JIT Implementation Manual
The Complete Guide to
Just-in-Time Manufacturing
Second Edition

Volume 4
Leveling —
Changeover and Quality Assurance

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What Is Level Production?

Differences in Reducing Patterns of Product and Parts Inventories

Usually, factories can effectively use a statistical inventory control method, such as the reorder point method, for handling products and replacement parts. Such methods are not suitable for inventories of assembly parts and other parts and materials being used in the factory. One reason for this is the different kinds of demand for these two kinds of inventory.

As shown in Figure 10.1, demand for products is more or less constant, which means that product inventory levels can be
expected to decline smoothly. By contrast, demand for parts is subject to sudden large orders that immediately deplete parts inventory, which is therefore more difficult to manage.

The kind of statistical inventory control that works well for “steady-demand” inventories, such as product and replacement parts inventories, does not work as well for “sudden-demand” inventories, such as assembly parts and materials.

**Approach to Leveling**

Customers buy just what they want, just when they want it, and in just the amount they want. Overall, this tends to result in a steady demand for products, as reflected in steady shipments from product warehouses.

If the factory can restock the warehouse just as steadily by manufacturing only what the warehouse needs, when it needs it, and in just the amount needed, we would see the same smooth trend reflected in the factory’s demand for parts and materials. However, most production schedules are drafted on the premise of lot production or, as we in JIT disparagingly call it, “shish-kabob production.”

Shish-kabob production may help raise production efficiency in assembly lines, but there is more to a company than assembly lines. We also have to consider shish-kabob production’s impact on other corporate activities, such as sales, distribution, and purchasing. Most factories also include various preassembly processes and parts processing lines. Therefore, just because shish-kabob production may suit assembly line operations does not mean it is a good approach from the perspective of the entire factory or company.

Let us suppose, for example, that the managers of a factory’s final assembly line decide to boost the line’s output performance by assembling only product X this week and only product Z next week. This means that all preassembly processes that specialize in product X will be too busy this week
and will sit idle all next week. Conversely, the processes dedicated to product Z will be idle this week and overworked next week.

Obviously, these preassembly processes need to be scheduled more evenly to enable them to keep up with the assembly line's demand, even though this means that many of the preassembly products will have to sit as inventory until the assembly line is ready to use them. Naturally, such scheduling creates various kinds of waste, such as surplus production waste, idle time waste, conveyance waste, and inventory waste.

It should be obvious enough by now that it does no good to seek improved efficiency and productivity for one section of the factory at the expense of other sections. Instead, we must center our operations on customer needs and try to achieve an even level of high productivity throughout the factory, with low costs and Just-In-Time scheduling. The JIT technique for doing precisely that is called production leveling.

Various Ways to Create Production Schedules

How do factories go about creating production schedules? Actually, each factory’s method seems to be different, and one can gain a sense of the factory’s history by examining the particular method it uses. Broadly speaking, there are four main production scheduling methods, each based primarily on the number of production opportunities per month:

- Once-a-month production
- Once-a-week production
- Once-a-day production
- Level production
Once-a-Month Production

Once-a-month production scheduling often happens when low demand for certain products results in only one production opportunity per month.

Generally, this method starts with a figure for how many products need to be made in a month, and from this figure we calculate the standard daily output that will add up to the desired monthly totals.

Figure 10.2 shows an example of once-a-month production. In this example, it has been decided that products X, Y, and Z would be manufactured in that order. Because the demand for these products varies, the factory is prepared to adjust the number of production days for each model to produce the correct totals to meet current demand.

Figure 10.2  Once-a-Month Production.
I have not included twice-a-month production scheduling as a type by itself because the twice-a-month approach is almost exactly like the once-a-month approach, except that everything works within a two-week time frame instead of a month.

In the past, once-a-month production scheduling did a pretty good job of serving factory needs. Back then, markets were more stable, product variety was much smaller, and factories could generally sell whatever they made. If we change our perspective from the producer's standpoint to the consumer's standpoint, however, we can see that traditional once-a-month production scheduling is a rather stubborn and selfish method (that is, a “product-out” method in which factories push their products onto the market). It is as if the factory people were saying: “Look, this is all we make, and we only make them once a month. So take it or leave it.”

Those days are long gone. Today, it is not easy to find factories that stick to the old once-a-month program. Most have switched to once-a-week production scheduling. But even that has not changed things that much.

**Once-a-Week Production**

Whether it be once-a-month or once-a-week production, the basic philosophy is the same. The big difference is that product warehouses and production opportunities are only one-fourth as big as they used to be.

Figure 10.3 illustrates once-a-week production.

As seen in the figure, the month’s estimated output is unconditionally divided into four equal weekly totals, with a separate production schedule created for each week. Sometimes the output for the current week must be raised or lowered depending upon how product inventory levels stood at the end of the previous week.

In today’s fast-paced manufacturing world characterized by increasing product diversity, manufacturers find themselves
compelled to break down monthly production schedules into at least four (weekly) parts.

**Once-a-Day Production**

Many factories are taking up the challenge of maintaining daily production schedules. The idea is to divide up the estimated monthly output into the number of working days in the month so that production of the entire assortment of models gets repeated once a day. This puts a focus on manufacturing using an integrated production line.

Figure 10.4 shows an example of once-a-day production scheduling.

As seen in Figure 10.4’s example, once-a-day production is a much more sophisticated and detailed way of scheduling production because it provides 20 times the production
opportunities of once-a-month production and produces 20 times less inventory.

Detailed as it is, however, once-a-day production does not necessarily mean level production. If we look at the production schedule for any particular day (see the example in Figure 10.4), we find that the factory spends all morning turning out product X, part of the afternoon producing product Y, and the rest of the afternoon with product Z. In other words,
the factory is still carrying out the same old “shish-kabob” production routine, but with more model changeovers.

**Leveling Production**

The fundamental concept underlying level production is that production of different product models—whether it be lot production or one-piece flow production—can be evenly spread out to match the current sales trends, which also require adjusting the production pitch accordingly and maintaining an integrated production line. As such, level production is a thoroughly “market-in” approach.

We might define production leveling as “making production of various product models and volumes completely even.”

Figure 10.5 shows an example of level production. Comparing this to the previous example of once-a-day production, we can see that they both add up to the same daily output totals. Level production, however, divides the daily output total by the amount of working time in the day (expressed in minutes) to obtain an hourly pitch time. This pitch time is called the cycle time.

In Figure 10.5’s example, the tact time is 9.6 minutes for product X, 16 minutes for product Y, and 24 minutes for product Z. The factory needs to organize its production line to maintain these tact times while using a mixed-flow production method.

**Differences between Shish-Kabob Production and Level Production**

One chief characteristic of level production is that, within a certain month, the same products are produced in the same quantities each day and within each time band in the day.

Let us examine the ways in which level production differs from “shish-kabob” production.
Production philosophy regarding the making of products constitutes a major point of difference between level production and “shish-kabob” production. Shish-kabob production goes hand in hand with the “product-out” production philosophy. The main points of the “product-out” philosophy are to develop products that are easy to manufacture and to set-up the production line to facilitate large-lot production of such
products. Level production instead emphasizes serving market needs, which means it follows the “market-in” philosophy.

**Difference 2: Production Method**

Shish-kabob production is made up of lots (the chunks on the “shish-kabob” skewer). Changeovers must be made after each lot is completed. In level production, all of the various models are mixed into each cycle time within the overall production line.

**Difference 3: Approach to Efficiency**

In shish-kabob production, we generally try to maximize efficiency at specific processes, such as the pressing or cutting processes. In level production, we try instead to maximize overall efficiency within the framework of the cycle time.

**Difference 4: Approach to Machines**

In shish-kabob production, we spend at least a few hours turning out the same product model, then we retool and begin manufacturing a different model for a while. To keep the line moving quickly, we need fast (the faster the better) and, preferably, general purpose machines that require little retooling to changeover to a different product model. Usually, such equipment is expensive and bulky.

By contrast, for level production we need equipment that is just fast enough to keep within the cycle time and that is small enough to be placed directly into the production line. This usually calls for small, inexpensive, and specialized machines.

**Difference 5: Inventory and Lead-Time**

Shish-kabob production inevitably includes production flow cut-off points between certain processes. Wherever such a cut-off point exists, there will necessarily be an accumulation of in-process inventory. In-process inventory means retention, and retention means a longer lead-time and a greater need for conveyance. In level production, we try to synchronize all processes within the cycle time. This effectively eliminates
in-process inventory and minimizes both lead-time and conveyance needs.

These are just the major points of difference between conventional shish-kabob production and level production. It is not hard to see which production method is better suited to today’s demands for fast turnaround and dynamism in production. Figure 10.6 summarizes the above differences in a tabular format.

### Leveling Techniques

#### Cycle Time and Cycle Tables

“How long does it take to make one product unit?” This is a very important question both for the equipment operators and the factory managers, and it is something we must know before we can draft a production schedule. If the factory is carrying out shish-kabob production, the general per-item manufacturing pitch can be decided based on the equipment capacity and available manpower. But this is not the best way to figure the production pitch. Calculating a pitch based on machinery and manpower is a production-centered approach. It may enable the factory to achieve a fast pitch, but even a lightning-speed pitch does no good unless the products can be readily sold. Otherwise, the factory is just stocking product warehouses and raising costs. We should look instead to current market needs as a basis for determining the manufacturing pitch.

#### Cycle Time

The cycle time is the amount of time (expressed in minutes and seconds) within which one item must be manufactured. In JIT, we obtain the cycle time by dividing the total production output required to match current market needs by the amount of work time (expressed in minutes) in the day.
## Differences between Shish-Kabob Production and Level Production

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<th>Level Production</th>
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<td><strong>Production Philosophy</strong></td>
<td>Product-out (production-centered) philosophy  “Produce just what is easy to make, just when it is easy to make it, and in just the amounts that are easy to make.”</td>
<td>Market-in (market-centered) philosophy “Produce just what is needed, just when it is needed, and in just the amounts needed.”</td>
</tr>
<tr>
<td><strong>Production Method</strong></td>
<td>Lot (shish-kabob) arrangement Arrange products into large model-specific lots to minimize changeovers.</td>
<td>Cycle time arrangement Arrange products into assortments that match market needs and can be manufactured within the cycle time in an in-line production configuration.</td>
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<td><strong>Approach to Efficiency</strong></td>
<td>Emphasis on individual process efficiency The production pitch is based on the rhythm of individual processes with maximum efficiency sought at each process.</td>
<td>Emphasis on overall line efficiency We try to improve the efficiency of the entire line within the framework of the cycle time.</td>
</tr>
<tr>
<td><strong>Approach to Machines</strong></td>
<td>High-speed, general purpose, large, and expensive machines We need faster machines to handle large lot volumes, which usually means we need a large, expensive, general purpose machine.</td>
<td>Moderate-speed, specialized, small, and inexpensive machines Our machines need only be fast enough to keep up the cycle time. The important thing is that the machines be small and specialized enough to fit right into the production line to handle one-piece flow operations. Such machines are usually much less expensive than large, general purpose machines.</td>
</tr>
<tr>
<td><strong>Inventory and Lead-time</strong></td>
<td>Large inventories and long lead-times When workpieces are worked on in lots, retention is inescapable. Retention accumulates in-process inventory and results in longer lead-times and a greater need for conveyance.</td>
<td>Small inventories and short lead-times When workpieces flow along one piece at a time within the cycle time, there is very little in-process inventory, which means shorter lead-times and almost no need for conveyance.</td>
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Figure 10.6  Differences between Shish-Kabob Production and Level Production.
PER-DAY PRODUCTION TOTAL = \frac{PER-MONTH PRODUCTION TOTAL}{WORKING DAYS IN MONTH}

\text{CYCLE TIME} = \frac{\text{AMOUNT OF WORK TIME (MINUTES) IN DAY}}{\text{PER-DAY PRODUCTION VOLUME}}

Specifically, we begin by dividing the month’s production output by the number of working days in the month. Then we divide each working day’s working time (minutes) by the required output for the day (see the equations on previous page). The result is the cycle time.

“Cycle List” and “Nonreserved Seat” Methods

We can use the particular cycle time for each item and the various product models in the mixed-flow operation to establish a single constant pattern of production flow.

Cycle lists are wheel-like illustrations that show the constant production pattern that gets repeated throughout the day to turn out the required variety and volume of products. If the proportionate shares of product models are 50 percent for product X, 30 percent for product Y, and 20 percent for product Z, we could express that pattern in a cycle list like the one shown in Figure 10.7.

It is best to follow the cycle list as closely as possible. However, an array of problems sometimes arises to cause variation in cycle times. When such variation is common, I always suggest adopting the “nonreserved seat” version of the cycle list. Each cycle scheduled in a nonreserved seat cycle list includes one or two steps that are kept available (“nonreserved”) to compensate for variations. (See Figure 10.8.)

The point of the nonreserved seat cycle list is to have the “nonreserved seat” section of the list compensate for variations caused by small accumulations of in-process inventory,
Figure 10.7  Cycle List.

Figure 10.8  "Nonreserved Seat" Cycle List.
which is evident from corresponding detached *kanban*. If the timing of the *kanban* is part of the problem, the cycle list itself needs to be revised.

**The “Reserved Seat” Method for Practical Use of Cycle Lists**

A workshop can more easily get used to working with a cycle list if it is already offset by a “reserved seat” system.

The “reserved seat” has proven most effective in workshops that have processes such as plating or painting—that is, any process that uses hangers for batch processing of workpieces. Due to certain quality issues, people in plating and painting workshops have a hard time getting away from the idea of shish-kabob production. Generally, if the factory is manufacturing three product models (X, Y, and Z), these processes would handle workpieces for each model in separate batches, as shown in Figure 10.9.

Processing model-specific batches of workpieces as shown in Figure 10.9 leads to the following problems:

**Problem 1**

In JIT’s pull production system, the lots are always pulled from downstream processes. At the painting process shown in the figure, this would require a large amount of in-process inventory between the painting process and the previous (upstream) process.
Problem 2
The processes downstream from the painting process handle mixed-model flow production. This would necessitate a large amount of in-process inventory between the painting process and the next (downstream) process.

Problem 3
Defects can easily arise from damage that occurs to workpieces when they are removed in batches from the hangers after being painted.

Problem 4
Since hangers always carry the same types of workpieces, a change in the proportions of product models in the production schedule causes variation-related problems in paint operations.

Problem 5
The painting process interrupts the overall production flow and makes it difficult to raise overall efficiency.

Figure 10.10 shows how all of these problems can be solved by leveling production at the painting process via the “reserved seat” method.

The “reserved seat” configuration of workpieces on hangers eliminates the need for in-process inventory while opening up space and providing adaptability toward model mix changes. Even the work of setting workpieces on hangers and removing them has been leveled to enhance operational smoothness and stability.

![Diagram]

Figure 10.10 Application of Reserved Seat Method at a Painting Process.

Product X workpieces (4) + Product Y workpieces (2) + Product Z workpieces (3) × 6 hangers
The “Baton Touch Zone” Method and Bypass Method

Line balancing is vital for successful assembly line operations. It is especially important to maintain a constant amount of work for each line worker when the line handles a mixed flow of various product models in small lots. In mixed-model assembly lines, the key is to keep the assembly workers performing the same tasks so that their efficiency will be roughly equal to single-model (mass production) assembly lines. If the workers have to change their tasks with each model, they are much more likely to make defects, such as assembly errors or omitted parts. In addition, their efficiency will suffer.

This is why production leveling and group technology (GT) are so important at the design stage. At the delivery stage, sequential delivery is also necessary. Another way to help level out manual labor on the line is by using a cooperative operation technique, such as the “baton touch zone” method or the “bypass” method.

The Baton Touch Zone Method

This method takes its name from the way relay runners pass batons within a zone to avoid the difficulty of passing the “work” of carrying the baton at any specific completion point. In the factory, the baton touch zone is a certain range of operations within which an operator may pass on his or her work to the next operator. The flexibility afforded by such a baton touch zone helps maintain line balancing when product models are changed. (See Figure 10.11.)

The Bypass Method

When the amount of manual work differs so much from product model to product model that the baton touch zone method will not work, we can use the bypass method to establish a separate “bypass” line that can accommodate the model change. (See Figure 10.12.)
However, we cannot make bypass lines from just any line. We must first establish mixed-model flow production and balance the line based on that type of production. Please remember that the bypass method should only be used as a last resort when the baton touch zone method is not feasible.

### Realizing Production Leveling

#### Developing Flow Production

If production is leveled for only one group of the factory’s production processes, such as only the assembly line, it may not work to raise the factory’s overall efficiency. To do that, the entire production system must be developed as a flow production system.
Figure 10.13 shows a sink cabinet manufacturer’s door preparation process before improvement. Before the improvement, the door preparation process was located on the second floor of the factory. The workers at that process would select doors from the assortment of doors in stock and hook them onto a hanger conveyor that would carry them down to the assembly line on the first floor.
Once production was leveled at the assembly line, the door preparation process was no longer able to keep up with the assembly line’s needs, and people began wondering if the door preparation process could establish mixed-model preparation operations to match the mixed-model assembly operations at the assembly line.

To make this improvement, the factory managers moved the door preparation process down to the first floor so that all workers and equipment could be on the same floor. They set-up this process as a U-shaped manufacturing cell right next to the door fastening process in the main assembly line. They then synchronized production in this cell to match that of the leveled mixed-model flow line. As a result, they reduced inventory to almost zero, achieved a major reduction in manpower, and took advantage of the open space on the second floor to set-up a long-wanted ping-pong table.

**Improved (Kaizen) Retooling**

Factories generally include both processing lines and assembly lines. The key point for production leveling of processing lines is to improve retooling. Being able to switch among product models and to improve the balance of assembly line operations are the main concerns of production leveling in assembly lines.

