

Belcore Specifications Review

課程大綱

1. Telcordia (Bellcore) Introduction
2. Bellcore GR-1221-CORE
3. Bellcore Special Concerns
4. Bellcore Required Reliability Tests
5. Production Qualification Test
 - 5.1 Qualification Test Plan
 - 5.2 Qualification Test Report
 - 5.3 Qualification Test Follow-up
6. Conditions Required Re-qualification
7. Qualification Maintenance
8. Reliability Calculation

Belcore Introduction

Belcore (Bell Lab Communication Research) Specifications:

Describes a minimum set of requirements that, in Belcore's view, the components manufacturers should try to meet for telecommunication applications.

Bellcore Introduction

1. Passive Components
2. Modules and Subsystems
3. Active Components
4. Reliability
5. Other Related Standards

Belcore Introduction

1. Passive Components

- **GR-1209-CORE Issue 3, Oct. 2000** **\$450.**
Generic Requirements for Passive Optical Components
- **GR-1221-CORE Issue 2, Jan. 1999** **\$150.**
Generic Reliability Assurance Requirements for Passive Optical Components
- **GR-2882-CORE Issue 1, Dec. 1995** **\$100.**
Generic Requirements for Optical Isolators and Circulators
- **GR-2883-CORE Issue 1, Dec. 1995** **\$100.**
Generic Requirements for Fiber Optic Filters

Belcore Introduction

1. Passive Components (Continue)

- **GR-326-CORE Issue 3, Dec. 1999** **\$1,000.**
Generic Requirements for Single-Mode Optical Connectors
and Jumper Assemblies
- **GR-2854-CORE Issue 2, Dec. 1997** **\$215.**
Generic Requirements for Fiber Optic Dispersion
Compensators
- **GR-1073-CORE Issue 1, Jan. 2001** **\$350.**
Generic Requirements for Singlemode Fiber Optic Switches

Bellcore Introduction

2. Modules and Subsystems:

- **GR-1312-CORE Issue 3, April 1999** **\$560.**
Generic Requirements for Optical Fiber Amplifiers and
Proprietary Dense WDM Systems
- **GR-63-CORE Issue 1, Oct. 1995** **\$175.**
Network Equipment-Building System (NEBS) requirements:
Physical Protection

Belcore Introduction

3. Active Components:

- **GR-468-CORE Issue 1, Dec 1998** \$540.
Generic Reliability Assurance Requirements for Optoelectronic
Devices Used in Telecommunication Equipment
- **GR-1209-CORE Issue 3, Oct. 2000**

Belcore Introduction

4. Reliability

- **SR-332 Issue 1, May, 2001** **\$1,000.**
Reliability Prediction for Electronic Equipment
- **GR-357-CORE Issue 1, March, 2001** **\$350**
Generic Requirement for Assuring the Reliability of
Components Used in Telecommunication Equipment

<http://www.telcordia.com>

Bellcore Introduction

5. Other Related Standards:

British Telecom Specifications:

- RC 8937A for Passive Optical Splitter
- RC 8938A for Passive Optical Wavelength Division Multiplexer

Lucent Technologies:

- RELQUAL Specification for product Compliance and Reliability Qualification of Optoelectronic Components, Modules, and Subsystems

Belcore Introduction

Comparison of Belcore and BT Specifications:

Belcore	BT
1. Assess device reliability through a set of environmental tests on specified number of devices. 2. Depending on the sample size and LTPD, the allowable number of failures can be determined.	1. Assess device reliability through failure rate estimation. By following a set of guideline provided by specification. 2. Device failure rate is derived from acceleration test data.

Belcore Introduction

Belcore Standard – GR-1209

1. Basic requirements for fiber optic branching components
2. A standard for not only qualification but for design and manufacturing
3. Define of all device optical parameters requirements
4. Mechanical, environmental and fiber pull test
5. (Tests in sequential)
6. (Short test duration)
7. (Integrity – the harshest conditions)
8. (Sampling plan – LTPD 20 (11/0))
9. (Pass/Fail criteria: in spec $\pm \leq 10\%$ of variation (0.5dB))

Bellcore Introduction

Bellcore Standard – GR-1221

1. Reliability Assurance Requirements – passive optical components including Reliability Assurance Program
2. Mechanical, environmental and raw material
3. Test in parallel
4. Long term reliability
5. Integrity – The Harshest conditions
6. Sampling Plan – LTPD 20 (11/0)
7. Device optical functional parameters measurement
8. Pass/Fail criteria: in spec $\pm \leq 10\%$ of variation (0.5dB)

Belcore Introduction

Belcore Standard – GR-1312

- Requirement for Optical Fiber Amplifiers (Gain Block Amp and EDFA) and DWDM systems (modules) including their qualification
- Test of the integration of the components (which are qualified to higher level of qualification, 1221 or 1209)
- Mechanical, fiber pull and environmental
- Tests in sequence or in parallel
- Not-so-harsh test conditions
- Short duration
- Sampling Plan – ???
- Pass/Fail criteria: in spec $\pm \leq 10\%$ of variation (0.5dB)

Bellcore Introduction

Bellcore Standard – GR-468

1. Reliability Assurance Requirement for Optoelectronic Devices (an equivalent to 1221)
2. Component level qual (Laser diode, LED, PD, ...)
3. Mechanical, environmental and electrical
4. Tests in parallel
5. Integrity tests - harsh test conditions
6. Long duration
7. Sampling Plan – LTPD 20 (11/0)
8. Optical electrical functional testing
9. Pass/Fail criteria: in spec $\pm \leq 10\%$ of variation (0.5dB)

Belcore Introduction

Belcore Acronyms:

CO – Central Office

RT – Remote Terminal

C – Controlled environment

P – Partially Controlled environment

U or – Uncontrolled environment

UNC

R# - Required

CR# - Conditional Required

O# - Option

Belcore GR-1221

GR-1221-CORE
Reliability Assurance Program

Belcore GR-1221

1. Quality conformity test can include
Visual Inspections,
Physical Dimensions,
Soldering,
Functional Performance,
Final Inspection and Testing
2. In addition, Device qualification is an essential!
3. R & QA (Reliability and Quality Assurance)

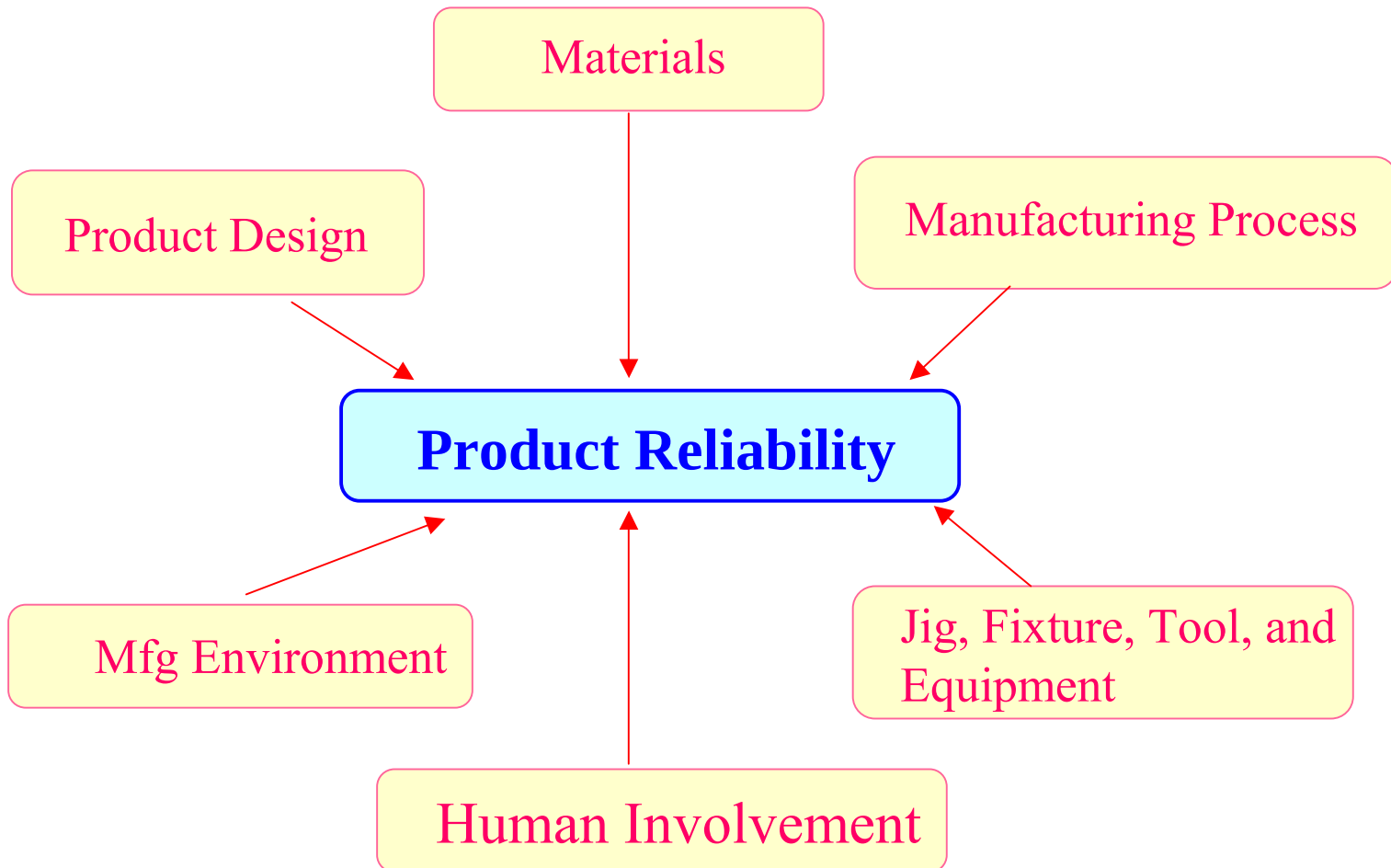
Bellcore GR-1221

Reliability Definition:

Reliability is the probability that a product will perform its intended function, satisfactorily for a specified period of time when operating under specified conditions.

