# FROM DUPONT: A STEP-BY-STEP GUIDE TO CONTINUOUS IMPROVEMENT

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## EDITOR'S NOTE

*In the 1980s, DuPont Connector Systems Division, like many businesses, felt pressure from its customers to improve quality. Their first effort to comply fell somewhat short of the objectives. Although goals were established and training took place, the desired level of improvement did not materialize. An evaluation revealed that there was a failure to recognize the importance of a structured program. This paper details the development of that formal approach developed by the Connector Systems Division. Also explained are various tools used for the effort. The paper should provide valuable insights for those involved in continuous improvement.*

Like most companies within the electronics industry, the Connector Systems Division of the DuPont Company experienced a significant resurgence in the importance of quality in the early 1980s. Most of our customers, companies such as IBM, AT&T, Hewlett Packard, Xerox, Motorola, began inquiring about our quality systems and approaches and stressed the need for all suppliers to significantly improve the quality levels of their products. Traditional defect levels, measured in percent defective, were no longer adequate; parts per million became the basis for new standards.

To ensure that we could continue to meet our customers' quality expectations and maintain a quality leadership position, Connector Systems formally adopted a philosophy that stressed the need to continuously improve the quality of all of our products and services.

We followed the classic approach. Management not only endorsed, but led, our efforts to implement continuous improvement. Goals such as 10x improvement, total customer satisfaction, total quality management, etc. were stated and the entire organization was energized around the effort. Consultants were called upon to conduct widespread training on statistical and problem-solving techniques at significant expense. Having displayed our commitment and involvement, we then waited to reap the rewards of our significant efforts.

The envisioned widespread rapid improvement never materialized. The excitement and enthusiasm associated with the kickoff of the program was short lived and many employees tended to view the effort as one more "program of the month" that had gone astray. Management walked away confused and we began questioning the value of quality improvement as a legitimate strategic approach to improving our competitiveness. While progress was made, we were clearly not realizing the needed rate of improvement and the benefits expected, given the priority and effort expended. We asked ourselves "why" and began examining our overall approach. Something was obviously missing.

We found three critical components of continuous quality improvement that had to be addressed: customer focus, employee empowerment/involvement, and a structured approach to implementation (Figure 1). We discovered that all three were essential for developing and sustaining a continuous improvement culture and realizing step change improvements. While we recognized the need to be customer focused and empower all our employees, we overlooked the need for a structured approach to continuous improvement. Being customer focused and developing a participative environment were not sufficient. If employees do not understand how to apply the newly acquired problem-solving and quality-improvement skills, they are likely to become frustrated quickly, resulting in little actual improvement.

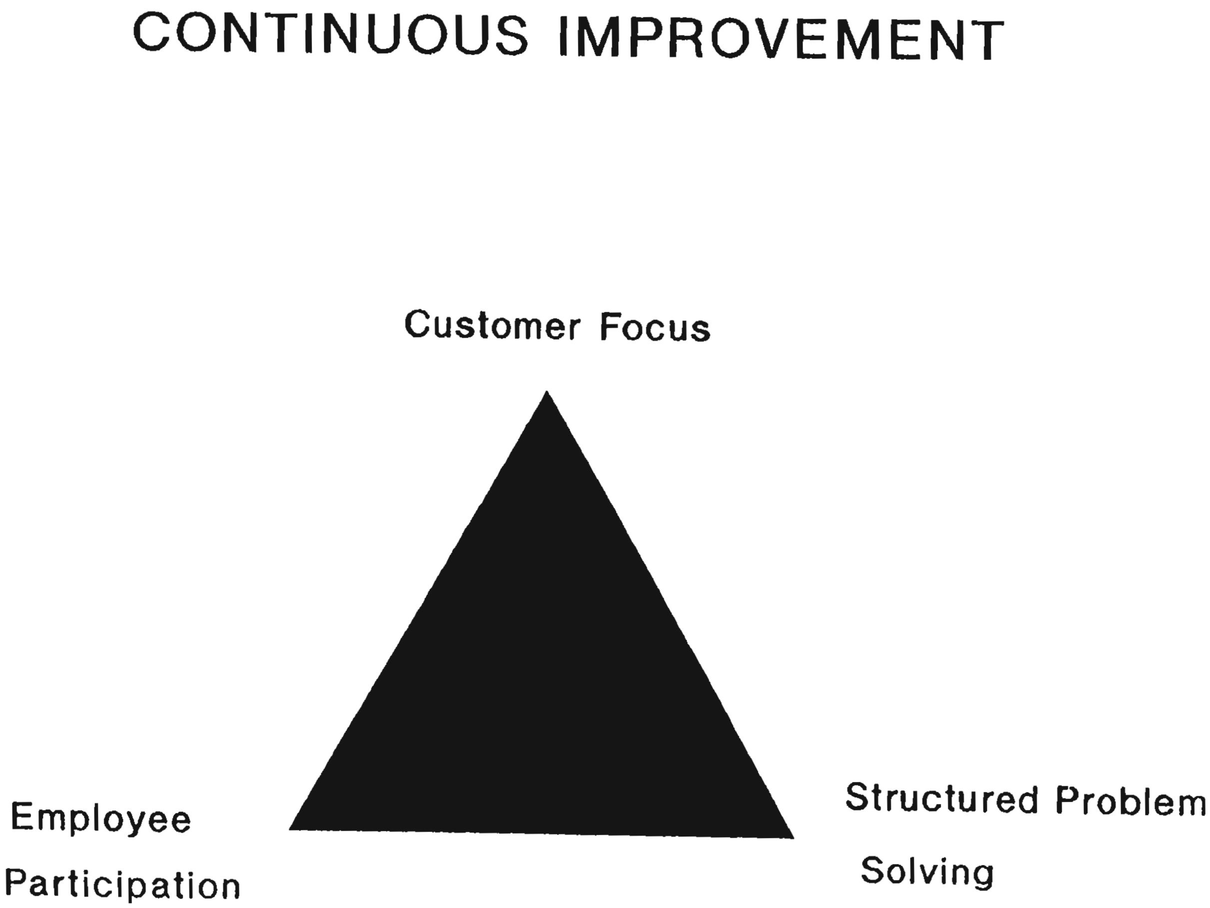


*Figure 1. Diagram illustrating continuous quality improvement concept.*

We failed to recognize that quality improvement was a process, not a program or set of skills. While people were taught techniques and skills, they were not taught how to apply those skills. To overcome this, a step-by-step approach to continuous improvement, the quality improvement process, was developed (Figure 2).