Figure 10.14 shows how one factory improved its shipment pickup operations so that goods completed by the assembly line are picked up eight times a day (once every hour), instead of just once a day. To make hourly pickup possible, the assembly line mainly had to improve its product model changeover procedures to shorten the changeover time. Once they did this, the post-assembly inventory dropped to one-eighth of its former level and accumulation of in-process inventory after the preparation and processing steps was eliminated, thus establishing smooth flow production.
Figure 10.14  Improving Changeover at an Assembly Line.
Chapter 11

Changeover

Why Is Changeover Improvement (Kaizen) Necessary?

One obsolete notion that still finds firm believers in many factories is that of “economic lot size.” Economic lot sizes are thought to be whatever lot size helps to minimize the sum of changeover costs and inventory costs. Factories traditionally have tried to keep their lot sizes as close to the ideal “economic lot size” as possible.

Factories have often economized not so much by approximating the ideal economic lot size, but by making lots a little larger and minimizing die changes by using more parts from fewer dies. These money-saving efforts probably had some value during the bygone days of limited product variety and large-scale mass production. However, today the trend is for diverse product models and small-lot production with short delivery deadlines. These radically different circumstances require a new approach to economic lot sizes.

The conventional idea of economic lot size assumes that inventory costs and changeover costs are constant; but changeover costs can vary significantly. Moreover, changeover improvements can drastically reduce the changeover costs.

Often, when factory managers look at costs within processes, they do not include costs related to in-process inventory in
overall inventory costs and they only recognize changeover costs. In terms of the entire factory’s efficiency, however, large-scale lot production incurs a wide array of waste-related costs, such as surplus production cost, idle time costs, conveyance costs, inventory costs, set-up and removal costs, and defect-related costs. And that is not all: Larger lot sizes also mean more in-process inventory, and the more in-process inventory a factory has, the longer the lead-time for its products. Aside from costs, the factory must deal with the accumulation of goods at certain points and a disruption in the overall flow of goods.

Many factories find themselves in dire straits trying to keep up with current market demands for wide variety and small lots, short delivery, and high quality. The kinds of improvements JIT brings to changeovers can shorten changeover time and enable various product models to be made more quickly and efficiently.

What Is Changeover?

Types of Changeover Operations

Changeover means a certain kind of set-up that we must make before beginning a different set of operations. Often, a changeover’s set-up procedure involves rearranging things. The following are the main types of changeover procedures performed in factories.

Type 1: Exchanging Dies and Blades

This kind of changeover is very common in machining shops and is usually a prime candidate for JIT improvement. Often the machine tool operators must retool their machines by exchanging metal dies, casts for injection molding, drill bits, saw blades, and the like.
Type 2: Changing Standard Parameters

Computer-programmed high precision cutters and chemical processing equipment often require operators who can change the standard parameters used for different processing tasks. Unfortunately, the more of this kind of changeover a machine needs, the more smooth operations depend on highly trained operators.

Type 3: Exchanging Assembly Parts or Other Materials

Whenever an assembly line switches to assembling a different product model, it needs to receive supplies of the parts and other materials that go into the new model. The related changeover procedures for this can include exchanging dies (die changing is not unique to processing lines!). In assembly lines, exchanging equipment components is sometimes referred to as “switchover” or “retooling.”

Type 4: General Set-up Prior to Manufacturing

This type of changeover includes all the miscellaneous set-up tasks that must be done before we can begin manufacturing products. These tasks can include arranging the equipment and assigning jobs to workers, checking drawings, and sweeping up.

Approach to Changeover Times

Many factory people think of changeover time as the period that begins when the operator starts performing changeover procedures and ends when he or she completes those procedures. This, however, is not really the case. Instead, we should remember the following definition of changeover time:

Changeover time begins when the current processing task is finished and ends when the next processing task produces a defect-free product.
More specifically, the part of this time period during which the machine does not add any value to the workpiece is called the “internal changeover time.” Many people tend to confuse the internal changeover time with the entire changeover time. The entire changeover time is the sum of the internal and external changeover times. This may be easier to remember in terms of an equation:

\[
\text{Changeover time} = \text{internal changeover time} + \text{external changeover time}
\]

- \textit{Internal changeover time}: Internal changeover time begins when the current processing task is finished and ends when the next processing task produces a defect-free product. Throughout this time, the machine does not add any value to the workpiece.

- \textit{External changeover time}: External changeover time is the time spent by the operator carrying out set-up procedures independent of the machine while the machine is operating.

Therefore, when seeking to improve changeover operations, we need to address possible changes in both the internal and external changeover procedures in order to make a comprehensive changeover improvement.

\section*{Procedure for Changeover Improvement}

Depending upon the type of work involved, changeover procedures fall into three categories: internal changeover, external changeover, and waste.

- \textit{Internal changeover procedures}: These procedures cannot be implemented unless the machine is stopped (not operating).
External changeover procedures: These procedures can be implemented whether or not the machine is stopped (not operating).

Waste: This includes searching for jigs and tools, waiting for the crane, and other nonproductive activities that are not directly related to changeover procedures. If there is too much of this, the factory itself may get stopped in its tracks.

Figure 11.1 shows how we can divide up various changeover improvement steps according to these three categories.

**Step 1:** Form a changeover *kaizen* team

Once people recognize a growing need for changeover improvement, they need to analyze the situation and form a changeover *kaizen* (improvement) team. At this point, it is vital that the newly formed team receive strong support from the company’s upper management.

**Step 2:** Analyze changeover operations

If we find that a certain changeover operation is taking an extra long time, we need to analyze it to find the reason. Using JIT changeover improvement tools, such as...
changeover result tables and changeover analysis charts, we can make the problems more obvious and explicit.

**Step 3:** Flush out wasteful operations and apply the 5S’s to eliminate waste

We can start by categorizing all current changeover operations into internal changeover operations, external changeover operations, and wasteful changeover operations. Then we can eliminate the waste, preferably by applying the 5S’s (the 5S’s are described in Chapter 4).

**Step 4:** Transform internal changeover into external changeover

People have often found clever ways to turn internal changeover tasks that had previously required an idle machine into external changeover tasks that can be performed while the machine is running. Whenever this has been done, it has resulted in considerable shortening of the overall changeover time.

**Step 5:** Improve remaining internal changeover

Once we have transformed at least some of the internal changeover work into external changeover work, we will have a clearer understanding of the remaining internal changeover procedures. At this point, we are ready to review these remaining procedures and see if there are ways to make them take less time. Sometimes we can do this by reducing or eliminating bolts, developing cassette units of replacement parts, or establishing parallel changeover procedures.

**Step 6:** Improve external changeover

Since the overall changeover time is the sum of the internal changeover time and the external changeover time, we should make time-saving improvements in both internal and external changeover. Ways of improving external changeover include establishing proper arrangement and orderliness (the first and foremost of the 5S’s), developing more specialized machines, and offering additional training in changeover-related skills.
Launching Changeover Kaizen Teams

Often, an acute need for changeover improvement is disguised in seemingly unrelated complaints, such as: “Lately, our capacity utilization rates have been dropping for some reason,” or, “We’re having trouble keeping up with the product diversification trend.” Even when the need for changeover improvement is obvious, individuals rarely get inspired enough to make the improvement by themselves.

Figure 11.2 shows one way to make the need for changeover improvement obvious to everyone, namely by plotting on a graph the relationship between the number of product models handled and the equipment capacity utilization rate.

The following are a few pointers for changeover improvement teams.

1. Learn the changeover improvement rules
   All changeover kaizen team members should meet at least once for a study session so that everyone can gain a firm understanding of the rules and “tricks” for changeover improvements.

2. Set-up and carry out a schedule of “public changeover demonstrations”
   Schedule a series of weekly changeover demonstrations that are open to everyone in the factory to watch. Try to include as many different types of equipment and production lines as possible in the series. The schedule of demonstrations should be drawn up in an attractive format and posted throughout the factory.

   Everyone who attends a changeover demonstration should be acknowledged as an observer and a possible source of improvement ideas. It might help to divide the improvement team members to review the demonstration together and brainstorm further improvement ideas.

   The public changeover timetable shown in Figure 11.3 may come in handy when reviewing public changeover
demonstrations. Be very careful to avoid negative talk about individual improvement ideas, such as: “That will never work,” or, “Even if we try that, it’s impossible.” People should feel free to put forth any idea without fear of it being shot down on the spot. Finally, use a change-over improvement list (shown in Figure 11.4) to write

<table>
<thead>
<tr>
<th>Model and Operating Rate Trend Chart</th>
<th>Machine code</th>
<th>Types</th>
<th>Operator</th>
<th>Date</th>
<th>Times</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Process</strong> Boring (No. 2 Mfg.)</td>
<td>M11</td>
<td>20</td>
<td>Fujiyoshi</td>
<td>1/10/89</td>
<td></td>
</tr>
<tr>
<td><strong>Process manager</strong></td>
<td>Yamagawa</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Model</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Types</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Capacity utilization rate</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Model</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Types</strong></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td><strong>Capacity utilization rate</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Model</strong></td>
<td>Jan 88</td>
<td>18</td>
<td></td>
<td>Dec 88</td>
<td>2.6</td>
</tr>
<tr>
<td><strong>Types</strong></td>
<td>Dec 88</td>
<td>12</td>
<td></td>
<td>Mar 89</td>
<td>%</td>
</tr>
<tr>
<td><strong>Capacity utilization rate</strong></td>
<td>Jan 88</td>
<td>18</td>
<td></td>
<td>Dec 88</td>
<td>2.6%</td>
</tr>
<tr>
<td><strong>Types</strong></td>
<td>Dec 88</td>
<td>12</td>
<td></td>
<td>Mar 89</td>
<td>%</td>
</tr>
</tbody>
</table>

**Figure 11.2** Graph Showing the Relationship between the Variety of Product Models and Equipment Capacity Utilization Rates.
down all of the proposed improvement ideas in detail, including a description of the proposed improvement, the parties involved, and other details. Make sure everyone in the changeover improvement team reads the list.

3. Be sure to carry out lateral development of improvements
The prime opportunity for changeover improvement is when we have succeeded in making an improvement on one machine or set of equipment, since we would then have the know-how to “laterally develop” the same improvement on other similar machines. For instance, if we have succeeded in reducing changeover time for a certain pressing unit to under ten minutes, we can go ahead and make the same improvement on the factory’s nine other presses, which gives us ten times the “bang” for the same initial “buck” of improvement effort.

No matter what kind of JIT improvement we have made, we should always be mindful of the great impact our improvement can have when developed laterally (or “horizontally”) to other machines, processes, or people.

**Analyzing Changeover Operations**

Before making an improvement in changeover operations, we need to compile some results to check out the following possible problems:

1. Variation in the frequency of changeover operations.
2. Variation in the changeover sequence or method depending upon the workers involved or on the general “mood” of the day.
3. Major variation in changeover times depending upon the product models.
4. Dies, jigs, and tools are not being put back properly and workers must waste time looking for them.
5. There seems to be an unnecessary number of bolt loosening and tightening operations involved in the changeover.
6. Only one worker knows how to perform the fine-tuning operations following changeover.
7. The workshop always needs to turn out about 10 test runs following changeover.
These kinds of problems tend to crop up in workshops that have not learned to perform changeover operations skillfully. To make such problems obvious enough to clearly recognize and resolve, we need to compile results data concerning changeover operations.

Figure 11.5 shows a “changeover results table.” By entering data describing current changeover operations, we can more easily discover which changeover operations are giving the workshop operators the most trouble and which are taking up too much time. Once we know such facts, we are in a better position to begin making improvements.

Once we recognize from the data entered on the changeover results table that a certain changeover operation is particularly difficult, we can target that changeover operation for improvement and perform a public changeover demonstration to analyze it. We need to enter the data from the demonstration on either a public changeover timetable (Figure 11.3) or a changeover operations analysis chart (Figure 11.6). Public changeover timetables are the more useful of the two when several operators are performing the changeover and are observing each others’ work. Changeover operations analysis charts are recommended when there is only one operator.
performing the changeover and when that operator needs
detailed changeover-related data from which to plan improve-
ments. If you do use a changeover operations analysis chart for
changeovers done by several workers, a separate chart form
should be filled out for each worker. These forms can then be
used as a basis for filling out a public changeover timetable that
will show how the workers’ operations relate to each other.

The thing to remember when filling out changeover opera-
tion analysis charts is to get into detail while observing and
describing each changeover operation. When the observer has
too many operations to observe, the improvement plans will
be too numerous and the improvements too vague. The most
important part of this chart is the categorization of changeovers.
The observer must carefully distinguish among internal change-
over operations, external changeover operations, and wasteful
operations. The type of improvement to be made may depend
very much on how the changeover operation is categorized.

**Identify Wasteful Operations and Apply the 5S’s to Eliminate Waste**

Waste is everywhere—in every workshop and in every oper-
ation. Naturally, there are bound to be various types of waste
lurking within changeover operations. If, after standing back and watching a changeover operation, we have found nothing in the operation that adds any value to the workpiece, we can put that operation in the “waste” category. This is not to say that it is simply a matter of removing the entire changeover operation as superfluous. Removing wasteful changeover operations always requires some consolidation and standardization of dies, jigs, and/or tools, the establishment of specialized lines, or other measures to incorporate the changeover's functions into other operations.

The next step is to distinguish between the essential and nonessential ingredients in each changeover operation and thoroughly remove the nonessential elements.

As shown in Figure 11.7, we need to distinguish waste in internal changeover operations from waste in external changeover operations.

**Waste in Internal Changeover Operations**

Waste in internal changeover operations includes “replacement waste,” such as when exchanging dies or blades, and “adjustment waste,” such as when making the necessary adjustment to achieve output of nondefective products following the changeover.

- **Replacement waste**
  Most of the waste created during replacement of dies or blades is related to removing and fastening bolts. We should regard bolts as our enemies. When necessary,
they are necessary evils; when unnecessary, we should find some way to eliminate them. When bolts are necessary evils, we can at least use small nets, C washers, or other devices that enable us to loosen or tighten the bolt with just one turn of the wrench.

All such improvements fall under the category of internal changeover improvement.

**Adjustment waste**
I have often heard factory workers explain, “That guy over there is the only one who can fine-tune that machine correctly.” Why in the world would a factory want to have a machine whose correct operation depended on one individual? Why hasn’t that individual taught others how to do the tricky adjustment correctly?

We must go even more deeply into this issue to ask, “Why does the fine-tuning have to be done to begin with?” Fine-tuning is only needed when machines have been allowed to stray from their standard settings. In JIT, we have a saying: “If you move your hands, make sure your feet and the standards stay put.” Factory managers and workers must find a way to operate the equipment without straying from the standard parameters. If that is impossible, they must improve the changeover operation to eliminate the need for additional adjustments.

**Waste in External Changeover Operations**
Almost all of the waste found in external changeover operations is in some way related to the 5S’s. This kind of waste is basically either “preparation waste” or “cleanup waste.”

**Preparation waste**
When it comes to preparation waste, the chief culprit is usually “searching waste.” Workers waste time searching for carts, jigs and tools, dies, blades, cleaning equipment, and various other misplaced items. None of that searching waste would exist if only the factory enforced the two most basic of the 5S’s—proper arrangement and orderliness.
■ Cleanup waste

Not surprisingly, the main cleanup-waste villain is “returning waste.” Workers waste time walking around to put back the same assortment of items—cleaning equipment carts, jigs and tools, dies, blades, and so on. Rarely do they stop to wonder if all that walking around is really necessary. A thorough implementation of the 5S’s—or even just 2S’s (proper arrangement and orderliness)—would teach them that in practically all cases, things can be quickly replaced locally, without any walking required.

Even after a workshop has eliminated all preparation waste and cleanup waste in its changeover operations, its total changeover time will still depend very much on how well the 5S’s (especially proper arrangement and orderliness) are enforced. Figure 11.8 shows the JIT form called “changeover 5S checklist.” In the figure, this checklist has been filled with data taken from a machining (boring line) workshop. The checklist helps us evaluate 5S enforcement in changeovers at each process.

The following symbols were used on the checklist to indicate how well specific operations were performed (parenthetical comments indicate how symbols are used to answer yes/no questions):

- ○ Can be done well (or “Yes”)
- △ Can be done, but not well (or “Mostly yes”)
- × Cannot be done (or “No”)

Turning Internal Changeover into External Changeover

Figure 11.9 shows a time graph analysis of improvements in changeover procedures. The graph indicates that the 5S’s were
<table>
<thead>
<tr>
<th>No.</th>
<th>5S checklist item</th>
<th>Date and Operator</th>
<th>Improvement plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Are different sets of jigs and tools used for changeover kept by each machine?</td>
<td>1/9</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1/10</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Are the jigs and tools within easy reach during changeovers?</td>
<td>1/11</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Are the jigs and tools laid out according to the order of use during changeover?</td>
<td>1/12</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Are the jigs and tools laid out in an orderly manner?</td>
<td>1/13</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Are there some carts reserved expressly for use in changeover and do they have a prescribed storage site?</td>
<td>1/14</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Are the items in the carts arranged in an orderly manner?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Does each machine carry instructions from the changeover operations manual?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Are the operators performing the changeover as instructed in the manual?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Have quality standards been set for each model?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Are the standards posted on each machine?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Are defect-free samples of each model on display for reference?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Are the samples displayed next to the appropriate machines?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Are the required measuring instruments kept next to each machine that needs them?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Are the measuring instruments all kept within easy reach?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Are the measuring instruments kept in an orderly manner?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Is it clear where blades and other replaced items should go after changeover?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Is it clear where blades and other replaced items should be before changeover?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Is the next workpiece kept next to the machine?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 11.8  Changeover 5S Checklist.**
applied to remove a lot of waste at Step 3 in the improvement. The most important part of the improvement was turning internal changeover to external changeover.

The following is a case study of the transformation of internal changeover into external changeover at a printed circuit board (PCB) assembly plant.

**From Internal Changeover to External Changeover at a PCB Assembly Plant**

Like most PCB lines, this one was staffed by many workers and involved the assembly of many components. The gist of this improvement was to question the need for a single PCB assembly line and to discover the advantages of splitting up the equipment and workforce into several model-specific assembly lines.

