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Design and implementation of just in time manufacturing in the automotive industry

Ivan M. Saldana Varela
Lehigh University

DESIGN AND IMPLEMENTATION OF JUST IN TIME MANUFACTURING IN THE AUTOMOTIVE INDUSTRY.

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Ivan M. Saldana Varela

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Date

Keith M. Gardiner

Advisor & Acting Director of MSE Program

Marlin U. Thomas

Marlin U. Thomas

Chairman, Industrial Engineering Dept.

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TABLE OF CONTENTS

List of Figures vii

Abstract 1

1. Introduction 2

1.1 Aims of Just In Time (JIT) 3

1.2 Basic Concept of JIT 4

2. Creation of One-Piece Production Flow 6

2.1 What is One-Piece Production Flow? 6

2.2.1 How to Create Flow 7

2.2 Creation of Flow in Process 8

2.2.1 Change from Crosswise Operation to Longitudinal 9

2.2.2 One-Piece Production and Conveyance 11

2.2.3 How to link processes 13

2.2.4 Small Lot Production 15

2.2.5 Mutual Relief System 16

2.2.6 Reduction of Lead Time 17

2.3 Summary 20

3. Production Smoothing 22

3.1 Necessity of Production Smoothing 22

3.2 What is Production Smoothing? 23

3.3 Realization of Production Smoothing 24
3.3.1 Cycle Table 26
3.3.2 Reserved Seat (Position) System 27
3.3.3 Bypass System 31
3.4 Summary 33

4. Standardization of Job 37
4.1 What is a Standard Job? 37
4.2 How to Prepare a Standardized Job 39
4.2.1 Cycle Time 39
4.2.2 Job Sequence 40
4.2.3 Standardized Work In Progress 42
4.3 Preparation Procedures of Standardized Job 43
4.3.1 Entering of Data into Capacity Chart 44
4.3.2 Determining the Standard Process Routine 47
4.3.3 Preparation of Job Guidance 57
4.4 How to Proceed According to the Standard Job Sheet 59
4.5 Summary 60

5. Case Study 61
5.1 Preliminary Production Evaluation (As Is) 61
5.2 Design of JIT Cell (To Be) 78
6. Discussion 91
7. References 95
8. Biography 98

LIST OF FIGURES

1. Improvement from Crosswise to Longitudinal Operation 10
2. One Piece Production and Conveyance 12
3. Example of Improvement by Full Work System 14
4. Improvement Example by Reducing Setup Time 16
5. Improvement Example by Mutual Relief System 18
6. Improvement Example of Reduction of Lead Time 19
7. Example of Creation of Total Flow 21
8. Comparison of Production Smoothing vs. Lot Production 25
9. Illustration of Production Smoothing 34
10. Part Production Capacity Chart 45
11. Standard Operation Routine Sheet 48
12. Allocation of Operation and Layout of Processes . 52
13. Example of Improvement (Non-standard Job) 54
14. Example of Improvement (Non-standard Job) 55
15. Example of Improvement (Non-standard Job) 56
16. Standard Operations Sheet 58

ABSTRACT

This thesis discusses the implementation of a materials and resources management systems design strategy called Just In Time (JIT). This manufacturing strategy focuses on line balancing and the standardization of work to be performed by the operators running a production line. Line balancing and standardization of work are the basic tools for improving process arrangements, manufacturing synchronization, and the shortening of production lead times. Just In Time proves to eliminate waste, improve product quality, and increases the manufacturing efficiency of the production line.

Applying Just In Time (JIT) is a company-wide effort a never ending "habit of improvement" process. From purchasing to distribution, through accounting and maintenance, there is no single function in the company left "untouched".

Finally, the implementation of Just In Time to a pilot line for a major motorcycle manufacturer in Spain is used as a case study for this thesis. A conclusion follows with recommendations for the future.

1. INTRODUCTION

The manufacturing sector, in an economic viewpoint, has been the source of good jobs, the source of technological progress, and the means to close the trade gap. In addition, the Common Market is no longer a joking matter. Eventually, Europeans envision a single currency with European Corporations and labor unions. North America, Japan and now Europe are emerging as major trading powers that can either threaten outsiders or become new engines of growth for all (37).

Although new figures show that manufacturing productivity gains may be overstated (28), the fact is that the U.S. has an underlying competitiveness problem.

The only real alternative is for U.S. manufacturers to produce more cheaply and better than their competitors. It is for this reason that CIM (Computer Integrated Manufacturing) is viewed as a competitive tool for the factory of the future. The ideal CIM system applies computer technology to all of the operational functions and information processing functions in manufacturing from order receipt, through design and production, to product shipment (5) in order to increase factory productivity.

As one of the underlying strategies within the CIM umbrella, Just In Time (JIT) production is a strategy which shortens the production lead time by having all processes produce the necessary parts at the necessary time and have on hand only the minimum stock necessary to permit the process to run (21). JIT offers a quicker response to the changes beyond the production line, it shortens the lead time from concept out to customer satisfaction.

1.1 Aims of Just In Time

To produce (convey) the necessary units in the necessary quantities at the necessary time.

Each company tries to secure profits in order to fulfill its social role and make a further development. There are two kinds of methods of securing profits: increasing selling prices, and reducing costs. However, the former method is not good in the present competitive environment. The objective of the JIT system is to realize cost reduction through elimination of wastes, especially waste generated from production. To achieve this, two key concepts are employed: Just In Time and visual control. Just In Time is the most suitable system to secure profits.

In this system, all processes produce the necessary goods in the necessary quantities at the necessary time. Visual control supports JIT by making the detection of wastes feasible. Therefore, JIT is one of the two pillars of this cost reduction system.

1.2 Basic Concept of Just In Time

The basic concept of JIT is to improve a production system so that all processes can produce the necessary goods in the necessary quantities at the necessary time. This improvement enables elimination of various wastes and minimization of production overhead cost, leading to cost minimization of production. Let's review the theory of this JIT objective of supplying only the right parts at the right time. The theory of the objective is:

(1) All overproduction is a waste because it needs to be stored, managed, and accounted for.

(2) All underproduction is a waste because it causes shortages and production holdups.

(3) All early production is a waste because it too must be stored, managed, and accounted for while it is waiting to be used.

(4) All late production is a waste because it causes production holdups.

There are two vital and absolutely necessary conditions that are keys to reaching this highly desirable situation. The first necessity is to have large amounts of production flexibility and be able to respond very quickly to the changing demands of the customer.

The second necessity is to have very , very short lead times so that when changes are made in the requirements, the response time is very short. Ultra-short lead times provide the desired production flexibility.

Now how do we get these ultra-short lead times and this highly flexible production? During the evolution of the JIT production, four very important and interdependent techniques were developed that have made it possible to dramatically shorten lead times and provide highly flexible production. These techniques are:

* One-piece flow production
* Small-lot production
* SMED - Single Minute Exchange of Dies
* Kanban - Shop floor production control

There are large numbers of new techniques that make up the total JIT System, but these four are the keys to very short lead times and flexible production. This thesis will concentrate on the first two techniques.

2. CREATION OF ONE-PIECE PRODUCTION FLOW

"Production through flow" is a special feature of the JIT production system. We must have an exact understanding of this concept to materialize the system which can produce the necessary goods at the necessary time in the necessary quantities.

2.1 What is One-Piece Production Flow?

The prime objective of the JIT system is to increase profit by reducing costs. Cost reduction is made possible by eliminating waste, especially by doing away with unnecessary inventories. One of the keys to achieving this goal is one-piece flow production.

To make the line operate effectively, it is important to separate the man from the machine. The machine must be equipped in a way that will allow the processing to be performed without the operator watching it. The operator must be able to load the machine and start the processing, then walk on to the next machine with full confidence the first machine will switch itself off when the processing is completed.

As a general rule of thumb, there are five operations performed on the average part. In contrast to the old system (batch production), the one-piece flow production system places all of the five required machines very close to each other in a straight line or "U" configuration. One person, trained to use all five machines, flows each part through this line one at a time. Each part is completed during the time it takes to complete the slowest process on the line, often just a minute or two. The result is that lead time is cut drastically from days into minutes, depending on the processes involved.

The one-piece flow production line is scheduled as a single unit and this reduces production scheduling time to one-fifth of the old method. Transportation between processes is eliminated and work-in-process (WIP) inventory is near zero which completely eliminates the need for WIP inventory tracking and control. The only WIP is the five pieces on the machines.

2.1.1 How to Create Flow

It should be important for creation of flow to comprehend the production not from the view point of individual processes but that of its total system. Although the method of creating flow varies due to the steps employed, the following points are very important as common factors:

(a) Allocation of operations and layout of processes which enables production within the cycle conveyance.

(b) One piece production and conveyance.

(c) Leveling of production.

Moreover, for the materialization of these common factors, the following points should also be taken in consideration:

* Balancing the production timing (synchronization) among various processes.
* Indicating abnormal condition (visible control):
    1. Specifying of address
    2. Specifying of quantity
    3. Making ANDON
    4. Establishing of full work system
    5. Making of production control boards
    6. Making of KANBANS
* Improvement of transportation by employing whirling-round tour system.
* Elimination of factors interrupting flow.

2.2 Creation of Flow in Process

The first step toward line balancing is to reallocate each process in accordance with the total layout within factory.

Ordinarily this step is proceeded by the following method.

2.2.1 Change from Crosswise Operation to Longitudinal

Although mass production within the same process has an advantage of increasing the processing speed, it often causes stacking of intermediate products and transportation, and can not transmit information withdrawn from the subsequent process to the preceding process smoothly, which often distance the flow. For the solution, we must shorten the distance between processes and balance the production timing.

Figure 1 is an example of improvement to synchronize each plural machine process with the main line, thus eliminating stacking of intermediate products. The points of improvement are as follows:

* A large lot production of each parts has been changed into small lot production by the changeover.
* Caulking process has been built into the main line.

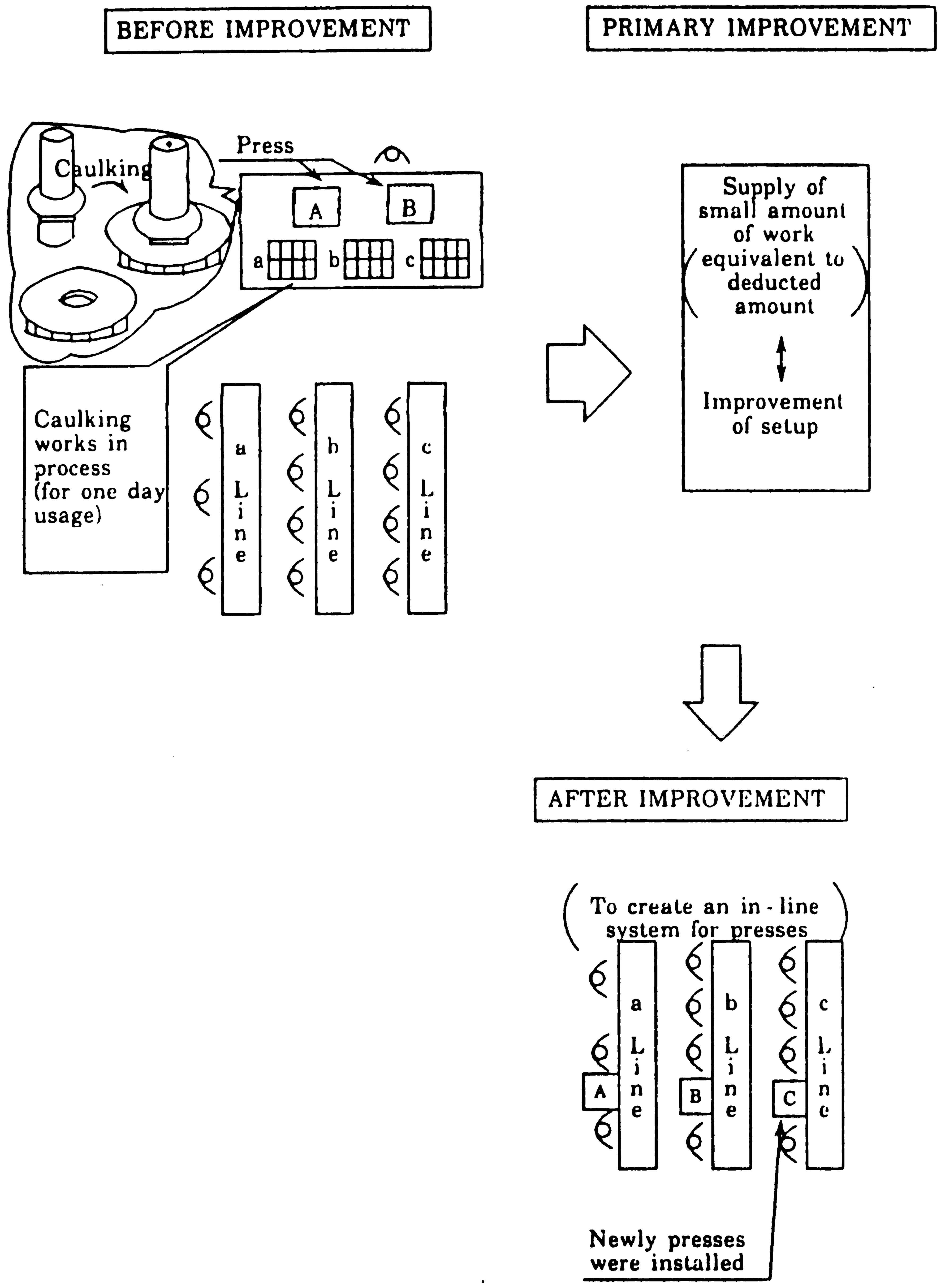


Figure 1:
<u>Improvement from crosswise to longitudinal operation (Assembly process)</u>

* One more small press has been introduced into the C line to enable production of the necessary goods in its own line.
* The process balancing of the main line has been reviewed to reduce work force by one caulker.

2.2.2 One-piece Production and Conveyance

One piece flow operation is one of the requirements for making rhythmic flow of products among processes. Its concept seems easy to comprehend, but its actual materialization is difficult, because storage between processes called Dango (accumulating) is often generated. This Dango has two demerits. First, it causes the delay in the countermeasure against bad quality because of the time lag arisen in pursuit of the real cause. Second, it disturbs the balanced production among workers. Figure 2 is one example of one piece production and conveyance regarding coating. In this example, products are painted in gray under booth 1, followed by being coated in black in booth 2, and carried one by one into the drying oven.

The key point of this improvement is to change the undercoating process to an air drying process by adjusting the standard quantity of works held to five pieces, reducing the number of drying processes through the drying

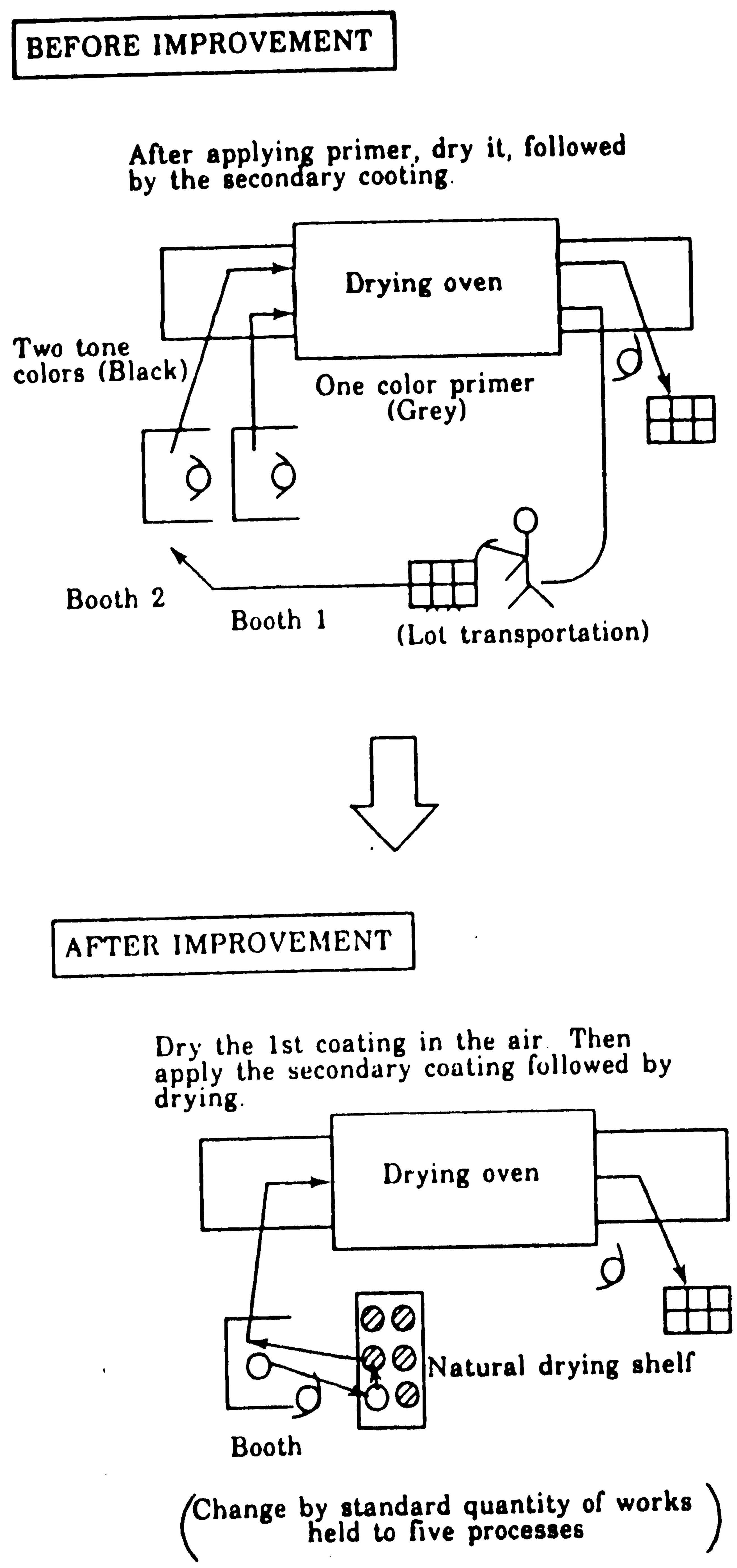


Figure 2: One-piece Flow Production and Conveyence.

oven to one. As a result, the following effects were obtained:

(1) One piece flow operation has been well achieved.

(2) The quantity of stacked intermediate products has been reduced.

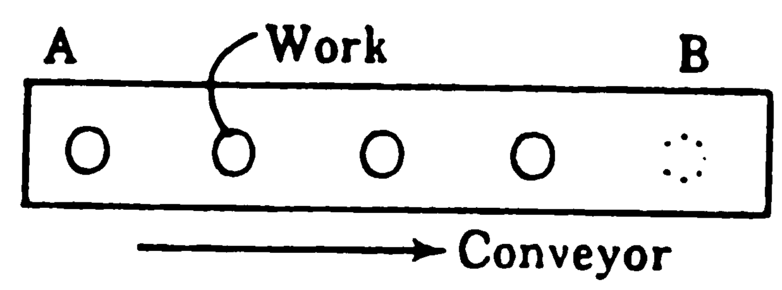
(3) Defects could be detected early.

(4) One worker could be eliminated by realizing no waiting time for coating.

2.2.3 How to Link Processes --Full Work System--

The system which can stop the flow when a problem occurs in the streamline flow, must be provided to find cause of the abnormal condition and return to normal condition. Also when a problem occurs in process, a device is needed to stop the line and avoid letting pieces accumulate under a certain standard quantity.

