

ENGINEERING PRACTICES STUDY 1154

TITLE: ENGINEERING PRACTICE STUDY TO REVIEW THE PROPOSED
DISPLACEMENT DAMAGE FORMAT FOR MIL-PRF-19500, AND APPLICABLE
SPECIFICATION SHEETS

10 March 2017

STUDY PROJECT

5961-2016-112

FINAL REPORT

Study Conducted by DLA LAND AND MARITIME

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I. **OBJECTIVES:** An Engineering Practice Study (EPS) was conducted to review the proposed Displacement Damage characterization format for MIL-PRF-19500 and applicable bipolar transistor, diode and MOSFET specification sheets. The purpose of this EPS was to obtain input from the military services, manufacturers, and user communities to help determine which format should be used for the new Displacement Damage characterization.

II. **BACKGROUND:** DLA received a request to add displacement damage testing in the qualification requirements of MIL-PRF-19500. The current RHA requirements in MIL-PRF-19500 only require total dose, with the implied level of displacement damage not guaranteed. Historically, if the displacement damage test is desired it must be specified in the contract. Some Space and nuclear hardened systems need parts that are guaranteed for both total dose and displacement damage environments. The addition of neutron characterization information would benefit users of RHA devices.

A coordination meeting was held at DLA Columbus to determine the feasibility and scope of adding a cost effective displacement damage qualification test. It was determined at the meeting that adding a Group E characterization is the best option if this type of data is included in the specification sheet. Additionally it was agreed to not make any changes to the existing RHA classification levels to avoid problems with part substitution and existing parts lists. Table E-III of MIL-PRF-19500 will be updated to reflect the new available characterization information in the specification sheets. All new neutron information provided will be in addition to the existing total dose information. It will be up to the user to determine how they combine the information. Neutron characterization is dependent on design, so as long as the design has not changed, the additional information will not affect existing part characteristics. Data will be provided using 1MeV equivalent neutrons in a new group E characterization based on the conditions from the existing subgroup 1 of the Group D table. Grouping of testing is proposed to be based on vertical geometry (base width, emitter depth, and collector width) and bulk properties (resistivity and lifetime). If these factors are the same then any size die would be considered structurally identical.

An initial EPS was circulated requesting a review of the request to add displacement damage to applicable specification sheets. The comments received by DLA Land and Maritime were reviewed and indicated that it would be beneficial to add the displacement damage characterization in MIL-PRF-19500 and the specification sheets but was inconclusive on the format that should be used for the requirements. This second EPS was circulated to finalize the format used for requiring the new displacement damage format.

III. **RESULTS:** The comments submitted to DLA Land and Maritime have been reviewed and indicate that the proposed recommendations should be used as the basis for the proposed changes in the applicable specification sheets. Attachments 1 - 4 represent the proposed recommendations. In addition, comments received would prefer if no additional part numbers or RAD levels be used to differentiate characteristics. This will be done by representing this information by qualification date and manufacturer in section 6 of the specification sheet.
See **attachment 1** for the proposal to update Table E-II RHA levels and requirements of MIL-PRF-19500.
See **attachment 2** for the proposal to clarify test method 1017, in Group D of MIL-PRF-19500.
See **attachment 3** for the proposal for Group E subgroup in MIL-PRF-19500 to require Neutron characterization
See **attachment 4** for the proposal for the specification sheet neutron characterization requirements.

IV. **CONCLUSIONS:** Based on the comments received we will initiate projects on MIL-PRF-19500 and applicable specification sheets with RHA devices using the proposed recommendations.

V. **RECOMMENDATIONS:** DLA Land and Maritime recommends that the accepted proposed changes of this EPS be incorporated in MIL-PRF-19500 and specification sheets with RHA devices.
(see **Attachments 1, 2, 3, and 4**).

ATTACHMENT 1: MIL-PRF-19500, Table E-II update to inform users that the displacement damage level will be designated in the specification sheet.

TABLE E-II. RHA levels and requirements. 1/ 2/

Radiation level		
RHA designation	Total ionizing dose (RAD(Si)) <u>3/</u>	Displacement Damage, Neutron fluence (N/Cm ²) <u>4/</u> <u>5/</u>
M	3×10^3	
D	1×10^4	
P	3×10^4	
L	5×10^4	
R	1×10^5	
F	3×10^5	
G	5×10^5	
H	1×10^6	

1/ See E.6.5.

