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July 17, 2026

MEMORANDUM FOR MILITARY/INDUSTRY DISTRIBUTION

SUBJECT: Initial Draft of Proposed Revision of Test Method 2011 "BOND STRENGTH (DESTRUCTIVE BOND PULL TEST)" of MIL-STD-883-2

Project Number: 5962-2026-004

The initial draft of this document is now available for viewing and downloading from the DLA Weapons Support (Columbus) -VA website using following URLs:

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The objective of this EP study is to obtain from the military services, device manufacturers, OEMs, and user community comments or concurrence regarding the proposed revision of test method 2011 of MIL-STD-883-2.

Concurrence or comments are required at this office within 30 days from the date of this letter. Comments received after this period will be retained for consideration during the next coordination cycle of this document. Comments submitted by military departments must be clearly identified as either "**Essential**" or "**Suggested.**" Essential comments must include supporting justification or data. Military review activities should forward their comments through their respective custodians, as applicable, allowing sufficient time for consolidation of the department's response. A lack of response to this draft will be interpreted as concurrence.

If this document is of interest to you, please provide your comments or suggested changes. The point of contact for this document is Mr. Chance Hunter, phone number 614-693-0496, e-mail: chance.hunter@dlamail.mil, or may be mailed via the US Postal Service to DLA Weapons Support (Columbus), ATTN: VAS (Attention: Chance Hunter), P.O. Box 3990, Columbus, OH 43218-3990.

Sincerely,

James Eschmeyer
Chief,
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Cc:

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METHOD 2011.XX

BOND STRENGTH (DESTRUCTIVE BOND PULL TEST)

1. **PURPOSE.** The purpose of this test is to measure bond strengths, evaluate bond strength distributions, or determine compliance with specified bond strength requirements of the applicable acquisition document. This test may be applied to the wire-to-die bond, wire-to-substrate bond, or the wire-to-package lead bond inside the package of wire-connected microelectronic devices bonded by soldering, thermocompression, ultrasonic, or related techniques. It may also be applied to bonds external to the device such as those from device terminals-to-substrate or wiring board or to internal bonds between die and substrate in non-wire-bonded device configurations such as beam lead or flip chip devices.

1.1 Definitions:

- a. **Bond, wire:** The adhesion or welding of a wire (typically gold, aluminum, or copper) to a bonding surface using a thermosonic or ultrasonic wire bonding process.

- b. **Ball bond:** The first bond during the thermosonic (ball) bonding process, in which the end of a small diameter wire (typically gold or copper) is bonded to a die bonding surface (typically an aluminum alloy die pad metallization).

Note: The ball bond includes the enlarged spherical or nail-head portion of the wire that is provided by the electronic flame-off, the underlying bonding pad, and the metallurgical weld interface between the ball bond and the bonding pad.

- c. **Stitch bond:** The second bond during the thermosonic (ball) bonding process, in which the wire typically bonded to the package bonding surface (e.g., leadframe, substrate, post, etc.).

Note: (1) A stitch bond may also be referred to as a crescent bond

(2) For some unique constructions (e.g., reverse bond), the second bond may be formed on top of a bump. See also "reverse bond" and "bump".

- d. **Wedge bond:** The attachment of a wire or a ribbon (aluminum, copper, or gold) to a die bonding surface (typically aluminum pad metallization) or the package bonding surface (usually a plated leadframe post or finger) using an ultrasonic bonding process.

- e. **Bonding surface:** Surface to which the wire is bonded, which may be any one of the following: a) the die pad metallization or die surface metallization (e.g., MOSFET), b) the package surface metallization (e.g., leadframe, substrate, post), c) a bump (see also "reverse bond" and "bump"), or a bonded stitch on die pad/flag or package surface metallization (see also "security bond" and "security loop").

- f. **Bonding process, thermosonic:** A bonding process in which two members are joined through the combined application of heat, pressure, and an ultrasonic oscillatory lateral motion.

- g. **Bonding process, ultrasonic:** A bonding process in which two members are joined through the combined application of pressure and an ultrasonic oscillatory lateral motion.

- h. **Bonding wire:** A wire that is bonded to a chip bonding surface in order to electrically connect the chip to any other point within the device package.

- i. **Ribbon (wire):** A flat wire (non-round).

Note: Throughout this test method the term "wire" covers both wire and ribbon (wire).

- j. **Aluminum wire:** An aluminum alloy wire in which the aluminum content is typically 98% or greater.

- k. **Copper wire:** A copper alloy wire in which the copper content is typically 99%, but also includes copper wire with a very thin coating of palladium or gold and palladium.

- l. Gold wire: A gold alloy wire in which the gold content is typically 99% or greater.
- m. Midspan: A location on the bonded wire that is approximately one half of the horizontal distance between the two bonds. (See Figure 2011-1)

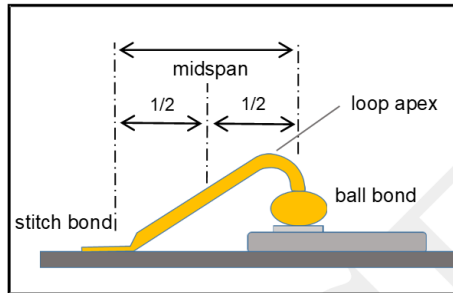


Figure 2011-1. Definition of midspan

- n. Outlier product: Product that meets manufacturer specifications and user requirements but exhibits anomalous characteristics with respect to a normal population (an example of which is depicted by the histogram in Figure 2011-2) and may be subject to a higher-than-normal level of failures in the user's application.

Note: (1) For purposes of this document, all Wire Bond Pull Tests have only a minimum pull value requirement and no upper limit, thus the upper specification limit (USL) is not applicable.

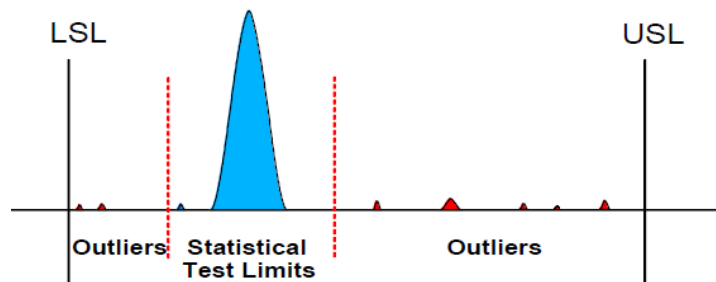


Figure 2011-2. Depiction of eight outliers, seven of which are outlier products

- o. Reverse bond: A thermosonic bond for which the ball is placed on the package bonding surface and the stitch is placed on a bump on the die. This is also known as "stitch on ball".
- p. Bump: A thermosonic ball bond from which the wire has been removed. It can be used as the underlying ball bond for reverse bonds on which the stitch (2nd bond) for the reverse bond is placed, or the ball bond placed on a stitch bond to form a security bond.
- q. Security bond: The placing of a bump (see also "bump") on top of a stitch bond to improve the mechanical strength of a stitch bond to withstand the shearing stress between the encapsulation material and the bonding surface.

Note: Security bonds are commonly used in surface mount LED (light emitting diode) packages which use non-filled encapsulants for the lens material that have higher coefficients of thermal expansion than silica filled encapsulants, and thus exert higher shear stresses on the stitch bond.

- r. Security loop: A security bond from which the wire has not been removed and the wire for the security loop is attached to the same bonding surface as a stitch bond.
- s. Wire bond pull, destructive: A process in which an instrument pulls on a thermosonic or ultrasonic bonded wire until failure.

- t. Wire bond pull force (destructive): The force required to cause any of the following to occur: the bonded wire to break; one of the bonds to separate from a bonding surface; or one of the bonding surfaces to separate from the die, leadframe, or substrate.

2. APPARATUS and MATERIAL. The apparatus and materials required for wire bond pull testing shall be as follows:

2.1 Inspection equipment

An optical microscope system with a minimum of 30X magnification is required to support the optical assessment of the resulting failure mode, such as whether the wire break was ductile or brittle or if the bond lifted from pad or leadframe/substrate with or without residues on pad or leadframe/substrate). However, a higher magnification may be necessary for verifying failure codes 1, 2, 3, 6, 7, 8, and 9 (see 3.2.1 for a detailed discussion of failure codes).

2.2 Workholder

The fixture used to hold the device, known as the "workholder" shall prevent any movement of the device during wire bond pull testing and shall allow positioning the hook for optimum force application to the wire.

2.3 Wire bond pull equipment

The apparatus shall consist of suitable equipment for applying a pulling force to the bonding wire as required per this test method until failure occurs within the wire, wire bond, or wire bonding surface. The equipment shall be capable of applying force at a constant rate. The equipment shall indicate the applied force in SI and/or English units and be calibrated over the full range of the expected values for the specific wire being pulled with an accuracy of ± 5 percent of the intended breaking load or ± 2.9 mN (± 0.3 gf), whichever is the greater tolerance. The required range of force values will vary by wire material and wire cross-section.

