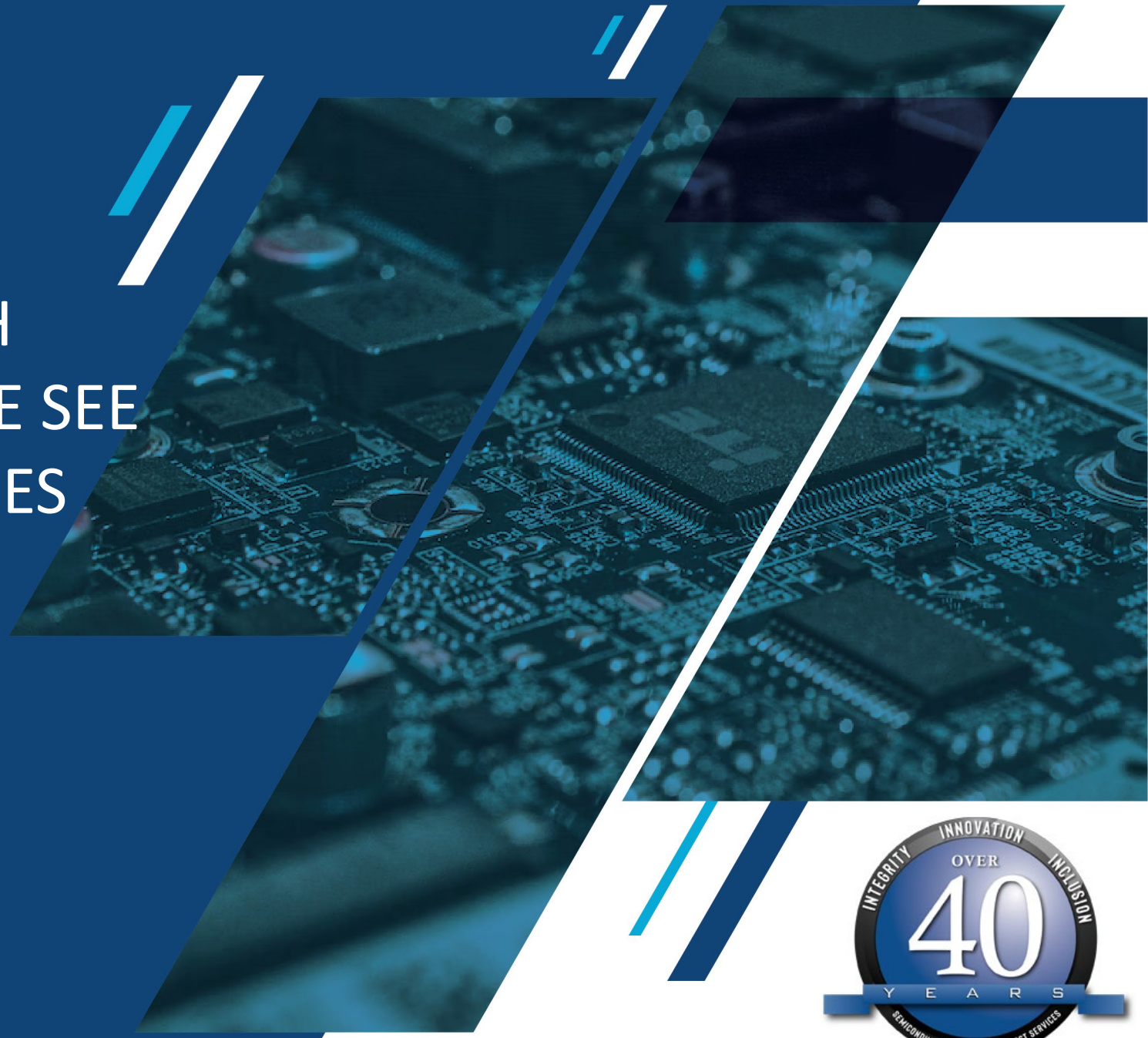
INTEGRA TECHNOLOGIES
An Employee Owned Company

STANDARDS, ISSUES WITH PEMs QUAL AND DATA WE SEE AT INTEGRA TECHNOLOGIES

ESSCON 2023
MARCH 8, 2023

SULTAN LILANI



INTEGRITY INNOVATION INCLUSION
OVER 40 YEARS
SEMICONDUCTOR ASSEMBLY AND TEST SERVICES

QUICK FACTS

INTEGRA TECHNOLOGIES
An Employee Owned Company

40-YEAR HISTORY

EMPLOYEE-OWNED COMPANY (ESOP)

U.S.-BASED MANUFACTURING

DIE PREP, ASSEMBLY, TEST & QUAL SERVICES

500+ ACTIVE CUSTOMERS FROM AVIONIC, MILITARY, AEROSPACE, MEDICAL, AUTOMOTIVE, COMMERCIAL AND INDUSTRIAL SECTORS IN 25+ COUNTRIES

~500 EMPLOYEES

TWO FACILITIES & LARGE CLEAN ROOMS

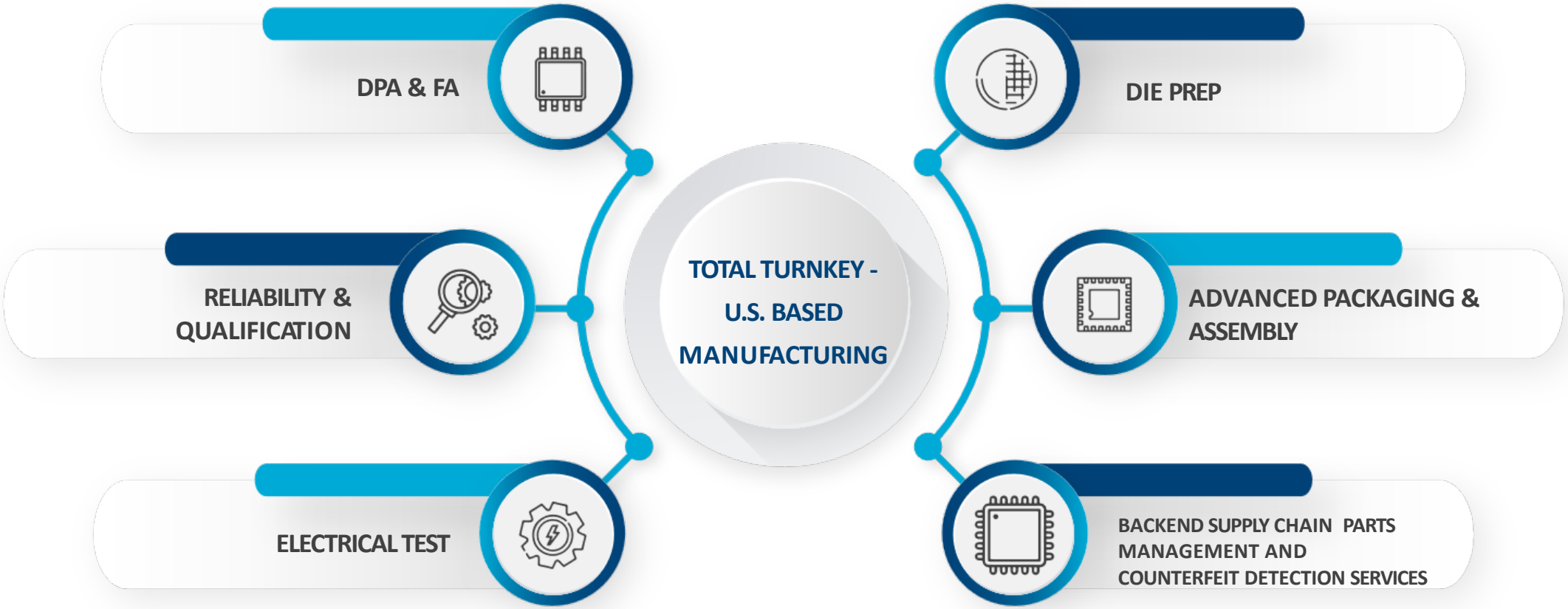
CORPORATE HEADQUARTERS – WICHITA, KS

INTEGRA - MILPITAS, CA

CREDENTIALS

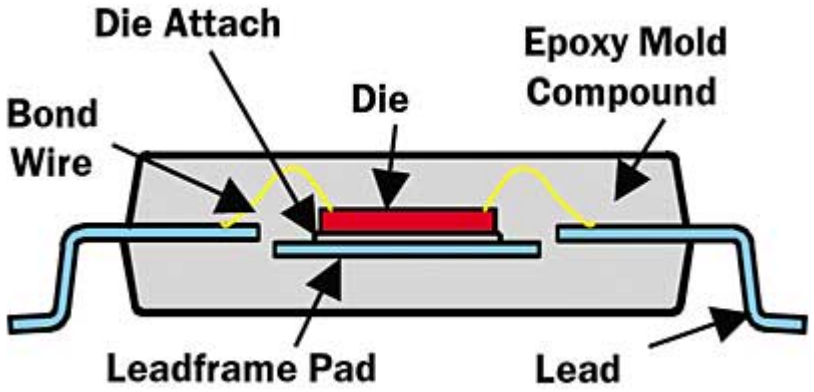
- AS9100 Rev D, ISO 9001:2015 Certified
- ISO 13485:2003 Certified
- MIL-PRF-38535 & MIL-STD-883 (DLA Certified for Q & V Assembly Services)
- ITAR Registered & Compliant
- DMEA Category 1A “Trusted”
- DLA Lab Suitability
- MIL-STD-883
- MIL-STD-750
- MIL-PRF-19500P
- ANSI/ESD S20.20-2014
- Class 1 Product Handling
- AS6171/17025

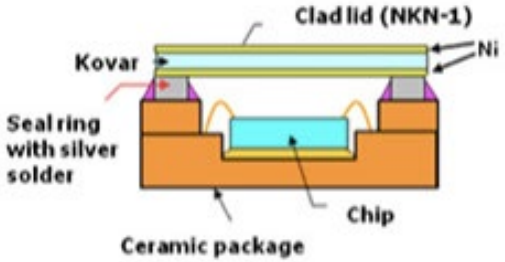
TURNKEY SOLUTIONS PROVIDER



PICTORIAL VIEW OF TYPICAL PEMs

- A PEM device typically uses organic packaging material, either injection or transfer molded or coated for environmental protection.
  - Plastic encapsulated IC's or Microcircuits are commonly referred to as, PEMs.
  - Plastic encapsulated Transistors and Diodes are typically referenced as PETs and PEDs, respectively.