For some factories, such a major reorganization of assembly operations is just too ambitious an undertaking. Naturally, keeping one assembly line means that changeover operations will be needed whenever the line changes product models.
The following three points are musts for assembly lines that include dozens of workers and that must carry out changeover operations when switching models:

1. All product-model changeover must take place within the cycle time.
2. The PCB substrate board sizes must not vary from model to model.
3. The line must use assembly work methods that prevent the need for operational balancing after changeover.

Before launching into the first and foremost of these three musts, a little more needs to be said about the second and third ones. If the same assembly line must handle substrate boards in various sizes, the boards should be carried in containers of equal size in order to avoid having to adjust the width of the conveyor belt during each model change.

The third must concerns the balance of assembly operations on the line. The options are either to reorganize and rebalance the assembly operations after each model change, or to use a flexible-operations method—such as cooperative operations or the baton touch zone—to avoid having to rebalance after model changes.

Figure 11.10 illustrates an example of the first and most important must, changeover within cycle time.

Before the improvement, whenever a model change occurred, all of the previous model's workpieces had to be completed and removed from the conveyor so that the conveyor width could be changed. While this was going on, the assembly workers were busy changing parts sets. They had managed to reduce their overall changeover time to 15 minutes. Since there were 10 people on the assembly line, we can figure the total labor “down time” as (15 minutes × 10 persons =) 150 minutes. Changing product models four times a day would incur a daily total labor down time of 600 minutes or 1.5 worker-days.
The following is a case study of how internal changeover was changed to external changeover in an injection molding process. Two workers handled the changeover operations before the improvement, but their respective responsibilities were not made very clear, resulting in a total changeover time of about 40 minutes. An analysis of their changeover operations revealed that all of their changeover operations were internal, meaning that they were being performed while the machines were stopped. (See Figure 11.11.)
Before improvement
Total changeover time: 40 minutes

After improvement
Total changeover time: 5 minutes

**Description of operation**

**Worker A**

1) Preheat mold
2) Move new mold onto loading stage
3) Prepare and arrange tools
4) Prepare injection parts supply boxes
5) Lower positioning notch

**Worker B**

1) Preheat mold
2) Move new mold onto loading stage
3) Prepare and arrange tools
4) Prepare injection parts supply boxes
5) Lower positioning notch

**External changeover**

1) Close injection molding machine
2) Remove bolts from right side
3) Open injection molding machine
4) Set previous mold onto unloading stage
5) Load new mold from loading stage
6) Close the injection molding machine
7) Insert and tighten bolts on tight side
8) Set parameters
9) Start injection molding machine
10) Switch chucks in auto-extraction device
11) Check quality of first product
12) Store away previous mold
13) Clean up tools

**Internal changeover**

1) Insert and tighten bolts
2) Open injection molding machine
3) Wait for crane, then operate crane
4) Attach hook, hand hook from crane
5) Remove bolts
6) Open injection molding machine
7) Attach previous mold to crane hook, use crane to move it to storage area
8) Detach hook and set it up on new mold
9) Move new mold to injection molding machine, set in position
10) Finish setting new mold in injection molding machine, then close the machine
11) Insert and tighten bolts
12) Detach hook and remove crane
13) Switch chucks in auto-extraction device
14) Set parameters and preheat molding machine
15) Switch injection parts supply boxes
16) Put away tools
17) Start molding machine
18) Stop machine to check quality of first product

**Post-changeover cleanup**

1) Clean up tools

**Internal changeover cleanup**

1) Find tools
2) Prepare and arrange tools
3) Remove hot runner (for coolant)
4) Wait for crane, then operate crane
5) Attach hook, hand hook from crane
6) Remove bolts
7) Open injection molding machine
8) Attach previous mold to crane hook, use crane to move it to storage area
9) Detach hook and set it up on new mold
10) Move new mold to injection molding machine, set in position
11) Finish setting new mold in injection molding machine, then close the machine
12) Insert and tighten bolts
13) Detach hook and remove crane
14) Switch chucks in auto-extraction device
15) Set parameters and preheat molding machine
16) Switch injection parts supply boxes
17) Put away tools
18) Start molding machine
19) Stop machine to check quality of first product

Figure 11.11 Changing Internal Changeover to External Changeover in an Injection Molding Process.
The improvement included reassigning the two workers’ tasks according to the sequence of the changeover operation and changing as much of the internal changeover procedures as possible into external changeover procedures. As a result, they were able to greatly reduce the overall changeover time to about five minutes.

*Changing Internal Changeover to External Changeover in a Wire Harness Molding Process*

Figure 11.12 shows an example of how internal changeover was changed to external changeover in a wire harness molding process.

In this process, some rubber is molded onto part of the wire harness. Before the improvement, the harness was set directly into the metal mold. This took a lot of time to do, and the workers had nothing to do during the actual molding process. An analysis came up with the following measurements:

- Harness setting time: 10 seconds (internal changeover)
- Idle time during molding process: 10 seconds

![Figure 11.12 Changing Internal Changeover to External Changeover in a Wire Harness Molding Process.](image)
As part of the improvement, two sets of molding jigs were created so that four harnesses could be set as external change-over operations. This greatly shortened each harness’s metal mold setting time and dramatically improved productivity in the molding process. It also completely eliminated the idle time during the molding process. As a result:

- Harness setting time: 10 seconds (external changeover)
- Mold jig replacement time: two seconds
- Idle time during molding process: none

**Improving Internal Changeover**

Two types of waste can be found in internal changeover operations: replacement waste, as when replacing dies or blades, and fine-tuning waste, as when adjusting the equipment to produce a defect-free product.

The following describes three methods for dealing with and eliminating these three types of waste:

- Replacement waste
- Fine-tuning waste
- Serial waste

**Eliminating Replacement Waste**

If we take a close look at changeover operations, we usually find that a lot of the work involves fastening and unfastening objects such as:

- Loosening and tightening bolts
- Setting up or removing supports or blocks
- Setting up or removing dies and blades
- Attaching or removing air hoses
- Attaching or removing chutes

None of the above fastening and unfastening procedures adds any value to the workpiece or product. Therefore, it is best if we can somehow eliminate them.
I suggest taking the following approach in improving changeover operations.

Step 1: Can we do without this part of the changeover procedure?
Our first question should be as simple as, “Why do we have to replace this die (or blade)?” This line of questioning may well lead to a standardizing or function-combining improvement that will eliminate this particular replacement operation.

Similarly, we may find a way to avoid having to use bolts altogether if we ask, “Why do we have to tighten and loosen bolts?”

Step 2: Can we reduce the number of times this operation must be done?
For example, we might ask, “Why does this die have to use eight bolts?” If we can reduce the number of bolts, we reduce the number of bolt tightening operations. When numerous bolts are being used, we should always ask whether all of them are really necessary.

Step 3: Can we reduce the time spent on this operation?
The most passive kind of improvement we can make is to keep operations the way they are and just reduce the amount of time spent on them. For instance, we can reduce the amount of time spent screwing in bolts and machine screws.

Other examples of alternatives for removing waste are:

- **Improving an operation by removing the need for certain tools.**
  Wrenches, screwdrivers, and hammers are just some of the tools commonly used in changeover operations. We can reduce the number of tools that must be picked up, handled, and put back by finding ways around them or by combining their functions into single tools. Figure 11.13
shows how the need for tools can be eliminated for certain bolt-tightening operations.

**Reduction of bolt tightening**

Bolts are our enemies. The fewer, the better. If we cannot reduce their number, we may at least be able to reduce the number of turns needed to tighten or loosen them. Turning bolts is a big waste of time. Only the final turn really performs the function of tightening or loosening the bolt; all the other turns are pure waste, just turning the screw threads through the nut. Figure 11.14 shows an example of a bolt that protrudes well past the nut. In general, a bolt is secure after about three turns, so there is no need for such a long bolt.
Improvement that eliminates the need to remove nuts and washers.

Figure 11.15 shows an improvement that enables dies to be changed without having to completely remove nuts and washer from bolts. Before this improvement, it took 200 seconds to remove the nuts and washers from the bolts each time the die was changed. After the improvement, the slip-off bolt allowed workers to change dies by just slightly loosening the nuts. This reduced the die replacement time to just 30 seconds.

Improvement that eliminates the need to remove bolts.

Figure 11.16 shows before and after illustrations of a bolted-in drill bit. Before the improvement, workers had to completely remove six bolts from the drill in order

![Diagram of before and after improvements with detailed descriptions of steps and time required for each step.]

**Figure 11.16** Eliminating the Need to Remove Bolts.
to exchange the drill bit. Exchanging the bit took about 240 seconds, including the time spent in removing the bolts and old bit and fastening the bolts and new bit.

After the improvement, the bolts had larger holes drilled next to them, connected by narrow slots. When the bolts are loosened just a couple of turns, they can be moved into the slot, where they remain loose while the bit is being exchanged. This improvement reduced the total bit replacement time to just 40 seconds.

*One touch tool bit exchange.* Figure 11.17 illustrates an improvement that made tool bit exchange on an NC lathe a one-touch operation. Before the improvement, the workers had to remove all of the bolts, then remove the tool bit and its holder and replace it with another tool bit and holder.

After the improvement, the tool bits were made detachable from their holders and all the holders were redesigned in a standard size. This enabled the workers to change only the tool bits while leaving the standard holder bolted to the base. The complete elimination of bolt loosening and tightening reduced the tool bit replacement time from 50 minutes to 3 minutes.
Improvement for boltless die exchange

Figure 11.18 illustrates an improvement that enables die exchanges to be made without using any bolts. In this case, the boltless fastener is a common hand-tightened vice. The operator just releases the vice lever to loosen the die for replacement. Once the operator has the new die in place, he or she just pulls the vice lever back to clamp the die into the standard position.

Removing Fine-Tuning Waste

How often I have heard factory workers mutter something along the lines of, “Hey, nobody can get that machine to work right except that guy over there.” What happens to flexibility and reliable productivity in a workshop when only one person is capable of performing certain changeovers and adjustments? Does the procedure really have to be so difficult or the machine so quirky that it takes an “old hand” to handle it? Does it have to depend on a special, experienced worker and is it really so difficult to standardize?

The most important question of all is whether the need for fine-tuning is preventable. In most cases, fine-tuning is needed simply because the standards are not being strictly adhered to. Workers often set machines up according to what
“looks” or “feels” right, then they make a trial run and adjust the machine until it works correctly and turns out a product that matches the defect-free sample.

Fine-tuning can include the following types of operations:

- Adjusting die positions
- Adjusting the die-shut height
- Adjusting the fastened height
- Adjusting feed roller width and height
- Adjusting conveyor width

While all appear to be necessary operations, none of them in fact add any value to the product. Adjustments do not always have to exist, no matter how necessary they may seem. Let us turn to a few examples of improvements that eliminated such fine-tuning operations.

**Protruding jigs eliminate the need for setting positions manually.**

Figure 11.19 illustrates an improvement that did away with the need for manual adjustment of dies following changeover at a pressing machine. Before the improvement, the press operator had to use his eyes and intuition to center the die within a bolster crossed by vertical and horizontal lines. This was not always easy to do on the first attempt, and subsequent manual adjustments were often needed.

After the improvement, the bolster contains two protruding jigs (stopper pegs) that fit into notches on the die to ensure proper positioning.

**Spacer blocks eliminate the need for manual positioning.**

Figure 11.20 shows how spacer blocks were used to eliminate workpiece length positioning prior to cutting. Before the improvement, the operator would visually adjust a movable limit switch block to the particular
length setting for each model. After the improvement, the movable block now has a simple hand-turned clamp lever that eliminates the need for wrenches or other tools. Furthermore, model-specific spacing blocks are used to eliminate the need for workpiece length positioning. As a result, the changeover time was reduced from 6 minutes to just 12 seconds.
Spacer blocks eliminate the need for manual dial positioning.

Figure 11.21 shows how spacer blocks can be used to eliminate the need for manual dial positioning. Before the improvement, inspectors used dial gauges to check product quality. Since different product models had different lengths, the inspectors had to adjust the dial position whenever a model change occurred.

After the improvement, model-specific spacer blocks were made for the inspectors to insert, when necessary, under shorter product models. This eliminated the need to adjust the dial position, which takes a lot longer than switching spacer blocks. To prevent errors due to selecting the wrong spacer block, the blocks were color coded—a technique promoted by JIT’s 5S campaign.

Standardization of die height
There are three types of standards used for changing die sets:
1. Matching bolster center with die center (X and Y axes). We call this the “centering position standard.”
2. Matching die with the die-shut height (Z axis). This is the “die height standard.”
3. Setting the height (Z axis) of the laterally (X and Y axes) positioned and fastened workpiece. This is called the “fastened height standard.”

Figure 11.22 shows how by standardizing the height of the dies, one workshop was able to eliminate the need for shut height adjustment.

Before the improvement, each die had a different height, which meant that the operator had to adjust the die-shut height. Since the die-shut had to be exact for each die, it often took over 20 minutes of adjustments to get it right.

The improvement was simply to make all die sets the same height. Specifically, bases with the same fastening hardware were added onto all of the shorter die sets. To equalize the die set heights, spacer blocks were added to all the shorter die sets to bring them up to the tallest set’s height. This effectively eliminated all that trial-and-error adjustment of the die-shut height, reduced changeover time to just two minutes, and ensured defect-free products the first time.

**Eliminating Serial Operations**

From the perspective of operational methods, changeover operations can be broken down into serial operations and
Serial operations are operations done in order from start to finish by one worker, and the total changeover time is simply the sum of the time spent by that worker on the series of operations.

Parallel operations involve splitting up the changeover operation into two or more segments, which are performed simultaneously by several workers. In this case, the changeover time is the amount of time required for the longest segment of the changeover operation.

Figure 11.23 shows an example of parallel operations in the replacement of a transfer machine’s blades. Before the improvement, one person performed the entire seven-step blade replacement operation as a serial operation. The total time required for this serial operation was calculated: Step 1 (3 minutes) + Step 2 (6 minutes) + Step 3 (6 minutes) + Step 4 (6 minutes) + Step 5 (3 minutes) + Step 6 (3 minutes) + Step 7 (5 minutes) = 32 minutes.

After the improvement, three workers worked simultaneously instead of one worker working alone. Worker A did Step 1 (6 minutes) and Step 2 (6 minutes), for a total of 12 minutes. Worker B did Step 3 (6 minutes) and Step 4 (6 minutes), for a total of 12 minutes. Worker C did Step 5 (6 minutes) and Step 6 (6 minutes), for a total of 12 minutes. The changeover time in this case is the amount of time required for the longest segment of the parallel operations, which is 12 minutes.
(6 minutes) + Step 5 (3 minutes) + Step 6 (3 minutes) + Step 7 (5 minutes) = 32 minutes.

After the improvement, the blade replacement changeover was reorganized into 5 steps and was worked into the overall workshop schedule so that instead of one worker performing it as a serial operation, three workers each performed about a third of it.

In other words:

- Worker A did step 1 (6 minutes) and step 2 (6 minutes), for a total of 12 minutes.
- Worker B did step 3 (6 minutes) and step 4 (6 minutes), for a total of 12 minutes.
- Worker C did step 1 (6 minutes) and step 2 (6 minutes), for a total of 12 minutes.

The total changeover time was therefore 12 minutes.

**Improving External Changeover**

So far, we have improved changeover by turning as much internal changeover into external changeover as possible and by improving the remaining internal changeover. These improvements should have resulted in a significant reduction in changeover time due to less stopped time for the machines, correspondingly higher capacity utilization rates, and more frequent changeovers (due to faster production turnaround).

However, we should not stop with improving the remaining internal changeover. That would leave a storehouse of external changeover waste safely hidden away. The key to maximizing the efficiency of changeover operations is to bring all possible improvements to both the internal and external changeover parts.

The key to improving external changeover operations is the 5S strategy, and particularly the two most basic of the 5S’s, proper arrangement (*seiri*) and orderliness (*seiton*).
Proper Arrangement and Orderliness
Applied to Die Storage Sites

Even modest-scale factories usually keep a stock of 10 or 20 dies on hand. As the product diversification trend continues, factories are likely to need increasingly large assortments of dies. Usually, the dies have sharply different frequencies of utilization. If there are 10 dies, two or three will be used 70 or 80 percent of the time, while the remaining seven or eight dies will be used only for special-order products.

Under such conditions, we might best begin making improvements by finding out just which dies are used how often, then storing the dies so that the more they get used, the closer they are kept to the people who use them. This alone will eliminate the need for a conveyor, and conveyor waste is a major form of waste.

Once we have figured out where the dies should be kept, we need to implement the “signboard strategy.” We can post signboards that indicate exactly where the dies go, such as by outlining the die shapes in their storage sites to make it obvious where all the dies should be placed.

Figure 11.24 shows an example of a properly arranged and orderly die storage site and signboard. The signboard's location and item indicators are the same as for in-process inventory signboards and serve the same function of making

![Figure 11.24 Die Storage Site Using Signboard Strategy.](image-url)
“what goes where” obvious to everyone. To enhance orderli-
ess, the dies are also grouped and color-coded according to
which models and machines they are used for.

Carts Reserved for Changeover

Factories that make large equipment items, such as NC
machines and printing presses, tend to use a lot of cranes,
hoists, and other kinds of large conveyance equipment.
These cranes, hoists, and the like are used to move every-
thing along, including tiny items, such as small jigs or work-
pieces. In such cases, workers end up spending a lot of time
just waiting to use the busy conveyance equipment. To avoid
such problems, the factory should be able to switch from
cranes and hoists to more agile and economical conveyance
deVICES, such as carts and conveyor belts.

Similarly, in press factories, we can find people using fork-
lifts to move boxes full of small dies. As with cranes and hoists,
people waste time looking or waiting for an available forklift.

