Reg. No.										

MANIPAL INSTITUTE OF TECHNOLOGY
MANIPAL
(A constituent unit of MAHE, Manipal)

V SEMESTER B. TECH (INDUSTRIAL AND PRODUCTION ENGINEERING)

END SEMESTER ONLINE EXAMINATIONS, JANUARY- FEBRUARY 2021

SUBJECT: TOTAL QUALITY MANAGEMENT [MME 3158]

REVISED CREDIT SYSTEM

Time: 3 Hours MAX. MARKS: 50

Instructions to Candidates:

- Answer **ALL** the questions.
- Missing data may be suitably assumed.
- Use of SQC tables permitted.

1A. Describe the customer perception of quality. **2**

1B. Briefly explain the twelve characteristics of successful quality leaders. **3**

1C. The following table is a record of measurements made of a certain quality characteristic on certain component. Calculate the average, variance and median of this characteristic value.

Characteristic value (mm)	Number of components
5.9 - 6.1	2
5.7 - 5.9	5
5.5 - 5.7	10
5.3 - 5.5	14
5.1 - 5.3	21
4.9 - 5.1	25
4.7 - 4.9	17
4.5 - 4.7	13
4.3 - 4.5	8
4.1 - 4.3	4
3.9 - 4.1	2

5

2A. Discuss briefly the contributions made by the following towards Total Quality Management:

(i) Joseph M. Juran (ii) W. Edwards Deming (iii) Kaoru Ishikawa
(iv) Walter A. Shewhart **2**

2B. Explain the classification of Quality costs. **3**

2C. A Double sampling plan is as follows:

$$N = 5000,\ n_1 = 100,\ c_1 = 2,\ n_2 = 100,\ c_2 = 4$$

(i) Use Poisson distribution table to compute the Probability of acceptance of a 2% nonconforming lot.

(ii) Calculate the value of Average fraction inspected if the submitted product is 2% nonconforming. **5**

3A. Write a note on Internal audits with regard to the implementation of Quality management systems. **2**

3B. Describe the control charts used for controlling the process dispersion. **3**

3C. A process has been operating in control at a μ of 65.00 mm and a σ of 0.15 mm with upper and lower control limits on the $\overline{X}$ chart as 65.225 mm and 64.775 mm respectively. Specifications on the dimension are 65 $\pm$ 0.50 mm.

(i) What is the probability of detecting a shift in the mean to 64.75 mm on the first subgroup sampled after the shift occurs? The subgroup size is 4.

(ii) What proportion of nonconforming product results from the shift described in part (i)? Assume a normal distribution of this dimension. Also compute C_p for the process.

(iii) Calculate the Natural tolerance limits and C_{pk} for this process considering the shift in the mean described in part (i). **5**

4A. Briefly explain the steps involved in Benchmarking process. **3**

4B. Explain: (i) MTBF (ii) LTPD (iii) AQL **3**

4C. An item is required to have a failure rate no greater than 0.1% per 1000 hours of operation. Assuming a constant failure rate, what is the probability that one of these units will survive for a required period of service of 10000, 2000 and 480 hours? Also compute the Mean life for this item. **4**

5A. Explain Conventional tolerancing and Statistical tolerancing with an example. **3**

5B. With a sketch explain the Process decision program chart. **3**

5C. A c chart is used to control the soldering imperfections of a certain mass produced circuit board. After 30 circuit boards have been inspected, a total of 66 bad solder joints was found.

(i) Calculate 3-sigma control limits and the central line for the c chart.

(ii) Find the probability of Type I error.

(iii) If the process suddenly shifts to a μ_c of 4.5, find the probability of not detecting this shift. **4**

TABLE ***A*** AREA UNDER THE NORMAL CURVE

Proportion of the total area of the standard normal curve from – ∞ to *z* (*z* represents a normalized statistic)

