ChE classroom

APPLICATION OF QUALITY MANAGEMENT TECHNIQUES TO ChE PROCESSES

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This paper reports on a study we performed on the application of the Deming Management method to a practical chemical engineering project. Our objective was to examine a practical application of the management technique when applied to a chemical engineering process. We will first describe some of the basic principles which Deming's technique is based upon, such as understanding that any job consists of a group of consecutive tasks (a process) and that each process has inputs (suppliers) and outputs (customers). Also, certain tools and procedures, such as forming teams, will be discussed. Finally, an application to a hypothetical chemical engineering industrial project, patterned after a real industrial case, will be presented.

Deming's work initially became popular in Japan in 1950, and in 1980 it began to take hold in the United States. Deming studied with Shewhart, learning his ideas of "statistical control." This became the basis of Deming's work. He is the author of *Quality, Productivity, and the Competitive Position,*[1] and *Out of the Crisis,* as well as other technical books and brochures on statistics and sampling together with numerous scholarly studies.[2] Several other related and pertinent studies are cited in the references to this paper.[3-12]

Our objective was to examine a practical application of the [Deming] management technique when applied to a chemical engineering process.

Some of Deming's basic concepts are captured in his fourteen points:

- Create constancy of purpose for the improvement of product and service
- Adopt the new philosophy
- Cease dependence on mass inspection
- End the practice of awarding business on price tag alone
- Improve constantly and forever the system of production and service
- Institute training and retraining
- Institute leadership
- Drive out fear
- Break down barriers between staff areas
- Eliminate slogans, exhortations, and targets for the workforce
- Eliminate numerical quotas
- Remove barriers to pride of workmanship
- Institute a vigorous program of education and retraining
- Take action to accomplish the transformation

Deming's management methods are different from those that have been traditionally taught. A summary of some of

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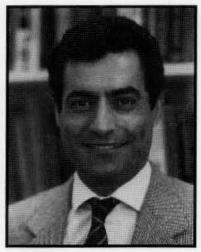

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the more contradictory ideas can be found in Table 1.

Application of Quality Management Techniques to a Hypothetical ChE Industrial Project

In this hypothetical project, patterned after a real industrial project, the goal was to increase the capacity of a system without investing capital. Ultimately, the required increased capacity was obtained by process improvement through reducing control time cycles.

Formation of a Team • A team was formed to study the process and to determine whether a capacity increase could be made by reducing the existing controlling time cycles instead of investing capital. Each person on the team was chosen to bring expertise from his/her respective area. (Forming a team is in line with Deming's point to "break down barriers between staff areas.") The team members and their corresponding areas of expertise were:

Production Technologist • processing; time cycles and equipment knowledge

Quality Assurance Lab Coordinator • analytical specification; alternative analytical methods

Process Development Engineer • process variable effects; laboratory capability

Customer Service Representative • customer concerns

Marketing Representative • projected future demands

Process Operator • hands-on experience in running the process; knowledge of process problems; potential alternatives

Operations Manager • authority to approve process changes or to authorize facility capital investments

In this case, the leader of the team was chosen to be the production technologist. The entire team did not attend all meetings. The marketing, customer service, and plant management representatives attended the first meeting to set the stage and participated later as deemed appropriate. The team chose to use a structured strategic problem-solving approach.

Note that the case described here is patterned after a case in a large chemical company. Nonetheless, these principles can be easily modified so that they are applicable to operations much smaller in size and personnel.

TABLE 1
Comparison of Traditional Business Techniques and Deming's Method

Traditional Approach	*Deming's Approach*
Quality is expensive.	Quality leads to lower cost.
Inspection is the key to quality.	Inspection is too late. If workers can produce defect-free goods, eliminate inspections.
Quality control experts and inspectors can assure quality.	Quality is made in the boardroom.
Defects are caused by workers.	Most defects are caused by the process.
The manufacturing process can be optimized by outside experts. No change in system afterward. No input from workers.	Process is never optimized; it can always be improved.
Use of work standards, quotas, and goals can help productivity.	Elimination of all work standards and quotas is necessary
Fear and reward are proper ways to motivate.	Fear leads to disaster.
Buy at lowest cost.	Buy from vendors committed to quality.

