2019 NASA NEPP Electronics Technology Working Group Meeting
June 17th, 2019
NASA Goddard

AS6294/1 and AS6294/3 – PEMs and PEDs for Space

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INTEGRA
TECHNOLOGIES

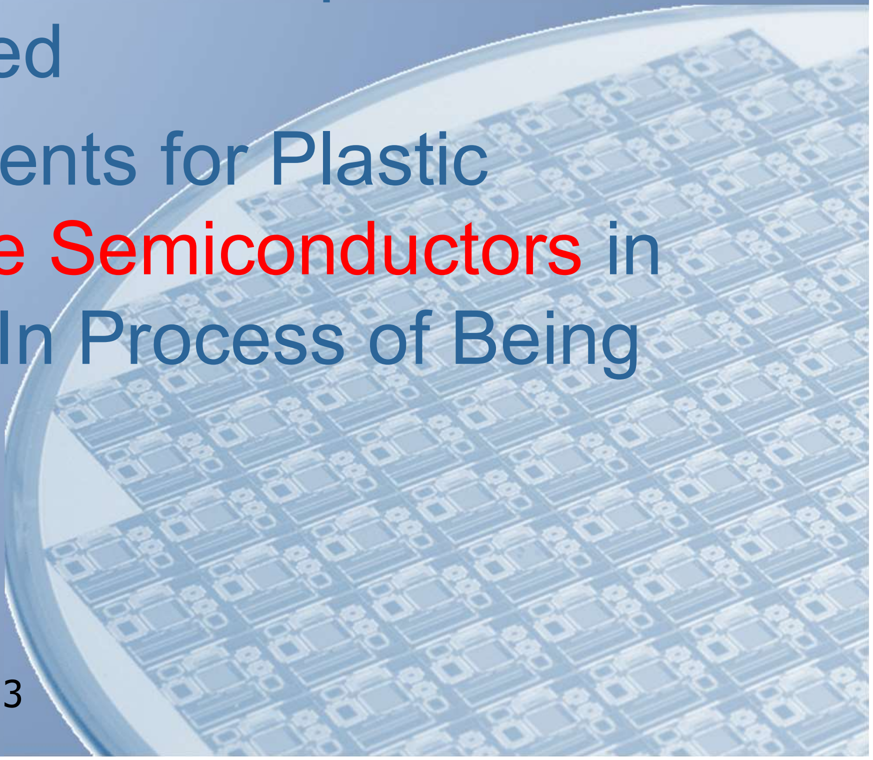
TECHNOLOGY QUALITY
OVER
35
YEARS
ON-TIME DELIVERY

AS6294 PEM Task Team

Celebrating over 30 years of providing high quality semiconductor development and test services.

2 Balloted Documents - AS6294/1 & /3

- Joint CE-12 / JC-14.3 PED / PEM Flows
  - AS6294/1 - Requirements for Plastic Encapsulated Microcircuits in Space Applications - Released
  - AS6294/3 - Requirements for Plastic Encapsulated Discrete Semiconductors in Space Applications – In Process of Being Released



SAE CE-12 PEM Task Team

- Leadership
  - Anduin Tow – CE12 Chair
  - Sultan Ali Lilani - Integra Technologies (PEM Task Team Chair)
  - David Locker – US Army (Team Lead – Avionics / Terrestrial PEMs)
  - Rod de Leon – Boeing Satellite (Team Lead – Space PEMs)

- Meetings: Weekly (started 2/25/2014)
  - Alternate weekly meetings between Space and Avionics / Terrestrial

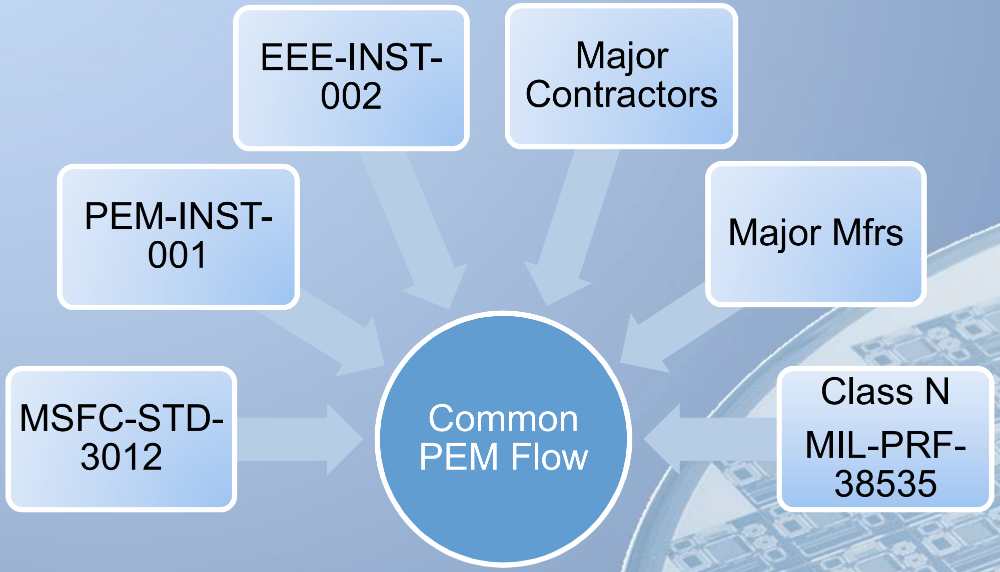
- Members
  - On average, 15 members attend weekly meetings (65+ members in distribution list)
  - Representatives from Boeing, Lockheed, NG, L-3, Aerospace, NASA, Xilinx, ON, TI, ADI, Intel, Army, Air Force, Honeywell, IRF, Rockwell Collins , DLA, BAE, Integra Technologies, Hi-Rel Lab. DPACI etc.

- What Motivated Us to Start the Task Team
  - PEMs being used for Avionics / Terrestrial and in some Space applications
    - Automotive grade parts are getting wider acceptance
    - Commercial parts are being used after screening and qualification
    - In some cases; Industrial grade parts are being used with no screening and qualification
  - Very little usage of Class N devices for Space application
  - Some usage of EP (Enhanced Plastic) devices
  - No one comprehensive flow existed that OEMs can use either for A/T or Space application. PEM-INST-001 or Marshall MSFC-STD-3012 s extensively used by many OEMs but frequently modified by OEMs for their application
  - There are many other flows that various OEMs use and significantly differ from PEM-INST-001
  - PEM-INST-001 and other flows are written around Microcircuits
    - However; we see Discrete devices also for used in plastic packages

Task team focus

Objective is to come up with a Standardized PEMs Flow for the Industry

Comparison of known Industry PEMs flow and Major Subcontractors, OEM, OCM practices



EEE-INST-002

Major Contractors

PEM-INST-001

Major Mfrs

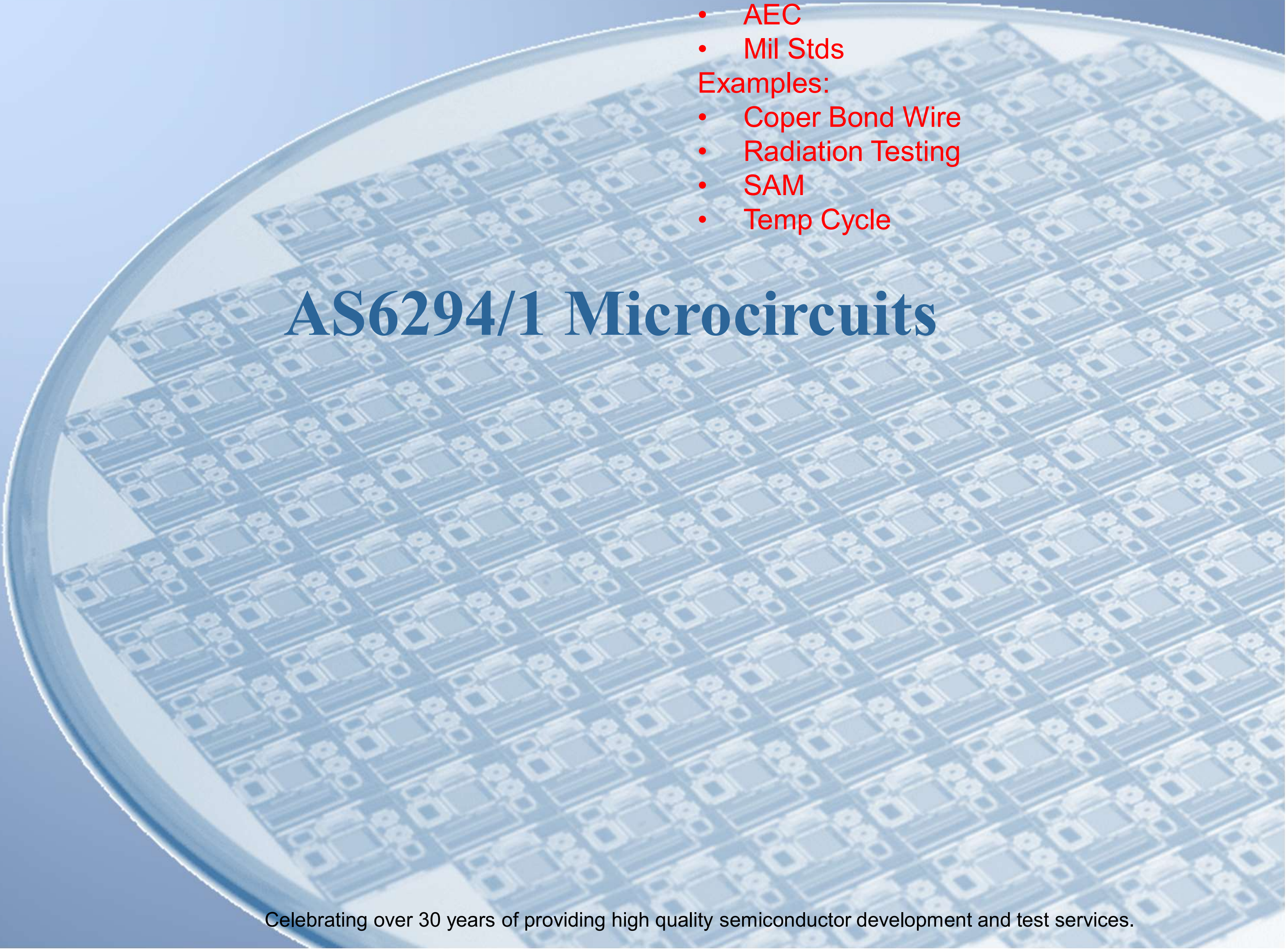
MSFC-STD-3012

Common PEM Flow

Class N

MIL-PRF-38535

Consensus was to use Marshall MSFC-STD-3012 as baseline and cross referenced Goddard PEM-INST-001, MIL Handbook & Standards, JEDEC-Standards documents

