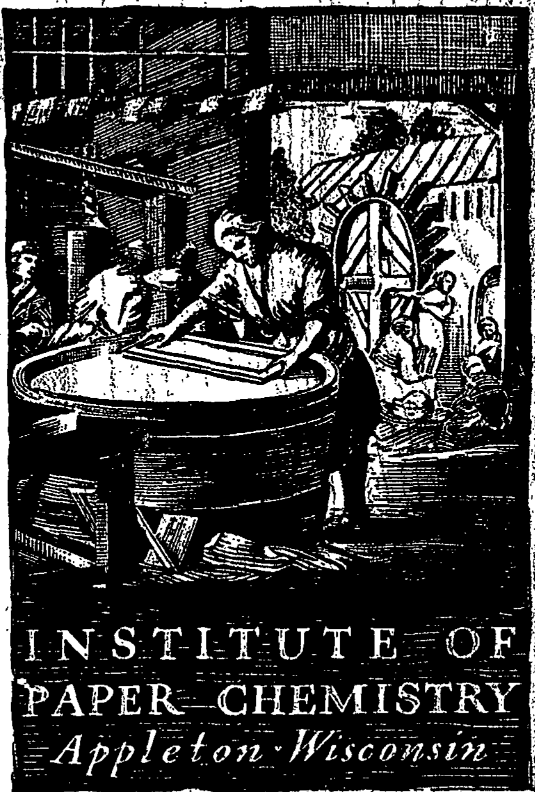

MONTHLY CALIBRATION OF PHYSICAL TESTERS

Project 1108

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THE INSTITUTE OF PAPER CHEMISTRY

APPLETON, WISCONSIN

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INTRODUCTION

At the beginning of each month, the calibration of each tester in the container laboratory is checked. Then, in order to verify these calibrations, standard samples of liner, corrugating medium and/or combined board are run on those testers where determinations are usually made on such materials. Standard container laboratory testing procedures are followed as closely as possible. This testing has been performed for about seven years, during which time the standard samples of liner, corrugating medium and combined board have frequently been changed. About three years ago it was decided to analyze past data and set up control charts for each material currently being tested on each machine. This report presents the statistical analyses which were performed on the data and the control limits which were set up and are currently being used to determine whether testers are in calibration.

MATERIALS

Standard samples of 42-lb. kraft liner, dry finish (Sample CNS 42), 26-lb. semichemical corrugating medium (Sample CNS 789) and A-flute combined board consisting of 42-lb. kraft liners with a bleached 26-lb. semichemical corrugating medium (Sample CNS 755) are presently being used for this monthly calibration of physical testers. In July, 1952, pouncing paper replaced 42-lb. kraft liner for calibration of the bursting strength testers.

SAMPLING PROCEDURE

The standard samples which are used for the monthly calibration testing are generally selected from the Institute's reserve stock of materials. When each supply of sample is depleted to the extent that there is only enough left to perform two more months' testing, a selection of new samples for testing is made from rolls or stocks of sufficient dimension to yield sheets measuring at least 14 inches square. After enough new sample has been cut for at least two years' testing, each sheet is visually inspected for spots, creases, holes, or cuts which would influence the test results. Specimens containing such imperfections are discarded. The sheets of good sample are marked according to a table of random numbers and arranged in numerical order. The new material is preconditioned and conditioned and then stored in the conditioned atmosphere. Each month enough sheets are taken from the top of the pile to complete the testing for that month.

PRECONDITIONING AND CONDITIONING

All materials, upon completion of random sampling, are preconditioned for at least 24 hours at less than 35% R.H., and 73 ± 3.5°F. and conditioned for at least 48 hours at 50 ± 2% R.H. and 73 ± 3.5°F. The stock of conditioned material is then stored in the conditioned atmosphere for future use. If at any time the humidity goes above 52%, the samples shall be preconditioned and conditioned as described above. If the relative humidity goes below 48%, the samples shall be reconditioned at 50 ± 2% R.H. for a period of time equivalent to the time the samples were exposed to the lower humidity, provided however, that in no case will the required time need to be in excess of 48 hours.

TESTING PROCEDURE

Immediately following the monthly calibration of physical testers on the first of each month, enough 14 in. by 14 in. sheets for that month's testing are taken from the stored stock of materials. These sheets are then marked for machine direction. The distribution and orientation of tests on the test specimens is presented in Figure 1. The testing is performed according to the various standard Container Section test procedures (P-methods) with the following elaborations.

