

## National Exams December 2012

### 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 assumptions 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 of size  $8\frac{1}{2}$  \* 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) If a company's focus is on increasing profit, what would likely be a longer term effect on their product's quality, market share, and competitiveness and why?
- 5 b) Explain the hierarchical structure of the quality planning and summarize Juran's steps in that process.
- 5 c) Explain the role of QFD in the product design and provide an example.
- 5 d) Discuss the advantages of the concurrent engineering approach to the product and process design when compared with the traditional approach.

Question 2 (20 marks)

- 6 a) Describe briefly the following basic SPC problem-solving tools: run chart, cause-and-effect diagram, and Pareto diagram. How can these tools be used in a process improvement? Show examples.
- 6 b) In what situations would you prefer to use a CUSUM chart instead of a traditional  $\bar{X}$  chart and vice versa? Why is a tabular CUSUM preferable to a V-mask procedure? What is FIR CUSUM? Give examples when you would use a one-sided and a two-side CUSUM.
- 8 c) Samples of size  $n = 5$  are taken from a process every 30 min. After collecting 25 such samples, we obtained:  $\sum_{i=1}^{25} \bar{X}_i = 205$ ,  $\sum_{i=1}^{25} R_i = 9$ . The specifications are:  $8 \pm 0.5$ .  
Find the control limits for the  $\bar{X}$  and  $R$  charts. What fraction of the output is nonconforming? To control future production, determine the minimum sample size  $n$  and the control limits for the  $\bar{X}$  chart satisfying the following requirement: If the process mean shifts to  $\mu_0 \pm 2\sigma$ , where  $\mu_0$  and  $\sigma$  are the process parameters calculated from the data above, the probability of detecting this shift on the two subsequent samples should be at least 0.7. Calculate the ARL and ATS for this chart when the process mean shifts to 7.9.

Question 3 (20 marks)

- 5 a) Explain the three phases in a typical product life cycle curve and discuss the distributions suitable for modeling each phase.
- 7 b) Provide the definitions of the reliability function  $R(t)$  and the failure rate  $h(t)$  and show the relation between them. Explain the memoryless property of the exponential distribution and why this distribution is useful in real applications.
- 8 c) Consider the Weibull distribution with shape parameter=3 and the characteristic life =500 hours. Calculate the mean time to failure.

Question 4 (20 marks)

- 7 a) Explain what is meant by a capable process. Should the process be in statistical control when performing capability analysis? Why or why not? Show the relation between  $C_p$  and  $C_{pk}$ .
- 6 b) Consider the data in Question 2c). Estimate the capability indexes  $C_p$  and  $C_{pk}$ . Is the process capable? If not, what would you suggest to increase process capability?
- 7 c) As a part of a contractual agreement, the supplier should demonstrate that  $C_p \geq 1.2$ . Formulate the appropriate hypothesis and determine the required sample size  $n$  and the critical value of  $C$  assuming supplier's risk = 0.05 when the actual value of the capability index  $C_p = 1.5$ , and the customer's risk = 0.05.

Question 5 (20 marks)

- 6 a) Consider the following attribute charts:  $p$ ,  $c$  and  $u$ . Explain what these charts are used for. Assume that the LCL for a  $p$  chart is zero and the number of defectives in a particular sample is zero. When should the process be stopped to investigate the occurrence of an assignable cause and when should it not be stopped? Explain and give an example.
- 7 b) A sample of 150 parts is taken from a production process every half an hour. The following data were obtained from 15 consecutive samples:

Sample No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
No. of nonconforming parts	2	6	0	6	4	4	2	3	12	5	4	3	1	7	2

Set-up a control chart, and revise if necessary. Estimate the proportion of nonconforming parts. If the process mean shifts to  $p_1 = 0.035$ , estimate the probability that the shift is detected on the first sample following the shift.

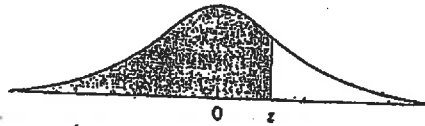
- 7 c) Assume that the process mean shifts from  $p_0$  to  $p_1 = p_0 + 1.5\sigma$ , where  $p_0$  and  $\sigma$  are the in-control process mean and standard deviation, respectively, estimated in 5b). Calculate the ARL and ATS for  $p_1$ .

