If a chart persists in staying out of control, or if it keeps going out of control at frequent intervals, this should be called to the attention of the supervisor.

6.0 *FREAKS AND OBVIOUS DEFECTS*

Follow the directions of the layout in disposing of shorts, opens and other obvious freaks.

Layouts

In addition to the general instructions given above, all process control activities should be covered by Process Control Layouts. The layout should include:

(1) Identification data describing the product, operation, characteristic to be controlled, etc.

(2) Points in the sequence of operation where samples are to be taken.

(3) Sample size, frequency of check and method of selecting the sample.

(4) Characteristics to be checked.

(5) Method of measurement or classification.

(6) Information to be recorded and plotted.

(7) Criteria for determining when action is needed.

(8) Action to be taken.

The following are examples of:

(a) A Process Control Layout.
(b) A Data Sheet for $\bar{X}$ and R charts.
(c) A Data Sheet for p-charts.
(d) A Standard Control Chart Form.

Also included (pages 212 and 213) are examples of shop control charts which have the proper marking, notes and comments.

PROCESS CONTROL LAYOUT

Title	
FRONT CONTACT ASSEMBLY	Assoc. Dwgs. P 483518 Used on 218-A Mercury Switch

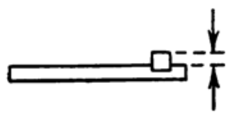
OPERATIONS AND METHODS	FACILITIES
The normal sample shall be 5 units every two hours from the front contact welder.	
1. *Contact Height* shall be .0185 shop min. to .0199 shop max. Record readings on form AP 510F. Plot a point on the $\bar{X}$, R chart for every 5 units checked.	Comparator
	
2. *Contact Positioning* shall be .077 min. to .083 max., measured from the midpoint of the height of the contact to the end of the lead wire. Record readings on form AP 510F. Plot a point on the $\bar{X}$, R chart for every 5 units checked.	Comparator
3. *Contact Weld.* Check to see whether the contact is firmly bonded to the wire by pushing against it with a tweezer. Check for weld splashes which result in a pile-up of metal at the weld. Record the number of defective units for poor welds and weld splashes on form AP333-y. Plot a point on the number-of-defectives chart for (a) poor welds and (b) splashes, plotting one point for every 20 units checked.	Tweezer Visual
Note: The process checker shall discuss the pattern or method of checking with the machine setter, supervisor, or engineer if he is in any doubt as to the method of carrying out these instructions. The process checker shall mark the pattern in accordance with the General Instruction for Process Control and shall notify the supervisor of any out-of-control conditions. Charts which continue out of control for more than 4 hours shall be hung on the "trouble board" for the supervisor's attention. All points shall be plotted immediately after the sample has been checked.	

Fig. 214. Example of process control information in a process control layout.

AP 510-F (7-52)

DATA SHEET FOR $\bar{X}$ AND R CHART

PRODUCT DATE

CHARACTERISTIC DEPT.

1	2	3	4	5	6	7	8	9	10	11	12
TOTAL											
$\bar{X}$											
R											
13	14	15	16	17	18	19	20	21	22	23	24
TOTAL											
$\bar{X}$											
R											

Fig. 215. Data sheet for $\bar{X}$ and R chart.

FORM NO. **DATA SHEET FOR PERCENT DEFECTIVE CHART**

PART NO.

PRODUCT

NO.

				LIST OF CHARACTERISTICS																		TOTAL DEFECTIVE	% DEFECTIVE	INITIALS
1																								
2																								
3																								
4																								
5																								
6																								
7																								
8																								
9																								
10																								

Fig. 216. Data sheet for p-chart.

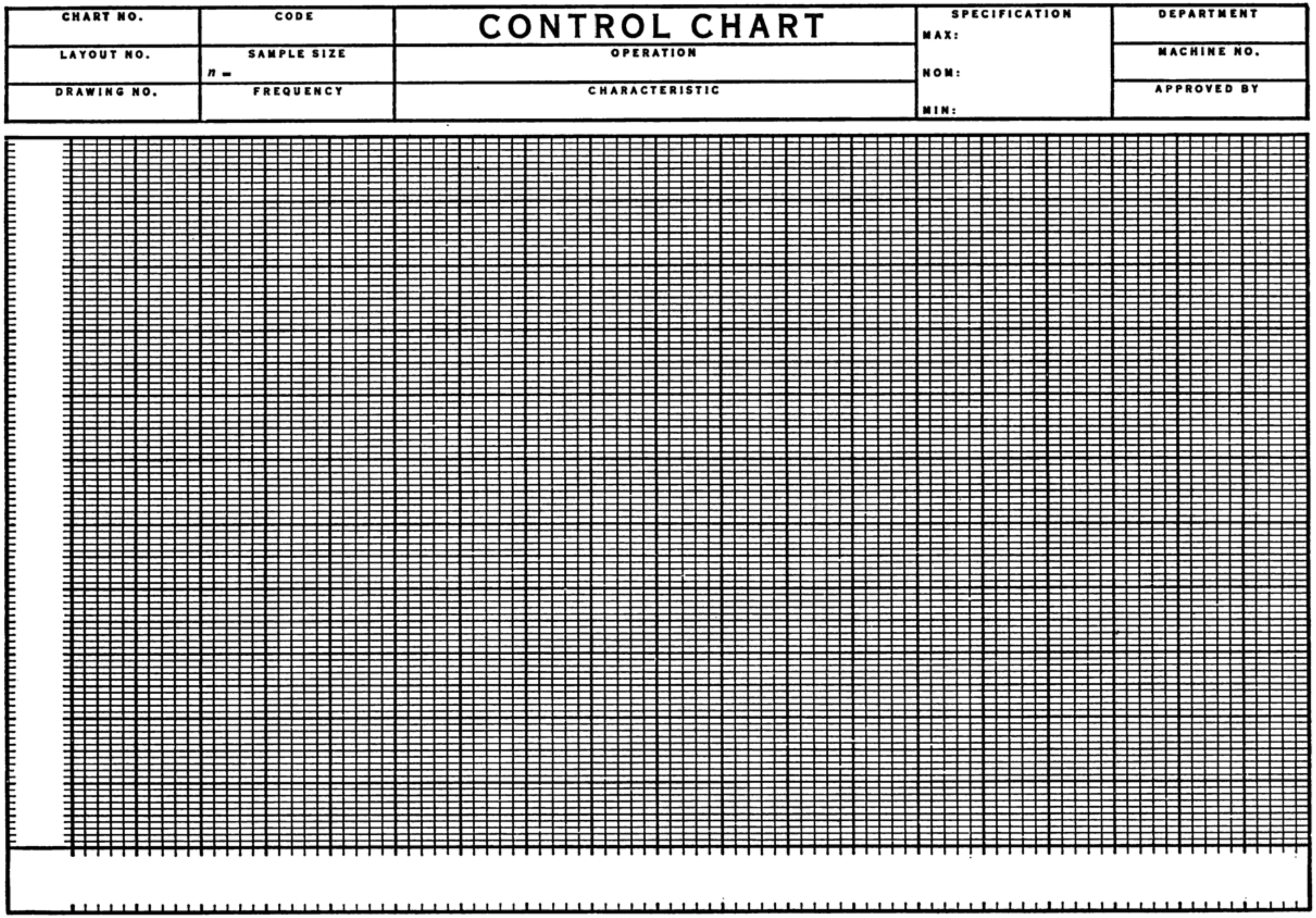


Fig. 217. Standard control chart form.

