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A Further Study of the Impact of Bias on Accountability (U)

Lockheed Martin Energy Systems, Inc.

March 1997

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Executive Summary

Introduction:

When measurements are obtained for the purpose of material accountability, any deviation of averages from 'true value' is one of great concern. The key term here is 'true value'. Any deviation of averages from their true value will result in inventory discrepancies. It will not matter that the bias is of no statistical significance. Even small biases will over a period of time result in large inventory discrepancies. The terms 'target value'; 'accepted value'; and 'certified value' are all very useful terms, and they certainly have their place in the statistical arena. However, the one of concern here is 'true value'. True value, of course, is never known, but even with best efforts, deviations from it are often much larger than we have historically-believed them to be. With all of this in mind and with the aid of statistical calculations, simulation techniques, and statistical reasoning, the following paragraphs appear to provide reasonable estimates of the truth.

Even relatively small deviations of averages from true value are often the major contributors to overall inventory discrepancies. This is true even though such deviations (i.e., biases) may be of no statistical significance.

When biases are of no statistical significance, no effort will be made to identify causes with the result being that no deliberate correction action will be taken. Such biases simply run their course until some random effect or other independent action changes them. Although such biases could be either of very short or very long duration, a maximum length of 75 data points appears to be a reasonable estimate of what might be typical.

When the standard deviation associated with bias in the data is equal to 25 percent of that for the individual data values, and the control chart's center line is assumed to be equal to the true value; the number of runs of eight observed is less than twice that observed when the data has no significant bias, and the control chart's center line is equal to true value. This is true regardless of the length of the bias and is interpreted to mean that control chart techniques are very unlikely to result in the correction of such biases. The net effect is that such biases are likely to be ruled statistically nonsignificant.

In the above case, the center line was assumed to be known exactly when, in fact, it could actually vary by an amount equal to that of the data's average. With this in mind, let us assume that control charts are of length 75 each; that all biases change at random with the beginning of each new chart; that biases for center lines and the data are independent of each other; and, that the standard deviation for all biases are expressed as a percent of the standard deviation for individuals. Under such conditions, regardless of bias sizes and the number of runs of eight observed, the percentage of such runs that are caused by biased data does not exceed 50 percent until bias in the data is considerably greater than that for the centerline line. This means that, under normal operating conditions, more than one half of the runs of eight are caused by either

random variation in the data or by biased center lines. This strongly supports the argument for making no process adjustment until the cause is found. It also means that the probability of looking for causes when none exist exceeds 50 percent rather than the 5 percent that we are accustomed to thinking about. This high percentage of failures to find causes can, of course, cause one to give up the search too soon when such causes really do exist. How likely then are we to identify and obtain correction of such deviations from true value? It could be that when the standard deviation associated with bias in the data is as large as 50 percent of that of individuals, the likelihood of actual bias detection followed by bias correction is relatively small.

Basic Conclusions:

It is possible, in theory, to apply propagation of variance (POV) techniques when assigning limits of uncertainty about inventory differences which are based on the art of measuring. However, because of our inability to obtain reliable estimates of true biases, it is misleading to attempt to apply them with any stated degree of confidence. When, for example, we say that we are 95 percent confident, we could be in error by almost any amount. Such error depends almost totally on how well we are able to estimate these small 'difficult to identify' deviations from true value. Even when biases are of significant size, large percentages of them are very often the result of randomness in the data and/or random variation in control chart center lines. Also, this study would not have seen those cases where both the center line and data have biases of the same direction and size (i.e., the biases are approximately equal and either both positive or both negative). In such cases the combined random variation would permit both biases to go undetected.

Although the above contains only statements of that which the writers believe to be true, the attached and its references provide a more in depth analysis of the study.

A Further Study of the Impact of Bias on Accountability

Introduction

It has long been recognized that reasonable precision factors (measures of the variation associated with individual measurements) do not explain most inventory discrepancies whose results are dependent on the art of measuring. The only way that such factors can explain most inventory discrepancies is to use those that are too large to be justified by the usual statistical methods. One might propose a number of theories for this phenomenon. One popular theory supposes the presence of small fluctuating biases that, although sufficiently large to affect inventory differences, are still too small to permit identification by the usual statistical methods. Should this be the case, it naturally follows that if one can not identify relatively small biases by the usual statistical methods; neither can one statistically-justify the use of any bias uncertainty factors that represent them.

Purposes of the Initial Study

Initial studies were conducted for the purpose of identifying the effects of relatively small biases on the accountability of measured items, determining just how large a bias might become before it is likely to be detected by statistical control charts, estimating the typical length of small but difficult to detect biases, and determining which test (runs of eight on one side of the mean or values beyond the three sigma control limits) is the more sensitive to bias detection.

Calculations/Simulations

Initial Calculations

Initial computer calculations were made for the purposes of estimating the relative effects of precision and bias on inventory discrepancies. These calculations assumed control charts each of length Y_i and each with a bias of X_i where X_i is the ratio of the standard deviation for individuals within charts to the standard deviation associated with chart biases. Y_i was allowed to assume lengths of 25 and of 50 through 400 in increments of 50. X_i was allowed to assume the whole number values of 1 through 10. With equal weight assigned to each measurement, the POV estimates for each of these 90 combinations of X_i and Y_i were performed.

Observations from Initial Calculations

Such biases, even the smaller ones, have very significant effects on the accountability of measured materials. A summary of the results are presented in Table A. Of the 90 such combinations, bias was the major contributor 79 times, was an equal contributor 3 times, and was the minor contributor only 8 times. Note that the relationships in this table remain true regardless of the total number of control charts involved and regardless of the total amount of material that is measured.

TABLE A

The Effects of Precision and Bias Uncertainty on Accountability

Ratio		Number of Measurements per Bias Group	Ratio of Measuring Uncertainty Attributed to Bias to That Attributed to Precision	Limit of Uncertainty Expressed as Percent of Total Uncertainty	
Precision Over Bias Uncertainty	Bias Uncertainty Over Precision			for Precision	for Bias
1	1.000 ¹	25	5.00	19.61	98.06
		50	7.07	14.00	99.01
		100	10.00	9.95	99.50
		150	12.20	8.16	99.67
		200	14.10	7.05	99.75
		250	15.80	6.31	99.80
		300	17.20	5.80	99.83
		350	18.60	5.38	99.86
		400	19.80	5.04	99.87
2	0.500	25	2.50	37.14	92.85
		50	3.54	27.22	96.23
		100	5.00	19.61	98.06
		150	6.10	16.17	98.68
		200	7.07	14.00	99.01
		250	7.91	12.55	99.21
		300	8.60	11.55	99.33
		350	9.29	10.71	99.43
		400	9.90	10.05	99.49
3	0.333	25	1.67	51.45	85.75

1

Example for interpretation: When the ratio of precision to that of bias uncertainty is 1 to 1 and the bias changes at random with every twenty-five data points, the limit of uncertainty attributed to precision is 19.61 percent of what total uncertainty should be while that attributed to bias uncertainty is 98.06 percent of what total uncertainty should be.

Ratio		Number of Measurements per Bias Group	Ratio of Measuring Uncertainty Attributed to Bias to That Attributed to Precision	Limit of Uncertainty Expressed as Percent of Total Uncertainty	
Precision Over Bias Uncertainty	Bias Uncertainty Over Precision			for Precision	for Bias
		50	2.36	39.06	92.06
		100	3.33	28.73	95.78
		150	4.07	23.87	97.11
		200	4.71	20.75	97.82
		250	5.27	18.64	98.25
		300	5.73	17.18	98.51
		350	6.19	15.94	98.72
		400	6.60	14.98	98.87
4	0.250	25	1.25	62.47	78.09
		50	1.77	49.24	87.04
		100	2.50	37.14	92.85
		150	3.05	31.14	95.03
		200	3.54	27.22	96.23
		250	3.95	24.53	96.95
		300	4.30	22.65	97.40
		350	4.64	21.05	97.76
		400	4.95	19.80	98.02
5	0.200	25	1.00	70.71	70.71
		50	1.41	57.74	81.65
		100	2.00	44.72	89.44
		150	2.44	37.90	92.54
		200	2.83	33.33	94.28
		250	3.16	30.15	95.35
		300	3.44	27.91	96.03
		350	3.71	25.99	96.56
		400	3.96	24.49	96.96
6	0.166	25	0.83	76.82	64.02

Ratio		Number of Measurements per Bias Group	Ratio of Measuring Uncertainty Attributed to Bias to That Attributed to Precision	Limit of Uncertainty Expressed as Percent of Total Uncertainty	
Precision Over Bias Uncertainty	Bias Uncertainty Over Precision			for Precision	for Bias
		50	1.18	64.70	76.25
		100	1.67	51.45	85.75
		150	2.03	44.11	89.74
		200	2.36	39.06	92.06
		250	2.64	35.48	93.49
		300	2.87	32.93	94.42
		350	3.10	30.74	95.16
		400	3.30	29.00	95.70
7	0.143	25	0.71	81.37	58.12
		50	1.01	70.35	71.07
		100	1.43	57.35	81.92
		150	1.74	49.75	86.75
		200	2.02	44.36	89.62
		250	2.26	40.48	91.44
		300	2.46	37.69	92.63
		350	2.65	35.27	93.58
		400	2.83	33.33	94.28
8	0.125	25	0.63	84.80	53.00
		50	0.88	74.93	66.23
		100	1.25	62.47	78.09
		150	1.53	54.82	83.64
		200	1.77	49.24	87.04
		250	1.98	45.15	89.23
		300	2.15	42.16	90.68
		350	2.32	39.56	91.84
		400	2.47	37.46	92.72
9	0.111	25	0.56	87.42	48.56

Ratio		Number of Measurements per Bias Group	Ratio of Measuring Uncertainty Attributed to Bias to That Attributed to Precision	Limit of Uncertainty Expressed as Percent of Total Uncertainty	
Precision Over Bias Uncertainty	Bias Uncertainty Over Precision			for Precision	for Bias
		50	0.79	78.63	61.78
		100	1.11	66.90	74.33
		150	1.36	59.34	80.49
		200	1.57	53.69	84.36
		250	1.76	49.47	86.91
		300	1.91	46.35	88.61
		350	2.06	43.61	89.99
		400	2.20	41.38	91.04
10	0.100	25	0.50	89.44	44.72
		50	0.71	81.65	57.74
		100	1.00	70.71	70.71
		150	1.22	63.37	77.36
		200	1.41	57.74	81.65
		250	1.58	53.45	84.52
		300	1.72	50.25	86.46
		350	1.86	47.40	88.05
		400	1.98	45.08	89.26

First Set of Simulated Conditions

Use the $N(0,1)$ distribution as a base from which all data is generated. Generate control charts of length Y_i . Introduce a bias into each of 20,000 such charts so that the ratio of the standard deviation of individuals within charts to the standard deviation of those 20,000 biases is equal to X_i . Choose X_i values, as needed, from among the whole numbers 1 through 10. Allow Y_i to take on lengths of 25, 50, 100, 200, 300, and 400. For each combination of X_i and Y_i , generate 20,000 charts. Test for runs of eight on one side of the mean and for values outside the three sigma control limits. Use zero as the center line for all control charts.

Observations from First Set of Simulated Conditions

When the standard deviation associated with bias uncertainty is equal to or less than 25 percent of that for individuals, standard control chart tests are unlikely to detect the bias and are even more unlikely to cause the initiation of corrective action. However, as the percentage exceeds 25, detection becomes increasingly more likely. This is based on the fact that the number of out-

of-control signals caused by the bias do not exceed those that are caused by the random variation of a nonbiased chart until this value exceeds 25 percent. This is true for all simulated conditions and is true for both the runs and out-of-limit tests. Runs of eight were more sensitive in the detection of bias than was the control limit test. For this reason, subsequent simulations dealt only with the runs test. For details see "A Study of the Impact of Bias on Accountability", T. R. Harvey and S. A. McGuire to W. H. Hopwood, Jr., April 11, 1996.

Second Set of Simulated Conditions

When dealing with biases that are relatively small and difficult to detect, any kind of deliberate corrective action is very unlikely. Such biases are more likely to run their course until such time that some random effect or some other unrelated action changes them. It was reasoned, however, that such nondeliberate changes would tend to make the short biases more frequent than the longer ones. With this in mind, a total of six simulations were made. In each case, bias lengths of 10, 25, and 50 through 400 in increments of 50 were considered. In most cases, the shorter lengths carried more weight than did the longer ones. However, in one case the weight was equalized among all lengths. In all cases, bias lengths of ten and twenty-five shared equally for those of lengths below fifty. The purpose was to search for a typical bias length. Table B provides a listing of the weights assigned to each of the six sets.

Table B
Relative Frequencies of Bias Lengths

Bias Length	Set 1	Set 2	Set 3	Set 4	Set 5	Set 6
400	1	1	1	1	1	0.15
350	2	1	1	4	0	0
300	3	2	1	7	0	0
250	4	2	1	10	0	0
200	5	3	1	13	0	0
150	6	3	1	16	0	0
100	7	4	1	19	1	1
50	8	4	1	22	1	1
25	4.5	2.5	0.5	12.5	0.5	0.5
10	4.5	2.5	0.5	12.5	0.5	0.5
TOTALS	45	25	9	117	4	3.15

Observations of Second Set of Simulated Conditions

When the standard deviation for bias uncertainty was equal to 25 percent of that for individuals, the average bias length for the simulations of sets 1 through 5 ranged from 63 to 88 with set three

being at the upper end of the range. The sixth simulation averaged about 42, but the conditions under which it was run was considered to be unrealistic. When the standard deviation for bias uncertainty was decreased to 10 percent of that for individuals, the average bias length ranged as high as 100. As a conservative estimate, 75 appeared therefore to be a typical average bias length for those small, difficult-to-detect biases. For more detail see "A Study of the Impact of Bias on Accountability", T. R. Harvey and S. A. McGuire to W. H. Hopwood, Jr., April 11, 1996.

Third Set of Simulated Conditions

Arguments for a Third Set of Simulations

Since relatively small biases are difficult to recognize, it becomes reasonable to assume that undetected biases are also likely to exist when prior data is used to establish the center line and control limits for control charts. In support of this argument is the fact that control chart center lines are normally based on the average of from 25 to 50 data points. This fact alone would indicate that control chart center lines would fluctuate with a standard deviation that is somewhere between 14 and 20 percent of that for individuals. This is true despite the fact that such deviations would be considered to be of no statistical significance. Remember also that such estimates assume that the method used to obtain these results is unbiased. If we assume, however, that its bias is of an approximate equal size, we could argue that the control chart's center line could fluctuate with a standard deviation that is somewhere between 20 and 28 percent of that for individuals. It is no wonder then that previous simulations focus on the 25 percent level when only the data is biased.