Big, expensive conveyance devices like forklifts, cranes,
and hoists must be shared among the various stations on
the production line. Naturally, there will be plenty of times
where the demand for such devices exceeds the current
supply. It may help to think of the conveyance devices as
another process on the line. When the flow of goods goes
from several processes to just one process (a shared convey-
ance device), the flow turns to a flood. The result is idle time
waste and retention waste.

So, what can be done? There is really only one answer:
Conveyance must become part of flow production or, to put
it more succinctly, we need to establish “flow conveyance.”
One of the best ways to integrate conveyance into a flow
production system is by establishing specialized carts and
conveyor belts that are reserved for certain uses.

Figure 11.25 shows a specialized cart that is reserved solely
for changeover operations. As can be seen in the figure, this
cart is equipped with two roller boards for sliding old and
new dies off and onto bolsters during die changeover operations. All of the jigs, measuring instruments, vices, and other tools needed for changeover operations are kept right on the cart’s shelves.

**External Changeover: Drill Bit Replacement**

Figure 11.26 shows an external changeover operation for changing drill bits in a machining center. Before the improvement, the worker stopped the machining center to set-up the drill bit. After the improvement, workers used a specially built cart for drill bit replacement, which they preset with various drill bits as an external changeover operation so that when it is time to change drill bits, they can wheel the cart right over to the machining center.

**Seven Rules for Improving Changeover**

In the heyday of large-scale mass production, production engineers used to agree that “the fewer changeovers, the better.”
However, in today’s market—where large product variety, small output volumes, and short delivery are all in demand—many factories are having to make frequent product model changeovers to match production to current market needs.

When market needs change, the factory must have the courage to improve its long-cherished changeover system. In years of improving changeovers, I have discovered certain “correct ways to do things” that appear valid in most every case. In this manual, I have presented these as the “Seven Rules for Improving Changeover.” We will look at them one by one.

**Rule 1: Changeover Begins and Ends with the 5S’s**

Changeover improvement begins with the 5S’s because all improvement begins with the 5S’s. In fact, thorough implementation of the 5S’s is especially essential for successful improvement of changeovers. Factories that do a very poor job in changeover operations can find their changeover time
cut in half very easily once they have established the 5S’s. The half that they lose is all the waste that arises from searching for things, distinguishing things, using things inefficiently, and moving things around.

The 5S’s are the very foundation for changeover improvement, and the most important of the 5S’s are proper arrangement (seiri) and orderliness (seiton).

**Salient Points**

- **Discard.** Get rid of everything that is not needed. If in doubt, throw it out. That goes for any kind of item or equipment. Use the red tag strategy to identify unneeded items. (For a description of the red tag strategy, see Chapter 4.)

- **Indicators.** Put up signs showing exactly where jigs, tools, in-process inventory, and other things belong. Use the signboard strategy to do this thoroughly. (For a description of the signboard strategy, see Chapter 4.)

- **Color-coding for orderliness.** Sort out items into model-specific or machine-specific groups and color code the items by group.

- **Tool consolidation/elimination for orderliness.** Ask why each tool is necessary and see if tool functions can be consolidated or certain tools eliminated while still getting the job done.

- **Specialization.** Develop specialized carts, tools, and other equipment that will improve changeover efficiency.

**Rule 2: Change Internal Changeover into External Changeover, Then Improve the Remaining Internal Changeover**

Many of us tend to count changeover time by including only internal changeover time. Instead, we should distinguish between internal and external changeover, and try to shift as much internal changeover as possible into the realm of
external changeover. After that, we are ready to start improving the remaining internal changeover. Any improvements made in internal changeover at this point will bring valuable results indeed.

**Salient Points**

- **Analyze current changeover operations.** Use a changeover operations analysis chart to flush out and elucidate all of the things that go into current changeover operations.
- **Ask “Why?” again and again.** Ask why each segment of the internal changeover operations must remain a part of internal changeover operations. See if it can be changed to an external changeover operation.

**Rule 3: Bolts Are Our Enemies**

When it comes to changeover improvements, bolts are Public Enemy No. 1. Whenever we see them, we should start thinking of ways to do without them. If we cannot get rid of them, we may at least be able to reduce their numbers or redesign them so that they can be sufficiently tightened or loosened with just one turn. This will help us eliminate waste caused by needlessly long bolts.

**Salient Points**

- **Take the “boltless” approach.** Bolts are rarely necessary. More desirable substitutes include autoclamps (QDC), fasteners with levers on top, cassette style snap-in components, knock pins, and the like.
- **Use fewer bolts.** If the equipment is bolted together by 12 bolts, see if it can be reduced to 10 bolts. Always ask how many bolts are really needed.
- **Make bolts shorter.** Do not use bolts that are any longer than needed. Only the last turn of the bolt or machine screw does the actual fastening and only the first turn does the loosening.
Eliminate the need to completely remove bolts. There are plenty of ways—such as using sliding bolts, bolts with side-slots, or bolts with C washers—in which bolts can be loosened sufficiently without being completely removed. This saves time wasted in putting removed bolts away, finding them again, and inserting them.

**Rule 4: If You Have to Use Your Hands, Make Sure Your Feet Stay Put**

A sure sign of a poorly planned changeover operation is when workers must walk here and there to perform it. Walking around in search of a wrench or a die or a cart is all a big waste of time. Remember, each second of walking is a second of wasted time. If a worker must take 20 steps to pickup a tool, that is 20 seconds of waste. Or rather, 40 seconds of waste: 20 seconds of waste to get the tool and another 20 seconds of waste to put it back. The changeover time gets longer with each step the changeover operators take.

**Salient Points**

- **Specialize.** Develop specialized carts and tools that will be used exclusively for changeover. Keep all tools laid out in an orderly manner and within arm’s reach throughout the changeover operation.

- **Keep all switches close at hand.** The rule against walking during changeover operations applies also to all switches and control panels used during such operations. Move them closer, even if that means modifying the equipment.

- **Establish parallel operations.** Leaving a changeover operation to just one worker not only takes longer (since the changeover steps must be done sequentially), but often requires the worker to walk around the equipment to make the necessary changes. We can save a lot of changeover time by using several workers and assigning
standardized segments of the changeover operation for them to do at the same time in parallel.

**Rule 5: Don’t Rely on Special Fine-Tuning Skills**

One of the strongest-held obsolete notions about changeover operations is that the equipment always requires some fine-tuning after changeover. Not only that, but often the fine-tuning is so difficult that it takes “an old hand” to do it. Factory people accept this situation as natural and inevitable. There is no sense in paying the price of relying on certain individuals when adjustments can be standardized so that anyone can do them or, better yet, can often be eliminated altogether by strictly adhering to changeover standards.

**Salient Point**

- *Abolish fine-tuning.* We must give up the notion that fine-tuning is necessary. It never has been necessary and never will be if we take measures to abolish it.

**Rule 6: Standards Are Standard; They Are Not Flexible**

One thing that often leads to fine-tuning after changeover is the attitude that changeover standards can be “fudged” a little. Standards usually prescribe specific X, Y, and sometimes Z positions for dies, blades, fasteners, and other new parts set-up during changeover operations. If the changeover work is off-standard, the whole factory is off-standard. Standards are no longer standards if they can be interpreted a little differently during each changeover operation. Standards are meant to be kept, not fudged.

**Salient Points**

- *Avoid having to make position adjustments.* Use stoppers, notches, centering cross lines, spacer blocks, or
other devices that enable components to fit snugly into their correct positions to avoid having to “fiddle” around with them.

- *Avoid having to make height adjustments*. Different dies or other components often have different heights, which means the press or other equipment must be adjusted for each changeover. Again, we can use height adjusters, such as spacer blocks, uniform bases, and stand-alone fasteners, to make component heights uniform to eliminate the need for height adjustments as part of internal changeover operations.

**Rule 7: Standardize All Changeover Operations**

A common myth among factory workers is that changeover is an independent kind of work in which each individual worker displays his or her “know-how” and familiarity with the equipment. This belief is hardly conducive to standardization, so we need to recognize it for what it is and discard it.

If standardization is impossible, improvement is impossible. Keeping that simple phrase in mind will help us make progress as we work to improve changeover operations.

**Salient Points**

- *Do not spend money on improvements*. Do not leap toward expensive solutions to improve problems. The more money we spend, the less we will use our ingenuity to solve these problems.

- *Make improvements right away*. Once someone has come up with an improvement idea, the time to act on it is *now*. Why now? Mainly because immediate action is most likely to inspire ingenious ideas and is least likely to involve expensive solutions. Right away does not mean “later today” or “later this week.” It means as soon as the improvement idea arises.
I have made a separate listing of the “Seven Rules for Improving Changeover.” Please feel free to photocopy this list and post it wherever it may serve as a reminder.

**Seven Rules for Improving Changeover**

- **Rule 1**  
  Changeover Begins and Ends with the 5S’s.

- **Rule 2**  
  Change Internal Changeover into External Changeover, then Improve the Remaining Internal Changeover.

- **Rule 3**  
  Bolts Are Our Enemies.

- **Rule 4**  
  If You Have to Use Your Hands, Make Sure Your Feet Stay Put.

- **Rule 5**  
  Don’t Rely on Special Fine-Tuning Skills.

- **Rule 6**  
  Standards Are Standard; They Are Not Flexible.

- **Rule 7**  
  Standardize All Changeover Operations.
Quality Assurance

Quality Assurance: The Starting Point in Building Products

As discussed in earlier chapters, the essential meaning and purpose of JIT production is to serve customer needs by making “only what is needed, only when it is needed, and only in the required amount.” Why, then, do we also speak of JIT as “ideas and techniques for the total elimination of waste”? Eliminating waste cuts costs and lower costs help serve customer needs for lower prices.

JIT puts so much emphasis on cost-cutting through waste elimination that JIT leaders can easily find themselves putting quality assurance considerations on the back burner. But they should never make quality assurance anything less than a top priority.

Quality assurance is essential to both JIT production and large-scale mass production. Quality is the most fundamental characteristic of production, no matter what production system we use.

In JIT, we are not so much concerned with low-defect targets, such as a certain number or percentage of defects per month. Instead, we look at each defect as it occurs and ask, “Why did that happen?” until we find the defect’s root cause. Then we go after that cause with an improvement that will prevent the same defect from happening again.
Let us always keep the following points in mind:

1. Always follow standard operations.
2. Establish “one-piece flow” whenever possible to minimize manufacturing lead-time.
3. Stop the line whenever a defective item is produced.
4. Act immediately to make an improvement that goes right to the source of the problem.
5. Remember: “Quality is built into products at each process.”

Figure 12.1 illustrates JIT’s five levels of quality assurance achievement. Where does your factory rank among these five levels?

**JIT’s Five Levels of Quality Assurance Achievement**

**Level 1: Factory Ships Defective Products**

At this level, the factory either does not use inspectors or uses them only superficially, so that there is little or nothing to stop defects from being produced and shipped to customers.

At this level, the physical presence of inspectors means nothing.

Factories that maintain a daily flow of defects going to customers have no choice but to deal with defectives as they are exposed by customer complaints. This is a very laborious way of dealing with defectives and is bound to put the factory into the red.

This may sound facetious, but the only way to totally eliminate defects at a Level-1 factory is to totally shut it down.

**Level 2: Factory Does Not Ship Defective Products**

When factories are having a hard time preventing customer complaints, management may decide to boost the number of inspectors if the company can afford the extra costs.
At this level, the inspectors’ job is to sort the defective products from the good ones. More money for inspection therefore simply means more thorough sorting. Completely thorough sorting will effectively prevent customer complaints, but it does nothing at all to reduce the factory’s production of defective goods.
The best we can say about a factory that has crawled out of the depths of the first quality assurance level to reach this level is that it saves itself the trouble, expense, and bad publicity of dealing with customer complaints. Not really worth a round of applause, is it?

The motto at this level might be “Lots of defectives but no customer complaints.”

Naturally, all those defectives and inspectors are costing the factory a fortune. The factory’s long-term survival is still in doubt.

**Level 3: Factory Is Reducing Defects**

When I enter a factory that has achieved Level 3 in quality assurance, I usually find some telltale signs of it, such as big banners proclaiming “Support the Zero Defects Campaign,” or something else to that effect. Right away, one gets the impression that the factory managers are trying to heighten awareness throughout the company that a zero-defect campaign is in force.

The kind of inspection carried out at this level is called “information-based inspection.” When a defective unit is found at the inspection process, the inspectors inform the process that produced the item, and thus the inspection process helps encourage workers to make improvements that will prevent the defect’s recurrence.

The motto at this level is, “Defectives produced in one production run are not repeated in subsequent production runs.”

The main ammunition in reducing defects is not so much extra inspectors as it is the application of IE improvement methods and the training of line workers in some of those methods.

**Level 4: Factory Processes Do Not Send Defectives Downstream**

The factory has not yet gotten past creating defective products. Still, whenever a defective is produced, the workers do their best to nip the problem in the bud and prevent further
defects. Accordingly, the motto at this level is, “When defec-
tives are produced at one process, they do not get passed to
the next process.

At this level, the process operators themselves become
inspectors, checking the quality of every item they produce.
W call this kind of arrangement “independent inspection.”

If the inspection work is centered on machines and tools,
the processes need to have automatic inspection devices or
poka-yoke devices. If the inspection work is mainly work
done by the operators, their inspection operations need to be
included in the set of strictly enforced standard operations.

**Level 5: Factory Processes Do Not Create Defectives to Begin With**

Some people pass off the idea of zero defects as being unreal-
istic. Parroting an old phrase, they say, “To err is human, so
there will always be at least a few defects.” Such people do
not understand the Zero Defects philosophy.

To understand what “zero defects” is all about, we need to
distinguish between errors and defects. They are *not* the same
thing. Defects are results and errors are the causes of those
results. We can say that the Zero Defects philosophy begins
with this crucial distinction between errors and defects.

No one will argue with the truism that “to err is human.”
But neither should anyone oppose the idea that while to
err is human, the ability to prevent errors from leading to
defects is also human. This is the idea that serves to inspire
zero-defect campaigners.

Feet firmly planted in this optimistic concept, we can work
confidently to minimize human errors and, better yet, come
up with ways to prevent people from making errors in the
first place. This latter strategy is like killing two birds with
one stone.

At the fifth level, inspection goes all the way back to the
source of defects. Factories at this level are ready to accept
the challenge of the “three zeros”: zero defects, zero waste, and zero delays.

Structures That Help Identify Defects

Defects as People-Made Catastrophes

In any factory, the essential ingredient is people. And whenever we have people, we will have mistakes. Mistakes can lead to defects and defeat. No matter how much we wish to avoid making mistakes, sooner or later we will make one.

There are basically two ways we can look at human errors. The first approach looks at mistakes as natural and inevitable. The idea is that “to err is human” and it’s only natural that people will make mistakes now and then. The second approach looks at mistakes as evil and declares, “People make mistakes, but they are also able to reduce their mistakes to almost zero.”

The measures we take to deal with the possibility of mistakes differ greatly depending upon which of the above two approaches we identify with. The first approach affirms the human tendency to err. Naturally, if errors are accepted as natural and allowed to occur freely, the factory must take after-the-fact measures in dealing with defects arising from errors. People end up pouring effort into keeping defective goods from being passed downstream to subsequent processes or, at least, to the customer. This approach requires a large number of inspection personnel and an extensive “defect filter” just before the shipment stage to sort out defective products.

The second approach challenges the inevitability of errors and takes a positive attitude toward focusing attention and efforts in trying to prevent them. This approach goes directly to the source of errors with improvements wrought via education, cultivation of greater discipline, and the establishment of flow
production, standard operations, and other error-preventing measures. The idea is to immediately alert supervisors to errors and to conditions that facilitate errors.

So, which approach is better? Obviously, the second one. In taking this approach, we must remember to aim our criticisms at the errors themselves and not at the people who make them. Another important thing is to build a strong commitment among the factory employees to prevent errors and achieve the zero-defect goal.

The springboard for taking anti-error measures all the way back to the source of errors is the realization that no matter how much effort and how many resources we invest in product inspection, mistakes will occur and lead to defects.

Defects are man-made catastrophes. If we can remember that, along with the motto “Quality is built into products at each process,” we can work in earnest to truly eliminate defects.

**Misunderstanding Found in Inspection**

The following happened at a certain factory’s quality assurance meeting.

The factory’s managers found themselves unable to slow the flow of product quality complaints from customers. They had hung banners proclaiming “Quality First,” “Quality Assurance Month,” and other messages intended to raise everyone’s quality-consciousness. But it ended in failure. Customer complaints remained as numerous as ever.

The factory superintendent was not happy. He bellowed at the others attending the quality assurance meeting, “Double the inspection staff!” Apparently, the superintendent had decided it was time to pull out all the stops and spare no expense in weeding out defective products before they are shipped to customers. Noble as it sounds, this approach is a big mistake.

If we look carefully, we can find a major misperception at work here. The superintendent has failed to make a clear
distinction between defects and customer complaints. The two are indeed very different matters.

Factories build things at processes in workshops. Obviously, the workshop has no intention of making defective items. Nevertheless, when the products are finished, some containing defects built in at earlier processes are shipped off to customers. The defects go unnoticed until the unlucky customers who receive these products try to use them.

Any defect in a product exists in the product from the moment it is built in. Usually, the defect is not recognized right away as such. Often, it is only the person using the product (the customer) who notices the defect. When that happens, the customer gets confused, disappointed, and perhaps even angry, and sends in a complaint to the manufacturer or distributor.

To put it another way, defects in products are latent when produced and are made apparent when the products are used.

Beefing up the inspection process is one way to reduce the number of customer complaints. But often, the latent defects are not apparent enough when the products are merely inspected. They may become apparent only after the product is put to regular use. (See Figure 12.2.)

In such cases, we cannot prevent customer complaints unless we undertake defect correction and prevention measures closer to the source of the defects.

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**Figure 12.2** The Relationship between Defects and Inspection.
The following are three principles that should guide our efforts at nipping defects in the bud.

