STATISTICAL PROCESS CONTROL (S P C) FOR DRY KILN OPERATIONS

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There is a series of value-maintaining treatments for each piece of green lumber processed. Each board has a unique physical profile. It calls for a precise drying schedule, planer speed, grade and trim solution, and packaging mode. The dry end operator's goal is to maximize the strength and appearance of each board. Technology is available to assist this effort.

The task in the dry end (Figure 1) is to develop the highest possible operating margin. Operating margin is the difference between total cost of production and total value received. The high-margin operator tries to maintain the widest possible margins between costs and total product value. Cost control is simple. Don't spend any money. Projects affecting product value can be extremely complex. They are often high risk. With the risk, however, comes the reward.

Returns to cost control projects are dollar for dollar. Each dollar saved does increase profit. However, other production functions, grade development for one, have higher return ratios. Grade recovery improvements have high return elasticities. The returns are frequently 8 or 10 to 1.

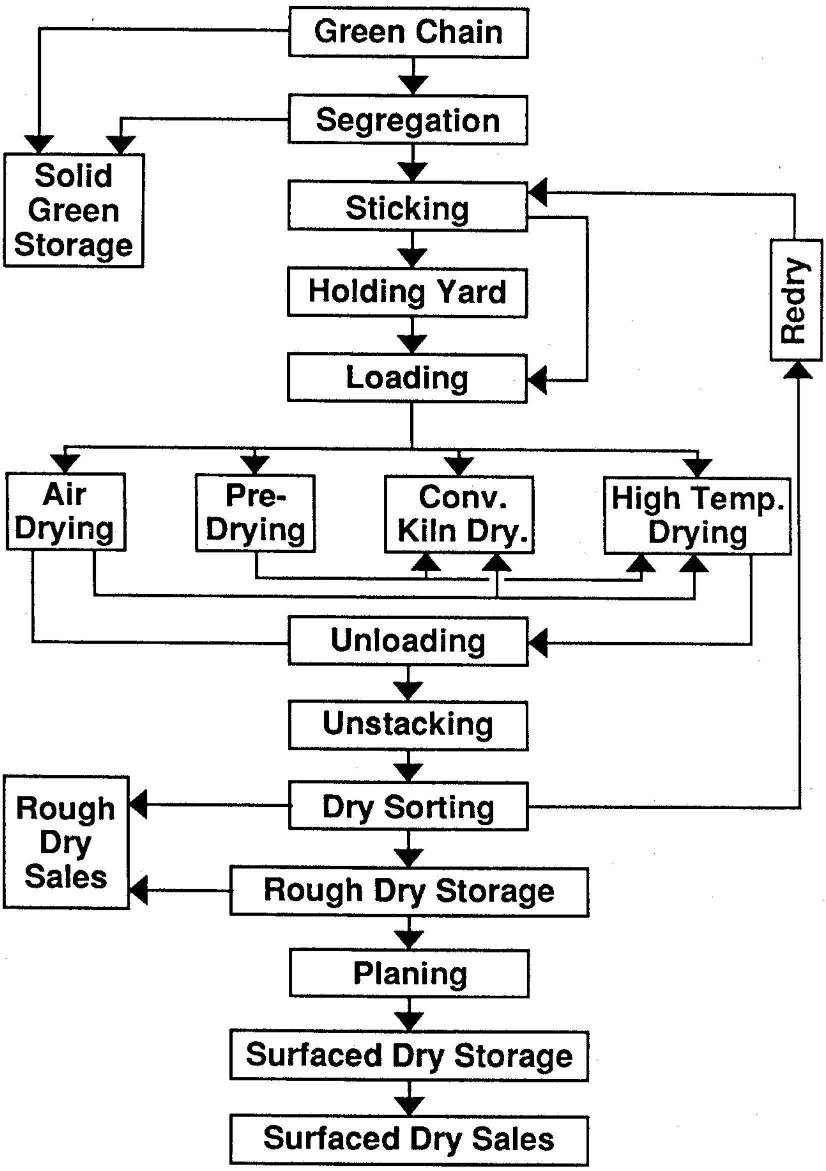
Product size control projects are good examples of high-margin operations. Mill operations reduce target size with the hope of improving volume recovery. Close process monitoring is important. Slight increases in sawing variation that go unnoticed can quickly erode any recovery gains.