The pull tester manufacturer's recommended pulling tool travel speed for the wire material being tested should be used. To verify that the pull speed for a test was in an acceptable range, the output of the loadcell shall be reviewed to ensure that the strain rate was consistent throughout the test.

2.3.1 Calibration

Before performing the wire bond pull test, it must be determined that the equipment has been calibrated in accordance with manufacturer's specifications and is presently in calibration.

Recalibration is required if the equipment is moved to another location.

2.4 Pulling hook

The pulling hook should be made of a strong, rigid material that will not deform during pull testing. The diameter of the wire used to make the hook utilized to apply force to the interconnect wire shall be large enough and its final shape shall be such to ensure that the force applied by the hook distributes the pull force through the wire to the bonds and does not cut through the wire. Table 1 provides the minimum diameter for the pulling hook to ensure the above requirement.

Table 1 – The minimum diameter of the pulling hook

Wire diameter	Hook diameter
≤ 50 microns (2 mils)	Minimum of 2.0 x wire diameter
> 50 microns (2 mils) to ≤ 125 microns (5 mils)	Minimum of 1.5 x wire diameter
> 125 microns (5 mils)	Minimum of 1.0 x wire diameter

For ribbon wire, use the equivalent round wire diameter which gives the same cross-sectional area as the ribbon wire being tested. The flat portion of the hook (horizontal) should be >1.25 x the equivalent diameter of the ribbon wire being tested.

The hook shall be smooth (no sharp edges) and free of defects and contamination which could compromise the test results or damage the wire being pulled.

2.5 Bond pull clamp (this would be used if loop was too low)

For the clamp pull tests, the clamp used shall be able to apply enough force to the wire being pulled to hold it firmly such that it will not slip during the test. The clamp shall be large enough to firmly hold the diameter of the wire or width and thickness of the ribbon to be pulled such that it does not move when being pulled. The external shape and dimensions of the clamp shall be optimized to allow for it to clamp onto the wire to be pulled, but also minimize the chance of it touching and possibly damaging other wires on the device that are intended to be pull tested.

3. PROCEDURE.

General. The test shall be conducted using the test condition specified in the applicable acquisition document consistent with the particular device construction. All bond pulls shall be counted and the specified sampling, acceptance, and added sample provisions shall be observed, as applicable. Unless otherwise specified, for conditions A, C, and D, the sample size number specified for the bond strength test shall determine the minimum sample size in terms of the minimum number of bond pulls to be accomplished rather than the number of complete devices in the sample, except that the required number of bond pulls shall be randomly selected from a minimum of 4 devices. Bond pulls in accordance with test conditions D, F, G, and H, while involving two or more bonds shall count as a single pull for bond strength and sample size number purposes. Unless otherwise specified, for conditions F, G, and H the sample size number specified shall determine the number of die to be tested (not bonds). For hybrid or multichip devices (all conditions), a minimum of 4 die or use all die if four are not available on a minimum of 2 completed devices shall be used. Where there is any adhesive, encapsulant or other material under, on or surrounding the die such as to increase the apparent bond strength, the bond strength test shall be performed prior to application. The stress required to achieve bond failure shall be observed and the physical location of the point of failure shall be recorded as being in one of the listed categories (see 3.2.1).

When flip chip or beam-lead chips are bonded to substrates other than those in completed devices, the following conditions shall apply:

- The sample of chips for this test shall be taken at random from the same chip population as that used in the completed devices that they are intended to represent.
- The chips for this test shall be bonded on the same bonding apparatus as the completed devices, during the time period within which the completed devices are bonded.
- The test chip substrates shall be processed, metallized, and handled identically with the completed device substrates, during the same time period within which the completed device substrates are processed.

3.1 Test:

3.1.1 Test condition A - Bond peel. This test is normally employed for bonds external to the device package. The lead or terminal and the device package shall be gripped or clamped in such a manner that a peeling stress is exerted with the specified angle between the lead or terminal and the board or substrate. Unless otherwise specified, an angle of 90 degrees shall be used. When a failure occurs, the force causing the failure and the failure category shall be recorded.

3.1.2 Test condition C - Wire pull (single bond). This test is normally employed for internal bonds at the die or substrate and the lead frame of microelectronic devices. The wire connecting the die or substrate shall be cut so as to provide two ends accessible for pull test. Cut the wire to be pulled at its mid-span. If the wire is too short to allow for each end to be properly pulled, cut the wire close to one bond in order to allow pull testing of the opposite bond. The wire should be long enough to ensure that the clamp can be firmly attached without contacting the neckdown region of the wire above the bond so that a wire break fail mode (code 5) is still possible. Care must be taken when cutting the wire to avoid damaging the rest of the wire and the bond to be tested. See Figures 2011-3a and 2011-3b for examples of acceptable and unacceptable clamp placement.

The wire shall be gripped in a suitable device and simple pulling action applied to the wire or to the device (with the wire clamped) in such a manner that the force is applied approximately normal to the surface of the die or substrate. When a failure occurs, the force causing the failure and the failure category shall be recorded.

Figure 2011-3 – Examples of acceptable and unacceptable placement of clamp on wire

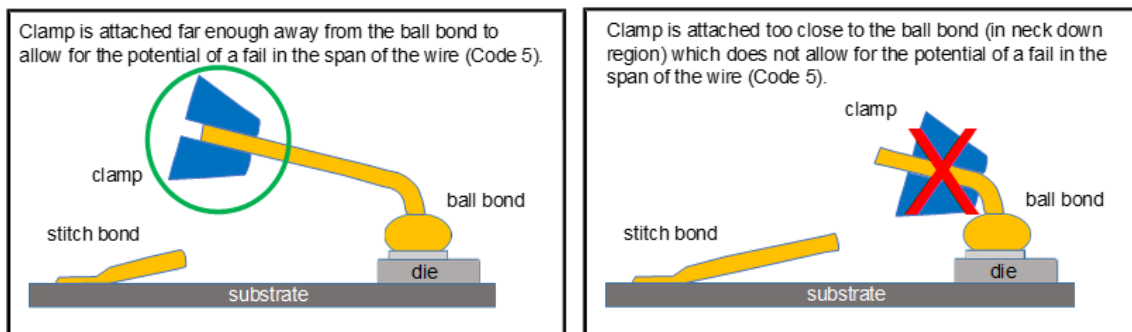


Figure 2011-3a Acceptable placement of clamp

Figure 2011-3b Unacceptable placement of clamp

Position the device so that the wire to be pulled is located below the clamping tool. Lower the clamping tool or raise the device depending upon the wire bond pull equipment being used, so the clamp is just above the wire to be pulled. Position the clamp onto the wire to be tested and then orient the sample or clamp to allow for the pulling of the wire in the direction prescribed in 3.1.2.1 or 3.1.2.2 based on the type of bond being pulled. Pull the wire in the prescribed direction.

3.1.2.1 Ball Pull Clamp Test (BPCT) – clamp pull of thermosonic ball bond

This test condition may be used on gold and copper wire thermosonic ball bonds. For pulling thermosonic ball bonds, the direction of pull shall be straight up from the ball bond (90° with respect to bonding surface). See Figure 2011-4.

3.1.2.2 Stitch Pull Clamp Test (SPCT) – clamp pull of thermosonic stitch bond

This test condition may be used on gold and copper wire thermosonic stitch bonds. For pulling thermosonic stitch bonds the direction of pull shall be straight up from the stitch bond (90° with respect to bonding surface). See Figure 2011-5.

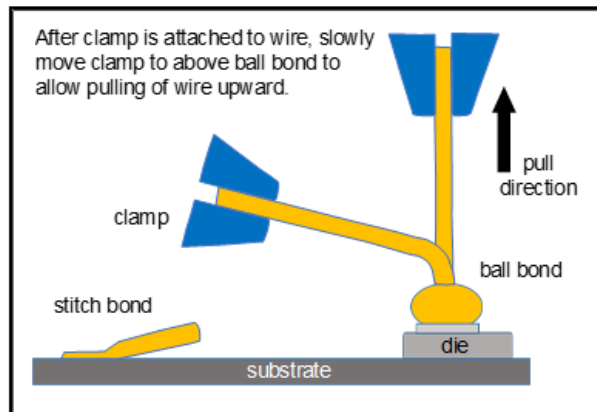


Figure 2011-4 Clamp placement for ball pull test

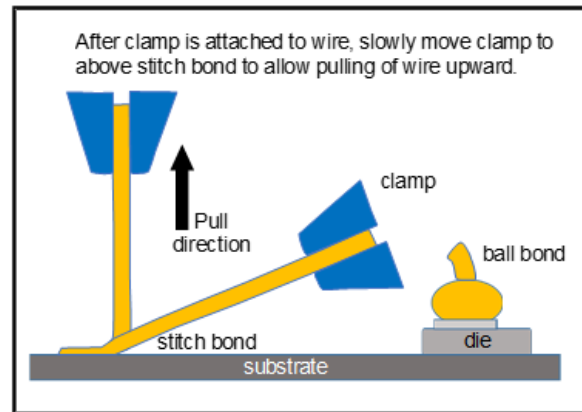


Figure 2011-5 Clamp placement for Stitch pull test

3.1.3 Test condition D - Wire pull (double bond). This procedure is identical to that of test condition C, except that the pull is applied by inserting a hook under the lead wire (attached to die, substrate or header or both ends) with the device clamped and hook contacting the wire between midspan and loop apex, without causing adverse wire deformation (for forward wedge and ball bonding, this would be between midspan and the die edge: for reverse bonding, this would be between midspan and the package edge) and the pulling force is applied in a perpendicular direction to the die or substrate surface. See Figure 2011-1. When a failure occurs, the force causing the failure and the failure category shall be recorded. The minimum bond strength shall be taken from table 12. Figure 2011-14 may be used for wire diameters not specified in Table 12. For wire diameter or equivalent cross section >0.005 inch, where a hook will not fit under the wire, a suitable clamp can be used in lieu of a hook.