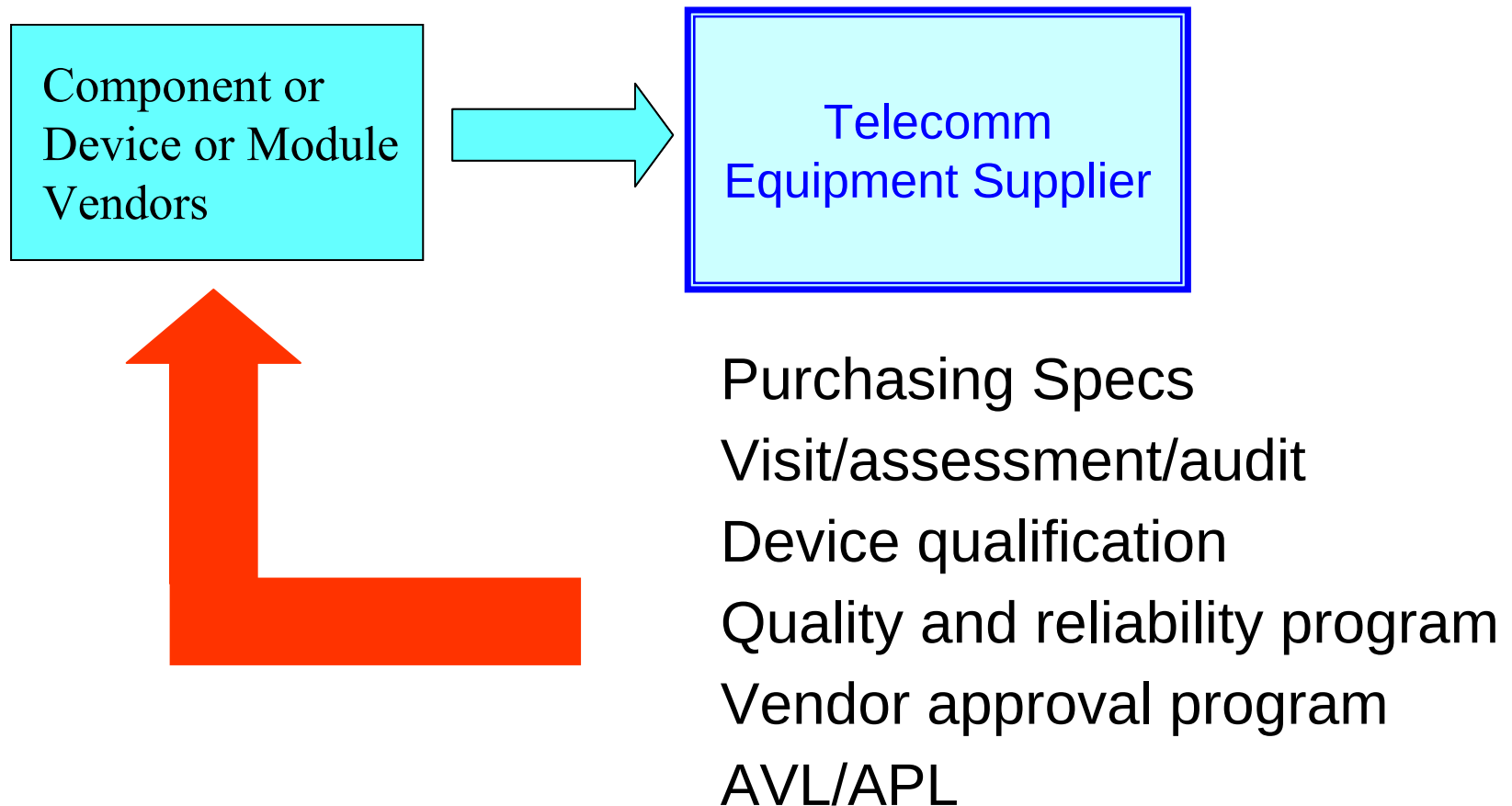
Belcore GR-1221

Factors Affecting Products Reliability



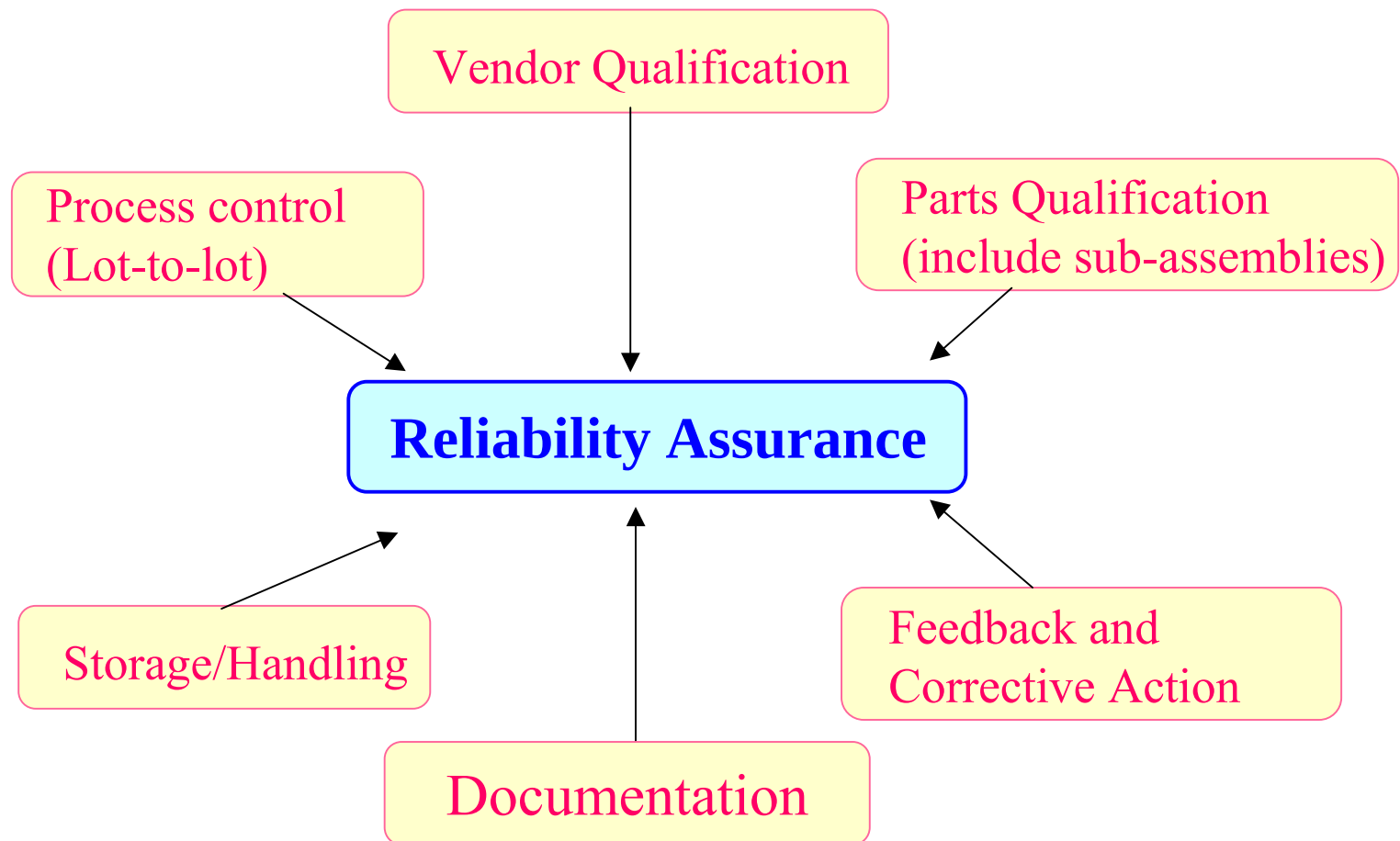
Belcore GR-1221

Reliability Assurance Program (Bellcore 357 and 1221)



Bellcore GR-1221

Reliability Assurance Program (Bellcore 357 and 1221)



Belcore Special Concerns

1. Stress Screening
2. Adhesives
3. Soldering
4. ESD Issue
5. Flammability

Bellcore Special Concerns

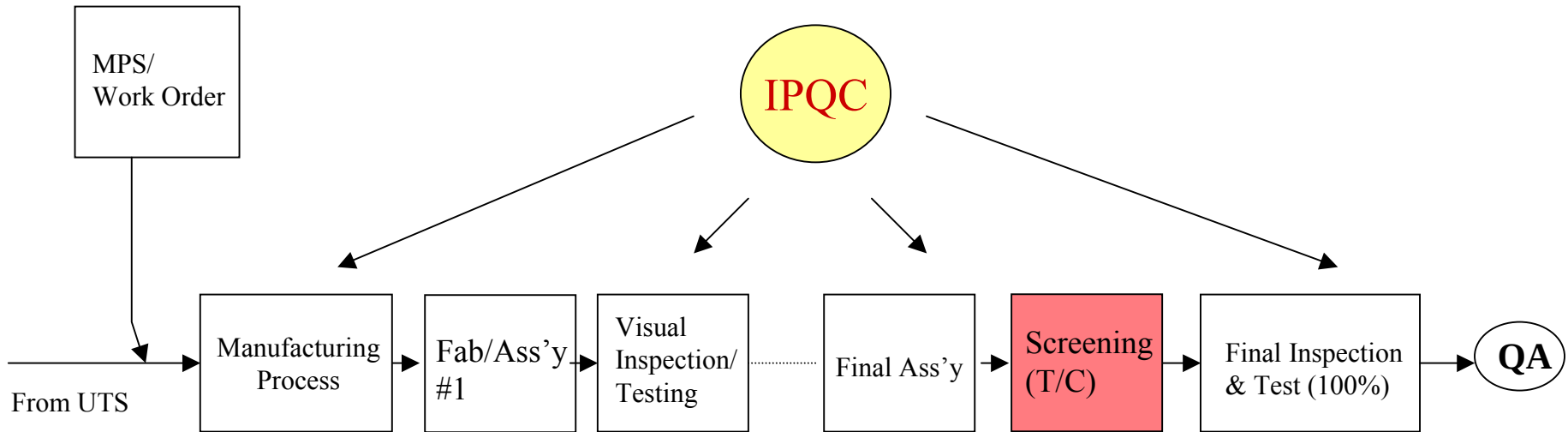
1. Stress Screening – (应力筛选)

A temperature cycle screen helps eliminate components that have any instability in the optical alignment of the components or have built-in mechanical stresses due to improper assembly operations

The recommended screening consists of 10 cycles between temperature limits of at least -40°C and 70°C for CO applications and -40°C and 85°C for RT/UNC applications

Bellcore Special Concerns

1. Stress Screening -



Bellcore Special Concerns

2. Adhesives -

Adhesives are commonly used in packaging passive optical components, and that adhesives are sensitive to moisture and temperature. Therefore, the reliability of optical adhesion is often the determining factor of the component reliability.

The passive fiber optic component manufacturer shall have documentation and implementation for storage, shelf-life, assembly operator training, pot life, cure cycle, manufacturing audit, and re-qualification in accordance with this spec.

Work instructions, posted at the work station, shall control the application of the adhesive in the device package, the allowable pot life (after mixing), and the steps in the curing cycle.

Belcore Special Concerns

2. Adhesives -

Requirements of Adhesives (*Thermosetting*):

1. High bonding strength
2. Low shrinkage
3. Dimensional stability
4. Slow thermal degradation
5. Moisture resistance
6. Chemical resistance

Bellcore Special Concerns

2. Adhesives - Controls

Shelf life (mfg date vs expiration date)

Pot A and Pot B mixing ratio (1:10)

Pot A and Pot B mixing process

Air bubble issue

Pot life

Viscosity (creep)

{ Curing temperature
Curing duration (fully cured)
Curing process (curing cycle)

Out-gassing

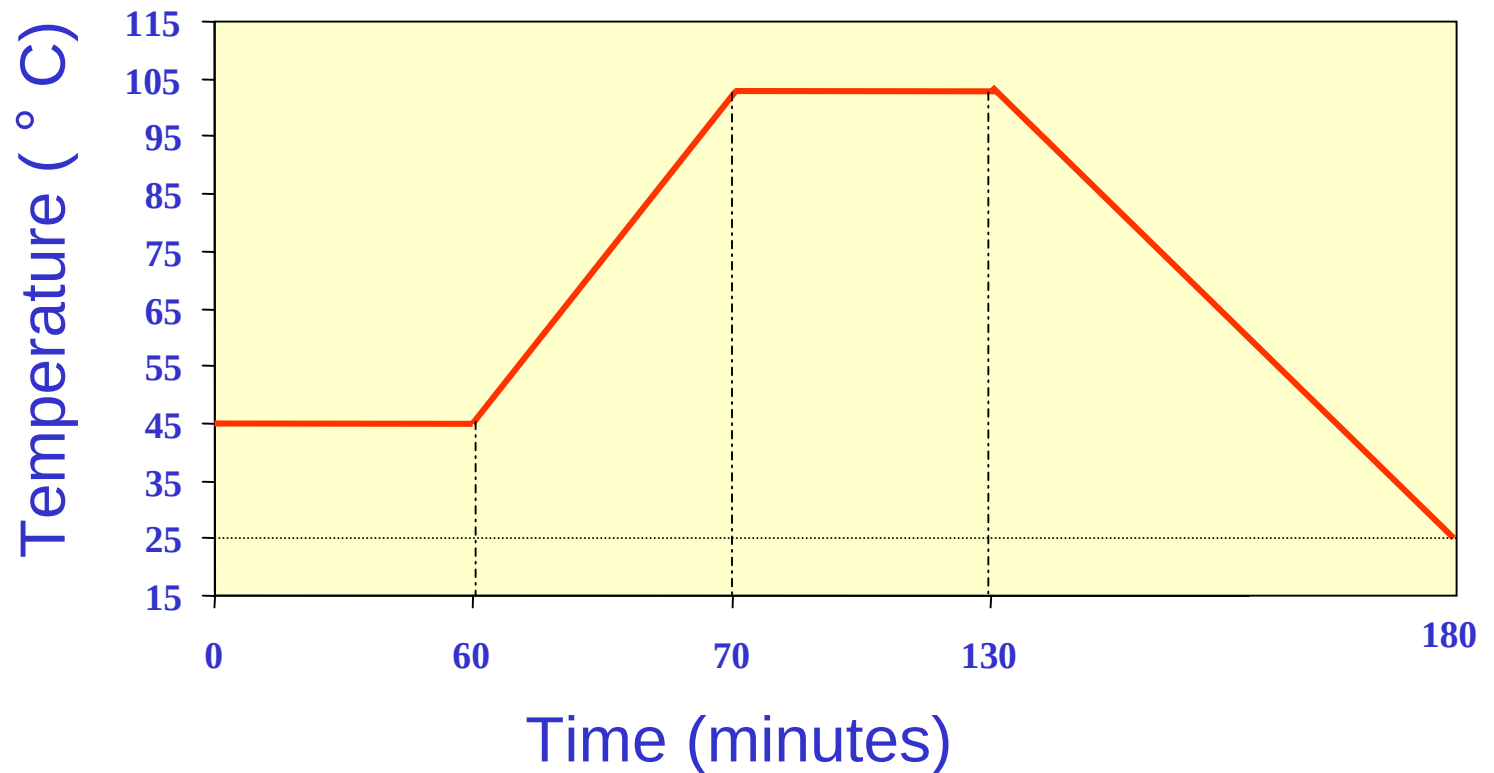
Tg (piston)

Degradation (crack)

Bellcore Special Concerns

2. Adhesives -

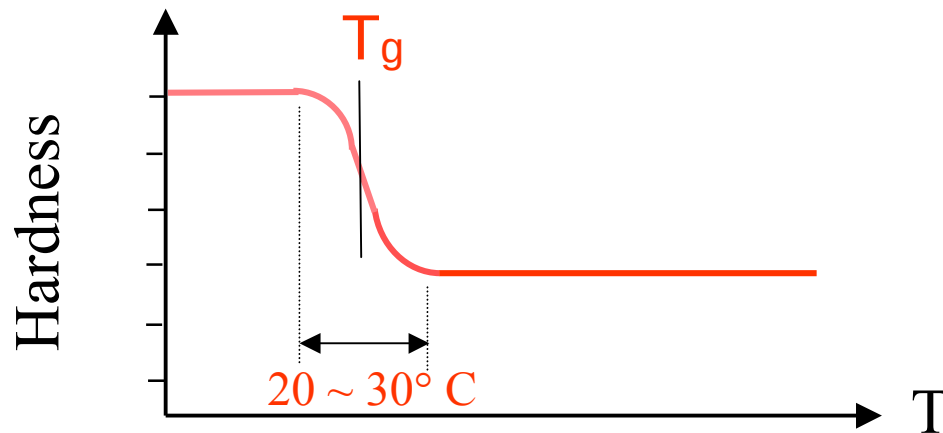
Curing Cycle (Step-baking Profile to 100 ° C)



Bellcore Special Concerns

2. Adhesives -

Glass Transition Temperature Region (T_g)



$T < T_g$: Hard and rigid

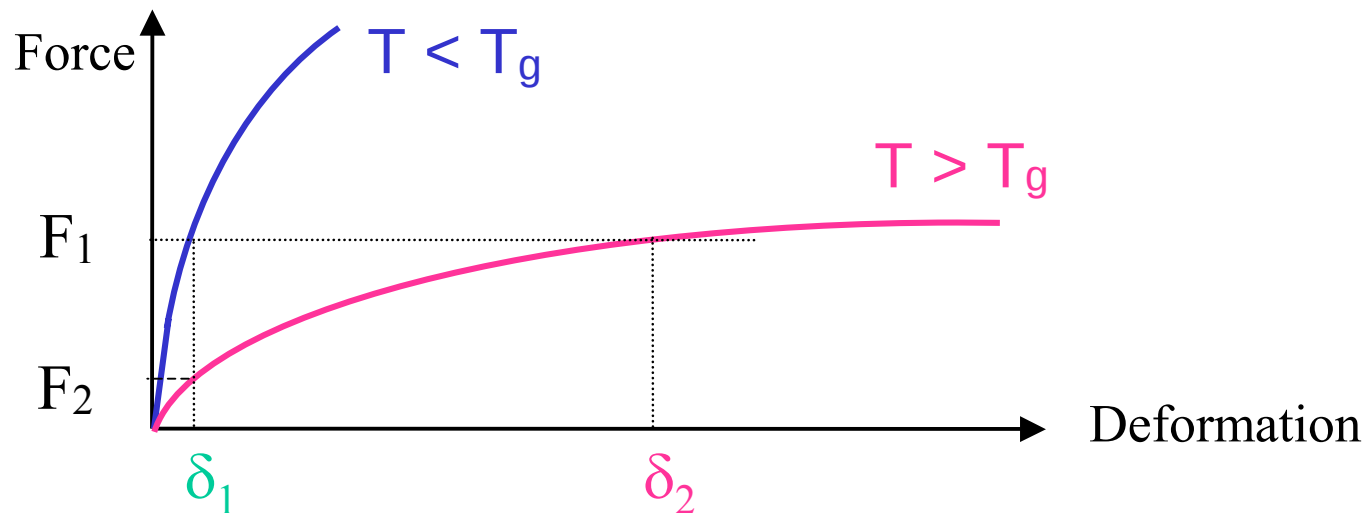
$T > T_g$: Soft and flexible

High T_g polymers: Higher degree of cross-linking, harder

Belcore Special Concerns

2. Adhesives -

Impact of T_g to Device Packaging



Dimension stability

Bellcore Special Concerns

2. Adhesives -

DSC (Differential Scanning Calorimeter)

