Device Hardware Reliability Test Plan

Version 2.2.1

November 2022

CTIA Certification LLC
1400 16th Street, NW
Suite 600
Washington, DC 20036

1.202.785.0081

programs@ctiacertification.org

https://ctiacertification.org/test-plans/

Table of Contents

List of Figures

List of Tables

Section 1 Introduction

1.1 Purpose

The purpose of this document is to define a minimum set of industry standardized smartphone hardware reliability test procedures. It is designed with the intent to minimize both test cost and test time within the industry by aligning test methodology amongst all participants.

With aligned test methodologies, smartphone manufacturers and network operators can run the same test procedures, while at the same time retaining the flexibility to define their unique acceptance criteria. This is accomplished by incorporating a standard stress test cycle for each test environment and allowing participants to define the number of stress cycles required to pass or fail. This provides the further benefit of allowing manufacturers and service providers to have an understanding of the device's performance margin against the common test requirement.

1.2 Scope

The scope of testing is limited to the hardware reliability of smartphones (generally less than 92mm in width).

1.3 Documents

The following documents are referenced in this test plan. Unless otherwise specified, the latest released version shall be used:

- IEC 60068-2-31, Environmental testing - Part 2-31: Tests - Test Ec: Rough handling shocks, primarily for equipment-type specimens
- IEC 60529, Degrees of Protection Provided by Enclosures (IP Code)

Section 2 Physical Shock

2.1 Tumble/Barrel Test

Reference:

Equipment used shall be in accordance with Appendix A of IEC 60068-2-31:2008 with the following addendums:

- The steel used as an impact surface shall be 3mm-thick EN10130 carbon steel with 7-10 um zinc plating. 316 stainless steel plate may be used instead, but this substitution must be noted in the test report.
- The surface roughness of the impact plate shall be machined to 1.6 microns Ra or better.
- Impact plates must be replaced every 7,500 impacts.
- Impact plates shall be resurfaced every 1,500 impacts to a surface roughness of 15 microns Ra or better.
- An ABS obstruction shall be placed at either end of the barrel in accordance with the following section.

Custom Equipment:

Studies conducted by the CTIA Certification working group on Device Hardware Reliability suggest that adding a physical obstruction to the falling edge of the tumble barrel described in IEC 60068-2-31:2008 significantly improves the randomness of the orientations of impact to a Device Under Test (DUT). The following are guidelines for manufacturing and installing the approved obstruction used in this test:

- Manufacturing geometry for the obstruction including plots, STEP, and STL files may be found included with this test plan.
- The obstruction shall be 3D printed or injection molded from ABS plastic and shall have an external surface roughness no larger than 128 Ra.
- The obstruction shall be applied to the surface of the tumble barrel using 1.0 mm thick 3M VHB double sided tape.
- The obstruction shall be placed in the orientation and location shown in Figure 2.1-1.
- The obstruction shall be replaced upon observation of any damage to the exterior surface.

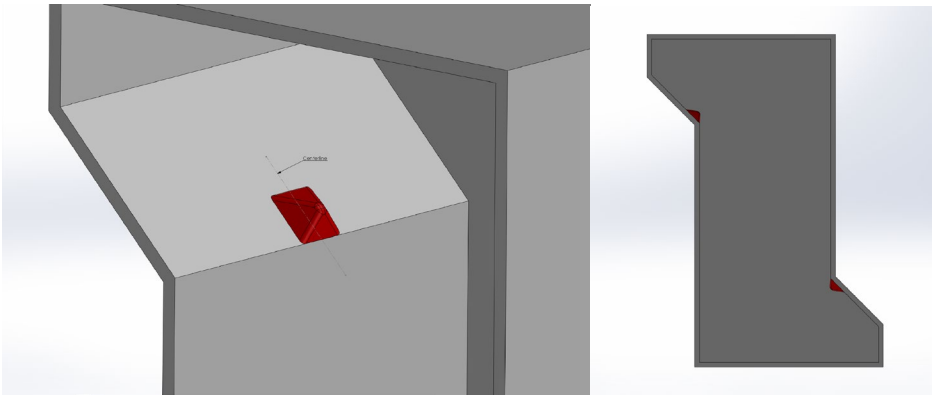


Figure 2.1-1 Obstruction Install Location

Purpose:

Mechanically stress all phone components to simulate end-user handling or shipping and to artificially age the DUT for forecasting purposes.

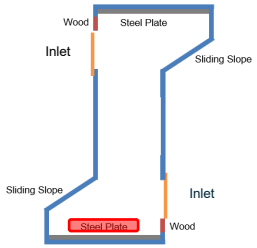
Procedure:

1. Ensure DUT meets Appendix A.
2. Deburr the test surface with a flat file, blow off all interior surfaces of the test barrel with compressed air, vacuum any debris, and wipe down the impact plates with a damp cloth. Inspect the ABS obstruction for damage and replace if necessary.
3. The test height shall be mixed 0.5 meter and 1 meter.
4. Sample size shall be 10 devices.
5. DUT shall be powered on during the test.
6. For DUT s with removable covers and batteries, the back cover shall be taped on.
    a. When taping a device with a removable battery, the tape shall be 3M model VHB 4926 double-sided tape or equivalent and shall be applied across the back of the device frame. The tape shall not contact the surface of the battery, or any locking features used to secure the back cover in place. The geometry and location of tape should be consistent across all DUTs and images of each DUT with tape applied shall be provided in the test report. The back cover shall then be pressed firmly to the tape surface. Thicker tape may be used if a gap exists between convenient taping surfaces and the back cover under normal circumstances.
7. The rotational speed (typically 10.2 drops / minute) of the tumbler shall be adjusted to prevent the DUT from hitting the sides of the chamber during each rotation.
8. Place the DUT in the 0.5 m tumble barrel in orientation ‘A’ as described in Figure 2.1-2.
9. Cycle the DUT in the 0.5 m barrel for a total of 100 falls or until the DUT suffers a fatal failure as defined in Appendix B (whichever comes first).
10. Stop the test and perform an inspection of critical features in accordance with Appendix B. Continue critical feature inspections every 50 cycles until 150 total cycles and perform full functional testing according to Appendix A and note any failures. After each inspection, the DUT should be placed in the barrel in the orientation listed in Table 2.1-1.
11. Place the DUT in the 1.0 m tumble barrel in orientation ‘A’ as described in Figure 2.1-2.

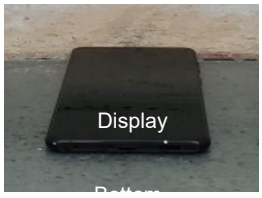
12. Cycle the DUT in the 1.0 m barrel for 10 cycles, then stop the test and perform a critical feature inspection. Continue cycling, inspections, and repositioning in accordance with Table 2.1-1 until a failure is found, or until the test runout is reached.
13. The runout of the test is 150 cycles at 1.0 meters drop height.
14. At each DUT inspection the tumbler barrel should be thoroughly vacuumed to remove any debris, and any significant damage to the impact plates should be noted and/or corrected before continuing the test.
15. Following each inspection, the DUT shall be replaced in the barrel in the orientation described in Table 2.1-1 and Figure 2.1-2. The test samples should be actively monitored during testing and any suspected failures seen through the equipment inspection window is cause to immediately terminate the test.

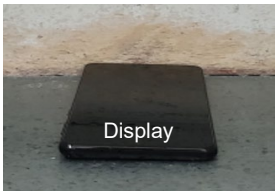
Table 2.1-1 Test Parameters

Cycles	Drop Height (m)	Inspection	Orientation
0	0.5	Full	A
50	0.5	Critical Only	B
100	0.5	Critical Only	C
0	1.0	Critical Only	D
10	1.0	Critical Only	A
20	1.0	Critical Only	B
30	1.0	Critical Only	C
40	1.0	Critical Only	D
50	1.0	Critical Only	A
75	1.0	Critical Only	B
100	1.0	Critical Only	C
150	1.0	Full	D



Vertical direction





A) Front Side Bottom B) Front Side Top C) Back Side Bottom D) Back Side Top

Figure 2.1-2 DUT Initial Orientations

Reporting:

Report results according to Appendix C.

Section 3 Water Ingress

The Original Equipment Manufacturer (OEM) shall declare the Ingress Protection level of the candidate device per IEC 60529. If the second numeral of the IP rating is 1, 2, 3, 4, 7, or 8, testing shall be conducted by a CTIA Certification Authorized Test Lab (ATL) in accordance with the sections below. For other IP ratings, these tests are optional, and the OEM shall provide a declaration of compliance, indicating the IPX level, to the ATL.

3.1 Common Requirements

All testing covered in the following sections shall be performed per IEC 60529 except as specifically addressed in those sections. Subsections 3.1.1 through 3.1.3 cover requirements common to all liquid ingress ratings presented in Section 3.

3.1.1 Water Quality

The following requirements apply to the water used to test all liquid ingress numerals presented in this test plan:

- Water used for testing shall be fresh water with a measured conductivity between 300 and 500 µS/cm.
- Water used for testing shall be in accordance with the standard temperature range defined in IEC 60068-1 (15-35°C) rather than dependent upon the temperature of the DUT as indicated by IEC 60529.