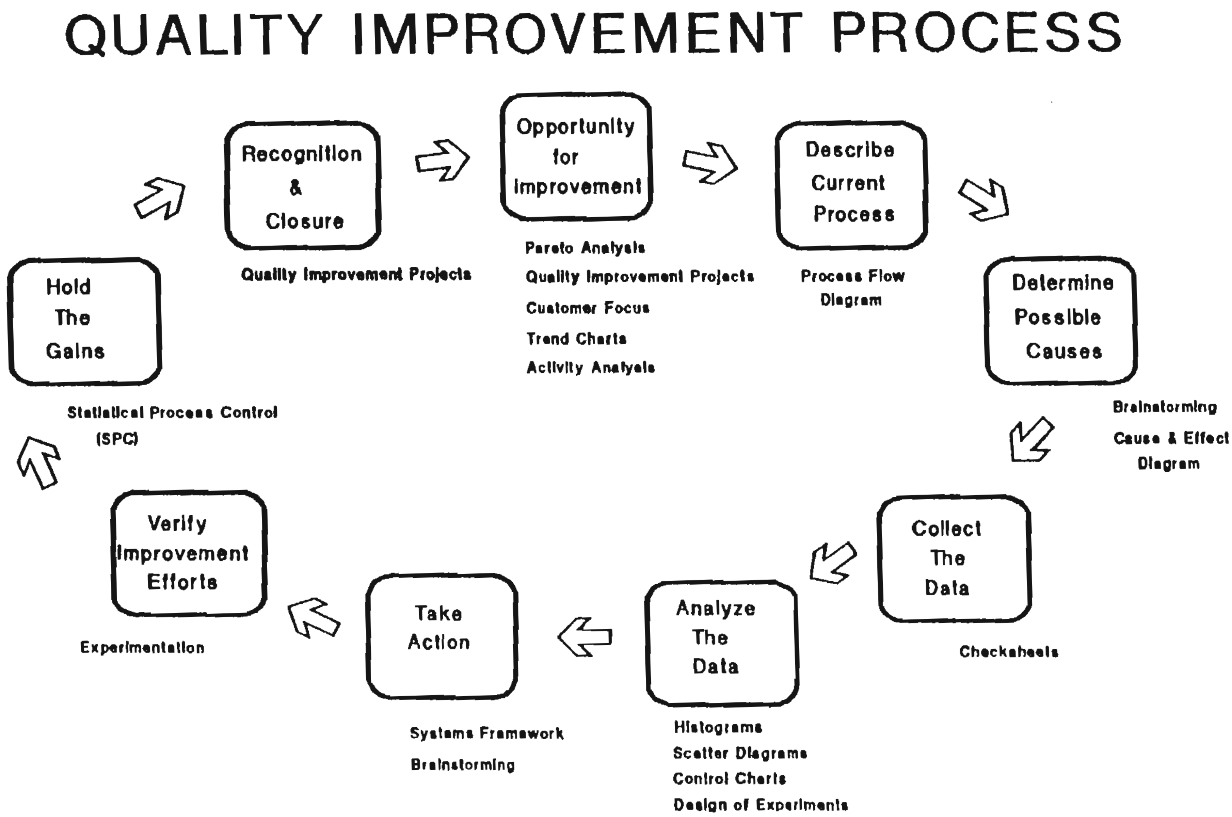


*Figure 2. Diagram showing step-by-step process leading to quality improvement.*

The blocks, beginning with Opportunity for Improvement, illustrate the steps included in the structured approach. The problem-solving and statistical technique most properly applied for each step is listed under the appropriate block. Notice that the process is continuous. That is, once one improvement has been made and verified, the flow is back to the beginning to identify the next opportunity for improvement; the process starts all over again. Each step and the applicable technique will be discussed in more detail in the following sections.

## IDENTIFYING AN OPPORTUNITY FOR IMPROVEMENT

The quality improvement process begins by identifying an opportunity for improvement. This is typically the easiest step, since there are many techniques and systems available for uncovering areas and processes that can be improved. The following are a few specific methods utilized by DuPont's Clearfield site.

## Customer Focus

All activities within and between organizations can and should be viewed as customer/supplier relationships (Figure 3). The output of an activity should be viewed as a product or service. The users or recipients should be viewed as customers. Likewise, those people who provide products and services used in performing your task should be viewed as suppliers.

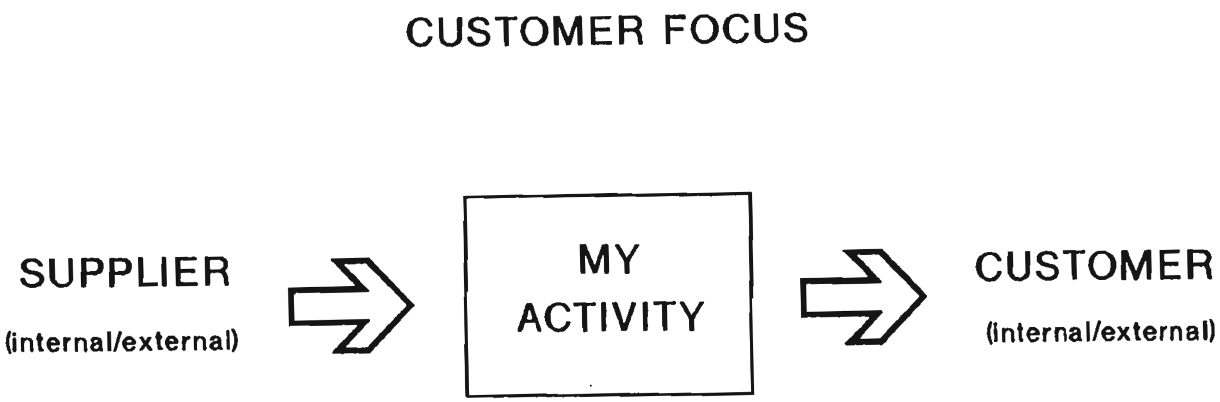


*Figure 3. Customer/supplier relationship.*

We tried to develop a culture where everyone throughout the entire organization, regardless of role or function, viewed their activities in this light and continually asked the following questions to identify opportunities for improvement:

* Who are my internal/external suppliers/customers?

* What do I need from them?

* What do they need from me?

* How can I better satisfy my customers?

* How can I better define my needs for my suppliers?

## Activity Analysis

Often it is not clear who the customers and suppliers are for a given activity. This is especially true in very functionally aligned organizations. Many times employees do not have a view of the bigger picture, not understanding what happens with a component they have produced once it is moved from their area. To aid employees we utilized a framework called an activity analysis (Figure 4), a formal method to help everyone identify their customers and suppliers.

## ACTIVITY ANALYSIS

| | |
|---|---|
| ACTIVITY: | |
| DEPT: | DATE: |
| PREPARED BY: | |

### INPUT

WHAT:

FROM:

### VALUE ADDED
### WORK ACCOMPLISHED IN DEPT

WHY DO:

VALUE ADDED:

IMPACT IF NOT DONE:

### OUTPUT

WHAT :

TO:

***Figure 4.*** *Activity analysis form used to help workers identify their suppliers and customers.*

## Pareto Diagrams

When everyone throughout the organization began viewing each activity in this way and strove to improve ability to satisfy their customers, finding opportunities for improvement was not a problem. Instead, the problem became deciding which opportunities should maximize benefits to customers and the organization. The following technique, Pareto analysis, was used to effectively select the opportunities with the largest impact.

A Pareto diagram is a special form of a vertical bar graph that helps determine which problems to solve in what order. The technique displays, in decreasing order, the relative contribution of each cause to the total problem (Figure 5). The theory is that, by concentrating on the "vital few," you can get the maximum improvement with the least amount of effort.

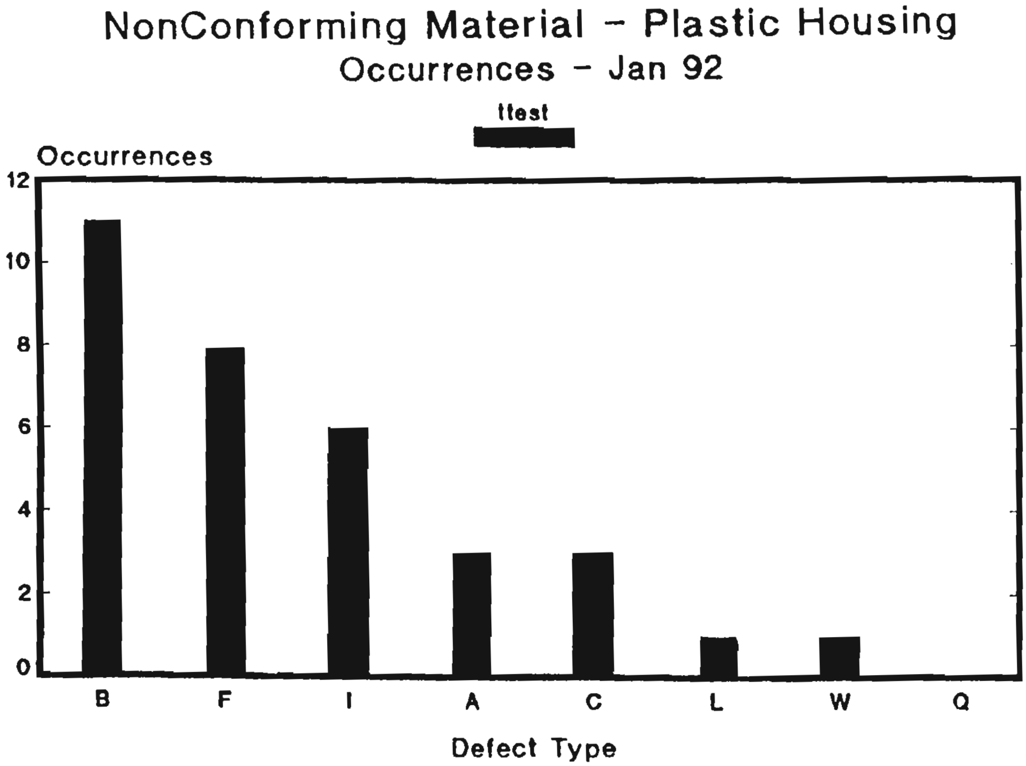


***Figure 5.*** *A Pareto diagram helps determine the priority of problems to solve.*

When using Pareto analysis, use common sense. The most frequent or most costly activities are not always the most important. The most frequent problems are not always the most costly. Remember the goal is to identify and work on the causes of a problem, not the symptoms.

