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Guidelines for Particle Impact Noise Detection (PIND) Testing, Operator Training, and Certification

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GUIDELINES FOR PARTICLE IMPACT NOISE DETECTION (PIND) TESTING, OPERATOR TRAINING AND CERTIFICATION

Contents

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Contents (cont'd)

GUIDELINES FOR PARTICLE IMPACT NOISE DETECTION (PIND) TESTING, OPERATOR TRAINING AND CERTIFICATION

(From JEDEC Board Ballot JCB-07-78, formulated under the cognizance of JC-13 Committee on Government Liaison.)

Introduction

All modern systems for military, space and satellite applications use many electronic components that perform complex control, navigational and monitoring functions of the systems. Proper functioning of these devices without interruptions is vital to the success of the missions and safety of the personnel and equipment. Towards achieving this objective, electronic components are manufactured and tested in accordance with the controls and requirements of applicable military standards, specifications and drawings. One critical factor that can cause catastrophic device failure is loose particles within the components.

The focus and importance of screening devices for particles occurred when a catastrophic system failure in the Delta Launch Vehicle Program was traced to a loose bit of wire within an electronic component. (1, 2, 3)

The significance of screening devices for particles was further elevated because of advances in the manned space vehicle, satellite and missile programs. As a result, space-level devices (Class S) and Class B devices that are used in flight and missile applications must be particle-free.

NASA, McDonnell Douglas and Texas Instruments developed and constantly improved techniques of detecting particles audibly and visibly within device cavities. A finalized version of the audible technique was adopted as a Particle Impact Noise Detection Test procedure "PIND" in MIL-STD-883, Test Method 2020. (4, 5, 6)

Despite progress in regard to testing concepts, PIND tester design, methods and media of attachment, there still exists a lack of correlation between equipment, inconsistency in the test results and conditions, lack of repeatability and false detections. (7, 8, 9, 10, 11) As a result, there is a general tendency by manufacturers to question the reliability of the PIND test.

Still PIND testing remains the key measuring indicator for controlling and maintaining a reliable process line relative to particle contamination. It is a useful tool to continuously refine and improve the assembly process.

Even though a wealth of information and knowledge about PIND test resides with various users and manufacturers, it is fragmented or communicated in the proceedings of various symposiums, NBS and NASA report, but not in an organized complete document on the subject.

The main objective of this Publication is to disseminate and share the relevant information on PIND testing to all interested parties. The concepts and materials presented here primarily deal with most of the cause factors that affect the "Measurement Variability” pertinent to "PIND" and how to control them.

Scope

This publication is intended only as a guideline to test facilities in their efforts to establish and maintain consistent PIND testing. Imposition of these suggestions, or any part thereof, is within the province of each test facility as to its respective needs.

SECTION I reviews specific PIND requirements on electronic devices and manufacturer facilities to satisfy customer needs and military specifications.

SECTION II discusses representative sources of particles that may be generated during device manufacturing. However, it should be noted that the nature, type and sources of particles can vary widely in different manufacturing facilities with different technologies, materials and processes and in no way is limited to those mentioned here. (12, 13)

SECTION III covers most aspects of the PIND system including test principles, calibration and maintenance, device attachment mediums and sources of interference and prevention methods.

SECTION IV covers operator education, training and certification. It is a guide to users for elimination of false particle detection due to improper testing by operators.

SECTION V covers the methods of loose particle recovery and failure analysis of PIND failures. The section includes process control measures for PIND testing and references made to product quality verification is included. With measurement consistency and reliable PIND results achievable and in control, manufacturers will be able to focus on the root causes of particles in the products and processes and will be able to eliminate the defects to enhance the device quality.

SECTION VI covers a brief summary of this publication.

JEDEC acknowledges that these publication materials are derived from information from the list of references, from participant companies' internal documents and discussions from PIND Task Group meetings of the JEDEC JC-13 (Government Liaison) and JC-13.5 (Government Liaison - Hybrid Microcircuit Technology) Committees.

SECTION 1

1.1 Specific test requirements

Before embarking on the PIND issues and problems in testing, a review of the specific test requirements (6) and constraints on the electronic device is in order. These requirements are imposed on manufacturers through government documents by procuring agencies and end-system users. The specific test methods are listed in MIL-STD-750, Test Method 2052 and MIL-STD-883, Test Method 2020. Examples of the requirement stipulations fall broadly under the following categories:

a) Class S device level requirements specified via device screening per Test Methods 5004 and 5010 of MIL-STD-883.
b) Class B device level and customer-specific requirements imposed via specifications.
c) Manufacturer line certification and/or process qualification requirements imposed via Performance Specification e.g. MIL-PRF-38535, MIL-PRF-19500, MIL-PRF-38534
d) Manufacturer process stability imposed through internal process controls and audits.
e) PIND test requirements outlined in MIL-PRF-38535, MIL-PRF-19500 and MIL-PRF-38534.

1.2 Acceptance conditions

1.2.1 MIL-PRF-38535 requirements for in-line screening of Class S devices

For microcircuits, the inspection lot (or sublots) shall be submitted to 100% PIND testing a maximum of five times in accordance with Method 2020 of MIL-STD-883, Condition A. PIND prescreening shall not be performed. The lot may be accepted on any of the five runs if the percentage of defective devices (PDA) is less than 1% (or one device, whichever is greater). All defective devices shall be removed after each run. Lots that do not meet the 1% PDA on the fifth run, or cumulatively exceed 25% defective shall be rejected and resubmission is not allowed.

