

## National Exams May 2015

### 98-Ind-A5, Quality Planning, Control and Assurance

Notes:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumption made.
2. This is a Closed Book examination.
3. Candidates may use one of two calculators, the Casio or Sharp approved models.
4. Candidates are permitted to bring into the examination room one aid sheet  
 $8\frac{1}{2}'' \times 11''$  written on both sides.
5. Any five questions constitute a complete paper. Only the first five questions as they appear in your answer book will be marked.
6. All questions are of equal value.
7. Relevant statistical tables are attached.

Question 1 (20 marks)

- 5 a) Discuss and compare the traditional, ASQ, and Taguchi's definitions of quality. Explain the difference between the corresponding loss functions.
- 5 b) Explain the concept of the Six Sigma philosophy and describe the related DMAIC methodology. Explain their role in quality improvement.
- 5 c) Explain various objectives of quality certification and its role in the modern supplier-producer relations. Describe briefly the structure of ISO 9000 and summarize the steps in ISO 9001 registration.
- 5 d) Discuss the advantages of the concurrent engineering approach to product and process design over the traditional approach. Explain QFD and its relation to customer satisfaction.

Question 2 (20 marks)

- 4 a) Describe the two types of variation in production processes. When is a process in statistical control? Explain the difference between the control limits and specification limits.
- 5 b)  $\bar{X}$  and  $R$  control charts are maintained on the tensile strength of a metal fastener. After analyzing 40 samples of size  $n = 5$ , we obtained
$$\sum_{i=1}^{40} \bar{x}_i = 18,800 \text{ and } \sum_{i=1}^{40} R_i = 800.$$
Find the control limits for both charts and estimate the process parameters. What assumptions are you making?
- 4 c) Consider the problem in 2b) and assume that the specifications on the tensile strength are  $475 \pm 30$ . Estimate the process fraction nonconforming.
- 7 d) For the  $\bar{X}$  chart in 2b), find the minimum value of  $k > 0$  for which the probability of detecting the shift in the process mean from  $\mu_0$  to  $\mu_0 + k\sigma$  on the next sample following the shift is greater than or equal to 0.6 ( $\mu_0$  and  $\sigma$  are the process parameters estimated in 2b).

Question 3 (20 marks)

- 5 a) Assume that a quality characteristic is normally distributed with mean  $\mu$ . Explain the difference between a confidence interval for  $\mu$  and the natural tolerance limits considering the same confidence level.
- 6 b) Should the process be in statistical control when performing capability analysis? Why or why not? Explain the meaning of the capability indexes  $C_p$  and  $C_{pk}$ , and the relation between them. Provide examples of the situations when these two indexes are not equal. What is the relation between the indexes  $C_p$ ,  $C_{pk}$ , and  $k$ ?

98-Ind-A5 May 2015

- 9 c) Suppose for a given process, the estimates of  $C_p$  and  $C_{pk}$  are 1.33 and 1.05, respectively. Assuming that the process follows a normal distribution, and two-sided specification limits are used (LSL and USL), estimate the process fraction nonconforming. Estimate  $C_{pm}$  if the target value  $T = (USL + LSL)/2$ . How would the process fraction nonconforming change if the process mean is centered?

Question 4 (20 marks)

- 5 a) Explain the difference between the following control charts: p, np, c, u and the chart for demerit points.
- 6 b) Explain why in real situations an inspection unit is usually defined as several physical units for c-chart, for example 1 inspection unit may consist of 5 parts. Assume that the lower control limit for a u chart is zero and, for a particular sample,  $u_i$  is equal to zero. When should you stop the process and search for an assignable cause and when should you not?
- 9 c) The number of workmanship nonconformities observed in the final inspection of disk-drive assemblies has been tabulated as shown below. Set-up the appropriate control chart with 3 sigma limits. Revise, if necessary. Estimate the in-control mean number of nonconformities per assembly.