Question 6 (20 marks)

- 7 a) Explain the following terms used in acceptance sampling: acceptable quality level(AQL), limiting quality level(LQL), producer's risk, consumer's risk, rectifying inspection, average outgoing quality, average outgoing quality limit. When is sequential sampling recommended and how is it different from other sampling procedures?
- 6 b) Summarize the main features of MIL-STD-105E and of the Dodge-Romig AOQL and LTPD sampling plans. Can the LQL level be stipulated in any of these plans, and if so, in which one?
- 7 c) Items are submitted for inspection using MIL-STD-105E in lots of size 1,000. The required AQL is 1.5%. Consider normal inspection and general inspection level II. Find a single sampling plan using MIL-STD-105E. Calculate the producer's and consumer's risk for the selected sampling plan if LQL is equal to 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	0.66276	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 Averages						Chart for Standard Deviations						Chart for Ranges					
	Factors for Control Limits			Center Line			Factors for Control Limits			Center Line			Factors for Control Limits			Center Line		
	A	A <sub>2</sub>	A <sub>3</sub>	c <sub>4</sub>	1/c <sub>4</sub>	U/c <sub>4</sub>	B <sub>3</sub>	B <sub>4</sub>	B <sub>5</sub>	B <sub>6</sub>	d <sub>3</sub>	1/d <sub>3</sub>	d <sub>4</sub>	d <sub>5</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	1.128	0.8865	0.853	0	3.686	0	3.267	0	3.267
3	1.732	1.023	1.954	0.8862	1.1284	0	2.568	0	2.276	1.693	0.5907	0.888	0	4.358	0	2.575	0	2.575
4	1.500	0.729	1.628	0.9213	1.0854	0	2.266	0	2.088	2.059	0.4857	0.880	0	4.698	0	2.282	0	2.282
5	1.342	0.577	1.427	0.9400	1.0638	0	2.089	0	1.964	2.326	0.4299	0.864	0	4.918	0	2.115	0	2.115
6	1.225	0.483	1.287	0.9515	1.0510	0.030	1.970	0.029	1.874	2.534	0.3946	0.848	0	5.078	0	2.004	0	2.004
7	1.134	0.419	1.182	0.9594	1.0423	0.118	1.882	0.113	1.806	2.704	0.3698	0.833	0.204	5.204	0.076	1.924	0.076	1.924
8	1.061	0.373	1.099	0.9650	1.0363	0.185	1.815	0.179	1.751	2.847	0.3512	0.820	0.388	5.306	0.136	1.864	0.136	1.864
9	1.000	0.337	1.032	0.9693	1.0317	0.239	1.761	0.232	1.707	2.970	0.3367	0.808	0.547	5.393	0.184	1.816	0.184	1.816
10	0.949	0.308	0.975	0.9727	1.0281	0.284	1.716	0.276	1.669	3.078	0.3249	0.797	0.687	5.469	0.223	1.777	0.223	1.777
11	0.905	0.285	0.927	0.9754	1.0252	0.321	1.679	0.313	1.637	3.173	0.3152	0.787	0.811	5.535	0.256	1.744	0.256	1.744
12	0.866	0.266	0.886	0.9776	1.0229	0.354	1.646	0.346	1.610	3.258	0.3069	0.778	0.922	5.594	0.283	1.717	0.283	1.717
13	0.832	0.249	0.850	0.9794	1.0210	0.382	1.618	0.374	1.585	3.336	0.2998	0.770	1.025	5.647	0.307	1.693	0.307	1.693
14	0.802	0.235	0.817	0.9810	1.0194	0.406	1.594	0.399	1.563	3.407	0.2935	0.763	1.118	5.696	0.328	1.672	0.328	1.672
15	0.775	0.223	0.789	0.9823	1.0180	0.428	1.572	0.421	1.544	3.472	0.2880	0.756	1.203	5.741	0.347	1.653	0.347	1.653
16	0.750	0.212	0.763	0.9835	1.0168	0.448	1.552	0.440	1.526	3.532	0.2831	0.750	1.282	5.782	0.363	1.637	0.363	1.637
17	0.728	0.203	0.739	0.9845	1.0157	0.466	1.534	0.458	1.511	3.588	0.2787	0.744	1.356	5.820	0.378	1.622	0.378	1.622
18	0.707	0.194	0.718	0.9854	1.0148	0.482	1.518	0.475	1.496	3.640	0.2747	0.739	1.424	5.856	0.391	1.608	0.391	1.608
19	0.688	0.187	0.698	0.9862	1.0140	0.497	1.503	0.490	1.483	3.689	0.2711	0.734	1.487	5.891	0.403	1.597	0.403	1.597
20	0.671	0.180	0.680	0.9869	1.0133	0.510	1.490	0.504	1.470	3.735	0.2677	0.729	1.549	5.921	0.415	1.585	0.415	1.585
21	0.655	0.173	0.663	0.9876	1.0126	0.523	1.477	0.516	1.459	3.778	0.2647	0.724	1.605	5.951	0.425	1.575	0.425	1.575
22	0.640	0.167	0.647	0.9882	1.0119	0.534	1.466	0.528	1.448	3.819	0.2618	0.720	1.659	5.979	0.434	1.566	0.434	1.566
23	0.626	0.162	0.633	0.9887	1.0114	0.545	1.455	0.539	1.438	3.858	0.2592	0.716	1.710	6.006	0.443	1.557	0.443	1.557
24	0.612	0.157	0.619	0.9892	1.0109	0.555	1.445	0.549	1.429	3.895	0.2567	0.712	1.759	6.031	0.451	1.548	0.451	1.548
25	0.600	0.153	0.606	0.9896	1.0105	0.565	1.435	0.559	1.420	3.931	0.2544	0.708	1.806	6.056	0.459	1.541	0.459	1.541