POTENTIAL CONVERNS WITH PEMs

- PEMs have predominately been designed for commercial and industrial applications – not Aerospace and Defense (A&D).
- Higher military temperature ranges are not generally available (except EP)
- Typical PEMs are COTs and screening by OCM are not always as stringent as A&D end applications require.
- Qualifications are typically at the inception of product release and is not lot-by-lot.
- Qualifications are typically not sequential as used by A&D.
- Reliability of plastic packages could vary dramatically from supplier to supplier.
- Copper bond wire PEMS are known to have Reliability concerns if not properly manufacturers

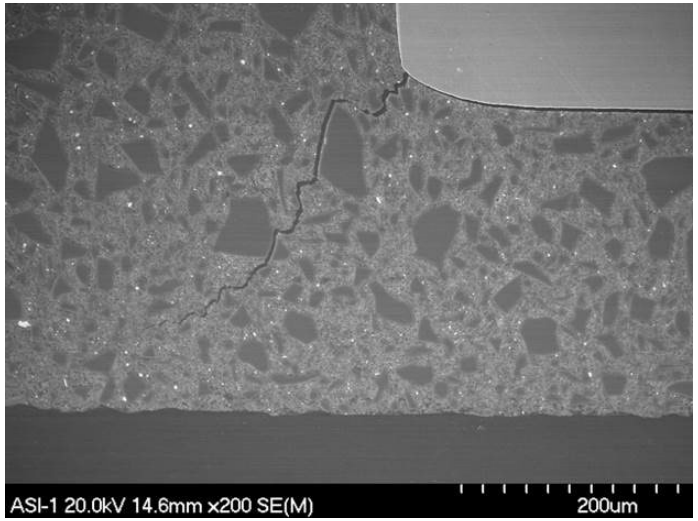
TYPICAL PEM QUAL FAILURE MODES

1. Pop Corning of Plastic Package
2. Delamination
3. Die Attach Voids
4. CTE Mis-match Between Molding Compound and Base Material
   - Cracked Package
   - Wire breaks
   - Cracked Die
5. Corrosion
6. Wire Lift
7. Contamination
8. Moisture Ingression / Current Leakage
9. Cracked Passivation

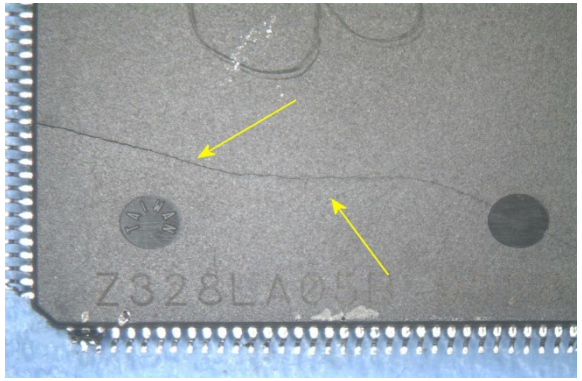
ADDITIONAL CONCERNS WITH COPPER BOND WIRE PEM

- Easily oxides in air – typically requires N2 or special flow of forming gas during mfg.
- Cu is harder – bonding process difficult - Requires optimal bonding process otherwise impacts yield and reliability
- Typically, Halogen free special molding compound required for Cu wire products
  - Biased humidity failures - corrosion
  - Green mold compound with a preferably low Cl content and high pH
  - Lower pH (more acidic) and the higher Cl content are, the poorer the reliability.
- Quality / Reliability concerns:
  - Bond pad aluminum deformation (splash)
  - Cratering / Cracks under the bond
  - Cu ball bond interface corrosion
  - IMC (intermetallic dielectric) cracking
  - Peeling of the bond pad interface – bond lifting is a major reliability concern

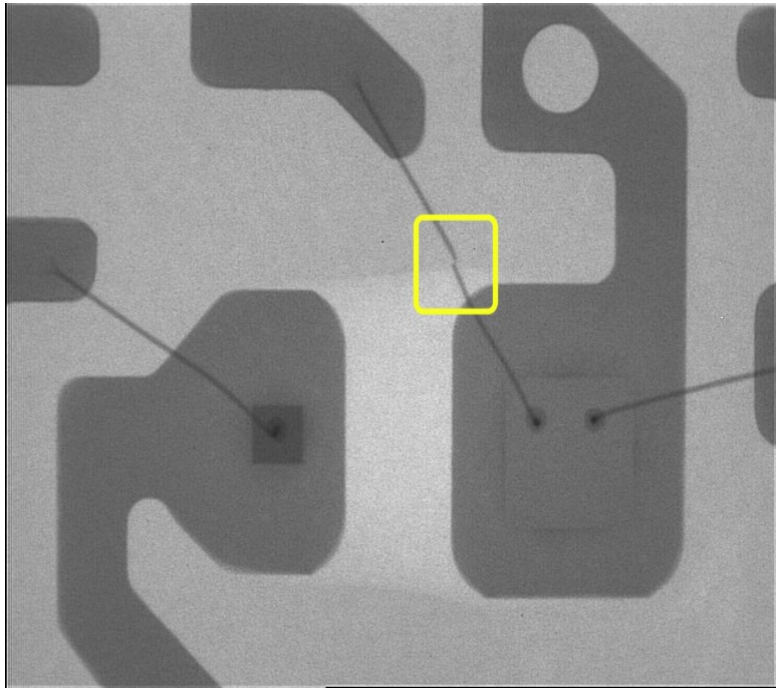
IMAGES OF TYPICAL PEM QUAL FAILURES



Pop-corning

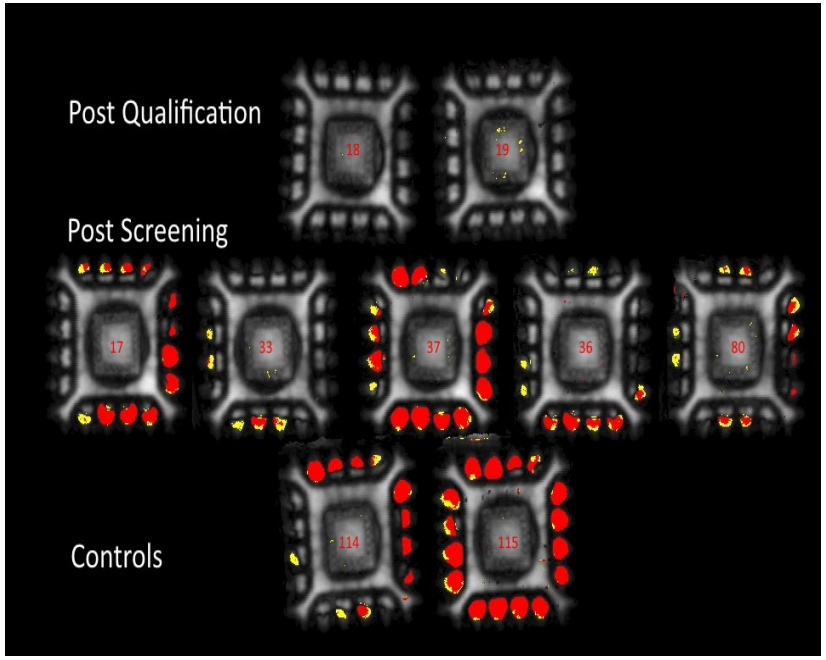


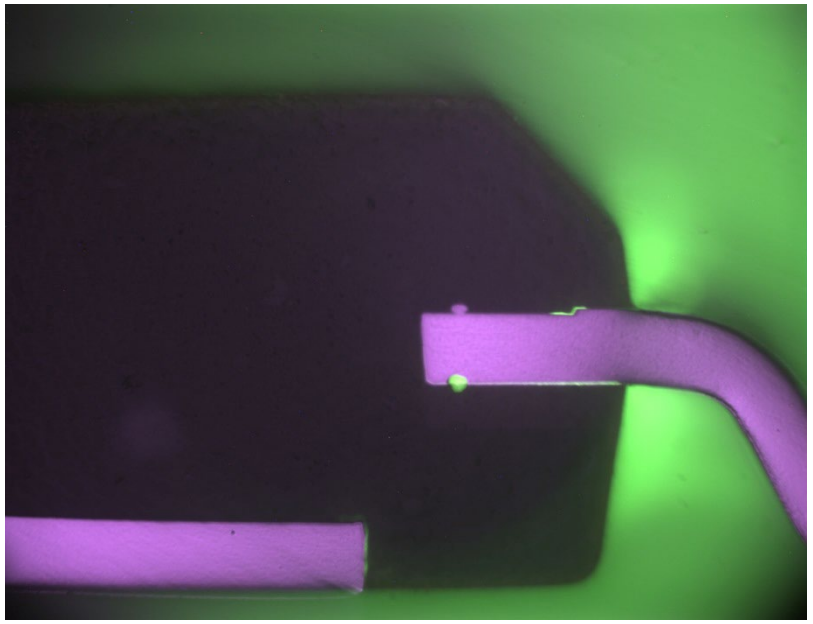
Package Cracks



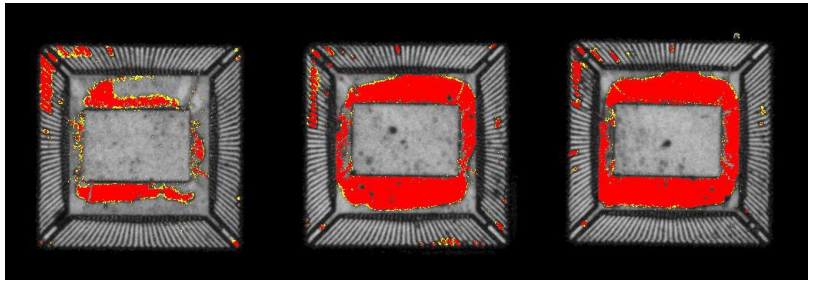
- Broken wire bond due to CTE mismatch
- Mismatch between molding compound and optical coupling material created shear forces resulting in a broken bond wire

IMAGES OF TYPICAL PEM QUAL FAILURES



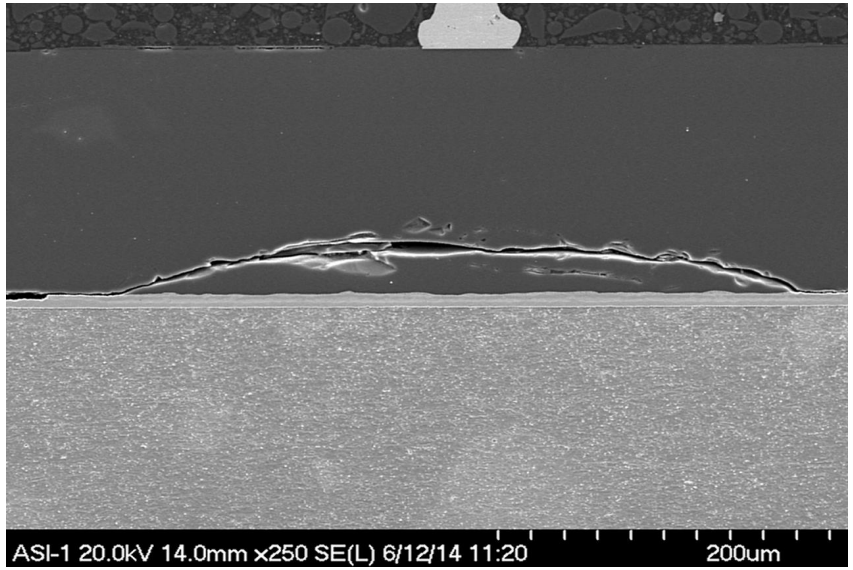


Delamination (Dye Penetrant Test)