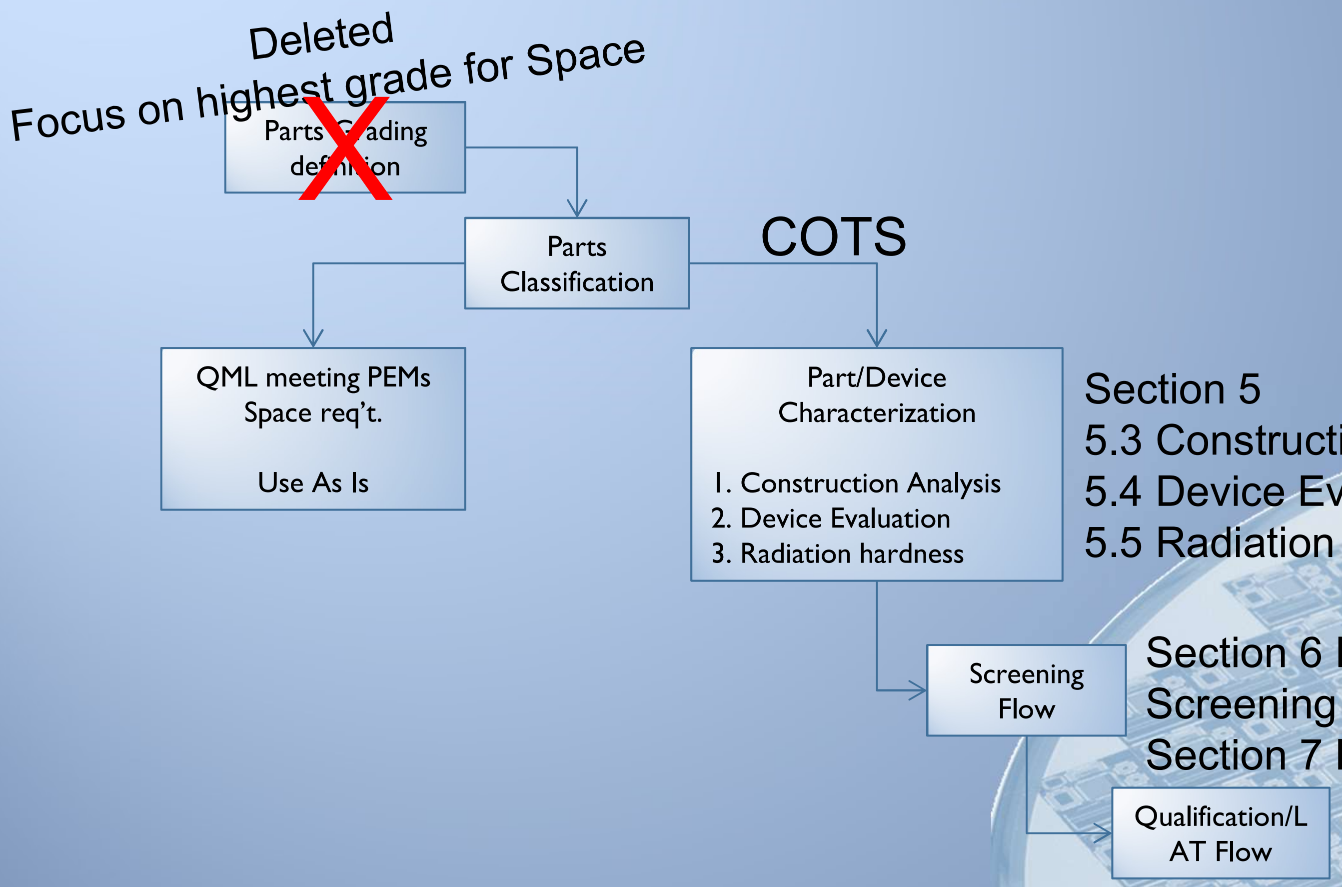


AS6294/1 Microcircuits

Leveraging Existing Standards
- JEDEC
- AEC
- Mil Stds

Examples:
- Coper Bond Wire
- Radiation Testing
- SAM
- Temp Cycle

Document foundation



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Focus on highest grade for Space

~~Parts Grading definition~~

Parts Classification

COTS

QML meeting PEMs Space req't.

Use As Is

Part/Device Characterization

1. Construction Analysis
2. Device Evaluation
3. Radiation hardness

Section 5
5.3 Construction Analysis
5.4 Device Evaluation
5.5 Radiation Hardness

Screening Flow

Section 6 Req'ts for Screening
Section 7 Burn-in Req'ts.

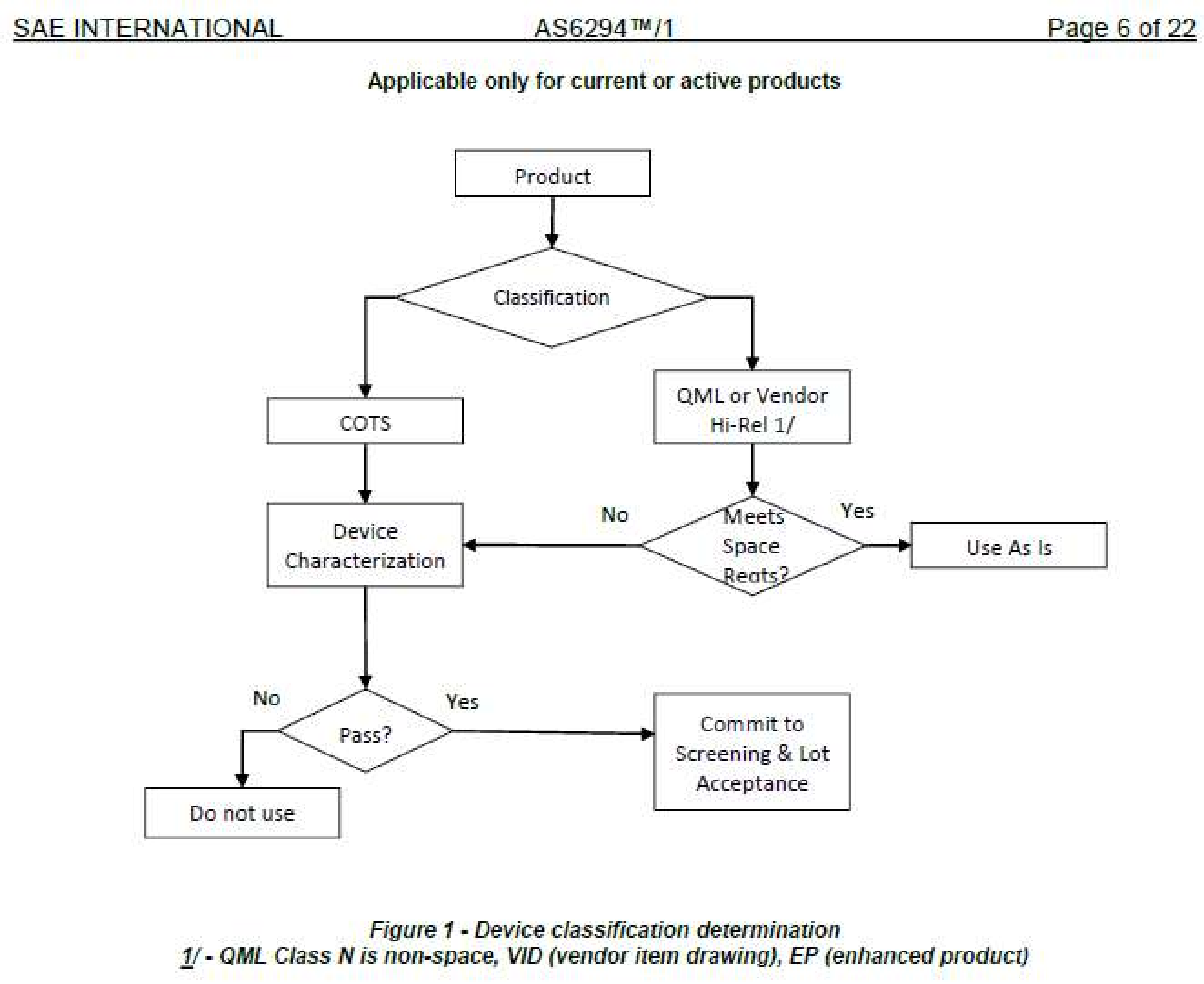
Qualification/LAT Flow

Section 8 Requirements for Lot Acceptance Testing

Document section overview

Parts Classification

Section 4
Device Classification determination



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Applicable only for current or active products

Figure 1 - Device classification determination
1/ - QML Class N is non-space, VID (vendor item drawing), EP (enhanced product)

Document section overview

Part/Device Characterization

1. Construction Analysis
2. Device Evaluation
3. Radiation Hardness

Section 5 Device Characterization
5.3 Construction Analysis
5.4 Device Evaluation
5.5 Radiation Hardness

