# Practical Aspects of MIL-DTL-23659 Appendix A Initiator Testing

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- **The following discussion is the opinion of the author. It does not necessarily represent the opinion of PerkinElmer Optoelectronics or of any of its customers, either government of commercial.**

- **The observations have been gathered through the years conducting these tests.**

## *This talk will address MIL-DTL-23659 Appendix A …*

- **General Rational for test plan**
- **Qualification Matrix**
- **Number of tests required**
- **Firing Property Tests**
- **All Fire Tests**
- **Safety Tests**
- **Leak Testing**



*… and some common misconceptions*

- **"This appendix furnishes general requirements for the certification of Exploding Foil Initiators (EFIs) that are used for safety sensitive initiation applications. The purpose of the certification program is to establish fundamental EFI characteristics including the electrical response characteristics, soundness of mechanical design, output, basic safety properties and resistance to deleterious service environments."**

- **"The certification provided for in this document will normally be an interim step toward type certification of an EFI in a system, and will typically be supplemented by additional testing peculiar to the specific service application for which the EFI is intended."**

# *The majority of units tested in MIL-DTL-23659 …*

PerkinElmer precisely.

| | Requirement | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| - | Quantity | 30 | 30 | 30 | 30 | 5 | 10 | 30 | 30 | 50 | 50 | 50 | 50 | 50 | 50 | 5 | 500 |
| A.4.2 | Visual Inspection | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | 500 |
| A.4.3 | Radiographic Examination | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | 500 |
| A.4.4 | Bridge Circuit Resistance | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | 500 |
| A.4.9 | Leakage | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | 500 |
| A.4.5 | Firing Properties, Ambient | X | | | | | | | | | | | | | | | 30 |
| A.4.5 | Firing Properties, Cold | | X | | | | | | | | | | | | | | 30 |
| A.4.5 | Firing Properties, Hot | | | X | | | | | | | | | | | | | 30 |
| A.4.6 | Max No Damage Current | | | | X | | | | | | | | | | | | 30 |
| A.4.7 | Thermal Cook-Off | | | | | X | | | | | | | | | | | 5 |
| A.4.10 | Electrical Cook-Off | | | | | | X | | | | | | | | | | 10 |
| A.4.11 | Maximum Allowable Electrical Sensitivity | | | | | | | X | | | | | | | | | 30 |
| A.4.12 | 1.5 Meter Drops | | | | | | | | X | X | X | X | | | | | 180 |
| A.4.13 | Electrostatic Discharge | | | | | | | | | | | | X | | | | 50 |
| A.4.8 | Temperature Shock/Humidity | | | | | | | | X | X | X | X | | | | | 180 |
| A.4.14 | Vibration | | | | | | | | X | X | X | X | | | | | 180 |
| A.4.15 | Shock | | | | | | | | X | X | X | X | | | | | 180 |
| A.4.2 | Visual Inspection | | | | | | | | X | X | X | X | | | | | 180 |
| A.4.3 | Radiographic Examination | | | | | | | | X | X | X | X | | | | | 180 |
| A.4.4 | Bridge Circuit Resistance | | | | | | | | X | X | X | X | | | | | 180 |
| A.4.9 | Leakage | | | | | | | | X | X | X | X | | | | | 180 |
| A.4.16 | All Fire Performance, Ambient | | | | | | | | | X | | | X | | | | 100 |
| A.4.16 | All Fire Performance, Cold | | | | | | | | | | X | | | X | | | 100 |
| A.4.16 | All Fire Performance, Hot | | | | | | | | | | | X | | | X | | 100 |
| A.4.5 | Firing Properties, Ambient | | | | | | | | X | | | | | | | | 30 |
| A.4.17 | High Firing Voltage | | | | | | | | | | | | | | | X | 5 |

**Consistency / Safety 150** **Safety 45** **Performance 305**

***… are for performance, not safety***

# *Why the $%#^@*^% do we have to test 500 detonators? …*

- **Different groups are tested to reveal different properties**
- **Building 500 detonators should ensure that the production issues are resolved and the qualification lot has similar characteristics, including variation, to production lots**
- **30 units are required to give good means and standard deviations for the threshold (firing properties) tests**
- **Successfully firing 300 units "demonstrates the EFI has a reliability of at least 0.99 at 95% confidence after being subjected to common environmental stimuli. To establish this reliability a test quantity of 298 EFIs must be fired with no failures in the all-fire performance tests."**

