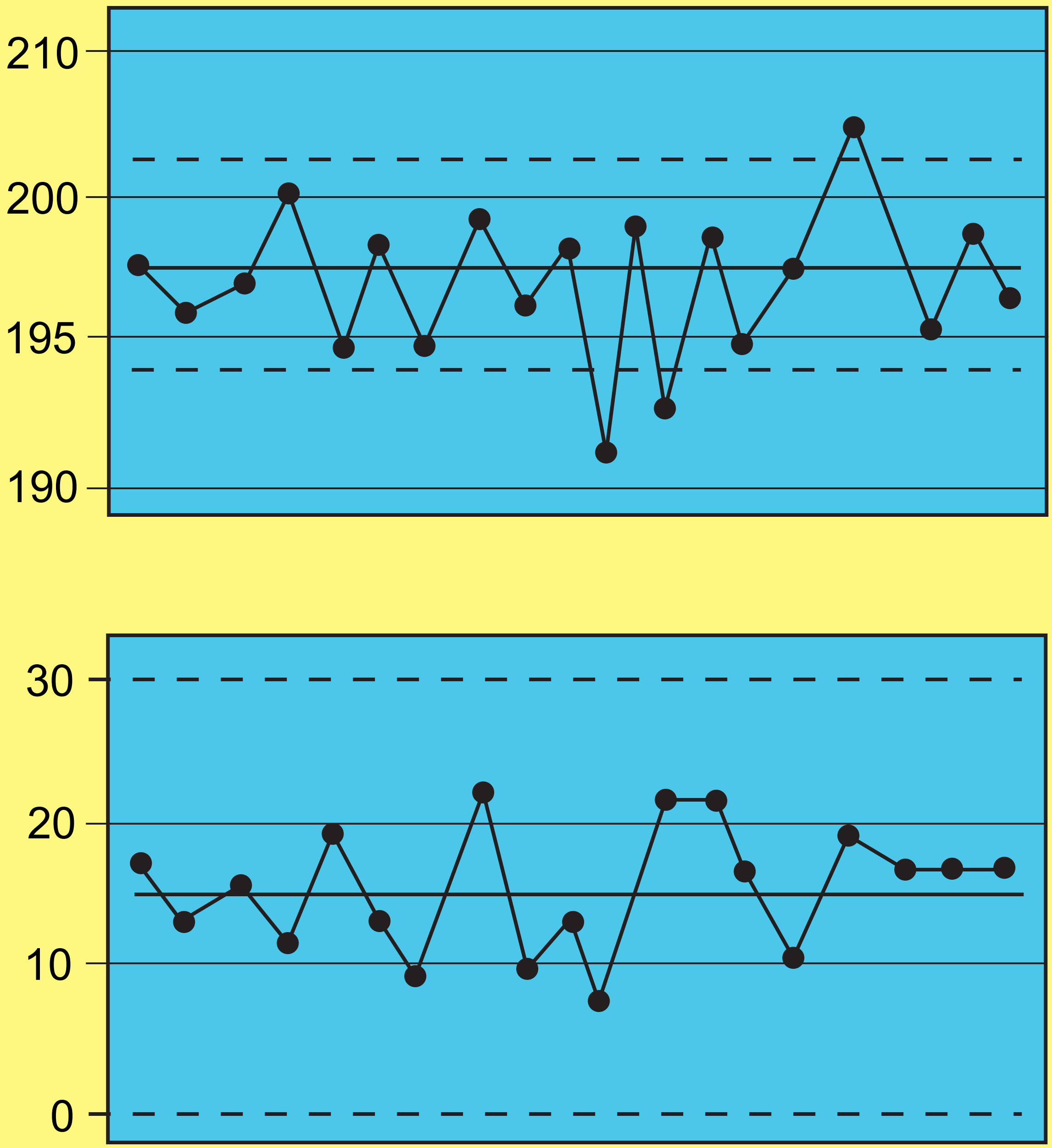
Introduction To
Statistical Process Control



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INTRODUCTION TO STATISTICAL PROCESS CONTROL
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I. INTRO TO STATISTICAL PROCESS CONTROL

A. TERMS

Assignable Cause – Something that brings about a change in population from which measurements are being made and is due to changes in the equipment, material or a change of operators.

Common Variation – Something which brings about a change in population and is due to the natural variation of the system.