z	0.09	0.08	0.07	0.06	0.05	0.04	0.03	0.02	0.01	0.00
– 3.5	0.00017	0.00017	0.00018	0.00019	0.00019	0.00020	0.00021	0.00022	0.00022	0.00023
– 3.4	0.00024	0.00025	0.00026	0.00027	0.00028	0.00029	0.00030	0.00031	0.00033	0.00034
– 3.3	0.00035	0.00036	0.00038	0.00039	0.00040	0.00042	0.00043	0.00045	0.00047	0.00048
– 3.2	0.00050	0.00052	0.00054	0.00056	0.00058	0.00060	0.00062	0.00064	0.00066	0.00069
– 3.1	0.00071	0.00074	0.00076	0.00079	0.00082	0.00085	0.00087	0.00090	0.00094	0.00097
– 3.0	0.00100	0.00104	0.00107	0.00111	0.00114	0.00118	0.00122	0.00126	0.00131	0.00135
– 2.9	0.0014	0.0014	0.0015	0.0015	0.0016	0.0016	0.0017	0.0017	0.0018	0.0019
– 2.8	0.0019	0.0020	0.0021	0.0021	0.0022	0.0023	0.0023	0.0024	0.0025	0.0026
– 2.7	0.0026	0.0027	0.0028	0.0029	0.0030	0.0031	0.0032	0.0033	0.0034	0.0035
– 2.6	0.0036	0.0037	0.0038	0.0039	0.0040	0.0041	0.0043	0.0044	0.0045	0.0047
– 2.5	0.0048	0.0049	0.0051	0.0052	0.0054	0.0055	0.0057	0.0059	0.0060	0.0062
– 2.4	0.0064	0.0066	0.0068	0.0069	0.0071	0.0073	0.0075	0.0078	0.0080	0.0082
– 2.3	0.0084	0.0087	0.0089	0.0091	0.0094	0.0096	0.0099	0.0102	0.0104	0.0107
– 2.2	0.0110	0.0113	0.0116	0.0119	0.0122	0.0125	0.0129	0.0132	0.0136	0.0139
– 2.1	0.0143	0.0146	0.0150	0.0154	0.0158	0.0162	0.0166	0.0170	0.0174	0.0179
– 2.0	0.0183	0.0188	0.0192	0.0197	0.0202	0.0207	0.0212	0.0217	0.0222	0.0228
– 1.9	0.0233	0.0239	0.0244	0.0250	0.0256	0.0262	0.0268	0.0274	0.0281	0.0287
– 1.8	0.0294	0.0301	0.0307	0.0314	0.0322	0.0329	0.0336	0.0344	0.0351	0.0359
– 1.7	0.0367	0.0375	0.0384	0.0392	0.0401	0.0409	0.0418	0.0427	0.0436	0.0446
– 1.6	0.0455	0.0465	0.0475	0.0485	0.0495	0.0505	0.0516	0.0526	0.0537	0.0548
– 1.5	0.0559	0.0571	0.0582	0.0594	0.0606	0.0618	0.0630	0.0643	0.0655	0.0668
– 1.4	0.0681	0.0694	0.0708	0.0721	0.0735	0.0749	0.0764	0.0778	0.0793	0.0808
– 1.3	0.0823	0.0838	0.0853	0.0869	0.0885	0.0901	0.0918	0.0934	0.0951	0.0968
– 1.2	0.0985	0.1003	0.1020	0.1038	0.1057	0.1075	0.1093	0.1112	0.1131	0.1151
– 1.1	0.1170	0.1190	0.1210	0.1230	0.1251	0.1271	0.1292	0.\1314	0.1335	0.1357
– 1.0	0.1379	0.1401	0.1423	0.1446	0.1469	0.1492	0.1515	0.1539	0.1562	0.1587
– 0.9	0.1611	0.1635	0.1660	0.1685	0.1711	0.1736	0.1762	0.1788	0.1814	0.1841
– 0.8	0.1867	0.1894	0.1922	0.1949	0.1977	0.2005	0.2033	0.2061	0.2090	0.2119
– 0.7	0.2148	0.2177	0.2207	0.2236	0.2266	0.2297	0.2327	0.2358.	0.2389	0.2420
– 0.6	0.2451	0.2483	0.2514	0.2546	0.2578	0.2611	0.2643	0.2676	0.2709	0.2743
– 0.5	0.2776	0.2810	0.2843	0.2877	0.2912	0.2946	0.2981	0.3015	0.3050	0.3085
– 0.4	0.3121	0.3156	0.3192	0.3228	0.3264	0.3300	0.3336	0.3372	0.3409	0.3446
– 0.3	0.3483	0.3520	0.3557	0.3594	0.3632	0.3669	0.3707	0.3745	0.3783	0.3821
– 0.2	0.3859	0.3897	0.3936	0.3974	0.4013	0.4052	0.4090	0.4129	0.4168	0.4207
– 0.1	0.4247	0.4286	0.4325	0.4364	0.4404	0.4443	0.4483	0.4522	0.4562	0.4602
– 0.0	0.4641	0.4681	0.4721	0.4761	0.4801	0.4840	0.4880	0.4920	0.4960	0.5000