***… is it really necessary to test that many?***

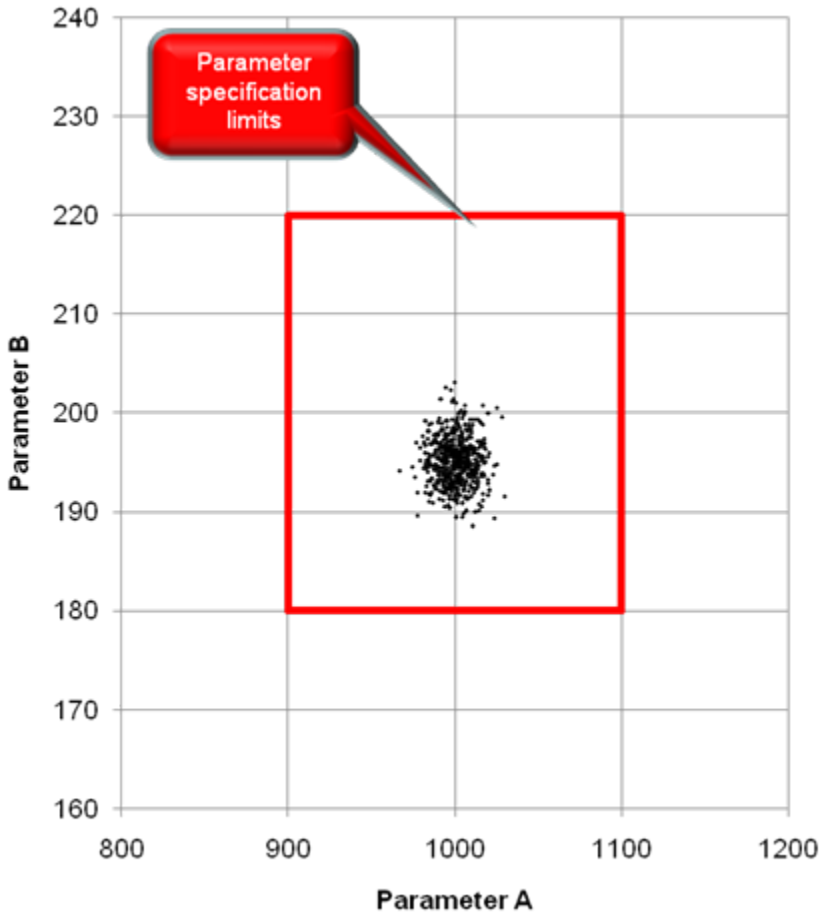
## *Do the 500 qualification detonators have similar …*

- **The Qualification Lot is often the "best" lot**
  - **Each step in the manufacture of the Qualification Lot is typically performed by a single, experienced assembler or technician who has just been trained to the manufacturing instructions and is observed by the development engineer**
  - **Custom piece parts for the Qualification Lot obtained from suppliers are often accepted after a First Article Inspection, and built by a single, experienced assembler or technician of the supplier**
- **The Qualification Lot, in almost all cases, contains a single batch of energetic material**
- **The Qualification Lot for EFI detonators is typically manufactured using chips from only a few wafers**

