JIT Implementation Manual

The Complete Guide to Just-in-Time Manufacturing

Second Edition

Volume 5

Standardized Operations – Jidoka and Maintenance/Safety

HIROYUKI HIRANO

CRC Press
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A PRODUCTIVITY PRESS BOOK

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Overview of Standard Operations

Why Do We Need Standard Operations?

It so happens that many of the most important elements in the daily activity of manufacturing begin with the letter "M."

In factories, we are trying to find the best possible combination of Men/Women, Materials, and Machines and we develop the most efficient Methods for making things, so that we can make better products while spending less Money.

Standard operations can be defined as an effective combination of workers, materials, and machines for the sake of making high-quality products cheaply, quickly, and safely. As such, standard operations comprise the backbone of JIT production.

Many people make the assumption that standard operations are nothing more than standard operating procedures. But this is not at all the case.

Standard operating procedures have to do with specific standards for individual operations and are just part of what we mean by standard operations. By contrast, standard operations involve the stringing together of individual operations in a specified order to achieve an effective combination for manufacturing products. Another name for standard operations would be "production standards." One might ask why such production standards are necessary in the daily business of manufacturing?

While this may seem like a simple question, it is actually rather difficult to answer. Please think about it for a moment. Why are production standards necessary for daily production activities?

In considering this question, let us suppose that we have asked some other manufacturer to do some manufacturing for us.

The person would probably ask such questions as: "How do you make these products?," "How much time and money does it take to make them?," and "When do you need them delivered?"

Why does the other manufacturer need to know all these things? Basically, because they need to fit the work we have asked them to do into their current production schedule. They will not know whether they can actually make the requested products on schedule unless they have established standard operations. Factories, therefore, need standard operations right from the start.

Standard operations serve the following goals:

1. Quality: "What quality standards must the product meet?"
2. Cost: "Approximately how much should it cost to make the products?"
3. Delivery: "How many products do you need delivered and by when?"
4. Safety: "Is the manufacturing work itself safe?"

At the very least, standard operations should be able to answer those four questions.

It should be clear enough by now why we define standard operations as an effective combination of workers, materials, and machines. We also need to remember that, like all improvement, improvement in standard operations is an endless process.

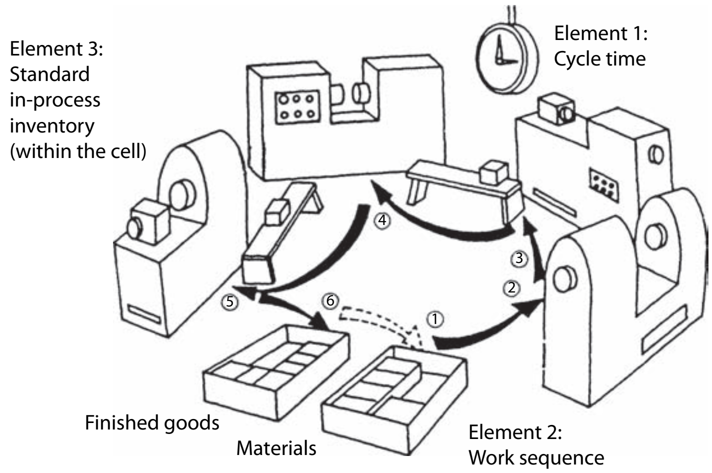


Figure 13.1 The Three Basic Elements of Standard Operations.

The Three Basic Elements of Standard Operations

While standard operations involve the effective combination of three "M" elements—men/women, materials, and machines—these elements differ from the three basic elements that go into standard operations. Figure 13.1 illustrates these elements as they are used to create standard operations in a U-shaped manufacturing cell.

Element 1*: Cycle time*

Cycle time is the amount of time it takes a worker to turn out one product (within a cell). We use the production output and the operating time to determine the cycle time.

Element 2*: Work sequence*

This refers to the order in which the worker carries out tasks at various processes as he or she transforms the initial materials into finished goods. It is not the same as the "flow of products" concept we use in flow production.

Element 3*: Standard in-process inventory*

This indicates the minimum amount of in-process inventory (including in-process inventory currently attached to machines) that is required within the manufacturing cell or process station for work to progress.

The contents of these three elements will differ from cell to cell, and it is the immediate supervisor's job to analyze the cell and determine exactly what each element will include.

Types of Standard Operation Forms

Although there are only three basic elements (cycle time, work sequence, and standard in-process inventory) in standard operations, there are five types of standard operation forms.

***Form 1**: Parts-production capacity work table*

This work table examines the current parts-production capacity of each process in the cell. (See Figure 13.2.)

***Form 2**: Standard operations combination chart*

This chart helps us make "transparent" (or obvious) the temporal process of the relationship between human work and machine work. (See Figure 13.3.)

***Form 3**: Standard operations pointers chart*

We use this chart to list important points about the operation of machines, exchanging jigs and tools, processing methods, and so on. (See Figure 13.4.)

Approval stamps	Parts-Production Capacity Work Table	Part No.	Type RY	Entered by Sato
		Part name 6" pinion	Quantity 1	Creation date 1/17/89

Process	Process name	Serial No.	Manual operation time (A)		Basic times: Auto feed time (B)		Basic times: Completion time C=A+B		Blades and bits: Retooling amount (D)	Blades and bits: Retooling time (E)	Per unit retooling time F=E+D	Total time per unit G=C+F	Production capacity I/G	Graph time (Manual work - - - / Auto feed ——)
			Min.	Sec.	Min.	Sec.	Min.	Sec.						
1	Pick up raw materials	—		1		—		1	—	—	—	1	—	
2	Gear teeth cutting	A01		4		35		39	400	2'10"	0.3"	39.3	717	4" 35"
3	Gear teeth surface fin.	A02		6		15		21	1,000	2'00"	0.1"	21.1	1,336	6" 15"
4	Forward gear surface fin.	A03		7		38		45	400	3'00"	0.5"	45.5	619	7" 38"
5	Reverse gear surface fin.	A04		5		28		33	400	2'30"	0.4"	33.4	844	5" 28"
6	Pin width measurement	B01		8		5		13	—	—		13	259	8" 5"
7	Store finished workpiece	—		1		—		1	—	—	—	1	—	

Figure 13.2 Parts-Production Capacity Work Table.

Standard Operations Combination Chart			
Process No.: 391-3637	**No. required:** 303 (600)	— Manual operations ..... Auto feed - - - Walking	**Entered by:** Kawano
Item name: Door jamb (lintel)	**Cycle time:** 89' (54' needed)		**Date:** 1/31/89
			Analysis No.: 1 of 1

Sequence	Description	Time: Manual	Time: Auto feed	Time: Walking	Operation times (in seconds): 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90
1	Pull out workpiece	3		2	
2	Process S101 gain (small) at circular saw bench	15	10	2	
3	Process S102 gain (large) at circular saw bench	23	18	2	
	B101 hinge fasten	12			

Figure 13.3 **Standard Operations Combination Chart.**

Summary Table of Standard Operations		Process name	Department	Date	Confirmation
		Processing sequence			
		Machine number			
No.	**Description of operation**	**Critical factors (correct/incorrect, safety, facilitation, etc.)**	**Diagram of operation**		

Figure 13.4 **Standard Operations Pointers Chart.**

Work Methods Table				Part no.	Required output	Dept.	Name	Confirmation		
				Part name	Breakdown no.		Date			
No.	**Description of operation**	**Quality: Check**	**Quality: Measure.**	**Critical factors (correct/incorrect, safety, facilitation, etc.)**	**Net time (min. and sec.)**	**Cycle time**	**Stand. in-process inv.**	● **Stand. in-process inv.**	✚ **Safety point**	◇ **Quality check point**

Figure 13.5 **Work Methods Chart.**

***Form 4**: Work methods chart*

This chart gives explicit instructions on how to follow standard operations at each process. (See Figure 13.5.)

***Form 5**: Standard operations chart*

This chart illustrates and describes the machine layout, cycle time, work sequence, standard in-process inventory,

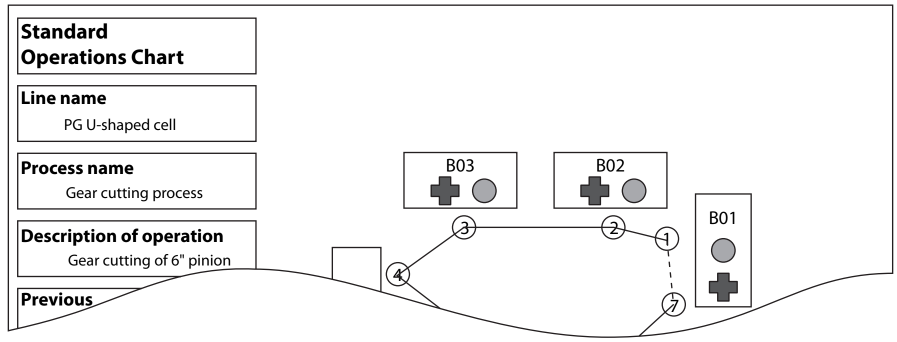


Figure 13.6 Standard Operations Chart.

and other factors in standard operations. Operators should use this chart to check how well they are following standard operations. (See Figure 13.6.)

How to Establish Standard Operations

Transparent Operations and Standard Operations

The first step toward establishing standard operations is to gain a grasp of the way operations are already. To do this, we need to make what is only dimly and vaguely understood as clear and "transparent" (obvious) as possible. This means we have to flush out all of the problems that are hidden within the current situation, look for their causes, and make improvements that will remove those causes and bring about standard operations.

Once we have established standard operations in this way, we still cannot afford to sit back and call the job done. We must repeat the process of flushing out problems and making operations completely transparent. As mentioned earlier, improvement is an endless process. Once we have made improvements, we establish them as standard operations. Then we are ready for another round of problem-hunting to further improve operations and achieve a higher standard. This spiral of improvement in standard operations is illustrated in Figure 13.7.

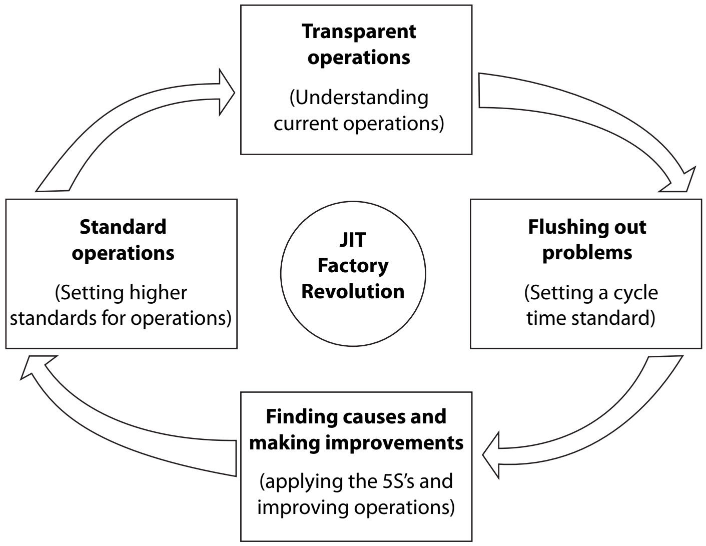


Figure 13.7 Spiral of Improvement in Standard Operations.

Steps in Establishing Standard Operations

Establishing standard operations is a four-step process, as described below.

Step 1: *Create a parts-production capacity work table*
List the processing capacity of each cell or process station as it currently stands.

Step 2: *Create a standard operations combination chart*
Time manual operations, auto feed operations, and walking to elucidate the relationship between human work and machine work.

Step 3: *Create a work methods chart*
The workshop will need one of these for passing along instructions to new workers.

Step 4: *Create a standard operations chart*
This schematic chart will provide a visual aid for quickly learning the machine layout, work sequence, and other important factors.

That is all there is to it. Usually, we can incorporate the standard operations combination chart with a standard operations chart to provide a useful reference chart for posting on the wall in the workshop. Figure 13.8 shows an example of such a combined chart.

How to Make Combination Charts and Standard Operations Charts

Even after we have gained an intellectual grasp of what standard operations combination charts and standard operations charts are all about, it is not always easy to actually create one. Perhaps the following exercise can serve as a reference for those who are about to attempt establishing standard operations for the first time in their workshops.

Exercise in Making Combination Charts and Standard Operations Charts

Using the parts-production capacity work table shown in Figure 13.9, make a combination chart and standard operations chart to suit the following two conditions:

Condition 1: Work sequence of processing—Raw materials →A01→A02→A03→A04→B01→finished goods

Condition 2: Required output is 613 units per day

1. Take 7 hours and 50 minutes as the amount of time per worker day, with no short breaks.
2. Take 2 seconds as the walking time for every instance of walking.
3. To keep this exercise simple, do not calculate changeover time.

Steps in creating charts:

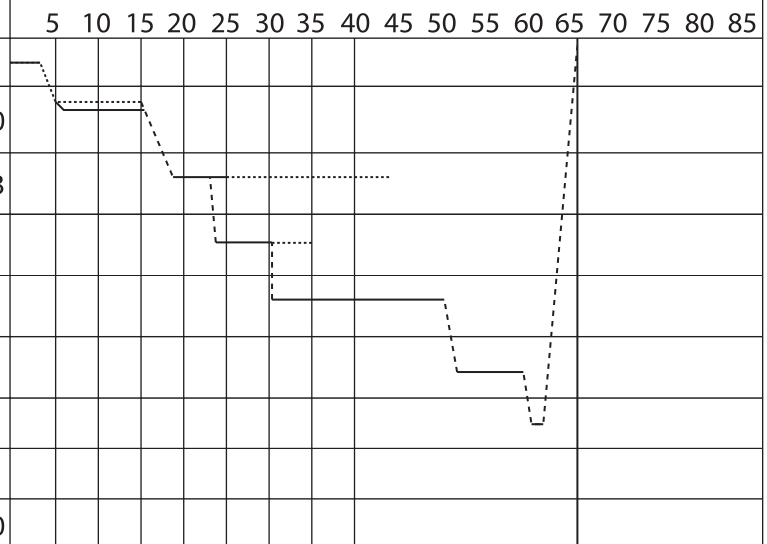
1. Calculate the cycle time. To obtain the cycle time, divide the operating time per day by the required output per day.

Standard Operations Combination Chart

Item No./Name 391-3637 Lintel	**Manufacture date** 9/30/83	**Number needed per day** 400	—— Manual operations
Process (cell) Preparation	**Department** First mfg. dept.	**Cycle time** 63"	········ Auto feed - - - - - Walking

No.	Name of operation	Time: Manual	Time: Auto feed
1	Remove workpiece	3	
2	S101 groove processing (small), using lifter	10	10
3	S101 groove processing (large), using lifter	5	23
4	B101 hinge hole processing at multi-spindle drilling	5	7
5	Insert edge (using vibrator) at work table	18	
6	Cut edge (using cutter) at work table	7	
7	Store workpiece	2	
	Total	50	40

Time: Walking (between operations)
2
2
2
2
2
1
2
Total 13



Standard operations chart	Quality check	Safety precautions	Standard in-process inventory	No. of manual operations	Cycle time	Total time	No.
	◇	✚	●				

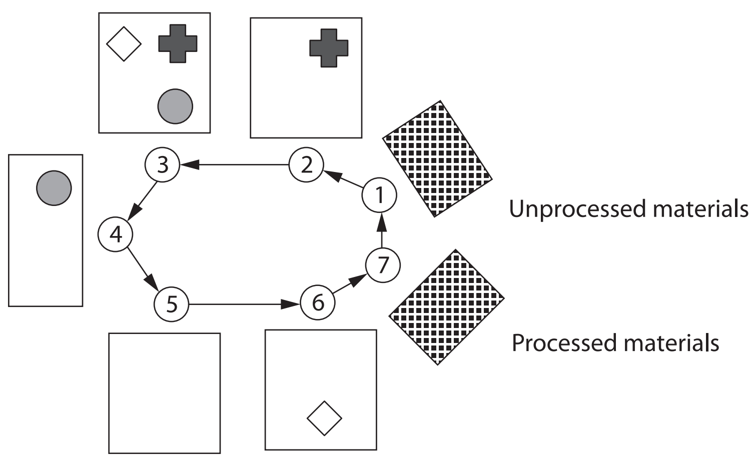


Figure 13.8 **Standard Operations Combination Chart with Standard Operations Chart (Schematic).**

Approval stamps	Parts-Production Capacity Work Table	Part No.	Type RY	Entered by Sato
		Part name 6" pinion	Quantity 1	Creation date 1/17/89

Process	Process name	Serial No.	Manual operation time (A)		Basic times: Auto feed time (B)		Basic times: Complet-ion time C=A+B		Blades and bits: Retooling amount (D)	Blades and bits: Retooling time (E)	Per unit retooling time F=E+D	Total time per unit G=C+F	Production capacity I/G	Graph time (Manual work - - -, Auto feed ———)
			Min.	Sec.	Min.	Sec.	Min.	Sec.						
1	Pick up raw materials	——		1		—		1	——	——	——	1	——	
2	Gear teeth cutting	A01		4		35		39	400	2'10"	0.3"	39.3	717	4" 35"
3	Gear teeth surface fin.	A02		6		15		21	1,000	2'00"	0.1"	21.1	1,336	6" 15"
4	Forward gear surface fin.	A03		7		38		45	400	3'00"	0.5"	45.5	619	7" 38"
5	Reverse gear surface fin.	A04		5		28		33	400	2'30"	0.4"	33.4	844	5" 28"
6	Pin width measurement	B01		8		5		13	——	——		13	259	8" 5"
7	Store finished workpiece	——		1		—		1	——	——	——	1	——	
Total				32	2	01	2	33	Daily operating time (i): 7 hours, 50 minutes					28,200 seconds

Figure 13.9 Parts-Production Capacity Work Table.

2. Create the standard operations combination chart. Drop a thick red line along the time axis to indicate the cycle time.
3. Create a standard operation chart. The point of this is to show the amount of standard in-process inventory.

How to Make Parts-Production Capacity Work Tables

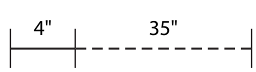
Figure 13.9 shows the parts-production capacity work table to be used in the above exercise. The following shows how the standard operations combination chart and standard operations chart should look when completed. First, the following are steps for filling out these charts:

1. Assign sequential numbers to indicate the work sequence.
2. Enter the process name.
3. Enter the machine's serial number.
4. Basic times:
   a. Manual operation time (__________): Enter the time required by the worker to perform each operation in the cell.
   b. Auto feed time (__________)**:** Enter the amount of "machine work" time.

c. Completion time: Enter the amount of time required for one workpiece to be completed (from start to finish in the cell).

Completion time = Manual operation time + auto feed time (if operations are performed serially)

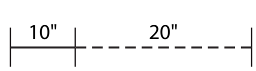
5. Blades and drill bits.
   a. Retooling volume: Enter the number of blades or bits to be exchanged.
   b. Retooling time: Enter the total time required for retooling.
6. Per-unit time = Completion time + per-unit retooling time
7. Production capacity: Enter the number of units that can be produced in one standard day (= daily operating time/ per-unit time).
8. Graph time: Enter the operating time (__________) and the auto feed time (__________) onto a graph. For example, for work sequence Step 2, enter the two lines as shown below to provide an easy-to-grasp indication to use when creating a standard operations combination chart.



Three patterns for the standard time are as follows:

Pattern 1: Serial Operations

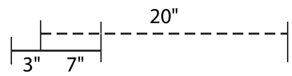
In this case, the machines' auto feed operations begin only after the worker's manual operations end. Thus, the two follow each other in a series with no overlap (that is, human work and machine work are completely separate), as follows:



Pattern 2: Partially Parallel Operations

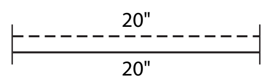
Here, the machine begins its work while the worker is still busy. The worker begins before the machine joins in and the machine keeps operating after the worker has finished.

This still allows some room for the separation of human work and machine work. The overlap between the two should be indicated as follows:



Pattern 3: Parallel Operations

In this case, the machine is completely unable to operate without human assistance, and thus there is no separation between human work and machine work, as is demonstrated in the following example.



