

Appendix

Appendix

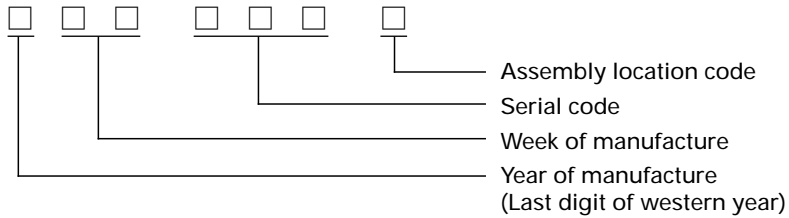
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1 Lot and Product Name Indications

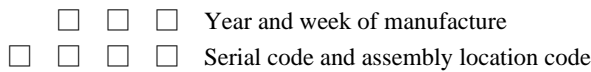
The lot and product name indications used for products manufactured by the Sony Semiconductor Network Company (Sony Semiconductor products) are as follows.

(1) Product Lot Indications (Traceability)

1. Full lot number indication

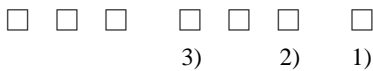


2. Divided indication



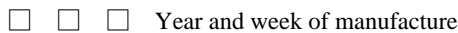
3. Lot indication omission order and abbreviated indication

When seven digits cannot be printed due to marking space limitations on products, the printed characters are omitted in the following order.



- 1) Assembly location code
- 2) One's digit of serial code
- 3) Serial code

Abbreviated indication

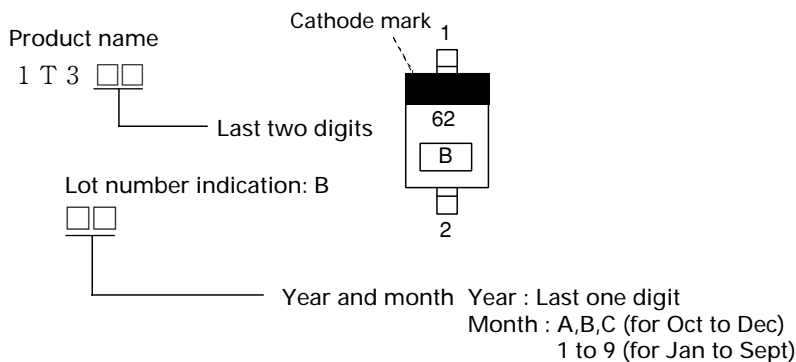


4. Marking on small products and lot indication on labels

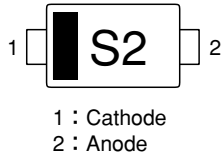
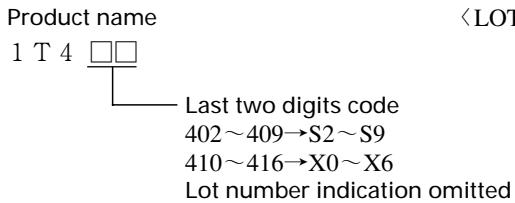
Indications are abbreviated on small diodes, discrete devices, laser diodes, laser couplers and other small products. In addition, some products may not display markings.

Examples of specific varicap indications on products and product shipping labels are shown below.

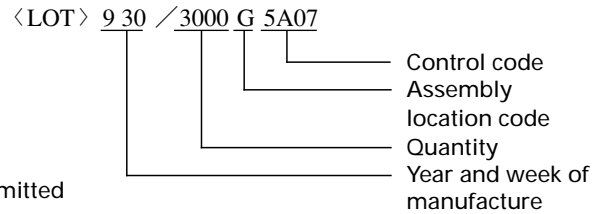
4-1 SMVC



4-2 S SVC



4-3 Label indication (example)

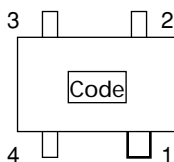


4-4 GaAs MES FET

4-4-1 Mini molded package

| Product name | Product name/modification code |
|--------------|--------------------------------|
| SGM2014AM | DA |
| SGM2016AM | MA |
| SGM2016AP | LA |
| 3SK165A | JA |
| 3SK166A | KA |

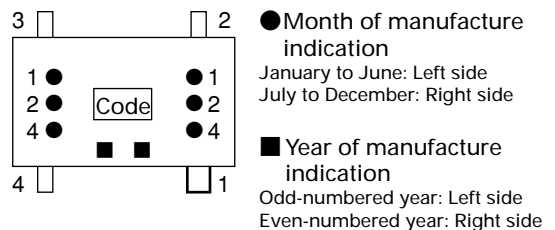
Marking method: Offset
(Laser marking introduced from 2000)
Indication method: Product name code only;
lot number not indicated
(See the figure below.)



4-4-2 Super-mini molded package

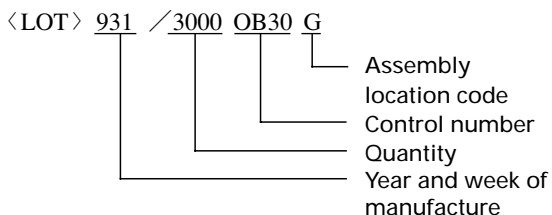
| Product name | Product name/modification code |
|--------------|--------------------------------|
| SGM2013N | A |
| SGM2014AN | DA |
| SGM2016AN | MA |

Marking method: Laser
Indication method: Product name code and
lot number
(See the figure below.)

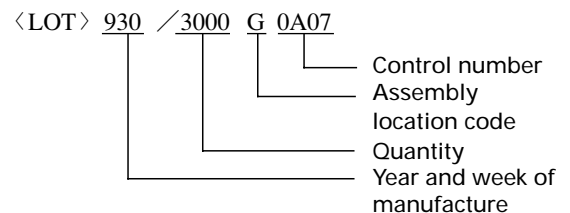


4-4-3 Label indications (example)

Mini molded package



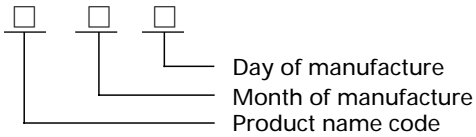
Super-mini molded package



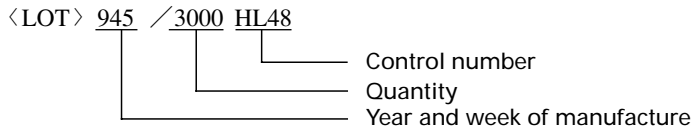
4-5 Small and large laser diodes

☆Indications are omitted on most small products.

When present, the indication is as follows.

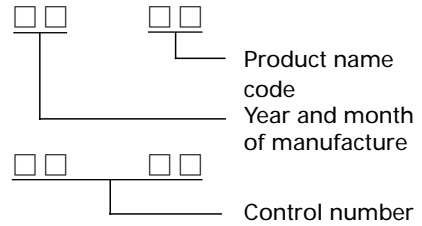


Label indication (example)
Small laser diode



4-6 Laser coupler

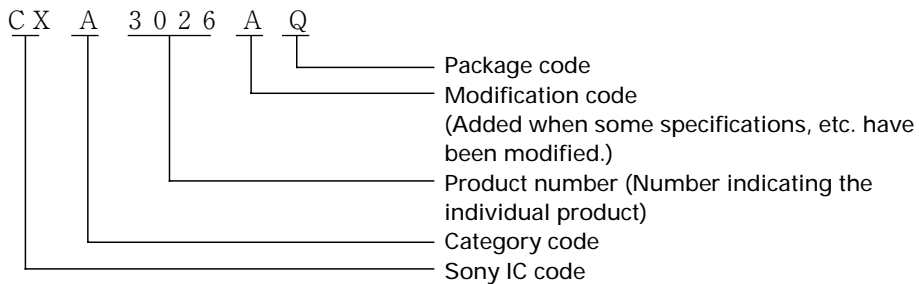
Indications are omitted on some products, but when present, the indication is as follows.



(2) Product Name Indications

1. IC

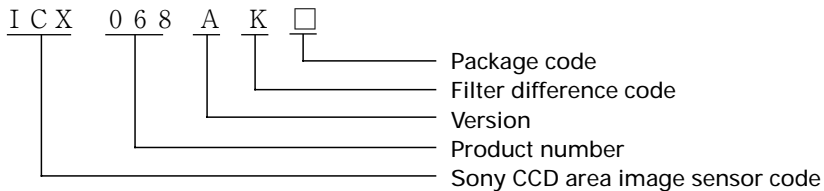
(Example)



2. CCD

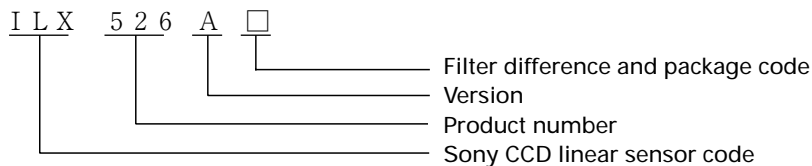
2-1 Area image sensor

(Example)



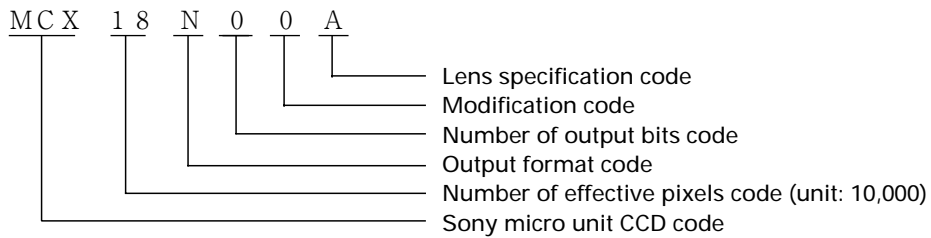
2-2 Linear sensor

(Example)