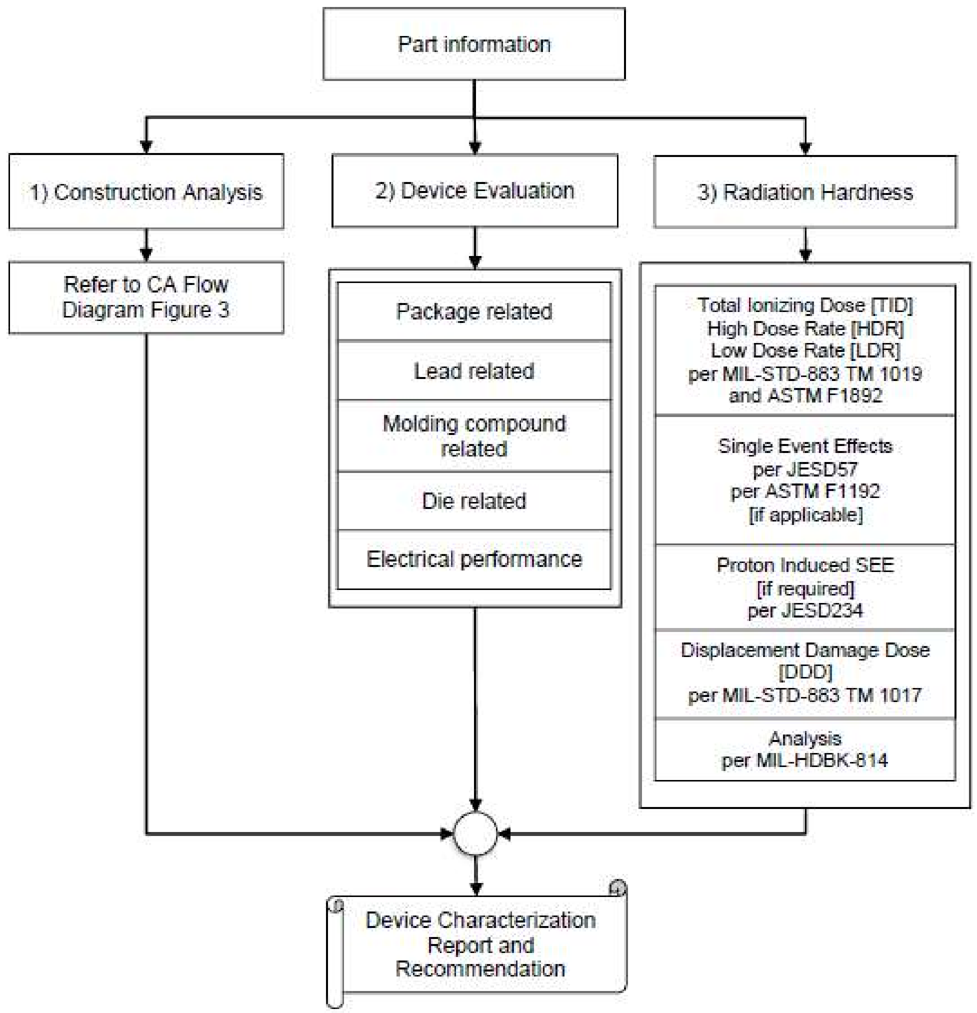

Figure 2 - Typical device characterization flow for PEMs

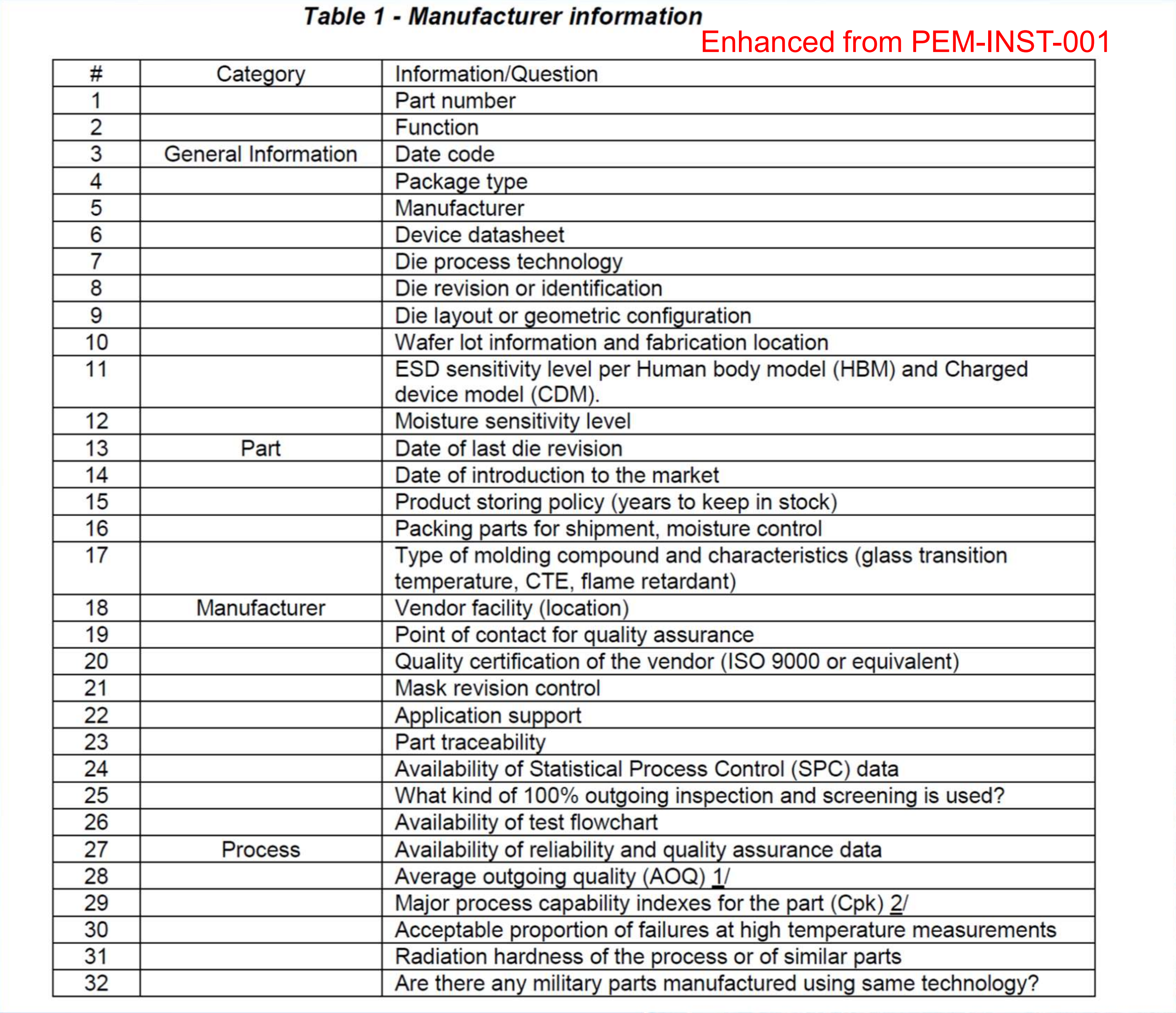

Table 1 - Manufacturer information

Enhanced from PEM-INST-001

#	Category	Information/Question
1		Part number
2		Function
3	General Information	Date code
4		Package type
5		Manufacturer
6		Device datasheet
7		Die process technology
8		Die revision or identification
9		Die layout or geometric configuration
10		Wafer lot information and fabrication location
11		ESD sensitivity level per Human body model (HBM) and Charged device model (CDM).
12		Moisture sensitivity level
13	Part	Date of last die revision
14		Date of introduction to the market
15		Product storing policy (years to keep in stock)
16		Packing parts for shipment, moisture control
17		Type of molding compound and characteristics (glass transition temperature, CTE, flame retardant)
18	Manufacturer	Vendor facility (location)
19		Point of contact for quality assurance
20		Quality certification of the vendor (ISO 9000 or equivalent)
21		Mask revision control
22		Application support
23		Part traceability
24		Availability of Statistical Process Control (SPC) data
25		What kind of 100% outgoing inspection and screening is used?
26		Availability of test flowchart
27	Process	Availability of reliability and quality assurance data
28		Average outgoing quality (AOQ) 1/
29		Major process capability indexes for the part (Cpk) 2/
30		Acceptable proportion of failures at high temperature measurements
31		Radiation hardness of the process or of similar parts
32		Are there any military parts manufactured using same technology?

Document section overview

Part/Device Characterization

1. Construction Analysis
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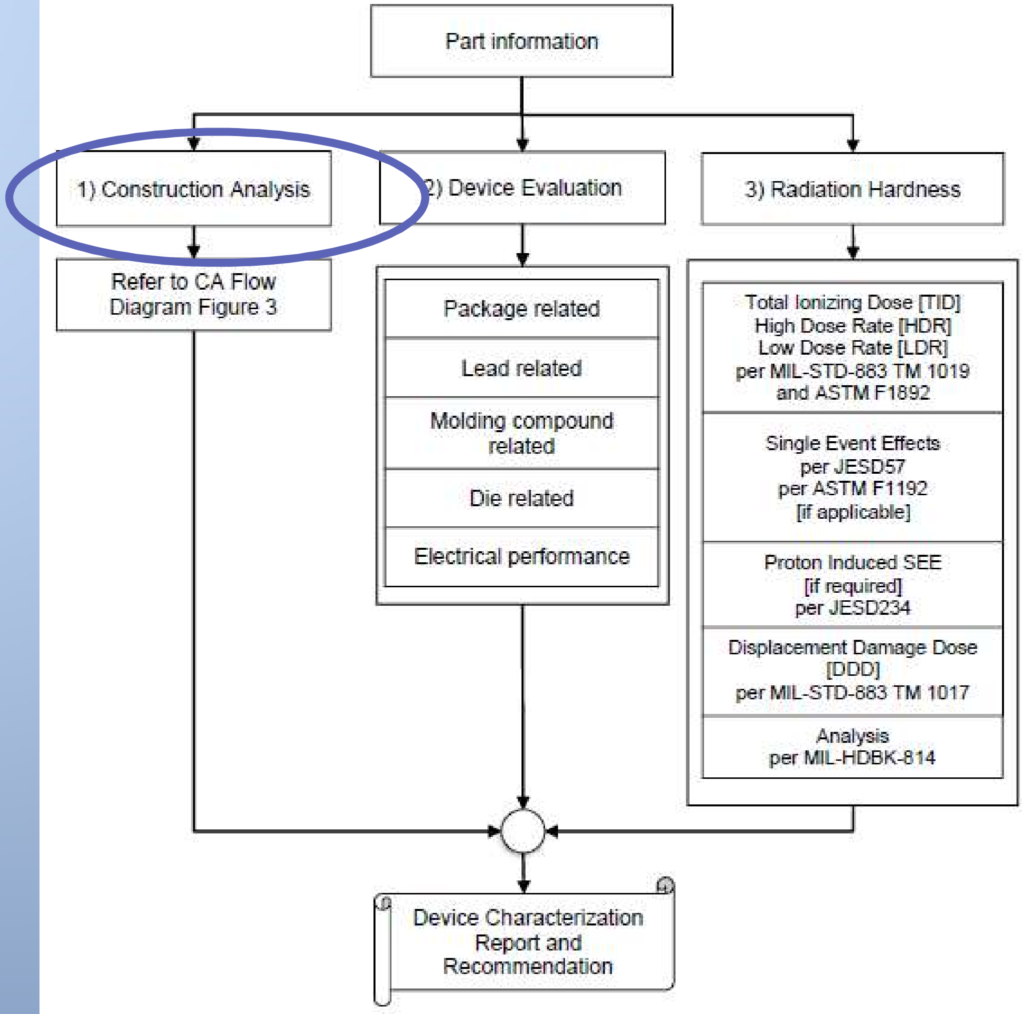
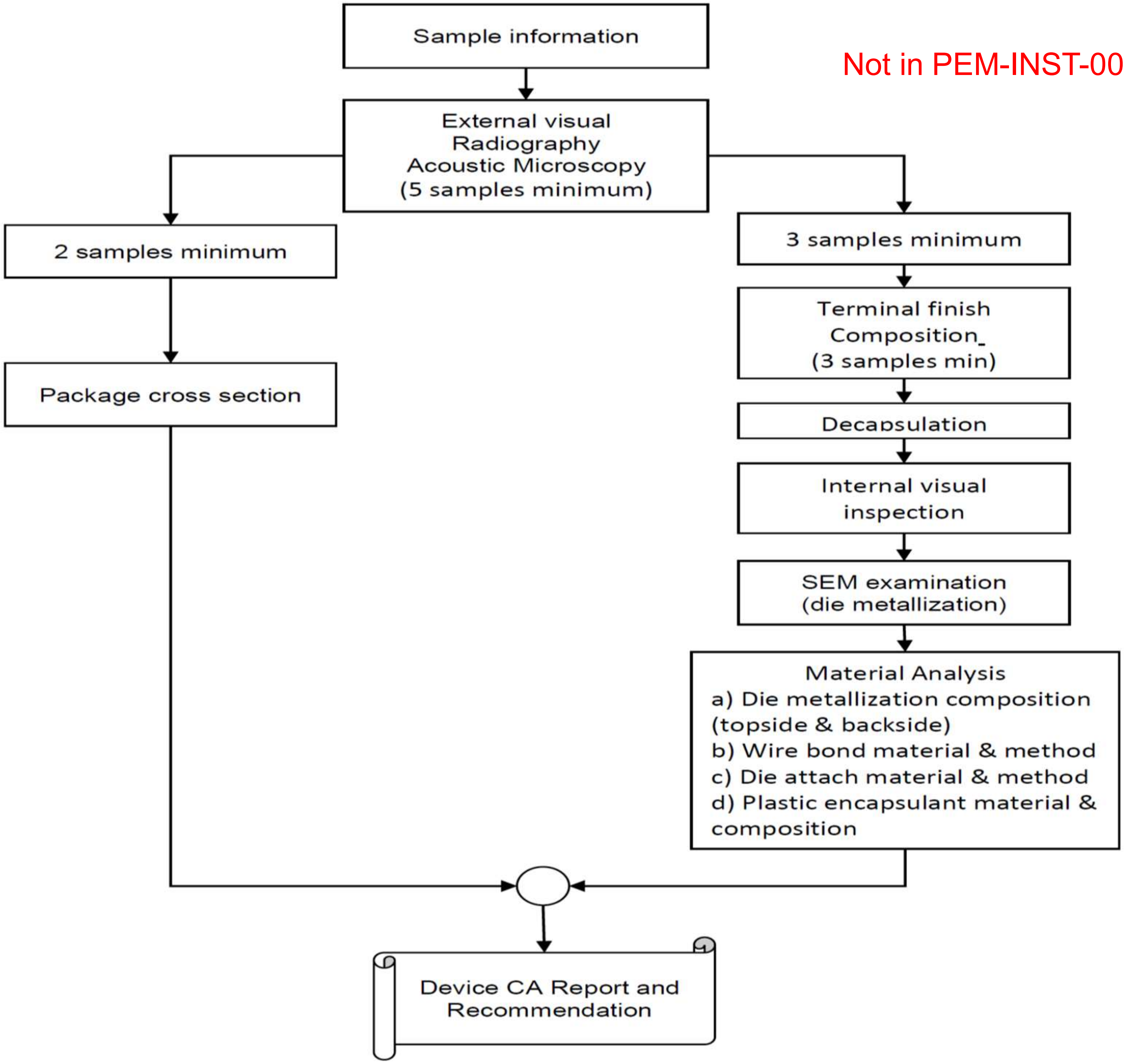