Day	1	2	3	4	5	6	7	8	9	10
No. of assemblies inspected	2	4	2	4	3	2	3	4	2	4
Total No. of nonconformities	8	21	10	30	18	10	20	24	15	26

Question 5 (20 marks)

- 5 a) Describe briefly the Taguchi methods applied in the product and process design. What are the usual objectives in the parameter design stage? Explain the meaning of an inner and outer array. What is a robust design?
- 9 b) An engineer wishes to test the effects of different levels of nickel, molybdenum and titanium on the tensile strength of a tool-grade steel. A  $2^3$  factorial experiment with 2 replications has been used. The low and high levels of nickel, molybdenum, and titanium are 10% and 20%, 3% and 6%, and 0.5% and 0.6%, respectively. The experimental data are in the table below.

	Factors			Replicates	
	Ni	Mo	Ti	I	II
10	3	0.5	271	270	
20	3	0.5	275	277	
10	6	0.5	283	280	
20	6	0.5	282	283	
10	3	0.6	286	290	
20	3	0.6	283	282	
10	6	0.6	284	286	

Find the estimates of the main effects and of the interaction effects. Identify significant effects by testing the appropriate hypotheses at significance level  $\alpha = 0.05$ .

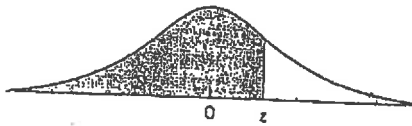
- 6 c) What combination of factor levels results in the highest mean tensile strength? Find the estimate of the mean response for the following values of the factors: nickel 16%, molybdenum 5% and titanium 0.55%.

Question 6 (20 marks)

- 5 a) The acceptance sampling plan MIL-STD-105E is AQL-based. Explain what this means and how the producer's and consumer's risks can be estimated when using this plan. Summarize the main features of MIL-STD-105E.
- 7 b) Discuss the advantages and disadvantages of using traditional acceptance sampling over sequential sampling. In what situations would you recommend using Dodge-Romig plans instead of the AQL-based plans? Explain the meaning of AOQL. What is the difference between the AOQL and LTPD plans?
- 8 c) Items are submitted for inspection using MIL-STD-105E. Find the single sampling plan for the following conditions: normal inspection, general inspection level II, lot size=1,500 and the AQL=0.40% nonconforming. Estimate the producer's and consumer's risk for this plan if the LQL=3%.

Appendix II Cumulative Standard Normal Distribution

$$\Phi(z) = \int_{-\infty}^z \frac{1}{\sqrt{2\pi}} e^{-u^2/2} du$$



z	0.00	0.01	0.02	0.03	0.04	z
0.0	0.50000	0.50399	0.50798	0.51197	0.51595	0.0
0.1	0.53983	0.54379	0.54776	0.55172	0.55567	0.1
0.2	0.57926	0.58317	0.58706	0.59095	0.59483	0.2
0.3	0.61791	0.62172	0.62551	0.62930	0.63307	0.3
0.4	0.65542	0.65910	0.62276	0.66640	0.67003	0.4
0.5	0.69146	0.69497	0.69847	0.70194	0.70540	0.5
0.6	0.72575	0.72907	0.73237	0.73565	0.73891	0.6
0.7	0.75803	0.76115	0.76424	0.76730	0.77035	0.7
0.8	0.78814	0.79103	0.79389	0.79673	0.79954	0.8
0.9	0.81594	0.81859	0.82121	0.82381	0.82639	0.9
1.0	0.84134	0.84375	0.84613	0.84849	0.85083	1.0
1.1	0.86433	0.86650	0.86864	0.87076	0.87285	1.1
1.2	0.88493	0.88686	0.88877	0.89065	0.89251	1.2
1.3	0.90320	0.90490	0.90658	0.90824	0.90988	1.3
1.4	0.91924	0.92073	0.92219	0.92364	0.92506	1.4
1.5	0.93319	0.93448	0.93574	0.93699	0.93822	1.5
1.6	0.94520	0.94630	0.94738	0.94845	0.94950	1.6
1.7	0.95543	0.95637	0.95728	0.95818	0.95907	1.7
1.8	0.96407	0.96485	0.96562	0.96637	0.96711	1.8
1.9	0.97128	0.97193	0.97257	0.97320	0.97381	1.9
2.0	0.97725	0.97778	0.97831	0.97882	0.97932	2.0
2.1	0.98214	0.98257	0.98300	0.98341	0.98382	2.1
2.2	0.98610	0.98645	0.98679	0.98713	0.98745	2.2
2.3	0.98928	0.98956	0.98983	0.99010	0.99036	2.3
2.4	0.99180	0.99202	0.99224	0.99245	0.99266	2.4
2.5	0.99379	0.99396	0.99413	0.99430	0.99446	2.5
2.6	0.99534	0.99547	0.99560	0.99573	0.99585	2.6
2.7	0.99653	0.99664	0.99674	0.99683	0.99693	2.7
2.8	0.99744	0.99752	0.99760	0.99767	0.99774	2.8
2.9	0.99813	0.99819	0.99825	0.99831	0.99836	2.9
3.0	0.99865	0.99869	0.99874	0.99878	0.99882	3.0
3.1	0.99903	0.99906	0.99910	0.99913	0.99916	3.1
3.2	0.99931	0.99934	0.99936	0.99938	0.99940	3.2
3.3	0.99952	0.99953	0.99955	0.99957	0.99958	3.3
3.4	0.99966	0.99968	0.99969	0.99970	0.99971	3.4
3.5	0.99977	0.99978	0.99978	0.99979	0.99980	3.5
3.6	0.99984	0.99985	0.99985	0.99986	0.99986	3.6
3.7	0.99989	0.99990	0.99990	0.99990	0.99991	3.7
3.8	0.99993	0.99993	0.99993	0.99994	0.99994	3.8
3.9	0.99995	0.99995	0.99996	0.99996	0.99996	3.9