1.2.2 MIL-PRF-38534 requirements for in-line screening of Class K devices

For hybrids, the inspection lot (or sublots) shall be submitted to 100% PIND testing a maximum of five times in accordance with Method 2020 of MIL-STD-883, Condition A or B (when specified). PIND prescreening shall not be performed. The lot may be accepted on any of the five runs if the percentage of defective devices (PDA) is less than 1% (or one device, whichever is greater). All defective devices shall be removed after each run. Lots that do not meet the 1% PDA on the fifth run, or cumulatively exceed 25% defective shall be rejected and resubmission is not allowed.

1.2.3 MIL-PRF-19500 requirements for in-line screening of JANTX, JANTXV and JANS devices

For semiconductors, the inspection lot (or sublots) shall be submitted to 100% PIND testing a maximum of five times in accordance with Method 2052 of MIL-STD-750, Condition A or B (when specified). PIND prescreening shall not be performed. The lot may be accepted on any of the five runs if the percentage of defective devices (PDA) **is less than 1% (or one** device, whichever is greater). All defective devices shall be removed after each run. Lots that do not meet the 1% PDA on the fifth run, or cumulatively exceed 25% defective shall be rejected and resubmission is not allowed.

1.2 Acceptance conditions (cont'd)

1.2.4 Manufacturer and customer required tests

Manufacturer and customer required tests are usually imposed through specification control drawings by the customer for Class B or H level products that are used in flight or missile applications. The accept/reject criteria are specified in these documents.

1.2.5 Quality assurance requirements (reference MIL-PRF documents)

Devices or lots that have failed to pass any test applied or acceptance criteria (PDA) shall not be downgraded to any lower quality assurance level, even though the test or criteria may not be a requirement of the lower level. (Failed devices or lots shall not be accepted.) (Ref. MIL-PRF-38535, MIL-PRF-19500 and /or MIL-PRF-38534.)

1.2.6 Qualification and manufacturer-imposed test (reference MIL-PRF documents)

When a test detects a problem (such as loose particles), the manufacturer shall subject all devices in the lot to those tests to eliminate rejects, and shall take steps to determine and eliminate the cause of failure. (Ref. MIL-PRF-38535, MIL-PRF-19500, MIL-PRF-38534)

SECTION 2

2.1 Sources of particles

Loose particles within electronic components can come from many sources. There have been extensive studies in this area to identify the types of particles that may be trapped within devices and to determine their source. The particle sources are generally listed under the following categories:

2.1.1 Material/handling

Particles in the form of foreign material may be introduced into devices during pre-seal handling and during assembly. Although some of these particles may appear to be attached during inspection, when subjected to thermal and mechanical stresses, they can loosen and dislodged from internal components of the device.

Trays or chip carriers used repeatedly without proper cleaning are a major source of unattached foreign material, such as silicon or ceramic dust. These can be trapped within the device during assembly. Similarly, lids being shipped, stored and carried in cardboard or other fiber-emitting material are an uncontrolled source of particles.

The third example is glass splatters on metal packages. During the glass-bead-attach process, the glass may splatter, leaving small particles of glass unconnected to the bead, but attached to the surface of the metal. Failure analysis has shown that these glass particles can become detached during stresses and will cause PIND failures.

2.1.2 Processing

There are many processing steps in device assembly that may induce particles. Examples of the particles and the corresponding process steps are listed below.

PARTICLE	PROCESS
Fiber glass	Package cleaning
Silicon	Scribing/die removal/eutectic mount
Epoxy flakes	Die mount/die removal
Bond wire	Wire bond/rework
Aluminum/gold	Wire bond/rework
Ceramic	Substrate scribe
Solder balls	Solder reflow seal
Weld splatter	Weld seal
Solder flakes	Eutectic mount
Gold flakes	Eutectic mount

2.1 Sources of particles (cont'd)

2.1.3 Environment

The environment to which the devices are exposed during manufacturing can also be a contributing factor in loose particle contamination in the form of dust, fibers, and other organic materials.

Some defined sources of particles are:

Storage boxes/cabinets
Human contamination
Furnace atmosphere conditions
Seal chamber conditions
Cure ovens
Assembly room atmosphere

2.1.4 Danger of particles

Contamination of electronic components by conductive loose particles may result in bridging of active metallization in integrated circuits, packages, substrates, etc. , causing catastrophic device failures.

2.1.5 Process controls

In most cases, once the source of particles are identified, it is possible to institute proper controls and procedures to eliminate or minimize particle contamination. It should be noted that the types and sources of particles may vary depending upon the manufacturing facilities, processes and materials and are not necessarily limited to the above.

SECTION 3

3.1 PIND test system

3.1.1 Testing principles and philosophy (3, 15)

The objective of PIND testing is to detect loose particles in electronic components by a nondestructive method. This test method is applicable only to devices with internal cavities that contain no moving elements by design.

The equipment used for the PIND test detects the presence of loose particles within the device by sensing the energy generated when particles strike the package or elements within the package.

An acoustic emission detection transducer, which is mounted on a vibration assembly (shaker), provides the surface for attachment of the device under test. The shaker is driven through a series of specified mechanical shock pulses and vibration cycles while monitored and controlled by the system electronics. The shocks are used to dislodge loose particles held either mechanically or electrostatically within the device. Shocks of constant and repeatable amplitudes are typically generated by a servo-system controlling the velocity of armature as it impacts on an internal anvil of the shaker. The resulting shock amplitude may be displayed by the controller. Vibration is typically sinusoidal and is generated and controlled by the system electronics.