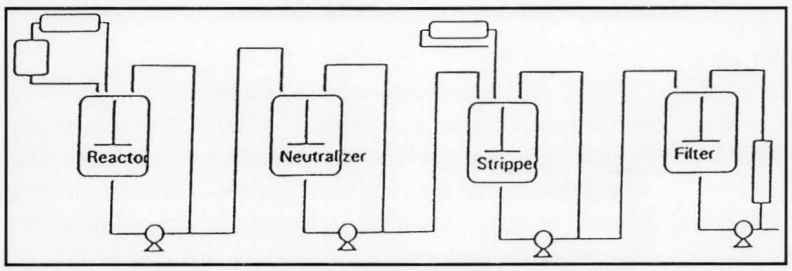

Figure 1. *Process flow diagram.*

Application of Strategic Problem-Solving Approach • In this case, the system being studied consisted of a series of four processes. The first process was a reactor, the second a neutralizer, the third a stripper, and the fourth a filtration unit. These four units are shown in Figure 1.

1. The first step was to define the ***problem statement.***

The goal of the project was to determine if it was possible to reduce the controlling time cycle from 15.1 to 7.5 hours in order to increase capacity from 5000 MT/yr to 10,000 MT/yr. The limitation on the process changes was that the product quality should not be compromised as determined by analysis or performance tests.

2. The next step was to define the ***reason for improvement.***

The reason for improvement was to increase the capacity to meet the required customer demand in two years without a $5 MM capital investment required to obtain the shorter time cycle.

3. The next step was to define the ***current situation.***

As described previously, four processes contributed to the existing system. Since the goal of the team was to reduce the controlling time cycle, the first step in describing the current situation was to determine the time cycles of each process and ultimately define the controlling time cycle(s). Therefore, the production technologist gathered

data from the last forty batches to identify the time cycle for each process. The control charts from these batches for each of the four consecutive process steps were then constructed. From the time cycle control charts, it was clear that the reaction and the stripping processes had relatively longer controlling time cycles. The production technologist applied statistical tools to the data from each process by calculating the mean, standard deviation, and upper and lower control limits. The statistical time cycles for these four processes are shown in Table 2.

The time-cycle analysis illustrated clearly that any reduction in the controlling time cycle had to be achieved by reducing the reaction and stripping time cycles. Therefore, to better understand the causes of the processes having the longer time cycles, the team further analyzed the reaction and stripping steps using control charts..

TABLE 2
Statistical Time Cycles

Unit	*Cycle Hours*
Reactor Time Cycle	12.7 ± 12.0
Neutralizer Time Cycle	5.4 ± 3.9
Stripper Time Cycle	15.1 ± 6.0
Filtration Time Cycle	4.5 ± 4.2

4. ***Analysis*** *of the chemical reaction.*

The team noticed from the control charts that the reaction time cycle was out of control. The average reaction time cycle was 12.7 hours, with a large standard deviation of 4 giving an expected range of 0.7 to 24.7 hours based on plus or minus three standard deviations. Not only was the range large, but also there existed special causes in the system. The data appeared to have some nonrandom patterns that were viewed as a clue to a special cause. Also, a second special cause pattern was observed since more than 8 points were below the mean.

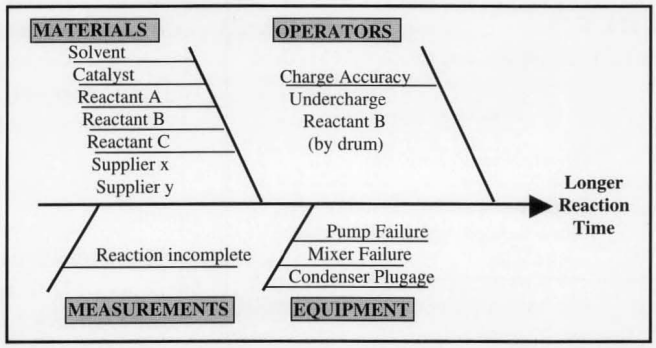

Figure 2. *Cause-and-effect diagram.*

Once special causes were identified, the team studied data obtained by the operator from the previous batches in order to identify the variation's cause. To assist in their search, the team had a meeting where they brainstormed the possible causes for the time cycle variation and used a cause-and-effect diagram, shown in Figure 2, to identify the most likely causes.

During the construction of the cause-and-effect diagram, the operator explained that when the time cycle gets exceptionally long, the next batch would run quicker if the overhead condenser of the reactor was steamed out prior to starting the batch. The production technologist thought this comment was rather interesting as he theorized that if the reactor vent was plugged, the desired reflux condition could no longer be obtained and perhaps this would result in an extended reaction time cycle. In light of this, the team looked more closely at the batch sheets and noticed that each time the reaction time cycle dropped from long to very short, the reaction pressure had dropped. This would parallel the steaming out of the condenser, *i.e.,* the condenser was steamed in four batches.

Since the operators do not record this information on the batch sheet, the production technologist never noticed the increased pressure or the fact that they were steaming the overhead.