***… variation as future production lots?***

# *Do the 500 qualification detonators have similar …*

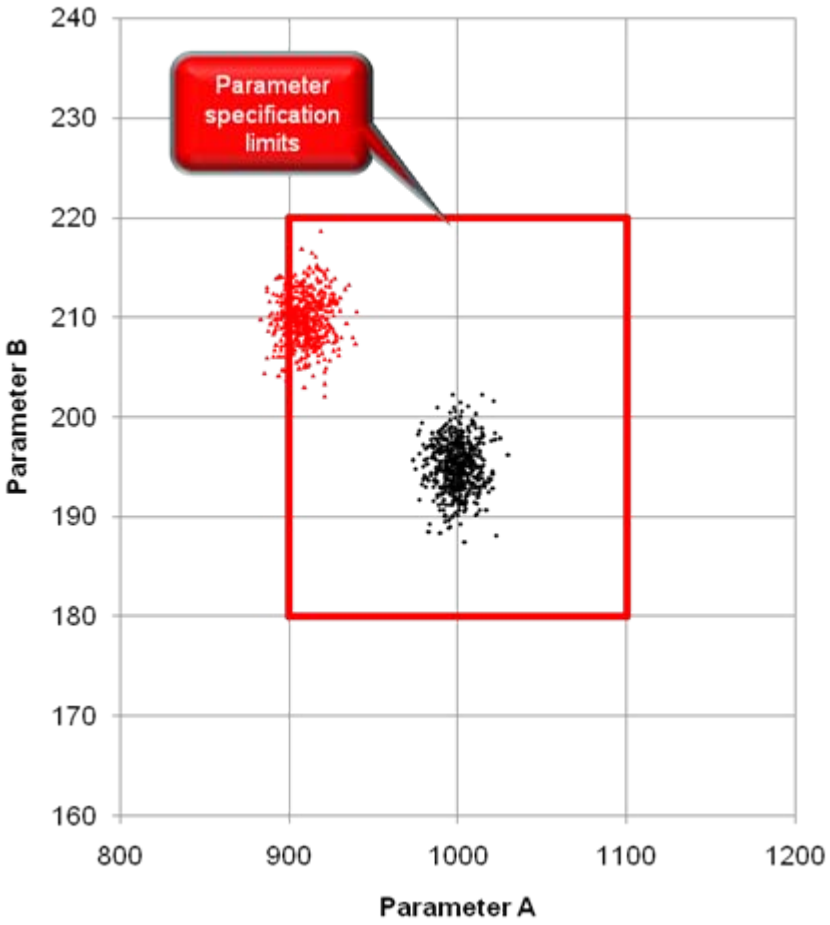
- **Many different parameters control performance of EFI detonators (2 shown to left)**
- **Drawing package specifies range of each parameter**
- **Suppliers often required to submit First Article**
- **Supplier will try to center process**
  - **Often drawings are centered around delivered hardware**




***… variation as future production lots?***

# *Later production detonators often have different …*

- **Many different parameters control performance of EFI detonators (2 shown to left)**
- **Drawing package specifies range of each parameter**
- **Suppliers often required to submit First Article**
- **Supplier will try to center process**
  - **Often drawings are centered around delivered hardware**
- **Some lot later, a supplier's supplier will make a small change, and material will be at drawing limit after screening**