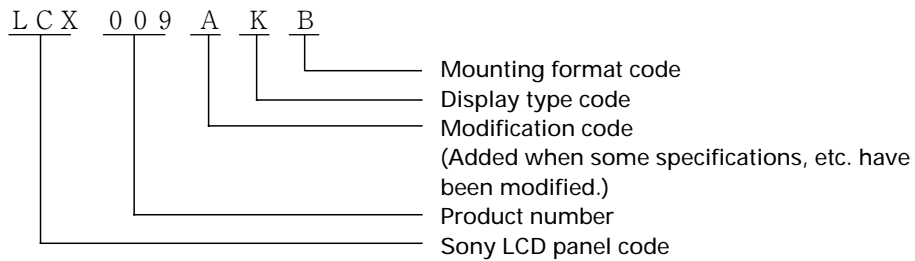
2-3 Micro unit CCD

(Example)



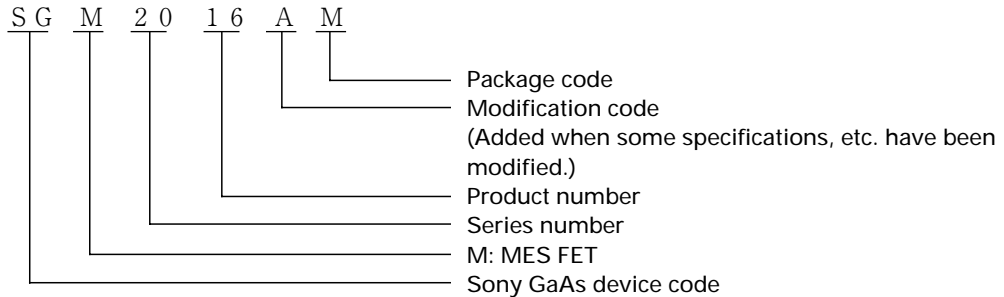
3. LCD

(Example)



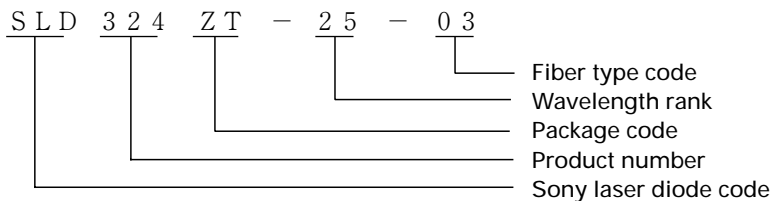
4. GaAs MES FET

(Example)

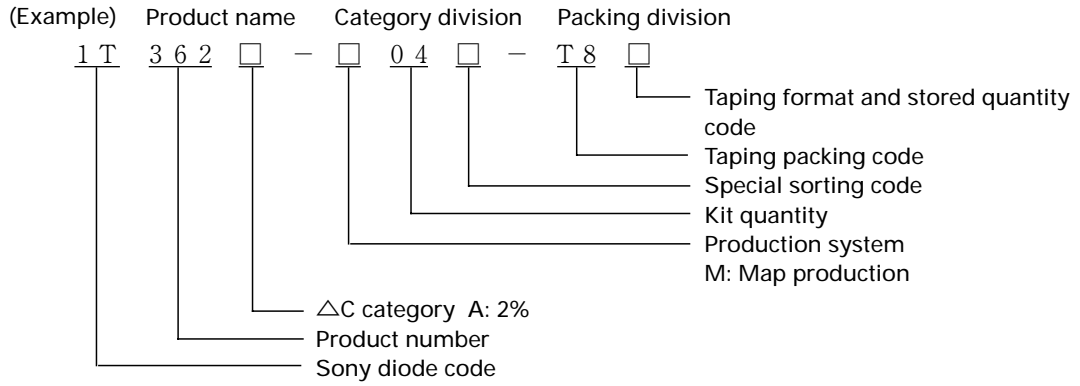


5. Laser diode

(Example)



6. Varicap (Varactor diode)



2 Sampling Inspections

Sampling inspections are used for shipping inspections, IPQC and other purposes.

Samples are taken from a lot and tested according to a predetermined sampling inspection plan, and these results are compared with lot judgment standards to judge whether that lot is accepted or rejected.

When n samples are taken at random from a lot having a defect rate of P , the probability $P(x)$ that x defective products are contained in this sample is expressed by the following equation.

$$P(x) = \frac{n!}{x!(n-x)!} P^x (1-P)^{n-x}$$

A simple description of sampling inspection by attributes is given below.

The extracted samples are inspected and divided into good and defective products, then these quantities are compared with the judgment number to judge whether that lot is accepted or rejected.

For example, the operating characteristic curve (OC curve) for a lot size $N = 1000$, a sample size $n = 20$ and an acceptance number $C = 1$ is shown in Fig. A-1.

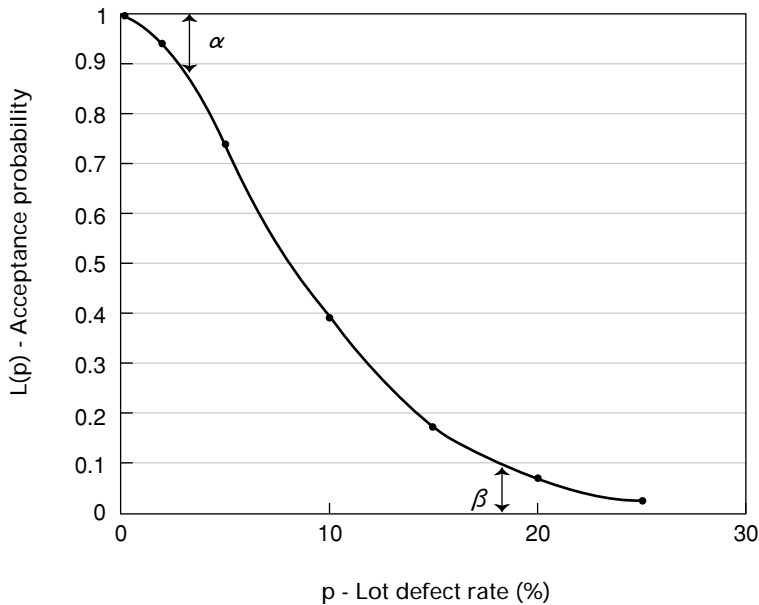


Fig. A-1 Operating Characteristic Curve

Fig. A-1 shows that when the lot defect rate is 10%, the probability $L(p)$ of that lot being accepted is approximately 40%.

Thus, even bad lots may be accepted.

This is a problem for consumers, so the probability that a lot having the same defect rate as the Lot Tolerance Percent Defective (LTPD) might be accepted (consumer risk β) is prescribed at 0.1 or less. Conversely, the probability that a good lot might incorrectly be rejected (producer risk α) is prescribed at 0.05 or less.

Acceptable Quality Level (AQL) refers to the process average upper limit which can be considered acceptable.

Based on the ANSI/ASQC Z1.4 (MIL-STD-105E) Table, when single sampling inspection is performed with AQL = 0.065%, a lot size of 4000, inspection level II and normal inspection, the sample character is L, the sample size is 200, Ac = 0, and Re = 1.

Therefore, when 200 samples are taken and inspected, the lot is accepted if there are three or less defects, or rejected if there are four or more defects. (Fig. A-2, Tables A-1, A-2, A-3, A-4, A-5)