In an example of the improvement shown in Figure 3 there is a large soldering machine which is designed to be stopped and to make one piece production when full work occurs. The full work is the opposite of no work. In the full work system, the line is checked at control points A and B if there is work in process. If controlled properly, the conveyer is adjusted to transfer products one by one to



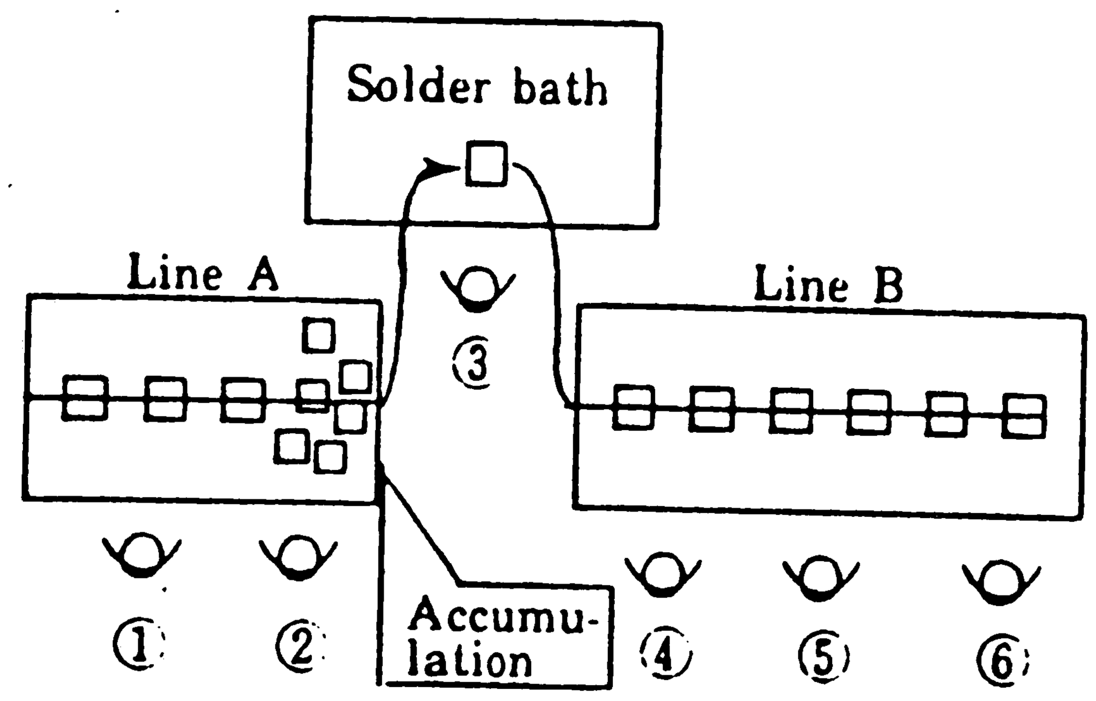
When process ③ and the subsequent processes should be stopped amnormally, works accumulate in process ②.

A	Available	Available	None	None
B	Available	None	Available	None

Only in this state, the conveyor is energized

When it becomes in the Full work system, the operation stops by means of the L.S.

BEFORE IMPROVEMENT



AFTER IMPROVEMENT

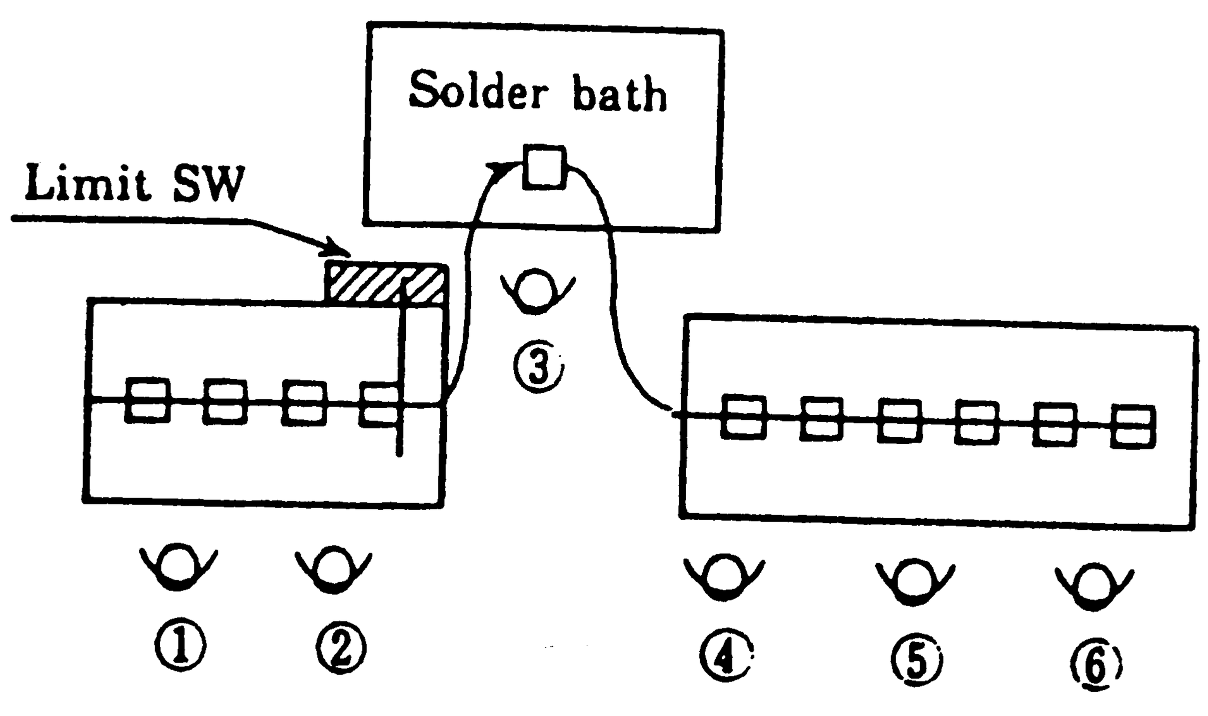


Figure 3:

Example of improvement by Full work system (In case of Assembly process) the next process at the same pitch in accordance with the information withdrawn from the subsequent process. If the worker at the next process (3) does not take the work, a worker at the preceding process does not need to stop or release the process line because a limit switch is automatically actuated to stop the conveyer and make rhythmic one piece flow production.

2.2.4 Small Lot Production

One of the prerequisites for the creation of flow is to minimize in-process inventory and stacking of intermediate products, in other words, to realize small lot production. However, when several kinds of goods are processed with one machine, a number of changeovers always occur. As a solution, the setup time must be reduced. The approaches to reducing the setup time have been studied by various departments. Figure 4 shows one of its simple examples. Before the improvement, the following two processes were used.

* to clamp with nut and bolt
* to secure with a spanner

After the improvement, these two processes were changed into one touch clamping method which can clamp by turning a lever by 90 degrees.

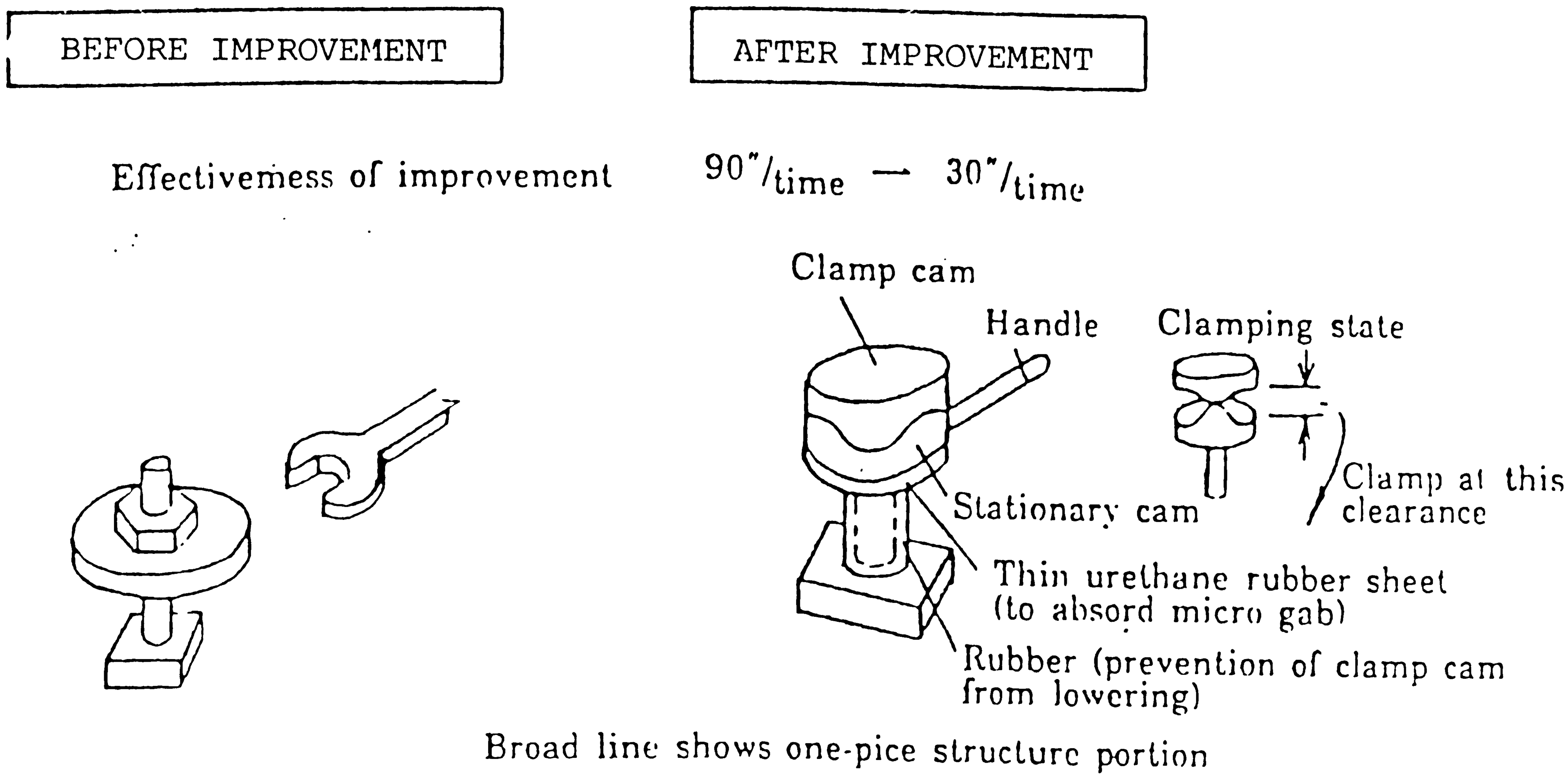


Figure 4: Improvement example by reducing setup time

Inventory is minimized in a JIT production system. It is recognized that inventory can hide quality problems, and that excess inventory is Muda (waste) and costs money while burdening the resources of the organization. JIT limits inventory through the use of small lot sizes in production operations, in delivery quantities and in line-side inventories. Additionally, material handling techniques and equipment are designed and applied to facilitate the use of small lot sizes and frequent delivery.

2.2.5 Mutual Relief System

Balancing operations among workers is important for rhythmic and smooth flow of products in a line. For this purpose, standard operations for each worker (operation procedure, cycle time, standard quantity of work held) must be determined and workers must be trained so that they can work in accordance with the standard operations sheet. If a new worker is allocated in an adjustment operation or process in the assembly line, operations will be delayed, the subsequent worker should have a waiting time which often leads to disturbances in the flow. As a solution, the mutual relief system shown in Figure 5 is effective. The points of the system are:

(1) To arrange that processes is designed so that the workers will be able to help each other.

(2) To predetermine processes or zones to be mutually helped. This improvement eliminates waiting time and stacking if intermediate products to make streamline flow.

2.2.6 Reduction of Lead Time --Improvement of Machine--

Layoutline forming (the creation of streamline flow) leads to the reduction of the lead time. However, due to the WIP existing in each process the flow is often disturbed and the production lead time is increased by the WIP manipulation between processes. These disturbance of the flow most frequently occurs especially in processes

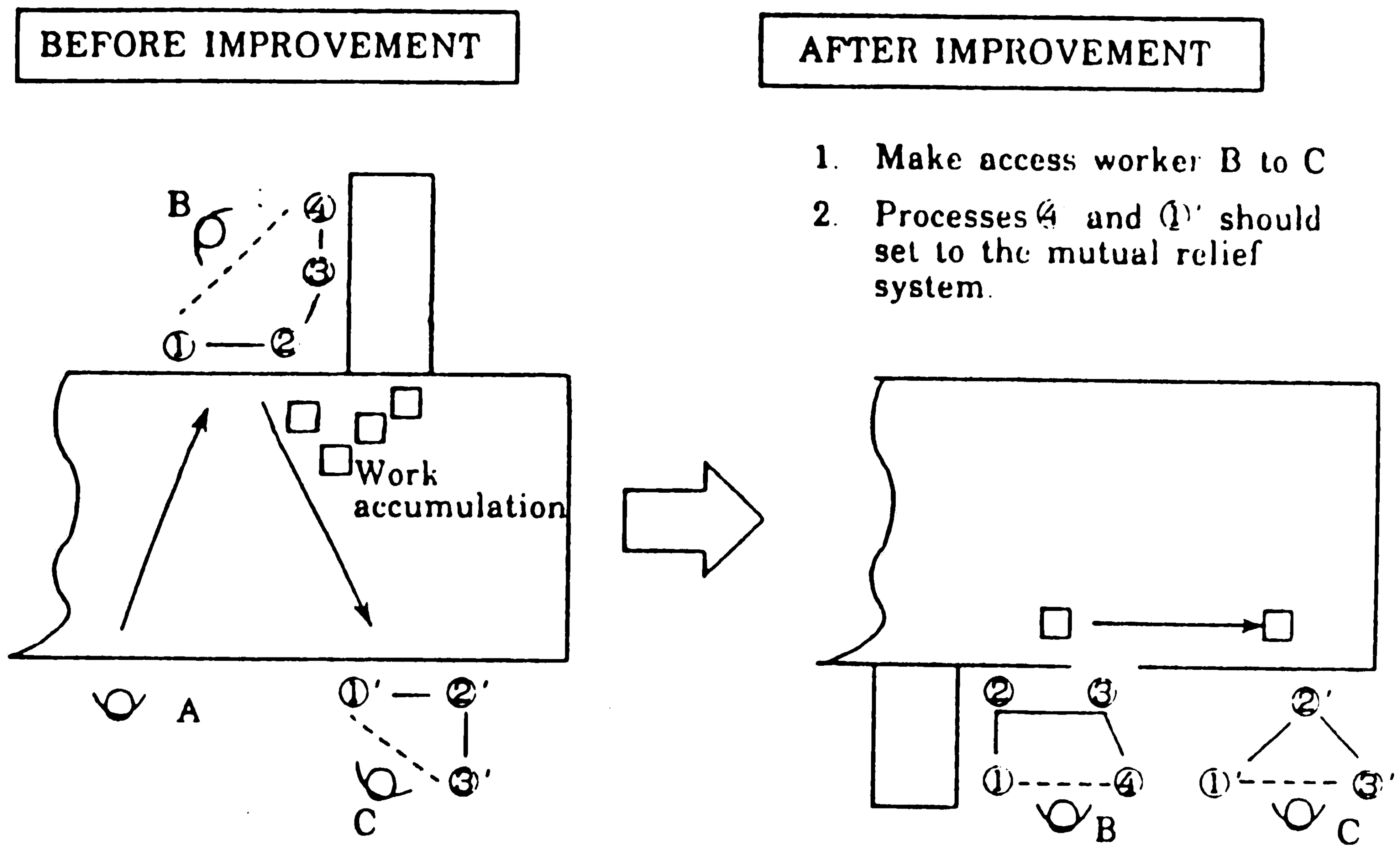


Figure 5: Improvement example of Mutual relief system (Assembly)

which employ large machines. Figure 6 is an example of the improvement of the line flow by the renovation of the equipment and the change of the machine layout.

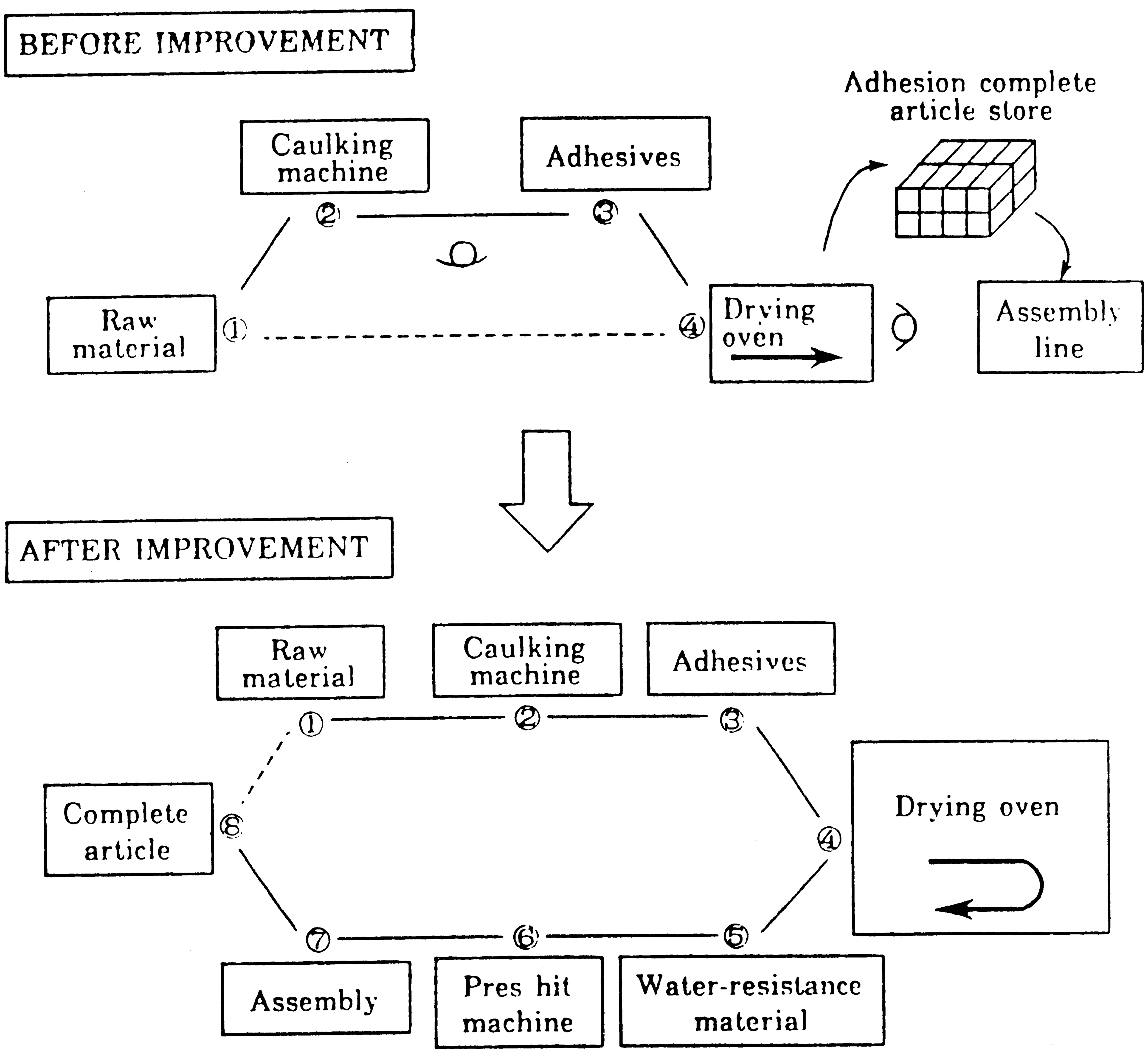


Figure 6: Improvement example of reduction of lead time

2.3 Summary

The flow does not refer to the movement of goods but that of satisfying the following conditions.

(1) Rhythmic flow of products in accordance with the order of process.

(2) Not partial flow but total flow through factory, and between factories.

(3) Not temporary flow but successive flow of products.

Figure 7 shows an example of the creation of total flow regarding a factory. But the flow from the subcontractor to supplier via factory described here will be adaptable to any case.

By this creation of total flow the result will be a strong and efficient factory which can produce the necessary goods at the necessary times in the necessary quantity thus enabling cost reduction.