Appendix II (Continued)

$$\Phi(z) = \int_{-\infty}^z \frac{1}{\sqrt{2\pi}} e^{-u^2/2} du$$

z	0.05	0.06	0.07	0.08	0.09	z
0.0	0.51994	0.52392	0.52790	0.53188	0.53586	0.0
0.1	0.55962	0.56356	0.56749	0.57142	0.57534	0.1
0.2	0.59871	0.60257	0.60642	0.61026	0.61409	0.2
0.3	0.63683	0.64058	0.64431	0.64803	0.65173	0.3
0.4	0.67364	0.67724	0.68082	0.68438	0.68793	0.4
0.5	0.70884	0.71226	0.71566	0.71904	0.72240	0.5
0.6	0.74215	0.74537	0.74857	0.75175	0.75490	0.6
0.7	0.77337	0.77637	0.77935	0.78230	0.78523	0.7
0.8	0.80234	0.80510	0.80785	0.81057	0.81327	0.8
0.9	0.82894	0.83147	0.83397	0.83646	0.83891	0.9
1.0	0.85314	0.85543	0.85769	0.85993	0.86214	1.0
1.1	0.87493	0.87697	0.87900	0.88100	0.88297	1.1
1.2	0.89435	0.89616	0.89796	0.89973	0.90147	1.2
1.3	0.91149	0.91308	0.91465	0.91621	0.91773	1.3
1.4	0.92647	0.92785	0.92922	0.93056	0.93189	1.4
1.5	0.93943	0.94062	0.94179	0.94295	0.94408	1.5
1.6	0.95053	0.95154	0.95254	0.95352	0.95448	1.6
1.7	0.95994	0.96080	0.96164	0.96246	0.96327	1.7
1.8	0.96784	0.96856	0.96926	0.96995	0.97062	1.8
1.9	0.97441	0.97500	0.97558	0.97615	0.97670	1.9
2.0	0.97982	0.98030	0.98077	0.98124	0.98169	2.0
2.1	0.98422	0.98461	0.98500	0.98537	0.98574	2.1
2.2	0.98778	0.98809	0.98840	0.98870	0.98899	2.2
2.3	0.99061	0.99086	0.99111	0.99134	0.99158	2.3
2.4	0.99286	0.99305	0.99324	0.99343	0.99361	2.4
2.5	0.99461	0.99477	0.99492	0.99506	0.99520	2.5
2.6	0.99598	0.99609	0.99621	0.99632	0.99643	2.6
2.7	0.99702	0.99711	0.99720	0.99728	0.99736	2.7
2.8	0.99781	0.99788	0.99795	0.99801	0.99807	2.8
2.9	0.99841	0.99846	0.99851	0.99856	0.99861	2.9
3.0	0.99886	0.99889	0.99893	0.99897	0.99900	3.0
3.1	0.99918	0.99921	0.99924	0.99926	0.99929	3.1
3.2	0.99942	0.99944	0.99946	0.99948	0.99950	3.2
3.3	0.99960	0.99961	0.99962	0.99964	0.99965	3.3
3.4	0.99972	0.99973	0.99974	0.99975	0.99976	3.4
3.5	0.99981	0.99981	0.99982	0.99983	0.99983	3.5
3.6	0.99987	0.99987	0.99988	0.99988	0.99989	3.6
3.7	0.99991	0.99992	0.99992	0.99992	0.99992	3.7
3.8	0.99994	0.99994	0.99995	0.99995	0.99995	3.8
3.9	0.99996	0.99996	0.99996	0.99997	0.99997	3.9