Applications:

1. Monitor the quality of adhesive from lot to lot
2. Simulate any curing profile
3. Measure the Tg of cured adhesive

Bellcore Special Concerns

2. Adhesives -

Effects of Moisture

- ❖ Soften the polymer modulus
- ❖ Lower T_g
- ❖ Degrade the bonding strength
- ❖ Water vapor deposit on optical surface

Bellcore Special Concerns

3. Soldering - (焊锡的控制)

1. Solder creep
2. Solder flux (contamination)
3. Un-equal applying of solder on holes
4. Soldering time too long- Tg issue
5. Cold soldering or false soldering
6. Sealing issue
7. Bending – mechanical adjustment
8. Solder crack, Au falling, and material fatigue

Bellcore Special Concerns

3. Soldering - (焊锡的控制)

Inspection setup for solderability

Belcore Special Concerns

3. Soldering - (焊锡的控制)

Solderability: Difference before Soldering

Belcore Special Concerns

4. ESD – Electro-Static-Discharge

Belcore TR-NWT-00870 Electrostatic Discharge
Control in the Manufacture of Telecommunications
Equipment

1. Wrist/Heel strap tester
2. Workstations connected to earth ground
3. Anti-static In-process trays and bins
4. ESD protective packaging

Bellcore Special Concerns

5. Flammability – Plastic materials

(UL Standard for safety)

UL1694

Test for Flammability of Small Polymeric Component Materials

UL 1950

Safety of Information Technology Equipment



Underwriters Laboratories, Inc.

BELLCORE 1209 / 1221 COMPARISON TABLE

Type of Test	GR-1209CORE Issue 1	GR-1221CORE Issue 2
Thermal Shock Test		$\Delta T = 100^{\circ}\text{C}$, 15 cycles, Dwell time ≥ 5 min., xfer < 10 seconds
High Temperature Storage Test (Dry Heat)		85°C , $< 40\%$ RH 2,000 hrs for qualification 5,000 hrs for information
Damp Heat Test (Temperature/Humidity Aging)	$85^{\circ}\text{C}/85\%$ RH for 336 hours	75°C , 90% RH 2,000 hrs for qualification 5,000 hrs for information
Low Temperature Storage		-40°C , 2,000 hrs for qualification 5,000 hrs for information
Water Immersion Test	43°C , pH = 5.5 ± 0.5 for 168 hours	
Temperature Cycling Test		-40°C to 70°C , $1^{\circ}\text{C}/\text{min}$, Dwell time ≥ 15 minutes 100 cycles pass/fail 500 for information
Temperature Cycling Test (Humidity)	$+75^{\circ}\text{C}$ to -40°C , $1^{\circ}\text{C}/\text{min}$ 42 cycles (14days): $+2^{\circ}\text{C}$ to 32°C : 80% RH $+32^{\circ}\text{C}$ to 75°C : 80% - 10% RH $< +2^{\circ}\text{C}$: Uncontrolled	85% - 95% at 75°C , $2^{\circ}\text{C}/\text{min}$, -40°C to 25°C uncontrolled Dwell time = 4 to 16 hrs 5 cycles
Mechanical Vibration Test	10 to 55 Hz, Vibration amplitude= 1.52mm , 2 hours each axes	20 to 2,000 Hz, 20G, 4 min per cycle and 4 cycles per axis
Mechanical Shock (Impact test)	1.8 meters, 8 drops 3 axes	1.8 meters, 8 drops for each 3 axes repeat for 5 times
Tensile Pulling Test	5 N for 1 minute	

Bellcore Required Reliability Tests

Mechanical
Integrity:

- 1. Mechanical Shock (Impact test)
- 2. Variable Frequency Vibration Test
- 3. Thermal Shock Test

Endurance

- 4. High Temperature Storage Test (Dry Heat)
- 5. High Temperature Storage Test (Damp Heat)
- 6. Low Temperature Storage Test
- 7. Temperature Cycling Test
- 8. Cyclic Moisture Resistance Test
- 9. Other Tests

1. Mechanical Shock

Impact test, Drop test

Option 1:

Number of shocks: 5x on 3 axes
Shock level: 500 G
Duration: 1 ms

Option 2:

Drop height: 1.8 m
Number of drops: 8x per 3axes
Number of cycles: 5

2. Vibration Test

Condition:

Acceleration: 20G (1.52 mm double amplitude, P-P)
Frequency: 20 ~ 2,000 Hz and return to 10Hz in 20 minutes
Duration: 4 min per cycle and 4 cycles per axis

3. Thermal Shock Test

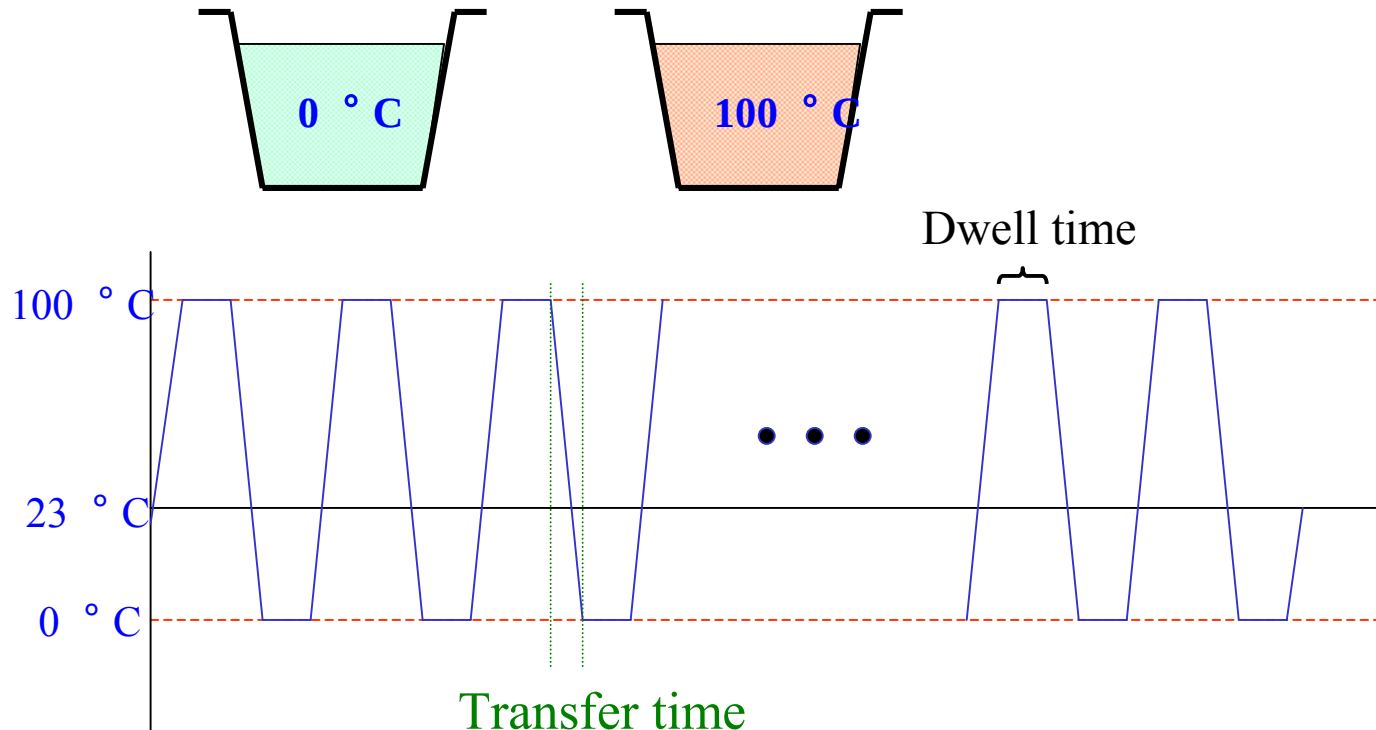
Condition:

Temperature range: $\Delta T = 100\text{ }^{\circ}\text{C}$ ($0\text{ }^{\circ}\text{C}$ to $100\text{ }^{\circ}\text{C}$), liquid-to-liquid

Dwell times: $\geq 5\text{ min}$ at temperature extremes

Transfer time: $\leq 10\text{ seconds}$

Number of cycles: 15



4. High Temperature Storage Test

Dry heat test, or thermal aging test.

- It is an acceleration test

Condition:

Temperature: $85^{\circ}\text{C} (\pm 2^{\circ}\text{C})$

Humidity: $< 40\% \text{ RH}$

Test duration: 2,000 hrs for qualification and
5,000 hrs for information

Measurements: initial, 168-, 500-, 1000-, 2000-, and
5000-hours interval,

Down time measurement at room temperature

4. High Temperature Storage Test

Insertion Loss (dB) (@ 1550nm,23°C)

S/N	Initial (2/1/99)	After 500 hours (2/23/99)	Δ	After 1000 hours (3/29/99)	Δ	After 2000 hours (5/14/99)	Δ
	0.72	0.87	0.15	0.81	0.09	0.78	0.06
	0.74	0.68	-0.06	0.63	-0.11	0.65	-0.09
	0.65	0.68	0.03	0.65	0.00	0.63	-0.02
	0.71	0.92	0.21	1.10	0.39	2.03	1.32
	0.77	0.77	0.00	0.65	-0.12	0.71	-0.06
	0.64	0.75	0.11	1.66	1.02	3.45	2.81
	0.63	0.67	0.04	0.62	-0.01	0.93	0.30
	0.64	0.79	0.15	0.88	0.24	2.07	1.43
	0.77	0.87	0.10	0.87	0.10	1.00	0.23
	0.81	0.62	-0.19	0.50	-0.31	0.63	-0.18
	0.63	0.73	0.10	0.64	0.01	0.67	0.04

5. Humidity Resistance Test

Damp test.

- It is an acceleration test

Condition:

Temperature: 75 ° C (± 2 ° C)

Humidity: 90 % (± 5%) RH

OR

Temperature: 85 ° C (± 2 ° C)

Humidity: 85 % (± 5%) RH

Test duration: 2,000 hrs for qualification and
5,000 hrs for information

Measurements: initial, 168-, 500-, 1000-, 2000-, and
5000-hours interval,

Down time measurement at room temperature

For CO: 500 hrs for qual, 2000 hrs for information

Table 4-3. Test Matrix for Demonstrating Acceleration Factors

[Relative Humidity as a Function of Temperature and Absolute Humidity]

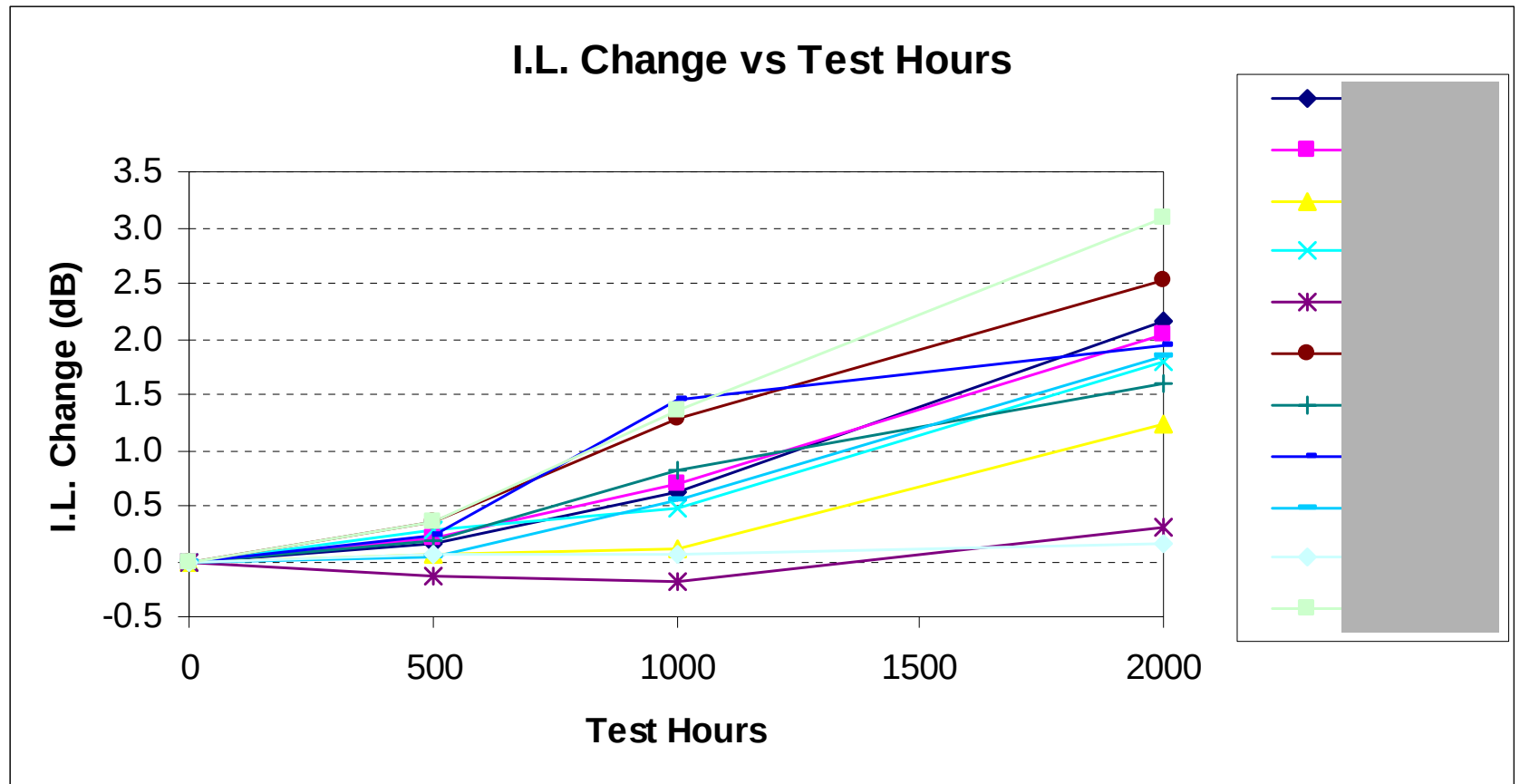
Absolute Humidity [gm/m ³]	Temperature [°C]							
	25	40	45	55	65	75	85	95
19.2	85	38	30	19	12	8	6	4
42.5	sat	85	67	42	27	18	12	9
54.0		sat	85	53	34	23	16	11
86.0			sat	85	55	37	25	18
134.0				sat	85	57	39	27
200.0					sat	85	58	41
211.0						90	61	43
293.0						sat	85	60
419.0							sat	85