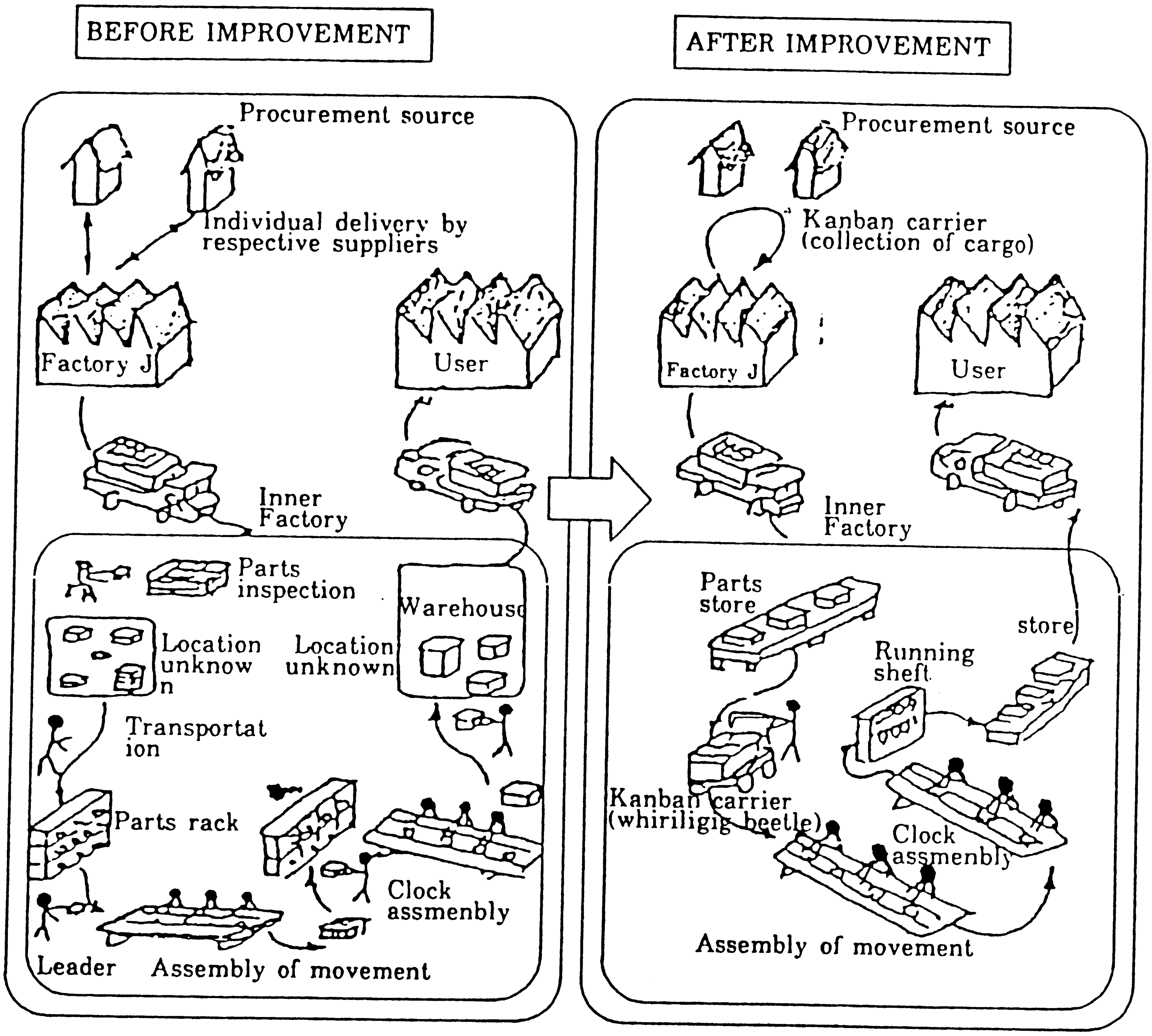


Figure 7: <u>Example of creation of total flow</u>

3. PRODUCTION SMOOTHING

The Just In Time production system is designed for balanced utilization of all production resources including work force, equipment, and material. Such design allows the flexibility to better control variability in the production process. Production smoothing levels the fluctuations of variety and volume in the production process over time.

3.1 Necessity of Production Smoothing

The cost of production is generally thought to be determined by quality and quantity of product, but in reality is not limited to these factors. The cost of production comprises QUALITY, QUANTITY, and TIMING. The important thing is to determine when to produce the product in the required quality and quantity.

In production articles of the same kind, there is a difference in the requirements for man hours, materials, and facilities, with large variations, in the cost of production, between the production of the required monthly quantity in ten (10) lots and the production of the same quantity each time the need arises (in one lot).

Therefore, a plan must be utilized to produce articles of good quality in good timing and at low costs and also in such a manner as to ensure safety of workers, with minimum man hours, materials and facilities.

If the required articles must be produced (or transported) in the required quantity and in the required time at low costs, then "production smoothing" must be a major prerequisite.

3.2 What is Production Smoothing?

Production smoothing is not the mere averaging of production on a weekly or daily basis but means the averaging (smoothing) of the amount of work and the type of work (including the amount of work for each type) in any time zone of production activities. An example of this concept may be shown in Table 1:

Production Plan

	Monthly requirement	Daily requirement (20 day/month)	UNIT	Tact time (operating hours: 480 min/day)
Product A	4,000	200	4	2.4 min.
Product B	3,000	150	3	3.2 min.
Product C	2,000	100	2	4.8 min
Product D	1,000	50	1	9.6 min
Total	10,000	500	10	Average 0.96 min (57.6 sec)

→ 480 min. / 500 pcs

A comparison of the foregoing production plan between the production smoothing (system) and the lot production (system) is shown in Figure 8.

3.3 Realization of Production Smoothing

The point in question is "production in cycle time", "production smoothing", "determination of line tact according to the required quantity". It means the production of articles in the "required quantity" in the "required time".

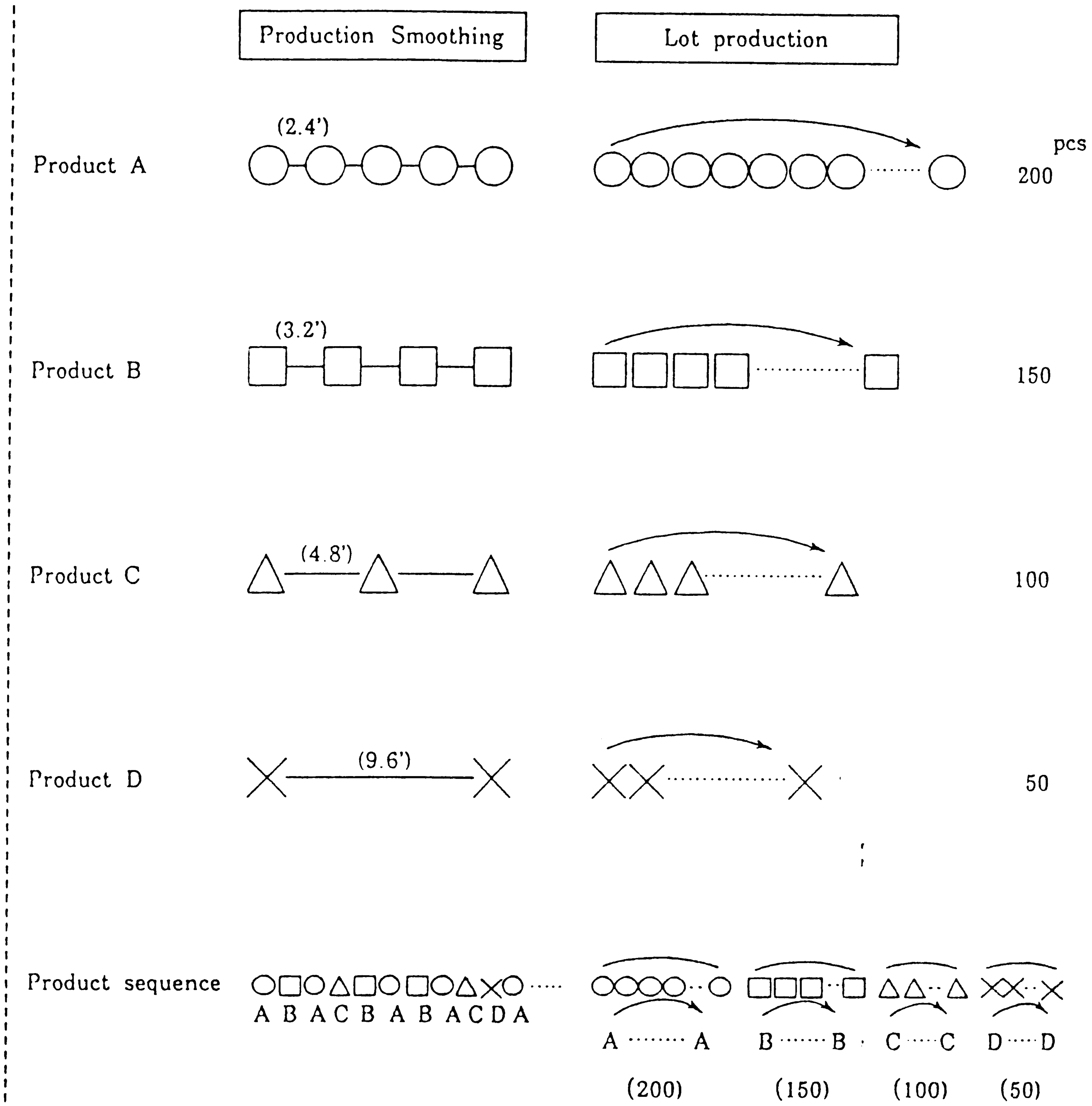
For this purpose, a cycle such that "one piece of product must be manufactured in so many minutes and so many seconds" must be considered.

$$\text{Cycle time} = \frac{\text{Operating time/shift}}{\text{Required quantity/shift}}$$

What is required here is the value (cycle time) obtained by the above equation, meaning that articles must be produced at the required time intervals.

The method of production smoothing is explained more in detail.

Figure 8: Production Smoothing vs. Lot Production.



Personnel assignment to production line	• Personnel assignment is made according to the production requirement of the day and does not require changes according to the type of product on the line.	• Personnel assignment is made each time according to the type of product on the line.

3.3.1 Cycle Table

When the production ratio is 50%, 30% and 20% for products A, B and C, respectively, on the same production line, the following cycle table is used for the flow of products.

A	B	A	C	A	B	A	C	A	B

------>

How many times this table should be rotated depends on the quantity of production. What is important here is that a production instruction has reached (the line) for each setting of work.

However, the production instruction may not always be given as specified. To compensate for variations of production, therefore, one or two non-reserved seat position are provided for each rotation of cycle table.

Non-reserved seat position:

A	B	A	C	A	B	A	C	A	

------->

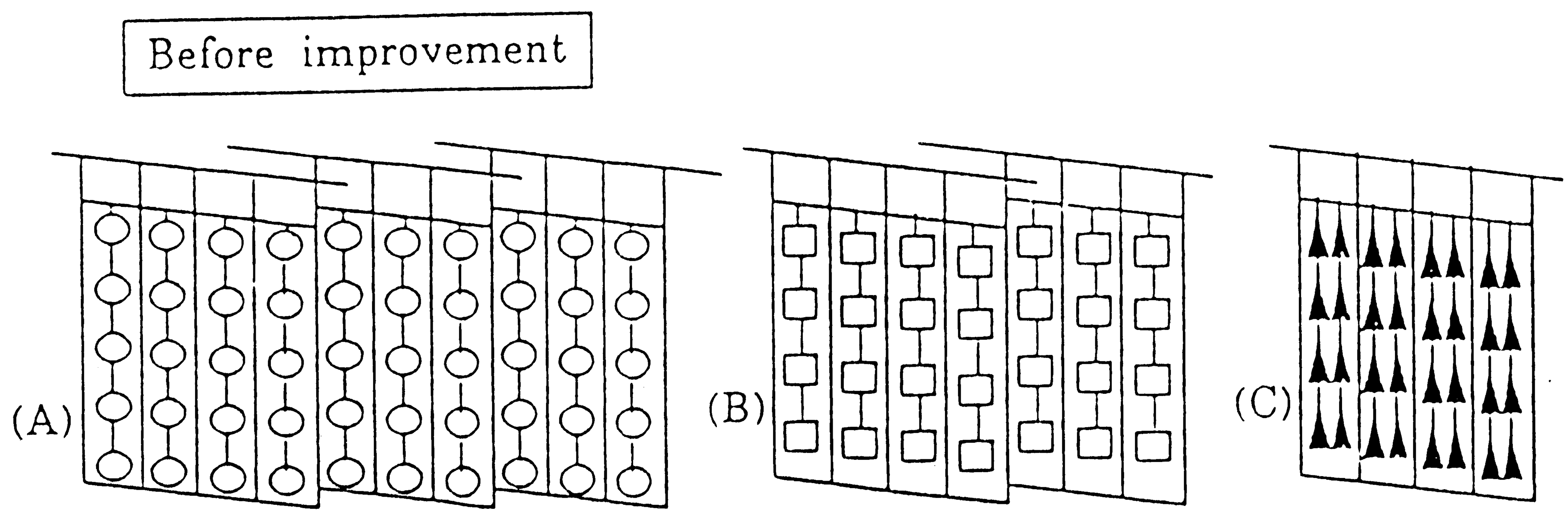
In the non-reserved seat position, work pieces are set in combination matching the A, B, C, cycle. If the process is still not in accordance with the production instruction, this means that there has been a change in the composition ratios of Products A, B, and C, and then it is necessary to review the cycle table.

3.3.2 Reserved Seat (Position) System

The practical application of a cycle table is the reserved seat position system. This system is often applied to such processes as painting and plating proceeded (electrolytic coating) in which parts are set on hangers.

An example of reserved seat position in plating shop.

In the past, the required daily quantity of parts A, B, and C was flowing in the line in one lot. The one lot production of daily quantity was divided into smaller lot sizes (4 lots/day) by changing the combination of parts in the hangers and mixing the parts with a reserved seat position included in the production instruction.



Problem:

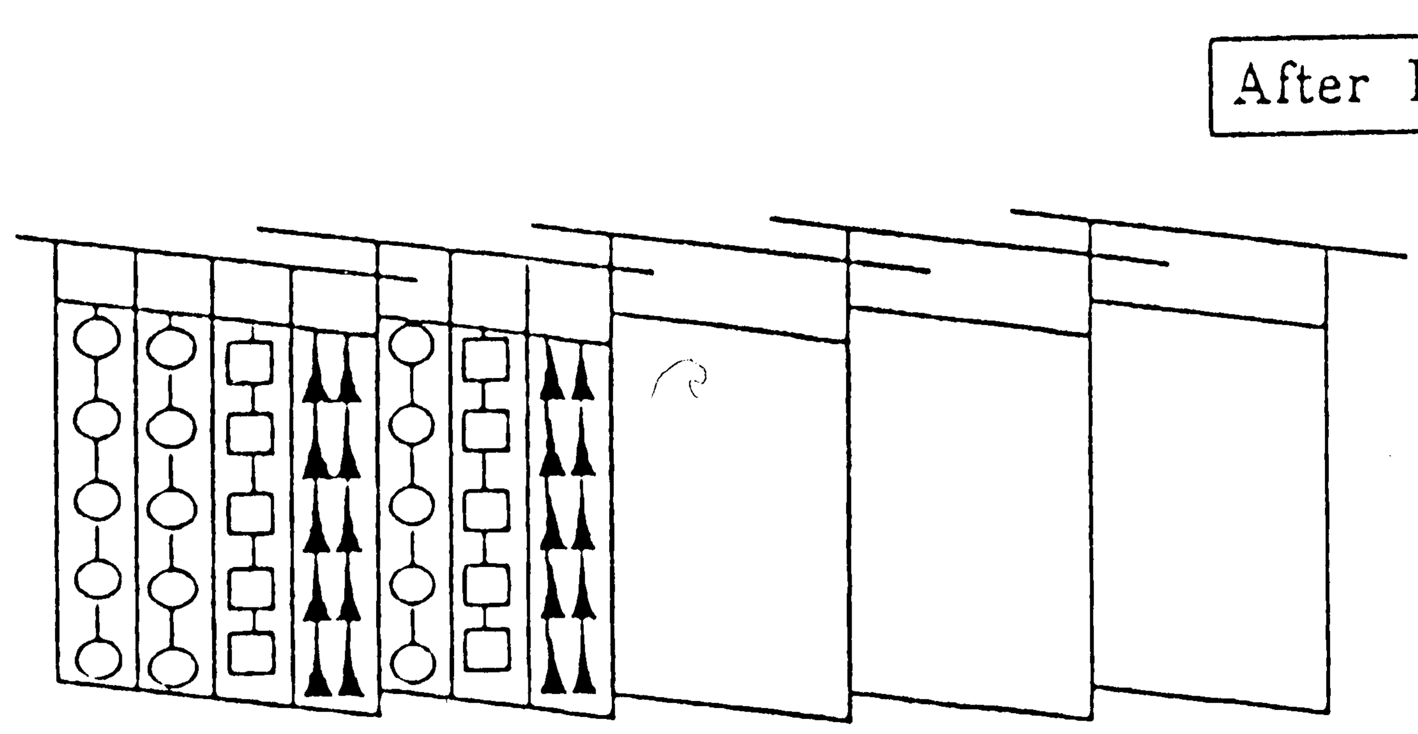
(a) As parts of the same type were hung on a single bar, the reduction of lot size has resulted in variations in work load for hanging and removal between large parts and small parts.

(b) As the required daily quantity was brought in from the preceding process in one time delivery, the preceding process had lot production once a day with at least two days inventory.

(c) As the preceding process was informed of the change in production quantity required (required quantity) only once a day, there was a delay in response to the change with difficulties in making a shift of its own.

(d) As delivery was made to the plating shop once a day, there was a requirement for a wide space for temporary storage of unfinished parts and storage of finished parts.

(e) The improvement of the efficiency in the plating shop was not linked with the improvement of the overall efficiency of the whole plant.



A flow of parts on the line, with a reserved seat position provided for each bar according to the daily production rate, was realized by quantifying (fixing the quantity of) the delivery to next process.

Effects:

(a) There was a reduction of variations in the number of man-hours required for bar handing and removal of parts.

(b) Delivery four time a day resulted in the reduction of inventory in the preceding process to one day's stock at the maximum.

(c) It was possible for the preceding process to know the required quantity or changes in the subsequent process four times a day for quick and easy adaptation.

(d) A reduction of storage space by one-third and one-half of the previous requirement was possible in the plating shop and the preceding process, respectively.

(e) There was a reduction in the number of damages to the products in storage with improved external quality as a result of the reduction of complete work stock.

An improvement of reserved seat position in the painting shop. In the past, the daily requirements of parts

A, B and C was produced in two lots (two-split production method) a day. To change this two-split production method to the smoothing production system with use of cycle time, reserved seats were assigned to parts supply hangers and a flow of parts one by one was realized.

Before Improvement

Painting was made once in the morning and once in the afternoon.

	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00
pcs A 500	250 →	→				250 →	→			
B 300			150 →	→				150 →	→	
C 200				100 →					100 →	

After Improvement

Reserved seat (position) tables ware prepared and reserved seats (positions) ware assigned to parts supply hangers.

Reserved Seat (position) Table

Hanger No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Parts A	○		○		○		○		○		○		○		○	
Parts B		△				△				△		△				△
Parts C				×				×						×		
Seat (position) sign	○	△	○	×	○	△	○	×	○	△	○	△	○	×	○	△
Sequence	A	B	A	C	A	B	A	C	A	B	A	B	A	C	A	B

Point of Improvement: In this case is the improvement of setup such as replacement of painting face mask and jig, paint and replacement of spray guns, etc.

Effects:

(a) Reduction of finished parts in stock.

(b) Reduction of space requirement for storage of finished parts.

(c) Reduction of unfinished parts in stock delivered from the preceding process.