**Principle 1: Don’t Make Surplus Products**

At the most basic level, we can say that simply making products creates opportunities for creating defects. Therefore, we can say that making extra products leads to extra defects.

In other words, factories should manufacture only the amounts needed by the customers. Making more than that leads to defects, and for several reasons. First of all, having surplus goods causes some goods to be retained as warehouse inventory. Having warehouse inventory requires stockpiling and conveying the warehoused goods. Finally, stockpiling and conveying inevitably leads to more dents and damage in the products during handling. This alone is reason enough to support the Just-In-Time philosophy.

**Principle 2: Simplify and Facilitate Production Operations**

While in theory the best way to prevent defects is to refrain from building any products at all, this is obviously not the answer.

While making the minimum number of required products, we should not only find ways to simplify the production process itself, but also, within that context, find ways to simplify and facilitate the handling of the process.

Two key techniques for doing this are *poka-yoke* (or mistake-proofing, described later in this chapter) and standard operations (described in Chapter 13).

**Principle 3: Once You Make a Product, Use It**

The person best able to discover defects in a product is the product’s user. Every manufacturer of products should be well aware of this fact.

Obviously, no factory worker thinks, “Let’s make some defective products.” Defects are always made by mistake and thus often go unnoticed.
Quite often, the defect is not noticeable to anyone except the user.

The user can be the end user (customer) or someone downstream in the factory, such as the assembly line worker who finds that defective semifinished product A will not fit together with defect-free semifinished product B to make product C.

Still, the best discover of defects—even minuscule defects—is the end user. This is because the end user puts the product to use more frequently and in more ways.

It follows that the most effective way to minimize defects is to make some use of the workpiece or product as soon as it is processed or assembled. The two best methods for this are flow production and multi-process operations (described in Chapters 5 and 6 respectively).

When we make mistakes during the manufacturing of products, those mistakes will remain hidden if we process and pass along the products in lots (as in “shish-kabob” production). By the time the defect is discovered, who knows how many defective units have been made?

So, let every production line worker remember this pair of truisms: “The best discoverer of defects is the user” and, “The best expert in creating defects is the operator.”

Factors behind Defects

All kinds of defects get produced in factories. Holes get drilled or punched in the wrong places, workpieces get incorrectly processed by damaged drills or saws, assembly workers overlook a component or two—the list is endless.

Even if everyone in the factory hates defects like the devil, they will still keep making defective goods.

When defects occur, it is only natural that factory managers and workers start asking simple questions, such as, “Why did that defect occur?”
To better understand how defects get made, let us first break the typical manufacturing company down into nine basic elements. It so happens that seven of these elements start with the letter M. It may be helpful to remember them as the “7M’s plus E&I.” Figure 12.3 lists these nine elements.

For factories, the most important functional elements are Man/Woman, Material, Machine, Money, Method, and Information. On a day-to-day basis, the essential elements for factories are Man/Woman, Material, Machine, Method, and Information.

Specifically, the factory first receives operation instructions (Information), then procures supplies of parts and materials (Material), sets up the machinery and other equipment (Machine), and employs operators (Man/Woman) to manufacture products using standard procedures (Method).

These five elements (4M’s plus I) are where defects most often occur in the factory. Let us look at these elements one by one.

**Element 1: Man/Woman**

People make mistakes for all sorts of reasons, including fatigue, negligence, getting the sequence of operations wrong, attaching the wrong component, and so on.

Now, I would be the first to admit that, as the saying goes, “to err is human.” If, however, we do nothing to reduce our mistakes, we will keep making them forever. The important thing is to remember not only that people are able to make mistakes, but also that people are able to reduce the number of mistakes they make.

Factories could not exist without people. The element Man/Woman is thus the central element. The other key elements—Material, Machine, and Information—are relatively peripheral. Figure 12.4 illustrates this concept.

After all, it is people that create and process information and that move materials around. It is also people that build,
<table>
<thead>
<tr>
<th>7M’s plus E&amp;I</th>
<th>Description</th>
<th>Importance to factory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Man</td>
<td>Directors, managers, sales people, operators, etc.</td>
<td>◯</td>
</tr>
<tr>
<td>Material</td>
<td>Products, assembled parts, parts, materials, raw materials, etc.</td>
<td>◯</td>
</tr>
<tr>
<td>Machine</td>
<td>Buildings, warehouses, machines, conveyance equipment, etc.</td>
<td>◯</td>
</tr>
<tr>
<td>Money</td>
<td>Management techniques, sales methods, production methods, etc.</td>
<td>◯</td>
</tr>
<tr>
<td>Method</td>
<td>Market surveys, product planning, price strategies, sales promotion, etc.</td>
<td>△</td>
</tr>
<tr>
<td>Management</td>
<td>Efficient management of the other six “M”s</td>
<td>◯</td>
</tr>
<tr>
<td>Engineering</td>
<td>Basic technologies, applied technologies, production technologies, etc.</td>
<td>◯</td>
</tr>
<tr>
<td>Information</td>
<td>Customer information, order data, production data, distribution data, etc.</td>
<td>◯</td>
</tr>
</tbody>
</table>

The double circles indicate highest degree of importance and the triangle the lowest degree

**Figure 12.3** Nine Basic Elements in Manufacturing Companies (7M’s plus E&I).
install, and operate machines. In the manufacturing world, people are the foundation for just about everything. Accordingly, any error reduction must rely heavily on factory-wide participation in programs that continually foster education, training, and management by objectives.

**Element 2: Material**

Imagine a newlywed couple who has been enjoying their most important wedding gift, a set of furniture with a fancy brand name, only to discover during the hot, humid summer that bugs are infesting the dresser drawers. They and other customers complain loudly to the furniture store, who in turn bombard the manufacturer with complaints and warranty claims.

To avoid this problem in the future, the manufacturer is searching for a more insect-resistant material for its furniture. The manufacturer receives all of its materials and assembly parts from an independent supplier. They find it hard to get the supplier to understand their need for stricter specifications concerning resistance to insect infestation and cannot reach an agreement to purchase materials that meet those stricter specifications. The supplier seems intent on doing things its “own way.”
Obviously the furniture manufacturer must find a way to gain understanding and achieve improvements from the supplier. The key to success in doing this is to think of the supplier as just another process in the furniture production line, and to work just as hard to integrate that process as all the other processes that happen inside the furniture factory.

**Element 3: Machine**

Factory managers must never allow themselves or their subordinates to become complacent in the belief that “the machines will do a great job if we just let them do the work.” Like people, machines can make mistakes. Reliability is a temporary feature in any machine.

Sometimes one of the machine’s functions starts deteriorating and produces defective goods. Older machines tend to lose their precision very quickly. Other machines are difficult to retool and require special attention for correct maintenance and replacement of jigs, drill bits, or blades.

The factory workers who still believe that manufacturing machines should just be expected to turn out products in rapid succession are dangerously deluded. They need to rid themselves of that delusion. And while they are at it, they should also relieve themselves of the burden of pouring fruitless hours of labor into maximizing equipment capacity utilization rates. The question of how much equipment capacity to utilize should be answered by customer orders, not by the machine’s potential capacity.

So much for wrong approaches: What is the right one?

The best approach is to develop devices that can be built onto or in the machine to automatically stop the machine’s operation upon detecting defects (or even potential defects). In JIT vocabulary, we call this approach “Human Automation” or “Automation with a Human Touch.”

The old-fashioned types among us need to do a complete about-face and replace old ideas. “Our widgets sell like pancakes, so let’s turn out as many as possible,” should be
replaced with a more realistic concept, such as, “We cannot afford defects, nor can we afford to make more than the market will support.”

Lastly, we also need to turn away from an emphasis on the equipment’s capacity utilization and instead focus on the degree of possible utilization. That means asking how consistently can we keep the equipment in working order.

**Element 4: Method**

The equipment layout, flow of goods, and operational methods differ so much between Toyota and Nissan factories, it is hard to believe they are both producing automobiles.

The way a manufacturer makes its products says a lot about the manufacturer’s history and philosophy. Once a manufacturer gets set in its way of making things, its employees begin to loathe any suggestion of radically changing the factory’s production methods to suit a big change in the business environment.

When manufacturers design their production systems with an emphasis on large lots and maximum output, we call it “product-out production.” Their main concern is to get the product out. By contrast, when manufacturers focus on a level production flow and output based on market needs, we call it “market-in production.” They bring the needs of the market into the factory.

It should be obvious by now which type of production is better for today’s market environment. Along with establishing “market-in production” throughout the factory, we need to implement and enforce standard operations among all factory workers.

We cannot do any of this, however, until we succeed in changing the way people think about manufacturing.

**Element 5: Information**

The spoken word is like software in a computer; we can never see it, but it makes everything happen—including
mistakes. Likewise, instructions given orally can be misunderstood, sometimes with disastrous consequences. There is an expression in Japanese to the effect that “the spoken word is a weapon that leaves no trace of itself.” If what you have to communicate is important, be sure to put it in writing.

Of course, that can create other problems. When everything gets put in writing, we soon have a factory full of memos, vouchers, notices—a paper trail too voluminous to read.

Another problem is that writing things down does not guarantee error-free communication. Poorly explained or poorly understood information becomes poorly written or poorly read information. Naturally, the more mistakes in communication we have, the more product defects we can expect to encounter.

Nonetheless, the first thing to do is to avoid oral instructions. Factories instead need written instructions that are brief and to the point. This is where computers make an excellent tool for the systematic processing and management of information.

Another way to prevent communication errors is JIT’s “visual control” approach, which uses signboards, kanban, and other tools to make operation instructions and other information obvious to everyone.

Figure 12.5 groups together the five elements of daily manufacturing activity just mentioned, the two main approaches people take to these elements, the kind of action that follows each approach, and the JIT improvement measures that correspond to JIT-oriented approaches.

The ideas presented in the figure include two main points:

- Point 1: Don’t Give Up before You Start!
  Taking a fatalistic attitude and saying, “Well, nothing can be done about errors since people naturally make mistakes,” or, “Everybody’s different, so different workers will inevitably do the same tasks differently,” is tantamount to giving up on improvement before we even start.
<table>
<thead>
<tr>
<th><strong>ELEMENT</strong></th>
<th><strong>APPROACH</strong></th>
<th><strong>ACTION</strong></th>
<th><strong>JIT MEASURE</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MAN/WOMAN</strong></td>
<td>Human errors must be accepted as inevitable</td>
<td>Focus management efforts on production output and operating time</td>
<td>No JIT measure</td>
</tr>
<tr>
<td>People make mistakes</td>
<td>We can reduce human errors</td>
<td>Get everyone involved in error-prevention activities</td>
<td>Education, discipline, management by objective</td>
</tr>
<tr>
<td><strong>MATERIAL</strong></td>
<td>Not much can be done about defective materials</td>
<td>Concentrate on keeping a steady supply of materials to avoid shortages</td>
<td>No JIT measure</td>
</tr>
<tr>
<td>Not all materials are defect-free</td>
<td>We can substantially reduce the amount of defective materials</td>
<td>Make sure material supplies are not only steady but also up to our standards</td>
<td>Give guidance to suppliers, inspect all supplied materials</td>
</tr>
<tr>
<td><strong>MACHINE</strong></td>
<td>Not much can be done about the defects machines sometimes produce</td>
<td>Make up for defects by emphasizing a high capacity utilization rate</td>
<td>No JIT measure</td>
</tr>
<tr>
<td>Machines sometimes produce defects</td>
<td>We can take steps to prevent machine-caused defects</td>
<td>Develop and install devices that stop machine-caused defects</td>
<td>Human automation, poka-yoke, total preventive maintenance</td>
</tr>
<tr>
<td><strong>METHOD</strong></td>
<td>Workers naturally develop their own style making each process a little different</td>
<td>Leave the “how” up to the individual workers, as long as their output is high enough</td>
<td>No JIT measure</td>
</tr>
<tr>
<td>Operation and manufacturing methods are often left up to the individual workers to develop</td>
<td>We can eliminate idiosyncrasies in operation and manufacturing methods</td>
<td>Establish one-piece flow production based on standard operations</td>
<td>Standard operations, flow production</td>
</tr>
<tr>
<td><strong>INFORMATION</strong></td>
<td>People cannot avoid explaining things or hearing incorrectly</td>
<td>Keep giving oral instructions</td>
<td>No JIT measure</td>
</tr>
<tr>
<td>Oral instructions are often misunderstood</td>
<td>We can minimize mistakes due to poorly explained or misunderstood oral instructions</td>
<td>Put communications in writing as concise match up information with the subjects discussed</td>
<td>Computer-based information systems, visual control (kanban, etc.)</td>
</tr>
</tbody>
</table>

Figure 12.5  The Five Main Elements behind Errors and Defects.
As long as we accept the status quo as inevitable, we stand absolutely no chance of improving it.

Point 2: Every Defect Has Its Source in People

How easy it is to blame defects on inanimate objects: “We got some bad materials,” or, “The machine broke down.”

If we stop to ask why, such as, “Why did defective materials get delivered here?” or, “Why did the machine break down?,” and if we keep asking why until we reach the ultimate culprit, we will invariably find that culprit to be a person or group of people.

As mentioned earlier, in the manufacturing world, people are the foundation for just about everything. Behind every defect lies at least one instance of human error.

Causes of Defects

To repeat something that bears repeating, all defects can be traced back to some kind of human error.

Cutting machines start turning out defective workpieces when the operator forgets to change the blade at the scheduled time. Another machine starts producing defects because it was overlooked during the last routine maintenance check. Assembly lines start spurting out defective products because an assembly worker got the models mixed up and started attaching the wrong parts.

No matter what the example, we can surely find a human goof at its source.

Figure 12.6 shows how some common kinds of defects are causally linked to typical human errors.

As can be seen in the figure, defects are broken down into two basic types. The first kind of error occurs during any operation that adds value to the product. We call this “processing defect.”

Processing defects come in two types—processing omissions and processing errors. Processing omissions are when
someone has overlooked any part of the processing that is required to make the finished product. Processing omissions can be further broken down into cases where an entire process has been overlooked, which we call “process omissions,” and cases where only some operations in a process were missed, which are called “operation omissions.”

Processing errors occur when processing that is expected in the final product has been performed incorrectly. This can include cases where the wrong kind of processing was performed, or the processing precision was not high enough, so that the final product is substandard in terms of processing.

In contrast to processing defects, factories also experience “material defects,” which means that the material itself is of inferior quality.

The first-level causes of material defects are “missing part” and “wrong part.” Missing part simply means that someone failed to attach a required part to the product during assembly as specified in the assembly instructions.

Wrong part means that the correct number of parts have been assembled, but that at least one of the parts is the
wrong one for that particular product model. The shape of the wrong part may be identical to the correct part, but the precision of processing in some other aspect of the part may be different enough to result in a defective finished product.

The second-level causes that lead to either processing defects or material defects are “error in adjustment,” “error in operation,” “error in setting up the workpiece,” “wrong workpiece,” “error in equipment maintenance,” and “error in preparation of blades, jigs, or tools.”

- **Error in adjustment.** This refers to errors made when adjusting equipment or jigs during equipment retooling operations.
- **Error in operation.** This occurs when the operator operates the equipment incorrectly.
- **Error in setting up the workpiece.** In this instance, the operator processes a workpiece that has been incorrectly positioned during set-up.
- **Wrong workpiece.** This is when workpieces for different models look alike, and the operator sets up and processes the wrong kind of workpiece.
- **Error in equipment maintenance.** This is when the equipment is in poor condition due to inadequate maintenance work or an oversight during maintenance checks.
- **Error in preparation of blades, jigs, or tools.** Here, a defect occurs due to an error or omission made during the preparation of blades, jigs, or tools required for processing.

Second-level causes lead to first-level causes. For example, an error in setting up the workpiece (second-level cause) can very easily result in a wrong part (first-level cause). Other second-level causes can lead to almost any of the first-level causes.

Which of these causes tend to happen most often? After analyzing a number of case studies, I have come up with “The Ten Worst Causes of Defects,” which are shown in Figure 12.7.
As you can see, processing omissions and errors are the two worst causes of defects. This is because the analysis of case studies showed these processing-related causes to be the most frequent phenomena.

By contrast, the case studies included relatively few instances of defects arising from improperly prepared equipment, blades, and jigs, or other equipment-related problems.

The results of this analysis support my earlier contention that people are at the bottom of nearly every defect in the factory. Therefore, we should regard the prevention of human errors as our primary objective. We should also implement _poka-yoke_ (or mistake-proofing) devices and standard operations as effective means of addressing problems in the element “Man/Woman’s” relationship with other elements, such as “Method” and “Information.”

### Overall Plan for Achieving Zero Defects

**Why Must Defects Occur?**

To answer that simple question, we need to take a deeper look into human errors and the other elements that cause the creation of defects.
We have already seen how the element “Man/Woman” stands as the primary cause behind almost all defects. This does not mean, however, that the “Man/Woman” element is the only element we need to address when making efforts to prevent defects.

We must begin by thinking of the factory itself as a living being. We should also remember that production is a system. Therefore, while viewing “Man/Woman” as the core element, we must develop devices to prevent the occurrence and creation of defects.

Figure 12.8 illustrates the overall plan for achieving zero defects in factories.

**Man/Woman**

- **Device 1: Basic training**
  
  People are the root cause of errors and defects. We must make sure a good foundation of basic training has been laid. This training should include topics such as
the overall role of people in factories, management by objective, and making a habit of following the regulations and standards.

- Device 2: Multiple skills training
  
  Many defects are the result of human ignorance. Factory workers are sincerely trying to make defect-free products, but their lack of certain knowledge and skills can make it hard for them to discover defects.

  As mentioned earlier, the people best able to discover defects are the users. They alone put the product to practical use and can therefore best judge whether the product is defective.

  It follows that products and workpieces should be used as soon as they are made. It is also more effective to have the person who made the product do the practical testing, rather than someone else. In one-piece flow production using multi-process operations, the operator accompanies each workpiece to the various processes in the workshop, and can therefore make a thorough inspection while “using” (processing) the workpiece at subsequent processes.