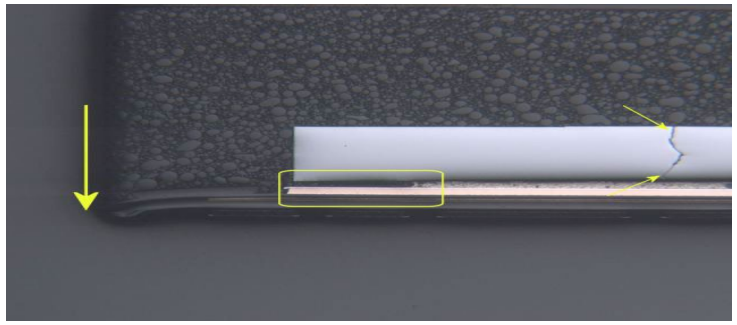


Delamination (SAM Images)

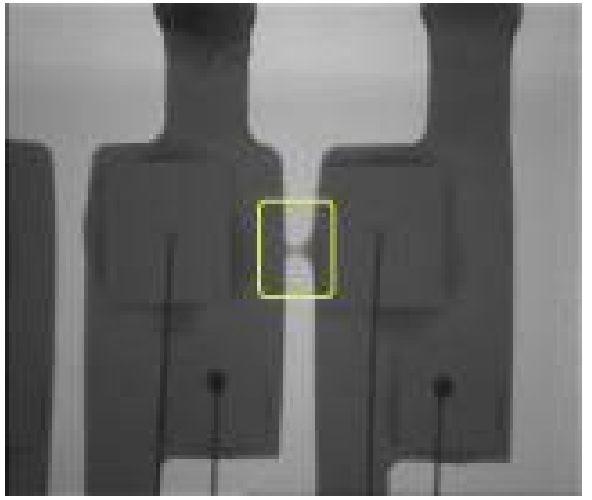
IMAGES OF TYPICAL PEM QUAL FAILURES



Broken die due to CTE mismatch
AuSi Eutectic die attach used in a plastic encapsulated microcircuit. CTE mismatch between the molding compound and die attach resulted in die cracking and open backside contact.

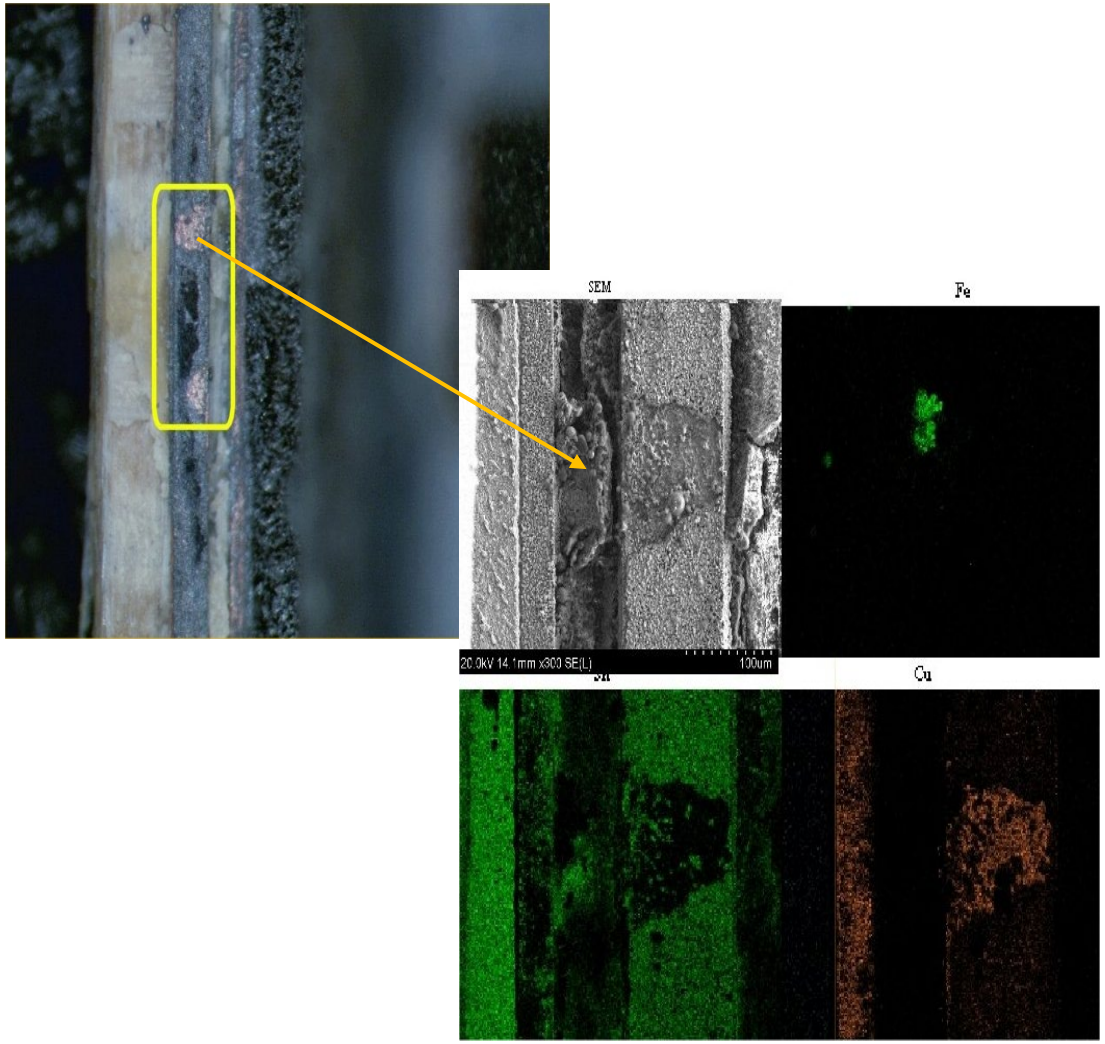


Cross section – PWB damage; void underneath the die and die cracking



X-Ray – Shorts

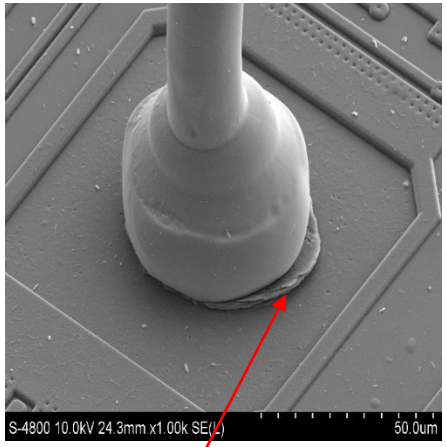
IMAGES OF TYPICAL PEM QUAL FAILURES

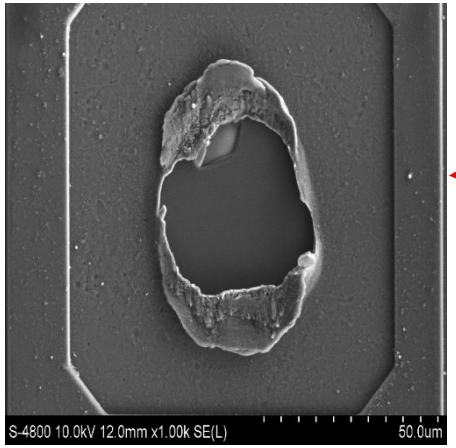


Leakage Failures

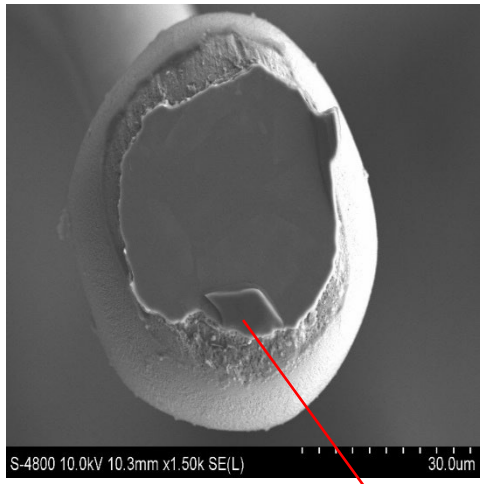
- Moisture Ingress with current leakages within hybrid device.
- SEM and elemental dot mapping indicates copper:iron:tin dendritic growth.