TABLE ***A*** *(continued)*

z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
+ 0.0	0.5000	0.5040	0.5080	0.5120	0.5160	0.5199	0.5239	0.5279	0.5319	0.5359
+ 0.1	0.5398	0.5438	0.5478	0.5517	0.5557	0.5596	0.5636	0.5675	0.5714	0.5753
+ 0.2	0.5793	0.5832	0.5871	0.5910	0.5948	0.5987	0.6026	0.6064	0.6103	0.6141
+ 0.3	0.6179	0.6217	0.6255	0.6293	0.6331	0.6368	0.6406	0.6443	0.6480	0.6517
+ 0.4	0.6554	0.6591	0.6628	0.6664	0.6700	0.6736	0.6772	0.6808	0.6844	0.6879
+ 0.5	0.6915	0.6950	0.6985	0.7019	0.7054	0.7088	0.7123	0.7157	0.7190	0.7224
+ 0.6	0.7257	0.7291	0.7324	0.7357	0.7389	0.7422	0.7454	0.7486	0.7517	0.7549
+ 0.7	0.7580	0.7611	0.7642	0.7673	0.7704	0.7734	0.7764	0.7794	0.7823	0.7852
+ 0.8	0.1881	0.7910	0.7939	0.7967	0.7995	0.8023	0.8051	0.8079	0.8106	0.8133
+ 0.9	0.8159	0.8186	0.8212	0.8238	0.8264	0.8289	0.8315	0.8340	0.8365	0.8389
+ 1.0	0.8413	0.8438	0.8461	0.8485	0.8508	0.8531	0.8554	0.8577	0.8599	0.8621
+ 1.1	0.8643	0.8665	0.8686	0.8708	0.8729	0.8749	0.8770	0.8790	0.8810	0.8830
+ 1.2	0.8849	0.8869	0.8888	0.8907	0.8925	0.8944	0.8962	0.8980	0.8997	0.9015
+ 1.3	0.9032	0.9049	0.9066	0.9082	0.9099	0.9115	0.9131	0.9147	0.9162	0.9177
+ 1.4	0.9192	0.9207	0.9222	0.9236	0.9251	0.9265	0.9279	0.9292	0.9306	0.9319
+ 1.5	0.9332	0.9345	0.9357	0.9370	0.9382	0.9394	0.9406	0.9418	0.9429	0.9441
+ 1.6	0.9452	0.9463	0.9474	0.9484	0.9495	0.9505	0.9515	0.9525	0.9535	0.9545
+ 1.7	0.9554	0.9564	0.9573	0.9582	0.9591	0.9599	0.9608	0.9616	0.9625	0.9633
+ 1.8	0.9641	0.9649	0.9656	0.9664	0.9671	0.9678	0.9686	0.9693	0.9699	0.9706
+ 1.9	0.9713	0.9719	0.9726	0.9732	0.9738	0.9744	0.9750	0.9756	0.9761	0.9767
+ 2.0	0.9773	0.9778	0.9783	0.9788	0.9793	0.9798	0.9803	0.9808	0.9812	0.9817
+ 2.1	0.9821	0.9826	0.9830	0.9834	0.9838	0.9842	0.9846	0.9850	0.9854	0.9857
+ 2.2	0.9861	0.9864	0.9868	0.9871	0.9875	0.9878	0.9881	0.9884	0.9887	0.9890
+ 2.3	0.9893	0.9896	0.9898	0.9901	0.9904	0.9906	0.9909	0.9911	0.9913	0.9916
+ 2.4	0.9918	0.9920	0.9922	0.9925	0.9927	0.9929	0.9931	0.9932	0.9934	0.9936
+ 2.5	0.9938	0.9940	0.9941	0.9943	0.9945	0.9946	0.9948	0.9949	0.9951	0.9952
+ 2.6	0.9953	0.9955	0.9956	0.9957	0.9959	0.9960	0.9961	0.9962	0.9963	0.9964
+ 2.7	0.9965	0.9966	0.9967	0.9968	0.9969	0.9970	0.9971	0.9972	0.9973	0.9974
+ 2.8	0.9974	0.9975	0.9976	0.9977	0.9977	0.9978	0.9979	0.9979	0.9980	0.9981
+ 2.9	0.9981	0.9982	0.9983	0.9983	0.9984	0.9984	0.9985	0.9985	0.9986	0.9986
+ 3.0	0.99865	0.99869	0.99874	0.99878	0.99882	0.99886	0.99889	0.99893	0.99896	0.99900
+ 3.1	0.99903	0.99906	0.99910	0.99913	0.99915	0.99918	0.99921	0.99924	0.99926	0.99929
+ 3.2	0.99931	0.99934	0.99936	0.99938	0.99940	0.99942	0.99944	0.99946	0.99948	0.99950
+ 3.3	0.99952	0.99953	0.99955	0.99957	0.99958	0.99960	0.99961	0.99962	0.99964	0.99965
+ 3.4	0.99966	0.99967	0.99969	0.99970	0.99971	0.99972	0.99973	0.99974	0.99975	0.99976
+ 3.5	0.99977	0.99978	0.99978	0.99979	0.99980	0.99981	0.99981	0.99982	0.99983	0.99983