3.1.2 Test Preparation

All DUTs shall conform with the following requirements and procedures:

- The sample size shall be 3 devices unless otherwise specified by mutual agreement of the vendor, client, and ATL.
- All DUT s shall be inspected in accordance with Appendix A prior to testing.
- DUT s shall have live (or test) SIM/UICC cards, memory cards, and new, fully-charged batteries.
- DUT s shall be powered on and performing local media playback at the initiation of the test.
- DUT s shall be weighed before the test using a mass scale with precision of at least +/- 0.01 gram.

3.1.3 Test Conclusion

After testing is complete, DUT s shall be handled and inspected in accordance with the following requirements:

- The DUT shall be removed from contact with the test fluid, and excess water removed with a dry paper towel or cloth. Removable parts may be disassembled and dried (e.g., SIM/UICC card, memory card, removable battery cover and battery). No moving air may be employed, and no disassembly prohibited to a normal user may be performed.
- Immediately after conclusion of the test, weigh the DUT as in section 3.1.2, and perform a full functional inspection per Appendix A.

- The DUT shall be stored for 72 hours powered on with display side down on a horizontal surface. The DUT may be connected to a charging cable if necessary.
- After the 72-hour soak-in process, the DUT shall be inspected again in accordance with Appendix A and weighed using a mass scale in the manner described in section 3.1.2.
- Report test results in accordance with Appendix C and include the following additional information:
    - Water conductivity measured in µS/cm.
    - Mass of the DUT before, immediately after, and 72 hours after the test.

3.2 Ingress Protection Based on IPX1

IPx1 testing shall be performed in accordance with IEC 60529 and section 3.1 of this test plan, with the following changes:

- Water flow shall be calibrated by placing a conical rainfall meter on the test chamber turntable and measuring accumulated liquid after 10 minutes. Target accumulation is 10 +5.0/-0.0 mm.
- The rainfall meter shall be placed immediately adjacent to the DUT on the test chamber turntable at the start of the test.
- At the conclusion of the test, the DUT shall be removed and kept in a vertical position until dried in accordance with section 3.1.3.
- At the conclusion of the test, the rainfall meter shall be removed and the measured accumulation recorded.
- Test results shall be reported in accordance with section 3.1.3 with the following additional information:
    - Accumulated liquid as measured via the rainfall meter at the end of the test.

3.3 Ingress Protection Based on IPX2

IPx2 testing shall be performed in accordance with IEC 60529 and section 3.1 of this test plan, with the following changes:

- Water flow shall be calibrated by placing a conical rainfall meter on the test chamber turntable and measuring accumulated liquid after 10 minutes. Target accumulation is 30 +5.0/-0.0 mm.
- The rainfall meter shall be placed immediately adjacent to the DUT on the test chamber turntable at the start of the test.
- The test chamber turntable shall be powered on and rotating at 1 RPM during the entire duration of the test.
- At the conclusion of the test, the DUT shall be removed and kept in a vertical position until dried in accordance with section 3.1.3.
- At the conclusion of the test, the rainfall meter shall be removed, and the measured accumulation recorded.

- Test results shall be reported in accordance with section 3.1.3 with the following additional information:
    - Accumulated liquid as measured via the rainfall meter at the end of the test.

3.4 Ingress Protection based on IPX3

IPx3 testing shall be performed in accordance with IEC 60529 and section 3.1 of this test plan, with the following changes:

- Testing shall be performed with a spray head in accordance with IEC 60529 section 14.2.3 part a. The oscillating tube test setup outline in section 14.2.3 part b is prohibited.
- At the conclusion of the test, the DUT shall be removed and kept in a vertical position until dried in accordance with section 3.1.3.

3.5 Ingress Protection based on IPX4

IPx4 testing shall be performed in accordance with IEC 60529 and section 3.1 of this test plan, with the following changes:

- Testing shall be performed with a spray head in accordance with IEC 60529 section 14.2.4 part a. The oscillating tube test setup outline in section 14.2.3 part b is prohibited.
- At the conclusion of the test, the DUT shall be removed and kept in a vertical position until dried in accordance with section 3.1.3.

3.6 Ingress Protection based on IPx7

IPx7 testing shall be performed in accordance with IEC 60529 and section 3.1 of this test plan, with the following changes:

- The immersion vessel for testing must be deep enough to suspend the test specimen with the bottom of the unit at the target depth without contacting the sides or bottom of the vessel.
- The immersion vessel used for testing must be constructed of chemically inert materials to avoid inducing electrolysis in the DUT.

3.7 Ingress Protection based on IPx8

IPx7 testing shall be performed in accordance with IEC 60529 and section 3.1 of this test plan, with the following changes:

- The immersion vessel for testing must be deep enough to suspend the test specimen with the bottom of the unit at the target depth without contacting the sides or bottom of the vessel.
- The immersion vessel used for testing must be constructed of chemically inert materials to avoid inducing electrolysis in the DUT.
- The DUT must be exposed to pressure of 1.5 meters WC or higher.

Section 4 Temperature & Humidity

Reference:

Based on MIL-STD-810H, method 507.6

Purpose:

Determine device response to thermal cycling in an elevated temperature-humidity environment. This test may reveal issues caused by extreme environments, end user handling scenarios, or long-term effects.

Procedure:

1. Perform the functional testing outlined in Appendix A.
2. A minimum of six (6) samples for each device shall be tested.
3. The test shall be conducted with the samples laid out in two orientations (see Figure 4-1 and Figure 4-2).
   a. Half of the test samples shall be oriented parallel to the chamber floor using fixtures that permit the maximum amount of airflow possible and minimize condensation surface area (Figure 4-1).

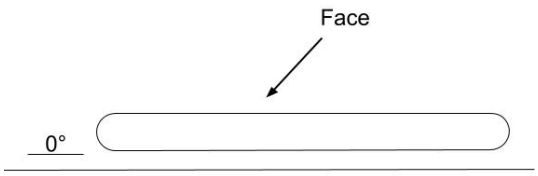


Figure 4-1 Orientation 1

   b. The remaining samples shall be oriented 60° to the chamber floor using fixtures that permit the most amount of airflow possible and minimize condensation surface area (Figure 4-2).

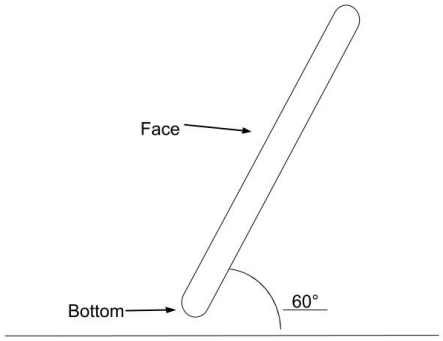


Figure 4-2 Orientation 2

4. Samples shall be in their powered-off state and placed on wire racks as close to the center of the chamber as possible with a minimum of 5 cm distance separating samples from each other on all sides and a minimum of 10 cm distance separating samples from the chamber walls, floor, and ceiling. DUT s shall not overhang or overlap one another regardless of the distance between them.

5. The chamber shall have a resolution of ± 2 °C, ± 5 %RH, and be calibrated to a NIST traceable standard or be monitored by a NIST traceable continuous recording sensor of at least of ± 2 °C, ± 5 %RH.
6. With the samples in place, condition the chamber to laboratory ambient conditions (23 ± 2°C & 50 ± 5 %RH) for a period of at least 24 hours.
7. Upon completing the conditioning, program the chamber according to the following cycle profile to run for a total of five (5) cycles (see Table 4-1 and Figure 4-3)

Table 4-1 Test Cycle Temperature and Humidity Profile

Time (HR)	Temp (°C)	%RH
0	30	95%
2	60	95%
8	60	95%
12	-20	0%
18	-20	0%
20	30	95%
24	30	95%

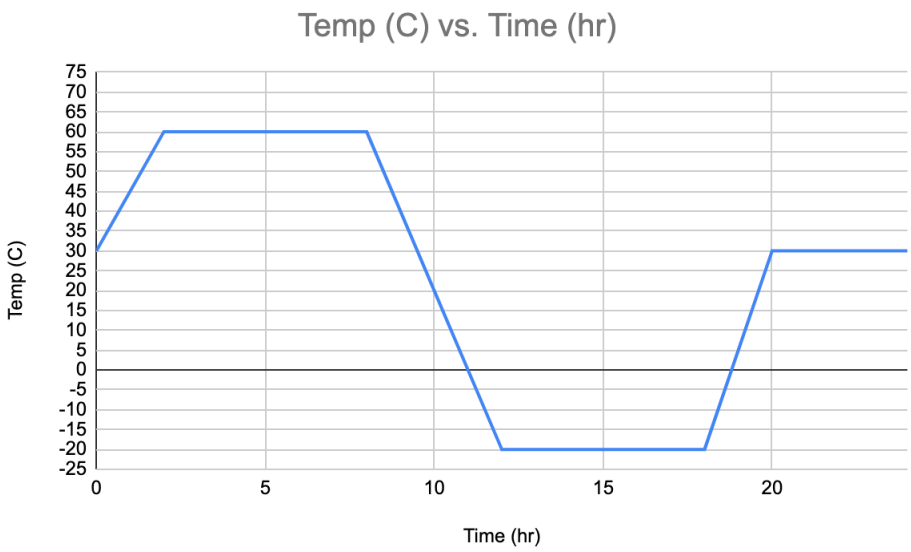


Figure 4-3 Test Cycle Temperature Profile

8. After completing five (5) cycles, halt testing and perform the functional testing outlined Appendix A .
   a. If no failures, as defined by Appendix B are detected, continue testing for another five (5) cycles, again with the DUT s in their powered-off state.
   b. If any samples present a failure, as defined by Appendix B, record the results, remove the affected sample(s) from testing, and continue on for an additional five (5) cycles with the remaining samples, again with the DUT s in their powered-off state.
   c. A one (1) hour reconditioning cycle at 30°C & 90%RH will be required before re-initiating the test unless analysis of all samples can be completed within one (1) hour of removing them from the chamber.
9. After completing the final five (5) cycles, set the chamber temperature and humidity to 23 ±2°C & 50 ± 5%RH, and hold for a period of at least eight (8) hours. Perform the functional testing outlined in Appendix A and record any failures.