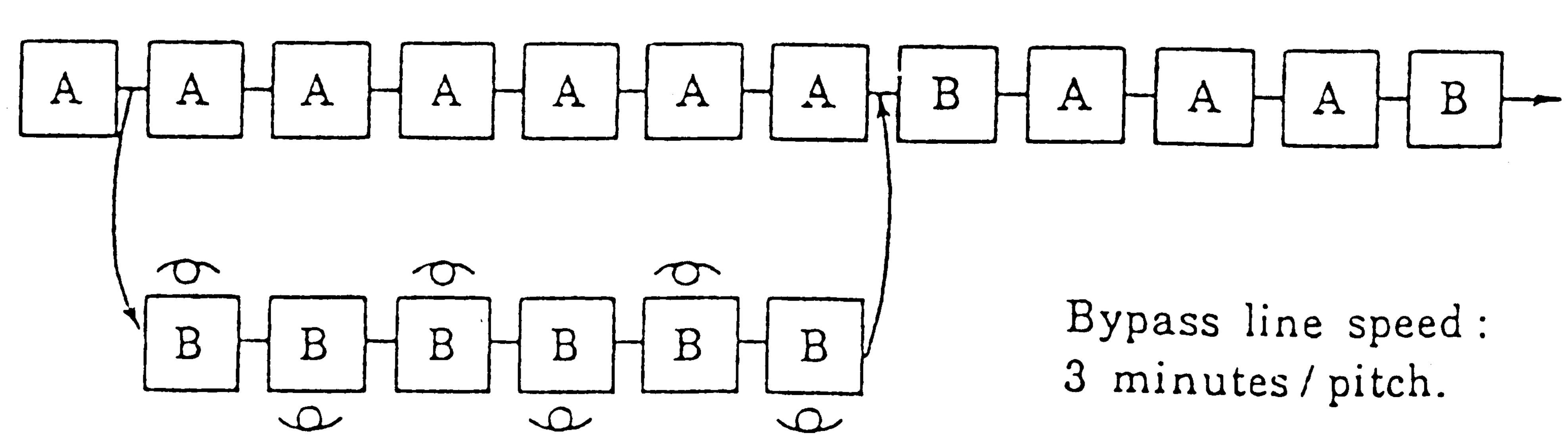
(d) Quick adaptation to change in the next process.

3.3.3 Bypass System

As work load for the production of Model B cars was greater than that for the production of Model A cars, excesses of work load Model B cars were grouped into one work load and a bypass line was formed.

(1) Formation for a high ratio of Model B cars.

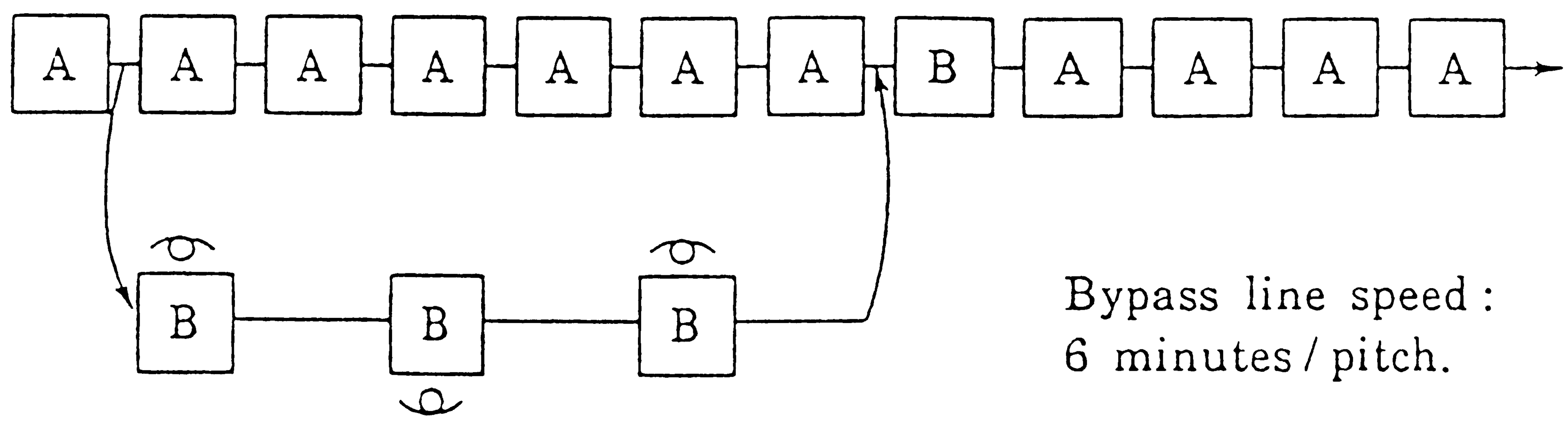
Mixed products line speed: 1 minute/pitch



Model B cars (high grade cars requiring more work load)

The formation of the bypass line is changed when there are changes in the production ratios of Model A and B cars.

(2) Formation for a low ratio of Model B cars.



The important point for adoption of the bypass line system is to schedule the process for the model which requires the least man hours, reduce the excess of work load through improvement of process and from a bypass line for the excess of work load which can not be avoided after all.

It is also important to ensure that there is no major change in production sequence before and after the bypass line.

3.4 Summary

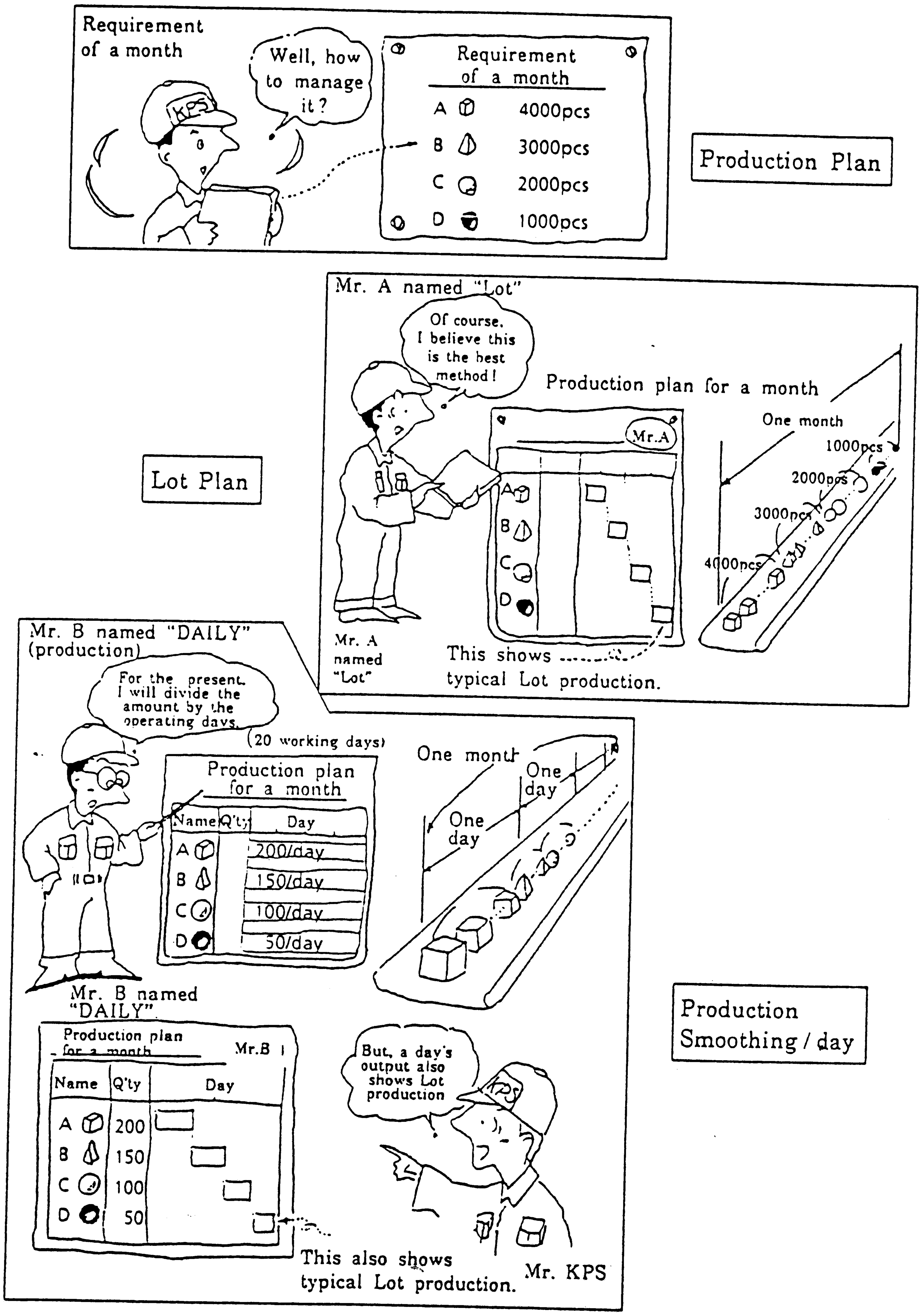
Cost reduction through "complete elimination of waste" means the production of articles of good quality at low costs in a safe production manner with versatile production facilities requiring a small energy consumption that match the minimum man hours, materials and cycle time.

For this purpose, production smoothing is a prerequisite. The increase of efficiency in one production process does not always bring about the improvement of overall efficiency of the company. What is looked for by the company is the improvement of efficiency as an integrated business establishment.

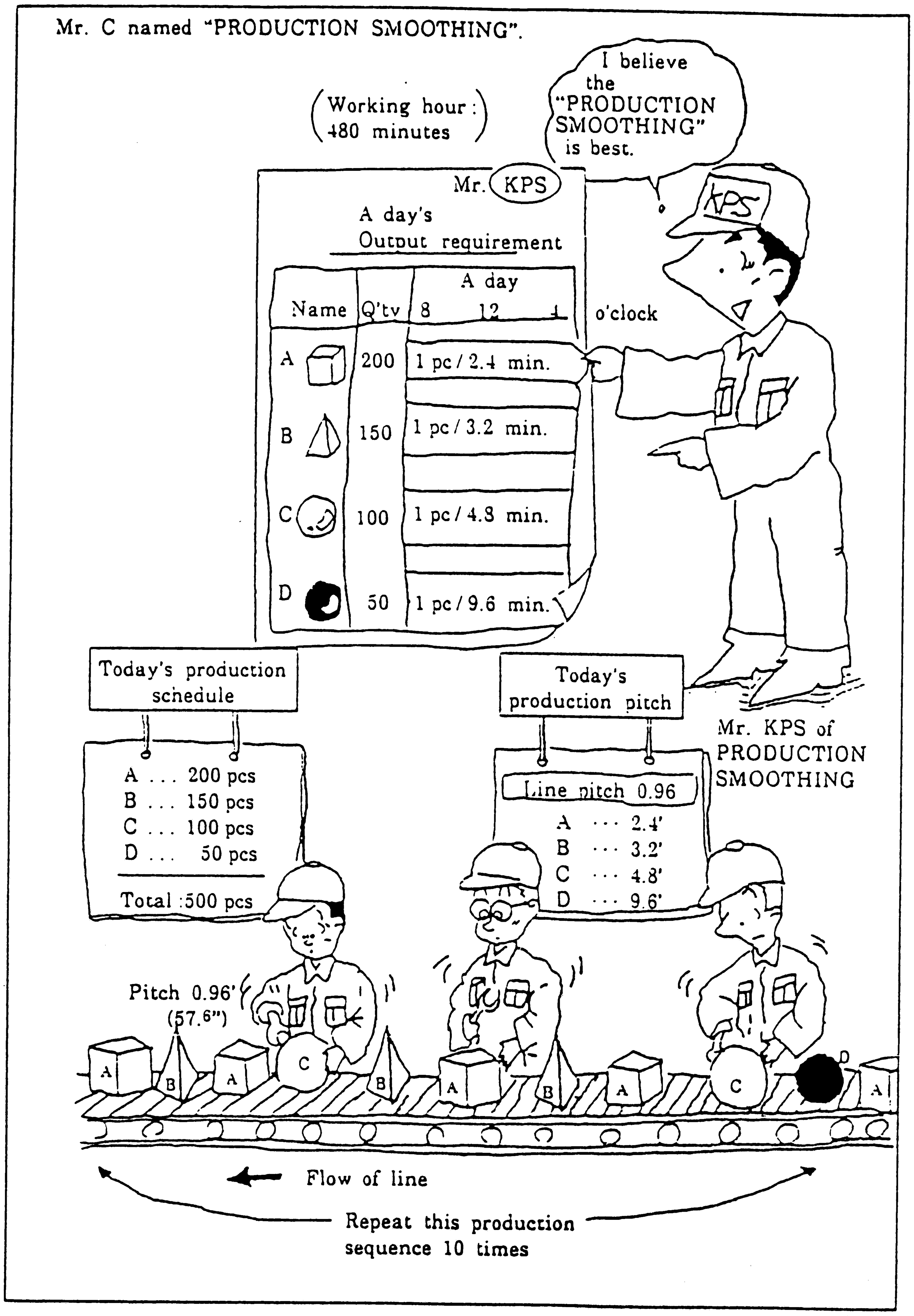
For this objective, it is essential to promote the production smoothing system as a business group, not limited to the company itself but including affiliated companies as well.

Figure 9 shows the "Production Smoothing" in the following illustration.

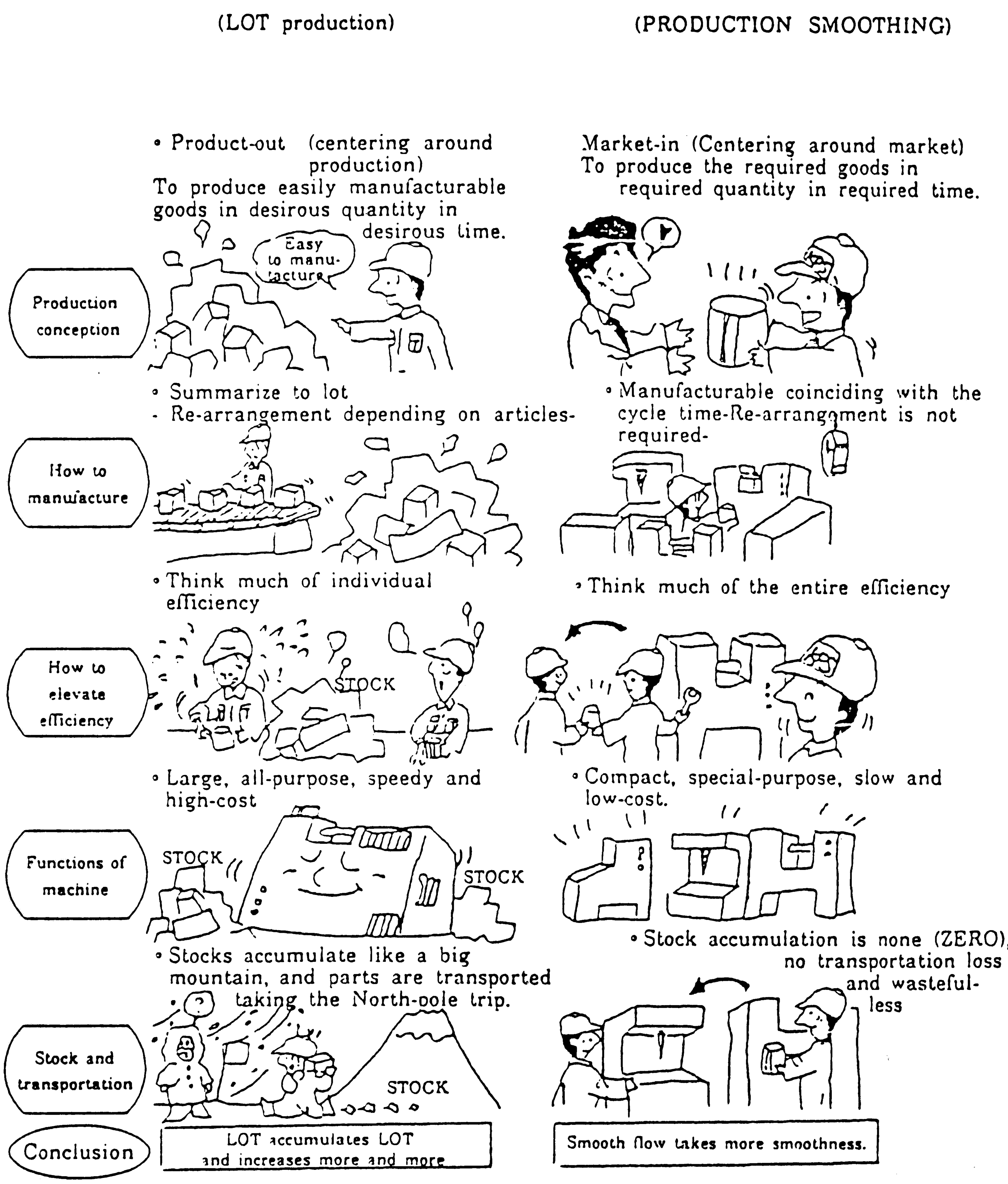
Figure 9: Illustration of Production Smoothing.



PRODUCTION SMOOTHING → MIXED PRODUCTION



WHY THE PRODUCTION SMOOTHING IS DIFFERENT FROM "LOT" PRODUCTION ?



4. STANDARDIZATION OF JOB

Standardization of job is one of the ways of eliminating various forms of waste and gathering value-added work around each operator in order to create a synchronized flow of all processes.

It is a rule that defines a work method for the production of goods of the required quality in a safe manner an at a low cost by efficiently combining "man", "materials" and "machinery", to form a basis for improvement of job performance.

4.1 What is a Standard Job?

Production is most efficient, quality is at its highest, and Muda (waste) is eliminated when tasks are organized in the perfect sequence. That is the concept of standardized work. Each team member's tasks are studied and a standardized work chart is developed, which visually depicts the actions required to complete the tasks, including the work operations, quality checks, walking, waiting, movement of material, etc. By measuring the time required for each action, the net time for a team member's total standardized work can be known. This net time can be compared to the tact time (daily total operating time at

100% efficiency/required total production) to assist in work-force planning and efficiency improvements.

By displaying all the elements of the job on the standardized work chart, those elements which add no value to the product (Muda) such as waiting, walking, and inventory are identified and then can be minimized or eliminated . The job sequence can also be studied and improved, especially as the team member understands that his or her work sequence need not to be the same as the sequence of the production process.

Standardized job sheets are displayed at the job site of each team member. This allows team members to regularly review their own job, provides a training aid for new team members, and explains the job being performed to those not familiar with it to enhance their cross training.

In addition, malfunctions which would generate during the execution of a work according to the standard job sheet become a clue to the next improvements, through which new and revised standard job sheet can be prepared. The standardized job should be variable at all times in which there is a room for many improvements.

4.2 How to Prepare a Standardized Job

The following three elements are especially important in the preparation of standardized work:

1) Cycle time
2) Job sequence
3) Standardized stock in hand

This is called as the "Three elements of standardized job". If any of them should be absent from the job, the standardized job is not established. The standardized job is prepared taking the three elements into consideration, of which details are described as follows.

4.2.1 Cycle Time

Cycle time means a time in which one unit (or one piece) of product must be manufactured within the specified time (minutes). This depends upon the amount of products and the operating time required.

$$\text{Required amount/day} = \frac{\text{Required amount in a month}}{\text{Operating days}}$$

$$\text{Cycle time} = \frac{\text{Operating time}}{\text{Required amount in a day}}$$

When the cycle time which means time required for the completion of a product has been determined, each worker's work load is determined. In this case, however, no allowance is included in the work load as generally specified in a motion study. The speed of process and standard of skillfulness are determined by the leader, based on the capability of skilled workers.

When the cycle time has been determined in this way, an individual difference will appear depending upon the workers abilities. Since an allowance is not included in the work load, if any waste should exist, it will be easily found out. As a result, improvements are made through the above procedures. In other words if something should deviate from the specified standard cycle time, a clue of improvement will be given immediately, consequently, some action will be made so as to revise the cycle time.

4.2.2 Job Sequence

The job sequence means a series of actions in which a job is performed throughout a period of time in which a raw material is processed by a worker. Actually, in this sequence, articles are transported, mounted on a machine, dismounted from it, and thus, it varies the form from a raw material to a product. In other words, the job sequence does not mean the flow sequence of products.

If this job sequence is not specified clearly, individual workers might manufacture products by choice in various job sequences. As a result, the products thus manufactured are according to various kind of job sequence depending upon the individuals workers' way of thinking.

If the job sequence should not be observed strictly, defective machined parts might be transferred to the down stream process. As a result, machine tools might be broken or the assembly line will be stopped. In the worst case, defective vehicles might be delivered to the customers.

The job sequence requires to clarify the existing job analysis, in which any waste, fluctuations and unreasonableness are not allowed. To meet the requirements of this job sequence, it is necessary to specify how to use both hands, position of feet, how to clamp a work, and other processes. Then the job sequence must be understandable for the workers and must be standardized.

As a result of the standardization of the job sequence thus described, high-quality products will be manufactured safely and acceptably, in which the will of the originator in the standardization of job is clearly presented.

