REPORT TO MANAGEMENT

It is questionable if any successful manufacturer, provided he intends to stay in business, has ever needed to be sold on the idea of having to maintain a quality level in his products. If he fails to set the pace himself his customers or competitors do it for him. A primary problem has been knowing when the quality level is right and when it may be dipping toward a dangerous low. However there may be a few times when the economic return does not justify the quality level being maintained. Since the customer always wants the best quality at the lowest possible price, the vendor must judge if the two are in proper balance.

I&EC's editors have asked two men from Monsanto's Plastics Division, where quality control is practically routine, to state a case for quality control and to show how statistical quality-control can assist in solving manufacturing problems.

From Vision to Supervision

A Case for Quality Control

QUALITY products will result if only raw materials meeting the required specifications are used and if no deviation from the approved standard of manufacture is allowed.

Since all manufacturing operations are plagued with quality problems, it is obvious that this statement, though correct, is an oversimplification of the problem. It just is not possible to obtain raw materials free of variation from lot to lot, nor can processes be held "on the beam" month after month or even hour after hour.

How to arrive at the proper quality level and then maintain it as consistently as possible constitutes the quality problem.

USUAL QUALITY CONTROL PRACTICE—RAW MATERIALS. The progressive manufacturer we are talking about has almost certainly established some kind of quality control over his raw materials. The simplest and most practical procedure has been taking grab samples and trying them out in the shop or if this is not feasible, to run a few tests on the sample to see if it conforms to the specifications (often the vendor's specifications).

Where the need has been apparent, more advanced techniques are used. A grab sample is considered inadequate and the problem of what constitutes a representative sample is recognized. The question which usually follows is: how important is raw material? Is it a key item that should have a minimum of tolerance or is it acceptable as long as it has the right color? Does it effect the process control, the final product, or both? These are all pertinent questions concerning raw materials, and the correct answers can go far toward controlling quality.

Our quality-conscious management will have instructed the control laboratory or inspection department to test all incoming raw materials and reject materials that fail to meet specifications. Also, it will have instructed the production supervision to check periodically the tabulation or log sheets summarizing recent receipts to see how well the vendors are doing. If the figures look fairly constant with no vendor deviating substantially, then the raw material situation is considered well in hand.

PROCESS CONTROL. The quality-conscious firm will use standard operating procedures, but it must be emphasized that a standard operating procedure does not mean the same thing to all production personnel. To many production men a standard procedure is one that outlines the method of manufacture but does not get so specific that, as he puts it, he does not have room to navigate. He knows he must be in a position to counteract the vagaries of his process.

To help him do this, processing data are recorded on log sheets. These log sheets are usually printed especially for the job. Everything is neat and orderly and operators usually have no trouble entering the data. Here again the data sheets are reviewed periodically to see how the process is operating. If something has gone wrong, these log sheets are often the only source of reference.

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Fold out

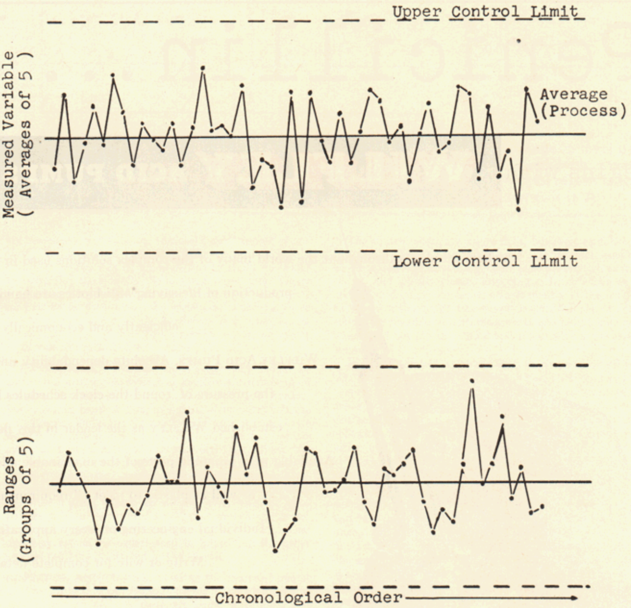

Figure 1

The log sheets, strictly for record purposes, are expected to serve as a means of policing the operator. Seldom are they referred to except in times of trouble, and then the task of searching out differences between the good and bad runs is difficult. The return is often considered questionable.