Reporting:

Report results according to Appendix C.

Section 5 Hardness/Scratch Resistance Testing

5.1 Pencil Hardness (Flexible Displays Only)

Reference:

ASTM D3363

Purpose:

Determine a device screen's physical hardness.

Procedure:

1. A minimum of three (3) samples shall be tested.
2. This test requires the use of a calibrated pencil hardness set equipped with leads ranging in hardness from 9B to 9H (see Figure 5.1-1) and a pencil alignment tool that applies the lead to the testing surface at a 45° angle under a constant pressure of 765g ±15g (7.5 Newtons).

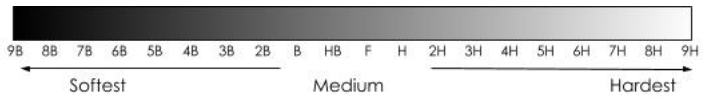


Figure 5.1-1 Pencil Hardness Scale

3. Testing shall be performed at 23°C ±2°C and 50 ±5% relative humidity on a smooth, flat surface.
4. Place the sample on a hard flat surface with the DUT in the "open" position laying as flat as possible (see Figure 5.1-2 for reference).

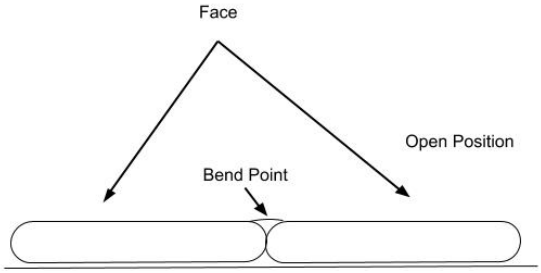


Figure 5.1-2 Open Position

5. The softest test lead is selected first.
6. The testing lead is placed into the lead holder with the lead extending between 5-6mm out from the lead holder. Then it is held at a 90° against the surface of a strip of No. 400 grit sandpaper and rubbed across the abrasive surface until a smooth and flat cross-section of the lead is obtained.
7. The lead holder containing the test lead is then inserted into the pencil alignment tool such that it rests against the sample surface at the requisite 45° angle and maintains the required 765g of pressure (See Figure 5.1-3). Secure the test lead and pencil holder using the knob equipped on the pencil alignment holder.

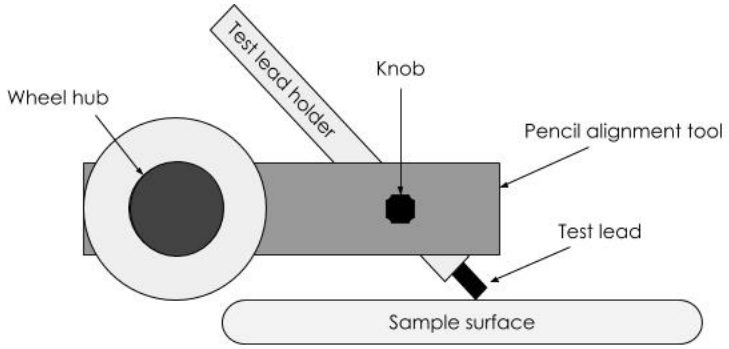


Figure 5.1-3 Testing Apparatus

8. Select a test area for the sample, wipe it with a lint free cloth, and place the test lead to rest against the test area. Holding the test instrument by the wheel hubs, push the apparatus forward at least 6.5mm forward along the surface and away from the operator. The allowable time between wiping the test area and drawing the lead across it is 15 seconds.
9. Within 15 seconds of drawing the lead across the test area, gently wipe the test area with a lint-free cloth and inspect the results, an illuminated hands-free magnifying lens (5X - 10X) may be used as necessary.

    a. If the test lead does not leave visible scratches then move on to the next step

    b. If the test lead does leave visible scratches then the hardness of the screen is recorded as the hardness of the previous test lead.

10. Repeat steps 6-9 three (3) times per test lead, selecting an untested location each time. One test location must traverse the 'Bend Point' as shown in Figure 5.1-2.
11. Continue testing by repeating steps 6-10 using the next lowest number test lead.

    a. Continue testing only until a hardness level is determined.

        - In the event a screen surpasses a hardness of "9H" on the Pencil Hardness scale the hardness is to be recorded as "> 9H".
        - In the event that a screen scratches.

Reporting:

Report results according to Appendix C.

5.2 Shore Hardness (Flexible Displays Only)

Reference:

N/A

Purpose:

Determine a sample equipped with a flexible screen's resistance to scratching at the location of the bend and at least one (1) of the screen faces.

Procedure:

1. This test requires the use of a calibrated NIST traceable Shore durometer equipped with Shore A and Shore D indentation fixtures.
2. A minimum of three (3) samples shall be tested.
3. Test samples shall be cleaned with a lint-free cloth prior to testing.
4. Place the sample on a hard flat surface with the DUT in the "open" position laying as flat as possible (see Figure 5.2-1 and Figure 5.2-2 for reference).

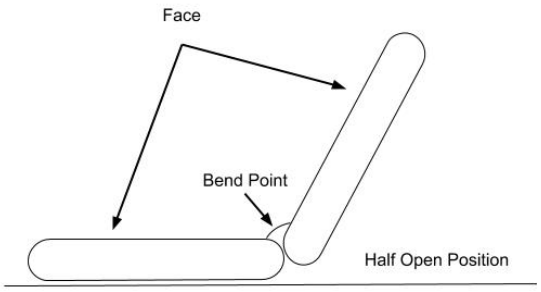


Figure 5.2-1 Half Open Position

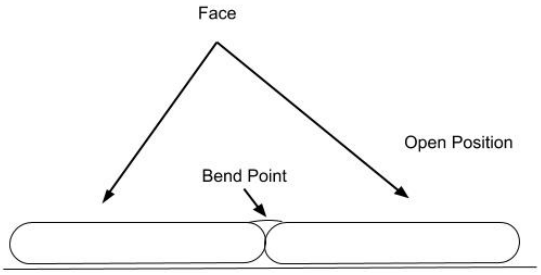


Figure 5.2-2 Open Position

5. The Shore A indenter for the instrument is pressed firmly into the specimen at the bend point, making sure that it is perpendicular to the surface. The indenter shall be engaged within 30 seconds of wiping the surface.
6. The hardness is read within one (1) second of firm contact with the testing location.
7. Inspect the DUT for permanent marking of the display membrane, anomalies to the display panel, and functionality of the touchscreen within 15 seconds of withdrawing the indenter. Report any findings.

8. If the Shore hardness is less than or equal to Shore 80A, record the result and end testing.
9. If the Shore hardness is greater than Shore 80A, repeat steps 3 through 6 with the Shore D indenter.
10. If the Shore D hardness exceeds a reading of 100, the results shall be reported as "N/A" and the sample(s) shall be tested in accordance with Section 1 of this document.
11. Repeat steps 3 through 9 using at least one (1) test sample face as the test location.

Reporting:

Report results according to Appendix C.

5.3 Moh's Hardness (Rigid Displays Only)

Reference:

Purpose:

Determine a device screen's physical hardness.

Procedure:

1. A minimum of three (3) samples shall be tested.
2. This test requires the use of a calibrated Moh's hardness test kit including picks covering 2-9 on the Moh's scale. Prior to performing the test, the picks shall be inspected for sharpness. If a pick has a dull point, it shall be inserted into a manual lathe or drill and rotated against a flat, 100-grit grind stone or surface-mounted sandpaper at a 20-degree angle until a sharp point is formed.
3. Testing shall be performed at 23°C ±2°C and 50 ±5% relative humidity on a smooth, flat surface.
4. Place the sample on a hard flat surface with the display up.
5. The softest pick is selected first. Ensure all picks used have sharp points – follow the kit manufacturer's instructions for sharpening if necessary.
6. Test samples shall be cleaned with a lint-free cloth prior to testing.
7. Hold the pick at roughly a 70 degree angle and apply approximately 7 pounds of pressure to the DUT display.
8. Draw the pick across the display for a minimum length of 1 inch. This must be performed within 15 seconds of wiping the surface.
9. If the pick does not catch in the display material, wipe the surface with a lint free cloth and inspect for damage to the material. This inspection must be performed within 15 seconds of testing. If no damage is seen, repeat steps 6-9 with the next pick on the scale.
10. If the pick catches in the display material, or persistent damage is seen after cleaning, record the display hardness as halfway between the current pick and the previous pick. For example, if the display shows no damage with the #4 pick, but catches and scratches with the #5 pick, record the hardness as 4.5.

