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LCD TV RELIABILITY TESTING: AN EFFECTIVE APPROACH

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PRESENTATION SLIDES

The following presentation was delivered at the:

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Introduction

- Presentation introduces a unique approach to predicting LCD TV Warranty Failure Rates, using Product Level and Sub-Assembly Level stress testing to maximise ability to induce failure of weaknesses in Design, Component and Process
- Real Life Case Study is used to illustrate success of the approach developed for use in Design and Pre-Shipment of a New Product
- Application of several Acceleration Models are used to calculate simulated test times allowing accurate and meaningful Fail rate predictions to be made

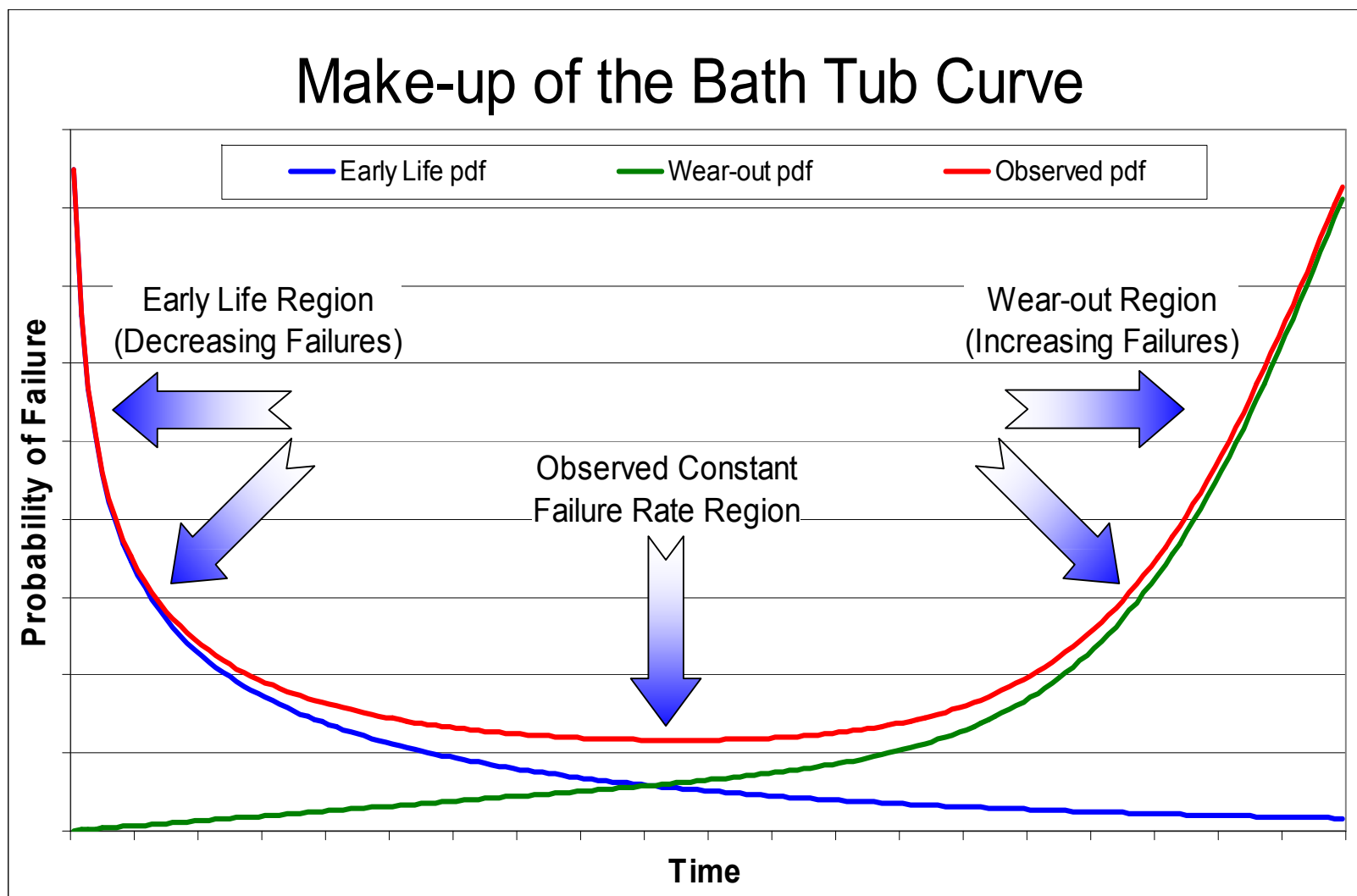


Background

- LCD TV Reliability has become a MAJOR concern over last 2 yrs for the manufacturers as TV Sales Prices have dropped quite dramatically
- Warranty Fail rates have not improved in line with Price Reductions, hence the cost of warranty failure support has become a greater % of the profit margin
 - In Europe the average cost per failure including logistics cost > \$150
 - If Failure Rates can drop by 2%, MAJOR Cost savings of at least \$3 per unit sold can be realised, \$20 Million/yr for a High Volume manufacturer