How to Make Standard Operations Combination Charts

Figure 13.10 shows a standard operations combination chart that was filled out from the above exercise. If you wish to perform the exercise and complete your own standard operations combination chart, please compare it afterward with the one in the figure.

The steps for filling out the standard operations combination chart are described below.

Step 1: *Draw a red line to indicate the cycle time.*

Cycle time = Total operating time/required output

Step 2: *Calculate whether the cell can be handled by just one worker.*

Using the parts-production capacity work table from the above exercise, see whether or not the sum of the manual working time and the walking time is less than the cycle time.

Step 3: *Enter a description of the process operations under the "Description of Operations" column.*

Standard Operations Combination Chart			
Process: Gear cutting	**Required output:** 613 units	—— **Manual operations** ········ **Auto feed** - - - - **Walking**	**Entered by:** Sato
Part name: A-0112 6" pinion	**Cycle time:** 46 seconds		**Date:** 1/17/89
			Breakdown no.:

Sequence	Description of Operation	Time: Manual	Time: Auto feed	Time: Walking
1	Pick up raw materials	1	—	2
2	Remove A01 workpiece, attach next and feed A01	4	35	2
3	Remove A02 workpiece, attach next and feed A01	6	15	2
4	Remove A03 workpiece, attach next and feed A01	7	38	2
5	Remove A04 workpiece, attach next and feed A01	5	28	2
6	Remove B01 workpiece, attach next and feed A01	8	5	2
7	Store finished workpiece	1	—	2

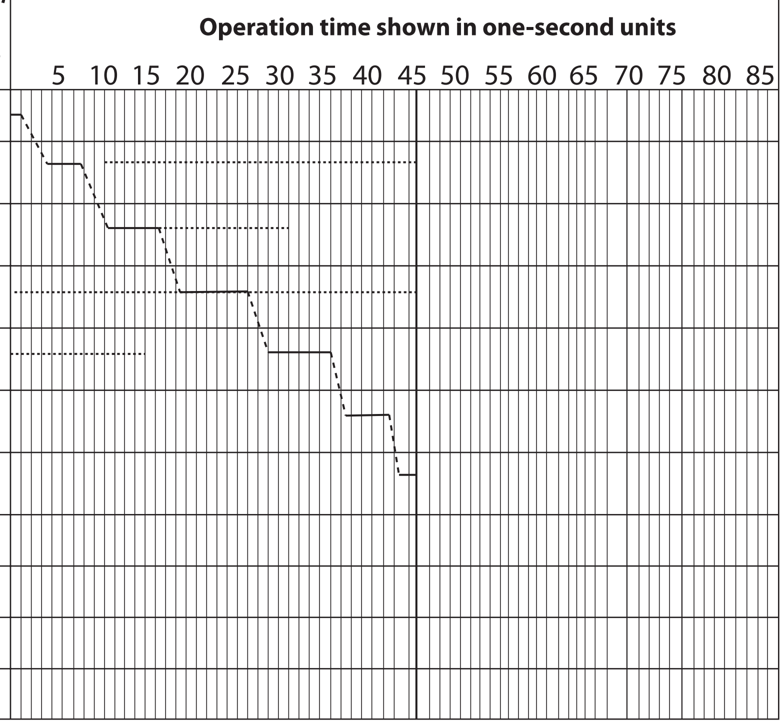


Figure 13.10 An Example of a Standard Operations Combination Chart.

Step 4: *Enter the various time measurements under the "Time" column.*

Step 5: *On the graph, draw solid lines for manual work time, broken lines for auto feed time, and wavy lines for walking time.*

If the auto feed time exceeds the cycle time, enter the extra time from the zero (start) position in the graph.

Step 6: *Check the combination of operations.*

When the auto feed time exceeds the cycle time and some of it must be entered from the zero position, it may overlap with the manual operation time. If it does, it indicates the manual work must wait for the auto feed (machine work) to finish, which means that the combination of operations does not work.

In such cases, we must find a better combination of operations. Idle time waste is to be avoided whenever possible.

Step 7*: Check whether the operations can be completed within the cycle time.*

Add up the time for all operations, including the time required for walking back to the first operation (picking up raw materials), and see if they all fit into the cycle time.

- If they add up to precisely the time marked with the red (cycle time) line, you have found a good combination of operations.
- If they go past the red line, make improvements to remove the excess time.
- If they fall short of the red line, see if other operations can be brought into the cell to reach the cycle time.

How to Make Standard Operations Charts

Figure 13.11 shows the standard operations chart completed from the exercise described in the previous section. After making your own standard operations chart, be sure to compare it to this one.

The following are the steps for filling in the standard operations chart.

Step 1*: Enter the work sequence.*

Enter circled numbers next to the machines to indicate the order in which they are used during the work sequence, then connect the machines with a solid line, as shown in Figure 13.11. Draw a broken line between the last step and first step in the work sequence.

Step 2*: Enter the quality check points.*

Enter diamond symbol next to all machines that require quality checks.

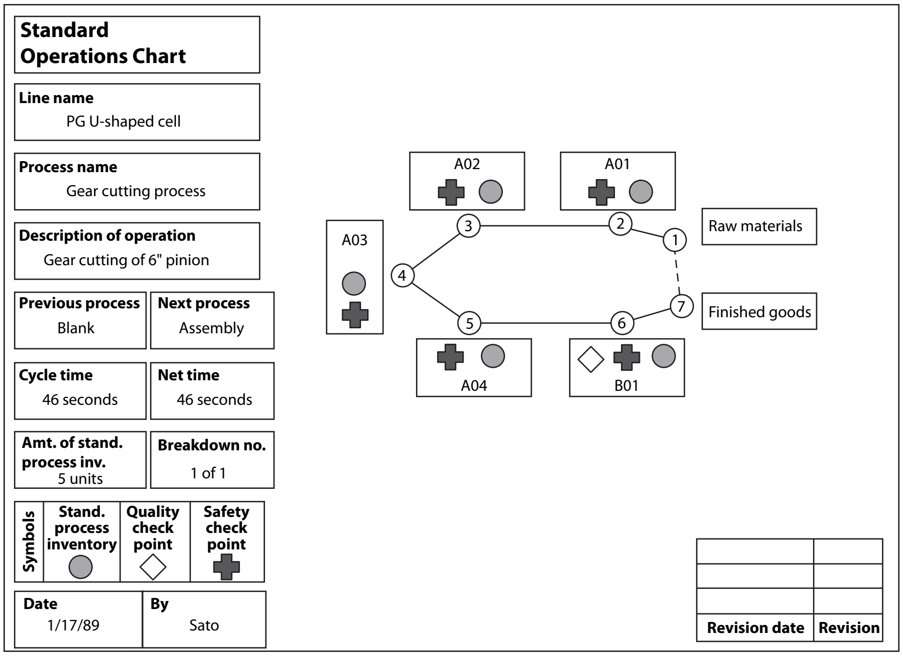


Figure 13.11 Standard Operations Chart.

***Step 3**: Enter the safety check points.*

Enter cross symbols next to all machines that require safety checks. Be sure to enter one of these marks next to any machine that uses a blade.

***Step 4**: Enter the symbols for standard in-process inventory.*

Enter shaded circle symbols where standard in-process inventory is required for whatever reason (separating human work and machine work, balancing processes, and so forth).

Step 5: *Enter the cycle time.*

Step 6: *Enter the net time.*

Enter the operation time for the sequence shown in the circled numbers. Do not include the time taken up by quality checks or blade exchanges that are done less than once per cycle.

***Step 7**: Enter the amount of in-process inventory.*

In this box, enter the number of shaded circles you entered in the graph at Step 4. Separation during auto feed counts as one unit of in-process inventory.

***Step 8**: Enter the breakdown number.*

Usually, both the standard operations combination chart and the standard operations chart are filled out by the same operator. However, sometimes the cell requires more than one operator, in which case we should use breakdown numbers to indicate which operator is which.

- First number = Operator's number in sequence
- Second number = Total number of operators

Standard Operations and Operation Improvements

How easy it is for factories to avoid the troublesome task of improving operations and instead opt for equipment improvements. One of the purposes of improvement is to lower costs, but companies find themselves spending a fortune on new or remodeled equipment, all in the name of making improvements. A factory's choice of equipment should be based on the needs of production operations, but many factories put the cart before the horse by changing production operations to suit the equipment. Production machines are tools for production and it makes no sense to have production suit the tools rather than vice-versa.

The following are a few examples of what we mean by "operation improvements."

Improvements in Devices That Facilitate the Flow of Goods and Materials

There are basically two ways to change the devices that facilitate the flow of goods and materials. One is to bring equipment closer to each other in the cell and arrange them according to the work sequence. This creates a "flow shop" type of workshop and is known as "layout improvement."

The other way is to switch from large-lot processing to small-lot or one-piece flow. This is called "flow unit improvement." Each of these types of improvement should initially be used to remove major forms of waste.

Improvement from Specialized Operations to Multi-Process Operations

Conventionally, factories assigned very specialized tasks to each worker, and workers generally remained at one place to perform those tasks while the in-process inventory was conveyed by hand or conveyor belt. This system required workers to spend a lot of time going to pickup things or put things down. We can eliminate the waste inherent in such specialized operations by training workers in the multiple skills needed to conduct multi-process operations, in which a single worker guides each workpiece throughout all of the workshop's processes with a minimum of walking waste.

Improvement of Motion in Operations

Whenever a worker takes a step or stretches out an arm, "motion waste" is created. Conventional industrial engineering has developed a method of motion analysis to identify wasteful motion. Wasteful motion can be caused by a poor equipment layout or sloppy housekeeping of parts and tools. We must reduce this kind of waste by making the equipment layout and organization of parts and tools more conducive to efficient operations.

Improvement by Establishing Rules for Operations

Operational procedures cannot be readily understood and followed by new workers if they vary from one worker to the next. It is only when the correct operational procedures have been clearly established as strictly enforced rules that everyone will perform operations the same way. Along with rules for correct procedures, there must also be rules that help establish level production.

Once we have laid the groundwork by improving operations, we are ready to begin thinking about how the equipment might be improved to better suit the improved operations. The following are a few ways to improve equipment.

Improve the Equipment to Better Serve Operations

Quite often, improved operations do away with a prior need for large equipment that can handle large lots or operate at high speed. Instead, the improved operations tend to call for smaller, slower, and more specialized equipment that can be counted on to produce high quality and be brought directly into the processing or assembly line.

Make the Machines More Independent to Separate People from Them

If the operator must press a switch and then hold the workpiece in place while the machine processes it, we should remodel the machine so that it can operate without human assistance or supervision. In JIT, this is called "separating people from machines," and it allows people and machines to work independently to add value to products simultaneously.

Improving Equipment to Prevent Defects

We can equip machines with detectors and switches that enable the machine to automatically detect defects (or potential defects), stop operating, and issue an alarm. Such devices are a key means of preventing defects.

It bears repeating that operation improvements should be made before equipment improvements. It should also emphasize that the most effective means of removing motion-related waste from operations is to make "operational device improvements." This means first changing the flow unit from large lots to small lots or one-piece flow, then changing the equipment to suit the new flow method.

Improving the Flow of Materials

The most important kind of operation improvement we can make is to change the way goods flow through the factory. However, such a change is not possible unless we are willing to give up the way we have been doing things and undergo an "awareness revolution" that negates the old tried-and-true methods as the worst possible methods.

In other words, changing the flow of goods requires changing our way of thinking, all our concepts about equipment and how to arrange it, and, most importantly, our ideas about how goods should proceed through the production line. We need to change just about everything that goes on in the factory.

Figure 13.12 shows an example of how the flow of goods was improved at a solder printing process for semiconductor wafers.

Before improvement, this processing line was run by four operators, each of whom worked independently of the other three. The line operated in 600-unit batches and used a large dryer. Sending such large lots through was a start-and-stop operation that reflected precious little ingenuity and resulted in frequent bottlenecks.

The improvement included training a single operator in the skills needed to handle five processes: printing (the front of the wafer), baking, printing (the back of the wafer), input to the reflow oven, and output from the reflow oven. The layout was changed to facilitate these tasks and to minimize motion-related waste. The reflow jig was changed to accommodate "two-piece" flow. They got rid of the large dryer, brought a compact ultraviolet-ray dryer out of storage and remodeled it to serve in place of the large dryer, but in an "in-line" location. Finally, they attached a return conveyor at the back of the reflow oven to match up the oven's input and output sites. As a result, they were able to cut the required manpower in half while doubling productivity.

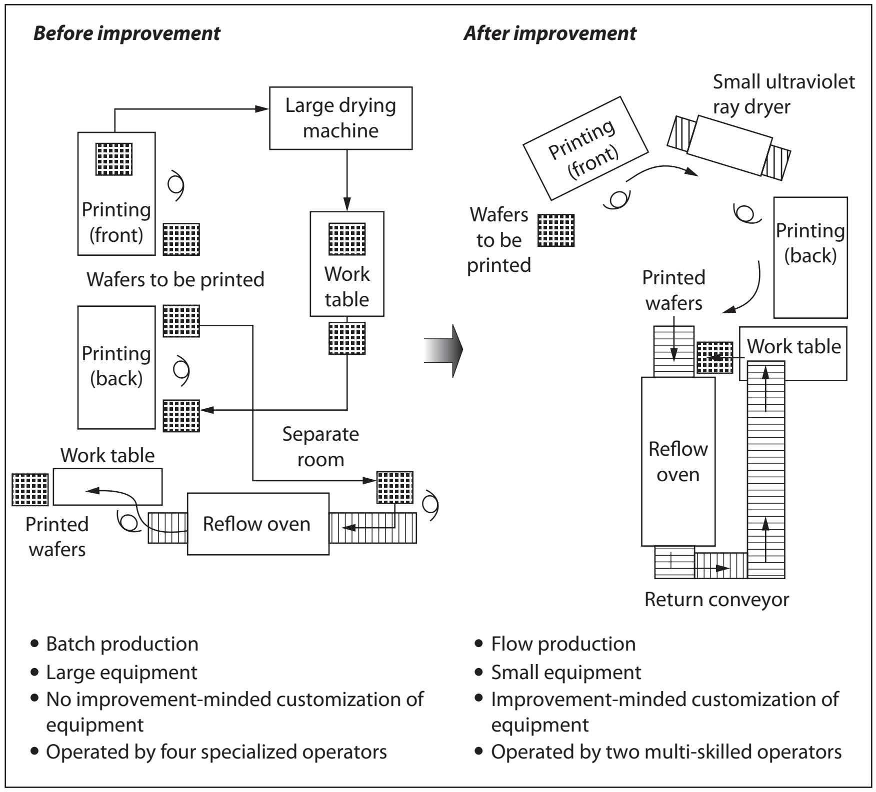


Figure 13.12 Improved Flow of Goods at a Solder Printing Process for Semiconductor Wafers.

Improving the Efficiency of Movement in Operations

Not all of what factory workers do on the job can truly be called "work" in the sense of adding value to goods. On the contrary, most of what the typical factory worker does adds no value. It is therefore not work, just motion. Motion study is an industrial engineering technique that helps distinguish between productive work and nonproductive motion in order to raise the work-versus-motion ratio.

When we use motion study to remove wasteful motion from operations, we try to make the job easier, and with more economical movement, more efficient work sequences, and better combinations of tasks.

The "principles of economy of motion" can be a very good tool for improving the motions of workers to remove

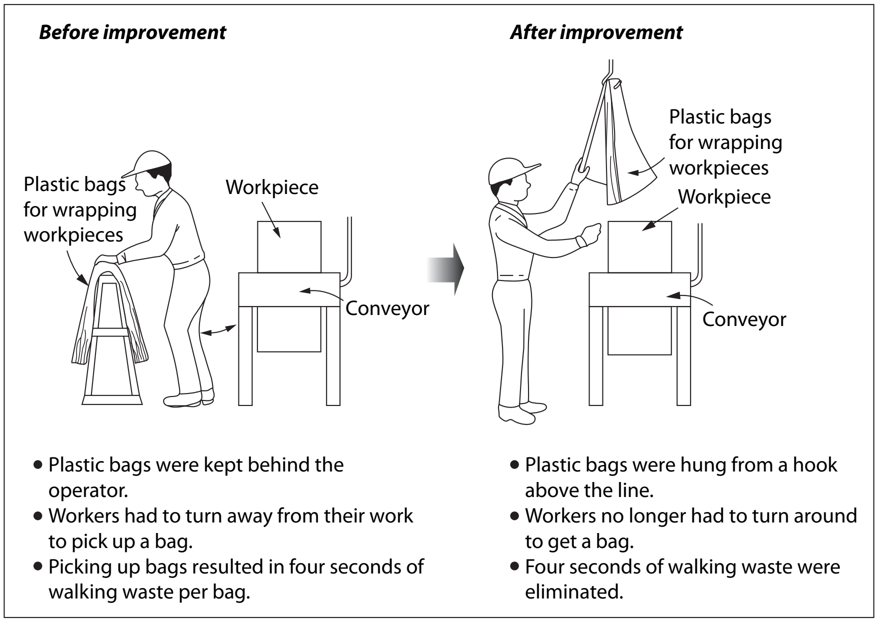


Figure 13.13 Improvement in Placement of Parts.

waste from human actions. (For further description of the "principles of economy of motion," see Chapter 3). Following these principles helps "tighten the cost belt" by removing the "fat" in the form of the 3 *Mu*'s (*muda* or waste, *mura* or inconsistency, and *muri* or irrationality). Naturally, this means improving human movements, but it also involves improvements in the ways thing are placed, the arrangement and use of jigs and tools, and the organization of the entire work environment.

1. Improvement in Placement of Parts

Figure 13.13 shows one improvement that involved moving a set of plastic bags used for wrapping workpieces from behind the operator and hanging them from a hook above the line to keep them within easy reach. This simple improvement saved four seconds of walking waste (per unit).

2. Improvement in Picking Up Parts

Figure 13.14 shows an example of how picking up parts at an assembly line was improved. Before the improvement, the

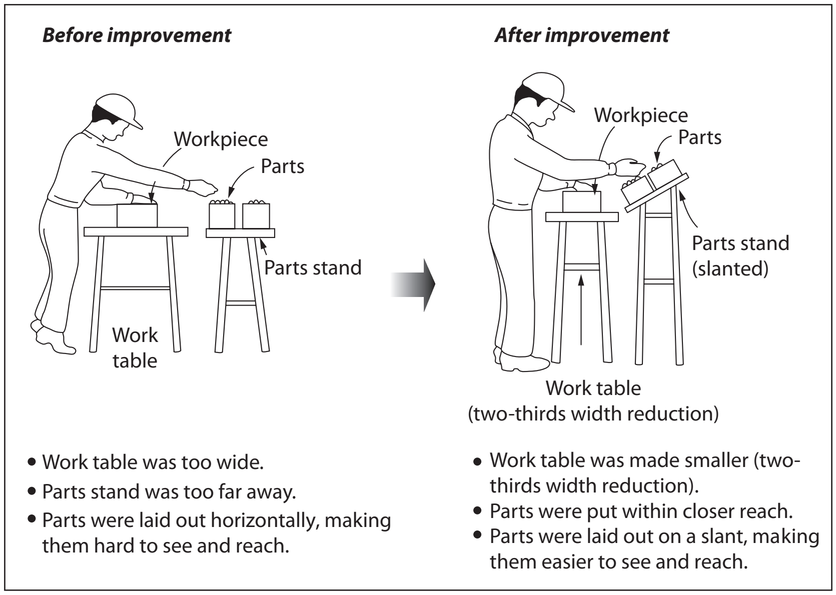


Figure 13.14 Improvement in Picking Up Parts.

parts were kept on a large work table located a little too far from the assembly line. All of the parts were laid out on the same horizontal level, making them hard to see and reach.

As part of the improvement, the work table was reduced to the minimum required size, was moved closer to the assembly line, and the parts boxes were set-up on a higher, slanted stand to make seeing and reaching them easier.