Statistical Process Control (SPC) is a management tool available to help dry kiln operators manage their high margin activities. **Statistical Process Control** techniques give dry end operators the ability to show the cause and effect of system changes. They can tell when the systems are in control and when they are not. **SPC** detects trends early. **SPC** concentrates on the average or target and on system variance. While commonplace in other manufacturing industries, **SPC** is relatively new to wood products.

Statistical Process Control assumes that the mean, median and mode of the production system are the same (Figure 2). **Statistical Process Control** can only be useful if the process can operate within set tolerance limits. In a capable process, 68.26% of the results will fall between plus or minus one standard deviation of the mean (Figure 3).

Out of 1000 events only 21.4 events should occur above the plus two standard deviation level. This introduces the test for significance (Figure 4). The hypothesis of the test is that the target or centerline is the median of the process. This means that 50% of the occurrences will occur above the centerline and 50% below. If that does occur, then the process is capable and it is in statistical control. If that does not happen, then either the centerline is in the wrong place or the estimate of the system variation is wrong.

Managers set control limits at three standard deviations. When placed above and below the centerline, the three standard deviations form a 6 Sigma process range. This allows a fairly wide area for process operation. **SPC** tracks



Don Arganbright, Project Leader
Forest Products Lab, Richmond, Calif.

Figure 1. Components of a lumber drying system.

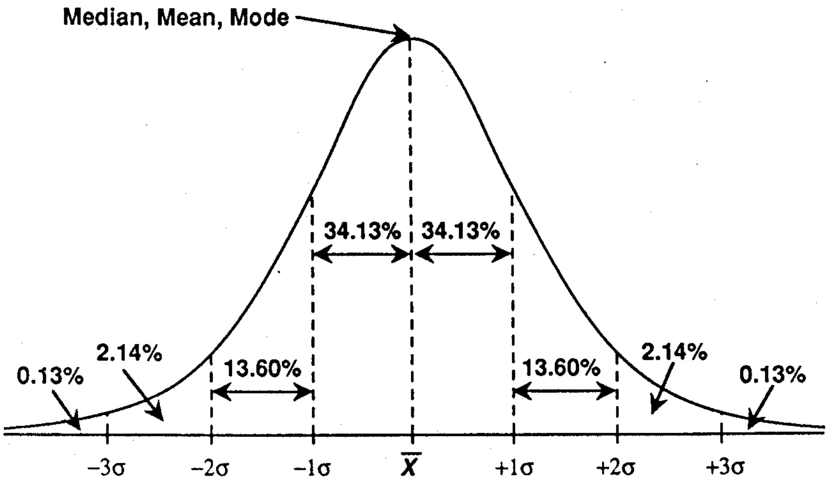


Figure 2. Normal distribution.

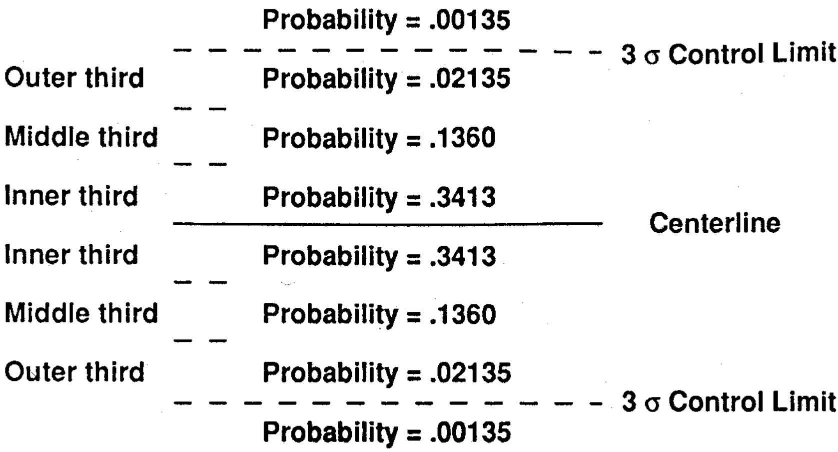


Figure 3. Probability of an event at various distances from centerline.

each result. The pattern of the results, even when remaining within the 3 Sigma limits, shows both of process capability and variance.