4.2.3 Standardized Work In Progress

The standardized work in progress (WIP) means a stock in process at a minimum level which is necessary to perform the job successfully. The stock in hand includes those products (stocks) mounted on machines.

The standardized WIP is variable depending upon the arrangements of machines in the workshop, as well as depending on the specified job sequence. Therefore, it depends upon the availability of stock to proceed the job smoothly.

The WIP is, when the job is made along the machining process, sufficient with the workpieces mounted on their respective machines. This means there is no stock between each process. On the contrary, is the job is performed just in reversed order of the specified process, it is recommended to provide one stock for each process or more depending upon the peculiar process.

The quantity of the standardized WIP may be increased in the following cases:

* Quality check is required.
* The next process is unable to commence unless the workpiece temperature is

lowered.

* Oil drainage is required from the part.

The setting of the number of standardized WIP should be made at a minimum level so that any abnormality can be detected easily. The difference between the indicated quantity and the real one will become a clue to the improvements.

4.3 Preparation Procedures of Standardized Job

The process of creating a standard job may be divided largely into the following steps.

Step	Process	Particulars
1st step	Preparation of a production capability table for each process.	Used for determining the present capability of individual processes.
2nd step	Preparation of a standard job combination table.	Indicates the progress of work of man and machinery with time.
3rd step	Preparation of a standard job instruction manual.	Used for guidanse of subordinate workers.
4th step	Preparation of standard job' sheets.	Used as a means of visible control and actualization (identification) of operation problems.

4.3.1 Entering of Data Into Capacity Chart

When the standardized job sheet is prepared, first enter the production capability for parts in their respective processes into the capacity chart classified by parts. Next, the following items should be entered into the list:

- Machining process sequence
- Description of process
- Machine number
- Basic time (manual operation time, automatic feeding time, and completion required time).
- Time required for tool replacement
- Number of workpiece
- Machining performance

This parts capability list is important because it is fundamental for the combination of jobs when the standardized job sheet is prepared.

Next, it will be explained how data is entered into the capacity chart (Figure 10).

1) Order of Processes: This is the sequence of numbers according to the order of processes.
2) Description of Operations: Description of process is entered for parts to be processed. Frequency

Figure 10: Part Production Capacity Chart.

Part production capacity sheet	Item no	Item name	Necessary quantity per day	Worker's name

Order of processes	Description of operations	Machine no.	Basic time: Manual operation time min.	Basic time: Manual operation time sec.	Basic time: Machine processing time min	Basic time: Machine processing time sec.	Basic time: Completion time per unit min.	Basic time: Completion time per unit sec	Tool's exchange: Exchange units	Tool's exchange: Exchange time	Production capacity (960 min) units	References manual operation ——— machine processing - - - - -
1	center drill	CD-300		07	1	20	1	27	80	1'00"	655	
2	chamfer	KA-350		09	1	35	1	44	20	30"	549	
									50	30"		
3	ream	KB-400		09	1	25	1	34	20	30"	606	
									40	30"		
4	ream	KC-450		10	1	18	1	28	20	30"	643	
2-1	mill	MS-100		(20)	(2	10)	(2	20)	1,000	7'00"	820	10" 10" 2'10"
2-2	mill	MS-101		(15)	(2	10)	(2	15)	1,000	7'00"		5" 10" 2'10"
	(two stands of machines)			18								[manual operation time per unit] = $\frac{20'' + 15''}{2}$ = 17.5" — 18"
3	bore	DA 235		(08)		(50)		(58)	500	5'00"	1,947	
	(two units processing at a time)			04				29				[manual operation time per unit] = $\frac{8''}{2}$ = 4"
4	gauge (1/5)			(18)								
	(one unit inspection in every five units)			09								[manual operation time per unit] . $\frac{18''}{2}$ = 9"
			total									

of removal of cutting chips from the machine.

Enter the detailed inspection and measuring results together with their frequencies. As for the machining process, if two or more machines are used for the same processing, respective machine performance should be entered individually. In case of two-gang processing, indication should be entered for individual machine.

3) Machine No: This refers to the number of the machine in question, which is represented by: CD-300, KA-350, KB-400, etc...

4) Basic Time: Manual operation time, automatic feeding, and and completion required time is entered. In the total column, the total time of manual operation time should be entered. The completion time per unit is the time required for a single unit to be processed. If two units are processed simultaneously, or one unit in every few units is inspected for quality control, the completion time per unit will be written on the reference column. In case two or more machines are used in the same process, the time required for completion should be entered by individual machines.

Walking time is excluded from the basic time.

———————— Real line shows the manually

operated time.

--------- Dotted lines show the automatic feeding time.

5) Tool's Exchange: The replacement required frequency and period should be entered, by calculating the number of units to be produced before changing the tool.
   The exchange time refers to the setup time.

4.3.2 Determining the Standard Process Routine

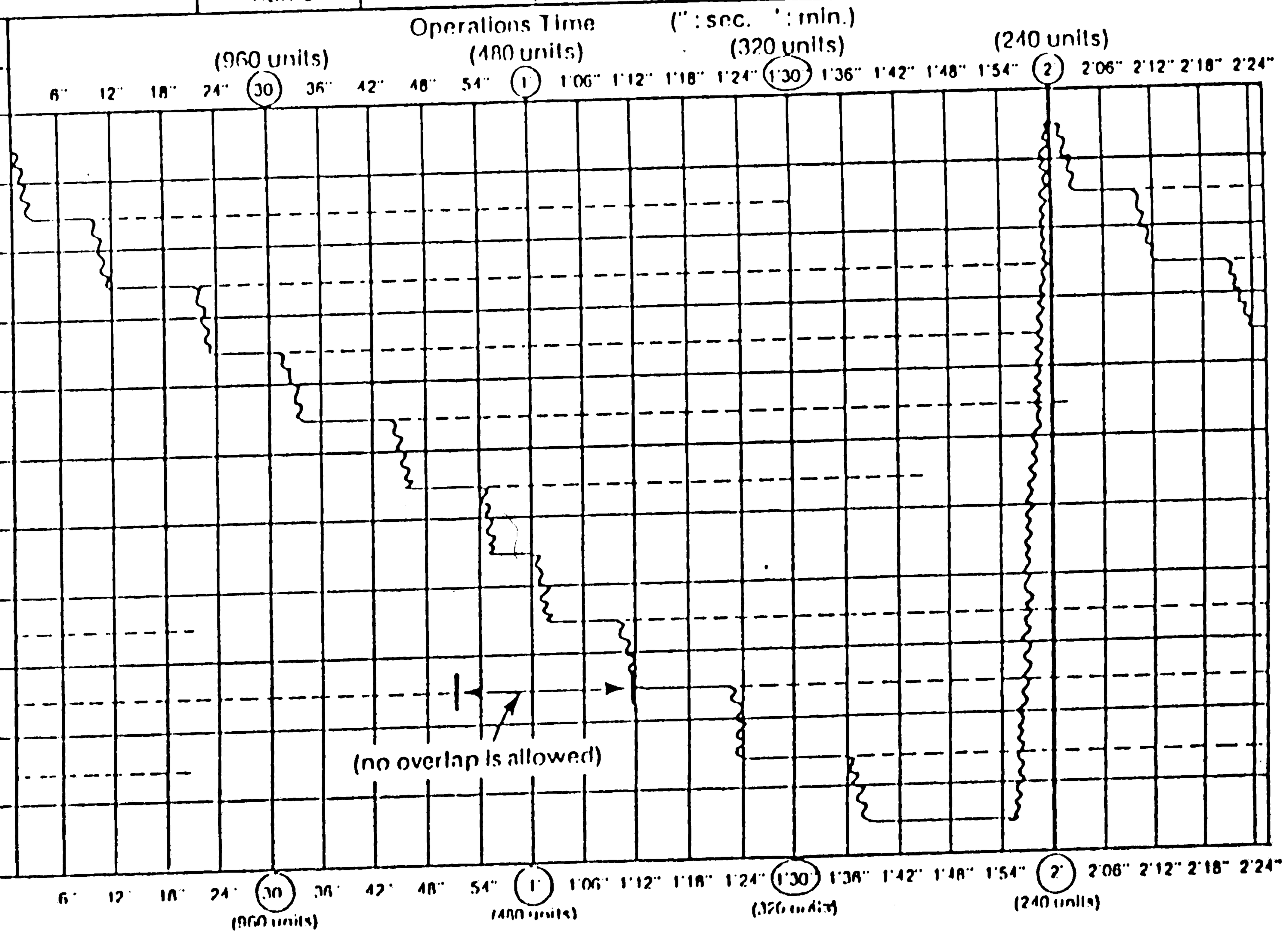
Upon completion of entering production capability in the table of capacity classified by parts, then, the cycle time is calculated by means of the required number of units per day and the operating time. Based on the cycle time, it is then determined how to execute the job by individual workers under the specified sequence. If the production process is simple, the cycle time is obtainable from the capacity chart classified by parts as it is.

If the production process is somewhat complicated, it will be unknown whether the machine has terminated its automatic feeding or not in the course of determining the job sequence. Therefore, in order to observe this period of time visibly, and to determine the job sequence, the "standard operations routine sheet" may be used as a tool.

Figure 11: Standard Operation Routine Sheet.

Item no.	3561-4630	Standard Operations Routine Sheet No. 1	Date	Oct. 15, '81	Necessary quantity per day	240 units	Manual operation ———
							Machine processing - - - - -
Process name	Machining: part 2		Worker's position & name		Cycle time	2 min.	Walking ∿∿∿∿

Order of operations	Names of operations	Time: Manual	Time: Machine
1	Pick up the material from the pallet	01"	--
2	CD-300: center drill	07"	1'20"
3	KA-350: chamfer	09"	1'35"
4	KB-400: ream	09"	1'25"
5	KC-450: ream	10"	1'18"
6	NE-200	08"	50"
7	GR-101	05"	—
8	SA-130	07"	1'10"
9	JI-500	10"	1'30"
10	HU-400	12"	55"
11	Wash, attach the nipple, put in the pallet	20"	--



In this standard operations routine sheet, the following data is entered:

- Process sequence
- Contents of job
- Process time (manual operation, walking and automatic feeding)
- Operating time

The procedure to prepare the standard operations routine sheet follows (see Figure 11):

* Job sequence: the sequence of jobs should be entered in order of 1, 2, 3, etc..
* Contents of job: Enter details of manual operation together with the machine number.
* Time: The manual operation and automatic feeding time as specified in the capacity chart is inputted.
* Required quantity/day: The required quantity which is obtained by dividing the required quantity for one month by the number of operating days.
* Cycle time: Obtained by dividing the one day operating time by the required quantity.
* Part No., part description and date prepared: These should be entered in accordance with

the capacity chart.

The entering of data into the standard operations routine sheet and its entering sequence should be carried out according to the following procedure:

1) Draw a red line over the cycle time plotted on the operating time scale in the graph.
2) The approximate range of process which one worker can handle should be predetermined. The total operations time, which is approximately equal to the cycle time in red, should be computed using the part production capacity chart (Figure 10). Some slack time for walking between machines must be allowed. The walking time should be measured.
3) The amount of manual operation and machine processing times for the first machine are first drawn on this sheet specified already by the capacity sheet.
4) The second operation of this worker must be determined. It should be remembered that the order of processes is not necessarily identical to the operations routine. The walking distance between machines, the point at which product quality is checked , and specific safety precautions must be taken into account at this

stage. Walking time is drawn on the sheet by a wavy line from the ending point of the preceding manual operation to the beginning point of the subsequent manual operation time.

5) Steps 3 and 4 are repeated until the whole operations routine can be determined. When performing the steps, if if the dotted line of the machine processing time reaches the unbroken line of the next manual operation, the operations sequence is not feasible and some other sequence must be chosen.

6) If the final wind-up points meets the red line of cycle time, the operations routine is an appropriate mix. If the final operations ends up before the cycle time line, consider whether more operations can be added. If the final operations overflows the cycle time line, ways to shorten the overflow must be considered. This could be achieved by improving various operations of this worker or perhaps the location of his tools.

The allocations of various operations among workers must be such that each worker can finish all of his assigned operations within the specified cycle time. Also, the layout of processes must be such that each worker has the same cycle so that production line balancing among various processes can be realized. An example of this allocation of operations and layout of processes is shown in Figure 12.

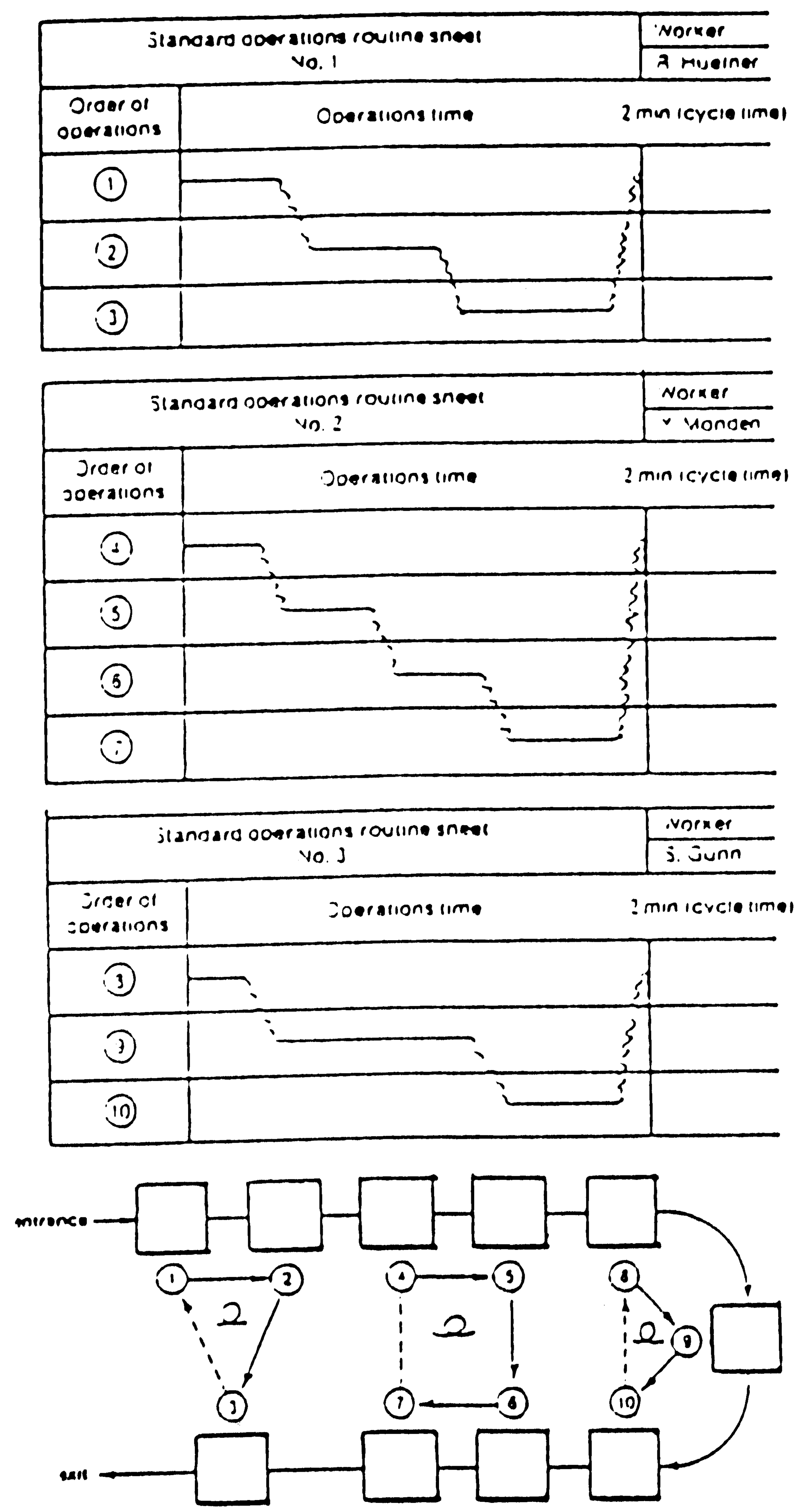


Figure 12: Allocation of Operations and Layout of Processes.

At the actual assignment of process to individual workers in the job combination, the defending zone of each worker's job should not be fixed (by assigning worker's charging zone). Therefore, it is recommended to overlap the worker's charging zone, as well as to provide sufficient flexibility to the charging range. In other words, the job should be well balanced an featured by a good team work.

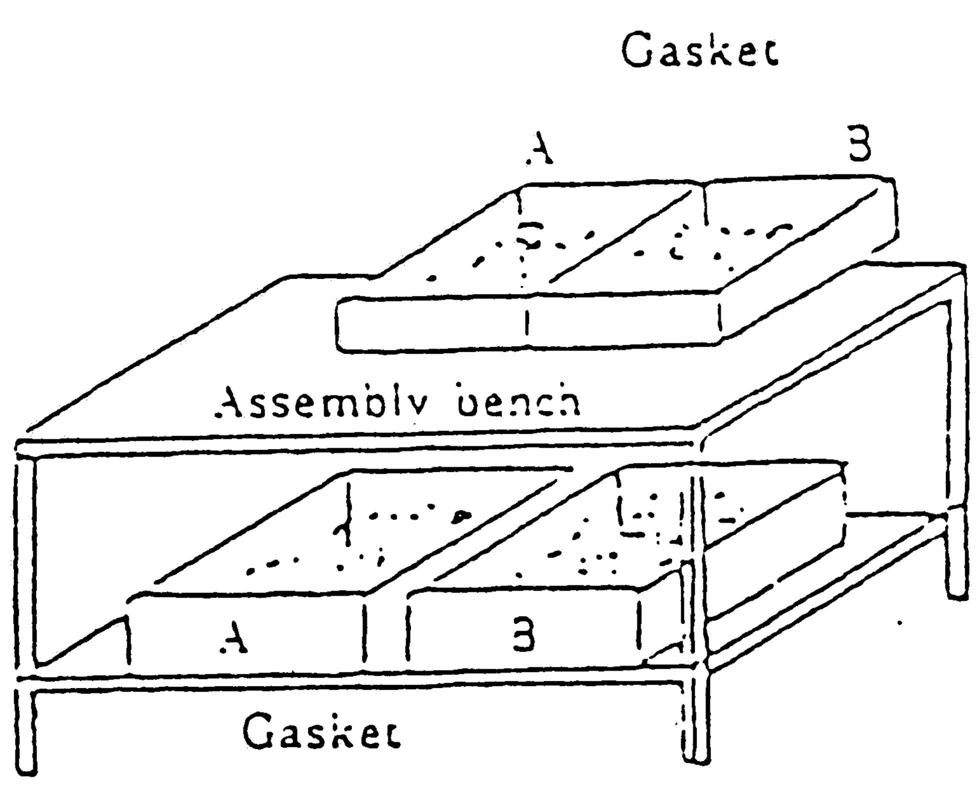
If the charge of an individual's job is pre-fixed, it is equivalent as a swimming relay event, in which, the next swimmer can not start unless the former swimmer may reach the goal. In the same way, unless the upper stream job is finished, the down stream worker will become idle. Also, when a worker's job is delayed articles will accumulate in the worker's process line. As a result, the down stream worker must become idle and wait the arrival of articles.

If any capability difference should exist individually for persons forming the line, such differences can be covered by the capability of the back and forth persons. If the distance between machines is excessive, the communication between workers will be insufficient. According to the improvements, the idea is for the workers to have a better communication.

There are frequent cases in which the creation of a standard job causes non-cyclic jobs (non-standard jobs) to obstruct the performance of the standard job. It is not too much to say that the disparity in hourly production shown by the production control board is mostly due to the effect of these non-standard jobs. Improvements of non-standard jobs is also one of the important points for overall improvement of the operation. Figures 13, 14, and 15 are examples of cases in which non-standard jobs were eliminated.

