27	0.115	0.266	0.0423	1.15	5
31	D225-2P	71	0.302	0.294	0.0888	3.02	5
32	D225-4P	804	3.421	0.294	1.0058	34.21	20
	TOTAL	36200	154.043		15.576		

Total clock time per day = 9,5 hrs

Less: Lunch: 0,5 hrs

2 x Tea breaks @ 0,25 hrs : 0,5 hrs

Total working time per day: = 8,5 hrs

But there are two bottleneck machines (the CNC machines)

$t = 17.0$ hrs

Standard CNC setup time = 0.42 hrs = S_i

$$\sum_{i=1}^{32} S_i = 32 \times 0.42 \qquad = 13.44 \text{ hrs}$$

Using formula (i):

$$L = \frac{\sum_{i=1}^{32} S_i}{t - \sum_{i=1}^{32} p_i d_i}$$

$$= \frac{13.44}{17.0 - 15.576}$$

$$= 9.44 \text{ days}$$

Use L = 10 days in order to allow some spare capacity for the occasional special shaft loaded by production control. The rounding upwards of actual calculated figures to get kanban levels will also free a certain amount of capacity for this purpose by slightly lowering the frequency of setups.

APPENDIX D: EXAMPLE OF A KANBAN TAG

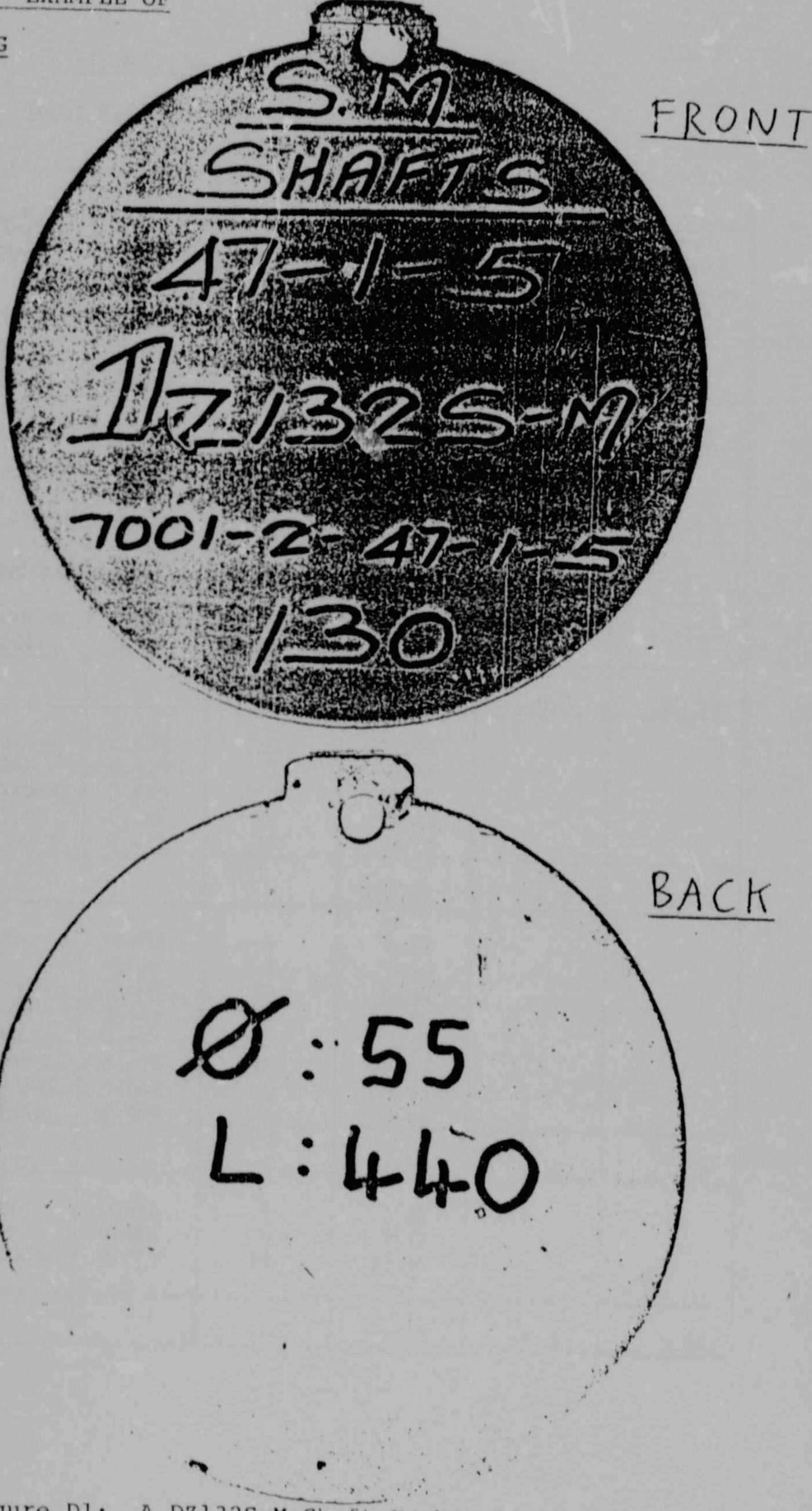

Figure D1: A DZ132S-M Shaft Kanban Tag

APPENDIX E: RAW MATERIAL REQUIREMENTS

Table E1: Calculation of Billet Requirements

a Billet Diameter [mm]	b Shaft Type	c Cut Length[m]	d Bin Qty (5 days' demand)	e Length Required (cxd)[m]	f Billet Length [m]	g Total Billets Required (e/f)
35	D90L	0.314	25	7.85		
	D90LD	0.335	15	5.03		
TOTAL 30mm				12.88	6.0	2.15
40	DX-DZ100/112	0.361	115	41.52		
	DX1--/112 LA	0.357	20	7.14		
	DZ100/112 LA	0.316	60	18.96		
	DZ100LDB	0.405	20	8.10		
	DZ100LDB	0.405	10	4.05		
TOTAL 40mm				79.77	6.0	13.30
55	DX132S-M	0.478	110	52.58		
	D132MA	0.429	5	2.15		
	DZ132S-M	0.440	130	57.20		
	DZ132MA	0.391	35	13.69		
	DZ132SDB	0.473	15	7.10		
TOTAL 55mm				132.72	6.0	22.12
60	C160M	0.573	5	2.87		