If a loose particle impacts the interior of the device under test while under vibration, the resultant acoustic noise may be detected by the transducer. The spectrum of this noise extends into the ultrasonic frequency range. The transducer output is fed into a band-pass filter centered at approximately 150 kHz, passing the acoustic signal while filtering out the shaker frequency and background noise. The signal is amplified 60 dB and provides input to an oscilloscope, an electronic threshold detection circuit and an audio circuit with speakers or headphones. If the peak amplified-signal exceeds the specified threshold levels of the detector circuit of the PIND system, or if the visual or audio monitor indicates particle noise, the device is considered a failure. Some systems use a latch-up fail-indicator lamp that is tripped by a signal that exceeds the threshold level. The threshold detectors are typically set at levels slightly above the system background noise to prevent detector latch-up from noise spikes.

The amplitude of the acoustic signal level at the input of the transducer is determined by the “effective” mass of the loose particle. If a sphere has an “effective” mass of one, other particles of the same mass, but having other shapes, will have an “effective” mass of less than one depending on their geometric shape and angle of attack at the moment of impact. PIND test equipment is capable of detecting effective masses in the 0.20 microgram ranges or greater.

3.2 Systems and components (6)

The following equipment is typical of what is needed to perform PIND test. (See Figure 1)

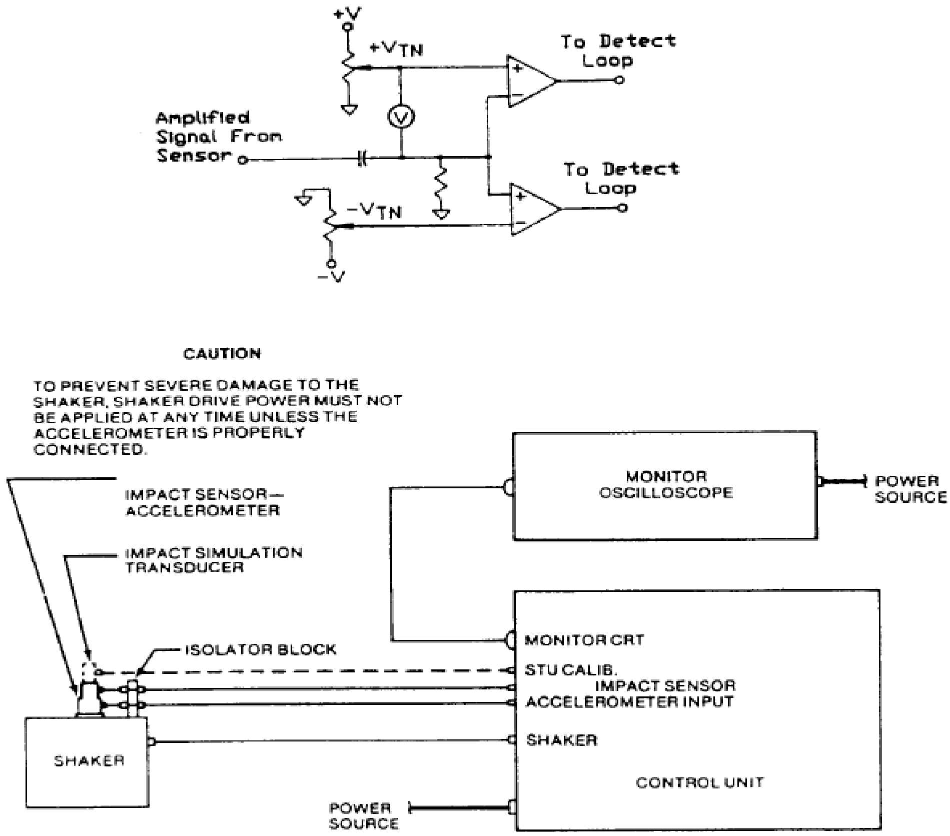


Figure 1 — TYpical equipment to perform PIND test

3.2.1 Control unit

The unit must be programmable with regard to time and shock-level and must have sufficient memory to allow for a sequence specified pre-test shocks, followed by a sequence of vibration and co-shocks.

3.2.2 Threshold detector

The detector must be capable of detecting particle noise voltage exceeding a preset threshold above the system noise peak during the vibration mode and provide both visual and aural warnings to the operator.

3.2.3 Shaker

The shaker must be capable of providing essentially sinusoidal motion to the device under test over the range of 5 - 20 g's peak at the frequencies from 40 Hz to 250 Hz. The shaker must also be capable of imparting shock pulses in the range of 800 g’s to 1200 g’s peak to the device under test. The duration of the main shock pulse should not exceed 100 ms. In addition, if an integral co-shock system is used, the shaker vibration may be interrupted or perturbed for a period of time not to exceed a specified time from the beginning of the last shock pulse in the sequence. The co-test duration is measured at the 50 ± 5% point.

3.2 Systems and components (6) (cont'd)

3.2.4 Transducer

When combined with the control, the unit must have an amplifier gain of 60 ± 2 dB, centered at the centered frequency for peak sensitivity of the PIND transducer. The noise output of the transducer must not exceed 10 mV peak.

3.2.5 Monitor oscilloscope

This should have a minimum response of 500 kHz and a sensitivity of 20 mV/cm.