CU WIRE-ALUMINIUM SPLASH/CRATERING/RESIDUAL SILICON



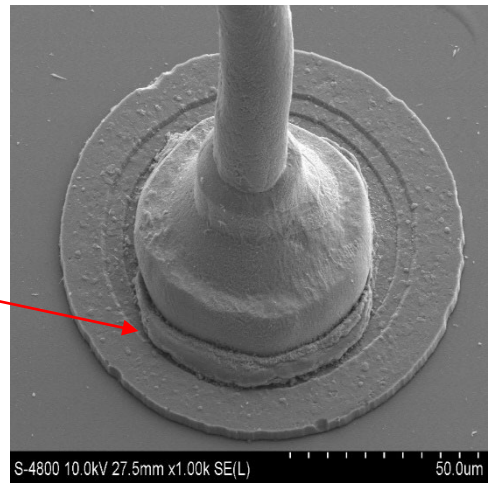


Cratering



Residual Silicon

Aluminum Splash



PEM QUAL CONDISERDATIONS

KNOW YOUR PEM QUAL STANDARDS

- SAE Standards
  - AS6294/1 for Space PEMs and AS9294/2 for Military PEMs
  - AS6294/3 for Space PEDs and AS6294/4 for Military PEDs
- NASA Standards
  - PEM-INST-001 (Goddard)
  - MSFC-STD-3012 (Marshal Space Flight Center)
- Mil Std
  - MIL-PRF-38535: General Specification for Integrated Circuits (Microcircuits)
    - Class N and Class P
    - Class Y (Flip Chip)
- AEC (Automotive)
  - AEC- Q100 – Microcircuits Quals
  - AEC - Q101: Discrete Semiconductor Quals
  - AEC-Q006: Copper Bond Wire Quals

TYPICAL PEM QUAL PLAN

- External Visual and Serialization: Qty=32
- Baseline SAM: Qty: 32
- Pre-Conditioning: Qty=32
  - Moisture Soak per appropriate MSL Level
  - Reflow at 235°C
- Electrical Testing at 25°C, min and max operating temp; Qty=32
- Sub-Group 1 Qual: Qty=22
  - 125°C Life Test for 1000 or 1500 hours
  - Electrical Testing at 25°C, min and max operating temp
  - Temp Cycle; 200 or 500 cycles
  - Electrical Testing at 25°C, min and max operating temp
  - SAM; 22 units
  - DPA : 5 units
- Subgroup 2 Qual: Qty=10
  - Biased or Unbiased HAST; 96 hours at 130°C/85%RH
  - Electrical Testing at 25°C, min and max operating temp

KEY CONSIDERTAIONS OF PEM QUAL PLAN

- Perform a detailed construction analysis or DPA on package before the qual. You will learn a lot of package weakness data before star of qual.
- Understand available OCM data – Does the product already show delamination even before the qual has started? Available Qual data from OCM? Comprehensiveness of OCM electrical testing?
- Canned qual plans are a good start but prepare a device specific qual plan based on:
  - Application
  - Package used
  - Available data from OCM
  - Upscreening as part of qual plan
  - Types of tests to be included in the qual plan and why
  - Pass / fail criteria for individual tests
  - Pass / fail criteria for the qual

KEY CONSIDERTAIONS OF PEM QUAL PLAN

- Over qualifying adds substantial cost while eliminating devices that might otherwise be reliable enough and lower priced.
- Even worse, under qualifying may lead to inadequate device reliability and system field failures.
- Electrical Testing Consideration
  - Understand how comprehensive electrical test coverage is your test supplier
  - Insufficient electrical test coverage will allow failing devices to be counted as passing and could lead to poor system and field reliability.
  - If package qualification, DC, some key AC (one or two) and functional test should be enough – select parameters that are sensitive to package related issues.
- Three temperature testing is recommended
- Screening before qual should take care of infant mortality failures

KEY CONSIDERTAIONS OF PEM QUAL PLAN

- Certain packages have inherent weakness to moisture ingression
  - Very thin packages
  - Small outline devices
  - Packages with back-side paddles
  - Flip chip packages with vents
- What is die to lead frame paddle or substrate ratio? Impacts SAM images
- What is the thermal characteristic of the device (high power device)?
- Does the product use copper bond wires?

KEY CONSIDERTAIONS OF PEM QUAL PLAN

- Dynamic life test is recommended. Typically, PEMs are not subjected to burn-in at OCMs for commercial or industrial grade product. Life Test is typically considered a die level test. However; some package anomalies can be found with life test. Check OCM's data on the plastic package being subjected to PEM qual.
- Pre-conditioning is simulation for real life storage and board assembly conditions.
- Pre-conditioning typically impacts humidity tests much more than life test. Many customers forego pre-conditioning for life test due to extremely low failure rate.

PEM QUAL: OPTIMAL HUMIDITY TESTING?

- Always do pre-conditioning before any of the humidity testing.
- Recommend to do SAM pre and post preconditioning to see effect of stress due to pre-conditioning
- Customize pre-conditioning to the appropriate MSL level of the package
- Typical humidity tests post pre-conditioning:
  - Unbiased HAST - 96 hours, +130 °C, 85% RH
  - Biased HAST - 96 hours, +130 °C, 85% RH- Preferred – Promotes galvanic reaction
  - TH – unbiased - 1000 hours – 85C, 85% RH
- For biased testing; calculate power dissipation. If more than 200mW; need to use on/off power cycle to avoid drying of die surface per JEDEC standard for biased HAST / THB

PEM QUAL: HOW WE HANDLE DELAMINATION

- Most common interfaces looked at during SAM:
  - Die surface, die attach, die paddle, and leads / lead frame
- Delamination occurs due to:
  - Stress-induced passivation damage over the die surface
  - Wire-bond degradation due to shear displacement
  - Accelerated metal corrosion
  - Die-attach adhesion
  - Intermittent electricals at high temperature
  - Popcorn cracking
  - Die cracking
  - Device latch-up
- Typical SAM steps
  - Before screening
  - After screening (same as pre-qual or before pre-conditioning)
  - Post pre-conditioning
  - Post stress (life test or temperature cycle or humidity test)

PEM QUAL: IS DELAMINATION REJECTABLE?

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NOT ALWAYS!

- 6.2 Delamination is not necessarily a cause for rejection. To evaluate the impact of delamination on device reliability, the semiconductor device supplier may either meet the delamination requirements shown in 9.2.1 or perform reliability assessment using JESD22-A113 and JESD47 or the semiconductor device supplier's in-house procedures. The reliability assessment may consist of stress testing, historical generic data analysis, etc. Annex A shows the logic flow diagram for the implementation of these criteria.

- If the SMDs pass electrical tests and there is delamination on the back side of the die paddle, heat spreader, or die back side (lead on chip only), but there is no evidence of cracking per 9.1 or other delamination and they still meet specified dimensional criteria, the SMDs are considered to pass that MSL.

From JEDEC-J-STD-020F

PEM QUAL: WHAT TO DO IF THERE ARE FAILURES?

- Understand the failure mode
- Not all failures are related to PEM qual
  - Ex: A single bit failure is most likely die related; not due to PEM
- Even delamination is not necessarily a failure if the Reliability tests passed
- Trust electrical test post reliability test results
- Do additional testing to validate suspected failure mode

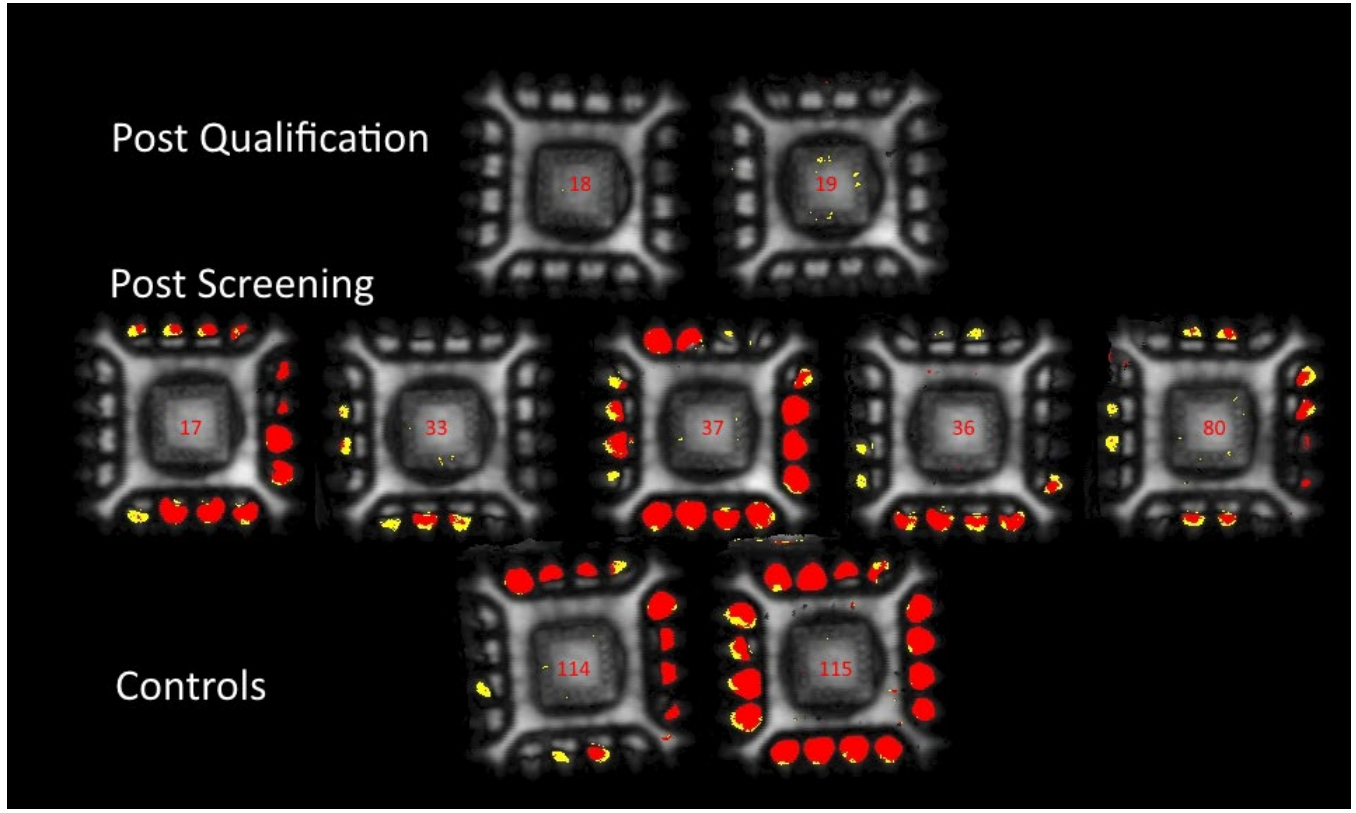
A CASE OF FALSE POSITIVE SAM

BACKGROUND

- Device:NB6N14SMNG
- Package: 16 QFN
- Problem
  - Post Screening samples subjected to Qualification per NASA PEM-INST-001
  - Pre-Qualification SAM revealed delamination on 33/36 devices in the area of wire bonds.
  - Post- Qualification SAM on 22 parts had no delamination or electrical test failures.
  - 2 Control samples did not change from pre-qualification to post-qualification indicating that the SAM setup was unchanged.
- Qualification Tests:
  - Pre- Conditioning - JESD22 Method A113 68 hours, +85 °C, 60% RH).
  - 1000 hours Life Test at 105C
  - -55 to 125°C Temp Cycle – 200 Cycles
- SAM Images: Taken per PEM-INST-001; section 5.3.3

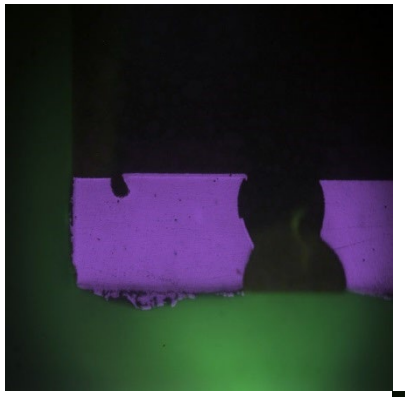
C SAM COMPARISION

- Pre-Qual / Post- Screening Images: Delamination indications on the leads
- Post Qual Images: No signs of delamination
- Control units Images: Delamination

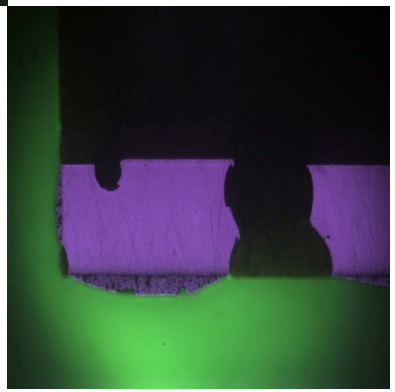


DYE PENETRANT TEST

- No Dye penetrated to the internal package interfaces on either the post screening or post qualification samples.
- No path for moisture ingress was observed in post screening or post qualification samples.



