TOTAL QUALITY MANAGEMENT – THE TIME HAS COME FOR METALLURGICAL PLANTS

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ABSTRACT

The principles of quality management are well developed and, from a practical standpoint, thoroughly implemented in the process industries of Japan. Although these principles are now applied to the U.S. manufacturing industry, and as a result, the steel industry, they have been largely ignored in the non-ferrous and precious metals industries. This paper presents the concepts and practical approaches to implement a total quality management program. Contrary to the beliefs of many managers, such a program increase yields, recoveries and output while it decreases unit costs. In fact, quality management incorporating statistical process control will be an essential ingredient for metallurgical plants to effectively compete in the future.

INTRODUCTION

As noted by Deming (1982), in 1950 Japan's net worth was negative, it had no significant natural resources and had a reputation for producing cheap, shoddy consumer goods. Their management, however, was open to new ideas and they accepted that quality was the only way to turn their economy around. Forty years later Japan's manufactured products are the envy of the world and are of the highest quality. Their approach to management of resources is completely different from the traditional American approach. Total quality management, having been established in the manufacturing industries, has continued to grow and is now pervasive throughout enterprise in the country. American industry continues to lose ground in world markets at the expense of Japanese companies.

Belatedly, some American manufacturing companies, notably Ford Motor Company, have begun to implement the types of quality management approaches used in the transformation of Japan's industry. These manufacturing companies are demanding that their suppliers use these same management approaches. Therefore, there is a tendency for the quality concepts to move "upstream" in the supplier chain. This has mostly occurred in the steel industry, with some influence in base metals supplied to the steel industry.

Unfortunately, the influence of quality management concepts has not been felt in most American companies in the base metals and precious metals industries. A large majority of senior management personnel in these industries is unfamiliar with essential quality management concepts such as statistical process control (SPC). Based on the thrashing American manufactured products have taken in world markets, one must expect that products from the chemical and metals process industries will be next unless the change to "Total Quality Management" is made soon.

TRADITIONAL APPROACH TO QUALITY CONTROL

Quality control has been an important function in organizations producing goods for sale where product specifications are important. Quality control has generally not been an important function where product specifications are not important at the point of sale. This is many times the case for commodities early in the production chain, for example, the shipment of concentrates.

The approach to quality control has usually followed sequence:

1. Produce the product with major emphasis on cost and quantity.
2. Measure the product after it is produced to determine whether it meets product specifications.
3. Ship products meeting specifications and reject products not meeting the specifications.

This sequence is almost universally followed by arguments between the production department and quality control department over the amount of product rejected.

In operations where quality is not a concern at the point of sale, the sequence generally skips step numbers two and three in the list above.

In the traditional management approach, quality control is generally thought to result in higher marginal costs of production. Tighter control requires more scrutiny, which requires more inspectors. Tighter controls also result in additional production costs because productivity is decreased as a result of additional controls in the production process. Where quality control is not practiced, costs would be the least since these controls would not be required. For this reason, operating managers, quite naturally, are most interested in avoiding additional emphasis on quality. This is particularly true when there is no requirement for quality control at the point of sale.

As was initially postulated by American quality pioneers, such as Walter A. Shewart and W. Edwards Deming, and amply proved in practice by Japanese heavy industry, the traditional American approach to quality management is almost entirely wrong.

TOTAL QUALITY MANAGEMENT: A NON-TRADITIONAL APPROACH

To maximize quality, variation must be minimized. Variation is sometimes called the fundamental cause of poor quality (Evans, 1989). V*ariation can also be called the fundamental cause of high unit costs.* For instance, low cyanide concentration in a leach circuit will result in lower recoveries. High cyanide concentration will result in excessive cyanide consumption. In either case, unit production costs are increased. Examples of the impact of variation on unit production costs are endless. Whether one talks about the flux control in smelting, reagent control in flotation, or density control in grinding, variation from design parameters will increase unit production costs; the more the variation the higher the costs.

The total quality management approach concentrates on reducing variation in the production process. To the degree this is successful it improves quality and unit costs at the same time. Therefore, the total quality management approach is essential not only to improve quality, but to optimize production costs. To survive in the increasingly competitive world market *these approaches are essential whether or not the quality control of product is important in the traditional sense.*

VARIATION

There are two types of variation: random and non-random. Random variation results from inherent characteristics of the production process. A reagent metering feeder will vary the quantity of reagent metered per unit time around some mean value. The amount of the random variation will be a function of the type of feeder, clearances in its construction, stability of the control loop, type of variable speed drive, etc. Non-random variation results from influences from outside the process system, which are generally under the operator's control. Such non-random variation might result from equipment disrepair, changes in feed characteristic without appropriate adjustment to the system by the operator, or other influences on the process.

The first requirement for improving quality (and costs) is an understanding of the nature of variation, and the means to determine the degree of random and non-random variation in the production process. The second requirement is to take appropriate action to reduce non-random variation. The third requirement is to take appropriate action to reduce the random variation. Actions effective in minimizing non-random variation are useless and counter productive when used to reduce random variation.