A. <u>Bursting Strength</u>

Samples of pouncing paper and corrugating medium are tested on each of the two Jumbo Mullen bursting strength testers (DE 35 and DE 105) using a 1,000-lb. clamping load. Samples of combined board are tested using a 200-lb. clamping load. The small Mullen tester (DE 1904) is used to test samples of corrugating medium at a 650-lb. clamping load. All specimens are tested best side up--20 specimens per sample for pouncing paper, 60 specimens per sample for corrugating medium and 40 specimens per sample for combined board. Eighty specimens per sample are tested on the small Mullen tester (DE 1904). On the Jumbo testers,

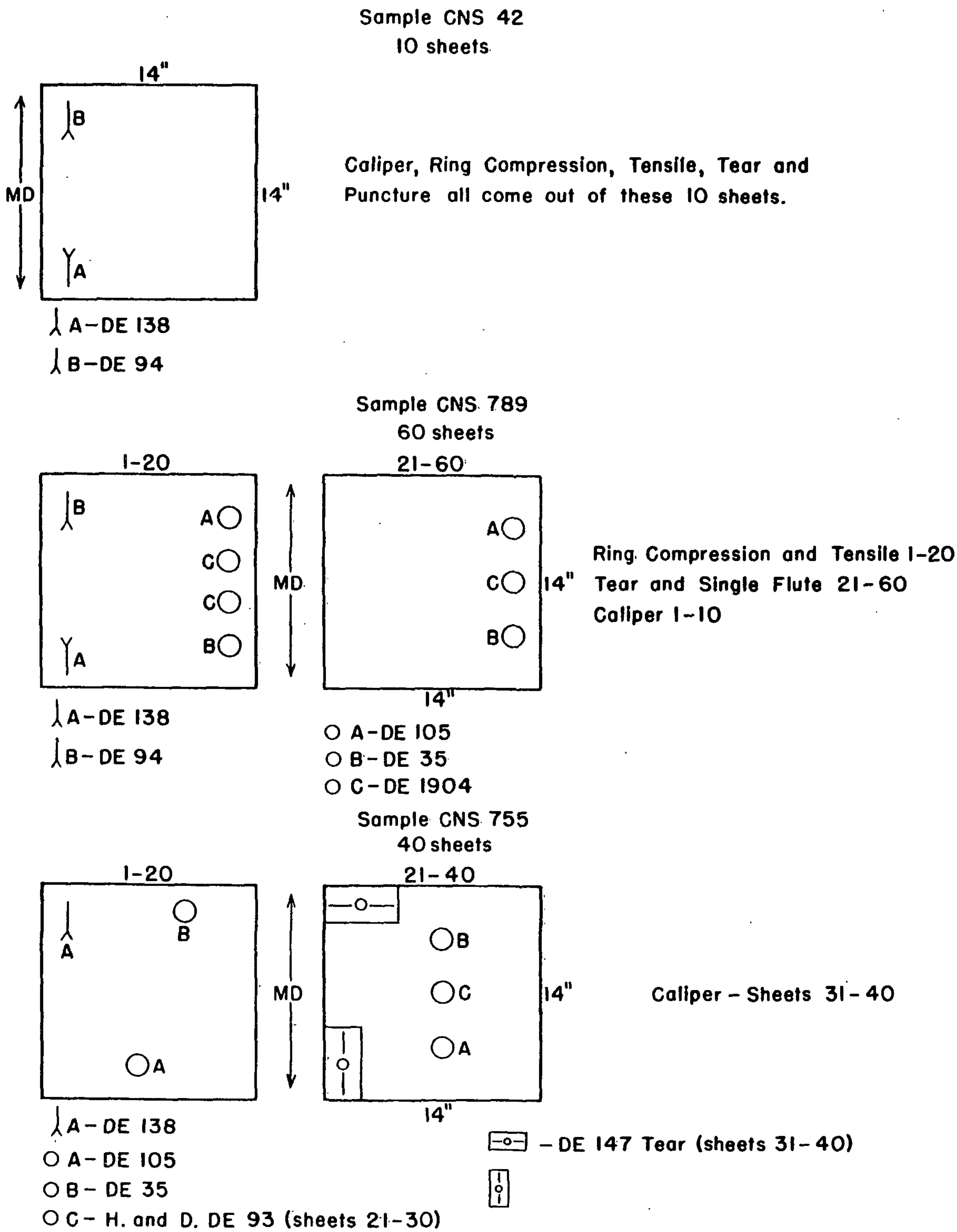

Figure I.
Distribution and Orientation of Tests

the results for pouncing paper and corrugating medium are recorded to the nearest pound per square inch (p.s.i.); the combined board results on the Jumbo testers are recorded to the nearest 5 p.s.i. and the corrugating medium results on the small Mullen tester are recorded to the nearest 0.5 p.s.i. The bursting strength results on the Jumbo and small Mullen testers are averaged to the nearest 0.1 p.s.i. and 0.01 p.s.i., respectively. The testing is performed on 12 by 12 inch ± 0.01 inch sheets of material as shown in Figure 1.

B. Puncture

Samples of kraft liner and corrugating medium are tested on each of the two G. E. puncture testers (DE 94 and DE 138). Combined board results are obtained only on Tester DE 138. All puncture results are obtained in the machine direction, best side up. Ten specimens per sample are tested on kraft liner, twenty specimens per sample on corrugating medium and fifteen specimens per sample on combined board. The results obtained on liner and combined board specimens for tester DE 138 are recorded to the nearest whole unit and averaged to the nearest 0.1 unit; the corrugating medium results are recorded to the nearest 0.5 unit and averaged to the nearest 0.01 unit. For tester DE 94, the test results are recorded to the nearest 0.1 unit and averaged to the nearest 0.01 unit.