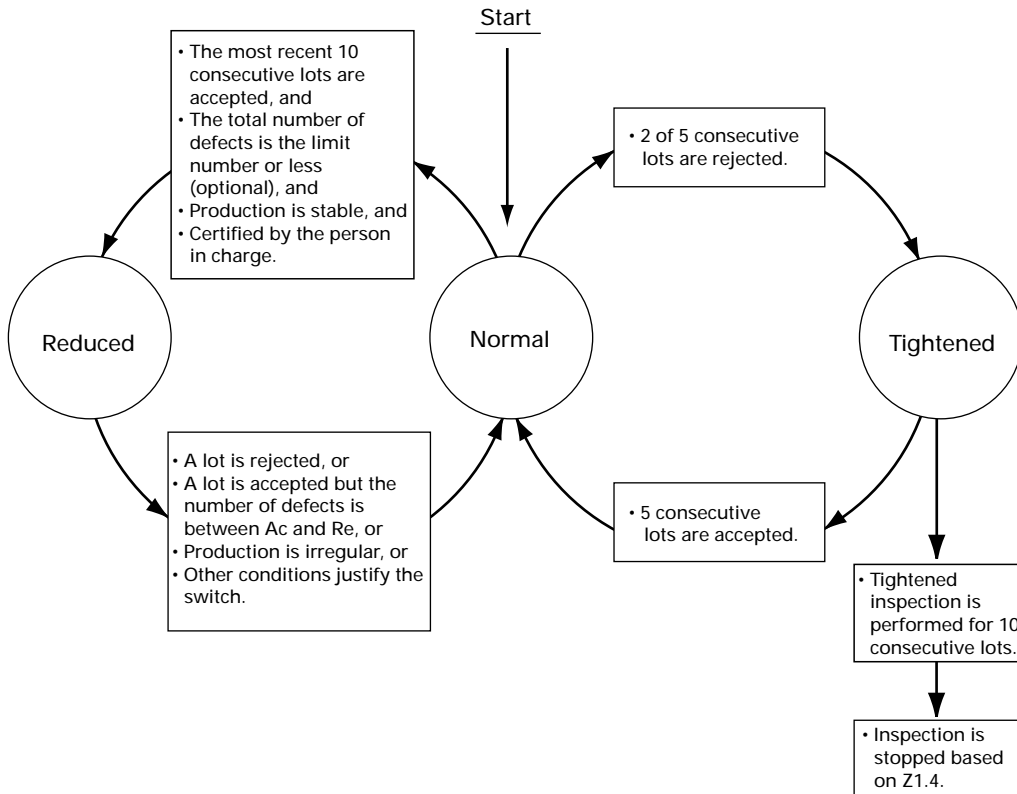


Fig. A-2 ANSI Z1.4 System Switching Rules

Table A-1 Sample Characters

| Lot size | Special inspection levels | | | | Normal inspection levels | | |
|-----------------|---------------------------|-----|-----|-----|--------------------------|----|-----|
| | S-1 | S-2 | S-3 | S-4 | I | II | III |
| 2 ~ 8 | A | A | A | A | A | A | B |
| 9 ~ 15 | A | A | A | A | A | B | C |
| 16 ~ 25 | A | A | B | B | B | C | D |
| 26 ~ 50 | A | B | B | C | C | D | E |
| 51 ~ 90 | B | B | C | C | C | E | F |
| 90 ~ 150 | B | B | C | D | D | F | G |
| 151 ~ 280 | B | C | D | E | E | G | H |
| 281 ~ 500 | B | C | D | E | F | H | J |
| 501 ~ 1200 | C | C | E | F | G | J | K |
| 1201 ~ 3200 | C | D | E | G | H | K | L |
| 3201 ~ 10000 | C | D | F | G | J | L | M |
| 10001 ~ 35000 | C | D | F | H | K | M | N |
| 35001 ~ 150000 | D | E | G | J | L | N | P |
| 150001 ~ 500000 | D | E | G | J | M | P | Q |
| 500001 ~ | D | E | H | K | N | Q | R |

ANSI / ASQC Z1.4

Table A-2 Normal Inspection Single Sampling Method (Main sampling table)

| Sample character | Sample size | AQL: Acceptable Quality Level (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 | | |
| | | Ac Re | Ac Re | Ac Re | Ac Re | Ac Re | Ac Re | Ac Re | Ac Re | Ac Re | Ac Re | Ac Re | Ac Re | Ac Re | Ac Re | Ac Re | Ac Re | 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 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| B | 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| C | 5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| D | 8 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| E | 13 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F | 20 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| G | 32 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| H | 50 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| J | 80 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| K | 125 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| L | 200 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| M | 315 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| N | 500 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| P | 800 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Q | 1250 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| R | 2000 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

ANSI / ASQC Z1.4

↓ = The first sampling plan below the arrow is used. If the sample size is larger than the lot size, the entire lot is inspected.

↑ = The first sampling plan above the arrow is used.

Ac = Acceptance number

Re = Rejection number

Table A-3 Tightened Inspection Single Sampling Method (Main sampling table)

| Sample character | Sample size | AQL: Acceptable Quality Level (Tightened 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 | | |
| | | Ac Re | Ac Re | Ac Re | Ac Re | Ac Re | Ac Re | Ac Re | Ac Re | Ac Re | Ac Re | Ac Re | Ac Re | Ac Re | Ac Re | Ac Re | 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 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| B | 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| C | 5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| D | 8 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| E | 13 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F | 20 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| G | 32 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| H | 50 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| J | 80 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| K | 125 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| L | 200 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| M | 315 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| N | 500 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| P | 800 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Q | 1250 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| R | 2000 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| S | 3150 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

ANSI / ASQC Z1.4

↓ = The first sampling plan below the arrow is used. If the sample size is larger than the lot size, the entire lot is inspected.
 ↑ = The first sampling plan above the arrow is used.
 Ac = Acceptance number
 Re = Rejection number

Table A-4 Reduced Inspection Single Sampling Method (Main sampling table)

| Sample character | Sample size | AQL: Acceptable Quality Level (Reduced 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 | | |
| | | Ac Re | Ac Re | Ac Re | Ac Re | Ac Re | Ac Re | Ac Re | Ac Re | Ac Re | Ac Re | Ac Re | Ac Re | Ac Re | Ac Re | Ac Re | 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 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| B | 2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| C | 2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| D | 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| E | 5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| F | 8 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| G | 13 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| H | 20 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| J | 32 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| K | 50 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| L | 80 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| M | 125 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| N | 200 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| P | 315 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Q | 500 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| R | 800 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

ANSI / ASQC Z1.4

↓ = The first sampling plan below the arrow is used. If the sample size is larger than the lot size, the entire lot is inspected.
 ↑ = The first sampling plan above the arrow is used.
 Ac = Acceptance number
 Re = Rejection number
 † = If the number of defects exceeds the acceptance number but does not reach the rejection number, that lot is accepted, but the inspection system returns to normal inspection from the next lot.

