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AMERICAN SOCIETY FOR TESTING AND MATERIALS
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Standard Practice for Machine/Process Potential Study Procedure[1]

This standard is issued under the fixed designation F 1503; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers the proper method for establishing process potentials for new or existing processes.

2. Referenced Documents

2.1 *ASTM Standards:*

F 1469 Guide for Conducting a Repeatability and Reproducibility Study on Test Equipment for Nondestructive Testing[2]

2.2 *ASME Standard:*

ASME-FAP-1 Quality Assurance Program Requirements for Fastener Manufacturers and Distributors[3]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *bilateral specifications*—specifications that have both upper and lower values.

3.1.2 *Pp*—an index that indicates the variability of the process with respect to tolerance.

3.1.3 *Ppk*—an index of process variability and centering. This is a widely-used index which considers the process mean, range, and its relation to the specification nominal.

3.1.4 *process parameters*—combination of people, equipment, materials, methods, and environment that produce output.

3.1.5 *unilateral specifications*—specifications that have only upper or lower values.

3.1.6 σ—an estimate of the standard deviation of a process characteristic.

4. Summary of Practices

4.1 A process potential study is conducted to provide a level of confidence in the ability of a machine/process to meet engineering specification requirements. This is accomplished through statistical process control techniques as defined in this practice.

4.2 For new equipment purchases, the purchaser's manufacturing engineering department, or equivalent discipline, shall have primary responsibility for ensuring that the requirements of this practice are met. The purchaser's quality assurance department shall be available to assist on an as-requested basis.

4.3 New manufacturing processes will not be accepted for use in production with *Pp* values less than 1.67. If a manufacturing process must be conditionally accepted, a process improvement/product control plan must be developed.

4.3.1 The process improvement/product control plan shall identify specific process improvement activities, which will be implemented to make the process fully capable as well as an interim inspection plan to ensure that nonconforming product is not shipped to a customer.

4.4 *Product Specifications*:

4.4.1 Prior to any process potential study, the product specifications (nominal dimension and tolerances) must be identified, and an appropriate method of variables type inspection selected.

4.4.2 This practice is limited to bilateral specifications whose distributions can be expected to approximate a normal curve. This practice should not be applied to unilateral specifications (flatness, concentricity, minimum tensile, maximum hardness, etc.).

4.5 *Gage Capability Analysis*:

4.5.1 All gaging systems used to evaluate product must have documentation for a gage repeatability and reproducibility study in accordance with Guide F 1469 before the process study is conducted.

4.5.1.1 Gaging systems which consume ≤10 % of the applicable product tolerance are considered acceptable.

4.5.1.2 Gaging systems which consume over 10 to 30 % of the applicable product tolerance are generally considered to be unacceptable. However, users of this guide may authorize their use depending on factors such as the criticality of the specification in question, the cost of alternative gaging systems, and so forth.

4.5.1.3 Gaging systems which consume more than 30 % of the product tolerance are unacceptable and must be replaced.

4.5.2 All gaging systems must be certified as accurate using standards traceable to NIST.

4.6 *Process Parameter Selection*:

4.6.1 For studies conducted at the equipment vendor's facility, all process parameters (for example, infeed rates, coolant, dies, pressures, fixtures, etc.) must be established and documented prior to the process qualification test so the requirements of 9.5 can be met.

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[1] This practice is under the jurisdiction of ASTM Committee F-16 on Fasteners and is the direct responsibility of Subcommittee F16.93 on Quality Assurance Provisions for Fasteners.

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[2] *Annual Book of ASTM Standards*, Vol 15.08.

[3] Available from American Society of Mechanical Engineers, 345 E. 47th Street, New York, NY 10017.

4.6.1.1 Process parameters may not be changed once a process qualification test has begun.

4.6.1.2 All process adjustments made during the process qualification study must be documented and included with information required in Section 10.1 of this practice.

NOTE 1—Process adjustments are defined as those adjustments made by the process due to internal process gaging (or other sources of feedback control), or by the operator as part of the normal operation of process.

4.6.2 The selection of process parameters is the responsibility of the purchaser's manufacturing engineering or equivalent discipline, or, in some cases, the machine supplier depending on preestablished contractual agreements.

4.6.2.1 The process parameters selected must be consistent with those intended to be used in production.

4.6.3 Process parameters may be systematically varied after a study is completed and additional process qualification studies performed for process optimization purposes.

5. Significance and Use

5.1 This practice is designed to evaluate a machine or process isolated from its normal operating environment. In its normal operating environment, there would be many sources of variation that may not exist at a machine builder's facility; or put another way, this study is usually conducted under ideal conditions. Therefore, it should be recognized that the results of this practice are usually a "best case" analysis, and allowances need to be made for sources of variations that may exist at the purchaser's facility.