## Trend Charts of Performance Metrics

Most companies recognize the importance of establishing and monitoring key performance metrics. "Management by fact" is a popular phrase to emphasize the importance of making decisions based on data, not on qualitative opinions or feelings. We found that there was a great deal of data being generated. The problem was not finding data, but presenting it in a summary format that facilitated its use. Trend charts proved very useful in understanding current status versus objectives (Figure 6).

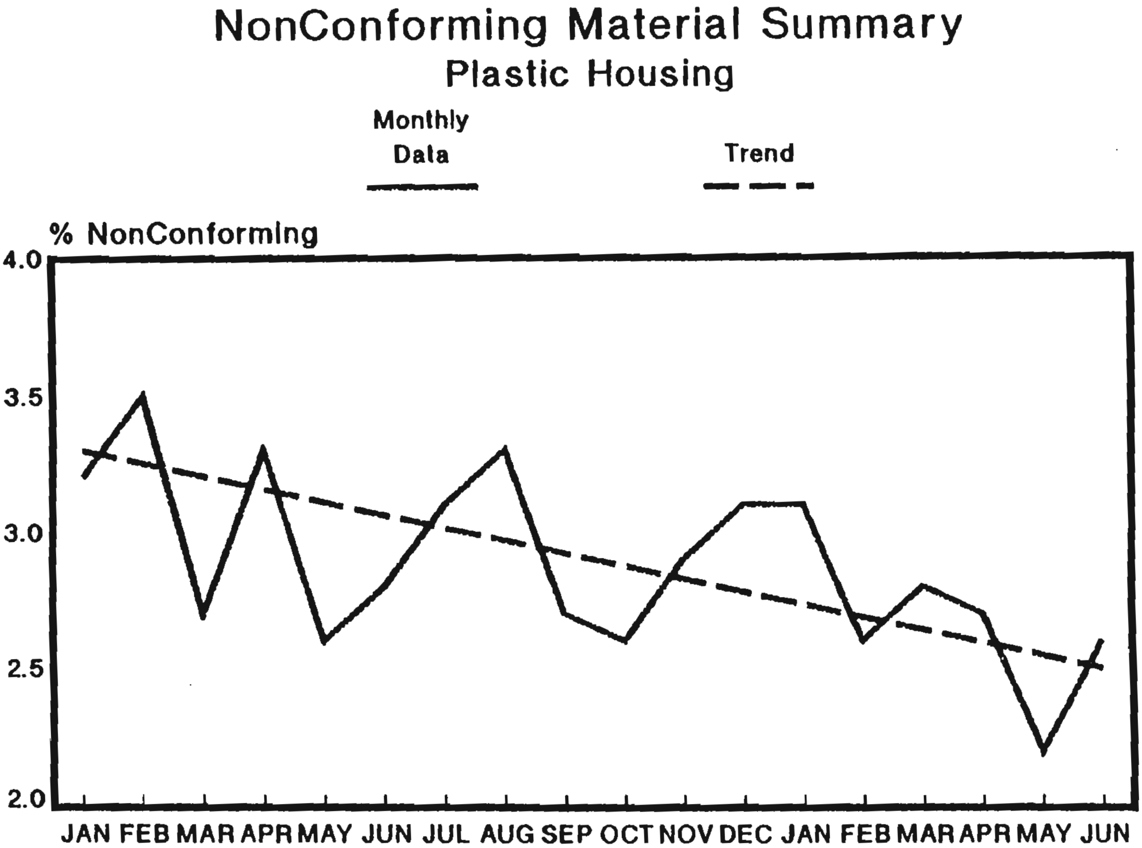


***Figure 6.** Trend charts help measure the degree of improvement against the objectives.*

Use of such charts enabled us to determine if enough progress was being made or the desired step change in performance was adequately realized. When this occurred, a formal quality improvement project was initiated.

## Quality Improvement Projects

Widespread employee participation is critical to any continuous improvement effort. We frequently brought together multifunctional employee teams to address specific issues and opportunities for improvement. To make these teams most effective, we found it essential that they understand what is expected of them, the team mission. In addition, we clearly established how progress would be measured and reported. To formalize this, a quality improvement project status form was developed (Figure 7).

## QUALITY IMPROVEMENT PROJECT STATUS

**Project Mission:** ______________________________

______________________________

______________________________

**Management Sponsor:** ______________________ **Date Initiated:** ______________

**Team Members:** ______________________________

______________________________

______________________________

**Measurement Basis:** ______________________________

| Action Item: | Person Resp. | Date Opened | Date Commit. | % Complete | Date Closed |
|---|---|---|---|---|---|
| | | | | | |

*Figure 7. The quality improvement project status form was developed to fully explain a project's mission and what is expected of team members working on the project, and to track progress.*

The form outlines the specific project with a mission statement, team members, management sponsor, and date initiated. It is key that the mission statement be concise and jointly agreed upon between the management sponsor and team. The overall objective should be clear. The form also defines how progress is to be measured. Frequently, teams set out improving something without considering how to know if they are making a difference. Finally, the form tracks actions, responsibilities, and expected completion dates. The form thus also serves as an effective communication vehicle for the team's activities and contributions.

## DESCRIBING THE CURRENT PROCESS

We stressed that every activity can and should be viewed as a process. Before the activity/process can be improved, members must fully understand it. It is not uncommon to talk with several people performing the same well-documented task and find very different actions or approaches being taken. We found flowcharting to be a useful technique to ensure a common understanding of what was really taking place as well as what was desired.

### Flowcharting

A flowchart is a graphic way to show the steps in a process. The completed diagram (Figure 8) provides an excellent way to document what happens and how the various steps of the process are related to each other.

When creating a flow diagram, it is important to define the boundaries, and not begin with too much detail too early. The focus initially should be on the basic process steps. More detail can be added as needed to increase the team's understanding. The people actually performing the activity typically have the greatest amount of knowledge about the process and should be involved in constructing the diagram. The ideal or documented flow should also be indicated where different on the diagram. Thus insights into possible improvements can be gained.

We did not view the diagram as a one-time activity to be developed at the start of the improvement project. As new knowledge was gained in subsequent steps of the quality improvement process, the diagrams were updated accordingly. The flowcharting process should be dynamic and serve as a common basis for communication throughout the quality improvement process.

## DETERMINING POSSIBLE CAUSES

The next step was to increase our understanding about the controlling factors that influence the condition we're trying to improve. To make a step change improvement, it is important that the most important factors/causes be identified and understood. Treating and focusing on symptoms will not typically result in much improvement. Brainstorming and cause and effect diagrams were widely utilized to help determine the root causes to be addressed.

### Brainstorming

To identify true root causes and develop creative solutions, it was important to expand our thinking to include all dimensions of a problem or solution. Brainstorming was used to help a quality improvement team create as many ideas as possible in the shortest possible time.