Table A-5 MIL-S-19500 Sampling Inspection Table

Confidence level 90%

| Max. Percent Defective (LTPD) or λ | Minimum Sample Sizes | | | | | | | | | | | | | | | | |
|--|----------------------|---------------|---------------|---------------|---------------|---------------|---------------|----------------|----------------|-----------------|-----------------|-----------------|-----------------|------------------|------------------|------------------|------------------|
| | 50 | 30 | 20 | 15 | 10 | 7 | 5 | 3 | 2 | 1.5 | 1 | 0.7 | 0.5 | 0.3 | 0.2 | 0.15 | 0.1 |
| 0 | 5 (1.03) | 8 (0.64) | 11 (0.46) | 15 (0.34) | 22 (0.23) | 32 (0.16) | 45 (0.11) | 76 (0.07) | 116 (0.04) | 153 (0.03) | 231 (0.02) | 328 (0.02) | 461 (0.01) | 767 (0.007) | 1152 (0.005) | 1534 (0.003) | 2303 (0.002) |
| 1 | 8 (4.4) | 13 (2.7) | 18 (2.0) | 25 (1.4) | 38 (0.94) | 55 (0.65) | 77 (0.46) | 129 (0.28) | 195 (0.18) | 258 (0.14) | 390 (0.09) | 565 (0.06) | 778 (0.045) | 1290 (0.027) | 1946 (0.018) | 2592 (0.013) | 3891 (0.009) |
| 2 | 11 (7.4) | 18 (4.5) | 25 (3.4) | 34 (2.24) | 52 (1.6) | 75 (1.1) | 105 (0.78) | 176 (0.47) | 266 (0.31) | 354 (0.23) | 533 (0.15) | 759 (0.11) | 1065 (0.080) | 1773 (0.045) | 2662 (0.031) | 3547 (0.022) | 5323 (0.015) |
| 3 | 13 (10.5) | 22 (6.2) | 32 (4.4) | 43 (3.2) | 65 (2.1) | 94 (1.5) | 132 (1.0) | 221 (0.62) | 333 (0.41) | 444 (0.31) | 668 (0.20) | 953 (0.14) | 1337 (0.10) | 2226 (0.062) | 3341 (0.031) | 4452 (0.031) | 6681 (0.018) |
| 4 | 16 (12.3) | 27 (7.43) | 38 (5.0) | 52 (3.9) | 78 (2.6) | 113 (1.8) | 158 (1.3) | 265 (0.75) | 398 (0.50) | 531 (0.37) | 798 (0.25) | 1140 (0.17) | 1599 (0.12) | 2663 (0.074) | 3997 (0.040) | 5327 (0.037) | 7994 (0.025) |
| 5 | 19 (13.8) | 31 (8.3) | 45 (6.0) | 60 (4.4) | 91 (2.9) | 131 (2.0) | 184 (1.4) | 308 (0.85) | 462 (0.57) | 617 (0.42) | 927 (0.28) | 1323 (0.20) | 1855 (0.14) | 3090 (0.085) | 4638 (0.056) | 6181 (0.042) | 9275 (0.028) |
| 6 | 21 (15.6) | 35 (9.4) | 51 (6.6) | 68 (4.9) | 104 (3.2) | 149 (2.2) | 209 (1.6) | 349 (0.94) | 528 (0.62) | 700 (0.47) | 1054 (0.31) | 1503 (0.22) | 2107 (0.155) | 3509 (0.093) | 5267 (0.062) | 7019 (0.047) | 10533 (0.031) |
| 7 | 24 (16.6) | 39 (10.2) | 57 (7.2) | 77 (5.3) | 116 (3.5) | 166 (2.4) | 234 (1.7) | 390 (1.1) | 567 (0.67) | 783 (0.51) | 1178 (0.34) | 1680 (0.24) | 2355 (0.17) | 3922 (0.101) | 5886 (0.067) | 7845 (0.051) | 11771 (0.034) |
| 8 | 26 (18.1) | 43 (10.9) | 63 (7.7) | 85 (5.6) | 128 (3.7) | 184 (2.6) | 258 (1.8) | 431 (1.1) | 648 (0.72) | 864 (0.54) | 1300 (0.36) | 1854 (0.25) | 2599 (0.18) | 4329 (0.108) | 6498 (0.072) | 8660 (0.054) | 12995 (0.036) |
| 9 | 28 (19.4) | 47 (11.5) | 69 (8.1) | 93 (6.0) | 140 (3.9) | 201 (2.7) | 282 (1.9) | 471 (1.2) | 709 (0.77) | 945 (0.58) | 1421 (0.38) | 2027 (0.27) | 2842 (0.19) | 4733 (0.114) | 7103 (0.077) | 9468 (0.065) | 14206 (0.038) |
| 10 | 31 (19.9) | 51 (12.1) | 75 (8.4) | 100 (6.3) | 152 (4.1) | 218 (2.9) | 306 (2.0) | 511 (1.2) | 770 (0.80) | 1025 (0.60) | 1541 (0.42) | 2199 (0.28) | 3082 (0.20) | 5133 (0.120) | 7704 (0.080) | 10268 (0.060) | 15407 (0.040) |
| 11 | 33 (21.0) | 54 (12.8) | 83 (8.3) | 111 (6.2) | 166 (4.2) | 238 (2.9) | 332 (2.1) | 555 (1.2) | 832 (0.83) | 1109 (0.62) | 1604 (0.42) | 2378 (0.29) | 3323 (0.21) | 5546 (0.12) | 8319 (0.083) | 11092 (0.062) | 15638 (0.042) |
| 12 | 36 (21.4) | 59 (13.0) | 89 (8.6) | 119 (6.5) | 178 (4.3) | 254 (3.0) | 356 (2.2) | 594 (1.3) | 890 (0.86) | 1187 (0.65) | 1781 (0.43) | 2544 (0.3) | 3562 (0.22) | 5936 (0.13) | 8904 (0.089) | 11872 (0.065) | 17808 (0.043) |
| 13 | 38 (22.3) | 63 (13.4) | 95 (8.9) | 126 (6.7) | 190 (4.5) | 271 (3.1) | 379 (2.26) | 632 (1.3) | 948 (0.89) | 1264 (0.67) | 1896 (0.44) | 2709 (0.31) | 3793 (0.22) | 6321 (0.134) | 9482 (0.089) | 12643 (0.067) | 18964 (0.045) |
| 14 | 40 (23.1) | 67 (13.8) | 101 (9.2) | 134 (6.9) | 201 (4.6) | 288 (3.2) | 404 (2.3) | 672 (1.4) | 1007 (0.92) | 1343 (0.69) | 2015 (0.46) | 2878 (0.32) | 4029 (0.23) | 6716 (0.138) | 10073 (0.092) | 13431 (0.069) | 20146 (0.046) |
| 15 | 43 (23.3) | 71 (14.1) | 107 (9.4) | 142 (7.1) | 213 (4.7) | 305 (3.3) | 426 (2.36) | 711 (1.41) | 1066 (0.94) | 1422 (0.71) | 2133 (0.47) | 3046 (0.33) | 4265 (0.235) | 7108 (0.141) | 10662 (0.094) | 14216 (0.070) | 21324 (0.047) |
| 16 | 45 (24.1) | 74 (14.6) | 112 (9.7) | 150 (7.2) | 225 (4.8) | 321 (3.37) | 450 (2.41) | 750 (1.44) | 1124 (0.96) | 1499 (0.72) | 2249 (0.48) | 3212 (0.344) | 4497 (0.241) | 7496 (0.144) | 11244 (0.096) | 14992 (0.072) | 22487 (0.048) |
| 17 | 47 (24.7) | 79 (14.7) | 118 (9.86) | 158 (7.36) | 236 (4.93) | 338 (3.44) | 473 (2.46) | 788 (1.48) | 1182 (0.98) | 1576 (0.74) | 2364 (0.49) | 3377 (0.344) | 4728 (0.246) | 7880 (0.148) | 11819 (0.098) | 15759 (0.074) | 23630 (0.049) |
| 18 | 50 (24.9) | 83 (15.0) | 124 (10.0) | 165 (7.54) | 248 (5.02) | 354 (3.51) | 496 (2.51) | 826 (1.51) | 1239 (1.0) | 1652 (0.75) | 2478 (0.50) | 3540 (0.351) | 4956 (0.251) | 8200 (0.151) | 12390 (0.100) | 16520 (0.075) | 24780 (0.050) |
| 19 | 52 (25.5) | 86 (15.4) | 130 (10.2) | 173 (7.76) | 259 (5.12) | 370 (3.58) | 518 (2.56) | 864 (1.53) | 1296 (1.02) | 1728 (0.77) | 2591 (0.52) | 3702 (0.358) | 5183 (0.256) | 8638 (0.153) | 12957 (0.102) | 17276 (0.077) | 25914 (0.051) |
| 20 | 54 (26.1) | 90 (15.4) | 135 (10.4) | 180 (7.82) | 271 (5.19) | 386 (3.65) | 541 (2.60) | 902 (1.56) | 1353 (1.04) | 1803 (0.78) | 2705 (0.52) | 3864 (0.364) | 5410 (0.260) | 9017 (0.156) | 13526 (0.104) | 18034 (0.078) | 27061 (0.052) |
| 25 | 65 (27.0) | 109 (16.1) | 163 (10.8) | 217 (8.08) | 326 (5.38) | 466 (3.76) | 652 (2.69) | 1086 (1.61) | 1629 (1.08) | 2173 (0.807) | 3259 (0.538) | 4656 (0.376) | 6518 (0.269) | 10863 (0.161) | 16295 (0.108) | 21726 (0.081) | 32589 (0.054) |