3.1.3.1 Wire Pull Test (WPT) – Hook pull near the midspan of the wire

This test may be used on thermosonic bonded gold and copper wire; on ultrasonic bonded gold, copper, and aluminum wire; and ultrasonic gold or aluminum ribbon.

For this test the hook shall be placed approximately at the midspan of the length of the wire that is not deformed by the formation of the bonds. See Figures 2011-6a through 2011-6f for variations in hook placement for different types of wire bonds. Each of the diagrams in Figure 2011-6a through 2011-6f shows a space between two lines for the approximate placement of the hook. This test method cannot provide an exact location for the placement of the hook due to differences in wire length and shape for each bonded wire. Whenever possible, it is recommended that each wire to be pulled be reviewed and a specific location be identified to minimize variability in the results if multiple samples of the same device are to be pull tested.

The hook shall be in a fixed position that restricts motion along a straight line between each bond, so that it will not rise to the highest point which could result in a test for only one bond (e.g., as for a ball bond).

Figure 2011-6 - Hook placement for Wire Pull Test (WPT) for different types of wire bonds

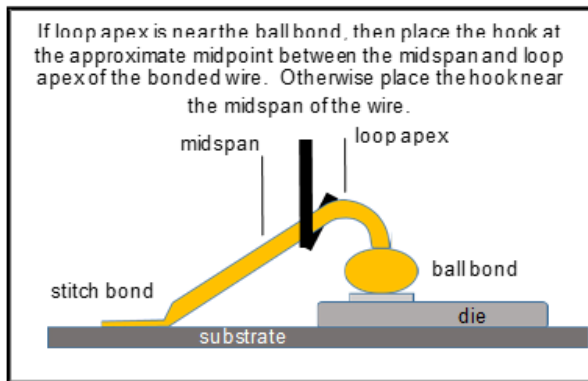


Figure 2011-6a Thermosonic (die to substrate)

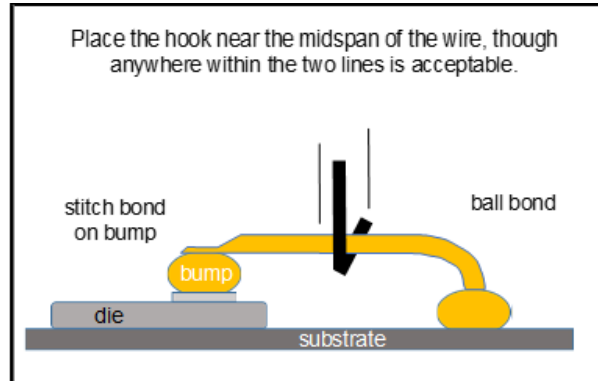


Figure 2011-6b Thermosonic (reverse)

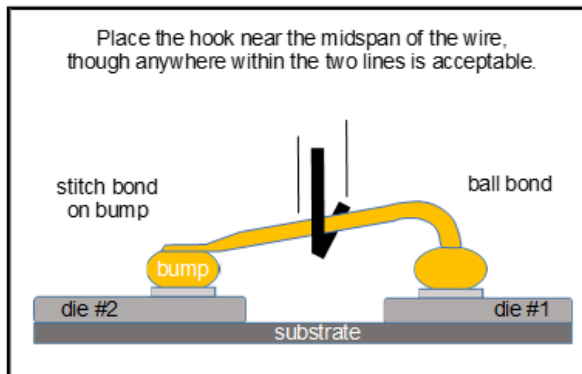


Figure 2011-6c Thermosonic (die to die)

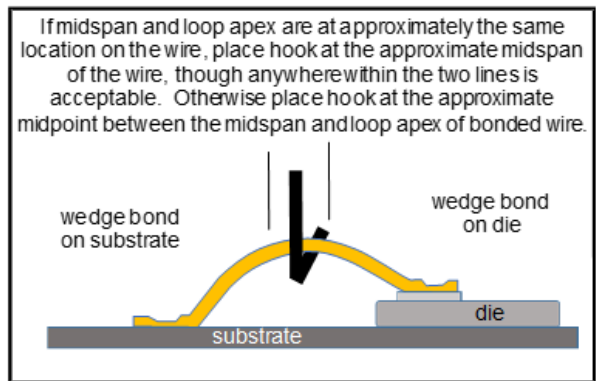


Figure 2011-6d Ultrasonic (die to substrate)

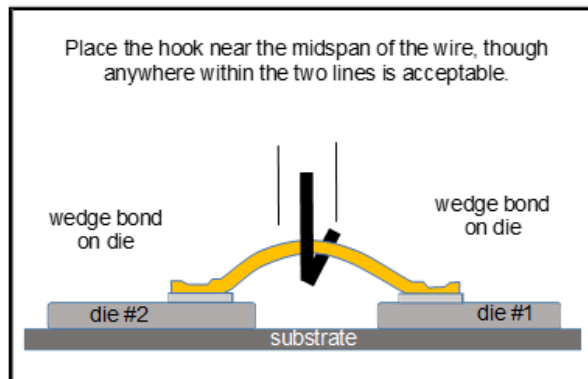


Figure 2011-6e Ultrasonic (die to die)

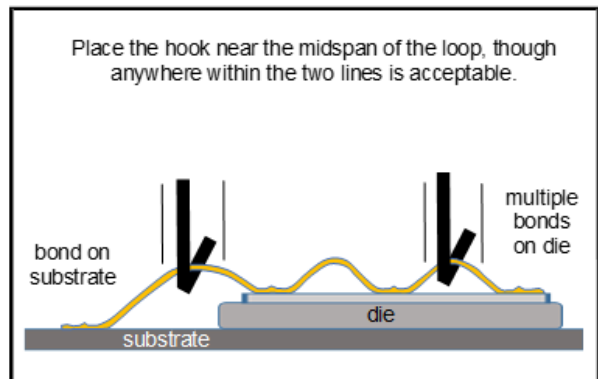


Figure 2011-6f Ultrasonic multi-loop wire/ribbon

3.1.3.1.1 Special considerations for pulling a bonded ribbon or wire with multiple loops

When performing (mid-span) wire pull testing on a bonded ribbon or wire with multiple loops see the requirements below for the number of loops to be pulled. If the bonded ribbon or wire has:

- 2 loops – Pull only one of the loops (as the middle bond will be weakened by the initial pull which could artificially lower the pull force for the 2nd loop).
- 3 or 4 loops – Pull the outer two loops.

- 5 or more loops – Pull the outer two loops. Optionally, additional loops may be pulled as long as neither bond for the loop has been previously subjected to pull testing (i.e., neither loop on each side of the loop to be pulled has been pull tested).

3.1.3.1.2 Special considerations for pulling wires and ribbons with low loop height

Wires with low loop height may prevent access of the hook for wire pull testing. Figure 2011-7 shows a module with multiple die and the ultrasonic bonds shown have low bond angles and thus an overall low loop height.