C. Caliper

Samples of kraft liner and corrugating medium are tested on each of the two Cady Micrometers (DE 41 and DE 152). Cady Micrometer

DE 152 is also used to test samples of combined board. Ten sheets of kraft liner are used to obtain 20 caliper results for each tester--each sheet is tested in two diagonally opposite corners. Only ten results are obtained on corrugating medium and combined board. The thickness indicated on the micrometer dials is recorded to the nearest 0.1 point and averaged to the nearest 0.01 point.

D. Torsion Tear

The Institute Torsion Tear tester, DE 147, is used to test combined board specimens. Ten tear results are obtained in each machine direction and recorded to the nearest whole scale unit (inch-ounces). The results for each direction are averaged separately to the nearest 0.1 inch-ounce. The specimens are cut 5.00 ± 0.05 inches in length (along the direction of the tear) and 2.25 ± 0.05 inches in width. Figure 1 shows test area orientation of torsion tear specimens.

E. Single-fluter

Eighty specimens of corrugating medium are tested each month by forming flutes on the Institute single-fluter No. 201 and then testing on the H. and D. compression tester. The temperature of the die should be 325 ± 5°F., the press load should be 650 ± 25 pounds and the time in press, 3 ± 0.5 seconds. The specimens are conditioned for 6 hours at 50% R.H. after forming. Before being single-fluted, each specimen is 3 ± 0.01 inches in the machine direction and 1 ± 0.01 inch across the machine direction. The compression results are recorded to the nearest

0.1 lb. (per 1/3 sq. in.) and "rolled" specimens are noted. The results are then converted to lb./sq. in. by multiplying by 3. Averages are calculated to the nearest 0.01 lb./sq. in.

F. H. and D. Flat Crush

The H. and D. Flat Crush tester, DE 93, is used to obtain compression results on combined board specimens. Ten circular specimens (5 square inches in area) are tested and the results recorded to the nearest pound. Test area orientation of flat crush specimens is presented in Figure 1. The averages are computed to the nearest 0.1 pound per square inch.

G. Ring Compression

Samples of kraft liner and corrugating medium are tested for compression strength using the Riehle Ring Compression tester DE 8. For each sample, twenty specimens are tested in the cross-machine direction--10 tests using a heavy holder and 10 tests using a light holder. Each test specimen is cut 6.00 ± 0.03 inches long and 0.50 ± 0.01 inch wide. The ring compressive strength is recorded to the nearest 0.5 pound and averaged to the nearest 0.01 pound.

H. Elmendorf Tear

Samples of kraft liner and corrugating medium are tested for tearing strength on the Elmendorf Tear tester, DE 10. Thirty results are obtained in each machine direction for kraft liner and in the cross-machine only for corrugating medium. For linerboard, only one specimen is torn at once; for corrugating medium, four specimens are torn at once. The indicated scale reading is recorded to the nearest 0.5. The results are averaged to the nearest 0.1 gram per sheet. This is calculated from the scale readings by multiplying the sum of the scale readings by 16 and dividing the product by the number of specimens torn. This result is then divided by the number of observed readings. The specimen is cut 3.0 ± 0.1 inches long by 2.50 ± 0.01 inches in the test direction.

I. Amthor Tensile and Stretch

Both tensile and stretch results are obtained each month on samples of kraft liner and corrugating medium. Ten readings are obtained in each machine direction for each material. The greatest load sustained by each specimen (tensile) is recorded to the nearest 0.1 pound for all samples except machine direction kraft liner which is recorded to the nearest whole pound. To convert a load reading to pounds per inch of width, the reading is divided by the width of the specimen. The stretch readings are recorded to the nearest 0.001 inch for any initial span. To convert a stretch reading, in inches, to per cent, the reading is multiplied by 100 and divided by the initial span in inches. The averages are computed to the nearest 0.01 lb./in. for tensile and to the nearest 0.01 per cent for stretch. The test specimens are 0.591 ± 0.005 inch wide and 9 ± 1 inches in the test direction.

STATISTICAL PROCEDURES

The statistical procedures employed in this study are those suggested by E. L. Grant in his book Statistical Quality Control.

Before outlining actual control chart methods, it might be well to discuss several pertinent statistical concepts. The actual computation of these statistics will be discussed later.

A. Average

Throughout this study, the word average and the symbol $\overline{X}$ are used to designate that measure of central tendency known as the arithmetic mean. The arithmetic mean of a set of N observed numbers is the sum of the numbers divided by N.

B. Standard Deviation

For control chart analysis with samples as large as those used in this study, the standard deviation is the most useful measure of the dispersion of the individual test results. The standard deviation is the root-mean-square deviation of the individual test results from their average. The standard deviation for each sample is denoted by σ. For sample distributions which roughly approximate the normal curve, 68.26% of the individual test results fall within one standard deviation on either side of the sample average ($\overline{X} \pm \sigma$), 95.46% fall within two standard deviations ($\overline{X} \pm 2\sigma$) and 99.73% within three standard deviations ($\overline{X} \pm 3\sigma$).

