

ENGINEERING PRACTICE STUDY

PROJECT NUMBER: 5961–2018–068

TITLE:

MIL–STD–750–4, TEST METHOD 4016:
PROPOSED REVISION TO CLARIFY THE TESTING PROCEDURES,
ADDRESS AUTOMATIC TEST EQUIPMENT AND REFORMAT CONTENT

30 JANUARY 2019

FINAL REPORT

STUDY CONDUCTED BY

DLA LAND AND MARITIME
Document Standardization Division (VA)
Active Device Branch (VAC) – VAC

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Approved by:
Thomas Hess
Chief

ATTCH 2

I. OBJECTIVES: The objective of this Engineering Practice (EP) Study was to obtain input from the military services, device manufacturers, laboratories, and user community concerning the proposed revision to test method 4016 of MIL-STD-750-4.

II. BACKGROUND: Test method 4016 of MIL-STD-750-4 had not been thoroughly reviewed for updating for a number of years. The current revision, 4016.4, was last updated with the issuance of change 3 to MIL-STD-750D on 29 February 2000. The changes made to the test method at that time were only editorial in nature.

DLA Land and Maritime had requested that military services (custodians and review activities), device manufacturers, OEMs, and laboratories using the subject test method to review a proposed revision. The proposed revision included both format and technical changes. A new test condition (condition B) was also proposed for inclusion.

III. RESULTS: All comments received regarding the proposed content and format changes were resolved and have been incorporated into the final draft of the test method. Both a clean reader draft (see attachment 1) and mark-up source draft with key (see attachment 2) have been included for viewing.

IV. CONCLUSIONS: The highlighted changes to the test method (see attachment 1) should be proposed for incorporation into the next standardization document change action to MIL-STD-750-4.

V. RECOMMENDATIONS: Prepare an initial draft of MIL-STD-750-4 with the results of this study used for the draft of test method 4016.5.

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METHOD 4016.5

REVERSE CURRENT LEAKAGE

1. **Purpose.** The purpose of this test method is to measure the reverse current leakage through a device at a specified reverse voltage.

2. **Test condition overview.** This test method has three different conditions: an ac method and two dc methods. A summary of each condition is as follows:

Condition A (dc method). The procedure for this condition uses a steady state dc reverse voltage to stimulate the device under test (DUT) and the resulting reverse current is measured. The measurement is typically performed under conditions of thermal equilibrium and thermal management is usually necessary.

Condition B (pulsed dc method). The procedure for this condition uses a dc reverse voltage pulse of the specified duration to stimulate the DUT and the resulting reverse current is measured. Thermal management is generally unnecessary for devices with low leakage currents.

Condition C (ac method). The procedure for this condition uses a curve tracer to stimulate the DUT. The reverse current can be determined by observing the curve tracer waveform at the specified reverse voltage.

3. **Definitions, symbols, and terms.** The following definitions, symbols, and terms shall apply to this test method.

3.1 **Symbols.** The following symbols shall apply for the purpose of this test method:

I_R Reverse current (dc).

I_{RM} Maximum (peak) reverse current (ac).

V_R Reverse voltage (dc).

V_{RM} Maximum (peak) reverse voltage (ac).

3.2 **Reverse current.**

- a. The current flowing from the external circuit into the cathode terminal.
- b. The current that flows from the external circuit into the cathode terminal at a specified reverse voltage V_R below the onset of breakdown.

3.3 **Maximum (peak) reverse current.** The value of maximum instantaneous reverse current measured under specified conditions of temperature and reverse voltage.

3.4 **Reverse voltage.**

- a. A positive cathode-anode voltage.
- b. The positive cathode-anode voltage that is specified as a test condition for reverse current (I_R).

4. General requirements.

4.1 Apparatus. The apparatus used to determine the reverse current leakage shall be capable of applying the specified reverse voltage to the DUT and measuring the resulting parameters.

4.1.1 Discrete test instrumentation. The apparatus required for this test method shall include the applicable test instrumentation and circuits shown on [figures 4016–1, 4016–2 and 4016–3](#) and the following as applicable to the specified test condition:

- a. Ammeter (A), resistor (R), variable voltage source, and voltmeter (V) as needed. Required for conditions A and B only.
- b. Electronic switch or pulse generator. Required for condition B only.
- c. Curve tracer. The curve tracer shall be a Tektronix Type 370, 371 or equivalent. Required for condition C only.
- d. Oscilloscope or automatic test equipment (ATE). Optional for all test conditions.