One might also argue that well documented standards obtained from an outside source should be used for such purposes. They, of course, would be better known. However, such standards are usually highly pure, not representative of that which is being measured, very expensive, and extremely difficult to obtain in the quantities needed. Although they are very necessary in helping the laboratory to maintain control of their instruments, they are of but little value when estimating overall measuring capabilities. Such control batches must represent production and, because of this, must originate from representative production batches.

Although the same measuring methods used to measure production samples are also used to establish center lines for control charts, it can still be argued that measurements for the two are essentially independent. That is, their biases will not fluctuate up and down together. In support of this is the fact that chart center lines are established in a relatively short period of time and will normally remain the same for the duration of the standard batch. If, for example, one sample is submitted from the standard for every ten production samples, a standard batch of length 75 would endure until a total of 750 production samples have been measured. Hence their bias levels would not correlate. One might also argue that the standard batches do receive special attention during their preparation and, although somewhat biased, should contain less bias than do their corresponding production measurements. For such reasons bias levels for the two were made independent for all simulations and, for the most part, bias levels for chart center line

biases were held to levels that were equal to or less than those for data. However, simulations were made where bias levels for production measurements were allowed to greatly exceed those made for the standard.

Third Set of Simulated Conditions

A total of eight sets of simulated conditions were performed for each of a sizable number of 'paired bias levels'. By 'paired bias levels', we mean that for any simulated condition, the bias levels for chart center line biases were held at one level while those for the corresponding production data were held at some level that may or may not have been the same as those for center line bias. For example, a 'paired bias level' identifier of 25/30 would indicate that for the chart center lines, the standard deviation associated with bias was 25 percent of that for individuals but, for the data, was 30 percent of that for individuals. For each of the eight simulated conditions a total of 50,000 control charts with length 75 each were generated from a $N(0,1)$ distribution. For some of these simulations, bias was introduced into each chart. For others, it was not. For some simulations even the random deviation of averages obtained from the $N(0,1)$ distribution was removed from each of the 50,000 charts. This was done by adjusting each value by a constant amount so that the chart's average would be as close to zero as possible. For some simulations, zero was recognized as the charts center line for each of the 50,000 charts. For others the chart's center line was deliberately biased. When bias was introduced, it was accomplished according to its assigned 'paired bias level' identifier. For example, when the identifier was 25/30, the amount of bias introduced for any biased center line was the 25 percent level while the amount of bias introduced for any biased set of data was set to the 30 percent level. For each 'paired bias level', Table C provides a listing of the eight conditions that were simulated.

Table C

ID Used as a Reference of a Condition	Value Recognized as Control Chart's Center Line	Condition of Each Set of Measured Data at Time of Testing	Number of Control Charts	Length of Each Control Chart
A	0	$N(0,1)$ adjusted to 0	50,000	75
B	0	$N(0,1)$	50,000	75
C	0	$N(0,1)$ adjusted to 0 + Bias	50,000	75
D	Biased	$N(0,1)$ adjusted to 0	50,000	75
E	0	$N(0,1) + \text{Bias}$	50,000	75
F	Biased	$N(0,1)$	50,000	75
G	Biased	$N(0,1)$ adjusted to 0 + Bias	50,000	75
H ²	Biased	$N(0,1) + \text{Bias}$	50,000	75

²

Although condition H in Table C, above, is the condition under which we actually live, the simulation of all of the eight conditions are necessary if we are to isolate the source of causes for runs of eight. Cross references to Tables C and D illustrate.

Table D

Source of the Causes for a Run of Eight	Estimate of I.D. Differences	I.D.	Comments
Random variation of data levels	B minus A E minus C F minus D H minus G	B-A E-C F-D H-G	Four estimates of the number of runs of eight that are due to those nonsignificant biases that may exist within any set of statistically-controlled data.
Random variation of individuals around their true value.	A	A	This is the only value obtained that estimates the number of runs of eight that are due to the random variation of individuals around their true value.
Variation in chart center lines	F minus B H minus E D minus A G minus C	F-B H-E D-A G-C	Four estimates of the number of runs of eight that are due to the variations of center lines among the 50,000 charts.
Actual biases in the data	H minus F E minus B G minus D C minus A	H-F E-B G-D C-A	Four estimates of the number of runs of eight that are due to the variations of averages among the 50,000 charts (averages based on 75 data points per chart).
Total	H	H	Contains all sources of variation

A run of eight is defined as eight successive values either above or below the chart's center line. Once a run of eight is seen the count starts all over again. Hence, a run of fifteen is one run of eight. A run of sixteen is two runs of eight. A run of twenty-three is two runs of eight, while a run of twenty-four is three runs of eight. For each 'paired bias level', the total number of counts of the number of runs of eight in 50,000 charts were obtained. In all cases, however, this total count was divided by 50 so that all values in both tables and charts that follow were based on the average number of runs of eight observed per 1,000 charts.

Observations from Third Set of Simulated Conditions:

The results obtained for the third set of simulations are presented in the tables and charts that follow. The Tables E and E.1 as well as the Charts E.1 through E.6 (the E Group) consists of those where the 'paired bias levels' always vary by the same amount. The corresponding F, G,

H, I, J and K groups consist of those 'paired bias levels' where the variation for chart centerline remains constant at the 20, 25, 30, 35, 40 and 45 percent levels, respectively.

In interpretation of these tables and charts, it is noted that lines 1 through 40 of the Tables E, F, G, H, I, J, and K represent counts of the number of runs of eight per 1,000 charts. Reference to Tables C and D is required for identification of the sources for each of lines 1 through 31. Additional Individual Differences (ID) notations for lines 21 through 40 require further explanation which is presented in the following paragraph.

Note that most of the lines have labels of 'high' and 'low'. However, these notations do not always mean that values are either high or low. They do, however, mean that the numbers are predominately high when labeled high and predominately low when labeled low. To illustrate, observe the first page of Table E at the intersection of column 60/60 and lines 21 through 24. As can be seen, the value 1,213 on line 21 agrees with the value 1,215 on line 23. Both are high values relative to the values of lines 22 and 24 (866 and 879 respectively). Hence, the two agreeing high values are labeled high, and the two agreeing low values are labeled low. Now look at the same lines under the column labeled 05/05. As can be seen, just the opposite is true. Although agreement between pairs remains, the high are now lows and the lows are now highs. They have just been called high and low for the lack of a better name. The point is they agree in pairs, and whether high or low, pairs are always the same as we move across columns. The same sort of relationship applies to rows 27 through 30. It is the difference among these pairs that provide us with some estimate of the interaction that exists between the two nonrandom sources of bias variation. That is, they provide us with an estimate of the number of runs of eight where the chart center lines and the data averages were co-contributors to the cause for runs of eight. Both line 39 and line 40 provide estimates of interaction. Although they at first appear to have been obtained independently, they were actually generated by the same set of numbers; and because of this will always generate the same exact values. Hence, both line 39 and 40 provide the same exact estimate of interaction. Their mathematical formula are as follows. As can be seen, their only differences are in their order of arrangement.

Line 39

$$\frac{[(F - B) + (D - A)]}{2} - \frac{[(H - E) + (G - C)]}{2} = \frac{(F - B + D - A - H + E - G + C)}{2}$$

Line 40

$$\frac{[(E - B) + (C - A)]}{2} - \frac{[(H - F) + (G - D)]}{2} = \frac{(E - B + C - A - H + F - G + D)}{2}$$

When considered together lines 16, 18, 36, 37 and 39 (or 40) contain the source of all causes for runs of eight. Line 50 contains their total and, as can be seen, is verified by its agreement with line 9 which also contains all sources. Lines 43 through 47 express each of the source totals as a percent of grand total while line 48 is the sum of the percents for all sources. Line 54 is equal to line 36 expressed as a percent of line 50, the total number of runs of eight. Line 55 is line 33 expressed as a percentage of line 50. Line 59 is line 37 expressed as a percent of line 50, and line 60 is line 34 expressed as a percent of line 50. Line 53 is the midpoint between lines 54 and 55, while line 58 is the midpoint between lines 59 and 60. The total range between minimum and maximum is the interaction.

Much information is available in these table and chart groups. To fully interpret the results would require many pages of explanation. However, the basic question under any of these 'paired bias levels' has to do with how well we are able to identify the existence of biases in the data. This information is of course provided by lines 58, 59 and 60. As an example, let's pick the 'paired bias level' 25/30 from Table G. As can be seen by line 58, we can expect that, on average, biases in the data will cause only 39.6 percent of the observed runs of eight. Because of the relatively low interaction, the minimum and maximum limits around this level are 38.9 percent and 40.3 percent, respectively. Hence, even under the best of conditions, about 60 percent of the runs of eight were the result of either random causes or of bias in the chart's center lines. The range for making correct decisions is, therefore, somewhere between very difficult and near impossible.

Tables E.1, F.1, G.1 and H.1 provide additional information that was obtained as a matter of interest. In general, these charts indicate the following:

1. Although all charts were biased to some degree, no run of eight was observed for sizeable percentages of them.
2. Of those charts where runs of eight were observed, sizeable percentages of them either indicated negative bias when it was actually positive or positive when it was actually negative.
3. Although a few runs were of lengths as high as 75, the high frequency of short runs kept the average run length relatively low.
4. On the average, sizeable percentages of the data were generated prior to the first observation of a run of eight.
5. The percent of charts containing runs of eight both below and above the centerline was relatively low.

Related Comments

Typically, control samples are measured at a much lower frequency than are the routine production samples they represent. For example, if one control sample is measured for every ten production samples, a total of eighty production samples would have been measured before a run of eight successive control samples could be observed on one side of the center line. It is therefore likely that should a large bias of length 75 exist, control sample results would not call attention to it. Even if control samples were submitted with each production sample, the above studies indicate that the probability of detection are still not good when biases are relatively small.

Now one might argue that such controls are not used to detect and control biases. This is accomplished by the controls that are maintained within the laboratory as well as in other areas of the plant. It is likely true that the laboratory's measuring of high purity standards can verify that laboratory instruments are very near unbiased when measuring such standards. However, this does not account for those biases that may result when the laboratory measures those routine production samples that are not so pure. Neither does it account for small sampling biases nor does it account for those small biases that may result in those areas where only procedural or administrative controls can be applied.

Remember we are concerned with biases that are relatively small and which, in many cases, would be of but little or no statistical significance even if they could be subjected to such tests. They are there, and in the absence of better methods, we lack the ability to both detect and eliminate them. Deviation from 'target values' is one thing. Deviation from 'true value' is another.

TABLE E
Average Number of Runs of Eight Per 1,000 Charts
Equal Bias Percentages

	A	B	C	D	E	F	G	H	I	J	K	L
1	ID	05/05	10/10	15/15	20/20	25/25	30/30	35/35	40/40	45/45	50/50	55/55
2	A	226	221	220	223	225	220	227	222	227	223	222
3	B	272	268	265	267	271	264	268	270	275	271	268
4	C	234	255	302	365	451	551	663	800	950	1,104	1,280
5	D	233	254	300	364	447	544	672	798	946	1,100	1,275
6	E	280	302	347	411	502	603	710	847	997	1,152	1,320
7	F	278	304	353	413	497	594	720	846	993	1,140	1,320
8	G	245	294	385	510	680	871	1,091	1,326	1,566	1,816	2,078
9	H	293	342	437	558	728	915	1,137	1,369	1,609	1,850	2,109
10												
11	ID	05/05	10/10	15/15	20/20	25/25	30/30	35/35	40/40	45/45	50/50	55/55
12	B-A	46	47	45	44	46	44	41	48	48	48	46
13	E-C	46	47	45	46	51	52	47	47	47	48	40
14	F-D	45	50	53	49	50	50	48	48	47	40	45
15	H-G	48	48	52	48	48	44	46	43	43	34	31
16	AVG	46.3	48.0	48.8	46.8	48.8	47.5	45.5	46.5	46.3	42.5	40.5
17												
18	A	226	221	220	223	225	220	227	222	227	223	222
19												
20	ID	05/05	10/10	15/15	20/20	25/25	30/30	35/35	40/40	45/45	50/50	55/55
21	F-B (High)	6	36	88	146	226	330	452	576	718	869	1,052
22	H-E (Low)	13	40	90	147	226	312	427	522	612	698	789
23	D-A (High)	7	33	80	141	222	324	445	576	719	877	1,053
24	G-C (Low)	11	39	83	145	229	320	428	526	616	712	798
25	AVG CENTERLINE	9.3	37.0	85.3	144.8	225.8	321.5	438.0	550.0	666.3	789.0	923.0
26												
27	H-F (Low)	15	38	84	145	231	321	417	523	616	710	789
28	E-B (High)	8	34	82	144	231	339	442	577	722	881	1,052
29	G-D (Low)	12	40	85	146	233	327	419	528	620	716	803
30	C-A (High)	8	34	82	142	226	331	436	578	723	881	1,058
31	AVG DATA	10.8	36.5	83.3	144.3	230.3	329.5	428.5	551.5	670.3	797.0	925.5
32												
33	HIGH AVG CENTERLINE	6.5	34.5	84.0	143.5	224.0	327.0	448.5	576.0	718.5	873.0	1052.5
34	HIGH AVG DATA	8.0	34.0	82.0	143.0	228.5	335.0	439.0	577.5	722.5	881.0	1,055.0
35												
36	LOW AVG CENTERLINE	12.0	39.5	86.5	146.0	227.5	316.0	427.5	524.0	614.0	705.0	793.5
37	LOW AVG DATA	13.5	39.0	84.5	145.5	232.0	324.0	418.0	525.5	618.0	713.0	796.0
38												
39	DIFF CENTERLINE	-5.5	-5.0	-2.5	-2.5	-3.5	11.0	21.0	52.0	104.5	168.0	259.0
40	DIFF DATA	-5.5	-5.0	-2.5	-2.5	-3.5	11.0	21.0	52.0	104.5	168.0	259.0
41												
42	SOURCE	05/05	10/10	15/15	20/20	25/25	30/30	35/35	40/40	45/45	50/50	55/55
43	Random B (% of Total)	15.8	14.0	11.1	8.4	6.7	5.2	4.0	3.4	2.9	2.3	1.9
44	Random I (% of Total)	77.3	64.5	50.3	39.9	30.8	24.0	19.9	16.2	14.1	12.0	10.5
45	Centerline (% of Total)	4.1	11.5	19.8	26.1	31.2	34.4	37.5	38.2	38.1	38.1	37.6
46	Data (% of Total)	4.6	11.4	19.3	26.0	31.8	35.3	36.7	38.4	38.4	38.5	37.7
47	Interaction (% of Total)	-1.9	-1.5	-0.6	-0.4	-0.5	1.2	1.8	3.8	6.5	9.1	12.3
48	TOTAL %	100	100	100	100	100	100	100	100	100	100	100
49												
50	TOTAL (Same as H above)	292.3	342.5	437.3	558.8	729.8	918.5	1,139.0	1,370.0	1,609.8	1,851.5	2,111.0
51												
52	AVERAGE IN LIMITS	05/05	10/10	15/15	20/20	25/25	30/30	35/35	40/40	45/45	50/50	55/55
53	% AVG CENTERLINE (LINE 53)	3.2	10.8	19.5	25.9	30.9	35.0	38.5	40.1	41.4	42.6	43.7
54	% MIN CENTERLINE (LINE 54)	2.2	10.1	18.6	25.6	30.7	34.4	37.5	38.2	38.1	38.1	37.6
55	% MAX CENTERLINE (LINE 55)	4.1	11.5	20.4	26.2	31.2	35.6	39.4	42.0	44.6	47.2	49.9
56												
57	AVERAGE IN LIMITS	05/05	10/10	15/15	20/20	25/25	30/30	35/35	40/40	45/45	50/50	55/55
58	% AVG DATA (LINE 58)	3.7	10.7	19.0	25.8	31.6	35.9	37.6	40.3	41.6	43.0	43.8
59	% MIN DATA (LINE 59)	2.7	9.9	18.8	25.6	31.3	35.3	36.7	38.4	38.4	38.5	37.7
60	% MAX DATA (LINE 60)	4.6	11.4	19.3	26.0	31.8	36.5	38.5	42.2	44.9	47.6	50.0