The mathematics of 6 Sigma quality control is straight forward. You are in control as long as the cumulative chances of the results do not exceed 26 out of 10,000 (.0026). Take a process where a run of results begin to occur above (or below) the centerline. The chance of a result being above the centerline is 50%. The chance of a second consecutive result being above the centerline is 50% times 50% or 25%. The chance a third consecutive result being above the centerline is 50% times 50% times 50% or 12.5%.

If the process is capable and variation is in control, the condition shown in Figure 5 can continue eight times ($.5^8 = .0039 > .0026$). When the ninth result occurs, consecutively above the centerline, the cumulative chance is $.5^9$ or .0020 which is less than .0026 and beyond 6 Sigma limits (Figure 6).

The mathematics of 6 Sigma quality control state that only 26 results out of 10,000 results will exceed the upper and lower control limits. A process that delivered 27 or more results beyond those limits is out of control.

Common sense plays a role here. The degree of out-of-control is slight if the 27 bad actors are randomly dispersed. No action may be warranted. If the 27 outliers occurred on one day or in one package or come from one dry kiln, the control factor would be different.

There are many tests for significance used in **SPC**. Eight of the more common tests are shown in Figure 7. These include:

1. One point beyond Zone A.
2. Nine points in a row in or beyond zone C.
3. Six points in a row steadily increasing or decreasing.
4. Fourteen points in a row alternating up and down.
5. Two out of three points in a row in or beyond zone A.
6. Four out of five points in a row in or beyond Zone B.
7. Fifteen points in a row in Zones C (above and below).
8. Eight points in a row on both sides of centerline with none in Zone C.

SPC installs quickly in kiln operations. Mills that have dry end data collection systems are half way home. For example, some moisture monitors have print out options (Figure 8). The dry end operators just need to segregate each kiln of lumber as it passes through the moisture sensor. The operator combines the results of each run with identifying data, such as date, kiln number, species, schedule used, lumber type, in a data base (Figure 9). The database software then submits the data to the **SPC** tests. Other management information, such as regression analysis and value loss averaging, is made available (Figures 10 and 11).

H_0: Centerline is median

or H_0: $P(x > ℄) = 1/2$

H_1: $P(x > ℄) \neq 1/2$

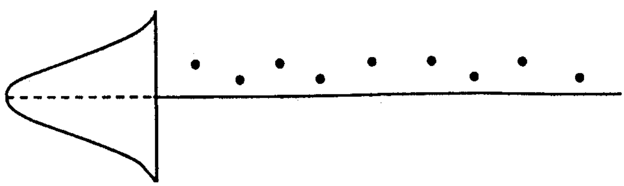
Sig. Level = 0.004

Sample Size = 9

Criterion: Reject H_0 in favor of H_1 if all 9 points lie either above or below the centerline.

Figure 4. Example of a significance test.

P (9 points in a row in Zone C or beyond)



$$1/2 \cdot 1/2 \cdot 1/2 \cdot 1/2 \cdot 1/2 \cdot 1/2 \cdot 1/2 \cdot 1/2 \cdot 1/2 = 1/512$$

Figure 5. Nine consecutive points above or below the centerline have a probability of only 1 in 512.

Test 2: Nine points in a row in Zone C or beyond

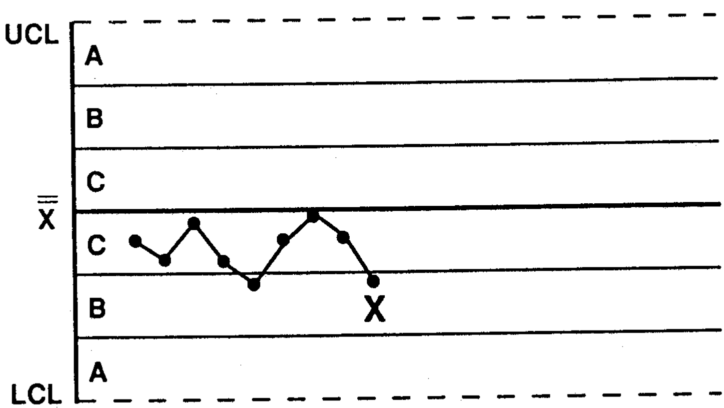


Figure 6. Tests for lack of statistical control.