3.2.6 Cabling requirements

The cabling between the various parts must be of such a construction, length and impedance as to introduce a minimum amount of noise into the system during the vibration of the unit under test. Cabling includes the mechanical connectors and the use of power filter/surge protectors.

3.2.7 Sensitivity Test Unit (STU)

This is used for periodic assessments of the PIND system performance and consists of:

a) A transducer with the same tolerance as the PIND transducer.

b) A circuit to excite the transducer with a specified pulse.

NOTE The STU should produce a pulse of 20 mV to 25 mV on the oscilloscope when the transducer is coupled to the PIND transducer with the attachment medium.

3.2.8 Visual displacement wedge

A graduated printed-scale that, when attached to the vibrated test-head, measures the amplitude of vibration.

3.2.9 Mounting medium

A medium such as double-sided tape is used to mount the test specimen on top of the impact-sensor-platform. Refer to the section on "Comparison of Attachment Mediums" for further details.

3.3 Calibration and equipment verification

3.3.1 Calibration requirements

Periodic calibration of the PIND test system is required to verify the capability and accuracy of various subsystems and controls. The essential requirements are as follows:

1) The inherent system noise (including the environment at the PIND test site) as measured at the output must be less than 10 mV peak (20 mV peak-to-peak) referenced to ground when observed for a period of 30 to 60 seconds. The detector threshold levels should be set to 20 mV peak above ground reference. The sinusoidal motion of the shaker assembly between 40 Hz and 250 Hz is verified between 5 g and 20 g acceleration. The impact-sensor (acoustic transducer) together with the system must be calibrated for a peak sensitivity of -77.5 ± 3 dB referenced to one volt per microbar at a frequency within 150 kHz to 160 kHz (This test is normally performed by the equipment manufacturer). The amplifier section of the PIND system is set at a gain of 60 dB ± 2 dB at the peak point between 150 kHz and 160 kHz. The frequency at which the maximum peak occurs may be determined by sweeping the frequency range and observing the output signal.

2) The sensitivity test transducer (STU) is used for periodic assessment of the PIND system detection capability. A signal pulse of 250 mV ± 20% is applied to the STU input. This must result in a PIND system output greater than 20 mV peak with the STU attached to the test transducer via the same attachment medium that is used for testing devices.

3) The shock calibration is normally performed between 800 g and 1,200 g to verify proper operation of shock mechanism. However, calibration at other levels may be performed to suit a specific application, device mass or testing requirements. The shock pulse duration is typically less than 100 s. If an integral co-shock system is used, the shaker vibration may be interrupted up to 250 ms from initiation of the last shock pulse in the sequence. The co-test duration is measured at the 50% ± 5% point. The suggested and typical specification tolerance of various parameters are listed in Table 1 below.

   In addition to periodic equipment calibration, the PIND system must be verified at the test site at least once per shift (continuous operation) or prior to initiation of test (noncontinuous). The detector system must be verified for proper operation (with the shaker deenergized) by use of the STU calibration on the platform. The STU must be actuated several times and the detector response monitored by audio, electronic and visual means.

   In addition, system background noise must be maintained at very low levels to achieve reliable testing.

3.3 Calibration and equipment verification (cont'd)

3.3.1 Calibration requirements (cont'd)

Table 1 — Suggested and Typical Specification Tolerance

Parameter	Typical limits	Unit
a) System noise	<10	mV pk
Threshold limit	20	mV pk
b) Tolerance		
1. Vibration frequency	<8	%
2. Vibration time	+/-1	second
3. Vibration amplitude peak	+/-10	%
4. Shock	+/-200	g
5. Amplifier gain	+/-2	dB

3.3.2 Detailed calibration steps

For examples of detailed calibration procedures for Dunegean Model 4501 and B.W. LPD2000 PIND test equipment, refer to manufacturers' manuals. Calibration steps may vary between models and equipment manufacturers.

Manufacturers recommend periodic factory calibrations for the critical items such as acoustic emission transducers and accelerometers. It is recommended that the user should refer to the calibration procedures outlined in the manufacturer's manual.

3.3.3 Calibration intervals

a) At period intervals of 6 to 12 months.
b) After equipment repair or modification of the equipment.
c) When the operation of the tester is suspect.

The calibration setup is configured depending upon the parameters of calibration such as acoustic emission, gain, threshold, audio vibration signals and excitation, shock, etc. (Refer to the equipment calibration manual.) A representative calibration checklist includes:

a) Accelerometer sensitivity . . . pc/g @ 100 Hz.
b) Impact sensor sensitivity . . . -77.5 +/- 3 dB re 1 V/ bar @ 155 kHz
c) STU test sensor sensitivity . . . 177.5 +/- 3 dB re 1 V/µbar @ 155 kHz
d) Keyboard Test
e) Display Test
f) Acoustic Emission Gain . . . 60 dB +/- 2 dB @ 155 kHz
g) Threshold . . . . 20 mV pk
h) (1) 200 g shock with a test load that is equal to the test specimen mass (low-end measurement)
   (2) 2000 g shock with a test load that is equal to the test specimen mass (high-end measurement).
i) (1) 10g and 20g. 40 Hz vibration with load.
   (2) 10 g and 20 g. 100 Hz vibration with load.
   (3) 10 g and 20 g. 250 Hz vibration with load.

3.3 Calibration and equipment verification (cont'd)

3.3.4 Control sample verification

A control sample should be used each time the machine is set up, conditions are changed or whenever the operator is away from the machine for an extended period of time (e.g., lunch break).