ELEMENTS OF A TOTAL QUALITY MANAGEMENT PROGRAM

The following elements are essential in any successful quality management program:

1. Management commitment to total quality management.

2. Training in simple statistical techniques, the nature of samples, collecting data, variation and the program to be implemented.

3. Organization structure emphasizing work group authority and accountability for results.

4. Statistical process Control (SPC) system to monitor and control process variable variation.

5. Formal performance reports based on output from the SPC system.

6. Systemized team approach to problem solving.

7. Continuing emphasis on reducing variation in the product process.

Management Commitment

To be effective the total quality management program must be executed by front line shift personnel. For this to work, however, top management must be totally committed to the program. There have been many instances where senior managers gave lip service to implementing quality programs simply to keep customers happy, or where managers wanted to go with the latest management fad. In these cases the program is doomed to failure. The system, when implemented, will cause problems to surface. Many of these problems will require decisions and actions by senior management. If such actions are not forthcoming, employees quickly become disillusioned with the program.

We recommend that a quality management manual is produced with the company's commitment to quality spelled out in the introduction and signed by the senior site executive. This commitment must include sufficient participation and training for site personnel to ensure their understanding of the program.

Training and Participation

Statistical process control will require operators, using charts prepared by engineering personnel, to compute means and ranges based on measurements of groups of data. These data will then be plotted on control charts and used to assess variation in the process. The plotted data will indicate the degree of random and non-random variation.

Following initial training in using the SPC approach, work teams consisting of operators, foreman, and metallurgists, working together as a team, establish the control methods for each plant area.

Organization Structure

While the traditional organization must remain intact, the quality management system will be driven from the bottom up. The primary responsibility of foremen will be to train operators, provide technical advise on data collected, ensure non-random variation is acted upon immediately and to work with more senior management personnel in the continuing effort to reduce random variation.

The primary responsibility of more senior managers will be to provide employees with a process control system and necessary training in its use. Senior management is also responsible to participate in problem solving teams and to make improvements to the process, where necessary, to reduce random variation.

Accountability for results will be pushed to the lowest possible level. Control charts will be used by the operators to assess performance over the short term. Summary performance reports prepared from the statistical process control system will be used to assess performance over the longer term. Operators must be given the necessary authority and latitude to make required adjustments to reduce non-random variation indicated by the control charts. Operators, close to the work, are also likely to have good suggestions for process system modifications necessary to reduce random variation.

Statistical Process Control (SPC)

The objective of SPC is to identify non-random variation in a critical process variable as soon after it occurs as possible. It also allows for identifying the degree of random variation that is an inherent part of the process itself.

The following steps are used to construct an SPC program:

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1. Divide the production operation into major process areas. A major process area usually has the following characteristics:
   - A major function with measurable output,
   - Contains equipment dedicated to a single task, and
   - Has an assigned regular work crew.

   Examples might include a grinding circuit, smelting furnace or flotation circuit.

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2. Identify each unit operation in the process control area. A unit operation normally has the following characteristics:
   - A specific operation performed in the process area, and
   - Usually results in a physical or chemical change to the feed or product material.

   Examples might include a ball mill, cyclone or filter.

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3. Identify the critical process variables for each unit operation. A critical process variable usually has the following characteristics:
   - A parameter significantly affecting the performance of the unit operation, and
   - A measurable and controllable quantity for which someone can be held accountable.

   Examples of process variables might include temperature, density, size, or flow rate.

A process control chart illustrating the process areas, unit operations and variables is included in the quality management manual. Accountabilities are also shown for control of each unit operation.

A control standard is then developed for each process variable. The control standard establishes the method and accountability for control. The format for a control standard can be flexible, but might include the following:

- Variable to be controlled
- Accountability
- Definitions*
- Process Standard
- Reason for Control
- Measurement
- Reporting*
- Control Chart*
- Operating Procedure
- Corrective Action

- Disposition of non-compliant product*

*Where applicable

The control standard is included in the quality management manual. Ideally, the control standards would be a part of an overall set of manuals for the plant which would also include a process description, safe job procedures, etc.

Control Charts. The heart of the SPC system is the control chart. There are several types of control charts, each used for a specific application. The most common chart used for process applications is the x bar and R chart. As noted by Ishikawa (1971), the x bar and R chart is actually two charts in one. The x bar portion of the chart mainly shows any changes in the mean value of the process, while the R portion shows any changes in the dispersion of the process as a function of time.

X bar points are calculated by taking the mean of from two to six sequential measurements of the variable. If only six measurements were taken during a shift or a full day, they would represent a plotted point for each shift or day. Otherwise, they might represent the mean of from two to six measurements taken during production of a lot, or during a period of time.

The R points represent the range of the highest to the lowest measurement in the same group of two to six measurements. Figure 1 below, from Ishikawa (1971), illustrates a typical x bar and R chart.