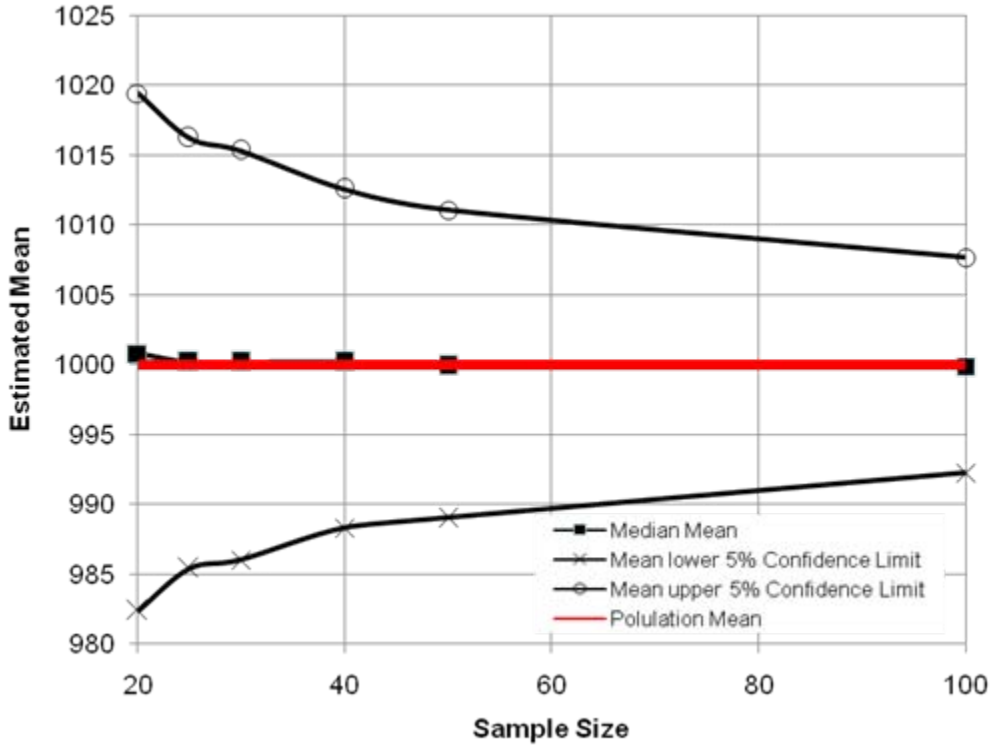



*… variation than qualification lot*

# *Firing Properties (threshold) tests are the only tests …*

- **Firing Properties or Threshold tests determine the mean and standard deviation of the firing energy**
- **Small shifts to device parameters should be observable as shifts in the mean threshold**

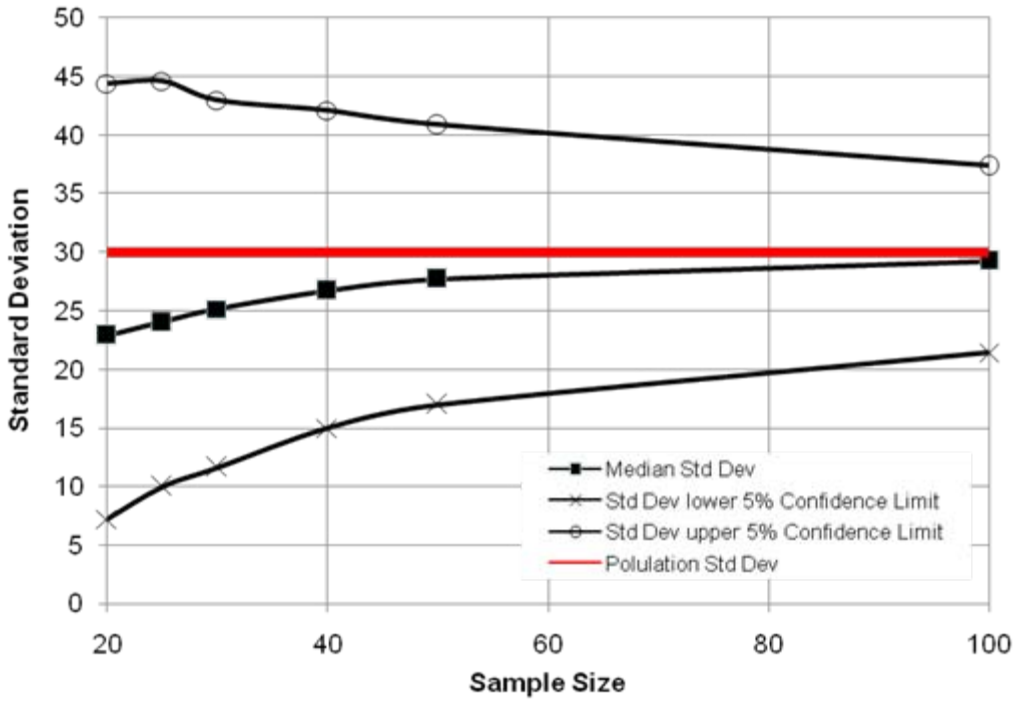
- **Mean is unbiased**
- **For a sample size of 30, mean will be within ½ Std Dev of true value 90% of the time**
- **If the Std Dev is 2% of the mean (good device), you should see threshold shifts greater than 1%**