The control sample(s) should be a metal can, such as a TO-5 that contains a particle of known size and material that produces a consistent output signal under vibration during test. A gold sphere of 0.002" diameter works well.

The control sample is attached to the transducer using the same medium that is being used for the STU and the devices being tested. The PIND tester is cycled and the peak output voltage of the control sample is noted. The peak is then compared to the "standard" output for that specific control sample. If the peak value within ± 20% of the standard value, the test equipment is operated satisfactorily. If not, the reason(s) should be determined and corrective action taken.

3.4 Threshold voltage window levels

This procedure may be used when threshold voltage levels are set with reference to background noise. Positive and negative threshold levels are the two critical parameters with which the emitted signals are compared during PIND testing.

3.4.1 Low threshold requirements

For low threshold requirements, it is very important to properly calibrate these settings taking into account factors such as the actual internal noise energies of the preamplifier gain sections, internal tolerances of the component, voltage offset differences in the window comparator of the detector section and the elimination of any subjectivity in the calibration procedure and the personnel.

3.4.2 Functional threshold calibration technique

The following functional threshold technique is suggested to satisfy the above while simulating actual device testing conditions. In this case, the PIND tester's detection system itself is used to detect the internal noise voltage level of the electronics. The actual threshold (detection level) is typically set at 20 mV peak.

The system is set-up for normal test operation with the impact sensor and cable connected to "Impact Sensor" input of the controller. The system is programmed for a specified acceleration and frequency (e.g., 10 g @ 100 Hz), and for 3 seconds vibration. The PIND equipment should then be operated in the manual mode without a device.

The dc reference-level at the input of the first comparator is monitored (by a Precision DC Voltmeter) while adjusting the threshold potentiometer until detections can be observed on the impact "Detect Lamp" on the front panel. The dc voltage level determines the equivalent background noise level of the system.

With further potentiometer adjustment, an offset voltage level is added to this value per the PIND test method specification requirements to set the actual detection threshold level. A similar calibration procedure is followed for the second comparator and its potentiometer to set the opposite polarity level.

3.4 Threshold voltage window levels (cont'd)

3.4.2 Functional threshold calibration technique (cont'd)

The two voltage levels measured may not be the same magnitude of voltage value due to possible differences in the input offset voltages of the comparators.

This calibration technique properly compensates for the offset differences in the detection circuitry, thus allowing detection of particle generated signals symmetrically. Also, note that since the calibration is an active adjustment, all dynamic responses are also verified. The threshold calibration must be done with the PIND equipment located at the test site to reflect the exact noise of the test environments.

It is generally a good practice to minimize the internal input noise of the amplifier section. This can be accomplished with the use of low noise operational amplifiers for the preamplifier gain stages of the analog board.

3.5 Transmission of acoustic signals

For reliable particle detection, the device under test must be subjected to the defined stimuli (sinusoidal vibration and mechanical shock); and the resulting acoustical signal from the device must be transmitted to the acoustic emission detection transducer with a minimum amount of attenuation and distortion.

In order to accomplish this, the following conditions must be met:

1) There should be intimate contact at the device/platform interface without any separation, trapped air or relative movement.

2) There should be a minimal acoustic coupling medium, to effect transfer signals from trapped particles within the device to the transducer, and test stimuli (impulse shock and vibration), from the shaker assembly to the device, without any spring or cushioning effect.

Proper care must be taken in the mounting of the devices, the fixturing, and the design and selection of the transducers, for a given application.

Studies conducted by Texas Instruments on two different transducer designs have shown that the maximum particle detection effectivity can only occur when the particle is bouncing in that portion of the package that is located over the center of the transducer.

These studies also show that the sensitivity and signal transmissibility response cannot be improved by increasing the platform size. Table 2 and Figures 2 and 3 show the transmissibility response as a function of distance from the center for I^{N} and 2" diameter platforms. 100% response was achieved within a distance of 0.25" from the center for both platforms.

Figure 4 showing STU sensor transmissibility indicates the response of the transducer when the output of the STU is used as input. It shows that the transducers are more responsive to the distributed STU output than to the localized output resulting from the impact of a single particle.

3.5 Transmission of acoustic signals (cont'd)

Table 2 — PIND Test - Standard Transducer profile of transducer surface

Test Location	Volts Peak	Transmissibility
Center	2.2	100
. 050" off/c	2.2	100
. 100" off/c	1.5	68
. 150" off/c	0.8	36
. 200" off/c	0.6	27
Test conditions: 20 g 65 Hz per 883 Method 2020 Notice 5 Response with 0.002" Au spherical loose particle in TO-5 package.		

