# National Exams May 2014

# 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 81/2"*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) Explain the role of QFD in the product design. Compare the concurrent engineering approach to the product and process design with the traditional approach. Which approach is preferable and why?

5 b) Describe the Taguchi's three stages in the product design. What objectives are typically considered in the parameter design stage? Explain briefly the inner and outer arrays, linear graphs, signal- to- noise ratios, and the graphs of marginal averages.

5 c) Compare the application of acceptance sampling and capability testing in quality assurance and explain which of these two quality assurance methods is preferable and why.

5 d) Explain why the Taguchi methods are controversial. What is EVOP, what is it used for, and how is it applied?

Question 2 (20 marks)

6 a) Explain the difference between the location diagram and the Pareto diagram and how these two basic SPC tools can be used in process improvement. Show examples.

7 b) Describe the situations where the traditional control charts are preferable to special control charts such as EWMA or CUSUM charts and show examples where the special charts are used. Should the nominal values be used to design the control charts? Why or why not?

7 c) What is a trend chart? Why two control charts are used for variables and only a single chart for attributes? Explain the difference between p-chart and u-chart. What is a demerit chart?

Question 3 (20 marks)

6 a) Consider an $\bar{X}$ chart. Explain the effect of the sample size on the control limits, OC function, and on the ARL. Why is an $\bar{X}$ chart more sensitive when the sample size increases?

7 b) The thickness of sheet metal (in millimeters) used for making automobile bodies is a characteristic of interest. Random samples of size 4 are taken every 20 minutes. After 20 samples, the summary information is:

$$\sum_{i=1}^{20} \bar{X}_i = 200 \qquad \sum_{i=1}^{20} S_i = 1.635$$

The specifications are: $9.95 \pm 0.3$mm.

Find the control limits for the $\bar{X}$ and S charts. Assuming the process to be in control, estimate the process mean and standard deviation. Estimate the proportion of the output which meets the specifications. Where should the process mean be located to maximize this proportion assuming that the process standard deviation remains unchanged?

7 c) To control future production, design an $\bar{X}$ chart satisfying the following requirement: when the process mean shifts from $\mu_0$ to $\mu_0 - 1.4\sigma$, ($\mu_0$ and $\sigma$ are the estimates of the in-control process parameters obtained in 3b)), we want the probability that the run length is at least 5 to be less than or equal to 0.2. Find the minimum sample size and calculate the control limits for this chart.

## Question 4 (20 marks)

5 a) Consider the process producing the metal sheets described in Question 3b). The sheet thickness specifications are: 9.95 $\pm$0.3mm. To perform capability study, a sample of size N=200 was taken from the in-control process and the sample mean and the sample standard deviations were calculated as: $\bar{X}$ =9.98, S=0.085. Estimate the capability indexes $C_p$ and $C_{pk}$ and find the natural tolerance limits for $\alpha$=0.01 and the confidence level 0.95. Comment on process capability.

7 b) Consider the data in 4a). Check the capability claim that $C_p$>1.05. Formulate and test the appropriate hypothesis at significance level 0.05. Would you accept the claim? You can use the approximate formula:

$$\chi^2_{\alpha,m} \doteq m(1-\frac{2}{9m}+Z_\alpha\sqrt{\frac{2}{9m}})^3$$

8 c) For the capability claim in 4b), calculate the probability of rejecting the claim when the true value of $C_p$=1.2.

## Question 5 (20 marks)

5 a) Explain the difference between p-chart and np-chart. Show the formulas for the mean and the standard deviation of the sample statistics plotted on both charts as well as the formulas for the calculation of the control limits for both charts.

7 b) The number of scratch marks for a particular piece of furniture is recorded for samples of size 20 inspection units (one inspection unit is defined as one piece of furniture). The data obtained from 25 samples are in the table below.

| Sample | No. of Scratch Marks | Sample | No. of Scratch Marks |
|---|---|---|---|
| 1 | 8 | 14 | 4 |
| 2 | 7 | 15 | 7 |
| 3 | 18 | 16 | 6 |

| | | | |
|---|---|---|---|
| 4 | 4 | 17 | 8 |
| 5 | 6 | 18 | 9 |
| 6 | 5 | 19 | 4 |
| 7 | 17 | 20 | 8 |
| 8 | 7 | 21 | 5 |
| 9 | 9 | 22 | 7 |
| 10 | 8 | 23 | 6 |
| 11 | 12 | 24 | 11 |
| 12 | 3 | 25 | 9 |
| 13 | 6 | | |

Construct the appropriate chart to control the process. Revise, if necessary. Estimate the expected number of scratches per piece of furniture when the process is in control.

8 c) To control future production, design an appropriate control chart satisfying the following requirements:

i. When the expected number of scratches per inspection unit shifts to 0.6, we want the probability of detecting this shift on the first or second sample following the shift to be at least 0.7.

ii. Simultaneously, the LCL should be positive.

Determine the sample size and the control limits. Use the in-control estimate of the process parameter obtained in 5b).

Question 6 (20 marks)

6 a) Discuss the advantages and disadvantages of 100% inspection and acceptance sampling. Which sampling plans used in industry control both producer's and consumer's risk? Explain the meaning of rectifying inspection, AQL, AOQL, and LTPD.