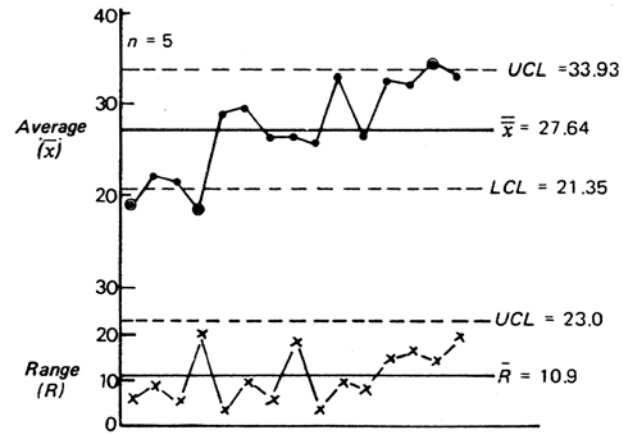

FIGURE 1: X BAR AND R CHART

The central line, represented by x bar, bar is the mean of the x bars taken over a long period (minimum of 100 sample measurements). The R bar represents the mean of the ranges taken over a long period (minimum of 100 sample measurements). Upper and lower control limits (UCL and LCL) are calculated based on simple published statistical formulas. Again, from Ishikawa:

TABLE 1

n	A_2	D_4
2	1.880	3.267
3	1.023	2.575
4	0.729	2.282
5	0.577	2.115
6	0.483	2.004

x bar chart:

$$UCL = x + A_2R \qquad (1)$$

$$LCL = A_2R \qquad (2)$$

R chart:

$$UCL = D_4R \qquad (3)$$

n = Sample size in one lot

It is important to recognize that the control limits have nothing to do with customer specifications or production requirements. They represent plus and minus three standard deviations around the mean, or x bar, bar central line. As has been said by Deming (1982), "…it is the process talking to us." Randomly plotted points within the x bar or R chart control limits represent random variation inherent in the process itself. Points outside the control limits, or a non-random pattern inside the control limits, represents non-random variation for which the operator must find the cause. Examples of non-random variation include:

- Any points outside of the control limits.
- A generally upward or downward trend (6 or 7 successive points) with only one crossing of the central line.
- Five or more crossings of the mean within fifteen data points or seven or more crossings within twenty data points.
- A recurring pattern (cycling).
- Seven or more successive points on the same side of the central mean.

Use of SPC control charts of this type clearly illustrate statistically significant non-random variation. Figures 2 and 3 from Ishikawa illustrate some examples of non-random variation within the control limits. Simply plotting each point measured on a graph will not provide obvious patterns of non-random variation.

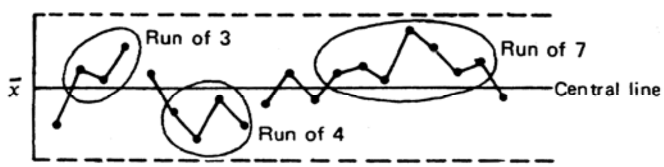

FIGURE 2: RUNS

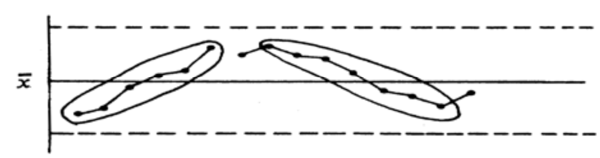

FIGURE 3: TRENDS

Other types of control charts are used for different circumstances, such as attribute charting. Attributes include number of defectives, percent defective, etc. The references listed at the end of this paper include details of these types of control charts.

<u>Corrective Action</u>. It is the job of the operator to monitor the designated variables. Further, the operator must take corrective action in accordance with the control standard to eliminate the non-random variation when it occurs.

Performance Reports

Results from the SPC control charts should be summarized and integrated into weekly and monthly management performance reports. These reports can summarize chart data for each work crew and area.

Problem Solving

In some instances, correction of non-random variation may be out of the operator's control and require problems to be solved. In almost all cases, reducing random variation will require the solving of problems outside the operator's control. In these instances, establishing a team consisting of operators, supervisors, engineers and in many cases suppliers is the most effective way to achieve a solution. The reduction of random variation, generally represented by the area within the chart's control lines, will require an improvement to the process control system.

The team approach must be applied through a systematic problem solving methodology with specific assignments for additional information or experiments made to appropriate team members. Technical personnel can apply their knowledge of experiment design to facilitate the information gathering.

Continuing Emphasis

It is most important that senior management act when the total quality management program indicates action is justified and necessary. Solving problems and eliminating non-random variation is only half the battle. Management must continue to emphasize the importance of always taking the next step, eliminating the next bottleneck, and in general, to continue to improve the process and reduce random variation.

CONCLUSION

No doubt, many may conclude that fancy charts are of no more value than a review of multi-point recorders each day, or checking results by a review of single points representing a graph of a particular process variable. We must emphasize that such charts are of little use in distinguishing between random and non-random variation. It is only non-random variation over which the operator has control.

To economically compete in the future, processing plants will need to take the next step in optimizing product quality and minimizing operating costs. This step cannot be taken without a commitment to total quality management incorporating statistical process control.

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