Appendix VI Factors for Constructing Variables Control Charts

Observations in Sample, n	Chart for Standard Deviations						Chart for Ranges										
	Chart for Averages			Chart for Center Line			Factors for Control Limits			Factors for Center Line			Factors for Control Limits				
	A	A <sub>2</sub>	A <sub>3</sub>	c <sub>4</sub>	1/c <sub>4</sub>	B <sub>2</sub>	B <sub>3</sub>	B <sub>4</sub>	B <sub>5</sub>	B <sub>6</sub>	d <sub>2</sub>	1/d <sub>2</sub>	d <sub>3</sub>	D <sub>1</sub>	D <sub>2</sub>	D <sub>3</sub>	D <sub>4</sub>
2	2.121	1.880	2.659	0.7979	1.2533	0	3.267	0	2.606	0.853	1.128	0.8865	0	3.686	0	3.267	
3	1.732	1.023	1.954	0.8862	1.1284	0	2.568	0	2.276	0.888	1.693	0.5907	0	4.358	0	2.575	
4	1.500	0.729	1.628	0.9213	1.0854	0	2.266	0	2.088	0.880	2.059	0.4857	0	4.698	0	2.282	
5	1.342	0.577	1.427	0.9400	1.0638	0	2.089	0	1.964	0.864	2.326	0.4299	0.864	4.918	0	2.115	
6	1.225	0.483	1.287	0.9515	1.0510	0.030	1.970	0.029	1.874	0.848	2.534	0.3946	0.848	5.078	0	2.004	
7	1.134	0.419	1.182	0.9594	1.0423	0.118	1.882	0.113	1.806	0.833	2.704	0.3698	0.833	5.204	0.076	1.924	
8	1.061	0.373	1.099	0.9650	1.0363	0.185	1.815	0.179	1.751	0.820	2.847	0.3512	0.820	5.306	0.136	1.864	
9	1.000	0.337	1.032	0.9693	1.0317	0.239	1.761	0.232	1.707	0.808	2.970	0.3367	0.808	5.393	0.184	1.816	
10	0.949	0.308	0.975	0.9727	1.0281	0.284	1.716	0.276	1.669	0.797	3.078	0.3249	0.797	5.469	0.223	1.777	
11	0.905	0.285	0.927	0.9754	1.0252	0.321	1.679	0.313	1.637	0.787	3.173	0.3152	0.787	5.535	0.256	1.744	
12	0.866	0.266	0.886	0.9776	1.0229	0.354	1.646	0.346	1.610	0.778	3.258	0.3069	0.778	5.594	0.283	1.717	
13	0.832	0.249	0.850	0.9794	1.0210	0.382	1.618	0.374	1.585	0.770	3.336	0.2998	0.770	5.647	0.307	1.693	
14	0.802	0.235	0.817	0.9810	1.0194	0.406	1.594	0.399	1.563	0.763	3.407	0.2935	0.763	5.696	0.328	1.672	
15	0.775	0.223	0.789	0.9823	1.0180	0.428	1.572	0.421	1.544	0.756	3.472	0.2880	0.756	5.741	0.347	1.653	
16	0.750	0.212	0.763	0.9835	1.0168	0.448	1.552	0.440	1.526	0.750	3.532	0.2831	0.750	5.782	0.363	1.637	
17	0.728	0.203	0.739	0.9845	1.0157	0.466	1.534	0.458	1.511	0.744	3.588	0.2787	0.744	5.820	0.378	1.622	
18	0.707	0.194	0.718	0.9854	1.0148	0.482	1.518	0.475	1.496	0.739	3.640	0.2747	0.739	5.856	0.391	1.608	
19	0.688	0.187	0.698	0.9862	1.0140	0.497	1.503	0.490	1.483	0.734	3.689	0.2711	0.734	5.891	0.403	1.597	
20	0.671	0.180	0.680	0.9869	1.0133	0.510	1.490	0.504	1.470	0.729	3.735	0.2677	0.729	5.921	0.415	1.585	
21	0.655	0.173	0.663	0.9876	1.0126	0.523	1.477	0.516	1.459	0.724	3.778	0.2647	0.724	5.951	0.425	1.575	
22	0.640	0.167	0.647	0.9882	1.0119	0.534	1.466	0.528	1.448	0.720	3.819	0.2618	0.720	5.979	0.434	1.566	
23	0.626	0.162	0.633	0.9887	1.0114	0.545	1.455	0.539	1.438	0.716	3.858	0.2592	0.716	6.006	0.443	1.557	
24	0.612	0.157	0.619	0.9892	1.0109	0.555	1.445	0.549	1.429	0.712	3.895	0.2567	0.712	6.031	0.451	1.548	
25	0.600	0.153	0.606	0.9896	1.0105	0.565	1.435	0.559	1.420	0.708	3.931	0.2544	0.708	6.056	0.459	1.541	