Reporting:

Report results according to Appendix C.

Section 6 PCBA Inspection

This section defines criteria for a visual inspection of a single device for PCBA quality, reliability, and workmanship by a CTIA Certification Authorized Test Lab (ATL). Inspections shall be performed in accordance with IPC-A-600K and IPC-A-610H in conjunction with the guidelines laid out in the following subsections.

6.1 Inspected Device Requirements

Devices used for PCBA inspection per Section 1 of this test plan shall be randomly selected from the samples delivered to the ATL. The OEM shall provide the ATL with any non-standard procedures and/or tooling necessary to safely disassemble one device without inducing damage to the PCBA. The inspected device's battery shall be fully drained before disassembly is attempted. Any incidental damage caused to the device during disassembly shall be noted, and if full inspection of the device is rendered impossible as the result of said damage, a second device shall be used to fulfill the requirements of this section.

6.2 Device Inspector Requirements

ATLs performing PCBA inspections under this test plan must have a Certified IPC Trainer (CIT) on staff, and the inspection report must be signed by a CIT. The device inspection may be performed by a Certified IPC Specialist (CIS). Each point of inspection shall be considered and reported as 'Acceptable' if it meets the requirements of Class II boards, 'Class I', or 'Non-Conforming'.

6.3 Inspection Per IPC-A-600K

All applicable PCBAs, Flex Circuits, and other features covered under the IPC-A-600K standard shall be inspected, with the following changes:

- This inspection shall encompass only features and defects termed as 'externally visible' under the guidelines of the specification.
- Ionic cleanliness inspections shall not be performed
- Minimum conductor spacing shall be inspected per the default spacing allowed under the IPC specification regardless of any overriding OEM specification. Any such overriding specifications may be declared by the OEM to the ATL and noted on the inspection report or declared to the operator.

6.4 Inspection Per IPC-A-610H

All applicable PCBAs, Flex Circuits, and other features covered under the IPC-A-610H standard shall be inspected, but only the following sections shall be considered during the inspection:

- Section 4.1.5 – Hardware Installation: Threaded Fasteners' shall be considered where applicable.
- Section 5 – Soldering' shall be considered in its entirety.
- Section 8 – Surface Mount Assemblies' shall be considered with the exception of 'Section 8.6 – Jumper Wires'.
- Section 9 – Component Damage' shall be considered in its entirety.

- Section 10 – Printed Circuit Boards & Assemblies' shall be considered in its entirety.

6.5 Inspection Deviations

Certain sections of the IPC specifications noted above may not pertain to the particular features, design choices, overriding specifications, etc. Some inspections may also be outside of the reasonable ability of an ATL to perform. In such cases, the inspection point shall be marked as 'Not Inspected' and an accompanying explanation for the omission shall be provided by the OEM or ATL.

Appendix A Device Functionality Validation

This appendix provides a comprehensive list of failure modes for handsets along with definitions and inspection methods. While those inspection methods are presented for each failure mode, the full inspection process may be completed using any methods so long as the following criteria are met:

- Inspection for multiple failure modes may be undertaken simultaneously provided all pass/fail criteria presented below are addressed (unless specifically noted). Any excluded inspection points must be noted on the test report.
- The inspection method employed must be identical for all same-model devices tested.
- OEM-specific automated testing tools may be employed
- Third-party inspection tools may be employed as agreed upon by the OEM, Client, and Authorized Test Lab. Any such tools used must be noted on the test report.

At the beginning of the test process, one device shall be picked at random from the samples provided by the OEM. This device will not be subjected to any tests, physical damage, or other potentially function-impacting stresses. This device will be used as the 'Reference Device' as noted below. A reference device must always be the same model as the DUT, and the IMEI and/or serial number of the reference device must be included in the test report.

When performing any test plan in this document, the DUT must first be inspected in accordance with this section. Any failures observed during this initial assessment must be noted on the test report, and the DUT must not be used for testing.

The tables below are organized by Group and Item in accordance with the CTIA Certification Wireless Device Triage Criteria and Definitions found on the CTIA Certification website. Each item is marked with a letter denoting its use as follows:

- 'M' – Mandatory: If supported by the device, this item must be executed any time this appendix is referenced for an inspection
- 'P' – Priority: If supported by the device, this item must be executed on every device as-received by the OEM and following any test which might impact the marked system
- 'I' – Incidental: If supported by the device, this item must be executed if evidence of malfunction of the marked system is encountered through the normal course of running this test plan

Table A.1 Group: Power

Item	Use	Functional Test	Pass	Fail
Function	M	If not obvious function, connect DUT to PC/Mac via USB, verify a response from the computer and/or DUT OS	Computer and/or DUT recognize the connection	Computer and/or DUT does not recognize the connection
Wired Charging	M	Connect DUT with 50%-90% charge to OEM charger with a power meter connected between the charger and mains power	Power meter shows >0.2mA is being passed to the DUT	Power meter shows no current is being passed to the DUT
Wired Fast Charging	M	Connect DUT with 50%-90% charge to OEM charger with a power meter connected between the charger and mains power. Compare to results from a reference device with an identical state of charge.	DUT current draw +/-10% of reference device current draw	DUT current draw >+/-10% of reference device current draw
Wireless Charging	P	Connect DUT with 0%-90% charge to OEM specified wireless charger with a power meter connected between the charger and mains power	Power meter shows >0.5mA is being passed to the DUT	Power meter shows no current is being passed to the DUT

Table A.2 Group: Battery

Item	Use	Functional Test	Pass	Fail
Low Charging Speed	M	Connect DUT with 50%-90% charge to OEM charger with a power meter connected between the charger and mains power. Compare to results from same test performed on a reference device with an identical state of charge.	DUT charge current >= 90% of reference device	DUT charge current < 90% of reference device
Fast Discharge	M	Measure the average discharge current of the DUT with a state of charge between 50% and 90%. The DUT should be in a controlled and static operating state and measurements should be taken for 10 minutes. Compare to results from a reference device with the same initial state of charge and operating state	DUT discharge current <= 110% of reference device	DUT discharge current > 110% of reference device
Poor Capacity/Will Not Hold Charge	I	See 'Power: Fast Discharge' above	DUT fuel gauge indicates charge loss <= 120% of reference device	DUT fuel gauge indicates charge loss > 120% of reference device
Physical Damage or Distortion	M	Visual Inspection	No visible change to DUT condition	Visible alteration of the DUT structure including bending, gaps, distention, etc.

Table A.3 Group: Display

Item	Use	Functional Test	Pass	Fail
Lines	M	Visual inspection on solid black, white, red, green, and blue display. If necessary, verification may be performed using a microscope with coaxial lighting at a maximum of 50x magnification	No anomalies observed	Any discolored lines observed
Bruising	M	See 'Display: Lines' above	No bruising persisting for more than 5 minutes	Any areas of bruising observed which persist for more than 5 minutes
Dead Pixels	M	See 'Display: Lines' above	No dead pixels observed	Any identified dead pixels
Operation	M	Visual Inspection	DUT display emits light	DUT powers on, but does not emit light
Brightness	P	DUT powered on with factory default settings, brightness turned all the way up, auto brightness turned off, set to home screen. Lumens recorded using a light meter or on-board sensors where applicable. Compare to results from same test performed on a reference device.	DUT display brightness +/-10% of reference device	DUT display brightness exceeds +/-10% of reference device
Color	M	Visual inspection on solid white display	DUT color shows little divergence from reference device	DUT color differs significantly from reference device
Lift	M	Measure any gap between display and DUT chassis	Gap is <0.4mm	Gap is >=0.4mm
Flexible Display Damage	M	Visual Inspection (Flexible display devices only)	No damage observed to flexible display	Flexible display shows gouges, ripples, peeling, or any other physical defect in comparison to reference device
Foreign Material	M	Visual inspection. If necessary, verification may be performed using a microscope with coaxial lighting at a maximum of 50x magnification	No foreign material observed within DUT	Any foreign material observed within DUT
Black Spots	M	Visual Inspection	No black spots observed on DUT display	Any black spots observed on DUT display
Light Bleed	M	Visual inspection on powered display showing a blank black image	Edges of display are similar in color and shade to reference device	Edges of display are noticeable lighter in color and/or shade compared with reference device
Burn-In	M	Visual inspection on solid white display set to maximum brightness	No burn in is observed on screen	Any burn in is observed on screen