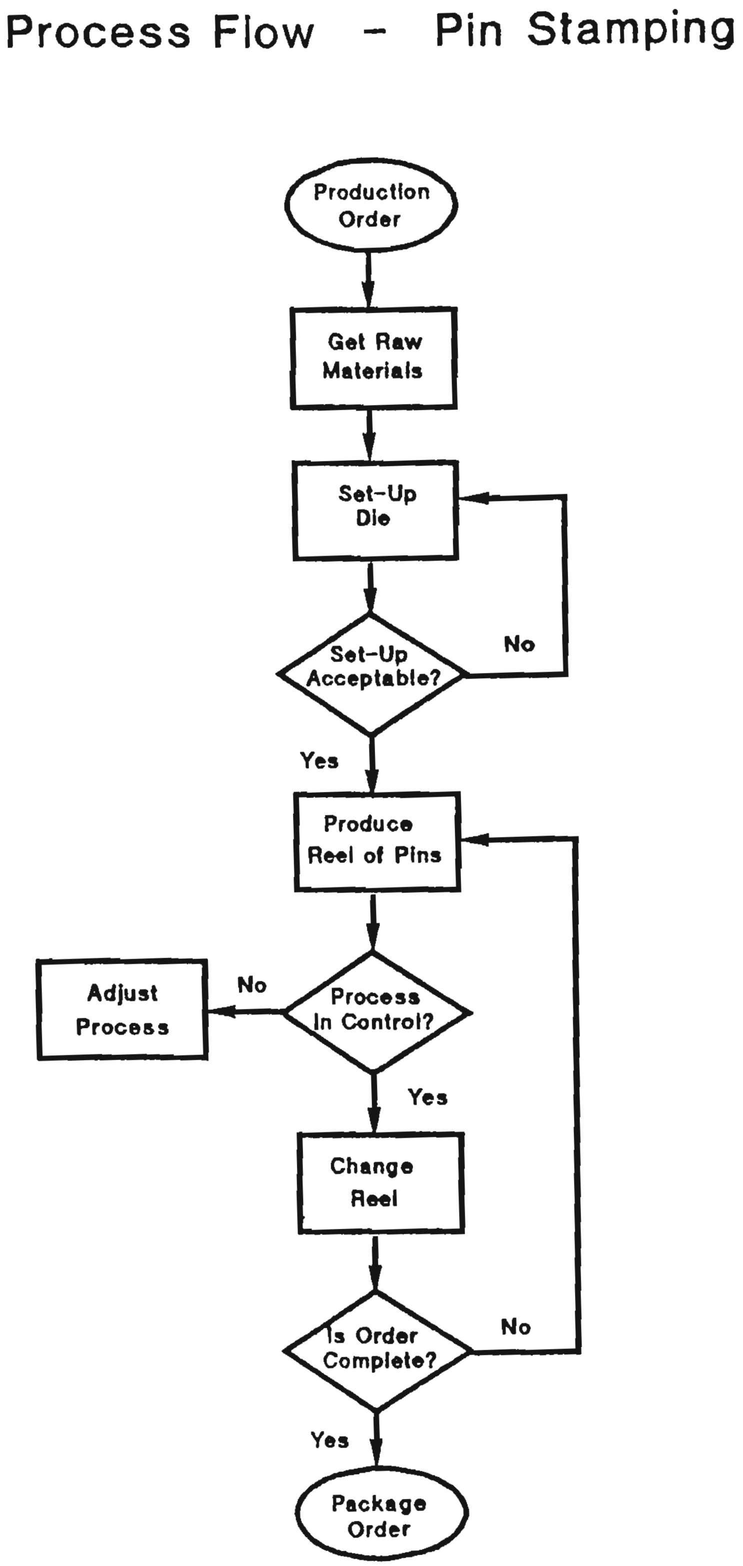


***Figure 8.*** *A flowchart illustrates the steps in a specific process, helping ensure that all participants have a common understanding.*

Brainstorming was used two ways, structured or unstructured. In the structured method, every person in a group must present an idea as his or her turn arises in the rotation, or pass until the next round. This approach has the advantage of ensuring participation from everyone in the group. However, it can also create a certain amount of pressure to contribute. In the unstructured method, team members simply give ideas as they think of them. It creates a more relaxed atmosphere but also risks having the most vocal team members dominate the meeting. For that reason, especially with inexperienced teams, the structured approach is recommended.

The following are brainstorming guidelines that our quality improvement teams found helpful:

* Write down the issue being brainstormed so that everyone will understand.

* Never criticize ideas presented.

* Write down every idea. Having the words visible avoids misunderstandings and may remind others of new ideas or enhancements.

* Record the words of the speaker; don't interpret.

* Do it quickly, 10-15 minutes usually works well.

There are many variations of the basic brainstorming technique. All are workable. We found that the most important thing was not the specific technique, but the ideas generated and the expanded thinking that resulted. The team used any techniques with which they felt comfortable and which accomplished the intended purpose.

## Cause and Effect Diagrams

While brainstorming was effective in generating ideas, the cause and effect diagram (sometimes referred to as a fishbone or Ishikawa diagram) was used to organize and illustrate the relationship between those ideas and some effect that the team was trying to improve. The cause and effect diagram was used in conjunction with brainstorming to systematically analyze the cause and effect relationships and to identify the root causes. Figure 9 is an example of a cause and effect diagram.

The cause grouping most frequently used was labor, equipment, methods, materials, and environment. However, the cause groupings were different for different applications, such as service versus manufacturing, process versus discrete part, etc. A grouping was selected that best served the specific improvement effort.

After completing the initial diagram, the team identified the most likely (major) causes. Each member selected the five causes he or she felt were most influential. Causes were then ranked by the number of votes received. Next, the team verified the impact of the causes on the effect. This required collecting data.

Development of the cause and effect diagram was not viewed as a one-time activity. As data was collected and causes were either verified or eliminated, the diagram was updated. Also, as more was learned about the process in further steps, new causes were uncovered that had to be added to the diagram. Like the flowchart, the cause and effect diagrams were treated as a dynamic document effectively used to facilitate communications and direct the team's future actions.

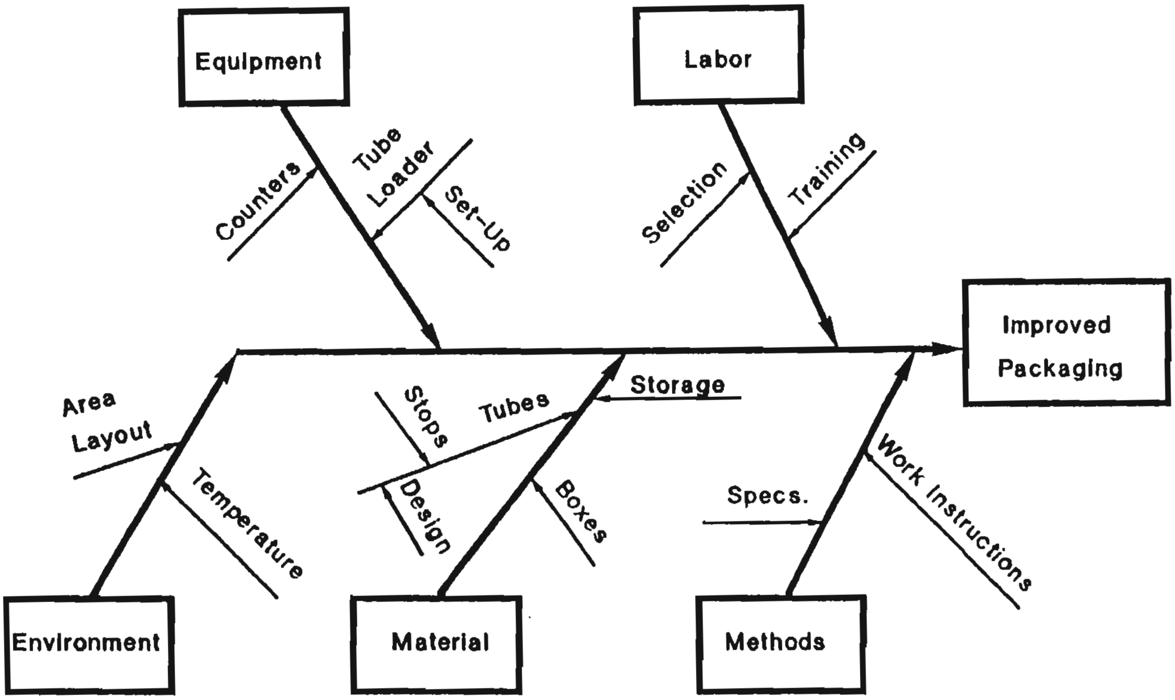


***Figure 9.*** *The cause and effect diagram shows potential causes of problems identified through ideas contributed by team members.*

## COLLECTING DATA

There is no substitute for valid data in solving a problem or making an improvement. "In God I Trust – All Others Bring Data" was the motto that we adopted. Without data, we found ourselves trying to make improvements in a world governed by opinion and speculation. Check sheets were the simple technique utilized to plan and collect the data needed to make intelligent judgments and decisions.

