Section 3 Reliability Testing and Reliability Prediction

For self-investigation

Section 3 Reliability Testing and Reliability Prediction

Figure list

For self-investigation

Section 3 Reliability Testing and Reliability Prediction

Figure list (continued)

For self-investigation

Section 3 Reliability Testing and Reliability Prediction

Table list

For self-investigation

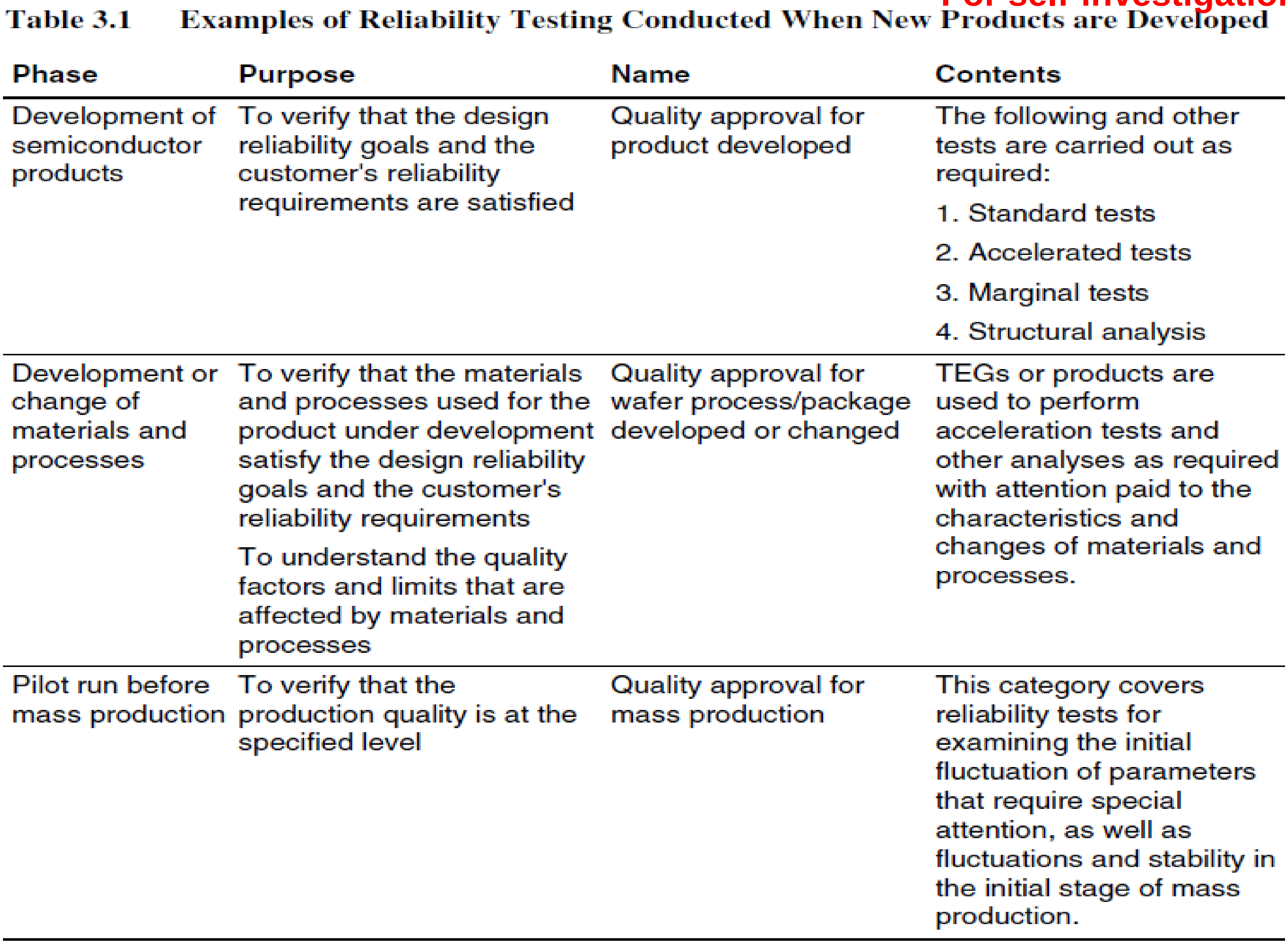

Table 3.1 Examples of Reliability Testing Conducted When New Products are Developed

Phase	Purpose	Name	Contents
Development of semiconductor products	To verify that the design reliability goals and the customer's reliability requirements are satisfied	Quality approval for product developed	The following and other tests are carried out as required: 1. Standard tests 2. Accelerated tests 3. Marginal tests 4. Structural analysis
Development or change of materials and processes	To verify that the materials and processes used for the product under development satisfy the design reliability goals and the customer's reliability requirements To understand the quality factors and limits that are affected by materials and processes	Quality approval for wafer process/package developed or changed	TEGs or products are used to perform acceleration tests and other analyses as required with attention paid to the characteristics and changes of materials and processes.
Pilot run before mass production	To verify that the production quality is at the specified level	Quality approval for mass production	This category covers reliability tests for examining the initial fluctuation of parameters that require special attention, as well as fluctuations and stability in the initial stage of mass production.

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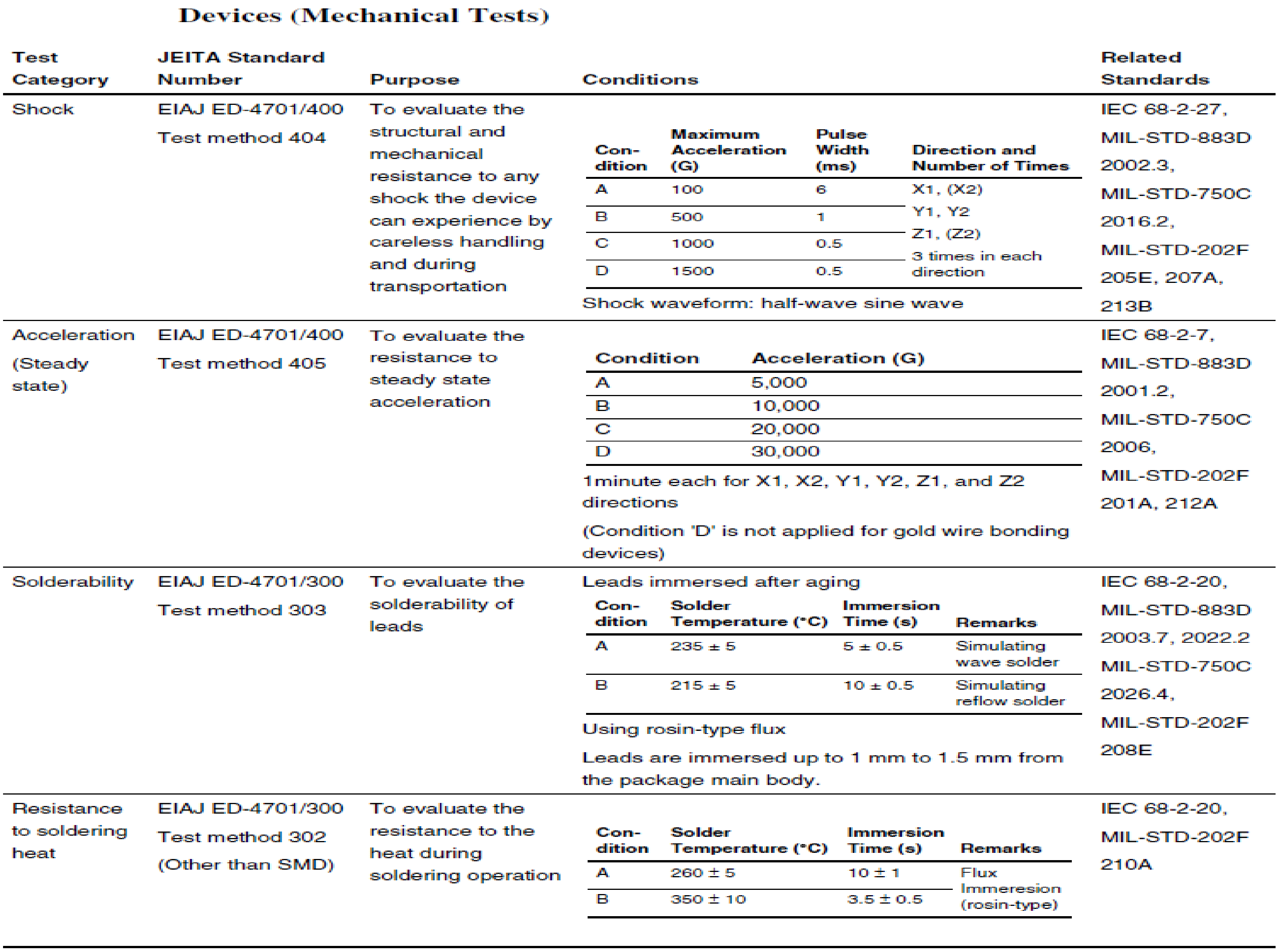

Table 3.2 Test Categories and Conditions for Environmental Tests of Semiconductor Devices (Mechanical Tests)

<table>
<tr><th>Test Category</th><th>JEITA Standard Number</th><th>Purpose</th><th>Conditions</th><th>Related Standards</th></tr>
<tr><td>Shock</td><td>EIAJ ED-4701/400
Test method 404</td><td>To evaluate the structural and mechanical resistance to any shock the device can experience by careless handling and during transportation</td><td>
<table>
<tr><th>Con-dition</th><th>Maximum Acceleration (G)</th><th>Pulse Width (ms)</th><th>Direction and Number of Times</th></tr>
<tr><td>A</td><td>100</td><td>6</td><td>X1, (X2)
Y1, Y2
Z1, (Z2)
3 times in each direction</td></tr>
<tr><td>B</td><td>500</td><td>1</td><td></td></tr>
<tr><td>C</td><td>1000</td><td>0.5</td><td></td></tr>
<tr><td>D</td><td>1500</td><td>0.5</td><td></td></tr>
</table>
Shock waveform: half-wave sine wave</td><td>IEC 68-2-27,
MIL-STD-883D 2002.3,
MIL-STD-750C 2016.2,
MIL-STD-202F 205E, 207A, 213B</td></tr>
<tr><td>Acceleration (Steady state)</td><td>EIAJ ED-4701/400
Test method 405</td><td>To evaluate the resistance to steady state acceleration</td><td>
<table>
<tr><th>Condition</th><th>Acceleration (G)</th></tr>
<tr><td>A</td><td>5,000</td></tr>
<tr><td>B</td><td>10,000</td></tr>
<tr><td>C</td><td>20,000</td></tr>
<tr><td>D</td><td>30,000</td></tr>
</table>
1minute each for X1, X2, Y1, Y2, Z1, and Z2 directions
(Condition 'D' is not applied for gold wire bonding devices)</td><td>IEC 68-2-7,
MIL-STD-883D 2001.2,
MIL-STD-750C 2006,
MIL-STD-202F 201A, 212A</td></tr>
<tr><td>Solderability</td><td>EIAJ ED-4701/300
Test method 303</td><td>To evaluate the solderability of leads</td><td>Leads immersed after aging
<table>
<tr><th>Con-dition</th><th>Solder Temperature (°C)</th><th>Immersion Time (s)</th><th>Remarks</th></tr>
<tr><td>A</td><td>235 ± 5</td><td>5 ± 0.5</td><td>Simulating wave solder</td></tr>
<tr><td>B</td><td>215 ± 5</td><td>10 ± 0.5</td><td>Simulating reflow solder</td></tr>
</table>
Using rosin-type flux
Leads are immersed up to 1 mm to 1.5 mm from the package main body.</td><td>IEC 68-2-20,
MIL-STD-883D 2003.7, 2022.2
MIL-STD-750C 2026.4,
MIL-STD-202F 208E</td></tr>
<tr><td>Resistance to soldering heat</td><td>EIAJ ED-4701/300
Test method 302
(Other than SMD)</td><td>To evaluate the resistance to the heat during soldering operation</td><td>
<table>
<tr><th>Con-dition</th><th>Solder Temperature (°C)</th><th>Immersion Time (s)</th><th>Remarks</th></tr>
<tr><td>A</td><td>260 ± 5</td><td>10 ± 1</td><td>Flux Immeresion (rosin-type)</td></tr>
<tr><td>B</td><td>350 ± 10</td><td>3.5 ± 0.5</td><td></td></tr>
</table></td><td>IEC 68-2-20,
MIL-STD-202F 210A</td></tr>
</table>

For self-investigation

<table>
<tr><th>Test Category</th><th>JEITA Standard Number</th><th>Purpose</th><th>Conditions</th><th>Related Standards</th></tr>
<tr>
<td>Resistance to soldering heat</td>
<td>EIAJ ED-4701/300
Test method 301
(SMD)</td>
<td>To evaluate the resistance to the heat during soldering operation</td>
<td>
Heating after humidification treatment
Humidification treatment condition examples
<table>
<tr><td>Simulating storage in moistureproof packing</td><td colspan="2">85°C, 30%, 168h</td></tr>
<tr><td>Simulating storage after opening packing</td><td colspan="2">30°C, 70%, 168h</td></tr>
<tr><td rowspan="2">Simulating non-moistureproof packing</td><td>A</td><td>85°C, 65%, 168 h</td></tr>
<tr><td>B</td><td>85°C, 85%, 168 h</td></tr>
</table>
Heating treatment conditions
(I) Infrared ray reflow and air-reflow (lead-free solder)
Preheat: 160 to 90°C, 80 to 140s
Peak temperature (Tp) (Tolerance: +5/-0°C)
<table>
<tr><th rowspan="2">Thickness (mm)</th><th colspan="3">Volume (mm^3)</th></tr>
<tr><th>< 350</th><th>350 - 2,000</th><th>> 2,000</th></tr>
<tr><td>< 1.6</td><td>260</td><td>260</td><td>260</td></tr>
<tr><td>1.6 – 2.5</td><td>260</td><td>250</td><td>245</td></tr>
<tr><td>> 2.5</td><td>250</td><td>245</td><td>245</td></tr>
</table>
<table>
<tr><th>Condition</th><th>Time (s) of (Tp - 5°C) or more</th></tr>
<tr><td>A</td><td>10 + 6/–0</td></tr>
<tr><td>B</td><td>20 + 6/–0</td></tr>
</table>
(II) Vapor phase reflow
<table>
<tr><th>Con-dition</th><th>Solder Temperature (°C)</th><th>Heating Time (s)</th><th>Remarks</th></tr>
<tr><td>II-A</td><td>$210 \pm ^{10}_{0}$</td><td>40 ± 4</td><td>Preheat: 150°C, 90s</td></tr>
</table>
(III) Wave solder bath
<table>
<tr><th>Con-dition</th><th>Solder Temperature (°C)</th><th>Heating Time (s)</th><th>Remarks</th></tr>
<tr><td>III-A</td><td>260 ± 5</td><td>5 ± 1</td><td>Simulating single</td></tr>
<tr><td>III-B</td><td>260 ± 5</td><td>10 ± 1</td><td>Simulating double</td></tr>
</table>
(IV) Solder bath
<table>
<tr><th>Con-dition</th><th>Solder Temperature (°C)</th><th>Heating Time (s)</th><th>Remarks</th></tr>
<tr><td>IV -A</td><td>350 ± 10</td><td>3.5 ± 0.5</td><td>Flux immersion</td></tr>
</table>
The leads are immersed vertically up to the flat or effective soldering area.
</td>
<td>IEC 68-2-20,
MIL-STD-202F 210A</td>
</tr>
</table>

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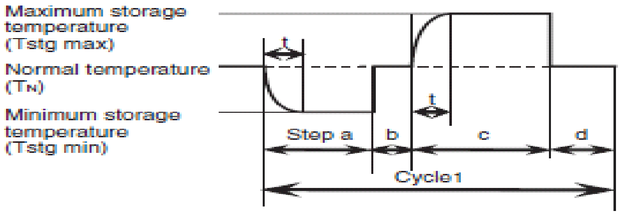
Table 3.3 Test Categories and Conditions for Environmental Tests of Semiconductor Devices (Weather Resistance Tests)

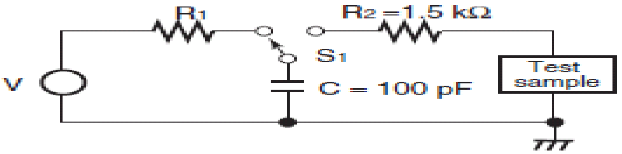
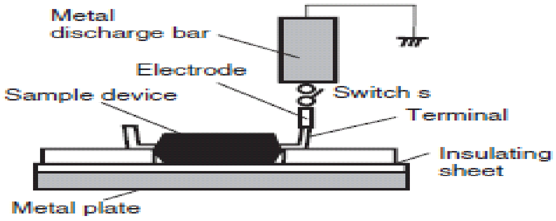
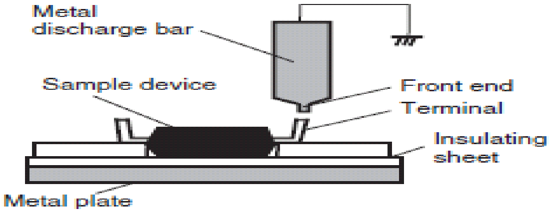
<table>
<tr><th>Test Category</th><th>JEITA Standard Number</th><th>Purpose</th><th>Conditions</th><th>Related Standards</th></tr>
<tr><td>Soldering heat stress series test</td><td>EIAJ ED-4701/100
Test method 104</td><td>To evaluate the durability against temperature and humidity cycles a plastic mold SMD can experience during storage and mounting</td><td>The series test is performed before specified tests.
Same as
EIAJ ED-4701/300, Test method 301
(Resistance to soldering heat)</td><td>JESD22-A112,
JESD22-A113</td></tr>
<tr><td>High-temperature storage</td><td>EIAJ ED-4701/200
Test method 201</td><td>To evaluate the resistance to prolonged high temperature storage.</td><td>The device is stored in the following conditions unless other wise specified.
• Tstg max (maximum rated storage temperature)
• 1,000 h</td><td>IEC 68-2-2,
MIL-STD-750C 1031.4,
MIL-STD-883D 1008.2</td></tr>
<tr><td>Low-temperature storage</td><td>EIAJ ED-4701/200
Test method 202</td><td>To evaluate the resistance to low-temperature storage</td><td>The device is stored in the following conditions unless other wise specified.
• Tstg min (minimum rated storage temperature)
• 1,000 h</td><td>IEC 68-2-1</td></tr>
<tr><td>High-temperature high-humidity storage</td><td>EIAJ ED-4701/100
Test method 103</td><td>To evaluate the resistance to high-temperature and humidity storage and operation</td><td><table><tr><th>Test condition</th><th>Ta (°C)</th><th>RH (%)</th></tr><tr><td>A</td><td>40 ± 2</td><td>90 ± 5</td></tr><tr><td>B</td><td>60 ± 2</td><td>90 ± 5</td></tr><tr><td>C</td><td>85 ± 2</td><td>85 ± 5</td></tr></table>1,000h (unless otherwise specified)</td><td>IEC 68-2-3,
MIL-STD-202F 103B</td></tr>
<tr><td>High-temperature high-humidity bias
(THB)</td><td>EIAJ ED-4701/100
Test method 102</td><td>To evaluate the corrosive resistance (of mainly wiring) to high-temperature and humidity storage and operation</td><td><table><tr><th>Condition symbol</th><th>Temperature (°C)</th><th>Humidity (%)</th><th>Time (h)</th></tr><tr><td>A</td><td>40</td><td>90</td><td>1000</td></tr><tr><td>B</td><td>60</td><td>90</td><td>1000</td></tr><tr><td>C</td><td>85</td><td>85</td><td>1000</td></tr></table>Power supply: Continuous, or intermittent (with a specified cycle) for high power dissipation devices
For SMDs, Moisture soaking and soldering heat stress series test (test method B-101) is performed as a preconditioning.</td><td></td></tr>
</table>