TABLE E
Average Number of Runs of Eight Per 1,000 Charts
Equal Bias Percentages

	M	N	O	P	Q	R	S	T	U	V
1	ID	60/60	70/70	80/80	90/90	95/95	99/99			
2	A	225	225	224	226	221	223			
3	B	271	270	271	274	270	270			
4	C	1,442	1,789	2,134	2,488	2,656	2,795			
5	D	1,440	1,797	2,139	2,500	2,652	2,759			
6	E	1,486	1,827	2,166	2,520	2,683	2,824			
7	F	1,484	1,837	2,177	2,532	2,688	2,793			
8	G	2,321	2,790	3,221	3,627	3,821	3,968			
9	H	2,352	2,824	3,251	3,651	3,845	3,989			
10										
11	ID	60/60	70/70	80/80	90/90	95/95	99/99			
12	B-A	46	45	47	48	49	47			
13	E-C	44	38	32	32	27	29			
14	F-D	44	40	38	32	36	34			
15	H-G	31	34	30	24	24	21			
16	AVG	41.3	39.3	36.8	34.0	34.0	32.8			
17										
18	A	225	225	224	226	221	223			
19										
20	ID	60/60	70/70	80/80	90/90	95/95	99/99			
21	F-B (High)	1,213	1,567	1,906	2,258	2,418	2,523			
22	H-E (Low)	866	997	1,085	1,131	1,162	1,165			
23	D-A (High)	1,215	1,572	1,915	2,274	2,431	2,536			
24	G-C (Low)	879	1,001	1,087	1,139	1,165	1,173			
25	AVG CENTERLINE	1,043.3	1,284.3	1,498.3	1,700.5	1,794.0	1,849.3			
26										
27	H-F (Low)	868	987	1,074	1,119	1,157	1,196			
28	E-B (High)	1,215	1,557	1,895	2,246	2,413	2,554			
29	G-D (Low)	881	993	1,082	1,127	1,169	1,209			
30	C-A (High)	1,217	1,564	1,910	2,262	2,435	2,572			
31	AVG DATA	1,045.3	1,275.3	1,490.3	1,688.5	1,793.5	1,882.8			
32										
33	HIGH AVG CENTERLINE	1214.0	1569.5	1910.5	2266.0	2424.5	2529.5			
34	HIGH AVG DATA	1,216.0	1,560.5	1,902.5	2,254.0	2,424.0	2,563.0			
35										
36	LOW AVG CENTERLINE	872.5	999.0	1,086.0	1,135.0	1,163.5	1,169.0			
37	LOW AVG DATA	874.5	990.0	1,078.0	1,123.0	1,163.0	1,202.5			
38										
39	DIFF CENTERLINE	341.5	570.5	824.5	1,131.0	1,261.0	1,360.5			
40	DIFF DATA	341.5	570.5	824.5	1,131.0	1,261.0	1,360.5			
41										
42	SOURCE	60/60	70/70	80/80	90/90	95/95	99/99			
43	Random B (% of Total)	1.8	1.4	1.1	0.9	0.9	0.8			
44	Random I (% of Total)	9.6	8.0	6.9	6.2	5.8	5.6			
45	Centerline (% of Total)	37.1	35.4	33.4	31.1	30.3	29.3			
46	Data (% of Total)	37.1	35.1	33.2	30.8	30.3	30.2			
47	Interaction (% of Total)	14.5	20.2	25.4	31.0	32.8	34.1			
48	TOTAL %	100	100	100	100	100	100			
49										
50	TOTAL	2,354.8	2,823.8	3,249.3	3,649.0	3,842.5	3,987.8			
51										
52	AVERAGE IN LIMITS	60/60	70/70	80/80	90/90	95/95	99/99			
53	% AVG CENTERLINE (LINE 53)	44.3	45.5	46.1	46.6	46.7	46.4			
54	% MIN CENTERLINE (LINE 54)	37.1	35.4	33.4	31.1	30.3	29.3			
55	% MAX CENTERLINE (LINE 55)	51.6	55.6	58.8	62.1	63.1	63.4			
56										
57	AVERAGE IN LIMITS	60/60	70/70	80/80	90/90	95/95	99/99			
58	% AVG DATA (LINE 58)	44.4	45.2	45.9	46.3	46.7	47.2			
59	% MIN DATA (LINE 59)	37.1	35.1	33.2	30.8	30.3	30.2			
60	% MAX DATA (LINE 60)	51.6	55.3	58.6	61.8	63.1	64.3			

Table E.1
 Condition H When Chart Bias (Length) is 75
 Bias of the Centerline Equal to Bias of Data
 The Bias Varies from 5% through 99% of Data's Variation

Paired Bias Levels	Average Number per 1,000 Charts		Average Percent of Total Number of Runs of Eight		Average Run Length	Average Number of Measurements Observed Before First Run of Eight
	Runs of Eight	Charts With at Least One Run of Eight	False Directional Notices	Charts With Both a High and Low Run of Eight		
05/05	293	262	24.9	1.37	9.0	39.7
10/10	342	293	21.7	1.22	9.1	38.5
15/15	437	350	20.1	1.02	9.3	37.9
20/20	558	407	18.5	0.92	9.7	36.5
25/25	728	465	18.4	0.88	10.0	34.9
30/30	915	518	18.1	0.73	10.5	32.9
35/35	1,137	565	17.6	0.60	11.0	31.3
40/40	1,389	605	17.9	0.57	11.7	29.4
45/45	1,609	636	18.2	0.51	12.2	28.2
50/50	1,850	663	18.7	0.48	12.9	26.9
55/55	2,109	695	19.0	0.46	13.5	25.7
60/60	2,352	716	19.2	0.40	14.2	24.7
70/70	2,824	752	19.8	0.37	15.7	22.6
80/80	3,251	779	20.4	0.37	17.1	21.2
90/90	3,651	799	20.5	0.28	18.7	19.7
95/95	3,845	816	20.7	0.25	19.3	19.4
99/99	3,989	820	21.2	0.32	19.9	18.9

CHART E.1
TOTAL NUMBER OF RUNS OF EIGHT UNDER ALL EIGHT EXPERIMENTAL CONDITIONS
EQUAL BIASES
 Reference Tables C and E

CHART E.2 NUMBER OF RUNS OF EIGHT ELIMINATED WHEN DATA AVERAGE IS FORCED TO BE ZERO EQUAL BIASES

Reference Tables C, D and E

CHART E.3
AVERAGE NUMBER OF RUNS OF EIGHT
DUE TO BIAS IN THE DATA AND BIAS IN THE CENTERLINE
EQUAL BIASES
 Reference Tables C, D and E

CHART E.4
PARTITIONING TOTAL NUMBER OF RUNS OF EIGHT
EQUAL BIASES
 Expressed As A Percentage Of Total Number of Runs of Eight
 Reference Tables C and E

CHART E.5 AVERAGE NUMBER OF RUNS OF EIGHT DUE TO BIAS IN CENTERLINE EQUAL BIASES

Expressed As A Percentage of Total Number of Runs of Eight
Reference Tables C and E

CHART E.6

AVERAGE NUMBER OF RUNS OF EIGHT DUE TO BIAS IN DATA EQUAL BIASES

Expressed As A Percentage of Total Number of Runs
Reference Tables C and E

TABLE F
Average Number of Runs of Eight Per 1,000 Charts
Unequal Bias Percentages

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	ID	20/05	20/10	20/15	20/20	20/25	20/30	20/35	20/40	20/45	20/50	20/55	20/60
2	A-20	222	225	226	223	225	225	222	228	228	222	225	221
3	B-20	270	271	274	267	272	269	268	271	273	267	273	271
4	C-20	234	259	302	365	451	550	667	807	958	1,111	1,271	1,445
5	D-20	364	368	363	364	368	369	366	368	367	367	361	366
6	E-20	282	309	349	411	502	601	717	856	1,002	1,156	1,316	1,487
7	F-20	411	419	413	413	416	416	413	418	419	414	413	416
8	G-20	378	402	443	510	601	696	805	934	1,076	1,237	1,391	1,548
9	H-20	428	450	490	558	650	746	856	982	1,119	1,276	1,432	1,589
10													
11	ID	20/05	20/10	20/15	20/20	20/25	20/30	20/35	20/40	20/45	20/50	20/55	20/60
12	B-A (20)	48	46	48	44	47	44	46	43	45	45	48	50
13	E-C (20)	48	50	47	46	51	51	50	49	44	45	45	42
14	F-D (20)	47	51	50	49	48	47	47	50	52	47	52	50
15	H-G (20)	50	48	47	48	49	50	51	48	43	39	41	41
16	AVG (20)	48.3	48.8	48.0	46.8	48.8	48.0	48.5	47.5	46.0	44.0	46.5	45.8
17													
18	A	222	225	226	223	225	225	222	228	228	222	225	221
19													
20	ID	20/05	20/10	20/15	20/20	20/25	20/30	20/35	20/40	20/45	20/50	20/55	20/60
21	F-B HIGH (20)	141	148	139	146	144	147	145	147	146	147	140	145
22	H-E LOW (20)	146	141	141	147	148	145	139	126	117	120	116	102
23	D-A HIGH (20)	142	143	137	141	143	144	144	140	139	145	136	145
24	G-C LOW (20)	144	143	141	145	150	146	138	127	118	126	120	103
25	AVG CENTERLINE (20)	143.3	143.8	139.5	144.8	146.3	145.5	141.5	135.0	130.0	134.5	128.0	123.8
26													
27	H-F LOW (20)	17	31	77	145	234	330	443	564	700	862	1,019	1,173
28	E-B HIGH (20)	12	38	75	144	230	332	449	585	729	889	1,043	1,216
29	G-D LOW (20)	14	34	80	146	233	327	439	566	709	870	1,030	1,182
30	C-A HIGH (20)	12	34	76	142	226	325	445	579	730	889	1,046	1,224
31	AVG DATA (20)	13.8	34.3	77.0	144.3	230.8	328.5	444.0	573.5	717.0	877.5	1,034.5	1,198.8
32													
33	HIGH AVG CENTERLINE	141.5	145.5	138.0	143.5	143.5	145.5	144.5	143.5	142.5	146.0	138.0	145.0
34	HIGH AVG DATA	12.0	36.0	75.5	143.0	228.0	328.5	447.0	582.0	729.5	889.0	1,044.5	1,220.0
35													
36	LOW AVG CENTERLINE	145.0	142.0	141.0	146.0	149.0	145.5	138.5	126.5	117.5	123.0	118.0	102.5
37	LOW AVG DATA	15.5	32.5	78.5	145.5	233.5	328.5	441.0	565.0	704.5	866.0	1,024.5	1,177.5
38													
39	DIFF CENTERLINE	-3.5	3.5	-3.0	-2.5	-5.5	0.0	6.0	17.0	25.0	23.0	20.0	42.5
40	DIFF DATA	-3.5	3.5	-3.0	-2.5	-5.5	0.0	6.0	17.0	25.0	23.0	20.0	42.5
41													
42	SOURCE	20/05	20/10	20/15	20/20	20/25	20/30	20/35	20/40	20/45	20/50	20/55	20/60
43	Random B % of Total (20)	11.3	10.8	9.8	8.4	7.5	6.4	5.7	4.8	4.1	3.4	3.2	2.9
44	Random I % of Total (20)	52.0	49.8	46.1	39.9	34.6	30.1	25.9	23.2	20.3	17.4	15.7	13.9
45	Centerline % of Total (20)	33.9	31.4	28.7	26.1	22.9	19.5	16.2	12.9	10.5	9.6	8.2	6.4
46	Data % of Total (20)	3.6	7.2	16.0	26.0	35.9	44.0	51.5	57.4	62.8	67.8	71.4	74.1
47	Interaction % of Total (20)	-0.8	0.8	-0.6	-0.4	-0.8	0.0	0.7	1.7	2.2	1.8	1.4	2.7
48	TOTAL %	100	100	100	100	100	100	100	100	100	100	100	100
49													
50	TOTAL (Same as H above)	427.3	451.8	490.5	558.8	650.8	747.0	856.0	984.0	1,121.0	1,278.0	1,434.0	1,589.3
51													
52	AVERAGE AND LIMITS	20/05	20/10	20/15	20/20	20/25	20/30	20/35	20/40	20/45	20/50	20/55	20/60
53	% AVG CENTERLINE_20 (Line 53)	33.5	31.8	28.4	25.9	22.5	19.5	16.5	13.7	11.6	10.5	8.9	7.8
54	% MIN CENTERLINE_20 (Line 54)	33.1	31.4	28.1	25.6	22.1	19.3	16.2	12.9	10.5	9.6	8.2	6.4
55	% MAX CENTERLINE_20 (Line 55)	33.9	32.2	28.7	26.2	22.9	19.6	16.9	14.6	12.7	11.4	9.6	9.1
56													
57	AVERAGE AND LIMITS	20/05	20/10	20/15	20/20	20/25	20/30	20/35	20/40	20/45	20/50	20/55	20/60
58	% AVG DATA_20 (Line 58)	3.2	7.6	15.7	25.8	35.5	44.0	51.9	58.3	64.0	68.7	72.1	75.4
59	% MIN DATA_20 (Line 59)	2.8	7.2	15.4	25.6	35.0	43.6	51.5	57.4	62.8	67.8	71.4	74.1
60	% MAX DATA_20 (Line 60)	3.6	8.0	16.0	26.0	35.9	44.3	52.2	59.1	65.1	69.6	72.8	76.8

