Designation: D 4583 – 95 (Reapproved 2004)

Standard Practice for
Carbon Black—Calculation of Process Indexes From an Analysis of Process Control Data[1]

This standard is issued under the fixed designation D 4583; 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 (*1*) a statistical procedure for analyzing the test data generated in the statistical process control of a carbon black manufacturing process; (*2*) a format for reporting process capability determined from the analysis of control chart data of an individual production run, and (*3*) a format for reporting process performance determined from the analysis of control chart data of an individual production run.

1.2 This practice specifically applies to the analysis of pelleted carbon black samples taken during the manufacturing process prior to storage. This practice does not apply to shipment samples taken from hopper cars or other containers or packages.

1.3 This practice is specifically designed to be used for those test methods given in Classification D 1765 which specify target values. However, these techniques are applicable to other test methods on carbon black.

1.4 This practice describes the calculation for two methods of determining capability factors from an analysis of process control data.

1.4.1 Process capability (*Cp*) is a measurement of variation calculated from the process control chart data with the use of an estimated standard deviation ($\hat{\sigma}$) from the mean value of the moving range (*R*) chart. The calculation of the process capability (*Cp* and *Cpk*) indexes can be used as historical information or to predict future performance of the process, but are only valid when the process is in a state of statistical control.

1.4.2 Process performance (*Pp*) is a measurement of variation calculated from the process control chart data using sample standard deviation(s). The calculation of the process performance (*Pp* and *Ppk*) indexes are used for a historical reference of a process' performance and does not require a state of statistical control.

2. Referenced Documents

2.1 *ASTM Standards:* [2]
D 1765 Classification System for Carbon Blacks Used in Rubber Products

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:* [3,4]

3.1.1 *average moving range ($\overline{R}$)*—the arithmetic mean of *n* moving ranges, $\overline{R} = \Sigma R/n$.

3.1.2 *Cpk index*—an index that indicates how well the common cause process variability is actually contained within the specifications. (See 6.4.)

3.1.3 *moving range (R)*—the absolute difference between consecutive, individual test values.

3.1.4 *Ppk index*—indicates how well the common and special cause process variability is actually contained within the specifications. (See 6.6.)

3.1.5 *process capability index (Cp)*—an index that compares the magnitude of common cause process variability to the range of upper and lower specification limits (*USL* and *LSL*) without regard to where the process is centered; *Cp* index = $(USL - LSL)/(6\hat{\sigma})$. (See 6.3.)

3.1.6 *process performance index(Pp)*—an index that compares the magnitude of common and special cause process variability to the range of the upper and lower specification limits (*USL* and *LSL*) without regard to where the process is centered; *Pp* index = $(USL - LSL)/(6s)$. (See 6.5.)

4. Significance and Use

4.1 This practice will provide the following: (*1*) a statistical summary of individual production run data plotted on a control

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chart; (2) a statistical summary of data from multiple production runs; (3) a procedure to relate the average and variation of these data groups to specification limits, and (4) indexes for comparing different manufacturing units for projecting future capabilities or as historical reference.

5. Procedure

5.1 *Sampling*:

5.1.1 In order to provide uniformity and the ability to make valid comparisons of process capability and process performance indexes, all samples used for these calculations shall be collected in the same way. Samples that are to be tested for properties on which capability or performance indexes will be calculated shall be collected as follows:

5.1.1.1 All samples shall be taken from the process at the finished pellet discharge and tested individually. Compositing of samples is not permitted.

5.1.1.2 Samples normally shall be taken every 4 h. All results obtained on material that is put into finished product storage tanks shall be included.

5.1.1.3 Averaging of results is not permitted. Each result, as defined by the appropriate test method, is to be recorded and used in performing the calculations described in Section 6.

5.2 *Process Capability*:

5.2.1 A minimum of 30 test data generated during production periods in which the process is in statistical control are recommended for estimating a process capability standard deviation. In that case, the number (n) of moving ranges averaged will be 29.

5.2.2 Calculate Cp and Cpk as shown in 6.3 and 6.4. The Cp index and the Cpk index must be greater than 1.00 in order to indicate the capability of the process to meet the established specifications. The Cpk index is inherently less than or equal to the Cp index (for one-sided specifications, only the Cpk index is applicable).

5.2.3 The Cp index indicates whether or not the process is capable of meeting a specification. Maximum performance is achieved when the process is perfectly centered and the Cpk is equal to the Cp.

5.2.4 In comparing one manufacturing unit to another, the larger Cpk index demonstrates a greater capability to conform to the specification range of the specified property.

5.2.5 *A process capability summary* can be used to evaluate a production unit over a period of time such as weekly, monthly, or quarterly. (See Fig. 1.) After each production run, or after 30 or so tests, the values of n, $\bar{x}$, ± difference from target, MR, $3\hat{\sigma}$, Cp, and Cpk are recorded on the summary form. At the conclusion of the appropriate time interval, the grand average ($\overline{\overline{x}}$), average difference from target, average Cp, and average Cpk can be displayed at the foot of the appropriate column. These average values, especially the Cpk, can be used to compare the quality levels of different manufacturing units.

PROCESS CAPABILITY SUMMARY

PLANT: _____ UNIT: _____ GRADE: _____ PROPERTY: _____ AS OF DATE: _____

MATERIAL SPEC: _____

RANGE: _____

TARGET: _____

Production Period	n	$\bar{X}$	Difference +/− Target	MR	3σ	Cp	Cpk

FIG. 1 Sample Process Capability Summary Sheet