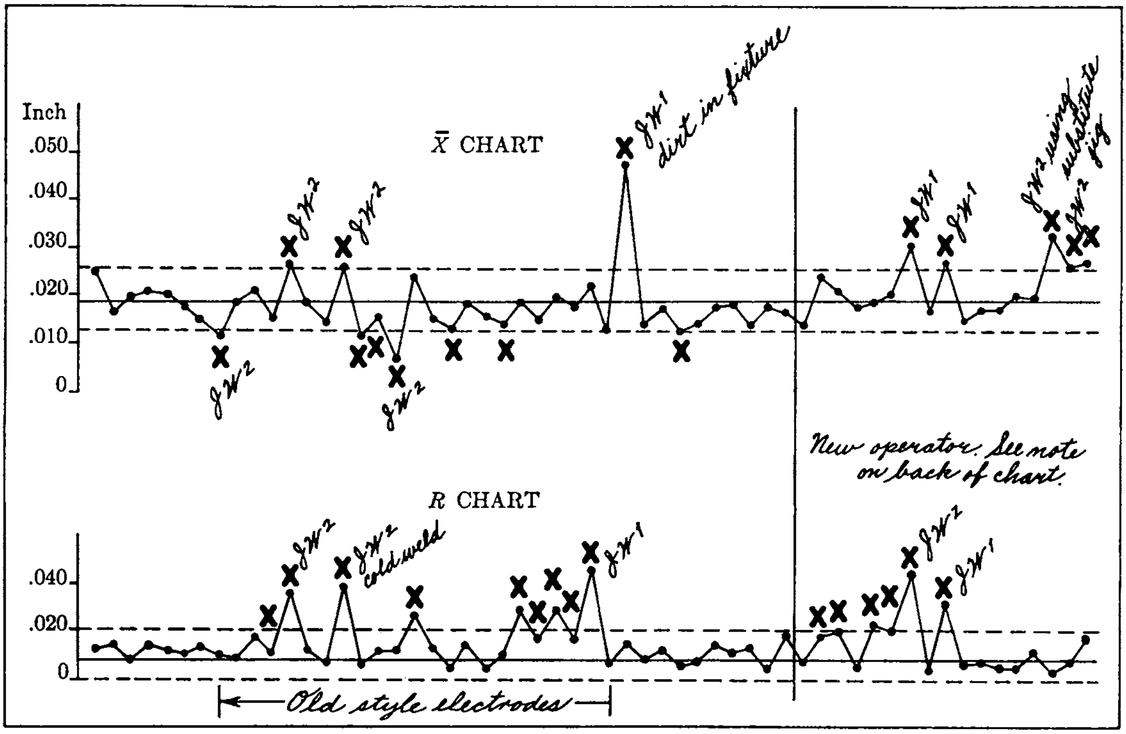


Fig. 218. Example of notes on a shop control chart. The number following the signature is a code number indicating the type of action taken: for example, "1" means the machine was adjusted; "2" means the operator was given instructions, etc. The initials are those of the machine setter or other person making immediate use of the chart.

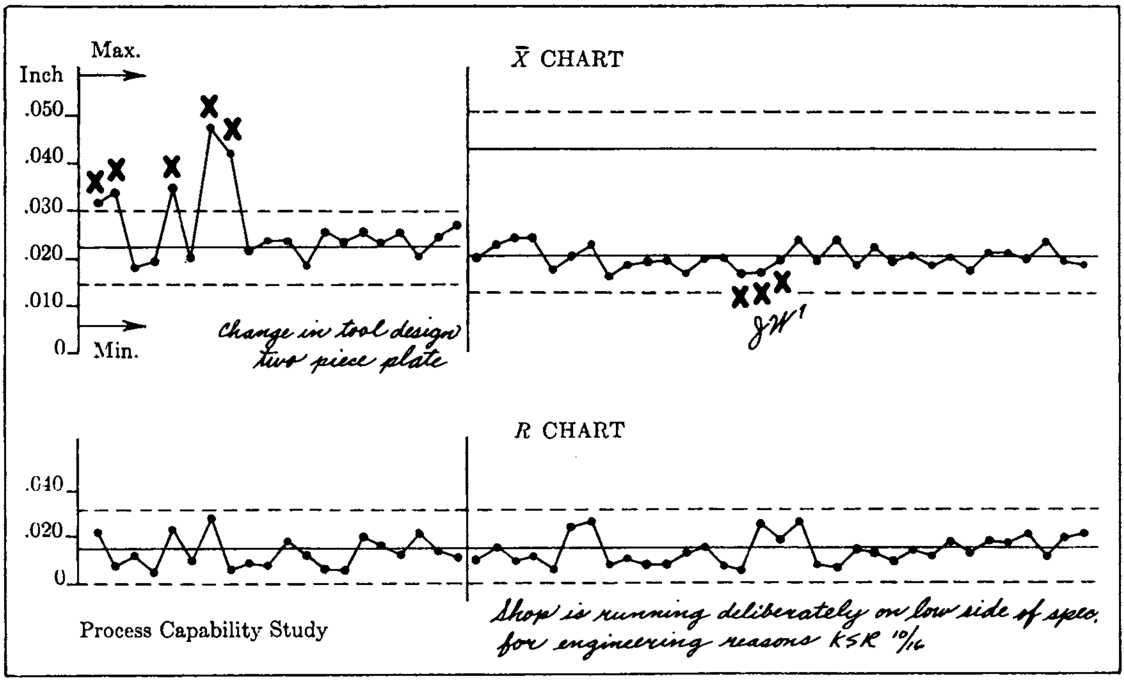


Fig. 219. Engineering comments written on a shop control chart. If the chart is being used primarily for engineering information, it should be labeled "engineering study."