Control Chart – Graphic means for detecting assignable variations from common variations, that is the variation greater than the random fluctuation.

Lower Control Limit (LCL) – The line below the centerline on a control chart.

Upper Control Limit (UCL) – The line above the centerline on a control chart.

Mean – Average of sample data.

Natural Variability – Variability common to the process, generally cannot be reduced or eliminated without changes to the process itself.

Range – The difference between the highest and lowest values in the sample.

Population – The total number of objects or units with a particular characteristic.

Sample – Part of the population selected according to some rule or plan.

Representative Sample – The items from the population are selected in such a way that the properties of the sample correspond to the properties of the population.

Random Sample - Each item in the population has an equal chance of being selected.

B. INTRODUCTION TO SPC

The biggest problem most people have with using today's methods of quality control is the fear that statistics are too difficult for the average person to understand.

True, Statistical Process Control, or SPC, is based on some very powerful and complex math. But SPC improves quality, productivity and profits because it can be used, and used easily, by everyone in industry - from management offices to the production line.

1. What Is SPC?

Let's look at the three words which form SPC – Statistics, Process, and Control:

- **Statistics** - A way to collect, classify, present and interpret numerical data (information expressed in numbers).
- **Process -** A combination of machines, equipment, people, raw materials, methods and environment that produces a product. A process is how something gets done.
- **Control -** Directing or regulating a process so that it behaves the way it is meant to behave.

So SPC is the use of numerical data to direct or regulate the methods used to produce a finished product.

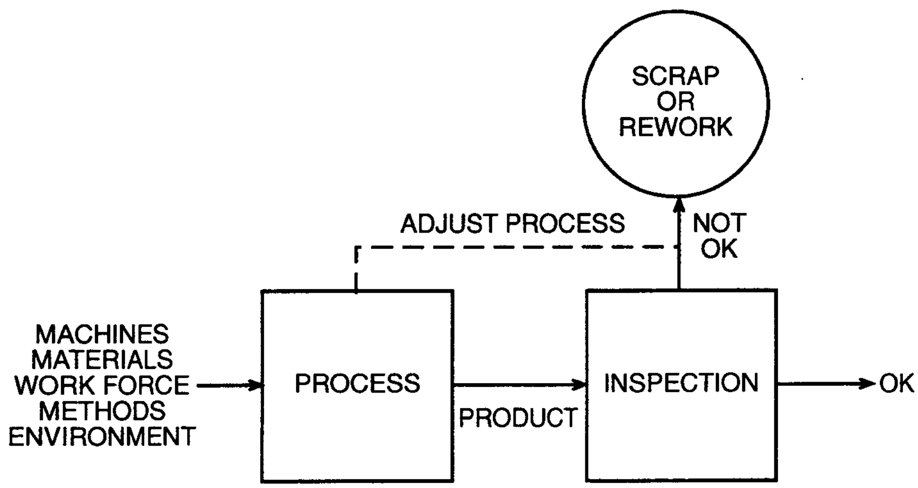
2. Then And Now

In the past, American quality control has been by inspection. After products were produced, the good was sorted from the bad, and the bad products either reworked or scraped. This has led to higher cost and lower quality.

This inspection method is called the ***Classic Control Cycle***, shown in Figure 1-1.

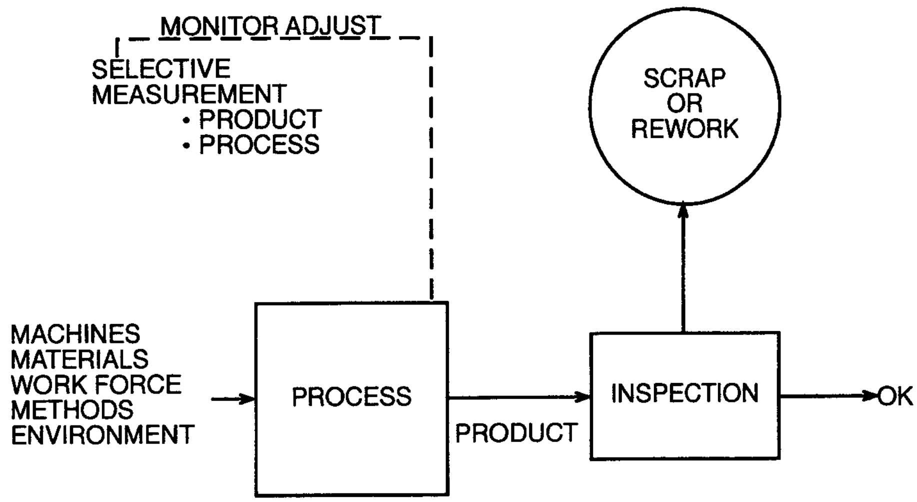
Using the classic control method, bad products go through the entire production process before they are caught during inspection. As much time and material is spent producing a defective product as making a good one. Because inspection can never be perfect, some bad products are going to get shipped to the customer - and that's bad business.