TABLE F
Average Number of Runs of Eight Per 1,000 Charts
Unequal Bias Percentages

	N	O	P	Q	R	S	T	U	V	W
1	ID	20/70	20/80	20/90	20/95	20/99				
2	A-20	225	225	224	222	226				
3	B-20	269	269	271	267	272				
4	C-20	1,800	2,159	2,482	2,677	2,812				
5	D-20	365	365	365	365	365				
6	E-20	1,842	2,192	2,517	2,710	2,839				
7	F-20	415	413	413	415	411				
8	G-20	1,886	2,250	2,572	2,716	2,851				
9	H-20	1,921	2,287	2,605	2,747	2,877				
10										
11	ID	20/70	20/80	20/90	20/95	20/99				
12	B-A (20)	44	44	47	45	46				
13	E-C (20)	42	33	35	33	27				
14	F-D (20)	50	48	48	50	46				
15	H-G (20)	35	37	33	31	26				
16	AVG (20)	42.8	40.5	40.8	39.8	36.3				
17										
18	A	225	225	224	222	226				
19										
20	ID	20/70	20/80	20/90	20/95	20/99				
21	F-B HIGH (20)	146	144	142	148	139				
22	H-E LOW (20)	79	95	88	37	38				
23	D-A HIGH (20)	140	140	141	143	139				
24	G-C LOW (20)	86	91	90	39	39				
25	AVG CENTERLINE (20)	112.8	117.5	115.3	91.8	88.8				
26										
27	H-F LOW (20)	1,506	1,874	2,192	2,332	2,466				
28	E-B HIGH (20)	1,573	1,923	2,246	2,443	2,567				
29	G-D LOW (20)	1,521	1,885	2,207	2,351	2,486				
30	C-A HIGH (20)	1,575	1,934	2,258	2,455	2,586				
31	AVG DATA (20)	1,543.8	1,904.0	2,225.8	2,395.3	2,526.3				
32										
33	HIGH AVG CENTERLINE	143.0	142.0	141.5	145.5	139.0				
34	HIGH AVG DATA	1,574.0	1,928.5	2,252.0	2,449.0	2,576.5				
35										
36	LOW AVG CENTERLINE	82.5	93.0	89.0	38.0	38.5				
37	LOW AVG DATA	1,513.5	1,879.5	2,199.5	2,341.5	2,476.0				
38										
39	DIFF CENTERLINE	60.5	49.0	52.5	107.5	100.5				
40	DIFF DATA	60.5	49.0	52.5	107.5	100.5				
41										
42	SOURCE	20/70	20/80	20/90	20/95	20/99				
43	Random B % of Total (20)	2.2	1.8	1.6	1.4	1.3				
44	Random I % of Total (20)	11.7	9.8	8.6	8.1	7.9				
45	Centerline % of Total (20)	4.3	4.1	3.4	1.4	1.3				
46	Data % of Total (20)	78.7	82.2	84.4	85.2	86.1				
47	Interaction % of Total (20)	3.1	2.1	2.0	3.9	3.5				
48	TOTAL %	100	100	100	100	100				
49										
50	TOTAL (Same as H above)	1,924.3	2,287.0	2,605.8	2,748.8	2,877.3				
51										
52	AVERAGE AND LIMITS	20/70	20/80	20/90	20/95	20/99				
53	% AVG CENTERLINE_20 (Line 53)	5.9	5.1	4.4	3.3	3.1				
54	% MIN CENTERLINE_20 (Line 54)	4.3	4.1	3.4	1.4	1.3				
55	% MAX CENTERLINE_20 (Line 55)	7.4	6.2	5.4	5.3	4.8				
56										
57	AVERAGE AND LIMITS	20/70	20/80	20/90	20/95	20/99				
58	% AVG DATA_20 (Line 58)	80.2	83.3	85.4	87.1	87.8				
59	% MIN DATA_20 (Line 59)	78.7	82.2	84.4	85.2	86.1				
60	% MAX DATA_20 (Line 60)	81.8	84.3	86.4	89.1	89.5				

Table F.1
 Condition H When Chart Bias (Length) is 75
 Bias of the Centerline is Set to 20% of Data's Variation
 The Bias of the Data's Mean Varies from 5% through 99% of Data's Variation

Paired Bias Levels	Average Number per 1,000 Charts		Average Percent of Total Number of Runs of Eight		Average Run Length	Average Number of Measurements Observed Before First Run of Eight
	Runs of Eight	Charts With at Least One Run of Eight	False Directional Notices	Charts With Both a High and Low Run of Eight		
20/05	428	346	29.1	1.09	9.3	37.8
20/10	450	359	26.8	1.06	9.4	37.7
20/15	490	374	22.6	1.01	9.5	37.0
20/20	558	407	18.5	0.92	9.7	36.5
20/25	650	442	15.6	0.92	9.8	35.4
20/30	746	471	12.9	0.82	10.1	34.4
20/35	856	504	11.1	0.80	10.3	33.4
20/40	982	534	9.3	0.70	10.7	32.4
20/45	1,119	561	8.3	0.60	11.0	31.5
20/50	1,276	590	6.8	0.59	11.4	30.3
20/55	1,432	612	6.2	0.62	11.8	29.3
20/60	1,589	633	5.6	0.55	12.2	28.3
20/70	1,921	674	4.8	0.47	13.1	26.6
20/80	2,287	710	4.1	0.47	14.0	25.1
20/90	2,605	736	3.4	.036	14.9	23.4
20/95	2,747	745	3.2	0.36	15.5	23.1
20/99	2,877	756	3.0	0.34	15.8	22.5

CHART F.1
TOTAL NUMBER OF RUNS OF EIGHT UNDER ALL EIGHT EXPERIMENTAL CONDITIONS
UNEQUAL BIASES (Centerline Bias Percentage = 20%)
 Reference Table C and E

CHART F.2
NUMBER OF RUNS OF EIGHT ELIMINATED WHEN DATA AVERAGE IS FORCED TO BE ZERO
UNEQUAL BIASES (Centerline Bias Percentage = 20%)
 Reference Tables C, D and E

CHART F.3
AVERAGE NUMBER OF RUNS OF EIGHT
DUE TO BIAS IN THE DATA AND BIAS IN THE CENTERLINE
UNEQUAL BIASES (Centerline Bias Percentage = 20%)
 Reference Tables C, D and E

CHART F.4
PARTITIONING TOTAL NUMBER OF RUNS OF EIGHT
UNEQUAL BIASES (Centerline Bias Percentage = 20%)
 Expressed As A Percentage Of Total Number Of Runs Of Eight
 Reference Tables C and E

CHART F.5
AVERAGE NUMBER OF RUNS OF EIGHT DUE TO BIAS IN CENTERLINE
UNEQUAL BIASES (Centerline Bias = 20%)
 Expressed As A Percentage Of Total Number Of Runs Of Eight
 Reference Tables C and E

CHART F.6
AVERAGE NUMBER OF RUNS OF EIGHT DUE TO BIAS IN DATA
UNEQUAL BIASES (Centerline Bias Percentage = 20%)
 Expresses As A Total Number Of Runs Of Eight
 Reference Tables C and E

TABLE G

**Average Number of Runs of Eight Per 1,000 Charts
Unequal Bias Percentages**

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	ID	25/05	25/10	25/15	25/20	25/25	25/30	25/35	25/40	25/45	25/50	25/55	25/60
2	A-25	223	222	225	228	225	227	223	226	227	228	223	225
3	B-25	270	270	270	276	271	271	270	271	273	271	269	272
4	C-25	232	260	302	363	451	549	669	810	938	1,112	1,279	1,440
5	D-25	441	451	455	450	447	445	450	448	453	450	447	450
6	E-25	280	308	351	411	502	595	714	853	982	1,158	1,318	1,486
7	F-25	490	498	501	500	497	496	496	497	501	500	498	499
8	G-25	455	483	534	590	680	781	884	1,013	1,151	1,297	1,462	1,597
9	H-25	508	533	581	641	728	830	929	1,060	1,194	1,339	1,498	1,641
10													
11	ID	25/05	25/10	25/15	25/20	25/25	25/30	25/35	25/40	25/45	25/50	25/55	25/60
12	B-A (25)	47	48	45	48	46	44	47	45	46	43	46	47
13	E-C (25)	48	48	49	48	51	46	45	43	44	46	39	46
14	F-D (25)	49	47	46	50	50	51	46	49	48	50	51	49
15	H-G (25)	53	50	47	51	48	49	45	47	43	42	36	44
16	AVG (25)	49.3	48.3	46.8	49.3	48.8	47.5	45.8	46.0	45.3	45.3	43.0	46.5
17													
18	A	223	222	225	228	225	227	223	226	227	228	223	225
19													
20	ID	25/05	25/10	25/15	25/20	25/25	25/30	25/35	25/40	25/45	25/50	25/55	25/60
21	F-B HIGH (25)	220	228	231	224	226	225	226	226	228	229	229	227
22	H-E LOW (25)	228	225	230	230	226	235	215	207	212	181	180	155
23	D-A HIGH (25)	218	229	230	222	222	218	227	222	226	222	224	225
24	G-C LOW (25)	223	223	232	227	229	232	215	203	213	185	183	157
25	AVG CENTERLINE (25)	222.3	226.3	230.8	225.8	225.8	227.5	220.8	214.5	219.8	204.3	204.0	191.0
26													
27	H-F LOW (25)	18	35	80	141	231	334	433	563	693	839	1,000	1,142
28	E-B HIGH (25)	10	38	81	135	231	324	444	582	709	887	1,049	1,214
29	G-D LOW (25)	14	32	79	140	233	336	434	565	698	847	1,015	1,147
30	C-A HIGH (25)	9	38	77	135	226	322	446	584	711	884	1,056	1,215
31	AVG DATA (25)	12.8	35.8	79.3	137.8	230.3	329.0	439.3	573.5	702.8	864.3	1,030.0	1,179.5
32													
33	HIGH AVG CENTERLINE	219.0	228.5	230.5	223.0	224.0	221.5	226.5	224.0	227.0	225.5	226.5	226.0
34	HIGH AVG DATA	9.5	38.0	79.0	135.0	228.5	323.0	445.0	583.0	710.0	885.5	1,052.5	1,214.5
35													
36	LOW AVG CENTERLINE	225.5	224.0	231.0	228.5	227.5	233.5	215.0	205.0	212.5	183.0	181.5	156.0
37	LOW AVG DATA	16.0	33.5	79.5	140.5	232.0	335.0	433.5	564.0	695.5	843.0	1,007.5	1,144.5
38													
39	DIFF CENTERLINE	-6.5	4.5	-0.5	-5.5	-3.5	-12.0	11.5	19.0	14.5	42.5	45.0	70.0
40	DIFF DATA	-6.5	4.5	-0.5	-5.5	-3.5	-12.0	11.5	19.0	14.5	42.5	45.0	70.0
41													
42	SOURCE	25/05	25/10	25/15	25/20	25/25	25/30	25/35	25/40	25/45	25/50	25/55	25/60
43	Random B % of Total (25)	9.7	9.1	8.0	7.7	6.7	5.7	4.9	4.3	3.8	3.4	2.9	2.8
44	Random I % of Total (25)	44.0	41.7	38.7	35.6	30.8	27.3	24.0	21.3	19.0	17.0	14.9	13.7
45	Centerline % of Total (25)	44.5	42.1	39.7	35.7	31.2	28.1	23.1	19.3	17.8	13.6	12.1	9.5
46	Data % of Total (25)	3.2	6.3	13.7	21.9	31.8	40.3	46.7	53.2	58.2	62.8	67.2	69.7
47	Interaction % of Total (25)	-1.3	0.8	-0.1	-0.9	-0.5	-1.4	1.2	1.8	1.2	3.2	3.0	4.3
48	TOTAL %	100	100	100	100	100	100	100	100	100	100	100	100
49													
50	TOTAL (Same as H above)	507.3	532.3	581.8	640.8	729.8	831.0	928.8	1,060.0	1,194.8	1,341.8	1,500.0	1,642.0
51													
52	AVERAGE AND LIMITS	25/05	25/10	25/15	25/20	25/25	25/30	25/35	25/40	25/45	25/50	25/55	25/60
53	% AVG CENTERLINE_25 (Line 53)	43.8	42.5	39.7	35.2	30.9	27.4	23.8	20.2	18.4	15.2	13.6	11.6
54	% MIN CENTERLINE_25 (Line 54)	43.2	42.1	39.5	34.8	30.7	26.7	23.1	20.2	17.8	13.6	12.1	9.5
55	% MAX CENTERLINE_25 (Line 55)	44.5	42.9	39.8	35.7	31.2	28.1	24.4	20.2	19.0	16.8	15.1	13.8
56													
57	AVERAGE AND LIMITS	25/05	25/10	25/15	25/20	25/25	25/30	25/35	25/40	25/45	25/50	25/55	25/60
58	% AVG DATA_25 (Line 58)	2.5	6.7	13.6	21.5	31.6	39.6	47.3	54.1	58.8	64.4	68.7	71.8
59	% MIN DATA_25 (Line 59)	1.9	6.3	13.4	21.1	31.4	38.9	46.7	53.2	58.2	62.8	67.2	69.7
60	% MAX DATA_25 (Line 60)	3.2	7.1	13.8	21.9	31.7	40.3	47.9	55.0	59.4	66.0	70.2	74.0

TABLE G
Average Number of Runs of Eight Per 1,000 Charts
Unequal Bias Percentages