For self-investigation

<table>
<tr><th>Test Category</th><th>JEITA Standard Number</th><th>Purpose</th><th>Conditions</th><th>Related Standards</th></tr>
<tr>
<td>Unsaturated pressurized vapor</td>
<td>EIAJ ED-4701/100
Test method 102</td>
<td>To evaluate with acceleration the resistance to storage and use in high-temperature and humidity</td>
<td>Unsaturated pressure inside chamber
<table>
<tr><th>Con-dition</th><th>Tempe-rature</th><th>Relative Humidity</th><th>Vapor Pressure (Pa)</th></tr>
<tr><td>A</td><td>110°C</td><td>85%</td><td>1.2×10^5</td></tr>
<tr><td>B</td><td>120°C</td><td>85%</td><td>1.7×10^5</td></tr>
<tr><td>C</td><td>130°C</td><td>85%</td><td>2.3×10^5</td></tr>
</table>
For SMDs, moisture soaking and soldering heat stress series test (test method 104) is performed as a preconditioning.</td>
<td></td>
</tr>
<tr>
<td>Temperature cycle</td>
<td>EIAJ ED-4701/100
Test method 105</td>
<td>To evaluate the resistance to sudden changes in temperature the device can experience during storage, transportation, or in use.</td>
<td>For SMDs, Test method 104 is performed as a preconditioning.


t: The longer one out of 5minutes, or 10% of either step a or step c.
<table>
<tr><th>Step</th><th>Temperature</th><th>Time</th></tr>
<tr><td>a</td><td>Minimum storage temperature (Tstg min)</td><td>Select a condition from the table below</td></tr>
<tr><td>b</td><td>Normal temperature 5 to 35°C (T_N)</td><td></td></tr>
<tr><td>c</td><td>Maximum storage temperature (Tstg max)</td><td></td></tr>
<tr><td>d</td><td>Normal temperature 5 to 35°C (T_N)</td><td></td></tr>
</table>
Dwell time of temperature cycle
<table>
<tr><th rowspan="2">Mass of the sample (m) g</th><th>Step b</th><th>Step a</th></tr>
<tr><th>Step d</th><th>Step c</th></tr>
<tr><td>$m \leq 15$
$15 < m \leq 150$
$150 < m \leq 1500$</td><td>5 minutes or shorter</td><td>10 minutes or longer</td></tr>
<tr><td>$1500 < m$</td><td colspan="2">Specified in the individual specifications</td></tr>
</table>
Tstg min and Tstg max are defined by the individual specifications. 10 cycles are performed for evaluating.</td>
<td>IEC 68-2-14,
MIL-STD-883D 1010.7,
MIL-STD-750C 1051.2,
MIL-STD-202F 102A</td>
</tr>
</table>

Table 3.4 Test Categories and Conditions for Environmental Tests of Semiconductor Devices (Other Tests)

Test Category	JEITA Standard Number	Purpose	Conditions	Related Standards
Human body model electrostatic discharge. (HBM/ESD)	EIAJ ED-4701/300 Test method 304	To evaluate the resistance to static electricity that can be generated in handling	 V: Specified DC voltage (both polarities) Ta: 25°C Times applied: 3 Terminals applied to: All terminals except the reference one (MM/ESD: Reference test) C = 200 pF R2 = 0 Ω Times applied: 1	MIL-STD-883C 3015.6, JESD22-A114
Charged device model electrostatic discharge. (CDM/ESD)	EIAJ ED-4701/300 Test method 305	To evaluate the resistance to electrostatic discharges in a charging model that simulates the handling before the device is mounted	Test circuit (a) Discharging with a switch  (b) Discharging by contact  Test voltage: Specified (both polarities) in the individual specification (Recommended: 500 V) Ta: 25°C Terminals applied: 1 Lead applied to: All terminals	

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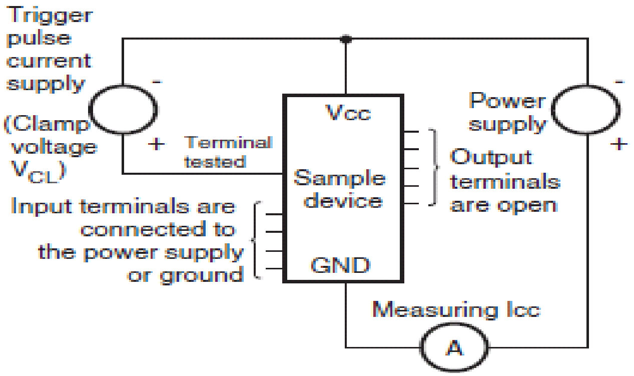
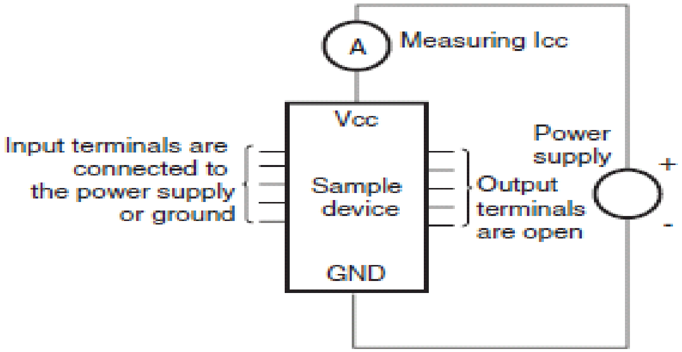
Test Category	JEITA Standard Number	Purpose	Conditions	Related Standards
Latch-up	EIAJ ED-4701/300 Test method 306	To evaluate the resistance of a CMOS device to electric noise	Method 1: Pulse current application Current: Specified trigger pulse current (both polarities) Ta = 25°C Times applied: 1 Circuit (for positive polarity)  Method 2: Supply overvoltage Voltage: Specified trigger pulse Ta = 25°C Times applied: 1 Circuit 	JESD 17

Failure mechanism oriented reliability test
How to verify quality for long time?
Acceleration test is the last way to assure.

Ⅰ. Temperature acceleration

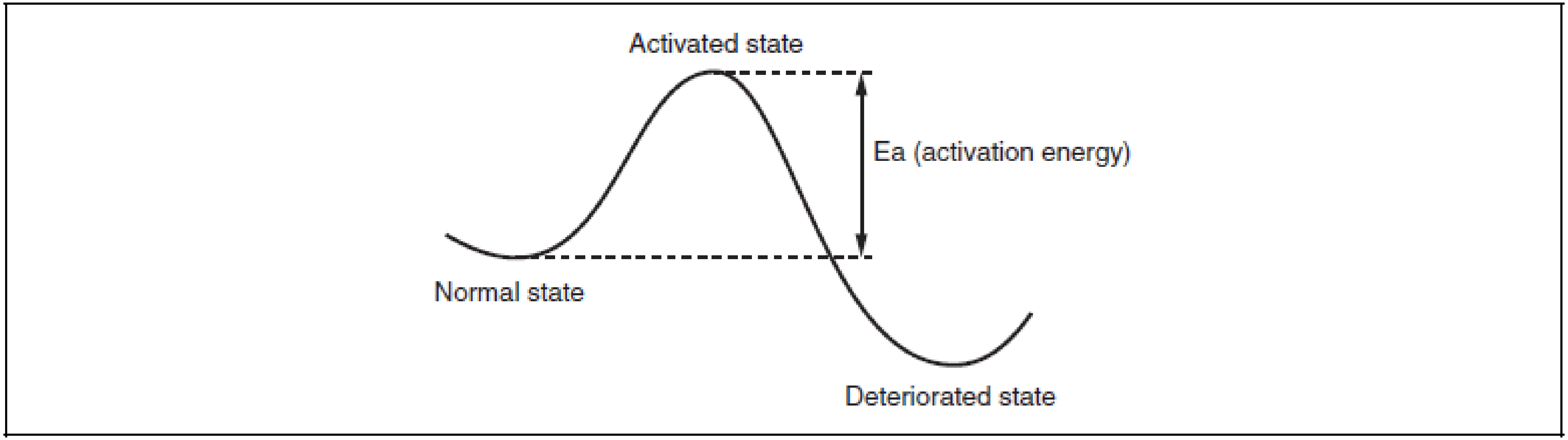


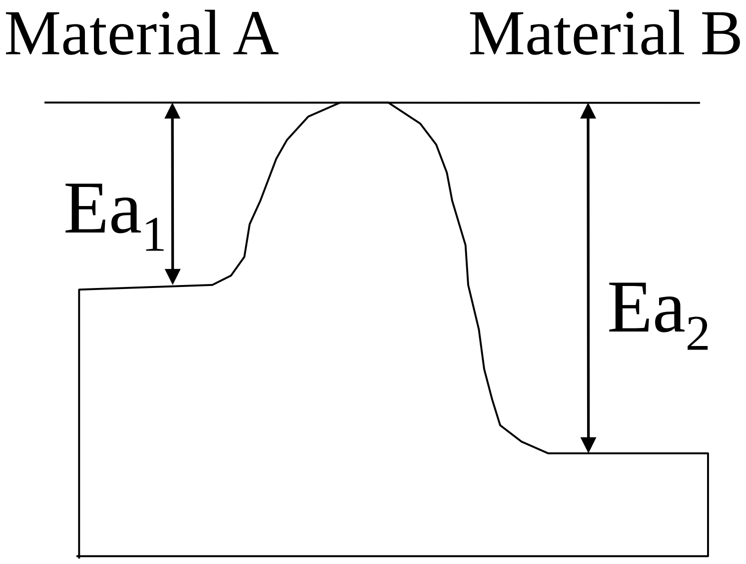
Figure 3.1 Activation Energy

Ⅰ. Temperature acceleration

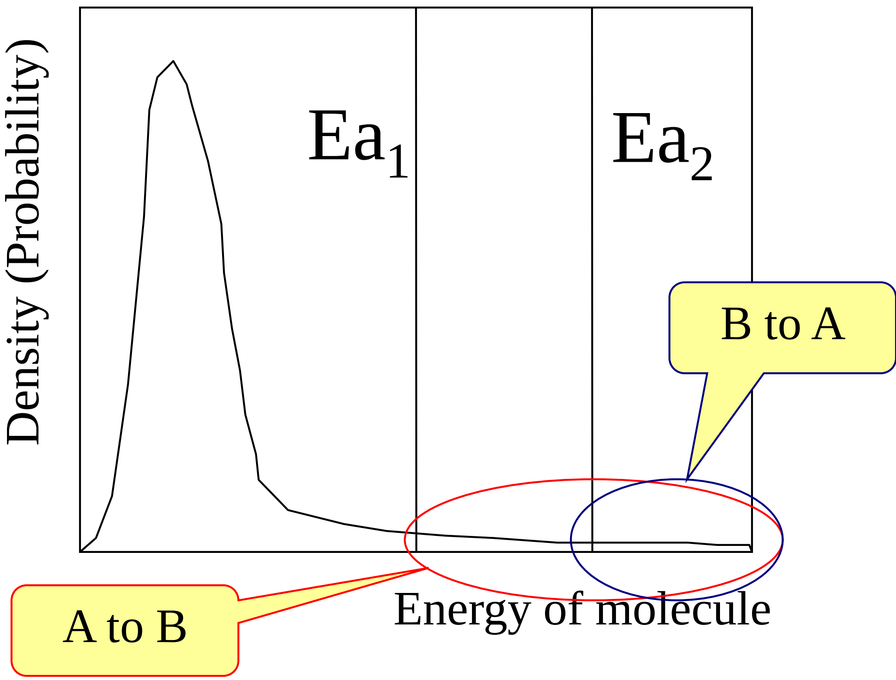
Cumulative Energy Distribution Function

$$P(T) = \exp(-Ea/kT)$$

（In gas chemical reaction, distribution of the energy exceeding Ea is proportional to exp(-Ea/kT).）



Chemical reaction



Thermal energy distribution

Ⅰ. Temperature acceleration

Chemical reaction model

Reciprocal number of chemical reaction speed

$$\text{Life}=\text{Const}\cdot\exp(Ea/kT)\propto 1/P(T)$$

Ea; Activation energy (eV)

K;Boltzmann constant (8.617835×10^{-5}eV/K)

T;Absolute Temperature (K)　　0 °C ＝ 273.15 K

$$\ln(\text{Life})=Ea/k*1/T+\ln(\text{Const})$$

$Y=\ln(\text{Life})$　　$X=1/T$

Gradient will relevant to Ea; Activation Energy

Ⅰ. Temperature acceleration

How to get the Activation energy ?

(1) Perform reliability test at different temperature
(2) Plot the life of each temperature
(3) Calculate the gradient of below graph

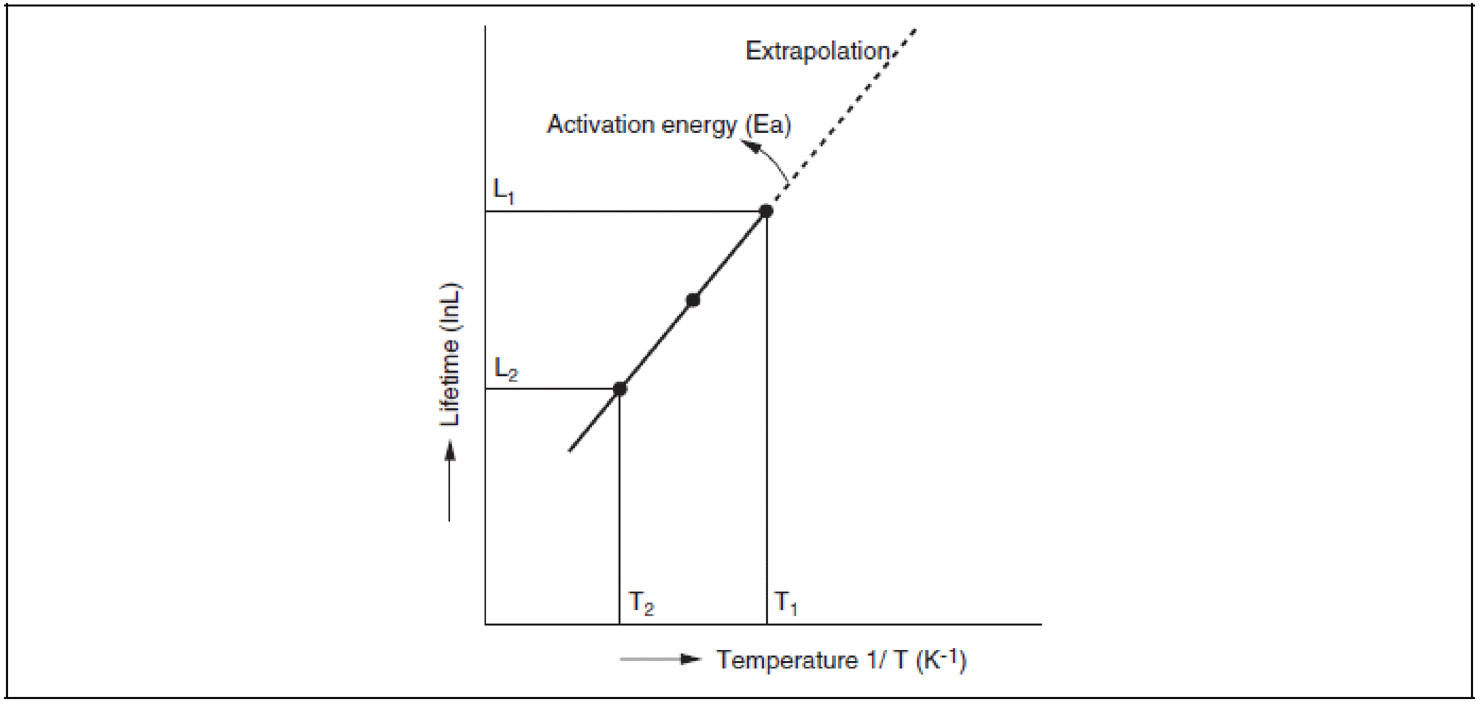


Figure 3.2 Graph of the Arrhenius Model

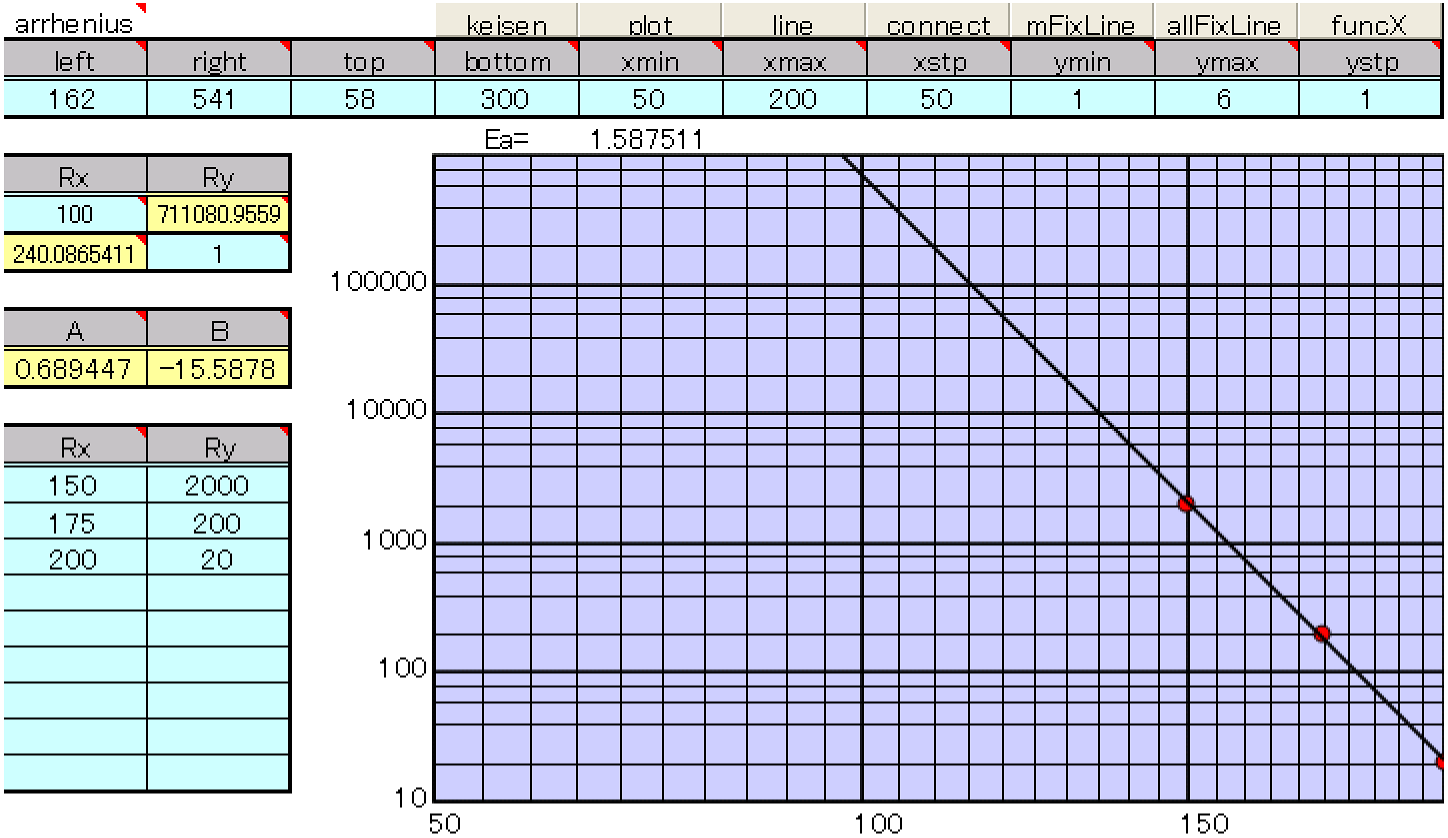
I . Temperature acceleration

Emi plot example (Essential mechanism illustrator)