Table A-4 Group: Touchscreen

Item	Use	Functional Test	Pass	Fail
One Finger Tap	M	Navigate to and open An OEM-native maps app with one finger	Able to navigate to and open An OEM-native maps app with a single finger tap.	Not able to navigate to and open An OEM-native maps app with a single finger tap
Double Tap	M	With An OEM-native maps app open, tap an area of the map twice rapidly with one finger	Maps zooms in on the location tapped	Maps fails to zoom in on the location tapped
One Finger Hold	M	With An OEM-native maps app open, touch and hold a single finger to an area of the map	Maps sets the area selected as a new destination, red flag moves to selected location	Maps fails to set the area selected as a new destination, and/or the red flag fails to move to selected location
One Finger Swipe	M	With An OEM-native maps app open, swipe lightly vertically on area of the map, swipe again from the opposite direction. Repeat test from horizontal directions	Maps moves in the direction of all swipe gestures	Maps fails to move in the direction of any swipe gestures
One Finger Flick	M	With An OEM-native maps app open, flick rapidly vertically on area of the map, swipe again from the opposite direction. Repeat test from horizontal directions	Maps moves in the direction of all flick gestures	Maps fails to move in the direction of any flick gesture
Two Finger Rotation	M	With An OEM-native maps app open, place two fingers on map, keeping the two fingers parallel and on the screen, rotate your fingers 90 degrees to the right. Repeat test going 90 degrees to the left.	Maps rotates in all directions of the two finger gestures	Maps fails to rotate in any directions of the two finger gestures
Two Finger Scale	M	With An OEM-native maps app open, place two fingers on map, keeping the two fingers together and parallel and on the screen, spread your fingers apart from each other and then back together.	Maps zooms in on the area surrounding the initial finger placement and then zooms out again when gesture is complete.	Maps fails to zooms in on the area surrounding the initial finger placement and/or fails to then zooms out again when gesture is complete.
Operation	M	Perform all other tests in the ‘Group: Touchscreen’ section	DUT passes at least one test	DUT fails all tests

Table A-5 Group: Mechanical

Item	Use	Functional Test	Pass	Fail
Power Key	M	Actuate the power key	DUT function and key haptics are consistent with the reference device	DUT function and key haptics are not consistent with the reference device
Volume Keys	M	Actuate the volume keys	DUT function and key haptics are consistent with the reference device	DUT function and key haptics are not consistent with the reference device
Utility Keys/Switches/Buttons	M	Actuate all other keys, switches and buttons	DUT function and key/switch/button haptics are consistent with the reference device	DUT function and key/switch/button haptics are not consistent with the reference device
Audio Plug Insertion	M	Insert an appropriate headset plug into the audio port on the DUT	DUT recognizes the headset, and insertion force/feel is consistent with the reference device	DUT does not recognize the headset, and/or insertion force/feel is inconsistent with the reference device
Data connector Insertion	M	Insert an appropriate USB plug into the audio port on the DUT	DUT recognizes the connected USB device, and insertion force/feel is consistent with the reference device	DUT does not recognize the inserted USB device, and/or insertion force/feel is inconsistent with the reference device
Stylus	M	Functional inspection	DUT stylus seats properly and all buttons/switches perform as expected	DUT stylus does not seat properly and/or buttons and switches do not perform as expected
SIM Tray/Slot	M	Eject and insert a production SIM card appropriate to the DUT	SIM card is recognized by the DUT and seats firmly in the slot/tray	SIM card is not recognized by the DUT and/or the slot/tray does not behave consistent with the reference device when used
External Storage Tray/Slot	M	Eject and insert a flash memory card appropriate to the DUT	memory card is recognized by the DUT and seats firmly in the slot/tray	Memory card is not recognized by the DUT and/or the slot/tray does not behave consistent with the reference device when used
Slider	M	Actuate the DUT slider 10 times	DUT function and slider haptics are consistent with reference device	DUT function and slider haptics are not consistent with the reference device
Hinge	M	Actuate the DUT hinge 10 times	DUT function and hinge haptics are consistent with reference device	DUT function and hinge haptics are not consistent with the reference device

Table A-6 Group: Audio

Item	Use	Functional Test	Pass	Fail
Volume	P	Using software controls to modulate volume, play a test audio clip at 20%, 50%, and 100% maximum volume	DUT playback volume is similar to a reference device at each volume level	DUT volume does not change or is significantly inconsistent with reference device
Speaker Function	M	Perform local audio playback of a test clip on all DUT speakers, isolating each if possible.	DUT produces audio from all onboard speakers	DUT does not produce audio from one or more onboard speakers
Speaker Quality	M	See 'Audio: Speaker Function' above	DUT audio quality is consistent with reference device on all speakers	DUT audio quality is inconsistent with reference device on one or more speakers
Headset Audio	M	Insert an appropriate headset into the audio port on the DUT and play a test audio clip	Headset audio functions and quality is consistent with reference device	Headset audio does not function and/or quality is inconsistent with reference device
Microphone Function	I	Record and reproduce audio using the DUT microphone	DUT successfully records and plays back audio	DUT does not record and playback audio
Microphone Quality	I	See 'Audio: Microphone Function' above	DUT recorded audio quality is consistent with reference device	DUT recorded audio quality is inconsistent with reference device

Table A-7 Group: Sensors

Item	Use	Functional Test	Pass	Fail
Proximity	M	Place a call on the DUT and cover the top 1/3rd of the DUT with an opaque material	DUT display darkens and touchscreen becomes non-functional while material is present	DUT display is unaffected while material is present, or display does not recover when material is removed
Accelerometer/ Gyroscope/ Magnetometer	M	With An OEM-native maps app open, place the DUT face up on a flat table and rotate the entire DUT	Location indicator maintains geostationary direction while DUT is rotated	Location indicator moves with DUT
Barometer	P	Check readings on a barometer/altimeter app on the DUT with an elevation change of at least 5 meters	DUT barometer shows noticeable change with elevation change	DUT barometer does not show noticeable change with elevation change
Lux Sensor	M	With automatic display brightness turned on, cover the top 1/3rd of the DUT with an opaque material	DUT display darkens when material is present, and brightens when it is removed	DUT display does not darken when material is present and/or does not lighten when it is removed
Fingerprint	P	Unlock the DUT using a fingerprint 10 times	DUT successfully unlocks at least 9 of 10 attempts	DUT fails to unlock 2 or more times

Table A-8 Group: Camera

Item	Use	Functional Test	Pass	Fail
Front Camera Function	M	Point each available camera lens at a blank white surface and take a picture. Repeat with a colorful object with a surface no less than 3 meters behind it	DUT successfully focuses and takes a picture in each scenario	DUT fails to take a picture or does not focus on the subject
Front Camera Quality	M	See 'Camera: Front Camera Function' above	DUT image contains no dark spots on the white background and color and fidelity are consistent with reference device	DUT image contains dark spots on the white background and/or color and fidelity are inconsistent with reference device
Rear Camera Function	M	See 'Camera: Front Camera Function' above	DUT successfully focuses and takes a picture in each scenario	DUT fails to take a picture or does not focus on the subject
Rear Camera Quality	M	See 'Camera: Front Camera Function' above	DUT image contains no dark spots on the white background and color and fidelity are consistent with reference device	DUT image contains dark spots on the white background and/or color and fidelity are inconsistent with reference device

Table A-9 Group: Calls

Item	Use	Functional Test	Pass	Fail
Audio Call Placement	M	Place a call from the DUT to the reference device using a production SIM card	Call is established and maintained for at least 30 seconds	Call is not established or drops before 30 seconds
Audio Call Reception	M	Place a call from the reference device to the DUT using a production SIM card	Call is established and maintained for at least 30 seconds	Call is not established or drops before 30 seconds
Call Audio Quality	M	See 'Calls: Audio Call Placement' above	DUT sent and received audio quality is consistent with reference device	DUT sent and received audio quality is inconsistent with reference device
Video Call Function	P	Place a video call from the DUT to the reference device using a production SIM card	Call is established and audio and video connection maintained for at least 30 seconds	Call is not established or audio and video connection maintained for less than 30 seconds
Call Video Quality	P	See 'Calls: Video Call Function' above	DUT sent and received audio and video quality is consistent with reference device	DUT sent and received audio and video quality is inconsistent with reference device

Table A-10 Group: Connectivity

Item	Use	Functional Test	Pass	Fail
Cellular Data Function	M	With Wi-Fi not connected and connected to cellular data service, open default browser and visit a speed testing website and perform a speed test.	DUT download and upload speeds are comparable to the reference device	DUT download and upload speeds are significantly less than the reference device
Cellular Data Speed	P	With Wi-Fi not connected and connected to cellular data service, open default browser and visit a speed testing website to perform speed test. Perform test 5 times, record and compare results to reference device tested 5 times in approximately the same location and orientation. Visit the CTIA YouTube channel and play latest uploaded video with a length of at least 5 minutes.	Average of DUT download speeds is within +/-10% of average download speeds recorded on reference device. Video successfully played with minimal loading time and no loss of connection.	Average of DUT download speeds is outside +/-10% of average download speeds recorded on reference device. Video unable to be successfully played with minimal loading time and/or no loss of connection.
Wi-Fi	I	With Mobile Data turned off, attempt to connect DUT to a Wi-Fi network, if successful open default browser and visit a speed testing website to perform speed test. Perform test 5 times, record and compare results to reference device tested 5 times in approximately the same location and orientation. Visit CTIA YouTube channel and play latest uploaded video with a length of at least 5 minutes.	Average of DUT download speeds is within +/-10% of average download speeds recorded on reference device. Video successfully played with minimal loading time and no loss of connection.	Average of DUT download speeds is outside +/-10% of average download speeds recorded on reference device. Video unable to be successfully played with minimal loading time and/or no loss of connection.
GPS	I	With Wi-Fi not connected and connected to cellular data service, open An OEM-native maps app. Select local landmark location and choose directions to that location from DUT current	Distance and arrival times are the same between both devices	Distance and arrival times vary between both devices