Figure 2 - Typical device characterization flow for PEMs

Not in PEM-INST-001



Sample information

External visual
Radiography
Acoustic Microscopy
(5 samples minimum)

2 samples minimum

Package cross section

3 samples minimum

Terminal finish
Composition
(3 samples min)

Decapsulation

Internal visual
inspection

SEM examination
(die metallization)

Material Analysis
a) Die metallization composition (topside & backside)
b) Wire bond material & method
c) Die attach material & method
d) Plastic encapsulant material & composition

Device CA Report and
Recommendation

Figure 3 - Typical construction analysis test flow for PEMs

Document section overview

Part/Device
Characterization

1. Construction Analysis
2. Device Evaluation
3. Radiation Hardness

Section 5 Device Characterization
5.3 Construction Analysis
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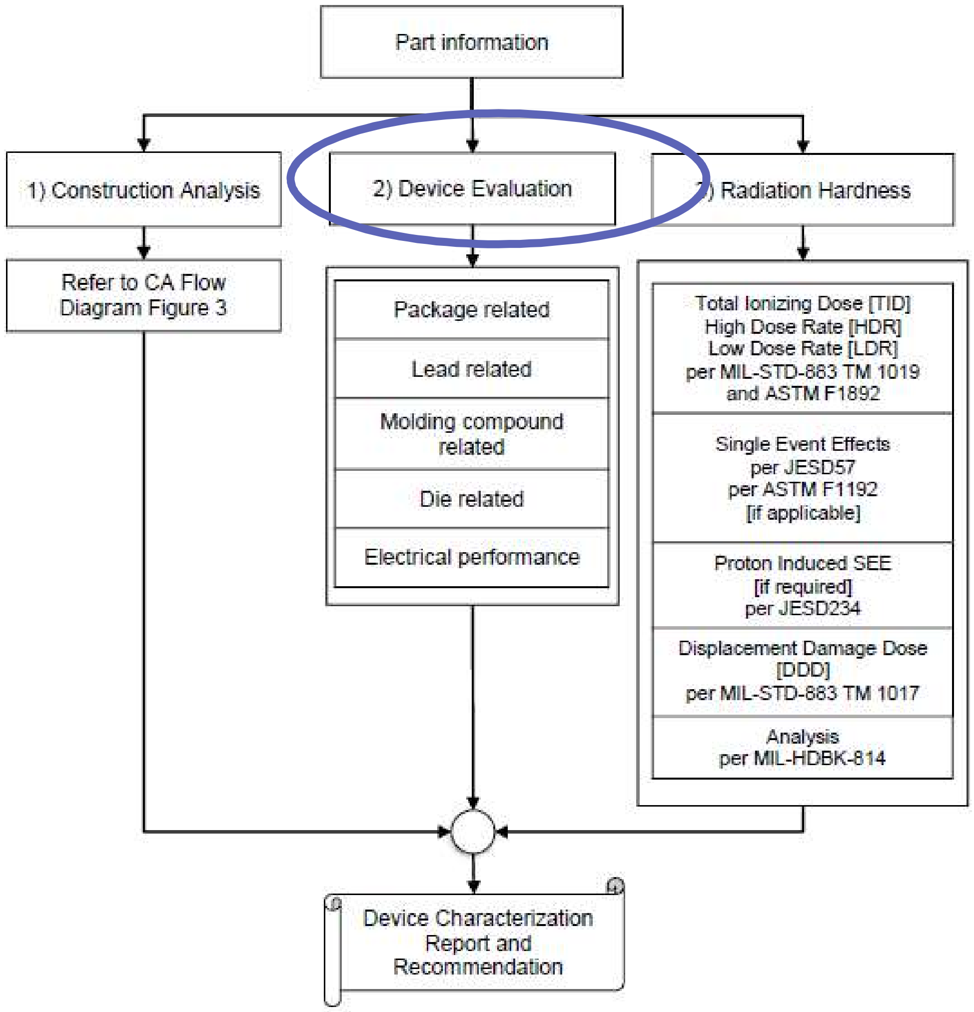

Figure 2 - Typical device characterization flow for PEMs

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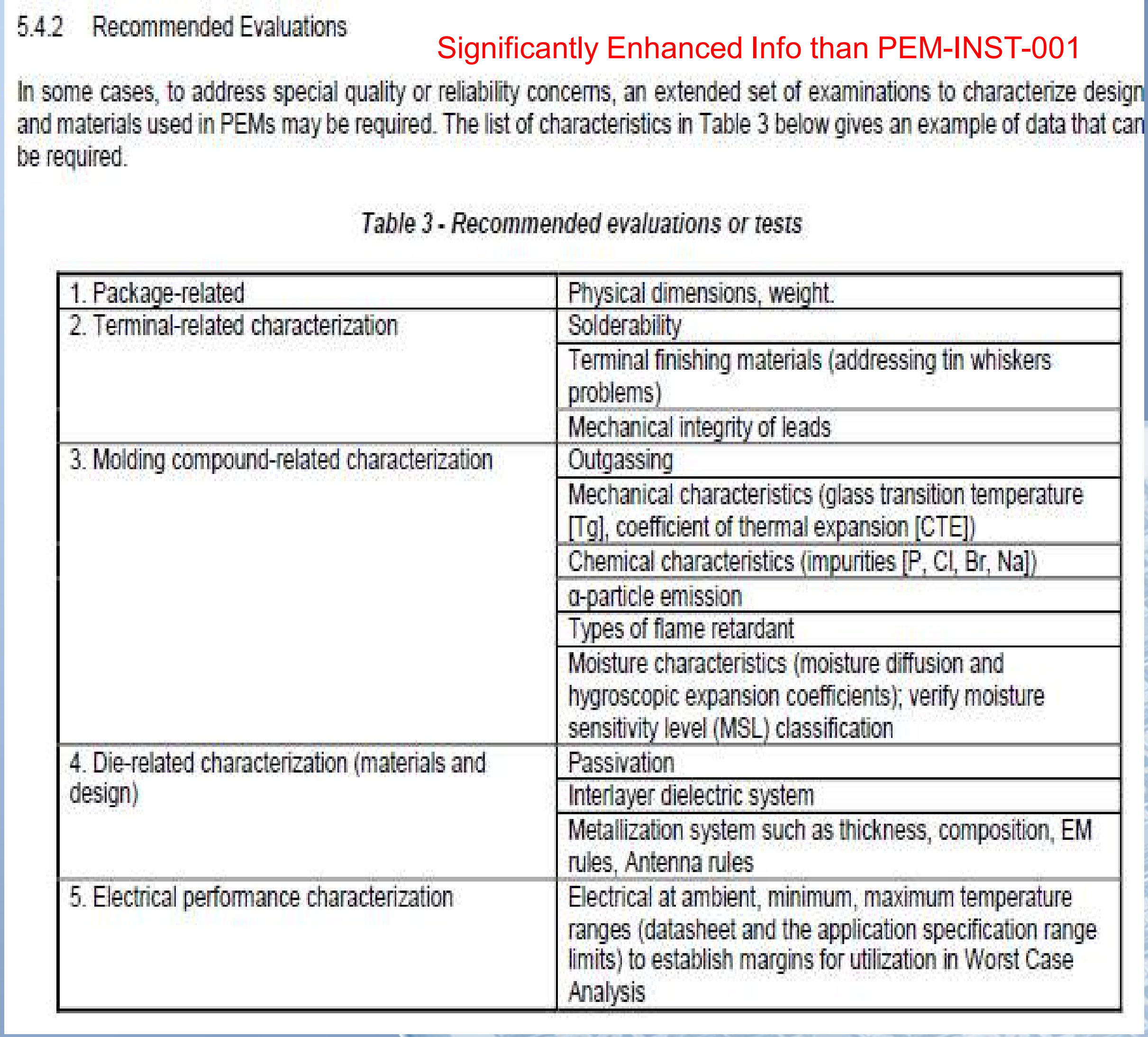

Significantly Enhanced Info than PEM-INST-001

5.4.2 Recommended Evaluations

In some cases, to address special quality or reliability concerns, an extended set of examinations to characterize design and materials used in PEMs may be required. The list of characteristics in Table 3 below gives an example of data that can be required.

Table 3 - Recommended evaluations or tests

1. Package-related	Physical dimensions, weight.
2. Terminal-related characterization	Solderability
	Terminal finishing materials (addressing tin whiskers problems)
	Mechanical integrity of leads
3. Molding compound-related characterization	Outgassing
	Mechanical characteristics (glass transition temperature [Tg], coefficient of thermal expansion [CTE])
	Chemical characteristics (impurities [P, Cl, Br, Na])
	α-particle emission
	Types of flame retardant
	Moisture characteristics (moisture diffusion and hygroscopic expansion coefficients); verify moisture sensitivity level (MSL) classification
4. Die-related characterization (materials and design)	Passivation
	Interlayer dielectric system
	Metallization system such as thickness, composition, EM rules, Antenna rules
5. Electrical performance characterization	Electrical at ambient, minimum, maximum temperature ranges (datasheet and the application specification range limits) to establish margins for utilization in Worst Case Analysis

Document section overview

Part/Device
Characterization

1. Construction Analysis
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Section 5 Device Characterization
5.3 Construction Analysis
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Radiation evaluation shall address all threats appropriate for the technology, application, and environment, including total ionizing dose (**TID**), Enhanced Low Dose Rate Sensitivity (**ELDRS**), single event effects (**SEE**), and displacement damage degradation (**DDD**) as defined in the project ionizing radiation control document.