(1) Easy input 150°C–2000h, 175°C–200h, 200°C–20h

(2) Easy Calculation Ea = 1.5875eV

(3) Easy predict 100 °C–711080h



left	right	top	bottom	xmin	xmax	xstp	ymin	ymax	ystp
162	541	58	300	50	200	50	1	6	1

Ea= 1.587511

Rx	Ry
100	711080.9559
240.0865411	1

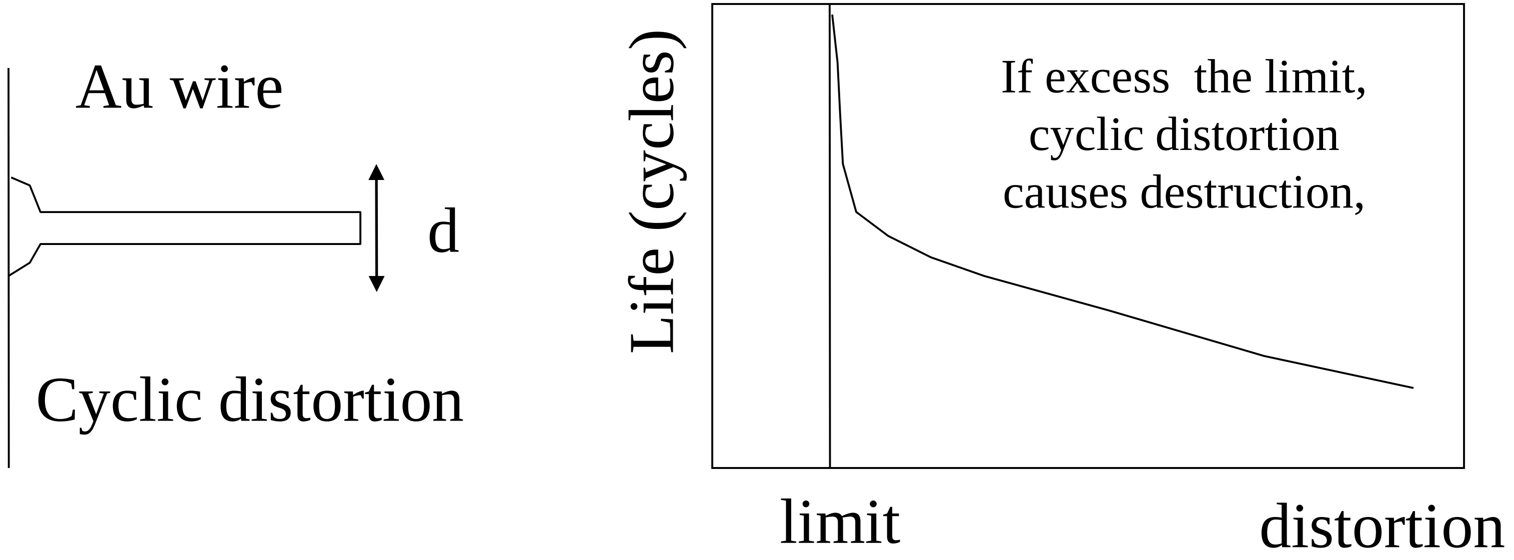
A	B
0.689447	-15.5878

Rx	Ry
150	2000
175	200
200	20

Ⅱ． Stress acceleration

Metal Fatigue Destruction

$$\mathrm{Life} = \mathrm{Const} \cdot S^{-n}$$



If excess the limit, cyclic distortion causes destruction,

Ⅱ． Stress acceleration

(1) Perform reliability test at different stress
(2) Plot the life of each stress
(3) Calculate the gradient of below graph

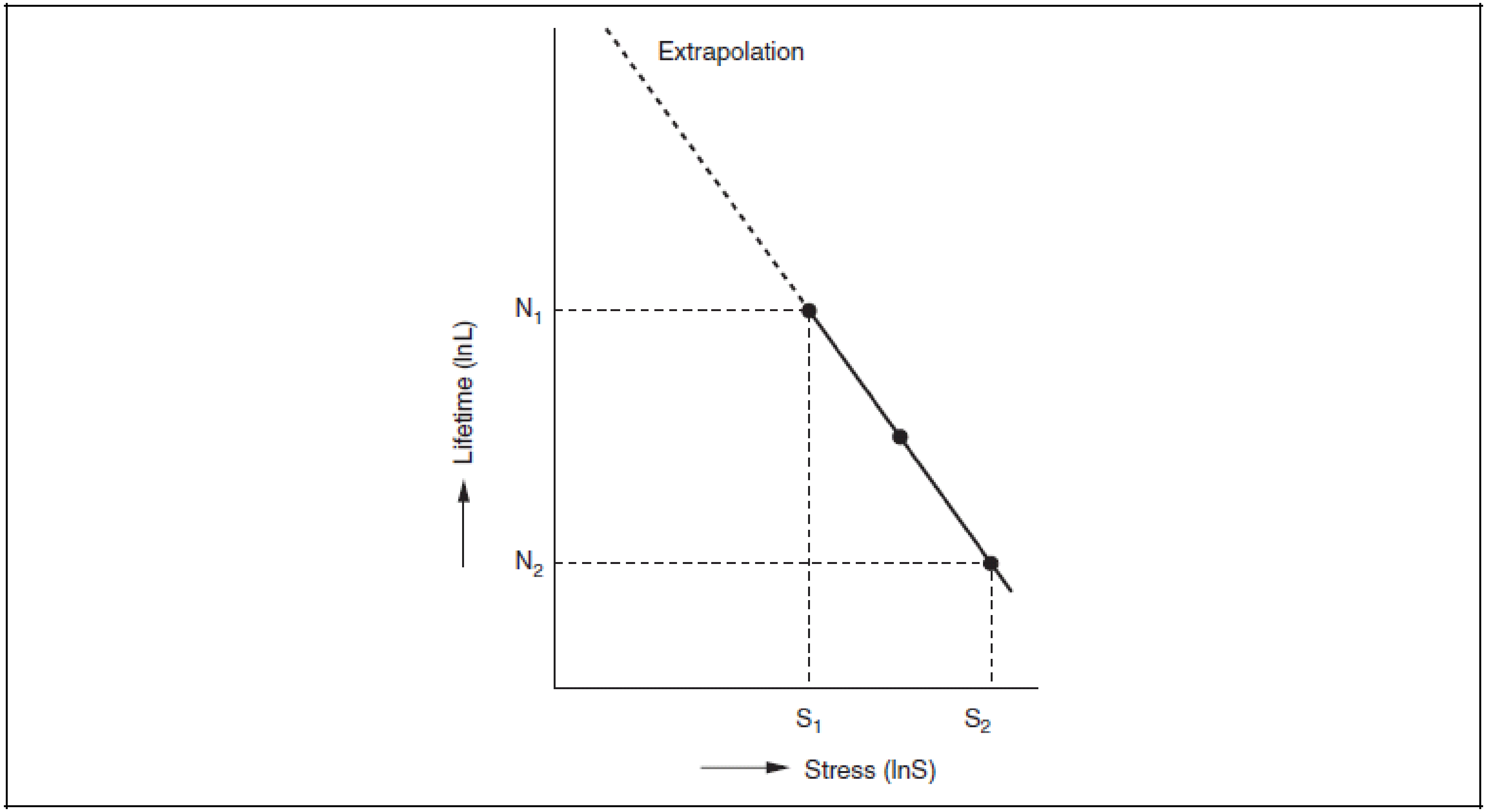


Figure 3.3 Schematic of the Eyring Model

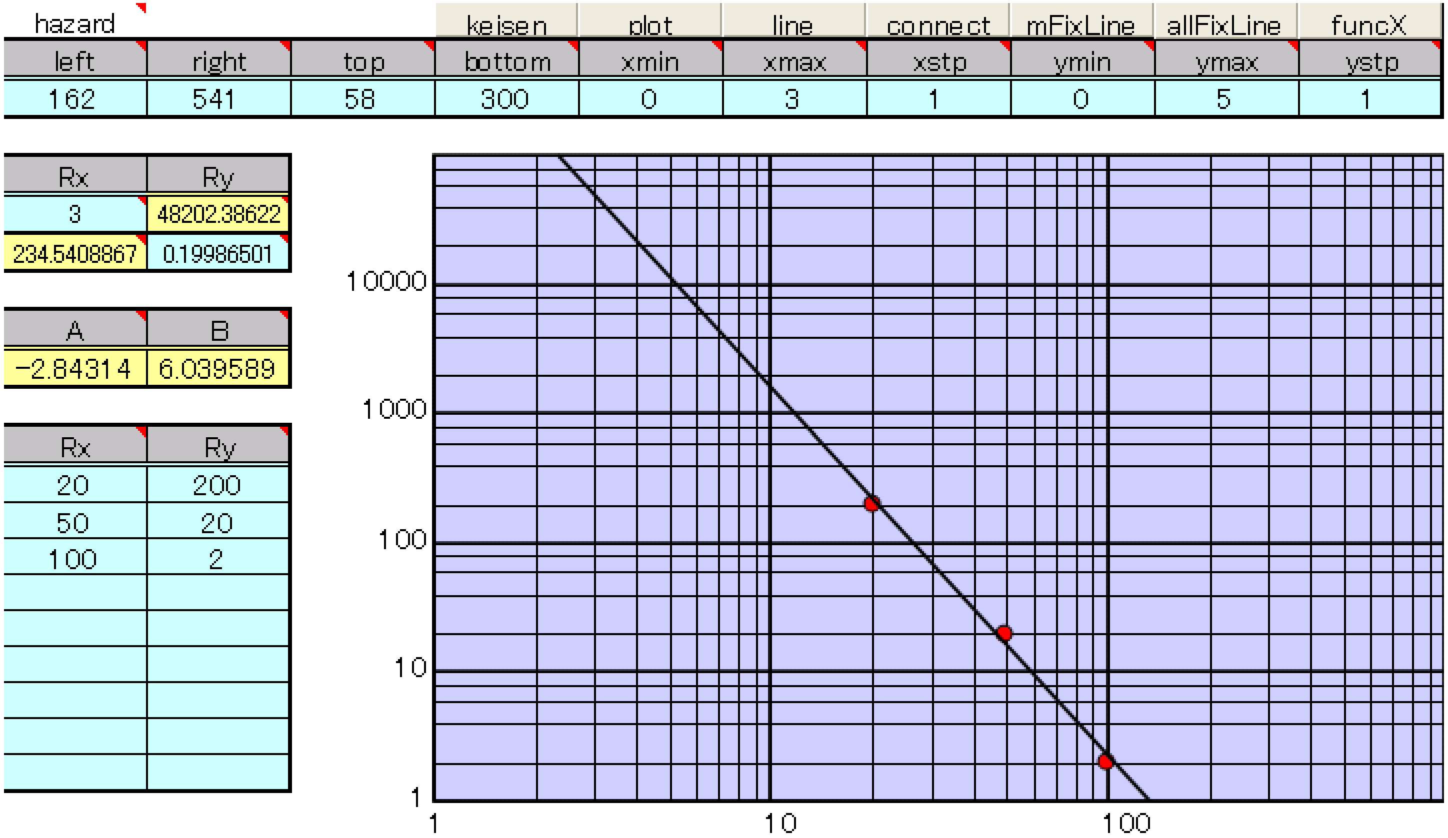
Ⅱ． Stress acceleration

Emi plot example (Essential mechanism illustrator)

(1) Easy input 20–200cycles, 50–20cycles, 100–2cycles

(2) Easy Calculation n= 2.84

(3) Easy predict 3–48202cycles



hazard

			keisen	plot	line	connect	mFixLine	allFixLine	funcX
left	right	top	bottom	xmin	xmax	xstp	ymin	ymax	ystp
162	541	58	300	0	3	1	0	5	1

Rx	Ry
3	48202.38622
234.5408867	0.19986501

A	B
−2.84314	6.039589

Rx	Ry
20	200
50	20
100	2

Ⅲ. Stress – Strength model

(1) Stress in the field will have distribution
(2) Strength of the Device will have distribution
(3) If Strength excess the strength, destruction occurs.
(4) Strength may decrease according to field time.

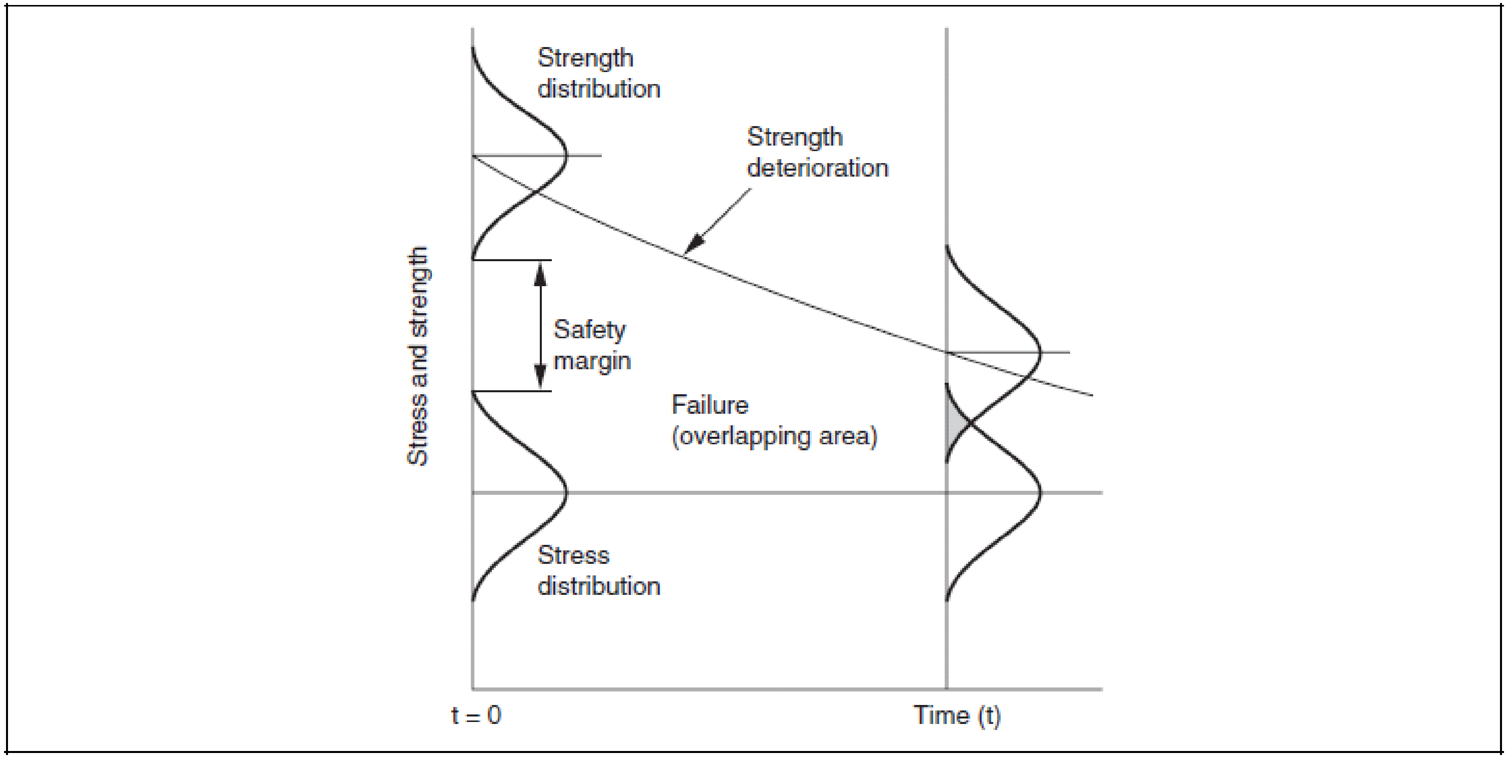


Figure 3.4 Stress Strength Model

Ⅲ. Stress – Strength model

(1) Step Stress test for Stress Strength model
(2) Quite reasonable high speed acceleration
(3) Stress stability is really important