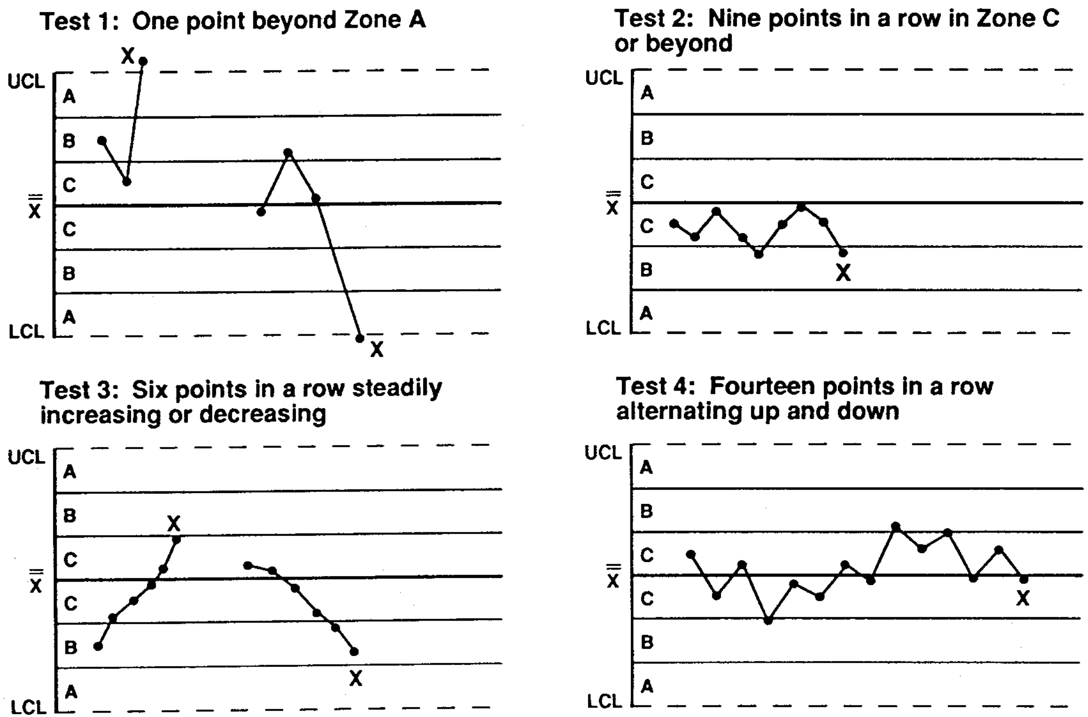


Figure 7. Tests for special causes on statistical control charts.

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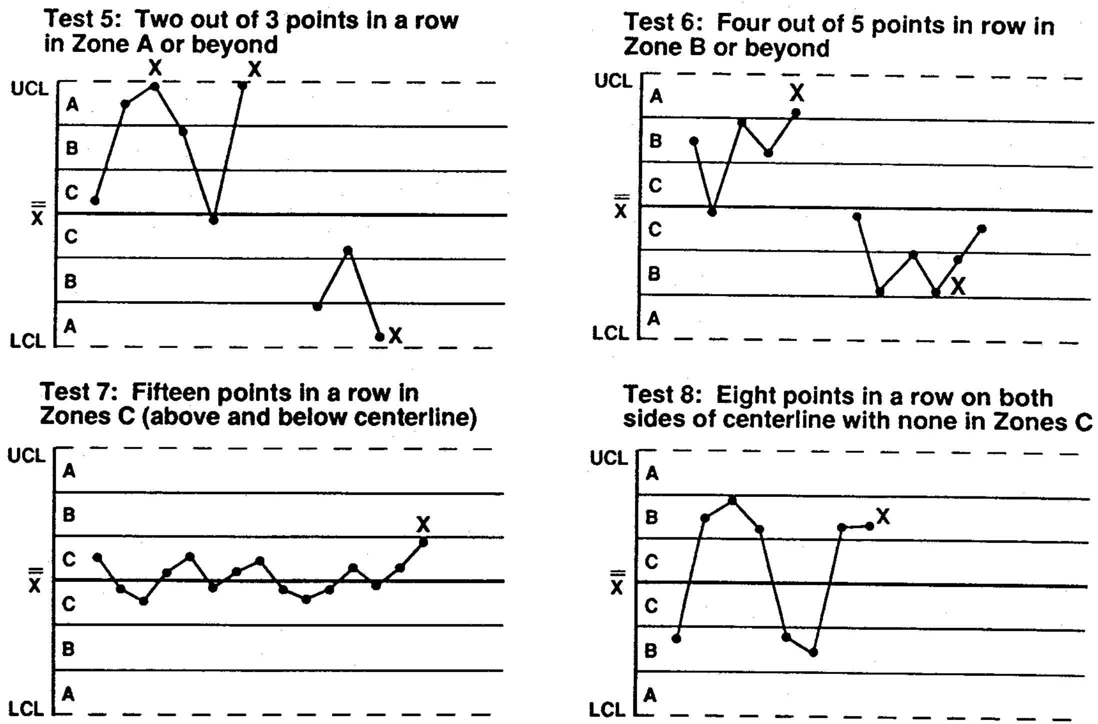