5. Humidity Resistance Test

Insertion Loss (dB) (1550 nm)

No.	Serial No.	Initial (2/1/99)	After 500 hrs (2/23/99)	Δ	After 1000 hrs (3/22/99)	Δ	After 2000 hrs (5/4/99)	Δ
1		0.38	0.54	0.16	1.01	0.63	2.54	2.16
2		0.40	0.60	0.20	1.09	0.69	2.43	2.03
3		0.55	0.60	0.05	0.67	0.12	1.79	1.24
4		0.49	0.78	0.29	0.96	0.47	2.28	1.79
5		0.48	0.35	-0.13	0.30	-0.18	0.78	0.30
6		0.45	0.80	0.35	1.72	1.27	2.97	2.52
7		0.47	0.66	0.19	1.28	0.81	2.06	1.59
8		0.52	0.74	0.22	1.98	1.46	2.46	1.94
9		0.47	0.51	0.04	1.02	0.55	2.32	1.85
10		0.49	0.54	0.05	0.56	0.07	0.66	0.17
11		0.50	0.86	0.36	1.85	1.35	3.58	3.08

5. Humidity Resistance Test

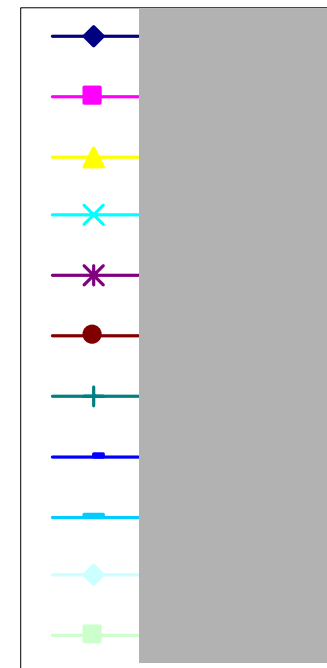
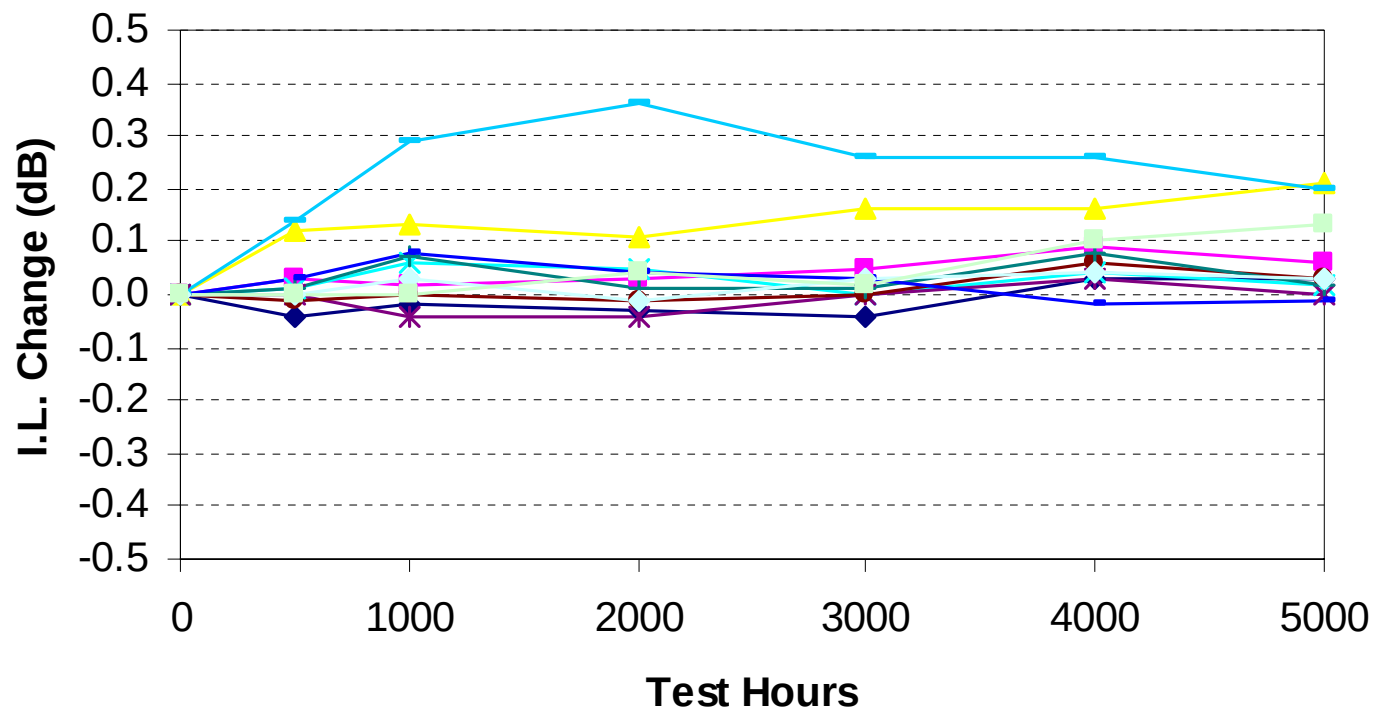


Damp Heat Test (75°C/90%RH, 500 hours for qualification, 2000 hours for information)

Insertion Loss (dB) (1550 nm)

No.	Serial No.	Initial 6/2/2000	After 500 hrs 6/23/2000	Δ	After 1000 hrs 7/14/2000	Δ	After 2000 hrs 8/29/2000	Δ	After 3000 hrs 11/22/2000	Δ	After 4000 hrs 1/12/2001	Δ	After 5000 hrs 2/26/2001	Δ
1		0.31	0.27	-0.04	0.29	-0.02	0.28	-0.03	0.27	-0.04	0.34	0.03	0.34	0.03
2		0.31	0.34	0.03	0.33	0.02	0.34	0.03	0.36	0.05	0.40	0.09	0.37	0.06
3		0.26	0.38	0.12	0.39	0.13	0.37	0.11	0.42	0.16	0.42	0.16	0.47	0.21
4		0.25	0.26	0.01	0.31	0.06	0.30	0.05	0.25	0.00	0.29	0.04	0.27	0.02
5		0.38	0.38	0.00	0.34	-0.04	0.34	-0.04	0.38	0.00	0.41	0.03	0.38	0.00
6		0.35	0.34	-0.01	0.35	0.00	0.34	-0.01	0.35	0.00	0.41	0.06	0.38	0.03
7		0.23	0.24	0.01	0.30	0.07	0.24	0.01	0.24	0.01	0.31	0.08	0.25	0.02
8		0.27	0.30	0.03	0.35	0.08	0.31	0.04	0.30	0.03	0.25	-0.02	0.26	-0.01
9		0.44	0.58	0.14	0.73	0.29	0.80	0.36	0.70	0.26	0.70	0.26	0.64	0.20
10		0.46	0.46	0.00	0.49	0.03	0.45	-0.01	0.49	0.03	0.50	0.04	0.49	0.03
11		0.38	0.38	0.00	0.38	0.00	0.42	0.04	0.40	0.02	0.48	0.10	0.51	0.13

I.L. Change vs Test Hours



6. Low Temp Storage Test

Condition:

Temperature: $-40^{\circ}\text{C} (\pm 5^{\circ}\text{C})$

Humidity: Uncontrolled

Test duration: 2,000 hrs for qualification and
5,000 hrs for information

Measurements: initial, 168-, 500-, 1000-, 2000-, and
5000-hours interval,

Down time measurement at room temperature

Remarks:

The strength of the epoxy joint shall be tested after 2,000 and 5,000 hours

7. Temperature Cycling Test

Condition:

Temperature: -40 ° C to 85 ° C (± 2 ° C) for RT/UNC
-40 ° C to 70 ° C (± 2 ° C) for CO

Dwell time at extremes: ≥ 15 minutes

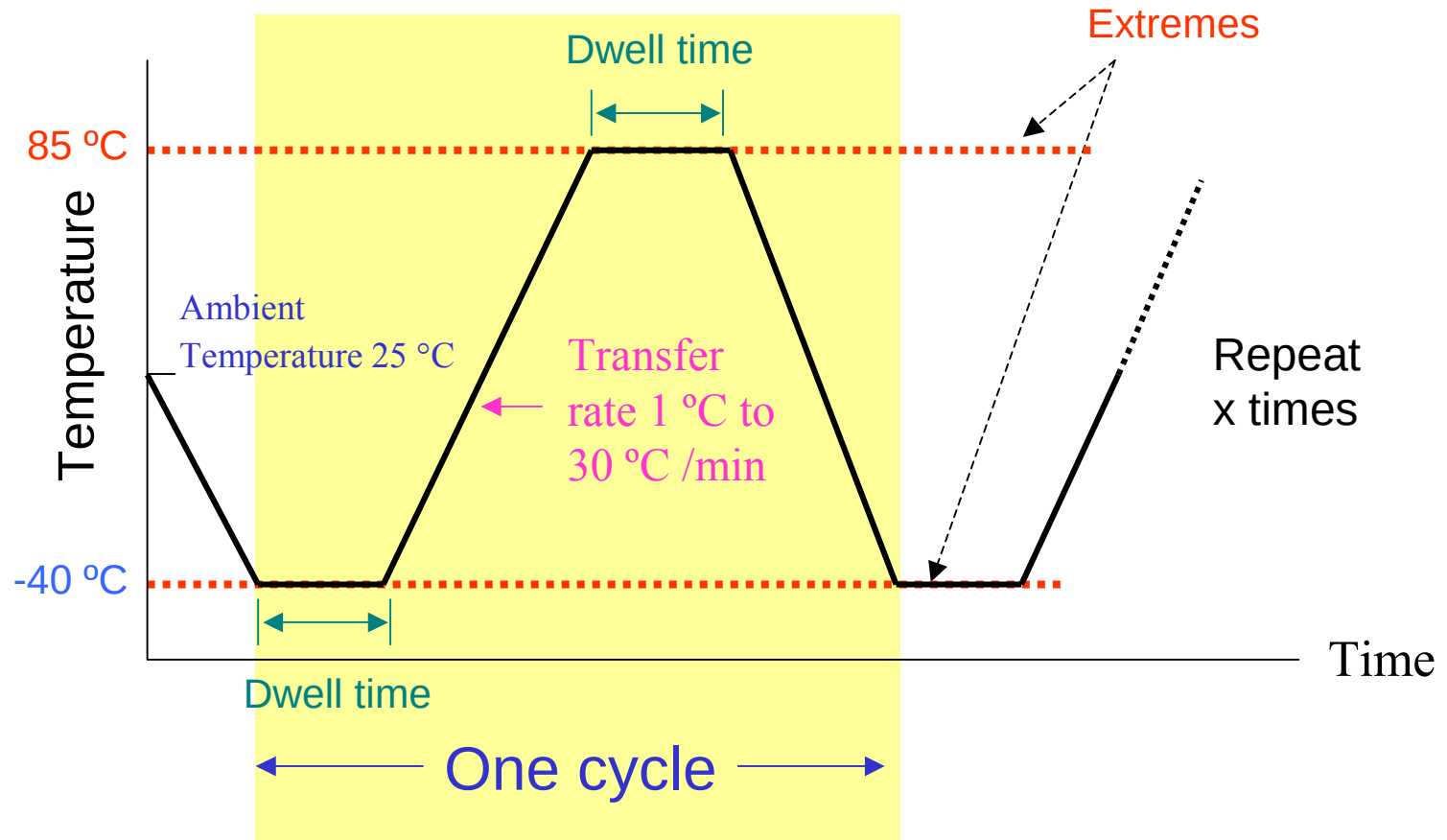
Number of cycles: 500 cycles for pass/fail, 1000 for information (RT/UNC)
100 cycles for pass/fail, 500 for information (CO)

Remarks:

Air flow in T/C Chamber

The purpose of T/C test is to
Demonstrate the long-term
Mechanical stability of the package

7. Temperature Cycling Test



8. Cyclic Moisture Resistance Test

Condition:

Temperature:

Dwell time at extremes: ≥ 15 minutes

Relative Humidity:

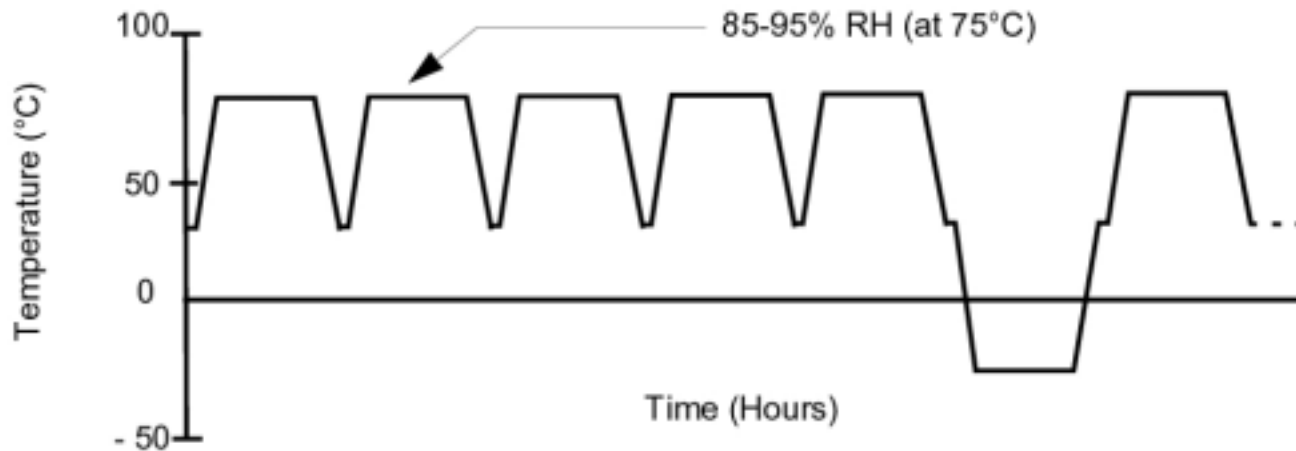
85-95% at 75 °C,

Uncontrolled otherwise.