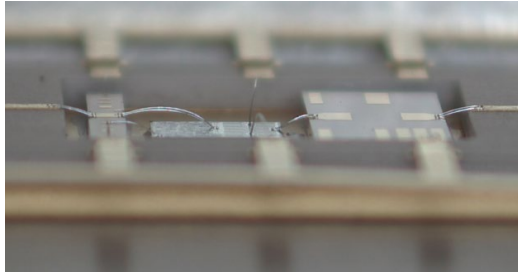


Figure 2011-7 – Wires with low bond angles

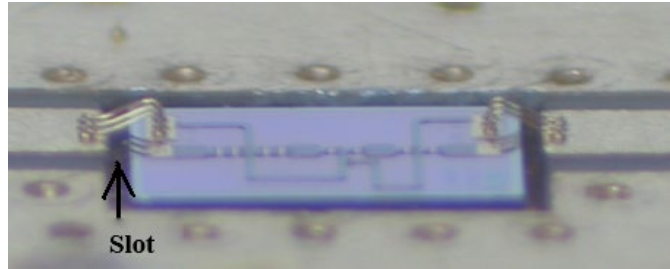


Figure 2011-8 - Device with slots to allow for hook placement

A test coupon with either slots (see Figure 2011-8) or attached metallized ceramic chips may be used to replicate the wire loop profile and permit access of the hook to the wire to be tested. These wires are to be bonded at the same time the production devices are bonded using the same setup, operator, and schedule. The test coupon wires are to be pull tested in lieu of the inaccessible wires on the production device. Failures on the test coupon shall be considered as failures to production device and appropriate action is to be taken in accordance with the applicable specification.

NOTE: RF/microwave hybrids that require extremely flat loops which may cause erroneous wire pull data may use the following formula to determine the proper wire pull value.

$$V_1 = V_2 \sin \Theta$$

Where: V_1 = New value to pull test.

V_2 = Table I value for size wire tested.

Θ = Greatest calculated wire loop angle (Figure 2011-9).

Also, RF/microwave hybrids that contain wires that cannot be accessed with a pull hook must be duplicated on a test coupon in such a way to allow hook access for purposes of pull testing. These wires are to be bonded at the same time the production hybrids are bonded using the same setup, operator, and schedule. The test coupon wires are to be pull tested in lieu of the tuning or inaccessible wires on the production hybrid, see figure 2011-14a and figure 2011-14b. Failures on the test coupon shall be considered as failures to production units and appropriate action is to be taken in accordance with the applicable specification

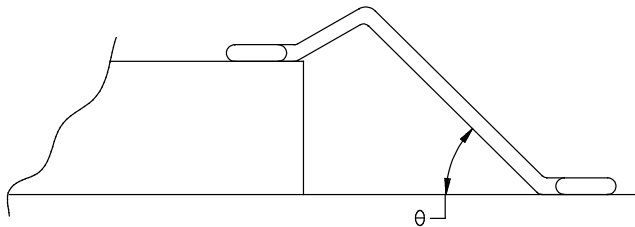


FIGURE 2011-9. Wire loop angle.

3.1.3.1.3 Special considerations for pulling wires on stacked die

Stacking configurations for packages with multiple dice can pose challenges in wire pull testing as not all wires or bonds will be exposed to allow for proper pull testing. For some die stacks, not all wires will be accessible by a hook or clamp once fully assembled. For other die stacks, some of the bonds may not be able to freely move during the pull test (e.g., are encapsulated by die adhesive material).

To enable wire pull testing for process monitoring, special test vehicles of partially assembled product should be used to allow for the pulling of wires and bonds that are not accessible once all dice are bonded. The test vehicle shall be bonded at the same time the production devices are bonded using the same processes, procedures, and controls.

When developing the test vehicle build plan, ensure that the wires chosen for pull testing cover the extremes found within the package. For example, pulling wires with the lowest and highest loop profile or pulling the top and bottom wires in a stack to sample the extremes for bonding preheat.

Figure 2011-10 shows a stack of 8 dice, with four dice stacked like shingles going to the right, and then four dice stacked going to the left. The wires shown for the lower four dice cannot be pulled by a hook as the upper four dice create interference with the pull test. The bond on the fourth die in the stack has the additional issue that it is within the die attach film and thus would not be free to move during wire pulling test. Therefore, it is recommended that to assess the integrity of the wire bonds on the four lower dice, a test vehicle with just the bottom four dice be used for wire pull testing and actual product be used for pull testing of the wire bonds on the top four dice.

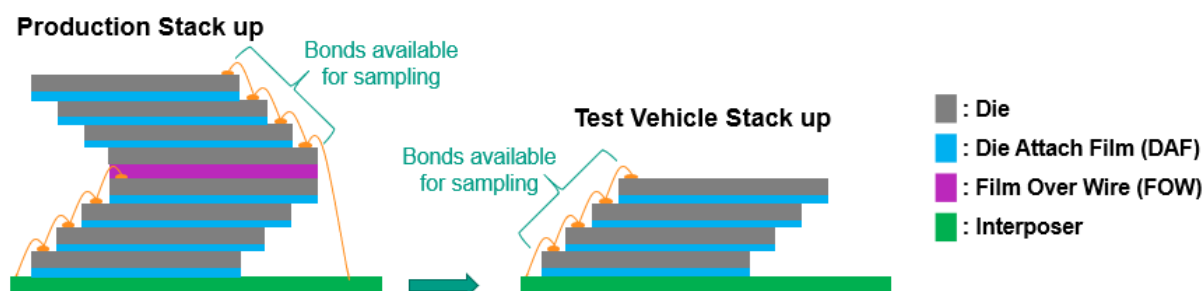


Figure 2011-10 – Reverse “shingle” stack

Figure 2011-11 shows a vertical stack of five dice of the same size. The ball bonds for the lower four dice are fully immersed in the die attach film of the die above it. Pulling these wires would not provide a realistic assessment of the bond strength as the film would alter the pull force value. It is also not feasible to build test vehicles ranging from 1 die, 2 die, and up to the total number of dice in the production stack. Therefore, the recommendation for pull testing of a vertical stack is as follows:

- 1) Build a test vehicle along with production product that consists of just the bottom die of the stack and pull the wires on that die.
- 2) Pull the wires of the top die of a fully assembled stack.

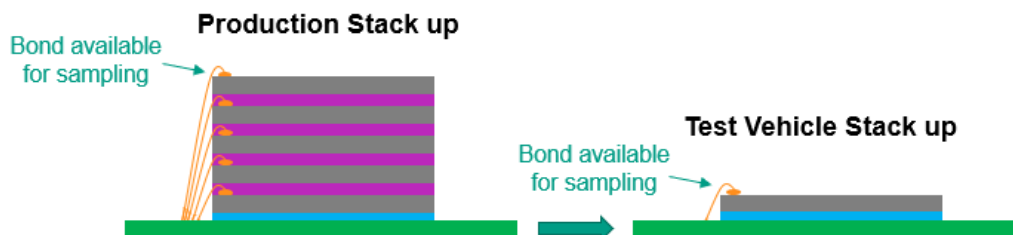


Figure 2011-11 – Vertical stack of dice of the same size

3.1.3.2 Ball Pull Test (BPT) – Hook pull near the neck of the thermosonic ball bond

This test may be used for process development and product qualification on thermosonic ball bonds of gold and copper wire.

For this test the hook shall be placed as close to the ball bond as possible or within the range shown in the images below. See Figures 2012-11a through 12c for hook placement for different types of wire bonds. Each of the diagrams in Figure 2011-12 shows a space between two lines for the approximate placement of the hook. This test method cannot provide an exact location for the placement of the hook due to differences in wire length and shape for each bonded wire. Whenever possible, it is recommended that each ball bond to be pulled be reviewed and a specific location be identified to minimize variability in the results if multiple samples of the same device are to be pull tested.

The hook shall be in a fixed position that restricts motion away from the ball bond (the point of interest), since moving away from the point of interest could result in a test that is more of the wire and less of the ball bond.

Figure 2011-12 - Hook placement for Ball Pull Test (BPT) for different types of wire bonds

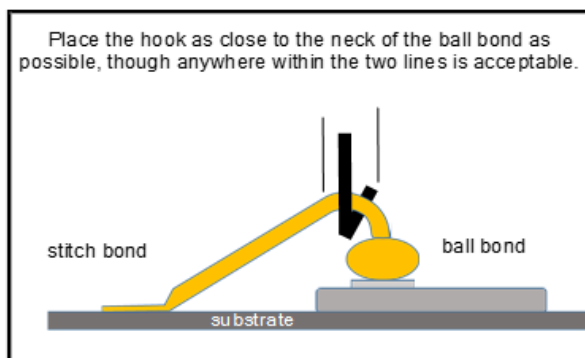


Figure 2011-12a Thermosonic (die to substrate)

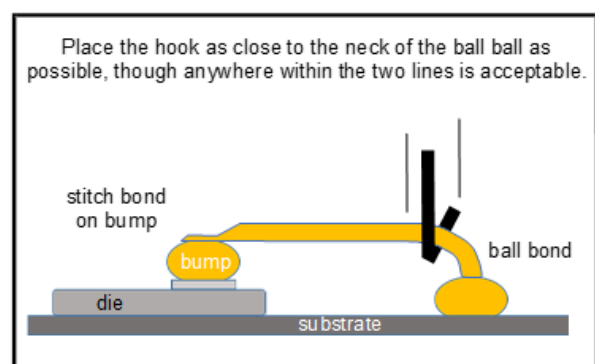


Figure 2011-12b Thermosonic (reverse)