C. Standard Error

The sample averages ($\overline{X}$ values) and sample standard deviations (σ values) do themselves form frequency distributions. These frequency distributions have their own measures of central tendency (average) and dispersion (standard deviation). The average of such a distribution of

$\bar{X}$ values is the best possible estimate of the average of the population from which these samples were drawn; the average of the sample standard deviations is used with a factor (c_2) to determine the estimated population standard deviation (σ'). The spread of these distributions depends not only on the spread of the population, but also on the sample size, N--the larger the value of N, the less the spread of the $\bar{X}$ and σ values. The standard deviation of the frequency distribution of $\bar{X}$ values is equal to $\sigma'/\sqrt{N}$ -- i.e., the standard deviation of the population divided by the square root of the sample size. The standard deviation of the frequency distribution of σ values is equal to $\sigma'/\sqrt{2N}$--the standard deviation of the population divided by the square root of twice the sample size. <u>These standard deviations of the $\bar{X}$ and σ frequency distributions are referred to as standard errors and are used to compute control limits for sample averages and standard deviations.</u>

The following outline describes the techniques used in setting up the control charts for the calibration data.

I. Starting the Control Chart

A. Purpose of chart

The control chart analysis is used to determine the level and variability of a process and also to set up limits within which sample averages and standard deviations would be expected to lie so long as the process is not changed.

B. Collection of data

1. Using past data. For this study, all of the previous monthly calibration results, which had been obtained on samples of materials

currently being used for monthly calibration testing, were recorded and analyzed. Each month's data was considered to be a sample.

2. Collecting new data.

a. The individual testing results should be recorded accurately in the order in which they are obtained.

b. It is important that notes be made concerning any occurrences which might provide help in investigating assignable causes of variation should the control chart analysis show that such causes exist.

c. On statistical grounds, it is desirable that control limits be based on 20 or 25 samples. However, it may be desirable to make preliminary calculations from 8 or 10 samples and modify the limits as more samples are obtained.

C. Calculation of sample averages ($\overline{X}$)

1. The individual results in each sample are added together and the sum is divided by the number of items in the sample-- i.e., $\overline{X} = \Sigma X/N$.

D. Calculation of sample standard deviations (σ)

1. Sample standard deviations are calculated from the formula

$$\sigma = \sqrt{\frac{\Sigma X^2}{N} - \overline{X}^2}$$

where X is an individual test result

and N is the number of specimens included in each sample.

E. Calculation of population average ($\overline{X}'$)

1. The population average is estimated from $\Sigma\overline{X}/M$

where $\Sigma\overline{X}$ is the sum of all the sample averages

and M is the number of samples included in the population estimate.

F. Calculation of population standard deviation (σ')

1. The population standard deviation is estimated from

$$\sigma' = \frac{\Sigma \sigma}{M} / c_2$$

Where $\Sigma \sigma$ is the sum of the individual sample standard deviations,

M is the number of samples included in the population estimate,

c_2 is the ratio between the average of the sample standard deviations of a given size and the standard deviation of the population from which the samples were taken. Values of c_2 for various sample sizes are presented in Table I.

G. Calculation of trial control limits

1. Trial control limits, obtained in the following manner, are appropriate for analyzing the data which were used in their calculation. These limits show whether the samples which were used constitute a homogeneous population. If such a homogeneous population did not exist, the trial control limits will require modification before being applied to future data.

2. The trial control limits for averages are equal to $\bar{X}' \pm 2 \sigma'/\sqrt{N}$. Using these limits, the averages taken from a normal distribution will fall outside the limits one out of twenty times by chance alone with no assignable cause of variation present. If $3 \sigma'/\sqrt{N}$ limits are used, the probability of an average falling outside the control limits merely by chance is only 0.27%, or less than 1 in 100 times.

TABLE I

FACTORS FOR ESTIMATING σ' FROM $\overline{\sigma}$

No. of Observations in Subgroup	$c_2 = \overline{\sigma}/\sigma'$
2	0.5642
3	0.7236
4	0.7979
5	0.8407
6	0.8686
7	0.8882
8	0.9027
9	0.9139
10	0.9227
11	0.9300
12	0.9359
13	0.9410
14	0.9453
15	0.9490
16	0.9523
17	0.9551
18	0.9577
19	0.9599
20	0.9619
21	0.9638
22	0.9655
23	0.9670
24	0.9684
25	0.9697
30	0.9748
35	0.9784
40	0.9811
45	0.9832
50	0.9849
55	0.9863
60	0.9874
65	0.9884
70	0.9892
75	0.9900
80	0.9906
85	0.9912
90	0.9916
95	0.9921
100	0.9925

3. The trial control limits for standard deviations are equal to $\overline{\sigma} \pm 2\,\sigma'/\sqrt{2N}$ or $\overline{\sigma} \pm 3\,\sigma'/\sqrt{2N}$.