B-4 INSTRUCTIONS FOR PROCESS CHECKERS

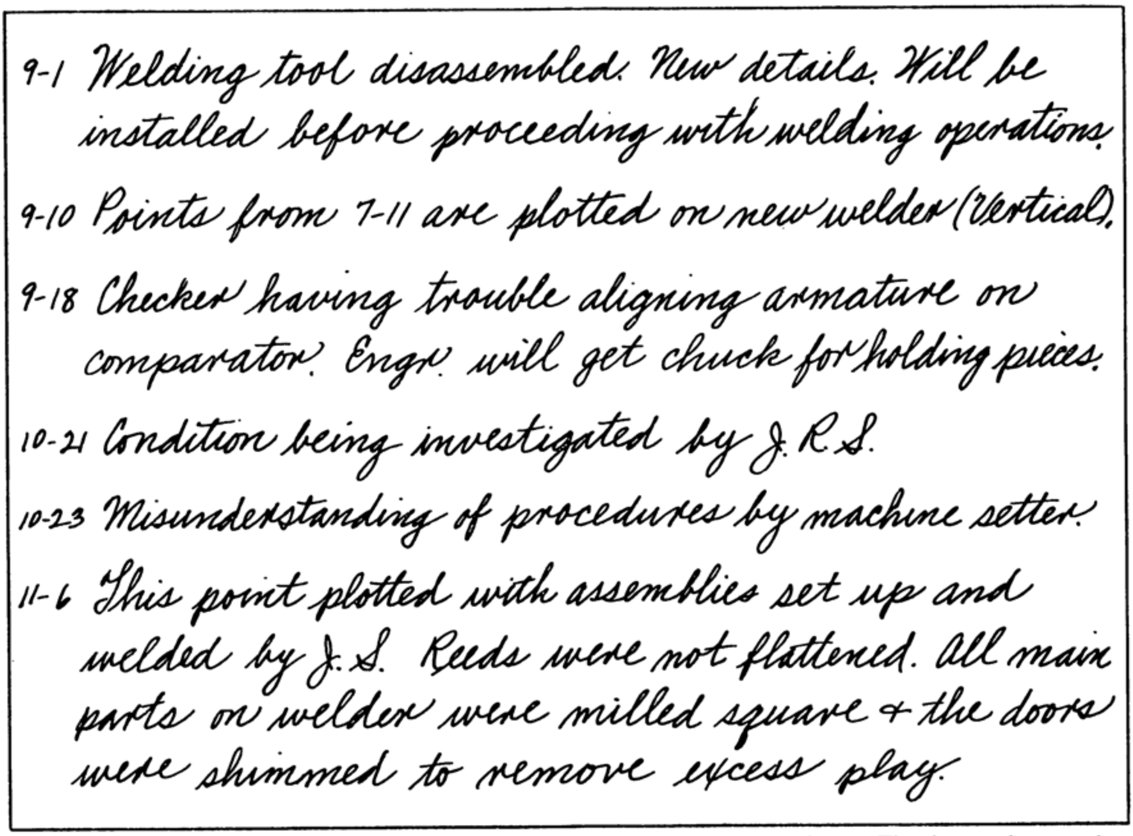
The following information is intended to be used by Operating process checkers. The term "process checker" means anyone in the Operating organization who is responsible for taking samples and plotting charts. This person may be a "checker" who is specially set aside to do this type of work for the group; he may be the operator himself, the operator's helper, the machine setter, a layout operator, a group leader, etc. The process checker is expected to know and do the following things in connection with shop control charts.

B-4.1 What the process checker should know

A process checker needs to know how to select samples properly; how to check the necessary characteristics; how to make calculations such as averages, ranges or percentages; how to plot the charts and recognize unnatural patterns.

The Quality Control Team is responsible for seeing that the process checker is adequately trained for this job. The training should include careful practice and drill in the interpretation of the patterns, including the marking of x's as described in the "General Instruction for Process Control." Each process checker should have a copy of this instruction and should be familiar with its provisions, as well as with the provisions of all specific process control layouts which the checker is expected to use.

A new process checker should work with some member of the Quality Control Team (generally the quality control engineer) long enough to make sure that the job routines are thoroughly understood. Much of the success of the control charts depends on the promptness and reliability of the process checker.



9-1 Welding tool disassembled. New details. Will be installed before proceeding with welding operations.

9-10 Points from 7-11 are plotted on new welder (Vertical).

9-18 Checker having trouble aligning armature on comparator. Engr. will get chuck for holding pieces.

10-21 Condition being investigated by J. R. S.

10-23 Misunderstanding of procedures by machine setter.

11-6 This point plotted with assemblies set up and welded by J. S. Reeds were not flattened. All main parts on welder were milled square & the doors were shimmed to remove excess play.

Fig. 220. Machine setter's comments written on the back of a shop control chart. The dates refer to points which were out of control on the chart.

B-4.2 Taking samples

Since all the information on the control charts will come from samples, it is important to see that the samples are selected properly. The proper taking of samples is governed by statistical laws. If the one who selects the samples breaks the statistical laws, the samples can easily give false or misleading results.

Some of the things a process checker needs to know in taking samples are spelled out in the layout. The layout ordinarily states the sample size, the normal interval between checks, and what product the sample should represent. For example, it may be required to check the last few pieces made; or to take the sample from a pan containing all the parts made since the last check; or to take some parts from each of four operators, etc. All such provisions in the layout must be carefully and strictly carried out. In addition the process checker is responsible for the following:

(1) Samples should give an unbiased picture of the process. Do not deliberately take units that you have reason to believe may be different from the others. If you walk up to a machine or operator and take the last 5 pieces made, that will be an unbiased sample of the process as it was being run at that moment. If you select 5 pieces purely by chance from a pan of pieces, that will be an unbiased sample of the process as it was run during the time the parts were being made.

Do not take samples all from one side of the pan or all from the tray on top of a pile of trays. Do not deliberately pick out the units which look oversize, dented, etc. Do not take samples deliberately where there is something abnormal about the process—for example, set-up parts or work which you know the operator has spoiled. On the other hand, do not deliberately pick the parts which you believe to be good.

(2) Do not take part of the sample from one machine, operator, etc., and part from another unless you have been instructed to do so by the layout.

(3) If checking is to be done at intervals such as one-half hour, do not take the sample always exactly at 10:00, 10:30, etc. If you did this, people would be able to anticipate the sampling and might do their work differently.

(4) Always use the sample originally selected. Do not re-sample. That is, if you do not like what you find in one sample, do not decide to ignore that sample and take another. This would prevent the control chart from giving the proper information.

(5) If you find a "freak" in the sample, handle this as instructed in the layout. If the layout does not cover this point, get special instructions from your supervisor.

(6) The sampling intervals in the layout are supposed to be sufficient for normal conditions when the job is not in unusual trouble. In an emergency the supervisor may ask you to take more frequent samples. If you take more frequent samples, be sure to plot *all* the samples. Do not throw any of the data away.

This does not apply to set-up checks if the layout says they are not to be plotted.

If the supervisor finds that the sample size, the sample frequency, or the method of selecting the sample as specified in the layout is not suitable for the job, he should take steps to get the layout changed. Until it is changed, do not alter the method of taking samples. If you change the method of sampling, you may unconsciously violate the statistical rules. Then you will lose information that is needed for running the job.

B-4.3 Plotting and marking the charts

A process checker is expected to know the following rules for plotting and marking control charts.

(1) Plot the chart promptly, as soon as you have the data. Process control charts, if they are to do any good, must be always up-to-date.

(2) Watch the arithmetic. Be careful in calculating, especially the range (R). Be

sure you really have the highest and lowest measurement when you subtract. Watch the decimal point if there is one. Avoid plus and minus numbers if possible, because it is very easy to make mistakes on these.

To avoid errors, use numbers as simple as possible. For example, if the measurements are .1276, .1249, etc. (all the numbers starting with .12) it would be sufficient to work with 76 and 49. Call it to the attention of the supervisor if you think you see a chance to simplify numbers.