	C160L	0.619	5	3.10		
	DX160M-L	0.586	50	29.30		
	D160SA	0.558	10	5.58		
	D160LA	0.661	5	3.31		
	DZ160M-L	0.673	40	26.92		
	DZ160MDB	0.682	5	3.41		
	DZ180MDB	0.682	5	3.41		
TOTAL 60mm				77.90	6.5	11.98
70	C180M	0.646	5	3.23		
	C180L	0.684	5	3.42		
	DX-DZ180 M-L	0.673	35	23.56		
TOTAL 70mm				30.21	6.0	5.04

Table E.1 (continued)

a	b	c	d	e	f	g
Billet Diameter [mm]	Shaft Type	Cut Length[m]	Bin Qty (5 days' demand)	Length Required (cxd)[m]	Billet Length [m]	Total Billets Required (e/f)
80	C220M	0.726	5	3.63		
	C200L	0.765	5	3.83		
	D200L	0.726	20	14.52		
	D200LA	0.781	5	3.91		
	Howden D200LA	0.716	35	25.06		
	C225M-2P	0.861	5	4.31		
	C225M-4P	0.861	5	4.31		
	D225-2P	0.828	5	4.14		
	D225-4P	0.858	20	17.16		
TOTAL 80mm				80.87	6.5	12.44

SM SHAFT BILLET STOCKS

Week end: ________

SIZE	RE-ORDER LEVEL	STOCK LEVEL				
		MON	TUE	WED	THUR	FRI
35mm DIA	3					
40mm DIA	14					
55mm DIA	23					
60mm DIA	12					
70mm DIA	5					
80mm DIA	13					

Figure E1: Billet Cutter's Stock Card

APPENDIX F

MANUFACTURING PRIORITY FOR MINIMUM LINE SETUP TIME

INDUSTRIAL MOTOR SHAFT LINE

NEXT JOB PRIORITY	CURRENT JOB	
	D90L	D90LD
1	D90LD	D90L
2	DX-DZ100-112 (STD) (102 mins)	DX-DZ100-112 (STD) (102 mins)
3	DZ100-112 LA (STD) (110 mins)	DZ100-112 LA (STD) (110 mins)
4	DZ132 S-M (112 mins)	DZ132 S-M (112 min)
5	DX132 S-M (119 mins)	DX132 S-M (119 mins)
6	DX100-112 LA (121 mins)	DX100-112 LA (121 mins)
7	DZ132 MA (124 mins)	DZ132 MA (124 mins)
8	DX160 M-L DZ160 M-L DX-DZ180 M-L D200L (148 mins)	DX160 M-L DZ160 M-L DX-DZ180 M-L D200L (148 mins)
9	D225-4P (155 mins)	D225-4P (155 mins)

NOTE: Time values given in minutes represent the estimated extra setup time needed if a lower priority job than 1 is selected.