FIGURE 1-1
Classic Control Cycle



The ***SPC Control Cycle*** (Figure 1-2) is different. In SPC, the process is monitored during production. Records are kept on how the process is working. Based on these records, action is taken to make sure the process is always producing good products, not bad. This reduces scrap and production costs, and improves quality.

FIGURE 1-2
SPC Cycle



3. Why Use SPC?

SPC has become the new standard for quality control because it:

- Increases customer satisfaction.
- Decreases scrap, rework, and inspection costs.
- Decreases operating costs.
- Improves productivity.
- Sets a predictable and consistent level of quality.
- Eliminates or reduces the need for inspection by the customer.

4. For Success

SPC is not an overnight cure for production problems. It must be used as an ongoing program by all levels of personnel. The goal is to improve quality.

Remember: The key concept in SPC is that if the effect each cause has on a process is known, and if a certain level of process performance can be expected, then corrective action can be taken when performance does not meet expectations.

C. VARIABILITY

Understanding variability is the key to SPC – which is probably becoming more clear already. Variability simply means that no two things are exactly alike.

No two snowflakes, no two fingerprints, no two people - no two parts produced on a production line - are exactly alike. Even though two fingerprints may look alike, they look very different when seen through a microscope. These differences are called "variation."

Variability is always present, and nothing can be done to avoid it.

Because variability is always present and cannot be prevented, a technician must learn to recognize the types of variability and control the variables that can be controlled.

There are two types of variation - ***Inherent and Assignable***.

Inherent variation is the kind that can't be prevented. It is always present, and happens randomly, or without a set pattern. Inherent variation can't be eliminated or corrected.

Assignable variation, however, can be corrected. It is variation which occurs regularly and which can be pinpointed to a specific cause.

SPC's purpose is to keep track of variation in production. SPC helps separate inherent from assignable variation, so that the assignable causes of variation can be eliminated.

D. STATISTICS

There are several basic SPC tools that are useful in an industrial environment. One of the most useful is the control chart.

A control chart is a very powerful way to check the stability of a process over time. These charts show the difference between normal and abnormal operating conditions and determine whether or not corrective action is needed. They help determine if variation is inherent or assignable.

Only two statistical concepts must be learned in order to build a control chart. These two concepts are called "central tendency" and "dispersion".

1. Central Tendency - Mean

Measures of central tendency show where the data is clustered or grouped together near a central point. The measure of central tendency we will use is the mean (average).

The mean is calculated by adding all the observations and dividing by the number of observations.

2. Dispersion – Range, Standard Deviation

Not only is it important to know the central tendency of data, but also to know the amount of scatter about the central point. It is possible that the data may be closely grouped near the central point, it may be uniform, or there may be large numbers of extreme values. Some description of spread is needed. The two most common measures of dispersion are range and standard deviation.

The range is calculated by subtracting the smallest observation from the largest.

Sigma (σ) is the standard deviation. The advantage of using it is that it is a very efficient estimator of dispersion. Unfortunately, it is very difficult to calculate. Because statistical calculators are available, calculators will generally be used to obtain the standard deviation.

The types of control charts for variables used in this manual are X-bar ($\overline{X}$) control charts and range (R) control charts. Although each chart is separate, they usually appear as one, which is called an $\overline{X}$-R chart.