H. Plotting the $\overline{X}$ and σ control charts

1. Two examples of control charts are presented in Figures 2 and 3. The $\overline{X}$ chart, which is used for plotting sample averages in order to control the process level, is presented in the upper half of each chart. The σ chart, which is used for plotting sample standard deviations in order to control within sample variability, is shown in the lower half of each chart.

2. The vertical scale at the left of the control charts is used for the statistical measures $\overline{X}$ and σ.

3. The horizontal scale is used for sample identification.

4. The central line on the $\overline{X}$ chart is drawn as a solid horizontal line at the value of $\overline{X}'$. The upper and lower control limits for $\overline{X}$ are drawn as dotted horizontal lines at the levels computed as described in Section G above.

5. The central line on the σ chart is drawn as a solid horizontal line at the computed value of $\overline{\sigma}$. The upper and lower control limits for σ are drawn as dotted horizontal lines at the computed levels.

II. Drawing Preliminary Conclusions from the Charts

A. Indication of homogeneity or lack of homogeneity

1. If all points lie within the trial control limits on both the $\overline{X}$ and σ charts, it is presumed that the samples constitute a homogeneous population. If such is the case, the trial control limits may

be extended horizontally across the control chart and applied to future data.

2. Lack of homogeneity is indicated by points falling outside the trial control limits on either the $\bar{X}$ or σ chart. If the charts show lack of homogeneity, try to judge what may be the assignable causes of variation and whether they can be eliminated. Also, revise the control limits before applying them to future data. This is explained further in the following section.

III. Revision of Central Line and Control Limits

A. If process has been in control

1. If both the average ($\bar{X}$) and dispersion (σ) have been in control satisfactorily, extend the trial control limits horizontally across the control chart and apply them to future data.

2. As data accumulate, review the limits. Although all points fall within the control limits, lack of control may be indicated by extreme runs of points. For example, consider that grounds exist for suspicion that the process average has shifted when the control chart shows:

a. 7 successive points all on same side of central line.

b. 11 successive points--10 on same side.

c. 14 successive points--12 on same side.

d. 17 successive points--14 on same side

e. 20 successive points--16 on same side.

B. If process shows lack of control

1. If charts show lack of control, try to judge what may be the assignable causes of variation and whether they can be eliminated.

2. Another estimate of σ' should be determined on the basis of a homogeneous population. This is done by removing the samples showing lack of control on the σ chart and calculating a revised $\overline{\sigma}$ and new control limits for σ. If there are still samples outside these revised limits, remove these samples and repeat. Estimate σ' from $\overline{\sigma}/c_2$ using final revised $\overline{\sigma}$ obtained after all out-of-control standard deviations have been eliminated. Consider this as a value of σ' which might be obtained if process were brought into control.

3. If dispersion is in control but average out of control, trial limits and central line on σ chart may be used. Decide whether the central line on the $\overline{X}$ chart should be at an aimed-at level (sometimes merely a matter of machine setting) or whether it should be based on the past data, a revision of $\overline{X}'$. A revised $\overline{X}'$ may be obtained by the elimination of out-of-control points.

4. When, finally, the estimated $\overline{X}'$ and σ' have been determined from a homogeneous population and the control limits about $\overline{X}'$ and $\overline{\sigma}$ have been determined, the control chart may be applied to future data.

IV. Use of Control Charts for Action on the Process

A. Indication of control or lack of control

1. Lack of control is indicated by points falling outside the control limits on either the $\overline{X}$ or σ charts.

2. When a process is "out-of-control," it means that assignable causes of variation are present.

3. When a process is "in control," one may act as though no assignable causes of variation are present.

4. Although all points fall within control limits, lack of control may be indicated by extreme runs of points (as previously discussed in Section III-A, 2).

B. Three kinds of action

1. To remove assignable causes of variation brought to attention by out-of-control points.

2. To establish process average.

3. To establish process dispersion.

C. To continue control of process

1. Leave process alone when in control.

2. Hunt for and remove assignable causes of variation when not in control.

3. Change in dispersion often calls for fundamental changes in machines or methods.

Two examples of control charts are presented in Figures 2 and 3. The monthly averages and standard deviations for samples of combined board tested on Cady Micrometer DE 152 are plotted in Figure 2. This is an example of a tester which has been kept "in control" at the 95% level over a long period of time. The monthly averages and standard deviations for samples of pouncing paper tested on Jumbo Mullen Burst DE 35 using a 1000-lb. clamping load are plotted in Figure 3. This represents a tester which was occasionally "out-of-control" and was brought into control again.