Dwell Time @ Extremes: 3 to 16 hours

Number of cycles:

5 complete cycles (each complete cycle has 5 sub-cycles)



9. Other Tests

Straight Tensile Pulling, Side Pulling and Twist Test

Test on fiber and cable.

Test conditions:

5 N for 1 minute

9. Other Tests

HALT

Highly Accelerated Life Test

Combine:

Mechanical,
Temperature, and
Humidity together.

9. Other Tests

Package Drop Test

- To simulate the real world shipping and delivery impact

Product Qualification Test

1. Why We Need Qualification (qual) Test ?
2. Qualification Strategy
3. Qualification Test Steps
 - 3.1 Develop a qualification test plan
 - 3.2 Conduct the tests
 - 3.3 Generate a test report
 - 3.4 Perform the failure analysis
 - 3.5 Take corrective actions
 - 3.6 Repeat the qualification if necessary
4. Conditions Required Re-qualification
5. Qualification Maintenance

Product Qualification Test

Why need qualification (qual) test ? (產品鑑定試驗)

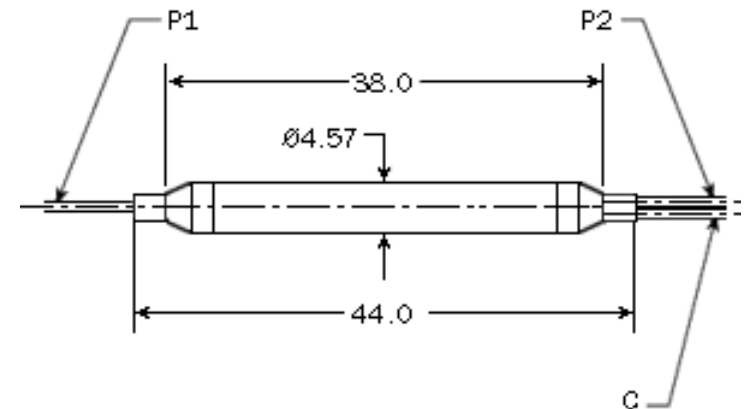
1. To demonstrate the product conforming to the performance specifications.
2. To qualify a new or current manufacturing process.
(or, after a major design, material, or process change)
3. To obtain the product reliability information.
4. To identify the potential failure mechanism and take early corrective actions accordingly.
5. To convince customers and get their confidence.
6. Or, to verify the key material (component or sub-assembly) performance to be used in the device.

100 GHz WDM

DiCon's 100 GHz WDM is designed to multiplex and demultiplex signals in multi-wavelength systems based on the ITU 100 GHz grid. The component uses a thin film filter mounted between a pair of GRIN lens collimators. The 100 GHz WDM is housed in a compact, environmentally stable package that offers superior resistance to humidity and temperature and is suitable for mounting on a printed circuit board or within a module.



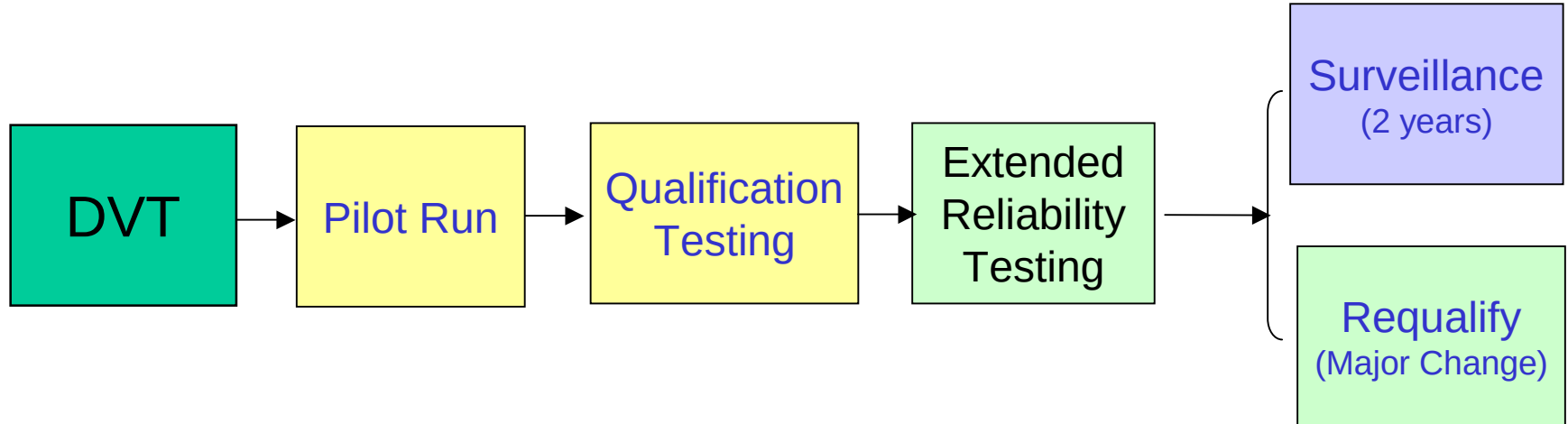
Housing Dimensions



- Narrow 0.2 nm passbands for 100 GHz channel spacing in C and L bands
- Low insertion loss
- High isolation for demultiplexing applications
- Rugged, environmentally stable package
- Tested to Telcordia GR-1221

Product Qualification Test

Qualification Strategy



Qualification Test Steps:

1. To develop a qualification test plan
2. To conduct the tests
3. To generate a test report
4. To perform the failure analysis
5. To take corrective actions
6. To repeat the qualification if necessary

Product Qualification Test

1. To develop a qualification test plan

Table of Contents

1. Purpose
2. Test sample description
3. Device configuration
4. Test and measurement equipment
5. Measurement setup
6. Type of test
7. Pass/fail criteria
8. Test schedule.

Product Qualification Test

1. To develop a qualification test plan (continue)

1.1 Purpose

Specify the purpose(s) of this qualification test

Example 1:

The purpose of this qualification test plan is to demonstrate the newly designed 3-port WDM devices conform to its performance specifications and to qualify its current manufacturing processes.

Example 2:

This qualification test plan describes the methodology for evaluating Lithium Niobate wedges when new sources of supply or process changes are proposed. Lithium Niobate (LiNbO_3) wedges are critical elements assembled in optical devices. The qualification methodology specified herein is designed to assure these components can be assembled into devices with high manufacturing yields and provide high reliability service for the end user. All wedge component specifications must be satisfied in addition to the performance and reliability requirements of the next higher assembly.

Product Qualification Test

1. To develop a qualification test plan (continue)

1.2 Test sample description

Specify how the sample devices are selected, where and when the samples are made, and what is the sample size (how many devices).

Example 3:

All devices used in this qualification test will be built in-house at the current Wavelength Locker production line between October and November, 2001 according to Company standard work instructions and product specifications. Fifty-five (*NOT* 55) devices in total will be randomly selected from the production line and divided into five test groups. Each test group has eleven devices.

Industrial Standards & Customer Requirements

- Sample Size Determination

Sample Size & Lot Tolerance Percentage Defective (LTPD)

LTPD[%]	50	30	20	15	10	7	5	3	2	1.5
Acceptance Number ©	Minimum Sample Size									
0	5	8	11	15	22	32	45	76	116	153
1	8	13	18	25	38	55	77	129	195	258
2	11	18	25	34	52	75	105	176	266	354
3	13	22	32	43	65	94	132	221	333	444
4	16	27	38	52	78	113	158	265	398	531
5	19	31	45	60	91	131	184	308	462	617
6	21	35	51	68	104	149	209	349	528	700
7	24	39	57	77	116	166	234	390	589	783
8	26	43	63	85	126	184	258	431	648	864
9	28	47	69	93	140	201	282	471	709	945
10	31	51	75	100	152	218	306	511	770	1025

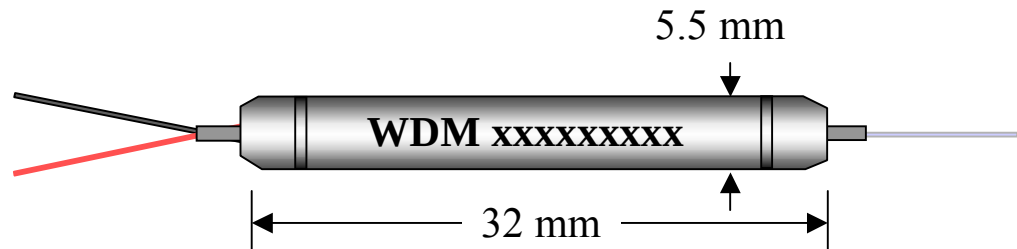
Product Qualification Test

1. To develop a qualification test plan (continue)

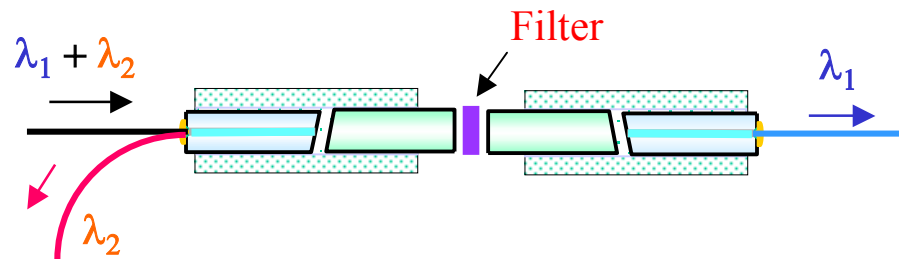
1.3 Device configuration

Example 4:

Physical dimension:



Working principle:



Device configuration:

Product Qualification Test

1. To develop a qualification test plan (continue)

1.4 Test and measurement equipment

List all test and measurement equipment are to be used for this qualification

Example 5:

All test and measurement equipment are within the manufacturer suggested calibration Period and being certified by

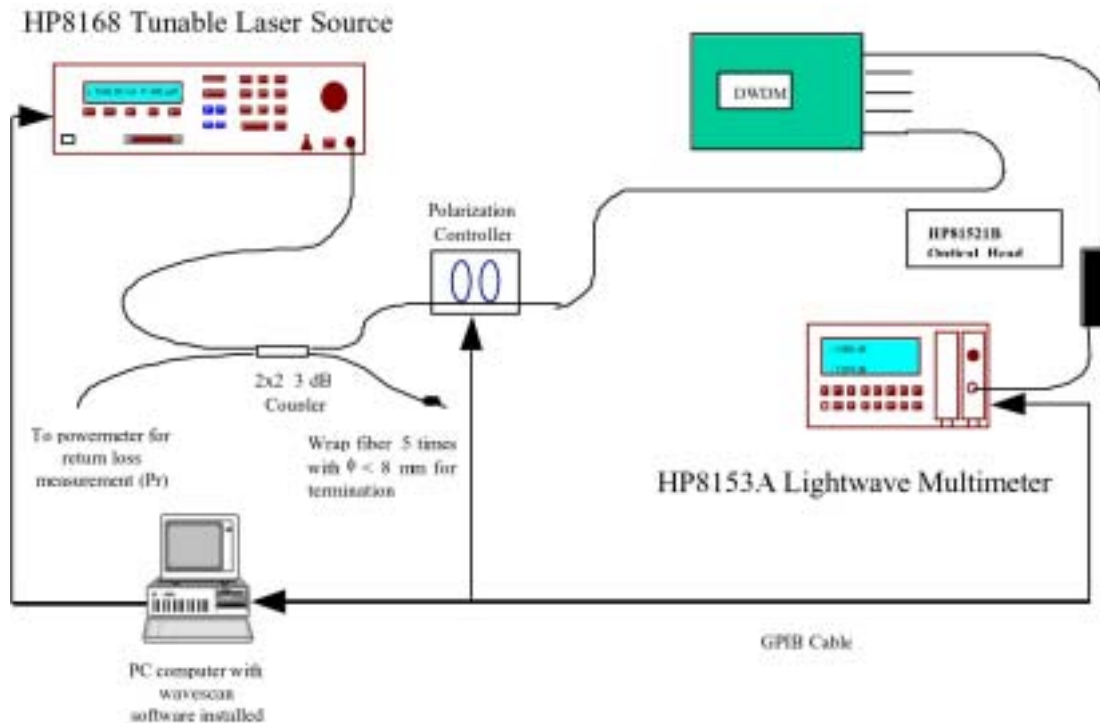
1. Thermotron Environmental Chamber (SM 16C)
2. Blue M temperature Oven (CROT-146)
3. Microprocessor controlled TE Cooler (AHP-301CP)
4. Microprocessor controlled Hot Plate (HP46515)
5. Fujikura FSM-20CS Arc Fusion Splicer
6. HP 8153A Lightwave Multimeter
7. HP 8168F Tunable Laser Source
8. Advantest Wavelength Meter (TQ8325)
9. . . .

Product Qualification Test

1. To develop a qualification test plan (continue)

1.5 Measurement setup

Example 6:



Product Qualification Test

1. To develop a qualification test plan (continue)

1.6 Type of test

Example 7:

Type of test		Test conditions	Sample size
Damp Heat		75 ° C/90%RH, 1000 hours for qualification, 2000 hours for information	11
High Temperature Storage		75 ° C, 2000 hours for qualification, 5000 hours for information.	11
Temperature Cycling		-40 ° C~75 ° C, 100 cycles for qualification, 500 cycles for information.	11
Mechanical Integrity	Vibration	20G, 20-2,000 Hz, 4 min/ cycle, 4 cyc/axes.	11
	Shock	500g, 1 ms, 5 times/direction, 6 directions.	↓
	Fiber Pull	5 N for 1 minute.	

