Workshop Report: Southwest Region

A Success Story in Statistical Process Control at Texas Instruments, Austin, TX

Leading edge technology and increasingly higher quality targets offer plenty of challenge to TI's PWB Group at Austin. Thanks to the training and involvement of all employees in the prevention of defects, their performance continues to improve in quality, delivery, and WIP control.

Peter W. M. John, Ph.D.

No wonder the PWB (Printed Wiring Boards) group at the Austin, TX facility of Texas Instruments is proud. They brought their manufacturing operation from the brink of disaster to world-class in three years, a story they shared in the July 1989 workshop. The keys to their successful turnaround are Statistical Process Control (SPC) and Statistical Quality Control (SQC).

The PWB group makes printed wiring boards (printed circuit boards); see accompanying box. Much of their product goes to the U.S. Department of Defense. In late 1985 and 1986, their manufacturing process deteriorated so badly that more than half their lots were being rejected. WIP (Work-in-Process) stacked up. More than half their orders were delinquent. Waste, scrap, and rework were at unbelievable levels. It was time for radical change — time to go to SPC/SQC.

They had dabbled in SPC/SQC before. Beginning in 1982 they had outside experts talk to various groups of workers and give training courses. But, apart from x-bar charts on some shop and office walls and a small start on quality circles, there was little or no implementation until the catastrophe of 1986 got their attention like a whack with a 2 × 4. Then management made the decision to go wholeheartedly for SPC/SQC. It required a complete cultural change in their system.

What Did TI Do?

First and foremost, higher management became actively involved in a highly visible way. There was no doubt that the people at the top were solidly behind SPC/SQC.

They confronted four vital truths:

1. You cannot inspect quality into a process. You must focus on prevention of defects, rather than detection.
2. To focus on prevention, you need to know more about your process, taking nothing for granted.
3. You must train everybody from managers to the rawest recruits in the principles and philosophy of SPC/SQC.
4. You must control variability. If you do not, it will destroy you — relentlessly.

In hindsight, these truths are self-evident. Like many ideas, they are not obvious until circumstances force them to your attention.

Results: Complete Turnaround

The payoff has been a complete turnaround in the manufacturing process. It is now a model of quality and profitability. Two examples from the plating shop illustrate this improvement.

The plating shop runs three shifts, five days a week, and is responsible for six different plating lines. The amount of scrap has fallen to about 15 percent of the level that prevailed in 1986 when the SPC/SQC program began.

In one plating stage, the activator palladium concentration has been brought under control. The operators now make the decisions to add more chemical by looking at their x-bar charts, rather than by intuition. The saving is $50,000 per year in that step alone. A plating scrap graph is shown in Fig. 1.

Even better ideas coming out of the group's quality circles have resulted in savings of $328,000 in the first five months of this year.

How TI Did It

TI management jumped right in and made a commitment to SPC/SQC from the top down. They appointed two full-time quality control facilitators with responsibility, among other things, for a serious program to train everybody. That part was obvious.

They also set about understanding what really went on in their manufacturing process. They identified, in some cases for the first time, the factors that controlled their processes and learned how to reduce their variability. To
PWB Plating Scrap

Fig. 1. This graph represents the relative dollars scrapped for plating defects, normalized to 1986 = 10.

do this they conducted numerous designed experiments. They did not confine themselves to the simple Taguchi experiments. They used more advanced experimental designs, such as Box-Behnken designs, to investigate quadratic response surfaces and locate optimum levels. They learned that the variability in some measurements was much worse than they had believed and had to be reduced significantly.

In the plating example, mentioned earlier, they learned that measurement variability accounted for 95 percent of the recorded variability of the palladium concentration.

Two Key Statistics: Cp and Cpk
Cp and Cpk are two commonly-used measures of process capability. Both compare the process variability to the specification limits and give the engineer an indication of how small the fraction of defectives will be. They are defined as follows:

\[ Cp = \frac{USL - LSL}{6\sigma} \]

\[ Cpk = \frac{\text{mean} - \text{closest SL}}{3\sigma} \]

where USL, LSL are the upper and lower specification limits, and \( \sigma \) is the process standard deviation.

Cp is the simpler of the two. The PWB group uses its reciprocal as a measure of capability. Cp measures the capability if your process is on target—if the process average is indeed halfway between the specification limits.

When your process is not exactly
Fixing the Vital Few, Then the Trivial Many

The table below helps demonstrate how ambitious the 1.3 Cpk target is.

<table>
<thead>
<tr>
<th>Cpk</th>
<th>Number of defects</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.05</td>
<td>133,600 ppm (part per million)</td>
</tr>
<tr>
<td>0.67</td>
<td>71,800 ppm</td>
</tr>
<tr>
<td>0.80</td>
<td>16,400 ppm</td>
</tr>
<tr>
<td>0.90</td>
<td>6,900 ppm</td>
</tr>
<tr>
<td>1.00</td>
<td>2,700 ppm</td>
</tr>
<tr>
<td>1.33</td>
<td>66 ppm</td>
</tr>
<tr>
<td>1.67</td>
<td>&lt;1 ppm</td>
</tr>
<tr>
<td>4.00</td>
<td>&lt;1 ppb (part per billion)</td>
</tr>
</tbody>
</table>

Data obtained from R&M 2000 Variability Reduction Program

As higher Cpk values are attained, there are fewer defects to measure improvement or changes against, thus making the diagnostic journey longer. If getting to 1.3 has taken five years, 1.5 may take another five years. This is an example of fixing the vital few and now attacking the trivial many.

Where Does TI Go From Here?

There remain more production steps to be integrated into the program. There is the self-imposed increase in the Cpk target to 1.5 to meet. There are suppliers to be trained and certified. Training the workforce must not slacken. Can they sit back after that? No!

One reason is that quality gets into your blood. There are two other less subjective reasons. You must press forward because your competitors on both sides of the ocean are improving their manufacturing capabilities too. Furthermore, the design engineers continually impose new and much more complicated demands upon the manufacturing engineers. The improvements made by PWB in three years are all the more impressive when we recall that 1989 boards are much more advanced than 1986 boards.

What was good enough for last year's products will not be compet-

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About TI Austin Products . . .

The circuit boards manufactured at the Austin facility are primarily multilayer in design. Many mechanical and electro chemical processes are used in making a circuit board. Basically copper clad epoxy laminate is photo imaged and chemically etched, bonded together in a high pressure/temperature press, drilled using an NC (numerical control) machine, photo imaged a second time, plated with copper and tin lead metals, chemically etched to remove excess copper, and finally routed into discrete part form.

The product mix in Austin varies from standard multilayer, flex, rigid flex to high tolerance microwave circuit boards and state-of-the-art polymer-on-metal surface mount circuit boards.
itive next year. As Satchel Paige said, "Don't look back. Something may be gaining on you."

Would TI have made its whole-hearted improvement effort without the catastrophe of 1986? Perhaps so, but not for a while. The moral is not to wait until you are hit by a $2 \times 4$.

The members of the PWB team have learned how to make boards more reliably, more quickly, and more cheaply. If we measure quality by such yardsticks as reduced waste or increased Cpk, they have fulfilled their mission. But have they improved quality in the sense of building better boards? Have they also increased the MTBF (Mean Times Between Failures)?

The workshop did not address that question. But it must be understood that we cannot be content with process improvement alone. We must also strive continuously for product improvement. Manufacturing engineers cannot sit back and leave that to the design engineers; it is the mission of the manufacturing engineers too.


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