TABLE *B* RIGHT TAIL AREA OF THE χ^2 DISTRIBUTION

ν	γ										
	0.995	**0.990**	**0.975**	**0.950**	**0.900**	**0.500**	**0.100**	**0.050**	**0.025**	**0.010**	**0.005**
1	**0.00**	**0.00**	**0.00**	**0.00**	**0.02**	**0.45**	**2.71**	**3.84**	**5.02**	**6.63**	**7.88**
2	**0.01**	**0.02**	**0.05**	**0.10**	**0.21**	**1.39**	**4.61**	**5.99**	**7.38**	**9.21**	**10.60**
3	**0.07**	**0.11**	**0.22**	**0.35**	**0.58**	**2.37**	**6.25**	**7.81**	**9.35**	**11.34**	**12.84**
4	**0.21**	**0.30**	**0.48**	**0.71**	**1.06**	**3.36**	**7.78**	**9.49**	**11.14**	**13.28**	**14.86**
5	**0.41**	**0.55**	**0.83**	**1.15**	**1.61**	**4.35**	**9.24**	**11.07**	**12.83**	**15.09**	**16.75**
6	**0.68**	**0.87**	**1.24**	**1.64**	**2.20**	**5.35**	**10.65**	**12.59**	**14.45**	**16.81**	**18.55**
7	**0.99**	**1.24**	**1.69**	**2.17**	**2.83**	**6.35**	**12.02**	**14.07**	**16.01**	**18.48**	**20.28**
8	**1.34**	**1.65**	**2.18**	**2.73**	**3.49**	**7.34**	**13.36**	**15.51**	**17.53**	**20.09**	**21.96**
9	**1.73**	**2.09**	**2.70**	**3.33**	**4.17**	**8.34**	**14.68**	**16.92**	**19.02**	**21.67**	**23.59**
10	**2.16**	**2.56**	**3.25**	**3.94**	**4.87**	**9.34**	**15.99**	**18.31**	**20.48**	**23.21**	**25.19**
11	**2.60**	**3.05**	**3.82**	**4.57**	**5.58**	**10.34**	**17.28**	**19.68**	**21.92**	**24.72**	**26.76**
12	**3.07**	**3.57**	**4.40**	**5.23**	**6.30**	**11.34**	**18.55**	**21.03**	**23.34**	**26.22**	**28.30**
13	**3.57**	**4.11**	**5.01**	**5.89**	**7.04**	**12.34**	**19.81**	**22.36**	**24.74**	**27.69**	**29.82**
14	**4.07**	**4.66**	**5.63**	**6.57**	**7.79**	**13.34**	**21.06**	**23.68**	**26.12**	**29.14**	**31.32**
15	**4.60**	**5.23**	**6.26**	**7.26**	**8.55**	**14.34**	**22.31**	**25.00**	**27.49**	**30.58**	**32.80**
16	**5.14**	**5.81**	**6.91**	**7.96**	**9.31**	**15.34**	**23.54**	**26.30**	**28.85**	**32.00**	**34.27**
17	**5.70**	**6.41**	**7.56**	**8.67**	**10.09**	**16.34**	**24.77**	**27.59**	**30.19**	**33.41**	**35.72**
18	**6.26**	**7.01**	**8.23**	**9.39**	**10.87**	**17.34**	**25.99**	**28.87**	**31.53**	**34.81**	**37.16**
19	**6.84**	**7.63**	**8.91**	**10.12**	**11.65**	**18.34**	**27.20**	**30.14**	**32.85**	**36.19**	**38.58**
20	**7.43**	**8.26**	**9.59**	**10.85**	**12.44**	**19.34**	**28.41**	**31.41**	**34.17**	**37.57**	**40.00**
21	**8.03**	**8.90**	**10.28**	**11.59**	**13.24**	**20.34**	**29.62**	**32.67**	**35.48**	**38.93**	**41.40**
22	**8.64**	**9.54**	**10.98**	**12.34**	**14.04**	**21.34**	**30.81**	**33.92**	**36.78**	**40.29**	**42.80**
23	**9.26**	**10.20**	**11.69**	**13.09**	**14.85**	**22.34**	**32.01**	**35.17**	**38.08**	**41.64**	**44.18**
24	**9.89**	**10.86**	**12.40**	**13.85**	**15.66**	**23.34**	**33.20**	**36.42**	**39.36**	**42.98**	**45.56**
25	**10.52**	**11.52**	**13.12**	**14.61**	**16.47**	**24.34**	**34.38**	**37.65**	**40.65**	**44.31**	**46.93**
26	**11.16**	**12.20**	**13.84**	**15.38**	**17.29**	**25.34**	**35.56**	**38.89**	**41.92**	**45.64**	**48.29**
27	**11.81**	**12.88**	**14.57**	**16.15**	**18.11**	**26.34**	**36.74**	**40.11**	**43.19**	**46.96**	**49.65**
28	**12.46**	**13.57**	**15.31**	**16.93**	**18.94**	**27.34**	**37.92**	**41.34**	**44.46**	**48.28**	**50.99**
29	**13.12**	**14.26**	**16.05**	**17.71**	**19.77**	**28.34**	**39.09**	**42.56**	**45.72**	**49.59**	**52.34**
30	**13.79**	**14.95**	**16.79**	**18.49**	**20.60**	**29.34**	**40.26**	**43.77**	**46.98**	**50.89**	**53.67**
40	**20.71**	**22.16**	**24.43**	**26.51**	**29.05**	**39.34**	**51.80**	**55.76**	**59.34**	**63.69**	**66.77**
50	**27.99**	**29.71**	**32.36**	**34.76**	**37.69**	**49.33**	**63.17**	**67.50**	**71.42**	**76.15**	**79.49**
70	**43.28**	**45.44**	**48.76**	**51.74**	**55.33**	**69.33**	**85.53**	**90.53**	**95.02**	**100.42**	**104.22**
100	**67.33**	**70.06**	**74.22**	**77.93**	**82.36**	**99.33**	**118.50**	**124.34**	**129.56**	**135.81**	**140.17**