A second trend on the chart also indicated a special cause where the batches with exceptionally long reaction time were not part of the upward trend effect. Three batches having a reaction time of 20, 18, and 20 appeared suspicious, although these points were not outside of the control limits. The team looked on the batch sheets for these three points and noticed that the final pounds out of the batch were higher by approximately 200 pounds, as indicated by the manometer reading. The team determined that possible explanations could be equipment failure or overcharge of a raw material. Later, the operator mentioned that sometimes a whole drum of raw material B was charged instead of weighing out 100 lbs because it was believed that the accuracy of this charge was not all that critical since it was only about one drum in a 5000-gallon reactor. The production technologist was not absolutely certain of the sensitivity of the product to raw material B, but thought that based on the data it would be worth ensuring the raw material charges were more accurately measured from batch to batch. To assist with this situation, the team worked through the Purchasing Department to get the material packed in the amount that they were to charge to each batch so that weighing was not necessary.

It is worth noting that the operator spoke freely about not charging the batch correctly because he knew the team was interested in achieving improvement and not in pointing fingers. This is in line with Deming's point to "drive out fear" in the workplace. Important information can be lost when people are afraid to come forward.

5. ***Solutions*** *to reaction bottleneck.*

The team implemented what was thought to be the solution to removing the special cause variation to the process by requesting steaming of the condenser between batches. This would ensure that the vent would be clear. Also, packaging the raw material B in preweighed containers would eliminate weighing and would help ensure that overcharges of material B would not occur.

*6. **Results**/analysis from eliminating reaction special causes*

Next, the team monitored the process for another forty batches. Based on the results, it appeared that the upward trend seen with steaming the condenser had disappeared and that the spikes in the data were reduced. But several points again appeared below the mean, indicating a special cause.

The team theorized that the factors causing the reaction time to go faster on a series of batches such as this would probably be related to a raw material stock. All their raw materials were single sourced except for one—raw material C. Since it is more likely to have variability between two suppliers as opposed to two lots from one supplier, it is preferable to have only one supplier. The team looked further to see if lots were received from two different suppliers for raw material C during this time period and found that producer x supplied during the period that the points below the mean were obtained, while producer y supplied during the period for other points.

The team requested material from only supplier x for the next forty batches and found that the process was in control, with no indications of special causes present. In addition, the time cycle was reduced to an average of 6.0 with an Upper Control Limit (UCL) of 9.2 and a Lower Control Limit (LCL) of 2.8, which was a great improvement over the original process having a UCL of 25 and a LCL of 0.7. Now the team was in a position to discuss the possibility of additional process improvements to further reduce the time cycle.

TABLE 3
Improvements in the Process Time Cycle

Process Step	*Before*	*After*
Reaction	12.7 ± 12	6.0 ± 3.3
Neutralization	5.4 ± 3.9	5.4 ± 3.9
Stripping	15.1 ± 6.0	6.5 ± 4.2
Filtration	4.5 ± 4.2	4.5 ± 4.2

Since all other process steps were 6 hours or less at this point, the stripping time had to be reduced next. As mentioned earlier, the average stripping time was 15.1 hours. From the data, the stripping process appeared to be in control, as no indications of being out of control were apparent. The only way to reduce the time cycle was, therefore, to somehow change the system. Since the process was in control, changes to the system could be made and the effects observed without concern of mislead by special causes.

The team discussed alternatives to reducing the stripping time. Since the team had to avoid a capital expenditure, the idea that seemed most promising was the use of steam stripping to remove the solvent. Furthermore, since this was a process change, the process development engineer had to evaluate the ideas and provide technical support.

This idea was proven in the lab, and a plant trial was successfully completed. The resulting process showed that the new average time for stripping was only 6.5 hours, allowing the whole system to have a controlled time cycle of less than 7.5 hours and resulting in the desired doubling in capacity.

Table 3 shows the improvements that were made in the process time cycles. In order to ensure that the reaction and stripping process improvements were implemented in a manner to ensure consistency, a new process batch sheet was written that incorporated the process changes.

The original goals of the team were now met. Further discussion revealed that perhaps additional work on converting this process into a continuous process, as opposed to a batch process, might be beneficial since the demand had continued to grow through the years. The team drafted a memo to process development suggesting the long-term investigation of such an idea.

CONCLUSIONS

In this hypothetical study, the fundamental definitions and tools introduced by Deming were used. The tools were applied to a hypothetical chemical engineering project, patterned after an industrial project, that incorporated real process industry occurrences. They were both technical (steaming of the condenser between batches and steam stripping to remove the solvent) as well as procedural (working with the suppliers to pack the raw material in preweighed containers to eliminate weighing and overcharge as well as using a single source for raw material supply). In addition to the standard chemical engineering principles, we hope that these fundamental tools will be used by others to enhance the capabilities of the more traditional technical problem solving methods.

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