5.2 Further comment on the significance of statistical analysis and capability studies can be found in ASME FAP-1.

6. Material Selection

6.1 Material (for example, steel slugs, bar, wire, prefinished parts, etc.) used for process qualification studies shall be selected at random. The variability of material used for process qualification studies should be consistent with the variability of material the machine is likely to see in production.

6.2 Presorting of material is not permissible for process qualification purposes.

6.3 In some cases, process potential results may be influenced by the specific product specifications selected for the study. The specific product selected for qualifying a new manufacturing process should be based on that which will yield the most conservative results. If the relationship between specific product specifications and process potential is unknown, two or more distinct studies should be performed with different products to qualify and accept the new process.

7. Procedure-Process Potential Study

7.1 Operate the process for a sufficient period of time to ensure that the process is stable and all initial setup adjustments are complete.

7.2 Control charting techniques should be utilized to determine the stability and capability of the process.

7.2.1 When possible, a standard $\bar{X}$, R chart (Fig. 1) should be used with subgroup size n equals 2 through 5.

7.2.1.1 Sampling frequencies should be established to ensure that all likely sources of variability occur, and can be evaluated within the scope of the process potential study.

7.2.1.2 A minimum of 25 subgroups are required to establish control.

7.2.2 When the quantity of sample measurements cannot be practically obtained, it is permissible to utilize a chart for individuals and moving ranges, Fig. 2.[4]

7.2.2.1 A minimum of 25 subgroups are required to establish control.

7.2.3 After the study is complete, calculate and plot the control limits, $\bar{\bar{X}}$ and $\bar{R}$ (or MR), for each specification identified in 4.4.1 (see Table 1). If during the study the process was out of control, the process potential study is not valid. The root cause(s) of the out-of-control condition(s) must be identified and eliminated and the study repeated.

7.2.3.1 If the out-of-control condition is associated with no more than two subgroups on the range chart, one point on the $\bar{X}$ or individuals chart and the root cause of the out-of-control condition is identified and corrected, new control limits may be calculated by excluding the out-of-control points. A second study is not required.

7.2.3.2 In some instances, control chart analysis may reveal out-of-control conditions that are inherent to the process. Trends due to tool wear or grinding wheel wear are typical examples. If the cause of the out-of-control condition is known, the out-of-control condition is both repeatable and predictable, and the condition cannot be eliminated, the process potential study may be considered acceptable and *Pp* and *Ppk* values calculated in accordance with 8.1-8.3.

TABLE 1 Process Average and Range

Calculate the average Range ($\bar{R}$) and the Process Average $\bar{\bar{X}}$

For the study period, calculate:

$$\bar{R} = \frac{R_1 + R_2 + \ldots + R_k}{k}$$

$$\bar{\bar{X}} = \frac{\bar{X}_1 + \bar{X}_2 + \ldots + \bar{X}_k}{k}$$

Where k is the number of subgroups, R_1 and $\bar{X}_1$ are the range and average of the first subgroup, R_2 and $\bar{X}_2$ are from the second subgroup, etc.

8. Calculating Results

8.1 Estimate the process standard deviation as follows:

$$\sigma = \bar{R}/d_2 \quad (1)$$

where:

d_2 = constants for sample size 2 to 10, see Table 2.

8.2 Calculate *Pp* by dividing the total product tolerance by 6 σ.

8.3 Calculate *Ppk* as follows:

$$Ppk = \text{minimum of } (USL - \bar{\bar{X}})/3\,\sigma \text{ or } (\bar{\bar{X}} - LSL)/3\,\sigma \quad (2)$$

where

USL = upper specification limit, and

LSL = lower specification limit.

9. Analysis of Results

9.1 The qualification of a manufacturing process shall be based on a review of the statistical parameters *Pp* and *Ppk*. *Pp*

[4] *Understanding Statistical Process Control*, Wheeler and Chambers, Statistical Process Controls, Inc., 5908 Toole Drive, Suite C, Knoxville, TN 37919.