3 Saturated Vapor Pressure Table

Table A-6 Saturated Water Vapor Pressure

1/4

Unit: Pa

| t/°C | 0.0 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 |
|------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| 0. | 611.21 | 615.67 | 620.15 | 624.67 | 629.21 | 633.78 | 638.38 | 643.01 | 647.67 | 652.36 |
| 1. | 657.08 | 661.83 | 666.61 | 671.42 | 676.26 | 681.14 | 686.04 | 690.98 | 695.94 | 700.94 |
| 2. | 705.97 | 711.03 | 716.13 | 721.26 | 726.41 | 731.61 | 736.83 | 742.09 | 747.38 | 752.70 |
| 3. | 758.06 | 763.45 | 768.88 | 774.34 | 779.83 | 785.36 | 790.92 | 796.52 | 802.15 | 807.82 |
| 4. | 813.52 | 819.26 | 825.03 | 830.84 | 836.69 | 842.57 | 848.49 | 854.45 | 860.44 | 866.47 |
| 5. | 872.54 | 878.64 | 884.79 | 890.97 | 897.19 | 903.44 | 909.74 | 916.07 | 922.45 | 928.86 |
| 6. | 935.31 | 941.80 | 948.34 | 954.91 | 961.52 | 968.17 | 974.86 | 981.60 | 988.37 | 995.19 |
| 7. | 1002.0 | 1008.9 | 1015.9 | 1022.9 | 1029.9 | 1037.0 | 1044.1 | 1051.2 | 1058.4 | 1065.7 |
| 8. | 1072.9 | 1080.3 | 1087.6 | 1095.1 | 1102.5 | 1110.0 | 1117.6 | 1125.2 | 1132.8 | 1140.5 |
| 9. | 1148.2 | 1156.0 | 1163.8 | 1171.7 | 1179.6 | 1187.6 | 1195.6 | 1203.7 | 1211.8 | 1219.9 |
| 10. | 1228.1 | 1236.4 | 1244.7 | 1253.0 | 1261.4 | 1269.9 | 1278.4 | 1286.9 | 1295.5 | 1304.2 |
| 11. | 1312.9 | 1321.7 | 1330.5 | 1339.3 | 1348.2 | 1357.2 | 1366.2 | 1375.3 | 1384.4 | 1393.5 |
| 12. | 1402.8 | 1412.1 | 1421.4 | 1430.8 | 1440.2 | 1449.7 | 1459.3 | 1468.9 | 1478.5 | 1488.2 |
| 13. | 1498.0 | 1507.8 | 1517.7 | 1527.7 | 1537.7 | 1547.7 | 1557.9 | 1568.0 | 1578.3 | 1588.6 |
| 14. | 1598.9 | 1609.3 | 1619.8 | 1630.3 | 1640.9 | 1651.6 | 1662.3 | 1673.0 | 1683.9 | 1694.8 |
| 15. | 1705.7 | 1716.7 | 1727.8 | 1739.0 | 1750.2 | 1761.4 | 1772.8 | 1784.2 | 1795.6 | 1807.1 |
| 16. | 1818.7 | 1830.4 | 1842.1 | 1853.9 | 1865.8 | 1877.7 | 1889.7 | 1901.7 | 1913.8 | 1926.0 |
| 17. | 1938.3 | 1950.6 | 1963.0 | 1975.5 | 1988.0 | 2000.6 | 2013.3 | 2026.0 | 2038.8 | 2051.7 |
| 18. | 2064.7 | 2077.7 | 2090.8 | 2104.0 | 2117.2 | 2130.5 | 2143.9 | 2157.4 | 2170.9 | 2184.5 |
| 19. | 2198.2 | 2212.0 | 2225.8 | 2239.7 | 2253.7 | 2267.8 | 2281.9 | 2296.1 | 2310.4 | 2324.8 |
| 20. | 2339.2 | 2353.8 | 2368.4 | 2383.1 | 2397.8 | 2412.7 | 2427.6 | 2442.6 | 2457.7 | 2472.9 |
| 21. | 2488.2 | 2503.5 | 2518.9 | 2534.4 | 2550.0 | 2565.7 | 2581.4 | 2597.3 | 2613.2 | 2629.2 |
| 22. | 2645.3 | 2661.5 | 2677.7 | 2694.1 | 2710.5 | 2727.1 | 2743.7 | 2760.4 | 2777.2 | 2794.1 |
| 23. | 2811.0 | 2828.1 | 2845.2 | 2862.5 | 2879.8 | 2897.2 | 2914.8 | 2932.4 | 2950.1 | 2967.9 |
| 24. | 2985.8 | 3003.7 | 3021.8 | 3040.0 | 3058.3 | 3076.6 | 3095.1 | 3113.6 | 3132.3 | 3151.1 |
| 25. | 3169.9 | 3188.9 | 3207.9 | 3227.0 | 3246.3 | 3265.6 | 3285.1 | 3304.6 | 3324.3 | 3344.0 |
| 26. | 3363.9 | 3383.8 | 3403.9 | 3424.0 | 3444.3 | 3464.7 | 3485.2 | 3505.7 | 3526.4 | 3547.2 |
| 27. | 3568.1 | 3589.1 | 3610.2 | 3631.5 | 3652.8 | 3674.2 | 3695.8 | 3717.4 | 3739.2 | 3761.1 |
| 28. | 3783.1 | 3805.2 | 3827.4 | 3849.7 | 3872.2 | 3894.7 | 3917.4 | 3940.2 | 3963.1 | 3986.1 |
| 29. | 4009.2 | 4032.5 | 4055.8 | 4079.3 | 4102.9 | 4126.6 | 4150.5 | 4174.4 | 4198.5 | 4222.7 |
| 30. | 4247.0 | 4271.5 | 4296.0 | 4320.7 | 4345.5 | 4370.5 | 4395.5 | 4420.7 | 4446.0 | 4471.5 |
| 31. | 4497.0 | 4522.7 | 4548.5 | 4574.5 | 4600.5 | 4626.7 | 4653.1 | 4679.5 | 4706.1 | 4732.8 |
| 32. | 4759.7 | 4786.7 | 4813.8 | 4841.0 | 4868.4 | 4895.9 | 4923.6 | 4951.4 | 4979.3 | 5007.4 |
| 33. | 5035.6 | 5063.9 | 5092.4 | 5121.0 | 5149.7 | 5178.6 | 5207.7 | 5236.8 | 5266.2 | 5295.6 |
| 34. | 5325.2 | 5355.0 | 5384.8 | 5414.9 | 5445.1 | 5475.4 | 5505.9 | 5536.5 | 5567.2 | 5598.1 |
| 35. | 5629.2 | 5660.4 | 5691.8 | 5723.3 | 5754.9 | 5786.8 | 5818.7 | 5850.8 | 5883.1 | 5915.5 |
| 36. | 5948.1 | 5980.8 | 6013.7 | 6046.8 | 6080.0 | 6113.3 | 6146.9 | 6180.5 | 6214.4 | 6248.4 |
| 37. | 6282.5 | 6316.9 | 6351.3 | 6386.0 | 6420.8 | 6455.8 | 6490.9 | 6526.2 | 6561.7 | 6597.3 |
| 38. | 6633.1 | 6669.1 | 6705.2 | 6741.5 | 6778.0 | 6814.7 | 6851.5 | 6888.5 | 6925.6 | 6963.0 |
| 39. | 7000.5 | 7038.2 | 7076.0 | 7114.1 | 7152.3 | 7190.7 | 7229.2 | 7268.0 | 7306.9 | 7346.0 |
| 40. | 7385.3 | 7424.8 | 7464.4 | 7504.2 | 7544.3 | 7584.5 | 7624.8 | 7665.4 | 7706.2 | 7747.1 |
| 41. | 7788.2 | 7829.6 | 7871.1 | 7912.8 | 7954.6 | 7996.7 | 8039.0 | 8081.5 | 8124.1 | 8167.0 |
| 42. | 8210.0 | 8253.2 | 8296.7 | 8340.3 | 8384.1 | 8428.2 | 8472.4 | 8516.8 | 8561.5 | 8606.3 |
| 43. | 8651.3 | 8696.5 | 8742.0 | 8787.6 | 8833.5 | 8879.5 | 8925.8 | 8972.3 | 9018.9 | 9065.8 |
| 44. | 9112.9 | 9160.2 | 9207.7 | 9255.5 | 9303.4 | 9351.6 | 9399.9 | 9448.5 | 9497.3 | 9546.3 |
| 45. | 9595.6 | 9645.0 | 9694.7 | 9744.6 | 9794.7 | 9845.0 | 9895.6 | 9946.4 | 9997.4 | 10049. |
| 46. | 10100. | 10152. | 10204. | 10256. | 10308. | 10361. | 10414. | 10467. | 10520. | 10573. |
| 47. | 10627. | 10681. | 10735. | 10790. | 10845. | 10899. | 10955. | 11010. | 11066. | 11122. |
| 48. | 11178. | 11234. | 11291. | 11348. | 11405. | 11462. | 11520. | 11578. | 11636. | 11694. |
| 49. | 11753. | 11812. | 11871. | 11930. | 11990. | 12049. | 12110. | 12170. | 12231. | 12292. |
| 50. | 12353. | 12414. | 12476. | 12538. | 12600. | 12663. | 12725. | 12788. | 12852. | 12915. |

Remarks: From SONNTAG (1990). The temperature scale is ITS-90.

Table A-6 Saturated Water Vapor Pressure

2/4

Unit: Pa

| t/°C | 0.0 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 |
|------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| 51. | 12979. | 13043. | 13107. | 13172. | 13237. | 13302. | 13368. | 13433. | 13499. | 13566. |
| 52. | 13632. | 13699. | 13766. | 13833. | 13901. | 13969. | 14037. | 14106. | 14175. | 14244. |
| 53. | 14313. | 14383. | 14453. | 14523. | 14594. | 14665. | 14736. | 14807. | 14879. | 14951. |
| 54. | 15023. | 15096. | 15169. | 15242. | 15316. | 15389. | 15464. | 15538. | 15613. | 15688. |
| 55. | 15763. | 15839. | 15915. | 15991. | 16068. | 16145. | 16222. | 16299. | 16377. | 16455. |
| 56. | 16534. | 16613. | 16692. | 16771. | 16851. | 16931. | 17012. | 17093. | 17174. | 17255. |
| 57. | 17337. | 17419. | 17501. | 17584. | 17667. | 17750. | 17834. | 17918. | 18003. | 18087. |
| 58. | 18173. | 18258. | 18344. | 18430. | 18516. | 18603. | 18690. | 18778. | 18866. | 18954. |
| 59. | 19043. | 19131. | 19221. | 19310. | 19400. | 19491. | 19581. | 19672. | 19764. | 19856. |
| 60. | 19948. | 20040. | 20133. | 20226. | 20320. | 20414. | 20508. | 20603. | 20698. | 20793. |
| 61. | 20889. | 20985. | 21082. | 21179. | 21276. | 21374. | 21472. | 21571. | 21669. | 21769. |
| 62. | 21868. | 21968. | 22069. | 22170. | 22271. | 22372. | 22474. | 22577. | 22679. | 22783. |
| 63. | 22886. | 22990. | 23094. | 23199. | 23304. | 23410. | 23516. | 23622. | 23729. | 23836. |
| 64. | 23944. | 24052. | 24160. | 24269. | 24379. | 24488. | 24598. | 24709. | 24820. | 24931. |
| 65. | 25043. | 25155. | 25268. | 25381. | 25494. | 25608. | 25723. | 25837. | 25953. | 26068. |
| 66. | 26184. | 26301. | 26418. | 26535. | 26653. | 26772. | 26890. | 27010. | 27129. | 27249. |
| 67. | 27370. | 27491. | 27612. | 27734. | 27857. | 27979. | 28103. | 28226. | 28351. | 28475. |
| 68. | 28600. | 28726. | 28852. | 28979. | 29106. | 29233. | 29361. | 29489. | 29618. | 29748. |
| 69. | 29877. | 30008. | 30138. | 30270. | 30402. | 30534. | 30667. | 30800. | 30933. | 31068. |
| 70. | 31202. | 31338. | 31473. | 31609. | 31746. | 31883. | 32021. | 32159. | 32298. | 32437. |
| 71. | 32577. | 32717. | 32858. | 32999. | 33140. | 33283. | 33425. | 33569. | 33713. | 33857. |
| 72. | 34002. | 34147. | 34293. | 34439. | 34586. | 34734. | 34882. | 35030. | 35179. | 35329. |
| 73. | 35479. | 35630. | 35781. | 35933. | 36085. | 36238. | 36391. | 36545. | 36700. | 36855. |
| 74. | 37010. | 37166. | 37323. | 37480. | 37638. | 37796. | 37955. | 38115. | 38275. | 38436. |
| 75. | 38597. | 38758. | 38921. | 39084. | 39247. | 39411. | 39576. | 39741. | 39907. | 40073. |
| 76. | 40240. | 40408. | 40576. | 40744. | 40914. | 41084. | 41254. | 41425. | 41597. | 41769. |
| 77. | 41942. | 42116. | 42290. | 42464. | 42640. | 42815. | 42992. | 43169. | 43347. | 43525. |
| 78. | 43704. | 43884. | 44064. | 44245. | 44426. | 44608. | 44791. | 44974. | 45158. | 45343. |
| 79. | 45528. | 45714. | 45900. | 46088. | 46275. | 46464. | 46653. | 46843. | 47033. | 47224. |
| 80. | 47416. | 47608. | 47801. | 47994. | 48189. | 48384. | 48579. | 48776. | 48972. | 49170. |
| 81. | 49368. | 49567. | 49767. | 49967. | 50168. | 50370. | 50572. | 50775. | 50979. | 51183. |
| 82. | 51388. | 51594. | 51800. | 52007. | 52215. | 52424. | 52633. | 52843. | 53053. | 53265. |
| 83. | 53477. | 53689. | 53903. | 54117. | 54332. | 54547. | 54764. | 54981. | 55198. | 55417. |
| 84. | 55636. | 55856. | 56076. | 56298. | 56520. | 56743. | 56966. | 57190. | 57415. | 57641. |
| 85. | 57868. | 58095. | 58323. | 58552. | 58781. | 59011. | 59242. | 59474. | 59707. | 59940. |
| 86. | 60174. | 60409. | 60644. | 60881. | 61118. | 61356. | 61594. | 61834. | 62074. | 62315. |
| 87. | 62557. | 62799. | 63042. | 63286. | 63531. | 63777. | 64024. | 64271. | 64519. | 64768. |
| 88. | 65017. | 65268. | 65519. | 65771. | 66024. | 66278. | 66532. | 66788. | 67044. | 67301. |
| 89. | 67559. | 67817. | 68077. | 68337. | 68598. | 68860. | 69123. | 69386. | 69651. | 69916. |
| 90. | 70182. | 70449. | 70717. | 70986. | 71255. | 71526. | 71797. | 72069. | 72342. | 72616. |
| 91. | 72890. | 73166. | 73442. | 73719. | 73998. | 74277. | 74556. | 74837. | 75119. | 75401. |
| 92. | 75685. | 75969. | 76254. | 76540. | 76827. | 77115. | 77404. | 77693. | 77984. | 78276. |
| 93. | 78568. | 78861. | 79155. | 79450. | 79746. | 80043. | 80341. | 80640. | 80940. | 81240. |
| 94. | 81542. | 81844. | 82148. | 82452. | 82757. | 83064. | 83371. | 83679. | 83988. | 84298. |
| 95. | 84609. | 84921. | 85234. | 85547. | 85862. | 86178. | 86495. | 86812. | 87131. | 87451. |
| 96. | 87771. | 88093. | 88415. | 88739. | 89063. | 89389. | 89715. | 90043. | 90371. | 90701. |
| 97. | 91031. | 91362. | 91695. | 92028. | 92363. | 92698. | 93035. | 93372. | 93711. | 94050. |
| 98. | 94391. | 94732. | 95075. | 95418. | 95763. | 96109. | 96455. | 96803. | 97152. | 97502. |
| 99. | 97853. | 98204. | 98557. | 98911. | 99266. | 99623. | 99980. | 100338. | 100697. | 101058. |
| 100. | 101419. | 101782. | 102145. | 102510. | 102875. | 103242. | 103610. | 103979. | 104349. | 104720. |