Item	Use	Functional Test	Pass	Fail
		location. Compare to results from same test performed on a reference device.		
Bluetooth	P	Connect DUT to a Bluetooth-enabled headset or speaker. Visit CTIA YouTube channel and play latest uploaded video with a length of at least 5 minutes.	Video audio is successfully played through wireless speaker with no issues or loss of connectivity.	Video audio is not successfully played through wireless speaker with no issues and/or loss of connectivity.
NFC	I	Using an RFID tag known to communicate with the DUT and an appropriate NFC app, bring the tag slowly toward the DUT. Begin the motion at 10 cm from the DUT and note the distance from the DUT at which detection is triggered. Compare with the reference device.	Detection distance is within 10% of the reference device	Detection distance is more than 10% off of the reference device
Wired Data Connection	P	Connect the DUT to a PC/Mac via USB and transfer a file with a minimum size of 1 MB	File transfer is successful and completes in approximately the same time as the reference device	File transfer is unsuccessful and/or takes much longer to complete than the reference device
RF Performance	M	Place the DUT and reference device in the same orientation within 1 meter of each other. Care should be taken to eliminate any surrounding or nearby RF obstructions. Toggle airplane mode on then off simultaneously on both devices and allow both to camp on a production network. Verify both devices are connected on the same PLMN. Using an RF statistics app or tool as provided by the device OEM or agreed upon by the OEM, Test Lab, and Client, measure the RSRP, SiNR, and RSRQ for both devices.	DUT measurements do not differ by more than 20% from the reference device for SiNR and 10% for RSRP	DUT measurements differ by more than 20% from the reference device for SiNR/RSRQ and 10% for RSRP

Table A-11 Group: Vibration

Item	Use	Functional Test	Pass	Fail
Vibration Function	P	Switch to vibrate-only mode on the DUT	DUT vibrates as expected	DUT fails to vibrate during expected times or exhibits non-standard behavior in comparison to reference device

Table A-12 Group: Stylus

Item	Use	Functional Test	Pass	Fail
Stylus Function	M	Functional Inspection	DUT stylus functions comparably to the reference device	DUT stylus does not function comparably to the reference device

Table A-13 Group: External Storage

Item	Use	Functional Test	Pass	Fail
Storage Media Function	I	Insert a compatible SD card with a size commensurate with the maximum allowable by the DUT. Format the card and transfer a file to it of minimum size 1 MB.	DUT successfully recognizes, formats, and transfers a file to the card.	DUT fails to recognize, format, or transfer a file to the card

Table A-14 Group: SIM

Item	Use	Functional Test	Pass	Fail
SIM Card Recognized	I	Perform all tests from 'Group: Calls'	DUT successfully completes at least one test	DUT fails all tests

Table A-15 Group: LED

Item	Use	Functional Test	Pass	Fail
Notification LED	P	Visual Inspection	Auxiliary LED performs consistent with the reference device	Auxiliary LED does not perform consistent with the reference device

Table A-16 Group: Flashlight

Item	Use	Functional Test	Pass	Fail
Flashlight Function	P	Visual Inspection	Flashlight turns on and off as expected in comparison to reference device. Flashlight brightness is consistent with reference device	Flashlight fails to turn on and/or off as expected in comparison to reference device. Flashlight is noticeably dimmer than reference device flashlight.

Table A-17 Group: Physical Damage

Item	Use	Functional Test	Pass	Fail
Display Glass Cracking	M	Visual Inspection	DUT display contains no cracks	DUT display contains webbed or hairline cracks
Back Cover Damage	M	Visual Inspection	DUT back cover contains no cracks	DUT back cover contains webbed or hairline cracks
Housing Gap	I	Measure gap with feeler gauge	Gap is <0.4mm as measured with feeler gauge	Gap is >=0.4mm as measured with feeler gauge

Item	Use	Functional Test	Pass	Fail
Damage SIM Tray	I	See 'Mechanical: SIM Tray/Slot'	DUT fails test but no physical deformation or damage is visible	DUT fails test and physical deformation and/or damage is visible
Bent Device	P	Place DUT display-down on a flat surface and measure the gap between the surface and the display	Measured gap is less than 1 mm greater than the reference device	Measured gap is larger than 1 mm greater than the reference device
Loose Part Inside	I	Shake the DUT	DUT does not rattle	DUT rattles
Flip Hinge	I	See 'Mechanical: Hinge'	DUT fails test but no deformation or damage is visible	DUT fails test and deformation and/or damage is visible
Camera Lens Cover Damage	I	Take a picture with the affected camera lens	Picture quality in unaffected compared to reference device	Picture quality is degraded compared to reference device
Liquid Damaged	P	Visual inspection	Visible LDI is not tripped	Visible LDI is tripped, or any other functional failure is present as the result of liquid exposure

Table A-18 Group: Software

Item	Use	Functional Test	Pass	Fail
Home Button/Gesture	I	Compare to reference device with the same SW version	Performs as expected in comparison to reference device	Does not perform as expected in comparison to reference device
Back Button/Gesture	I	Compare to reference device with the same SW version	Performs as expected in comparison to reference device	Does not perform as expected in comparison to reference device
Software Update	I	Compare to reference device with the same SW version	Performs as expected in comparison to reference device	Does not perform as expected in comparison to reference device
Custom Bootloader	I	Compare to reference device with the same SW version	Performs as expected in comparison to reference device	Does not perform as expected in comparison to reference device
App Crashing	I	Compare to reference device with the same SW version	Performs as expected in comparison to reference device	Does not perform as expected in comparison to reference device
Will Not Boot	I	Power on the DUT	DUT powers on normally	DUT powers on but fails to load into normal OS and/or cannot get to the lock screen or home screen

Item	Use	Functional Test	Pass	Fail
UI Speed	I	Compare to reference device with the same SW version	Performs as expected in comparison to reference device	Does not perform as expected in comparison to reference device

Appendix B Critical Inspection Procedure

This appendix describes an inspection procedure for 'critical' inspections which is designed to capture major functional failures in an operationally inexpensive manner. Any failures seen during this procedure, whether the failure is specific to the procedure or is observed incidentally during the inspection, should immediately stop the test and trigger a full inspection in accordance with Appendix A. Any of the following steps may be replaced using an OEM testing tool. Other diagnostic tools may be utilized subject to approval by both vendor and client. Any such diagnostic tools used should be noted on the test report.

1. Visually inspect the exterior of the DUT for cracking, bending, or gaps.
2. Toggle the display on and off using the physical power button.
3. Toggle volume up and down using the physical volume buttons. Turn the DUT volume to 'vibrate' and verify the vibration functions.
4. Operate any other switches, sliders, and hinges and verify normal function.
5. Plug the DUT into an OEM charger and verify feedback that charging is active.
6. With the display on a blank white image, visually inspect for bruising, lines, dead pixels, discoloration, flickering, debris, or other display defects.
7. Place a call on a production network and verify two-way audio on both receiver and speakerphone. Verify proximity sensor function.
8. Open 'Google Maps' and verify location acquisition and display rotation.
9. Open the front- and rear-facing cameras and point at a blank white background. Inspect for dark spots.
10. Point each camera at a colored background or scene and verify normal function (camera focuses, is not blurry, picks up color, zooms, etc.)
11. Toggle Wi-Fi and verify SSID(s) are seen in the available connections list.
12. Toggle Bluetooth and verify peripheral devices are seen in the pairing list.

Appendix C Test Data Reporting Guidelines

The result of the preceding test plan shall be presented in a detailed test report as defined by the criteria in this appendix. A report presenting the results of any test case listed in this document does not need to be in a standardized format, but must clearly present all of the following information:

- Name, location, and contact information for the laboratory performing the test
- Date report produced
- Name of the test case as listed in this document
- Revision level of this document under which the test was performed
- Revision level of any applicable specifications listed in the References section of the test case
- Name, job title, and signature of the performing lab technician
- Name, job title, and signature of an engineer that reviewed the report
- IMEI, model number, and the inspection and test dates for each sample
- Pre-test inspection results as performed under Appendix A
- Model, serial number, and calibration date (if applicable) of any and all serialized test equipment used
- List all test parameters including those in this document along with any equipment settings used
- Pre- and post-test images of each sample
- Detailed images and descriptions of any failure seen during testing
- Overall test result
- Any other information as specifically defined in the Reporting section of the test case

For simplicity, a test report template has been developed for use by test laboratories – Generic CTIA Certification Device Hardware Reliability Test Report Template.

Appendix D Reuse of Samples

Samples cannot be reused within or across tests unless explicitly permitted by either the table below or with agreement between the carrier(s) and vendor. Sample reuse should only be permitted in cases where previous testing cannot conceivably cause cumulative damage to the test sample.

Test	ID	Sample Reuse
Physical Shock - Tumble Test	2.1	Samples **shall not** be reused from any other test
Ingress Testing – IPX2	3.1	Samples **shall not** be reused from any other test

Appendix E Optional Test Cases

The test cases listed in this appendix are under development, optional, or have been deemed potentially useful, but only for certain devices. Execution of these tests should be undertaken upon agreement between the carrier and the OEM.

E.1 Rough-Surface Drop Test (Optional)

This test method is optional and may be used at the discretion of the OEM and/or service provider.