### Check Sheets

Check sheets were used when we needed to gather data to identify patterns. Usually the data was based on observations of how frequently something happened. We found check sheets to be a simple and easy way to organize data collection (Figure 10). Check sheets were widely used to answer the question, "how often does some set of events or conditions happen?" It began the process of turning opinions into facts.

Based on some of the steps taken by our team, here are some tips on making check sheets more effective:

* Design a form that is clear and easy to use, making sure that all columns are labeled and there is enough space to type the data.

* Make provisions for entering comments.

* Make sure observations included are as random as possible.

* Define exactly what event is being observed.

* Look for patterns, not only after the fact, but as the data is being collected.

* Ensure that the sampling process is as efficient as possible so that people have enough time to do it realiably.

Once the data was collected, it needed to be analyzed to quantify the cause/effect relationships. Then the major factors that must be controlled or improved were identified and an improvement plan put in place.

## ANALYZING THE DATA

There are many techniques available for analyzing data. However, our training was focused on just a few of these (histograms, scatter diagrams, control charts, and experimental design). Our experience indicated that the vast majority of problems and improvement efforts could be addressed effectively with these.

Training was provided to all employees with the exception of experimental design. Training on those techniques was limited to engineering personnel (however, all engineering disciplines were trained: design engineering, quality engineering, manufacturing engineering, etc.).

### Histograms

Histograms were used to display the distribution of the data collected (Figure 11). Both the dispersion (amount of variation) and central tendency (a value where the data tends to be clustered around) can typically be seen from the histogram.

Of particular interest when viewing the histogram is to get a sense of the spread of the distribution versus specifications or requirements. Is there one central tendency, does there appear to be multiple peaks indicating data from significantly different sources, etc.? Is the data symmetrical or skewed (more data on one side of the central tendency than the other)? All inferences derived from a simple histogram were used to gain knowledge about the causes and effects and further point to the real root causes/factors needing improvement.

### Scatter Diagrams

Scatter diagrams were used to determine if two variables were related in some fashion. The diagram displays what happens to one variable as the other one changes (Figure 12). The diagrams can be helpful in verifying possible cause and effect relationships while identifying whether a correlation exists and the strength of the correlation. While it cannot prove that one variable actually causes the other, it can provide valuable insight and practical direction.

# DATA COLLECTION SHEET

Machine ID: ____________________

| | | | Defect Type | | | | |
|---|---|---|---|---|---|---|---|
| Date | Shift | Operator | Missing Pins | Damaged Housing | Bent Terminals | Fail True Pos. | Fail Leg Length |
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| | | Total Quantity | | | | | |

***Figure 10.*** *One data-gathering tool was the check sheet, such as the one shown here, used to reveal patterns of how often a specific set of circumstances occurred.*

## Statistical Process Control Charts

Statistical process control (SPC) charts were widely used to monitor and control a process around a target or process aim (Figure 13). However, SPC charts were used just as effectively as a data analysis tool.

When making inferences from any collection of data, it is important to know that the data has been collected under controlled conditions; that is, no unsuspected or unusual change occurred in the process during the data collection time frame. We found control charts to be an effective tool for doing that since their basis is to identify abnormal (assignable) causes that take place in the process. If abnormal causes were indicated, the data was not used to draw inferences about the process until the causes were understood and their effects eliminated from the data.

## Statistical Design of Experiments

Experimentation is defined as a planned course of action to answer a specific question. This is a very natural part of our learning experience. From the beginning of our existence, we learn by trial and error. We try different things and find out what works and what doesn't. That is experimentation.

Statistical design of experiments is the process of planning the experiment so that appropriate data will be collected, which, when analyzed by statistical methods, will result in valid and objective conclusions. Using statistically designed experiments is a way to increase the efficiency and effectiveness of the experimentation process we naturally follow.

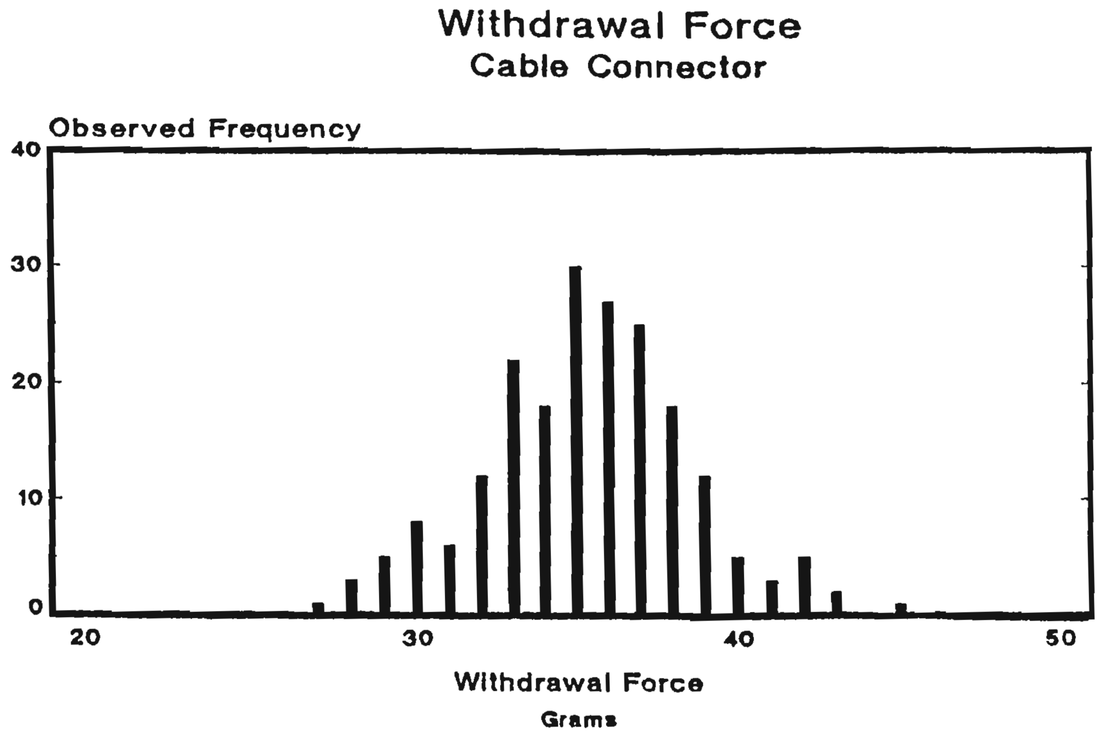


*Figure 11. Histogram displays distribution of data collected.*

While experimental designs can be quite complex, we utilized simple techniques such as hypothesis testing and simple comparative experiments to very effectively evaluate potential cause and effect relationships. A number of easy-to-use statistical software packages are available to eliminate the rigorous number crunching required. Thus we found that these techniques were well within the capability of most employees. However, care should be taken to ensure that users understand the methods' limitations and required assumptions.

The following are key points to keep in mind when using statistical design of experiment techniques:

* Keep the design as simple as possible.