Remarks: From SONNTAG (1990). The temperature scale is ITS-90.

Table A-6 Saturated Water Vapor Pressure

Unit: kPa

| t/°C | 0.0 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 |
|------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 100. | 101.4 | 101.8 | 102.1 | 102.5 | 102.9 | 103.2 | 103.6 | 104.0 | 104.3 | 104.7 |
| 101. | 105.1 | 105.5 | 105.8 | 106.2 | 106.6 | 107.0 | 107.3 | 107.7 | 108.1 | 108.5 |
| 102. | 108.9 | 109.3 | 109.6 | 110.0 | 110.4 | 110.8 | 111.2 | 111.6 | 112.0 | 112.4 |
| 103. | 112.8 | 113.2 | 113.6 | 114.0 | 114.4 | 114.8 | 115.2 | 115.6 | 116.0 | 116.4 |
| 104. | 116.8 | 117.2 | 117.6 | 118.0 | 118.4 | 118.8 | 119.2 | 119.7 | 120.1 | 120.5 |
| 105. | 120.9 | 121.3 | 121.7 | 122.2 | 122.6 | 123.0 | 123.4 | 123.9 | 124.3 | 124.7 |
| 106. | 125.1 | 125.6 | 126.0 | 126.4 | 126.9 | 127.3 | 127.8 | 128.2 | 128.6 | 129.1 |
| 107. | 129.5 | 130.0 | 130.4 | 130.8 | 131.3 | 131.7 | 132.2 | 132.6 | 133.1 | 133.6 |
| 108. | 134.0 | 134.5 | 134.9 | 135.4 | 135.8 | 136.3 | 136.8 | 137.2 | 137.7 | 138.2 |
| 109. | 138.6 | 139.1 | 139.6 | 140.0 | 140.5 | 141.0 | 141.5 | 141.9 | 142.4 | 142.9 |
| 110. | 143.4 | 143.9 | 144.3 | 144.8 | 145.3 | 145.8 | 146.3 | 146.8 | 147.3 | 147.8 |
| 111. | 148.3 | 148.8 | 149.3 | 149.8 | 150.3 | 150.8 | 151.3 | 151.8 | 152.3 | 152.8 |
| 112. | 153.3 | 153.8 | 154.3 | 154.8 | 155.3 | 155.8 | 156.4 | 156.9 | 157.4 | 157.9 |
| 113. | 158.4 | 159.0 | 159.5 | 160.0 | 160.5 | 161.1 | 161.6 | 162.1 | 162.7 | 163.2 |
| 114. | 163.7 | 164.3 | 164.8 | 165.4 | 165.9 | 166.4 | 167.0 | 167.5 | 168.1 | 168.6 |
| 115. | 169.2 | 169.7 | 170.3 | 170.8 | 171.4 | 172.0 | 172.5 | 173.1 | 173.6 | 174.2 |
| 116. | 174.8 | 175.3 | 175.9 | 176.5 | 177.0 | 177.6 | 178.2 | 178.8 | 179.4 | 179.9 |
| 117. | 180.5 | 181.1 | 181.7 | 182.3 | 182.9 | 183.4 | 184.0 | 184.6 | 185.2 | 185.8 |
| 118. | 186.4 | 187.0 | 187.6 | 188.2 | 188.8 | 189.4 | 190.0 | 190.6 | 191.2 | 191.8 |
| 119. | 192.5 | 193.1 | 193.7 | 194.3 | 194.9 | 195.5 | 196.2 | 196.8 | 197.4 | 198.0 |
| 120. | 198.7 | 199.3 | 199.9 | 200.6 | 201.2 | 201.8 | 202.5 | 203.1 | 203.8 | 204.4 |
| 121. | 205.0 | 205.7 | 206.3 | 207.0 | 207.6 | 208.3 | 208.9 | 209.6 | 210.3 | 210.9 |
| 122. | 211.6 | 212.2 | 212.9 | 213.6 | 214.2 | 214.9 | 215.6 | 216.3 | 216.9 | 217.6 |
| 123. | 218.3 | 219.0 | 219.7 | 220.3 | 221.0 | 221.7 | 222.4 | 223.1 | 223.8 | 224.5 |
| 124. | 225.2 | 225.9 | 226.6 | 227.3 | 228.0 | 228.7 | 229.4 | 230.1 | 230.8 | 231.5 |
| 125. | 232.2 | 232.9 | 233.7 | 234.4 | 235.1 | 235.8 | 236.6 | 237.3 | 238.0 | 238.7 |
| 126. | 239.5 | 240.2 | 240.9 | 241.7 | 242.4 | 243.2 | 243.9 | 244.6 | 245.4 | 246.1 |
| 127. | 246.9 | 247.6 | 248.4 | 249.2 | 249.9 | 250.7 | 251.4 | 252.2 | 253.0 | 253.7 |
| 128. | 254.5 | 255.3 | 256.0 | 256.8 | 257.6 | 258.4 | 259.1 | 259.9 | 260.7 | 261.5 |
| 129. | 262.3 | 263.1 | 263.9 | 264.7 | 265.5 | 266.3 | 267.1 | 267.9 | 268.7 | 269.5 |
| 130. | 270.3 | 271.1 | 271.9 | 272.7 | 273.5 | 274.3 | 275.2 | 276.0 | 276.8 | 277.6 |
| 131. | 278.5 | 279.3 | 280.1 | 281.0 | 281.8 | 282.6 | 283.5 | 284.3 | 285.1 | 286.0 |
| 132. | 286.8 | 287.7 | 288.5 | 289.4 | 290.3 | 291.1 | 292.0 | 292.8 | 293.7 | 294.6 |
| 133. | 295.4 | 296.3 | 297.2 | 298.0 | 298.9 | 299.8 | 300.7 | 301.6 | 302.4 | 303.3 |
| 134. | 304.2 | 305.1 | 306.0 | 306.9 | 307.8 | 308.7 | 309.6 | 310.5 | 311.4 | 312.3 |
| 135. | 313.2 | 314.1 | 315.1 | 316.0 | 316.9 | 317.8 | 318.7 | 319.7 | 320.6 | 321.5 |
| 136. | 322.4 | 323.4 | 324.3 | 325.3 | 326.2 | 327.1 | 328.1 | 329.0 | 330.0 | 330.9 |
| 137. | 331.9 | 332.8 | 333.8 | 334.8 | 335.7 | 336.7 | 337.6 | 338.6 | 339.6 | 340.6 |
| 138. | 341.5 | 342.5 | 343.5 | 344.5 | 345.5 | 346.5 | 347.4 | 348.4 | 349.4 | 350.4 |
| 139. | 351.4 | 352.4 | 353.4 | 354.4 | 355.4 | 356.4 | 357.5 | 358.5 | 359.5 | 360.5 |
| 140. | 361.5 | 362.6 | 363.6 | 364.6 | 365.6 | 366.7 | 367.7 | 368.8 | 369.8 | 370.8 |
| 141. | 371.9 | 372.9 | 374.0 | 375.0 | 376.1 | 377.1 | 378.2 | 379.3 | 380.3 | 381.4 |
| 142. | 382.5 | 383.5 | 384.6 | 385.7 | 386.8 | 387.8 | 388.9 | 390.0 | 391.1 | 392.2 |
| 143. | 393.3 | 394.4 | 395.5 | 396.6 | 397.7 | 398.8 | 399.9 | 401.0 | 402.1 | 403.2 |
| 144. | 404.4 | 405.5 | 406.6 | 407.7 | 408.9 | 410.0 | 411.1 | 412.3 | 413.4 | 414.5 |
| 145. | 415.7 | 416.8 | 418.0 | 419.1 | 420.3 | 421.4 | 422.6 | 423.8 | 424.9 | 426.1 |
| 146. | 427.3 | 428.4 | 429.6 | 430.8 | 432.0 | 433.1 | 434.3 | 435.5 | 436.7 | 437.9 |
| 147. | 439.1 | 440.3 | 441.5 | 442.7 | 443.9 | 445.1 | 446.3 | 447.5 | 448.7 | 450.0 |
| 148. | 451.2 | 452.4 | 453.6 | 454.9 | 456.1 | 457.3 | 458.6 | 459.8 | 461.0 | 462.3 |
| 149. | 463.5 | 464.8 | 466.0 | 467.3 | 468.5 | 469.8 | 471.1 | 472.3 | 473.6 | 474.9 |
| 150. | 476.2 | 477.4 | 478.7 | 480.0 | 481.3 | 482.6 | 483.9 | 485.2 | 486.5 | 487.8 |