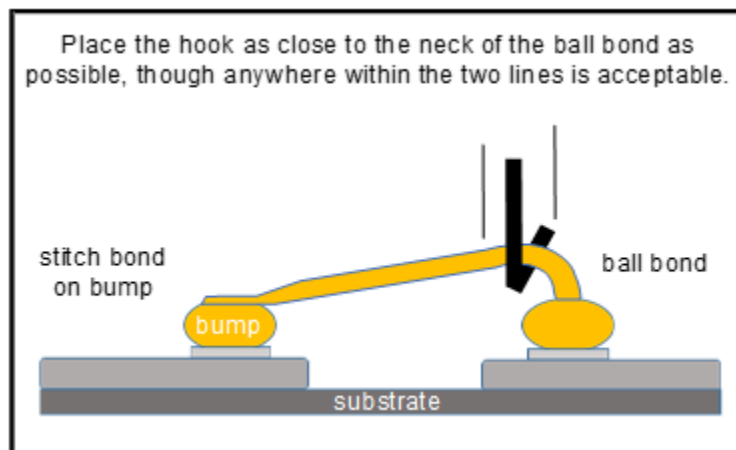


Figure 2011-12c Thermosonic (die to die)

3.1.3.3 Stitch Pull Test (SPT) – Hook pull near the thermosonic stitch bond

This test may be used on thermosonic stitch bonds of gold and copper wire.

For this test the hook shall be placed as close to the stitch bond as possible or within the range shown in the images below. See Figures 2011-13a through 13c for hook placement for different types of wire bonds. Each of the diagrams in Figure 2011-13 shows a space between two lines for the approximate placement of the hook. This test method cannot provide an exact location for the placement of the hook due to differences in wire length and shape for each bonded wire. Whenever possible, it is recommended that each stitch bond to be pulled be reviewed and a specific location be identified to minimize variability in the results if multiple samples of the same device are to be pull tested.

The hook shall be in a fixed position that restricts motion away from the stitch bond (the point of interest), since moving away from the point of interest could result in a test that is more of the wire and less of the stitch bond.

Figure 2011-13 - Hook placement for Stitch Pull Test (SPT) for different types of wire bonds

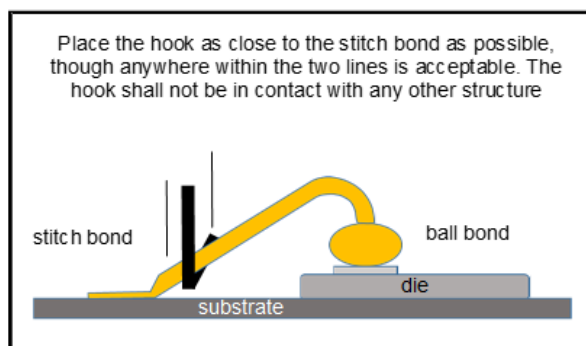


Figure 2011-13a Thermosonic (die to substrate)

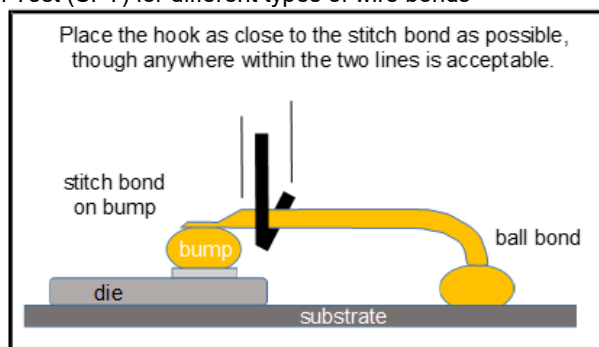


Figure 2011-13b Thermosonic (reverse)

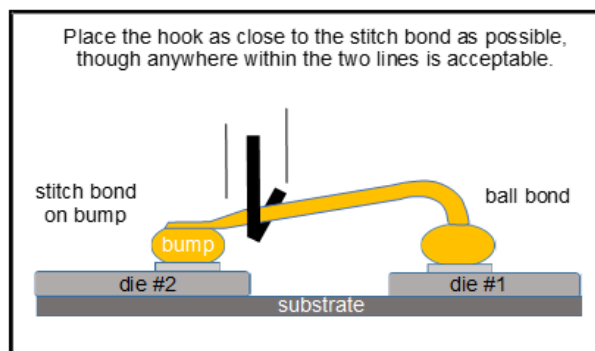


Figure 2011-13c Thermosonic (die to die)

3.1.4 Test condition F - Bond shear (flip chip). This test is normally employed for internal bonds between a semiconductor die and a substrate to which it is attached in a face-bonded configuration. It may also be used to test the bonds between a substrate and an intermediate carrier or secondary substrate to which the die is mounted. A suitable tool or wedge shall be brought in contact with the die (or carrier) at a point just above the primary substrate and a force applied perpendicular to one edge of the die (or carrier) and parallel to the primary substrate, to cause bond failure by shear. When a failure occurs, the force at the time of failure, and the failure category shall be recorded.

3.1.5 Test condition G – Push-off test (beam lead). This test is normally employed for process control and is used on a sample of semiconductor die bonded to a specially prepared substrate. Therefore, it cannot be used for random sampling of production or inspection lots. A metallized substrate containing a hole shall be employed. The hole appropriately centered, shall be sufficiently large to provide clearance for a push tool, but not large enough to interfere with the bonding areas. The push tool shall be sufficiently large to minimize device cracking during testing, but not large enough to contact the beam leads in the anchor bond area. Proceed with push-off tests as follows: The substrate shall be rigidly held and the push tool inserted through the hole. The contact of the push tool to the silicon device shall be made without appreciable impact (less than 0.01 inch/minute (0.254 mm/minute) and forced against the underside of the bonded device at a constant rate. When failure occurs, the force at the time of failure, and the failure category shall be recorded.

3.1.6 Test condition H – Pull-off test (beam lead). This test is normally employed on a sample basis on beam lead devices which have been bonded down on a ceramic or other suitable substrate. The calibrated pull-off apparatus (see 2) shall include a pull-off rod (for instance, a current loop of nichrome or Kovar wire) to make connection with a hard setting adhesive material (for instance, heat sensitive polyvinyl acetate resin glue) on the back (top side) of the beam lead die. The substrate shall be rigidly installed in the pull-off fixture and the pull-off rod shall make firm mechanical connection to the adhesive material. The device shall be pulled within 5 degrees of the normal to at least the calculated force (see 3.2), or until the die is at 2.54 mm (0.10 inch) above the substrate. When a failure occurs, the force at the time of failure, the calculated force limit, and the failure category shall be recorded.

3.1.7 Wire Ball Bond Shear. Procedure in accordance with JEDEC JESD22-B116 Wire Bond Shear Test Method.

3.2 Failure criteria. Any bond pull which results in separation under an applied stress less than that indicated in table I as the required minimum bond strength for the indicated test condition, composition, and construction shall constitute a failure.

3.2.1 Failure category. Failure categories are as follows: When specified, the stress required to achieve separation and the category of separation or failure shall be recorded.

a. For internal wire bonds:

Table 2 – General description of wire bond pull failure codes for all bond types

Code #	Description of failure code	Break in wire Codes 4 - 6 Fail in bond with leadframe/substrate/post Codes 7 - 9 Fail in bond with die Codes 1 - 3
0 (zero)	Operator error or wire damaged/missing prior to test	
1	Fracture or chip-out of die (includes cratering)	
2	Lifted die metallization or failure within die metallization	
3	Lift of bond from die metallization	
4	Break in wire in the neckdown region of the first bond	
5	Break in the span of the wire	
6	Break in wire in the neckdown region of the second bond	
7	Lift of bond from substrate/leadframe/post metallization	
8	Lifted substrate/leadframe/post metallization	
9	Fracture or lift of substrate/leadframe/post	

Table 3 – Detailed pull failure codes for standard thermosonically bonded wires

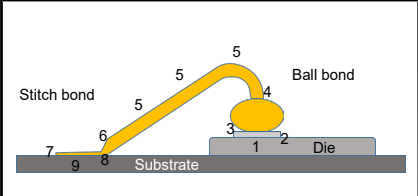
Code	Failure codes – standard thermosonic bonds	 Fail Codes Thermosonic (Standard)
0	Operator error or wire damaged/missing prior to test	
a-1	Fracture or chip-out of die including cratering (portion of dielectric material and possibly other layers remains attached to ball bond)	
a-2	Lifted die metallization (partial or complete lifting of aluminum, copper, NiPdAu, or other die bond pad metallization plating) or failure within the metallization of the die bonding pad	
a-3	Lift of ball bond from die metallization (separation between ball bond and die pad metallization)	
a-4	Break in wire in the neckdown region above the ball bond in the heat affected zone (length equal to 2x wire diameter above ball)	
a-5	Break in the span of the wire (from 2x wire diameter above the ball bond to just above the stitch bond)	
a-6	Break in wire in the neckdown region of the stitch bond (portion of the wire deformed by the capillary, but not bonded to the substrate/leadframe/post)	
a-7	Lift of stitch bond from substrate/leadframe/post metallization (some to no remnant of stitch on substrate/leadframe/post)	
a-8	Lifted substrate/leadframe/post metallization (partial to complete lifting of copper land on substrate or of plated metal on leadframe/post)	
a-9	Fracture or lift of substrate/leadframe/post (portion of substrate material remains attached to stitch bond)	