TABLE *C* FACTORS FOR ESTIMATING σ FROM $\overline{R}$, $\overline{s}$, OR $\overline{\sigma}_{RMS}$ AND σ_R FROM $\overline{R}$

Number of observations in subgroup, *n*	Factor d_2, $d_2 = \frac{\overline{R}}{\sigma}$	Factor d_3, $d_3 = \frac{\sigma_R}{\sigma}$	Factor c_2, $c_2 = \frac{\overline{\sigma}_{RMS}}{\sigma}$	Factor c_4, $c_4 = \frac{\overline{s}}{\sigma}$
2	1.128	0.8525	0.5642	0.7979
3	1.693	0.8884	0.7236	0.8862
4	2.059	0.8798	0.7979	0.9213
5	2.326	0.8641	0.8407	0.9400
6	2.534	0.8480	0.8686	0.9515
7	2.704	0.8332	0.8882	0.9594
8	2.847	0.8198	0.9027	0.9650
9	2.970	0.8078	0.9139	0.9693
10	3.078	0.7971	0.9227	0.9727
11	3.173	0.7873	0.9300	0.9754
12	3.258	0.7785	0.9359	0.9776
13	3.336	0.7704	0.9410	0.9794
14	3.407	0.7630	0.9453	0.9810
15	3.472	0.7562	0.9490	0.9823
16	3.532	0.7499	0.9523	0.9835
17	3.588	0.7441	0.9551	0.9845
18	3.640	0.7386	0.9576	0.9854
19	3.689	0.7335	0.9599	0.9862
20	3.735	0.7287	0.9619	0.9869
21	3.778	0.7242	0.9638	0.9876
22	3.819	0.7199	0.9655	0.9882
23	3.858	0.7159	0.9670	0.9887
24	3.895	0.7121	0.9684	0.9892
25	3.931	0.7084	0.9696	0.9896
30	4.086	0.6926	0.9748	0.9914
35	4.213	0.6799	0.9784	0.9927
40	4.322	0.6692	0.9811	0.9936
45	4.415	0.6601	0.9832	0.9943
50	4.498	0.6521	0.9849	0.9949
55	4.572	0.6452	0.9863	0.9954
60	4.639	0.6389	0.9874	0.9958
65	4.699	0.6337	0.9884	0.9961
70	4.755	0.6283	0.9892	0.9964
75	4.806	0.6236	0.9900	0.9966
80	4.854	0.6194	0.9906	0.9968
85	4.898	0.6154	0.9912	0.9970
90	4.939	0.6118	0.9916	0.9972
95	4.978	0.6084	0.9921	0.9973
100	5.015	0.6052	0.9925	0.9975

TABLE *D* FACTORS FOR DETERMINING FROM $\overline{R}$ THE 3-SIGMA CONTROL LIMITS FOR $\overline{X}$ AND R CHARTS

Number of observations in subgroup, *n*	Factor for $\overline{X}$ chart, A_2	Factors for *R* chart	
		Lower control limit D_3	Upper control limit D_4
2	1.88	0	3.27
3	1.02	0	2.57
4	0.73	0	2.28
5	0.58	0	2.11
6	0.48	0	2.00
7	0.42	0.08	1.92
8	0.37	0.14	1.86
9	0.34	0.18	1.82
10	0.31	0.22	1.78
11	0.29	0.26	1.74
12	0.27	0.28	1.72
13	0.25	0.31	1.69
14	0.24	0.33	1.67
15	0.22	0.35	1.65
16	0.21	0.36	1.64
17	0.20	0.38	1.62
18	0.19	0.39	1.61
19	0.19	0.40	1.60
20	0.18	0.41	1.59

TABLE *E* FACTORS FOR DETERMINING FROM $\bar{s}$ AND $\bar{\sigma}_{RMS}$ THE 3-SIGMA CONTROL LIMITS FOR $\bar{X}$ AND s OR σ_{RMS} CHARTS