* Take advantage of existing knowledge and experience when designing the specific experiment.

* Take an iterative approach to experimentation. Learn from present experiments to plan the next iteration. Learn as you go.

* Focus on practical differences versus statistical significance. Just because two things turn out to be statistically different doesn't mean that the difference is large enough to be of any practical value.

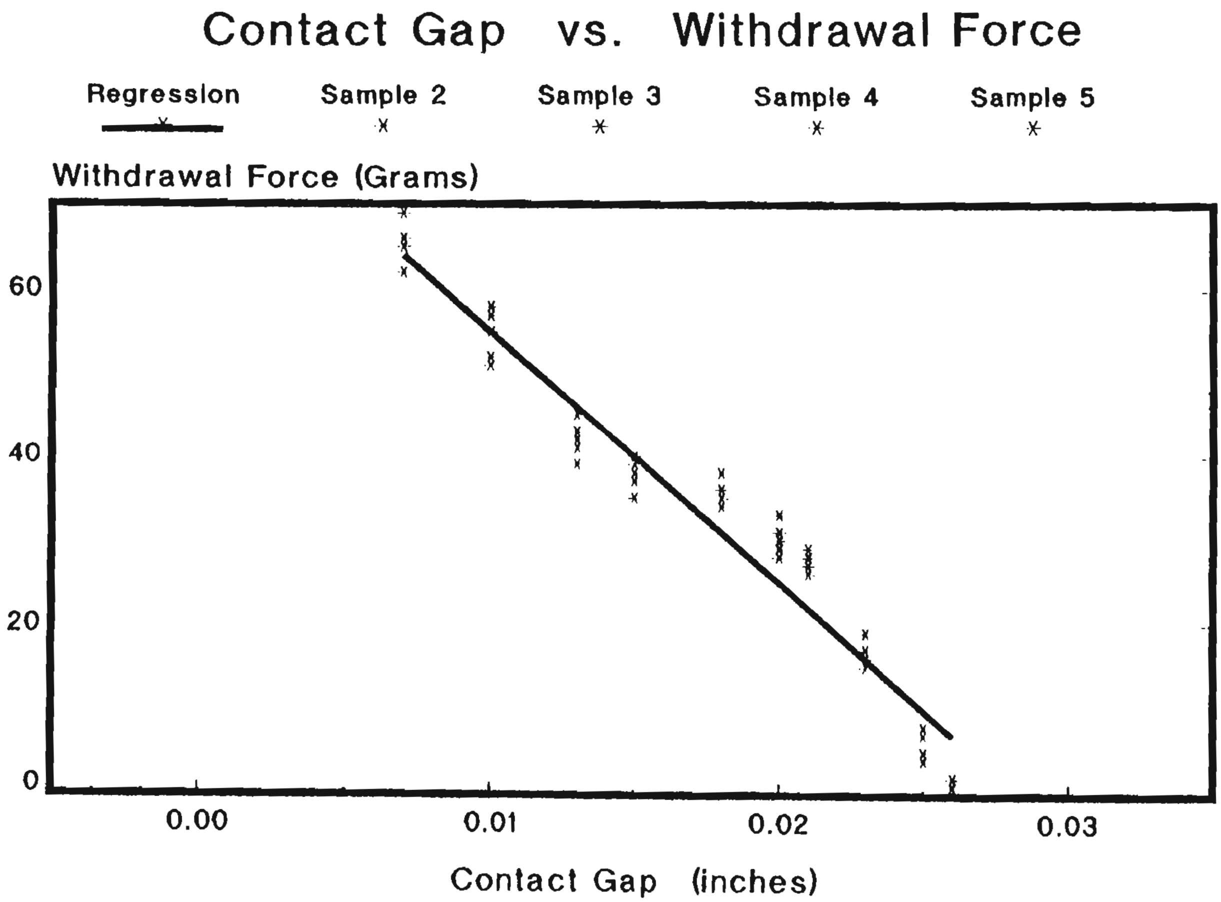


*Figure 12. Scatter diagrams determine if two variables are related in any way.*

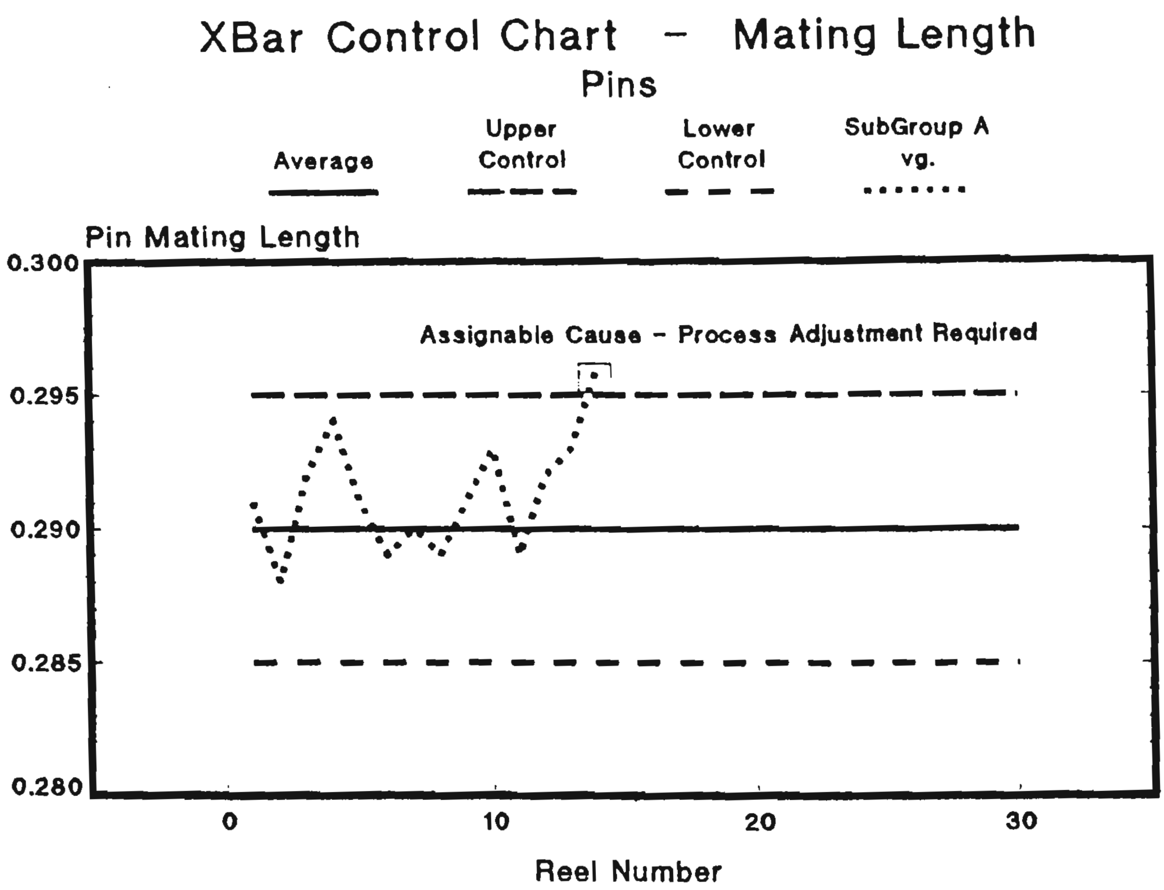


***Figure 13***. *SPC not only monitors and controls a process, but also acts as a data analysis tool.*

## TAKING ACTIONS

Once you understand the process and the cause/effect factors that must be controlled and improved to achieve the quality improvement project objectives, it is time to take specific actions based on that increased understanding. The systems framework was the technique utilized to define and plan specific actions to achieve the desired improvement.