7 b) Describe briefly the main features of MIL-STD-105E. What kind of sampling plans are included in this standard? Explain the difference between MIL-STD-105E and the LTPD-based Dodge-Romig sampling plans.

7 c) Items are submitted for inspection in lots of 2,000. The required AQL is 0.5%. Consider normal inspection and general inspection level II. Find a single sampling plan using MIL-STD-105E. Calculate the producer's and consumer's risks for LQL=2%.

**Appendix VI** Factors for Constructing Variables Control Charts

| Observations in Sample, $n$ | Chart for Averages: Factors for Control Limits | | | Chart for Standard Deviations: Factors for Center Line | | Chart for Standard Deviations: Factors for Control Limits | | | | Chart for Ranges: Factors for Center Line | | Chart for Ranges: Factors for Control Limits | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $A$ | $A_2$ | $A_3$ | $c_4$ | $1/c_4$ | $B_3$ | $B_4$ | $B_5$ | $B_6$ | $d_2$ | $1/d_2$ | $d_3$ | $D_1$ | $D_2$ | $D_3$ | $D_4$ |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |

For $n > 25$

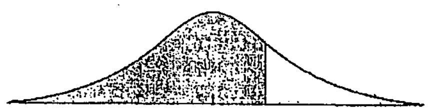
$$A = \frac{3}{\sqrt{n}}, \quad A_3 = \frac{3}{c_4\sqrt{n}}, \quad c_4 \cong \frac{4(n-1)}{4n-3},$$

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

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

## 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 |

**TABLE 10-33** AQL Conversion Table

| *For Specified AQL Values Falling Within These Ranges* | *Use This AQL Value* |
|---|---|
| — 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

| | *Inspection Levels* | | | | |
|---|---|---|---|---|---|
| | *Special* | | *General* | | |
| *Lot Size* | *S–3* | *S–4* | *I* | *II* | *III* |
| 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 | Sample size | 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Ac 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 |
| A | 2 | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | 0 1 | ↓ | ↓ | 1 2 | 2 3 | 3 4 | 5 6 | 7 8 | 10 11 | 14 15 | 21 22 | 30 31 |
| B | 3 | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | 0 1 | ↑ | ↓ | 1 2 | 2 3 | 3 4 | 5 6 | 7 8 | 10 11 | 14 15 | 21 22 | 30 31 | 44 45 |
| C | 5 | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | 0 1 | ↑ | ↓ | 1 2 | 2 3 | 3 4 | 5 6 | 7 8 | 10 11 | 14 15 | 21 22 | 30 31 | 44 45 | ↑ |
| D | 8 | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | 0 1 | ↑ | ↓ | 1 2 | 2 3 | 3 4 | 5 6 | 7 8 | 10 11 | 14 15 | 21 22 | 30 31 | 44 45 | ↑ | ↑ |
| E | 13 | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | 0 1 | ↑ | ↓ | 1 2 | 2 3 | 3 4 | 5 6 | 7 8 | 10 11 | 14 15 | 21 22 | 30 31 | 44 45 | ↑ | ↑ | ↑ |
| F | 20 | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | 0 1 | ↑ | ↓ | 1 2 | 2 3 | 3 4 | 5 6 | 7 8 | 10 11 | 14 15 | 21 22 | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ |
| G | 32 | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | 0 1 | ↑ | ↓ | 1 2 | 2 3 | 3 4 | 5 6 | 7 8 | 10 11 | 14 15 | 21 22 | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ |
| H | 50 | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | 0 1 | ↑ | ↓ | 1 2 | 2 3 | 3 4 | 5 6 | 7 8 | 10 11 | 14 15 | 21 22 | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ |
| J | 80 | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | 0 1 | ↑ | ↓ | 1 2 | 2 3 | 3 4 | 5 6 | 7 8 | 10 11 | 14 15 | 21 22 | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ |
| K | 125 | ↓ | ↓ | ↓ | ↓ | ↓ | 0 1 | ↑ | ↓ | 1 2 | 2 3 | 3 4 | 5 6 | 7 8 | 10 11 | 14 15 | 21 22 | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ |
| L | 200 | ↓ | ↓ | ↓ | ↓ | 0 1 | ↑ | ↓ | 1 2 | 2 3 | 3 4 | 5 6 | 7 8 | 10 11 | 14 15 | 21 22 | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ |
| M | 315 | ↓ | ↓ | ↓ | 0 1 | ↑ | ↓ | 1 2 | 2 3 | 3 4 | 5 6 | 7 8 | 10 11 | 14 15 | 21 22 | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ |
| N | 500 | ↓ | ↓ | 0 1 | ↑ | ↓ | 1 2 | 2 3 | 3 4 | 5 6 | 7 8 | 10 11 | 14 15 | 21 22 | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ |
| P | 800 | ↓ | 0 1 | ↑ | ↓ | 1 2 | 2 3 | 3 4 | 5 6 | 7 8 | 10 11 | 14 15 | 21 22 | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ |
| Q | 1250 | 0 1 | ↑ | ↓ | 1 2 | 2 3 | 3 4 | 5 6 | 7 8 | 10 11 | 14 15 | 21 22 | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ |
| R | 2000 | ↑ | ↑ | 1 2 | 2 3 | 3 4 | 5 6 | 7 8 | 10 11 | 14 15 | 21 22 | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ |

Acceptable Quality Levels (normal inspection)

↓ = 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.