	N	O	P	Q	R	S	T	U	V	W
1	ID	25/70	25/80	25/90	25/95	25/99				
2	A-25	225	221	219	227	225				
3	B-25	272	268	266	272	271				
4	C-25	1,796	2,144	2,465	2,651	2,791				
5	D-25	449	450	452	449	448				
6	E-25	1,833	2,182	2,496	2,678	2,823				
7	F-25	504	500	501	498	495				
8	G-25	1,962	2,279	2,610	2,764	2,888				
9	H-25	1,994	2,306	2,636	2,794	2,916				
10										
11	ID	25/70	25/80	25/90	25/95	25/99				
12	B-A (25)	47	47	47	45	46				
13	E-C (25)	37	38	31	27	32				
14	F-D (25)	55	50	49	49	47				
15	H-G (25)	32	27	26	30	28				
16	AVG (25)	42.8	40.5	38.3	37.8	38.3				
17										
18	A	225	221	219	227	225				
19										
20	ID	25/70	25/80	25/90	25/95	25/99				
21	F-B HIGH (25)	232	232	235	226	224				
22	H-E LOW (25)	161	124	140	116	93				
23	D-A HIGH (25)	224	229	233	222	223				
24	G-C LOW (25)	166	135	145	113	97				
25	AVG CENTERLINE (25)	195.8	180.0	188.3	169.3	159.3				
26										
27	H-F LOW (25)	1,490	1,806	2,135	2,296	2,421				
28	E-B HIGH (25)	1,561	1,914	2,230	2,406	2,552				
29	G-D LOW (25)	1,513	1,829	2,158	2,315	2,440				
30	C-A HIGH (25)	1,571	1,923	2,246	2,424	2,566				
31	AVG DATA (25)	1,533.8	1,868.0	2,192.3	2,360.3	2,494.8				
32										
33	HIGH AVG CENTERLINE	228.0	230.5	234.0	224.0	223.5				
34	HIGH AVG DATA	1,566.0	1,918.5	2,238.0	2,415.0	2,559.0				
35										
36	LOW AVG CENTERLINE	163.5	129.5	142.5	114.5	95.0				
37	LOW AVG DATA	1,501.5	1,817.5	2,146.5	2,305.5	2,430.5				
38										
39	DIFF CENTERLINE	64.5	101.0	91.5	109.5	128.5				
40	DIFF DATA	64.5	101.0	91.5	109.5	128.5				
41										
42	SOURCE	25/70	25/80	25/90	25/95	25/99				
43	Random B % of Total (25)	2.1	1.8	1.5	1.4	1.3				
44	Random I % of Total (25)	11.3	9.6	8.3	8.1	7.7				
45	Centerline % of Total (25)	8.2	5.6	5.4	4.1	3.3				
46	Data % of Total (25)	75.2	78.7	81.4	82.5	83.3				
47	Interaction % of Total (25)	3.2	4.4	3.5	3.9	4.4				
48	TOTAL %	100	100	100	100	100				
49										
50	TOTAL (Same as H above)	1,997.3	2,309.5	2,637.8	2,794.3	2,917.3				
51										
52	AVERAGE AND LIMITS	25/70	25/80	25/90	25/95	25/99				
53	% AVG CENTERLINE_25 (Line 53)	9.8	7.8	7.1	6.1	5.5				
54	% MIN CENTERLINE_25 (Line 54)	8.2	5.6	5.4	4.1	3.3				
55	% MAX CENTERLINE_25 (Line 55)	11.4	10.0	8.9	8.0	7.7				
56										
57	AVERAGE AND LIMITS	25/70	25/80	25/90	25/95	25/99				
58	% AVG DATA_25 (Line 58)	76.8	80.9	83.1	84.5	85.5				
59	% MIN DATA_25 (Line 59)	75.2	78.7	81.4	82.5	83.3				
60	% MAX DATA_25 (Line 60)	78.4	83.1	84.8	86.4	87.7				

Table G.1

Condition H When Chart Bias (Length) is 75

Bias of the Centerline is Set to 25% of Data's Variation

The Bias of the Data's Mean Varies from 5% through 99% of Data's Variation

Paired Bias Levels	Average Number per 1,000 Charts		Average Percent of Total Number of Runs of Eight		Average Run Length	Average Number of Measurements Observed Before First Run of Eight
	Runs of Eight	Charts With at Least One Run of Eight	False Directional Notices	Charts With Both a High and Low Run of Eight		
25/05	508	387	31.8	1.02	9.5	36.9
25/10	533	395	28.7	0.99	9.6	36.6
25/15	584	417	24.9	0.92	9.7	36.1
25/20	614	437	21.6	0.85	9.9	35.6
25/25	728	468	17.9	0.73	10.0	34.9
25/30	803	495	15.2	0.73	10.3	33.8
25/35	929	522	13.2	0.75	10.5	33.0
25/40	1,069	551	11.4	0.70	10.9	31.7
25/45	1,149	578	10.2	0.63	11.2	31.0
25/50	1,339	599	8.8	0.57	11.6	30.1
25/55	1,498	620	8.0	0.56	12.0	28.8
25/60	1,641	641	7.1	0.52	12.3	28.0
25/70	1,994	685	5.7	0.47	13.2	26.3
25/80	2,306	713	4.9	0.43	14.1	24.9
25/90	2,636	738	4.1	0.38	15.1	23.4
25/95	2,794	749	4.1	0.40	15.6	22.6
25/99	2,916	756	4.0	0.33	16.0	22.3

CHART G.1
TOTAL NUMBER OF RUNS OF EIGHT UNDER ALL EIGHT EXPERIMENTAL CONDITIONS
UNEQUAL BIASES (Centerline Bias Percentage = 25%)
 Reference Table C and E

CHART G.2
NUMBER OF RUNS OF EIGHT ELIMINATED WHEN DATA AVERAGE IS FORCED TO BE ZERO
UNEQUAL BIASES (Centerline Bias Percentage = 25%)
Reference Tables C, D and E

CHART G.3
AVERAGE NUMBER OF RUNS OF EIGHT
DUE TO BIAS IN THE DATA AND BIAS IN THE CENTERLINE
UNEQUAL BIASES (Centerline Bias Percentage = 25%)
 Reference Tables C, D and E

CHART G.4
PARTITIONING TOTAL NUMBER OF RUNS OF EIGHT
UNEQUAL BIASES (Centerline Bias Percentage = 25%)
 Expressed As A Percent Of Total Number Of Runs Of Eight
 Reference Tables C and E

CHART G.5
AVERAGE NUMBER OF RUNS OF EIGHT DUE TO BIAS IN CENTERLINE
UNEQUAL BIASES (Centerline Bias = 25%)
 Expressed As A Percentage Of Total Number Of Runs Of Eight
 Reference Tables C and E

CHART G.6
AVERAGE NUMBER OF RUNS OF EIGHT DUE TO BIAS IN DATA
UNEQUAL BIASES (Centerline Bias Percentage = 25%)
Expressed As A Percentage Of Total Number Of Runs Of Eight
Reference Tables C and E

TABLE H
Average Number of Runs of Eight Per 1,000 Charts
Unequal Bias Percentages

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	ID	30/05	30/10	30/15	30/20	30/25	30/30	30/35	30/40	30/45	30/50	30/55	30/60
2	A-30	224	225	225	226	224	220	226	221	224	222	223	225
3	B-30	269	271	271	270	267	264	270	268	272	270	271	272
4	C-30	235	256	308	363	444	551	664	796	950	1,117	1,270	1,445
5	D-30	551	551	554	550	545	544	550	555	550	543	545	556
6	E-30	282	305	355	414	495	603	714	843	994	1,161	1,315	1,484
7	F-30	598	598	601	601	594	594	601	599	599	591	598	607
8	G-30	559	585	630	697	779	871	984	1,097	1,229	1,382	1,533	1,698
9	H-30	606	635	676	744	824	915	1,027	1,141	1,272	1,426	1,573	1,733
10													
11	ID	30/05	30/10	30/15	30/20	30/25	30/30	30/35	30/40	30/45	30/50	30/55	30/60
12	B-A (30)	45	46	46	44	43	44	44	47	48	48	48	47
13	E-C (30)	47	49	47	51	51	52	50	47	44	44	45	39
14	F-D (30)	47	47	47	51	49	50	51	44	49	48	53	51
15	H-G (30)	47	50	46	47	45	44	43	44	43	44	40	35
16	AVG (30)	46.5	48.0	46.5	48.3	47.0	47.5	47.0	45.5	46.0	46.0	46.5	43.0
17													
18	A	224	225	225	226	224	220	226	221	224	222	223	225
19													
20	ID	30/05	30/10	30/15	30/20	30/25	30/30	30/35	30/40	30/45	30/50	30/55	30/60
21	F-B HIGH (30)	329	327	330	331	327	330	331	331	327	321	327	335
22	H-E LOW (30)	324	330	321	330	329	312	313	298	278	265	258	249
23	D-A HIGH (30)	327	326	329	324	321	324	324	334	326	321	322	331
24	G-C LOW (30)	324	329	322	334	335	320	320	301	279	265	263	253
25	AVG CENTERLINE (30)	326.0	328.0	325.5	329.8	328.0	321.5	322.0	316.0	302.5	293.0	292.5	292.0
26													
27	H-F LOW (30)	8	37	75	143	230	321	426	542	673	835	975	1,126
28	E-B HIGH (30)	13	34	84	144	228	339	444	575	722	891	1,044	1,212
29	G-D LOW (30)	8	34	76	147	234	327	434	542	679	839	988	1,142
30	C-A HIGH (30)	11	31	83	137	220	331	438	575	726	895	1,047	1,220
31	AVG DATA (30)	10.0	34.0	79.5	142.8	228.0	329.5	435.5	558.5	700.0	865.0	1,013.5	1,175.0
32													
33	HIGH AVG CENTERLINE	328.0	326.5	329.5	327.5	324.0	327.0	327.5	332.5	326.5	321.0	324.5	333.0
34	HIGH AVG DATA	12.0	32.5	83.5	140.5	224.0	335.0	441.0	575.0	724.0	893.0	1,045.5	1,216.0
35													
36	LOW AVG CENTERLINE	324.0	329.5	321.5	332.0	332.0	316.0	316.5	299.5	278.5	265.0	260.5	251.0
37	LOW AVG DATA	8.0	35.5	75.5	145.0	232.0	324.0	430.0	542.0	676.0	837.0	981.5	1,134.0
38													
39	DIFF CENTERLINE	4.0	-3.0	8.0	-4.5	-8.0	11.0	11.0	33.0	48.0	56.0	64.0	82.0
40	DIFF DATA	4.0	-3.0	8.0	-4.5	-8.0	11.0	11.0	33.0	48.0	56.0	64.0	82.0
41													
42	SOURCE	30/05	30/10	30/15	30/20	30/25	30/30	30/35	30/40	30/45	30/50	30/55	30/60
43	Random B % of Total (30)	7.7	7.6	6.9	6.5	5.7	5.2	4.6	4.0	3.6	3.2	3.0	2.5
44	Random I % of Total (30)	36.9	35.4	33.3	30.3	27.1	24.0	21.9	19.4	17.6	15.6	14.2	13.0
45	Centerline % of Total (30)	53.4	51.9	47.5	44.5	40.1	34.4	30.7	26.2	21.9	18.6	16.5	14.5
46	Data % of Total (30)	1.3	5.6	11.2	19.4	28.1	35.3	41.7	47.5	53.1	58.7	62.3	65.4
47	Interaction % of Total (30)	0.7	-0.5	1.2	-0.6	-1.0	1.2	1.1	2.9	3.8	3.9	4.1	4.7
48	TOTAL %	100	100	100	100	100	100	100	100	100	100	100	100
49													
50	TOTAL (Same as H above)	606.5	635.0	676.5	746.8	827.0	918.5	1,030.5	1,141.0	1,272.5	1,426.0	1,575.5	1,735.0
51													
52	AVERAGE AND LIMITS	30/05	30/10	30/15	30/20	30/25	30/30	30/35	30/40	30/45	30/50	30/55	30/60
53	% AVG CENTERLINE_30 (Line 53)	53.8	51.7	48.1	44.2	39.7	35.0	31.2	27.7	23.8	20.5	18.6	16.8
54	% MIN CENTERLINE_30 (Line 54)	53.4	51.4	47.5	43.8	39.2	34.4	30.7	26.2	21.9	18.6	16.5	14.5
55	% MAX CENTERLINE_30 (Line 55)	54.1	51.9	48.7	44.5	40.1	35.6	31.8	29.1	25.7	22.5	20.6	19.2
56													
57	AVERAGE AND LIMITS	30/05	30/10	30/15	30/20	30/25	30/30	30/35	30/40	30/45	30/50	30/55	30/60
58	% AVG DATA_30 (Line 58)	1.6	5.4	11.8	19.1	27.6	35.9	42.3	48.9	55.0	60.7	64.3	67.7
59	% MIN DATA_30 (Line 59)	1.3	5.1	11.2	18.7	27.1	35.3	41.7	47.5	53.1	58.7	62.3	65.4
60	% MAX DATA_30 (Line 60)	2.0	5.6	12.3	19.5	28.1	36.5	42.8	50.4	56.9	62.6	66.4	70.1

TABLE H

**Average Number of Runs of Eight Per 1,000 Charts
Unequal Bias Percentages**

	N	O	P	Q	R	S	T	U	V	W
1	ID	30/70	30/80	30/90	30/95	30/99				
2	A-30	221	228	228	228	225				
3	B-30	268	274	275	273	272				
4	C-30	1,781	2,133	2,490	2,648	2,800				
5	D-30	555	545	553	551	546				
6	E-30	1,821	2,167	2,522	2,677	2,829				
7	F-30	604	593	599	600	595				
8	G-30	1,987	2,321	2,662	2,822	2,904				
9	H-30	2,024	2,349	2,692	2,850	2,932				
10										
11	ID	30/70	30/80	30/90	30/95	30/99				
12	B-A (30)	47	46	47	45	47				
13	E-C (30)	40	34	32	29	29				
14	F-D (30)	49	48	46	49	49				
15	H-G (30)	37	28	30	28	28				
16	AVG (30)	43.3	39.0	38.8	37.8	38.3				
17										
18	A	221	228	228	228	225				
19										
20	ID	30/70	30/80	30/90	30/95	30/99				
21	F-B HIGH (30)	336	319	324	327	323				
22	H-E LOW (30)	203	182	170	173	103				
23	D-A HIGH (30)	334	317	325	323	321				
24	G-C LOW (30)	206	188	172	174	104				
25	AVG CENTERLINE (30)	269.8	251.5	247.8	249.3	212.8				
26										
27	H-F LOW (30)	1,420	1,756	2,093	2,250	2,337				
28	E-B HIGH (30)	1,553	1,893	2,247	2,404	2,557				
29	G-D LOW (30)	1,432	1,776	2,109	2,271	2,358				
30	C-A HIGH (30)	1,560	1,905	2,262	2,420	2,575				
31	AVG DATA (30)	1,491.3	1,832.5	2,177.8	2,336.3	2,456.8				
32										
33	HIGH AVG CENTERLINE	335.0	318.0	324.5	325.0	322.0				
34	HIGH AVG DATA	1,556.5	1,899.0	2,254.5	2,412.0	2,566.0				
35										
36	LOW AVG CENTERLINE	204.5	185.0	171.0	173.5	103.5				
37	LOW AVG DATA	1,426.0	1,766.0	2,101.0	2,260.5	2,347.5				
38										
39	DIFF CENTERLINE	130.5	133.0	153.5	151.5	218.5				
40	DIFF DATA	130.5	133.0	153.5	151.5	218.5				
41										
42	SOURCE	30/70	30/80	30/90	30/95	30/99				
43	Random B % of Total (30)	2.1	1.7	1.4	1.3	1.3				
44	Random I % of Total (30)	10.9	9.7	8.5	8.0	7.7				
45	Centerline % of Total (30)	10.1	7.9	6.4	6.1	3.5				
46	Data % of Total (30)	70.4	75.1	78.0	79.3	80.0				
47	Interaction % of Total (30)	6.4	5.7	5.7	5.3	7.5				
48	TOTAL %	100	100	100	100	100				
49										
50	TOTAL (Same as H above)	2,025.3	2,351.0	2,692.3	2,851.3	2,932.8				
51										
52	AVERAGE AND LIMITS	30/70	30/80	30/90	30/95	30/99				
53	% AVG CENTERLINE_30 (Line 53)	13.3	10.7	9.2	8.7	7.3				
54	% MIN CENTERLINE_30 (Line 54)	10.1	7.9	6.4	6.1	3.5				
55	% MAX CENTERLINE_30 (Line 55)	16.5	13.5	12.1	11.4	11.0				
56										
57	AVERAGE AND LIMITS	30/70	30/80	30/90	30/95	30/99				
58	% AVG DATA_30 (Line 58)	73.6	77.9	80.9	81.9	83.8				
59	% MIN DATA_30 (Line 59)	70.4	75.1	78.0	79.3	80.0				
60	% MAX DATA_30 (Line 60)	76.9	80.8	83.7	84.6	87.5				