NEXT JOB PRIORITY	CURRENT JOB		
	DX-DZ100-112 (STD)	DX100-112 LA	DZ100-112 LA (STD)
1	DZ100-112 LA (STD)	DZ100-112 LA (STD)	DX-DZ100-112 (STD)
2	DX100-112 LA (40 mins)	DX-DZ100-112 (STD) (7 mins)	DX100-112 LA (33 mins)
3	D90L D90LD (98 mins)	D90L D90LD (84 mins)	D90L D90LD (106 mins)
4	DZ132 S-M (108 mins)	DX132 S-M (87 mins)	DZ132 S-M (120 mins)
5	DX132 S-M (115 mins)	DZ132 S-M (94 mins)	DX132 S-M (127 mins)
6	DZ132 MA (120 mins)	DZ132 MA (106 mins)	DZ132 MA (132 mins)
7	DX160 M-L DZ160 M-L DX-DZ180 M-L (141 mins)	D225-4P (123 mins)	DX160 M-L DZ160 M-L DX-DZ160 M-L (153 mins)
8	D200L (144 mins)	DX160 M-L DZ160 M-L DX-DZ180 M-L (127 mins)	D200L (156 mins)
9	D225-4P (151 mins)	D200L (130 mins)	D225-4P (163 mins)

NOTE: Time values given in minutes represent the estimated extra setup time needed if a lower priority job than 1 is selected.

NEXT JOB PRIORITY	CURRENT JOB		
	DX132 S-M	DZ132 S-M	DZ132 MA
1	DZ132 S-M	DX132 S-M	DZ132 S-M
2	DZ132 MA (1[illegible] mins)	DZ132 MA (11 mins)	DX132 S-M (5 mins)
3	D90L D90LD DX-DZ100-112 (STD) (128 mins)	D90L D90LD DX-DZ100-112 (STD) (121 mins)	D90L D90LD DX-DZ100-112 (STD) (122 mins)
4	DX100-112 LA (133 mins)	DX100-112 LA DZ100-112 LA (STD) (140 mins)	DZ100-112 LA (STD) (134 mins)
5	DZ100-112 LA (STD) (140 mins)	DX160 M-L (146 mins)	DX100-112 LA (141 mins)
6	D160 M-L (153 mins)	DZ160 M-L DX-DZ180 M-L (154 mins)	DX160 M-L DZ160 M-L DX-DZ 180 M-L (155 mins)
7	D225-4P (157 mins)	D200L (157 mins)	D200L (158 mins)
8	DZ160 M-L DX-DZ180 M-L (161 mins)	D225-4P (164 mins)	D225-4P (165 mins)
9	D200L (164 mins)		

<u>NOTE</u>: Time values given in minutes represent the estimated extra setup time needed if a lower priority job than 1 is selected.

NEXT JOB PRIORITY	CURRENT JOB		
	DX160 M-L	DZ160 M-L	DX-DZ180 M-L
1	DZ160 M-L	DX160 M-L	DZ160 M-L
2	DX-DZ180 M-L (86 mins)	DX-DZ180 M-L (36 mins)	DX160 M-L (50 mins)
3	D200L (128 mins)	D200L (128 mins)	D200L (90 mins)
4	DZ132 S-M (143 mins)	D225-4P (146 mins)	D225-4P (110 mins)
5	D225-4P (146 mins)	DX-DZ100-112 (STD) DZ132 S-M DZ132 MA (151 mins)	DX-DZ100-112 (STD) DZ132 S-M (115 mins)
6	DX132 S-M (150 mins)	D90L D90LD (154 mins)	D90L D90LD (118 mins)
7	DX-DZ100-112 (STD) (151 mins)	DX132 S-M (158 mins)	DX132 S-M (122 mins)
8	D90L D90LD (154 mins)	DZ100-112 LA (163 mins)	DZ100-112 LA (STD) DZ132 MA (127 mins)
9	DZ100-112 LA (STD) DZ132 MA (163 mins)	DX100-112 LA (170 mins)	DZ100-112 LA (134 mins)
10	DX100-112 LA (170 mins)		

NOTE: Time values given in minutes represent the estimated extra setup time needed if a lower priority job than 1 is selected.