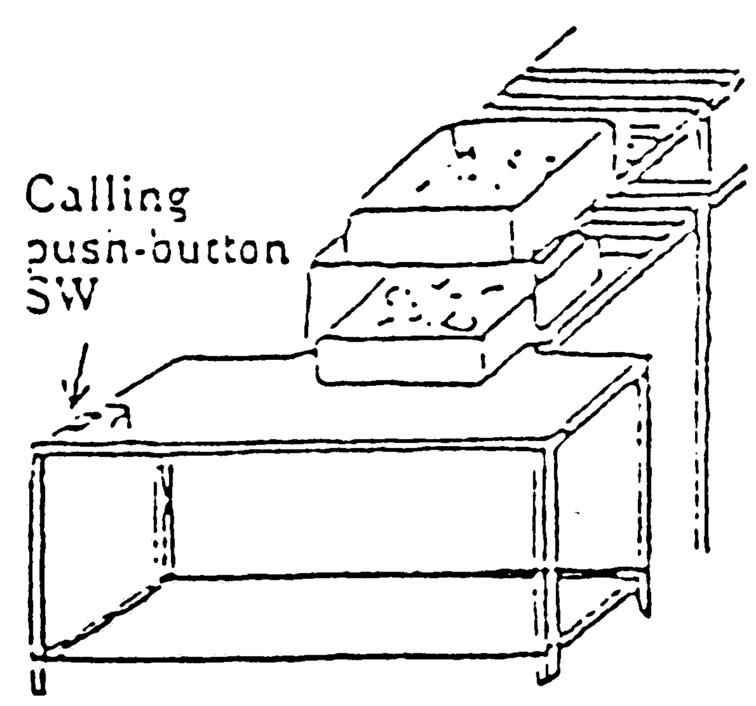
Figure 13: Example of Improvement.

① The case in which parts taking in small quantities (non - standard job) was eliminated (Assembly process)



BEFORE IMPROVEMENT

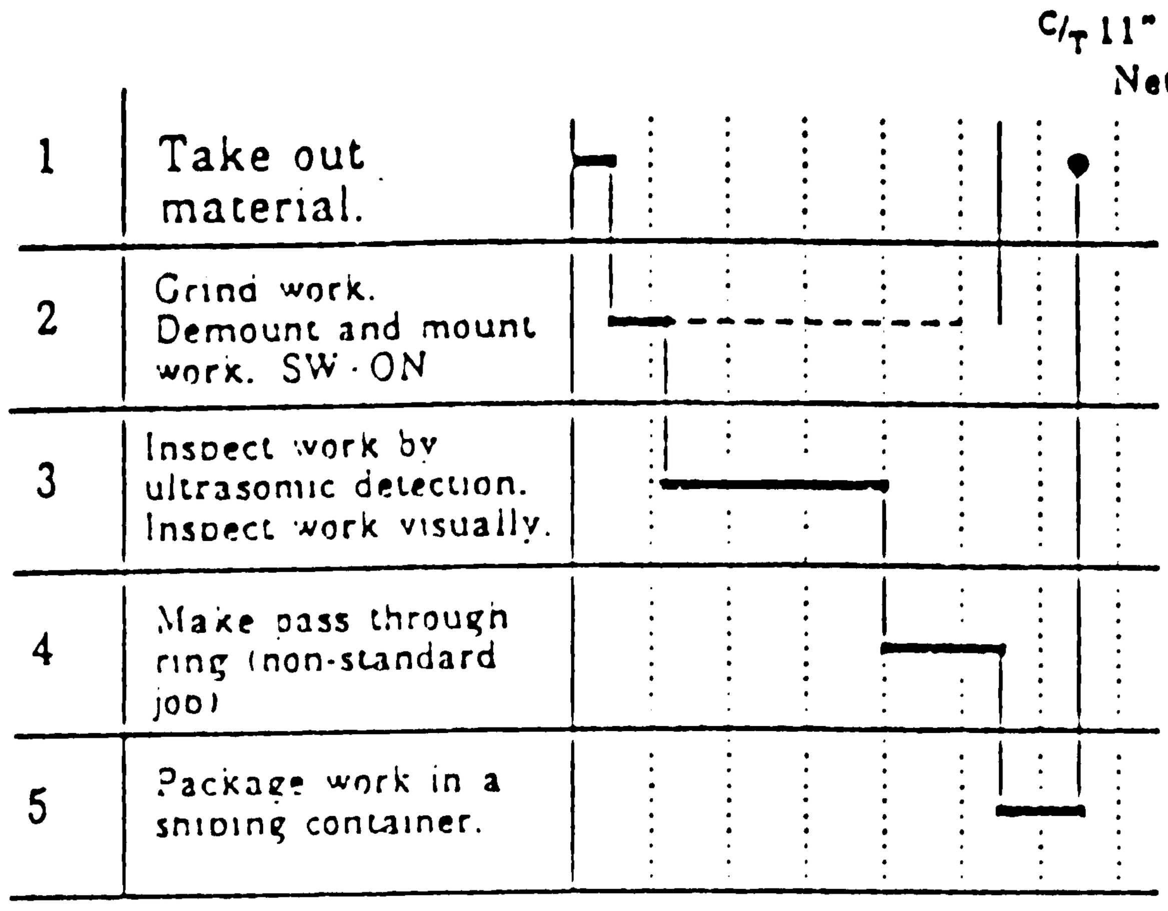
Gaskets were taking out from polyethyleneboxes under the bench to boxes on the assembly bench (One time parts taking out every 15 times assembly)



AFTER IMPROVEMENT

- Box size was decreased. Then, gaskets were taken out from polyethylene boxes directly, and thus, parts taking out small quantilies process was eliminated.
- Resupply of gaskets was made during the other process by depressing a calling indication lamp push-button.

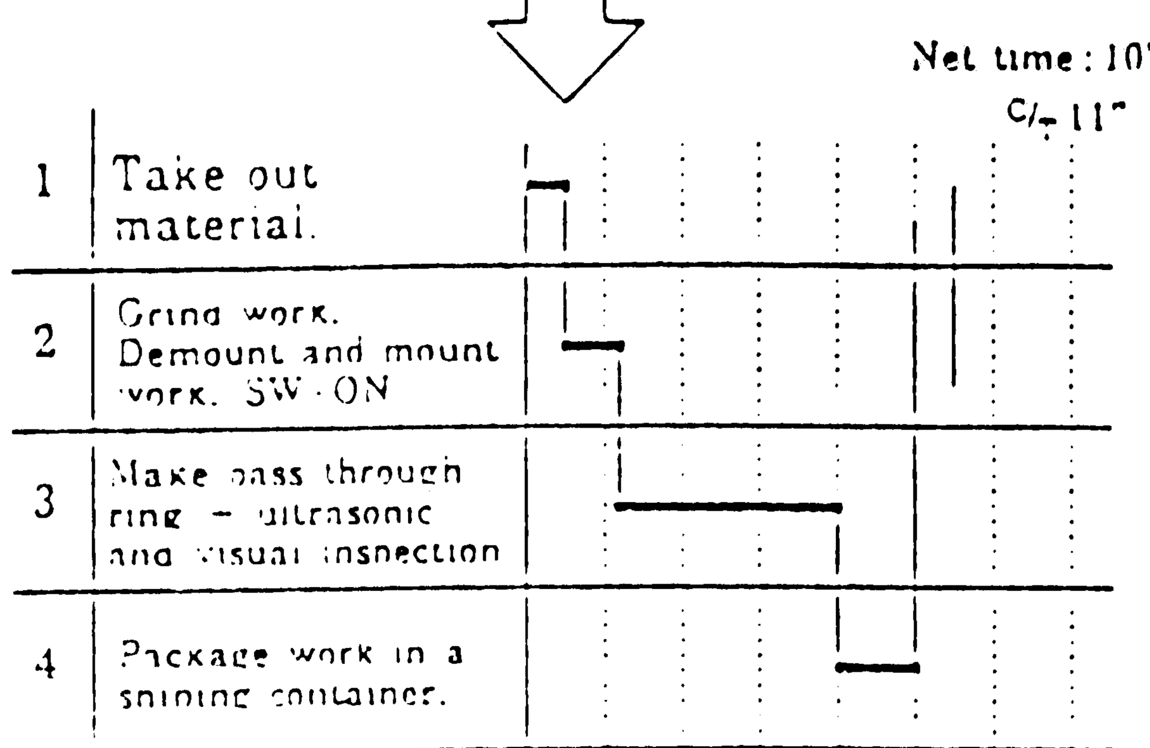
② The case in which a non-standard job in product inspection was eliminated



Combined standard job sheet (1)

Before Improvement

In the machining process of valves, the grinding operation and ultrasonic inspection were performed after surface treatment. On rare occasions of burnt deposits. (expansion of shaft due to surface treatment), a ring (through) test was performed as a non-standard job.



Combined standard job sheet (2)

For Improvement

Jigs were devised to allow ultrasonic inspection and ring (through) test at the same time after finish grinding. This improvement enabled the completion of ring (through) test (a non-standard job) within the cycle time of standard jobs.

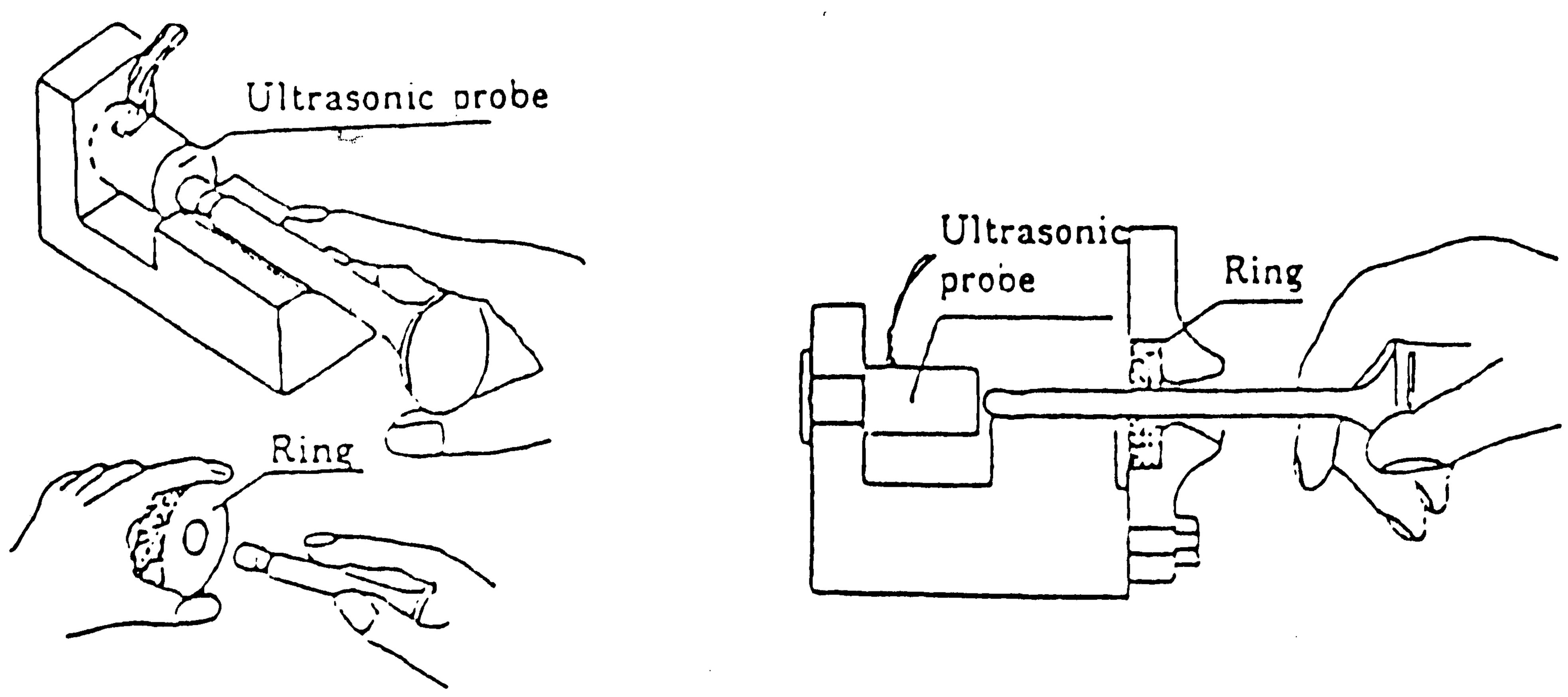
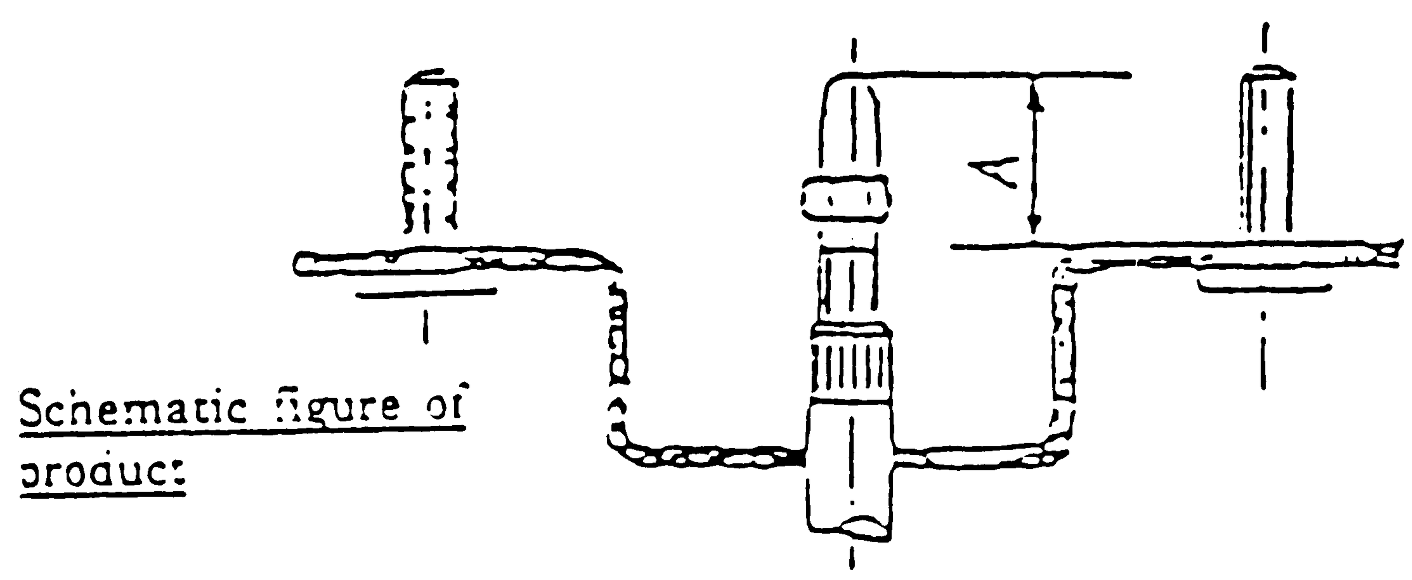


Figure 14: Example of Improvement (Non-standard Job).

(3) The case in which a non-standard job in product inspection was eliminated (Assembly process)



Before Improvement	After Improvement
In the above illustration, the dimension A was measured with a measuring instrument (a), then a turning (rotation) stop device (b) was set on the work and the dimension was adjusted with adjustment device (c). After adjustment, the dimension was checked again with measuring instrument (a). If the specified dimension could not be obtained, the foregoing steps were repeated until the desired dimension was obtained.	A dimension adjustment measuring tool (d) was set on the work. Adjustment of the dimension was made with ratchet handle while reading the dimension on the dial gage and the job was completed when the specified dimension was obtained.

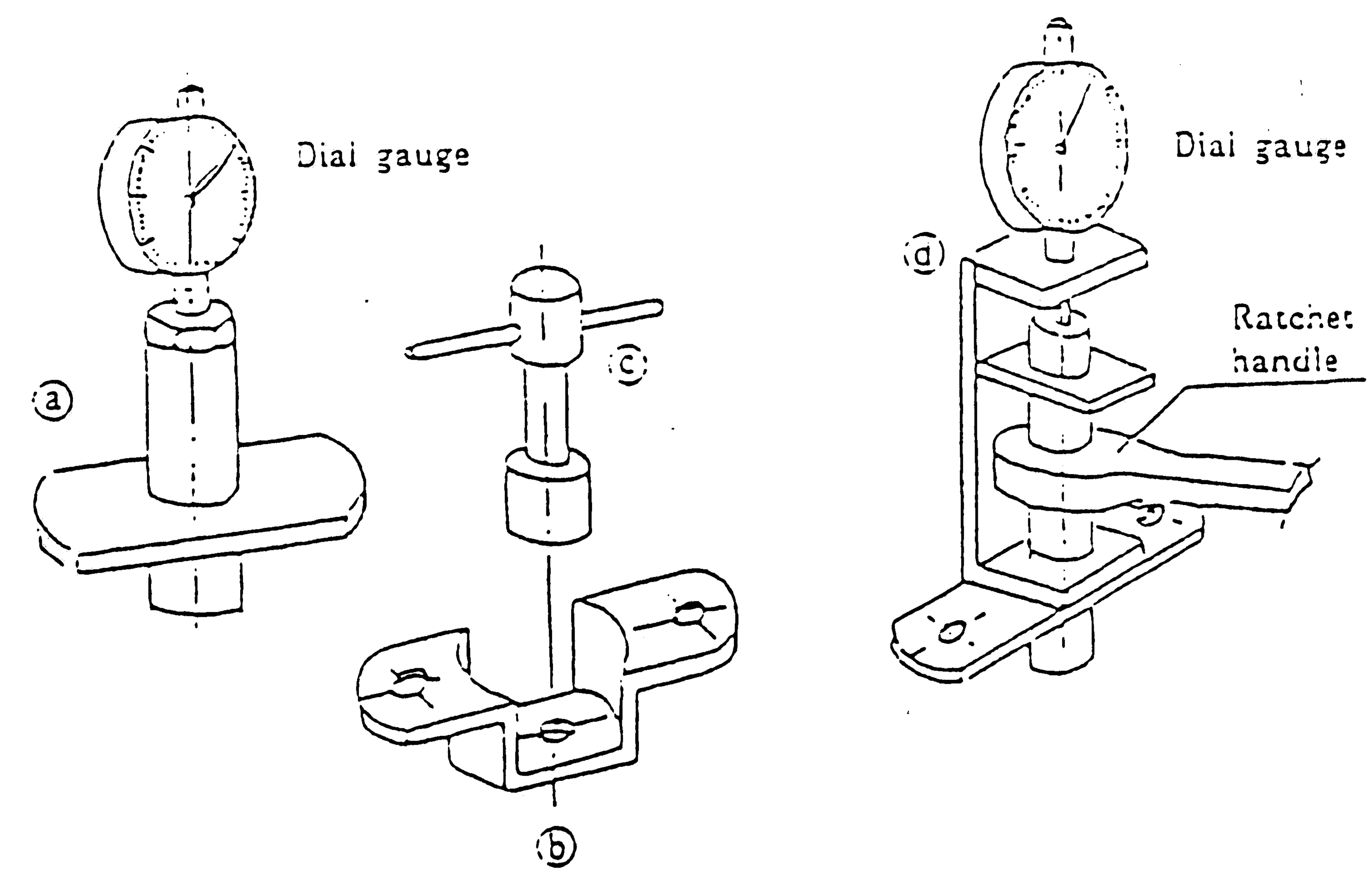


Figure 15: Example of Improvement (Non-standard Job).

4.3.3 Preparation of Job Guidance

The guidance is a standard, through which trainees (workers) are trained adequately by the leader on the standardized job. The job guidance should be prepared in accordance with the contents of the part production capacity chart, and the standard operations routine.

The job guidance should contain the arrangement of machines for one worker. The following jobs are entered, and show how to carry them out:

* Cycle time
* Job sequence
* Standardized WIP
* Net operating time
* Positions to check product quality
* Positions to pay attention to worker safety

By displaying such a STANDARD JOB SHEET, see Figure 16, the foreman and leader can show their will, that is, "We are going to do the job as shown in this sheet".

The foreman and leader have many subordinates. Therefore, it is difficult to remember for the leader all instructions given to their subordinates thoroughly and individually. By referring to the standard job sheet the leader can easily confirm whether the workers are doing their job correctly. In addition, he can add new items to the sheet, or revise it by removing waste or by finding a defect.