Figure 7. Continued.

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KILN # 9

DATE 12-7-88

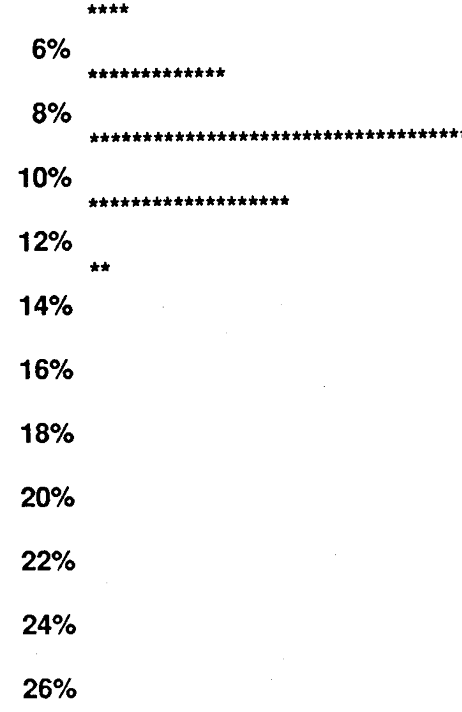
2 x 4

Dry	Below	–	8%	999
Wet A	8%	–	10%	1988
Wet B	10%	–	14%	1217
Wet C	14%	–	16%	6
Wet D	Over		16%	1
Total				4211

Average moisture content --- 8%

Distribution of samples in 2% intervals

Below	–	6%	268
6%	–	8%	731
8%	–	10%	1988
10%	–	12%	1093
12%	–	14%	124
14%	–	16%	6
16%	–	18%	
18%	–	20%	
20%	–	22%	
22%	–	24%	
24%	–	26%	1
Over	–	26%	



Wagner Electronic Products
Rogue River, Oregon

Figure 8. Printout from in-line moisture meter.

09 / 18 / 89	KILN QUALITY CONTROL SYSTEM	18 : 12 : 03

LUMBER REFERENCE #000204 SPECIES DF GRADE LM SIZE 2 X 4
DATE 01 / 13 / 89 BF 26347 LF 0 KILN #01 SCHEDULE 00000

DISTRIBUTION OF SAMPLES – 2% INTERVALS

BELOW 6%	66	5%	2%
6% – 8%	102	7%	5%
8% – 10%	485	33%	32%
10% – 12%	600	41%	44%
12% – 14%	181	12%	15%
14% – 16%	24	2%	2%
16% – 18%	4	0%	
18% – 20%			
20% – 22%	2	0%	
22% – 24%			
24% – 26%			
OVER 26%			

MOISTURE DISTRIBUTION SUMMARY

BELOW 8%	168	11%	6%
8% – 10%	485	33%	32%
10% – 14%	781	53%	59%
14% – 16%	24	2%	2%
OVER 16%	6	0%	
TOTAL	1464		
Piece Weighted Ave.		10.0%	10.5%
Footage Weighted Ave.			10.3%
Record Number		1 of	379

Summary File (ON / OFF) Print Background Report Kiln / Size Summary Display
Bar Graph (ON / OFF) Change sort / summary Modify record End or Quit
Home / End - Top / End of the file Insert / Delete - Insert / Delete record
PgUp / PgDn - Previous / Next kiln Up Arrow / Dn Arrow - Previous / Next record

Brent Mills, Performance Technology, Lake Oswego, Oregon

Figure 9. Moisture information in data base with identifying data.