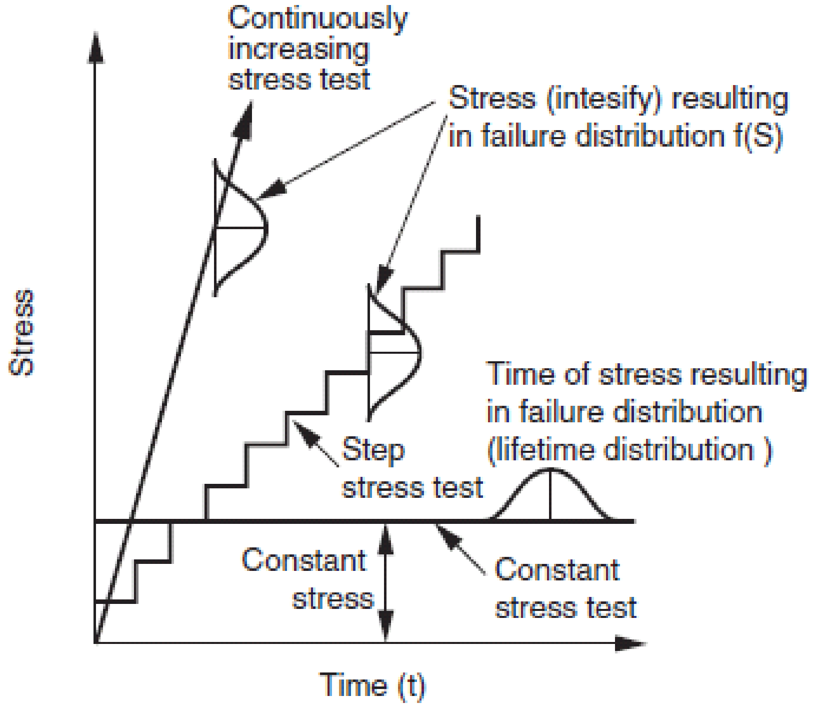
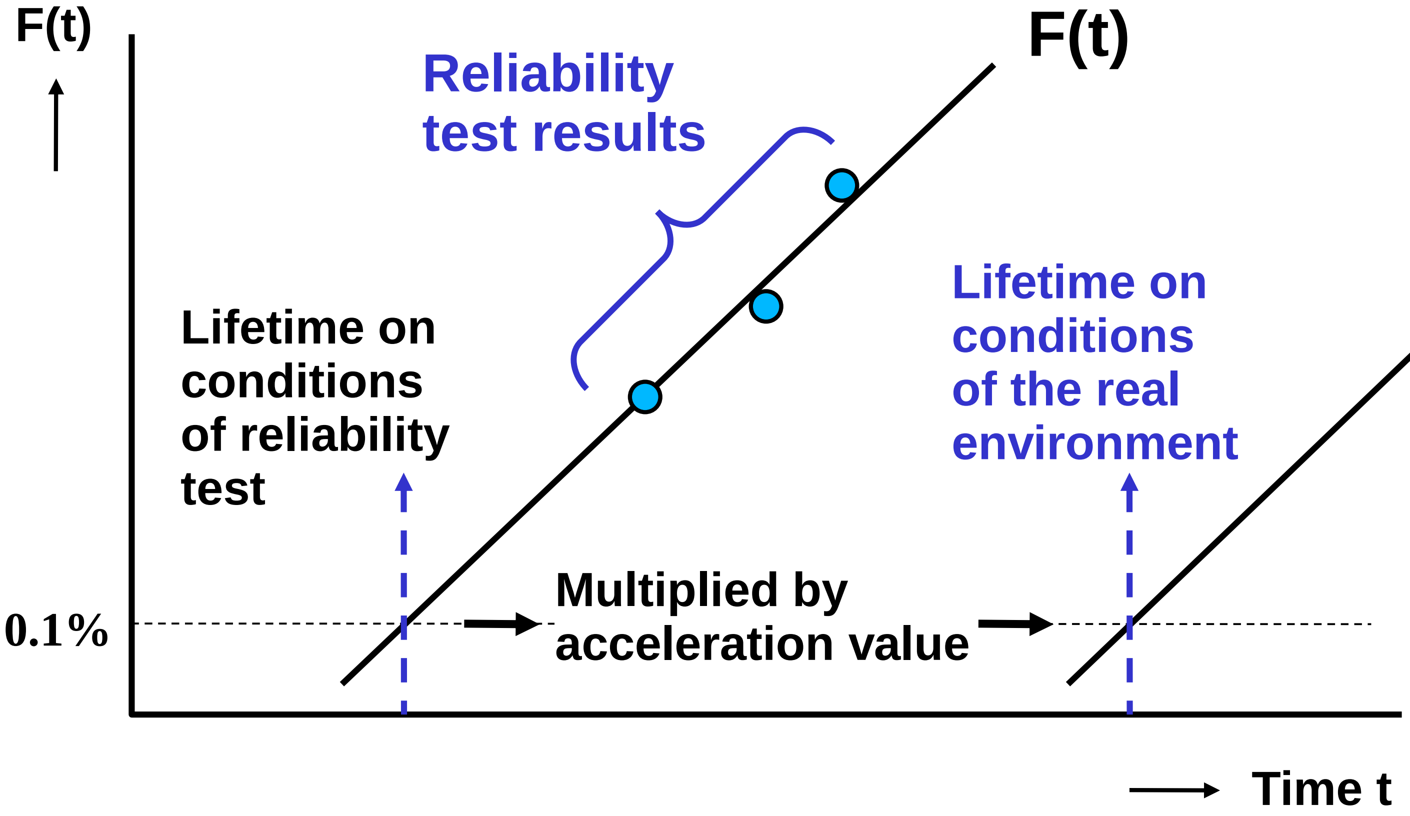


Figure 3.5 The Outline of Each Stress Tests

Table 3.5 Distribution of Representative Accelerated Lifetime Tests

Applied Stress Method	Purpose	Accelerated Test	Main Stressor	Failure Mechanism
Constant stress method	Investigation of the effects of constant stress on a device	High-temperature storage test	Temperature	Junction degradation, impurities deposit, ohmic contact, inter-metallic chemical compounds
		Operating lifetime test	Temperature Voltage Current	Surface contamination, junction degradation, mobile ions, EMD
		High temperature high-humidity storage	Temperature Humidity	Corrosion, surface contamination, pinhole
		High temperature high-humidity bias	Temperature Humidity Voltage	Corrosion, surface contamination, junction degradation, mobile Ions
Cyclic stress method	Investigation of the effects of repeated stress	Temperature cycle	Temperature difference Duty cycle	Cracks, thermal fatigue, broken wires and metallization
		Power cycle	Temperature difference Duty cycle	Insufficient adhesive strength of ohmic contact
		Temperature-humidity cycle	Temperature difference Humidity difference	Corrosion, pinhole, surface contamination
Step stress method	Investigation of the stress limit that a device can withstand	Operating test	Temperature Voltage Current	Surface contamination, junction degradation, mobile ions, EMD
		High-temperature reverse bias	Temperature Voltage	Surface contamination, junction degradation, mobile ions, TDDB

Useful failure function F(t) to estimate reliability ?



Generally in the wear out failure period, time until 0.1% of failure occurs is defined as the lifetime.

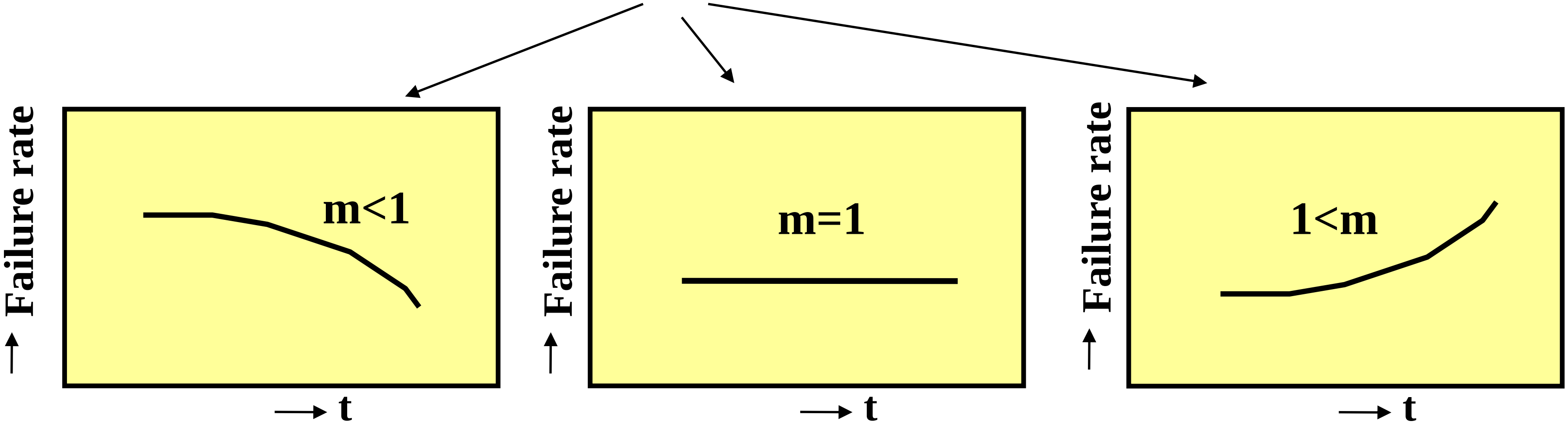
Weibull distribution

$$f(t) = m\, t^{(m-1)} / \eta^{m} \ \exp(-(t/\eta)^{m})$$

$$R(t) = \exp(-(t/\eta)^{m})$$

$$\text{Failure rate} = f(t) / R(t) = m\, t^{(m-1)} / \eta^{m}$$

$$= A \cdot t^{(m-1)}$$



For self-investigation

Weibull distribution to find the failure rate time dependency

$$F(t) = 1 - \exp(-(t/\eta)^m)$$

$$\ln(F(t)) = (t/\eta)^m$$

$$\log(-\ln(F(t))) = m \cdot \log(t) - m \cdot \log(\eta)$$

$$Y = m \cdot X + C$$

$Y = \log(-\ln(F(t)))$ $X = \log(t)$

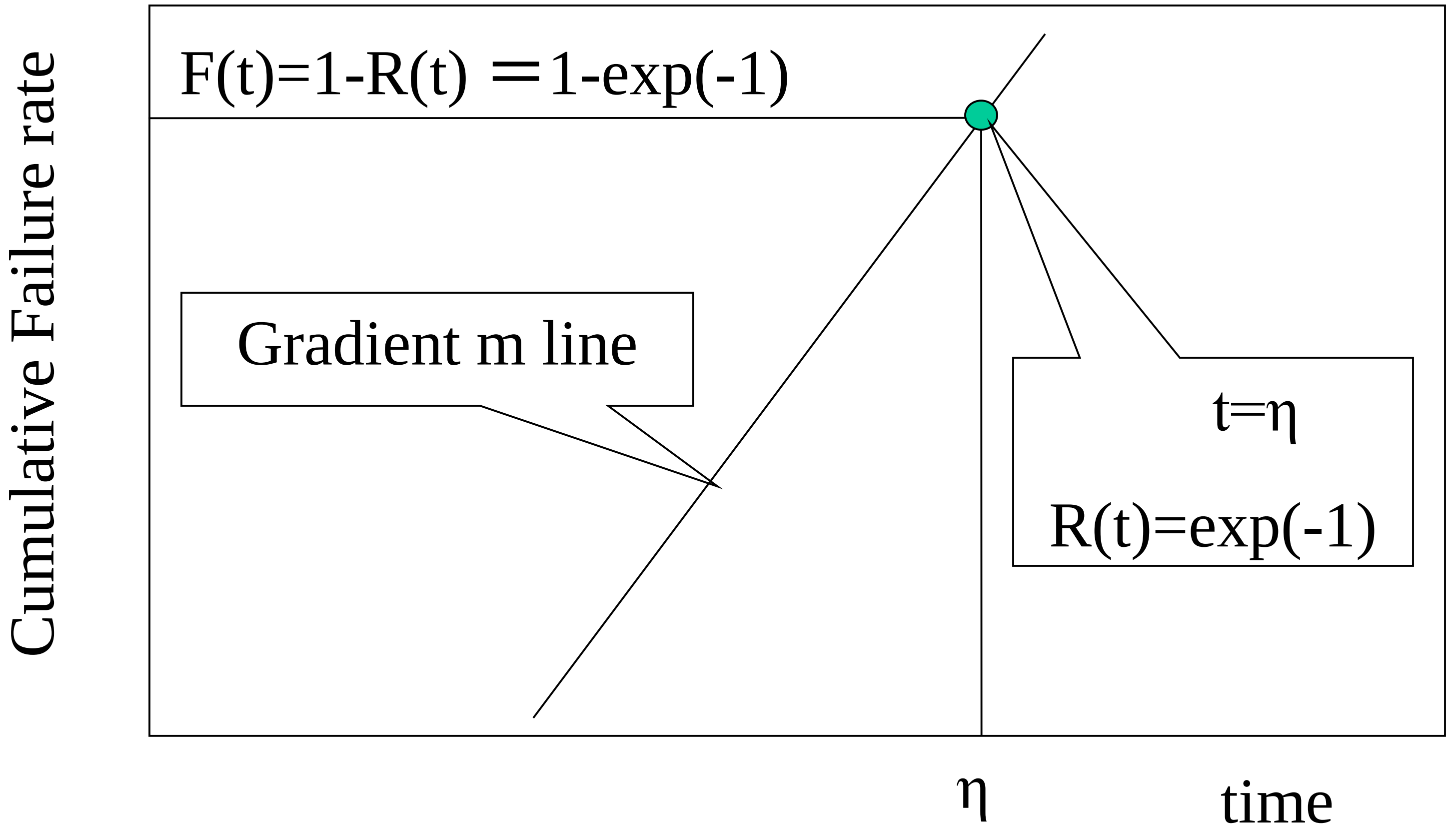
$C = -m \cdot \log(\eta)$

For self-investigation

Weibull distribution to find the failure rate time dependency

$$R(t) = \exp(-(t/\eta)^m)$$

$$R(\eta) = \exp(-1)$$



For self-investigation

Weibull distribution to find the failure rate time dependency

$$R(t) = \exp(-(t/\eta)^m)$$

$$R(\eta) = \exp(-1)$$

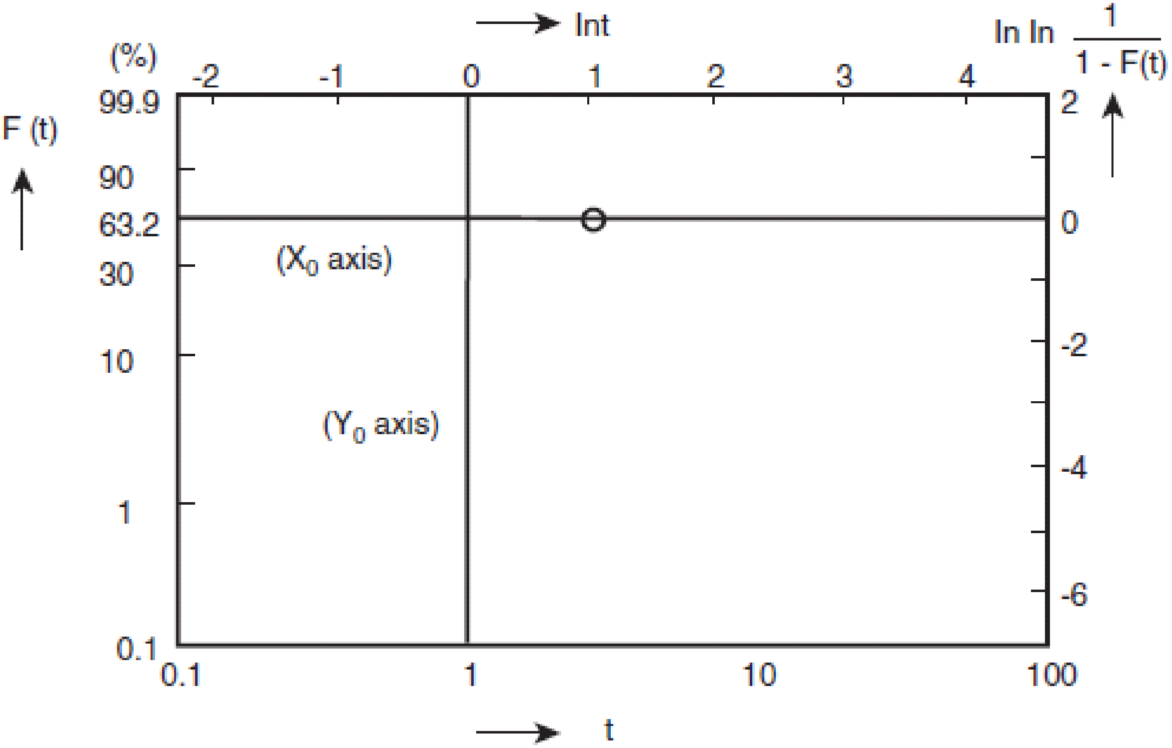


Figure 3.6 Basic Format of Weibull Probability Paper

For self-investigation

Weibull distribution to find the failure rate time dependency

(1) Weibull parameter can be get by chart paper
(2) We had better to use PC software Emi (easy & accurate)
(3) PC soft is useful for future prediction too (small m)