*… capable of determine device consistency or small process shifts*

# *Firing Properties (threshold) tests are the only tests …*

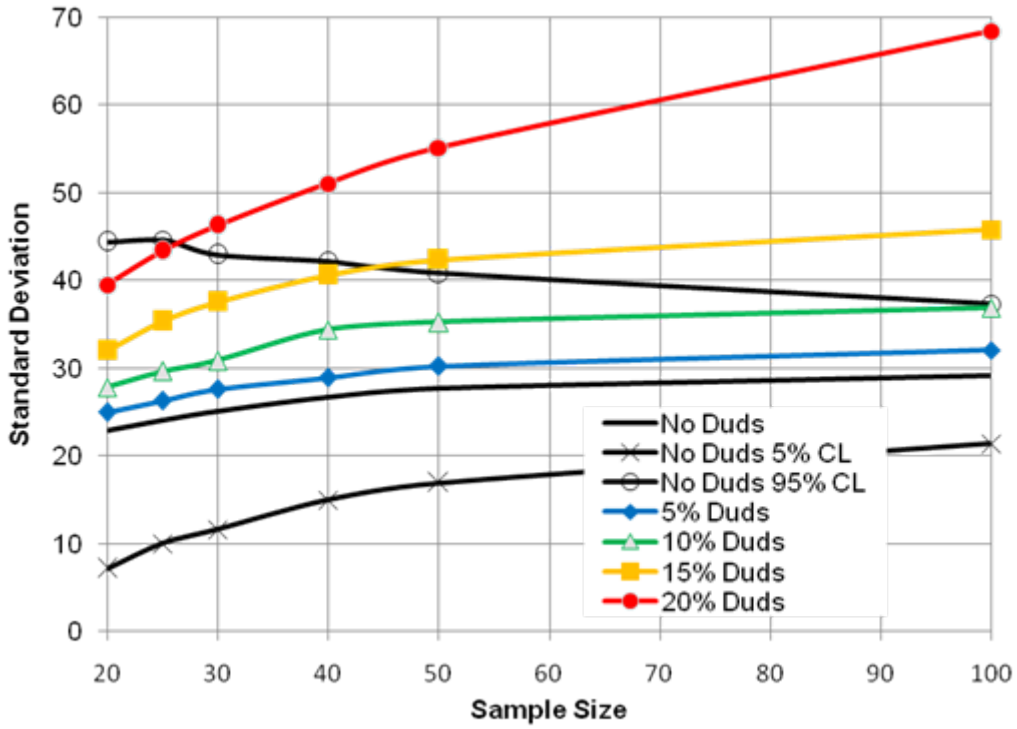
- **Firing Properties or Threshold tests determine the mean and standard deviation of the firing energy**
- **Small shifts to device parameters should be observable as shifts in the mean threshold**
- **<u>Significant</u> shifts in the standard deviation could mean design has insufficient margin**
- **Std Dev is normally biased low**
- **For a sample size of 30, it will be within 40% to 140% of the true value 90% of the time**
- **Can only see large relative changes in Std Dev**




***… capable of determine device consistency or small process shifts***

# *Firing Properties (threshold) tests will not find …*

- **Only approximately 50% of detonators will fire during threshold tests**
- **Increase in Std Dev due to large fraction of defective detonators is small compared with normal variation**
- **Hard to distinguish sub threshold failure from defective detonator**
- **For a sample size of 30, the Std Dev will be lower than the 95% upper confidence limit, even when 15% of the detonators are defective**




*… even large fraction of defective devices*

## *The 300 firings proves 99% reliability @ 95% confidence …*

- **Successfully firing 300 units "demonstrates the EFI has a reliability of at least 0.99 at 95% confidence after being subjected to common environmental stimuli. To establish this reliability a test quantity of 298 EFIs must be fired with no failures in the all-fire performance tests."**
  - **Only 150 units are tested after being subjected to common environmental stimuli, 150 are tested after no environments**
  - **Later lots will be made by different people, and with different materials from the supply chain**
  - **Some changes will be known, but many changes will be unknown**
  - **The 300 units successfully fired do not establish design reliability**
- **Need to perform all-fire tests periodically**

***… but only of the qualification lot, not the design***

# *The majority of units tested in MIL-DTL-23659 …*

PerkinElmer precisely.