- LCD TV Designs are being upgraded continually to stay ahead of customer expectations, hence New Product Release is under continual focus to meet planned market release dates when maximum sales revenue can be realised
 - This makes achieving high levels of Reliability even more critical



Electronic Product Failure Distribution





LCD TV Failure Distribution

- Often a new product will display three different failure distributions
 - Infant Mortality
 - Weak Manufacturing errors, defects lack of process control
 - Freak Population
 - Manufacturing anomalies requiring longer time to fail
 - Main Population
 - Defect free parts that continue to function into wearout
- Testing has shown each to have following fail levels during 12 mth warranty
 - Infant Mortality 100 – 1000 ppm
 - Freak population 2000 – 10,000 ppm
 - Main Population 10,000 – 30,000 ppm
- Quality objective to remove first distribution prior to shipment and apply ongoing Early Life Testing to reduce Freak Population



LCD TV Accelerated Stress Testing

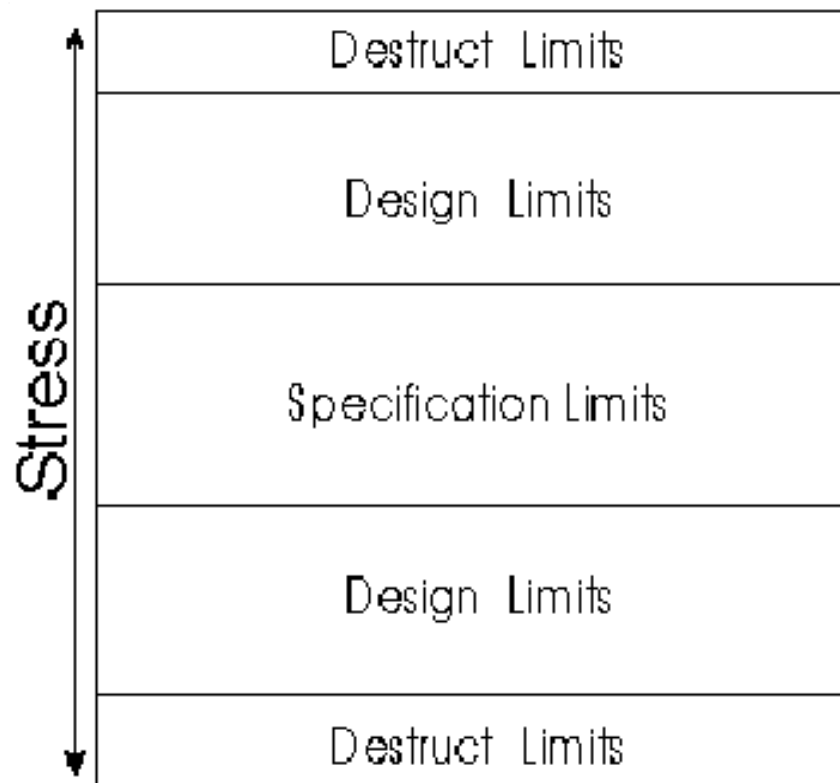
- Objective of High Stress Level testing beyond 'Normal Use' Operational Stress Levels is to STIMULATE Defects
 - All defects may not be resolved if it is agreed the high level of stress has caused the defect rather than weakness of Design or Component
 - Testing is short and provides excellent Return On Investment