3. Improvement from One-Handed Task to Two-Handed Task

Figure 13.15 shows how the task of assembling push buttons on telephones was improved from being a one-handed task to a two-handed task.

Before the improvement, there was no jig to hold the workpiece in place. Instead, the assembly worker had to hold down the workpiece with her left hand while using her right hand to insert the push buttons one by one.

After the improvement, the assembly worker simply sets the workpiece into a stabilizing jig and then can use both

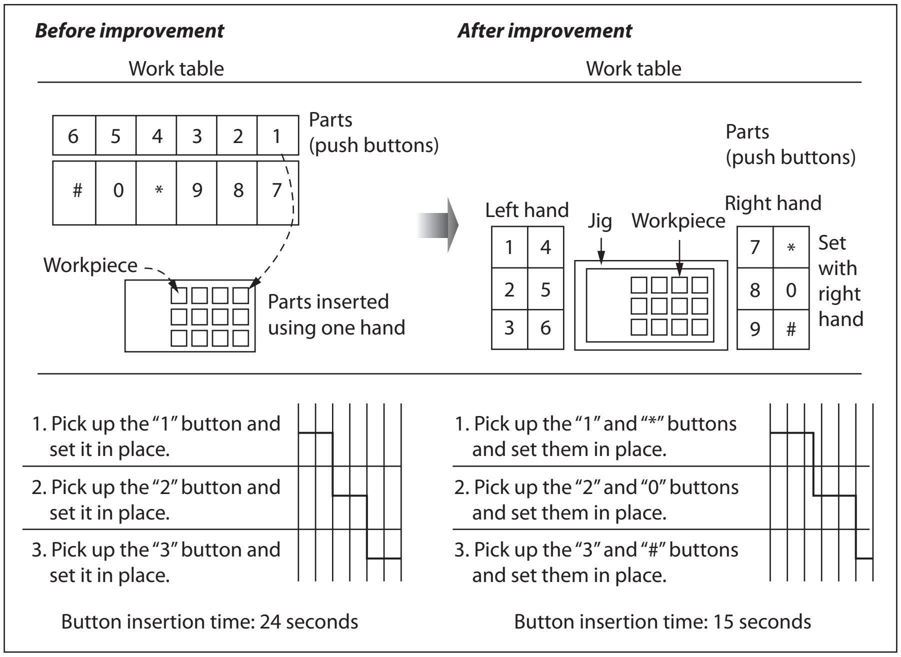


Figure 13.15 Improvement from One-Handed Task to Two-Handed Task.

hands to insert the push buttons. In addition, the arrangement of push buttons to be inserted was changed to match their arrangement after insertion. This helped to keep workers from accidentally inserting push buttons in the wrong places.

4. Improvement That Eliminates Walking Waste

Figure 13.16 shows an improvement example in which walking waste was removed from speaker cabinet processing operations.

This workshop had been using the conventional layout in which each machine was operated by a different worker, each of whom picked up workpieces from large piles of in-process inventory. Obviously, such a layout is not conducive to the concept of cycle time, and instead they tried to maintain a 33-second pitch, beginning at the process where V cuts were made in the speaker cabinets' processed particle boards.

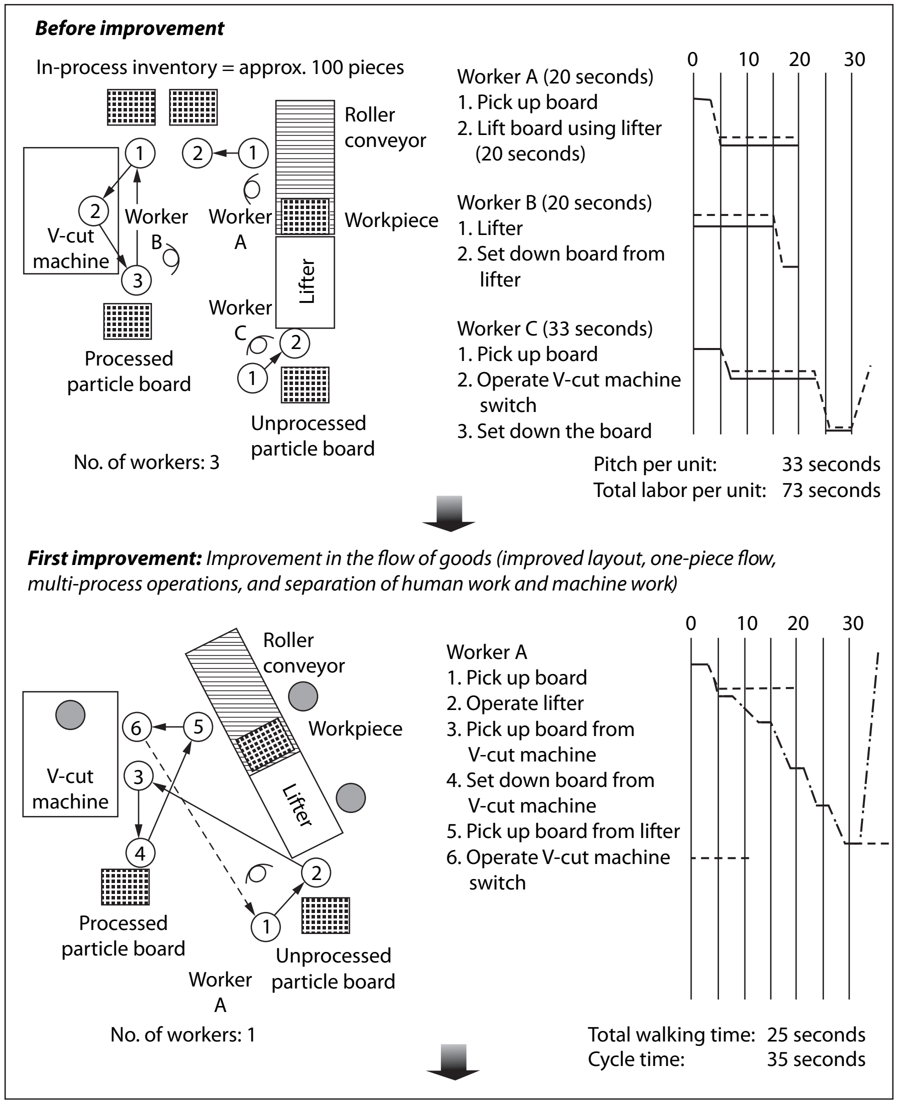


Figure 13.16 First and Second Improvements in Speaker Cabinet Processing Operations.

- The workshop was run by three workers.
- There were about 100 pieces of in-process inventory.
- The pitch per unit was 33 seconds.
- The total labor per unit was 73 seconds.

As a first improvement, a fundamental change was made in the flow of goods. The V-cut machine was installed in a pit and could not be moved, so they moved the lifter as close to the V-cut machine as possible. Once before, the lifter had

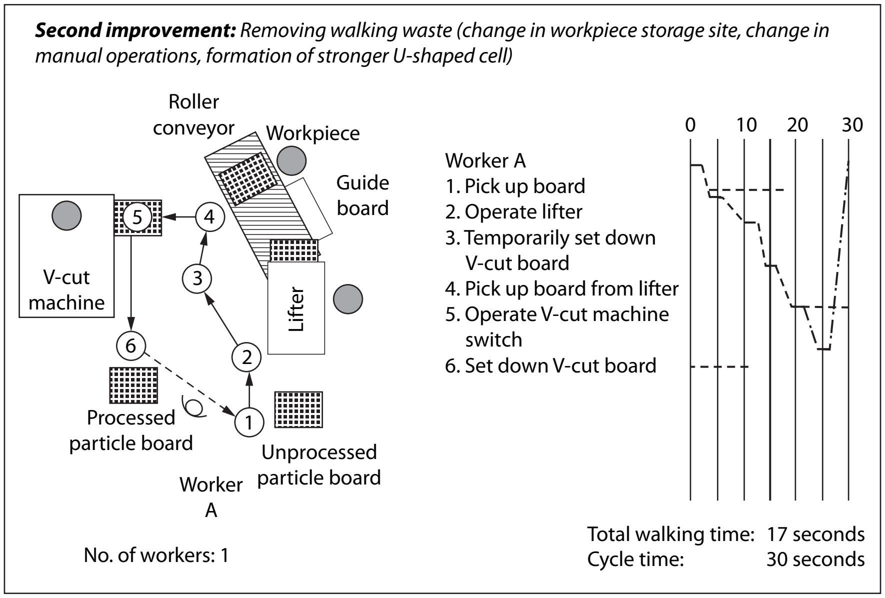


Figure 13.16 (continued)

been moved closer to the V-cut machine, but this was not understood as an improvement at the time. The distance the lifter could be moved was restricted by the electrical cord, and no extension cord was available in the factory. Therefore, they had to compromise in improving the layout.

In the first improvement, they managed to reduce the labor force from three workers to just one by establishing multi-process operations. Naturally, this change included eliminating the stack of in-process inventory between the lifter and the V-cut machine. Fortunately, worker A (the single remaining worker) was an old hand in that factory who was able to pickup the "one piece flow" way of doing things quite readily. Both the lifter and the V-cut machine could feed the workpieces downstream automatically, which enabled the separation of human work and machine work. These changes brought the following results:

- Reduction of labor force from three workers to one.
- Reduction of total in-process inventory to just three workpieces.
- Establishment of a 35-second cycle time.

The improvement, however, was not totally satisfactory. First of all, the worker had to walk a rather complicated pattern to complete the work cycle. Whenever we have complexity, we usually have waste, and it pays to remember "simple is best." Improvement team members counted 25 steps taken by the worker during the work cycle, which means 25 seconds of walking waste (each step is roughly equal to one second of waste). These drawbacks led improvement team members to regroup and launch a second improvement effort.

They determined that they needed to make the equipment layout more compact, but they were faced with the problem of the lifter's fully extended power cord which prevented them from moving the lifter any closer to the V-cut machine. The roller conveyor had no power cord and could be moved freely, although they ended up "bending" the roller conveyor so that its output end is close to the V-cut machine, as shown at the bottom of Figure 13.16.

They then wondered if the roller conveyor could convey the particle boards at its new angle without dropping them. They tried one board; the conveyor dropped it and ruined it.

Then they started brainstorming for solutions to this problem. They tried attaching a guide board to the side of the roller conveyor to keep the particle board from dropping. It worked.

Next, they found a way to avoid having to move the boards in a direction opposite that of the processing flow. To do this, they established a temporary storage site for boards output from the V-cut machine and changed the work sequence around, as shown at the bottom of Figure 13.16. This reduced walking time, which was 17 seconds after the first improvement, to just eight seconds. It also resulted in a five-second reduction in the cycle time, going from 35 seconds after the first improvement to 30 seconds.

If we compare the results of the second improvement to the way things were before the first improvement, we can note the following:

- Workforce reduced to one (reduction of two workers).
- In-process inventory reduced to four workpieces (reduction of about 96 workpieces).
- Pitch per unit (cycle time) reduced to 30 second (reduction of three seconds).
- Total labor per unit reduced to 30 seconds (reduction of 43 seconds).

Both the first and second improvements were made right away, before people had time to apply for money for expensive improvements. The two improvements cost nothing but realized dramatic cost savings. They estimated that the cost savings were roughly proportional to the time invested in studying means of improvement.

Improving the Separation of Worker

Figure 13.17 shows how an improvement involving separation of human work and machine work was achieved for a groove processing operation that uses a lifter.

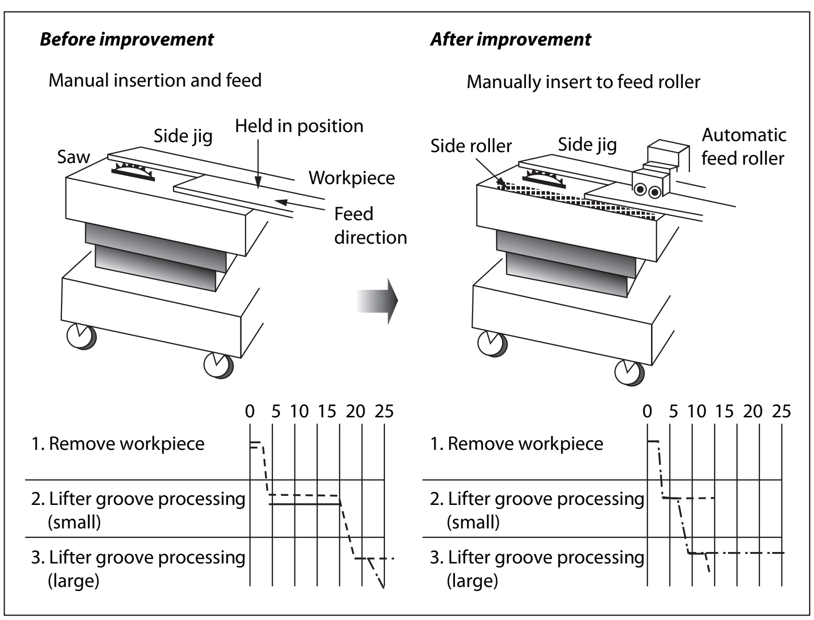


Figure 13.17 Separation of Human Work and Machine Work at a Groove Processing Lifter.

Before the improvement, the operator had to use both hands to align the workpiece along the side jig on top of the lifter and then had to push the workpiece along as the groove was cut. This meant that the operator was unable to separate himself from the machine at any time during the process.

The improvement included attaching a roller to the top of the lifter so that workpieces could be fed automatically over the groove cutter and a side roller to keep the workpiece from shifting sideways. These devices allowed the operator to separate himself from the machine once he had set the workpiece against the rollers and shortened the groove processing cycle time by eight seconds, as shown in Figure 13.17.

How to Preserve Standard Operations

Standard Operations and Multi-Skilled Workers

Once we have established standard operations, it is by no means a given that the workshop's operators will be able to perform them right away. It takes time to get used to the new procedures and to become proficient in them. Usually, each operator works a little differently, and the first task is to eliminate such individual differences. At this point, it is vital that operators be given a lot of guidance until they feel they know the new procedures like the backs of their hands.

We must be extra careful when training workers in the multiple skills they will need for multi-process operations. Workers should gradually expand the range of their skills, and not go any faster than they are able in learning new ones.

Figure 13.18 shows how a U-shaped manufacturing cell was used for on-the-job multiple skills training for operators. In the figure, the trainee (worker A) is able to perform only the first five steps before the cycle time is up, then returns to

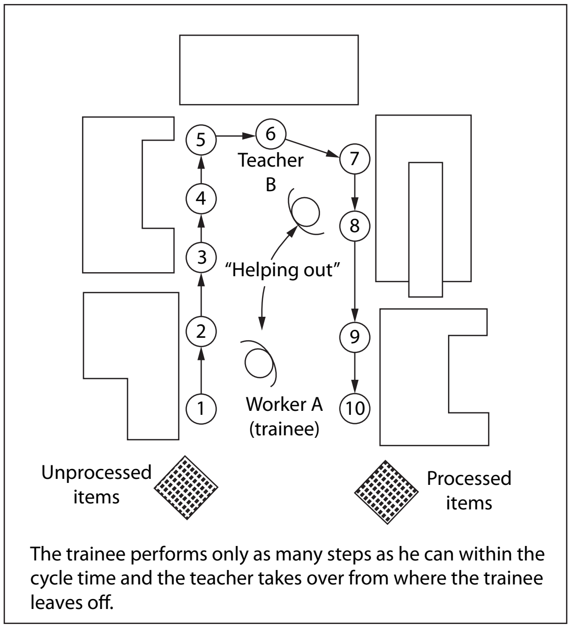


Figure 13.18 Multiple Skills Training.

Step 1. At Step 6, the teacher takes over and performs the rest of the steps in the work sequence.

Gradually, the trainee is able to take on additional steps and still remain within the cycle time. The trainee may perform Steps 1 to 7 for a while, then move on to Steps 1 to 8, 1 to 9, and finally the entire 10-step process.

The Ten Commandments for Preserving Standard Operations

I loathe to recall how often I have seen people work hard to establish rules for standard operations, only to stash the rules away in some desk drawer and forget about them. It makes me wonder why they even bothered to make the rules in the first place.

Please remember that standard operations are meaningless unless they are maintained.

The following are "ten commandments" that have evolved over the years for preserving standard operations.

Commandment 1: Standard operations must be established factory-wide.

No matter how often or how strongly the factory-floor workers are reminded to maintain standard operations, they will not be maintained unless top management gets behind the effort. Maintaining standard operations should be included as a company-wide project, along with zero-defects campaigns and cost-cutting activities.

Commandment 2: Make sure everyone understands what standard operations mean.

Everyone—from the president down to the newest factory worker—must fully understand how important standard operations are in achieving JIT production. Study group and in-house seminars are good ways to get this message across.

Commandment 3: Workshop leaders must be confident in their skills when training others in standard operations.

Training workers in the new procedures called for by standard operations will go much more smoothly when the workshop leaders who do the training are positive and confident about the change to standard operations. The leaders should appear as if they had already been making things the new way for years.

Commandment 4: Post reminders in the workshop.

Once standard operations have been established at a workshop, signboards and other visual tools should be used to remind workers of their duty to maintain the standard operations.

Commandment 5: Post standard operations signs in obvious places.

Post signs containing graphics- and text-based descriptions of the standard operations at places where the workers can see them easily and compare their own operational procedures to those described on the signs.

Commandment 6: When necessary, get a third person to help out.

Sometimes, bringing in a well-trained new person from some other department is a good way to clear up misunderstandings in learning and maintaining standard operations.

Commandment 7: Reprimand the workshop leader when standard operations are not being maintained.

When workers' actions or work sequences differ from those prescribed by standard operations, we have proof that standard operations are not being maintained. When a factory manager discovers this, instead of chewing out the workers, he should reprimand the workshop leader, right there in front of everyone. This tactic is more effective in strengthening the bond between workshop leaders and their charges.

Commandment 8: Reject the status quo.

Improvement is endless. Even after standard operations have been established, workshop operators cannot afford to become complacent in the belief that they have found the optimum method of operations. It is much better if they believe that the status quo—no matter how successful—is a bad system that must be improved. Only then will their minds remain open to the possibility of further improvement.

Commandment 9: Conduct periodic improvement study groups.

Improvements must be carried out continually. The longer improvements continue, the stronger the company becomes. Unless we work to improve things, they tend to backslide. Strong manufacturing companies are ones that "keep the ball rolling" by sponsoring regular improvement study groups to review current conditions and study possible improvements.

Commandment 10: Take on the challenge of establishing new standard operations.

There is always room for improvement. To establish a new and better set of standard operations, we need to take another critical look at current conditions, flush out the inherent problems, and implement improvements.

The place to discover needs for improvement is in the workshop. Just stand there and watch closely for five minutes. Odds are that the workshop will show you several things in need of improvement. You do not have to think them up—they just come naturally.

Chapter 14

Jidoka
Human Automation

Steps toward *Jidoka*

There are many ways to make the same product. Sometimes all it takes is a very simple tool to process the workpiece. Other times, workers are using both hands to hold something in place during processing when a simple jig could do the trick just as well. Sometimes we can let the machine do part of the work and sometimes we can let the machine do all of it. In other words, there are many ways—various operational methods and flow methods—we can use to make similar products.

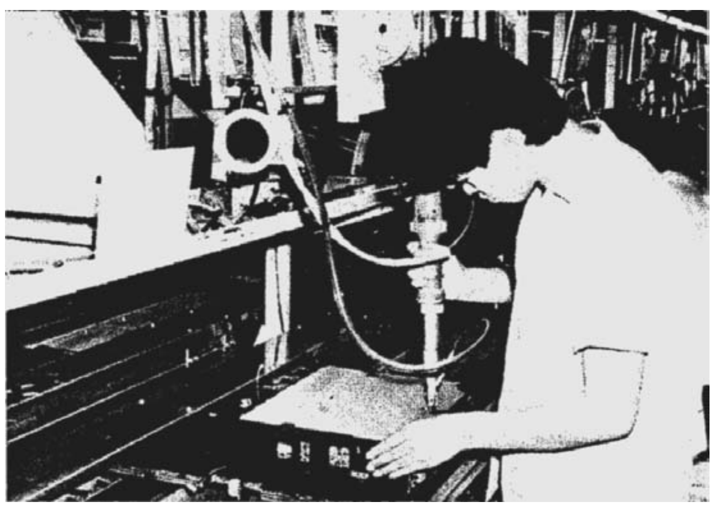
There are four steps we should take in developing *jidoka,* and each of these steps is concerned with the relationship between people and machines.