E. CONTROL CHARTS

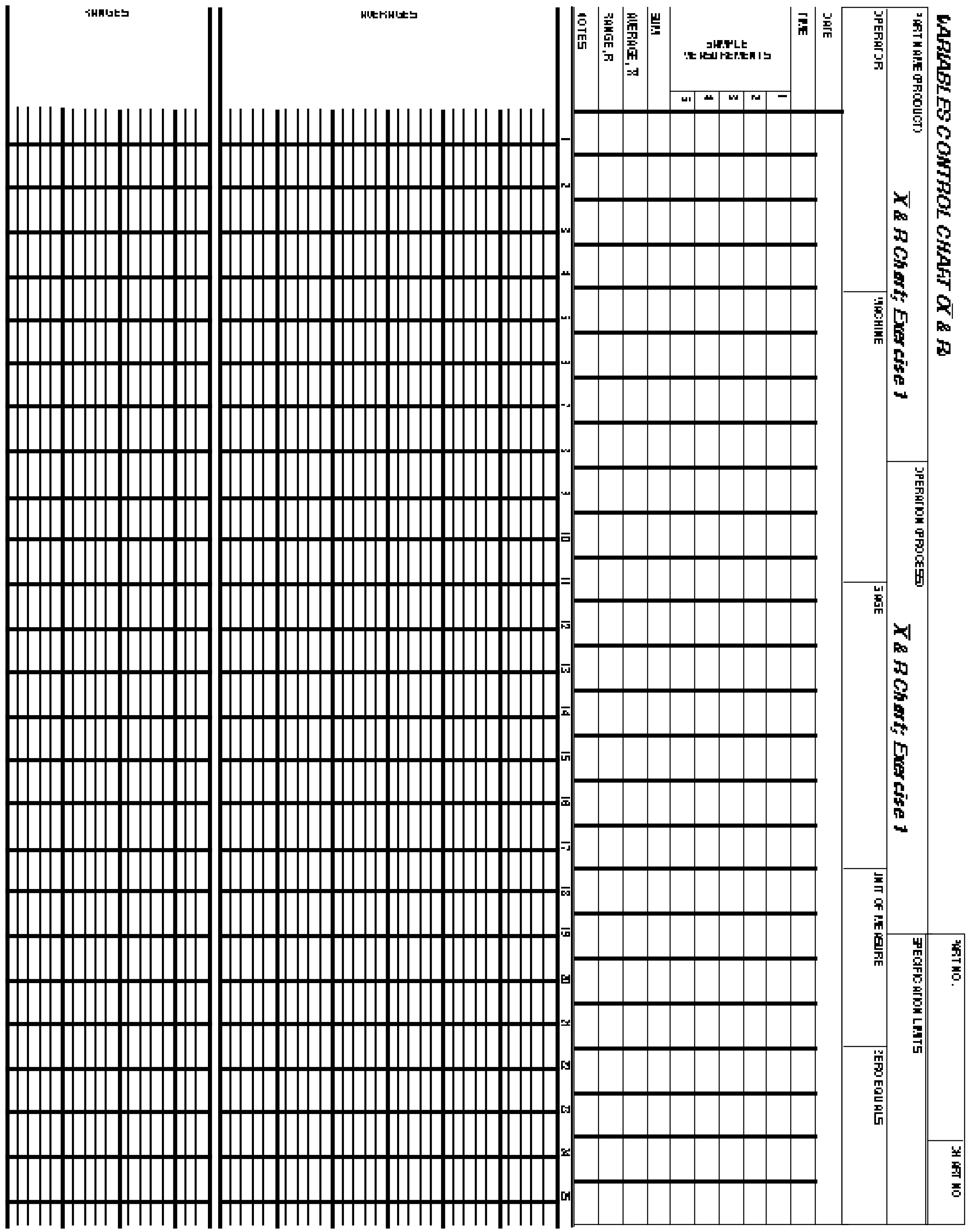
A control chart (Figure 1-3) is a statistical tool used to check the stability of a process over time. Its basic functions are:

- To describe what control there is.
- To help get control.
- To help judge whether control has been attained.
- To detect change in process performance.
- To estimate the process capability.
- To signal when corrective action is needed.

The types of control charts for variables used in this manual are X-bar ($\overline{X}$) control charts and range (R) control charts. Although each chart is separate, they usually appear as one (an $\overline{X}$ chart and an R chart.)

The ($\overline{X}$) chart measures and monitors the average performance of the process over time. The range (R) control charts measure and monitor the process variability within a sample.

FIGURE 1-3
Control Chart



1. Building The $\overline{X}$-R Chart

Preparation

1. Choose a variable (characteristic):

   The characteristic chosen should be a measurable quantity, which can be expressed in numbers (size, length, weight, etc).