Table H.1
 Condition H When Chart Bias (Length) is 75
 Bias of the Centerline is Set to 30% of Data's Variation
 The Bias of the Data's Mean Varies from 5% through 99% of Data's Variation

Paired Bias Levels	Average Number per 1,000 Charts		Average Percent of Total Number of Runs of Eight		Average Run Length	Average Number of Measurements Observed Before First Run of Eight
	Runs of Eight	Charts With at Least One Run of Eight	False Directional Notices	Charts With Both a High and Low Run of Eight		
30/05	606	426	33.7	0.98	9.7	36.1
30/10	635	435	30.8	0.88	9.8	35.7
30/15	668	434	30.8	0.89	9.9	35.1
30/20	744	447	27.7	0.84	10.1	34.5
30/25	824	471	23.5	0.81	10.3	33.8
30/30	915	518	18.1	0.73	10.5	32.9
30/35	1,027	543	15.4	0.67	10.8	32.0
30/40	1,141	565	14.0	0.67	11.1	31.0
30/45	1,272	587	12.4	0.64	11.4	30.3
30/50	1,426	612	10.7	0.60	11.7	29.4
30/55	1,573	629	9.6	0.55	12.2	28.3
30/60	1,733	652	9.1	0.53	12.6	27.5
30/70	2,024	682	7.0	0.46	13.3	25.9
30/80	2,349	714	6.3	0.43	14.2	24.6
30/90	2,692	743	5.4	0.35	15.2	23.1
30/95	2,850	753	5.2	0.37	15.8	22.6
30/99	2,932	757	4.9	0.36	16.1	22.2

CHART H.1
TOTAL NUMBER OF RUNS OF EIGHT UNDER ALL EIGHT EXPERIMENTAL CONDITIONS
UNEQUAL BIASES (Centerline Bias Percentage = 30%)
 Reference Tables C and E

CHART H.2
NUMBER OF RUNS OF EIGHT ELIMINATED WHEN DATA AVERAGE IS FORCED TO BE ZERO
UNEQUAL BIASES (Centerline Bias Percentage = 30%)
 Reference Tables C, D and E

CHART H.3
AVERAGE NUMBER OF RUNS OF EIGHT
DUE TO BIAS IN THE DATA AND BIAS IN THE CENTERLINE
UNEQUAL BIASES (Centerline Bias Percentage = 30%)
 Reference Tables C, D and E

CHART H.4
PARTITIONING TOTAL NUMBER OF RUNS OF EIGHT
UNEQUAL BIASES (Centerline Bias Percentage = 30%)
 Expressed As A Percentage Of Total Number of Runs of Eight
 Reference Tables C and E

CHART H.5
AVERAGE NUMBER OF RUNS OF EIGHT DUE TO BIAS IN CENTERLINE
UNEQUAL BIASES (Centerline Bias = 30%)
Expressed As A Percentage of Total Number of Runs of Eight
Reference Tables C and E

CHART H.6
AVERAGE NUMBER OF RUNS OF EIGHT DUE TO BIAS IN DATA
UNEQUAL BIASES (Centerline Bias Percentage = 30%)
 Expressed As A Percentage of Total Number of Runs of Eight
 Reference Tables C and E

TABLE I

**Average Number of Runs of Eight Per 1,000 Charts
Unequal Bias Percentages**

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	ID	35/05	35/10	35/15	35/20	35/25	35/30	35/35	35/40	35/45	35/50	35/55	35/60
2	A-35	226	219	223	224	224	225	227	226	221	223	222	226
3	B-35	273	269	269	269	269	270	268	272	268	271	267	274
4	C-35	233	255	304	367	447	546	663	808	947	1,113	1,272	1,438
5	D-35	662	665	669	659	672	672	672	676	666	663	666	667
6	E-35	281	303	349	415	497	596	710	855	992	1,161	1,314	1,479
7	F-35	717	713	716	707	725	718	720	727	714	709	714	717
8	G-35	682	707	759	811	891	972	1,091	1,211	1,354	1,478	1,627	1,775
9	H-35	728	755	809	857	937	1,022	1,137	1,254	1,394	1,517	1,663	1,809
10													
11	ID	35/05	35/10	35/15	35/20	35/25	35/30	35/35	35/40	35/45	35/50	35/55	35/60
12	B-A (35)	47	50	46	45	45	45	41	46	47	48	45	48
13	E-C (35)	48	48	45	48	50	50	47	47	45	48	42	41
14	F-D (35)	55	48	47	48	53	46	48	51	48	46	48	50
15	H-G (35)	46	48	50	46	46	50	46	43	40	39	36	34
16	AVG (35)	49.0	48.5	47.0	46.8	48.5	47.8	45.5	46.8	45.0	45.3	42.8	43.3
17													
18	A	226	219	223	224	224	225	227	226	221	223	222	226
19													
20	ID	35/05	35/10	35/15	35/20	35/25	35/30	35/35	35/40	35/45	35/50	35/55	35/60
21	F-B HIGH (35)	444	444	447	438	456	448	452	455	446	438	447	443
22	H-E LOW (35)	447	452	460	442	440	426	427	399	402	356	349	330
23	D-A HIGH (35)	436	446	446	435	448	447	445	450	445	440	444	441
24	G-C LOW (35)	449	452	455	444	444	426	428	403	407	365	355	337
25	AVG CENTERLINE (35)	444.0	448.5	452.0	439.8	447.0	436.8	438.0	426.8	425.0	399.8	398.8	387.8
26													
27	H-F LOW (35)	11	42	93	150	212	304	417	527	680	808	949	1,092
28	E-B HIGH (35)	8	34	80	146	228	326	442	583	724	890	1,047	1,205
29	G-D LOW (35)	20	42	90	152	219	300	419	535	688	815	961	1,108
30	C-A HIGH (35)	7	36	81	143	223	321	436	582	726	890	1,050	1,212
31	AVG DATA (35)	11.5	38.5	86.0	147.8	220.5	312.8	428.5	556.8	704.5	850.8	1,001.8	1,154.3
32													
33	HIGH AVG CENTERLINE	440.0	445.0	446.5	436.5	452.0	447.5	448.5	452.5	445.5	439.0	445.5	442.0
34	HIGH AVG DATA	7.5	35.0	80.5	144.5	225.5	323.5	439.0	582.5	725.0	890.0	1,048.5	1,208.5
35													
36	LOW AVG CENTERLINE	448.0	452.0	457.5	443.0	442.0	426.0	427.5	401.0	404.5	360.5	352.0	333.5
37	LOW AVG DATA	15.5	42.0	91.5	151.0	215.5	302.0	418.0	531.0	684.0	811.5	955.0	1,100.0
38													
39	DIFF CENTERLINE	-8.0	-7.0	-11.0	-6.5	10.0	21.5	21.0	51.5	41.0	78.5	93.5	108.5
40	DIFF DATA	-8.0	-7.0	-11.0	-6.5	10.0	21.5	21.0	51.5	41.0	78.5	93.5	108.5
41													
42	SOURCE	35/05	35/10	35/15	35/20	35/25	35/30	35/35	35/40	35/45	35/50	35/55	35/60
43	Random B % of Total (35)	6.7	6.4	5.8	5.4	5.2	4.7	4.0	3.7	3.2	3.0	2.6	2.4
44	Random I % of Total (35)	30.9	29.0	27.6	26.1	23.8	22.0	19.9	18.0	15.8	14.7	13.3	12.5
45	Centerline % of Total (35)	61.3	59.9	56.6	51.6	47.0	41.7	37.5	31.9	29.0	23.7	21.1	18.4
46	Data % of Total (35)	2.1	5.6	11.3	17.6	22.9	29.5	36.7	42.3	49.0	53.4	57.3	60.7
47	Interaction % of Total (35)	-1.1	-0.9	-1.4	-0.8	1.1	2.1	1.8	4.1	2.9	5.2	5.6	6.0
48	TOTAL %	100	100	100	100	100	100	100	100	100	100	100	100
49													
50	TOTAL (Same as H above)	730.5	754.5	808.0	858.3	940.0	1,022.3	1,139.0	1,256.3	1,395.5	1,518.8	1,665.3	1,811.3
51													
52	AVERAGE AND LIMITS	35/05	35/10	35/15	35/20	35/25	35/30	35/35	35/40	35/45	35/50	35/55	35/60
53	% AVG CENTERLINE_35 (Line 53)	60.8	59.4	55.9	51.2	47.6	42.7	38.5	34.0	30.5	26.3	23.9	21.4
54	% MIN CENTERLINE_35 (Line 54)	60.2	59.0	55.3	50.9	47.0	41.7	37.5	31.9	29.0	23.7	21.1	18.4
55	% MAX CENTERLINE_35 (Line 55)	61.3	59.9	56.6	51.6	48.1	43.8	39.4	36.0	31.9	28.9	26.8	24.4
56													
57	AVERAGE AND LIMITS	35/05	35/10	35/15	35/20	35/25	35/30	35/35	35/40	35/45	35/50	35/55	35/60
58	% AVG DATA_35 (Line 58)	1.6	5.1	10.6	17.2	23.5	30.6	37.6	44.3	50.5	56.0	60.2	63.7
59	% MIN DATA_35 (Line 59)	1.0	4.6	10.0	16.8	22.9	29.5	36.7	42.3	49.0	53.4	57.3	60.7
60	% MAX DATA_35 (Line 60)	2.1	5.6	11.3	17.6	24.0	31.6	38.5	46.4	52.0	58.6	63.0	66.7

TABLE I
Average Number of Runs of Eight Per 1,000 Charts
Unequal Bias Percentages

	N	O	P	Q	R	S	T	U	V	W
1	ID	35/70	35/80	35/90	35/95	35/99				
2	A-35	222	225	221	226	229				
3	B-35	271	269	266	273	273				
4	C-35	1,779	2,165	2,509	2,658	2,784				
5	D-35	670	664	661	673	666				
6	E-35	1,814	2,195	2,543	2,692	2,809				
7	F-35	718	712	709	717	715				
8	G-35	2,075	2,394	2,720	2,823	2,982				
9	H-35	2,113	2,425	2,748	2,850	3,006				
10										
11	ID	35/70	35/80	35/90	35/95	35/99				
12	B-A (35)	49	44	45	47	44				
13	E-C (35)	35	30	34	34	25				
14	F-D (35)	48	48	48	44	49				
15	H-G (35)	38	31	28	27	24				
16	AVG (35)	42.5	38.3	38.8	38.0	35.5				
17										
18	A	222	225	221	226	229				
19										
20	ID	35/70	35/80	35/90	35/95	35/99				
21	F-B HIGH (35)	447	443	443	444	442				
22	H-E LOW (35)	299	230	205	158	197				
23	D-A HIGH (35)	448	439	440	447	437				
24	G-C LOW (35)	296	229	211	165	198				
25	AVG CENTERLINE (35)	372.5	335.3	324.8	303.5	318.5				
26										
27	H-F LOW (35)	1,395	1,713	2,039	2,133	2,291				
28	E-B HIGH (35)	1,543	1,926	2,277	2,419	2,536				
29	G-D LOW (35)	1,405	1,730	2,059	2,150	2,316				
30	C-A HIGH (35)	1,557	1,940	2,288	2,432	2,555				
31	AVG DATA (35)	1,475.0	1,827.3	2,165.8	2,283.5	2,424.5				
32										
33	HIGH AVG CENTERLINE	447.5	441.0	441.5	445.5	439.5				
34	HIGH AVG DATA	1,550.0	1,933.0	2,282.5	2,425.5	2,545.5				
35										
36	LOW AVG CENTERLINE	297.5	229.5	208.0	161.5	197.5				
37	LOW AVG DATA	1,400.0	1,721.5	2,049.0	2,141.5	2,303.5				
38										
39	DIFF CENTERLINE	150.0	211.5	233.5	284.0	242.0				
40	DIFF DATA	150.0	211.5	233.5	284.0	242.0				
41										
42	SOURCE	35/70	35/80	35/90	35/95	35/99				
43	Random B % of Total (35)	2.0	1.6	1.4	1.3	1.2				
44	Random I % of Total (35)	10.5	9.3	8.0	7.9	7.6				
45	Centerline % of Total (35)	14.1	9.5	7.6	5.7	6.6				
46	Data % of Total (35)	66.3	71.0	74.5	75.1	76.6				
47	Interaction % of Total (35)	7.1	8.7	8.5	10.0	8.0				
48	TOTAL %	100	100	100	100	100				
49										
50	TOTAL (Same as H above)	2,112.0	2,425.8	2,750.3	2,851.0	3,007.5				
51										
52	AVERAGE AND LIMITS	35/70	35/80	35/90	35/95	35/99				
53	% AVG CENTERLINE_35 (Line 53)	17.6	13.8	11.8	10.6	10.6				
54	% MIN CENTERLINE_35 (Line 54)	14.1	9.5	7.6	5.7	6.6				
55	% MAX CENTERLINE_35 (Line 55)	21.2	18.2	16.1	15.6	14.6				
56										
57	AVERAGE AND LIMITS	35/70	35/80	35/90	35/95	35/99				
58	% AVG DATA_35 (Line 58)	69.8	75.3	78.7	80.1	80.6				
59	% MIN DATA_35 (Line 59)	66.3	71.0	74.5	75.1	76.6				
60	% MAX DATA_35 (Line 60)	73.4	79.7	83.0	85.1	84.6				

Table I.1
 Condition H When Chart Bias (Length) is 75
 Bias of the Centerline is Set to 35% of Data's Variation
 The Bias of the Data's Mean Varies from 5% through 99% of Data's Variation