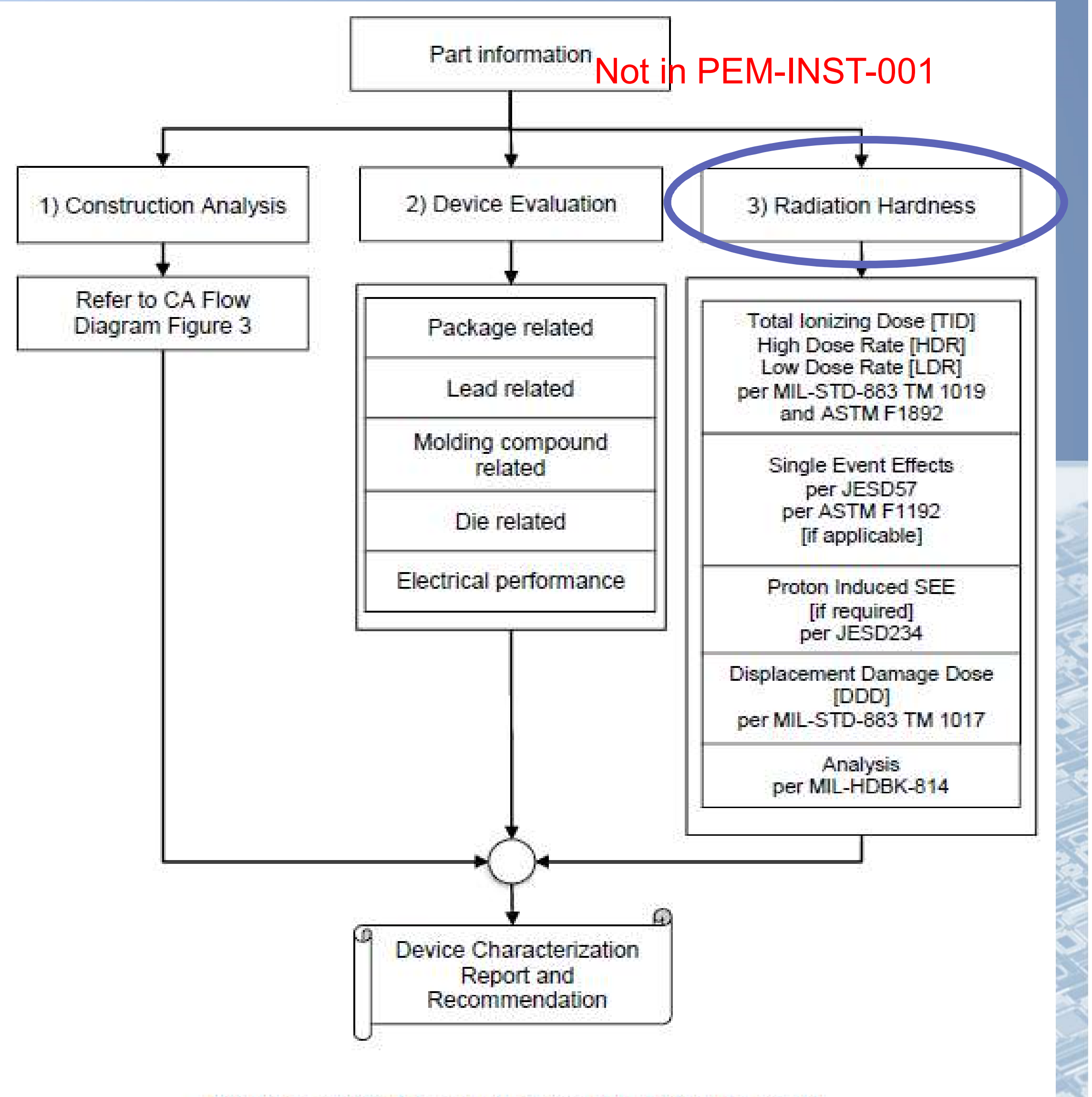


Figure 2 - Typical device characterization flow for PEMs

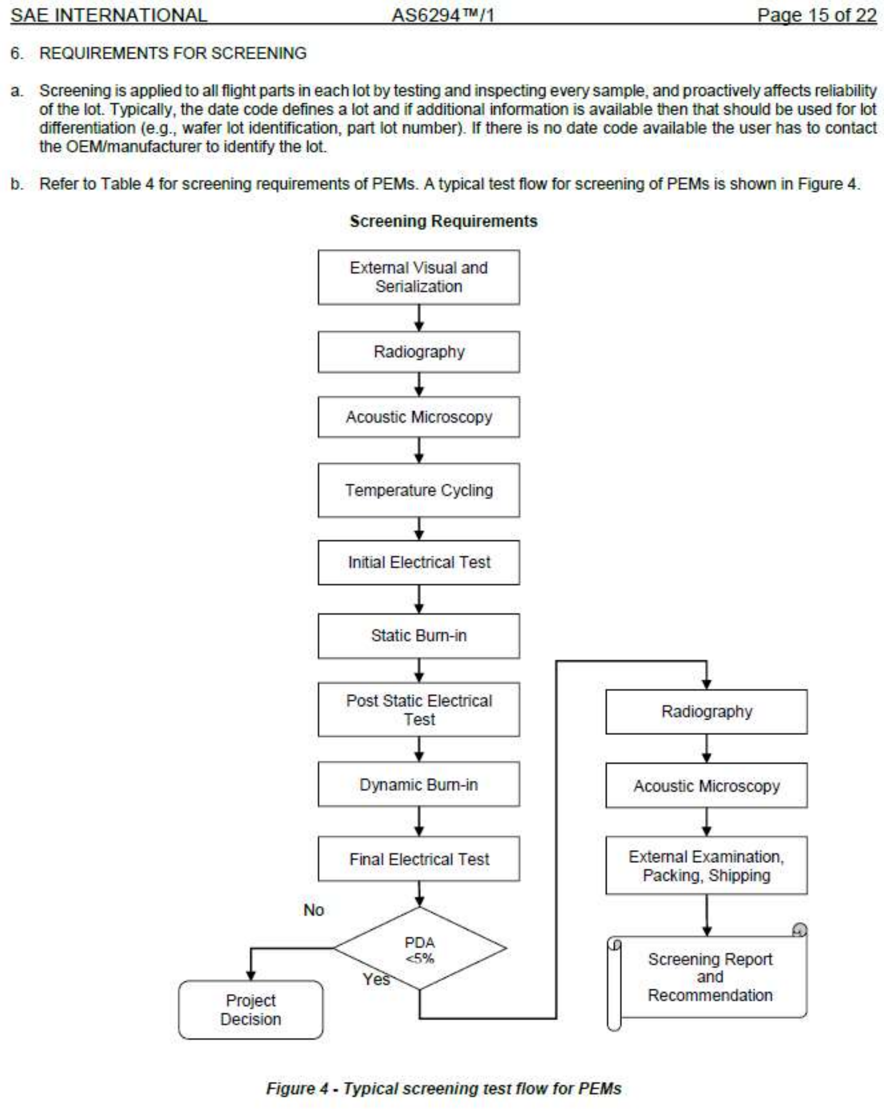
Document section overview

Screening Flow

Section 6 Req’ts for Screening

Section 7 Burn-in req’ts.

Section 7 Burn-in req’ts. In accordance with JEP163 as applicable



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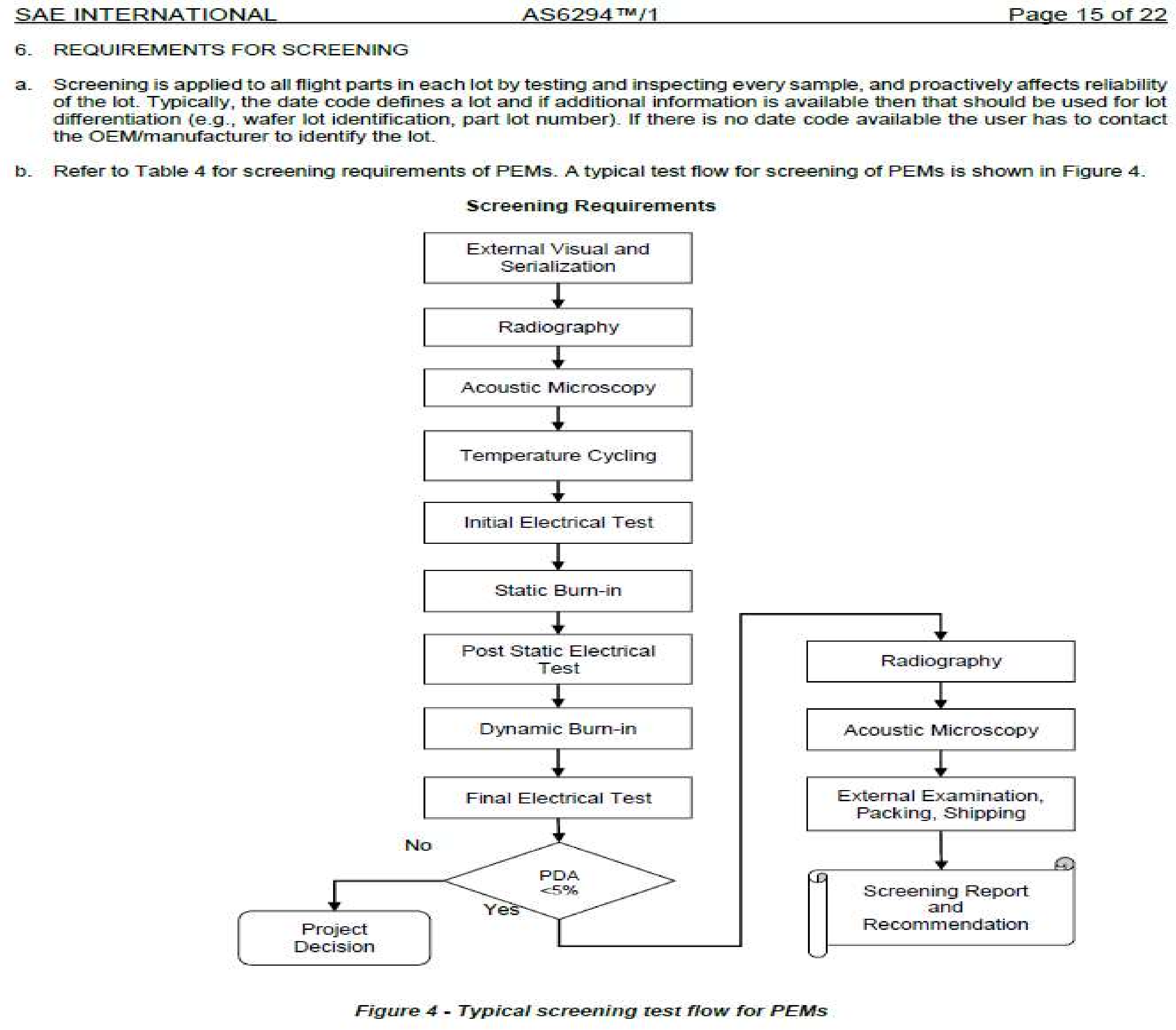
6. REQUIREMENTS FOR SCREENING

a. Screening is applied to all flight parts in each lot by testing and inspecting every sample, and proactively affects reliability of the lot. Typically, the date code defines a lot and if additional information is available then that should be used for lot differentiation (e.g., wafer lot identification, part lot number). If there is no date code available the user has to contact the OEM/manufacturer to identify the lot.

b. Refer to Table 4 for screening requirements of PEMs. A typical test flow for screening of PEMs is shown in Figure 4.