Emi ; Essential mechanism illustrator

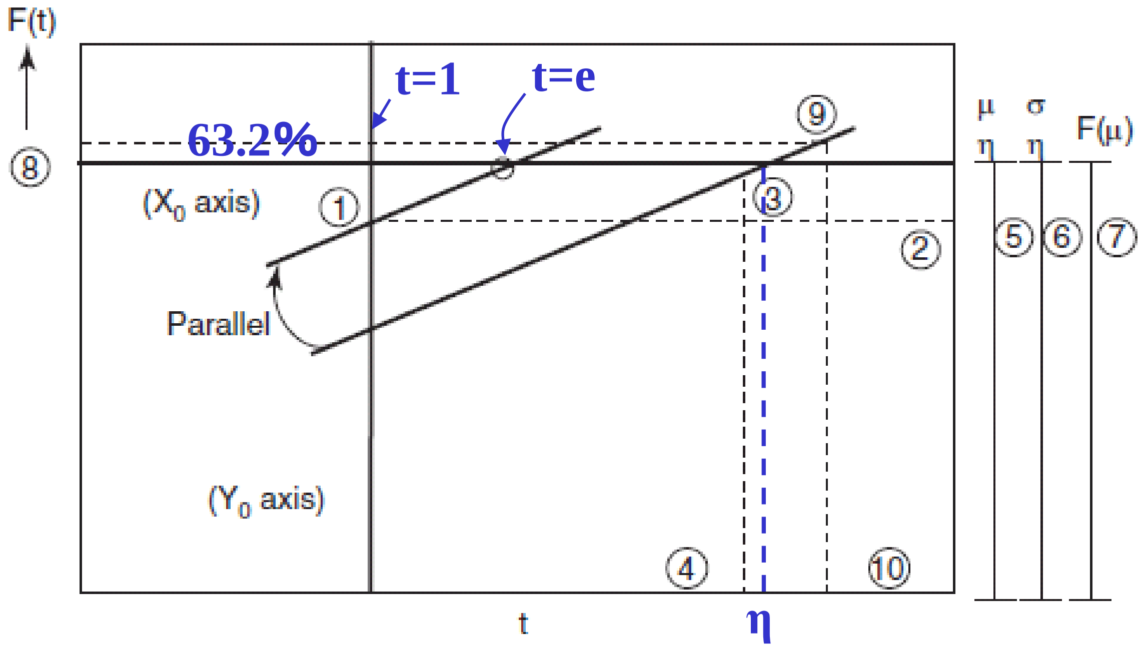


Figure 3.9 Procedure for Use of Weibull Probability

For self-investigation

Weibull distribution to find the failure rate time dependency

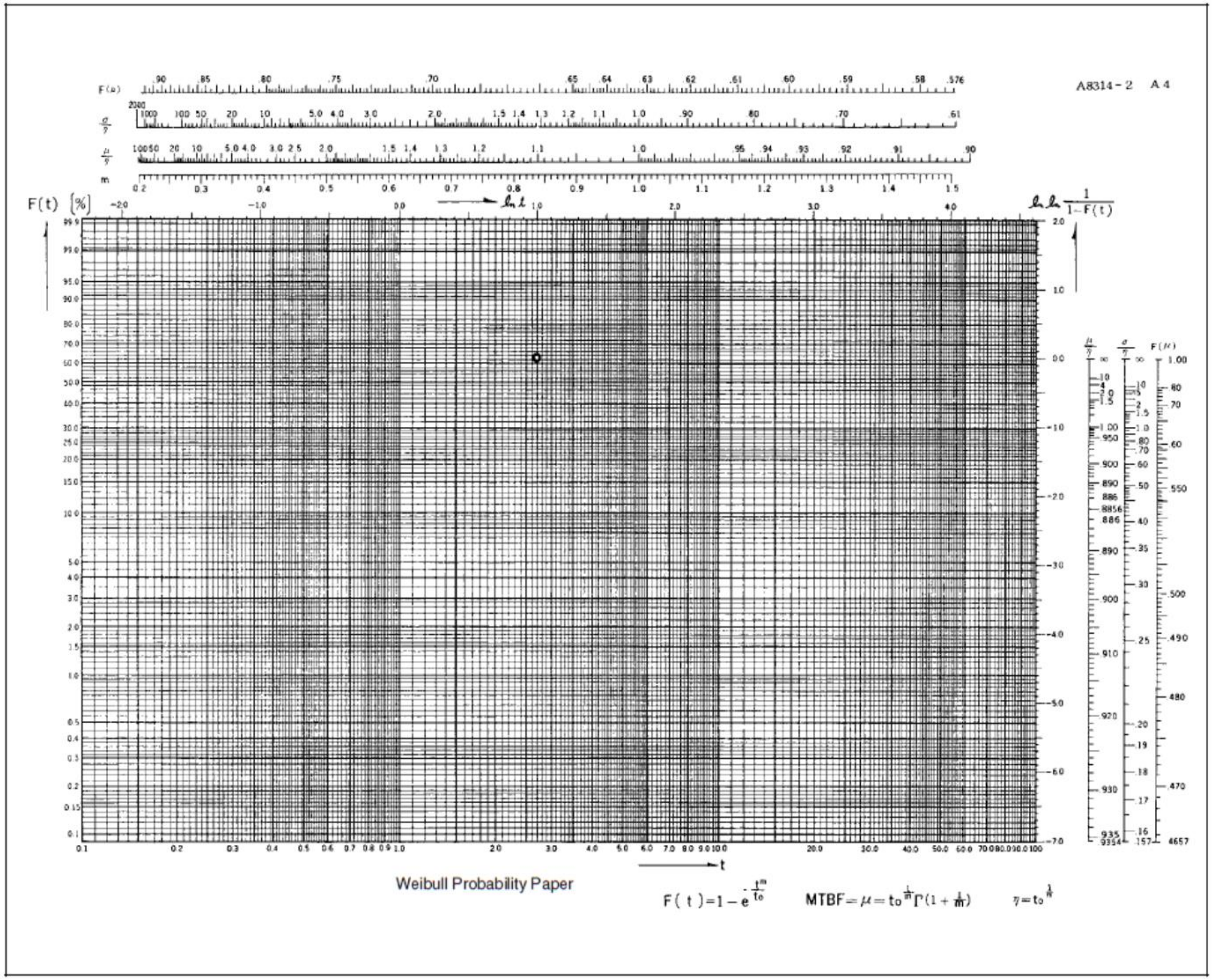


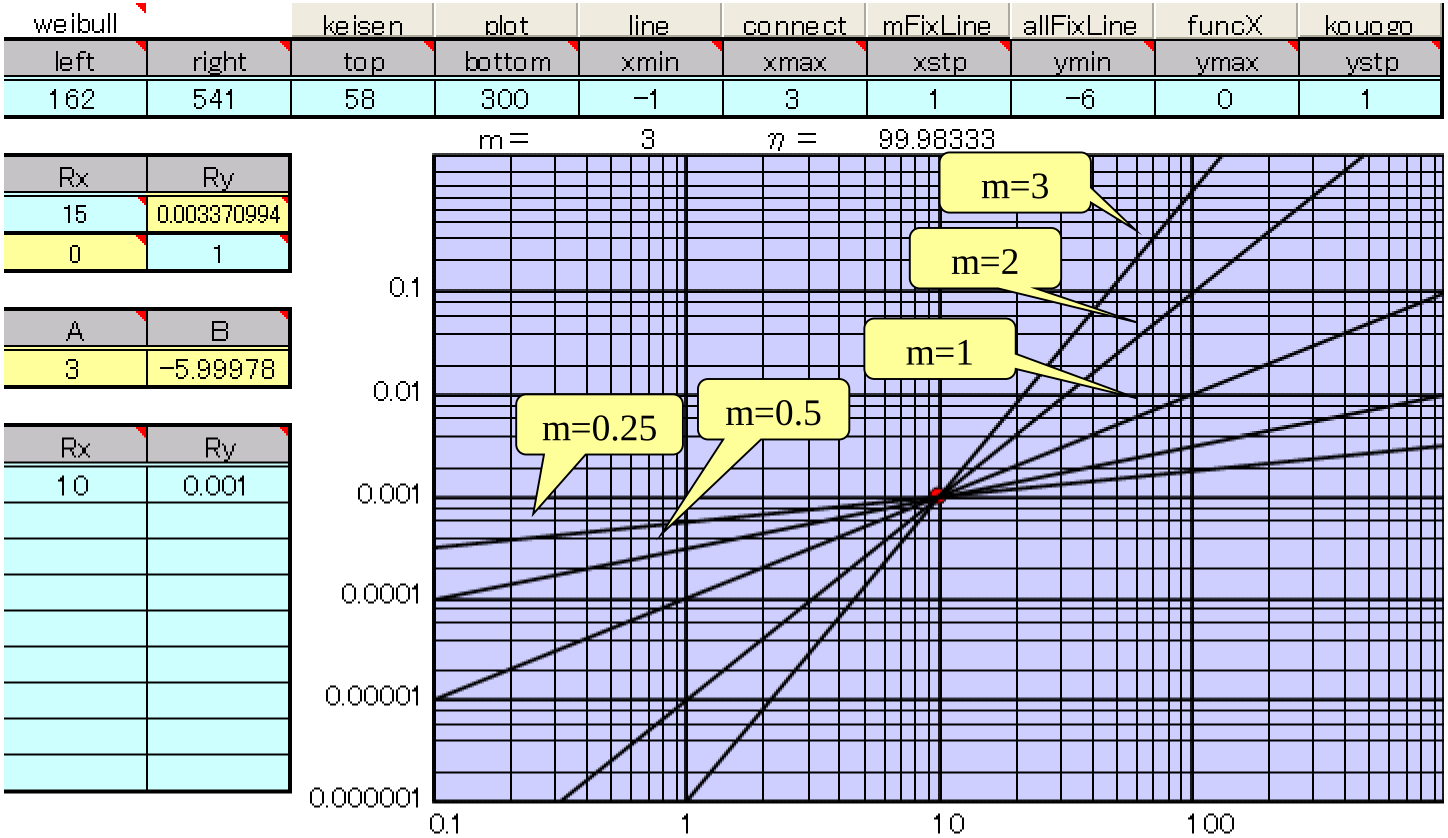
Figure 3.8 Example of Weibull Probability Paper

For self-investigation

Weibull distribution to find the failure rate time dependency

Emi plot example (Essential mechanism illustrator)

(1) 10 year η case
(2) m dependency
(3) Very small m can be calculated



weibull		keisen	plot	line	connect	mFixLine	allFixLine	funcX	kouogo
left	right	top	bottom	xmin	xmax	xstp	ymin	ymax	ystp
162	541	58	300	−1	3	1	−6	0	1

m= 3 η = 99.98333

Rx	Ry
15	0.003370994
0	1

A	B
3	−5.99978

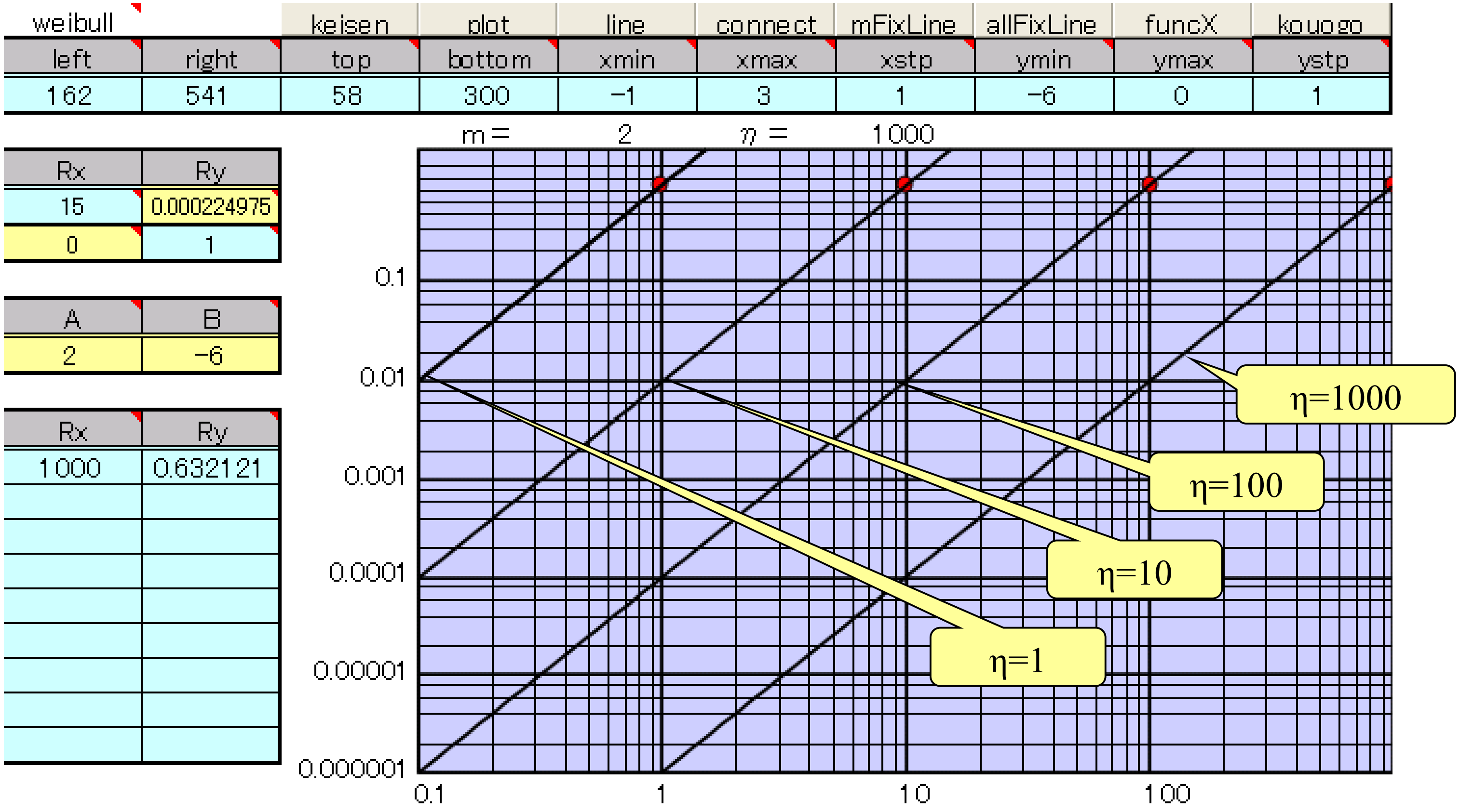
Rx	Ry
10	0.001

For self-investigation

Weibull distribution to find the failure rate time dependency

Emi plot example (Essential mechanism illustrator)

(1) m = 2 case
(2) η dependency
(3) Very small failure rate can be calculated



weibull		keisen	plot	line	connect	mFixLine	allFixLine	funcX	kouogo
left	right	top	bottom	xmin	xmax	xstp	ymin	ymax	ystp
162	541	58	300	−1	3	1	−6	0	1

m= 2 η = 1000

Rx	Ry
15	0.000224975
0	1

A	B
2	−6

Rx	Ry
1000	0.632121

For self-investigation

Weibull distribution to find the failure rate time dependency

(1) m>>1 ; wear out failure
(2) m = 1 ; random failure
(3) m <<1 ;initial failure
(4) m is not constant multiple failure mode
or screening reslts

To plot the weibull chart, sample size must be the same

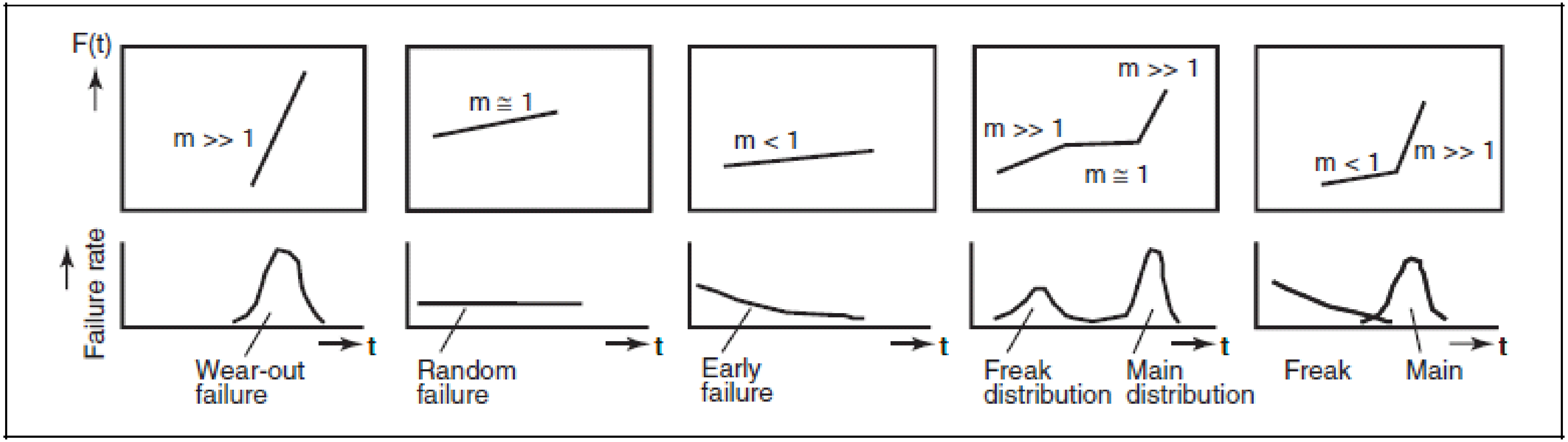


Figure 3.10 Example of Weibull Probability Results

For self-investigation

Hazard distribution to find the failure rate time dependency

hazard function H(t) and R(t) $R(t)=\exp(-H(t))$

H(t) is cumulated defect count at time t

$\lambda(t_i)$is failure rate between $t_i \sim t_i +1$

$$H(t) = \Sigma\lambda(t_i)*\Delta t_i$$

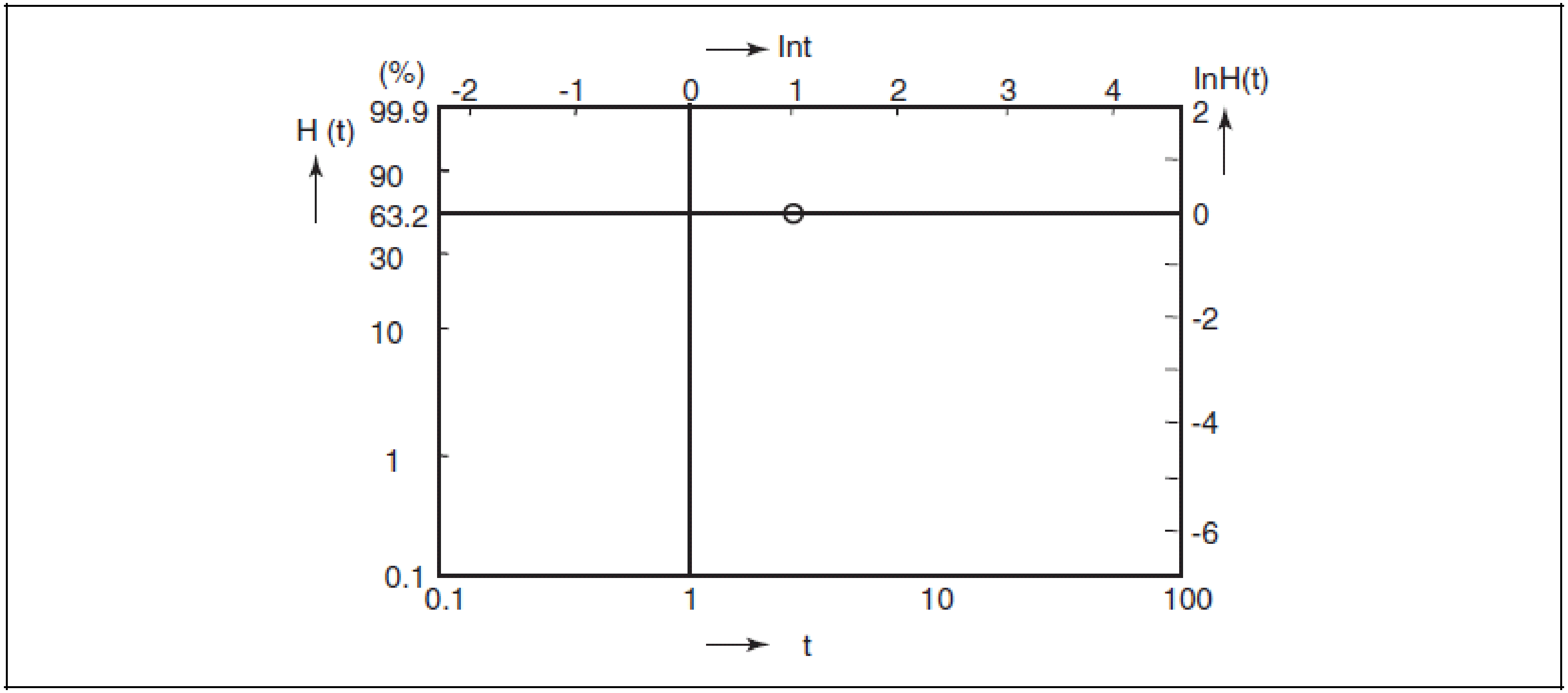
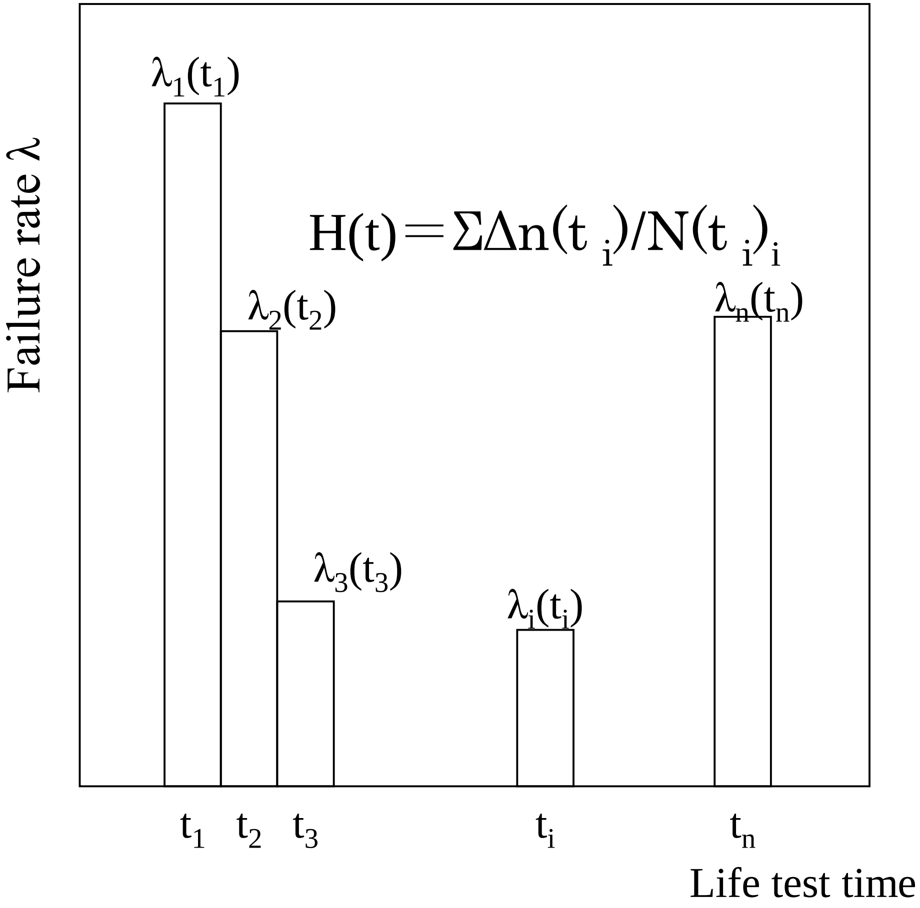


Figure 3.11 Basic Format of Weibull Type Cumulative Hazard Paper

For self-investigation

Hazard distribution to find the failure rate time dependency

$$H(t) = \Sigma\lambda(t_i)*\Delta t_i$$
$$= \Sigma\Delta n(t_i)/(N(t_i)*\Delta t_i)*\Delta t_i$$
$$= \Sigma\Delta n(t_i)/N(t_i)$$



Hazard function H(t) is a function of each time's operating count N and failure count Δn

Each time's count must not be the same!