NEXT JOB PRIORITY	CURRENT JOB	
	D200L	D225-4P
1	D225-4P	D200L
2	DX-DZ180 M-L (14 mins)	DX160 M-L DZ160 M-L DX-DZ180 M-L (34 mins)
3	DX160 M-L DZ160 M-L (16 mins)	DX132 S-M (42 mins)
4	D90L D90LD DX-DZ100-112 (STD) DZ132 S-M (42 mins)	D90L D90LD DX-DZ100-112 (STD) DZ132 S-M (49 mins)
5	DX132 S-M (49 mins)	DX100-112 LA (54 mins)
6	DZ100-112 LA (STD) DZ132 MA (54 mins)	DZ100-112 LA DZ132 MA (61 mins)
7	DX100-112 LA (61 mins)	

<u>NOTE</u>: Time values given in minutes represent the estimated extra setup time needed if a lower priority job than 1 is selected.

APPENDIX G: VENDOR KANBAN SYSTEM SPECIFICATION

GEC

GEC Small Machines Company/ Maatskappy
A division of/'n afdeling van
GEC Electric Motor Manufacturers
(Pty) Ltd/(Edms) Bpk.

Reg. No. 59/00027/07
Aberdeen Road/weg, Benoni 1500
Private Bag/Privaatsak 1026,
Benoni 1500,
Telephone/Telefoon: (011) 915-1010
Telex/Teleks: 4-29494 SA
Telegrams/Telegramme: 'Enelectico'

KANBAN COMPONENT AND/OR RAW MATERIAL SUPPLY SYSTEM

1. PURPOSE

This specification defines the general procedure to be followed in order to control stock levels of bought-in components, and to ensure that the Supplier is informed of the Company's requirements within a reasonable lead time.

2. SCOPE

This procedure is intended to serve as an outline of the kind of system to be developed in consultation with each Supplier. The details of the system, and any special modifications to it, will depend on the particular circumstances of each Supplier, and on the type of components or raw materials supplied.

3. ROUTINE

3.1 Three bins will be provided for each component, at a location close to the point of consumption. The three bins will each contain the same quantity of that component, and will be identified by

a red,
a yellow,
and a green metal tag.

3.2 Each tag will permanently display a description of the component and/or its part number, as well as the fixed quantity required for that bin.

3.3 Components will be consumed first from the green bin, then from the yellow bin, and finally from the red bin.

3.4 As soon as a bin is emptied, its tag will be delivered to the Supplier. The mechanism for this delivery of tags will be specially designed according to each Supplier's circumstances.

3.5 The receipt of the tag serves as the sole authorisation for the Supplier to deliver exactly that quantity of the component which is displayed on the tag.

3.6 The priority to be given to each 'order' placed in this manner will be derived from the colour of the tag:

3.6.1 The green tag is not an urgent order, since both the yellow and the red bins have yet to be emptied. It serves as an advance warning that a particular component will be required in the near future. If it is convenient, the Supplier may decide to deliver the quantity shown on the green tag.

3.6.2 A yellow tag is a more urgent order, since it signifies that consumption of the last (red) bin has begun. The Supplier should endeavour to deliver a double quantity (yellow and green tags) of that component as soon as possible.

3.6.3 A red tag is a top priority order since it signifies that no components are left. The Supplier must deliver a triple quantity (red plus yellow plus green tags) immediately. This should be possible since the advance warnings of the green and yellow tags have already been received.

3.7 As a rule, deliveries should be made on receipt of the yellow tag, since the red tag indicates a stock-out, which should be avoided.

3.8 The fixed bin quantities of each component will be decided in consultation with the individual Supplier; taking into account the rate of consumption of the component, as well as that Supplier's lead ime.

3.9 The tag, or tags, must be returned to the bins, along with the components delivered, and the bins will be replenished in the order

red,
yellow,
green.

3.10 Records of deliveries made will be by means of the existing Goods Received Note, issued by the clerk, and on this basis the Supplier will be paid.

4.0 SPECIFIC SYSTEMS

The above routine serves to outline the logic of JIT/KANBAN deliveries. However, in the case of certain Suppliers, it may be advantageous to use dedicated stillages to serve as the bins, and to circulate these stillages in place of the tags.

A two-bin, rather than a three-bin system may also be possible in the case of certain Suppliers.

Special packaging arrangements may be beneficial too.

Other ideas for specific systems may, of course, develop in the course of discussions with the Supplier.

CONSTRUCTED BY: Martin Horn .... M HORN

APPROVED BY: .... J J VAN DYK

off8/mhl
7 July 1986

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