Above all, if the chart looks unusual or "queer" after it is plotted, check the arithmetic before you do anything else. The following is a useful list of checks:

a. If you use mental arithmetic most of the time, check a point occasionally by doing it with pencil and paper.
b. If you habitually obtain averages by taking a total and then dividing by 5, check yourself occasionally by multiplying the total by .2.
c. Glance over the individual values occasionally, and guess what $\bar{X}$ would be.
d. Occasionally add your R value to the lowest individual value in the sample, and see how the sum agrees with the highest individual value.
e. Check percentages occasionally by multiplying the percentage and the sample size, and see how the result agrees with the number of defective units.

(3) Watch the scale of the chart. Be sure you understand it and can plot the points in the proper place. In particular, note that the scale on the R chart may be different from the scale on the $\bar{X}$ chart. This makes the R chart a little more difficult to plot until you become accustomed to the change in scale, but it increases the readability and usefulness of the chart for the people who need to use it.

It is a good idea to check the plotting on any chart occasionally by finding the $\bar{X}$, R or p values (or other values to be plotted) on the vertical scale at the left-hand side of the sheet and then using a straight-edge to check the proper location of the point.

Tell your supervisor if you find that the scale is difficult to use.

(4) Plot all the points on the chart, including the points which go out of control. The chart would be of little or no value if it showed only the best points. If the layout states that when a point goes out of control you should have the process corrected immediately and then take another sample, both samples should be plotted. The chart will show that the process was corrected and brought back into control.

(5) Carefully follow the frequency of checks as specified in the layout.

(6) Identify all points by date, machine number, shift, etc.

(7) As soon as each point is plotted, check to determine whether it should be marked with an "x." Follow the directions in the General Instruction for Process Control. Mark the point if (a) the point itself goes outside of the dotted control limit, or (b) the point is part of an unnatural pattern when considered with the immediately preceding points. The General Instruction for Process Control tells how many preceding points should be considered and how the check should be made. Do not consider the plotting finished until you have marked all the x's that are called for.

(8) Be sure to put notes on the chart to record any change in the process which the supervisor, from his experience, feels could affect the pattern. For example:

- New lot of piece parts.
- Solder with higher proportion of tin.
- Different soldering tip.
- Fixture repaired.
- New operator or inspector.
- Different machine.

These notes will be needed if trouble should develop later in the process.

Finally, the person who takes the data needs to have a good understanding of the requirements. He should know where to check the parts (at edge, center, etc.) He should know how many checks to make on each part. He should know how to use the gage and record the measurements accurately. In the case of visual checks he must have a clear understanding of the criteria or visual standards. If in doubt about any of these things, he should check with the supervisor immediately. A chart is of little use unless it is based on accurate data.

B-4.4 Appearance of control charts

Process checkers occasionally tend to worry about the appearance of their control charts. It is difficult in the shop to keep the charts looking neat and clean. Neatness of course is an asset, and the process checker, in plotting the points and marking x's, should be careful to do a tidy and accurate job. Careless plotting of points and drawing of lines, or smudged erasures, only make the charts more difficult to read.

If the control charts can be neat and clean as well as useful, so much the better.

On the other hand, charts that are actually being used are likely to become well-thumbed, spattered with grease and oil, and scribbled up with marks and notes. Charts that show this evidence of being discussed and used are much more likely to be doing their intended job.

B-4.5 Why should the Operating people plot their own charts?

In a quality control program of the type described in this Handbook, it is essential for the Operating people to plot their own charts. Quality control programs tend to be short-lived and ineffective when people outside of the Operating organization take over the job of plotting and maintaining the charts. The reasons for this are the following:

(1) Process control charts when properly used are part of the "make" operations. They are one of the essential tools for doing the Operating job. They are similar to screw drivers, fixtures, jigs and other essential equipment.

(2) The Operating people should do everything necessary to make the product and make it right. This includes the process control charts.

In the earliest stages of a quality control program, the Operating people sometimes need help in starting the first charts. The earliest charts may be plotted by inspectors, statistical clerks, quality control engineers, etc. However, all such charts should be turned over to the Operating department to plot at the earliest possible moment.

Operating people need their own charts in the same way that the driver of a car needs his own eyes when driving along a crowded highway. No driver would wish to drive blindfolded while someone else watched the traffic and road conditions and instructed the driver when to turn, speed up, stop for traffic signals or attempt to pass another vehicle.

When the Operating department obtains data for its own benefit and plots and uses its own charts, the process controls are functioning in the way they were intended to function. The Operating people are (a) sure of what action to take, (b) able to take it with the least possible delay, and (c) completely responsible for running their own job.

PART C
Action on Control Charts

C-1 IMPORTANCE OF PROMPTNESS IN ACTING ON SHOP CHARTS

In all cases the planning of shop control charts assumes that the checks will be made on schedule, that the diagnosis will be made promptly, and that the remedy will be immediately effective. Any delay in action may have the following adverse effects:

(1) Delay may mean that unnecessary amounts of undesirable product are produced. This will reduce yields, increase scrap and increase the amount of product rejected by Inspection.

(2) Delay may mean that the cause of trouble is harder to identify, and in many cases can not be identified at all. It is an axiom in quality control that the time to identify assignable causes is while those causes are active.

C-2 FIRST TYPE OF ACTION: To be taken by the Process Checker

As soon as the process checker observes that a chart is out of control, he should immediately initiate the action called for in the process control layout. The chart is "out of control" when any of the recent points are marked with x's in accordance with the standard tests (pages 23–28), or when such other indications are obtained as are described in the pertinent layout. The action to be taken by the process checker ordinarily consists of notifying some responsible person that an out-of-control condition exists. This person may be the machine setter, layout operator, supervisor, or in some cases the individual operator.

In addition to notifying this person that action needs to be taken, the process checker may be asked to take other steps to make sure that the action is not delayed. Some supervisors provide a special hook or board on which the process checker can place the charts which are not brought back into control immediately. In other cases the process checker merely notifies the supervisor or adds a note to the chart when action has not been taken. The principal requirement is that something must be done about every chart that shows a need for action. It must not be possible for charts to be neglected.

C-3 SECOND TYPE OF ACTION: To be taken by the Operator, Machine Setter, Layout Operator or other responsible person

Depending on the nature of the process and the condition of the chart which is out of control, the machine setter should check the process, machine, equipment, parts, operator or methods. If possible, he should correct the out-of-control condition immediately. If immediate action is not possible he should promptly initiate the proper action and also inform the supervisor. If action is to be delayed for any reason, the responsible person should write a note on what has been done. Notes that are brief enough can be written on the face of the chart. Longer notes or explanations should be written on a separate sheet of paper attached to the back of the chart. See Figure 220 on page 213.

If the machine setter or other responsible person is unable to tell what action should be taken, he should promptly notify the supervisor and get special help. The supervisor should in all cases hold his people responsible for either (a) taking action themselves, or (b) initiating action on the part of someone else.

C-4 THIRD TYPE OF ACTION: To be taken by the Supervisor

The supervisor should investigate immediately any cases where his people need help in using the charts. In addition to this, he should watch the "trouble board" or other provision made for singling out the charts which have not been brought back into control. He should also spot check all charts on the job occasionally to make sure that the provisions for taking action are being carried out. In general, the cases which are brought to the supervisor's attention will be one of two types.