For self-investigation

Hazard distribution to find the failure rate time dependency

Hazard distribution is Log – Log curve

Hazard function of weibull distribution

$$R(t)=\exp(-H(t))$$

Weibull distribution $R(t)=\exp(-(t/\eta)^{m})$

$$H(t)=(t/\eta)^{m}$$

$$\mathrm{Log}(H(t))=m\cdot\log(t)-m\cdot\log(\eta)$$

$Y=\mathrm{Log}(H(t))$ $X=\log(t)$ $C=-m\cdot\log(\eta)$

$$Y=mX+C$$

For self-investigation

Hazard distribution to find the failure rate time dependency

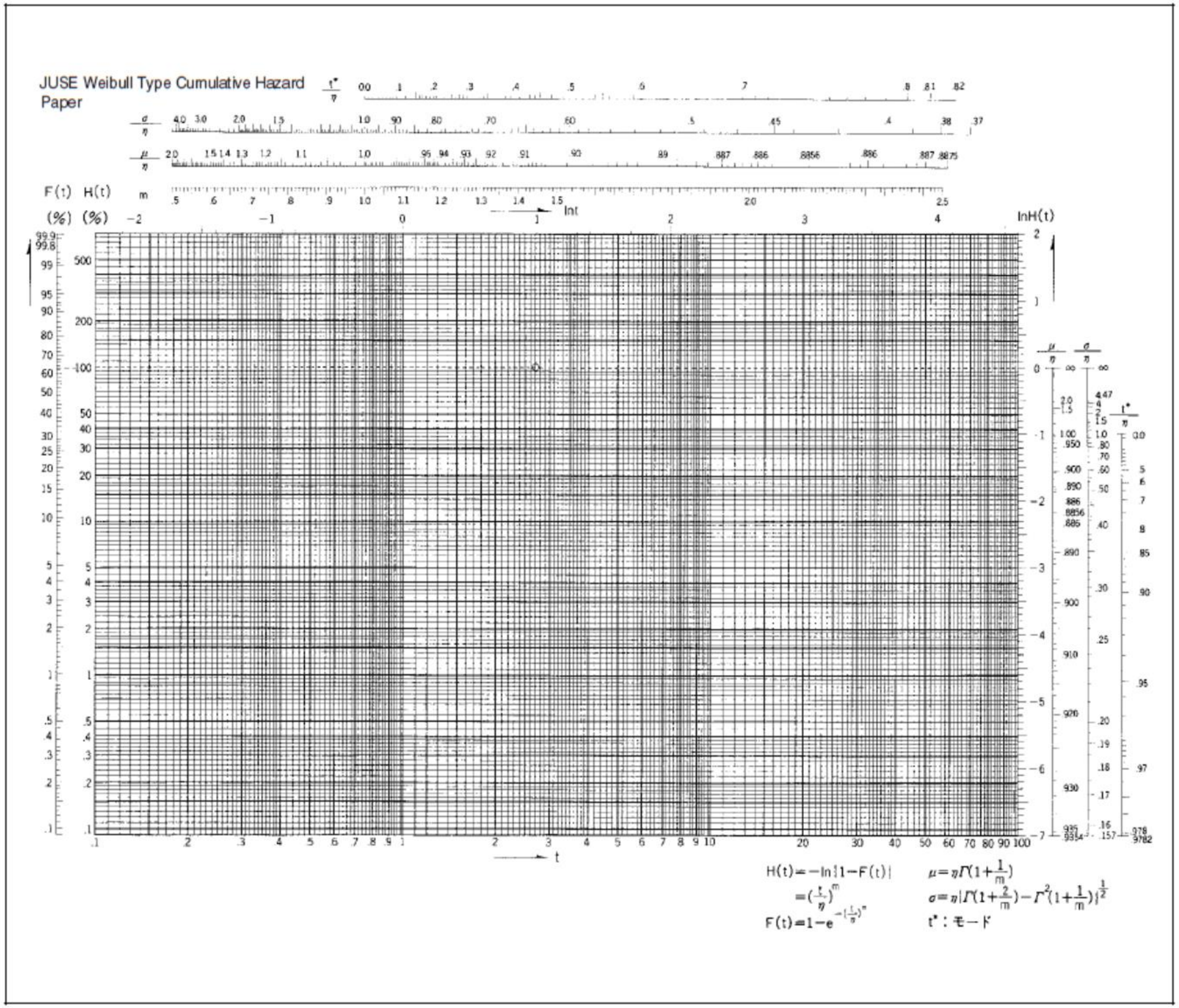


Figure 3.12 Example of Weibull Type Hazard Paper

For self-investigation

Hazard distribution to find the failure rate time dependency

Hazard function of weibull distribution

$$R(t) = \exp(-H(t))$$

$$F(t) = 1 - \exp(-H(t))$$

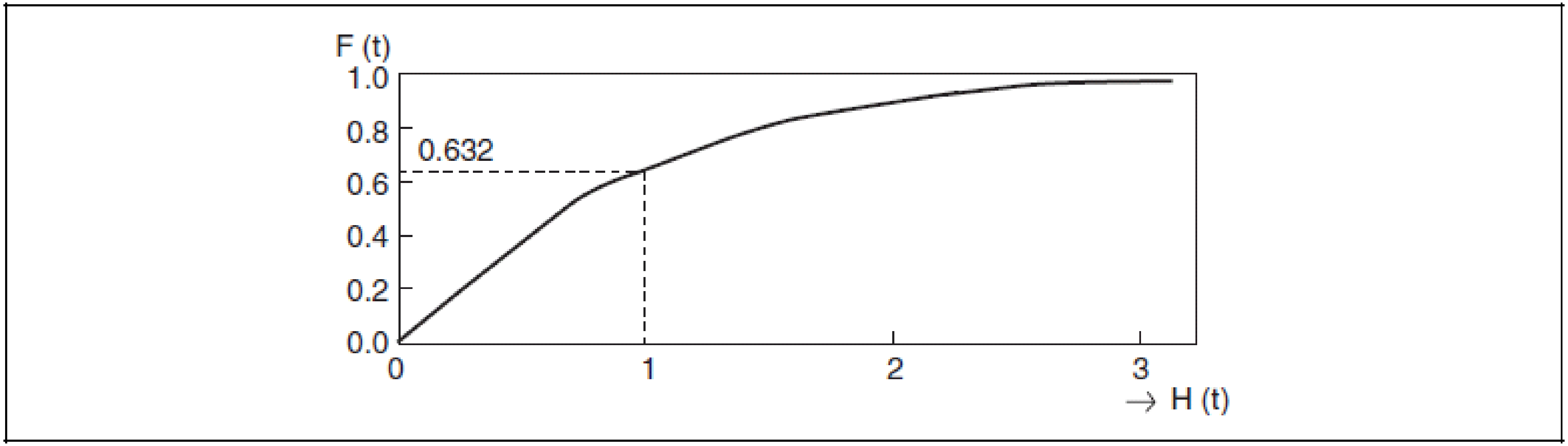
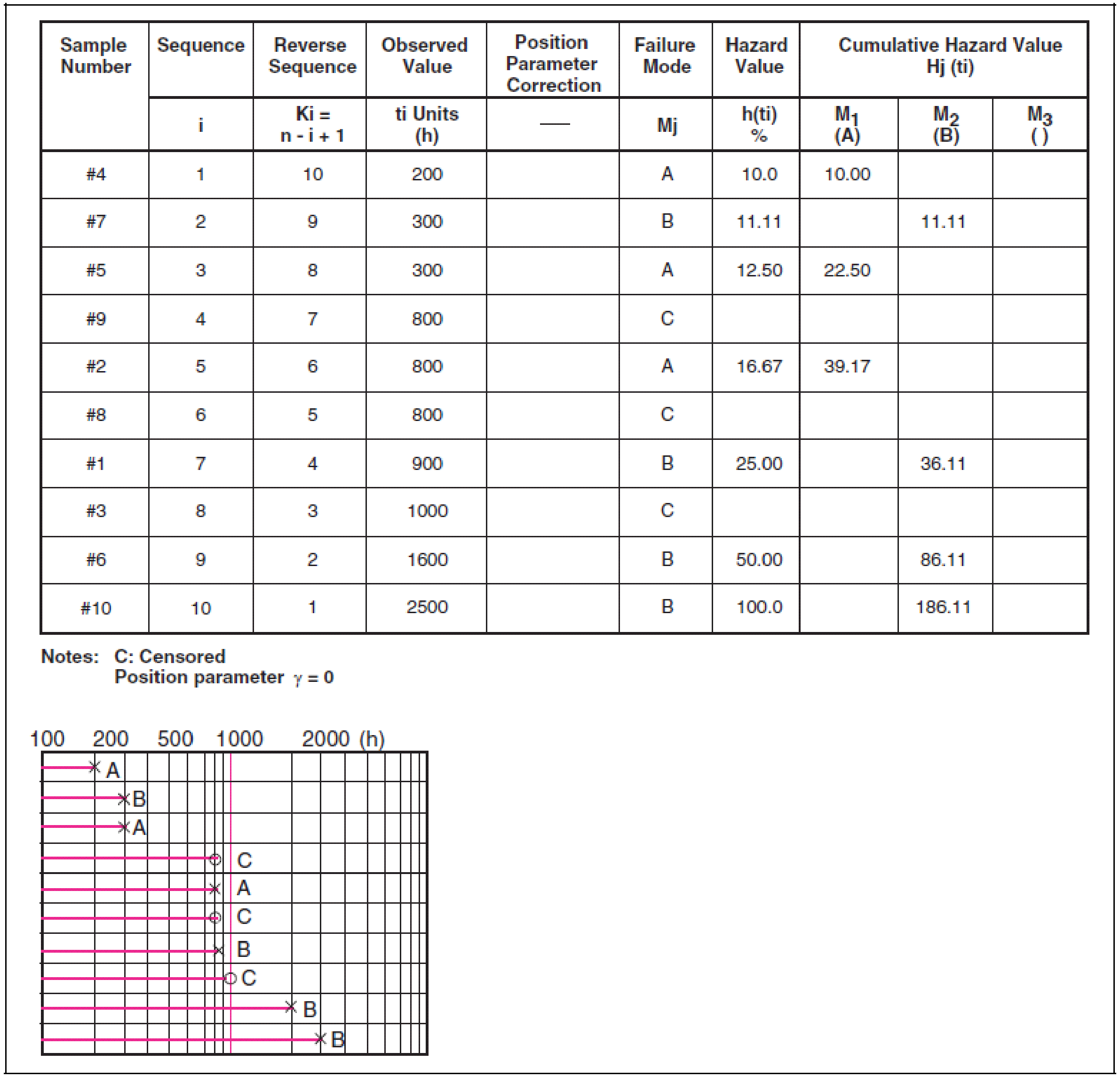


Figure 3.13 Relationship between F(t) and H(t)

Hazard distribution to find the failure rate time dependency

For self-investigation

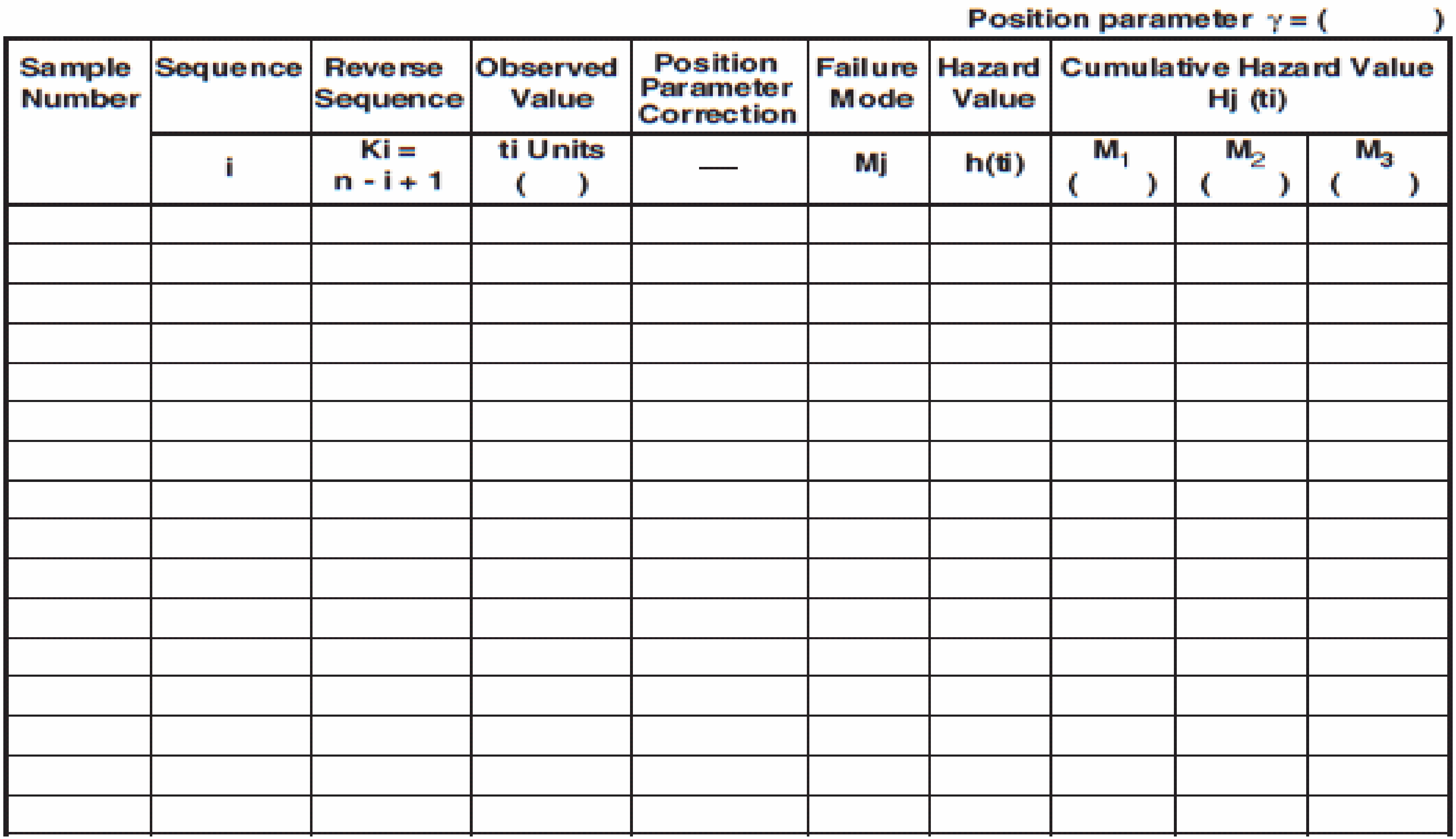


Sample Number	Sequence	Reverse Sequence	Observed Value	Position Parameter Correction	Failure Mode	Hazard Value	Cumulative Hazard Value Hj (ti)		
	i	Ki = n - i + 1	ti Units (h)	—	Mj	h(ti) %	M_1 (A)	M_2 (B)	M_3 ( )
#4	1	10	200		A	10.0	10.00		
#7	2	9	300		B	11.11		11.11	
#5	3	8	300		A	12.50	22.50		
#9	4	7	800		C				
#2	5	6	800		A	16.67	39.17		
#8	6	5	800		C				
#1	7	4	900		B	25.00		36.11	
#3	8	3	1000		C				
#6	9	2	1600		B	50.00		86.11	
#10	10	1	2500		B	100.0		186.11	

Notes: C: Censored
Position parameter $\gamma = 0$

Figure 3.14 Fill-in Example of Work Sheet

Hazard distribution to find the failure rate time dependency



Position parameter γ = (   )