Typical equipment to perform PIND test

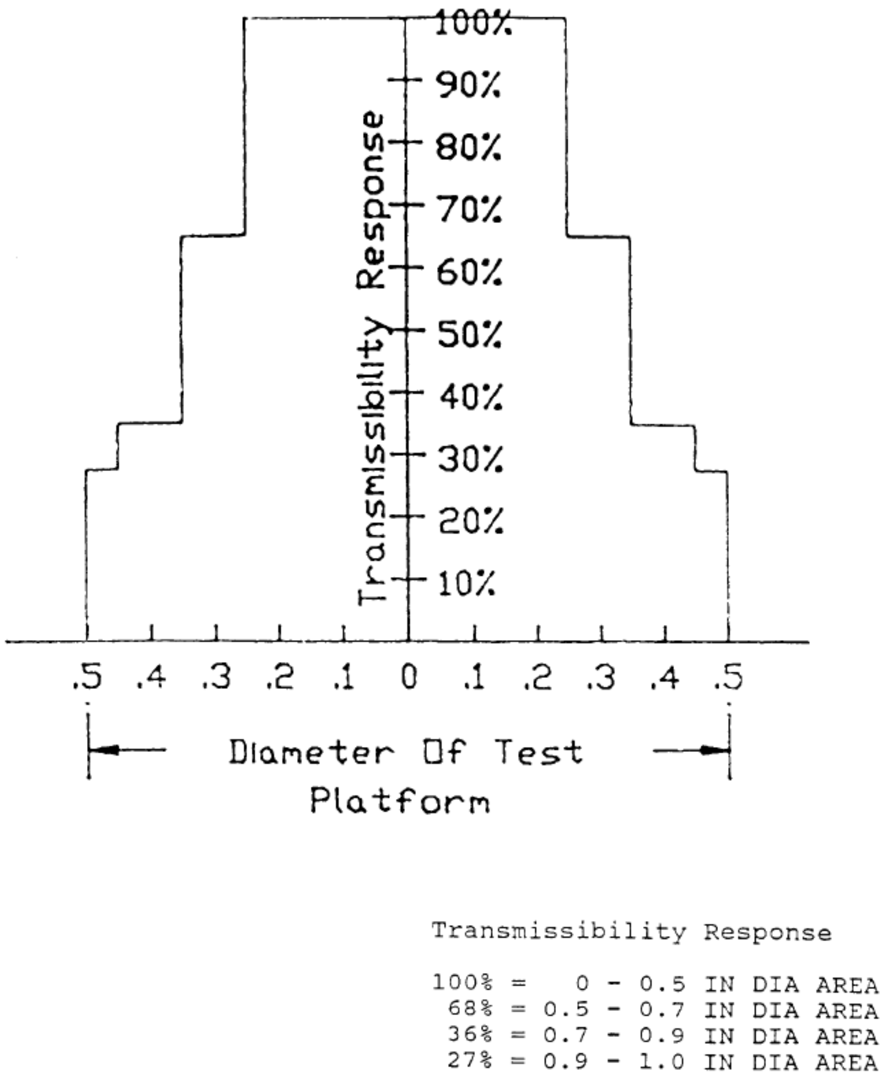
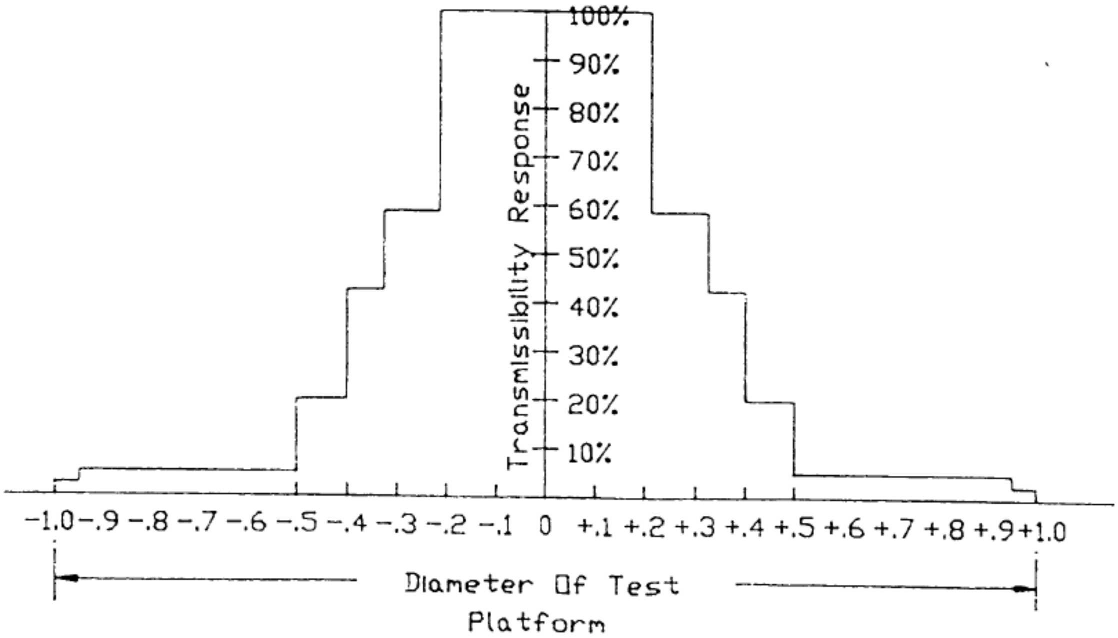