Product Qualification Test

1. To develop a qualification test plan (continue)

1.7 Pass/fail criteria

Usually the change (Δ) of a parameter before and after test is the indicator for pass or fail.

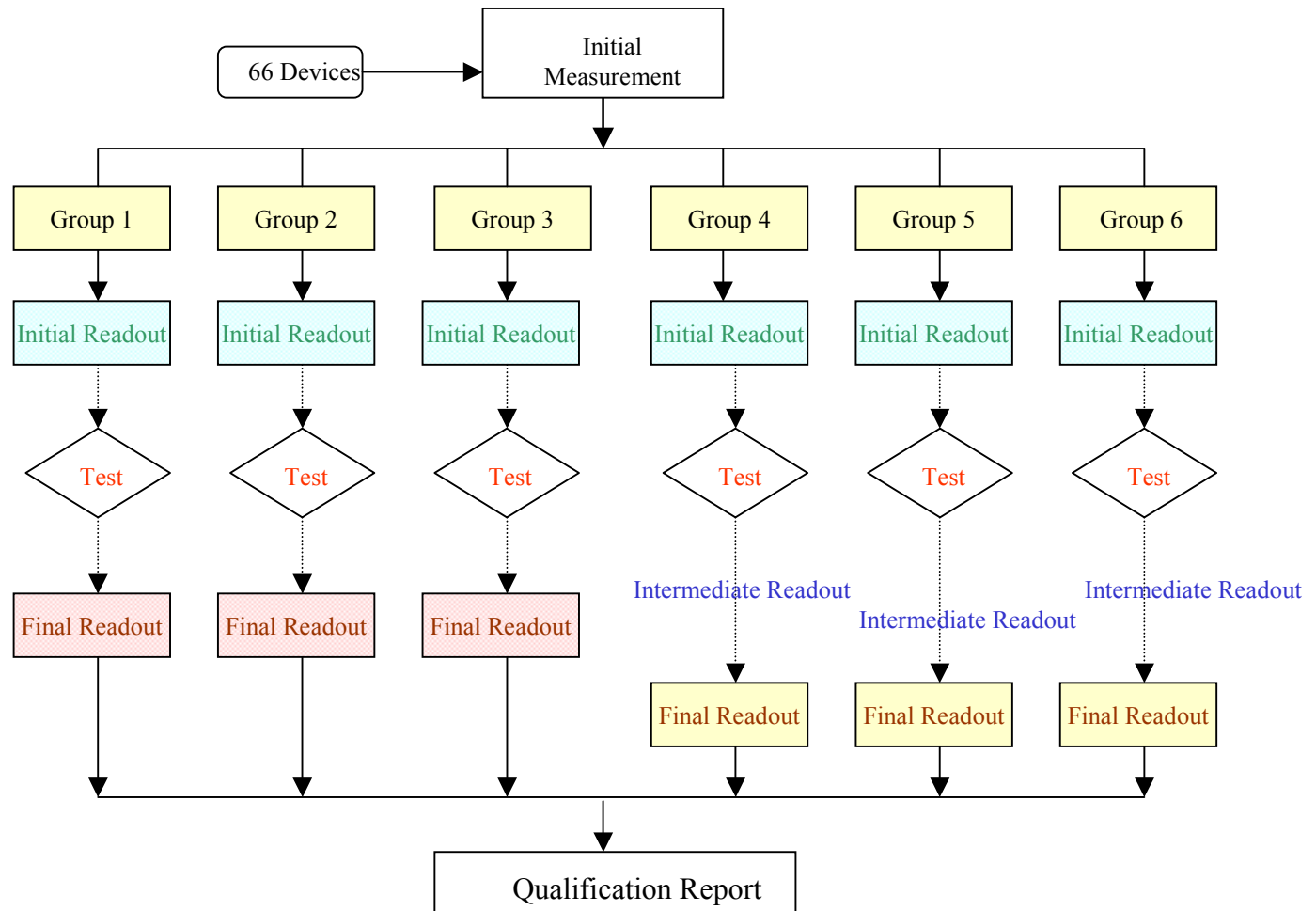
Example 8:

Parameters	Allowable Δ change after test	Unit
Insertion Loss	$< \pm 0.5$	dB
PDL	$< \pm 0.2$	dB
Isolation	$< \pm 5.0$	dB
Return Loss	$< \pm 5.0$	dB

Product Qualification Test

1. To develop a qualification test plan (continue)

1.8 Test schedule

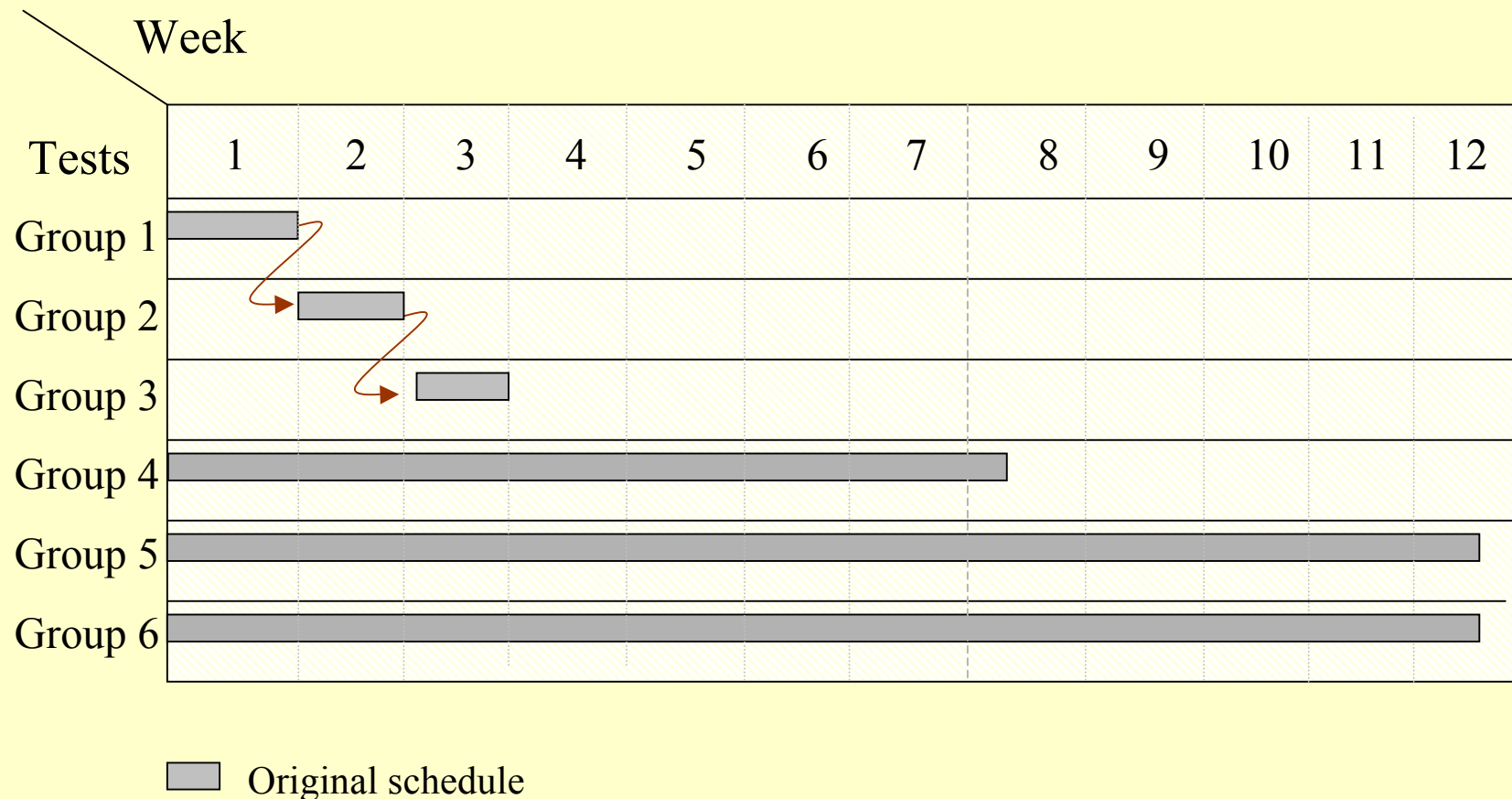


Product Qualification Test

1. To develop a qualification test plan (continue)

1.8 Test schedule

Example 9:



Product Qualification Test

2. To conduct the tests

Based on the qual test plan and schedule, perform the test on-time.

Monitor the chamber and oven status (temperature and humidity).

Standardize the measurement setup and get correlation data among the measurement stations.

Record the measurement data precisely, clearly, and, most important, **honestly!**

Product Qualification Test

3. To generate a test report

Table of Contents

1. Introduction
2. Qualification test summary
3. Test results
 - Test results summary
 - Data analysis and comments
4. Conclusion
5. Appendix – Raw data and Failure Analysis

Product Qualification Test

3. To generate a test report (continue)

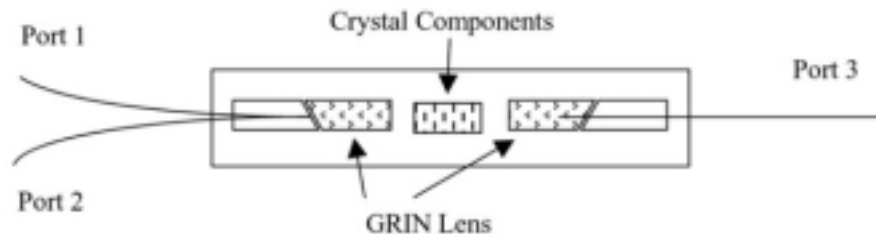
3.1 Introduction

To briefly state the purpose of this test, the product to be qualified and its applications

Example 10:

The PM Beam Combiner is a bi-directional device which splits or combines orthogonally Polarized light. It is ideal for combining polarized light from two pump lasers for increased Power input into a Raman amplifier or an EDFA system

The QA department conducted a qualification program for the purpose of assessing the Device reliability performance in compliance with Bellcore GR-1221-CORE



Product Qualification Test

3. To generate a test report (continue)

3.2 Qualification test summary

Briefly state the followings:

- ◆ Test sample,
- ◆ Test period (e.g. from 9/15/2001 ~ 12/20/2001),
- ◆ Who did the test (in-house or contract Lab.),
- ◆ Which tests were conducted, and its conditions,
- ◆ Which parameters were measured, and under what conditions (temperature, ...)
- ◆ List of Test and measurement equipment,
- ◆ Drawing of Optical measurement setup,
- ◆ Tabulate the pass/fail criteria

Product Qualification Test

3. To generate a test report (continue)

3.3 Test summary

Example 11:

Test results summary

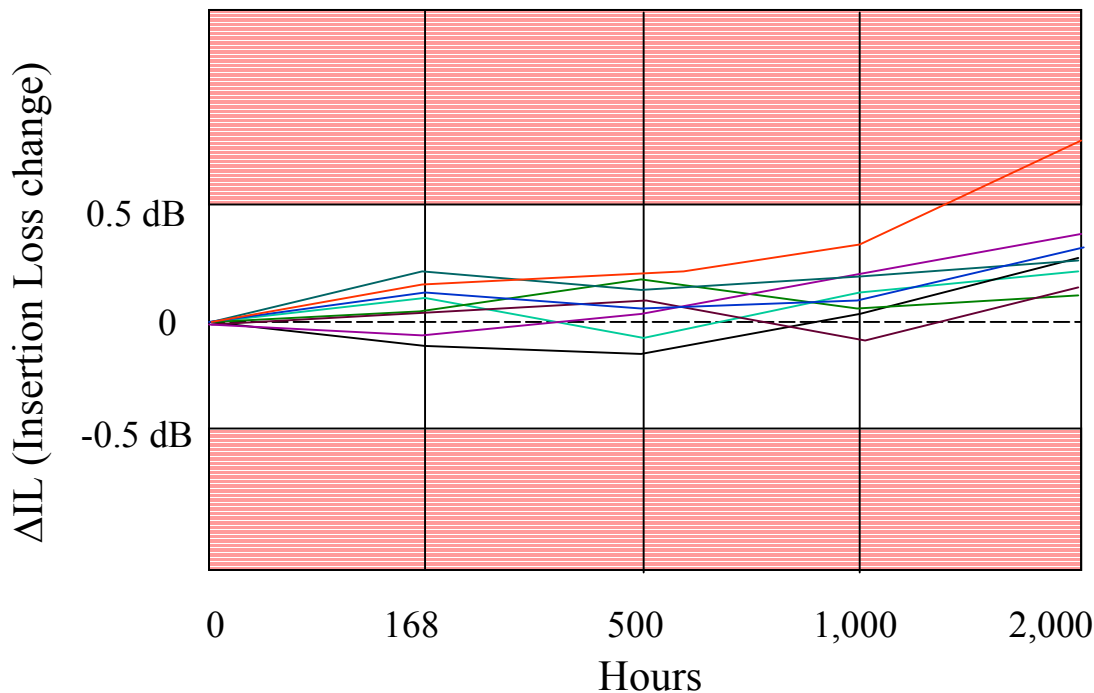
Type of Test	Results (SS/Rej)	Observation	Complete
High temperature storage	11/0	Pass after 2,000 hrs.	Dec. 15, 2001
Low temperature storage	11/0	Pass after 2,000 hrs.	Dec. 20, 2001
Damp heat test	11/1*	Pass after 1000 hrs, 1 out of 11 pcs failed on IL after 2,000 hrs	Dec. 24, 2001
Temperature cycling test	11/0	Pass after 500 cycles	Sep. 15, 2001

Product Qualification Test

3. To generate a test report (continue)

3.3 Test summary

Example 12: Data analysis and comments



For Serial number 120346 which failed on IL ($\Delta IL > 0.5$ dB) measured at $\lambda_c = 1550$ nm, 23°C after 2,000 hours,

A detailed Failure analysis report is in Appendix I

Product Qualification Test

3. To generate a test report (continue)

3.4 Conclusion

This section entails the conclusion of the qualification test. It includes brief comments of any particular problems which should require extra emphasis or explanations.

Example 13:

Fifty-five total devices were randomly selected and tested during this qualification program based on qualification test plan *[your document number]*. The test results reported in this document demonstrate that the product have successfully met the reliability assurance requirements specified in GR-1221-CORE for Central Office applications.