4.1.2 Electronic switch or pulse generator. When specified, switch SW1 as shown in the test circuit (see figure 4016–2) shall consist of either an electronic switch or a pulse generator to provide pulses of short-duty cycle to minimize device heating.

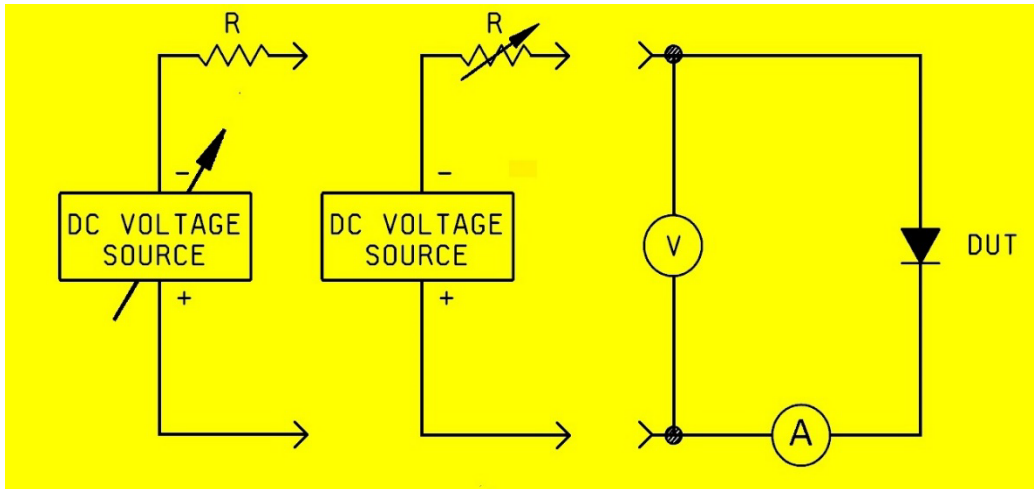
4.1.3 ATE. ATE can be used in lieu of the discrete test instrumentation and circuit shown on [figures 4016–1, 4016–2 and 4016–3](#). When used, the ATE shall be capable of establishing the required test conditions and measuring the required electrical parameters specified for the reverse current leakage tests.

4.2 Accessories for testing. Accessories for testing can include cold plates, fans, fluid or gas coolants, heat sinks, thermal compounds, thermocouples, etc., as needed for thermal management. Accessories may be necessary for condition A and are optional for conditions B and C.

5. Detailed requirements.

5.1 Procedure.

5.1.1 Condition A (dc method) (see [figure 4016–1](#)). The specified steady state dc reverse voltage V_R shall be applied to the DUT by varying either the variable voltage source or the resistor (R) of the test circuit. The dc reverse voltage V_R shall be measured using a dc voltmeter (V). The reverse current leakage I_R shall be measured using an ammeter (A). The voltmeter connections shall be made at specified points on the DUT (see figure 4016–1) and always within the current connection points. As needed, appropriate thermal management shall be used and the DUT shall be monitored so as not to exceed the specified temperature rise.



NOTE: To assure accurate measurement of reverse leakage current I_R , the voltage drop across the ammeter shall be subtracted from the measured value of reverse voltage. Resistor (R) shall be chosen to limit the current flow in the event the device goes into reverse breakdown.

FIGURE 4016-1. Steady state dc voltage reverse current leakage test circuit (condition A).

5.1.2 Condition B (pulsed dc method) (see figure 4016-2). The specified dc reverse voltage V_R pulse shall be applied to the DUT by adjusting the electronic switch (or when used, the pulse generator or ATE) to achieve the specified amplitude, frequency, and pulse width values (see 5.3). An oscilloscope (or ATE) shall be used to measure the pulse characteristics. After adjusting pulse parameters to the correct values for the required dc reverse voltage V_R , measure dc reverse current leakage I_R .

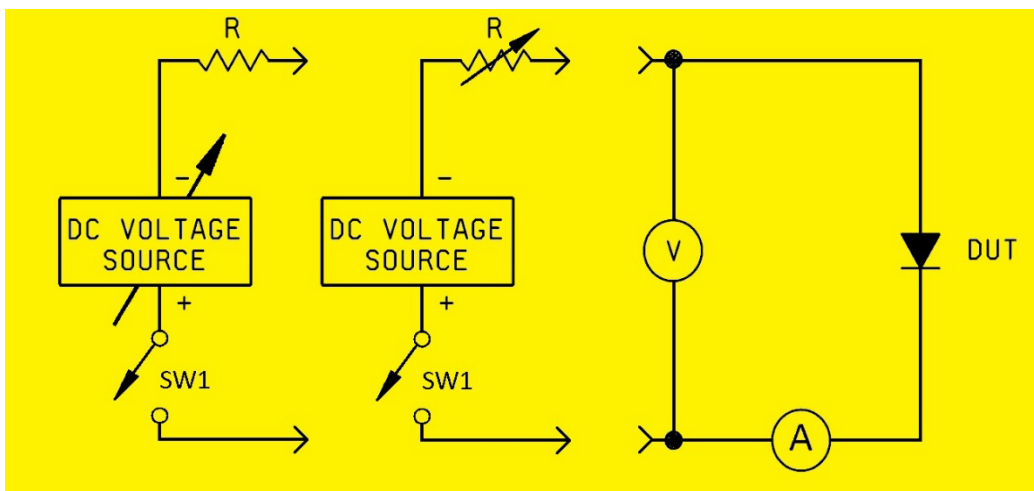
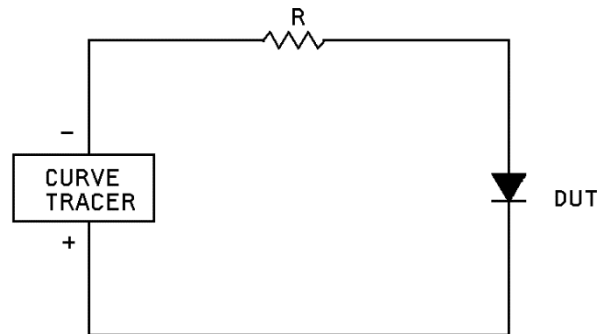


FIGURE 4016-2. Pulsed dc reverse current leakage test circuit (condition B).

5.1.3 Condition C (ac method) (see figure 4016–3). The DUT shall be tested by applying a positive voltage to the cathode and limiting the voltage to within the manufacturer's ratings for peak reverse voltage V_{RM} . The peak reverse current leakage shall be determined by observing the curve tracer waveform at the specified peak reverse voltage V_{RM} . Current and voltage shall be measured on the curve tracer.



NOTE: The resistor (R) is a selectable value within the curve tracer.

FIGURE 4016–3. AC voltage test circuit for reverse current leakage (condition C).

5.2 Measurements. The parameter to be measured shall be the dc reverse current leakage I_R (conditions A and B) or peak reverse current I_{RM} (condition C).

5.2.1 Details for conditions A. When steady state dc techniques are used, device thermal equilibrium shall be achieved before the measurements are made.

5.2.2 Details for condition B. When pulse techniques are used, suitable peak reading methods shall be used to measure the parameters of the pulse amplitude, frequency, duty cycle, waveform and width.

5.3 DC reverse voltage pulse parameters. The dc reverse voltage pulse parameters shall be as specified (see 6.a.2). When the pulse parameters are not specified, the following guidelines should be followed: In order to avoid significant heating of the junction during the test for reverse current, the width of the reverse voltage pulse used should not exceed 8.3 milliseconds and the repetition rate of the pulses should be low enough to impose a duty cycle of no more than 2 percent.

6. Summary. The following details should be specified in the applicable performance specification sheet or acquisition document:

a. Test condition letter.

1) For condition A: The dc reverse voltage.

2) For condition B: The peak dc reverse voltage and the specific pulse parameters (pulse width, repetition rate, and wave form shape) if the pulse differs the guidelines of 5.3.

3) For condition C: The peak reverse voltage.

b. Thermal resistance of minimum heat dissipater on which device is mounted in °C/W (where applicable).

c. Thermal equilibrium or pulse condition such as specified in test method 4000. (If pulse testing is not specified, thermal equilibrium dc test method correlation will be applicable. This may include pulse measurement intended to correlate to steady-state dc measurement as described in test method 4000.)

7. Test condition supersession. The past revisions of this test method (4016.4 and earlier) detailed only two test methods (dc method or ac method). This revision added a new test condition (condition B) to address a dc pulse method. The original test conditions and identifying names have been superseded as follow:

a. Test condition A has superseded the "dc method" of past revisions.

b. Test condition C has superseded the "ac method" of past revisions.

METHOD 4016.4.5

REVERSE CURRENT LEAKAGE

1. **Purpose.** The purpose of this test method is to measure the reverse current leakage through a device at a specified reverse voltage ~~using a dc method or an ac method, as applicable.~~

2. **Test condition overview.** This test method has three different conditions: an ac method and two dc methods. A summary of each condition is as follows:

Condition A (dc method). The procedure for this condition uses a steady state dc reverse voltage to stimulate the device under test (DUT) and the resulting reverse current is measured. The measurement is typically performed under conditions of thermal equilibrium and thermal management is usually necessary.

Condition B (pulsed dc method). The procedure for this condition uses automatic test equipment (ATE) to apply a dc reverse voltage pulse of the specified duration to stimulate the DUT and the resulting reverse current is measured. ~~In order to avoid significant heating of the junction during the test for reverse current, the width of the voltage pulse used to make the measurement should not exceed 8.3 milliseconds and the repetition rate of the pulses should be low enough to impose a duty cycle of no more than 2 percent.~~ Thermal management is generally unnecessary for devices with low leakage currents.

Condition C (ac method). The procedure for this condition uses a curve tracer to stimulate the DUT. The reverse current can be determined by observing the curve tracer waveform at the specified reverse voltage.

3. **Definitions, symbols, and terms.** The following definitions, symbols, and terms shall apply to this test method.

3.1 **Symbols.** The following symbols shall apply for the purpose of this test method:

I_R Reverse current (dc).

I_{RM} Maximum (peak) reverse current (ac).

V_R Reverse voltage (dc).

V_{RM} Maximum (peak) reverse voltage (ac).

3.2 **Reverse current.**

- a. The current flowing from the external circuit into the cathode terminal.
- b. The current that flows from the external circuit into the cathode terminal at a specified reverse voltage V_R below the onset of breakdown.

3.3 **Maximum (peak) reverse current.** The value of maximum instantaneous reverse current measured under specified conditions of temperature and reverse voltage.

3.4 **Reverse voltage.**

- a. A positive cathode-anode voltage.
- b. The positive cathode-anode voltage that is specified as a test condition for reverse current (I_R).

4. General requirements.

4.1 Apparatus. The apparatus used to determine the reverse current leakage shall be capable of applying the specified reverse voltage to the DUT and measuring the resulting parameters.

4.1.1 Discrete test instrumentation. The apparatus required for this test method shall include the applicable test instrumentation and circuits shown on figures 4016-1, 4016-2 and 4016-3 and the following as applicable to the specified test condition:

- a. Ammeter (A), resistor (R), variable voltage source, and voltmeter (V) or oscilloscope as needed. Required for conditions A and B only.
- b. Electronic switch or pulse generator. Automatic test equipment (ATE). The ATE shall be capable of establishing the required test conditions and measuring the required electrical parameters to perform the specified reverse current leakage tests. Required for condition B only.
- c. Curve tracer. The curve tracer shall be a Tektronix Type 370, 371 or equivalent. Required for condition C only.
- d. Oscilloscope or automatic test equipment (ATE). Optional for all test conditions.

4.1.2 Electronic switch or pulse generator. When specified, switch SW1 as shown in the test circuit (see figure 4016-2) shall consist of either an electronic switch or a pulse generator to provide pulses of short-duty cycle to minimize device heating.

4.1.3 ATE. ATE can be used in lieu of the discrete test instrumentation and circuit shown on figures 4016-1, 4016-2 and 4016-3. When used, the ATE shall be capable of establishing the required test conditions and measuring the required electrical parameters specified for the reverse current leakage tests.

4.2 Accessories for testing. Accessories for testing can include cold plates, fans, fluid or gas coolants, heat sinks, thermal compounds, thermocouples, etc., as needed for thermal management. Accessories may be necessary for condition A and are optional for conditions B and C.

5. Detailed requirements.

5.1 Procedure.

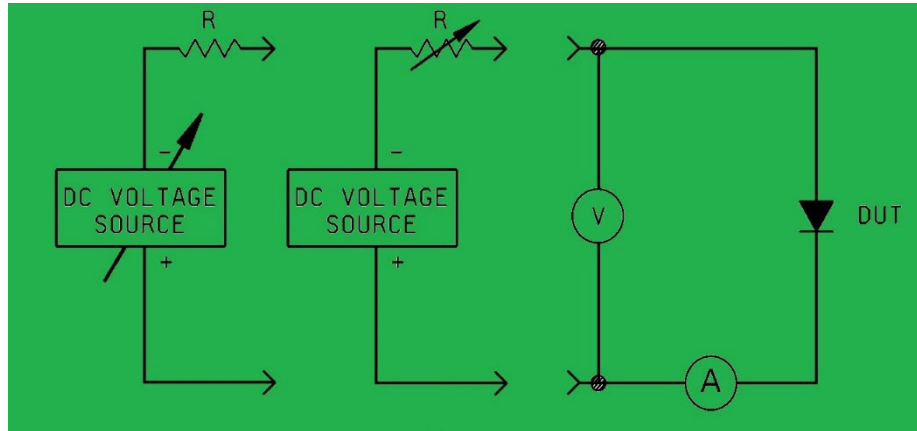
~~2. DC method.~~

~~2.1 Test circuit. See figure 4016-1.~~

~~2.2 Procedure.~~

~~2.2.1 Reverse current. The dc voltage shall be adjusted to the specified value by voltmeter (V) and the reverse current (I_R) shall be measured by current meter (I).~~

5.1.1 Condition A (dc method) (see figure 4016-1). The specified steady state dc reverse voltage V_R shall be applied to the DUT by varying either the variable voltage source or the resistor (R) of the test circuit. The dc reverse voltage V_R shall be measured using a dc voltmeter (V). The reverse current leakage I_R shall be measured using an ammeter (A). The voltmeter connections shall be made at specified points on the DUT (see figure 4016-1) and always within the current connection points. As needed, appropriate thermal management shall be used and the DUT shall be monitored so as not to exceed the specified temperature rise.



NOTE: To assure accurate measurement of reverse leakage current I_R , the voltage drop across the ammeter shall be subtracted from the measured value of reverse voltage. Resistor (R) shall be chosen to limit the current flow in the event the device goes into reverse breakdown.

FIGURE 4016-1. Steady state dc voltage reverse current leakage test circuit (condition A dc method).

5.1.2 Condition B (pulsed dc method) (see figure 4016-2). The specified dc reverse voltage V_R pulse shall be applied to the DUT by adjusting the electronic switch (or when used, the pulse generator or by programming the ATE) to achieve the specified amplitude, frequency, and pulse width values (see 5.3 6.a.2). An oscilloscope (or The ATE) shall be used to measure the pulse characteristics. After adjusting pulse parameters to the correct values for the required dc reverse voltage V_R , measure dc reverse current leakage I_R .

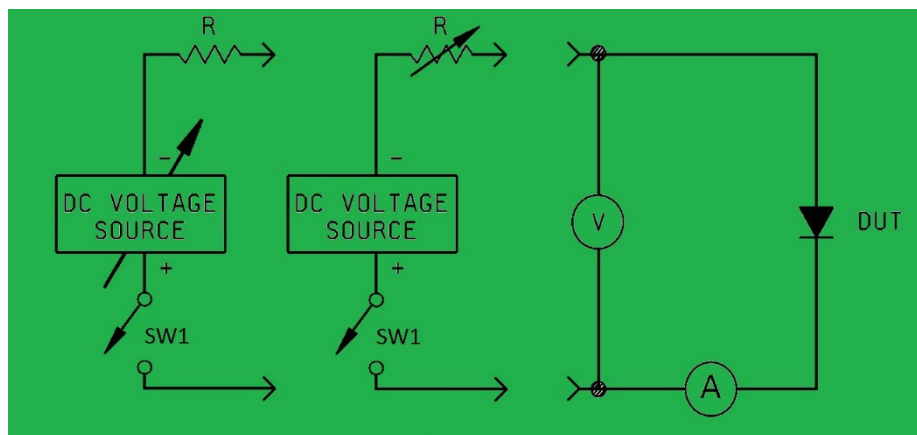


FIGURE 4016-2. Pulsed dc reverse current leakage test circuit (condition B).