Table 4 – Detailed pull failure codes for reverse thermosonically bonded wires

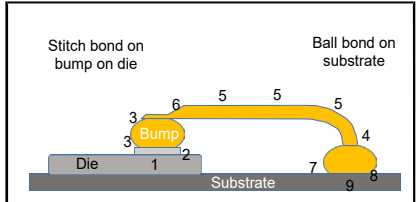
Code	Failure codes –reverse thermosonic bonds (ball on substrate, stitch [on bump] on die)	 Fail Codes –Thermosonic (Reverse)
0	Operator error or wire damaged/missing prior to test	
a-1	Fracture or chip-out of die including cratering (portion of dielectric material and possibly other layers remains attached to ball bond on die)	
a-2	Lifted die metallization (partial or complete lifting of aluminum, copper, NiPdAu, or other die bond pad metallization plating) or failure within the metallization of the die bonding pad	
a-3	Lift of stitch bond from bump (underlying ball bond) (some to no remnant of stitch on ball bond) or lift of bump (underlying ball bond) from die bonding pad (stitch still attached to bump)	
a-4	Break in wire in the neckdown region above the ball bond in the heat affected zone (length equal to 2x wire diameter above ball)	
a-5	Break in the span of the wire (from 2x wire diameter above the ball bond to just above the stitch bond)	
a-6	Break in wire in the neckdown region of the stitch bond (portion of the wire deformed by the capillary, but not bonded to bump)	
a-7	Lift of ball bond from substrate/leadframe/post metallization (separation between ball bond and substrate/leadframe/post pad metallization)	
a-8	Lifted substrate/leadframe/post metallization (partial to complete lifting of copper land on substrate or of plated metal on leadframe/post)	
a-9	Fracture or lift of substrate/leadframe/post (portion of substrate material remains attached to ball bond)	

Table 5 – Detailed pull failure codes for die to die thermosonically bonded wires

Code	Failure codes – die to die thermosonic bonds
0	Operator error or wire damaged/missing prior to test
a-1	Fracture or chip-out of die including cratering (portion of dielectric material and possibly other layers remains attached to ball bond)
a-2	Lifted die metallization (partial or complete lifting of aluminum, copper , NiPdAu, or other metallization plating) or failure within the metallization of the die bonding pad
a-3	Lift of ball bond or bump from die metallization (separation between ball bond and die pad metallization, some to no intermetallic formed), or lift of stitch bond from bump (underlying ball bond)
a-4	Break in wire in the neckdown region above the ball bond in the heat affected zone (length equal to 2x wire diameter above ball)
a-5	Break in the span of the wire (from 2x wire diameter above the ball bond to just above the stitch bond)
a-6	Break in wire in the neckdown region of the stitch bond (portion of the wire deformed by the capillary, but not bonded to bump)
a-7	Not applicable
a-8	Not applicable
a-9	Not applicable

Stitch bond on bump on die

Ball bond on die

Die #2

Substrate

Die #1

Fail codes – Thermosonic (Die to Die)

Table 6 – Detailed pull failure codes for standard ultrasonically bonded wires

Code	Failure codes – standard ultrasonic bonds
0	Operator error or wire damaged/missing prior to test
a-1	Fracture or chip-out of die including cratering (portion of dielectric material and possibly other layers remains attached to wedge bond)
a-2	Lifted die metallization (partial or complete lifting of aluminum, copper , NiPdAu, or other metallization plating) or failure within the metallization of the die bonding pad
a-3	Lift of wedge bond from die metallization (separation between wedge bond and die pad metallization)
a-4	Break in wire in the neckdown region of the wire at the wedge bond on the die (portion of the wire deformed by the bonding tool, but not bonded to the die, and up to 2x wire diameter away from the wedge bond)
a-5	Break in the span of the wire (more than 2x wire diameter away from either wedge bond)
a-6	Break in wire in the neckdown region of the wire at the wedge bond on the substrate/leadframe/post (portion of the wire deformed by the bonding tool, but not bonded to the substrate/leadframe/post, and up to 2x wire diameter away from the wedge bond)
a-7	Lift of wedge bond from substrate/leadframe/post metallization (little to no remnant of stitch on substrate/leadframe/post)
a-8	Lifted substrate/leadframe/post metallization (partial to complete lifting of copper land on substrate or of plated metal on leadframe/post)
a-9	Fracture or lift of substrate/leadframe/post (portion of substrate material remains attached to wedge bond)

Wedge bond on substrate

Wedge bond on die

Substrate

Die

Fail codes – Ultrasonic (Standard)

Table 7 – Detailed pull failure codes for die to die ultrasonically bonded wires

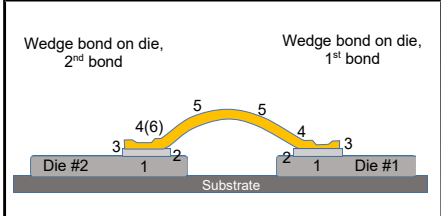
Code	Failure codes – die to die ultrasonic bonds	 Fail codes – Ultrasonic (Die to Die)
0	Operator error or wire damaged/missing prior to test	
a-1	Fracture or chip-out of die including cratering (portion of dielectric material and possibly other layers remains attached to wedge bond)	
a-2	Lifted die metallization (partial or complete lifting of aluminum, copper, NiPdAu, or other metallization plating) or failure within the metallization of the die bonding pad	
a-3	Lift of wedge bond from die metallization (separation between wedge bond and die pad metallization)	
a-4	Break in the wire in the neckdown region at the wedge bond on the die (portion of the wire deformed by the bonding tool, but not bonded to the die, and up to 2x wire diameter away from the wedge bond)	
a-5	Break in the span of the wire (more than 2x wire diameter away from either wedge bond)	
a-6	Not applicable (Optional: If able to track which bond was made 1 st and 2 nd , code 4 may be used for a break in the neckdown region of the wire at the wedge bond above the 1 st die bonded (portion of the wire deformed by the bonding tool, but not bonded to the die, and up to 2x wire diameter away from the wedge bond) and code 6 is for a similar break above the 2 nd die bonded.)	
a-7	Not applicable	
a-8	Not applicable	
a-9	Not applicable	

Table 8 – Detailed pull failure codes for substrate to substrate ultrasonically bonded wires

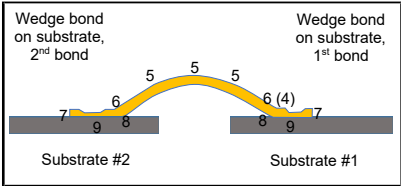
Code	Failure codes – substrate to substrate ultrasonic bonds	 Fail codes – Ultrasonic (Substrate to Substrate)
0	Operator error or wire damaged/missing prior to test	
a-1	Not applicable	
a-2	Not applicable	
a-3	Not applicable	
a-4	Not applicable (Optional: If able to track which bond was made 1 st and 2 nd , code 4 may be used for a break in the wire in the neckdown region at the wedge bond above the 1 st substrate/leadframe/post bonded (portion of the wire deformed by the bonding tool, but not bonded to the substrate/leadframe/post, and up to 2x wire diameter away from the wedge bond) and code 6 is for a similar break above the 2 nd substrate/leadframe/post bonded)	
a-5	Break in the span of the wire (more than 2x wire diameter away from either wedge bond)	
a-6	Break in the wire in the neckdown region at the wedge bond on the substrate/leadframe/post (portion of the wire deformed by the bonding tool, but not bonded to the substrate/leadframe/post, and up to 2x wire diameter away from the wedge bond)	
a-7	Lift of wedge bond from substrate/leadframe/post metallization (little to no remnant of stitch on substrate/leadframe/post)	
a-8	Lifted substrate/leadframe/post metallization (partial to complete lifting of copper land on substrate or of plated metal on leadframe/post)	
a-9	Fracture or lift of substrate/leadframe/post (portion of substrate material remains attached to wedge bond)	

Table 9 – Detailed pull failure codes for multi-loop ultrasonically bonded wires/ribbons