Step 1: Manual labor

Manual labor simply means that all of the work is being done by hand. This makes sense only when the labor costs are cheap and/or the manual work can be done very quickly, such as in the manual assembly line shown in the photograph.

Step 2: Mechanization

Mechanization means leaving part of the manual operations to a machine. We have reached a stage where the work is shared between the worker and the machine, but the worker still does the lion's share. (See photo.)



Step 3: Automation

At this step, all manual labor in processing is taken over by the machine. The worker just sets the workpiece up at the machine and presses a switch to start the machine. The worker can leave the machine alone at that point, but there is no way to know whether the machine is producing defective goods. (See photo.)

Step 4: *Jidoka* (human automation)

As at the automation step, the worker simply sets up the workpieces, presses the ON switch, and leaves the machine to do the processing. In this case, however, the worker need not worry about defects. The machine itself will detect when a defect has occurred and will automatically shut itself off. In addition to defect detection devices, *jidoka* sometimes includes auto-input (auto-feed) and auto-output (auto-extract) devices that completely eliminate the need for worker participation.

The Difference between Automation and *Jidoka*

In an earlier chapter, we discussed the distinction between "moving" and "working" as it pertains to workers' on-the-job activities. The same thing can be said about machines: Sometimes machines are actually working (adding value to something), and at other times they are just moving. How many factories have introduced expensive new machinery to automate and cut labor costs only to discover that, once the machines are operating, there are suddenly new demands for human labor? Perhaps a certain machine cannot do the entire job as planned and requires some human assistance. Or maybe another machine tends to spurt out defective goods and requires a human supervisor. When they add up all the costs, it turns out that they are losing money by automating.

The reason for this all-too-common problem is that the machines are allowed to "move" instead of "work." Or rather, people think that as long as the machines are moving, they are working. But what good does automation equipment do if it cannot actually handle the entire process or if it keeps running even when it produces defective goods? Eventually, such machines need a human supervisor.

By contrast, *jidoka* enables factories to keep equipment running without human assistance or supervision. Current equipment can be upgraded cheaply as "human automated" machines, which actually work while they move and do not disrupt the flow of goods. Indeed, were it not such a mouthful, we might well call them "flow-oriented human automated machines."

Separating workers from machines is not a one-step process. First, we must analyze the worker's operations, then apply *jidoka* to each of them, one at a time. Bold schemes to fully automate in one fell swoop always end up costing a fortune. And, interestingly enough, the more money we spend in automating, the more the new equipment is likely to disrupt the flow of goods. Instead, we need to keep in mind the ratio of labor costs to equipment costs at each step of the way. That is why *jidoka* must proceed carefully, one step at a time.

The Three Functions of *Jidoka*

Jidoka starts by looking at operations that are being performed manually or only partially by machine, distinguishing the human work from the machine work, then taking a closer look at the human work. During each part of the manual operations, we need to ask, "What is the worker's right hand doing?," "What is his left hand doing?," and so on. Then we can ask, "How can we free his left hand from having to do something?" and "How can we free his right hand?" Gradually, we reduce the human work and increase the machine work.

It makes sense to mechanize or automate when the result is lower costs and higher productivity, such as when using an electric motor frees the left hand or using some mechanism frees the right hand. Freed hands can be used for other work. Once we have gotten to the point where the worker's hands and feet are all free after the machine starts operating, we can physically separate the worker from the machine. In JIT, we call this separating human work from machine work. However, as mentioned earlier, it does no good to separate people from machines if the machines cannot be trusted to continue producing high-quality products. Neither does it save money to have the machine do the work while a worker stands by watching out for defects. After all, the whole point of automation is to cut costs.

So, the key is to develop automated machines that do not produce defective goods. To do that, we have to apply human wisdom to change machines that merely "move" into ones that "work." The development of defect-prevention devices for automated equipment is the heart and soul of *jidoka*. The machines must be able to detect by themselves when defects occur, stop themselves, and sound an alarm to inform people about the abnormality. The machine does not have to be able to tell what kind of abnormality has occurred—especially since abnormalities vary widely among different machines, processes, and users—but they do need to let the nearby people know that something strange has happened. The companies that make the manufacturing equipment do not know exactly how their equipment will be used; it is up to the users to customize it to suit their particular needs.

When we have customized our manufacturing equipment to operate reliably and automatically without the risk of turning out an endless stream of defective goods, a single worker can handle several machines or even several groups of machines. Imagine how high productivity soars when that happens!

We usually start by applying *jidoka* to processing equipment. If we succeed at that, we are ready to take on the challenge of bringing *jidoka* to assembly operations. On assembly lines, the purpose of *jidoka* is to get operators to press the stop button (the red "emergency" button) whenever any kind of defect, missing part, omitted task, or other abnormality occurs. Once they have stopped the line this way, they need to make an immediate improvement to solve the problem. They also need to constantly strive to eliminate various forms of waste from their operations to keep raising productivity.

The three main functions of *jidoka* can be summarized as follows:

Function 1: Separation of human work from machine work. *Jidoka* calls for the gradual shifting of all human work to machine work, thereby separating people from the machines.

Function 2: Development of defect-prevention devices. Instead of requiring human supervisors, machines should have the ability to detect and prevent the production of defective goods. Such machines are truly "working" and not just "moving."

Function 3: Application of jidoka *to assembly operations.* Like processing equipment, assembly lines must be stopped as soon as a defect occurs and corrective measures must be taken right away.

Separating Workers: Separating Human Work from Machine Work

What Does Separating Workers Mean?

I remember a factory visit during which one of the company's top managers took special pains to point out a recent acquisition—a late-model numerically controlled machining center. Full of pride, he had us watch the new machine at work. An operator pushed the start button and then stood by throughout the entire two-minute process, just keeping an eye on what was happening.

Naturally, I asked the manager why the operator was staying by the machine. The manager pointed out several reasons—the machine spurts out metal shavings, the operator needs to make sure it is operating correctly, and so on. In other words, the operator had merely switched jobs. Instead of being an operator, he was now a supervisor.

So there it was, the latest in NC machine technology, and still worthless as far as cutting costs goes. I suppose its greatest value to the company was as an amusing new "toy" for the top managers to show off to visitors—evidence that the company was keeping up with the latest fashions in modernization. No one seemed to be paying any attention to what the new machine meant in terms of improving the production system.

Consider, for example, the production configuration shown in Figure 14.1. There are three operators (A, B, and C), each of whom is assigned to one of three machines (1, 2, and 3). After the operators finish their manual task, they set the workpiece

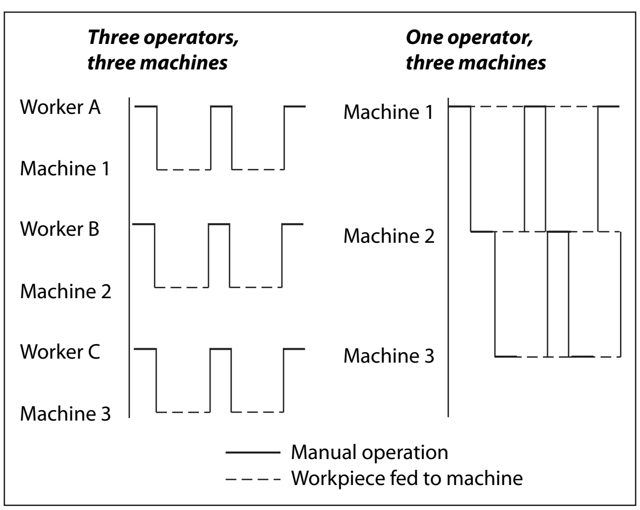


Figure 14.1 Separating Workers from Machines.

into the machine and wait for the machine to go through its process, thereby creating idle time waste.

To remove this idle time waste, the company decided to implement *jidoka*. First, they remodeled the machines to separate the workers from them. Next, they changed the equipment layout to bring the machines closer together. This made it possible for just one worker to handle all three machines consecutively, eliminating idle time waste. The key improvement that made this productivity-boosting overhaul possible was separating workers; that is, separating human work from machine work.

Procedure for Separating Workers

What is the best way to go about separating workers from their machines? For example, if part of Worker X's job is to use his left hand to hold a workpiece against a drilling machine while the machine drills holes into the workpiece, how can he separate himself from the drilling machine? Let us also suppose his job includes using his right hand to turn a wheel that feeds workpieces into a lathe. How on earth can he leave the machines to do all the work? That is precisely what we need to figure out. We must enable him to leave every single processing task to the machines.

Consider lathes as another example. Lathes operate using three kinds of motion: the lathe turning motion, the cutting motion, and the workpiece feed motion. If the operator needs to assist the lathe in making any of these kinds of motion, he cannot be separated from the lathe. (See Figure 14.2.)

If, for instance, the operator's job consisted only of guiding the bite's lateral motion and the lathe took care of the two other motions, the operator still cannot be separated from the machine. Likewise with the drilling machine mentioned above, the drilling machine will often execute the drill's rotary motion and the workpiece feed motion while

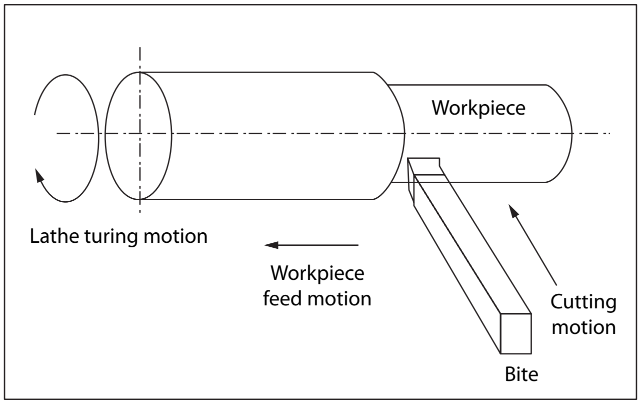


Figure 14.2 Three Kinds of Motion Made by a Lathe.

the operator simply holds on to the workpiece. Even then, the operator cannot be separated.

Here is how we could separate the operator from the lathe:

Operation 1: Return to starting position

With conventional lathes, the operator must help guide the workpiece during processing, then must extract the processed workpiece from the lathe and set the lathe's bite and other apparatus to their starting positions to prepare the lathe for accepting another workpiece.

Operation 2: Extract processed workpiece

The operator extracts the processed workpiece from the lathe and sets it down at the designated storage site. This is considered the next process after the lathe process.

Operation 3: Set-up the next unprocessed workpiece

This means picking up an unprocessed workpiece and setting it up for processing. In the case of lathes, this includes setting the centering supports and the chuck supports. If the machine is a drilling machine, the operator needs to set-up the measuring jig and the V block.

Operation 4: Starting the machine

After the operator is done setting up the lathe, he or she presses the "start" switch to begin feeding the workpiece into the lathe.

Operation 5: Processing the workpiece

In terms of the types of motion that occur, processing the workpiece in the lathe can be broken down into the cutting motion and the feed motion. The cutting motion is the speed at which the lathe turns the workpiece on the spindle. In other machines, the types of motion are different. Drills include the rotational motion of the drill and the vertical motion of the lifter; cutting machines feature the rotational motion of the blade, and so on.

Sometimes the workpiece is moved through the cutting tool, and sometimes the cutting tool is moved through the workpiece.

The above five operations can be expressed in a combination chart to help distinguish human work from machine work. (See Figure 14.3.)

As long as operations proceed as described above, there is simply no way that the operator can be completely separated from the machine. The machine must be customized to

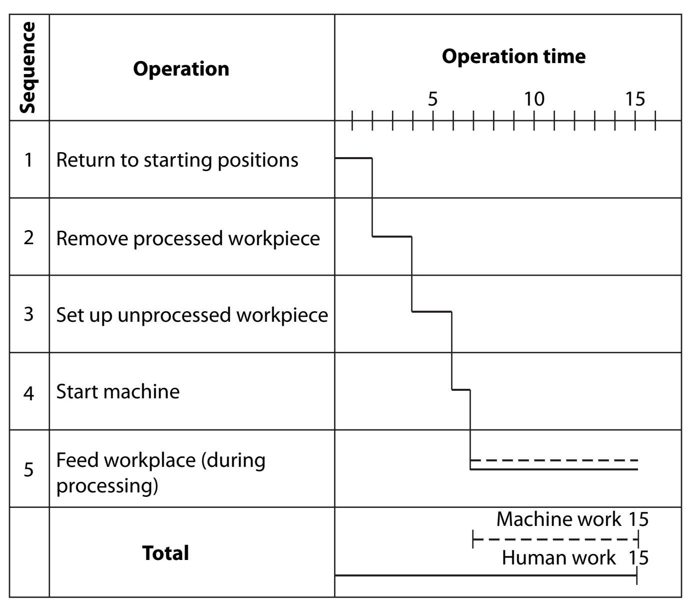


Figure 14.3 Combination Chart to Clarify Human Work from Machine Work.

enable the operator's separation. The following describes a procedure for separating the lathe operator.

Step 1: Apply *jidoka* to the cutting motion

Lathes and other cutting machines generally use rotational motion to move either the workpiece or the cutting tool. Almost all modern machines have rotational motors for automatic rotation. The rare exceptions to this are the hand-operated cutting and drilling machines that are sometimes used for woodworking.

So we generally do not have to worry about automating the rotational motion, since it is nearly always automated already. Nonetheless, we should start by considering this step and noting it on a combination chart such as the one shown in Figure 14.4.

Step 2: Apply *jidoka* to the feed motion

Once the cutting motion has been automated, we are ready to apply *jidoka* to the feed motion. For lathes, this means automating the cutting motion (as opposed to

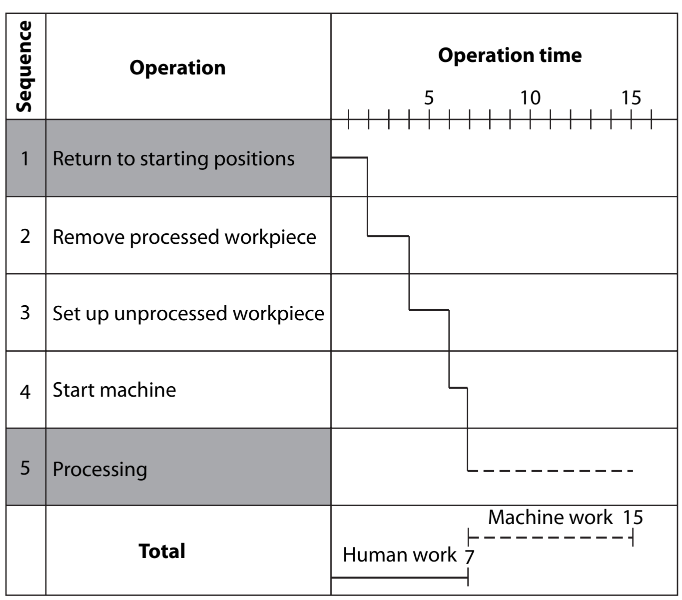


Figure 14.4 Applying Human Automation to Feeding Workpieces (to Separate the Worker).

the lathe turning motion) or workpiece feed motion. For drilling machines, it involves automating either the workpiece feed motion or the workpiece guide motion.

Once the cutting motion and the feed motion have been automated, we are able to separate the operator from the machine, at least during the processing of the workpiece. This takes us to the first stage in *jidoka*: separating the worker.

At this stage, the operator still has to extract the processed workpiece from the machine and set-up the next workpiece for processing before starting the machine. We call this pair of manual operations the “output/input” procedure or the “detach/attach” procedure. (See Figure 14.4.)

Step 3: Apply *jidoka* to the task of returning to starting position

In order for a lathe to handle processing all by itself, it must be able to fully stop both the cutting (rotational) motion and the feed motion when the processing is completed. Next, it should be able to return the cutting tool and workpiece to the positions they occupied prior to processing. This is the next step for *jidoka*, which is expressed in the combination chart shown in Figure 14.5.

Step 4: Apply *jidoka* to removing the processed workpiece

Removing and setting up workpieces are two of the operations encompassed by machine-centered material handling. In JIT production, we should consider applying *jidoka* to both of these operations. In deciding whether or not we should automate them, our main criterion is the amount of equipment cost incurred. The more complicated automating the material handling operation becomes and the more precision required of it, the more expensive it will be. Generally, setting up workpieces requires more precision than removing them. Removing them is often simply a matter of loosening the jig that holds the workpiece in place and taking the workpiece from the platform or table where it lies. Not much

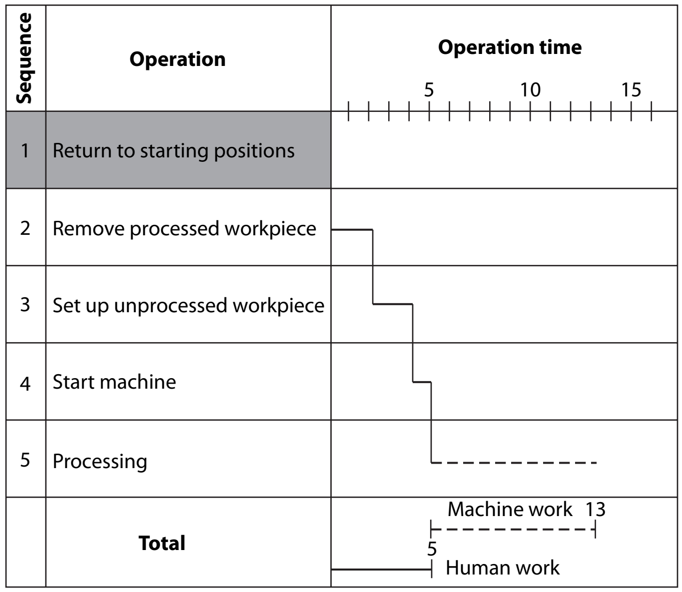


Figure 14.5 Human Automation of Return to Starting Positions (Input/Output Procedure).

precision is needed for setting down the processed workpiece either. Consequently, inexpensive devices such as pneumatic cylinders are often adequate for automating the removal of workpieces.

By contrast, it usually entails a lot more complexity and precision to set-up a workpiece into a jig or against a block correctly. Here, cheap pneumatic cylinders will not do the trick. Instead, set-up tasks usually require the precision and versatility of industrial robots. Therefore, it makes more sense to avoid trying to automate the set-up procedure if it turns out that doing it by manual labor is cheaper than buying industrial robots to do the job. Instead, we should channel our *jidoka* efforts toward the less demanding procedure of removing workpieces. (See Figure 14.6.)

Once we have automated the removal of workpieces from a machine, the operator no longer needs to remove each workpiece after setting it up and having the machine process it. This means that the operator's job

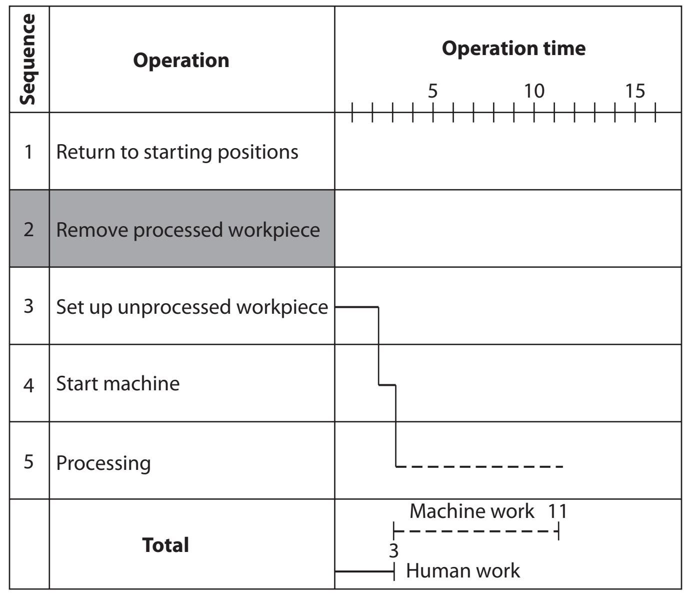


Figure 14.6 Human Automation of Removing Processed Workpieces (with Manual Set-up).