- Testing product in old style 40C and 25C Tests at nominal Voltage Levels with Low Humidity is to SIMULATE field defects
 - All defects **MUST** be resolved, but **WIDE RANGE** of defects are **NOT DETECTED** in such Low Stress Level Testing
 - Most Process Issues **NOT** detected; Component Weaknesses **NOT** detected unless very Major Issues with high defect rates
 - Testing is **LONG** duration and **POOR** Return On Investment



LCD TV Accelerated Stress Testing

- Objective of Accelerated Stress Testing at Sub-Assy and Product Level is NOT to Damage the product, but test sufficiently to understand full range of weakness in Design and Process



- To improve Reliability we **MUST INVESTIGATE** via High Stress Level Testing, then decide which issues to resolve, NOT to avoid Testing and MISS the issues



LCD TV Accelerated Stress Testing

- Applying Stress at Sub-Assy level avoids the arguments over stress CAUSING defects rather than DETECTING them

- Focus is on Early Life Performance (ELP) testing to stimulate weakness in Process and Components, though Design issues can also be highlighted (Component Layout causing solder issues, detached component leads, etc.)

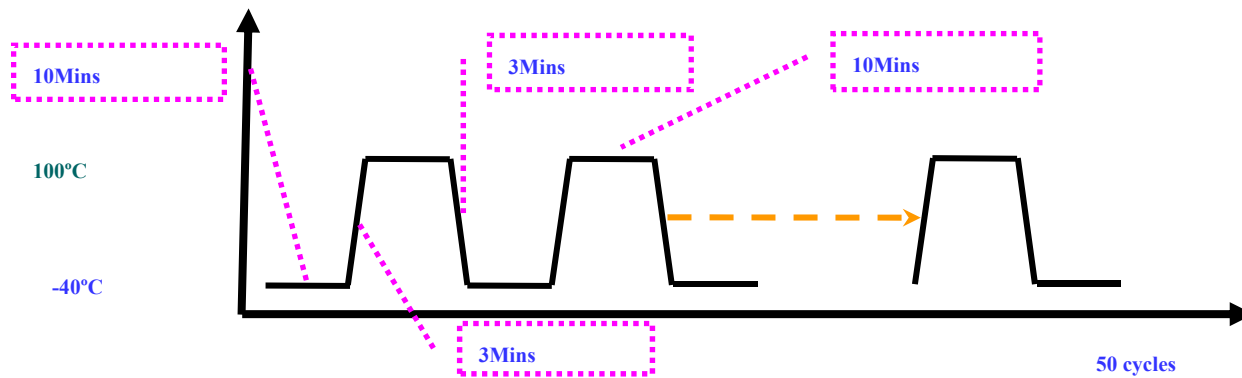
- The benefits of ELP testing are both Time Savings and also Cost Savings
 - Avoid High Costs of TV products, no need to wait for representative TV samples and Final Software levels
 - Complete testing in short time and get results for immediate improvement



Power and Main Board Level Reliability Testing

Thermal shock : Cycle 50 cycles from -40°C (10 mins) ~ 100°C (10 mins) with a ramp rate of 40-55°C/Min (Refer to IPC9701), Random Vib. : 10G, 1hr

Design Verify Test – 1000 cycles, ORT - 50 / 100 cycles



Both power board and main board				
Test No.	Stress Test	Test Codition	Test Time	Test Q'ty
1	Thermal Shock	From -40°C (10mins) ~ 100°C(10mins) , ramp rate of 40°C--55°C/Min (Refer to IPC9701)	25hrs	30PCS
2	Random Vibration	10G	1hr	30PCS
3	ICT/FT Test	N/A	N/A	30PCS