For n > 25

$$A = \frac{3}{\sqrt{n}}, \quad A_3 = \frac{3}{c_4\sqrt{n}}, \quad c_4 = \frac{4(n-1)}{4n-3},$$

$$B_2 = 1 - \frac{3}{c_4\sqrt{2(n-1)}}, \quad B_4 = 1 + \frac{3}{c_4\sqrt{2(n-1)}},$$

$$B_5 = c_4 - \frac{3}{\sqrt{2(n-1)}}, \quad B_6 = c_4 + \frac{3}{\sqrt{2(n-1)}}.$$

APPENDIX V  
(Continued)

Degrees of freedom for the denominator ( $v_2$ )	Degrees of freedom for the numerator ( $v_1$ )																		
	1	2	3	4	5	6	7	8	9	10	12	15	20	24	30	40	60	120	$\infty$
1	161.4	199.5	215.7	224.6	230.2	234.0	236.8	238.9	240.5	241.9	243.9	245.9	248.0	249.1	250.1	251.1	252.2	253.3	254.3
2	18.51	19.00	19.16	19.25	19.30	19.33	19.35	19.37	19.38	19.40	19.41	19.43	19.45	19.45	19.46	19.47	19.48	19.49	19.50
3	10.13	9.55	9.28	9.12	9.01	8.94	8.89	8.85	8.81	8.79	8.74	8.70	8.66	8.64	8.62	8.59	8.57	8.55	8.53
4	6.59	5.94	5.69	5.53	5.42	5.35	5.30	5.26	5.23	5.21	5.19	5.17	5.15	5.14	5.13	5.12	5.11	5.10	5.09
5	5.01	4.40	4.17	4.01	3.90	3.83	3.78	3.74	3.71	3.69	3.67	3.65	3.63	3.62	3.61	3.60	3.59	3.58	3.57
6	4.00	3.43	3.21	3.05	2.94	2.87	2.82	2.78	2.75	2.73	2.71	2.69	2.67	2.66	2.65	2.64	2.63	2.62	2.61
7	3.34	2.81	2.60	2.44	2.33	2.26	2.21	2.17	2.14	2.12	2.10	2.08	2.06	2.05	2.04	2.03	2.02	2.01	2.00
8	2.95	2.45	2.25	2.09	1.98	1.91	1.86	1.82	1.79	1.77	1.75	1.73	1.71	1.70	1.69	1.68	1.67	1.66	1.65
9	2.68	2.20	2.00	1.84	1.73	1.66	1.61	1.57	1.54	1.52	1.50	1.48	1.46	1.45	1.44	1.43	1.42	1.41	1.40
10	2.48	1.99	1.79	1.63	1.52	1.45	1.40	1.36	1.33	1.31	1.29	1.27	1.25	1.24	1.23	1.22	1.21	1.20	1.19
11	2.33	1.85	1.65	1.49	1.38	1.31	1.26	1.22	1.19	1.17	1.15	1.13	1.11	1.10	1.09	1.08	1.07	1.06	1.05
12	2.22	1.74	1.54	1.38	1.27	1.20	1.15	1.11	1.08	1.06	1.04	1.02	1.00	0.99	0.98	0.97	0.96	0.95	0.94
13	2.14	1.66	1.46	1.30	1.19	1.12	1.07	1.03	1.00	0.98	0.96	0.94	0.92	0.91	0.90	0.89	0.88	0.87	0.86
14	2.08	1.60	1.40	1.24	1.13	1.06	1.01	0.97	0.94	0.92	0.90	0.88	0.86	0.85	0.84	0.83	0.82	0.81	0.80