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FINAL INSPECTION AND SHIPMENT. Final products which are judged satisfactory to ship can vary tremendously, depending on the quality standard of the manufacturer. The progressive concern we are using as an example will have set up some criterion for approving its products prior to shipping. Unless the customer had definite specifications to be met, the ship versus return system was used. If the returns were excessive, the incentive to evaluate the quality prior to shipment became quite obvious.

The solution has been to install an inspection department whose job is to reduce the shipment of off-grade material and cut customer returns to a minimum. The inspection function was usually a sorting operation, a job of separating the good from the bad, and somehow the costs of making these rejects is not so apparent when the customer is not directly concerned.

STATISTICAL QUALITY CONTROL PRACTICE. Much has been written and many talks delivered on the subject of setting up a quality-control department to facilitate maximum use of statistical quality-control procedures. Who reports to whom and how high up is often treated as if it were of major importance. In some cases it is. We believe that these factors need not be of major importance

A. This is a process in excellent control

B. Eliminate the cyclic effect and the process will be as good as A

C. This upward trend needs correcting

to our progressive manufacturer who recognizes the need to produce quality products. What he needs is to have his supervision start using the statistical procedures available to it. To make this possible, a few individuals—in many cases one is sufficient—should become expert in the basic concepts of statistical quality-control. These persons acting as teachers and consultants can get statistical-control programs under way in the various departments.

It is frequently pointed out that quality cannot be inspected into a product; it must be built in. Likewise, statistical quality-control should not be considered something apart from production since it is the procedure to be used by production to build quality into the product.

Assume now that our company has individuals adequately expert in statistical procedure. How then will they assist the manufacturers?

SAMPLING A PRODUCT OR PROCESS. The procedure to be used in sampling, the frequency of sampling, and the interpretation of the test results, are all items which have been studied extensively and for which statistical procedures have been developed. All the manufacturer needs to determine is what risk he is willing to assume for accepting a bad raw material, or what risk he is willing to assume for shipping a poor lot of material. Sampling plans can be developed which will hold within the probabilities. In other words, for either receiving or shipping, statistical sampling plans can be developed to fit the risks involved.

STATISTICAL METHODS. Reference has been made to the customary log sheets for recording operating data, and the question is rightly raised here. "How will statistical methods improve this procedure?"

Though the information needed to answer this question is available in the log sheet, it certainly is not readily apparent even to the most experienced operator. Through statistical-control procedures most of the answers can be easily discernible to all who examine the charts.

The statistical procedures referred to are the control-chart procedures originally proposed by Walter A. Shewhart of the Bell Telephone Laboratories. The data of our production log sheets, when plotted on charts such as that shown in Figure 1, can reveal answers to most of the questions posed above. To take full advantage of all statistical interpretations possible, the usual practice is to plot in chronological order the average of five test results on the variable being measured, and on a companion chart, to plot the maximum difference obtained in the five test values.

Upper and lower control limit values can be calculated from a series of such "statistics" and the probability of a value exceeding this limit can also be calculated. If more than 99% of the values are normally within these limits, then certainly values outside should be considered unusual enough to warrant investigation.

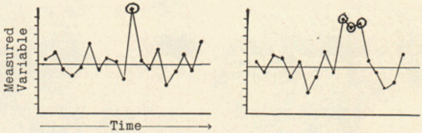
Let us accept the statement that plotting averages and ranges is the method to obtain optimum information, but for the ease of presentation, consider plotting the log sheet data as individual values. It is quite possible that our data would produce the six charts across the top of these pages.

Chart A shows a random scattering of values quite equally distributed about the average value. Chart B shows a cyclic effect and it is apparent that if this cycle were eliminated the process could be equal to that in A. Chart C reveals an upward trend in the data, charts D and E show a few values which seem out of place or questionable, and chart F indicates that although the variability in test results is about the same as in chart A, a change of level occurred.