(for a series of two workpieces) changes from "remove/set-up/remove/set-up" to simply "set-up/set-up."

Step 5: Apply *jidoka* to setting up the unprocessed workpiece and starting the machine

At this point, the only remaining manual operation is setting up the workpiece and hitting the start button. Often, the same device that is able to set-up the workpiece automatically and precisely is also able to activate the machine automatically.

When a lot of precision is needed for the set-up procedure, automation may require expensive mechanisms, such as industrial robots. Therefore, we need to make a careful study of costs: Which is cheaper in the long run—manual set-up or automated set-up?

Figure 14.7 shows how the combination chart would look if we manage to automate both the set-up procedure and the machine activation procedure. As shown in the figure, this step brings the process to full automation as an "unmanned process."

Sequence	Operation	Operation time (5, 10, 15)
1	Return to starting positions	
2	Remove processed workpiece	
3	Set up unprocessed workpiece	
4	Start machine	
5	Processing	- - - - - - - - - - -
	Total	Machine work 8

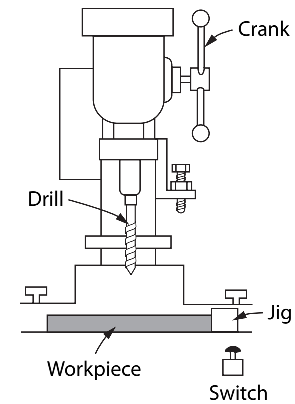
Figure 14.7 Human Automation of Setting Up Unprocessed Workpiece and Starting Machine (Totally Unmanned Process).

To summarize, the key points in automating processes and bringing factory automation technologies into the factory are: operators must be completely separated from the machines and the machines must be equipped with defect-detection devices, and automation must be developed one step at a time with continual attention paid to comparing manual labor costs with equipment investment costs.

It cannot be repeated enough that *jidoka* should never be used to the detriment of cost performance. Many companies have ended up taking a big loss after investing lots of money in fully automated production lines.

Case Study: Separating Workers at a Drilling Machine

In Chapter 13, we have already seen one case study of separating workers from machines. Figure 14.8 shows another example that involves a typical table-top drill wherein only the rotary motion of the drill has been automated. The operator



Sequence	Operation	Operation time (5, 10, 15)
1	Return crank position	
2	Turn switch off	
3	Remove processed workpiece	
4	Set up unprocessed workpiece	
5	Turn switch on	
6	Feed and hold workpiece	
	Total	Machine work; Human work 13

Figure 14.8 Table-Top Drill Operation before Improvement.

has two manual procedures to perform while using this drill: turning the crank with one hand to lower the drill to the workpiece and holding the workpiece in place with the other hand. Obviously, this drill keeps its operator busy and the operator cannot leave it at any time during the drilling process.

Improvement 1: Jidoka *of "Feed"*

By applying *jidoka* to the "feed" step, we can begin to separate the worker from the machine. In other words, at this stage we eliminate the need for the operator to hold the crank with his right hand and lower the drill after setting up the unprocessed workpiece and turning the start switch on. Figure 14.9 shows how the same drilling machine can be automated so that once the start switch has been pressed, the drill is automatically lowered to drill the hole, then is automatically raised back to its starting position, after which the machine shuts itself off. This frees the worker's right hand, but he still must use his left hand to hold the workpiece in place during processing. Thus, he is not completely separate from the machine.

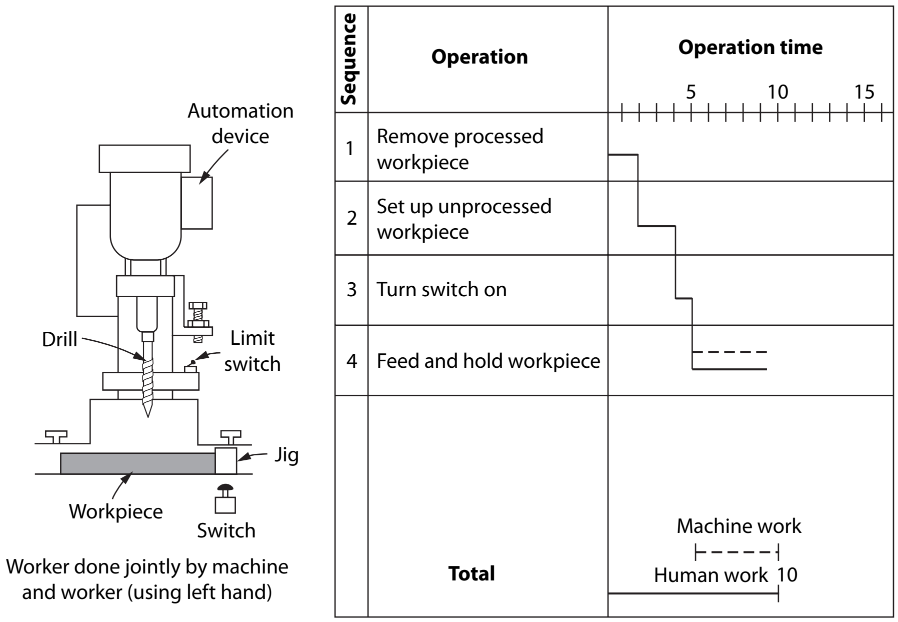


Figure 14.9 **Improvement 1: Human Automation of "Feed" Motion.**

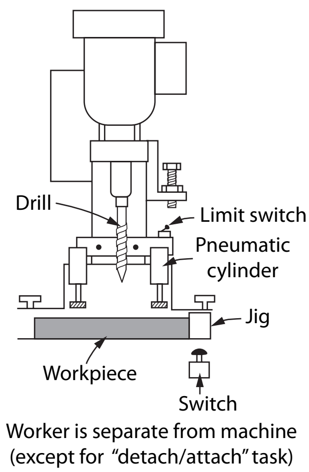
Improvement 2: Jidoka *of "Hold" Motion*

Our first improvement separated the worker's right hand from the machine by automating the "feed" motion. But the worker still must use his left hand to hold the workpiece in place while it is being drilled. So, he cannot be completely separated from the machine. To free both the worker's hands, we must also automate the "hold" motion that keeps his left hand busy.

Figure 14.10 shows how a pneumatic cylinder, activated by the machine's start switch, can be used to hold the workpiece in place during drilling. This enables the worker to be separate from the machine during the entire drilling operation. The worker's only remaining work is the "detach/attach" pair of tasks, in other words, removing processed workpieces and setting up unprocessed ones.

Improvement 3: Jidoka *of "Detach" Movement*

After the second improvement, the worker is able to be separate from the machine only while the workpiece is being



Sequence	Operation	Operation time (5, 10, 15)
1	Remove processed workpiece	
2	Set up unprocessed workpiece	
3	Turn switch on	
4	Feed and hold workpiece	
	Total	Human work 5 Machine work 10

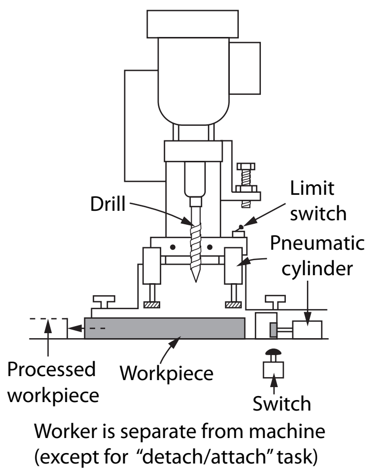
Figure 14.10 Improvement 2: Human Automation of "Hold" Motion.

processed (drilled). The next step is to eliminate half of the remaining pair of tasks—removing or "detaching" processed workpieces and setting up or "attaching" new ones.

Figure 14.11 shows the same drilling machine, this time with an automation device consisting of another pneumatic cylinder that pushes the processed workpiece out of the machine after the drill has returned to the starting position. The only human work remaining at this point is to set-up each workpiece in the drilling machine and press the start switch.

Ways to Prevent Defects

As mentioned earlier, it does no good to separate the worker from the machine if there is a chance that the machine will start spewing out defective goods during the worker's absence. The solution to this problem is to make the machine both capable of detecting actual or potential defects and able to shut itself off and alert operators to the problem whenever abnormalities are detected. Only then does separating



Sequence	Operation	Operation time (5, 10, 15)
1	Set up unprocessed workpiece	
2	Turn switch on	
3	Feed (automatic)	
	Total	Human work 3; Machine work 8

Figure 14.11 **Improvement 3: Human Automation of "Detach" Motion.**

workers really make sense. Consequently, developing and installing defect-preventing devices is a key part of *jidoka.*

The following are a few examples of defect-preventing devices.

How to Prevent Defects in Tapping Operations

Figure 14.12 shows an example of a defect-preventing device used in tapping operations. Before this improvement, this

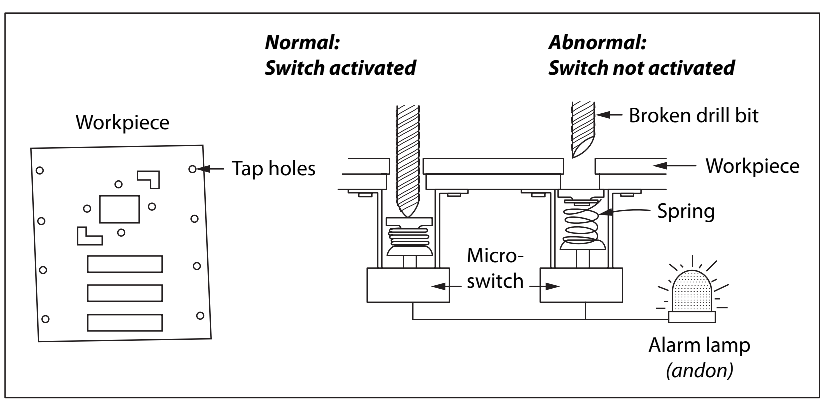


Figure 14.12 **Defect-Preventing Device for Tapping Operations.**

tapping machine, which uses 12 drill bits to simultaneously tap 12 places in the workpiece, experienced occasional defects such as broken drill bits, tapping omissions, and incomplete tapping. The factory had inspectors check every workpiece after being tapped to sort out the defective ones.

After the improvement, a microswitch was installed underneath each tap hole. If any of the 12 microswitches is not pressed during the tap operation, the tapping machine stops itself and lights an alarm lamp (*andon*) to alert the operators to the problem. This eliminates the need for human supervision and downstream inspection by preventing defects from recurring or being sent downstream.

How to Keep Injection Mold Burr Defects from Being Passed Downstream

Figure 14.13 shows a defect-preventing device to prevent injection mold burr defects from being passed downstream.

Before the improvement, molded workpieces were visually inspected for burr defects and were deburred when such defects were found. However, inspection oversights and other human errors occasionally resulted in the passing of workpieces with burr defects downstream. The defects went

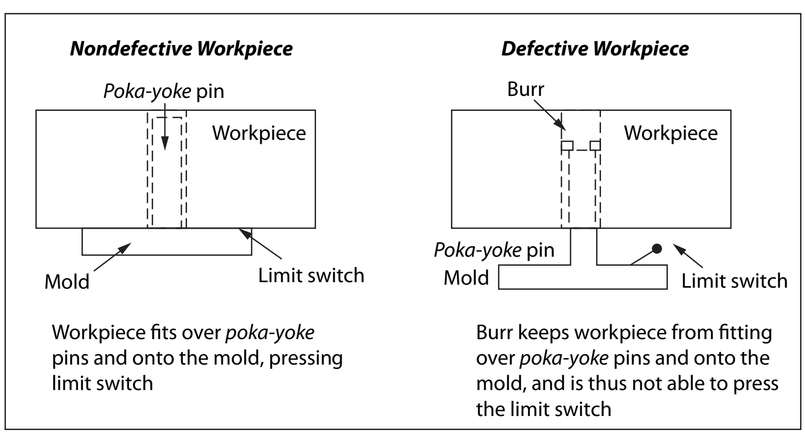


Figure 14.13 Defect-Preventing Device that Prevents Injection Mold Burr Defects from Being Passed Downstream.

unnoticed here until the final assembly stage, which caused a lot of trouble.

After the improvement, the lead wire soldering process that follows the injection molding process was equipped with a mold with *poka-yoke* pins that fit into the molded workpiece, which detected the presence of a burr in the mold and automatically stopped the lead wire soldering machine whenever one was detected. This device effectively prevents any workpieces with burr defects from reaching the final assembly process.

How to Keep Drilling Defect from Being Passed Downstream

Figure 14.14 shows a device that keeps drilling defects from being passed downstream.

This machine performs drilling and finishing in a continuous two-step process. Sometimes, however, it omits the drilling step. When this happens, the finishing drill bit breaks when trying to enter the place where the hole was omitted. Although the best thing would be to have a device that prevents drilling omissions from occurring in the first place, it was decided that it would be simpler to have a device that

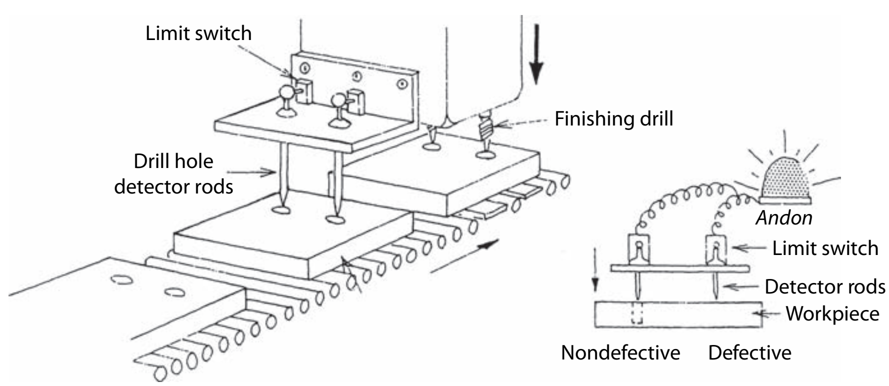


Figure 14.14 Device to Keep Drilling Defects from Being Passed Downstream.

would confirm the drilled holes just before the hole finishing step in the two-step process.

The defect-preventing device consists of a plate attached to the input side of the drill hole finishing machine. Two rods are suspended through this plate. When the drill hole finishing machine processes one workpiece, the defect-preventing device tests the next one on the conveyor by lowering the two rods through the drill holes. If a drill hole is missing, the rod cannot be lowered fully and is instead pressed back against a limit switch. When either of the limit switches are activated, the drilling and finishing machines are both stopped and an *andon* alarm is activated, as shown in Figure 14.14.

Extension of *Jidoka* to the Assembly Line

We usually apply *jidoka* to processing equipment, but we can also extend it to assembly operations to prevent defects from being passed downstream and/or to prevent overproduction. Most assembly line applications of *jidoka* are based on "A-B control" and fall into one of two categories: the full work system or the stop position system.

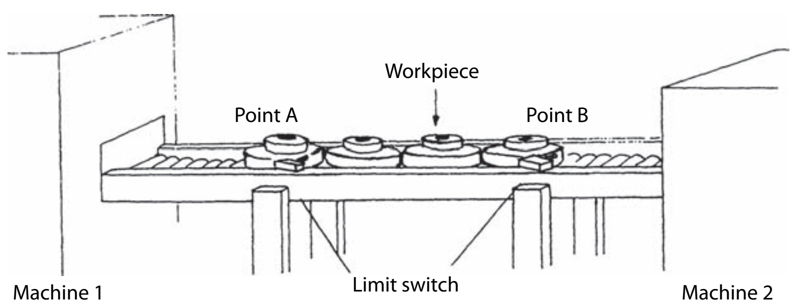
Full Work System

"A-B control" refers to a method for maintaining and controlling a constant flow of work by checking the passage of work between two points (A and B). The full work system helps maintain one-piece flow operations and prevents overproduction by detecting when a full workload has been reached, even when abnormalities occasionally force the line to stop. (The full work system is also discussed in Chapter 5.)

Figure 14.15 illustrates the control method used in the full work system. As can be seen in the figure, the flow of workpieces is allowed to continue only under Condition 2, in which there is a workpiece at point A but not at point B.

Point		A	B	Description
Condition	1	Yes	Yes	If there are workpieces at points A and B, moving the conveyor would cause a pile-up at point B.
	2	Yes	No	Conveyor moves only under this condition.
	3	No	Yes	If there is a workpiece at point B but not at point A, moving the conveyor would cause a gap in work-piece flow while leaving a workpiece at point B.
	4	No	No	If there are no workpieces at points A and B, moving the conveyor would simply cause a gap in workpiece flow.

Figure 14.15 A-B Control under the Full Work System.



- If point A's limit switch is still set to ON when the cycle time is up, the system interprets it as a "full work" condition and shuts off Machine 1.
- When point B's limit switch gets switched to OFF, the system interprets it as a "no work" condition and shuts off Machine 2.

Figure 14.16 Full Work System Used for Machining Line.

Figure 14.16 shows an example of a full work system applied to a machining line. In this example, when the cycle time is up and the limit switch at point A is still set to ON, the system shuts off Machine 1 because producing any more goods from Machine 1 would only cause an overproduction of goods beyond the cycle time. When the limit switch at point B is switched to OFF (that is, when there are no more workpieces at point B), the system interprets this as a "no work" situation and shuts off machine B.

Stopping at Preset Positions

When an abnormality or other problem occurs on a conveyor line, such as an assembly line, the assembly workers press a stop button to stop the line immediately in order to identify the problem and solve it right way.

The following are the most common types of problems encountered on assembly lines:

1. Missing assembly part
2. Defective assembly part
3. Delay due to error in assembly method
4. Failure to keep up with assembly pitch

The assembly line should include stop buttons (also known as "SOS buttons") next to each worker. Whenever any of the assembly workers notice an abnormality, they must immediately press the SOS button to stop the line and look into the problem.

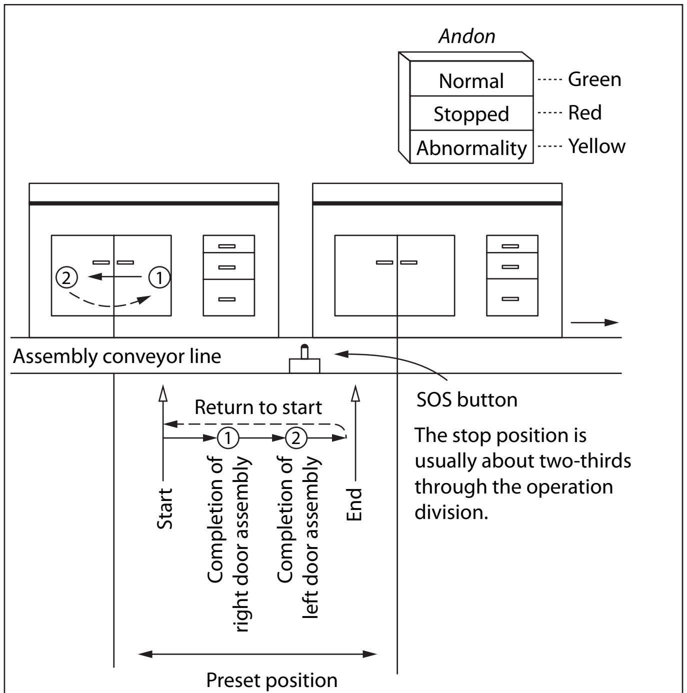
All factories have problems. We could even go as far as to say that a factory without problems is not a factory. Different problems crop up from day to day.