2/ The highest level may be qualified without qualifying any lower level.

3/ Test in accordance with test method 1019 of MIL-STD-750.

4/ Test in accordance with test method 1017 of MIL-STD-750. Unless otherwise specified in the specification sheet, or contract, the minimum neutron fluence shall be 2×10^{12} N/cm².

5/ Parametric degradations, as defined in the specification sheet, due to ionizing radiation and due to displacement damage, shall be combined by the user for their application environment.

ATTACHMENT 2: Clarification to note 2 of MIL-PRF-19500, Table E-VII.

TABLE E-VIII. Group D inspection (RHA inspections. 1/

Test	MIL-STD-750		JANS		JANTXV	
	Method	Condition	Quantity/ (accept number)	Notes	Quantity (accept number)	Notes
<u>Subgroup 1 2/</u> Neutron irradiation Qualification and conformance inspection End-point electrical parameters	1017	+25°C As specified in accordance with specification sheet	11(0)	3/	(a) 11(0)	4/
<u>Subgroup 2 5/</u> Steady-state total dose irradiation Qualification and conformance inspection End-point electrical parameters	1019	+25°C As specified in accordance with specification sheet	4(0) 2(0) 1(0)	6/ 8/ 9/	11(0)	7/
<u>Subgroup 3 10/</u> Power transistor electrical dose rate test End-point electrical parameters	3478	+25°C As specified in accordance with specification sheet	11(0)	3/	11(0)	4/

1/ Parts used for one subgroup test may not be used for other subgroups but may be used for higher levels in the same subgroup. Unless testing is performed within the time limits of the test method, total exposure shall not be considered cumulative. Group D tests may be performed prior to device screening (see E.6.5).

2/ Unless by design, waive neutron tests for MOS devices, bipolar elements are an integral part of the device function. waive neutron tests for MOS devices.

3/ In accordance with wafer lot. If one part fails, seven additional parts may be added to the test sample with no additional failures allowed, 18 devices, c = 1.

4/ In accordance with inspection lot. If one part fails, seven additional parts may be added to the test sample with no additional failures allowed, 18 devices, c = 1.

5/ JANTXV devices shall be inspected using either the JANTXV quantity/accept number criteria as specified, or by using the JANS criteria on each wafer.

6/ For device types with greater than or equal to 4,000 die per wafer, selected from a random locations on the wafers.

7/ In accordance with inspection lot. If one part fails, 16 additional parts may be added to the test sample with no additional failures allowed, 27 devices, c = 1. For devices which require more than one bias, the sample size shall be 11(0) for each bias.

8/ For device types with greater than 500 and less than 4,000 die per wafer, selected from random locations on each wafer.

9/ For device types with less than or equal to 500 die per wafer, selected from random locations on each wafer.

10/ Upset testing during qualification on first conformance inspection shall be conducted when specified in contract or order when specified, the same devices may be tested in more than one subgroup.

ATTACHMENT 3: Proposed new Group E subgroup for MIL-PRF-19500. This subgroup would be the location for the neutron characterization testing.

TABLE E-IX of MIL-PRF-19500. Group E inspections (all quality levels)

<u>Subgroup 12</u>			
Neutron Irradiation	1017	Displacement Damage Characterization. For RHA devices, each supplier shall submit displacement damage characterization data. Samples may be taken from any wafer of the qualification lot. As a minimum, testing shall be at $2E+12$ n/cm ² , and two additional levels chosen by the manufacturer. If the device degrades less than 5 percent of the specification at the highest fluence level, a single data point may be sufficient. The data presented in the specification sheets demonstrates exposure versus data and does not indicate pass or fail criteria. Alternate package options may be substituted for characterization.	3 devices (for each Neutron Fluence level)

Associated subgroup for the specification sheets

TABLE (X). Group E

<u>Subgroup 12</u>				
Neutron Irradiation		1017	Displacement Damage Characterization, See MIL-PRF-19500 and 6.X herein.	

ATTACHMENT 4: Proposed format of the neutron characterization table for the specification sheets
(using MIL-PRF-19500/255 as an example).

* 6.6 Application data.