(1) *Where the necessary action is known but cannot be taken immediately.* In this case the supervisor should write an explanation on the control chart and should discuss the matter fully at the next meeting of the Quality Control Team.

(2) *Where the necessary action is not known and the supervisor must determine it.* This requires ability on the part of the supervisor to investigate and interpret. Since every chart which calls for investigation is a valuable medium for training, the supervisor's investigation should be carried out with the help of the machine setter or other responsible person.

Investigation to determine what action is necessary should proceed as follows:

a. Make certain that x's are properly marked on all charts in accordance with the standard tests. The charts are far easier to interpret after the x's are marked.

b. Relate the chart patterns, if possible, to things you know about the operation or the process. The longer you have had control charts on the job, the easier this will be.

c. If the reasons for the behavior of the chart cannot be discovered immediately, take the following steps:

1. Identify any bad or unusual product as specifically as you can. For example:
   - Which operator made these units?
   - Which machine?
   - Which lot of material did they come from?
   - At what bench were they processed?
   - At what time of day?
   - From which beaker did the etching solution come that was used for etching these units?
   - What had the beaker been used for before these units were etched?

   Remember also that inspection and testing can be a variable as well as the product. The likeliest cause might be a new gage or test set, or a new process checker. Careful identification of the product associated with unusual patterns will often give clues to unsuspected changes in the process or the method of testing.

2. Beware of assuming too readily that "we are doing everything the same way" or that "nothing has changed." There must be a change in the process if the control chart is showing a different pattern.

3. Charts that are difficult to interpret by themselves often become clear when they are seen in conjunction with other charts. Form the habit of looking at all the charts on your job in a regular order, starting with the earliest operations and going through to the end. Watch for charts that react together, or a chart at a later operation which lags behind another chart by about the time interval that is required for processing. Occasionally you may need to start a new chart to throw light on a chart you already have.

   If there is difficulty in interpreting a p-chart, try substituting an $\bar{X}$ and R chart.

4. For special help in interpreting patterns see pages 161–180. The examples of causes given there will help to stimulate your own ideas. They should make you think of similar causes which might apply to your own job.

5. Most causes are associated with ele-

ments in the process which do not involve "singleness"; that is, more than one operator, more than one machine, more than one chuck on the machine, more than one surface condition, etc. A single machine or operator may behave like more than one under certain conditions: for example, looseness of a bearing, excessive play in a fixture, fatigue on the part of a human being.

As causes are discovered which are capable of affecting the control charts on your job, jot them down on the chart so you will have a permanent record. The things you discover about causes on one product will often prove to be helpful in studying other products.

6. If necessary, discuss the pattern with others who have expert knowledge of the job. This should include design engineers, product engineers, maintenance personnel and inspectors as well as your own people. Unusual patterns, or patterns with unusual causes, should be discussed promptly with the other members of the Quality Control Team.

7. If the causes are deeply hidden, it may be necessary to set up a "designed experiment" to isolate the source of the trouble. This is explained in the Engineering Section, Part B.

In interpreting control charts remember that only a small part of the information necessary to solve the problem will come from the control charts. Most of the information must come from job knowledge. Nevertheless, in spite of the fact that statistical analysis will not solve the whole problem, the supervisor should be careful not to underestimate its importance. Without the statistical help furnished by the control charts, the job knowledge of the supervisor will not have maximum effectiveness. The same can be said of the knowledge of the engineer.

As soon as the reasons for any unusual behavior of the chart are known or suspected, do what is indicated to bring the chart back into control. Remember that shop charts must be brought into control as quickly as possible in order to restore or maintain an economical situation.

C-5 FOURTH TYPE OF ACTION: To be taken by the Quality Control Team

While shop people are expected to take immediate action as indicated above, the Quality Control Team is fundamentally responsible for making sure that the shop control charts work. If the shop is not reaping benefits in the form of fewer troubles, or if the shop people have difficulty in determining what action to take, the Team should immediately check the following list of possible reasons and correct any of these conditions which they find to be responsible:

(1) It may be that the shop is maintaining charts which are not needed, or, on the other hand, the Team may have failed to set up all the charts that are needed.
(2) The shop may be using incorrect methods of selecting samples, incorrect frequency of samples, incorrect control limits, etc.
(3) The measurements, calculations or plotting may be in error so that the chart is not showing a valid picture of the process.
(4) The shop may be failing to take the indicated action when charts go out of control.
(5) The Quality Control Team may not be taking an active enough interest in the causes for out-of-control conditions.

Among the things which the Team may need to do directly in connection with shop charts are the following:

a. Reinstruct the operator or process checker.
b. Provide a better method of checking the machine setting.
c. Provide a way of getting better piece parts.
d. Issue an order for overhauling a machine.
e. Get better maintenance on fixtures, test sets, soldering tips, etc.
f. Have a gage checked.
g. Confer with a supplier.
h. Change a method.
i. Modify a tool.
j. Modify the layout.
k. Modify the specification.
l. Conduct a designed experiment.

C-6 USING SHOP CHARTS TO EXPERIMENT WITH THE PROCESS

When properly guided by the decisions of a Quality Control Team, process control charts can be used to experiment with a going process. Changes in the process are introduced deliberately and preferably one at a time. The effect of the change is observed by noting the pattern on the control charts. It is important to allow sufficient time for the change to affect the pattern (that is, an adequate series of points). The effect of the change will not necessarily be evident from the first one or two points.

The following are forms of experimentation which may be carried on with control charts:

(1) *Engineering studies.* All engineering studies in the shop should be tied in closely with the process control charts. The engineer needs the information on the charts in planning his studies. The supervisor needs the charts to enable him to cooperate effectively with the engineer's activities. Some of the most valuable engineering experiments are carried out during production, and these need to be checked constantly by reference to the shop charts.

Furthermore, it is important for large shop-type variables to be under control, or at least to be properly evaluated and allowed for, if the engineering experiments are to be successful. Once the Quality Control Team is set up and functioning, it tends to assume a more and more important role in the planning and conducting of production experiments.

(2) *Running near the high or low side of a specification.* Supervisors often find it necessary to have parts on the high or low side of nominal in order to compensate for other conditions in the process. With control charts it is possible to say just where the distribution of parts should run, and maintain it there consistently without danger of its shifting too far. Because of the charts, the supervisor, the engineer and the person responsible for making the piece parts are all fully aware of what is being done. Other elements in the process can be adjusted to fit the off-center distribution. This avoids the danger of getting into trouble because of an unforeseen combination of distributions.

The distribution may be run off-center on either a permanent or temporary basis. A few words of caution are necessary.

(a) Whenever you find it advisable to run toward one side of a specification, be sure to discuss this thoroughly at your quality control meetings. It may be that the specification can be changed to coincide with the most desirable operating level.

(b) It is not always wise to shift a distribution to compensate for a temporary trouble. In most cases it is better to attack the main trouble directly and correct it at its source.

(c) Running a distribution temporarily on one side may affect other characteristics in ways you have not foreseen. This can be the source of many supposedly "mysterious" troubles.