DISCUSSION OF RESULTS

The values of $\bar{\bar{X}}'$ and σ' (population estimates of the average and standard deviation) for each tester are presented in Table II along with the

TABLE II

	N	$\bar{X}'$	σ'	Averages 2 S.E. U.C.L.	Averages 2 S.E. L.C.L.	Averages 3 S.E. U.C.L.	Averages 3 S.E. L.C.L.	Standard Deviation 2 S.E. U.C.L.	Standard Deviation 2 S.E. L.C.L.	Standard Deviation 3 S.E. U.C.L.	Standard Deviation 3 S.E. L.C.L.	+2 S.E. Limits, %
Jumbo Mullen Burst												
Pouncing Paper												
DE 35, 1000-lb. clamp	20	124.000	5.362	126.398	121.602	127.597	120.403	6.855	3.463	7.703	2.615	1.9
DE 105, 1000-lb. clamp	20	124.303	5.268	126.667	121.939	127.849	120.757	6.759	3.415	7.595	2.579	1.9
Corrugating Medium												
DE 35, 1000-lb. clamp	60	52.920	4.851	54.172	51.668	54.798	51.042	5.676	3.904	6.119	3.461	2.4
DE 105, 1000-lb. clamp	60	52.615	4.655	53.817	51.413	54.418	50.812	5.446	3.746	5.871	3.321	2.3
Combined Board												
DE 35, 200-lb. clamp	40	283.109	22.303	290.161	276.057	293.687	272.531	26.869	16.893	29.363	14.399	2.5
DE 105, 200-lb. clamp	40	282.469	21.085	289.137	275.801	292.471	272.467	25.400	15.972	27.757	13.615	2.4
Small Mullen Burst												
Corrugating Medium												
DE 1904, 650-lb. clamp	80	45.519	4.899	46.615	44.423	47.163	43.875	5.627	4.079	6.014	3.692	2.4
Caliper												
Kraft Liner												
DE 41	20	15.924	0.380	16.094	15.754	16.179	15.669	0.486	0.246	0.546	0.186	1.1
DE 152	20	15.924	0.269	16.044	15.804	16.104	15.740	0.343	0.175	0.385	0.133	0.8
Corrugating Medium												
DE 41	10	10.954	0.347	11.174	10.734	11.284	10.624	0.476	0.164	0.554	0.086	2.0
DE 152	10	10.958	0.414	11.220	10.696	11.351	10.565	0.568	0.196	0.661	0.103	2.4
Combined Board												
DE 152	10	209.588	2.266	211.022	208.154	211.739	207.437	3.105	1.077	3.612	0.570	0.7
G. E. Puncture												
Kraft Liner												
DE 94, In M.D., Best Up												
DE 138, In M.D., Best Up	10	36.387	1.109	37.089	35.685	37.440	35.334	1.519	0.527	1.767	0.279	1.9
Corrugating Medium												
DE 94, In M.D., Best Up												
DE 138, In M.D., Best Up	20	10.208	0.514	10.438	9.978	10.553	9.863	0.656	0.332	0.737	0.251	2.3
Combined Board												
DE 94, In M.D., Best Up												
DE 138, In M.D., Best Up	15	220.471	9.421	225.335	215.607	227.767	213.175	12.381	5.501	14.101	3.781	2.2

TABLE II (Continued)

	N	$\overline{X}'$	σ'	Averages 2 S.E. U.C.L.	Averages 2 S.E. L.C.L.	Averages 3 S.E. U.C.L.	Averages 3 S.E. L.C.L.	Standard Deviation 2 S.E. U.C.L.	Standard Deviation 2 S.E. L.C.L.	Standard Deviation 3 S.E. U.C.L.	Standard Deviation 3 S.E. L.C.L.	+2 S. Limit %
Amthor Tensile, DE 45												
Kraft Liner												
In M.D.	10	97.644	5.822	101.326	93.962	103.167	92.121	7.976	2.768	9.278	1.466	3.8
Cross M.D.	10	43.537	2.249	44.959	42.115	45.670	41.404	3.081	1.069	3.584	0.566	3.3
Corrugating Medium												
In M.D.	10	51.075	4.420	53.871	48.279	55.269	46.881	6.054	2.102	7.042	1.114	5.5
Cross M.D.	10	21.586	0.930	22.174	20.998	22.467	20.705	1.274	0.442	1.482	0.234	2.7
Amthor Stretch, DE 45												
Kraft Liner												
In M.D.	10	1.971	0.132	2.055	1.887	2.097	1.845	0.182	0.062	0.212	0.032	4.3
Cross M.D.	10	4.049	0.752	4.525	3.573	4.763	3.335	1.030	0.358	1.198	0.190	11.8
Corrugating Medium												
In M.D.	10	1.276	0.153	1.372	1.180	1.420	1.132	0.209	0.073	0.243	0.039	7.5
Cross M.D.	10	2.104	0.418	2.368	1.840	2.500	1.708	0.572	0.200	0.665	0.107	12.5
Riehle Ring Compression, DE 8												
Kraft Liner												
Cross M.D., Best In	20	87.927	5.161	90.235	85.619	91.389	84.465	6.596	3.332	7.412	2.516	2.6
Corrugating Medium												
Cross M.D., Best In	20	50.330	4.860	53.504	47.156	54.591	46.069	6.211	3.139	6.979	2.371	6.3
Elmendorf Tear, DE 10												
Kraft Liner												
In M.D., Best In	30	372.000	25.020	381.136	362.864	385.704	358.296	30.849	17.929	34.079	14.699	2.5
Cross M.D., Best In	30	398.283	26.332	407.899	388.667	412.707	383.859	32.466	18.870	35.865	15.471	2.4
Corrugating Medium												
Cross M.D., Best In	30	145.040	8.302	148.072	142.008	149.588	140.492	10.237	5.949	11.309	4.877	2.1
H. and D. Flat Crush, DE 93												
Combined Board	10	26.816	0.949	27.416	26.216	27.716	25.916	1.300	0.452	1.512	0.240	2.2
Single-flute Flat Crush												
Corrugating Medium, Best Up	80	48.390	5.482	49.616	47.164	50.229	46.551	6.296	4.564	6.729	4.131	2.5
Torsion Tear												
Combined Board												
In M.D.	10	285.733	11.658	293.107	278.359	296.794	274.672	15.971	5.543	18.578	2.936	2.6
Cross M.D.	10	249.665	9.241	255.509	243.821	258.431	240.899	12.659	4.395	14.725	2.329	2.3