Figure 4 - Typical screening test flow for PEMs



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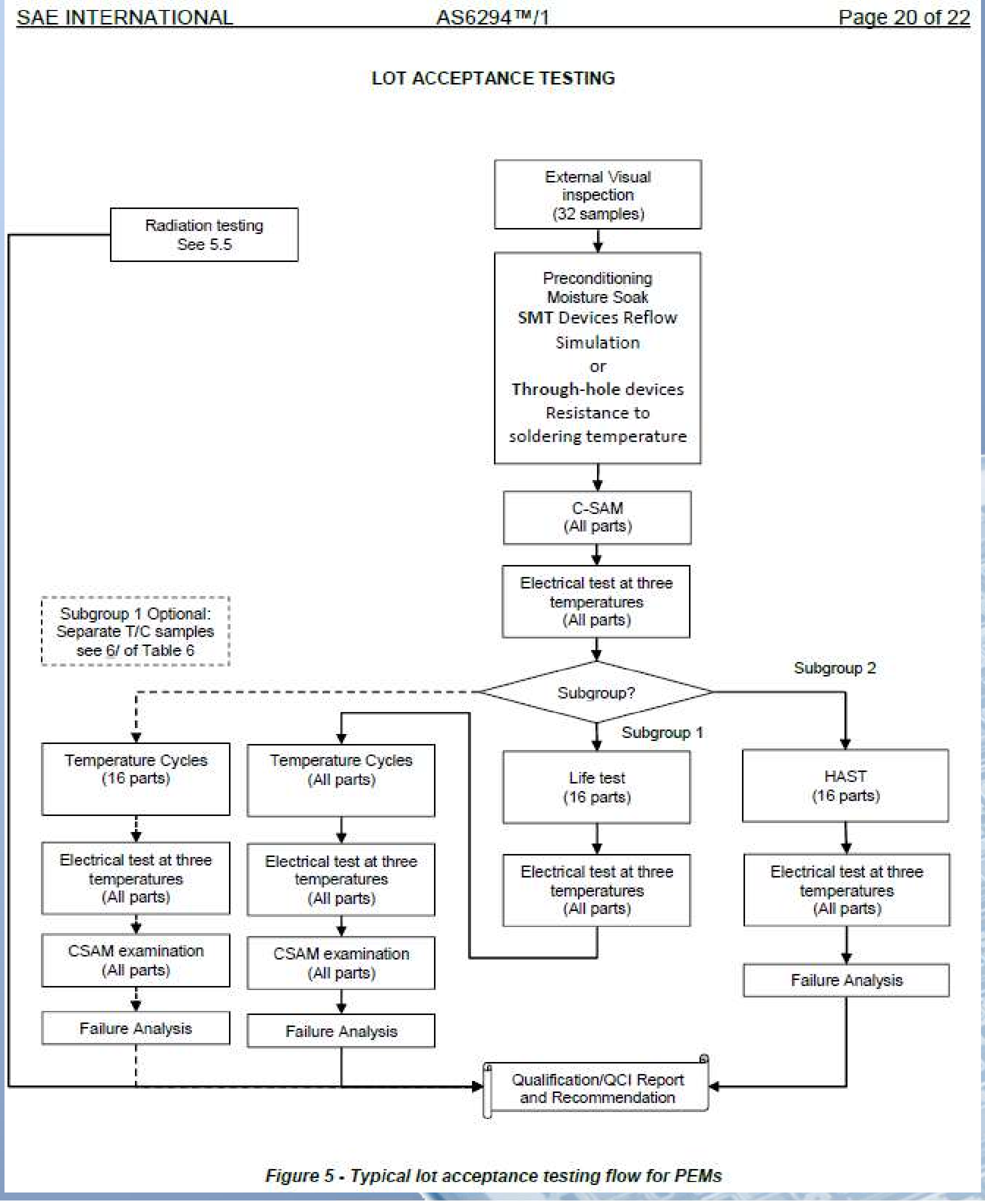
Screening Requirements

Figure 4 - Typical screening test flow for PEMs

Document section overview

Qualification/LAT Flow

Section 8 Requirements for Lot Acceptance Testing



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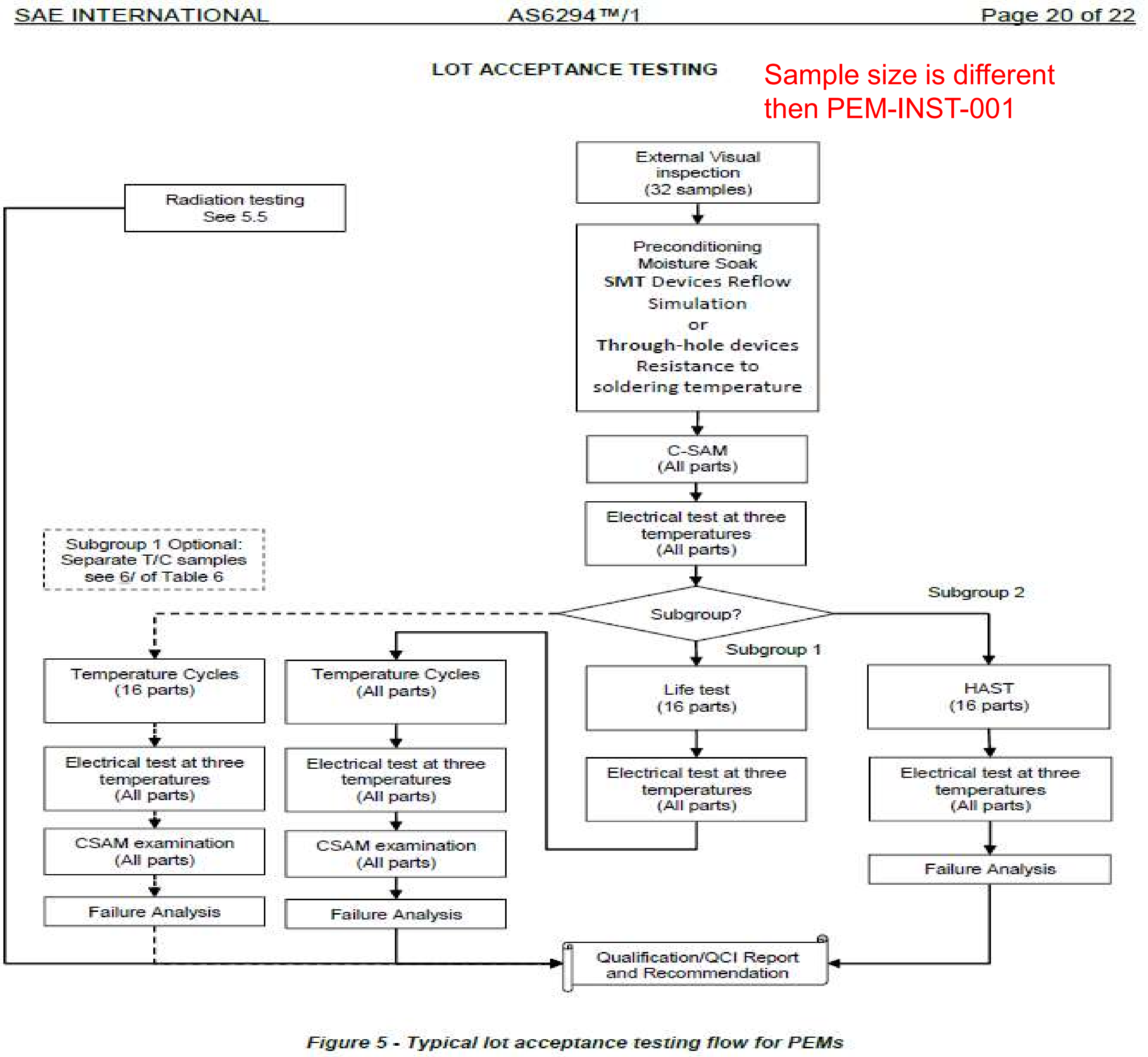
LOT ACCEPTANCE TESTING

Figure 5 - Typical lot acceptance testing flow for PEMs



LOT ACCEPTANCE TESTING

Sample size is different then PEM-INST-001

External Visual inspection (32 samples)

Preconditioning Moisture Soak **SMT Devices Reflow** Simulation or **Through-hole devices** Resistance to soldering temperature

C-SAM (All parts)

Electrical test at three temperatures (All parts)

Subgroup?

Radiation testing See 5.5

Subgroup 1 Optional: Separate T/C samples see 6/ of Table 6

Temperature Cycles (16 parts)

Electrical test at three temperatures (All parts)

CSAM examination (All parts)

Failure Analysis

Temperature Cycles (All parts)

Electrical test at three temperatures (All parts)

CSAM examination (All parts)

Failure Analysis

Subgroup 1

Life test (16 parts)

Electrical test at three temperatures (All parts)

Subgroup 2

HAST (16 parts)

Electrical test at three temperatures (All parts)