In general, try to decide on the best place for the process to run and then keep the process there as consistently as possible. This does not apply to cases involving tool wear where we deliberately let the distribution drift from one side to the other for economic reasons.

Experimenting with a process is quite permissible and even desirable under the guidance of a Quality Control Team. However, it is seldom advisable for the shop to attempt such experimenting alone. The shop needs the advantage of the product engineer's technical knowledge and the quality control engineer's statistical experience for this type of experimentation to be successful. In many cases it is necessary to run formal "designed experiments" as discussed in the Engineering Section.

C-7 MEANING OF AN "ECONOMICAL STATE OF CONTROL"

A perfect state of control is never attainable in a production process. The goal of the process control charts is not perfection, but a reasonable and economical state of control. The problems of defect prevention are similar in many ways to those of accident prevention. We know that it is impossible to eliminate accidents entirely; but we also know that accidents can be driven to greater and greater infrequency by vigorously tracking down assignable causes and then considering all practical means of minimizing or eliminating those causes. The same thing is true of the prevention of defects and other shop troubles.

For practical purposes, therefore, a controlled process is not one where the chart never goes out of control. If a chart never went out of control we would seriously question whether that operation should be charted. For shop purposes a controlled process is considered to be one where only a small percentage of the points go out of control and where out-of-control points are followed by proper action.

In cases where the assignable cause is beyond the operator's control and there is no practical remedy which can be applied immediately, the chart may continue out of control for a number of points until new material or facilities become available or suitable countermeasures are developed. It is necessary to distinguish between such cases and cases where action is merely being neglected. One way of doing this is to put proper notes on the chart.

Charts on the work of new operators are not expected to show control; the charts themselves are being used as a medium for training. Also, on new products or products that are still under development, many of the shop charts are doubling as process capability studies. Out-of-control patterns on such charts may be contributing important information on the cause and effect relationships between the major variables.

While action should always be taken promptly when a shop chart goes out of control, the action itself is more important than the actual degree of control. Operators should understand that they will not be subject to criticism when a point goes out of control.

C-8 SUMMARY CONTROL CHARTS

As an aid to maintaining an economical state of control, the Quality Control Team may wish to set up a "summary control chart" to picture the degree of control of all charts being used on the job. Summary control charts are particularly useful where there is a large number of individual charts (for example, one or more charts for each of a number of operators; or a large number of separate charts on individual operations). The summary control chart is constructed as follows:

(1) Group together all the control charts which are to be summarized. If a particular operation has many similar charts because there are many individual operators or machines, group together all the charts at that operation. It is also possible to combine charts at different operations: for example, all the charts for a particular

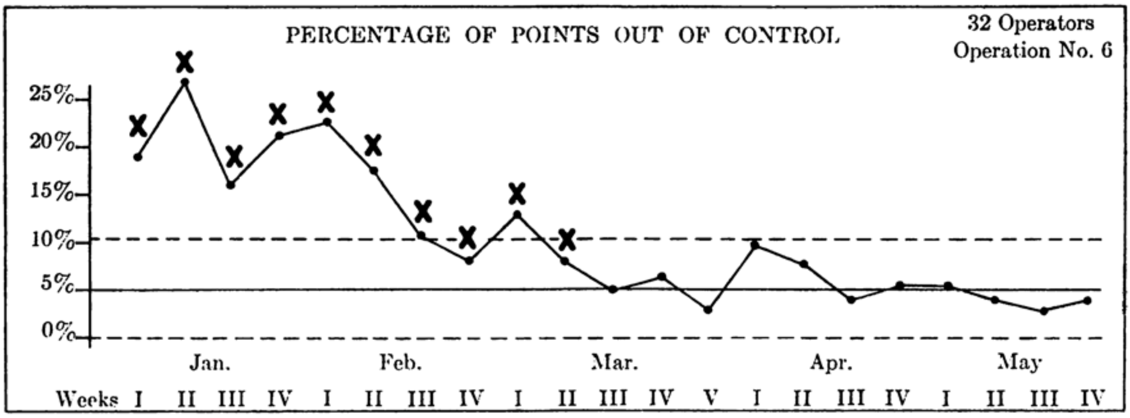


Fig. 221. Summary control chart.

Operating section or pay group, or all the charts for an entire product line or shop. Group the charts in any way that will be useful in studying the state of control.

(2) Choose a time interval for plotting the summary points. The usual choice is one week, but daily or monthly points may be plotted if desired.

(3) Count the total number of points plotted on all charts during the chosen interval, and also the number of points marked with x's when applying the standard control chart tests. Divide the number of "points marked" by the number of "points plotted" to obtain the percentage of points out of control. Obtain control limits for this chart by using the moving range.

This type of chart serves as an indicator of progress in addition to making it easier to study and manage a large number of charts.

Figure 221 shows a summary control chart covering 32 individual control charts. The steady improvement on this job is more easily seen on the summary chart than by looking at the 32 charts individually.

PART D
Quality Control Teams

The importance of the Quality Control Team has been emphasized throughout the Shop Section. It appears in the planning and installation of the charts (Part A), the training of the process checker (Part B), and the use of the charts as a guide to action (Part C). The following are further details on the activities of this Team.

D-1 REGULAR MEETINGS OF THE TEAM

As outlined in the Fundamental Section, the Quality Control Team consists of the product engineer, the Operating supervisor and the quality control engineer assigned to a given area. The primary purpose of the team is to make sure that there will be direct and constant co-operation between Operating and Engineering in all problems having to do with quality control, and also that the statistical methods will be used properly and consistently. The first step in forming a Quality Control Team is to arrange a meeting between the supervisor and the engineers, to consider the job from the point of view of process control and to plan the first capability studies or charts. Thereafter, the team should meet regularly once a week, or every other week, or once a month, depending upon conditions on the job. Meetings should be more frequent in the early stages of the program than after the process has begun to come into control. It is seldom necessary to meet more often than once a week. It is not advisable, even on a well controlled job, to have meetings less often than once a month.

The principal business of a quality control meeting should be to look at control charts. One member of the team should gather up all the charts that are currently in use and bring them to the meeting.

The following action is normally taken at each meeting:

(1) Check up on the action that was promised at the last meeting.

(2) Go over all charts in order (by operation) and note any progress. Note also any characteristics that are giving trouble and any charts that seem to be reacting together. Discuss and tie down the causes for unnatural patterns. If this is not possible immediately, plan the next step to take.

(3) Remove any charts that are no longer needed. Agree on changes for any charts that need to be changed. Plan new charts or new capability studies if required. See that someone is provided to collect the data and do the plotting.

(4) Decide on new action as indicated by the current state of the job. This may be action which can be taken by the Team members themselves or it may involve other organizations or departments. Agree on the person who will take this action and set a time for it.

Among the other things done, but not necessarily at every meeting, are the following:

(1) The group may plan or write those portions of the layout which cover the taking of samples, recording of data and plotting or marking of charts.

(2) They may decide on the best way to train a new process checker.

(3) They may plan special meetings with the operators or machine setters either to keep them informed of progress or to introduce new sampling plans or charts.

(4) They may discuss the results reported by

Final Inspection or study the effect of a proposed new Final Inspection sampling plan.