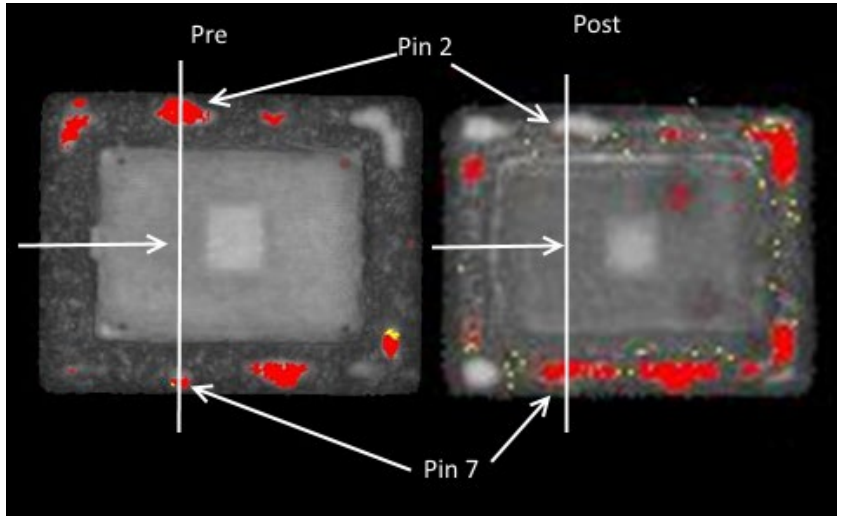
Dye Penetrant Post Qualification



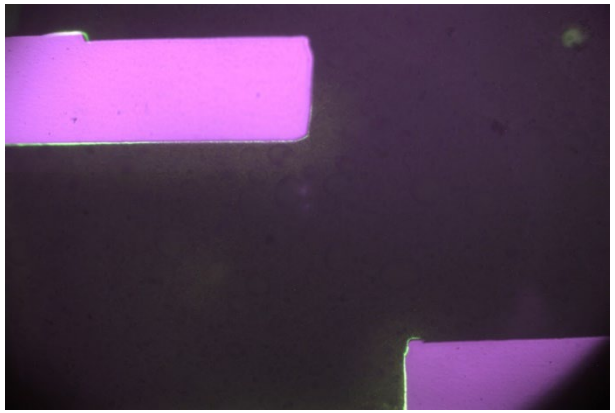
Dye Penetrant Pre Qualification

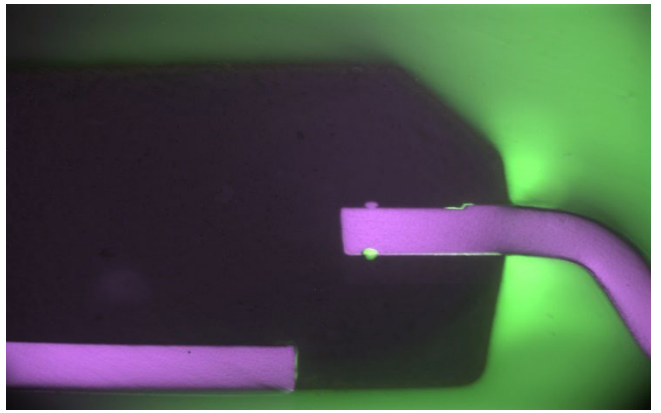
EXAMPLE OF WATER INGRESS MASKING DELAMINATIN IN C SAM

Pin 7 (Die Penetrant shows delamination)



Pin 2 (Die Penetrant shows delamination)



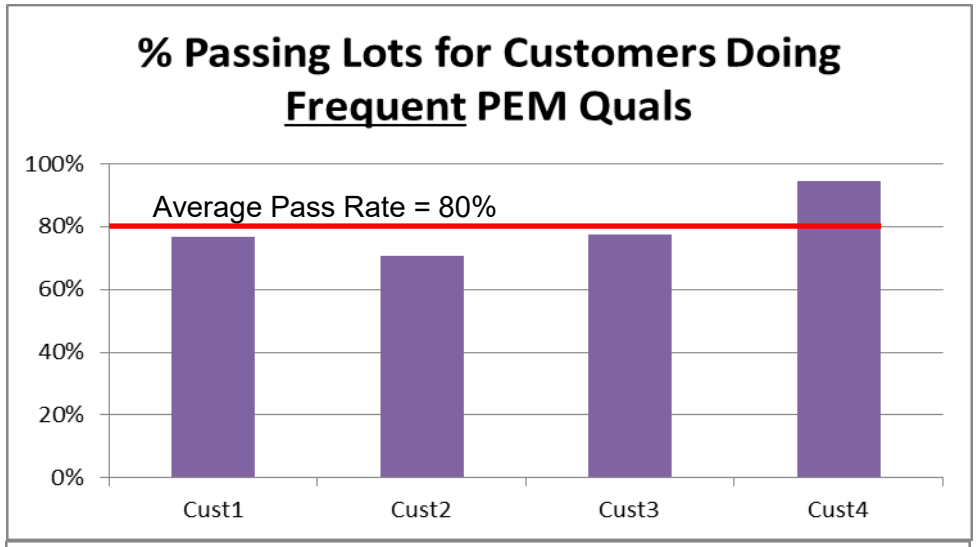


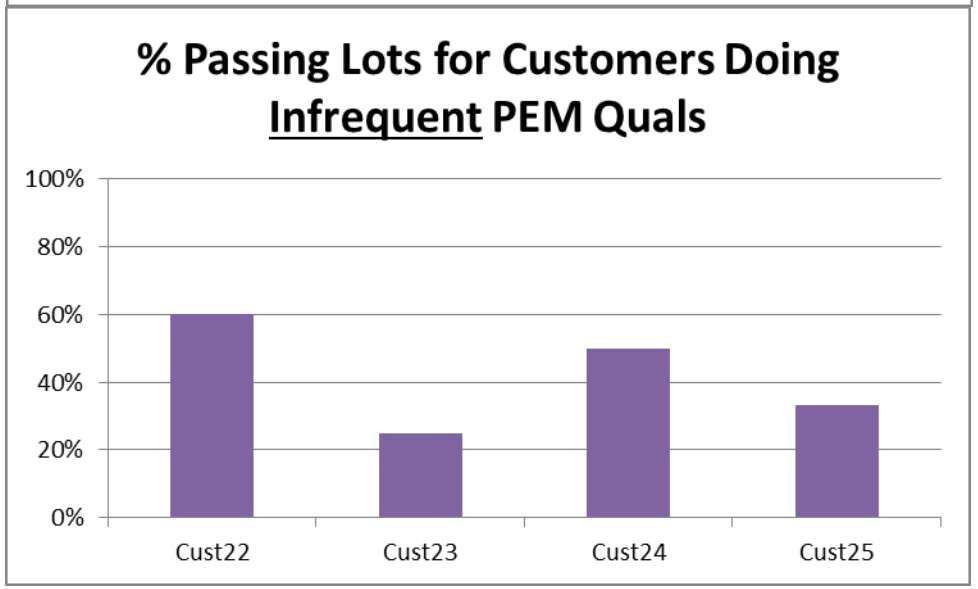
INTEGRA PEM QUAL DATA OVERVIEW

Total Number of Parts Processed:	**111,183**
Total Number of Lots:	**791**
Total Number of Passing Lots:	**496**
Passing Lot Percentage:	**63%**
Total Number of Failing Lots:	**295**
Failing Lot Percentage:	**37%**
Total Customer Part Numbers:	**455**
Total Manufacturer Part Numbers:	**410**
Total Number of Manufacturers:	**73**
Total Number of Customers:	**42**
Unique Pin/Package Combinations:	**165**

- Notes:
- No qualifications conducted by semiconductor manufacturers are included.
- Plastic packaged semiconductor devices only - no passives.
- Predominant test temperatures are -40, 25 85 and -55, 25 125.
- Testing temperature order is usually room, cold, hot.
- Once a qual fails it is usually stopped.
- Failures are for electric test only (no mechanical failures).
- Vast majority of testing performed to manufacturers datasheet limits.
- Virtually all electrical test programs written by Integra Technologies.