### Systems Framework

The systems framework (Figure 14) is a structured way to plan specific actions needed to improve a process. It begins by viewing and understanding the current state.The flow diagram, cause and effect diagrams, and data summaries will generate this understanding. Next, the team looks at where they want to be, the ideal state (the quality improvement project mission will provide guid-

## The Systems Framework

| Experience | Improvement | Barriers | Benefits |
|---|---|---|---|
| What is our current experience?<br>What is happening now? | What would be Ideal?<br>What needs improved? | What must be put in place to go forward? | What are the benefits in going forward? |
| * Develops understanding of the current state | * Develops understanding of where we want to go<br>* Expands thinking towards something better | * Considers what barriers will hinder progress<br>* Defines what must be put in place to make progress | * Develops understanding of the driving forces |

***Figure 14.*** *The systems framework helps to plan specific actions needed to improve a process.*

ance here). Then the barriers preventing the ideal state are identified and actions are either planned to remove or minimize them, or the ideal state is compromised to consider the barrier. Throughout this process, it is important to keep the mission and benefits in focus.

## VERIFYING IMPROVEMENT EFFORTS

After the planned actions were implemented, their effectiveness was verified. A good rule of thumb to use for verification of actions is: if you cannot turn the effect on and off as you desire, then you likely do not adequately understand the process or the cause/effect relationships governing the intended improvements. It is not enough to make a problem go away; if you do not understand "WHY," it will likely be back again sometime in the future.

There are several techniques we utilized to verify and document the effectiveness of actions taken. Experimentation was the most frequent. Simple comparative experiments were usually sufficient. The desired set of conditions were established and the desired effect verified. Then the original operating conditions were restored to verify that the desired effect was reduced. Finally, the new conditions were reinstated permanently.

### Before-and-After Comparison

The metrics used to identify the opportunity for improvement can also be used to verify the effectiveness of actions taken. For example, if a Pareto analysis was used to identify a significant opportunity, redoing the Pareto chart after implementation of the corrective actions should indicate that the improvement was made. Figure 15 illustrates a before-and-after Pareto chart for a plastic component. Notice that "bow" was the major reason for rejects in the before condition and the chart generated from data after implementation of corrective actions shows that nearly all rejects for bow were eliminated. Similar comparisons can be made with trend charts (Figure 16). Note the step-change improvement that occurred in September.

## HOLDING THE GAINS

After the improvements have been implemented and verified, the quality improvement project was still not viewed as complete. Actions were taken to ensure that changes became permanent and that any future departure from the new improved process state would be recognized and corrected. SPC was highly effective for "holding the gains" applicable to most situations. Key metrics from the process were monitored using SPC techniques. After the improvement, new control limits reflecting the process's expected improved performance were established and used to monitor the process going forward. Should the process drift away from this level, an out-of-control signal would be generated and the process corrected. Figure 17 illustrates the guidelines we established for selecting the most appropriate SPC chart.

We stressed that process changes be documented to ensure that discoveries made during the quality improvement project were not lost with time and that those key learnings were shared throughout the organization. We required all operating instructions and control procedures be updated, and old versions removed from use. Also, when questions arose after the change was implemented, about something being done differently, the answers were readily available. A little effort documenting at the time of the change can help eliminate re-inventing the wheel.

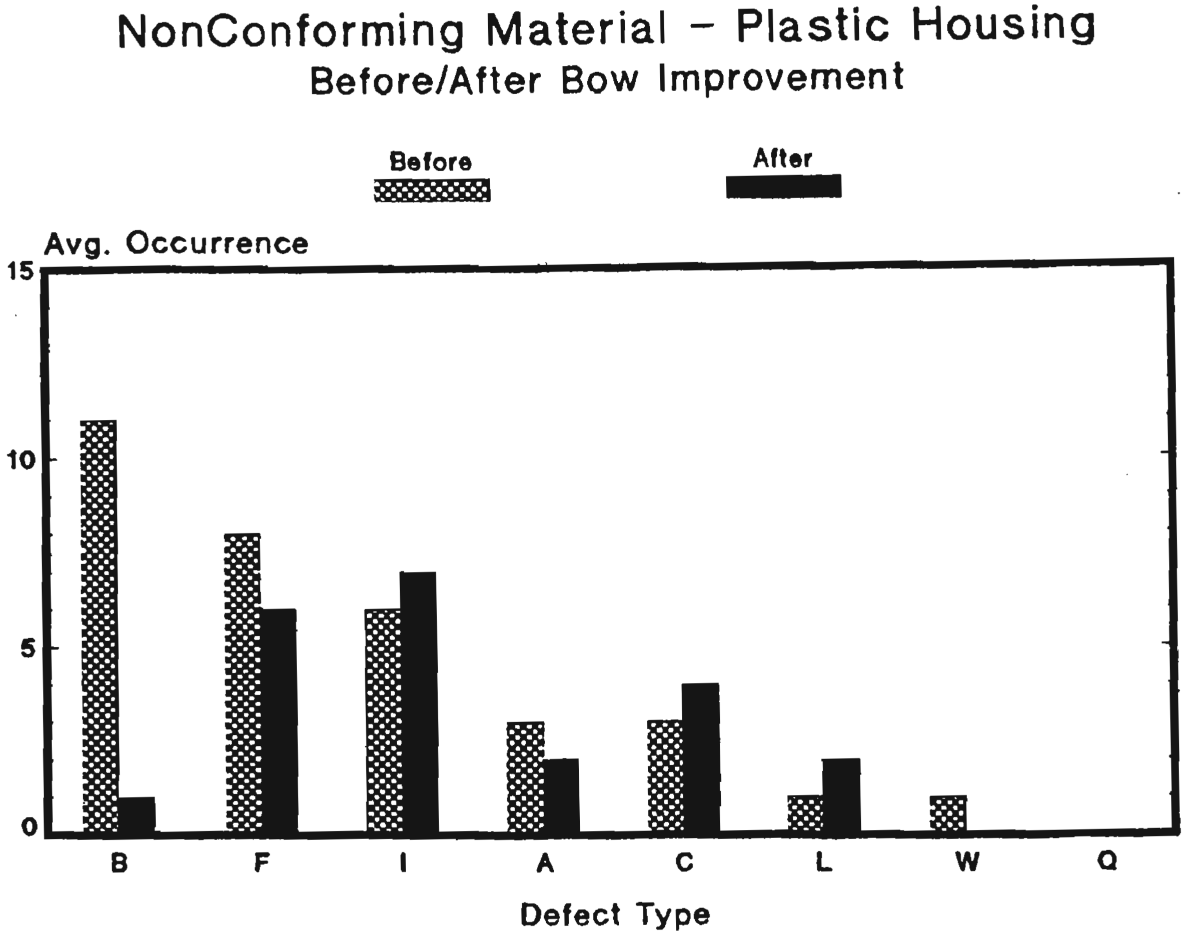


***Figure 15.*** *Pareto chart comparing conditions before and after corrective actions were taken.*

## RECOGNITION AND CLOSURE

After completion and verification of the improvement, and after the implementation of controls to "hold the gains," the quality improvement project was officially closed. At this point, the team was recognized for its efforts. Recognition took many forms, from significant monetary awards to management recognition during site information meetings, or in an organizational newsletter or bulletin board. We viewed that formally recognizing the team was far more important than the format used or amount of the monetary award. Recognizing the team's efforts is essential to developing and sustaining continuous improvement as part of our organizational culture. It also reinforces win/win relationships and teamwork.

Upon closure of the project, the management sponsor would report the team's accomplishments to the steering committee (in many cases, the teams gave the final management review). That specific quality improvement team was then dissolved and members freed up to begin work on other improvement efforts. Note that the quality improvement process is never ending. Once one improvement project is completed, we go right back to the start and begin a new improvement effort.