Number of observations in subgroup, n	Factor for $\bar{X}$ chart using $\bar{\sigma}_{RMS}$, A_1	Factor for $\bar{X}$ chart using $\bar{s}$, A_3	Factors for s or σ_{RMS} charts: Lower control limit B_3	Factors for s or σ_{RMS} charts: Upper control limit B_4
2	3.76	2.66	0	3.27
3	2.39	1.95	0	2.57
4	1.88	1.63	0	2.27
5	1.60	1.43	0	2.09
6	1.41	1.29	0.03	1.97
7	1.28	1.18	0.12	1.88
8	1.17	1.10	0.19	1.81
9	1.09	1.03	0.24	1.76
10	1.03	0.98	0.28	1.72
11	0.97	0.93	0.32	1.68
12	0.93	0.89	0.35	1.65
13	0.88	0.85	0.38	1.62
14	0.85	0.82	0.41	1.59
15	0.82	0.79	0.43	1.57
16	0.79	0.76	0.45	1.55
17	0.76	0.74	0.47	1.53
18	0.74	0.72	0.48	1.52
19	0.72	0.70	0.50	1.50
20	0.70	0.68	0.51	1.49
21	0.68	0.66	0.52	1.48
22	0.66	0.65	0.53	1.47
23	0.65	0.63	0.54	1.46
24	0.63	0.62	0.55	1.45
25	0.62	0.61	0.56	1.44
30	0.56	0.55	0.60	1.40
35	0.52	0.51	0.63	1.37
40	0.48	0.48	0.66	1.34
45	0.45	0.45	0.68	1.32
50	0.43	0.43	0.70	1.30
55	0.41	0.41	0.71	1.29
60	0.39	0.39	0.72	1.28
65	0.38	0.37	0.73	1.27
70	0.36	0.36	0.74	1.26
75	0.35	0.35	0.75	1.25
80	0.34	0.34	0.76	1.24
85	0.33	0.33	0.77	1.23
90	0.32	0.32	0.77	1.23
95	0.31	0.31	0.78	1.22
100	0.30	0.30	0.79	1.21

TABLE *F* FACTORS FOR DETERMINING FROM σ THE 3-SIGMA CONTROL LIMITS FOR $\overline{X}$, R, AND s OR σ_{RMS} CHARTS

Number of observations in subgroup, n	Factors for $\overline{X}$ chart, A	Factors for R chart		Factors for σ_{RMS} chart		Factors for s chart	
		Lower control limit D_1	Upper control limit D_2	Lower control limit B_1	Upper control limit B_2	Lower control limit B_5	Upper control limit B_6
2	2.12	0	3.69	0	1.84	0	2.61
3	1.73	0	4.36	0	1.86	0	2.28
4	1.50	0	4.70	0	1.81	0	2.09
5	1.34	0	4.92	0	1.76	0	1.96
6	1.22	0	5.08	0.03	1.71	0.03	1.87
7	1.13	0.20	5.20	0.10	1.67	0.11	1.81
8	1.06	0.39	5.31	0.17	1.64	0.18	1.75
9	1.00	0.55	5.39	0.22	1.61	0.23	1.71
10	0.95	0.69	5.47	0.26	1.58	0.28	1.67
11	0.90	0.81	5.53	0.30	1.56	0.31	1.64
12	0.87	0.92	5.59	0.33	1.54	0.35	1.61
13	0.83	1.03	5.65	0.36	1.52	0.37	1.59
14	0.80	1.12	5.69	0.38	1.51	0.40	1.56
15	0.77	1.21	5.74	0.41	1.49	0.42	1.54
16	0.75	1.28	5.78	0.43	1.48	0.44	1.53
17	0.73	1.36	5.82	0.44	1.47	0.46	1.51
18	0.71	1.43	5.85	0.46	1.45	0.48	1.50
19	0.69	1.49	5.89	0.48	1.44	0.49	1.48
20	0.67	1.55	5.92	0.49	1.43	0.50	1.47
21	0.65			0.50	1.42	0.52	1.46
22	0.64			0.52	1.41	0.53	1.45
23	0.63			0.53	1.41	0.54	1.44
24	0.61			0.54	1.40	0.55	1.43
25	0.60			0.55	1.39	0.56	1.42
30	0.55			0.59	1.36	0.60	1.38
35	0.51			0.62	1.33	0.63	1.36
40	0.47			0.65	1.31	0.66	1.33
45	0.45			0.67	1.30	0.68	1.31
50	0.42			0.68	1.28	0.69	1.30
55	0.40			0.70	1.27	0.71	1.28
60	0.39			0.71	1.26	0.72	1.27
65	0.37			0.72	1.25	0.73	1.26
70	0.36			0.74	1.24	0.74	1.25
75	0.35			0.75	1.23	0.75	1.24
80	0.34			0.75	1.23	0.76	1.24
85	0.33			0.76	1.22	0.77	1.23
90	0.32			0.77	1.22	0.77	1.22
95	0.31			0.77	1.21	0.78	1.22
100	0.30			0.78	1.20	0.78	1.21

TABLE *G* SUMMATION OF TERMS OF POISSON'S EXPONENTIAL BINOMIAL LIMIT
1,000 × probability of *c* or less occurrences of event that has average number of occurrences equal to μ_c or μ_{np}