(5) They may plan and carry out formal Designed Experiments or Cost Reduction Cases.

(6) They may plan and write periodic progress reports to keep other people informed of what they are doing and how the job stands.

In any case, the meetings should be conducted on a systematic basis and should be covered by a set of minutes or notes. Among other things, the minutes should include a summary of current cost reduction cases, planned or completed, involving the use of statistical quality control.

Among the problems brought up by a discussion of the charts are likely to be the following:

Tools, fixtures, gages, test sets.
Specifications, layouts, cases of tight tolerances.
Questions on the capability of machines, materials, methods.
New designs and engineering experiments.
Problems involving wage incentives, schedules, efficiency, capacity, inspection, work done by other departments and other matters of joint interest to Operating and Engineering.

The control charts provide a logical and impersonal approach to these problems. Both supervisors and engineers find that it is easier to get together and easier to get things done.

D-2 QUALITY CONTROL COVERAGE

The ideal amount of quality control coverage on the job is arrived at by studying all operations systematically (starting with the most troublesome as indicated on pages 187–189) in order to determine

(a) their capabilities, and
(b) whether permanent controls are needed.

It is not possible to keep track of quality control coverage by merely watching the number of control charts, since many of the operations may not require any charts. It is necessary, however, for all operations to be *studied.*

SUMMARY OF 2100 ORGANIZATION
STATISTICAL QUALITY CONTROL APPLICATIONS TO SHOP OPERATIONS

	NO. OF OPERATIONS (See note below)				
Product Line	*"A"*	*"B"*	*"C"*	*"D"*	*Total*
Rectifiers	26	8		149	183
General Purpose	93	6		60	159
Ballast Lamps			91	102	193
Small Runners	40		157	371	568
Miniatures	18	71	78	98	265
Carriers	22	35	149	173	379
Resistance Lamps	25	39	8	11	83
Repeaters	111	12		65	188
Glow Lamps	79	39	42	65	225
Chemicals	1	25	24	54	104
Grids		6	5	14	25
Glass	3	1	3	32	39
Total (2100 org.)	418	242	557	1194	2411

Note:
"A"—The operation has been thoroughly studied and charted. All that is required in the future is routine maintenance of the present controls.
"B"—The operation has been studied or charted, but there is further work to be done.
"C"—The operation has not been studied or charted from the point of view of quality control.
"D"—The operation has been studied, but no permanent controls are required.

Fig. 222. Report on number of operations studied.

Progress can therefore be measured by the number of operations that have been studied.

The term "operations" is used here in the same sense as in studies for Wage Incentive purposes. That is, it is the total number of distinct activities, or sets of closely related activities, required to produce the product. The Quality Control Team, in checking on quality control coverage, should use the list of operations which has already been made up for Wage Incentives.

At intervals of approximately six months, the Team should place each of the operations in one of the categories shown in Figure 222. One of the objectives of the Team should be to reduce the number of operations in category "C," and eventually to have all operations in categories "A" or "D."

At the time when the report in Figure 222 was issued, the quality control programs in this shop were about three years old.

Report on number of charts

In addition to keeping a record of the number of operations covered, it is helpful to keep records of the number of charts installed, by types. Figure 223 shows the record of control charts which accompanied the report on operations in Figure 222. Note that a separate record is kept of $\bar{X}$ and R charts, p-charts used to protect quality, p-charts used to reduce dropouts, and other miscellaneous charts. Note also that the teams have given an estimate of the total number of charts which they think may be required when the job is completely covered.

It is not possible to give a good estimate of the ultimate number of charts until a large number of operations have been studied.

D-3 REPORTS ON PROGRESS

Since management has a vital interest in the progress of the quality control program, one of the important duties of the Quality Control Team should be to keep management informed at regular intervals. Not later than one year after the start of quality control activities the team should issue a formal Progress Report. Thereafter, reports should be issued at intervals of approximately six months. The reports may cover quality improvement, cost reduction, reduction in the amount of inspection or any other of the goals of a quality control program. The following have been used successfully as indicators of progress.

Yields.
Scrap.
Percent defective.
Amount of re-work.
Repairs (or time spent on repair, in minutes).

	NO. OF CHARTS				
Product Line	$\bar{X}$, R	p *Qual.*	p *Drop.*	*Misc.*	*Total*
Rectifiers	28	1	11	4	44
General Purpose	67	31	22	1	121
Ballast Lamps					
Small Runners	8	14			22
Miniatures	37	233	3		273
Carriers	63	64	6		133
Resistance Lamps	120	18		1	139
Repeaters	59	9	12		80
Glow Lamps	92	53	48		193
Chemicals	170	12		87	269
Grids	30				30
Glass	53	21		31	105
Total (2100 Org.)	727	456	102	124	1409
Total (Inspection)		19		124	143
GRAND TOTAL	727	475	102	248	1552
ESTIMATE OF ULTIMATE NUMBER OF CHARTS	900	500	400	200	2000

Fig. 223. Report on number of charts in use in the shop.

Shop efficiency.
Informal cost reduction.
Formal cost reduction cases.
Number of inspectors.
Size of inspection samples.
Number of operators.
Amount of product rejected by Inspection.
Amount of product requiring detailing.
Number of complaints.
Improvement in Quality Assurance quality ratings (see page 270).
Number of control charts in use.
Number of operations studied and charted.
Number of operators working on jobs covered by process control.
Percentage of points out of control on control charts (see pages 221–222).
Number of jobs on sampling inspection.
Down-time on machines.
Changes obtained in specifications.
Amount of production.
Reduction of back schedules.
Estimates of savings.

Estimates of savings may be based on both tangible and intangible results.

Suitable material for Progress Reports can be obtained from

- Minutes of quality control meetings.
- Records of quality control coverage.
- Quality Assurance rates (see page 270).
- Records of the Inspection department.
- Records of Accounting.
- Cost reduction cases.

The reports should be concise and factual, should be expressed numerically and in the form of charts wherever possible, and should include a brief statement of quality control plans for the immediate future.

D-4 COST REDUCTION

It often develops during the meetings of the Quality Control Team that large cost reduction savings can be realized by applying quality control methods to the job. These savings may result from

A. A reduction in Final Inspection.
B. A reduction in the amount of sorting performed by Operating.
C. The use of process control charts to keep distributions centered and to keep processes in control.
D. The use of engineering studies to improve existing processes or to develop new processes.

Frequently the taking out of formal Cost Reduction Cases is one of the primary objectives of the Quality Control Team.

Many advantages are gained when Cost Reduction Cases are taken out jointly in the name of all members of the team. Progress on the case is reviewed periodically at the quality control meetings. The case and its aims are explained to the machine setters and operators so as to get their fullest co-operation. When the case is closed, a meeting is held to explain the accomplishment to the operators and others. Members of management often sit in as interested listeners at this meeting.

The cost reduction which results from the use of quality control methods, or which is evaluated and made permanent by the use of these methods, should be summarized periodically like any other report on progress. As the quality control program develops, an increased proportion of the effort should be applied to direct cost reduction.