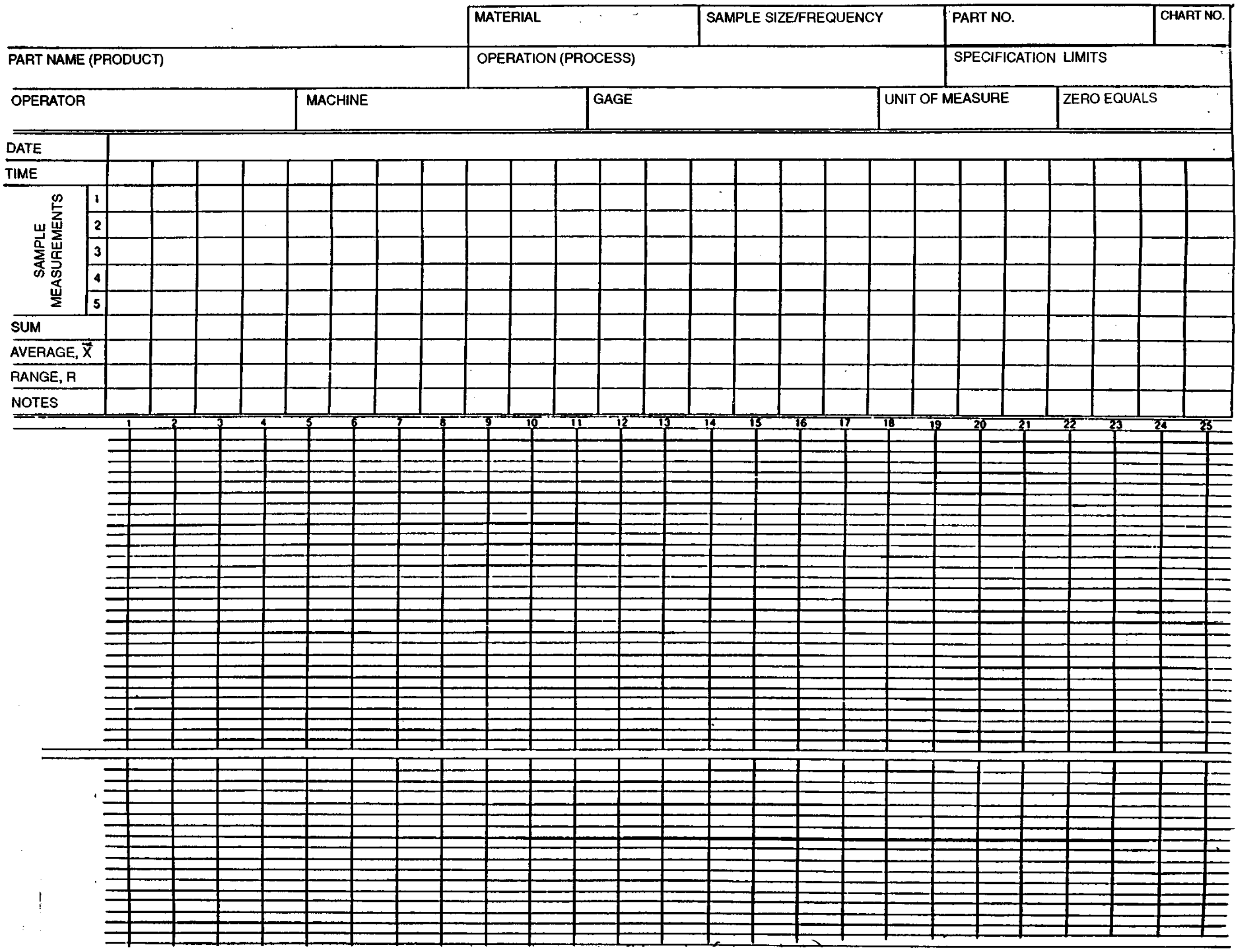

FIG. 1 Variables Control Chart ($\bar{X}$ and R)

and *Ppk* are both numerical indexes that provide a measure of a process's variability relative to predefined product specifications. *Pp* considers the tolerance range only, whereas *Ppk* considers both the tolerance range as well as how close the process average was to the nominal specification. *Pp* and *Ppk* will have the same numerical value when the process average is centered around nominal. As the process average moves away from nominal, *Ppk* will decrease.

9.2 The decision to accept or qualify a manufacturing process shall be based on the following criteria:

9.2.1 *Accept—Ppk* equals 1.67 or greater. Process is capable of consistently producing product within specification, if controlled properly, using statistical process control (SPC) techniques.

TABLE 2 Process Standard Deviation

Estimate the process standard deviation (the estimate is shown as $\hat{\sigma}$ "sigma hat").
Using the existing sample size calculate:

$$\hat{\sigma} = \bar{R}/d_2$$

Where $\bar{R}$ is the average of the subgroup ranges (for periods with the ranges in control) and d_2 is a constant varying by sample size, as shown in the table below:

n	2	3	4	5	6	7	8	9	10
d_2	1.13	1.69	2.06	2.33	2.53	2.70	2.85	2.97	3.08

9.2.2 *Conditional Acceptance—Ppk* equals 1.33 to 1.67. Process is marginally capable. SPC techniques may be used; however, special care must be taken to ensure that the process average is as close to nominal as possible. Occasional 100 % sorting of product may be required.