For n > 25

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

$$B_3 = 1 - \frac{3}{c_4 \sqrt{2(n-1)}}, \quad B_4 = 1 + \frac{3}{c_4 \sqrt{2(n-1)}}$$

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

Table 13-4 Sample Size Code Letters (MIL STD 105E, Table I)

Lot or Batch Size	Special Inspection Levels				General Inspection Levels		
	S-1	S-2	S-3	S-4	I	II	III
2 to 8	A	A	A	A	A	A	B
9 to 15	A	A	A	A	A	B	C
16 to 25	A	A	B	B	A	B	C
26 to 50	A	B	B	B	B	C	D
51 to 90	B	B	C	C	C	D	E
91 to 150	B	B	C	C	C	D	E
151 to 280	B	C	D	D	D	E	F
281 to 500	B	C	D	E	E	F	G
501 to 1200	C	C	E	F	F	G	H
1201 to 3200	C	D	E	F	G	H	J
3201 to 10000	C	D	F	G	H	J	K
100001 to 35000	C	D	F	H	J	K	L
35001 to 150000	D	E	G	J	K	L	M
500001 to 500000	D	E	G	J	L	N	P
500001 and over	D	E	H	K	M	P	Q



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
B	3	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
C	5	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
D	8	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
E	13	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
F	20	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
G	32	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
H	50	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
J	80	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
K	125	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
L	200	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
M	315	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
N	500	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
P	800	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
Q	1250	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
R	2000	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1

= 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.

Table 7-4 Sample Size and Critical Value Determination for Testing  
 $H_0: C_p = C_{p0}$

Sample Size, $n$	(a) $\alpha = \beta = 0.10$		(b) $\alpha = \beta = 0.05$	
	$C_p(\text{High})/$ $C_p(\text{Low})$	$C/C_p(\text{Low})$	$C_p(\text{High})/$ $C_p(\text{Low})$	$C/C_p(\text{Low})$
	10	1.88	1.27	2.26
20	1.53	1.20	1.73	1.26
30	1.41	1.16	1.55	1.21
40	1.34	1.14	1.46	1.18
50	1.30	1.13	1.40	1.16
60	1.27	1.11	1.36	1.15
70	1.25	1.10	1.33	1.14
80	1.23	1.10	1.30	1.13
90	1.21	1.10	1.28	1.12
100	1.20	1.09	1.26	1.11

Source: Adapted from Kane (1986), with permission of the American Society for Quality Control.