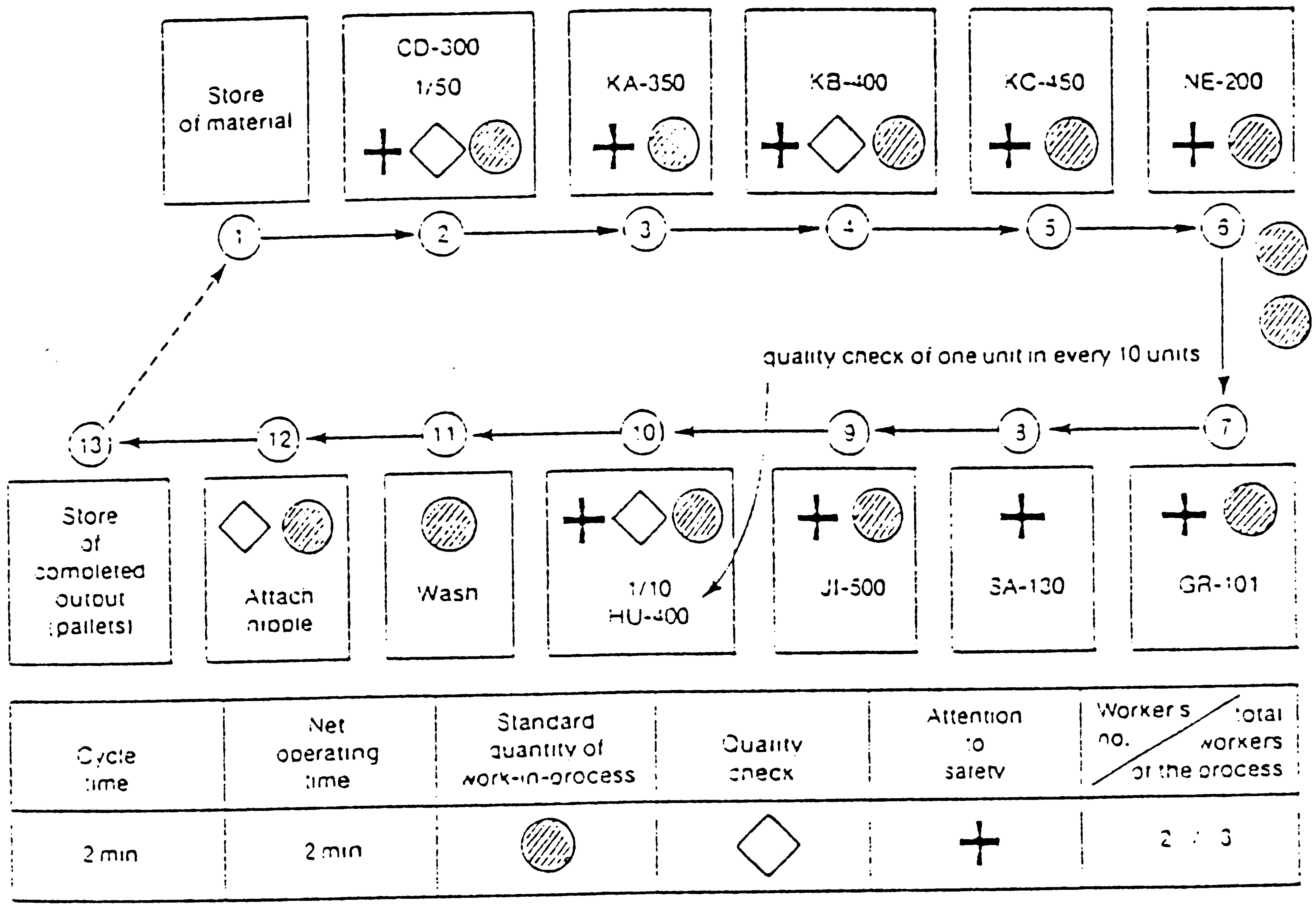


Figure 16: <u>Standard Operations Sheet.</u>

4.4 How to Proceed According to the Standard Job Sheet

The foreman and leader must go through the activity so that all workers should observe the standardized job strictly.

In order to make understand and observe the contents of the standardized operation sheet successfully by the workers, the foreman and leader should show the actual example of the standardized job to the workers. Then, make workers do the standardized job until they can fully understand it.

Check the performing results of the standardized job. If any abnormality should occur, adequate countermeasures should be taken to pursuit the causes thoroughly and the discrepancy should be rectified immediately. The contents of the modification and the reason must be transmitted to all the members.

The foreman and leader must pay special attention to the abnormalities of the standardized job at all times. Even if it is a careless miss, it is essential to investigate the causes, in other words, the above should not be treated as a simple careless miss.

4.5 Summary

The life of a manufacturing plant is entirely dependent on the production line. Therefore, the supervisors in the first line who are entrusted with the operation of the production line must must have a strong desire for constant improvement.

In this sense, standard jobs can be effective only when the supervisor create them with all their efforts and have their workers observe and practice them strictly. It should be emphasized that the standard jobs can not be an efficient tool for improvement of production lines if the the supervisor does not take pride and property of each of the standard jobs he creates.

5. CASE STUDY

It should be clear by now the theoretical process in designing a JIT cell. It is intended to present this case study, not to leave the reader in mere theory but to bring him/her closer to reality.

The case study does not pretend to offer a methodology in design nor to present the details of design and implementation. Mainly, the benchmarks through the design process and its implementation will be given.

5.1 Preliminary Production Evaluation (As Is)

The design project, including a preview analysis of the plant, was performed in four months. The production line to be evaluated manufactured bearings. Fifty five (55) different types of bearings were manufactured through two parallel production lines (line X and line Y). Not all products were processed through the same machines nor the products had the same operating times when processed through the same machines.

There were at the moment five (5) operators attending each line. Containers, with a capacity of 130 pieces for line X and 52 pieces for line Y, were used as a material handling device between cells along the production lines. The name (manufacturer) and number of each machine appears in the layout.

A brief comment under each heading of the As-Is section will be made. The number preceding each paragraph makes allusion to each subject heading.

1. The two lines were in parallel. Line Y had two gravity conveyers that were not used. The machines with dotted lines in line X did not exist, and the pieces were sent to the equivalent machines in line Y.

2. There was a production of approximately 73,000 bearings to be manufactured. The company expected to reach a production of 110,000 parts by 1990. Although there are fifty five different types of bearings (shafts), not all of them were manufactured monthly. The 80-20 rule was evident (see ABC CURVE). Shipments of finished products are done on a weekly basis.

3. A monthly requirements plan is elaborated two weeks ahead of real production. The forecasts

done at the beginning of the year are accurate to 70% of the quantities to be manufactured. The forecast is updated every month. After the monthly plan is decided, the foreman of the line decides weekly what pieces to manufacture and on what days

4. As it can be seen the 20-80 rule is evident, seven (7) references, making a 14% of the product mix in demand, represents 70% of the production quantity to be manufactured.

5. The inventory level for raw material is of one month, or twenty (20) working days. The rather high WIP is due to the capacity of the containers moving between cells along the line, making it a batch processing within a lot size production.

6. The extreme values of capacities were calculated. The piece with least processing time along the one line, will offer the largest quantity of units able to be produced by the line. To be able to do these calculations correctly, the operating times given by the Methods (or Process) Dept. of the company have to be evaluated, even perhaps updated. These operating times are the

foundations in which the design will be based.

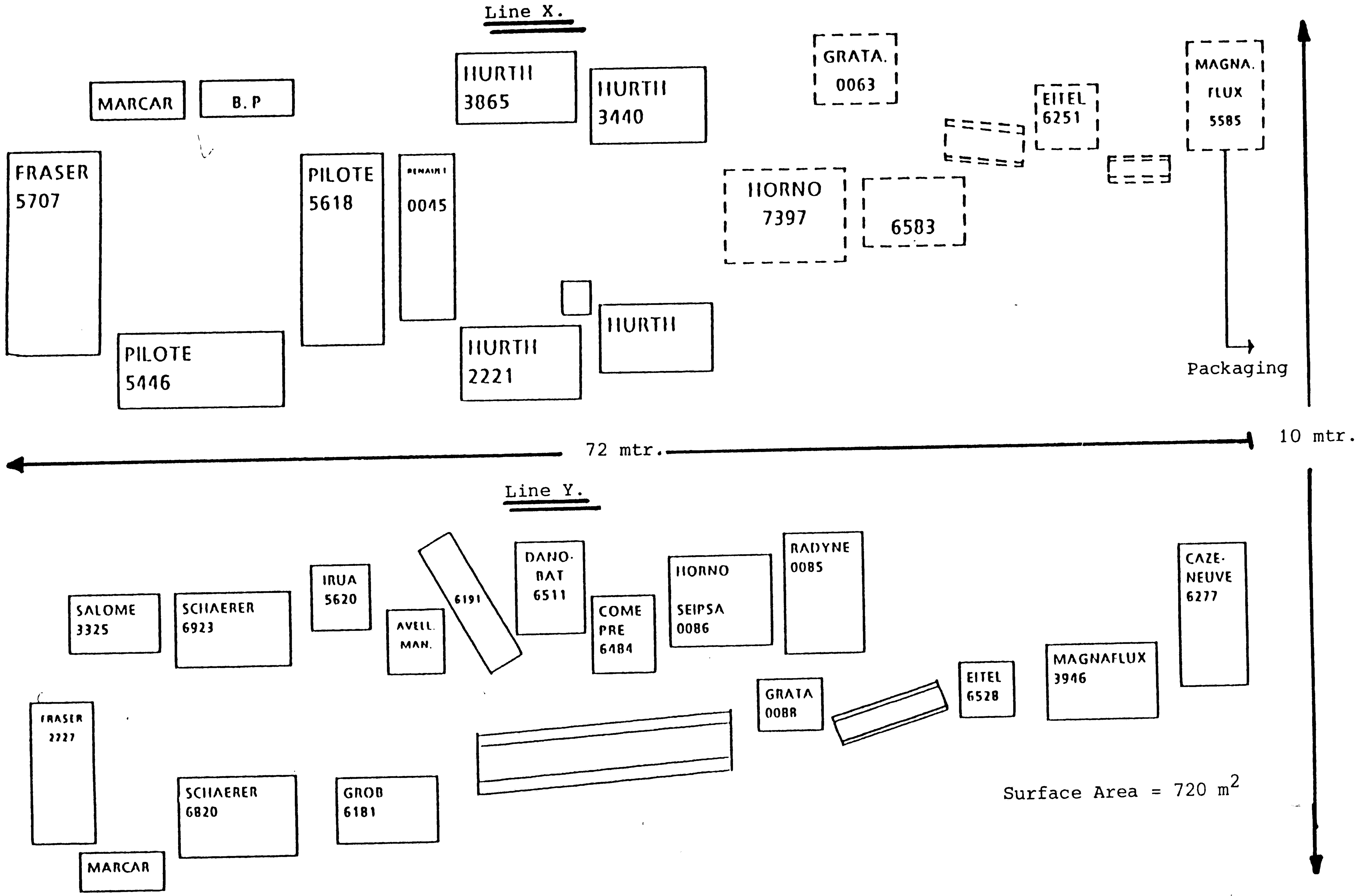
7. The bearings, as raw material, have two suppliers. Both of them deliver on a weekly basis.

8. Since the material was batch processed within the line, it took one piece (in reality a batch) at least four shifts to be finished. To contrast this value, it is compared to the net processing time of one piece, the time to finish a piece with no downtime or WIP in the Production line, which is of forty (40) minutes.

9. Most of the operators have been in the company for more than twenty (20) years. Their skills are specialized to one type of machine. Team work is not promoted. The important fact is to meet the daily quota. All the operators are part of a workers union.

AS – IS

1. LAYOUT
2. DEMAND
3. SCHEDULING SYSTEM
4. ABC CURVE
5. INVENTORY LEVEL
6. PRODUCTION CAPACITY
7. REPLENISHMENT
8. FLOW ANALYSIS
9. HUMAN RESOURCES



Line X.
MARCAR
B.P
FRASER 5707
PILOTE 5618
0045
HURTH 3865
HURTH 3440
GRATA. 0063
EITEL 6251
MAGNA. FLUX 5585
HORNO 7397
6583
HURTH
HURTH 2221
PILOTE 5446
Packaging
72 mtr.
10 mtr.
Line Y.
SALOME 3325
SCHAERER 6923
IRUA 5620
AVELL. MAN.
6191
DANO-BAT 6511
COME PRE 6484
HORNO SEIPSA 0086
RADYNE 0085
CAZE-NEUVE 6277
FRASER 2227
GRATA 0088
EITEL 6528
MAGNAFLUX 3946
SCHAERER 6820
GROB 6181
MARCAR
Surface Area = 720 m2

1. Layout

2. DEMAND

CHARACTERISTICS

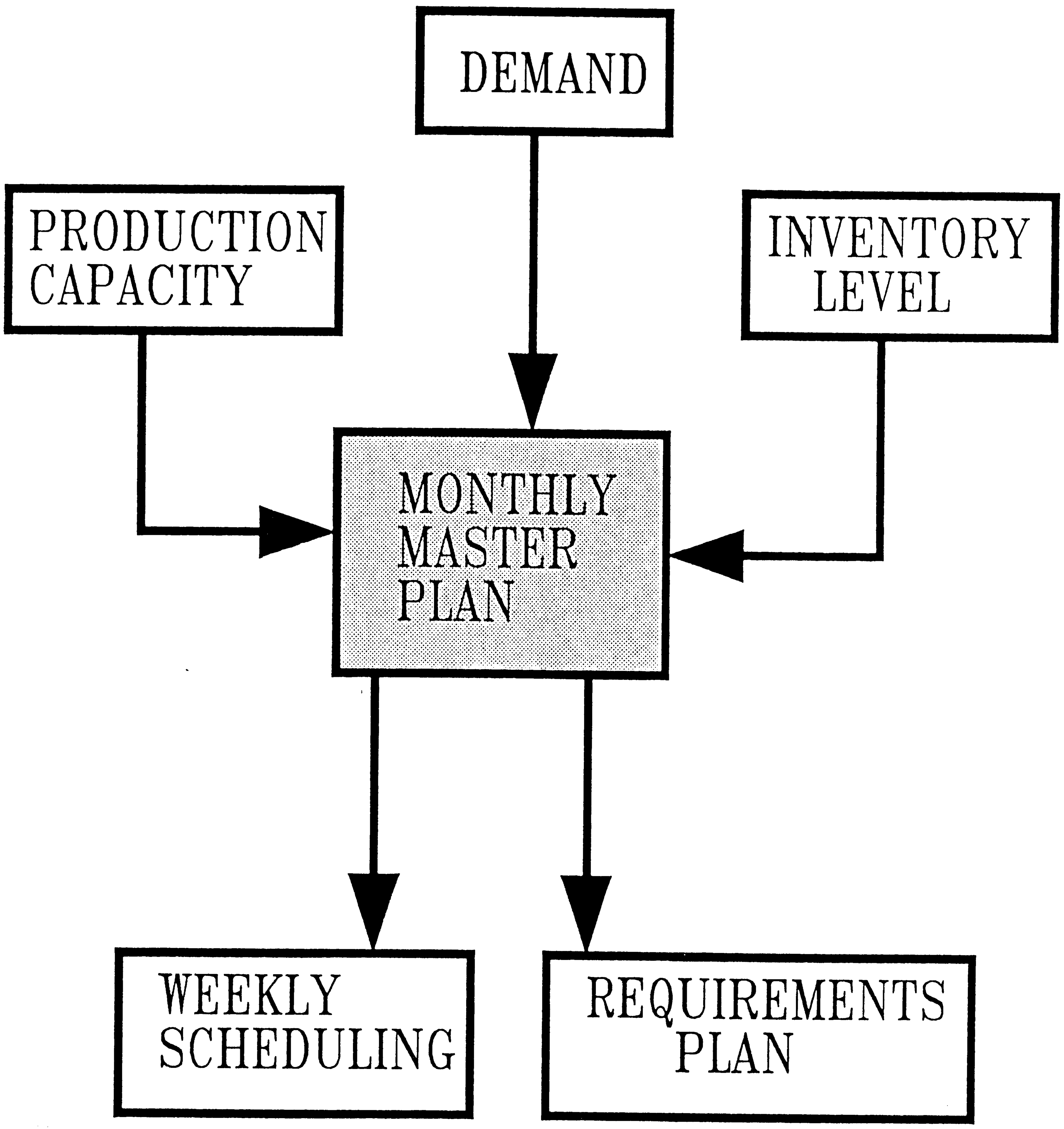
There is an annual forecast received at the beginning of the year.

The program of pieces to be manufactures in the Nth month is received in the middle of the Nth-1 month.

Withdrawal of products:

- Variable frequency - two to four times/week
- Withdrawal quantities tend to be homogeneous throughout the month (25%).

3. SCHEDULING SYSTEM



4. ABC CURVE

7 REFERENCES TIPE A = 70% PRODUCTION

11 REFERENCES TIPE B = 17% PRODUCTION

33 REFERENCES TIPE C = 13% PRODUCTION

ABC OF PRODUCTS

SHAFTS TIPE A:

REFERENCE	ANNUAL QUANTITY	%	ANNUAL COST
3722-SPF	15.000	21.1	42 M Pts
3769-SPF	9.000	12.7	26
1280-CPPF	7.000	9.85	18
3758-SPF	6.000	8.45	20
8019-CPE	4.716	6.65	35
3280-CPF	4.000	5.65	12
3279-CPF	4.000	5.65	11.5
8 SHAFTS	49.7716	70.0	164.5

SHAFTS TIPE B:

REFERENCE	ANNUAL QUANTITY	%	ANNUAL COST
3905-SPF	1.250	1.76	3.1 M Pts.
9174-CPE	1.205	1.7	9.8
1399-CPF	1.100	1.55	3.1
671400-CPF	1.100	1.55	3.0
191300-SPF	1.100	1.55	3.0
191400-SPF	1.100	1.55	3.2
4624-SPF	1.100	1.55	2.7
4625-SPF	1.100	1.55	2.4
1398-CPF	1.100	1.55	5.6
4019-SPF	1.000	1.41	2.7
391300-SPF	800	1.13	2.0
11 SHAFTS	11.955	16.87	40.6

SHAFTS TIPE C:

REFERENCE	ANNUAL QUANTITY	%	ANNUAL COST
4000-SPF	600	0.84	1.6 M Pts
4100-SPF	600	0.84	1.4
5833-CPF	561	0.79	2.1
5832-CPF	561	0.79	2.5
5831-CPF	561	0.79	2.2
3908-CPF	500	0.70	1.3
2700-SPF	500	0.70	1.3
3900-SPF	500	0.70	1.2
8100-CPE	390	0.55	3.5
8101-CPE	390	0.55	3.0
1100-SPF	300	0.42	0.8
0400-SPF	300	0.42	0.8
4331-SPF	300	0.42	0.9
4839-SPF	300	0.42	0.8
4840-SPF	300	0.42	0.8
4841-SPF	300	0.42	0.8
5789-SPF	275	0.39	0.8
7000-CPE	252	0.35	?
5802-SPF	240	0.34	1.25
5838-SPF	240	0.34	0.65
5385-SPF	220	0.31	0.6
5386-SPF	220	0.31	0.55
5790-SPF	165	0.23	0.5
5791-SPF	165	0.23	1.9
0200-CPE	159	0.22	1.5
0300-CPE	159	0.22	1.3
7500-CPE	51	0.1	0.65
5540-SPF	50	0.1	0.15
5541-SPF	50	0.1	0.20
5796-SPF	50	0.1	0.15
5803-SPF	50	0.1	0.15
4978-SPF	50	0.1	0.1
4622-SPF	50	0.1	0.1
33 SHAFTS	9.409	13.24	34.8

5. INVENTORY LEVEL

A. FINISHED PRODUCT:

Type A = 4,200 parts = 19 days

Type B = 1,250 parts = 23 days

Type C = 1,300 parts = 30 days

B. WORK IN PROCESS:

Line X: 1,335 parts = 6.5 days

Line Y: 360 parts = 2.75 days

6. PRODUCTION CAPACITY

Line X:

Max. capacity for part with least processing time = 4,148 shafts/month.

Max. capacity for part with largest processing time = 1,198 shafts/month.

Real average production = 3,979 shafts/month.

Utilization = 95%

Line Y:

Max. capacity for part with least processing time = 3,665 shafts/month.

Max. capacity for part with largest processing time = 2,296 shafts/month.

Real average production = 2,482 shafts/month.