The same goes for the factory's assembly line. Assembly line problems range from missing parts to defective parts and unbalanced operations. When the problems are numerous, pressing the SOS button each time may result in a line that is almost always stopped, which is counterproductive.

Although it is important to stop the line to identify and solve the problems, line supervisors believe it is equally, if not more, important for the line to operate smoothly and productively.

The system of stopping at preset positions is a good way to find a middle path through the mixed intentions of supervisors who want the line stopped in order to identify and solve problems, but who also want to keep the line running productively.

Figure 14.17 shows this system being used for an assembly conveyor line.



Relation with andon

Order	Description of operation	*Andon*	Color	Sound
1	Start attaching right door	Normal	Green	None
2	Abnormality (press SOS button)	Abnormality	Yellow	Chimes
3	Conveyor stops at preset position	Stopped	Red	Buzzer

During this interval, supervisors try to solve the problem without stopping the line.

Figure 14.17 Stopping at Preset Positions on an Assembly Conveyor Line.

Let us suppose an assembly worker has just started an assembly operation and is about to fasten the right door onto the product. While doing this, the worker notices an abnormality and immediately presses the nearby SOS button, which is usually located about two-thirds the way along the path covered by the assembly worker during the assembly operation.

Once this worker presses the SOS button, the *andon* changes color from green (normal) to yellow (abnormality). Usually a number identifying the specific process along the assembly line is displayed, and a chime or bell rings to alert the supervisor. (For further description of *andon,* see Chapter 9.)

The supervisor comes immediately to the process where the abnormality has occurred and tries to identify and solve the problem while the line is still operating. If the supervisor can solve the problem before the preset stop position is reached, he or she presses a switch to turn off the yellow *andon* light and the chimes, and the situation returns to normal.

On the other hand, if the supervisor cannot solve the problem before the preset stop position is reached, he or she must stop the conveyor before the problem is passed to the next process. Stopping the line changes the *andon* color from yellow to red and the sound of the alarm switches from soft chimes to a loud buzzer or siren.

This system of preset stop positions helps extend the defect-preventing concept of *jidoka* to assembly lines. The preset stop positions provide an immediate response to problems.

Jidoka *to Prevent Oversights in Parts Assembly*

At the very least, the point of assembly operations is to assemble all of the parts without leaving any behind. When even this basic obligation is not kept, such as when an assembly worker simply forgets to attach a certain part, the result is a defective product. This is where *poka-yoke* devices can be used as an extension of *jidoka* to prevent such defects that arise from the omission of parts. (For further descriptions of *poka-yoke* devices, see Chapter 12 of this manual.)

Figure 14.18 shows an example of this extension of *jidoka* to prevent the omission of a parts tightening operation. Before the improvement, the assembly worker used an impact wrench to tighten the fasteners in the workpieces being assembled. Occasionally, the worker would forget to perform this fastening operation, and naturally the result was a defective product.

Instead of relying on the worker's memory and vision to use the impact wrench to tighten the workpieces, a pneumatic

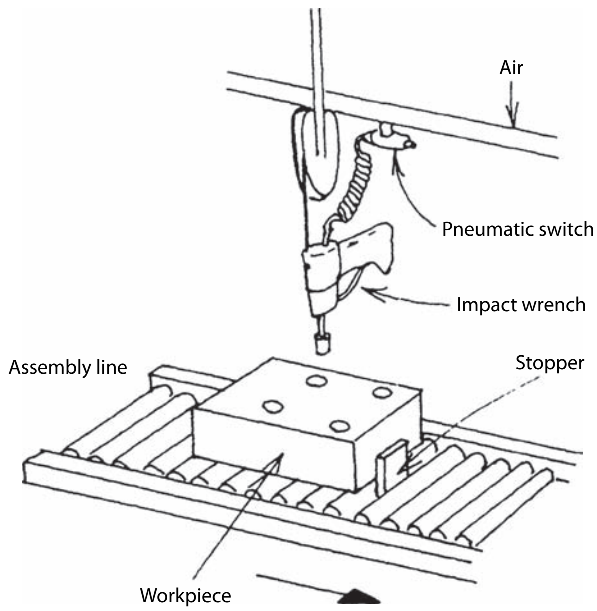


Figure 14.18 Extension of *Jidoka* to Prevent Omission of Workpiece Parts Tightening.

switch was installed. When the worker uses the impact wrench, the switch is activated, which causes the stopper to be lowered so the workpiece can continue on the conveyor. If the worker forgets to use the impact wrench, the stopper holds the workpiece in place. This device reduced the number of untightened workpieces to zero.

Another Jidoka *to Prevent Oversights in Attaching Nameplates*

One of the basic requirements for productive assembly line operations is to keep operations level, well-ordered, and within the cycle time. If the operational procedures are allowed to vary between one workpiece and the next, or if the workers are allowed to use their own discretion concerning how to do things, the assembly line is bound to produce products with missing or improperly assembled parts.

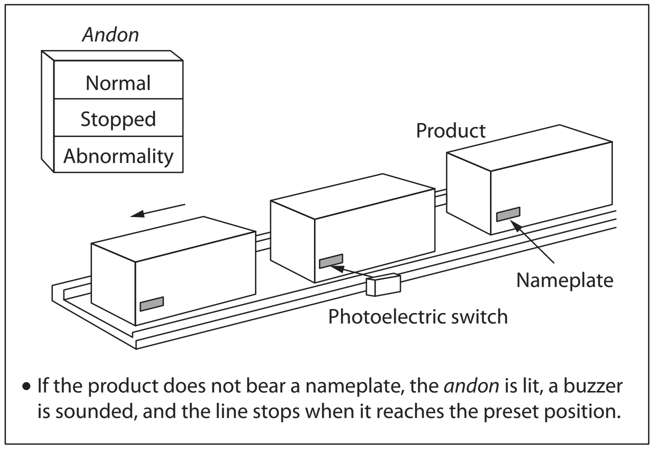


Figure 14.19 Extension of *Jidoka* to Prevent Omission of Nameplate Attachment.

Figure 14.19 shows how *jidoka* was extended to the assembly line to prevent omissions at the nameplate attachment process.

Before the improvement, an assembly worker would sometimes overlook attaching a nameplate to a product. This happened more often when the worker had just come back from a break. When this problem was first noticed, the supervisor made it a point to remind workers to be careful about attaching nameplates to every product. Still, workers occasionally forgot. Finally, the supervisor decided the assembly line should have a *poka-yoke* device that would prevent products without nameplates from proceeding down the line.

The *poka-yoke* device consists of a photoelectric switch that reflects a light beam off of the shiny metal nameplate. This switch uses the reflected beam to detect whether the nameplate has been attached. If it detects a missing nameplate, it lights the "abnormality" *andon* and sounds a buzzer. The line is not stopped until the product reaches a preset position. This device prevented any more products from being shipped without nameplates.

Chapter 15

Maintenance and Safety

Existing Maintenance Conditions on the Factory Floor

I have met many factory managers who pretty much accept machine breakdowns as part of the inevitable facts of factory life. But when I look around at their factories, I invariably notice at least some of the following conditions:

- Floors dirtied by puddles of oil leaked from machines
- Metal shavings scattered all over machines and the floor
- Machines so dirty that people avoid touching them
- Clogged air ducts that emit dust into the room
- Level gauges so dirty that they are hard to read
- Oil and dirt around the oil inlet ports
- Muddy oil in the oil tanks
- Leaks in the hydraulic and pneumatic equipment
- Loose bolts and nuts
- Strange noises coming from machines
- Machines vibrating abnormally
- Dirt and dust piled up on the photoelectric sensors and limit switches
- Abnormally hot motors
- Sparks flying from shorted wires
- Loose V belts

- Damaged V belts still being used
- Broken gauges and measuring instruments still being used
- Cracks filled with cardboard, jerry-rigging, and other temporary repairs

It was not at all hard to come up with this list of nearly 20 objectionable conditions. In fact, this list is based only on my observations in and around factory equipment; it would be a much longer list if I included all the other undesirable conditions I have run into in other parts of factories.

When I look around a factory and see many of these conditions existing, I can tell that JIT production was never even attempted there. Whether the factory uses small machines or large ones, there is no excuse for breakdowns. As I have mentioned elsewhere in this manual, factory managers need to emphasize the equipment's possible utilization rate over its capacity utilization rate.

The following pages explain why JIT production insists on zero breakdowns.

What Is Maintenance?

Why Is "Possible Utilization Rate" Necessary?

One way to look at JIT production is to compare it to the body's circulatory system, in which the blood flows to the various organs "just-in-time" to be used. Just as the factory handles large and small parts for its products, so too does the body have its large arteries and small veins and capillaries.

In JIT production, however, any delay in the flow of small parts (in the "veins" or processing line) soon stops the flow of large parts (in the "arteries" or assembly line).

To prevent such problems, JIT production vitally depends on maintaining a condition of zero breakdowns. This makes proper maintenance an essential part of JIT production. That is why it is more important to maximize the equipment's "possible utilization rate" (the availability of functioning equipment) than to raise its capacity utilization rate. People need to know the equipment will be in working order whenever they need it.

The key to achieving zero breakdowns is not maintenance in terms of repairing broken down equipment, but rather "preventive maintenance" that treats the causes of breakdowns before the breakdowns actually happen.

Why Accidents Happen

Why do accidents happen? The simplest and most direct answer is "deterioration." From the day a machine is installed, its condition gradually deteriorates over years of use, and sooner or later the combination of deteriorated parts or the accumulated deterioration of a single part will cause the machine to break down.

Almost any machine will have some telltale symptoms of ill health before it actually breaks down. For example, the machine may no longer be able to meet the required quality standards and may stop intermittently. Figure 15.1 shows the downhill path most machines follow before breaking down.

STAGE 1	**Latent minor defects**
STAGE 2	**Apparent minor defects**
STAGE 3	**Performs below expectations**
STAGE 4	**Stops intermittently**
STAGE 5	**Stops (breaks down)**

Figure 15.1 Stages on the Path to Equipment Breakdown.

The important thing is to learn to recognize where each machine is on that path.

Stage 1: Latent Minor Defects

Though difficult to see or hear, the machine's rotating parts are operating under increasing friction and its fastened parts are getting a little looser. These and other subtle defects characterize the first stage of equipment deterioration.

Stage 2: Apparent Minor Defects

The same defects described in the first stage have now become somewhat noticeable to the eye or ear. In addition, the machine may be vibrating more, making more noise, and leaking small amounts of oil, water, or air. But none of these defects are major enough to impair the machine's functioning.

Stage 3: Performs below Expectations

At this stage, it has become difficult to get the machine to perform with the desired precision and within the dimensional tolerances. The machine is turning out products with widely varying quality and suddenly it needs more adjusting than it used to require. It can no longer keep up with quality standards and is producing lower yields.

Stage 4: Stops Intermittently

At this stage, the machine has to be shut off fairly often to make adjustments to bring the product quality back into line. The machine frequently turns out damaged or dented goods, but can usually be started up again after making simple adjustments or repairs.

Stage 5: Stops or Breaks Down

At this final stage, the machine functions so poorly that it stops itself, which is to say it breaks down.

We should keep in mind that machines usually break down due to deterioration, and these kinds of breakdowns never happen all of a sudden; they happen in stages. One or more of the machine's deteriorating parts are left to deteriorate and eventually this deterioration accumulates or combines in a simple or complicated way to cause a breakdown.

If we respond to deterioration only when it reaches the fifth stage, we still will have to deal soon with various machines that are currently at the other four stages in the path. In other words, we cannot hope for a true reduction in breakdowns until we work our way up the path and treat deterioration before it results in breakdowns.

Maintenance Campaigns

When we let factory equipment deteriorate, sooner or later it will break down. In view of this, how can we achieve zero breakdowns? We must take measures to slow or halt equipment deterioration before it reaches the breakdown stage.

In JIT production, we do this by promoting and establishing a cycle of four basic maintenance activities within the staff hierarchy of each company division. Figure 15.2 illustrates this fourfold company-wide approach.

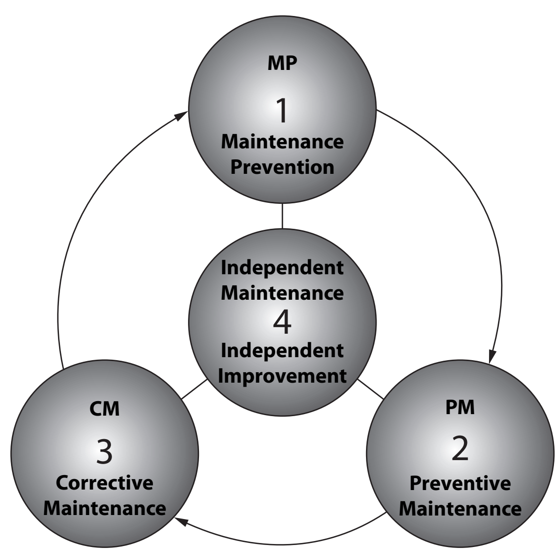


Figure 15.2 Production Maintenance Cycle for Zero Breakdowns and Zero Defects.

Measure 1: Maintenance Prevention (MP)

Maintenance prevention mainly pertains to equipment design. It involves using the data provided by independent maintenance and independent improvement activities to design equipment that is less likely to break down or experience faulty operation, and is more conducive to deterioration-preventive measures. Another important design criterion that is influenced by MP is the challenge to make equipment that can be maintained more easily, more quickly, correctly, and safely.

Measure 2: Preventive Maintenance (PM)

Preventive maintenance centers on daily checking and maintenance procedures that form part of independent maintenance and independent improvement activities. It also seeks to raise the reliability of the equipment while reducing the risk of faulty operation and slowing the progress of equipment deterioration. In addition, PM involves studying and selecting operational methods and equipment to help make maintenance activities easier to perform.

Measure 3: Corrective Maintenance (CM)

Corrective maintenance comprises the maintenance procedures taken in response to a breakdown, with a view toward preventing the problem's recurrence and improving the equipment's condition. In addition to reversing deterioration and raising reliability, corrective maintenance seeks to make the equipment easier to maintain on a daily basis.

Measure 4: Independent Maintenance, Independent Improvement

To reduce breakdowns, we give up the conventional notion that the equipment operators should simply operate the equipment while leaving all the maintenance work to the maintenance technicians. After all, the equipment operators are the ones who know the equipment best—they are the first to notice when the machine's motor starts sounding funny or when formerly clean parts of the machine are streaked with oil or dirt. Equipment operators should embrace with pride the idea that they can take care of their own machines. They should put that concept into practice by cleaning, checking, and oiling their machines. They can even replace parts and perform minor repairs.

Meanwhile, the maintenance technicians can still play an important role by promoting and teaching accurate and prompt repair methods to the equipment operators for improved independent maintenance and independent improvement activities. In so doing, they can help make the whole MP-PM-CM cycle run more smoothly.

CCO: Three Lessons in Maintenance

These days, when JIT consultants describe how to maintain a neat and orderly factory, they find it difficult to limit the basics to just five (the 5S's). Some list 6S's and others 7S's. Adding more S's is not always an improvement. Nonetheless, many Japanese companies are inclined to include *shukan* (custom) as the sixth S.

For our purposes, let us recognize that implementing and enforcing the 5S's daily is a good practice for companies. This is especially true when it comes to the 5S's as they relate to equipment maintenance.

In particular, equipment maintenance activities should include three main customs: Cleanliness, Checking, and Oiling (CCO). We refer to them together this way because they should always be carried out as a threefold unit that forms the core of independent maintenance activities.

Let us take a closer look at each part of the CCO formula.

Cleanliness (C)

As part of the 5S's, cleanliness (*seiso*) is the routine housekeeping work that is essential for maintaining the day-to-day health of the factory. As applied specifically to equipment, maintaining cleanliness is the best way to make a daily examination of the equipment. (Cleanliness is described in more detail in Chapter 4.)

Unfortunately, once people have cleaned up their workshop, they let it go for days, offering such excuses as, "We're too busy to get to that right now" or "Hey, it's still clean."

Sometimes it is the workshop supervisor who causes problems. For example, a supervisor might insist that cleanliness tasks be performed outside of regular working hours or that daily cleanliness activities do not improve productivity enough to be worth the trouble. But the fact remains that cleanliness will never lead to zero defects and zero breakdowns unless it is kept up as an integral part of daily production activities.

First of all, maintaining cleanliness is not something to be done at the odd moment between one production operation and the next. Instead, we should view it as an essential part of preproduction activities, just like changeover prior to processing a new model or setting up parts trays before assembling a new model.

In other words, equipment operators need to fully recognize the importance of maintaining cleanliness and make it (along with checking and oiling) just as much a part of their daily routine as anything else they do day in and day out in the factory.

To help operators stay on top of their CCO duties, workshop supervisors should post a "cleanliness inspection checklist" in the workshop, which operators can use to keep track of how well the daily cleaning tasks are being carried out. (This checklist is shown in Chapters 4 and 16.)

Just as each workshop should have tools and other equipment reserved expressly for changeover operations, so should it include the specific tools necessary to maintain cleanliness.

Checking (C)

Maintenance should be understood as an activity designed to prevent equipment from breaking down. The purpose of checking, therefore, is to determine whether the equipment is about to break down.

Checking is undeniably part of maintenance activities—but not something to be left entirely up to the maintenance technician. Since the operator is the one who knows best how well or poorly the equipment is operating, the operator has the kind of concrete problem-consciousness needed for effective daily checking and, when necessary, prompt response.

In recognition of the operator's superior qualifications as an equipment checker, we should not downplay his or her checking duties by relegating them to "spare time" or "overtime." They must be clearly established as part and parcel of the operator's daily routine.

Figure 15.3 shows a cleanliness inspection checklist and some cleanliness check cards. In this example, the workshop also includes a "cleanliness control board" on which operators post cleanliness check cards. The cards note whether the check ended normally or whether an abnormality was found. This control board enables the supervisor to immediately understand whenever an abnormality is found, so that a prompt response can be made.

Oiling (O)

The Just-In-Time concept of "just what is needed, just when it is needed, and just in the amount needed" can be applied directly to the activity of oiling. In other words, we need to give each machine just the kind of oil it needs, just when it

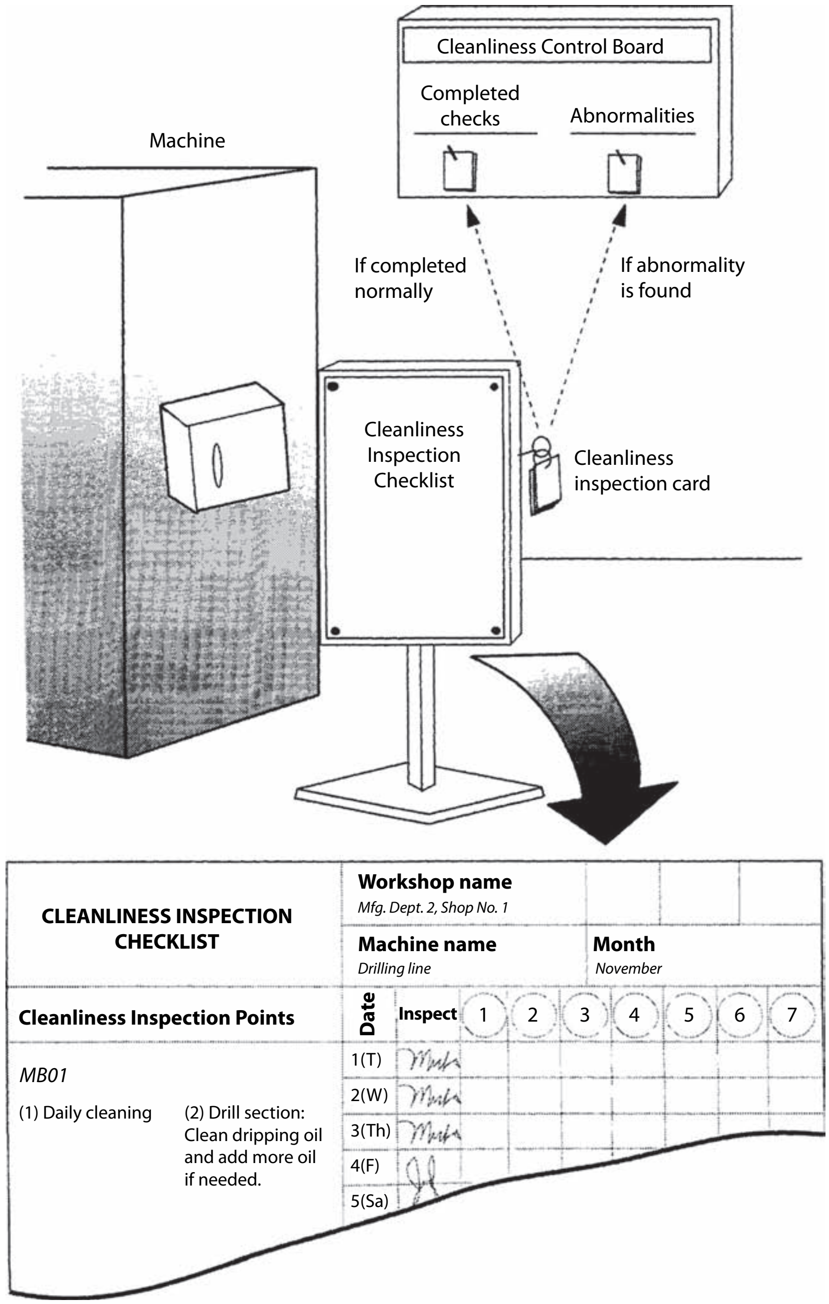


Figure 15.3 Cleanliness Inspection Checklist and Cleanliness Check Cards.

is needed, and in just the amount needed. (Proper oiling is also discussed in Chapter 4.)