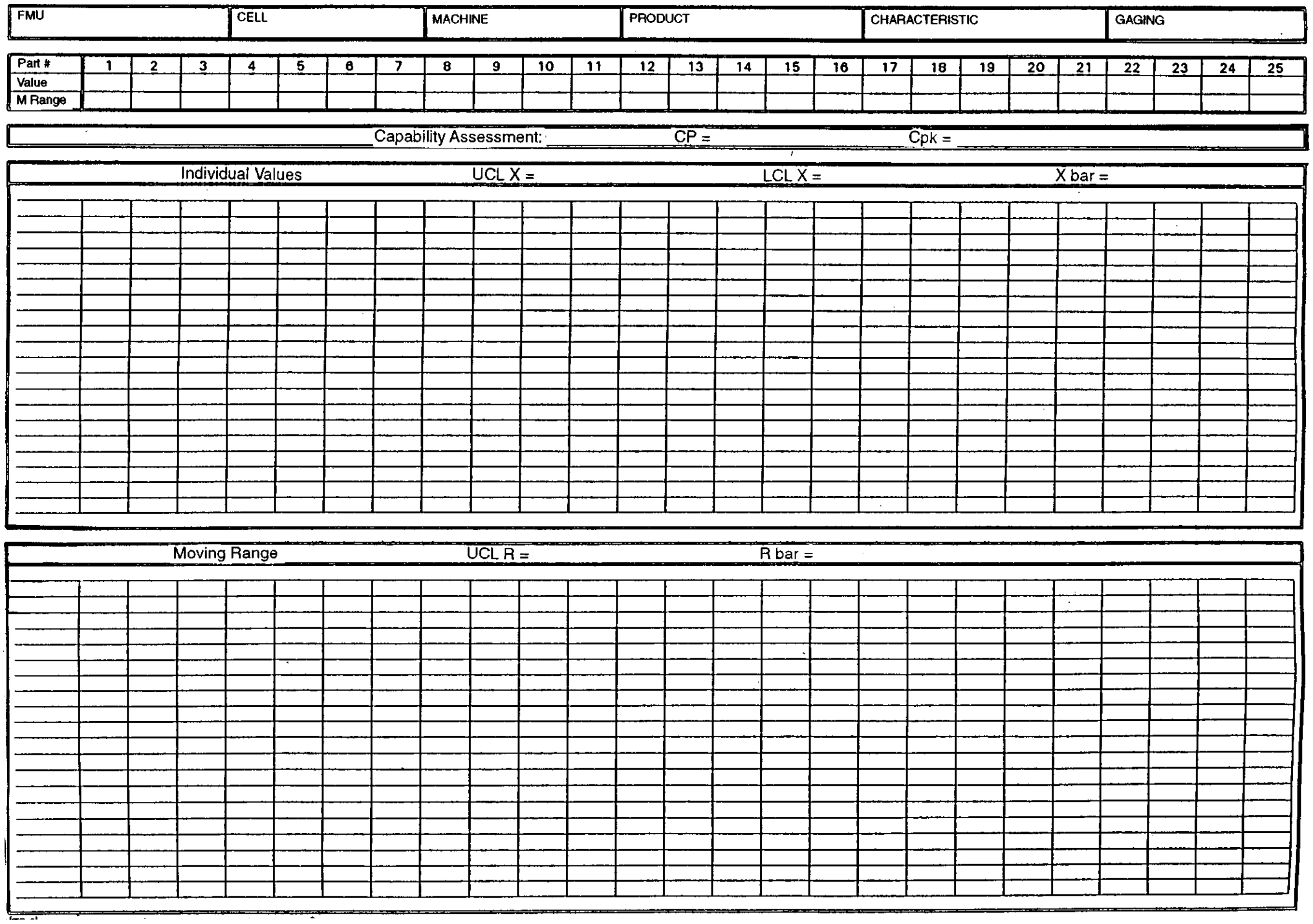

FIG. 2 Individual and Moving Ranges

9.2.3 *Reject—Ppk* equals less than 1.33. Process is incapable of producing product within specification. This will require 100 % sorting by the machine operator.

9.3 A process with *Ppk* < 1.33 may also be accepted if both of the following conditions exist.

9.3.1 *Pp* $\geq$ 1.67, and

9.3.2 The process is such that the process average can be controlled by the machine operator through normal process adjustments.

9.3.3 The requirements identified in 4.3 shall be imposed on any process that receives conditional acceptance.

9.4 In many cases, capability may vary depending on the degree of control exercised during the study (that is, the type and frequency of adjustments made). The purchaser is responsible for reviewing all adjustments made during the study and ensuring that the same level of control can/will be used in production.

9.5 If the original process potential study is conducted at the equipment vendor's facility, a follow-up study must be performed after the process is set up and running in the appropriate manufacturing facility to confirm results.

10. Documentation

10.1 Documentation of each gage repeatability/reproducibility study and process qualification analysis conducted must be forwarded to the purchaser's quality assurance department for review.