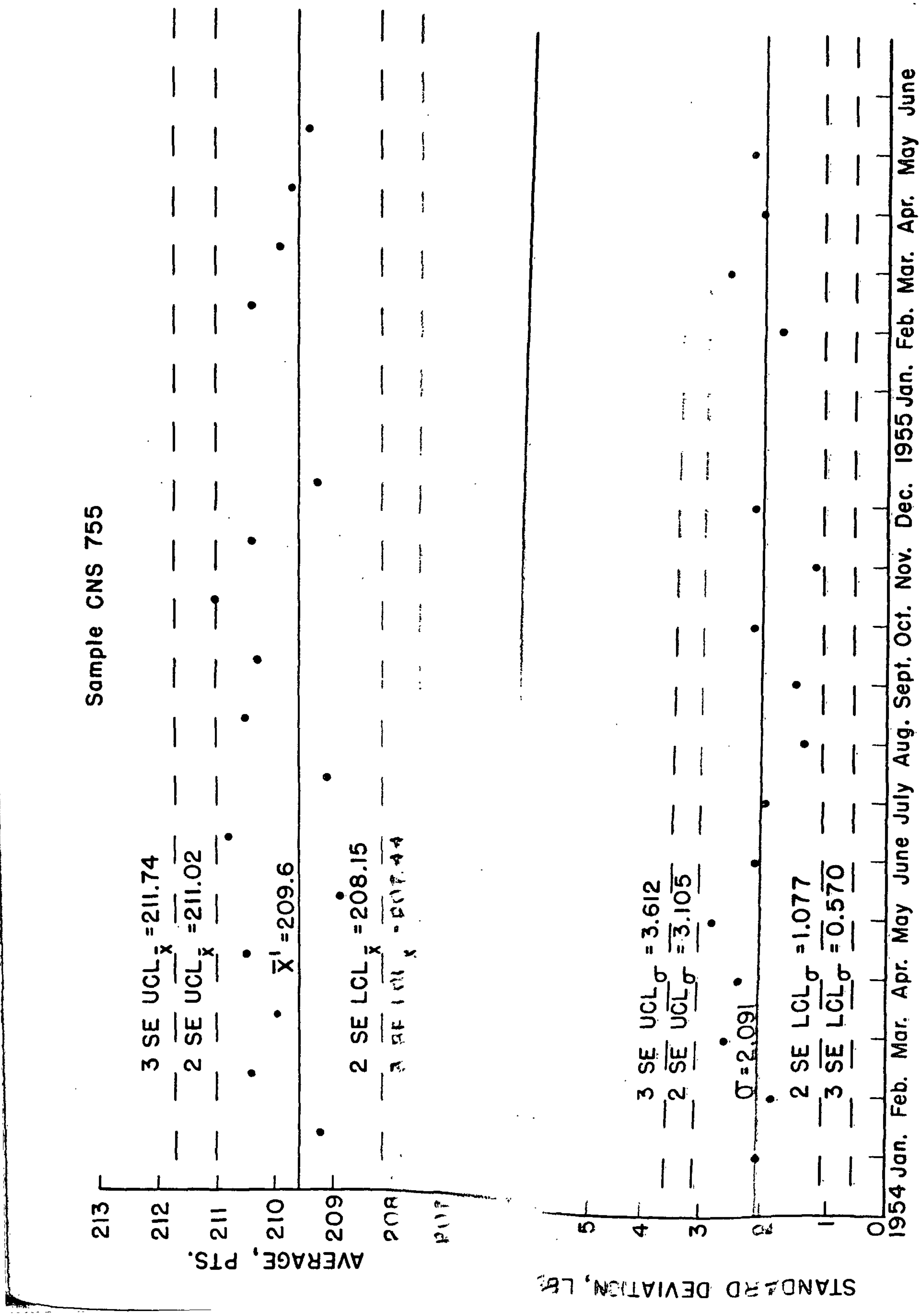

Figure 2.