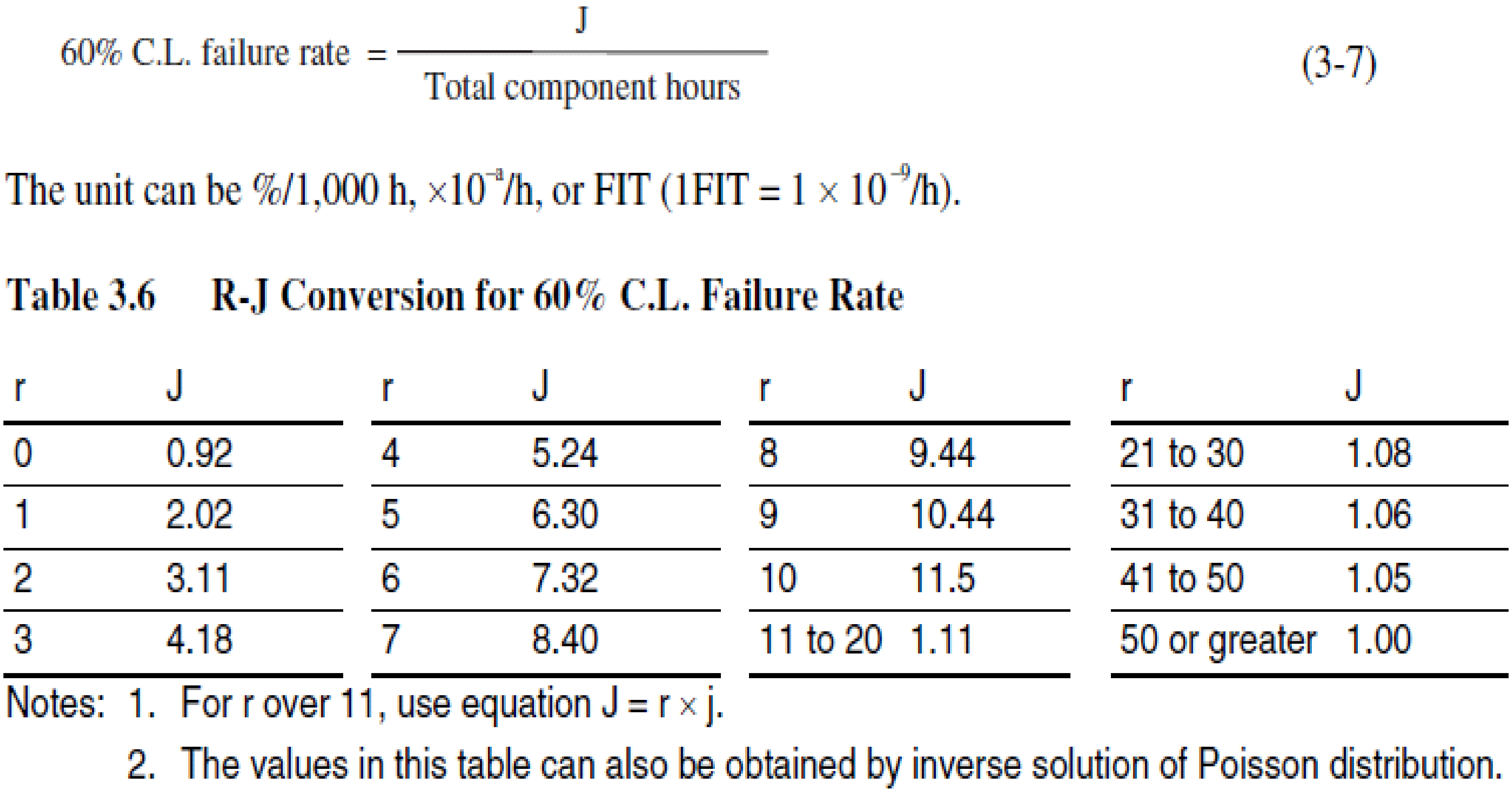
Sample Number	Sequence	Reverse Sequence	Observed Value	Position Parameter Correction	Failure Mode	Hazard Value	Cumulative Hazard Value Hj (ti)		
	i	Ki = n - i + 1	ti Units ( )	—	Mj	h(ti)	M_1 ( )	M_2 ( )	M_3 ( )

Figure 3.15 Example of Work Sheet Used for Data on Cumulative Hazard Paper

For self-investigation

How to estimate field reliability with confidence

Even if zero failure, it has probability to failure.



$$60\%\ \text{C.L. failure rate} = \frac{J}{\text{Total component hours}} \qquad (3\text{-}7)$$

The unit can be %/1,000 h, $\times 10^{-a}$/h, or FIT (1FIT = 1×10^{-9}/h).

Table 3.6 R-J Conversion for 60% C.L. Failure Rate

r	J	r	J	r	J	r	J
0	0.92	4	5.24	8	9.44	21 to 30	1.08
1	2.02	5	6.30	9	10.44	31 to 40	1.06
2	3.11	6	7.32	10	11.5	41 to 50	1.05
3	4.18	7	8.40	11 to 20	1.11	50 or greater	1.00

Notes: 1. For r over 11, use equation J = r × j.

2. The values in this table can also be obtained by inverse solution of Poisson distribution.

How to estimate field reliability with confidence

For self-investigation

Plot all the data at the same weibull chart.

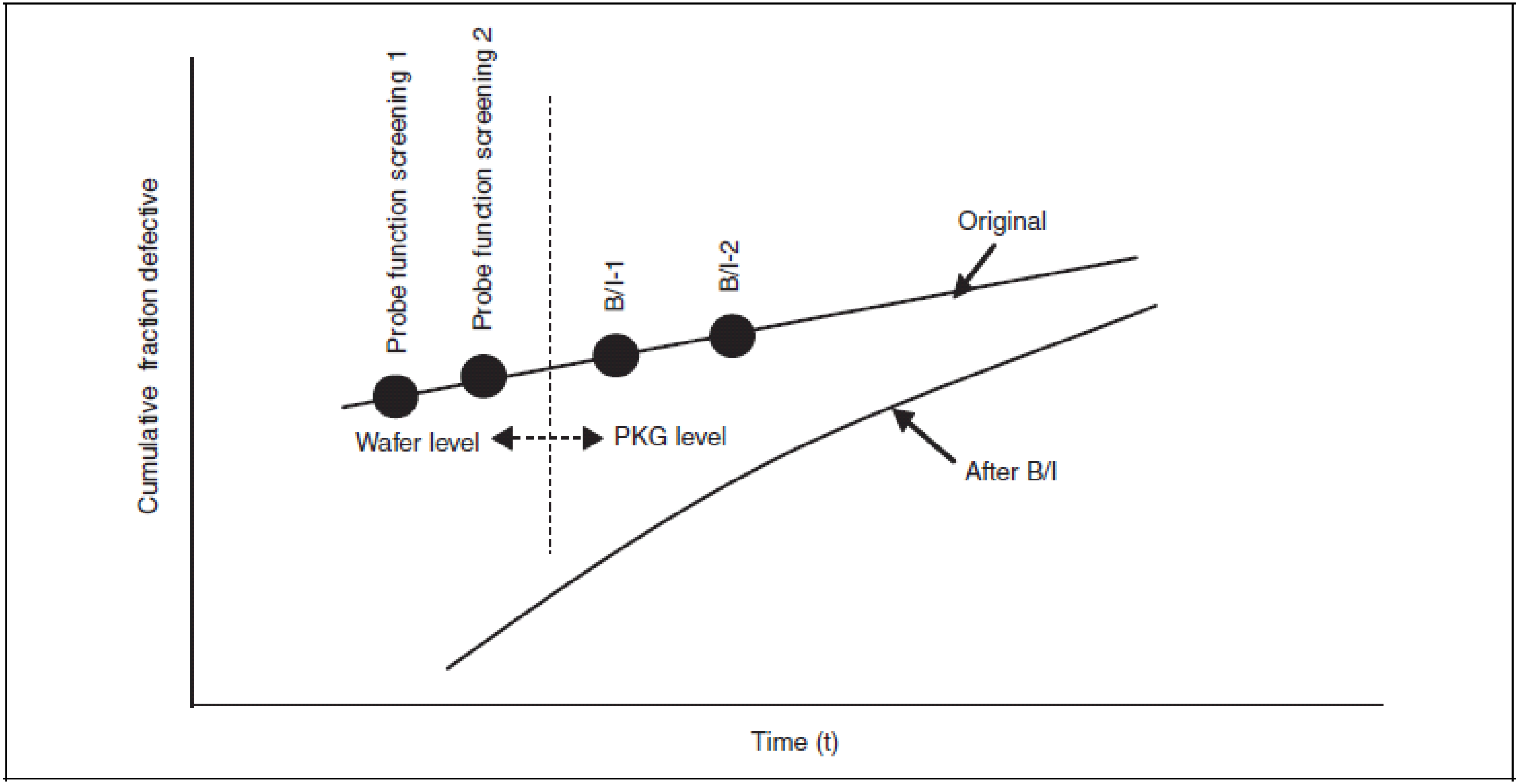


Figure 3.16 Life Prediction through Weibull Plotting

For self-investigation

How to estimate field reliability with confidence

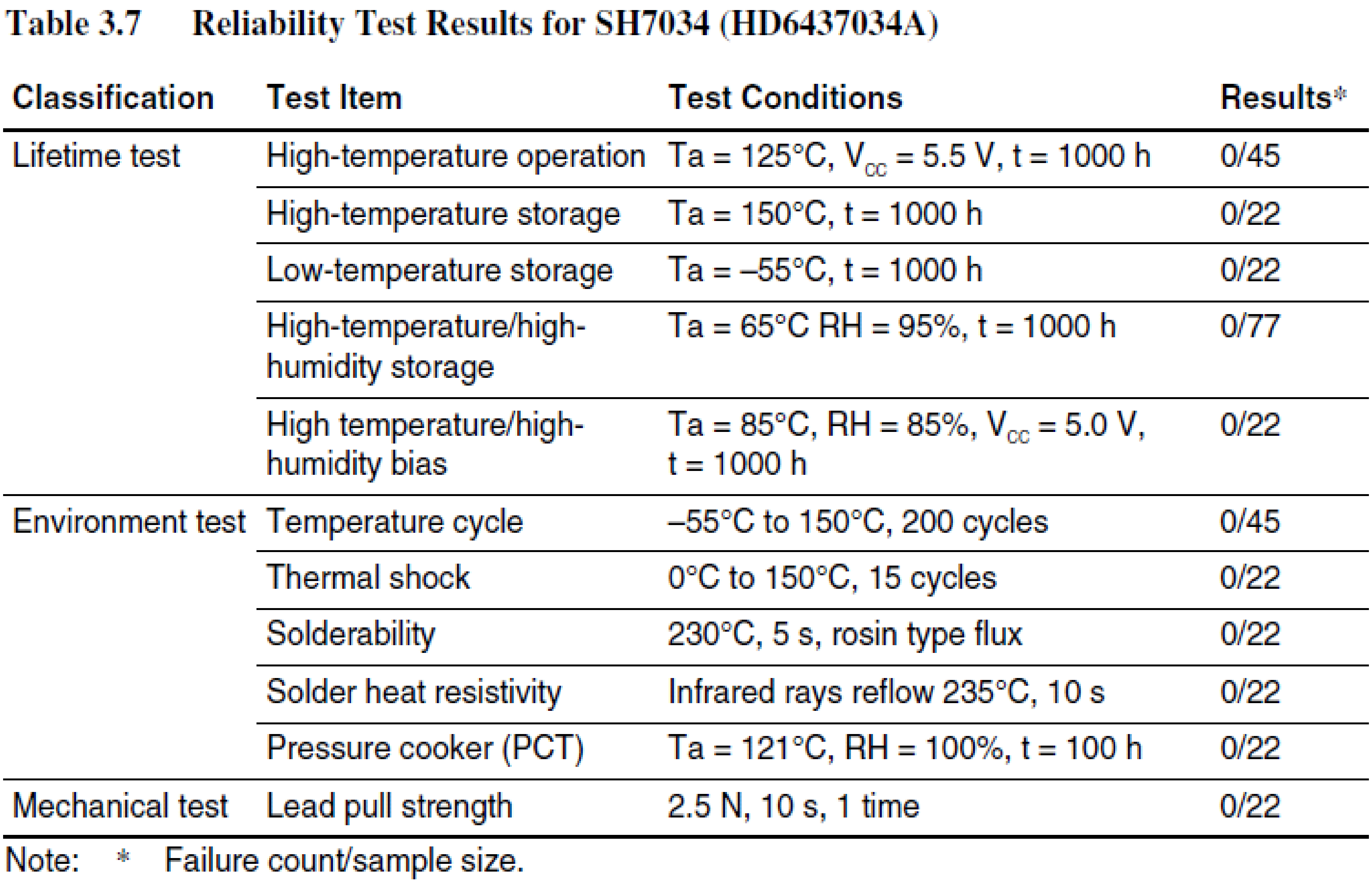


Table 3.7 Reliability Test Results for SH7034 (HD6437034A)

Classification	Test Item	Test Conditions	Results*
Lifetime test	High-temperature operation	Ta = 125°C, V_{CC} = 5.5 V, t = 1000 h	0/45
	High-temperature storage	Ta = 150°C, t = 1000 h	0/22
	Low-temperature storage	Ta = –55°C, t = 1000 h	0/22
	High-temperature/high-humidity storage	Ta = 65°C RH = 95%, t = 1000 h	0/77
	High temperature/high-humidity bias	Ta = 85°C, RH = 85%, V_{CC} = 5.0 V, t = 1000 h	0/22
Environment test	Temperature cycle	–55°C to 150°C, 200 cycles	0/45
	Thermal shock	0°C to 150°C, 15 cycles	0/22
	Solderability	230°C, 5 s, rosin type flux	0/22
	Solder heat resistivity	Infrared rays reflow 235°C, 10 s	0/22
	Pressure cooker (PCT)	Ta = 121°C, RH = 100%, t = 100 h	0/22
Mechanical test	Lead pull strength	2.5 N, 10 s, 1 time	0/22

Note: * Failure count/sample size.

For self-investigation

How to estimate field reliability with confidence

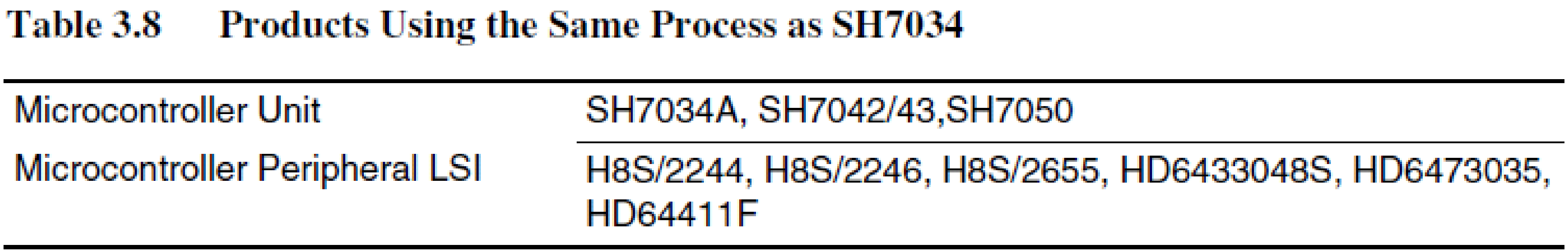


Table 3.8 Products Using the Same Process as SH7034

Microcontroller Unit	SH7034A, SH7042/43,SH7050
Microcontroller Peripheral LSI	H8S/2244, H8S/2246, H8S/2655, HD6433048S, HD6473035, HD64411F

For self-investigation

How to estimate field reliability with confidence

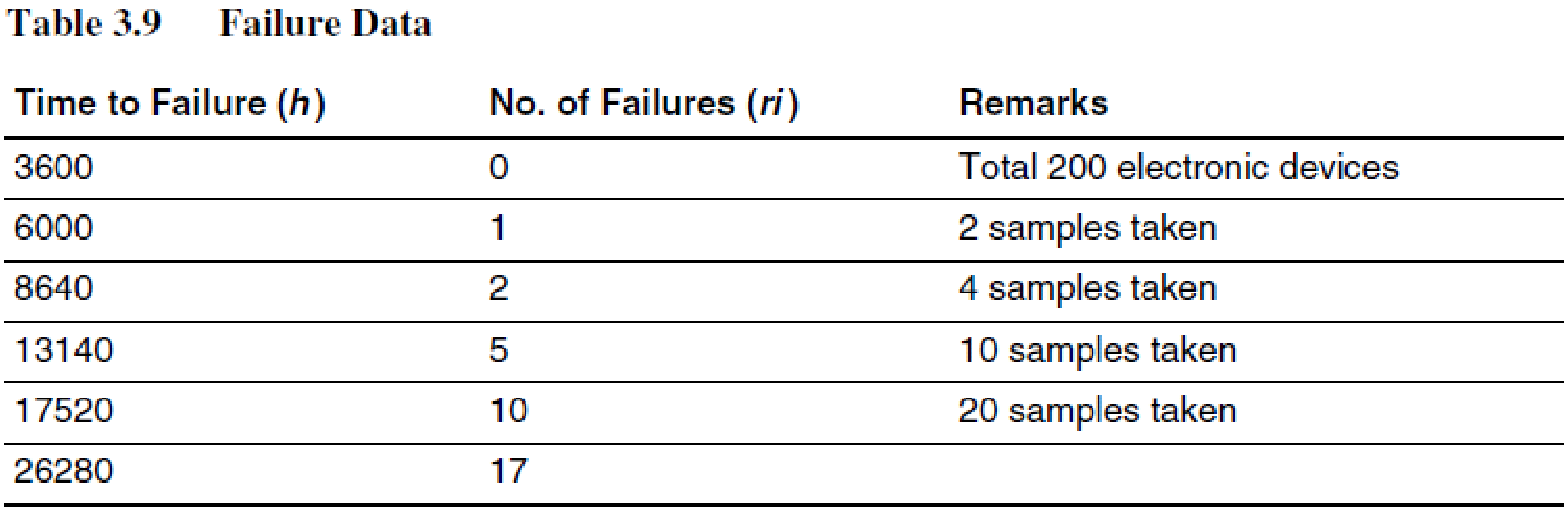


Table 3.9 Failure Data

Time to Failure (*h*)	No. of Failures (*ri*)	Remarks
3600	0	Total 200 electronic devices
6000	1	2 samples taken
8640	2	4 samples taken
13140	5	10 samples taken
17520	10	20 samples taken
26280	17	