OVERALL CUSTOMER PEM QUAL SUCCESS RATE



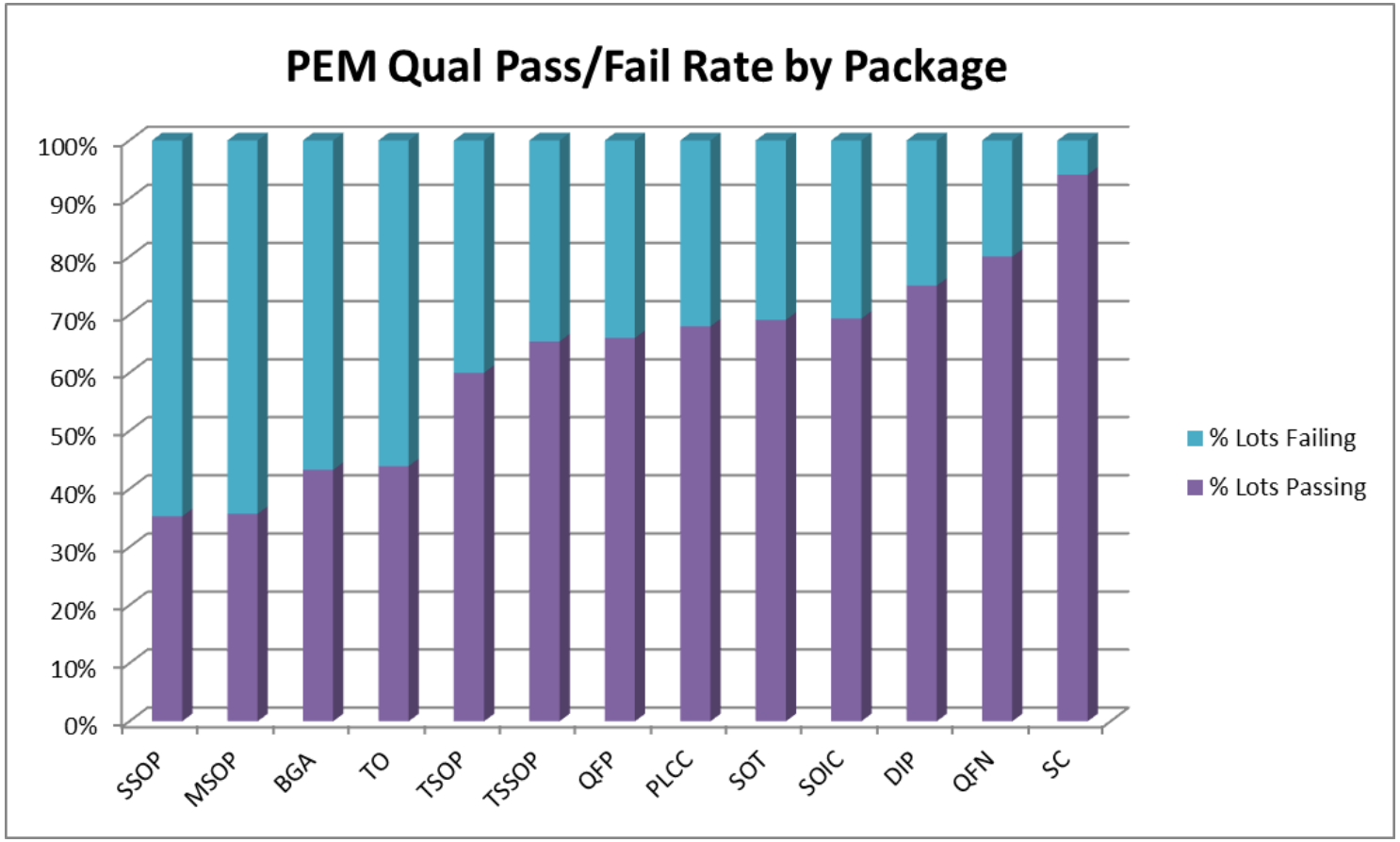


Customers who are more experienced with PEM Quals tend to have better success. These 4 customers averaged over 100 PEM Qual lots each over the 15-year analysis period.

The average pass rate over the entire population is 63%.

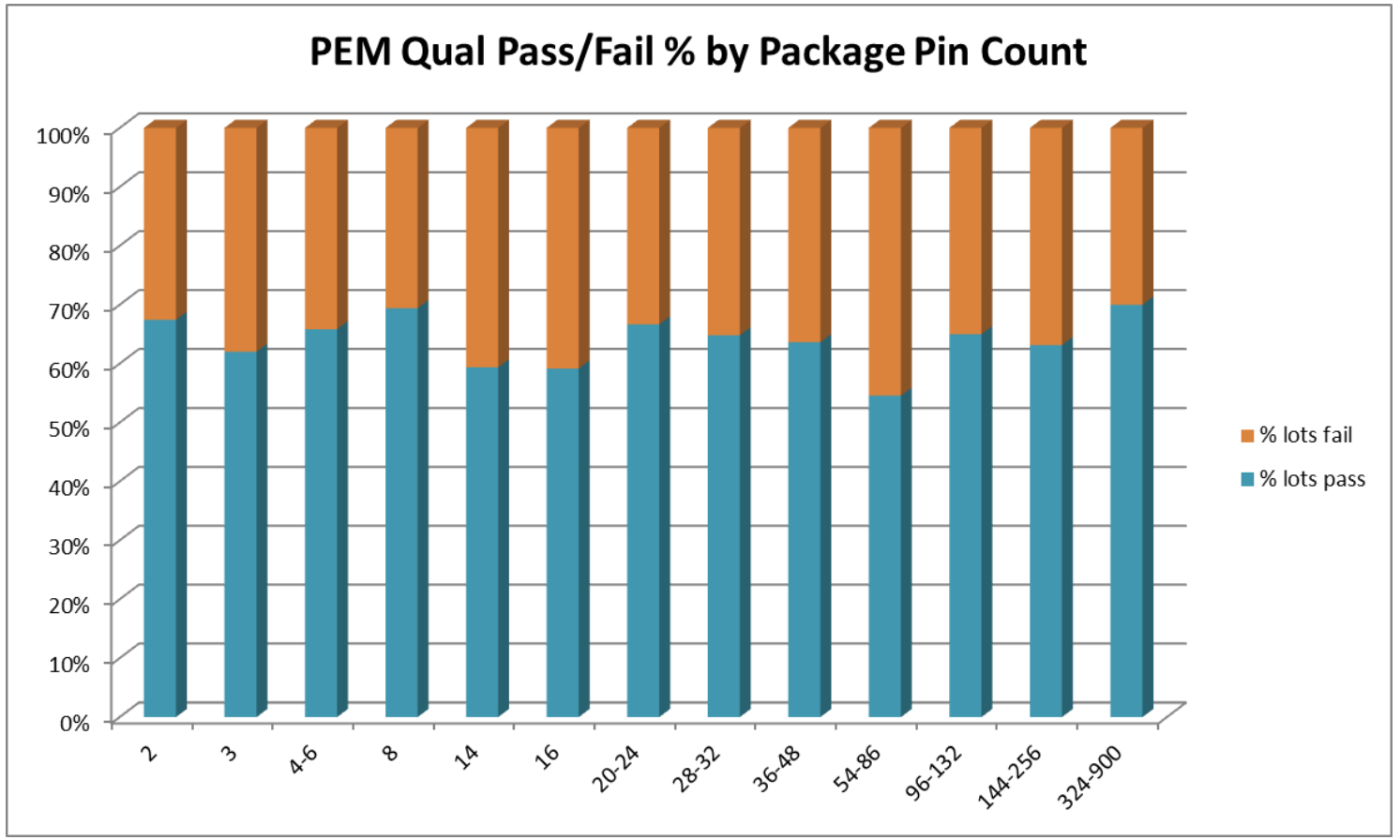
Customers who are less experienced with PEM Quals tend to have less success. These 4 customers averaged ~4 PEM Qual lots each over the 15-year analysis period.

OVERALL PEM QUAL SUCCESS RATE BY PACKAGE



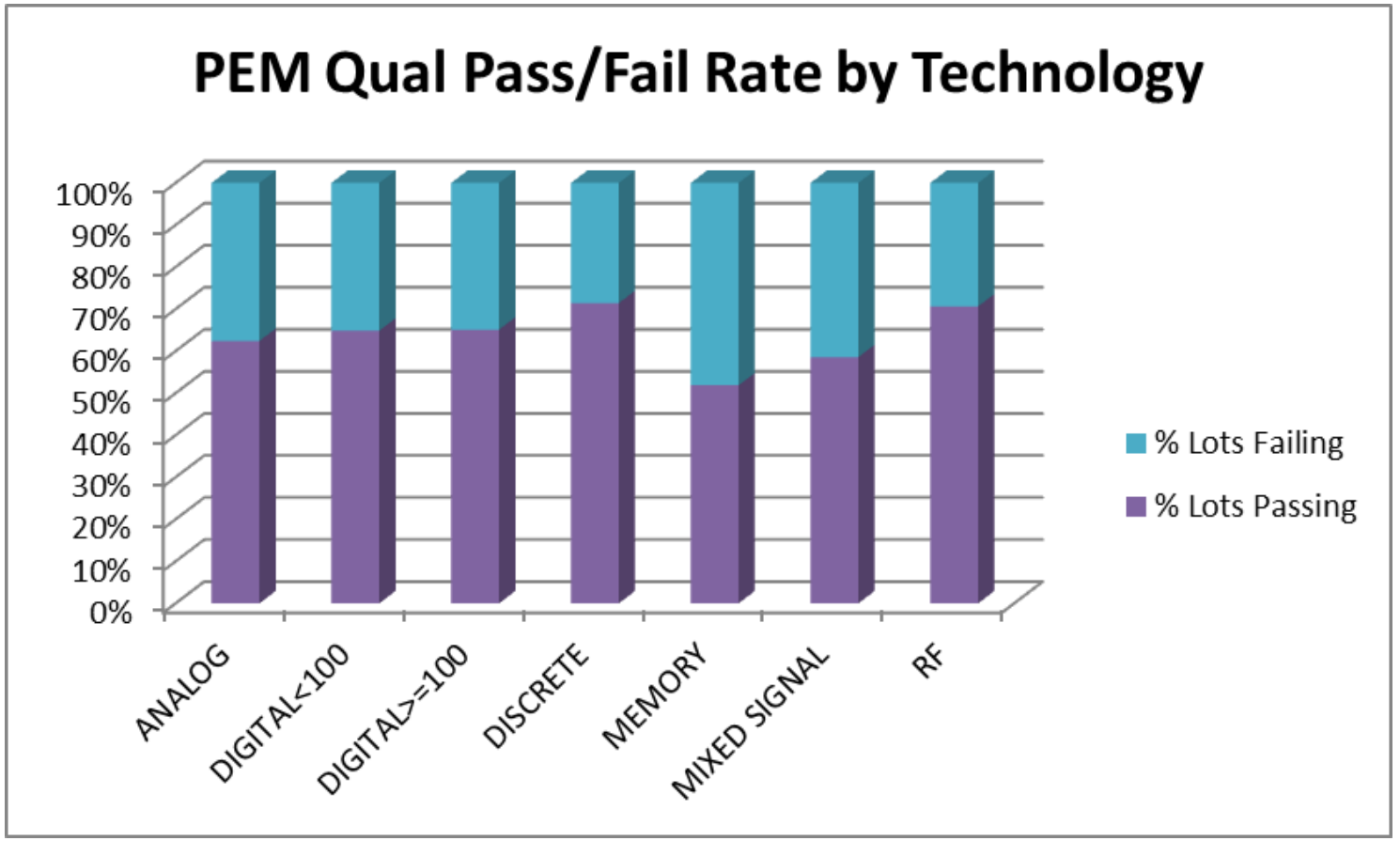
There are meaningful differences between package types in their ability to pass a PEM Qual.