Paired Bias Levels	Average Number per 1,000 Charts		Average Percent of Total Number of Runs of Eight		Average Run Length	Average Number of Measurements Observed Before First Run of Eight
	Runs of Eight	Charts With at Least One Run of Eight	False Directional Notices	Charts With Both a High and Low Run of Eight		
35/05	728	468	35.8	0.81	10.1	34.8
35/10	755	475	33.4	0.78	10.1	34.4
35/15	809	492	29.4	0.77	10.2	34.0
35/20	861	504	26.0	0.79	10.4	33.4
35/25	916	516	23.5	0.71	10.5	32.9
35/30	1,022	542	20.1	0.67	10.8	32.1
35/35	1,138	563	17.7	0.63	11.1	31.1
35/40	1,233	580	15.8	0.64	11.3	30.6
35/45	1,374	608	14.5	0.57	11.6	29.7
35/50	1,517	622	13.1	0.59	12.0	28.7
35/55	1,663	646	11.6	0.59	12.3	28.0
35/60	1,809	663	10.5	0.50	12.7	27.3
35/70	1,981	677	9.6	0.50	13.2	26.2
35/80	2,428	721	7.7	0.47	14.5	24.3
35/90	2,748	743	6.5	0.38	15.5	22.9
35/95	2,850	754	6.2	0.34	15.8	22.7
35/99	3,006	762	5.8	0.35	16.3	21.9

CHART I.1
TOTAL NUMBER OF RUNS OF EIGHT UNDER ALL EIGHT EXPERIMENTAL CONDITIONS
UNEQUAL BIASES (Centerline Bias Percentage = 35%)
 Reference Tables C and E

CHART I.2
NUMBER OF RUNS OF EIGHT ELIMINATED WHEN DATA AVERAGE IS FORCED TO BE ZERO
UNEQUAL BIASES (Centerline Bias Percentage = 35%)
 Reference Tables C, D and E

CHART I.3
AVERAGE NUMBER OF RUNS OF EIGHT
DUE TO BIAS IN THE DATA AND BIAS IN THE CENTERLINE
UNEQUAL BIASES (Centerline Bias Percentage = 35%)
 Reference Tables C, D and E

CHART I.4
PARTITIONING TOTAL NUMBER OF RUNS OF EIGHT
UNEQUAL BIASES (Centerline Bias Percentage = 35%)
 Expressed As A Percentage Of Total Number of Runs of Eight
 Reference Tables C and E

CHART I.5
AVERAGE NUMBER OF RUNS OF EIGHT DUE TO BIAS IN CENTERLINE
UNEQUAL BIASES (Centerline Bias = 35%)
 Expressed As A Percentage of Total Number of Runs of Eight
 Reference Tables C and E

CHART I.6
AVERAGE NUMBER OF RUNS OF EIGHT DUE TO BIAS IN DATA
UNEQUAL BIASES (Centerline Bias Percentage = 35%)
 Expressed As A Percentage of Total Number of Runs of Eight
 Reference Tables C and E

TABLE J

**Average Number of Runs of Eight Per 1,000 Charts
Unequal Bias Percentages**

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	ID	40/05	40/10	40/15	40/20	40/25	40/30	40/35	40/40	40/45	40/50	40/55	40/60
2	A-40	225	224	225	227	223	224	223	222	225	225	225	225
3	B-40	271	270	271	275	268	270	272	270	272	272	269	271
4	C-40	230	258	308	366	443	546	673	800	946	1,113	1,276	1,438
5	D-40	797	798	795	803	796	804	807	798	796	799	800	799
6	E-40	276	305	358	413	489	595	721	847	997	1,158	1,318	1,474
7	F-40	844	848	839	851	840	852	855	846	842	845	851	847
8	G-40	811	833	879	937	1,009	1,098	1,200	1,326	1,460	1,562	1,710	1,866
9	H-40	852	880	928	983	1,059	1,145	1,240	1,369	1,497	1,600	1,750	1,903
10													
11	ID	40/05	40/10	40/15	40/20	40/25	40/30	40/35	40/40	40/45	40/50	40/55	40/60
12	B-A (40)	46	46	46	48	45	46	49	48	47	47	44	46
13	E-C (40)	46	47	50	47	46	49	48	47	51	45	42	36
14	F-D (40)	47	50	44	48	44	48	48	48	46	46	51	48
15	H-G (40)	41	47	49	46	50	47	40	43	37	38	40	37
16	AVG (40)	45.0	47.5	47.3	47.3	46.3	47.5	46.3	46.5	45.3	44.0	44.3	41.8
17													
18	A	225	224	225	227	223	224	223	222	225	225	225	225
19													
20	ID	40/05	40/10	40/15	40/20	40/25	40/30	40/35	40/40	40/45	40/50	40/55	40/60
21	F-B HIGH (40)	573	578	568	576	572	582	583	576	570	573	582	576
22	H-E LOW (40)	576	575	570	570	570	550	519	522	500	442	432	429
23	D-A HIGH (40)	572	574	570	576	573	580	584	576	571	574	575	574
24	G-C LOW (40)	581	575	571	571	566	552	527	526	514	449	434	428
25	AVG CENTERLINE (40)	575.5	575.5	569.8	573.3	570.3	566.0	553.3	550.0	538.8	509.5	505.8	501.8
26													
27	H-F LOW (40)	8	32	89	132	219	293	385	523	655	755	899	1,056
28	E-B HIGH (40)	5	35	87	138	221	325	449	577	725	886	1,049	1,203
29	G-D LOW (40)	14	35	84	134	213	294	393	528	664	763	910	1,067
30	C-A HIGH (40)	5	34	83	139	220	322	450	578	721	888	1,051	1,213
31	AVG DATA (40)	8.0	34.0	85.8	135.8	218.3	308.5	419.3	551.5	691.3	823.0	977.3	1,134.8
32													
33	HIGH AVG CENTERLINE	572.5	576.0	569.0	576.0	572.5	581.0	583.5	576.0	570.5	573.5	578.5	575.0
34	HIGH AVG DATA	5.0	34.5	85.0	138.5	220.5	323.5	449.5	577.5	723.0	887.0	1,050.0	1,208.0
35													
36	LOW AVG CENTERLINE	578.5	575.0	570.5	570.5	568.0	551.0	523.0	524.0	507.0	445.5	433.0	428.5
37	LOW AVG DATA	11.0	33.5	86.5	133.0	216.0	293.5	389.0	525.5	659.5	759.0	904.5	1,061.5
38													
39	DIFF CENTERLINE	-6.0	1.0	-1.5	5.5	4.5	30.0	60.5	52.0	63.5	128.0	145.5	146.5
40	DIFF DATA	-6.0	1.0	-1.5	5.5	4.5	30.0	60.5	52.0	63.5	128.0	145.5	146.5
41													
42	SOURCE	40/05	40/10	40/15	40/20	40/25	40/30	40/35	40/40	40/45	40/50	40/55	40/60
43	Random B % of Total (40)	5.3	5.4	5.1	4.8	4.4	4.1	3.7	3.4	3.0	2.7	2.5	2.2
44	Random I % of Total (40)	26.4	25.4	24.3	23.1	21.1	19.5	18.0	16.2	15.0	14.0	12.8	11.8
45	Centerline % of Total (40)	67.8	65.3	61.5	58.0	53.7	48.1	42.1	38.2	33.8	27.8	24.7	22.5
46	Data % of Total (40)	1.3	3.8	9.3	13.5	20.4	25.6	31.3	38.4	44.0	47.4	51.6	55.8
47	Interaction % of Total (40)	-0.7	0.1	-0.2	0.6	0.4	2.6	4.9	3.8	4.2	8.0	8.3	7.7
48	TOTAL %	100	100	100	100	100	100	100	100	100	100	100	100
49													
50	TOTAL (Same as H above)	853.5	881.0	927.8	983.3	1,057.8	1,146.0	1,241.8	1,370.0	1,500.3	1,601.5	1,752.3	1,903.3
51													
52	AVERAGE AND LIMITS	40/05	40/10	40/15	40/20	40/25	40/30	40/35	40/40	40/45	40/50	40/55	40/60
53	% AVG CENTERLINE_40 (Line 53)	67.4	65.3	61.4	58.3	53.9	49.4	44.6	40.1	35.9	31.8	28.9	26.4
54	% MIN CENTERLINE_40 (Line 54)	67.1	65.2	61.3	58.0	53.7	48.1	42.1	38.2	33.8	27.8	24.7	22.5
55	% MAX CENTERLINE_40 (Line 55)	67.8	65.4	61.5	58.6	54.1	50.7	47.0	42.0	38.0	35.8	33.0	30.2
56													
57	AVERAGE AND LIMITS	40/05	40/10	40/15	40/20	40/25	40/30	40/35	40/40	40/45	40/50	40/55	40/60
58	% AVG DATA_40 (Line 58)	0.9	3.9	9.2	13.8	20.6	26.9	33.8	40.3	46.1	51.4	55.8	59.6
59	% MIN DATA_40 (Line 59)	0.6	3.7	9.0	13.5	20.4	25.6	31.3	38.4	44.0	47.4	51.6	55.8
60	% MAX DATA_40 (Line 60)	1.3	4.0	9.5	14.1	20.8	28.2	36.2	42.2	48.2	55.4	59.9	63.5

TABLE J
Average Number of Runs of Eight Per 1,000 Charts
Unequal Bias Percentages

	N	O	P	Q	R	S	T	U	V	W
1	ID	40/70	40/80	40/90	40/95	40/99				
2	A-40	229	224	222	222	221				
3	B-40	275	272	270	269	270				
4	C-40	1,808	2,139	2,488	2,662	2,786				
5	D-40	797	801	796	801	798				
6	E-40	1,844	2,176	2,520	2,684	2,811				
7	F-40	843	852	848	849	844				
8	G-40	2,157	2,469	2,781	2,916	3,060				
9	H-40	2,193	2,503	2,814	2,949	3,088				
10										
11	ID	40/70	40/80	40/90	40/95	40/99				
12	B-A (40)	46	48	48	47	49				
13	E-C (40)	36	37	32	22	25				
14	F-D (40)	46	51	52	48	46				
15	H-G (40)	36	34	33	33	28				
16	AVG (40)	41.0	42.5	41.3	37.5	37.0				
17										
18	A	229	224	222	222	221				
19										
20	ID	40/70	40/80	40/90	40/95	40/99				
21	F-B HIGH (40)	568	580	578	580	574				
22	H-E LOW (40)	349	327	294	265	277				
23	D-A HIGH (40)	568	577	574	579	577				
24	G-C LOW (40)	349	330	293	254	274				
25	AVG CENTERLINE (40)	458.5	453.5	434.8	419.5	425.5				
26										
27	H-F LOW (40)	1,350	1,651	1,966	2,100	2,244				
28	E-B HIGH (40)	1,569	1,904	2,250	2,415	2,541				
29	G-D LOW (40)	1,360	1,668	1,985	2,115	2,262				
30	C-A HIGH (40)	1,579	1,915	2,266	2,440	2,565				
31	AVG DATA (40)	1,464.5	1,784.5	2,116.8	2,267.5	2,403.0				
32										
33	HIGH AVG CENTERLINE	568.0	578.5	576.0	579.5	575.5				
34	HIGH AVG DATA	1,574.0	1,909.5	2,258.0	2,427.5	2,553.0				
35										
36	LOW AVG CENTERLINE	349.0	328.5	293.5	259.5	275.5				
37	LOW AVG DATA	1,355.0	1,659.5	1,975.5	2,107.5	2,253.0				
38										
39	DIFF CENTERLINE	219.0	250.0	282.5	320.0	300.0				
40	DIFF DATA	219.0	250.0	282.5	320.0	300.0				
41										
42	SOURCE	40/70	40/80	40/90	40/95	40/99				
43	Random B % of Total (40)	1.9	1.7	1.5	1.3	1.2				
44	Random I % of Total (40)	10.4	8.9	7.9	7.5	7.2				
45	Centerline % of Total (40)	15.9	13.1	10.4	8.8	8.9				
46	Data % of Total (40)	61.8	66.3	70.2	71.5	73.0				
47	Interaction % of Total (40)	10.0	10.0	10.0	10.9	9.7				
48	TOTAL %	100	100	100	100	100				
49										
50	TOTAL (Same as H above)	2,193.0	2,504.5	2,814.8	2,946.5	3,086.5				
51										
52	AVERAGE AND LIMITS	40/70	40/80	40/90	40/95	40/99				
53	% AVG CENTERLINE_40 (Line 53)	20.9	18.1	15.4	14.2	13.8				
54	% MIN CENTERLINE_40 (Line 54)	15.9	13.1	10.4	8.8	8.9				
55	% MAX CENTERLINE_40 (Line 55)	25.9	23.1	20.5	19.7	18.6				
56										
57	AVERAGE AND LIMITS	40/70	40/80	40/90	40/95	40/99				
58	% AVG DATA_40 (Line 58)	66.8	71.3	75.2	77.0	77.9				
59	% MIN DATA_40 (Line 59)	61.8	66.3	70.2	71.5	73.0				
60	% MAX DATA_40 (Line 60)	71.8	76.2	80.2	82.4	82.7				

Table J.1
 Condition H When Chart Bias (Length) is 75
 Bias of the Centerline is Set to 40% of Data's Variation
 The Bias of the Data's Mean Varies from 5% through 99% of Data's Variation

Paired Bias Levels	Average Number per 1,000 Charts		Average Percent of Total Number of Runs of Eight		Average Run Length	Average Number of Measurements Observed Before First Run of Eight
	Runs of Eight	Charts With at Least One Run of Eight	False Directional Notices	Charts With Both a High and Low Run of Eight		
40/05	868	507	36.9	0.87	10.4	33.4
40/10	865	504	35.1	0.72	10.4	33.6
40/15	938	524	31.3	0.76	10.6	32.8
40/20	981	532	28.2	0.72	10.7	32.3
40/25	1,057	548	25.2	0.70	10.8	31.9
40/30	1,146	566	23.0	0.70	11.1	31.3
40/35	1,248	585	20.0	0.67	11.3	30.5
40/40	1,373	604	17.9	0.59	11.6	29.8
40/45	1,489	620	16.1	0.47	11.9	29.0
40/50	1,623	641	14.9	0.50	12.3	28.1
40/55	1,765	658	13.5	0.53	12.6	27.4
40/60	1,899	669	12.5	0.46	13.0	26.6
40/70	2,196	701	10.5	0.48	13.8	25.4
40/80	2,496	729	9.1	0.38	14.7	24.0
40/90	2,813	752	7.9	0.38	15.6	22.8
40/95	2,941	758	7.3	0.35	16.1	22.2
40/99	3,083	769	7.1	0.38	16.5	21.7

CHART J.1
TOTAL NUMBER OF RUNS OF EIGHT UNDER ALL EIGHT EXPERIMENTAL CONDITIONS
UNEQUAL BIASES (Centerline Bias Percentage = 40%)
 Reference Tables C and E