However, opportunities for improvement were also identified for long term humidity resistance. *[your company name]* is committed to ensure that continual process improvements and periodic surveillance qualifications will continue to be performed on this product family.

4. To Perform the Failure Analysis

4.1 Background check:

Product name

Model number

Serial number

Manufacturing date

Process run-card

Internal failed or customer's return

Field applications

Failure mode (or failed reason)

Product Qualification Test

4. To Perform the Failure Analysis (continue)

4.2 Root cause analysis:

Performing visual inspection on fiber pigtail and packaging sealing.

Functional evaluation (Optical re-test) to confirm the failures (IL, PDL, channel Isolation, ...)

X-ray photo analysis

Removal of out-house

Surface analysis

-
-
-

Product Qualification Test

4. To Perform the Failure Analysis (continue)

4.2 Root cause analysis (continue):

Example 13:

Source: Qualification, Damp Heat

Defect Mode: High IL, Low RL

Failure Mechanism: Contamination

Root Cause: Migration of Uncured UV adhesive

Product Qualification Test

4. To Perform the Failure Analysis (continue)

4.3 Conclusion/Recommendation:

Example 14:

Conclusion:

After investigation, it was concluded that the high IL failure was due to the Damaged fiber at the edge of the V-groove. The root cause of the fiber Breakage was

Recommended Corrective Actions:

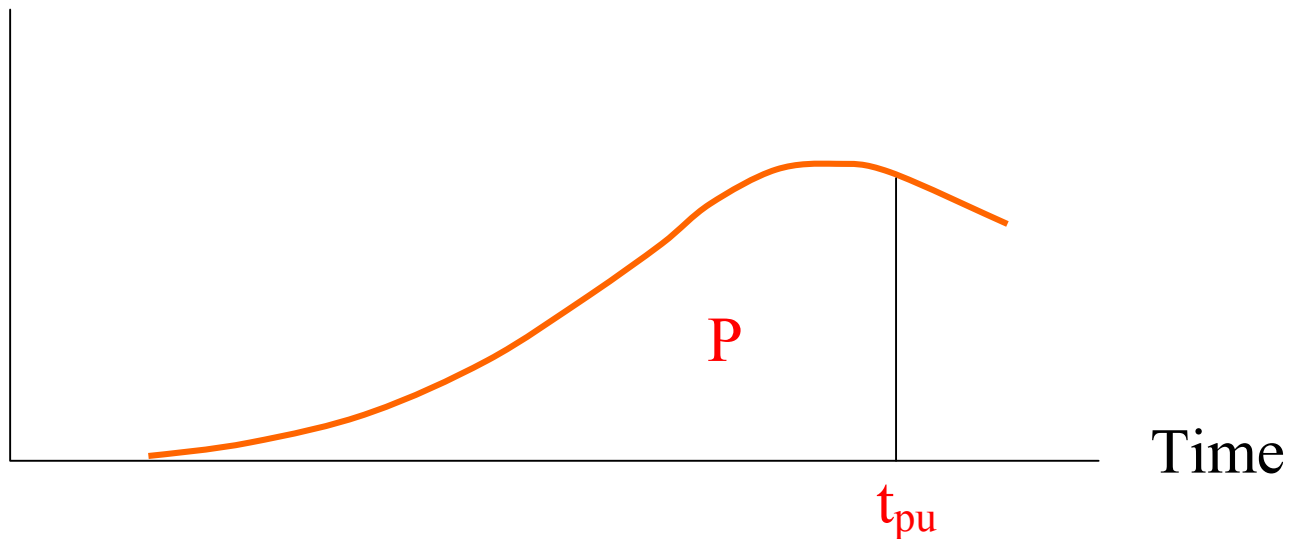
1. Visual inspection of fiber in V-groove
2. Re-train and re-certify the operators of applying Epoxy
3.
4.

Product Qualification Test

4. To Perform the Failure Analysis (continue)

Remarks: Acceleration Test

1. Under normal usage conditions, assume a device follows its times-to-failure life distribution:



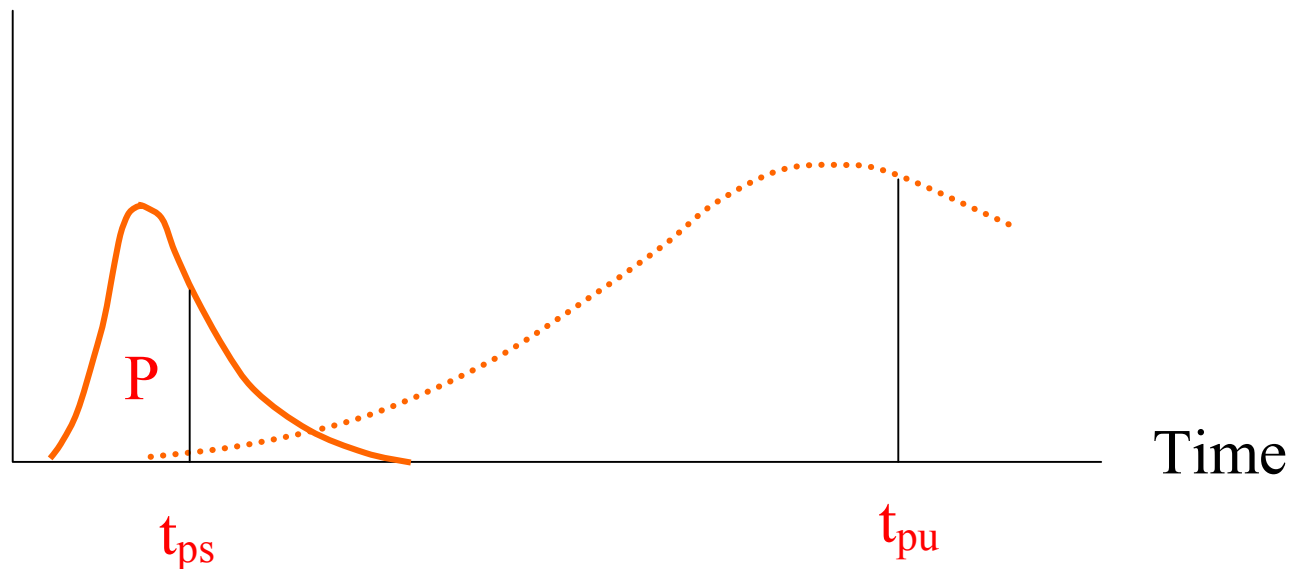
t_{pu} = time at which $p\%$ of a population will fail as a result of known failure mechanism under normal use conditions.

Product Qualification Test

4. To Perform the Failure Analysis (continue)

Remarks: Acceleration Test

2. Consider the life distribution when subjected to high-stress operating conditions, expressed in terms of stress times-to-failure:

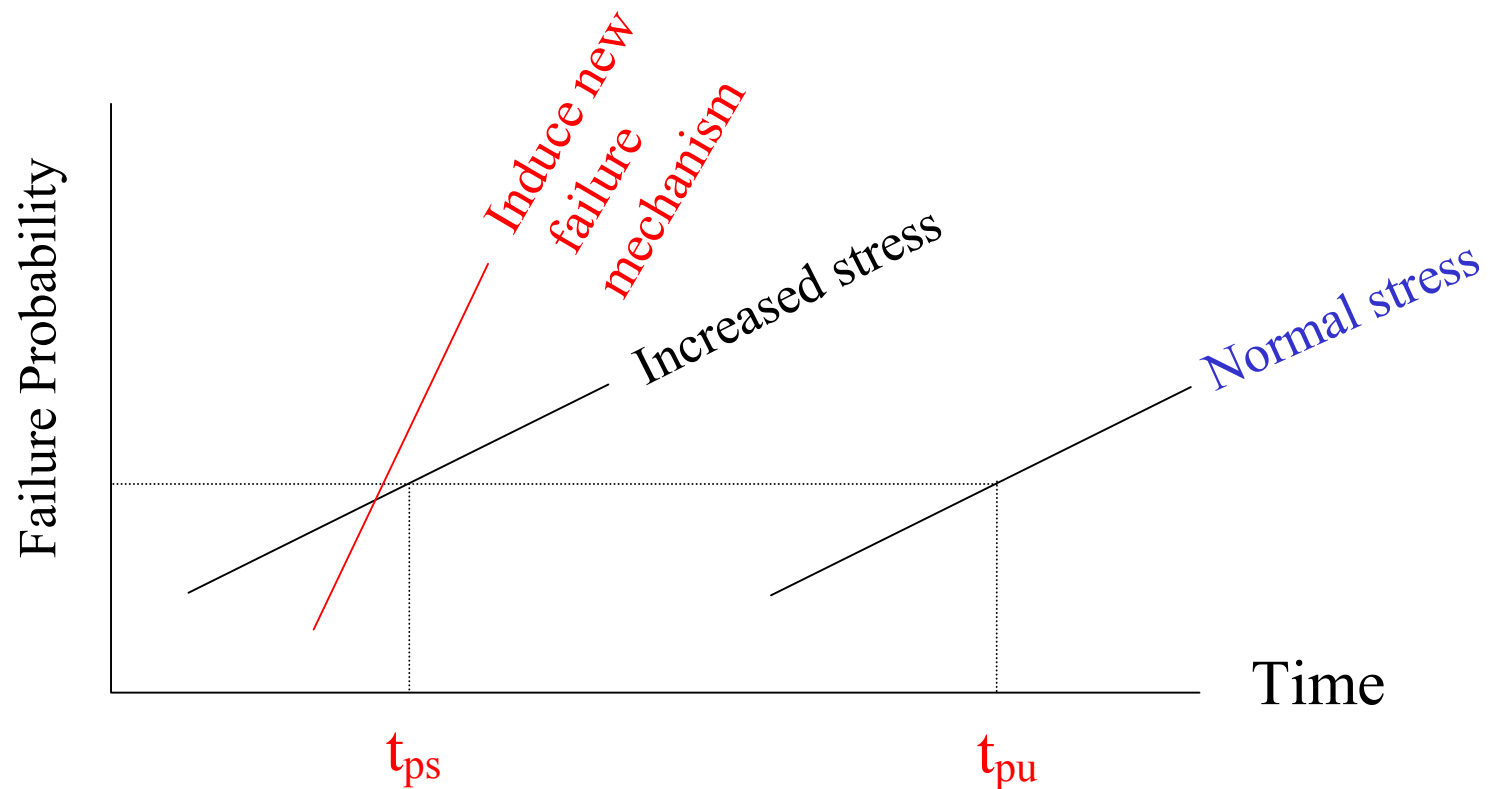


t_{ps} = time at which $p\%$ of a population will experience the same failure mechanism under increased stress conditions.

Product Qualification Test

4. To Perform the Failure Analysis (continue)

Remarks: **Acceleration Test**



Product Qualification Test

5. To Take Corrective Actions

Identify what action(s) need to take:

Material?

Process? Which steps?

Enhance the jig, fixture, or tools

Operator re-training?

Or even re-design the product?

6. To repeat the qualification if necessary

Full set

Or partially ?

Conditions Required Re-qualification

1. Design change
2. Key materials change
3. Major processing or assembly change
4. Production move to other site



Causes:

Performance enhancement, Cost reduction,
Quality and reliability problem in manufacturing or field use

Qualification Maintenance

Periodic re-qualification
On-going reliability program
Reliability monitoring
Qualification Surveillance

In the absence of significant changes in the Product and manufacturing process, each device family should be re-qualified every **2 years** or more often.

Question: What if the re-qualification failed ?

Reliability Calculation

1. Arrhenius Equation
2. Acceleration Factor
3. Mean Time To Failure (MTTF) and FITs
4. Failure Rate Estimation
5. Chi-square (χ^2) Distribution
6. The Real Meaning of Failure Rate (λ)

Acceleration Test

Arrhenius Model (or Arrhenius Equation):

$$R = A * \exp - \left(\frac{E_a}{K * T} \right)$$

Where: R = Reaction Rate

A = Scaling Factor

E_a = Activation Energy (electron volts)

T = Temperature (Kelvin, °K)

K = Boltzmann's constant = 8.617×10^{-5} eV/°K

Acceleration Test

Acceleration factor $A_F = \frac{t_{pu}}{t_{ps}}$, and

$$R = A * \exp - \left(\frac{Ea}{K * T} \right)$$

Therefore,

$$A_F = \frac{R_s}{R_u} = \frac{A * \exp - \left(\frac{Ea}{K * T_s} \right)}{A * \exp - \left(\frac{Ea}{K * T_u} \right)} = \exp \left\{ - \left(\frac{Ea}{K * T_s} \right) - \left[- \left(\frac{Ea}{K * T_u} \right) \right] \right\}$$

$$= \exp \left[\frac{Ea}{K} \left(\frac{1}{T_u} - \frac{1}{T_s} \right) \right]$$

Acceleration Test

Example 1:

$$T_u = 296 \text{ K } (23^\circ \text{C})$$

$$T_s = 358 \text{ K } (85^\circ \text{C})$$

$$E_a = 0.35 \text{ eV}$$

$$k = 8.62 \times 10^{-5}$$

$$A_{\text{HTS}} = \exp \left[\left(\frac{0.35}{8.62 \times 10^{-5}} \right) \left(\frac{1}{296} - \frac{1}{358} \right) \right] = 10.7$$

Therefore, for high temperature test (Dry heat) @ 85°C
For 2,000 hours equals:

*At Room temperature = $10.7 * 2,000 = 21,400$ hours*

Acceleration Test

Example 1: (continued)

Another point of view:

11 devices tested for 2,000 hours at 85 °C. Assume the use condition is at 23 °C :

$$\begin{aligned}\text{Total device hours} &= 11 * 2,000 * 10.7 (A_F) \\ &= 235,400 \text{ hrs} \\ &= 9,800 \text{ days} \\ &\approx 26 \text{ years}\end{aligned}$$

(Assume there is no failure)

Acceleration Test

Arrhenius Model Extension:

$$A_F = \exp \left\{ \left[\frac{E_a}{K} \left(\frac{1}{T_U} - \frac{1}{T_S} \right) \right] + \eta \times (RH_U^n - RH_S^n) \right\}$$

E_a is the activation energy,

K is Boltzmann's constant,

T_U and T_S are the temperatures in Kelvin,

η is humidity factor (determined by relative humidity experiments)
= -5×10^{-4}

n is relative humidity factor (determined by relative humidity experiments)
= 2, and

RH_U and RH_S are the relative humidity (%).