**Information**

- Device 3: Visual control
  
  At a typical factory, a quality control inspector comes by each workshop once a month to check on defects. He or she conducts analyses, writes up quantitative results, and then puts the data away in a desk. That is usually the end of it.

  It does little good to collect data on the occurrence of defects and improvements if they are not going to be shared and discussed with the shop-floor workers. The analytical data should not only be explained to the workers, but should also be translated into graphical representations that help the workers see what the data means. This is part of visual control, and it is vital that visual control be rooted in the workshops.
Material

- Device 4: Preventive (independent) inspection
  Downstream inspection is powerless to prevent the production of defective goods. The best defect prevention is the kind that detects and corrects errors before they lead to defects. That kind of defect prevention can only be obtained by combining processing or assembly with inspection, all in the same place.

Machine

- Device 5: Poka-yoke
  One of the tools used by the JIT production system is “human automation.” Human automation means customizing factory machines so that they not only manufacture products, but also detect defects and automatically stop the machine whenever a defect occurs or is about to occur.

  Human automation also includes the development and use of poka-yoke (mistake-proofing) devices that help keep machines from producing defective goods.

- Device 6: Company-wide preventive maintenance
  One important way to prevent defects and ensure high productivity is to make sure the factory equipment is operating in top condition, both in terms of its functions and its capacity.

  Upkeep of equipment should not be left to the maintenance staff alone. After all, it is the equipment operators and not the maintenance technicians who spend all day working with the equipment and who best understand its operating “health.” Operators need to learn what they can do on a daily basis to keep the equipment in top shape.

Method

- Device 7: Flow production
  As mentioned above, the best way to discover defects is to use the product just as soon as it is made. One-piece
flow production enables factory floor workers to do just that.

Device 8: Standard operations
Wherever we find operators who think, “I don’t really know the best way to do this,” or, “It’s up to me to decide how this should be done,” we can be sure to find lots of defective products.

By drawing up a chart that describes the correct equipment layout and operational procedures, we can establish a clearly defined set of standard operations that everyone in the factory can understand and follow.

**Basic Strategy for Zero Defects**

Device 9: The 5S’s (proper arrangement, orderliness, cleanliness, cleaned up, and discipline)
We have just described the various defect-prevention devices that fall under the categories of the factory’s five main functional elements (Man/Woman, Material, Machine, Method, and Information). However, none of these devices stand much of a chance of working well unless we have first laid a strong foundation. The strongest and most appropriate foundation for preventing defects is the one we create by implementing the 5S’s (proper arrangement, orderliness, cleanliness, cleaned up, and discipline).

**The Poka-Yoke System**

**The Poka-Yoke Concept and Methodology**

In Japan, quality control experts coined the term “poka-yoke,” which translates to “mistake-proofing.” *Poka-yoke* refers to where the mistake is made—*poka* refers to the operation and *yoke* to the prevention of mistakes.
Poka-yoke devices are already in use throughout Japan. You will find them in most factories that employ at least 10 or 20 workers. Very few factories, however, have homegrown poka-yoke devices that cleverly solve factory-specific problems. Figure 12.9 shows how poka-yoke devices can be divided into three main types.

The three types of poka-yoke devices shown in Figure 12.9 are described below.

**Stop Devices**

- Stop for abnormalities. This kind of device can detect certain abnormalities that can lead to defects. When it detects...
such an abnormality, the device stops the machine’s current operation or function. This is analogous to staying home from work when you have a bad cold.

- Stop for defects. This kind of device can detect when the machine has produced a defective product and immediately stops the machine’s current operation or function so that it does not turn out more defective products. This is analogous to leaving work to go home to bed when a cold is compounded by a bad fever.

**Control Devices**

- Error control. This kind of device prevents operators from straying from standard operations and making errors. An analogy for this would be closing your eyes when you see a dust cloud coming your way.
- Flow control. This kind of device keeps defective goods from being passed to the next process. An analogy for this would be the way an eye that has a speck of dust on it begins watering to remove the dust.

**Warning Devices**

- Warning signal. This kind of device uses lamps and/or buzzers to warn people when an abnormality that may lead to a defect has occurred. This is analogous to a wind chime that sounds only when the wind is strong enough to constitute a certain degree of a fire hazard.
- Defect signal. This kind of device uses lamps and/or buzzers to warn people when a defect has occurred. The analogy in this case is a fire alarm that alerts people that a fire has started.

As you can see, *poka-yoke* devices operate in one of two ways: as a device that informs us when a defect may be about to occur, or as a device that informs us when a defect has actually occurred. It should be obvious which kind of
operation is more valuable. As the saying goes, an ounce of prevention is worth a pound of cure. That is why JIT leaders stress the need to develop devices that detect abnormalities and give advance warning about the potential for defects.

It is not always easy, however, to predict when a defect is likely to occur. In such cases, we have to respond to the defect as it arises. When a defect occurs in the factory, we should treat it as a true emergency. The alarm lights and buzzer should grab our attention and bring immediate action to resolve the problem that created the defect.

**Poka-Yoke Approaches**

Imagine a *kaizen* team member standing in a workshop that has been producing defective goods and asking himself, “What kind of *poka-yoke* device shall I use?

Basically, he can take one of three approaches:

1. He can look at the shape of the part being processed and check whether it is usable or unusable.
2. He can study the sequence of processing steps carried out by the operator.
3. He can check the quantitative parameters of the operations.

If he takes the first approach, he needs to check the standards regarding the shape, dimensions, and weight of the part of other material involved and see if any of those standards are not being met. He can use this method to sort defective good from nondefective ones. We call this method the “item characteristics method.”

If he takes the second approach, which we call the “operation step method,” he may discover that at least one of the steps is sometimes not being done correctly, and can then develop a *poka-yoke* device to prevent operator negligence at that step.
If he takes the third approach, he needs to study numerical data describing the various quantifiable parameters of the operation, such as the number of times an operation is repeated, the number of parts involved, the time required, and so on. Variations or gaps in these numerical data can help him sort out defective and defect-free products. We call this the “statistical method.”

Let us look a little more closely at each of these approaches and their corresponding methods.

**Item Characteristics Method**

- **Shape method.** For this method, we need to have standards set for various shape characteristics, such as holes, angles, dents or creases, protrusions, curves, and so on. Then we can compare each item’s shape characteristics against these standards to see if the item is defective.

- **Dimension method.** In this case, we need to have standards set for various dimensions, such as height, length, width, thickness, diameter, and the like. We then compare each item’s dimensional characteristics against these standards to see if the item is defective.

- **Weight method.** Armed with weight standards, we can simply weigh each item to check for extra mass that indicates a defect. We can also check the weight balance between the right and left halves of certain items.

**Operation Step Method**

- **In-process sequence method.** The purpose of *poka-yoke* here is to find out when operators stray from standard operations, either in their own work or in the way they work with the equipment, and to keep them from continuing the sequence of operations in that process.

- **Between-process sequence method.** In this case, *poka-yoke* devices work to stop operations whenever a process within a series of processes is performed incorrectly or is overlooked.
Statistical Method

- Counter method. Here, we check the workshop against the current standards for the number of times an operation should be repeated or the number of parts involved. *Poka-yoke* devices can detect when the numbers are wrong and can issue a warning.
- Remainder method. Sometimes, parts are grouped into sets before being processed or assembled. A *poka-yoke* device can detect when any part remains in used sets and can sound an alarm to notify everyone that a part has been omitted.
- Other statistical methods. Other numerical values that can be monitored by *poka-yoke* devices include pressure, electrical current, temperature, and time. *Poka-yoke* devices can notify us whenever any of these values are off standard.

Poka-Yoke Detection Devices

There are all kinds of devices that can be used to detect abnormalities. Generally, such detection devices can be categorized into contact devices and noncontact devices.

Let us look at a few typical examples in each of these two categories.

Contact Devices

- Microswitches and limit switches. These types of detectors are the ones most commonly used as *poka-yoke* devices. They work best in detecting the presence and position of workpieces, dies, and bits or blades. Microswitches offer a variety of actuators to choose from, according to the specific application. Figure 12.10 lists the main types of actuators and their respective features.
- Other contact devices. Although microswitches and limit switches are the most often used types of contact
<table>
<thead>
<tr>
<th>Shape</th>
<th>Name</th>
<th>Pretravel</th>
<th>Overtravel</th>
<th>Operating Force</th>
<th>Vibrating/Shock Resistance</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Pin push button type" /></td>
<td>Pin push button type</td>
<td>Small</td>
<td>Small</td>
<td>Large</td>
<td>Very good</td>
<td>Operated by a short straight stroke, this switch features a snap-action mechanism that responds to direct contact with the pin. It therefore offers the highest precision for position detection. However, it also has the least amount of overtravel among all the actuators, and therefore requires a reliable stopper.</td>
</tr>
<tr>
<td><img src="image" alt="Roller push button type, attached to panel" /></td>
<td>Roller push button type, attached to panel</td>
<td>Small</td>
<td>Large</td>
<td>Large</td>
<td>OK</td>
<td>Roller attached to the panel assembly is suitable for use with rapidly moving cams or docks.</td>
</tr>
<tr>
<td><img src="image" alt="Hinged lever" /></td>
<td>Hinged lever</td>
<td>Large</td>
<td>Medium</td>
<td>Small</td>
<td>OK</td>
<td>Operable under a small operating force, suited for use with rapidly moving cams or docks. Also features large stroke. Levers are available in various shapes and configurations to suit different types of operation.</td>
</tr>
<tr>
<td><img src="image" alt="Hinged roller lever" /></td>
<td>Hinged roller lever</td>
<td>Large</td>
<td>Medium</td>
<td>Small</td>
<td>OK</td>
<td>This is a hinged lever with a roller attached. Also suitable for rapidly moving cams or docks. Requires less operating force on the pin than does the hinged lever and uses a larger stroke.</td>
</tr>
<tr>
<td><img src="image" alt="Unidirectional hinged roller lever" /></td>
<td>Unidirectional hinged roller lever</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>OK</td>
<td>This is a hinged roller lever that can also be operated using a unidirectional operating device. If the operating device presses from the opposite direction, the roller section bends and prevents the actuator from operating. As such, this device is especially suited for applications where reverse-direction operation is to be avoided.</td>
</tr>
<tr>
<td><img src="image" alt="Roller/leaf spring type" /></td>
<td>Roller/leaf spring type</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Good</td>
<td>This is leaf spring with a roller attached. Can be used with high-speed cams.</td>
</tr>
</tbody>
</table>

Figure 12.10  Microswitch Actuators: Types and Features.
switches, there are some other kinds of “touch switches” that feature highly sensitive detection of workpiece positions. In addition, differential transformers can be used to detect changes in electromagnetic force as a type of contact pressure and trimetron switches can be used for dial gauge applications.

Noncontact Switches

- Photoelectric switches. Photoelectric switches can be used with devices that transmit and reflect light. As detectors, photoelectric switches come in two types: unidirectional switches that detect the interruption of light transmission between two photoelectric switches, and reflector switches that use reflected light beams. Reflector switches are further broken down into dispersion reflectors and feedback reflectors. (See Figure 12.11.)

Photoelectric switches are also sometimes classified according to function. Some have external amplifiers, others have built-in amplifiers, and still others include built-in power supplies. Figure 12.12 shows how photoelectric switches are classified according to detection method and function. Figure 12.13 shows how photoelectric switches

![Use of photoelectricity as a detection method diagram](image)

Figure 12.11  Photoelectric Switch Detector.
<table>
<thead>
<tr>
<th>Detection method</th>
<th>Unidirectional method</th>
<th>Reflection method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Object</td>
<td>Switches with separate amplifiers</td>
<td>Switches with built-in amplifiers</td>
</tr>
<tr>
<td>Light-blocking</td>
<td>Switches with built-in amplifiers</td>
<td>Switches with built-in power supplies</td>
</tr>
<tr>
<td>Light-transmitting objects</td>
<td>Switches with separate amplifiers</td>
<td>Switches with built-in amplifiers</td>
</tr>
<tr>
<td></td>
<td>Switches with built-in power supplies</td>
<td></td>
</tr>
</tbody>
</table>

Figure 12.12  The Relationship between Object, Detection Method, and Function of Photoelectric Switches.

Photoelectric switch with built-in amplifier

(Uses)

- For confirming passage of solid (light-reflecting) objects
- For detecting translucent objects
- For confirming supply of parts
- For confirming passage of wafers

Figure 12.13  The Use of Photoelectric Switches.
with built-in amplifiers are used. Figure 12.14 shows how fiber optic switches are used.

- Proximity switches. Proximity switches are activated when they come close to an object. Some proximity switches use electromagnetism to detect proximity. Figure 12.15 shows various ways of using proximity switches.

- Positioning sensors. Noncontact switches also include sensors that help position objects correctly. Figure 12.16 shows some ways these can be used.

- Outer diameter and width sensors. These sensors use groups of parallel light beams to obtain a precisely measured image of the object being detected. These sensors can continually measure object dimensions, such as outer diameter and width. Figure 12.17 shows some ways of using outer diameter and width sensors.

- Displacement sensors. Displacement sensors, which usually use lasers or other optical media, can measure an object’s directional dimensions without touching the object. They can also measure various colors and materials characteristics. Figures 12.18A and 12.18B show several uses for displacement sensors.

- Metal passage sensors. These noncontact sensors can detect the passage of metal objects. Their uses include detection of fast-moving metal objects and counting very small metal objects. Figure 12.19 shows how metal passage sensors can be used.

- Color mark sensors. Color mark sensors can be used to sense the difference between two slightly different colors and to detect very small marks. Figure 12.20 shows how color mark sensors can be used.

- Vibration switch. These sensors can detect vibration in almost any kind of material. They can also be used to detect the passage, width, and missing drill bits in various objects. Figure 12.21 shows some ways of using vibration switches.
Figure 12.14 The Use of Fiber Optic Switches.
Double-feed sensor. Double-feed sensors generally work in one of two ways: as top-and-bottom sensors or as edge sensors. Figure 12.22 shows how double-feed sensors can be used.

This concludes our brief description of contact and noncontact detectors, switches, and sensors that are used daily in factories. There are many types of detectors that
have not been described here, and new, more sophisticated kinds are being developed all the time. This is an area where a constant need for data gathering and practical research exists. Figure 12.23 lists the various kinds of switches and sensor described in previous pages.
For further reference, please check the follow product catalogs listed under the manufacturer.
- Electronics Co., Ltd.
- Sensor Catalog, 1985
- Optical Displacement Sensors
- Amplifier-Equipped Proximity Switches
Figures 12.18A  Uses of Displacement.

- Fiber Optic Switches
- Ultra-Compact Photoelectric Switches
- Matsushita Electric Industrial Co., Ltd.
- Control Devices, 1984–85
- MP Photoelectric Switches
- Microswitches
Figures 12.18B (continued)

- Triode MQ Photoelectric Switches
- Limit Switches
- Color Mark Sensors
- Hitachi Electric Co., Ltd.
- Best Control Devices from Omron, 7th Ed.
Figure 12.19  Uses of Metal Passage Sensors.
Figure 12.20  How to Use Color Mark Sensors.
Figure 12.21 Uses of Vibration Switches.
Double-feed sensor

### Top-and-bottom detector

<table>
<thead>
<tr>
<th>Controller</th>
<th>Sensor</th>
<th>Standard type</th>
<th>Compact type</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Diagram" /></td>
<td><img src="image2.png" alt="Diagram" /></td>
<td><img src="image3.png" alt="Diagram" /></td>
<td><img src="image4.png" alt="Diagram" /></td>
</tr>
</tbody>
</table>

### Edge detector

<table>
<thead>
<tr>
<th>Controller</th>
<th>Sensor</th>
<th>Standard type</th>
<th>Compact type</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image5.png" alt="Diagram" /></td>
<td><img src="image6.png" alt="Diagram" /></td>
<td><img src="image7.png" alt="Diagram" /></td>
<td><img src="image8.png" alt="Diagram" /></td>
</tr>
</tbody>
</table>

(Uses)

- Detection from above and below
- Tube lip detector
- Confirming pieces in aluminum boxes
- Metal fragment detector for metal containers
- Edge detector (A)
- Edge detector (B)
- Double lead frame detector

Figure 12.22 Uses of Double-Feed Sensors.
<table>
<thead>
<tr>
<th>Detector devices</th>
<th>Item characteristics method</th>
<th>Operat-ion step method</th>
<th>Statistical methods</th>
<th>Detection devices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contact type</td>
<td>Shape method</td>
<td>Dimension method</td>
<td>Weight method</td>
<td>Between-process sequence method</td>
</tr>
<tr>
<td></td>
<td>In-process sequence method</td>
<td>Counter method</td>
<td>Remainder method</td>
<td>Line and position detectors</td>
</tr>
<tr>
<td></td>
<td>Surface detectors</td>
<td>Weight detectors</td>
<td>Dent detectors</td>
<td>Color detection</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Foreign matter detectors</td>
<td>Repetition detectors</td>
<td>Times</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Current gauges</td>
<td>Voltage gauges</td>
<td>Temperature gauges</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Alarm devices</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-contact type</td>
<td>Pressure gauges</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Temperature gauges</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Current gauges</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Counters</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Timers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gauges</td>
<td>Buzzers</td>
<td></td>
<td>Alarm devices</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lamps and blinking lights</td>
<td></td>
<td>Andon</td>
<td></td>
</tr>
</tbody>
</table>

Figure 12.23  *Poka-Yoke* Detection Devices and Their Uses.
Pokayoke Case Studies for Various Defects

The following pages describe 28 examples of pokayoke devices, beginning with a table that categorizes these examples according to the type of defect causes they work to prevent.