Caliper — Cady Micrometer, DE 152 – Combined Board

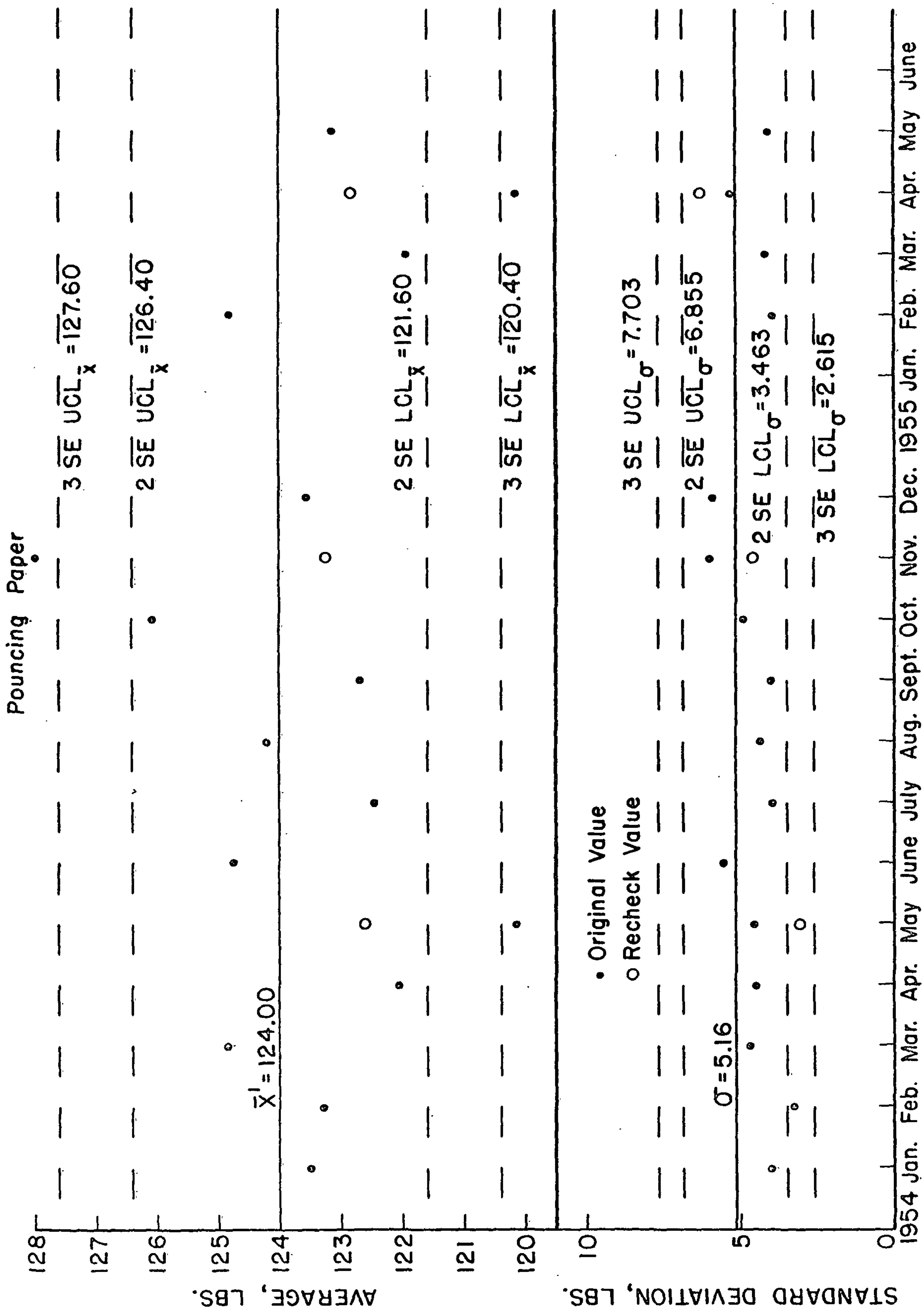

Figure 3.
Jumbo Mullen Burst, DE 35--1,000 lb. Clamp

control limits presently being used. Also presented are the two standard error (95%) intervals in per cent. Approximately 95% or 19 out of 20 future sample averages would be expected to fall within this interval from the estimated population average.

It should be understood that these results are frequently altered when evidence of a shift in level is present or when the test sample is changed.

It may be seen from Table II that in the case of Bursting Strength and Caliper the two testers used for each of these tests are interchangeable. Table II also indicates that most of the testers are maintained within a 2.5% level with 95% probability.

ADDENDUM

The following actions are taken when average test values deviate beyond 2 or 3-sigma limits:

1. <u>Between 2 and 3-sigma limits</u>. A recheck sample is tested. If the recheck average falls within the 2-sigma limits, the machine is returned to service. If the recheck average falls outside of the 2-sigma limits, the test machine is removed from service and calibrated.
2. <u>Beyond 3-sigma limits</u>. If the test average falls outside of the 3-sigma limits, the machine is removed from service and calibrated.