OVERALL PEM QUAL SUCCESS RATE BY PACKAGE PIN COUNT



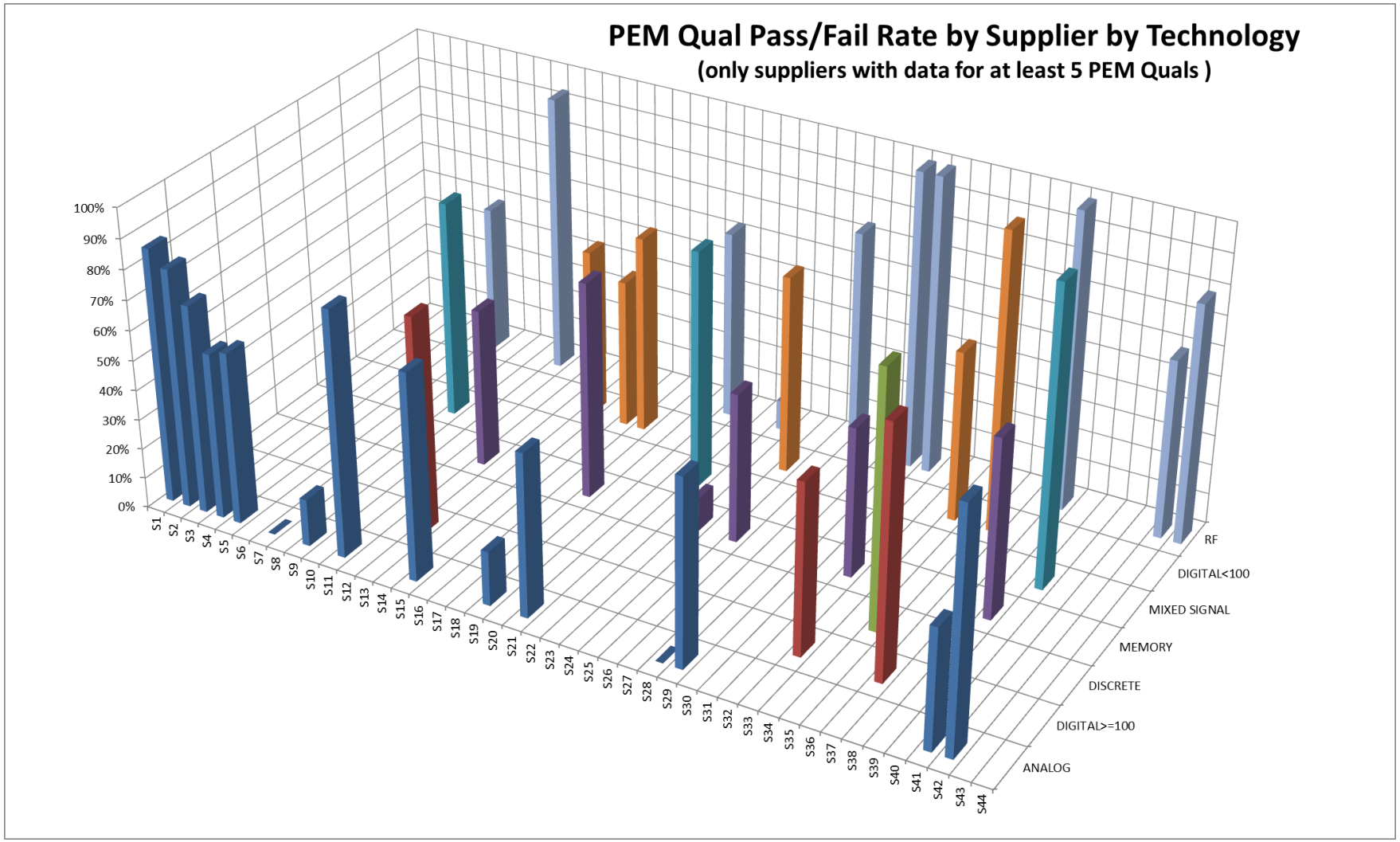
Despite the sensitivity to package type shown on the previous page, there does not appear to be a meaningful sensitivity to package pin count.

OVERALL PEM QUAL SUCCESS RATE BY DEVICE TECHNOLOGY



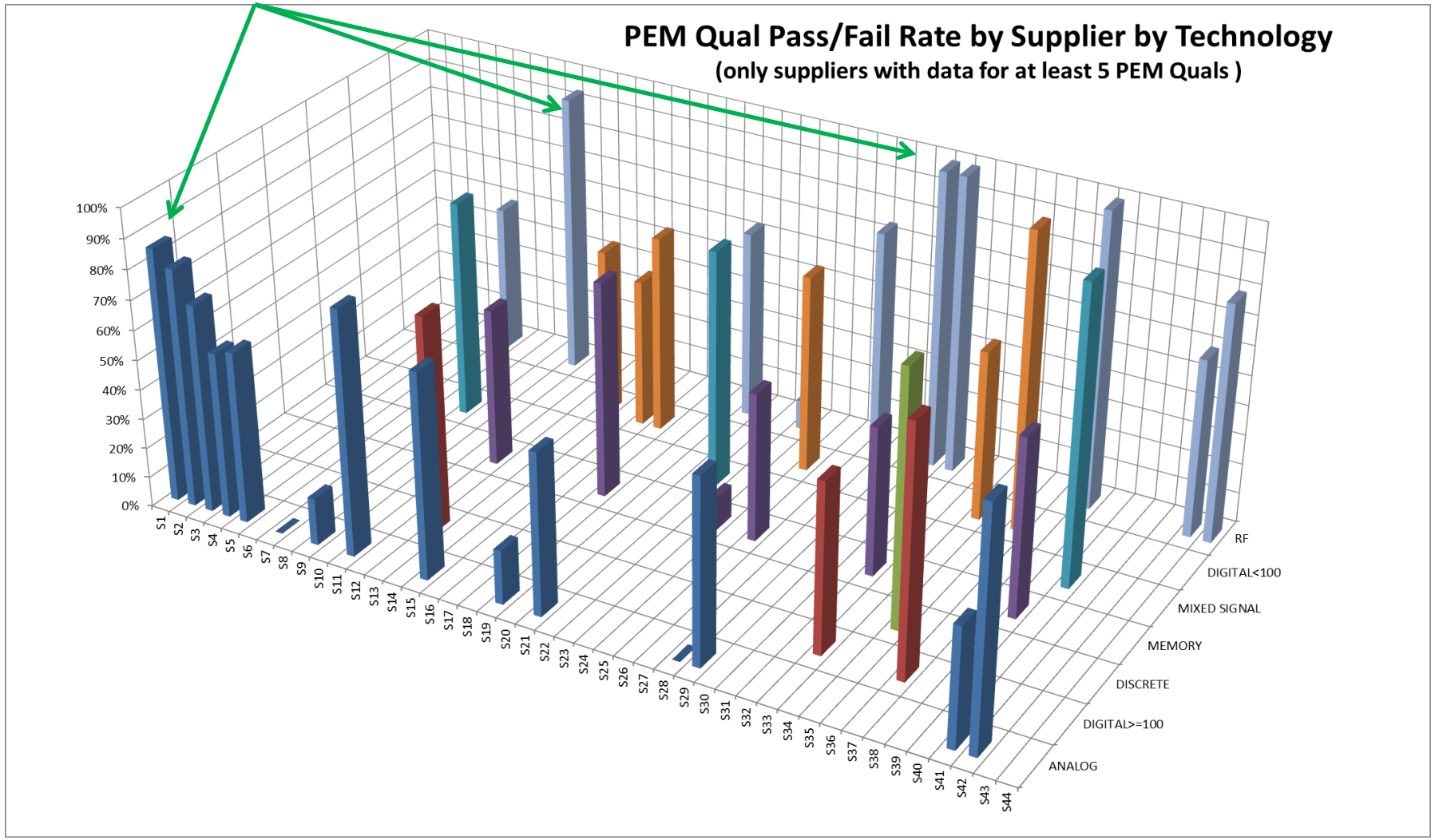
There is not a great deal of sensitivity to technology, with the exception of memory. It should be noted that the memory devices we evaluated tended to more often come in packages that were previously shown to be less reliable.

OVERALL PEM QUAL SUCCESS RATE BY DEVICE TECHNOLOGY BY SUPPLIER



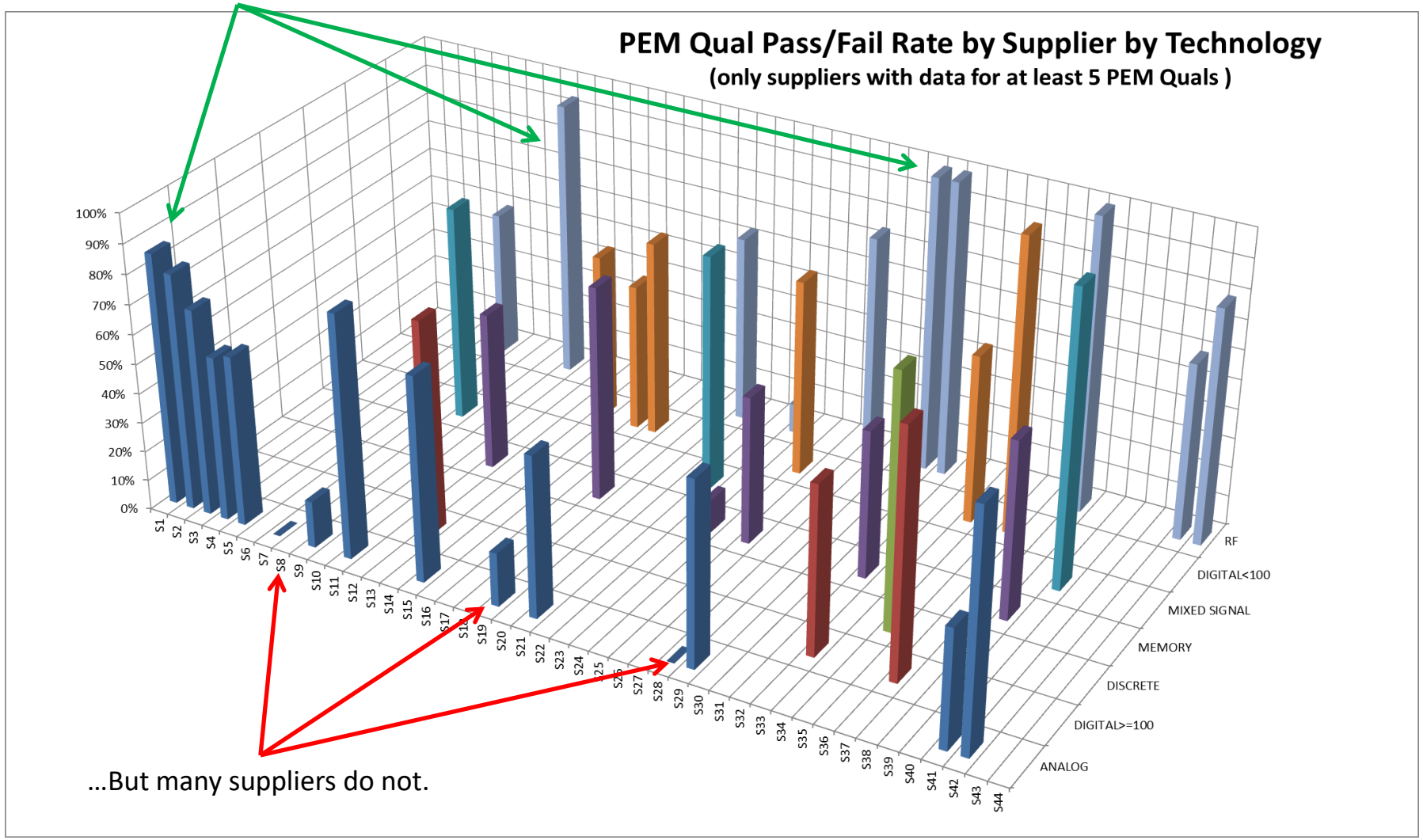
OVERALL PEM QUAL SUCCESS RATE BY DEVICE TECHNOLOGY BY SUPPLIER

Many suppliers have good PEM Qual results….