<table>
<thead>
<tr>
<th>Cause of Defect</th>
<th>Theme</th>
</tr>
</thead>
<tbody>
<tr>
<td>Processing omissions (6)</td>
<td></td>
</tr>
<tr>
<td>1. Preventing hole count errors during hole punching</td>
<td></td>
</tr>
<tr>
<td>2. Preventing deburring omissions</td>
<td></td>
</tr>
<tr>
<td>3. Preventing omission of spindle hole punch process</td>
<td></td>
</tr>
<tr>
<td>4. Preventing omission of grinding process</td>
<td></td>
</tr>
<tr>
<td>5. Preventing omission of assembly step</td>
<td></td>
</tr>
<tr>
<td>6. Prevent omission of hole drilling</td>
<td></td>
</tr>
<tr>
<td>Processing errors (7)</td>
<td></td>
</tr>
<tr>
<td>7. Preventing board insertion errors</td>
<td></td>
</tr>
<tr>
<td>8. Preventing pin dimension errors</td>
<td></td>
</tr>
<tr>
<td>9. Preventing errors in aligning press dies</td>
<td></td>
</tr>
<tr>
<td>10. Preventing variation in hose cut lengths</td>
<td></td>
</tr>
<tr>
<td>11. Preventing bridge defects</td>
<td></td>
</tr>
<tr>
<td>12. Preventing insufficient torque when tightening bolts</td>
<td></td>
</tr>
<tr>
<td>13. Preventing drilling defects</td>
<td></td>
</tr>
<tr>
<td>Error in setting up workpiece (6)</td>
<td></td>
</tr>
<tr>
<td>14. Preventing incorrect drill position during drilling process</td>
<td></td>
</tr>
<tr>
<td>15. Preventing defects due to error in setting up product</td>
<td></td>
</tr>
<tr>
<td>16. Preventing incorrect attachment of bracket</td>
<td></td>
</tr>
<tr>
<td>17. Preventing processing errors due to workpiece set in wrong direction</td>
<td></td>
</tr>
<tr>
<td>18. Preventing incorrect positioning of workpiece prior to drilling</td>
<td></td>
</tr>
<tr>
<td>19. Preventing tap processing errors</td>
<td></td>
</tr>
<tr>
<td>Cause of Defect</td>
<td>Theme</td>
</tr>
<tr>
<td>---------------------------------------</td>
<td>----------------------------------------------------------------------</td>
</tr>
<tr>
<td>Missing item (5)</td>
<td>20. Preventing omission of inserted part</td>
</tr>
<tr>
<td></td>
<td>21. Preventing omission of name</td>
</tr>
<tr>
<td></td>
<td>22. Preventing omission of brush</td>
</tr>
<tr>
<td></td>
<td>23. Preventing omission of items during packing</td>
</tr>
<tr>
<td></td>
<td>24. Preventing omission of E rings</td>
</tr>
<tr>
<td>Wrong part</td>
<td>25. Prevention of wrong part assembly</td>
</tr>
<tr>
<td></td>
<td>26. Preventing mixing of nondefective and defective items</td>
</tr>
<tr>
<td>Wrong workpiece</td>
<td>27. Preventing errors in gear assembly</td>
</tr>
<tr>
<td>Error in preparation of blades, jigs, or tools</td>
<td>28. Preventing errors in attachment of left and right drawer rails</td>
</tr>
</tbody>
</table>
### Theme 1

<table>
<thead>
<tr>
<th>Defect cause category</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Preventing hole count errors during hole punching</td>
<td>Processing omission</td>
</tr>
</tbody>
</table>

**Problems**

Sometimes, the operator at the hole punching process fails to check the number of punched holes and punches fewer than the specified number.

<table>
<thead>
<tr>
<th>Before improvement</th>
<th>After improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>The operator counted the holes as he or she was punching them. This left room for counting errors and led to problems arising from having too few holes.</td>
<td>Installed a limit switch to confirm the punching of holes and to count the number of punched holes.</td>
</tr>
</tbody>
</table>

**Nondefective item**

- Limit switch for counting holes
- Limit switch for checking workpiece position

**Defective item**

- Limit switch for counting holes
- Buzzer
- Jig
**Theme 2**

<table>
<thead>
<tr>
<th>Defect cause category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preventing deburring omissions</td>
</tr>
</tbody>
</table>

**Problems**

Sometimes, after the diecasting process, the operator forgets to deburr the workpiece and instead sends it directly downstream. This has led to complaints from customers.

**Before improvement**

Pre-shipment inspectors visually checked products to confirm deburring. However, some products that lacked deburring still were sent to customers, leading to customer complaints.

**After improvement**

A *poka-yoke* pin was attached to the base to detect when the deburring process is omitted. This device effectively eliminated all deburring omissions.

**Nondefective item**

![Sectional view of product](image1)

**Nondefective (processed) item**

![Sectional view of product](image2)

**Defective item**

![Location of defect](image3)

**Defective (unprocessed) item**

![Pin prevents unprocessed item from being set onto base](image4)
## Theme 3

### Defect cause category

| Preventing omission of spindle hole punch process | Processing omission |

### Problems

Normally, spindle holes are punched in the workpiece, and then the workpiece is bent. However, sometimes the workpiece is bent before its spindle holes are punched.

#### Before improvement

The process sequence was:
1. Hole punching
2. Bending

If the order gets reversed and the workpiece is bent before the holes are punched, it is impossible to punch the holes after bending. The operators tried carefully to avoid this mistake, but it still happened occasionally.

#### After improvement

Pins were attached to the die used for bending so that workpieces without spindle holes cannot be set onto the die. This effectively prevented any hole punch omissions.

### Correct processing sequence

<table>
<thead>
<tr>
<th>Cutting</th>
<th>Hole punching</th>
<th>Bending</th>
</tr>
</thead>
</table>

- After cutting: Cannot be set onto die
- After hole punching: Can be set onto die

#### Poka-yoke pin

Die

### Incorrect processing sequence

<table>
<thead>
<tr>
<th>Cutting</th>
<th>Bending</th>
<th>Hole punching</th>
</tr>
</thead>
</table>

- Cannot punch holes
**Theme 4**

<table>
<thead>
<tr>
<th>Defect cause category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preventing omission of grinding process</td>
</tr>
<tr>
<td>Processing omission</td>
</tr>
</tbody>
</table>

**Problems**

Pre-shipment inspectors often found defective products in which the grinding process was omitted, due to operators’ misplacement of workpieces or their skipping of workpieces when stopping processing to take a break.

**Before improvement**

The operator worked with the grinding machine in front, the unprocessed workpieces at the left, and the processed ones at the right. Sometimes, the operator would mistakenly place an unprocessed workpiece in the processed pile at the right.

**After improvement**

A chute with adjustable dimensions was attached between the grinding machine and the box for processed workpieces. The sides of the chute were tapered to allow only ground (processed) workpieces to pass through.

**Nondefective (processed) item**

![Diagram of nondefective (processed) item]

**Defective (unprocessed) item**

![Diagram of defective (unprocessed) item]
### Theme 5

<table>
<thead>
<tr>
<th>Defect cause category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preventing omission of assembly step</td>
</tr>
</tbody>
</table>

### Problems

If the operator is absent or for some other reason fails to insert a right-angle piece onto the workpiece, the defect is not noticed until the inspection at the end of the assembly line.

<table>
<thead>
<tr>
<th>Before improvement</th>
<th>After improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operator inserted right-angle pieces into workpieces as they were conveyed to downstream processes.</td>
<td>Two limit switches were installed. If the limit switches do not detect the right-angle piece on the workpiece, the conveyor is automatically stopped. This reduced assembly omissions for this process to zero.</td>
</tr>
</tbody>
</table>

![Diagram showing the process before and after improvement](image_url)
**Theme 6**

<table>
<thead>
<tr>
<th>Defect cause category</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Preventing omission of hole drilling</td>
<td>Processing omission</td>
</tr>
</tbody>
</table>

**Problems**

Operators sometimes mistake one model for another and do not drill holes in models where holes are required.

**Before improvement**

The processing sequence for one model was cutting → hole drilling → pressing and for another model it was simply cutting → pressing. Sometimes, operators mistake one model for another and do not drill required holes.

**After improvement**

Since the press jig must be changed when changing models, two *poka-yoke* pins were attached to the jig for the model requiring holes so that the model cannot be pressed unless its holes have been drilled. This prevented omission of hole drilling in the model that required it.

**Nondefective item**

![Nondefective item diagram](image)

**Defective item**

![Defective item diagram](image)
## Theme 7

<table>
<thead>
<tr>
<th>Problem</th>
<th>Before improvement</th>
<th>After improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preventing board insertion errors</td>
<td>Two adjacent boards—the detection circuit board and the control circuit board—have</td>
<td>Guide pins were attached to different positions on the two slots and notches were</td>
</tr>
<tr>
<td></td>
<td>the same connection pin configurations and appear similar in general. This makes</td>
<td>made in corresponding positions on the boards to prevent incorrect insertion of</td>
</tr>
<tr>
<td></td>
<td>it easy to insert them into the wrong slots.</td>
<td>boards.</td>
</tr>
<tr>
<td>Processing errors</td>
<td>Processing errors</td>
<td></td>
</tr>
</tbody>
</table>

**Defect cause category**

| Preventing board insertion errors                                      | Processing errors                                                                 |

**Problems**

Whenever a wrong board gets inserted into a slot, it does not get noticed until the final inspection process.

![Diagram showing before and after improvements]
**Theme 8**

<table>
<thead>
<tr>
<th>Defect cause category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preventing pin dimension errors</td>
</tr>
</tbody>
</table>

**Problems**

When a pin is attached during the board assembly process, it must not protrude more than 10 mm. Some that measured more than 10 mm slipped through the inspection process and were passed downstream.

**Before improvement**

After attaching the pin to a board, the operator checked the board to make sure the pin did not protrude more than 10 mm, and then passed the board to the next process.

**After improvement**

To make it easier for operators to check pin lengths, they developed a jig that included a guide pin set into the jig so that the board and pin would not fit if the board’s pin was longer than 10 mm.
### Theme 9

<table>
<thead>
<tr>
<th>Defect cause category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preventing errors in aligning press dies</td>
</tr>
<tr>
<td>Processing error/error in jig preparation</td>
</tr>
</tbody>
</table>

**Problems**

Sometimes the operator inserted the top die upside-down onto the bottom die, which caused defective castings and/or damaged dies.

**Before improvement**

The two guide pins for the two halves of the die were of equal size, which enabled the top half of the die to be placed correctly or upside-down onto the bottom half. When placed upside-down, it resulted in defective castings and/or damaged dies.

**After improvement**

The die was redesigned to have guide pins in different sizes making it impossible to place the top half of the die upside-down onto the bottom half.

[Diagram of top half of die with guide pins and bottom half of die with guide pins]
**Theme 10**

<table>
<thead>
<tr>
<th>Defect cause category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preventing variations in hose cut lengths</td>
</tr>
</tbody>
</table>

**Problems**

Under current conditions, operator was unable to stretch hose out straight to measure length prior to cutting. This resulted in some variation in hose cut lengths.

<table>
<thead>
<tr>
<th>Before improvement</th>
<th>After improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>The operator clamped down one end of the hose and wound the hose around three guide pegs before cutting it using the fixed-position cutter. However, the hose could rest at various points along the guide pegs, which caused some variation in the hose cut length.</td>
<td>The guide pegs were tapered so that, when pulled tight, the hose would always slip down to the bottom of the pegs. This ensured uniform hose cut lengths.</td>
</tr>
</tbody>
</table>

![Diagram of hose cutting process](image)

Hose clamp → Hose → Guide pegs → Cutter → Hose → Improved guide peg

Pulling hose tight causes hose to slip to bottom of guide peg.
Theme 11

<table>
<thead>
<tr>
<th>Preventing bridge defects</th>
<th>Processing error</th>
</tr>
</thead>
</table>

**Problems**

The soldering process on a motor safety mechanism involved many soldering points and little space between the points. It was difficult for newer operators to avoid making bridge defects.

**Before improvement**

As can be seen in the drawing below, the motor safety mechanism has five soldering points, which are all close together. Newer operators and operators who made careless mistakes produced solder bridges between some points, resulting in defective products.

**After improvement**

The insulator was improved by adding dividers between each pair of soldering points to prevent solder bridges from forming. This reduced solder bridge defects to zero.

**Example of bridge defect**

**Dividers between soldering points on insulator**
### Theme 12

<table>
<thead>
<tr>
<th><strong>Defect cause category</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Preventing insufficient torque when tightening bolts</td>
</tr>
<tr>
<td>Processing error</td>
</tr>
</tbody>
</table>

#### Problems

Sometimes, operators do not notice when the pneumatic drill’s gauge shows abnormally low air pressure, which results in insufficient torque on the bolts.

<table>
<thead>
<tr>
<th>Before improvement</th>
<th>After improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>The conveyor kept operating even when the pneumatic drill’s air pressure was low, which resulted in insufficient torque on the bolts.</td>
<td>When the pneumatic drill’s air pressure drops to 5 kg/cm² or less, an alarm lamp starts blinking, a bell rings, and the conveyor automatically stops.</td>
</tr>
</tbody>
</table>

---

**Bolt tightening process**
Theme 13

<table>
<thead>
<tr>
<th>Preventing drilling defects</th>
<th>Processing error</th>
</tr>
</thead>
</table>

Problems

Drill is sometimes withdrawn from workpiece before completely drilling a hole, causing a defective hole that creates problems in the assembly process.

<table>
<thead>
<tr>
<th>Before improvement</th>
<th>After improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>The drill is able to drill holes completely, but sometimes it is withdrawn too soon, leaving an incomplete (defective) hole. It was left up to the operator to determine by “instinct” whether or not the hole was drilled completely. This led to oversights and problems at the assembly line.</td>
<td>Two limit switches were installed on the drilling machine. Limit Switch 1 is activated whenever the drill is lowered and is deactivated when the drill is fully raised. Limit Switch 2 is activated when the drill is lowered completely. If Limit Switch 1 gets deactivated before Limit Switch 2 is activated, a buzzer sounds to alert the operator that the hole was not drilled completely.</td>
</tr>
</tbody>
</table>

![Diagram of drilling machine with limit switches and buzzer](image)
Theme 14

<table>
<thead>
<tr>
<th>Preventing incorrect drill position during drilling process</th>
<th>Error in setting up workpiece</th>
</tr>
</thead>
</table>

Problems

During the drilling process, the operator occasionally sets up the workpiece in an upside-down position and then drills holes in it. The holes end up in the wrong places, and this defect is generally not noticed until the assembly line.

Before improvement

When setting up the workpiece, the operator is supposed to set the grooved section of the workpiece against the jig, then drill two holes in the workpiece.

Newer operators sometimes insert the workpiece upside-down, which causes the holes to be drilled in the wrong places. Even veteran operators make this mistake occasionally out of carelessness.

After improvement

A limit switch was installed in the jig to detect the presence of an upside-down workpiece alongside the jig. If the workpiece is set correctly, the limit switch fits into the workpiece groove and is not activated. If set upside-down, the limit switch is activated and the machine is unable to operate. This effectively reduced drilling position defects at this process to zero.

Correct workpiece position

Incorrect workpiece position
### Theme 15

<table>
<thead>
<tr>
<th>Defect cause category</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Preventing defects due to error in setting up product</td>
<td>Error in setting up workpiece</td>
</tr>
</tbody>
</table>

**Problems**

When pressing the product, if the die is not set just right, the press turns out a defective product.

<table>
<thead>
<tr>
<th>Before improvement</th>
<th>After improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>The operator set the product in the die, checked its position, then pressed it. Sometimes, however, the position was not exactly right and the resulting product was defective.</td>
<td>A limit switch was installed that does not allow the press to operate unless the product is set exactly right. This improvement reduced press defects at this process to zero.</td>
</tr>
</tbody>
</table>

![Diagram of press and product set-up limit switch and ON/OFF circuit](image)
Theme 16

<table>
<thead>
<tr>
<th>Defect cause category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preventing incorrect attachment of bracket</td>
</tr>
</tbody>
</table>

**Problems**

When attaching a bracket to a case, it is easy to get the case reversed since the case is symmetrical on the right and left sides.

**Before improvement**

The correct way to set-up the case is to have the front groove at the bottom. However, operators sometimes set the case upside-down, which causes the bracket to get attached at the wrong place.

**After improvement**

A **poka-yoke** lip was glued onto the jig so that the case cannot sit flat on the jig unless its front groove is on the bottom. This reduced bracket attachment defects to zero.

**Nondefective item**

![Nondefective item](image1)

**Defective item**

![Defective item](image2)

**Nondefective item**

![Nondefective item](image3)

**Defective case set-up**

![Defective case set-up](image4)
**Theme 17**

<table>
<thead>
<tr>
<th>Defect cause category</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Preventing processing errors due to workpiece set in wrong direction</td>
<td>Error in setting up workpiece</td>
</tr>
</tbody>
</table>

**Problems**

Workpiece is sometimes set in reverse and then is bent, which causes problems in the assembly line and has led to delayed shipments.

<table>
<thead>
<tr>
<th>Before improvement</th>
<th>After improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>The operator was supposed to check the direction of the workpiece before setting it in the jig. Occasionally, the operator mistakenly inserted the workpiece in reverse.</td>
<td>Two <em>poko-yoke</em> guide pins were set in the jig to match the holes in the workpiece. This prevents the workpiece from being set in the jig in reverse and consequently reduced the corresponding defect to zero.</td>
</tr>
</tbody>
</table>

**Nondefective item**

![Diagram of nondefective item]

*Poka-yoke* guide pins prevent reverse placement of workpiece

**Defective item**

![Diagram of defective item]
**Theme 18**

<table>
<thead>
<tr>
<th>Defect cause category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preventing incorrect positioning of workpiece prior to drilling</td>
</tr>
<tr>
<td>Error in setting up workpiece</td>
</tr>
</tbody>
</table>

**Problems**

Since the workpiece does not have a distinctive shape, it is easy to set it on the drill jig upside-down or in reverse. Either of these errors causes drilling defects that are generally not discovered until the assembly process.