The management of this activity should be made as visible as possible so that everyone can understand it. Figure 15.4 shows how the visual control tool known as *kanban* can be used

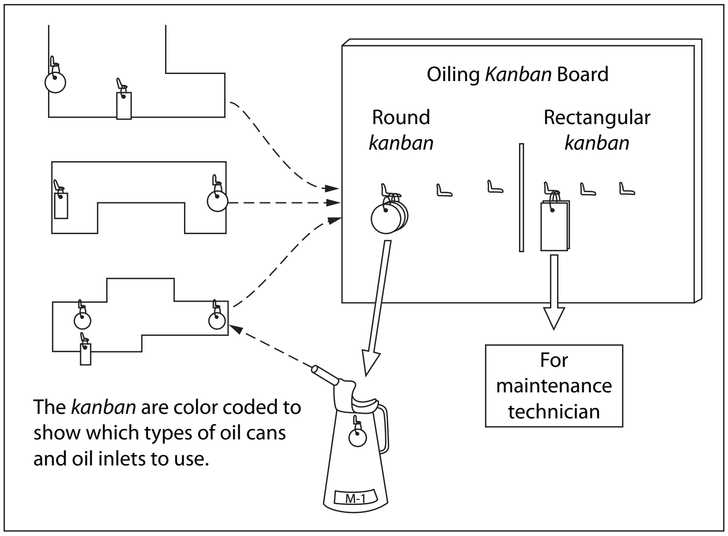


Figure 15.4 ***Kanban*** **for Oiling.**

to indicate what kind of oil goes where. These *kanban* also employ another visual control method known as color coding.

Here is how the *kanban* are used in the example shown in Figure 15.4.

1. Separate *kanban* are established for each machine and each oil inlet port.
2. Round *kanban* indicate oiling done by the workshop supervisor and rectangular ones indicate oiling done by the maintenance technician.
3. The *kanban* are color coded to indicate which type of oil and which inlet port to use, and to mark other material, such as oil cans and oiling tools.
4. The oiling times and amounts used are entered on the inspection checklist or in a log book.

Preventing Breakdowns

Some people are stronger than others. Some people catch colds easily while others can go all year without even a stuffy nose. Everyone knows that different people have different physical constitutions that make them more or less susceptible to contagious diseases.

Likewise, some types of factory equipment are stronger and less likely to break down, while other types are weaker and tend to break down more easily. We can refer to this characteristic as the equipment's "constitution."

Generally, the types of equipment that tend to break down more easily are those that operate using more complex moving parts, such as limit switches and cylinders. The types of equipment that have a stronger constitution are the ones that operate using simple coupling devices, such as cams and gears. It is also much less obvious when limit switches and cylinders are not operating correctly than when gears go on the blink.

Figure 15.5 shows two devices for holding down workpieces in a drilling machine. One device is a pair of pneumatic cylinders. If either of the pneumatic cylinders malfunctions, there is a safety hazard in that the cylinder might begin to operate while the worker is still setting up the workpiece, and the worker could get a pinched hand. For safety reasons, it makes more sense to use the other device, which is simply a pair of springs.

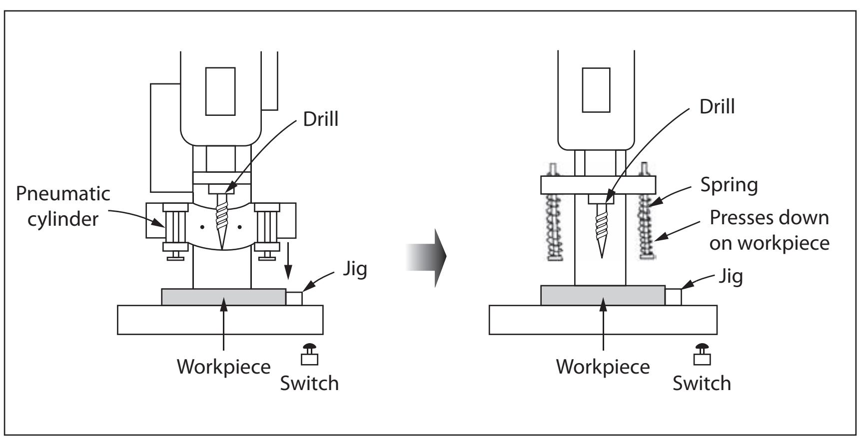


Figure 15.5 Safety Improvement from Pneumatic Cylinders to Springs.

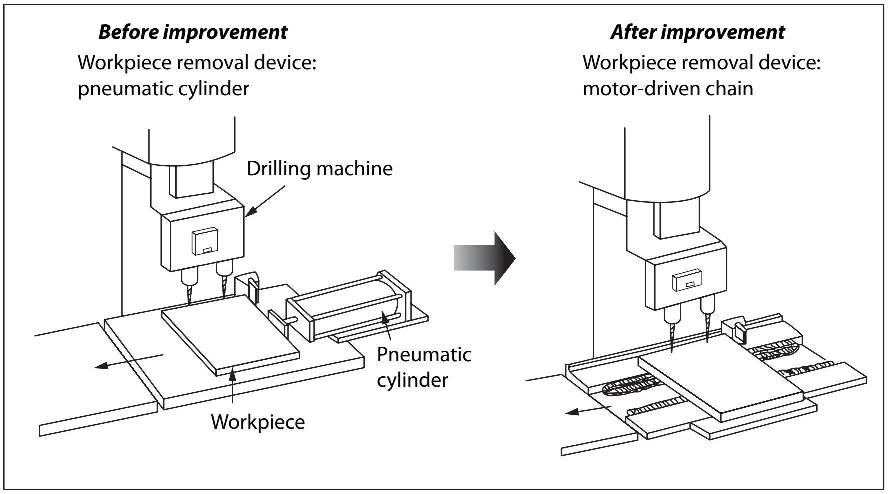


Figure 15.6 Use of Motor-Driven Chain as Automatic Workpiece Removal Device.

Figure 15.6 shows an improvement made in the method of automatically removing processed workpieces from a drilling machine. To facilitate maintenance and reduce defects, the workpiece removing device was changed from a cylinder to a motor-driven chain.

Once a breakdown occurs, we must find the cause and make an improvement that will prevent the same kind of breakdown from occurring again. To do this, the people who are dealing with the breakdown must see it first-hand, get the data first-hand, and then make a decision about how to respond effectively to the problem. Stopgap measures are not the answer. Whatever is done to fix the problem must be a preventive measure, not just a temporary patch job.

Why Do Injuries Occur?

It is pretty safe to say that every factory has at least one “Safety First” type of sign or banner on display. Factor managers and employees are conscious of the need for assuring safety, but accidents still happen, and they often happen

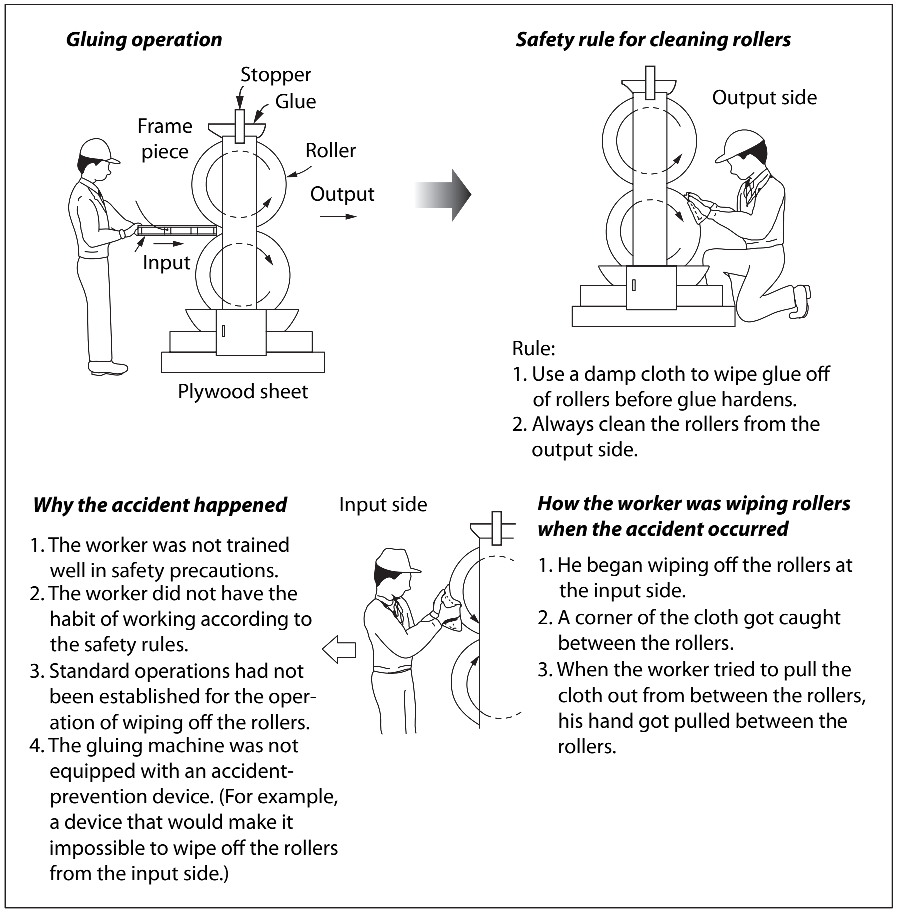


Figure 15.7 An Accident at a Plywood Gluing Process.

when a machine breaks down. If people want to give more than lip service to safety, they must address the need to prevent breakdowns.

Figure 15.7 shows an example of how an accident occurred during a plywood gluing operation. Naturally, the factory where this happened was not without its "Safety First" banner.

The accident actually happened at the end of the day, when a worker was cleaning the glue roller that presses together the sheets of plywood. As soon as the last set of plywood sheets was pressed, the worker took a damp cloth and began holding it against the rotating rollers to wipe off the excess glue before it hardened. The worker did this from the same side he had input the plywood sheets—a violation of the safety rule stating that the rollers must always be cleaned from the output side.

The worker broke this rule as a matter of habit. As shown in Figure 15.7, the rollers rotate in opposite directions to press the plywood between them. When wiping the rollers at the input side, an edge of the cloth would sometimes get pulled between the rollers. The worker relied on his reflexes to pull the cloth back before the rollers got a good grip on it. In other words, the worker gave higher priority to his reflexes than to the concept of "safety first." In hindsight, it seemed obvious to everyone that the worker's behavior would eventually lead to an accident.

The only way to effectively prevent this kind of accident from happening again is to clarify just why it occurred and take every countermeasure necessary to prevent a recurrence.

The main reason for this accident's occurrence include the following:

1. The worker was not adequately trained to be aware of the dangers inherent in his job and to take safety precautions.
2. The safety rule saying that workers must wipe the rollers from the output side was put into the book, but not into the mind of the worker. The supervisor is responsible for seeing to it that workers make a habit of obeying the rules.
3. Safety had not been built into the operational procedures. The way to do this is by establishing safety-conscious standard operations.
4. The equipment lacked an accident-prevention device, such as boards installed just in front of the rollers on the input side that would block access to the rollers for wiping. The worker would then be required to wipe the rollers from the output side.

What Is Safety?

Factory managers are faced with many ongoing needs, such as the need to raise productivity and improve quality. However, no need should ever take priority over the need to assure safety.

In other words, no boost in productivity or quality can ever be justified if it is at the expense of safety. Safety is everything in manufacturing—it is where manufacturing must start and end.

You would not know this judging from the kinds of excuses workers give after an accident and/or injury. Some say, “I was daydreaming” or “I was hurrying to catch up.” Workshop supervisors must speak the plain truth and make it known when the rules are bent or broken, or when workers fail to make a habit of doing things the safe way.

Another way to prevent accidents is to develop devices that make it difficult, if not impossible, to “daydream” or “hurry up” at safety’s expense. Rather than simply dispensing tongue lashings after accidents occur, supervisors should take preventive action by checking up regularly on safety practices and sternly warning workers who fail to obey the safety rules. After all, the correct or incorrect behavior of factory workers is a direct reflection upon the ability of the supervisors and factory managers to carry out their duties responsibly. Achieving zero injuries and zero accidents is a goal the entire company should pursue together, and a key part of such a company-wide safety campaign is devising ways to prevent shop-floor injuries and accidents.

Let us review the accident example shown in Figure 15.7 and the lessons to be learned from that incident. The following summarizes the four improvement points to be made to prevent similar accidents from recurring.

1. Establish more complete basic training
   The entire training program needs to be reviewed and improved so that workers are taught not only about the flow of goods in the factory and the features of

the equipment, but also about the proper attitude and approach toward safety assurance.

2. Get into the habit of obeying the rules
   Workers should make maintaining the 5S's and following the safety rules so habitual that they rarely need to think about it. When safety assurance requires that workers use their hands and voices to keep each other informed of what is happening, such behavior must become a natural habit. Workshop supervisors need to be especially strict in enforcing this.
3. Establish standard operations
   Along with training to teach the habit of obeying the rules, establishing safety-conscious standard operations and maintaining them with visual control tools will enable anyone to understand how things should be done. It will help supervisors keep tabs on whether operations are being done by the book.
4. Develop devices that prevent injuries and accidents
   No matter how well the rules are taught and enforced, people will occasionally make mistakes. We can still help prevent injuries and accidents that arise from human error by developing devices that make it difficult or impossible to err in an unsafe manner. We have seen how *poka-yoke* devices can prevent defects from being produced. We must extend the *poka-yoke* concept and create "safety *poka-yoke*" devices that prevent accidents.

Strategies for Zero Injuries and Zero Accidents

Thorough Implementation of Standard Operations and Rules

The first principle in safety assurance is to establish and maintain standards. The lion's share of injuries and other accidents occur when something is done in a nonstandard and abnormal manner.

We use standards to clearly distinguish between what is normal and what is abnormal. In factories, we should use visual control methods to make it obvious to anyone when things are nonstandard and abnormal.

Orderliness (*seiton*) calls for the creation of standard locations for items to assure safety in the physical layout of the factory. Likewise, standard operations require the creation of operation standards to help eliminate injuries and accidents. Standard operations are like the pillar supporting safe operations and training workers to maintain standard operations is like a crossbeam connected to that pillar. Together, they provide the main support for the structure of production operations. The point of this analogy is to underscore the importance of standards for factory layout and production operations.

Figure 15.8 shows a standard operations chart marked with crosses at all key safety points. Of course, the specific safety standards are described in the standard operations manual and operations guide to keep workers informed of safety-conscious procedures and safety precautions. Each company needs to invest enough resources to thoroughly educate and train workers in standard operations that help assure safety.

The more workers must assist in machine work, the greater the risk of injury. Therefore, the separation of workers from machines achieved through *jidoka* can be an important contribution to safety. (For a further description of how *jidoka* separates workers, see Chapter 14.)

Obviously, separating workers from machines that use sharp tools, such as saw blades or drill bits, helps to assure safety. The same goes for presses and other manufacturing equipment. Figure 15.9 shows how the worker was separated from the machine in the case of a lathe used for punching

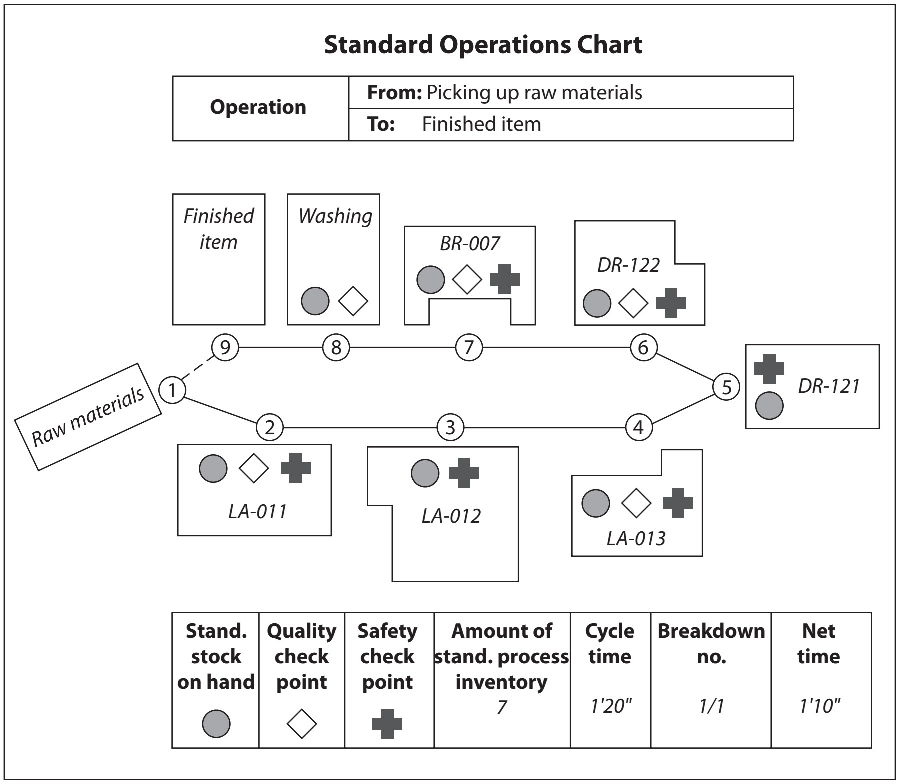


Figure 15.8 Standard Operations Chart Marked with Safety Points.

holes. Before the improvement, the lathe operator had to control the cutting motion and set the lathe back to the starting position. This kept him at the machine and kept productivity at a rather low level. Moreover, it exposed the operator to risk of injury from the rotating hole-punching bar and other moving parts of the lathe.

After the improvement, a hydraulic cylinder was used to control the cutting motion and the position setback was also automated, thereby enabling the operator's separation from the lathe. This not only significantly boosted safety assurance, but also doubled productivity

Another safety-enhancing improvement having to do with presses is the simple relocation of start buttons. Figure 15.10 shows a group of five presses handled by a single worker in a U-shaped manufacturing cell using multi-process operations.