TABLE IV. Group E inspection Neutron vendor characterization

	MIL-STD-750			Delta Parameter Value 4/		Unit	Neutron Level (n/cm2)
		Conditions		Mean	St Dev		
		Neutron exposure					
		Sample Size = 5					
Delta Collector to base		Bias condition D; VCB	ΔI_{CB01}	414 399 753	123 79 93	pA dc	3.6E11 6.1E11 2.3E12
		Bias condition D; VEB	ΔI_{EB01}	402 424 674	189 84 126	pA dc	3.6E11 6.1E11 2.3E12
voltage, collector to		Bias condition D; I _C = pulsed (see 4.5.1)	$\Delta V_{(BR)CEO}$	1.31 1.64 2.77	0.71 0.77 0.59	V dc	3.6E11 6.1E11 2.3E12
Delta Collector to		Bias condition C; VCE	ΔI_{CES}	319 319 581	96 71 75	pA dc	3.6E11 6.1E11 2.3E12
Delta Collector to base		Bias condition D; VCB	ΔI_{CB02}	368 367 663	122 67 93	pA dc	3.6E11 6.1E11 2.3E12
		Bias condition D; VEB		30.9 30.4 54.4	17.1 2.83 14.0	pA dc	3.6E11 6.1E11 2.3E12
current transfer ratio		V _{CE} = 10 V dc; I _C =	$\Delta 1/h_{FE1} 5/$	5.80E-04 9.74E-04 3.45E-03	2.22E-05 2.68E-05 6.33E-05		3.6E11 6.1E11 2.3E12
		V _{CE} = 10 V dc; I _C =	$\Delta 1/h_{FE2} 5/$	2.73E-04 4.79E-04 1.75E-03	1.94E-05 1.57E-05 3.27E-05		3.6E11 6.1E11 2.3E12
		V _{CE} = 10 V dc; I _C = 10	$\Delta 1/h_{FE3} 5/$	1.05E-04 2.09E-04 8.15E-04	1.66E-05 1.13E-05 1.29E-05		3.6E11 6.1E11 2.3E12
		V _{CE} = 10 V dc; I _C =	$\Delta 1/h_{FE4} 5/$	2.34E-05 7.42E-05 3.37E-04	1.20E-05 8.63E-06 4.87E-06		3.6E11 6.1E11 2.3E12
		V _{CE} = 10 V dc; I _C =	$\Delta 1/h_{FE5} 5/$	3.74E-04 4.84E-04 1.31E-03	1.46E-05 2.41E-05 1.05E-04		3.6E11 6.1E11 2.3E12
saturation voltage		I _C = 150 mA dc; I _B =	$\Delta V_{CE(sat)1}$	1.86 2.58 7.34	0.32 0.30 0.20	mV dc	3.6E11 6.1E11 2.3E12

Delta Collector-emitter saturation voltage	3071	I _C = 500 mA dc; I _B = 50 mA dc	$\Delta V_{CE(sat)2}$	3.18 4.70 13.0	1.00 0.94 0.64	mV dc	3.6E11 6.1E11 2.3E12
Delta Base-emitter saturation voltage	3066	Test condition A; I _C = 150 mA dc; I _B = 15 mA dc; pulsed (see 4.5.1)	$\Delta V_{BE(sat)1}$	2.90 1.94 3.22	0.49 0.44 0.39	mV dc	3.6E11 6.1E11 2.3E12
Delta Base-emitter saturation voltage	3066	Test condition A; I _C = 500 mA dc; I _B = 50 mA dc; pulsed (see 4.5.1)	$\Delta V_{BE(sat)2}$	1.40 0.60 0.80	1.14 0.89 0.45	mV dc	3.6E11 6.1E11 2.3E12

1/ This data represents typical characterization of the process

2/ For characterization requirements, see MIL-PRF-19500, Table E-IX.

3/ Electrical characteristics apply to the 2N2221A and the 2N2222A with all corresponding AL, UA, UB, and UBC suffix versions unless otherwise noted.

4/ For post radiation degradation (total dose and displacement damage) these values, at the users neutron fluence of interest, must be combined with the Group D, Subgroup 2 endpoints per users requirements.

5/ See method 1019 of MIL-STD-750 for how to determine [h_{FE}] by adding the neutron $\Delta 1/h_{FE}$ with the total dose $\Delta 1/h_{FE}$. Notice the [h_{FE}] is not the same as h_{FE} and cannot be measured directly. The [h_{FE}] value can never exceed the pre-radiation minimum h_{FE} that it is based upon.