METHOD FOR CALCULATION OF PER CENT WITHIN LIMITS

1.   SCOPE

1.1   This method describes the procedure to be used for calculation of Per cent Within Limits**.**

2.   RELEVANT DOCUMENTS

2.1   MTO Test Methods LS-100

3.   DEFINITIONS

3.1   Per cent Within Limits (PWL) is an estimate of the percentage of the population (lot) that is within specification limits, determined by using the mean and standard deviation of the lot.

3.2   Mean ($\overline{X}$) is the arithmetic average of a set of test results.

3.3   Lot Standard Deviation (s) is the square root of the value found by summing the squares of the difference between each test result and the mean of the test results divided by the number of test results minus one (n-1).

3.4   Quality Index (Q_i) is a statistic which, when used with appropriate tables, provides an estimate of PWL of a lot. It can be based on an Upper or Lower Specification Limit, yielding Q_U or Q_L respectively.

4.   GENERAL

4.1   All test results for a lot will be combined to calculate the Mean and Standard Deviation of the lot which will then be used to determine the Per cent Within Limits (PWL), according to the procedures in Section 5.

4.2   Any necessary rounding-off of test results or calculations will be in accordance with LS-100.

4.3   The lot mean will be reported to one decimal place. The Lot Standard Deviation, Lower Quality Index, and Upper Quality Index will be reported to two decimal places.

5.   CALCULATIONS

5.1   The Quality Index, Q_i, for the lower and upper specification limits shall be as determined from the following formulae:

$$Q_L = \frac{\overline{X} - LL}{s} \qquad\qquad Q_U = \frac{UL - \overline{X}}{s}$$

where: Q_L = Lower Quality Index Value
               Q_U = Upper Quality Index Value
               LL = Lower Specification Limit
               UL = Upper Specification Limit

5.2 PWL shall be determined from the following formula: PWL = $(P_L + P_U)$ - 100

where: PWL = Per cent Within Limits
P_L = Per cent Within Lower Limit
P_U = Per cent Within Upper Limit

P_L and P_U are each determined from Table 1 based on Q_L and Q_U and the number of test results (n).

Where a lower limit is not specified, P_L will be 100. Where an upper limit is 100% or is not specified, P_U will be 100.

5.3 Notes for Table 1:

1. Enter the table using the number of test results and Q value.

2. If the value of Q_L or Q_U does not correspond exactly to a value in Table 1, use the next highest value of Q_L or Q_U from the table. The maximum P_L or P_U is 100.

3. Move across the table horizontally from the appropriate Q value to get P_L or P_U.

4. For negative values of Q_L or Q_U, enter the table using the absolute value of Q. P_L or P_U is equal to 100 minus the value from Table 1 for P_L or P_U.

6. EXAMPLES

6.1 Mean $(\overline{X})$ = 35.4 Lower Specification Limit (LL) = 30
Standard Deviation (s) = 3.22 Number of Test Results (n) = 42

$$Q_L = \frac{\overline{X} - LL}{s} = \frac{35.4 - 30}{3.22}$$

Q_L = 1.68

Look in Table 1 under n = 42 (see column n = 38 to n = 69).

As Q_L = 1.68 does not correspond exactly to a value in the table, use the next highest value in the column, 1.73.

Look across the table to the corresponding value of P_L = 96.

P_U = 100 (no upper limit is specified).

PWL = $(P_L + P_U)$ - 100
= (96 + 100) - 100
= 96

6.2   Mean ($\overline{X}$) = 95.3 Lower Specification Limit (LL) = 91.5
       Standard Deviation (s) = 2.87 Upper Specification Limit (UL) = 97.0
       Number of Test Results (n) = 12

$$Q_L = \frac{\overline{X} - LL}{s} = \frac{95.3 - 91.5}{2.87} \qquad Q_U = \frac{UL - \overline{X}}{s} = \frac{97.0 - 95.3}{2.87}$$

   Q_L = 1.32 Q_U = 0.59

   From Table 1 P_L = 91
                 P_U = 72

   PWL = (P_L + P_U) - 100
        = (91 + 72) - 100
        = 63

6.3   Mean ($\overline{X}$) = 222.4 Upper Specification Limit (UL) = 220
       Standard Deviation (s) = 8.72 Number of Test Results (n) = 61

$$Q_U = \frac{UL - \overline{X}}{s} = \frac{220 - 222.4}{8.72}$$

   Q_U = -0.28

   From Table 1, a Q_i of 0.28 gives a P_i of 61, however, as Q_U is negative.

      P_U = 100 - 61
          = 39

   P_L = 100 (no lower limit is specified)

   PWL = (P_L + P_U) - 100
        = (100 + 39) - 100
        = 39

TABLE 1: Values for P_L and P_U for a Given Quality Index and Number of Tests
(see notes Section 5.3)