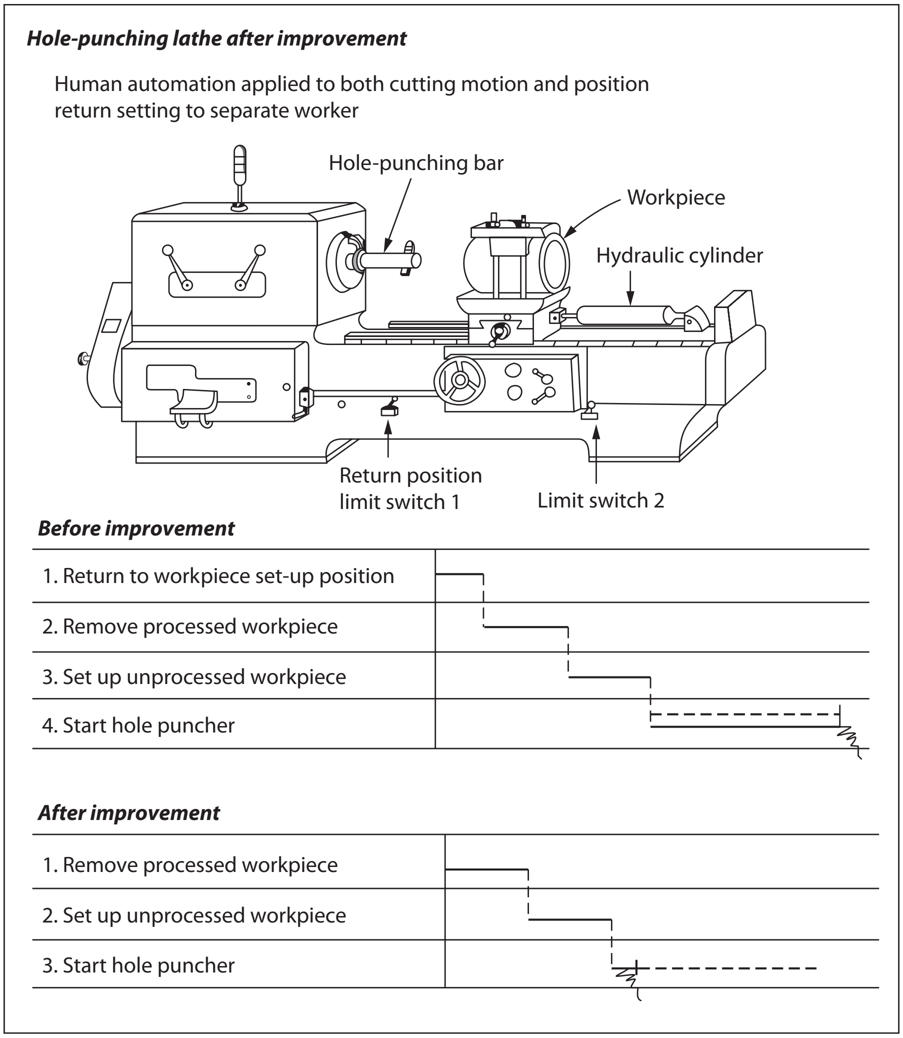


Figure 15.9 Separation of a Worker from a Hole-Punching Lathe.

The start button on each press was moved to the next press in the cell so that the worker can start the previous press as he comes to the next one and is always at a safe distance from the press when it starts operating.

A common safety problem with presses is that sometimes, just after the operator sets up the workpiece and presses the start button, he notices the workpiece is slightly out of position and, without thinking, tries to quickly correct it before the press comes down—a sort of "reflex" response that often leads to accidents. Obviously, nobody gets injured intentionally, but sometimes workers let their reflexes overcome their

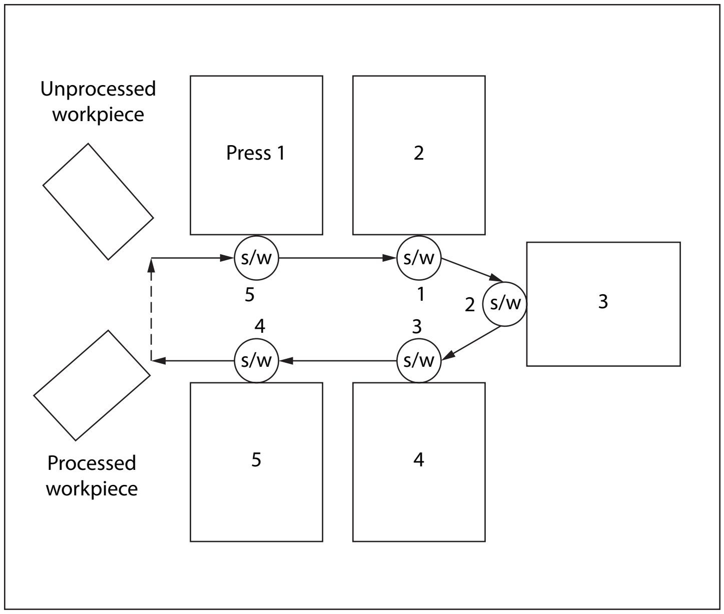


Figure 15.10 Separation of a Worker from Presses.

rational judgment. This is another good reason for separating workers from machines whenever possible.

Poka-Yoke *Applied to Safety*

Poka-yoke devices are mistake-proofing devices that can work to prevent defects or, in this case, accidents and injuries. Since careless human behavior is a leading cause of accidents, safety *poka-yoke* devices can provide a very effective means of preventing accidents.

The following are a few examples of safety *poka-yoke* devices.

Attaching a Safety Plate to a Drilling Machine

Generally, workers are not allowed to wear work gloves when operating drilling machines because it increases the danger of injury from the spinning drill. Figure 15.11 shows how attaching an acrylic safety plate in front of the drill not only enables the operator to avoid touching the drill bit, but also prevents him from getting his hands pinched by the pneumatic cylinders holding down the workpiece.

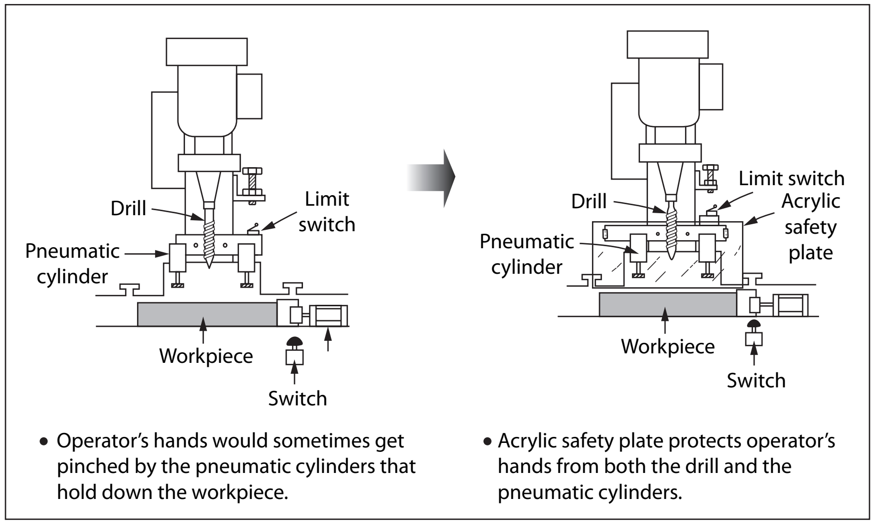


Figure 15.11 The Use of a Safety Plate for a Drilling Machine.

Safety Cage on a Press

Presses cause more injuries than most other types of manufacturing equipment. As described earlier, presses tempt their operators to act on reflex rather than on reason. As a result, many presses are equipped with start switches that require two-hand operation. Some also have "electronic eyes" that shut off the press if any foreign object intrudes into the danger zone.

The best safety device is one that enables complete separation of the worker from the press, since it allows the worker to remove himself from the press area while the press is operating. While safety is more important than productivity, it is obviously much better to find a way of ensuring total safety without sacrificing productivity. The best devices improve both safety and productivity.

Figure 15.12 shows a press upon which a safety cage was installed. The operator sets up the workpiece, shuts the cage door, and then starts the press. Once he shuts the cage door, the operator is completely cut off from the press. Using this safety cage is better than using a two-hand start switch since it enables the operator to be separated from the press, which boosts productivity by freeing the operator for other tasks.

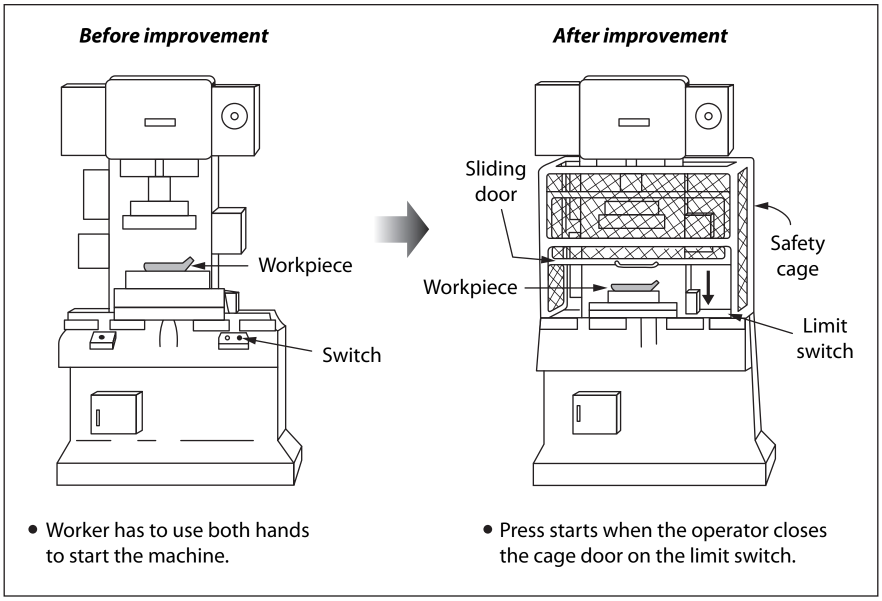


Figure 15.12 A Press with a Safety Cage.

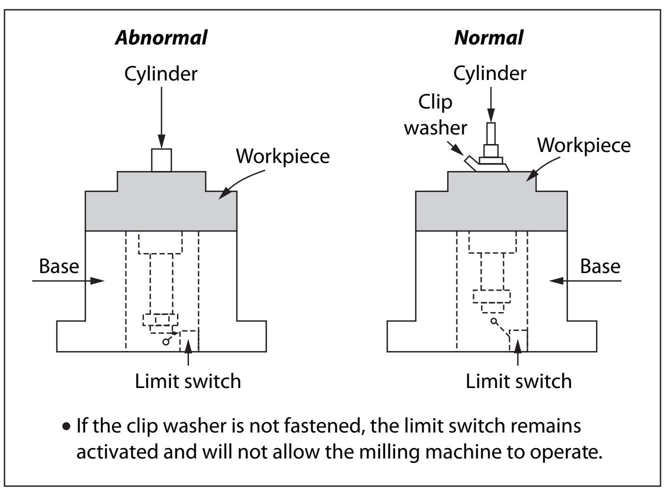


Figure 15.13 A Safety *Poka-Yoke* Device for a Milling Machine.

Safety Poka-Yoke *for a Milling Machine*

Figure 15.13 shows a safety *poka-yoke* that was developed for a milling machine.

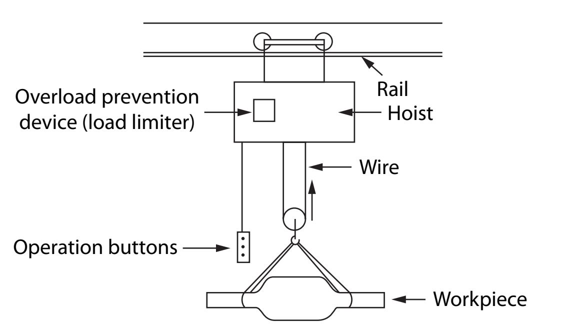
When operating the milling machine, the operator first sets up the workpiece, then uses a clip washer to hold the workpiece in place before starting the milling machine. If the operator ever forgets the washer, the workpiece can be ejected from the machine, which is dangerous indeed. Milling machine operators were warned of this danger and told to be very careful not to forget.

After the improvement, a limit switch was installed in the base and the cylinder presses upon this switch unless it is held by the fastened clip washer. This limit switch prevents the milling machine from operating unless the clip washer is fastened.

Safety Poka-Yoke *for a Crane*

Figure 15.14 shows a safety *poka-yoke* that was developed for a crane.

The crane's rail was not well reinforced and therefore had a rather modest load capacity. Overloading the crane was very dangerous, but workers seldom took the trouble to weigh things before using the crane to pick them up. Instead, they just looked at the item and guessed the weight. To assure safety when using the crane, they installed an overload prevention device that eliminated the need to even estimate the weight of the item to be picked up. This not only makes the crane safer to use, but also helps prevent the hoist from breaking down from overloading.



• If the workpiece is heavier than the rated maximum load, the load limiter is activated and prevents the workpiece from being suspended.

Figure 15.14 A Safety *Poka-Yoke* Device for a Crane.

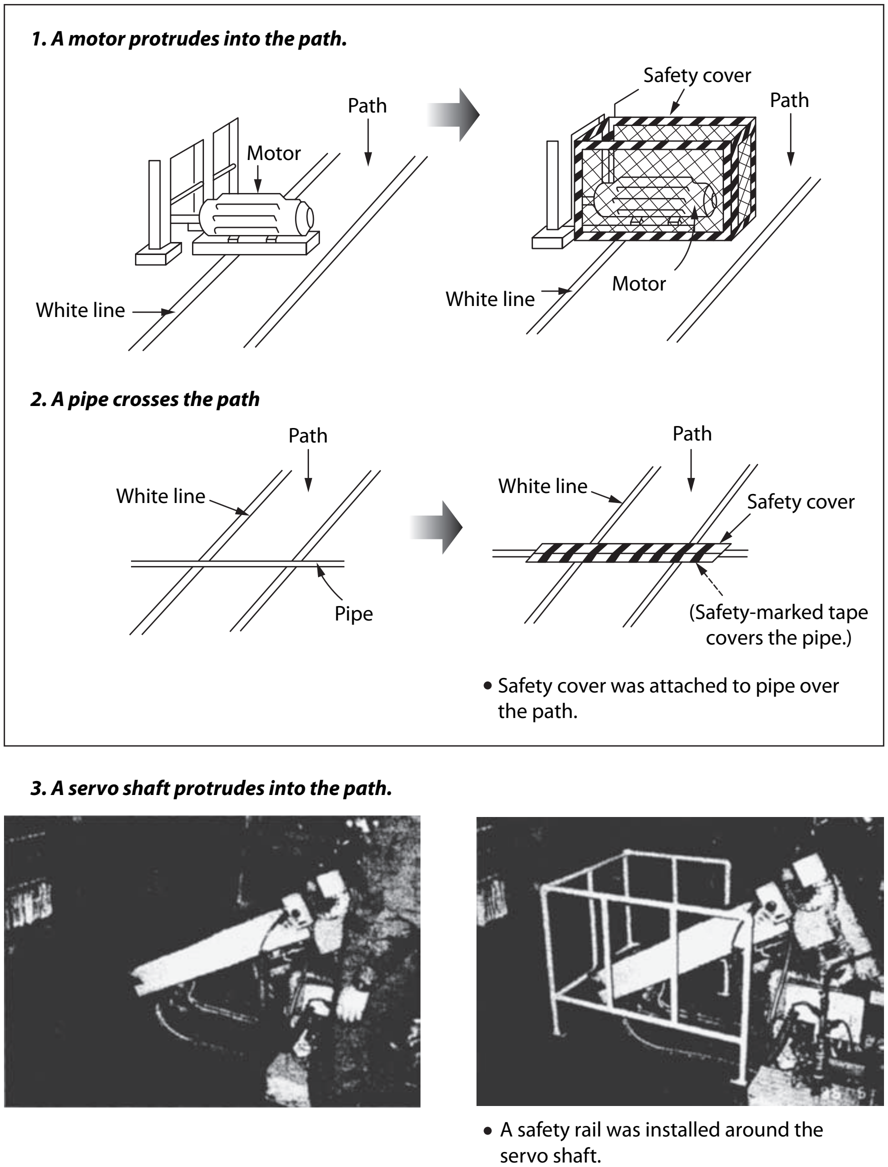


Figure 15.15 Visual Safety Assurance.

Visual Safety Assurance

Figure 15.15 shows an example of visual safety assurance. In this factory, the path that workers use to get around the factory contains obstacles, such as transversing pipes and protruding pieces of equipment. The best improvement would be to find some way to reroute the pipes and move the equipment out of the path. But for practical reasons the factory decided on a second-best improvement, which was to mark all such obstacles with easily visible safety covers and hazard markings.

Full-Fledged Maintenance and Safety

Faulty machine operation is another cause of injuries and accidents. When a machine suddenly stops working, the operator who goes to check what is wrong with the machine may be at some risk since the machine may begin operating just as unexpectedly as it stopped.

The key to eliminating such risks is to practice preventive maintenance to keep the equipment's "possible utilization rate" as high as possible.

The way to work toward achieving a 100-percent possible utilization rate is to establish and promote a comprehensive maintenance program that focuses not only on equipment operators, but the entire company. It must include the following two features:

1. *Thorough training in CCO.*
   Cleanliness, Checking, and Oiling (CCO) must become a daily habit for all equipment operators—an integral part of their routine tasks.
2. *Development of machines with "strong constitutions" that do not easily break down.*
   Some types of machines are weaker in "constitution" than others. As mentioned earlier, machines that operate using limit switches and cylinders are weaker than those that operate using direct coupling devices, such as gears and cams. Whenever possible, if we use the stronger types of drive mechanisms to do the job, we will find our machines less likely to break down.

In summary, various ways of improving safety assurance have been discussed including: preventive maintenance in pursuit of a 100-percent possible utilization rate, standardization of operations, full-fledged safety training, wider use of visual and audio safety-enhancing devices throughout the factory, and safety-oriented *poka-yoke* devices.

When all is said and done, safety is our main concern.

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About the Author

Hiroyuki Hirano believes Just-In-Time (JIT) is a theory and technique to thoroughly eliminate waste. He also calls the manufacturing process the equivalent of making music. In Japan, South Korea, and Europe, Mr. Hirano has led the on-site rationalization improvement movement using JIT production methods. The companies Mr. Hirano has worked with include:

Polar Synthetic Chemical Kogyo Corporation
Matsushita Denko Corporation
Sunwave Kogyo Corporation
Olympic Corporation
Ube Kyosan Corporation
Fujitsu Corporation
Yasuda Kogyo Corporation
Sharp Corporation and associated industries
Nihon Denki Corporation and associated industries
Kimura Denki Manufacturing Corporation and associated industries
Fukuda ME Kogyo Corporation
Akazashina Manufacturing Corporation
Runeau Public Corporation (France)
Kumho (South Korea)
Samsung Electronics (South Korea)
Samsung Watch (South Korea)
Sani Electric (South Korea)

Mr. Hirano was born in Tokyo, Japan, in 1946. After graduating from Senshu University's School of Economics, Mr. Hirano worked with Japan's largest computer manufacturer in laying the conceptual groundwork for the country's first full-fledged production management system. Using his own interpretation of the JIT philosophy, which emphasizes "ideas and techniques for the complete elimination of waste," Mr. Hirano went on to help bring the JIT Production Revolution to dozens of companies, including Japanese companies as well as major firms abroad, such as a French automobile manufacturer and a Korean consumer electronics company.

The author's many publications in Japanese include: *Seeing Is Understanding: Just-In-Time Production* (*Me de mite wakaru jasuto in taimu seisanh hoshiki*), *Encyclopedia of Factory Rationalization* (*Kojo o gorika suru jiten*), *5S Comics* (*Manga 5S*), *Graffiti Guide to the JIT Factory Revolution* (*Gurafiti JIT kojo kakumei*), and a six-part video tape series entitled *JIT Production Revolution, Stages I and II*. All of these titles are available in Japanese from the publisher, Nikkan Kogyo Shimbun, Ltd. (Tokyo).

In 1989, Productivity Press made Mr. Hirano's *JIT Factory Revolution: A Pictorial Guide to Factory Design of the Future* available in English.