Figure 2 — Transmissibility response of a standard 1" diameter test platform

3.5 Transmission of acoustic signals (cont'd)

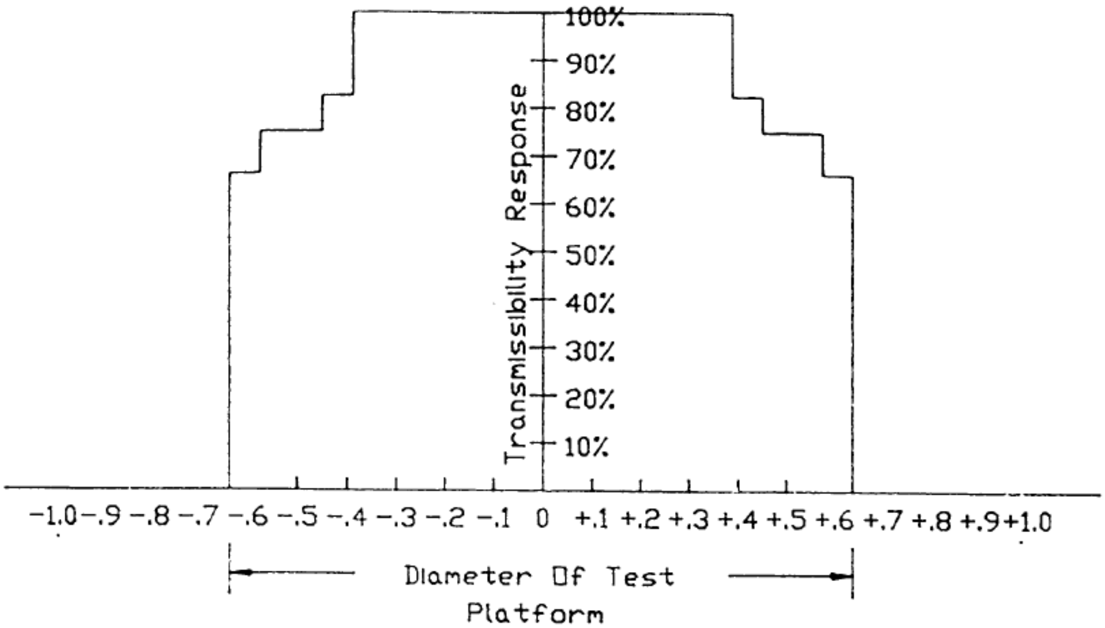


Transmissibility Response

100%	=	0 - 0.5	IN DIA	AREA
60%	=	0.5 - 0.7	IN DIA	AREA
47%	=	0.7 - 0.9	IN DIA	AREA
23%	=	0.9 - 1.0	IN DIA	AREA
7%	=	1.0 - 1.2	IN DIA	AREA
5%	=	1.2 - 1.9	IN DIA	AREA
3%	=	1.9 - 2.0	IN DIA	AREA