Board Level Reliability Test Results

New products

- High Volume Board level ELP Test will find range of defects that are used to drive down Field Fail Rate quickly
 - Typical Fail rates experienced up to 10,000 ppm
 - **Analysis suggests NONE of the defects would be found in normal TV Reliability Testing**
 - **All defects considered MAJOR type defects:**
 - Tuner defects most common reason for failure, sole supplier issue
 - Defective PCB, Supplier issue admitted, changed supplier
 - Transformer defect, Bad Supplier Workmanship accepted – Wiring Defect
 - Cracked Ceramic Capacitor Issue
 - Range of Solder Issues

Sample Sizes tested at New Product Level generally around 150-200 pcs, ongoing 50 pcs per product type for first 3-4 mths of production



Board Level Reliability Test Results

Mass Production

- ELP has proven to be VERY SUCCESSFUL at Board Level, showing excellent capability to detect weaknesses in short duration/high stress level testing of Mass Production

- In other LCD TV makers approx 4000 - 6000 ppm detected during ongoing Main Board and Power Board testing
 - **Only 25% would be found in normal TV Reliability Testing**
 - **Would take LONG TIME and HIGH COST of HIGH VOL samples**
 - **50% of the defects were component!!**
 - IC defects due to contamination growth inside component that is accelerated in stress test
 - IC package delamination
 - Crystal Component failures
 - Ceramic Cap fails, etc.



LCD Panel Reliability Testing

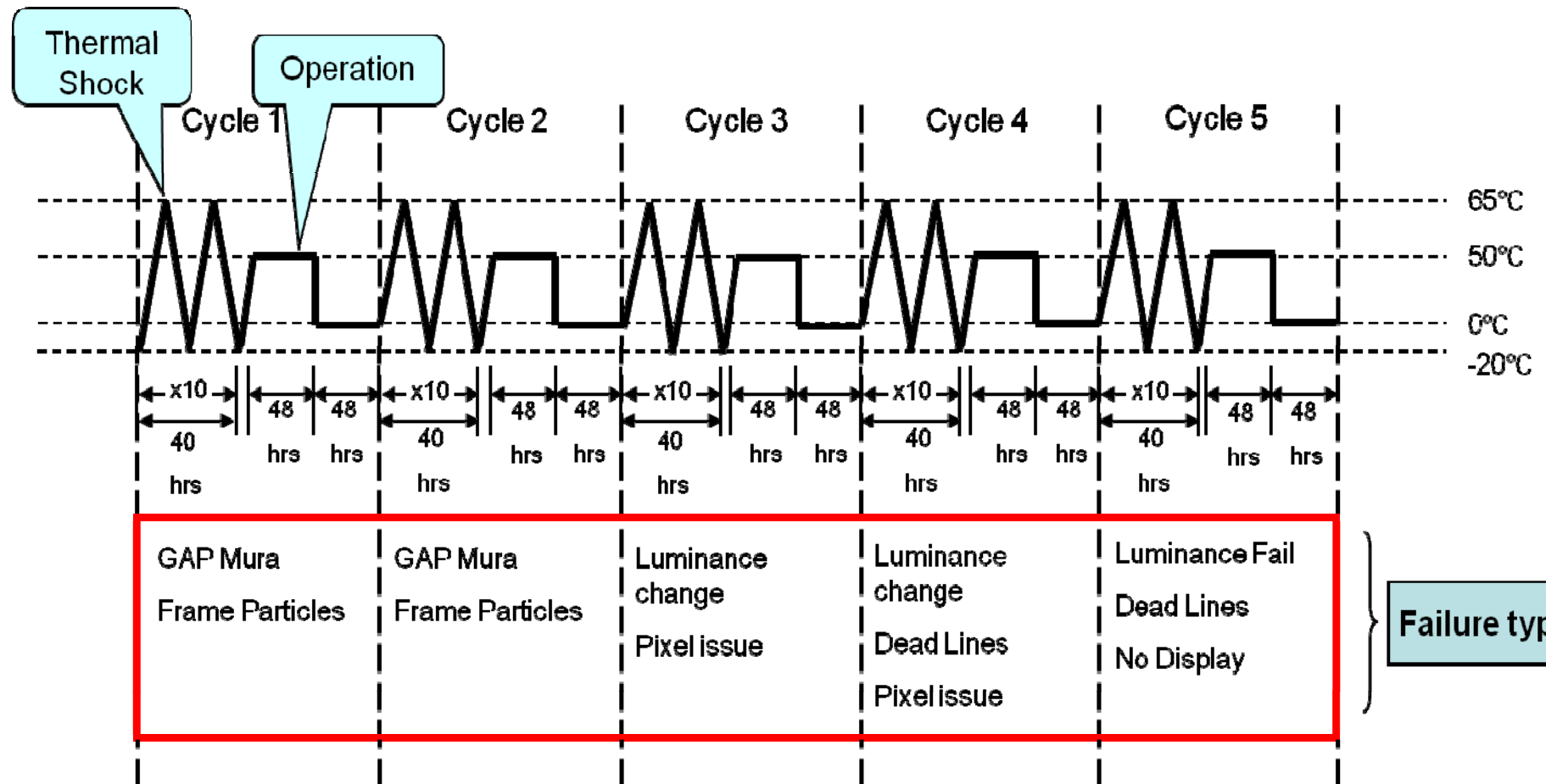
- Panel testing has historically been done as part of a product Life Test, RARELY finding any defects until a very large volume of product have been tested
 - Stress tests are always applied individually and NOT sequentially, hence minimal cumulative stress applied
- Several LCD TV makers have suffered serious panel epidemic fail issues in the last 2-3 years, hence requiring a quick method to evaluate any risk with new high volume panel or new technology
 - Protects Assembly Line from high defect rates such as Dead lines and highlights issues that may become serious warranty or long Life issues
- Most common warranty issues affecting LCD panel reliability are Dead Line/Block problems and Luminance Issues when panel drops < 50% of new level
- Accelerated Stress Testing has been shown to stimulate these key defect types, providing ability to develop solutions pre-M.P.