   The characteristic should have a direct effect on the process or product and provide the prospect of reducing or preventing costs such as waste.

2. Choose sample groups:

   There are two main criteria for choosing a good sample group. First, the properties of the sample should be like the properties of the population. Secondly, the sample should represent the population.

   Choosing items that were produced one after another is often a good way to select a quality sample group.

3. Choose sample size and frequency of sampling:

   Four or five is a good sample size. It is relatively quick and easy, and tends to lower variation within a sample. The sample size should be the same each time the process is sampled.

   Large samples of 20-25 are sensitive to changes in the process average. Also, the larger the sample size, the tighter the control limits.

   The frequency to use in collecting the sample data must be decided on an individual basis. Sometimes, hourly checks are needed, sometimes weekly.

4. Secure control chart paper:

   The chart form is handy and easy to use. Fill in the spaces at the top of the form with the needed information. Remember that the more completely filled out the form is, the more the control chart can be used as a communication tool.

5. Plot data on control chart:

   The sample data is then plotted on the control chart as shown in Figure 1-5. Calculate the range and mean to establish graph points on the chart. The upper and lower control limits and center line will be determined by other personnel.

2. Drawing Conclusions From The Chart

Conclusions from the control charts can be made after the central tendency lines and the upper and lower control limits are drawn. As a guideline, early estimates of the control limits can be made after about ten sample groups have been collected. It is better to wait until at least 25 sample groups have been collected. Firm control limits can then be established.

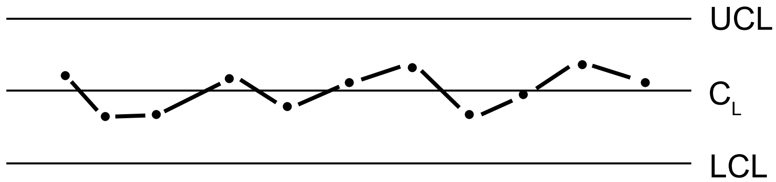
Points outside the control limits mean that the process is not in control. It also means that assignable causes of variation are present.

Points within the control limits are a first indication that the process is in control. Even though all points are within the control limits, lack of control may still be indicated. For example, seven points in a row between the center line and a control line may indicate lack of control. Normally, points should fall randomly above and below the center line.

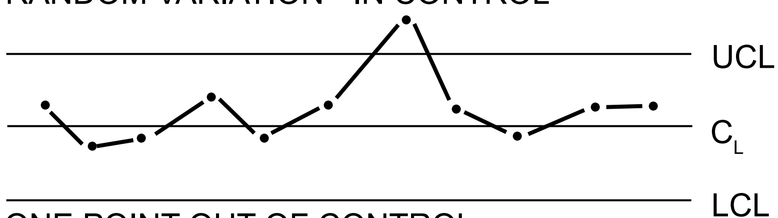
Here are some factors (Figure 1-4) that indicate a lack of control:

1. A point outside the control limits.
2. Seven or more points on the same side of the center line.
3. A trend up or down.
4. A repetitive pattern in the chart indicating a cycle.

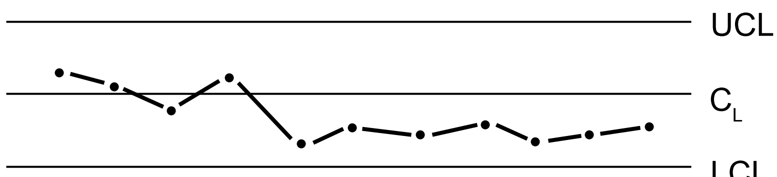
FIGURE 1-4
Graphical Examples



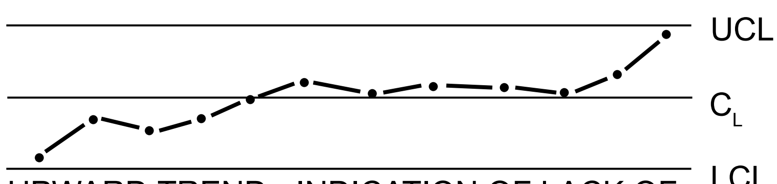
RANDOM VARIATION - IN CONTROL



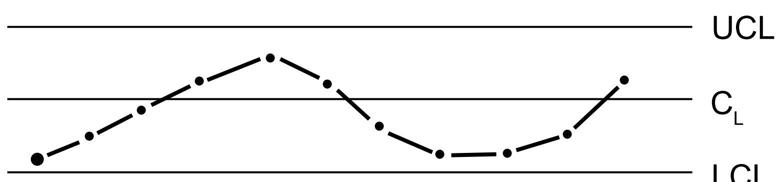
ONE POINT OUT OF CONTROL -
INDICTION OF ASSIGNABLE CAUSE