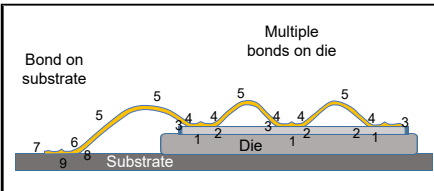
Code	Failure codes – multi-loop ultrasonic wire/ribbon bonds	 Fail Codes - Ultrasonic Multi-loop Wire/Ribbon
0	Operator error or wire damaged/missing prior to test	
a-1	Fracture or chip-out of die including cratering (portion of dielectric material and possibly other layers remains attached to wedge bond)	
a-2	Lifted die metallization (partial or complete lifting of aluminum, copper, NiPdAu, or other metallization plating) or failure within the metallization of the die bonding pad	
a-3	Lift of wedge bond from die metallization (separation between wedge bond and die pad metallization)	
a-4	Break in the wire in the neckdown region at the wedge bond on the die (portion of the wire/ribbon deformed by the bonding tool, but not bonded to the substrate/leadframe/post, and up to 2x wire diameter away from the wedge bond or up to 2x ribbon thickness away from the wedge bond)	
a-5	Break in the span of the wire (more than 2x wire diameter or 2x ribbon thickness away from either wedge bond)	
a-6	Break in the wire in the neckdown region at the wedge bond on the substrate/leadframe/post (portion of the wire/ribbon deformed by the bonding tool, but not bonded to the substrate/leadframe/post, and up to 2x wire diameter away from the wedge bond or up to 2x ribbon thickness away from the wedge bond)	
a-7	Lift of wedge bond from substrate/leadframe/post metallization (little to no remnant of stitch on substrate/leadframe/post)	
a-8	Lifted substrate/leadframe/post metallization (partial to complete lifting of copper land on substrate or of plated metal on leadframe/post)	
a-9	Fracture or lift of substrate/leadframe/post (portion of substrate material remains attached to wedge bond)	

Table 10 – Detailed pull failure codes for external bonds connection device to wiring board or substrate

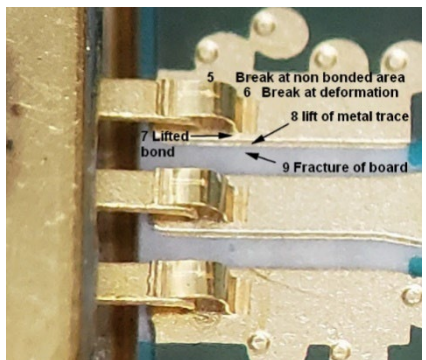
Code	Failure codes – external bonds connection device to wiring board or substrate	
0	Operator error or wire damaged/missing prior to test	
b-1	Not applicable	
b-2	Not applicable	
b-3	Not applicable	
b-4	Not applicable	
b-5	Lead or terminal break at point not affected by bonding process	
b-6	Lead or terminal break at deformation (welding affected region)	
b-7	Failure in bond interface (in solder or at a point of weld interface between lead or terminal and the board or substrate conductor to which the bond was made)	
b-8	Conductor lifted from board or substrate	
b-9	Fracture within the board or substrate	

Table 11 – Detailed pull failure codes beam lead devices

Code #	Failure code – beam lead devices	
0	Operator error or wire damaged/missing prior to test	1 Broken silicon 2 4 5 6 7 SUBSTRATE 8 Lifted substrate/metallization
d-1	Broken silicon.	
d-2	Beam lifting on silicon.	
d-3	Not applicable (use d-2)	
d-4	Beam broken at edge of silicon	
d-5	Beam broken between bond and edge of silicon	
d-6	Beam broken at bond	
d-7	Lifted bond	
d-8	Lifted substrate/leadframe/post metallization	
d-9	Not applicable	

TABLE 12. Minimum bond strength.

Test condition	Wire diameter 1/			Wire composition 1/	Construction 2/	Minimum bond strength (grams force)	
	Mils (Controlling)	Inches (Conversion)	Microns (Conversion)			Pre seal Or Pre mold	Post seal or post mold and any other processing and screening when applicable
A	---	---	---	---	---	Given in applicable document	Given in applicable document
C or D	0.6	0.0006 in	15	Aluminum Gold	Wire	1.3 1.7	-- 1.3
C or D	0.7	0.0007 in	18	Aluminum Gold Copper	Wire	1.5 2.0 2.0	1.0 1.5 2.0
C or D	0.8	0.0008 in	20	Aluminum Gold Copper	Wire	1.8 2.3 2.4	1.1 1.8 2.4
C or D	0.9	0.0009 in	23	Aluminum Gold	Wire	2.1 2.6	1.2 2.1
C or D	1.0	0.0010 in	25	Aluminum Gold	Wire	2.5 3.0	1.5 2.5
C or D	1.2	0.0012 in	30	Aluminum Gold	Wire	2.8 3.6	1.8 2.8
C or D	1.25	0.00125 in	32	Aluminum Gold	Wire	Same bond strength limits as the 0.0013 in wire	
C or D	1.3	0.0013 in	33	Aluminum Gold	Wire	3.0 4.0	2.0 3.0
C or D	1.5	0.0015 in	38	Aluminum Gold	Wire	4.0 5.0	2.5 4.0
C or D	1.7	0.0017 in	43	Aluminum Gold	Wire	4.8 5.9	3.0 4.8
C or D	2.0	0.002 in	50	Aluminum Gold	Wire	6.0 7.5	3.8 6.0
C or D	2.6	0.0026 in	65	Aluminum Gold	Wire	7.8 10.0	6.0 7.8
C or D	3.0	0.0030 in	75	Aluminum Gold	Wire	12.0 15.0	8.0 12.0
C or D	4.0	0.004 in	100	Aluminum Gold	Wire	17.0 22.0	12.0 17.0
C or D	5.0	0.005 in	125	Aluminum Gold	Wire	27 36	20 27
C or D	6.0	0.006 in	150	Aluminum Gold	Wire	40 50	30 40
C or D	8.0	0.008 in	200	Aluminum Gold	Wire	60 85	52 60

C or D	10	0.010 in	250	Aluminum Gold	Wire	95 125	73 95
C or D	12	0.012 in	300	Aluminum Gold	Wire	130 170	100 130
C or D	15	0.015 in	380	Aluminum Gold	Wire	190 240	150 190
C or D	20	0.020 in	500	Aluminum Gold	Wire	280 350	220 280
C or D	24	0.024 in	600	Aluminum Gold	Wire	360 460	300 360
F	Any	Any	Any	Any	Flip-clip	5 grams-force x number of bonds (bumps)	
G or H	Any	Any	Any	Any	Beam lead	30 grams force in accordance with linear millimeter of nominal undeformed (before bonding) beam width. <u>3/</u>	

1/ For wire diameters not specified, use the curve of figure 2011-14 to determine the

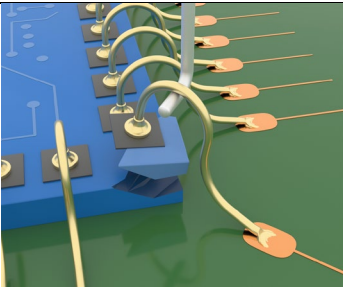
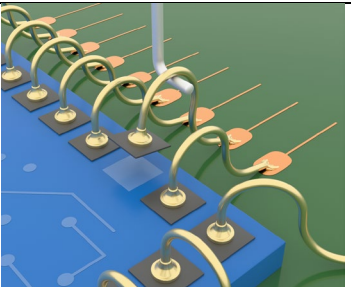
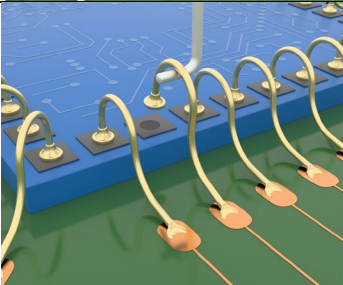
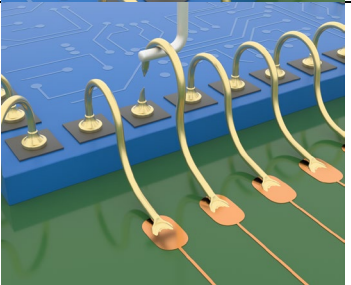
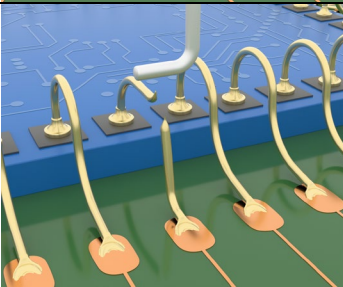
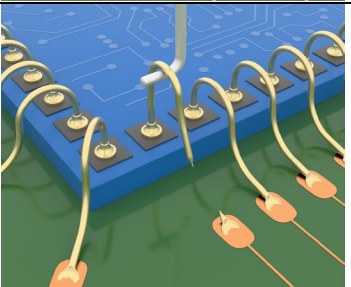
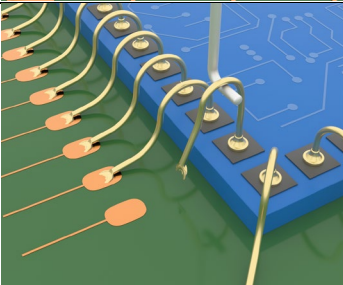
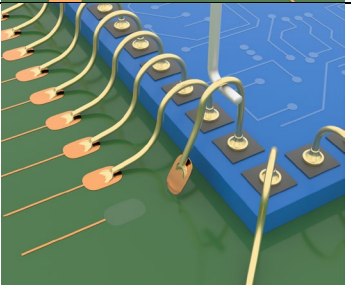
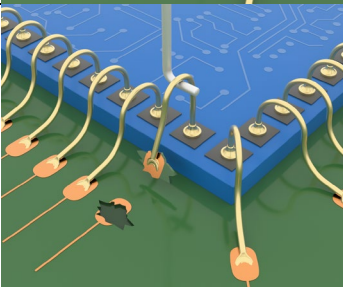
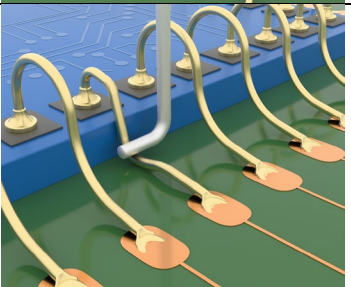
Bond pull limit