**Before improvement**

When the workpiece is set in reverse, the drill holes go in the wrong places and result in a defective product. Usually, this is not noticed until the assembly process, which causes problems for delivery and upsets customers.

**After improvement**

Instead of relying on the operators to carefully check the workpiece position, a *poka-yoke* jig was created. This jig does not allow the workpiece to be set in any position except the correct one.

**Nondefective item**

- Drill hole

**Defective item**

- **Upside-down**
- **Reverse**
**Theme 19**

<table>
<thead>
<tr>
<th>Defect cause category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preventing tap processing errors</td>
</tr>
</tbody>
</table>

**Problems**

If the workpiece is not set just right in the jig at the tapping process, the tap will process the wrong part of the workpiece, resulting in a defective product.

**Before improvement**

Sometimes the workpiece was not set flat on the jig (as shown in the drawing below). If the operator makes this mistake and taps the workpiece, the product will be defective.

**After improvement**

A new jig with a *poka-yoke* side plate was developed to prevent the operator from inadvertently setting the back edge of the workpiece on the back of the jig. This new jig achieved two improvement points:

1. It raised the back guide edge for the workpiece.
2. It also provides a guide edge in the middle for the workpiece.

---

**Normal set-up**

![Diagram of normal set-up](image)

**Abnormal set-up**

![Diagram of abnormal set-up](image)
**Theme 20**

<table>
<thead>
<tr>
<th>Before improvement</th>
<th>After improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preventing omission of inserted part</td>
<td>Missing item</td>
</tr>
<tr>
<td>An insert part must be attached to the workpiece prior to diecasting. However, this part is often omitted. To prevent this, a special inspection process was added so that each workpiece can be inspected. Even so, complaints regarding missing insert parts have been received from customers.</td>
<td></td>
</tr>
<tr>
<td>A special inspection process was added so that each workpiece can be inspected to confirm placement of the insert part. Check marks were made on workpieces with insert parts, but sometimes the marks were made on workpieces that actually did not have an insert part.</td>
<td>A sensor was installed at the deburring process that follows the diecasting process. This sensor detects the presence or absence of the insert part. If the part is not there, the sensor prevents the press from operating.</td>
</tr>
</tbody>
</table>

![Insert part](image1)

![Exterior view of workpiece](image2)

![Press](image3)

![ON/OFF circuit](image4)

![Cutaway view of workpiece](image5)
Theme 21

<table>
<thead>
<tr>
<th>Defect cause category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preventing omission of nameplate</td>
</tr>
<tr>
<td>Missing item</td>
</tr>
</tbody>
</table>

Problems

When operators are distracted or stop for breaks, they tend to forget to glue on the nameplate.

Before improvement

When the problem of missing nameplates was discovered, operators were admonished to be more careful about remembering to glue them on. However, the problem persisted.

After improvement

A photoelectric switch was installed to detect whether or not the nameplate has been attached. If not attached, the switch activates a lamp and buzzer to alert the operator. This device effectively prevented the operators from forgetting to attach nameplates.
**Theme 22**

<table>
<thead>
<tr>
<th>Defect cause category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preventing omission of brush</td>
</tr>
</tbody>
</table>

**Problems**

Two brushes are supposed to be attached to a mouthpiece unit, but sometimes operators fail to attach one of them.

**Before improvement**

A separate inspector was assigned to this process to ensure that both brushes are attached to each mouthpiece unit. In addition, the piles of mouthpieces with and without brushes were moved farther apart to avoid mix-ups.

**After improvement**

Two improvements were made to prevent omission of either of the brushes.

1) An automatic brush assembling machine was developed.

   ![Diagram of automatic brush assembling machine]

   The machine will not operate if a brush is omitted. A sensor detects when a brush is missing and automatically informs the operators.

2) *Poka-yoke* device

   When the mouthpiece/brush units are sent via the chute to the box for finished products, the chute has a *poka-yoke* notch in it that will catch mouthpieces that are not raised in the middle by brushes on both sides, as shown in the drawing below.

   ![Diagram of poka-yoke device]

   *Poka-yoke* notch
### Theme 23

<table>
<thead>
<tr>
<th>Defect cause category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preventing omission of items during packing</td>
</tr>
</tbody>
</table>

#### Problems

There are six items to be included in each box at the packing process. Sometimes the packers forget to include all of the items.

<table>
<thead>
<tr>
<th>Before improvement</th>
<th>After improvement</th>
</tr>
</thead>
</table>
| The two packers divide up three tasks:  
  1. Assembling boxes  
  2. Cleaning off items to be packed  
  3. Packing items  
When the inspectors have an extra heavy workload or when the packers are especially busy, boxes with missing items are sometimes shipped to customers. | Photoelectric switches were installed at the top and bottom front edges of the supply boxes containing items to be packed. These switches are activated whenever a packer reaches into a box to pickup an item. If a switch on any of the supply boxes is not activated, the box being packed is blocked by a stopper. If all of the photoelectric switches have been activated, the stopper allows the box to proceed and the box then passes a limit switch which deactivates all the photoelectric switches in preparation for the next round of packing. |

![Diagram of packing process and photoelectric switches](image-url)
### Theme 24

<table>
<thead>
<tr>
<th>Defect cause category</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Preventing omission of E rings</td>
<td>Missing item</td>
</tr>
</tbody>
</table>

#### Problems

Sometimes workers forget to attach E rings and ship the product without them.

#### Before improvement

Workers are supposed to visually confirm that E rings are attached. However, sometimes workers forget both to attach them and to confirm attachment, so products occasionally are shipped without E rings.

#### After improvement

Instead of visually checking for the presence of E rings, a pneumatic device was developed that automatically attaches the E rings and uses a microswitch to confirm their attachment.

### Nondefective item

![Nondefective item diagram](image1)

### Defective item

![Defective item diagram](image2)

---

**Workpiece**

![E ring](image3)

**Pneumatic cylinder**

![Pneumatic cylinder](image4)

**Microswitch**

![Microswitch](image5)
Theme 25

<table>
<thead>
<tr>
<th>Defect cause category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prevention of wrong part assembly</td>
</tr>
</tbody>
</table>

**Problems**

Several model changes are made each day at this factory’s assembly line, and sometimes the assembly workers mix up the various models’ parts and end up assembling the wrong parts.

**Before improvement**

To keep the changeover times between models short, the assembly line workers simply put some of the smaller parts from other models into a parts storage stand. This made it easy for them to pickup the wrong part by mistake.

**After improvement**

A revolving rack was installed in place of the previous parts storage stand. The model-specific parts revolve within the rack, as shown below. On one side of the rack, an indicator panel shows which model’s parts can be set for the drawer. The workers push a button to select which model they want and to open the drawer. This device effectively prevented workers from mixing up the parts.
**Theme 26**

<table>
<thead>
<tr>
<th>Defect cause category</th>
<th>Problems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preventing mixing of nondefective and defective items</td>
<td>The people who inspect integrated circuits (ICs) for specified characteristics sort out the ones that meet the specifications from those that do not. The two boxes that the ICs are sorted into are right next to each other, and the inspectors sometimes put defective ICs into the nondefective IC box and vice-versa. This has resulted in complaints from customers who received defective ICs.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Before improvement</th>
<th>After improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>The inspectors used an IC tester to check the ICs' characteristics and placed the IC into the defective box or the nondefective box depending upon the test results.</td>
<td>As shown in the drawing below, the IC tester was connected to a divider switch mechanism that automatically diverts ICs to the proper box according to the test results. The inspectors need only place the ICs onto the chute. This eliminated errors in sorting ICs.</td>
</tr>
</tbody>
</table>

[Diagram showing the process before and after improvement]
### Theme 27

<table>
<thead>
<tr>
<th>Defect cause category</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Preventing errors in gear assembly</td>
<td>Wrong workpiece</td>
</tr>
</tbody>
</table>

**Problems**

The product’s time switch includes a switch for selecting between two cycle settings, 50 Hz and 60 Hz, each of which connects to one of two adjacent gears. There is a three-teeth difference between these two gears, which is not enough of a difference to make them easily distinguishable by sight. Consequently, sometimes the gears get assembled in the wrong places.

<table>
<thead>
<tr>
<th>Before improvement</th>
<th>After improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>The assembly workers had to assemble the two slightly different gears right next to each other, and it was easy to get them mixed up and put them in the wrong place.</td>
<td>The gear posts were improved as shown below. In addition, since the gears are made of plastic, it was decided that the 50 Hz gear would be made of white plastic and the 60 Hz of blue plastic to make it easy to tell them apart. These two improvements succeeded in reducing gear assembly errors to zero.</td>
</tr>
</tbody>
</table>

- The 50 Hz gear will not fit onto the 60 Hz gear’s post.
- The 60 Hz gear will not fit onto the 50 Hz gear’s post.
**Theme 28**

<table>
<thead>
<tr>
<th>Defect cause category</th>
<th>Preventing errors in attachment of left and right</th>
</tr>
</thead>
</table>

**Problems**

At the process where workers attach drawer rails, the rail jig sometimes slips between attaching one rail and the next, resulting in a mismatch of rails on the right and left sideboards. Other problems result when a worker forgets to turn the jig over backwards to do the other sideboard’s rails.

**Before improvement**

Workers used the same jig to attach drawer rails on both the left and right sideboards.

If the jig is shifted at all between rail settings or if the worker forgets to turn the jig over, for the other sideboard’s rails, the rails do not match on the right and left sideboards and the drawer cabinet cannot be assembled.

**After improvement**

The jig for attaching rails was set in a frame so that it could not slip between rail settings and had to be turned over backwards to attach the other sideboard’s rails. (See drawing below.)

This new jig eliminated all rail attachment errors.

**Nondefective and defective items**

![Diagram showing nondefective and defective items](image)

Left sideboard

If the rail positions do not match, the drawer cabinet cannot be assembled.

Right sideboard

Jig for attaching rails

Jig flips over like a page in a book

Drawer rails

Jig for attaching rails

Left sideboard

Work table

Right sideboard
How to Use *Poka-Yoke* and Zero Defects Checklists

We have seen many ways in which *poka-yoke* and zero defects devices can be developed to solve particular problems.

In terms of human resources, we need to maintain a program of continual education and training. As for equipment and operations, we need to review the various jigs, tools, equipment layout, and operation methods to see how the *poka-yoke* concept can be applied to eliminate defects caused by human error.

The *poka-yoke* approach to zero defects leads to profound improvements. If someone is a knowledgeable and experienced industrial engineer or quality control engineer, we would expect him or her to devise various ways to make defect-reducing improvements. However, we can also seek and expect fresh ideas from *kaizen* team members and newer factory floor workers, as well as the “old hands.”

In a company-wide quality assurance program, the central wellspring for improvement ideas should be the rank-and-file workers. Factories cannot always count on the “professionals” to produce strokes of genius. Instead, everyone must pull together, and when they can do that, they will need powerful tools for improvement that everyone can use.

One such tool is the JIT checklist for *poka-yoke* and zero defects. In Japan, we use the nickname “*poka-zero*” for this sheet. (See Figure 12.24.)

Workers will need a little instruction in order to use the *poka-yoke/zero-detect* checklists correctly. Below is a step-by-step description of the checklist.

**Division, Department, Process, Model**

First, enter the company division, department, and the name of the process where the item in question is being checked.
### Poka-Yoke/Zero Defects Checklist

<table>
<thead>
<tr>
<th>#</th>
<th>Operation (machine)</th>
<th>Operation</th>
<th>Standard Inspect</th>
<th>Defect description</th>
<th>Defect cause</th>
<th>Defect cause</th>
<th>3-point evaluation</th>
<th>3-point response</th>
<th>Description of response (evaluation)</th>
<th>Deadline</th>
<th>Person in charge</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Remove workpiece</td>
<td>Manual operation</td>
<td>None</td>
<td>Damaged</td>
<td>Workpieces rubbed</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>8</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>S101 lifter</td>
<td>Manual operation</td>
<td>None</td>
<td>Dented</td>
<td>Workpieces collided</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>S101 small groove process</td>
<td>Manual operation</td>
<td>2 × 600</td>
<td>None</td>
<td>Defective groove width</td>
<td>8</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>8</td>
<td>Use limit switch to check length</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bent groove</td>
<td>Wrong jig</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Store workpiece</td>
<td>Manual operation</td>
<td>None</td>
<td>Damaged</td>
<td>Workpieces rubbed</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>8</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dented</td>
<td>Workpieces collided</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 12.24** Poka-Yoke/Zero Defects Checklist.

Under the “model” column, put the machine model, product model, or product name of the item for which the “poka-zero” evaluation is being done.

**Date, Entered by, No.**

The person filling out the check sheet should enter the current date and his or her name. In the “No.” column, put a checklist number or some other number that will help identify and manage the checklists.
If the operation pertains to the same process and the same model, put a serial number for the operation here.

**Operation**

As the evaluator watches the actions of each operator, he or she should vertically fill in the name of the operations in the order in which they are performed. In the next four columns to the right, fill in the operation method, description of defects, and cause of defects for each operation listed vertically.

**Operation Method**

This is where to fill in the basic method of operation. Generally, we divide the operation into human work and machine work by using one of the following two descriptions:

- Manual operation
- Mechanical operation

If the operation is mechanical, write down the specific name of the machine, such as “lathe” or “drilling machine.”

**Standards**

Write down any standard values given in the specifications, drawings, or quality control manual. If there are no clearly specified standards, enter “None.”

**Inspection**

Note whether an inspection was conducted following the operation in question. If one was conducted, describe the inspection method.

- **None**: No inspection.
- **All**: The inspector inspected every workpiece from the operation.
- **All/auto**: A machine automatically inspected every workpiece from the operation.
- **Sample**: Indicates sampling inspection.

**Description of Defect**

Give a short description of the type of defect, such as “wrong part” or “wrong hole position.”

**Cause of Defect**

Write down the main cause of the defect just described. For example, if the defect was described as “wrong part,” you might write “error in use of similar parts.” If it was “wrong hole position,” you might put “workpiece set-up backwards.”

**Three-Point Evaluation**

The checklist includes a three-point evaluation for “scoring” how often the defect in question occurs and how big an impact it has on other processes and on the company.

- **Frequency of occurrence**: Score from one to three points as shown below.
  - one point       Does not occur at all
  - two points      Sometimes
  - three points    Often
- **Impact on processes**: Score the degree of impact the defect has on other processes.
  - one point       No impact
  - two points      Some impact, but can be reversed by making repairs
  - three points    Wreaks havoc on other processes, especially downstream ones
- **Impact on company**: Indicate what impact the defect might have on the company if shipped to customers.
  - one point: No impact
  - two points: Might draw customer complaints, but can be quickly taken care of through after-sales service
  - three points: Can cause major problems for the company. It might take a lot of time and money to restore the company’s image to its former level.

- **Total points**: Multiply the points scored in each of the previous three categories

  \[
  \text{Total points} = \text{Frequency} \times \text{impact on processes} \times \text{impact on company}
  \]

  If the total points range between four and nine, the defect should be treated with *poka-yoke* /zero defects countermeasures. If the total points range between 12 and 27, the defect should be treated *immediately* and urgently with *poka-yoke* /zero defects countermeasures.

**Three-Point Response**

Here, we score the estimated degree of urgency and difficulty involved in responding to the defect.

- **Urgency**: Analyze the response measures and estimate how urgently they are needed.
  - one point: Not urgent at all
  - two points: Need to minimize the defect’s impact, but it is not urgent
  - three points: Must act immediately to prevent this defect from recurring

- **Difficulty**: Analyze the response measures and estimate their degree of difficulty.
one point: Can easily prevent defect’s recurrence by modifying jig or stand.

two points: Can prevent defect’s recurrence by developing and installing a *poka-yoke* device or zero-defects device within the process.

three points: It will either be difficult to respond within the process to prevent the defect’s recurrence, or it will require a lot of equipment investment.

- **Countermeasure:** Describe which level the *poka-yoke* or zero-defects countermeasure will address.

  three points: If countermeasure requires setting up a separate inspection process to sort out defective goods.

  The more fundamental the level the *poka-yoke* or zero-defects countermeasure will address, the higher the score should be among points one, two, and three.

- **Total points:** Use the following formula to compute the total for the three previous items.

\[
\text{Total points} = \text{Urgency} \times \text{difficulty} \times \text{countermeasure method}
\]

If the total points range between four and nine, the countermeasure will be relatively easy to carry out. If the total points range between 12 and 27, the defect-eliminating countermeasure will be quite difficult. It will require the cooperation of everyone in devising specific countermeasures.

**Description of Response (Evaluation)**

Write a detailed description of the countermeasure proposal and include whatever *poka-yoke* devices it includes. Add any evaluation remarks you might have.
Deadline and Person in Charge

Be sure to set a deadline for the countermeasure’s implementation and enter the name of the person in charge of the countermeasure. This will help keep track of progress in poka-yoke/zero-detects projects.

After completing this checklist, send reports to all departments concerned regarding items deemed especially urgent or important. Enlist their cooperation and investigative expertise in devising successful poka-yoke/zero defects measures.

Begin using the poka-zero checklist at major processes in the factory, then broaden its application to all processes. Ultimately, each factory should encourage its affiliated factories, such as its suppliers and subcontractors, to do the same.

This section has described just one example of how poka-yoke/zero defects checklists are used. Do not hesitate to revise this checklist to suit the needs of your own factory and its various processes.
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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
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niques for the complete elimination of waste,” Mr. Hirano went on to
help bring the JIT Production Revolution to dozens of companies, includ-
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automobile manufacturer and a Korean consumer electronics company.

The author’s many publications in Japanese include: Seeing Is Under-
standing: Just-In-Time Production (Me de mite wakaru jasuto in taimu
seisanb hoshiki), Encyclopedia of Factory Rationalization (Kojo o gorika
suru jiten), 5S Comics (Manga 5S), Graffiti Guide to the JIT Factory Revo-
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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: