NOTICE OF CHANGE

METRIC

MIL-HDBK-815
NOTICE 1
10 January 2002

DEPARTMENT OF DEFENSE
HANDBOOK

DOSE-RATE HARDNESS ASSURANCE
GUIDELINES

TO ALL HOLDERS OF MIL-HDBK-815:

1. THE FOLLOWING PAGES OF MIL-HDBK-815 HAVE BEEN REVISED AND SUPERSEDE THE PAGES LISTED:

NEW PAGE	DATE	SUPERSEDED PAGE	DATE
2	7 November 1994	2	Reprinted without change
3	10 January 2002	3	7 November 1994
4	10 January 2002	4	7 November 1994
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38	10 January 2002	38	7 November 1994
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41	10 January 2002	41	7 November 1994

2. RETAIN THIS NOTICE AND INSERT BEFORE TABLE OF CONTENTS.

3. Holders of MIL-HDBK-815 will verify that page changes and additions indicated above have been entered. This notice page will be retained as a check sheet. This issuance, together with appended pages, is a separate publication. Each notice is to be retained by stocking points until the standard is completely revised or canceled.

Custodian
Army – CR
Navy – EC
Air Force – 19
DLA–CC

Review activities
Army – AR, SM
Navy – AS, CG, MC, OS, SH
Air Force – 11, 99
NASA – NA
DTRA – DS

Preparing activity
DLA - CC

(Project 59GP-0177)

AMSC N/A

FSC 59GP

DISTRIBUTION STATEMENT A. Approved for public release; distribution is unlimited.

1.6.1 Design documentation. This is a collection of information on the design hardening techniques used, the survivability/vulnerability analysis, configuration and quality control, test data, procurement specifications, management, and any other information necessary for production of the systems: 1/

1.6.1.1 Typical documentation. These documents may vary between systems, but a common set would contain the following:

a. An introduction. Providing a general systems operation and functional description.

b. An HCI Index. Providing a hardness critical item list which relates hardness critical parts to their application. The hardness criticality is indicated and cross-referenced to analysis.

c. A hardness assurance plan. Presenting the management organization and technical requirements which are to be implemented throughout the production period.

d. An analysis discussion. Containing the survivability/vulnerability analysis and any related information.

1/ For a more complete description of the HADD, see 6.1 herein.

2. APPLICABLE DOCUMENTS

2.1 General. The documents listed below are not necessarily all of the documents referenced herein, but are the ones that are needed in order to fully understand the information provided by this handbook.

2.2 Government documents.

2.2.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the latest issue of the Department of Defense Index of Specifications and Standards (DoDISS) and supplement thereto.

SPECIFICATIONS

DEPARTMENT OF DEFENSE

MIL-PRF-19500 - Semiconductor Devices, General Specification for.

MIL-M-38510 - Microcircuits, General Specification for.

MIL-PRF-38535 - Integrated Circuits (Microcircuits) Manufacturing, General Specification for.

STANDARDS

DEPARTMENT OF DEFENSE

MIL-STD-202 - Test Method Standard, Electronic and Electrical Component Parts.

MIL-STD-750 - Test Method Standard for Semiconductor Devices.

MIL-STD-883 - Test Method Standard, Microcircuits.

HANDBOOKS

DEPARTMENT OF DEFENSE

MIL-HDBK-814 - Ionizing Dose and Neutron Hardness Assurance Guidelines for Microcircuits and Semiconductor Devices.

MIL-HDBK-816 - Guidelines for Developing Radiation Hardness Assurance Device Specifications.

MIL-HDBK-817 - System Development Radiation Hardness Assurance.

(Unless otherwise indicated, copies of the specifications, standards, and handbooks are available from the Document Automation and Production Services (DAPS), Building 4D (DPM-DODSSP), 700 Robbins Avenue, Philadelphia, PA 19111-5094.)

2.3 Non-Government publications. The following documents form part of this document to the extent specified herein. Unless otherwise specified, the issues of the documents which are DoD adopted are those listed in the latest issue of the DoDISS, and supplement thereto.

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM E666 - Standard Practice for Calculating Absorbed Dose from Gamma or X Radiation.

ASTM E668 - Standard Practice for Application of Thermoluminescence-Dosimetry (TLD) Systems for Determining Absorbed Dose in Radiation-Hardness Testing of Electronic Devices.

ASTM F448 - Standard Test Method for Measuring Steady-State Primary Photocurrent.

ASTM F526 - Standard Test Method for Measuring Dose for Use in Linear Accelerator Pulsed Radiation Effects Tests.

ASTM F744 - Standard Test Method for Measuring Dose Rate Threshold for Upset of Digital Integrated Circuits.

(Application for copies should be addressed to the American Society for Testing and Materials (ASTM), 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.)

(Non-Government standards and other publications are normally available from the organizations that prepare or distribute the documents. These documents also may be available in or through libraries or other informational services.)

2.4 Order of precedence. In the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. DEFINITIONS

3.1 Acronyms used in this handbook. The acronyms used in this handbook are as follows:

a. CCB - Configuration Control Board
b. HA - Hardness assurance
c. HADD - Hardness assurance design documentation
d. HCC - Hardness-critical category
e. HCI - Hardness critical item
f. HM - Hardness maintenance
g. HNC - Hardness noncritical
h. PMPCB - Parts, Material and Process Control Board
i. SPO - System Project Office. (The SPO is the overall controlling organization for the project under consideration. It is intended to be a generic term so as to standardize, for the purposes of this document, such expressions as system, system project, Project Manager's Office, Project Manager, procurement agency, and contracting agency.)

3.2 Definitions and symbols. For the purpose of this handbook the following definitions and symbols shall apply.

3.2.1 Burnout. Burnout is the failure of a device subjected to electrical overstress. Typically, thermal damage has occurred within one or more device junctions or within the device metallization.

3.2.2 Confidence level. Confidence level (C) is the probability (usually given in percent) that at least a portion (P_{DIST}) of the parts in the lot will survive.

3.2.3 Cumulative probability. Cumulative probability (P_{DIST}) is the percentage or proportion of a probability distribution which is below a given upper limit or above a given lower limit.

3.2.4 Design margin break point. Design margin break point (DMBP) is a categorization method which provides a criterion which may apply to all parts in a system and is based on a single fixed value of design margin.

3.2.5 Dose rate. Dose rate (γ) is the dose rate level under consideration. It is usually stated in terms of rads(Si)/second.

3.2.6 Dose rate design margin. Dose rate design margin ($DM\gamma$) is the ratio of the mean failure dose rate to a specified dose rate.

3.2.7 Dose rate to failure value. Dose rate failure value (γ_{FAIL}) is the dose rate level for the part under test at which a parameter designated as PAR_{RAD} equals PAR_{FAIL}.

3.2.8 Environment. Dose rate effects may be caused by a variety of ionizing radiation environments. These environments may consist of neutrons, photons, electrons, or single particle ionization. The methods which are used to harden against the various environments may vary from one environment to another. For example, shielding can be an effective tool for some low energy x-rays but may be ineffective for higher energy gamma rays. In contrast, even though the hardening methods may be different, one may find that the hardness assurance procurement procedures may be similar regardless of the environment.

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APPENDIX B

DOSE-RATE TESTING

10. Scope.

10.1 Scope. This appendix covers the various radiation sources used when performing dose-rate testing. This appendix is a mandatory part of the handbook. The information contained herein is intended for guidance only.

10.2 Radiation testing. The most common radiation sources which are used for dose-rate testing of semiconductor components are the linear accelerator (Linac) and the flash x-ray (FXR) machine. Because of the wide variety of components, and much wider variety of ways that a component may be used in a circuit, a radiation test plan and report are required for the proper documentation and performance of the tests. Except for dosimetry, test details will vary from one device type to another.

10.2.1 Linacs. In general, Linacs are useful for testing devices in dose-rate ranges from 1×10^6 to 1×10^{11} rads(Si)/s, with variable pulsewidths.

10.2.2 FXRs. FXR machines cover the same dose-rate range. A few large machines can reach 10^{12} rads(Si)/s. Those that can be operated in the electron beam mode can go above 10^{13} rads(Si)/s. All operate at only a single pulsewidth.

20. APPLICABLE DOCUMENTS

20.1 Non-Government publications. The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of the documents which are DoD adopted are those listed in the latest issue of the DoDISS and supplement thereto. Unless otherwise specified, the issues of documents not listed in the DoDISS are the issues of the documents cited in the solicitation.

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM E666 - Standard Practice for Calculating Absorbed Dose from Gamma or X Radiation.

ASTM E668 - Standard Practice for Application of Thermoluminescence-Dosimetry (TLD) Systems for Determining Absorbed Dose in Radiation-Hardness Testing of Electronic Devices.

ASTM F448 - Standard Test Method for Measuring Steady-State Primary Photocurrent.

ASTM F526 - Standard Test Method for Measuring Dose for Use in Linear Accelerator Pulsed Radiation Effects Tests.

(Copies of these documents may be obtained from American Society for Testing and Materials (ASTM), 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.)

Note: Several standard test methods and standard practices have been developed for use in measuring the ionizing radiation environment. These documents should be consulted when radiation tests are performed.