2/ For ribbon wire, use the equivalent round wire diameter which gives the same

Cross-sectional area as the ribbon wire being tested.

3/ For condition G or H, the bond strength shall be determined by dividing the breaking force by the total of the nominal beam widths before bonding.

Table 14 – Failure code illustration

Failure Code 1 Fracture or chip-out of die (includes cratering)		Failure Code 2 Lifted die metallization or failure within die metallization	
Failure Code 3 Lift of bond from die metallization		Failure Code 4 Break in wire in the neckdown region of the first bond	
Failure Code 5 Break in the span of the wire		Failure Code 6 Break in wire in the neckdown region of the second bond	
Failure Code 7 Lift of bond from substrate/leadframe/post metallization		Failure Code 8 Lifted substrate/leadframe/post metallization	
Failure Code 9 Fracture or lift of substrate/leadframe/post		Failure Code 0 Operator error or wire damaged/missing prior to test (One example shown)	

4. SUMMARY. The following details shall be specified in the applicable acquisition document:

- a. Test condition letter (see 3).
- b. Minimum bond strength if other than specified in 3.2 or details of required strength distributions if applicable.
- c. Sample size number and accept number or number and selection of bond pulls to be tested on each device, and number of devices, if other than 4.
- d. For test condition A, angle of bond peel if other than 90°, and bond strength limit (see 3.2).
- e. Requirement for reporting of separation forces and failure categories, when applicable (see 3.2.1).

NOTE: See B120 Annex (informative) Guidance for performing pull testing on stacked bonds (reverse, security, and others)

NOTE: The minimum bond strength should be taken from table 12. Figure 2011-14 may be used for wire diameters not specified in table 12.

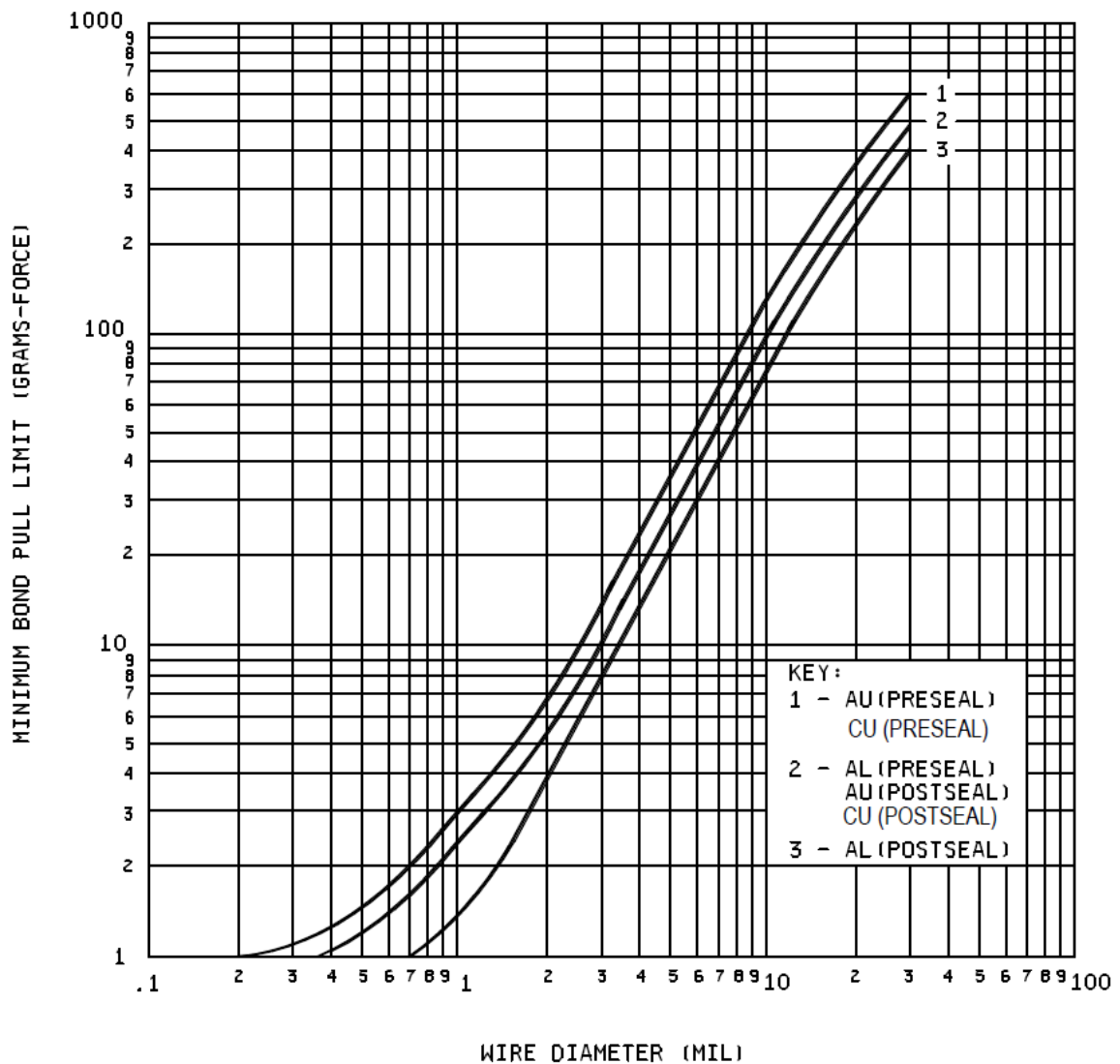


FIGURE 2011-14. Minimum bond pull limits.

For Historical Reference Only: Failure code diagram from Mil-STD 883 Method 2011.10

3.2.1 Failure category. Failure categories are as follows: When specified, the stress required to achieve separation and the category of separation or failure shall be recorded.

- a. For internal wire bonds:
 - (a-0) Wire broken or missing prior to test.
 - (a-1) Wire break at neckdown point (reduction of cross section due to bonding process).
 - (a-2) Wire break at point other than neckdown.
 - (a-3) Failure in bond (interface between wire and metallization) at die.
 - (a-4) Failure in bond (interface between wire and metallization) at substrate, package post, or other than die.
 - (a-5) Lifted metallization from die.
 - (a-6) Lifted metallization from substrate or package post.
 - (a-7) Fracture of die.
 - (a-8) Fracture of substrate.
 - (a-9) Break in wire at neckdown on the substrate or package post.
- b. For external bonds connecting device to wiring board or substrate:
 - (b-1) Lead or terminal break at deformation point (weld affected region).
 - (b-2) Lead or terminal break at point not affected by bonding process.
 - (b-3) Failure in bond interface (in solder or at point of weld interface between lead or terminal and the board or substrate conductor to which the bond was made).
 - (b-4) Conductor lifted from board or substrate.
 - (b-5) Fracture within board or substrate.
- c. For flip-chip configurations:
 - (c-1) Failure in the bond material or pedestal, if applicable.
 - (c-2) Fracture of die (or carrier) or substrate (removal of portion of die or substrate immediately under the bond).
 - (c-3) Lifted metallization (separation of metallization or bonding pedestal from die (or carrier) or substrate).
- d. For beam lead devices:
 - (d-1) Silicon broken.
 - (d-2) Beam lifting on silicon.
 - (d-3) Beam broken at bond.
 - (d-4) Beam broken at edge of silicon.
 - (d-5) Beam broken between bond and edge of silicon.
 - (d-6) Bond lifted.
 - (d-7) Lifted metallization (separation of metallization) from die, separation of bonding pad.
 - (d-8) Lifted metallization.