RUN OF POINTS ON ONE SIDE OF CENTRAL LINE - INDICATION OF LACK OF CONTROL



UPWARD TREND - INDICATION OF LACK OF CONTROL



CYCLIC PATTERN - INDICATION OF LACK OF CONTROL

F. EXAMPLES

An actual control chart is provided here for example. The chart uses actual production data.

Two formulas are necessary to work with control charts, ***range*** and ***mean***.

1. Explanation of Formulas

Range

$R = X_{Highest} - X_{Lowest}$

The range of a group of data is the difference between the highest and lowest reading.

Example:

$X_1 = 5$
$X_2 = 1$
$X_3 = -4$
$X_4 = 3$
$X_5 = 2$

$X_{Highest} = 5$
$X_{Lowest} = -4$

$R = 5 - (-4)$
$R = 5 + 4$
$R = 9$

Mean

$$\overline{X} = \frac{X_1 + X_2 + \ldots X_n}{n}$$

The mean of a sample group of data is found by adding the individual readings then dividing by the number of readings.

Example:

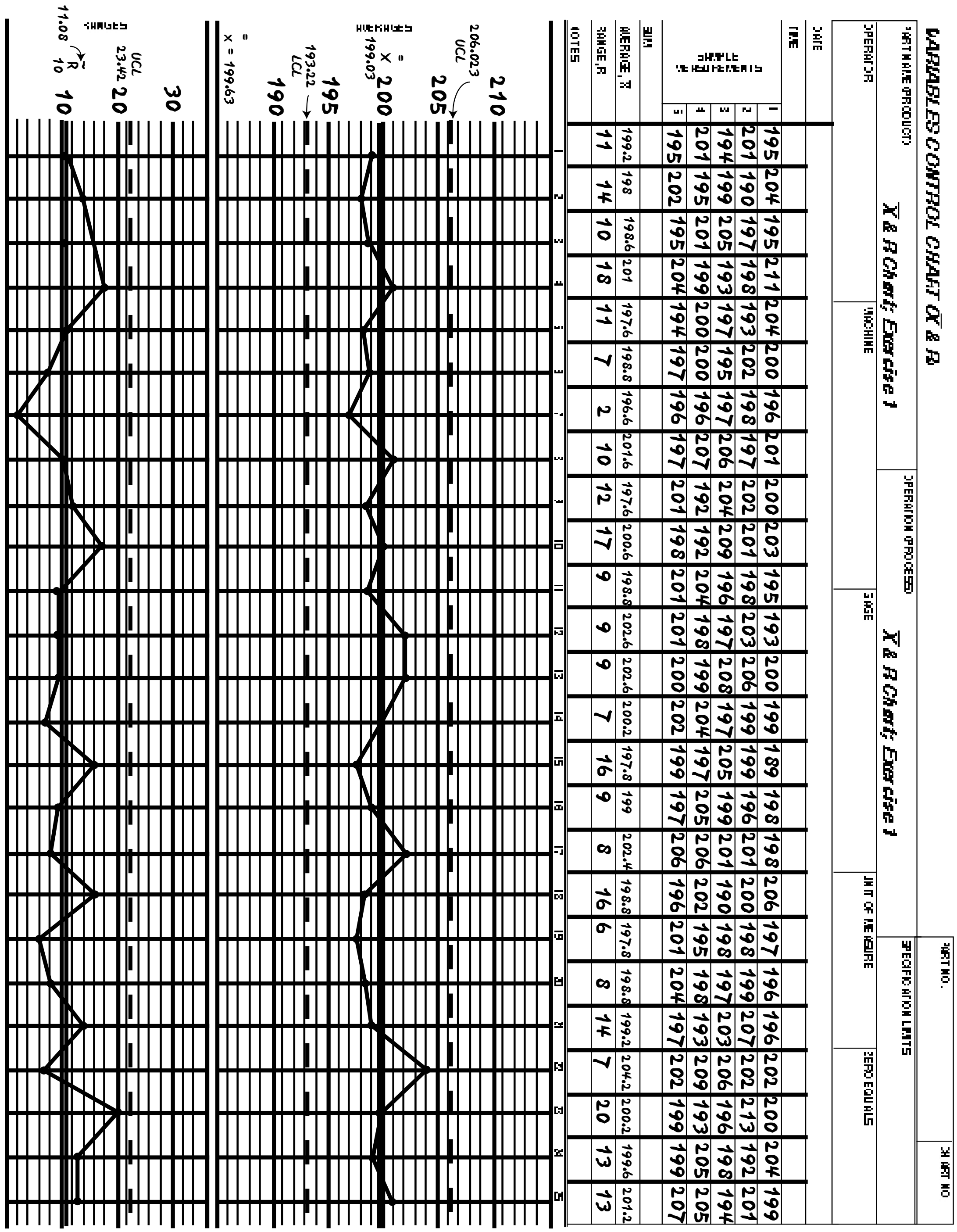
$X_1 = 5$
$X_2 = 1$
$X_3 = -4$
$X_4 = 3$
$X_5 = 2$