A number of relevant test methods are available in the military standards system. The following can be found in MIL-STD-883:

Method 1020 “Dose Rate Induced Latchup Test Procedure”

Method 1021 “Dose Rate Upset Testing of Digital Microcircuits”

Method 1023 “Dose Rate Response of Linear Microcircuits”

30. CAUTIONS

30.1 Cautions. There are a number of test variables which must be considered when dose-rate tests are performed. Clearly, good engineering practice must be exercised, and correct radiation test procedures must be followed. Some of the test concerns are as follows.

30.1.1 Air ionization. The radiation pulse can cause air ionization which can result in a spurious component of the measured signal. The presence of these signals can be checked by irradiation of the test fixture without the device being installed. The effect can be minimized by coating the DUT chip and bond wires with silicone or a similar material.

30.1.2 Secondary emission. Charge emission from, or charge injection into, the test device and test circuit can also result in a spurious component of the measured signal. In contrast to air ionization, secondary emission effects are generally not field dependent, and therefore it is possible to separate the two effects. Secondary emission can be reduced by shielding the surrounding area and irradiating the device only.

30.1.3 Orientation. The effective dose to the semiconductor device can be altered by orientation. Severe dose gradients in a radiation field, along with package shielding may result in non-uniform, and even unknown doses in regions of the devices. Care must be taken in the positioning of devices in the radiation field.

30.1.4 Dose enhancement. High atomic number material near the active regions of the test device can cause an enhancement of the dose delivered to sensitive regions of the device when the device is irradiated at an FXR. The effect is energy dependent, increasing with lower energies. The extent of this effect must be considered in any FXR dose-rate testing.

30.1.5 Noise. Most pulsed radiation facilities are inherent sources of r-f noise. Such noise minimizing techniques as single-point ground, filtered power supply lines, etc., must be used when attempts are made to make quality data measurements through the radiation pulse.

30.1.6 Dosimetry. Accurate dose-rate monitors for dose-rate testing are not readily available. Generally, the total dose delivered in each pulse is measured along with some type of measurement of the pulse shape. The dose-rate is then calculated. Good dosimetry practice must be used in order to provide accurate dose-rate values.

30.1.7 Temperature. Many dose-rate effects are temperature sensitive. A notable example is latchup in integrated circuits. The temperature during the test should be controlled, and for latchup, a elevated test temperature must be chosen.

30.1.8 Total dose. Some dose-rate effects, such as upset, are generally nondestructive to the device. Therefore, some devices may be screened on a 100 percent basis to determine the upset threshold. However, each pulse of the radiation source imparts some total dose to the device. The accumulated total dose delivered to the device during dose-rate testing may alter the response of the device or cause total dose failure. Care must be taken to ensure that the total dose delivered to the device during dose-rate testing does not cause damage to the device which can mask the dose rate effects.

40. REFERENCES

40.1 References. The documents listed in this section were used as references for the preparation of this appendix.

40.1.1 “TREE Preferred Procedures, Selected Electronic Parts,” DNA 2028H, January 31, 1982.

40.1.2 “Practice for the Application of Thermoluminescence-Dosimetry (TLD) Systems for Determining Absorbed Dose in Radiation-Hardness Testing of Electronic Devices,” ASTM E668.

40.1.3 “Method of Dose Measurement for Use in Linear Accelerator Pulsed Radiation Effects Tests,” ASTM E526.

APPENDIX C

ONE-SIDED TOLERANCE FACTORS

10. SCOPE

10.1 Scope. The purpose of this appendix is to present some of the techniques necessary for dose-rate hardness assurance. A complete treatment is not given, only the information required to use this document is presented. This appendix is a mandatory part of the handbook. The information contained herein is intended for guidance only.

10.1.1 Overview. Hardness assurance applications generally involve statistical techniques to determine the adequacy of design margins in achieving required survival probabilities.

20. APPLICABLE DOCUMENTS. This section is not applicable to this appendix.

30. SAMPLING

30.1 Sampling. Most hardness assurance techniques require some sort of sampling and statistical extrapolation to the parent population. The results of sampling are most frequently reported in terms of a confidence, C, that at least a proportion, P, of the lot will not fail under actual test.

30.1.1 Tests. Two kinds of test are often performed on the selected sample to determine the population characteristics.

30.1.1.1 Sampling by attribute. The first is termed “sampling by attribute”. In sampling by attribute, some characteristic of the item is monitored. For example, upset testing at a single dose rate would determine whether or not the semiconductor devices within a selected sample of devices would upset or not at that dose rate. This would be a “go-no-go” situation. Either the device upset or not at the particular dose rate. No information would be obtained on the exact threshold for upset or the distribution of the threshold for upset. This kind of test is often handled by using the method of Lot Tolerance Percent Defective (LTPD), to make predictions about failure probabilities.

30.1.1.2 Sampling by variable. The second method of sampling is termed “sampling by variable”. In this case, a measurement is made of some critical parameter in a sample. For example, the upset threshold of each semiconductor device in a sample may be measured in terms of the threshold dose rate for upset. Sampling by variable lends itself well to the application of statistical techniques, provided the statistical distribution of the data is known.

30.2 Normal and log-normal statistics. For hardness assurance applications, normal and log-normal statistics are often used (see 50.1.1 herein). A check should always be made to see if the application of a particular statistical distribution to the data is proper. Most often, for radiation effects, the log-normal distribution is assumed, even though the actual distribution of data is not known. There is evidence that even if the log-normal distribution is not exactly correct, its use can still provide good engineering approximations to the hardness assurance problem. In log-normal distribution, the logarithms of the quantities are distributed normally.

40. SAMPLING BY VARIABLES - ONE-SIDED TOLERANCE LIMITS

40.1 One-sided tolerance limits. One statistical technique used with sampling by variable data is the method known as the one-sided tolerance limit. If a parameter is known to be normally distributed, then the estimates of lot quality can be obtained with small samples. Thus, if the parameter, x, is normally distributed (x may be the logarithm of a parameter), and n items are sampled, then a lot is rejected if the limiting quantity, L, exceeds a value, L_{MAX}, where:

$$L = m + K_{TL}(n, C, P)s,$$

where:

- m is the measured mean of the sample,
- s is the standard deviation of the sample,
- C is the required confidence level, and
- P is the required survival probability, or lot quality.

The one-sided tolerance limit factor, K_{TL}, is a function of the sample size, n, the confidence, C, and the lot quality, P. The statistical statement that can be made is that if more than the proportion, P, devices of the parent distribution has values of x less than L_{MAX}, then the lot will be rejected with probability, C. L_{MAX} may be a parameter selected such that if its value is exceeded, then failure will occur.

40.2 Minimum parameter formulation. In many hardness assurance applications, the critical parameter may be a minimum and not a maximum. The formulation is similar, and a lot is rejected if the quantity, L, is less than L_{MIN} where

$$L = m - K_{TL}(n, C, P)s,$$

where the quantities have been previously defined. In this case, L_{MIN} may be a parameter value, selected such that if the actual value falls below this value, system failure will occur.

40.3 One-sided tolerance. Table VIII is a table of one-sided tolerance factors for some of the most frequently used lot qualities and 90 percent confidence.

TABLE VIII. One-sided tolerance limits, K_{TL}.

C = 0.9					
	P				
N	0.9	0.95	0.99	0.999	0.9999
3	4.259	5.311	7.340	9.651	11.566
4	3.188	3.957	5.438	7.129	8.533
5	2.742	3.400	4.666	6.111	7.311
6	2.493	3.091	4.243	5.555	6.645
7	2.332	2.894	3.972	5.202	6.222
8	2.218	2.755	3.783	4.955	5.927
9	2.133	2.649	3.641	4.771	5.708
10	2.065	2.568	3.532	4.628	5.538
11	2.011	2.503	3.443	4.514	5.402
12	1.966	2.448	3.371	4.420	5.290
13	1.928	2.403	3.309	4.341	5.196
14	1.895	2.363	3.257	4.273	5.116
15	1.867	2.329	3.212	4.215	5.046
16	1.842	2.299	3.172	4.164	4.986
17	1.819	2.272	3.137	4.119	4.932
18	1.800	2.249	3.105	4.078	4.884
19	1.781	2.228	3.077	4.042	4.841
20	1.765	2.208	3.052	4.089	4.802
21	1.750	2.190	3.028	3.979	4.766
22	1.736	2.174	3.006	3.952	4.734
23	1.724	2.159	2.987	3.926	4.704
24	1.712	2.145	2.969	3.903	4.677
25	1.701	2.132	2.952	3.882	4.651
30	1.657	2.080	2.884	3.794	4.546
35	1.623	2.041	2.833	3.729	4.470
40	1.598	2.010	2.793	3.678	4.411
45	1.575	1.986	2.761	3.638	4.363
50	1.559	1.965	2.735	3.605	4.324
60	1.532	1.933	2.694	3.552	4.262
70	1.511	1.909	2.662	3.513	4.215
80	1.494	1.890	2.637	3.482	4.178
90	1.481	1.874	2.617	3.456	4.148
100	1.470	1.861	2.601	3.435	4.124