For self-investigation

How to estimate field reliability with confidence

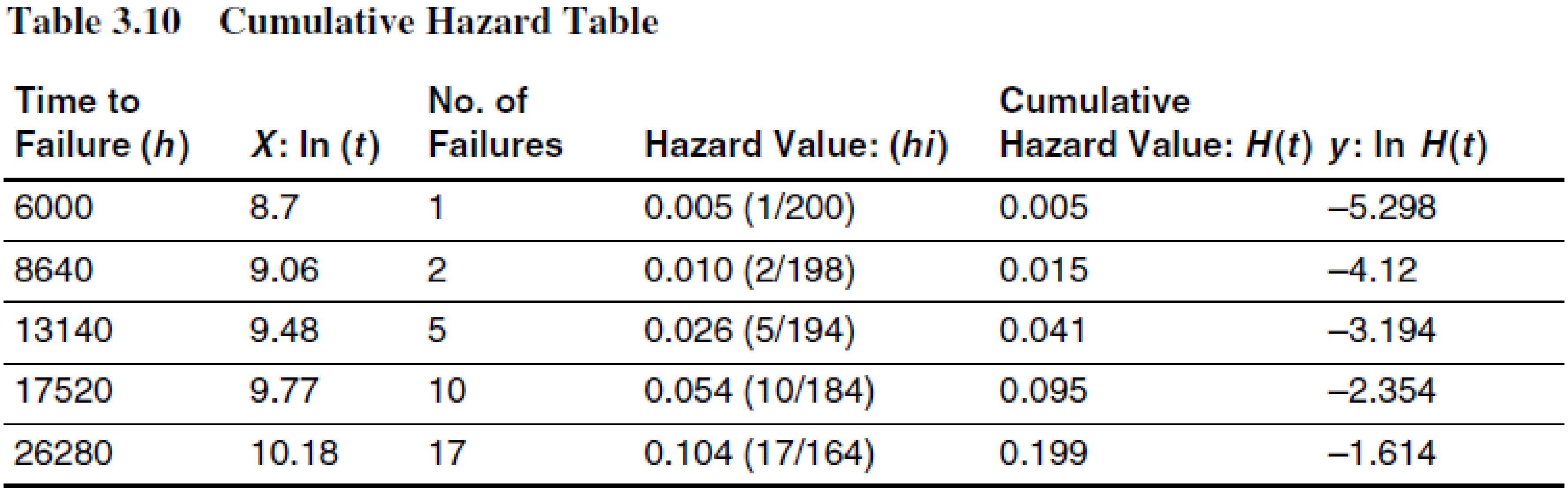


Table 3.10 Cumulative Hazard Table

Time to Failure (*h*)	*X*: ln (*t*)	No. of Failures	Hazard Value: (*hi*)	Cumulative Hazard Value: *H*(*t*)	*y*: ln *H*(*t*)
6000	8.7	1	0.005 (1/200)	0.005	–5.298
8640	9.06	2	0.010 (2/198)	0.015	–4.12
13140	9.48	5	0.026 (5/194)	0.041	–3.194
17520	9.77	10	0.054 (10/184)	0.095	–2.354
26280	10.18	17	0.104 (17/164)	0.199	–1.614

For self-investigation

How to estimate field reliability with confidence

Get m and η value from hazard analysis

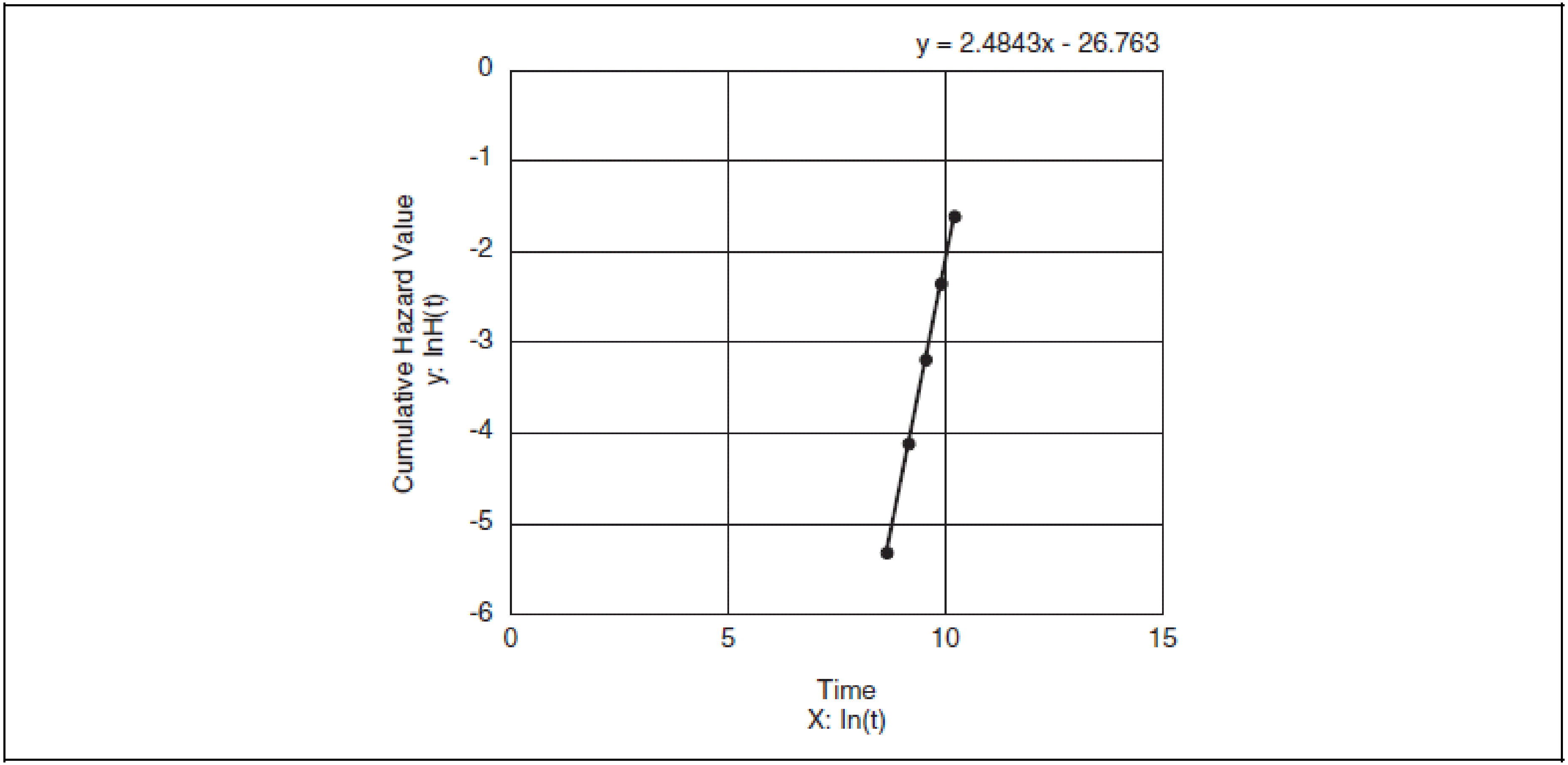


Figure 3.17 Lifetime Distribution from Weibull Cumulative Hazard Paper

For self-investigation

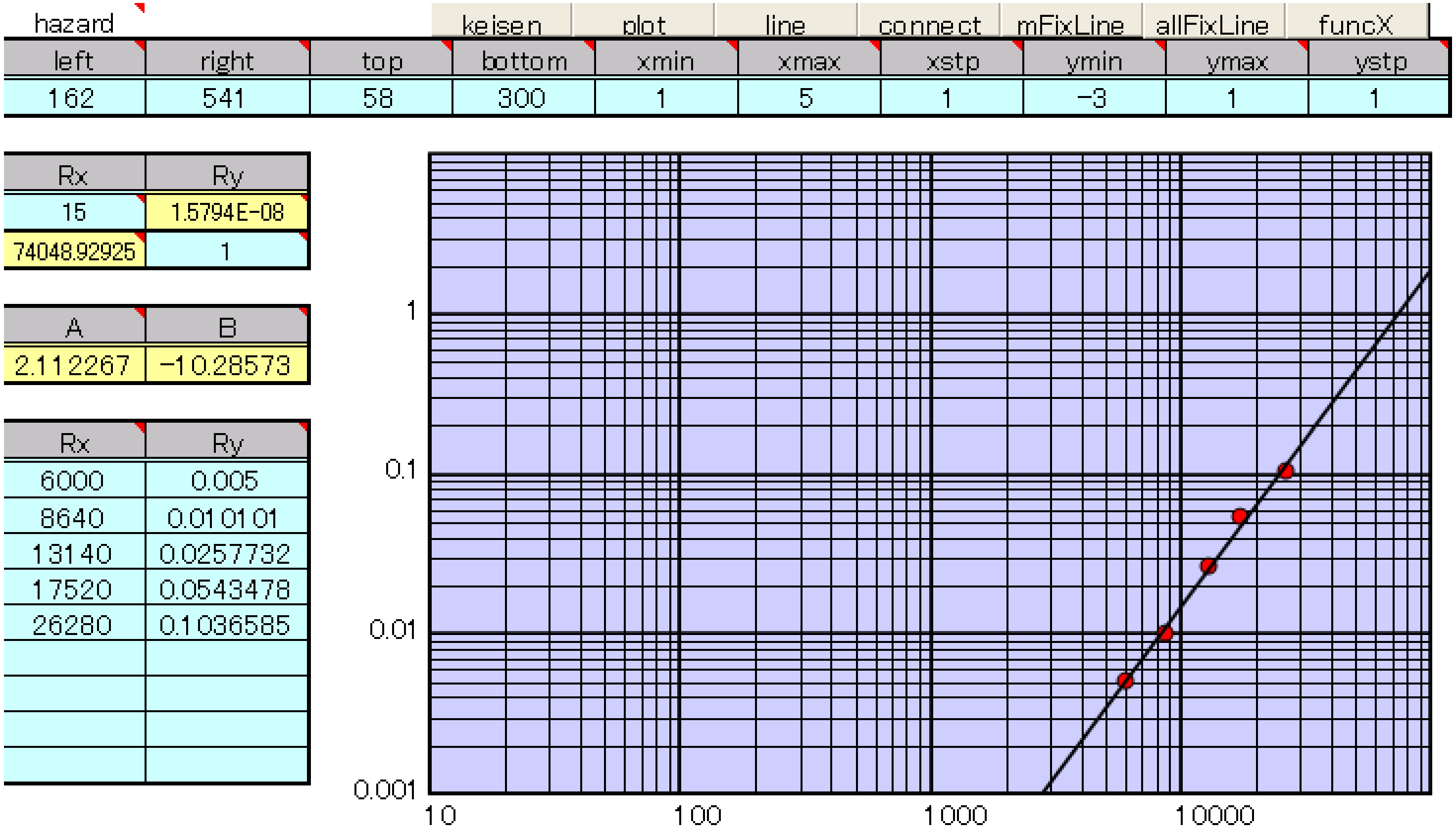
How to estimate field reliability with confidence

Emi plot example (Essential mechanism illustrator)

(1) $H(t) = \Sigma\lambda(t\ i)*\Delta t\ i = \Sigma\Delta n(t\ i)/N(t\ i)$

(2) Plot H(t) for log – log paper.

(3) Get the most suitable m. (It looks like straight line)



hazard

left	right	top	bottom	xmin	xmax	xstp	ymin	ymax	ystp
162	541	58	300	1	5	1	-3	1	1

Rx	Ry
15	1.5794E-08
74048.92925	1

A	B
2.112267	-10.28573

Rx	Ry
6000	0.005
8640	0.010101
13140	0.0257732
17520	0.0543478
26280	0.1036585

For self-investigation

How to estimate field reliability with confidence

Predict weibull distribution by m and η value

of hazard analysis

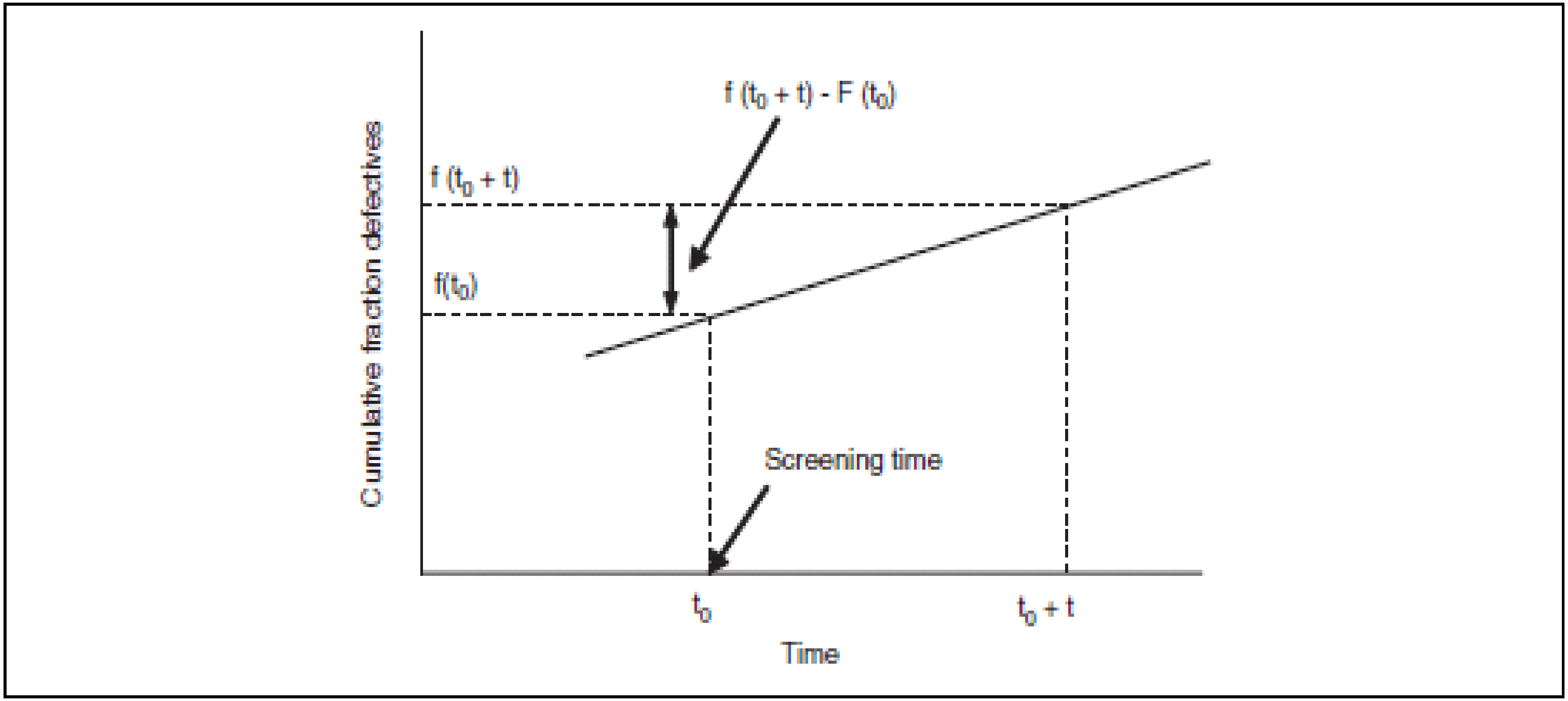


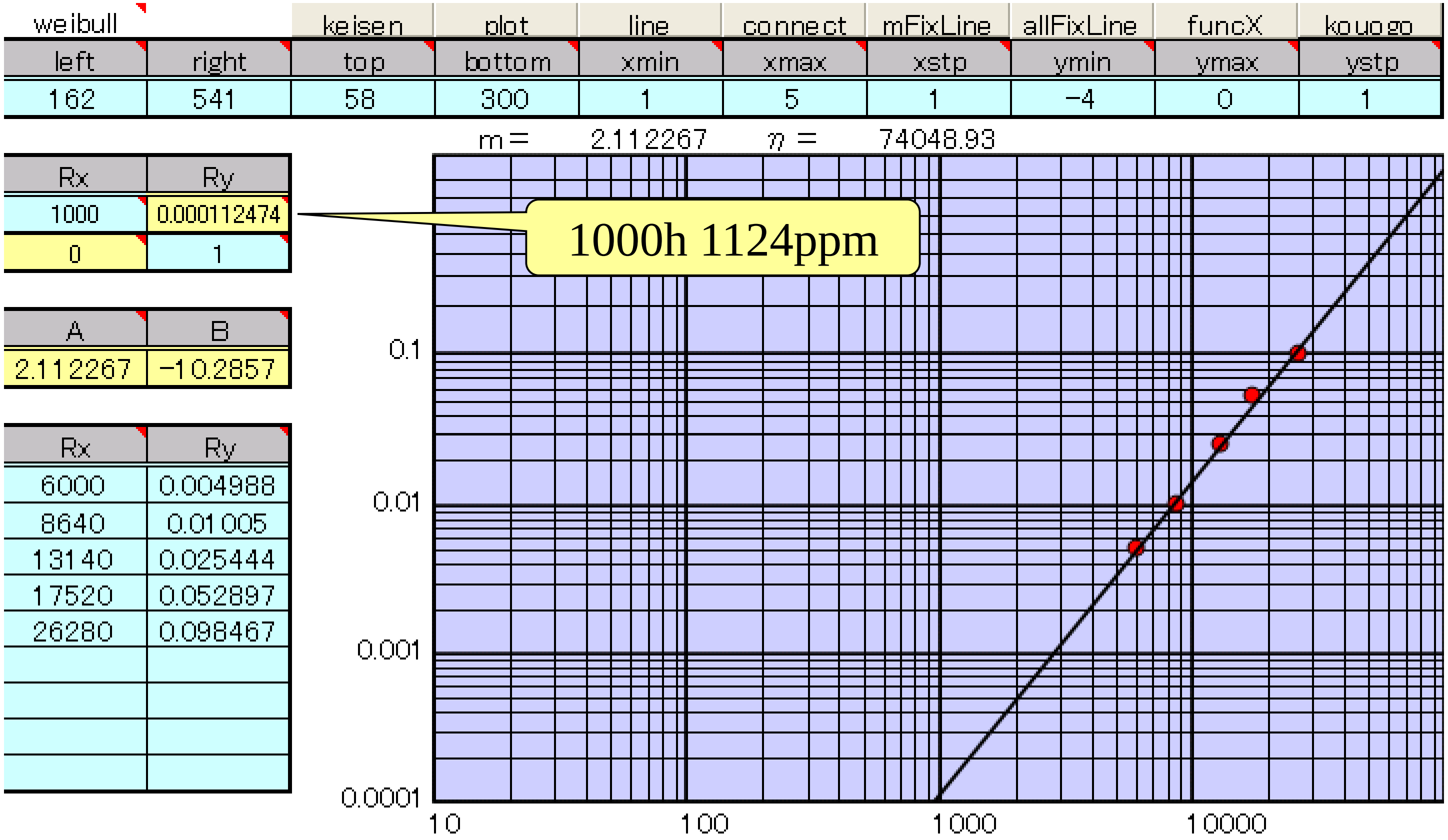
Figure 3.18 Future Product Life

For self-investigation

How to estimate field reliability with confidence

Emi plot example (Essential mechanism illustrator)

(1) Plot F(t), by F(t) = 1 – exp(- H(t))
(2) Same m value compared with log-log plot
(3) Weibull analysis is capable from different sample size



weibull		keisen	plot	line	connect	mFixLine	allFixLine	funcX	kouogo
left	right	top	bottom	xmin	xmax	xstp	ymin	ymax	ystp
162	541	58	300	1	5	1	−4	0	1

m= 2.112267 η = 74048.93

Rx	Ry
1000	0.000112474
0	1

A	B
2.112267	−10.2857

Rx	Ry
6000	0.004988
8640	0.01005
13140	0.025444
17520	0.052897
26280	0.098467

1000h 1124ppm

Renesas Electronics Corporation