Remarks: From WAGNER & PRUSS (1993). The temperature scale is ITS-90.

Table A-6 Saturated Water Vapor Pressure

4/4

Unit: kPa

| t/°C | 0.0 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 |
|------|--------|--------|--------|--------|---------|--------|--------|--------|--------|--------|
| 150. | 476.2 | 489.1 | 502.2 | 515.7 | 529.5 | 543.5 | 557.8 | 572.5 | 587.4 | 602.7 |
| 160. | 618.2 | 634.1 | 650.3 | 666.9 | 683.7 | 700.9 | 718.5 | 736.4 | 754.6 | 773.2 |
| 170. | 792.2 | 811.5 | 831.2 | 851.3 | 871.8 | 892.6 | 913.8 | 935.5 | 957.5 | 980.0 |
| 180. | 1003. | 1026. | 1050. | 1074. | 1098. | 1123. | 1149. | 1175. | 1201. | 1228. |
| 190. | 1255. | 1283. | 1311. | 1340. | 1369. | 1399. | 1429. | 1460. | 1491. | 1523. |
| 200. | 1555. | 1588. | 1621. | 1655. | 1689. | 1724. | 1760. | 1796. | 1833. | 1870. |
| 210. | 1908. | 1946. | 1985. | 2025. | 2065. | 2106. | 2147. | 2189. | 2232. | 2276. |
| 220. | 2320. | 2364. | 2410. | 2456. | 2502. | 2550. | 2598. | 2647. | 2696. | 2746. |
| 230. | 2797. | 2849. | 2901. | 2954. | 3008. | 3063. | 3118. | 3174. | 3231. | 3289. |
| 240. | 3347. | 3406. | 3466. | 3527. | 3589. | 3651. | 3715. | 3779. | 3844. | 3909. |
| 250. | 3976. | 4044. | 4112. | 4182. | 4252. | 4323. | 4395. | 4468. | 4542. | 4617. |
| 260. | 4692. | 4769. | 4847. | 4925. | 5005. | 5085. | 5167. | 5249. | 5333. | 5417. |
| 270. | 5503. | 5590. | 5677. | 5766. | 5856. | 5946. | 6038. | 6131. | 6225. | 6320. |
| 280. | 6417. | 6514. | 6612. | 6712. | 6813. | 6915. | 7018. | 7122. | 7227. | 7334. |
| 290. | 7442. | 7551. | 7661. | 7772. | 7885. | 7999. | 8114. | 8231. | 8348. | 8468. |
| 300. | 8588. | 8710. | 8832. | 8957. | 9082. | 9209. | 9338. | 9467. | 9599. | 9731. |
| 310. | 9865. | 10000. | 10137. | 10275. | 10415. | 10556. | 10699. | 10843. | 10988. | 11136. |
| 320. | 11284. | 11434. | 11586. | 11740. | 11895. | 12051. | 12209. | 12369. | 12530. | 12693. |
| 330. | 12858. | 13024. | 13193. | 13362. | 13534. | 13707. | 13882. | 14059. | 14238. | 14418. |
| 340. | 14601. | 14785. | 14971. | 15159. | 15349. | 15541. | 15734. | 15930. | 16128. | 16328. |
| 350. | 16529. | 16733. | 16939. | 17147. | 17358. | 17570. | 17785. | 18002. | 18221. | 18442. |
| 360. | 18666. | 18892. | 19121. | 19352. | 19586. | 19822. | 20061. | 20302. | 20546. | 20794. |
| 370. | 21044. | 21297. | 21554. | 21814. | 22064.* | | | | | |

Note*: Critical point 373.946°C

Remarks: From WAGNER & PRUSS (1993). The temperature scale is ITS-90.

4 Basic Reliability Theory

4.1 Measures for Representing Reliability

Measures used to quantitatively represent reliability and their definitions are described below.

(1) Reliability: $R(t)$

Reliability indicates the probability for functioning correctly without failure until time t .

When n samples are used under the same conditions, if the number of failures occurring until time t has elapsed is expressed as $r(t)$, then the reliability $R(t)$ is given by the following equation.

$$R(t) = \frac{n-r(t)}{n}$$

(2) Failure Distribution Function (Unreliability): $F(t)$

This indicates the probability of failure occurring until time t , and is expressed by the following equation.

$$F(t) = \frac{r(t)}{n}$$

In addition, the following relationship is established between unreliability $F(t)$ and reliability $R(t)$.

$$R(t) + F(t) = 1$$

As shown in Fig. A-3, $R(t)$ decreases from 1 over time, while conversely $F(t)$ increases from 0 toward 1 over time.

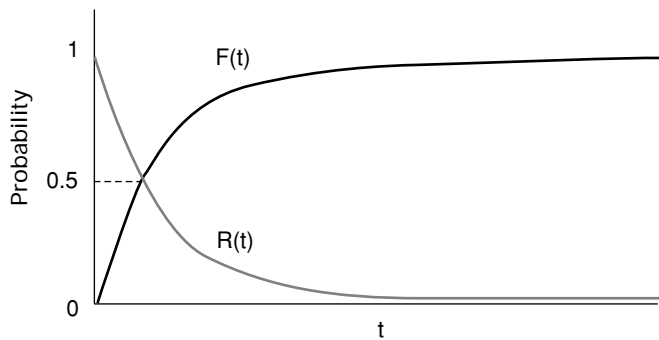


Fig. A-3 Relationship between $F(t)$ and $R(t)$

(3) Failure Probability Density Function: $f(t)$

This represents the probability of failure occurring per unit time when time t has elapsed.

$$f(t) = \frac{dF(t)}{dt} = - \frac{dR(t)}{dt}$$

(4) Failure Rate Function: $\lambda(t)$

This represents the probability of failure occurring in the next unit time for samples which have not yet failed when time t has elapsed.

$$\lambda(t) = \frac{f(t)}{1-F(t)} = \frac{f(t)}{R(t)}$$

4.2 Distributions Used in Reliability Analysis

Reliability analysis is a method for estimating the above-mentioned reliability measures. There are two types of methods: the parametric method which estimates reliability by postulating the distribution and the non-parametric method which does not postulate the distribution. However, data analysis for semiconductor devices generally uses the parametric method which has higher accuracy.

Typical distribution functions used to analyze reliability data are described below.

(1) Normal Distribution

The normal distribution is a typical continuous distribution used for quality control. In reliability analysis it is often applied to wear-out life where failures concentrate around a certain time.

The probability density function $f(t)$ and distribution function $F(t)$ are as follows.

$$f(t) = \frac{1}{\sqrt{2\pi}\sigma} \exp\left\{-\frac{(t-\mu)^2}{2\sigma^2}\right\} \quad (-\infty < t < +\infty)$$
$$F(t) = \frac{1}{\sqrt{2\pi}\sigma} \int_{-\infty}^t \exp\left\{-\frac{(x-\mu)^2}{2\sigma^2}\right\} dx \quad (-\infty < t < +\infty)$$

This distribution is given by the mean parameter μ and the dispersion (variance) parameter σ .

As shown in Fig. A-4 below, the normal distribution has a symmetrical bell shape centering on μ , and the probability of the value t being contained within the range of $\pm \sigma$, $\pm 2\sigma$ and $\pm 3\sigma$ to both sides of μ is 68.26%, 95.44% and 99.7%, respectively.