LCD Panel Reliability Testing

- Experimental approach involved use of non-operational rapid Thermal Cycling/Thermal Shock followed by periods of Operational testing at upper and lower temp spec limits for LCD

panel technology, at 50C, 90% RH test applied





LCD Panel Reliability Testing

- Results showed very positive response to the Sequential Stress applied, finding representative defects which would NOT be seen in normal testing
 - Accelerated Modelling is possible to then predict fail rates

Temp / Humidity Acceleration

2

$$AF = (RH_{test}/RH_{use}) \exp [-(0.5/k) (1/T_1-1/T_2)]$$

RH_{test} = Relative humidity during test.

RH_{use} = Relative humidity during application.

E = activation energy in electron volts.

K = Boltzmann's constant (8.6e-5 eV/K).

T_1 = temperature during stress test (K).

T_2 = temperature during application (K).

Temperature and Humidity Acceleration Factor Calculator	
RH_{use}	40
RH_{test}	90
T_{use} (°C)	25
T_{test} (°C)	50
Activation Energy (eV)	0.5
Humidity Exponent (n)	2
Acceleration Factor	23



LCD Panel Reliability Testing

Thermal Cycling / Shock Acceleration

$$AF = (\Delta T_{\text{accel}} / \Delta T_{\text{use}})^m$$

ΔT_{accel} = Temp Cycle Range during stress

ΔT_{use} = Temp Cycle Range during normal use

Coffin-Manson exponent (m) is dependent on the failure mechanism and can be influenced by the package materials. In this case we have chosen m = 4-5 for package delamination.