$$\bar{X} = \frac{5 + 1 + (-4) + 3 + 2}{5}$$

$$\bar{X} = 7/5$$

$$\bar{X} = 1.4$$

FIGURE 1-5
Completed Control Chart



G. THE CALCULATOR

The electronic calculator is a tool used to solve mathematical problems. It is, like any other tool, capable of working correctly only when used correctly The user must understand its features and functions.

1. Key Functions

Figure 1-6 shows a basic electronic calculator. The keys control the functions of the calculator used to solve a problem. These keys and their functions are shown as follows:

ON/C **Key -** This key is the **ON** and **Clear** Key. When the calculator is on this key clears or erases all functions in the calculator.

CE **Key -** This key is the **Clear Entry** key. This key erases the last entry made in the calculator without erasing all entries.

OFF **Key -** This key shuts the calculator **off**.

÷ **Key -** This key controls the **division** function of the calculator.

X **Key -** This key controls the **multiplication** function of the calculator.

− **Key -** This key controls the **subtraction** function of the calculator.

\+ **Key -** This controls the **addition** function of the calculator.

√ **Key** - This key controls the **square root** function of the calculator.

In working with decimals it is important the decimal point be placed properly within each number. Also, to ensure a correct answer the correct numbers and function key must be entered.

2. Examples

Calculate the mean of the following:

$X_1 = 3$
$X_2 = 4$
$X_3 = 3.5$

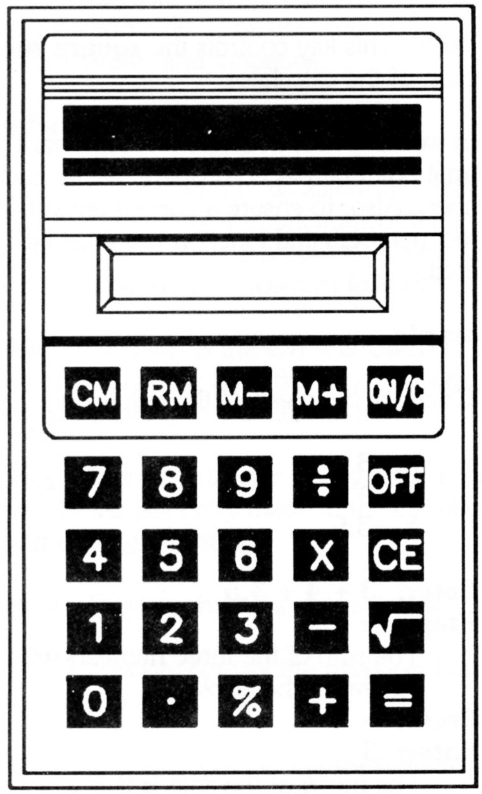
1. **Enter: 3 + 4 + 3.5**

2. **Press: =**
   The sum of the three numbers will appear in the display.

3. **Press: ÷**

4. **Enter: 3**
   The mean of the data is 3.5 which appears in the display.

FIGURE 1-6
Electronic Calculator



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