15	2.03	1.55	1.35	1.19	1.08	1.01	0.96	0.92	0.89	0.87	0.85	0.83	0.81	0.80	0.79	0.78	0.77	0.76	0.75
16	1.99	1.51	1.31	1.15	1.04	0.97	0.92	0.88	0.85	0.83	0.81	0.79	0.77	0.76	0.75	0.74	0.73	0.72	0.71
17	1.95	1.47	1.27	1.11	0.99	0.92	0.87	0.83	0.80	0.78	0.76	0.74	0.72	0.71	0.70	0.69	0.68	0.67	0.66
18	1.92	1.44	1.24	1.08	0.96	0.89	0.84	0.80	0.77	0.75	0.73	0.71	0.69	0.68	0.67	0.66	0.65	0.64	0.63
19	1.89	1.41	1.21	1.05	0.93	0.86	0.81	0.77	0.74	0.72	0.70	0.68	0.66	0.65	0.64	0.63	0.62	0.61	0.60
20	1.87	1.39	1.19	1.03	0.91	0.84	0.79	0.75	0.72	0.70	0.68	0.66	0.64	0.63	0.62	0.61	0.60	0.59	0.58
21	1.85	1.37	1.17	1.01	0.89	0.82	0.77	0.73	0.70	0.68	0.66	0.64	0.62	0.61	0.60	0.59	0.58	0.57	0.56
22	1.83	1.35	1.15	0.99	0.87	0.80	0.75	0.71	0.68	0.66	0.64	0.62	0.60	0.59	0.58	0.57	0.56	0.55	0.54
23	1.82	1.34	1.14	0.98	0.86	0.79	0.74	0.70	0.67	0.65	0.63	0.61	0.59	0.58	0.57	0.56	0.55	0.54	0.53
24	1.81	1.33	1.13	0.97	0.85	0.78	0.73	0.69	0.66	0.64	0.62	0.60	0.58	0.57	0.56	0.55	0.54	0.53	0.52
25	1.80	1.32	1.12	0.96	0.84	0.77	0.72	0.68	0.65	0.63	0.61	0.59	0.57	0.56	0.55	0.54	0.53	0.52	0.51
26	1.79	1.31	1.11	0.95	0.83	0.76	0.71	0.67	0.64	0.62	0.60	0.58	0.56	0.55	0.54	0.53	0.52	0.51	0.50
27	1.78	1.30	1.10	0.94	0.82	0.75	0.70	0.66	0.63	0.61	0.59	0.57	0.55	0.54	0.53	0.52	0.51	0.50	0.49
28	1.77	1.29	1.09	0.93	0.81	0.74	0.69	0.65	0.62	0.60	0.58	0.56	0.54	0.53	0.52	0.51	0.50	0.49	0.48
29	1.76	1.28	1.08	0.92	0.80	0.73	0.68	0.64	0.61	0.59	0.57	0.55	0.53	0.52	0.51	0.50	0.49	0.48	0.47
30	1.75	1.27	1.07	0.91	0.79	0.72	0.67	0.63	0.60	0.58	0.56	0.54	0.52	0.51	0.50	0.49	0.48	0.47	0.46
40	1.72	1.24	1.04	0.88	0.76	0.69	0.64	0.60	0.57	0.55	0.53	0.51	0.49	0.48	0.47	0.46	0.45	0.44	0.43
60	1.69	1.21	1.01	0.85	0.73	0.66	0.61	0.57	0.54	0.52	0.50	0.48	0.46	0.45	0.44	0.43	0.42	0.41	0.40
120	1.65	1.17	0.97	0.81	0.69	0.62	0.57	0.53	0.50	0.48	0.46	0.44	0.42	0.41	0.40	0.39	0.38	0.37	0.36
$\infty$	1.60	1.12	0.92	0.76	0.64	0.57	0.52	0.48	0.45	0.43	0.41	0.39	0.37	0.36	0.35	0.34	0.33	0.32	0.31