μ_c or μ_{np}	*c*									
	0	1	2	3	4	5	6	7	8	9
0.02	980	1,000								
0.04	961	999	1,000							
0.06	942	998	1,000							
0.08	923	997	1,000							
0.10	905	995	1,000							
0.15	861	990	999	1,000						
0.20	819	982	999	1,000						
0.25	779	974	998	1,000						
0.30	741	963	996	1,000						
0.35	705	951	994	1,000						
0.40	670	938	992	999	1,000					
0.45	638	925	989	999	1,000					
0.50	607	910	986	998	1,000					
0.55	577	894	982	998	1,000					
0.60	549	878	977	997	1,000					
0.65	522	861	972	996	999	1,000				
0.70	497	844	966	994	999	1,000				
0.75	472	827	959	993	999	1,000				
0.80	449	809	953	991	999	1,000				
0.85	427	791	945	989	998	1,000				
0.90	407	772	937	987	998	1,000				
0.95	387	754	929	984	997	1,000				
1.00	368	736	920	981	996	999	1,000			
1.1	333	699	900	974	995	999	1,000			
1.2	301	663	879	966	992	998	1,000			
1.3	273	627	857	957	989	998	1,000			
1.4	247	592	833	946	986	997	999	1,000		
1.5	223	558	809	934	981	996	999	1,000		
1.6	202	525	783	921	976	994	999	1,000		
1.7	183	493	757	907	970	992	998	1,000		
1.8	165	463	731	891	964	990	997	999	1,000	
1.9	150	434	704	875	956	987	997	999	1,000	
2.0	135	406	677	857	947	983	995	999	1,000	

TABLE G *(continued)*

μ_c or μ_{np}	c									
	0	1	2	3	4	5	6	7	8	9
2.2	111	355	623	819	928	975	993	998	1,000	
2.4	091	308	570	779	904	964	988	997	999	1,000
2.6	074	267	518	736	877	951	983	995	999	1,000
2.8	061	231	469	692	848	935	976	992	998	999
3.0	050	199	423	647	815	916	966	988	996	999
3.2	041	171	380	603	781	895	955	983	994	998
3.4	033	147	340	558	744	871	942	977	992	997
3.6	027	126	303	515	706	844	927	969	988	996
3.8	022	107	269	473	668	816	909	960	984	994
4.0	018	092	238	433	629	785	889	949	979	992
4.2	015	078	210	395	590	753	867	936	972	989
4.4	012	066	185	359	551	720	844	921	964	985
4.6	010	056	163	326	513	686	818	905	955	980
4.8	008	048	143	294	476	651	791	887	944	975
5.0	007	040	125	265	440	616	762	867	932	968
5.2	006	034	109	238	406	581	732	845	918	960
5.4	005	029	095	213	373	546	702	822	903	951
5.6	004	024	082	191	342	512	670	797	886	941
5.8	003	021	072	170	313	478	638	771	867	929
6.0	002	017	062	151	285	446	606	744	847	916

	10	11	12	13	14	15	16
2.8	1,000						
3.0	1,000						
3.2	1,000						
3.4	999	1,000					
3.6	999	1,000					
3.8	998	999	1,000				
4.0	997	999	1,000				
4.2	996	999	1,000				
4.4	994	998	999	1,000			
4.6	992	997	999	1,000			
4.8	990	996	999	1,000			
5.0	986	995	998	999	1,000		
5.2	982	993	997	999	1,000		
5.4	977	990	996	999	1,000		
5.6	972	988	995	998	999	1,000	
5.8	965	984	993	997	999	1,000	
6.0	957	980	991	996	999	999	1,000

TABLE *G* *(continued)*

μ_c or μ_{np}	*c* = 0	1	2	3	4	5	6	7	8	9
6.2	002	015	054	134	259	414	574	716	826	902
6.4	002	012	046	119	235	384	542	687	803	886
6.6	001	010	040	105	213	355	511	658	780	869
6.8	001	009	034	093	192	327	480	628	755	850
7.0	001	007	030	082	173	301	450	599	729	830
7.2	001	006	025	072	156	276	420	569	703	810
7.4	001	005	022	063	140	253	392	539	676	788
7.6	001	004	019	055	125	231	365	510	648	765
7.8	000	004	016	048	112	210	338	481	620	741
8.0	000	003	014	042	100	191	313	453	593	717
8.5	000	002	009	030	074	150	256	386	523	653
9.0	000	001	006	021	055	116	207	324	456	587
9.5	000	001	004	015	040	089	165	269	392	522
10.0	000	000	003	010	029	067	130	220	333	458