| | Requirement | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| - | Quantity | 30 | 30 | 30 | 30 | 5 | 10 | 30 | 30 | 50 | 50 | 50 | 50 | 50 | 50 | 5 | 500 |
| A.4.2 | Visual Inspection | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | 500 |
| A.4.3 | Radiographic Examination | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | 500 |
| A.4.4 | Bridge Circuit Resistance | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | 500 |
| A.4.9 | Leakage | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | 500 |
| A.4.5 | Firing Properties, Ambient | X | | | | | | | | | | | | | | | 30 |
| A.4.5 | Firing Properties, Cold | | X | | | | | | | | | | | | | | 30 |
| A.4.5 | Firing Properties, Hot | | | X | | | | | | | | | | | | | 30 |
| A.4.6 | Max No Damage Current | | | | X | | | | | | | | | | | | 30 |
| A.4.7 | Thermal Cook-Off | | | | | X | | | | | | | | | | | 5 |
| A.4.10 | Electrical Cook-Off | | | | | | X | | | | | | | | | | 10 |
| A.4.11 | Maximum Allowable Electrical Sensitivity | | | | | | | X | | | | | | | | | 30 |
| A.4.12 | 1.5 Meter Drops | | | | | | | | X | X | X | X | | | | | 180 |
| A.4.13 | Electrostatic Discharge | | | | | | | | | | | | X | | | | 50 |
| A.4.8 | Temperature Shock/Humidity | | | | | | | | X | X | X | X | | | | | 180 |
| A.4.14 | Vibration | | | | | | | | X | X | X | X | | | | | 180 |
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| A.4.9 | Leakage | | | | | | | | X | X | X | X | | | | | 180 |
| A.4.16 | All Fire Performance, Ambient | | | | | | | | | X | | | X | | | | 100 |
| A.4.16 | All Fire Performance, Cold | | | | | | | | | | X | | | X | | | 100 |
| A.4.16 | All Fire Performance, Hot | | | | | | | | | | | X | | | X | | 100 |
| A.4.5 | Firing Properties, Ambient | | | | | | | | X | | | | | | | | 30 |
| A.4.17 | High Firing Voltage | | | | | | | | | | | | | | | X | 5 |

**Consistency / Safety 150** **Safety 45** **Performance 305** **All-Fire after Environments 150**

***… are for performance, not safety***

## *Electrical Cook-Off tests are pure safety tests …*

- **A.4.10: The Electrical Cook-Off tests determine "The reaction of the bare EFI to exposure to common AC and DC voltage sources up to 500 volts shall be determined."**
- **A.6.7.1: "The input to the EFI shall be energized from a 60 hertz AC source at 440 VAC; the power source must be capable of sustaining a minimum short circuit current of 20 amperes."**
- **A.6.7.2: "The input to the EFI shall be energized from a DC source at 28 volts; the power source must be capable of sustaining a minimum short circuit current of 10 amperes."**

- **Almost any EFI will function when fired from a suitable capacitor charged to 500 volts.**
- **Many out-of-line safe arm and fire systems would fail this same electrical cook-off requirement.**

***… but it is not clear how the test methods meet the requirements***

# *Leak Tests for detonators have limited accuracy …*

- **Both through and bombardment leak measurements are highly dependent on test technique and measurement parameters**
  - **Measurement indicated on helium leak detector is indirectly related to actual leak rate**
  - **Leak rate measured by Bombardment leak equipment, *I*, is complex function of the real leak rate, L, and test parameters**

$$l = L\left(1 - e^{-LT/V}\right)e^{-Lt/V}P / P_{atm}$$

  - **Through leak tests usually underestimate actual leak rate**
  - **The typical "hermetically" sealed detonator with a leak rate of $10^{-6}$ cc/s will readily admit water and undergo a complete air exchange in a few hours.**
    - **To achieve a 10 year life, need to specify a leak rate of $10^{-10}$ cc/s, well beyond the ability of many leak detection systems.**

***… and are not typically able to show suitability during expected lifetime***

## *MIL-DTL-23659 contains many valuable tests …*

- **Firing Property Tests are an important tool to characterize shifts in production**
  - **They can help to establish design margins**
  - **They can not prove device reliability**
  - **They can not detect even significant fraction of defective devices**

- **All Fire Tests conducted during device qualification do not prove design reliability.**
  - **It is important to conduct periodic all-fire tests during production**

***… but it is important to understand their limitations***