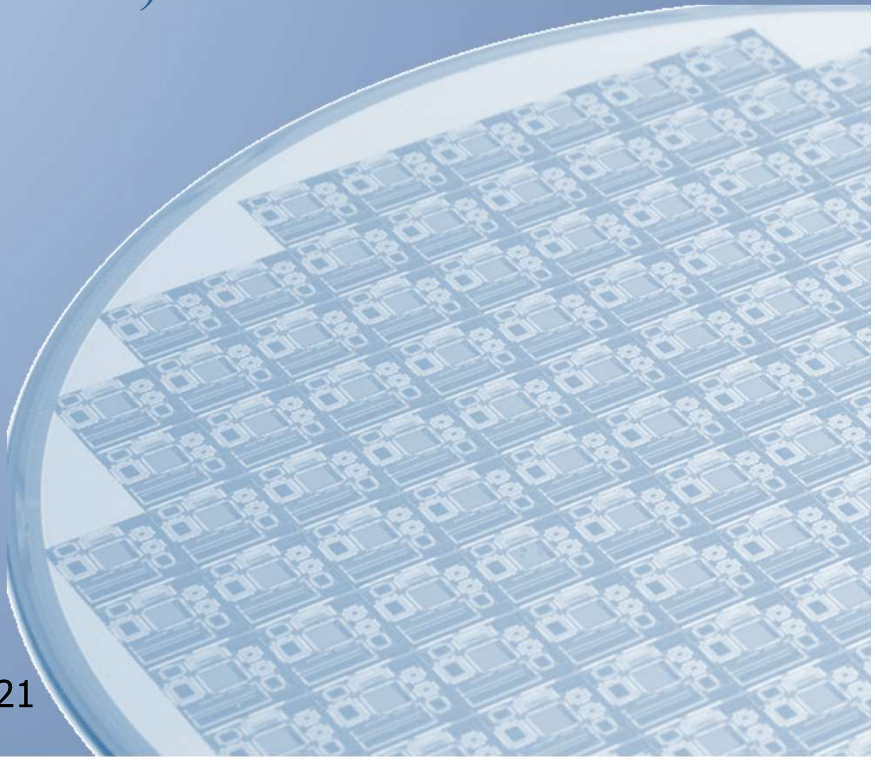
Failure Analysis

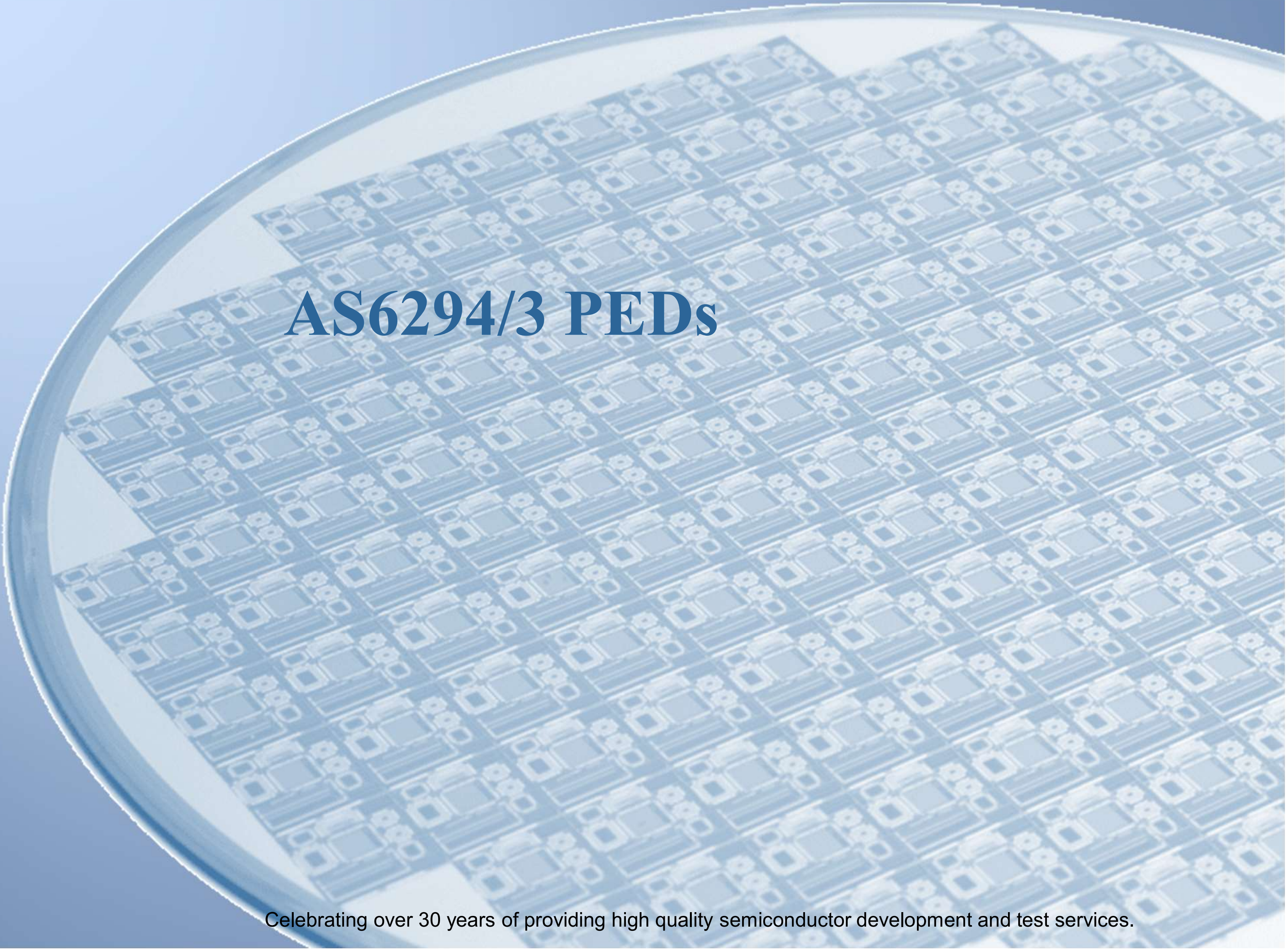
Qualification/QCI Report and Recommendation

Figure 5 - Typical lot acceptance testing flow for PEMs

Adaptation by Manufacturers

- Analog Devices (CSL, CSM, CSH) – Very similar flow for CSH)
- TI Space EP (Not exactly but has some of the tests
- Renesas / Intersil (Very similar flow)



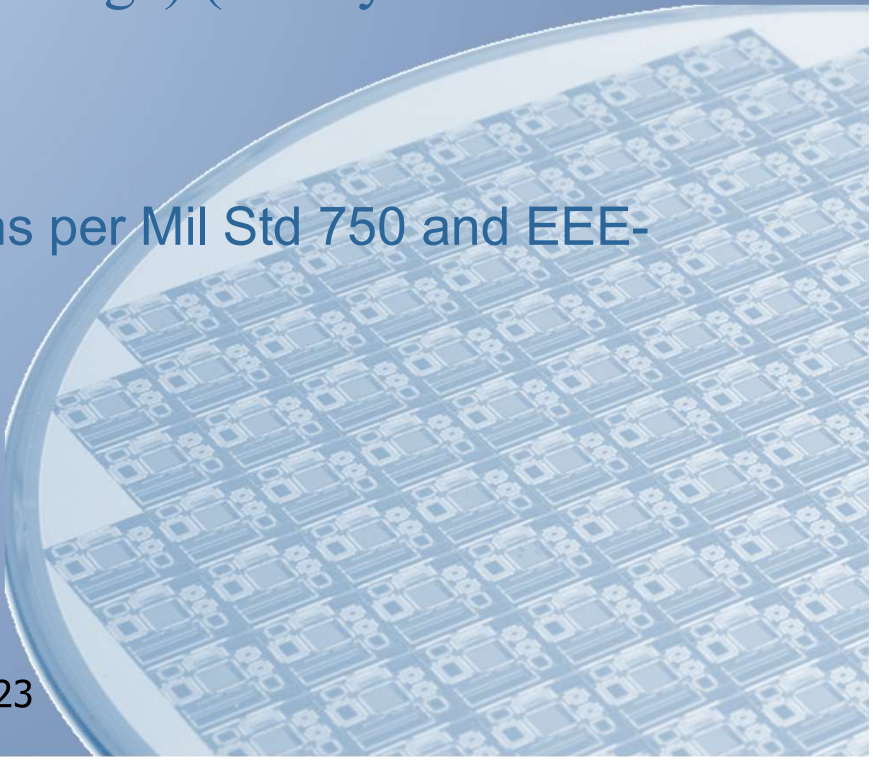


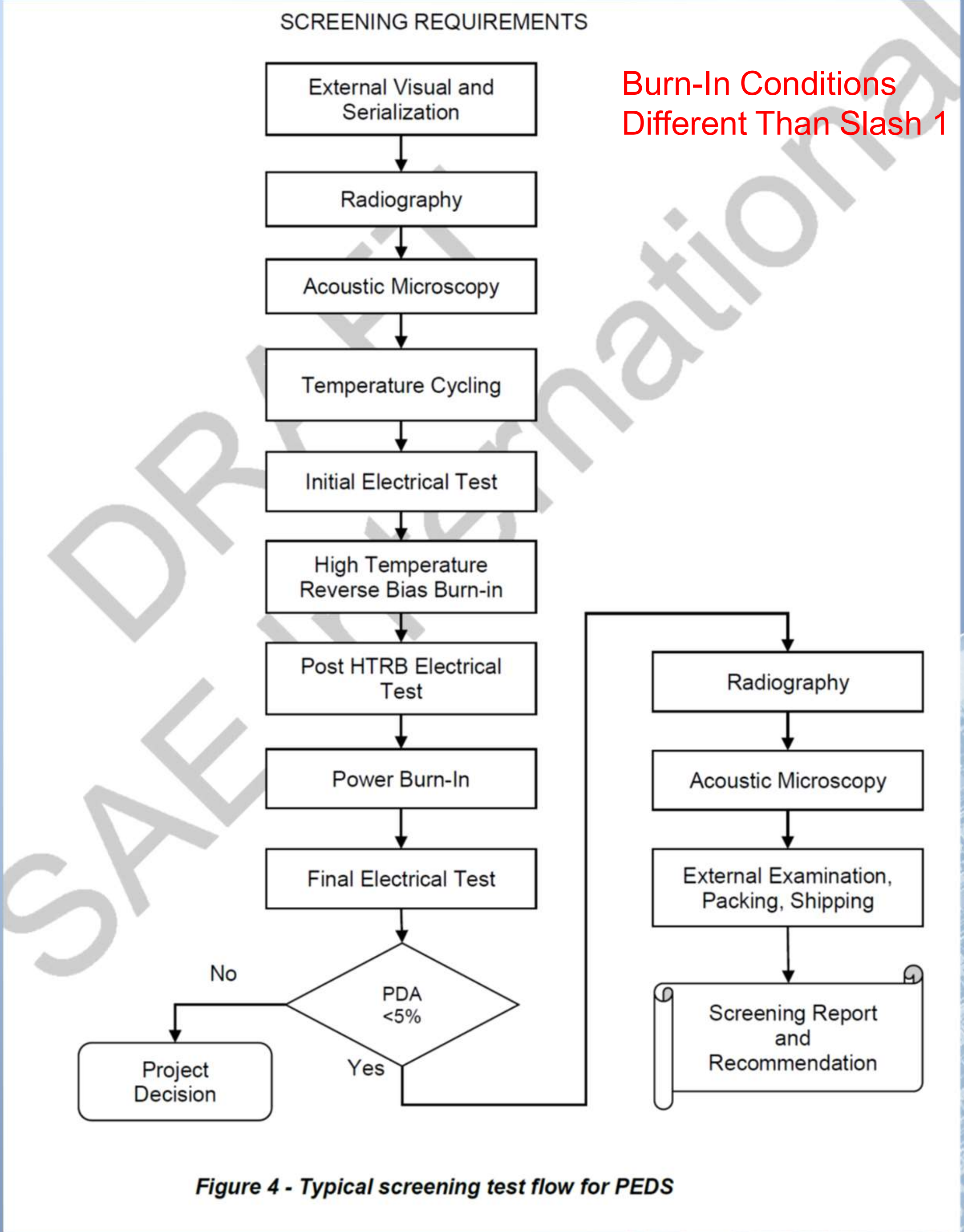
AS6294/3 PEDs

Celebrating over 30 years of providing high quality semiconductor development and test services.