	Estimated Expenditures			Estimated Annual Savings	
Case No. and Org.	Develop. Expense	New Plant	Other Expense	Capacity Level	Current Prod. Est.
————	Reduce (.....) shrinkage and salvage operations by changing the method of assembly and by controlling the manufacturing process through the use of Statistical Quality Control methods.				
	$300	$0	$0	$15100.00	$31400.00
	Conducted by: (..........................)			1260 Product Engineer	
	(..........................)			2286 Shop Supervisor	
	(..........................)			5220 Q. C. Engineer	

Fig. 224. Excerpt from a joint cost reduction case conducted by a Quality Control Team.

D-5 CONTROL CHART AUDITS

Quality Control Teams maintain a constant check on all process control layouts and process control charts. In addition, it is usually desirable to have a formal periodic review conducted by someone who is not a regular member of the Team. This is to make sure that quality control practices are uniform or consistent throughout the plant and are kept up-to-date. It also ensures that personnel changes, work load pressures, special investigations or human frailties are not permitting the process controls to be misunderstood or neglected.

A formal control chart audit should include a check on all of the following items:

Control charts

How many charts are of the $\bar{X}$ and R type?
How many charts are of the percent defective type?
(Include in this both p-charts and other attributes control charts.)
How many charts are of the percent dropout type?
(That is, charts showing dropouts rather than quality going to next operation.)
Is the chart setup correct?
Is the plotting correct?
Is the plotting being performed as specified?
Is the plotting up-to-date?
Are obsolete charts removed from the job?
Are out-of-control points marked with x's?
Are all specified tests being used for marking out-of-control patterns?
(The tests should include the checking of points inside the control limits as well as outside, as explained in the instructions to process checkers.)
Are the causes for out-of-control conditions noted on the control charts?
Are new performance studies needed?
Is the frequency of checks economic with respect to current performance?
Is action being taken properly on the basis of the charts?

Data

Are the data recorded as specified?
Is the specified form being used?
Are the records up-to-date?
Are the calculations correct?

Gages and test sets

Are the specified gages or test sets used?
Are the facilities properly maintained and inspected?

Inspection plans

(Because of their influence on the Operating process controls, these should be checked whether or not the audit of process controls is combined with a formal inspection audit.)

Is the specified sampling plan being used?
Are the correct methods of inspection used?
Is the specified lot size used?
Is the specified sample size used?
Is full inspection of the sample being performed?
Is the disposition of lots handled correctly?
Are rejected lots reinspected as specified?

Layout information

Are the latest issues in files and in use?
Are inspection criteria specified in the Inspection Layouts?
Are process control criteria specified in the Process Control Layouts?
Are the Inspection Layouts and Process Control Layouts cross-referenced in the Manufacturing Layouts?

Samples for process control

Are they selected by the process checker?
Are they measured by the process checker?
Are they selected at specified intervals and at the specified points in the process?

Since the intent of this audit is to bring the job up to date rather than to find fault, the members of the Team are notified well in advance of the audit.

When the audit is completed, recommendations for corrective action are sent to the Team members and this is followed by a more or less formal discussion. After the discussion a complete formal report is written showing audit items found, action to be taken, and the person or persons responsible. Follow-up on open items is made periodically to ensure closure of all items. A quarterly summary of open items is given to management.

D-6 ROUTINE DUTIES IN CONNECTION WITH PROCESS CONTROL CHARTS

Process control charts require a certain amount of maintenance and upkeep. These duties are divided among the Quality Control Team, the quality control engineering department and the process checker in the shop. If possible, there should be a statistical clerk to work with the quality control engineer and relieve him of details associated with calculating, plotting, filing and keeping records. The activities connected with the proper upkeep of charts are outlined as follows.

(1) *Original master chart.* This is prepared from data furnished by the Quality Control Team. The quality control engineer supervises the actual preparation of the chart. Calculating, plotting and lettering of headings and scales may be done by a statistical clerk. The master chart should be approved by the Quality Control Team before it is used in the shop.

(2) *Copies for the shop.* These should be reproduced from the master chart by the statistical clerk and furnished to the shop as needed. When changes are made in the master, unused copies of the original should be promptly destroyed. The statistical clerk ordinarily furnishes a holder or backing for the chart along with the shop copies.

(3) *Changes in the master chart.* These may include revising the scale, shifting the centerline (or centerlines) to a different point, adding new information, etc. Changes are authorized by the Quality Control Team and carried out by the quality control engineer with the help of the statistical clerk.

(4) *Permanent file of master charts.* This should be maintained by the statistical clerk under the direction of the quality control engineer. The master file should contain copies of all charts which have been used on the job.

(5) *New capability studies (growing out of charts already in use).* These are initiated by the Quality Control Team, which also makes provision for obtaining the necessary data. The data may be collected by the product engineer, the quality control engineer or, in many cases, the process checker. The quality control engineer supervises the collection of data and the calculations and plotting required for the study. The detailed work of calculating and plotting is done by the statistical clerk. The quality control engineer discusses the study with the other members of the Team and the Team decides jointly what action should be taken.

(6) *New performance studies to keep the charts up to date.* These are authorized by the Quality Control Team after a study of current charts. New performance studies are usually made when R charts or p-charts show significantly lower patterns. This indicates the advisability of calculating new control limits. Less frequently performance studies may be required as a result of a shift in $\bar{X}$ which is expected to become a permanent part of the process. The Team decides which period should be used as a basis for new calculations. The statistical clerk makes the calculations and plots a new master chart. The chart is approved by the quality control engineer before being used in the shop.

(7) *Storage.* As successive sheets are obtained and filled by the shop, the current sheet is mounted on top of the previous sheets in the same holder. When the sheets become too numerous, some provision is made for storing. The file of old charts should be kept in the shop area, if possible, and supervised by the process checker. Otherwise, the file is kept in the quality control department and is supervised by the statistical clerk.

From time to time, it may be desirable to reduce the bulk of these records. This is usually done by the quality control engineer after consultation with the product engineer and the Shop. In reducing the bulk of records, care should be taken to avoid throwing away information that will be valuable later. Records may be reduced by (a) making a suitable selection of representative charts from various periods, or (b) compiling a condensed history or summary by plotting representative periods side by side on a new chart. Condensed summaries consisting of brief selected periods, possibly several months apart, are sometimes used to convey to management a picture of the process improvement.

D-7 MANUAL FOR STATISTICAL CLERKS

Statistical clerks should be furnished with a brief manual covering the following information.

a. An explanation of technical terms and abbreviations in connection with the charts. For example, that the abbreviation I_b stands for Plate Current.
b. Simple tables showing frequently used values. For example, square root of 2 square root of 5.
c. Tables showing upper control limits for *p*-charts or *np*-charts, given the sample size and number of defects.
d. Directions for calculating control limits for the common kinds of control charts. This should include examples of actual calculations.
e. Sample charts properly plotted with the correct designations and with correctly proportioned scales.
f. Sample data sheets showing the form in which data are ordinarily submitted by the process checker and showing what the statistical clerk is expected to do with the data.
g. Definitions of common terms used in process control. For example, variable, process, lot, sample, etc.
h. Instructions for marking out-of-control patterns.
i. Any special instructions which may be needed on the job, such as directions for plotting charts in a designed experiment.