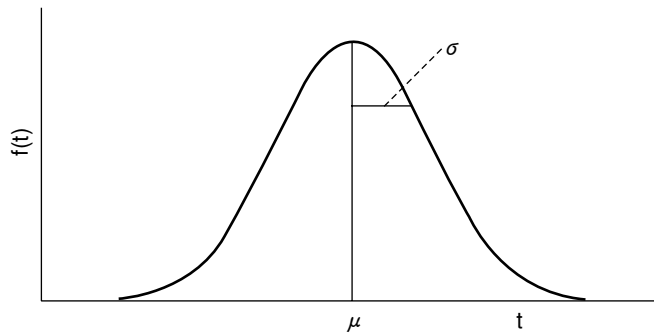


Fig. A-4 Normal Distribution

(2) Exponential Distribution

The exponential distribution represents the life distribution in the random failure region where the failure rate λ is constant over time.

The probability density function $f(t)$ and reliability $R(t)$ are as follows.

$$f(t) = \lambda e^{-\lambda t}$$

$$R(t) = e^{-\lambda t}$$

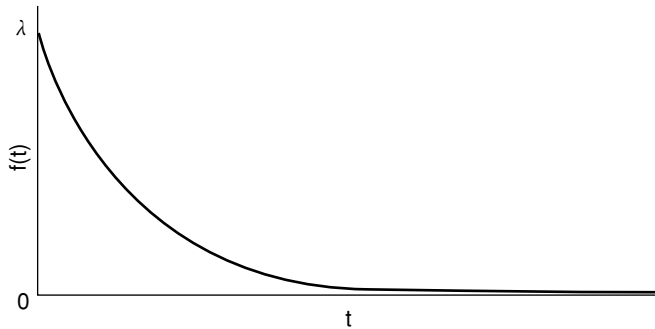


Fig. A-5 Exponential Distribution

The mean time to failure (MTTF) is given as follows from t_0 , which is the inverse of the failure rate λ .
 $1/\lambda = t_0 = \text{MTTF}$ (Mean Time To Failure)

In semiconductor device reliability, the electromigration life and hot carrier life are generally known to follow a logarithmic normal distribution.

(3) Logarithmic Normal Distribution

The logarithmic normal distribution is a distribution function where $\ln t$, which is the logarithm of the life time t , follows the above mentioned normal distribution.

The probability density function $f(t)$ and distribution function $F(t)$ are as follows.

$$f(t) = \frac{1}{\sqrt{2\pi}\sigma t} \exp\left[-\frac{1}{2}\left(\frac{\ln t - \mu}{\sigma}\right)^2\right] \quad (0 < t < \infty)$$

$$F(t) = \frac{1}{\sqrt{2\pi}\sigma} \int_0^t \frac{1}{x} \exp\left[-\frac{1}{2}\left(\frac{\ln x - \mu}{\sigma}\right)^2\right] dx$$

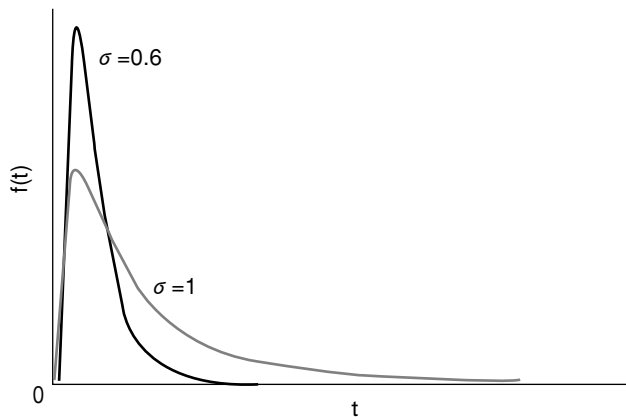


Fig. A-6 Logarithmic Normal Distribution

(4) Weibull Distribution

The Weibull distribution is a highly general-purpose distribution function which is expanded from the logarithmic distribution. In reliability data analysis, this model is frequently used to analyze life data in reliability tests, etc.

The probability density function $f(t)$ and distribution function $F(t)$ of this distribution are as follows.

$$f(t) = \frac{m}{\eta} \left(\frac{t-\gamma}{\eta} \right)^{m-1} \exp \left\{ - \left(\frac{t-\gamma}{\eta} \right)^m \right\}$$

$$F(t) = 1 - \exp \left\{ - \left(\frac{t-\gamma}{\eta} \right)^m \right\}$$

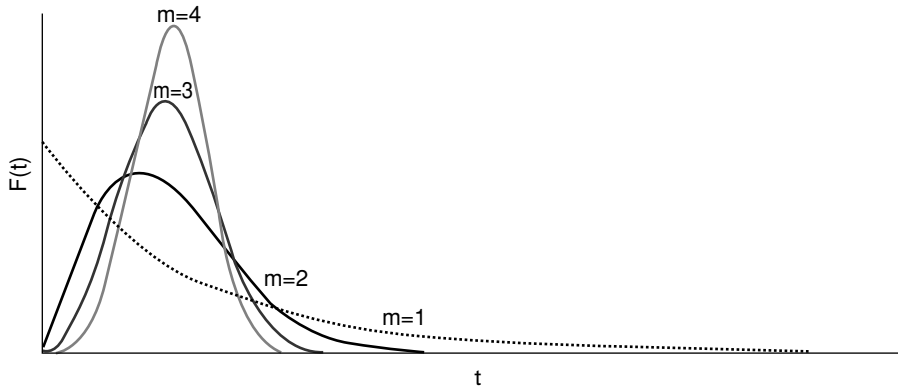


Fig. A-7 Weibull Distribution

Here, m is called the form parameter, η the measure parameter, and γ the position parameter.

In addition, assuming $t_0 = \eta^m$ (= characteristic life), the failure rate $\lambda(t)$ is expressed by the following equation.

$$\lambda(t) = \frac{m}{\eta} \left(\frac{t-\gamma}{\eta} \right)^{m-1} = \frac{m}{t_0} t^{m-1}$$

The following information concerning the failure pattern can be obtained from the value of the form parameter m .

- m value: Failure pattern
- $0 < m < 1$: Initial failure (DFR) pattern where the failure rate decreases over time
- $m = 1$: Random failure (CFR) pattern where the failure rate is constant (matches with the exponential distribution)
- $m > 1$: Wear-out failure (IFR) pattern where the failure rate increases over time

4.3 Example Data Analysis Method

This section describes an example reliability data analysis method using Weibull probability paper.

Weibull distributions are generally used to analyze life data, and this is because Weibull distributions can approximate the normal distribution, logarithmic normal distribution and exponential distribution life distribution models. In addition, Weibull distributions also have the advantage of allowing analysis even when two or more failure modes are present at the same time.

(1) Data analysis method using Weibull probability paper

Weibull probability paper makes it possible to estimate reliability distribution parameters more easily than by calculation from theoretical equations.

As mentioned above, the Weibull distribution failure distribution function is expressed by the following equation.

$$F(t) = 1 - \exp\left\{-\left(\frac{t-\gamma}{\eta}\right)^m\right\}$$

When $\gamma = 0$, the above equation changes as follows.

$$F(t) = 1 - \exp\left\{-\left(\frac{t}{\eta}\right)^m\right\}$$

Taking the natural logarithm of both sides two times, the equation can be transformed as follows.

$$\ln \ln \frac{1}{1-F(t)} = m \ln t - m \ln \eta$$

Replacing with X and Y,

$$X = \ln t$$

$$Y = \ln \ln \frac{1}{1-F(t)}$$

This equation becomes a linear first-degree equation with X and Y as follows.

$$Y = mX - m \ln \eta$$

Weibull probability paper is scaled paper which uses this relational formula to plot $Y = \ln \ln (1/(1-F(t)))$ on the vertical axis and $X = \ln t$ on the horizontal axis. By plotting the X and Y data on Weibull probability plotting paper, the value of m can be easily obtained from the slope of the resulting straight line, and the value of η from the time t at which $Y = 0$.

(2) Data Analysis Procedure

A specific data analysis procedure using Weibull probability paper is described below. (See Fig. A-8.)

- <Step 1> Arrange the obtained n life data in order from the smallest.
- <Step 2> Obtain the cumulative failure rate F(t) for the ith failure data from the following equation.

(1) Mean rank method

$$\frac{i}{n+1} \times 100(\%)$$

(2) Median rank method

$$\frac{i-0.3}{n+0.4} \times 100(\%)$$

<Step 3> Plot the obtained life data on the Weibull probability paper as follows.

| Horizontal axis t | Vertical axis F(t) |
|-------------------|--------------------|
| t ₁ | F(t ₁) |
| t ₂ | F(t ₂) |
| ⋮ | ⋮ |
| t _i | F(t _i) |
| ⋮ | ⋮ |
| t _n | F(t _n) |

- <Step 4> Draw an appropriate straight line through the plotted n points. At this time, make sure the line passes through the plotted points in the vertical axis range of F(t) = 30% to 70%. Even if the line does not pass through the plotted points in the range of F(t) = 10% or less or 90% or more, there is no substantial error.
- <Step 5> Draw a straight line parallel to the line in Step 4 and passing through the “m estimated point”. Read the vertical (ln ln 1/(1-F(t))) axis scale to the right of the point where this line intersects with the vertical main axis (ln t = 0). The absolute value of this value is the estimated value of form parameter m.
- <Step 6> The estimated value of measure parameter η can be obtained by reading the t axis scale at the intersection between the line in Step 4 and the horizontal main axis (Y = 0).
- <Step 7> The MTTF is obtained by reading the μ / η measure scale at the m point obtained in Step 5, and multiplying this value by the value of η obtained in Step 6.
- <Step 8> The unreliability F(tx) at time tx is obtained by reading the Y sub-axis F(t) value at tx on the straight line. In addition, the reliability R(tx) can be obtained from R(tx) = 100-F(tx).