Utilization = 75.8%

7. REPLENISHMENT

SUPPLIERS

One Spanish ---> 24 hrs. distance

One French ----> 48 hrs. distance

REPLENISHMENT

Parts	Quantity	Frequency
Type A	Fractioned lot sizes	1/week
Type B	Fract/Complete lot sizes	2 to 3/month
Type C	Complete lot sizes	Randomly

8. FLOW ANALYSIS

LEAD TIME

Average lead time = 35 hours for one piece.

Net processing time = 40 minutes for one piece.

AVERAGE LOT SIZE

Type A ---> 645 parts = 2.85 days

Type B ---> 99 parts = 1.8 days

Type C ---> 26 prts = 0.6 days*

SETUPS

There are approximately 65 setups performed in one moth = 75 hrs/month.

SCRAP

Amount of parts rejected = 1165/3 months.

Equivalent to 250 hrs. of a workers' time

93.6% ---> due to processing

6.4% ----> due to the suppliers

* In reality the minimum lot size = 51 parts

9. HUMAN RESOURCES

Direct labor = 27 workers

16 workers ---> 20+ years in Co.

9 workers ---> 15 to 20 years in Co.

90% of the workers are specialized.

The distribution of rank among the workers, follows a Gaussen curve.

13% of their salary is based in a productivity incentive.

5.2 Design of JIT Cell (To Be)

The change of layout was done in one weekend. On the first day of implementation, only one quarter (1/4) of the planned production was met. Workers were lost. Material and operators were moving in the wrong direction. The chaos was reality. But all this was expected. Workers were trained before implementing, the concept of cycle time was explained, as well as one piece production and conveyance. It took two weeks to achieve the production plan.

The SMED concepts were applied to lower the setup times of the machines. Preventive maintenance was promoted in order to avoid any downtime. Workers are in a job rotation program so they can be multi-skilled. Incentive is applied to quality, to reduce the number of rejected parts.

In general terms the results were as follows:

CONCEPT	REDUCTION
1. Surface area	23 %
2. WIP	69 %
3. Direct labor	23 %
4. Lead time	88 %

The design was performed taking only in consideration type A references. Presented here, is only the work done for line Y and more in particular with part 5225000671399 as reference. The work was done for both lines and taking in consideration all references type A.

Comments on the subjects follow:

1. Among the pieces processed through line Y, four (4) part families were determined. The quantities determined for each part is the real consumption for this year, with an adjustment for next years forecast.

2. The line was divided in three processes: before, during, and after heat treatment. Before heat treatment is where the pieces obtain most of their value added in the process. The installations of the heat treatment process are not worth being changed due to its cost. After heat treatment most of the activity is manual operations which can not be altered, plus inspection and packaging. If the hours of repair during a breakdown are performed during a second or third shift in which that specific machine is not supposed to work, those hours of repair are not accounted for.

3. The goal is to perform 15 setups in one month (average) to an equivalent of thirty (30) hours. The Single Minute Exchange Die (SMED) concepts were applied. Some twenty (20) setups are done presently.

4. An example of the operating times needed is shown. These times have to be obtained for all the references to be processed. The main point is to obtain the quantity of manual (operators) time is required per unit.

5. Having the operating times of each reference a table like the one shown is prepared to obtain the load handled by each machine. The requirements of time per machine per piece is known.

6. Dividing the amount of necessary minutes per reference in a month by the amount of available minutes, the number of workers needed to process the pieces is obtained.

7. A standard operations routine can then be developed, showing the divisions of task for each operator needed.

8. The layout and allocation of workers is shown. Not shown, is a worker covering the heat treat process and packaging and a second worker in the press straightening the bearings, this is a complete manual operation and also a labor intensive one.

TO - BE

1. DEMAND
2. MACHINE BREAKDOWNS
3. MACHINE SETUPS
4. OPERATING TIMES
5. MACHINE LOADING
6. LABOR REQUIREMENTS
7. STANDARD OPERATIONS ROUTINE SHEET
8. LAYOUT AND WORKERS ALLOCATION

1. DEMAND

Reference No.	Annual Demand
* 5225000653279	3099
* 5225000653280	3035
5225000671280	0
5225000671398	217
* 5225000671399	2285
* 5225000671400	2330
5225000675831	24
5225000675832	15
5225000675833	29
5220023830200	161
5220023830300	161
5220060717500	47
5220060757000	248
* 5224064608019	5938
5224064608100	947
5224064608101	1007
* 5224064609174	1653

TOTAL
17 references
21,196 parts

There are four (4) major part families.

* Type A reference.

2. MACHINE BREAKDOWNS

	HOURS OF REPAIR/DAY	DOWNTIME DURING SHIFTS PER DAY	REAL DOWNTIME IN A DAY
BEFORE HEAT TREATMENT	3.52	0.72	1.2
HEAT TREAT	4.3	0.85	0.4
AFTER HEAT TREATMENT	0.15	0	0.03

Units of time = hours

NON-STANDARD JOBS

For one day production....

- Before heat treatment = 2.73 hrs
- Heat treat = 0.7 hrs
- After heat treatment = 0.75 hrs

3. MACHINE SETUPS

GOAL: 2 hours to setup the whole line using two workers.

REFERENCE NO.	FRECUENCY	
8019 3280 3279 1399 1400 9174	EVERY TWO WEEKS	12 setups/month
8101 8100	MONTHLY	2 setups/month
1398 0200 0300 5700	BI-ANNUAL	4/6 setups/month
7500 5831 5832 5833	ANNUAL	4/12 setups/month
		TOTAL = 15 setups/month

4. OPERATING TIMES

LINE Y

Reference: 5000671399

MACHINE	DESCRIPTION	MANUAL TIME	MACHINE TIME	WALKING TIME	OPERATION TIME
2227	Shaper	47	281	59	328
PRESS	Mark	45	---	21	45
3325	Lathe	134	273	33	377
6829/ 6923	Lathe	85	826	59	890
6181	Grind	166	371	34	482
5620	Drill	256	164	44	420
BENCH	Bore	200	---	16	200
0086	Annealing	63	---	22	63
0085	Heat treat	83	629	16	692
0086	Tempering	60	---	16	60
0088	Brushing	84	259	11	412
		69			
6528	Straighten	918	---	15	918
3946	Inspection	450	---	16	450
BEANCH	Packaging	100	---	16	100

Time units = 10,000ths of a minute.

Manual (man) Time = 933

Walking Time = 266

**** Total Man Time = 1199 ****

LINE Y														
Machine	Description	500653279		5000653280		5000671399		5000671400		4064609174		4064608019		Load
		Seq	Oper Tm	Seq	Oper Tm	Seq	Oper Tm	Seq	Oper Tm	Seq	Oper Tm	Seq	Oper Tm	
2227	Shape	1	328	1	328	1	328	1	328	1	507	1	328	3'8 h
3325	Lathe	2	502	2	502	2	377	2	377	2	668	2	445	5'1 h
6820	Lathe	3	567	3	567	3	445	3	445	3	1433	3	454	6'6 h
6923	Lathe	3	567	3	567	3	445	3	445	3	1433	3	454	6'6 h
6181	Grind	4	401	4	401	4	482	4	482	4	362	4	620	5'2 h
5620	Drill					5	420	5	420					1'1 h
6511	Drill									5	471	5	471	2'2 h
6484	Mill/Bore									6	1441	6	1441	6'8 h
6191	Drill	5	130	5	130									4'5 h
0085	Heat treat	6	793	6	817	6	815	6	789	7	886	7	998	9'1 h
0088	Brushing	7	469	7	483	7	412	7	403	8	488	8	489	5 h
6528	Straighten	8	922	8	921	8	918	8	735	9	545	9	871	9 h
3946	Inspection	9	450	9	450	9	450	9	450	10	450	10	450	4'8 h
6277	Shape/bore									11	125	11	238	1 h
	Packaging	10	100	10	100	10	100	10	100	12	100	12	100	1 h
Production Hrs. Required...		16		15		13		12		15		36		← 107

Oper Tm = Operating Time, in 10,000ths of a minute.

5. MACHINE LOADING

LINE Y

Number of shifts/day = 2

Number of hours/day = 15,84

Amount of lost time/day = 4,97

Operating hours/day = 10,875

Operating minutes/month = 13050

Amount of lost time/day:

Non-standard jobs = 0,69 hrs

Breakdowns = 1 hr

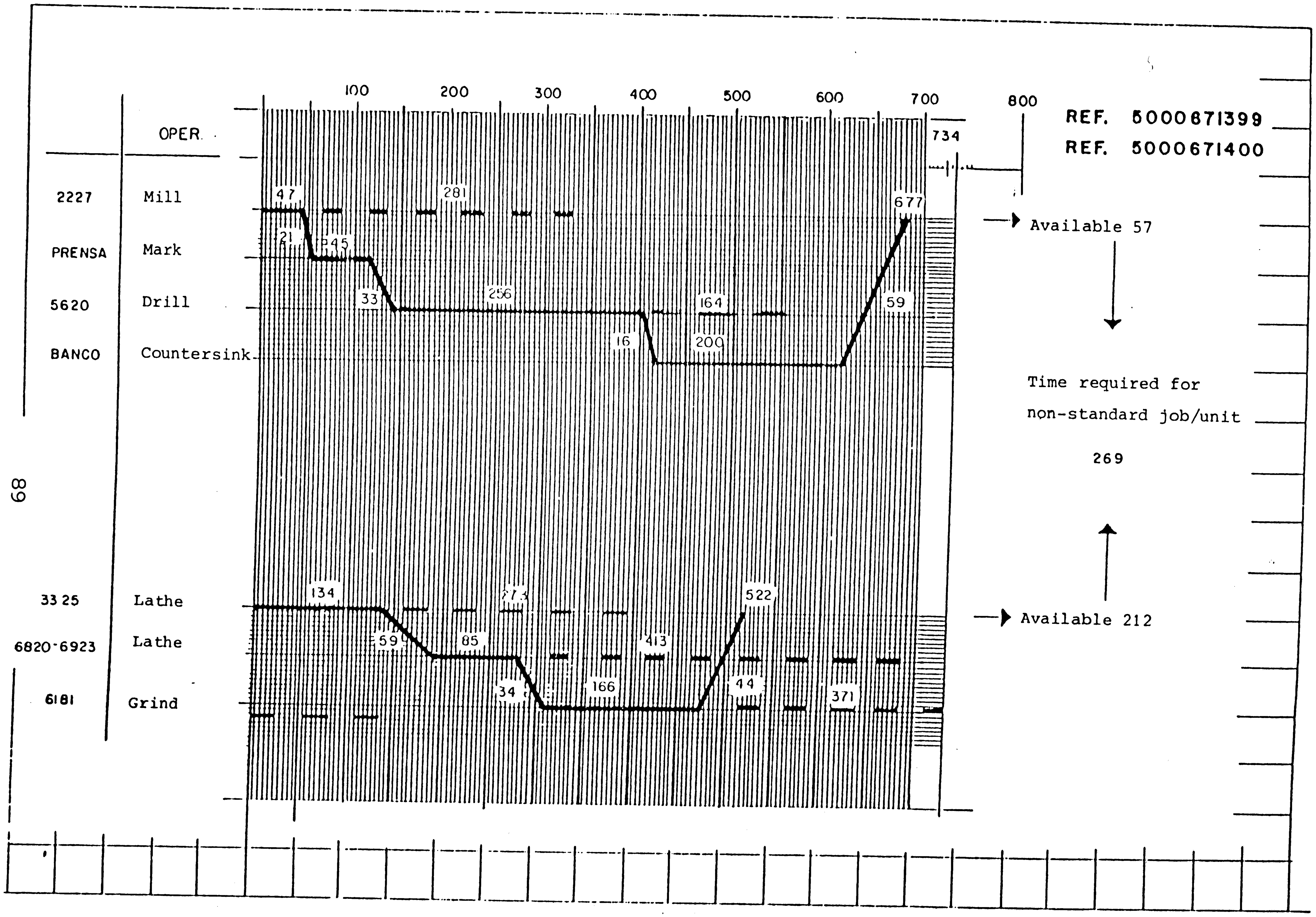
Personal needs & fatigue = 1,78 hrs

Setups = 1,5 hrs

TOTAL = 4,97 hrs

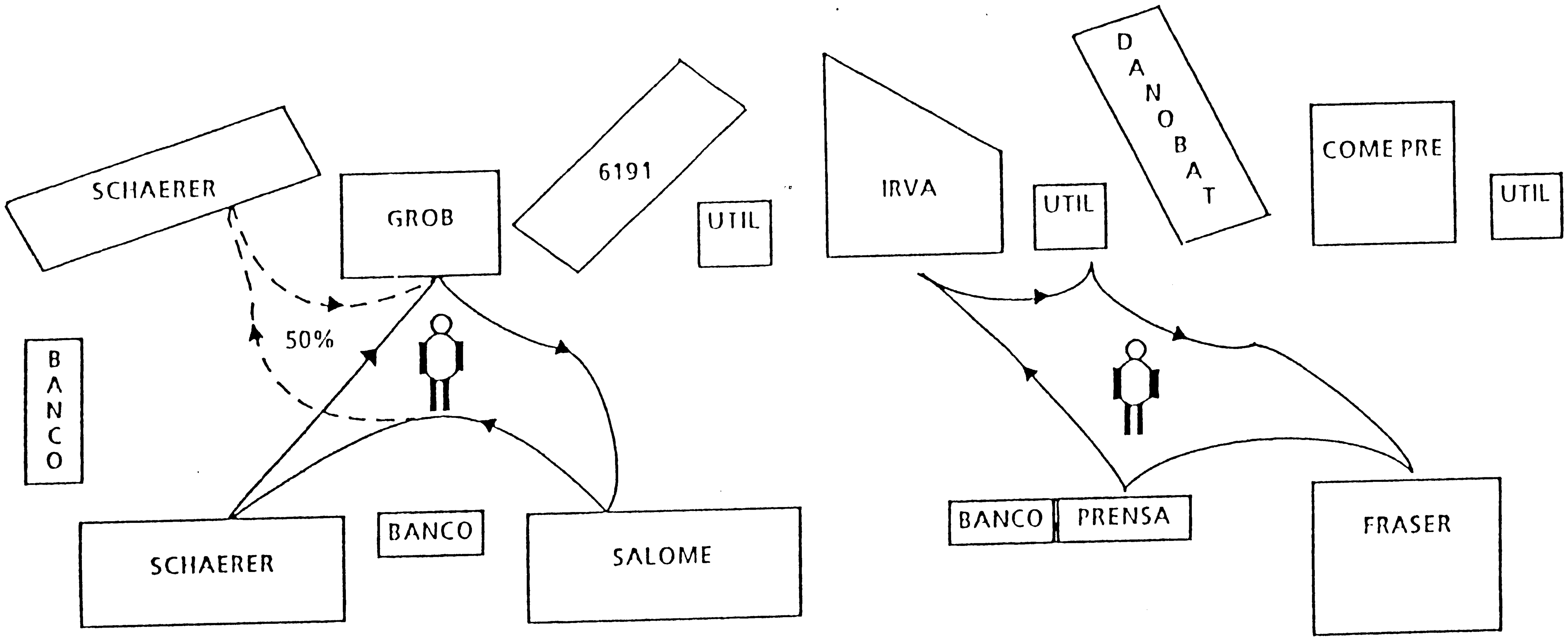
REFERENCE	DEMAND/MONTH (+8%)	Completion Time/Unit		Necessary Minutes per Reference in a Month.	%	Available Minutes per Reference in a Month.	CYCLE TIME		No. of Workers
		10,000 of min.	Sec.				10,000 of min.	Sec.	
5225000653279	305	890	320,4	1628,7	7,7	1004,85	550	197,6	1,6→2
5225000653280	298	890	320,4	1591,3	7,5	978,75	548	197	1,6→2
5225000671399	246	1199	431,6	1769,5	8,3	1083,15	733,8	264,1	1,6→2
5225000671400	229	1199	431,6	1647,3	7,7	1004,85	731,3	263,2	1,6→2
5224064608019	293	2427	873,7	4266,6	20,1	2623,05	1492	537,1	1,6→2
5224064609174	705	2427	873,7	10266,2	48,7	6355,3	1502	540,8	1,6→2
TOTAL	2076			21169,6		13050			

6. LABOR REQUIREMENTS



7. STANDARD OPERATIONS ROUTINE SHEET

LINE Y



Banco = Bench
Prensa = Press
Util = Working table

REF. 5000671399
5000671400

8. LAYOUT AND WORKERS ALLOCATION

6. DISCUSSION

As stated in the case study, the change of layout of the new line was performed in one weekend. Although operators were trained in classroom before implementation, only one quarter (1/4) of the production plan was met the first day the line began production. It took fifteen working days to adapt to one piece production and conveyance and meet the expected production plan.

Considerable reductions in Work-In-Process and lead time were obtained, 69% and 88%, respectively. Problems detected in the line are solved by the operators immediately. Incentives are given for quality, teamwork, and operational know-how of the machines. Promotions are awarded to operators who demonstrate the skills to operate the various machines. Preventive maintenance plays an important role in order to avoid machine breakdowns.

Advanced manufacturing systems affect each tier of production (assembly, subassembly, and components) in a different way so that, at each, the cost of failing to invest in process technology is quite different (15). Each tier will have its own special problems with respect to production flexibility and quality.

Assemblers realize high profits mainly from innovations in distribution and marketing (15); process technology -such as automation and robotics- is not as important to assemblers as is organizing the work force into flexible, focused production lines and introducing JIT.

Upon recognition of the matters related up to this stage, the Just In Time Production System performs on the following two basic concepts.

First of all, the thing that corresponds to the first recognition of putting in forth all efforts to attain low cost production is "reduction of cost through elimination of waste". This involves making up a system that will thoroughly eliminate waste by assuming that anything other than the minimum amount of equipment, materials, and workers (working time) which are absolutely essential to production are merely surplus that only raise the cost.

The thing that corresponds to the second recognition of a JIT system, is "to make full use of the workers' capabilities". Build up a system that will allow the workers to display their full capabilities by themselves.

Schonberger claims, "Japanese have had little trouble learning our techniques, and we will have little trouble learning theirs" (29). When a worker has been performing his job for twenty five (25) years in front of the same machine with labor incentives where quantity is the main ingredient, and one day he is told the concept of "job rotation", elimination of waste movements, U-turn layout, "shojinka" (meeting demand through flexibility), etc... he will react unfavorably to that change. Much can be said about JIT and its benefits, but the design stage of this type of manufacturing system begins by training the workers, training for evolution of the human factor.

Time is clearly one of the major parameters that requires study, understanding, and control (9). Just In Time shortens the lead time from concept out to customer satisfaction. This is so, partly, because innovations concerning productivity and quality improvement are nurtured on the shop floor, not in someone's office. In addition, the attitude for new improvements is a never ending process. This reduction in lead time is exemplified by the time it takes the Japanese to transform a car from the design table to the assembly line, a period of approximately forty five months, compared to sixty months in the American industry.

Therefore, Just In Time production system is the answer to the manufacturing world in the coming decades, this thesis should be a reminder that the gap between design and implementation lays, not in the technique and the theory behind it, but in complementing it with the human factor.

This thesis should lay the groundwork to further explore how companies should evolve with Just In Time and other CIM technologies. Technologies that change corporate cultures. Evolve not only in a management or strategic point of view, but in coping with the gap between design and its practical application. Companies, that in order to level with the competition will face a dead end if they do not apply them.

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BIOGRAPHY

Ivan M. Saldana Varela, the youngest son of Ana Maria Varela and Raoul Saldana, was born in June 4, 1965 in La Coruna, Spain. Raised in Puerto Rico, he attended the Colegio San Ignacio de Loyola before entering at Villanova University, Villanova, Pennsylvania. He graduated in August of 1986 from Villanova University with Dean's List in Mechanical Engineering. He obtained his Bachelors Degree in three years.

In the Fall of 1986, Ivan entered with a scholarship to Lehigh University in pursuit of his Masters of Science in Manufacturing Systems Engineering. During his year and a half at Lehigh, he worked as a Research Assistant in the Center for Design and Manufacturing Innovations. In January of 1988, he accepted an offer to work for Price Waterhouse Consulting Division in Madrid, Spain. A year after, he transferred to Arthur D. Little - Madrid.