Temp change between ambient on and off operational state = 50C,

Measured Average temp change in T/Cyc = 80C

$$AF = (\Delta T_{\text{accel}} (80) / \Delta T_{\text{use}} (50))^5 = \underline{11}$$



LCD Panel Reliability Testing

Fixed Temperature Testing

$$AF = (RH_{test}/RH_{use}) \exp [-(0.5/k) (1/T_1 - 1/T_2)]$$

Arrhenius Acceleration Factor Calculation

Use Temperature	25
Test Temperature	50
Activation Energy	0.5
Arrhenius Acceleration Factor	5

By combining all 3 stress accelerators, we have a very strong stress test that can also be modelled to calculate simulated field operational time and therefore enable prediction of expected defect/hazard rate



LCD Panel Accelerated Time Modeling

Field Operation Simulated Time

48 Thermal Cycles (-40 to +120C), takes 1 hr with a Cycling Ramp Rate of 10C per minute

Total Time = 24 Hrs x 11 = **264 hrs**

48 hrs at 50C / 90% RH test power on including 1st 2 hrs with Pwr Switch, 2 mins ON, 2 mins OFF

= 48 Hrs x 23 = **1104 hrs**

48 hrs at 0C / 40% RH test power on including 1st 2 hrs with Pwr Switch, 2 mins ON, 2 mins OFF

= 48 Hrs x 5 = **240 hrs**

Repeat Above Test Cycle 5X



LCD Panel Reliability Prediction

These Accelerated Test Times can now be split into TAB and B/L Simulated Operational Times for prediction of Dead Line and B/L Fail levels in field

- Simulated Test Time for Dead Line TAB fail issues
 264×5 (no. of test cycles) = 1320 hrs
- Simulated Test Time for Luminance fail issues
 $(1104 + 240) \times 5 =$ 6720 hrs
- As TAB fails will also be accelerated with the steady temp, Humidity Testing, we must add simulated test time to TAB simulated time for accurate assessment
= $1320 + 6720$ or 8040 hrs

This approach therefore allows calculation of Hazard Rate for each defect type and ultimately prediction of LCD panel fail rate within the warranty period

For example, if 1 Tab fails and 1 B/L fails were detected with 60 panels tested we would predict Cumulative Fail rates as:

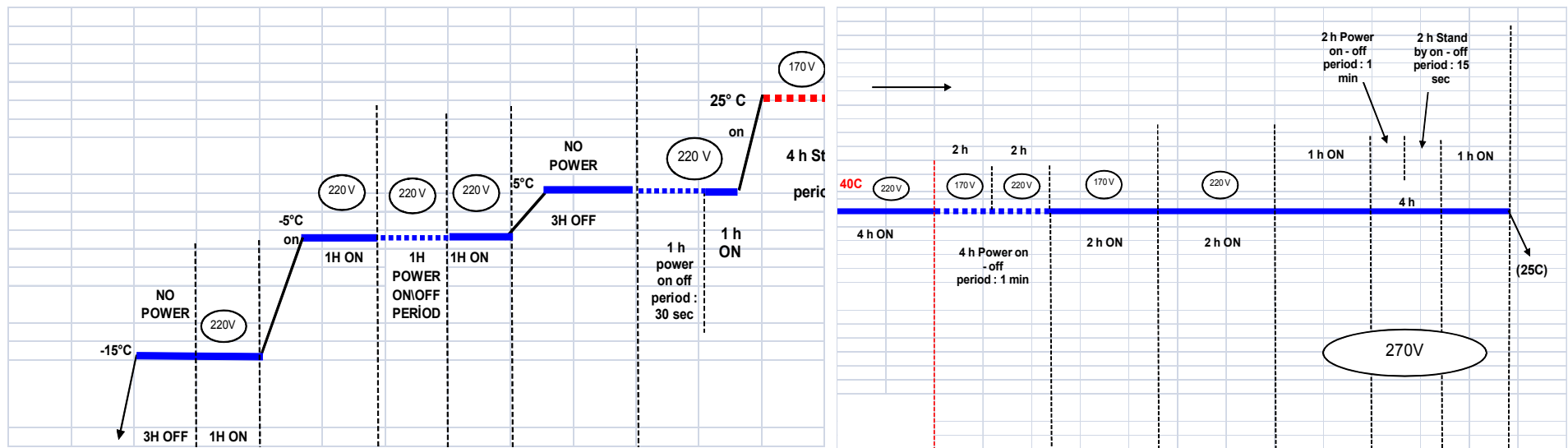
- B/L = $1 / (60 \times 6720) = 2.5 \times 10e6$ fails per hr
- TAB = $1 / (60 \times 8040) = 2.1 \times 10e6$
- Combined $4.6 \times 10e6$