P_L or P_U	Quality Index $(Q_L$ or $Q_U)$														
	n=3	n=4	n=5	n=6	n=7	n=8	n=9	n=10 to n=11	n=12 to n=14	n=15 to n=18	n=19 to n=25	n=26 to n=37	n=38 to n=69	n=70 to n=200	n>200
100	1.16	1.50	1.79	2.03	2.23	2.39	2.53	2.65	2.83	3.03	3.20	3.38	3.54	3.70	3.83
99	1.16	1.47	1.67	1.80	1.89	1.95	2.00	2.04	2.09	2.14	2.18	2.22	2.26	2.29	2.31
98	1.15	1.44	1.60	1.70	1.76	1.81	1.84	1.86	1.91	1.93	1.96	1.99	2.01	2.03	2.05
97	1.15	1.41	1.54	1.62	1.67	1.70	1.72	1.74	1.77	1.79	1.81	1.83	1.85	1.86	1.87
96	1.14	1.38	1.49	1.55	1.59	1.61	1.63	1.65	1.67	1.68	1.70	1.71	1.73	1.74	1.75
95	1.14	1.35	1.44	1.49	1.52	1.54	1.55	1.56	1.58	1.59	1.61	1.62	1.63	1.63	1.64
94	1.13	1.32	1.39	1.43	1.46	1.47	1.48	1.49	1.50	1.51	1.52	1.53	1.54	1.55	1.55
93	1.13	1.29	1.35	1.38	1.40	1.41	1.42	1.43	1.44	1.44	1.45	1.46	1.46	1.47	1.47
92	1.12	1.26	1.31	1.33	1.35	1.36	1.36	1.37	1.37	1.38	1.39	1.39	1.40	1.40	1.40
91	1.11	1.23	1.27	1.29	1.30	1.30	1.31	1.31	1.32	1.32	1.33	1.33	1.33	1.34	1.34
90	1.10	1.20	1.23	1.24	1.25	1.25	1.26	1.26	1.26	1.27	1.27	1.27	1.28	1.28	1.28
89	1.09	1.17	1.19	1.20	1.20	1.21	1.21	1.21	1.21	1.22	1.22	1.22	1.22	1.22	1.23
88	1.07	1.14	1.15	1.16	1.16	1.16	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17
87	1.06	1.11	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.13
86	1.04	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08
85	1.03	1.05	1.05	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
84	1.01	1.02	1.01	1.01	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99
83	1.00	0.99	0.98	0.97	0.97	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.95	0.95	0.95
82	0.97	0.96	0.95	0.94	0.93	0.93	0.93	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
81	0.96	0.93	0.91	0.90	0.89	0.89	0.89	0.89	0.89	0.88	0.88	0.88	0.88	0.88	0.88
80	0.93	0.90	0.88	0.87	0.86	0.86	0.86	0.85	0.85	0.85	0.85	0.84	0.84	0.84	0.84
79	0.91	0.87	0.85	0.84	0.83	0.82	0.82	0.82	0.82	0.81	0.81	0.81	0.81	0.81	0.81
78	0.89	0.84	0.82	0.80	0.80	0.79	0.79	0.79	0.78	0.78	0.78	0.78	0.77	0.77	0.77
77	0.87	0.81	0.78	0.77	0.76	0.76	0.76	0.75	0.75	0.75	0.75	0.74	0.74	0.74	0.74
76	0.84	0.78	0.75	0.74	0.73	0.73	0.72	0.72	0.72	0.71	0.71	0.71	0.71	0.71	0.71
75	0.82	0.75	0.72	0.71	0.70	0.70	0.69	0.69	0.69	0.68	0.68	0.68	0.68	0.68	0.67
74	0.79	0.72	0.69	0.68	0.67	0.66	0.66	0.66	0.66	0.65	0.65	0.65	0.65	0.64	0.64
73	0.76	0.69	0.66	0.65	0.64	0.63	0.63	0.63	0.62	0.62	0.62	0.62	0.62	0.61	0.61
72	0.74	0.66	0.63	0.62	0.61	0.60	0.60	0.60	0.59	0.59	0.59	0.59	0.59	0.58	0.58
71	0.71	0.63	0.60	0.59	0.58	0.57	0.57	0.57	0.57	0.56	0.56	0.56	0.56	0.55	0.55
70	0.68	0.60	0.57	0.56	0.55	0.55	0.54	0.54	0.54	0.53	0.53	0.53	0.53	0.53	0.52
69	0.65	0.57	0.54	0.53	0.52	0.52	0.51	0.51	0.51	0.50	0.50	0.50	0.50	0.50	0.50
68	0.62	0.54	0.51	0.50	0.49	0.49	0.48	0.48	0.48	0.48	0.47	0.47	0.47	0.47	0.47
67	0.59	0.51	0.47	0.47	0.46	0.46	0.46	0.45	0.45	0.45	0.45	0.44	0.44	0.44	0.44
66	0.56	0.48	0.45	0.44	0.44	0.43	0.43	0.43	0.42	0.42	0.42	0.42	0.41	0.41	0.41
65	0.52	0.45	0.43	0.41	0.41	0.40	0.40	0.40	0.40	0.39	0.39	0.39	0.39	0.39	0.39
64	0.49	0.42	0.40	0.39	0.38	0.38	0.37	0.37	0.37	0.37	0.36	0.36	0.36	0.36	0.36
63	0.46	0.39	0.37	0.36	0.35	0.35	0.35	0.34	0.34	0.34	0.34	0.34	0.33	0.33	0.33
62	0.43	0.36	0.34	0.33	0.32	0.32	0.32	0.32	0.31	0.31	0.31	0.31	0.31	0.31	0.31
61	0.39	0.33	0.31	0.30	0.30	0.29	0.29	0.29	0.29	0.29	0.28	0.28	0.28	0.28	0.28
60	0.36	0.30	0.28	0.27	0.27	0.27	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.25	0.25
59	0.32	0.27	0.25	0.25	0.24	0.24	0.24	0.24	0.23	0.23	0.23	0.23	0.23	0.23	0.23
58	0.29	0.24	0.23	0.22	0.21	0.21	0.21	0.21	0.21	0.21	0.20	0.20	0.20	0.20	0.20

TABLE 1: Values for P_L and P_U for a Given Quality Index and Number of Tests
(cont'd.)

57	0.25	0.21	0.20	0.19	0.19	0.19	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
56	0.22	0.18	0.17	0.16	0.16	0.16	0.16	0.16	0.16	0.15	0.15	0.15	0.15	0.15	0.15
55	0.18	0.15	0.14	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
54	0.14	0.12	0.11	0.11	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
53	0.11	0.09	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
52	0.07	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
51	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02
50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0