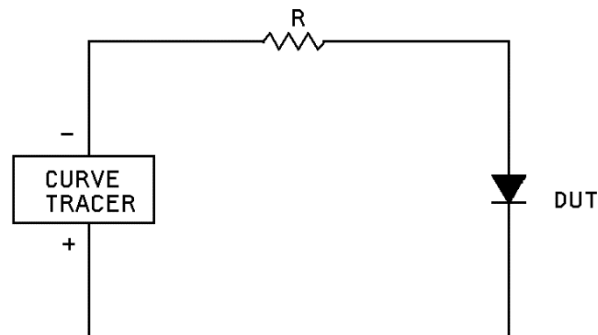
3. AC method.

3.1 Test circuit. See figure 4016-2.

3.2 Procedure.

3.2.1 Reverse current. A Tektronix 576-curve tracer or equivalent shall be used to apply voltage in the reverse direction only. The curve tracer supply shall be adjusted to obtain the specified peak reverse voltage across the device. Current and voltage shall be measured on the curve tracer.

5.1.3 Condition C (ac curve tracer method) (see figure 4016-3). The DUT shall be tested by applying a positive voltage to the cathode and limiting the voltage to within the manufacturer's ratings for peak reverse voltage V_{RM} . The peak reverse current leakage shall be determined by observing the curve tracer waveform at the specified peak reverse voltage V_{RM} . Current and voltage shall be measured on the curve tracer.



NOTE: The resistor (R) is a selectable value within the curve tracer.

FIGURE 4016-2.3. AC voltage test circuit for reverse current leakage (condition C ac method).

5.2 Measurements. The parameter to be measured shall be the dc reverse current leakage I_R (conditions A and B) or peak reverse current I_{RM} (condition C).

5.2.1 Details for conditions A. When steady state dc techniques are used, device thermal equilibrium shall be achieved before the measurements are made.

5.2.2 Details for condition B. When pulse techniques are used, suitable peak reading methods shall be used to measure the parameters of the pulse amplitude, frequency, duty cycle, waveform and width.

5.3 DC reverse voltage pulse parameters. The dc reverse voltage pulse parameters shall be as specified (see 6.a.2). When the pulse parameters are not specified, the following guidelines should be followed: In order to avoid significant heating of the junction during the test for reverse current, the width of the reverse voltage pulse used should not exceed 8.3 milliseconds and the repetition rate of the pulses should be low enough to impose a duty cycle of no more than 2 percent.

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MARK-UP AND SOURCE DRAFT

6. ~~4.~~ Summary. The following ~~conditions shall~~ details should be specified in the applicable performance specification sheet or acquisition document:

- a. ~~DC or ac method.~~ Test condition letter.
- b. ~~1) For condition A: The dc reverse test voltage (dc method) or~~
 - 2) For condition B: The ~~ATE~~ peak dc reverse voltage ~~pulse~~ and the specific pulse parameters (pulse width, repetition rate, and wave form shape) if the pulse differs the guidelines of ~~5.3~~
 - 3) For condition C: The peak reverse voltage (~~ac method~~).
- b e. Thermal resistance of minimum heat dissipater on which device is mounted in °CW (where applicable).
- c d. Thermal equilibrium or pulse condition such as specified in ~~JEDEC-JESD320~~ test method 4000. (If pulse testing is not specified, thermal equilibrium dc test method correlation will be applicable. This may include pulse measurement intended to correlate to steady-state dc measurement as described in ~~JEDEC-JESD320~~ test method 4000.)

7. Test condition supersession. The past revisions of this test method (4016.4 and earlier) detailed ~~on only two~~ test methods (dc method or ac method). This revision added a new test condition (condition B) to ~~cover~~ address a dc pulse ~~ATE~~ methods. The original test conditions and identifying names have been superseded as follow:

- a. Test condition A has superseded the "dc method" of past revisions.
- b. Test condition C has superseded the "ac method" of past revisions.

KEY to HIGHLIGHTING:

Text ~~highlighted in yellow~~ was added and ~~red text with strike-out~~ will be removed. The source of these changes were from a MIL-PRF-19500 qualified manufacturer. These changes were included in the initial draft.

Text or figures ~~highlighted in green~~ was added and ~~red text with strike-out and highlighted in blue~~ will be removed. The source of these changes were from comments made to the initial draft.