Note:  $F_{0.95, v_1, v_2} = 1/F_{0.05, v_2, v_1}$



**TABLE 10-33 AQL Conversion Table**

<i>For Specified AQL Values Falling Within These Ranges</i>	<i>Use This AQL Value</i>
— to 0.109	0.10
0.110 to 0.164	0.15
0.165 to 0.279	0.25
0.280 to 0.439	0.40
0.440 to 0.699	0.65
0.700 to 1.09	1.0
1.10 to 1.64	1.5
1.65 to 2.79	2.5
2.80 to 4.39	4.0
4.40 to 6.99	6.5
7.00 to 10.9	10.0

*Source: American Society for Quality Control (1980), ANSI/ASQC Z1.9-1980: American National Standard—Sampling Procedures and Tables for Inspection by Variables for Percent Nonconforming. Reprinted with the permission of ASQC.*

**TABLE 10-34 Sample Size Code Letters**

<i>Lot Size</i>	<i>Inspection Levels</i>				
	<i>Special</i>		<i>General</i>		
	<i>S-3</i>	<i>S-4</i>	<i>I</i>	<i>II</i>	<i>III</i>
2 to 8	B	B	B	B	C
9 to 15	B	B	B	B	D
16 to 25	B	B	B	C	E
26 to 50	B	B	C	D	F
51 to 90	B	B	D	E	G
91 to 150	B	C	E	F	H
151 to 280	B	D	F	G	I
281 to 400	C	E	G	H	J
401 to 500	C	E	G	I	J
501 to 1,200	D	F	H	J	K
1,201 to 3,200	E	G	I	K	L
3,201 to 10,000	F	H	J	L	M
10,001 to 35,000	G	I	K	M	N
35,001 to 150,000	H	J	L	N	P
150,001 to 500,000	H	K	M	P	P
500,001 and over	H	K	N	P	P

*Source: American Society for Quality Control (1980), ANSI/ASQC Z1.9-1980: American National Standard—Sampling Procedures and Tables for Inspection by Variables for Percent Nonconforming. Reprinted with the permission of ASQC.*

Table 13-5 Master Table for Normal Inspection—Single Sampling (MIL STD 105E, Table II-A)

Sample size code letter	Acceptable Quality Levels (normal inspection)																										
	0.010	0.015	0.025	0.040	0.065	0.10	0.15	0.25	0.40	0.65	1.0	1.5	2.5	4.0	6.5	10	15	25	40	65	100	150	250	400	650	1000	
A	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re
B	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re
C	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re
D	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re
E	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re
F	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re
G	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re
H	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re
I	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re
J	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re
K	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re
L	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re
M	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re
N	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re
P	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re
Q	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re
R	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re

Use first sampling plan below arrow. If sample size equals, or exceeds, lot or batch size, do 100 percent inspection.  
 Use first sampling plan above arrow.  
 Ac = Acceptance number.  
 Re = Rejection number.