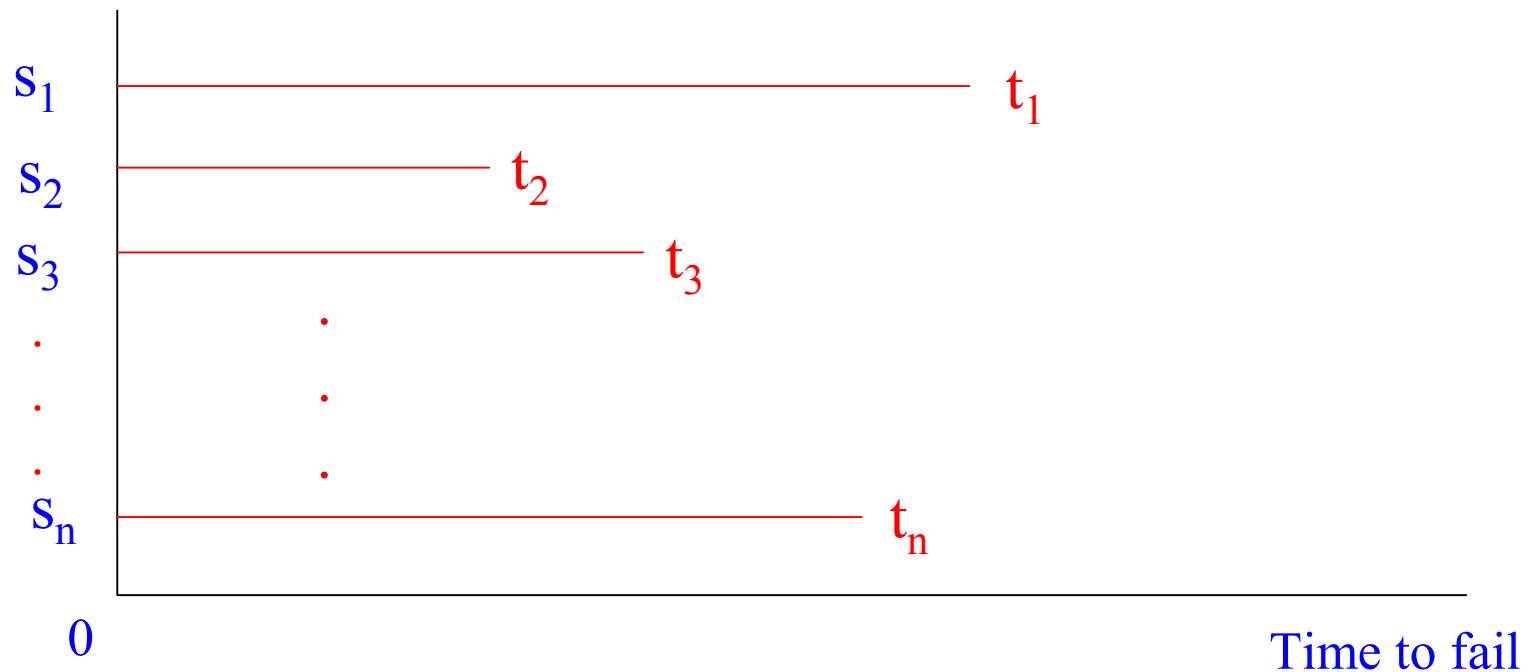
Acceleration Test

Example 2 :

Calculate the Accelerate Factor for (1) 75 °C/90%RH and
(2) 85 °C/85%RH, assume the use condition is 40 °C/50%RH.

Mean Time To Failure (MTTF)

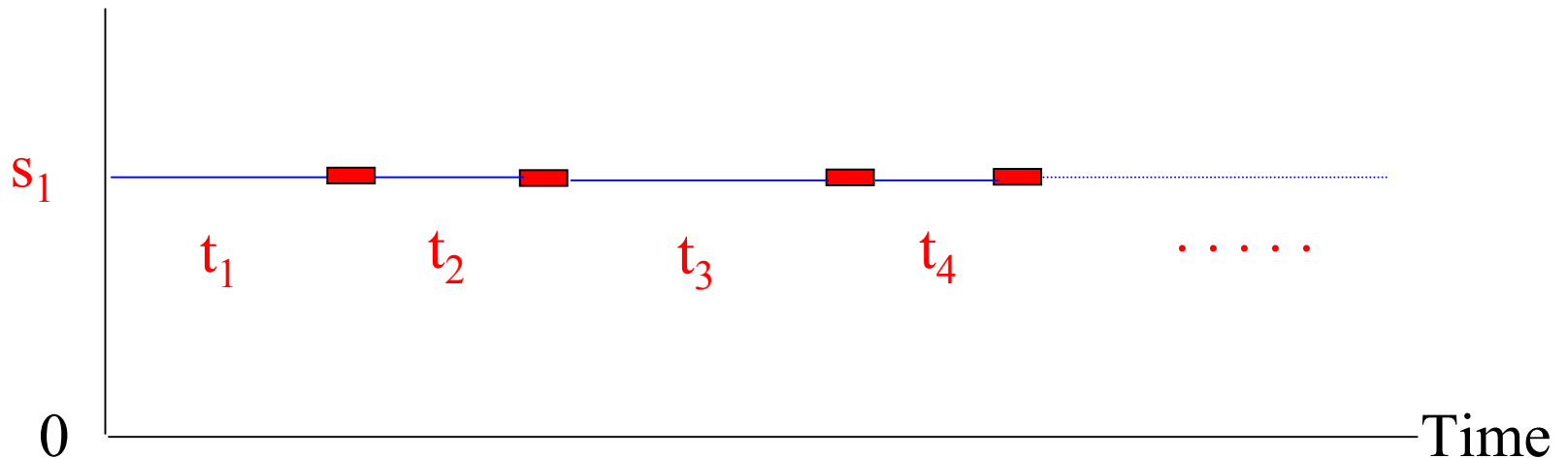
There are n identical devices and observe the time to failure for them. Assume that the observed time to failure are $t_1, t_2, \dots, t_n$. The estimated mean time to failure, MTTF is



$$\hat{MTTF} = \frac{1}{n} [t_1 + t_2 + \dots + t_n] = \frac{1}{n} \sum_{i=1}^n t_i$$

Mean Time To Failure (MTTF)

- MTBF (A Single equipment)



$$\text{MTBF} = \frac{1}{n} [t_1 + t_2 + \dots + t_n] = \frac{1}{n} \sum_{i=1}^n t_i$$

Mean Time To Failure (MTTF)

- **MTTF, MTBF, and MCBF**
 - Mean Time To Failure
 - Mean Time Between Failure
 - Mean Cycle Between Failure

$$\text{MTTF} = \frac{\text{Total device operating hours}}{\text{Number of failures}}$$

- **FIT (Failure In Time): λ**
 - The number of failures per billion (10^9) device hours

$$\lambda = \frac{\text{Number of failures}}{\text{Total device operating hours (in } 10^9 \text{ hrs)}}$$

Failure Rate Estimation

Based on Field Return Data:

1. Assumption:
 - 1.1 All devices shipped to field are in use
 - 1.2 All failed devices were returned
 - 1.3 The probability function of random failure is an exponential distribution:

$$f(t) = \lambda e^{-\lambda t} \quad t \geq 0, \text{ where } \lambda \text{ is the failure rate}$$

2. Failure definition:

Any device functional parameter performance not meet the specs.
but not include any administrative errors
3. Calculate the total devices hours:

$$\sum_i \text{shipped qty}_i \times (\text{current date} - \text{shipped date}_i)$$

Failure Rate Estimation

Based on Field Return Data: (continued)

4. Use Chi-square distribution (χ^2) to calculate the failure rate (λ):

$$\lambda_{\max} \leq \frac{\chi^2_{\alpha, 2(r+1)}}{2 * T}$$

where: χ^2 = Chi-square distribution

r = number of Failures

α = confidence level

T = total device hours

Failure Rate Estimation

Based on Field Return Data: (continued)

5. Example 3:

Cumulative total device hours in field = 30,500,000,000 hrs

Reliability failures = 200 pcs

Use 95% upper confidence limit

$$\lambda_{\max} = \chi^2_{(0.05, 2 \times (200+1))} / (2 \times 30,500,000,000)$$

$$= 7 \times 10^{-9}$$

$$= 7 \text{ FITs}$$

Failure Rate Estimation

Based on Field Return Data: (continued)

Or, we can use the following formula and Table provided by Bellcore TR-332:

$$\lambda_{\max} \leq \frac{u_f}{T}$$

Table 11-12. Upper 95% Confidence Limit (U) for the Mean of a Poisson Distribution

Failure Count f	Upper Confidence Limit U	Failure Count f	Upper Confidence Limit U	Failure Count f	Upper Confidence Limit U	Failure Count f	Upper Confidence Limit U
0	3.0						
1	4.7	41	53.2	81	97.4	121	140.7
2	6.3	42	54.3	82	98.5	122	141.8
3	7.8	43	55.5	83	99.6	123	142.9
4	9.2	44	56.6	84	100.7	124	143.9
5	10.5	45	57.7	85	101.8	125	145.0
6	11.8	46	58.8	86	102.9	126	146.1
7	13.1	47	59.9	87	104.0	127	147.2
8	14.4	48	61.1	88	105.1	128	148.2
9	15.7	49	62.2	89	106.2	129	149.3
10	17.0	50	63.3	90	107.2	130	150.4
11	18.2	51	64.4	91	108.3	131	151.5
12	19.4	52	65.5	92	109.4	132	152.5
13	20.7	53	66.6	93	110.5	133	153.6
14	21.9	54	67.7	94	111.6	134	154.7
15	23.1	55	68.9	95	112.7	135	155.7
16	24.3	56	70.0	96	113.8	136	156.8
17	25.5	57	71.1	97	114.8	137	157.9
18	26.7	58	72.2	98	115.9	138	158.9
19	27.9	59	73.3	99	117.0	139	160.0
20	29.1	60	74.4	100	118.1	140	161.1
21	30.2	61	75.5	101	119.2	141	162.2
22	31.4	62	76.6	102	120.2	142	163.2
23	32.6	63	77.7	103	121.3	143	164.3
24	33.8	64	78.8	104	122.4	144	165.4
25	34.9	65	79.9	105	123.5	145	166.4
26	36.1	66	81.0	106	124.6	146	167.5
27	37.2	67	82.1	107	125.6	147	168.6
28	38.4	68	83.2	108	126.7	148	169.6
29	39.5	69	84.3	109	127.8	149	170.7
30	40.7	70	85.4	110	128.9	150	171.8
31	41.8	71	86.5	111	130.0	151	172.8
32	43.0	72	87.6	112	131.0	152	173.9
33	44.1	73	88.7	113	132.1	153	175.0
34	45.3	74	89.8	114	133.2	154	176.0
35	46.4	75	90.9	115	134.3	155	177.1
36	47.5	76	92.0	116	135.3	156	178.2
37	48.7	77	93.1	117	136.4	157	179.2
38	49.8	78	94.2	118	137.5	158	180.3
39	50.9	79	95.3	119	138.6	159	181.4
40	52.1	80	96.4	120	139.6	160	182.4

Real Meaning of Failure Rate

Example 4:

A component failure rate is required to be 1,000 FIT, what is the MTTF of this component?

Solution:

$$\lambda = 1,000 \text{ FIT} = 1,000 / 10^9 \text{ hrs}$$

$$\text{MTTF} = 1 / \lambda$$

$$= 10^9 \text{ hrs} / 1,000$$

$$= 10^6 \text{ hours}$$

$$= 41,667 \text{ days}$$

$$= 114 \text{ years}$$

The MTTF of this component is 114 years!

Does this make sense? ← NO!

Real Meaning of Failure Rate

Correct Explanation 1:

The MTTF = 114 years won't make sense here.

1. Over 25 years, with 100 components, how many pcs will be failed ?

$$\lambda = 1,000 \text{ FIT} = 1,000 / 10^9 \text{ hrs}$$

$$\begin{aligned} & (1,000 / 10^9 \text{ hrs}) * 25 * (365 * 24 \text{ hrs}) * (100 \text{ pcs}) \\ &= (1,000 / 10^9 \text{ hrs}) * 25 * 8760 \text{ hrs} * 100 \text{ pcs} \\ &= (1,000 / 10^9 \text{ hrs}) * 219,000 \text{ hrs} * 100 \text{ pcs} \\ &= 21,900,000,000 / 10^9 \text{ pcs} \\ &= 21.9 \text{ pcs} \end{aligned}$$

22 pcs out of 100 of such components will be failed over 25 years period if the failure rate $\lambda = 1,000 \text{ FIT}$.

Real Meaning of Failure Rate

Correct Explanation 2:

The MTTF = 114 years won't make sense here.

2. Over 25 years, what is the survival rate if $\lambda = 1,000$ FIT ?

Failure rate $\lambda = 1,000$ FIT = $1,000 / 10^9$ hrs

Survival rate = $1 - (\text{failure rate} * 25)$

$$= 1 - [(1,000 / 10^9 \text{ hrs}) * 25 \text{ years}]$$

$$= 1 - [(1,000 / 10^9 \text{ hrs}) * 25 * (365 * 24 \text{ hrs})]$$

$$= 1 - 0.219$$

$$= 78.1\%$$

Conclusion:

The reliability will be 78% over 25 year if the failure rate $\lambda = 1,000$ FIT .

Real Meaning of Failure Rate

Example 5:

The reliability target of a high-reliable device is 4 FITs. That is to say, over 25 years life time with 1,000 devices, only 1 failure is allowed. Is is true?

$$\lambda = 4 \text{ FIT} = 4 / 10^9 \text{ hrs}$$

$$\begin{aligned} & (4 / 10^9 \text{ hrs}) * 25 * (365 * 24 \text{ hrs}) * (1,000 \text{ pcs}) \\ &= (4 / 10^9 \text{ hrs}) * 25 * 8760 \text{ hrs} * 1,000 \text{ pcs} \\ &= (4 / 10^9 \text{ hrs}) * 219,000 \text{ hrs} * 1,000 \text{ pcs} \\ &= 876,000,000 / 10^9 \text{ pcs} \\ &= 0.8 \text{ pcs} \\ &< 1 \text{ pcs} \end{aligned}$$