Key Features - AS6294/3

- First Discrete PEM Document
- Leveraging AS6294/1 and EEE-INST-002
- Closely Aligned to (Work In Progress) MIL-PRF-19500 Appendix J (Discrete plastic package) (Benny Damron Leading)
- Major Differences to Slash 1
  - Burn-in and Life Test Conditions per Mil Std 750 and EEE-INST-002





SCREENING REQUIREMENTS

External Visual and Serialization

Radiography

Acoustic Microscopy

Temperature Cycling

Initial Electrical Test

High Temperature Reverse Bias Burn-in

Post HTRB Electrical Test

Power Burn-In

Final Electrical Test

PDA <5%

No

Project Decision

Yes

Radiography

Acoustic Microscopy

External Examination, Packing, Shipping

Screening Report and Recommendation

Figure 4 - Typical screening test flow for PEDS

Burn-In Conditions
Different Than Slash 1

Leveraging EEE-INST-002

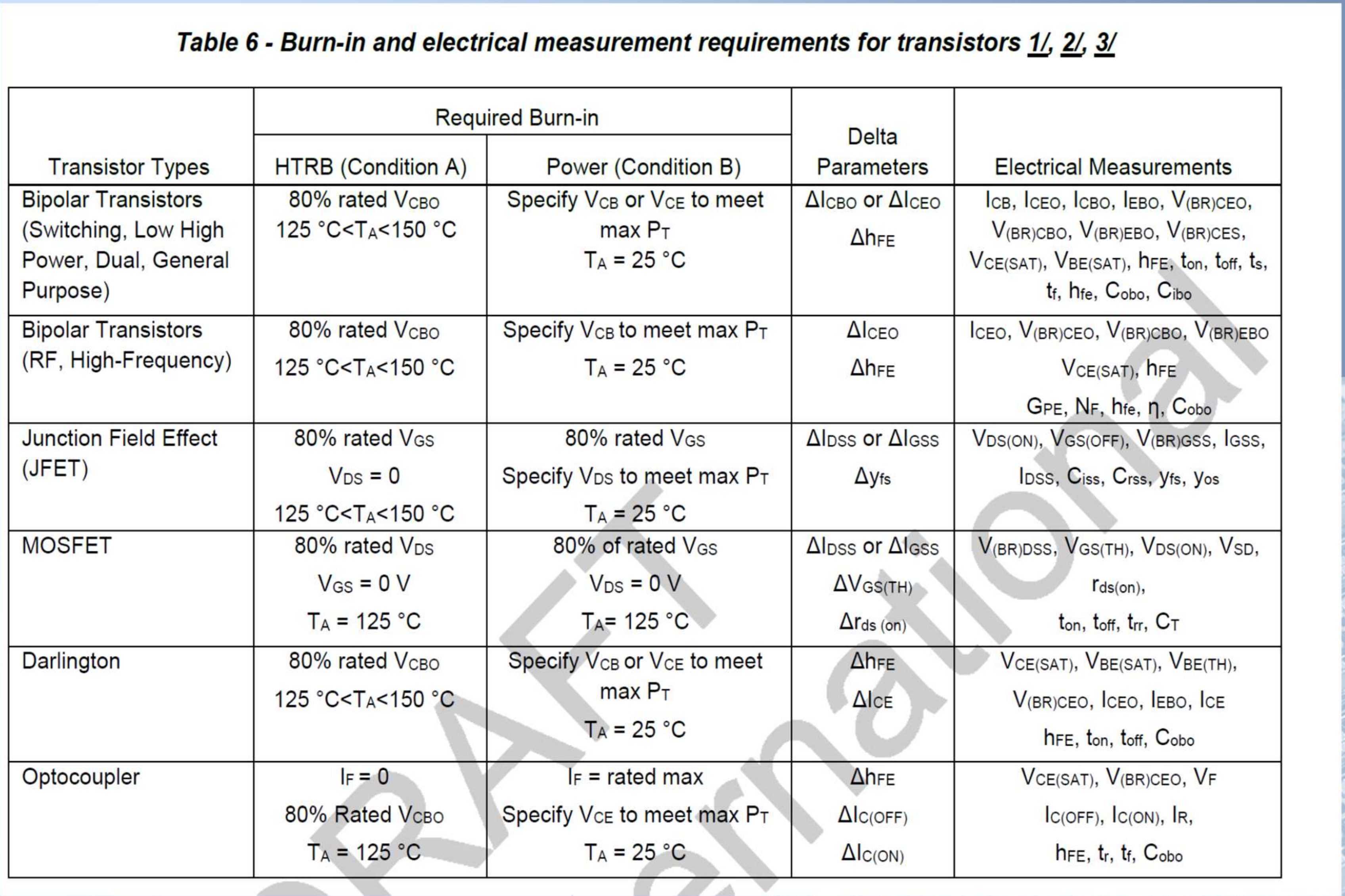
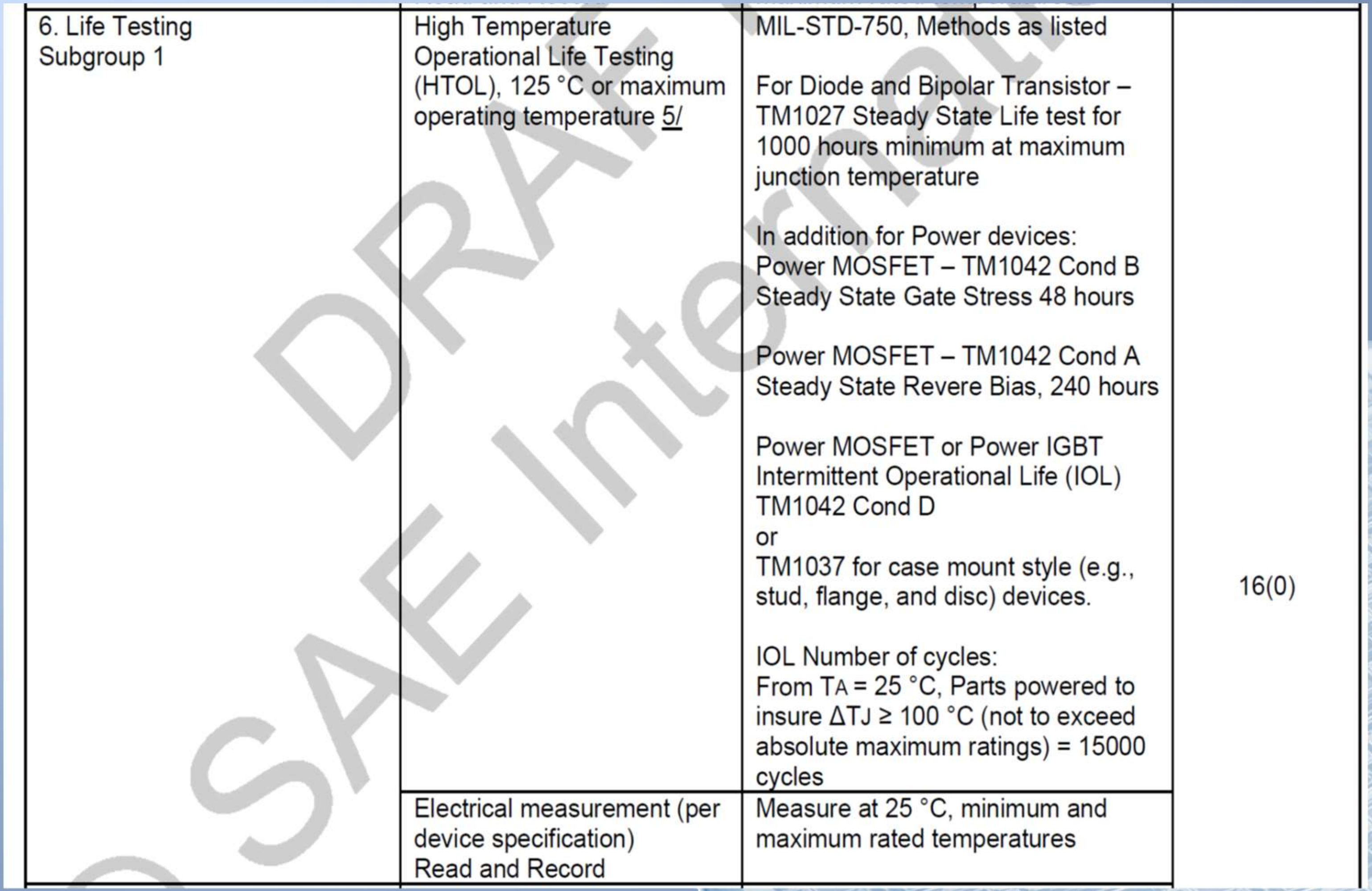


Table 6 - Burn-in and electrical measurement requirements for transistors 1/, 2/, 3/

Transistor Types	Required Burn-in		Delta Parameters	Electrical Measurements
	HTRB (Condition A)	Power (Condition B)		
Bipolar Transistors (Switching, Low High Power, Dual, General Purpose)	80% rated V_{CBO} 125 °C<T_A<150 °C	Specify V_{CB} or V_{CE} to meet max P_T T_A = 25 °C	ΔI_{CBO} or ΔI_{CEO} Δh_{FE}	I_{CB}, I_{CEO}, I_{CBO}, I_{EBO}, $V_{(BR)CEO}$, $V_{(BR)CBO}$, $V_{(BR)EBO}$, $V_{(BR)CES}$, $V_{CE(SAT)}$, $V_{BE(SAT)}$, h_{FE}, t_{on}, t_{off}, t_s, t_f, h_{fe}, C_{obo}, C_{ibo}
Bipolar Transistors (RF, High-Frequency)	80% rated V_{CBO} 125 °C<T_A<150 °C	Specify V_{CB} to meet max P_T T_A = 25 °C	ΔI_{CEO} Δh_{FE}	I_{CEO}, $V_{(BR)CEO}$, $V_{(BR)CBO}$, $V_{(BR)EBO}$ $V_{CE(SAT)}$, h_{FE} G_{PE}, N_F, h_{fe}, η, C_{obo}
Junction Field Effect (JFET)	80% rated V_{GS} V_{DS} = 0 125 °C<T_A<150 °C	80% rated V_{GS} Specify V_{DS} to meet max P_T T_A = 25 °C	ΔI_{DSS} or ΔI_{GSS} Δy_{fs}	$V_{DS(ON)}$, $V_{GS(OFF)}$, $V_{(BR)GSS}$, I_{GSS}, I_{DSS}, C_{iss}, C_{rss}, y_{fs}, y_{os}
MOSFET	80% rated V_{DS} V_{GS} = 0 V T_A = 125 °C	80% of rated V_{GS} V_{DS} = 0 V T_A= 125 °C	ΔI_{DSS} or ΔI_{GSS} $\Delta V_{GS(TH)}$ $\Delta r_{ds\ (on)}$	$V_{(BR)DSS}$, $V_{GS(TH)}$, $V_{DS(ON)}$, V_{SD}, $r_{ds(on)}$, t_{on}, t_{off}, t_{rr}, C_T
Darlington	80% rated V_{CBO} 125 °C<T_A<150 °C	Specify V_{CB} or V_{CE} to meet max P_T T_A = 25 °C	Δh_{FE} ΔI_{CE}	$V_{CE(SAT)}$, $V_{BE(SAT)}$, $V_{BE(TH)}$, $V_{(BR)CEO}$, I_{CEO}, I_{EBO}, I_{CE} h_{FE}, t_{on}, t_{off}, C_{obo}
Optocoupler	I_F = 0 80% Rated V_{CBO} T_A = 125 °C	I_F = rated max Specify V_{CE} to meet max P_T T_A = 25 °C	Δh_{FE} $\Delta I_{C(OFF)}$ $\Delta I_{C(ON)}$	$V_{CE(SAT)}$, $V_{(BR)CEO}$, V_F $I_{C(OFF)}$, $I_{C(ON)}$, I_R, h_{FE}, t_r, t_f, C_{obo}

Leveraging EEE-INST-002



6. Life Testing Subgroup 1	High Temperature Operational Life Testing (HTOL), 125 °C or maximum operating temperature 5/	MIL-STD-750, Methods as listed For Diode and Bipolar Transistor – TM1027 Steady State Life test for 1000 hours minimum at maximum junction temperature In addition for Power devices: Power MOSFET – TM1042 Cond B Steady State Gate Stress 48 hours Power MOSFET – TM1042 Cond A Steady State Revere Bias, 240 hours Power MOSFET or Power IGBT Intermittent Operational Life (IOL) TM1042 Cond D or TM1037 for case mount style (e.g., stud, flange, and disc) devices. IOL Number of cycles: From $T_A = 25$ °C, Parts powered to insure $\Delta T_J \geq 100$ °C (not to exceed absolute maximum ratings) = 15000 cycles	16(0)
	Electrical measurement (per device specification) Read and Record	Measure at 25 °C, minimum and maximum rated temperatures	