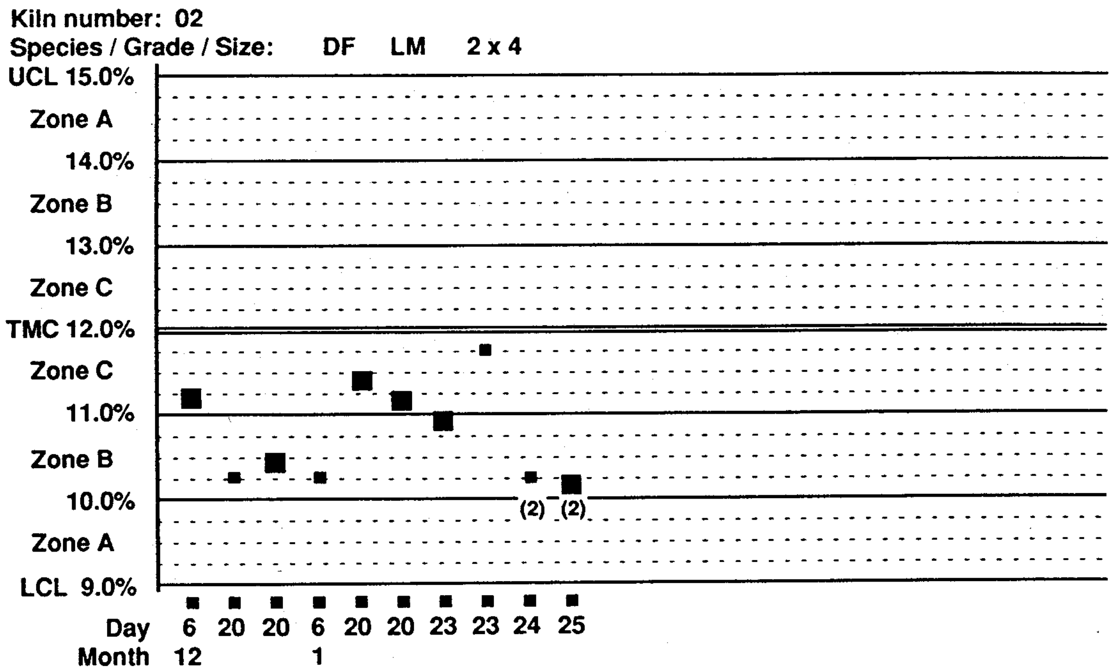
Kiln QC – Background Report
09 / 18 / 89

Condition: Kiln _No <[03]

Kiln	Date	Species & Grade		Lumber Size	Lumber BF	Lumber $/MBF	% Moisture Goal	% Moisture Ave.	Potential Improvement
02	12/06	DF	LM	2 x 4	70578	$ 265	12.0	11.0	$180.11
02	12/20	DF	LM	2 x 4	23956	$ 265	12.0	10.2	$112.05
02	12/20	DF	LM	2 x 4	10810	$ 265	12.0	10.5	$43.92
02	01/06	DF	LM	2 x 4	7810	$ 265	12.0	10.2	$36.94
02	01/20	DF	LM	2 x 4	19755	$ 265	12.0	11.4	$29.37
02	01/20	DF	LM	2 x 4	10477	$ 265	12.0	11.2	$22.85
02	01/23	DF	LM	2 x 4	6840	$ 265	12.0	10.9	$19.43
02	01/23	DF	LM	2 x 4	6497	$ 265	12.0	11.7	$4.46
02	01/24	DF	LM	2 x 4	11784	$ 265	12.0	10.2	$55.87
02	01/25	DF	LM	2 x 4	29568	$ 265	12.0	10.1	$149.35
		subtotal			198075	MBF	Ave. M.C.	10.8	$654.34

Standard deviation 0.587
Days reported 51 Production per day 3884
Annualized improvement potential $4,683.01

Figure 10. Tabulation report for kiln #2.



Test (2) occurs when nine points in a row are in Zone C or beyond. The suggestion is that the target cannot be achieved by the process being observed.

Test Counts: (1) 0 (2) 8 (3) 3 (4) 2 (5) 0 (6) 3 (7) 0 (8) 2

Figure 11. Statistical control chart.