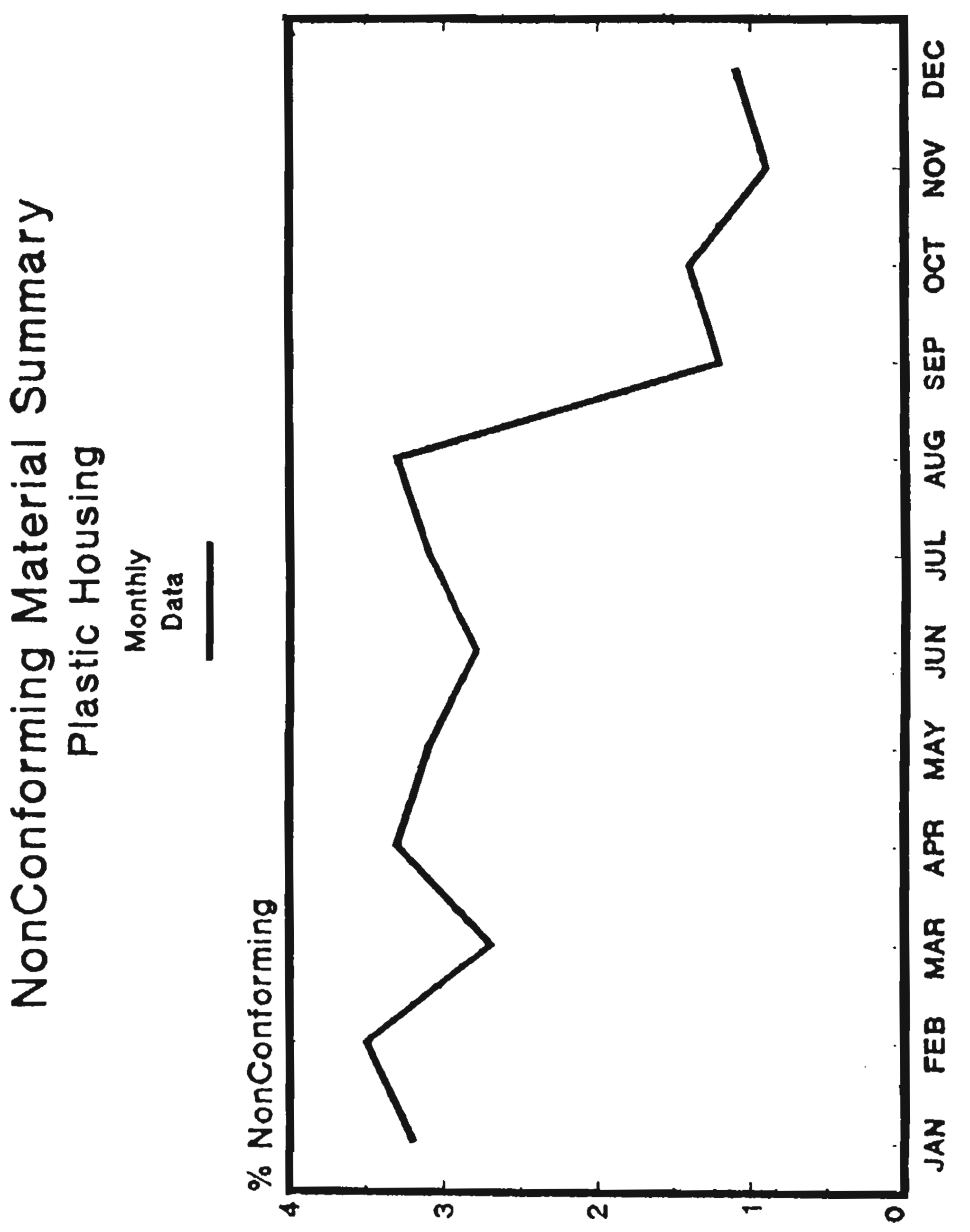


***Figure 16.*** *Before-and-after comparisons can also be made with a trend chart.*

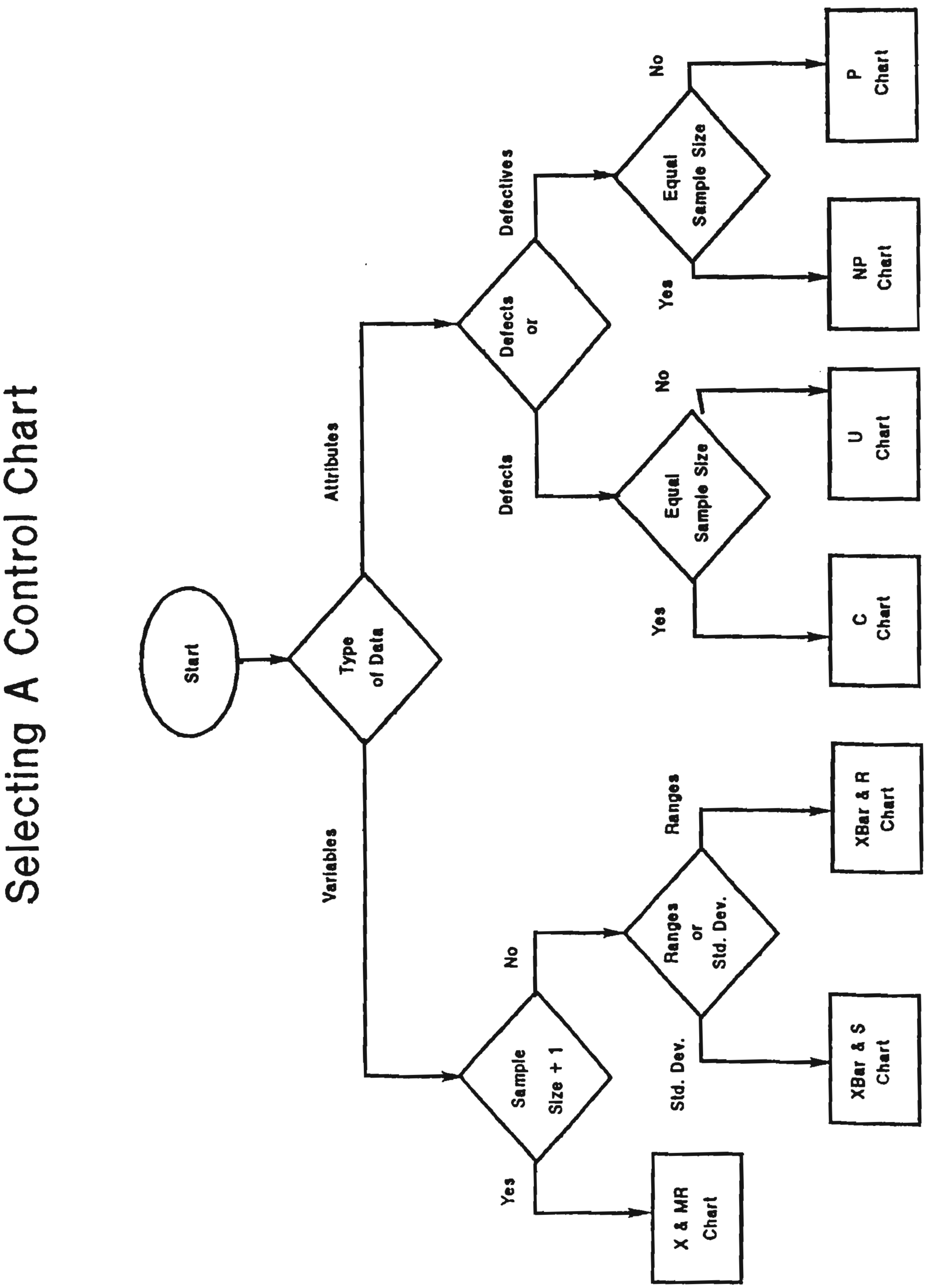


***Figure 17****. A control chart like the one shown here is used to monitor the improved performance level.*

## SUMMARY

Developing a culture of continuous improvement throughout the organization is required by every company hoping to meet today's, let alone towmorrow's, competitive challenges. Creating mission statements and quality policies focusing on the customer is necessary but not sufficient. Likewise, extensive training on popular statistical and problem-solving techniques will not likely result in needed improvements. Everyone must understand how and where to apply the techniques. They must view continuous improvement as a never-ending process. This chapter has presented an overview of the process developed by Connector Systems Division of DuPont. We believe this process can be adapted by any company to establish and maintain a culture of continuous improvement.