OVERALL PEM QUAL SUCCESS RATE BY DEVICE TECHNOLOGY BY SUPPLIER

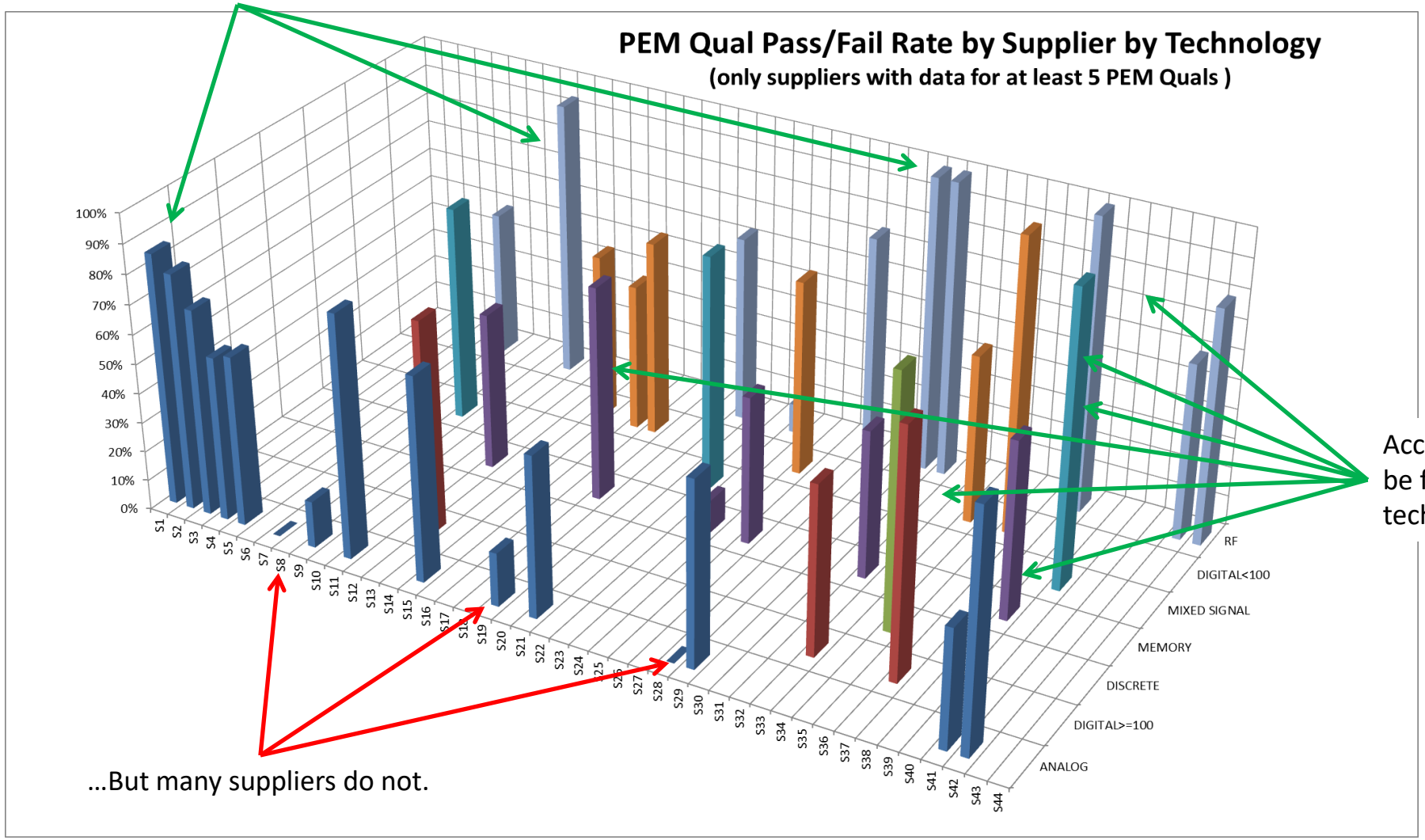
Many suppliers have good PEM Qual results….



…But many suppliers do not.

OVERALL PEM QUAL SUCCESS RATE BY DEVICE TECHNOLOGY BY SUPPLIER

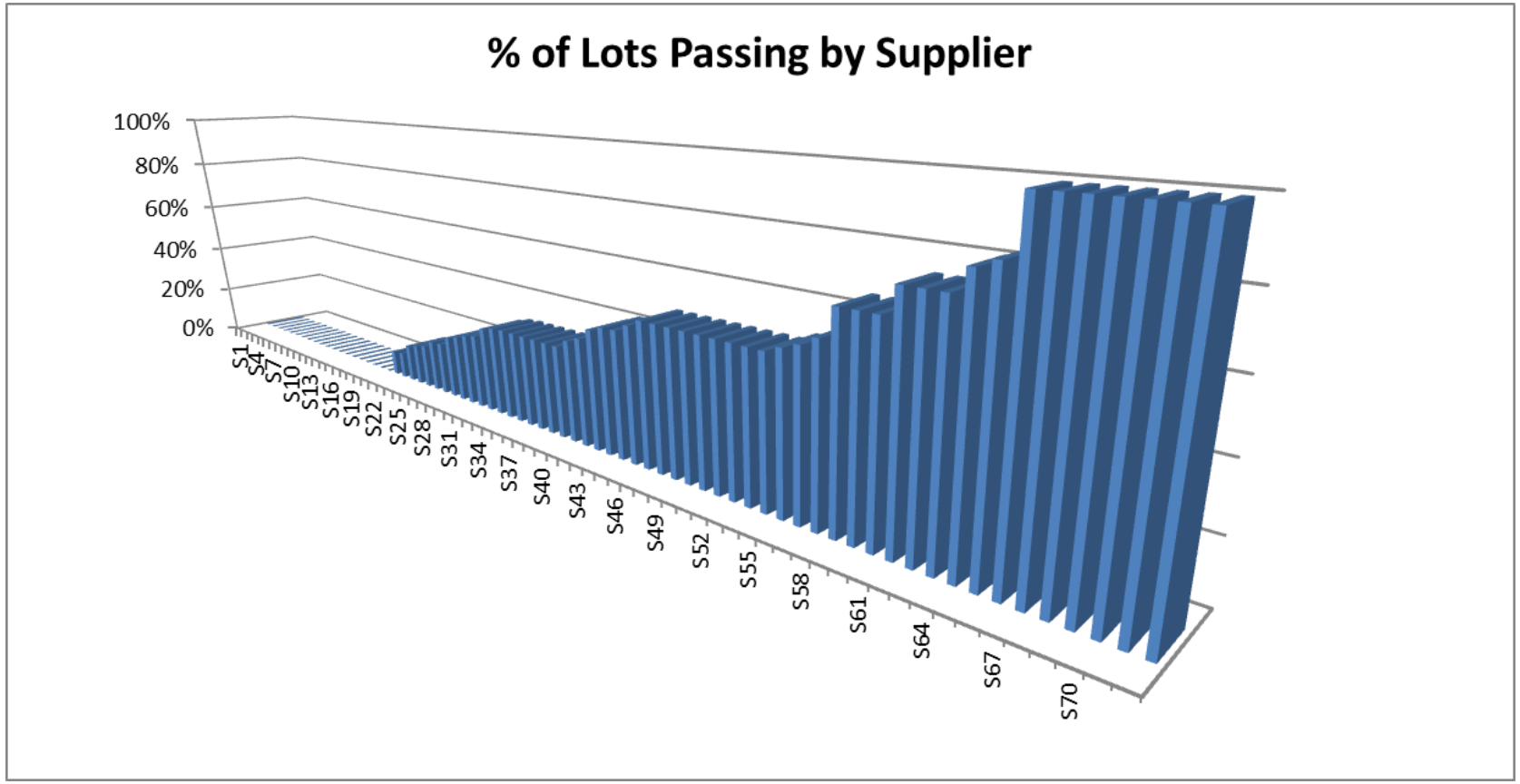
Many suppliers have good PEM Qual results….



Acceptable suppliers can be found for most technologies.

…But many suppliers do not.

OVERALL PEM QUAL SUCCESS RATE BY SUPPLIER



This is arguably the most important point of this data analysis – that PEM Qual success rates vary dramatically from supplier to supplier.

OVERALL PEM QUAL CONCLUSIONS

- There is a great variation in the success rate depending upon the supplier that is being evaluated, so it is prudent to evaluate multiple suppliers.
- Success rate is also influenced by the package being evaluated, although not to as great an extent as by the supplier.
- Acceptable PEM Qual success rates can be obtained with most technologies and pin counts.
- Understanding your application needs is essential for selecting the best PEM Qual flow. By matching the PEM Qual flow to the application needs, an accurate assessment can be made at the lowest evaluation cost.

OVERALL PEM QUAL CONCLUSIONS (CONTINUED)

- Clearly understand how comprehensive the electrical test coverage is that your test supplier is providing. Insufficient electrical test coverage will allow failing devices to be counted as passing and could lead to poor system and field reliability.
- PEM Quals are very complex flows with hundreds of processing steps and thousands of data points. Assure that trained project management staff is present at your test supplier to manage the flow execution and assure data integrity.
- Overall, PEM Quals can be used to effectively select devices for use in non-commercial environments. In this study, approximately two-thirds of industry devices will pass PEM Qualification.
- These conclusions are consistent with the conclusions when we last analyzed our database, although our data indicates that PEM Qual success rates are improving.

THANK YOU

QUESTIONS:

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