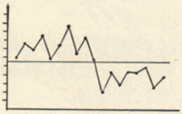
It is obvious from looking at these charts that, since chart A reveals no obvious shortcomings in the process control, it must therefore represent a fairly desirable state. Another look at chart A does reveal that most of the data are concentrated near the average value with a few values equidistant from the center line. This is to be expected. The expert marksman will hit the bull's eye dead center now and then, nick the bull's eye quite often, and place

Statistical presentation of log sheet data will do the following:

- Automatically adjust sampling and testing frequencies to fit the state of control. A period of trouble should mean more testing.
- Indicate what is considered normal operation to minimize the danger of over or under control.
- Give advance warning of impending trouble so preventive action can be taken before off-grade products are produced.
- Give readily observable clews to how much a process can be improved, or conversely, indicate if the process is incapable of being controlled within the limits required to produce a product which would consistently meet the specifications.
- Show how to determine, if it is a new product or process being demonstrated in the plant for the first time, when a sufficient number of trial runs have been made to justify the decision to approve the product or process, or reject it and ask research or development to add further refinements.



D and E. The circled values seem out of place or at least questionable



F. A change in level occurred, although variability in test results is the same as in A

the remaining shots *around* the bull's eye the rest of the time. If his shots formed any other pattern he would know something was wrong and that he could do better by correcting the trouble. So it is with our charts. Chart A represents a process in excellent control. In fact, since no pattern is discernible, the variations noted are those due to chance, and a deliberate change in manufacturing procedure, formulation or raw materials will be necessary to narrow the spread of test results.

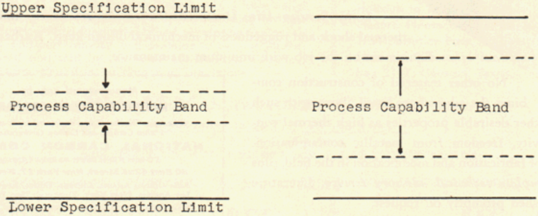
SPECIFICATIONS. Whether an improvement should be attempted with a process such as in chart A can depend on a host of considerations such as, the competitive position, the customer requirements, and the cost involved. If the specification limits for the examples shown in the charts were taken into account, it would be obvious to what degree the process satisfied the specifications. If all the process values were well within these limits, improving the process might seem questionable unless customer's requirement or competitor pressure dictated otherwise. However if some values are outside, even with the ideal process pattern shown in chart A, then improvements are likely to be costly and time consuming to develop. Less difficulty should be experienced in improving the other process patterns illustrated in the charts.

INSPECTION AND TESTING. During the course of manufacture, inspection and testing of some sort are required to determine how well processes are being controlled, and how near the final product will meet specifications. Simple plotting of these data in log sheet form gives no clew whatever as to how adequate the frequency of testing is.

The control chart procedure does, however, establish a means for determining this factor. If product quality varies widely and erratically, there is no alternative to frequent, and usually costly, inspection. In carefully controlled production, however, erratic quality is the exception, and with enough test pieces to establish the quality level, it is possible to both interpolate and extrapolate between and beyond the actual test pieces with a predetermined level of confidence.

It is immediately apparent that, in the case of Figure 2A, there is less need for frequent inspection than in the case of Figure 2B, although each requires constant vigilance to guard against faulty quality resulting from the patterns of charts B through F. Seldom is the arbitrary selection of test frequency optimum from the criteria of either quality control or economy of inspection.

There are few things as costly, or at least as distressing, as the lot marked REJECT. Nor is it likely that rejected lots will ever be a thing of the past. Yet much can be done in the way of preventive action, if corrective measures can be taken while the product is still well within the tolerance limits. Sound warnings are provided by the control chart when too much of the product lies below or above the established target, when trends develop, when control is shown to be erratic. This is the dynamic attitude of statistical quality-control, and it is perhaps the reason that few production men, once they have become used to the new terminology and the new way of thinking, will rarely back track from statistical quality-control to form procedures.



(A) (B)

Figure 2