	10	11	12	13	14	15	16	17	18	19
6.2	949	975	989	995	998	999	1,000			
6.4	939	969	986	994	997	999	1,000			
6.6	927	963	982	992	997	999	999	1,000		
6.8	915	955	978	990	996	998	999	1,000		
7.0	901	947	973	987	994	998	999	1,000		
7.2	887	937	967	984	993	997	999	999	1,000	
7.4	871	926	961	980	991	996	998	999	1,000	
7.6	854	915	954	976	989	995	998	999	1,000	
7.8	835	902	945	971	986	993	997	999	1,000	
8.0	816	888	936	966	983	992	996	998	999	1,000
8.5	763	849	909	949	973	986	993	997	999	999
9.0	706	803	876	926	959	978	989	995	998	999
9.5	645	752	836	898	940	967	982	991	996	998
10.0	583	697	792	864	917	951	973	986	993	997

	20	21	22
8.5	1,000		
9.0	1,000		
9.5	999	1,000	
10.0	998	999	1,000

TABLE G *(continued)*

μ_c or μ_{np}	c									
	0	1	2	3	4	5	6	7	8	9
10.5	000	000	002	007	021	050	102	179	279	397
11.0	000	000	001	005	015	038	079	143	232	341
11.5	000	000	001	003	011	028	060	114	191	289
12.0	000	000	001	002	008	020	046	090	155	242
12.5	000	000	000	002	005	015	035	070	125	201
13.0	000	000	000	001	004	011	026	054	100	166
13.5	000	000	000	001	003	008	019	041	079	135
14.0	000	000	000	000	002	006	014	032	062	109
14.5	000	000	000	000	001	004	010	024	048	088
15.0	000	000	000	000	001	003	008	018	037	070
	10	11	12	13	14	15	16	17	18	19
10.5	521	639	742	825	888	932	960	978	988	994
11.0	460	579	689	781	854	907	944	968	982	991
11.5	402	520	633	733	815	878	924	954	974	986
12.0	347	462	576	682	772	844	899	937	963	979
12.5	297	406	519	628	725	806	869	916	948	969
13.0	252	353	463	573	675	764	835	890	930	957
13.5	211	304	409	518	623	718	798	861	908	942
14.0	176	260	358	464	570	669	756	827	883	923
14.5	145	220	311	413	518	619	711	790	853	901
15.0	118	185	268	363	466	568	664	749	819	875
	20	21	22	23	24	25	26	27	28	29
10.5	997	999	999	1,000						
11.0	995	998	999	1,000						
11.5	992	996	998	999	1,000					
12.0	988	994	997	999	999	1,000				
12.5	983	991	995	998	999	999	1,000			
13.0	975	986	992	996	998	999	1,000			
13.5	965	980	989	994	997	998	999	1,000		
14.0	952	971	983	991	995	997	999	999	1,000	
14.5	936	960	976	986	992	996	998	999	999	1,000
15.0	917	947	967	981	989	994	997	998	999	1,000

TABLE *G* *(continued)*

μ_c or μ_{np}	*c*									
	4	5	6	7	8	9	10	11	12	13
16	000	001	004	010	022	043	077	127	193	275
17	000	001	002	005	013	026	049	085	135	201
18	000	000	001	003	007	015	030	055	092	143
19	000	000	001	002	004	009	018	035	061	098
20	000	000	000	001	002	005	011	021	039	066
21	000	000	000	000	001	003	006	013	025	043
22	000	000	000	000	001	002	004	008	015	028
23	000	000	000	000	000	001	002	004	009	017
24	000	000	000	000	000	000	001	003	005	011
25	000	000	000	000	000	000	001	001	003	006
	14	15	16	17	18	19	20	21	22	23
16	368	467	566	659	742	812	868	911	942	963
17	281	371	468	564	655	736	805	861	905	937
18	208	287	375	469	562	651	731	799	855	899
19	150	215	292	378	469	561	647	725	793	849
20	105	157	221	297	381	470	559	644	721	787
21	072	111	163	227	302	384	471	558	640	716
22	048	077	117	169	232	306	387	472	556	637
23	031	052	082	123	175	238	310	389	472	555
24	020	034	056	087	128	180	243	314	392	473
25	012	022	038	060	092	134	185	247	318	394
	24	25	26	27	28	29	30	31	32	33
16	978	987	993	996	998	999	999	1,000		
17	959	975	985	991	995	997	999	999	1,000	
18	932	955	972	983	990	994	997	998	999	1,000
19	893	927	951	969	980	988	993	996	998	999
20	843	888	922	948	966	978	987	992	995	997
21	782	838	883	917	944	963	976	985	991	994
22	712	777	832	877	913	940	959	973	983	989
23	635	708	772	827	873	908	936	956	971	981
24	554	632	704	768	823	868	904	932	953	969
25	473	553	629	700	763	818	863	900	929	950
	34	35	36	37	38	39	40	41	42	43
19	999	1,000								
20	999	999	1,000							
21	997	998	999	999	1,000					
22	994	996	998	999	999	1,000				
23	988	993	996	997	999	999	1,000			
24	979	987	992	995	997	998	999	999	1,000	
25	966	978	985	991	994	997	998	999	999	1,000