Reference:

N/A

Purpose:

Expose enclosure components, including the display cover lens and/or rear enclosure cover, to impact/shock/flexure in the presence of sharp contact damage. This is intended to expose opportunities for design improvement by inducing repeatable impact damage. Consistent fracture initiation sites and patterns may be used to identify weaknesses in device design.

Procedure:

1. Ensure DUT meets Appendix A.
2. Prepare the test surface, consisting of a taut sandpaper sheet secured to a ≥ 10 mm thick, well-secured steel base plate via magnets in each corner. The steel base plate (most often an integral part of the drop tower equipment) shall be cleaned prior to sandpaper attachment via compressed air / vacuum / damp wiping. It is recommended that the sandpaper be of FEPA rather than CAMI grit classification (i.e., containing the letter “P” before the grit number designation), such as P240 grit aluminum oxide paper. Other grit materials and/or sizes may be utilized upon agreement between vendor and OEM, and all relevant details shall be captured in the test report.
3. The test height shall be 0.5 meters, measured from top of the test surface to the anticipated first point of contact of the DUT. Lower or higher test heights may be utilized upon agreement between the vendor and OEM, and shall be clearly documented in the test report.
4. The quantity of nominal drop orientations per DUT shall be 2. These include: (1) the flat display face orientation, with the plane of the display / display cover glass oriented parallel (0 degrees) to the drop surface; and (2) an angled display face orientation with the long axis of the plane of the display oriented at 30.0 degrees with respect to the drop surface (and the short axis of the plane of the display oriented parallel (0.0 degrees) to the drop surface); see Figure E.1-1. The drop equipment shall be capable of reliably and repeatably achieving these nominal drop orientation targets within ±2.0° at the instant of first contact with the test surface. Alternate, additional, or fewer orientations (such as rear enclosure flat face and/or angled drops) may be utilized per agreement between OEM and vendor, and shall be clearly documented in the test report. Orientation angle and consistency may be best monitored via use of a high-speed video camera (or ideally camera pair at orthogonal angles) capable of at least 3000 frames per second at 1024 pixel x 720 pixel resolution.
5. DUT shall be powered on during the test.
6. For devices with removable covers, batteries or other components (stylus, SIM/SD card tray, etc.), the removable parts should not be taped/secured, in order to most

accurately represent end-user drop events and device response. However, any components which become detached or loosened during impact shall be documented in the test report, and shall be repositioned before subsequent impacts.

7. Load DUT into the test equipment, ensuring the DUT is correctly positioned to achieve the desired drop orientation and drop height.
8. Initiate release of the DUT in accordance with the utilized equipment's design/procedures.
9. After impact, inspect the DUT for obvious physical damage including cracked display/cover glass, a non-functioning display, or other enclosure deformation/gaps/breakage. If such physical damage is observed, stop testing of the DUT, note the failure, and proceed to assess the DUT against Appendix A.
10. If such damage is not observed, repeat drop testing and inspection for the subsequent test orientation(s).
11. After completion of the second (or otherwise final) drop orientation, perform full testing according to Appendix A and note any failures.
12. Remove the existing sandpaper, clean the steel base plate via compressed air / vacuum / damp wiping, and install a new sheet of sandpaper before testing each subsequent DUT.
13. While not required, it should be noted that post-test failure analysis (generally conducted by the OEM), such as determining the origin locations of display or cover glass failures, may provide insight into design contributions to failure. Clustering of failure locations near underlying design features in particular may provide beneficial insight.

Reporting:

Report results according to Appendix C.

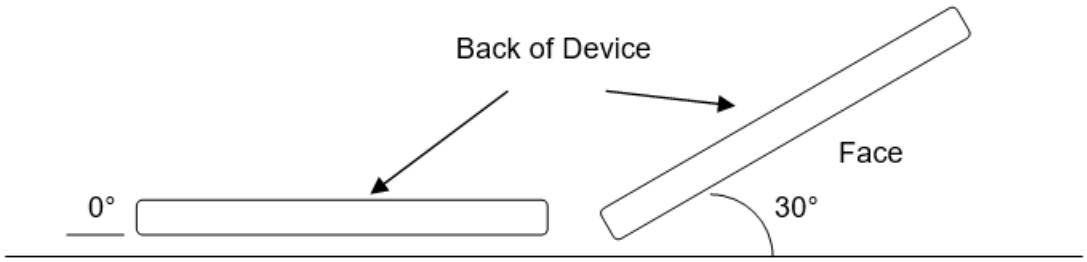


Figure E.1-1 Nominal Orientations for Optional Rough-Surface Drop Test.

E.2 Connector Reliability— I/O, Data (Under Development)

Reference:

N/A

Purpose:

Ensure strength of assembled system connector (i.e., micro USB, mini HDMI, micro HDMI) is above the required minimum force.

This test simulates the stresses caused by an end user bending the connector while it is plugged into the device. It also provides general assurance of connector jack durability against other heavy loading scenarios such as accidentally dropping the device on the connector side while the cable is connected to the device. This applies to all connectors except for audio, which is described in E.3.

Procedure:

1. Ensure DUT meets Appendix A.
2. Test shall be performed with a test adapter plug on 6 devices; 2 for up direction, 2 for down direction, 1 for left direction and 1 for right direction. At the vendor's discretion, samples may be reused to reduce the total number of samples required to complete the test program. An example test flow is shown in Appendix C.
3. Fix the DUT on the testing table on tensile tester (see Figure E.2-1 and Figure E.2-2 for fixing instructions) for "up" test direction.