For 300 hrs operation per mth, this converts to expected LCD panel fail level of .0014 (1400 ppm)



LCD TV Level Early Life Testing

By combining Voltage Variation, Temperature and Power Cycling, a very effective LCD TV Early Life Fail Test has been developed



This type of testing can be completed in only 32 hrs, hence High Volumes of product can be tested and shipped after test

Provides ability to find range of latent defects
Experience shows Fail rates of 5000 – 14000 ppm

- 50% of defects due to Component
- 25% due to Poor Design
- 25% due to Process Error



LCD TV Fail Prediction Model

By combining Temperature and Humidity, the maximum acceleration factor can be achieved, between 12 and 24 X:

RH_{use}	<input type="text" value="40"/>	RH_{use}	<input type="text" value="40"/>
RH_{test}	<input type="text" value="80"/>	RH_{test}	<input type="text" value="80"/>
T_{use} (°C)	<input type="text" value="25"/>	T_{use} (°C)	<input type="text" value="25"/>
T_{test} (°C)	<input type="text" value="50"/>	T_{test} (°C)	<input type="text" value="50"/>
Activation Energy (eV)	<input type="text" value="0.6"/>	Activation Energy (eV)	<input type="text" value="0.6"/>
Humidity Exponent (n)	<input type="text" value="1"/>	Humidity Exponent (n)	<input type="text" value="2"/>
Acceleration Factor	<input type="text" value="12"/>	Acceleration Factor	<input type="text" value="24"/>

Example of Real Life Case Study shows 2 diagnosed defects (not considered to be Early Life) in a total accelerated test time across a sample size of 20 pcs in 23,000 hrs

Equates to 2 defects within simulated operational hrs of 276,000 hrs to 552,000
Hazard rates are estimated between: 3.62319E-06 - 7.24638E-06 fails per hr

Assuming a 12 mth warranty period usage of 3600 hrs, Fail Rate = **1.3% - 2.6%**



LCD TV Long Life Testing

- Total Warranty Failure Rates for NEW products can be accurately predicted using 3 separate inputs:
 - Early Life fail rates from Sub-assy Accelerated Testing
 - Early Life fail rates at LCD TV level (more focused on Operational issues)
 - Longer Life fail rates using high stress MTTF test approach

- In Case Study shown fail rates:
 - Main Board and Pwr Board = 10000 ppm
 - LCD Panel = 1400ppm x 12 = 16800 ppm
 - Early Life LCD TV = 5000 – 14000 ppm
 - Longer Life LCD TV = 13000 – 26000 ppm

- Total Fail Rates therefore can average **44800 – 66800 ppm (4.4% - 6.7%)**
 - Provides many defects for solution and Reliability Improvement
 - Anticipate predicted fail rates can be reduced by 50% BEFORE Mass Production



Where to Get More Information

- Major Electronic Assembly Products such as LCD TVs can be tested in very different manners to maximise Defect Detection Capability
 - Traditional approach simply does not find enough defects
- Sub-Assy testing makes testing more effective, quicker and lower cost
- Design Level testing can be very efficient and prepare a more reliable product for mass production
- Reliability Growth can be achieved in Record Time
- Cost Avoidance in Field Warranty Costs can easily reach \$10 Million dollars in a 12 month period



Martin Shaw

- Reliability Solutions started in 1997 by Martin Shaw, previously of IBM from 1982-1997
- Expert in Electronic Product Quality & Reliability Improvement
- Over last 2 yrs been consulting with 3 of the World's top Contract LCD TV makers on Reliability Improvements to drive down Field Fail Costs
- Using past experience in Display Reliability Improvement over last 20 yrs, Martin has developed unique accelerated test programmes for LCD TV makers



Questions

Thank you for your attention.

Do you have any questions?