CHART J.2
NUMBER OF RUNS OF EIGHT ELIMINATED WHEN DATA AVERAGE IS FORCED TO BE ZERO
UNEQUAL BIASES (Centerline Bias Percentage = 40%)
 Reference Tables C, D and E

CHART J.3
AVERAGE NUMBER OF RUNS OF EIGHT
DUE TO BIAS IN THE DATA AND BIAS IN THE CENTERLINE
UNEQUAL BIASES (Centerline Bias Percentage = 40%)
 Reference Tables C, D and E

CHART J.4
PARTITIONING TOTAL NUMBER OF RUNS OF EIGHT
UNEQUAL BIASES (Centerline Bias Percentage = 40%)
 Expressed As A Percentage Of Total Number of Runs of Eight
 Reference Tables C and E

CHART J.5
AVERAGE NUMBER OF RUNS OF EIGHT DUE TO BIAS IN CENTERLINE
UNEQUAL BIASES (Centerline Bias = 40%)
 Expressed As A Percentage of Total Number of Runs of Eight
 Reference Tables C and E

CHART J.6
AVERAGE NUMBER OF RUNS OF EIGHT DUE TO BIAS IN DATA
UNEQUAL BIASES (Centerline Bias Percentage = 40%)
 Expressed As A Percentage of Total Number of Runs of Eight
 Reference Tables C and E

TABLE K

**Average Number of Runs of Eight Per 1,000 Charts
Unequal Bias Percentages**

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	ID	45/05	45/10	45/15	45/20	45/25	45/30	45/35	45/40	45/45	45/50	45/55	45/60
2	A-45	224	224	221	221	226	221	222	224	227	223	222	224
3	B-45	269	270	267	267	271	268	269	269	275	270	268	271
4	C-45	232	256	303	364	448	550	667	802	950	1,112	1,266	1,426
5	D-45	961	942	951	948	953	961	941	950	946	941	947	948
6	E-45	281	301	354	408	501	598	713	851	997	1,158	1,316	1,469
7	F-45	1010	984	997	990	999	1,004	987	993	993	988	992	994
8	G-45	952	981	1025	1,082	1,158	1,251	1,324	1,458	1,566	1,698	1,826	1,981
9	H-45	998	1027	1068	1,123	1,200	1,298	1,369	1,498	1,609	1,741	1,860	2,018
10													
11	ID	45/05	45/10	45/15	45/20	45/25	45/30	45/35	45/40	45/45	45/50	45/55	45/60
12	B-A (45)	45	46	46	46	45	47	47	45	48	47	46	47
13	E-C (45)	49	45	51	44	53	48	46	49	47	46	50	43
14	F-D (45)	49	42	46	42	46	43	46	43	47	47	45	46
15	H-G (45)	46	46	43	41	42	47	45	40	43	43	34	37
16	AVG (45)	47.3	44.8	46.5	43.3	46.5	46.3	46.0	44.3	46.3	45.8	43.8	43.3
17													
18	A	224	224	221	221	226	221	222	224	227	223	222	224
19													
20	ID	45/05	45/10	45/15	45/20	45/25	45/30	45/35	45/40	45/45	45/50	45/55	45/60
21	F-B HIGH (45)	741	714	730	723	728	736	718	724	718	718	724	723
22	H-E LOW (45)	717	726	714	715	699	700	656	647	612	583	544	549
23	D-A HIGH (45)	737	718	730	727	727	740	719	726	719	718	725	724
24	G-C LOW (45)	720	725	722	718	710	701	657	656	616	586	560	555
25	AVG CENTERLINE (45)	728.8	720.8	724.0	720.8	716.0	719.3	687.5	688.3	666.3	651.3	638.3	637.8
26													
27	H-F LOW (45)	-12	43	71	133	201	294	382	505	616	753	868	1,024
28	E-B HIGH (45)	12	31	87	141	230	330	444	582	722	888	1,048	1,198
29	G-D LOW (45)	-9	39	74	134	205	290	383	508	620	757	879	1,033
30	C-A HIGH (45)	8	32	82	143	222	329	445	578	723	889	1,044	1,202
31	AVG DATA (45)	-0.3	36.3	78.5	137.8	214.5	310.8	413.5	543.3	670.3	821.8	959.8	1,114.3
32													
33	HIGH AVG CENTERLINE	739.0	716.0	730.0	725.0	727.5	738.0	718.5	725.0	718.5	718.0	724.5	723.5
34	HIGH AVG DATA	10.0	31.5	84.5	142.0	226.0	329.5	444.5	580.0	722.5	888.5	1,046.0	1,200.0
35													
36	LOW AVG CENTERLINE	718.5	725.5	718.0	716.5	704.5	700.5	656.5	651.5	614.0	584.5	552.0	552.0
37	LOW AVG DATA	-10.5	41.0	72.5	133.5	203.0	292.0	382.5	506.5	618.0	755.0	873.5	1,028.5
38													
39	DIFF CENTERLINE	20.5	-9.5	12.0	8.5	23.0	37.5	62.0	73.5	104.5	133.5	172.5	171.5
40	DIFF DATA	20.5	-9.5	12.0	8.5	23.0	37.5	62.0	73.5	104.5	133.5	172.5	171.5
41													
42	SOURCE	45/05	45/10	45/15	45/20	45/25	45/30	45/35	45/40	45/45	45/50	45/55	45/60
43	Random B % of Total (45)	4.7	4.4	4.3	3.9	3.9	3.6	3.4	3.0	2.9	2.6	2.3	2.1
44	Random I % of Total (45)	22.4	21.8	20.7	19.7	18.8	17.0	16.2	14.9	14.1	12.8	11.9	11.1
45	Centerline % of Total (45)	71.9	70.7	67.1	63.8	58.6	54.0	48.0	43.4	38.1	33.6	29.6	27.3
46	Data % of Total (45)	-1.1	4.0	6.8	11.9	16.9	22.5	27.9	33.8	38.4	43.3	46.9	50.9
47	Interaction % of Total (45)	2.1	-0.9	1.1	0.8	1.9	2.9	4.5	4.9	6.5	7.7	9.3	8.5
48	TOTAL %	100	100	100	100	100	100	100	100	100	100	100	100
49													
50	TOTAL (Same as H above)	999.8	1,025.8	1,070.0	1,122.8	1,203.0	####	1,369.0	1,499.8	1,609.8	1,741.8	1,863.8	2,019.3
51													
52	AVERAGE AND LIMITS	45/05	45/10	45/15	45/20	45/25	45/30	45/35	45/40	45/45	45/50	45/55	45/60
53	% AVG CENTERLINE_45 (Line 53)	72.9	70.3	67.7	64.2	59.5	55.4	50.2	45.9	41.4	37.4	34.2	31.6
54	% MIN CENTERLINE_45 (Line 54)	71.9	69.8	67.1	63.8	58.6	54.0	48.0	43.4	38.1	33.6	29.6	27.3
55	% MAX CENTERLINE_45 (Line 55)	73.9	70.7	68.2	64.6	60.5	56.9	52.5	48.3	44.6	41.2	38.9	35.8
56													
57	AVERAGE AND LIMITS	45/05	45/10	45/15	45/20	45/25	45/30	45/35	45/40	45/45	45/50	45/55	45/60
58	% AVG DATA_45 (Line 58)	0.0	3.5	7.3	12.3	17.8	24.0	30.2	36.2	41.6	47.2	51.5	55.2
59	% MIN DATA_45 (Line 59)	-1.1	3.1	6.8	11.9	16.9	22.5	27.9	33.8	38.4	43.3	46.9	50.9
60	% MAX DATA_45 (Line 60)	1.0	4.0	7.9	12.6	18.8	25.4	32.5	38.7	44.9	51.0	56.1	59.4

TABLE K

**Average Number of Runs of Eight Per 1,000 Charts
Unequal Bias Percentages**

	N	O	P	Q	R	S	T	U	V	W
1	ID	45/70	45/80	45/90	45/95	45/99				
2	A-45	226	223	226	225	222				
3	B-45	273	269	271	272	267				
4	C-45	1,802	2,153	2,482	2,663	2,812				
5	D-45	942	936	954	947	960				
6	E-45	1,838	2,188	2,514	2,692	2,843				
7	F-45	984	986	996	986	1,004				
8	G-45	2,236	2,562	2,832	2,995	3,099				
9	H-45	2,270	2,590	2,866	3,027	3,121				
10										
11	ID	45/70	45/80	45/90	45/95	45/99				
12	B-A (45)	47	46	45	47	45				
13	E-C (45)	36	35	32	29	31				
14	F-D (45)	42	50	42	39	44				
15	H-G (45)	34	28	34	32	22				
16	AVG (45)	39.8	39.8	38.3	36.8	35.5				
17										
18	A	226	223	226	225	222				
19										
20	ID	45/70	45/80	45/90	45/95	45/99				
21	F-B HIGH (45)	711	717	725	714	737				
22	H-E LOW (45)	432	402	352	335	278				
23	D-A HIGH (45)	716	713	728	722	738				
24	G-C LOW (45)	434	409	350	332	287				
25	AVG CENTERLINE (45)	573.3	560.3	538.8	525.8	510.0				
26										
27	H-F LOW (45)	1,286	1,604	1,870	2,041	2,117				
28	E-B HIGH (45)	1,565	1,919	2,243	2,420	2,576				
29	G-D LOW (45)	1,294	1,626	1,878	2,048	2,139				
30	C-A HIGH (45)	1,576	1,930	2,256	2,438	2,590				
31	AVG DATA (45)	1,430.3	1,769.8	2,061.8	2,236.8	2,355.5				
32										
33	HIGH AVG CENTERLINE	713.5	715.0	726.5	718.0	737.5				
34	HIGH AVG DATA	1,570.5	1,924.5	2,249.5	2,429.0	2,583.0				
35										
36	LOW AVG CENTERLINE	433.0	405.5	351.0	333.5	282.5				
37	LOW AVG DATA	1,290.0	1,615.0	1,874.0	2,044.5	2,128.0				
38										
39	DIFF CENTERLINE	280.5	309.5	375.5	384.5	455.0				
40	DIFF DATA	280.5	309.5	375.5	384.5	455.0				
41										
42	SOURCE	45/70	45/80	45/90	45/95	45/99				
43	Random B % of Total (45)	1.8	1.5	1.3	1.2	1.1				
44	Random I % of Total (45)	10.0	8.6	7.9	7.4	7.1				
45	Centerline % of Total (45)	19.1	15.6	12.3	11.0	9.0				
46	Data % of Total (45)	56.8	62.3	65.4	67.6	68.1				
47	Interaction % of Total (45)	12.4	11.9	13.1	12.7	14.6				
48	TOTAL %	100	100	100	100	100				
49										
50	TOTAL (Same as H above)	2,269.3	2,592.8	2,864.8	3,024.3	3,123.0				
51										
52	AVERAGE AND LIMITS	45/70	45/80	45/90	45/95	45/99				
53	% AVG CENTERLINE_45 (Line 53)	25.3	21.6	18.8	17.4	16.3				
54	% MIN CENTERLINE_45 (Line 54)	19.1	15.6	12.3	11.0	9.0				
55	% MAX CENTERLINE_45 (Line 55)	31.4	27.6	25.4	23.7	23.6				
56										
57	AVERAGE AND LIMITS	45/70	45/80	45/90	45/95	45/99				
58	% AVG DATA_45 (Line 58)	63.0	68.3	72.0	74.0	75.4				
59	% MIN DATA_45 (Line 59)	56.8	62.3	65.4	67.6	68.1				
60	% MAX DATA_45 (Line 60)	69.2	74.2	78.5	80.3	82.7				

Table K.1

Condition H When Chart Bias (Length) is 75

Bias of the Centerline is Set to 45% of Data's Variation

The Bias of the Data's Mean Varies from 5% through 99% of Data's Variation

Paired Bias Levels	Average Number per 1,000 Charts		Average Percent of Total Number of Runs of Eight		Average Run Length	Average Number of Measurements Observed Before First Run of Eight
	Runs of Eight	Charts With at Least One Run of Eight	False Directional Notices	Charts With Both a High and Low Run of Eight		
45/05	1,000	535	38.7	0.70	10.7	32.3
45/10	1,035	544	36.1	0.70	10.8	32.0
45/15	1,067	549	33.3	0.70	10.9	31.6
45/20	1,134	566	30.4	0.69	11.0	31.1
45/25	1,188	572	27.6	0.66	11.2	30.7
45/30	1,285	588	24.4	0.59	11.4	30.2
45/35	1,378	602	22.4	0.62	11.7	29.6
45/40	1,500	622	20.4	0.58	11.9	28.7
45/45	1,600	635	18.6	0.53	12.2	28.4
45/50	1,733	653	16.5	0.53	12.6	27.6
45/55	1,885	672	15.6	0.50	12.9	26.9
45/60	2,009	683	14.2	0.52	13.3	26.0
45/70	2,292	713	12.1	0.45	14.0	24.9
45/80	2,588	734	10.2	0.38	14.9	23.6
45/90	2,890	756	9.0	0.34	15.9	22.5
45/95	3,021	767	8.5	0.35	16.3	22.0
45/99	3,103	769	8.2	0.33	16.6	21.7

CHART K.1
TOTAL NUMBER OF RUNS OF EIGHT UNDER ALL EIGHT EXPERIMENTAL CONDITIONS
UNEQUAL BIASES (Centerline Bias Percentage = 45%)
 Reference Tables C and E

CHART K.2
NUMBER OF RUNS OF EIGHT ELIMINATED WHEN DATA AVERAGE IS FORCED TO BE ZERO
UNEQUAL BIASES (Centerline Bias Percentage = 45%)
 Reference Tables C, D and E

CHART K.3
AVERAGE NUMBER OF RUNS OF EIGHT
DUE TO BIAS IN THE DATA AND BIAS IN THE CENTERLINE
UNEQUAL BIASES (Centerline Bias Percentage = 45%)
 Reference Tables C, D and E

CHART K.4
PARTITIONING TOTAL NUMBER OF RUNS OF EIGHT
UNEQUAL BIASES (Centerline Bias Percentage = 45%)
 Expressed As A Percentage Of Total Number of Runs of Eight
 Reference Tables C and E

CHART K.5
AVERAGE NUMBER OF RUNS OF EIGHT DUE TO BIAS IN CENTERLINE
UNEQUAL BIASES (Centerline Bias = 45%)
 Expressed As A Percentage of Total Number of Runs of Eight
 Reference Tables C and E

CHART K.6
AVERAGE NUMBER OF RUNS OF EIGHT DUE TO BIAS IN DATA
UNEQUAL BIASES (Centerline Bias Percentage = 45%)
Expressed As A Percentage of Total Number of Runs of Eight
Reference Tables C and E