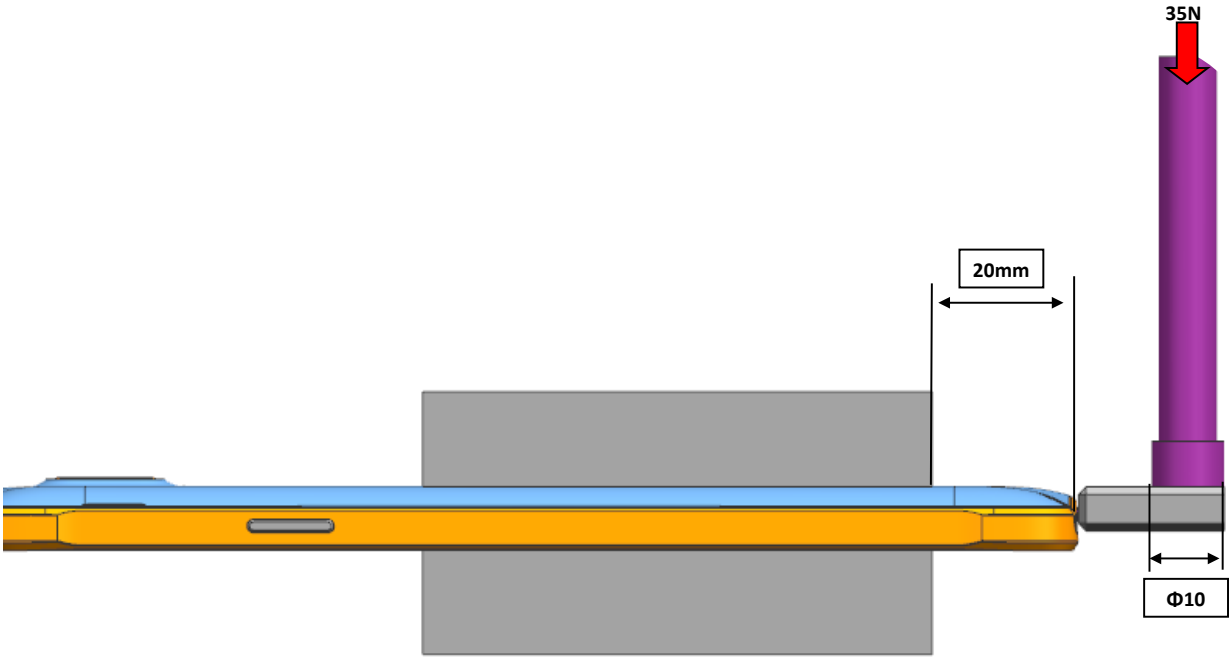


Figure E.2-1 USB Connector Reliability—Up/Down Direction Case

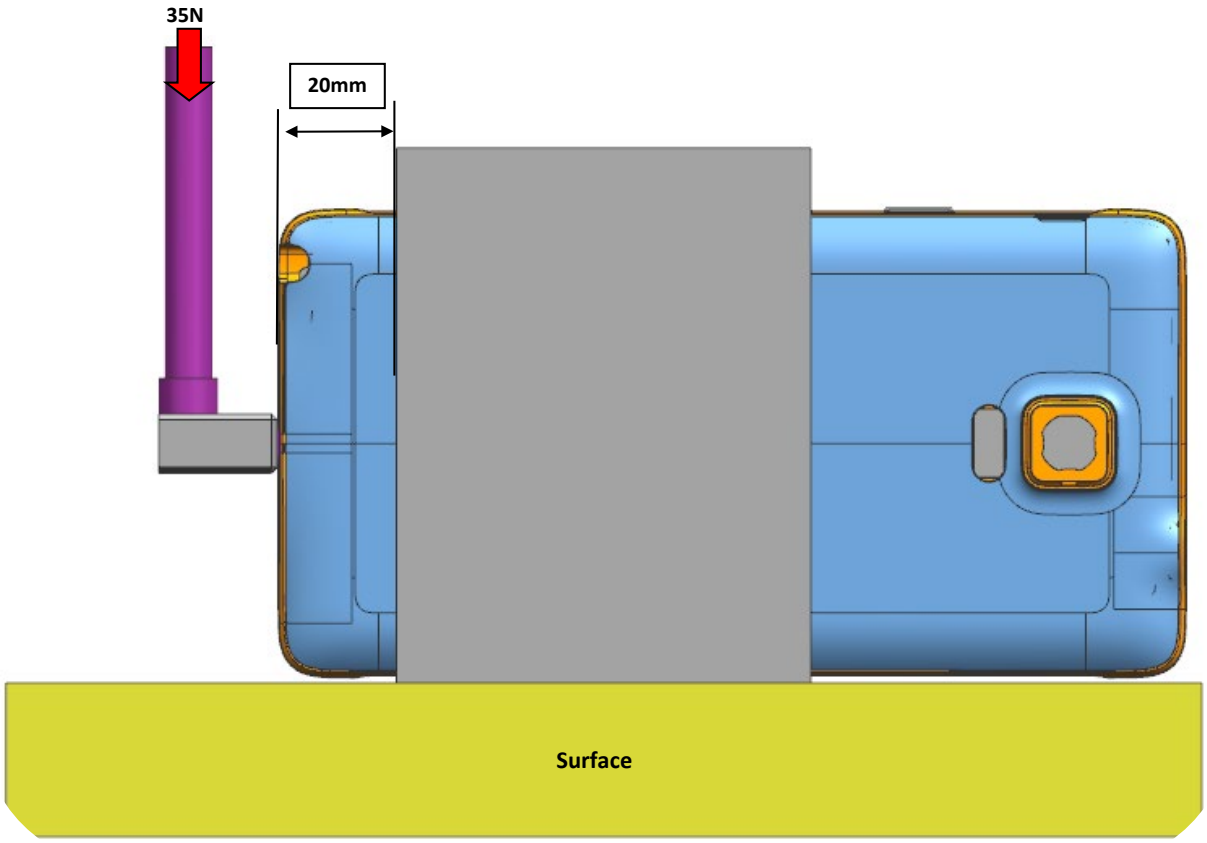


Figure E.2-2 USB Connector Reliability—Left/Right Direction Case

4. Attach the plug to connector receptacle.
5. Apply force to the centerline of the connector at 10 mm distance from tip end. Force should be constantly monitored and increased up to 35 N with rate of 10 mm/min. Connector or assembly physical break is indicated by sudden drop in force. Stop the test if break off force drop occurs below 35 N. After 35 N force has been reached, force is reduced gradually back to 0 N. Repeat test with second DUT.
6. Repeat the same test procedure with a new connector plug to “down” direction with total of 2 devices.
7. Repeat the test procedure with new connector plug to “left” direction with one DUT.
8. Repeat test procedure with new connector plug to “right” direction with one DUT.
9. At the end, perform relevant functional testing according to Appendix A and note any failures.

Reporting:

Report results according to Appendix A.

E.3 Connector Reliability—Audio (Under Development)

Reference:

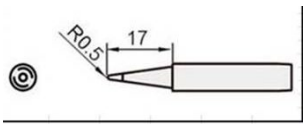
N/A

Purpose:

Ensure mechanical strength of assembled headset connector. Connector shall withstand 45 N force applied perpendicular to the connector plug. This test is only performed if the device has a separate audio connector.

Procedure:

1. Ensure DUT meets Appendix A.
2. Test shall be performed with a test adapter plug on 6 devices; 2 for up direction, 2 for down direction, 1 for left direction and 1 for right direction. At the vendor's discretion, samples may be reused to reduce the total number of samples required to complete the test program. An example test flow is shown in Appendix C.
3. DUT shall be powered on.
4. Test equipment, tensile tester, for this cycle test shall be speed and force/load controllable.
5. Force sensor shall have at minimum ±0.1 N accuracy up to 50 N force.
6. Test shall be conducted with 10 mm/min speed.
7. Test shall be performed with standard, stiff headset connector plug (see Figure E.3-1). For each test direction, test shall be conducted with a new, unused connector plug.



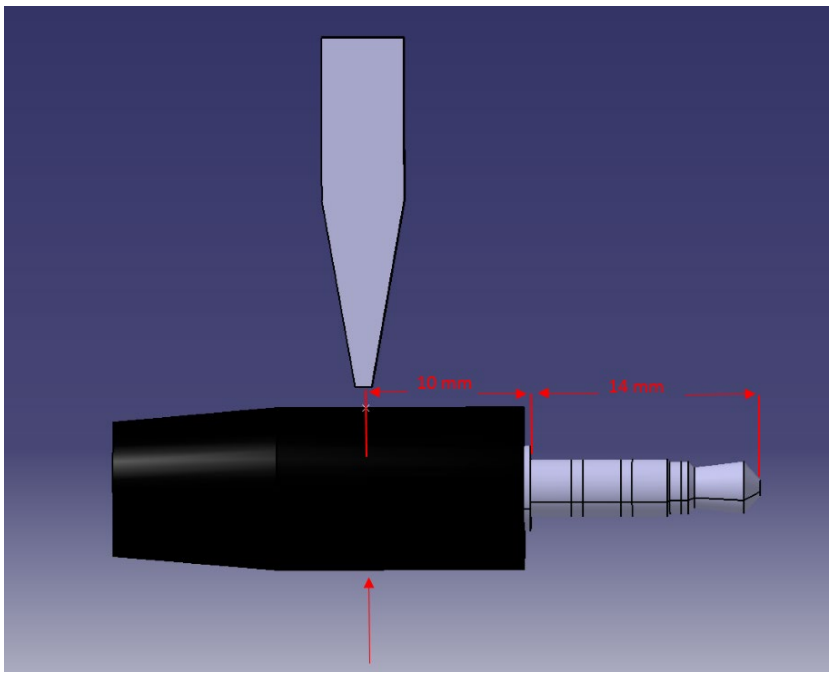


Figure E.3-1 Support for Left & Right Direction Test

8. DUT shall be 50% supported for up/down direction tests (see Figure E.2-1) and allowed to be up to 100% supported to left/right side tests (see Figure E.2-2).
9. During the test, perpendicular forces (Fp) are applied to the connector plug from 4 directions: Top, Bottom, Left and Right. Force shall be applied 24 mm from the tip of the connector. Tip of the connector plug shall be inserted at minimum 14 mm deep into the connector.
10. Lifting connector receptacle from Printed Wire Board (PWB) is considered testing up direction and pushing down toward PWB is downward. Left or Right direction is from looking at the receptacle from its opening as PWB places bottom side of receptacle.
11. Fix the DUT on the testing table on tensile tester (see Figure E.2-1 and Figure E.2-2 for fixing instructions) for “up” test direction.
12. Attach the plug to connector receptacle.
13. Apply force to the centerline of the connector at 24 mm distance from tip end.
14. Force shall be constantly monitored and increased up to 45 N with rate of 10mm/min. Connector or assembly physical break is indicated by sudden drop in force. Record the break off force if it occurs below 45 N.
15. After 45 N force has been reached, force is reduced gradually back to 0 N. Repeat test with second DUT.
16. Repeat the same test procedure with a new connector plug to “down” direction with total of 2 devices.
17. Repeat the test procedure with new connector plug to “left” direction with one DUT.
18. Repeat test procedure with new connector plug to “right” direction with one DUT.
19. At the end, perform relevant functional testing according to Appendix A and note any failures.

Reporting:

Report results according to Appendix A.

Appendix F Revision History

Date	Version	Description
September 2015	1.0	• Initial release
August 2017	1.1	• Removed reference to IPC-TR-467 • Renamed Section 2.1 from “Drop Testing” to “Smooth-Surface Drop Test” • Added Section 2.2 Rough-Surface Drop Test • Added Appendix B Fatal Failure Definition • Added Appendix C Example Sample Reuse Test Flow • Restructuring and editorial updates
January 2021	2.0	• Updated Appendices A and B • Updated Tumble/Barrel Test • Added solution to secure smartphone removal parts (e.g., stylus, SIM/SD card, etc.) during tumble testing • Updated Appendix C, which now defines test data reporting guidelines • Updated Appendix D, new reuse allowances • Updated Appendix E to reflect the removal of deprecated test cases from the test plan • Updated IPx2 Procedure • Reclassification and removal of select test cases • Created test plan addendum containing deprecated test cases
April 2021	2.1	• Incorporated new liquid ingress protection testing criterion. Replaced section 3 • Incorporated PCBA inspection guidelines. • Added Section 4.
November 2022	2.2	• Added Section 4: Temperature and Humidity. • Added Section 5: Hardness/Scratch Resistance Testing. • Replaced Rough Surface Drop Test in E.1 and made it Optional. • Replaced Section 2.1: Tumble Barrel Testing. • Replaced Appendix A and B with updated inspection process and failure definitions. • Updated IPx1 and IPx2 rainfall values to properly reflect IEC 60529. • Added new Appendix B: Critical Inspection Procedure • Corrected errors in the first bullets of Section 3.2 and Section 3.3
November 2022	2.2.1	• Fixed typos in section 2.1 Tumble/Barrel Test.