Figure 3 — Transmissibility response of a 2" diameter PIND transducer platform

3.5 Transmission of acoustic signals (cont'd)




```
STU  - Sensor
Transmissibility

100%  =    0  - 0.85 IN DIA AREA
 83%  = 0.85 - 0.95 IN DIA AREA
 77%  = 0.95 - 1.15 IN DIA AREA
 67%  = 1.15 - 1.25 IN DIA AREA
 17%  = 1.25 - 1.35 IN DIA AREA
  0%  = 1.35 - 1.45 IN DIA AREA
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NOTE The STU sensor is approximately 1" in diameter. The data was taken with the STU centered and then moved incrementally until the outer edge of the STU transducer was even with the outer edge of the transducer platform.

Figure 4 — Transmissibility response of 2" PIND transducer test platform using STU output as signal source

3.6 Comparison of attachment mediums (14, 16)

There are several types of attachment mediums available for mounting devices onto the PIND test equipment.

One of these mediums is an acoustic couplant-gel that has shown repeatable results in testing. However, the application and cleaning of the material is very time consuming. Further, it is messy and if handled improperly can damage the PIND test equipment. Care must be exercised in cleaning the equipment as well as the devices after PIND testing, adding a second operation to the PIND test cycle. The results of the testing may be affected by consistency of coating between the transducer and the device under test. A controlled dispensing unit may be used to ensure that a measured amount of couplant is used.

3.6 Comparison of attachment mediums (14, 16) (cont'd)

A second attachment medium is double-sided tape. Circular tape dots are somewhat difficult to remove from their backing, and care must be taken when mounting to ensure smooth application to the transducer platform. Considering all the pros and cons, the tape is much easier to work with than the acoustic couplant. Texas Instruments performed a study in 1987 comparing eight different mounting mediums. A summary of these results are:

MATERIAL	**COMMENTS**
(1) Scotch #447 Tape	Best results
(2) Scotch #411 Tape	Good
(3) Scotch #412 Tape	Thick, attenuates
(4) Sperry Ultrasonic Couplant #50A4084	Messy clean-up of equipment and devices
(5) Scotch #465 Tape	Smearing effect
(6) Scotch #443 High Tack Tape	Too strong/inadequate contact
(7) Scotch #415 D. C. Polyester Tape	Too thin/inadequate contact
(8) Permacel P-50	Variable adhesion

In addition to Scotch #447, Scotch #411 also showed favorable results in the study, even though some variations in signal amplitude were noted during the repeated STU test verification. However, all signals tripped the threshold detector indicating proper operation. (The signal deviation is postulated due to the thickness of the tape. #411 is 0.015" thick and #447 is 0.010" thick.)

The study showed that Permacel P-50 could not be recommended because the adhesive thickness is not uniformly controlled by the manufacturer. This causes inconsistent signal transmission from the device to the transducer and frequent malfunctions in testing. (See Figure 5).

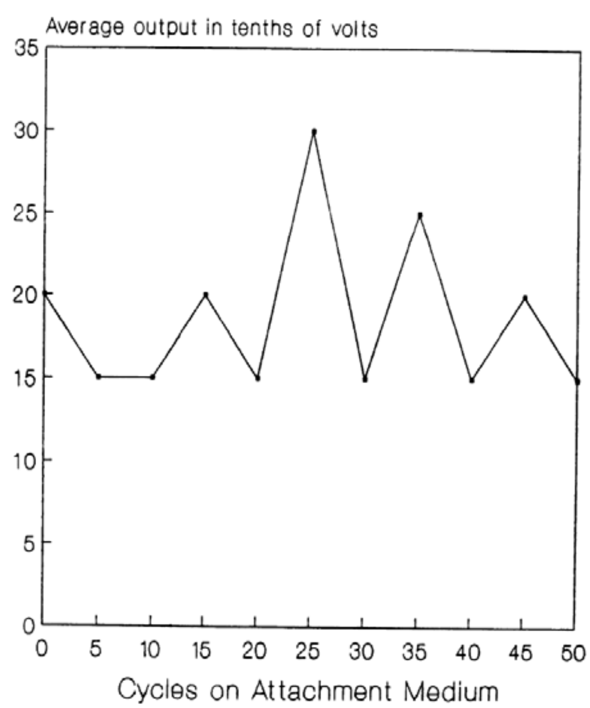

Figure 5a — Transmillsbility for viscous couplant

3.6 Comparison of attachment mediums (14, 16) (cont'd)

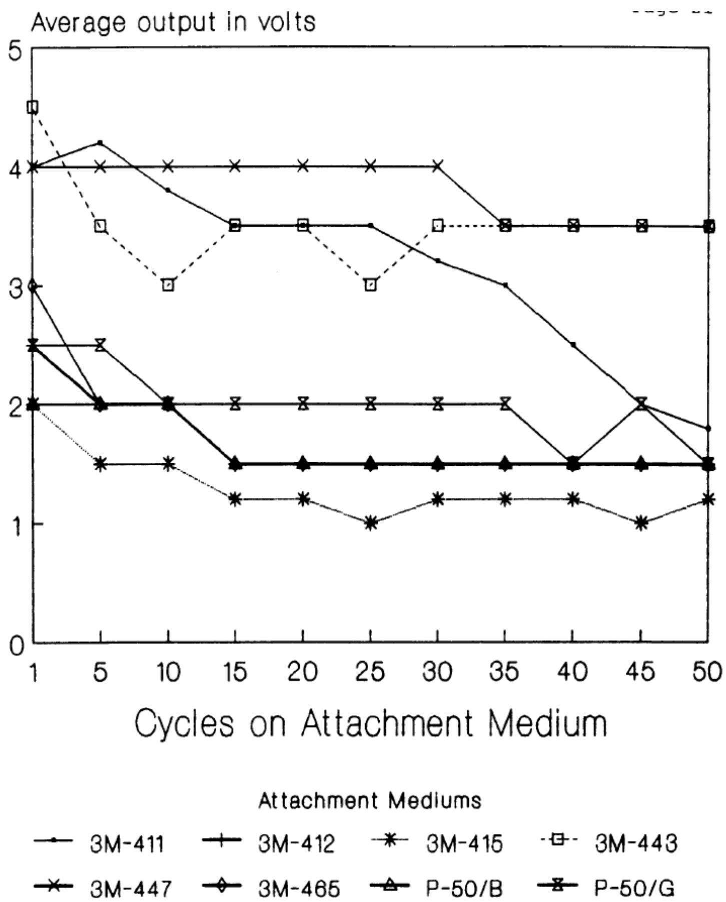

Figure 5b — Particle impact detection comparison of attachment mediums

3.7 Sensitivity test unit

The following Table 3 shows the signal output a STU on the first test-cycle-run with new attachment medium. An evaluation of this type followed by the measurement of output voltage relative to the number of "use" cycles of the medium may be used to determine the best medium to use for a particular application.

Table 3 — Output in Volts P-P

Attachment medium	Sensitivity
Scotch #411 T	0.08
Scotch #412 T	0.06
Scotch #415 T	0.07
Scotch #447 T	0.08
Scotch #465 T	0.07
Scotch #552 T	0.08
P-50/B T	0.04
P-50 G T	0.06
Viscous Couplant Gel	0.08

3.8 Equipment preventive maintenance

The PIND test equipment is prone to damage due to misuse or improper care during testing. If such damage occurs, the equipment may have to be returned to the manufacturer for repair.

Equipment damage may be minimized by following the guidelines listed below.

1) Keep the PIND test area and equipment free of dust and debris
2) Do not use high pressure blow-off-nozzles near the equipment.
3) Make sure all cables are tightly and properly connected prior to equipment use.
4) Make sure all connecting cables are in good repair, and are handled and stored properly when not in use.
5) Take extreme care not to hit or damage the accelerometer and/or impact sensor connection to shaker during mounting of devices or cleaning of the transducer and/or shaker.
6) If water soluble couplant is used as a mounting medium, restrict the couplant to the top (platform) of the transducer.
7) Keep the shaker and transducer base clean and dry at all times.
8) Always cover the shaker when not in use.

3.9 Reasons for maintenance and symptoms of misuse

If water or water-soluble couplant is allowed to drip down the sides of the transducer or onto the exposed accelerometer/impact sensor connection, it will eventually degrade the equipment. A typical symptom of this problem could be the registering of "no shock" or uncontrolled vibration during testing. Dust particles may work their way inside the shaker assembly and cause the equipment to indicate false failure. The shaker must be overhauled when this occurs.

NOTE It is not recommended to disassemble the shaker in any way to overhaul it. Irreversible damage may occur if an unqualified technician attempts to disassemble the shaker assembly.

Improperly connected cables during the use of the PIND test equipment may also be indicated by a “no shock” registration or uncontrolled vibration. This condition can also cause irreversible damage.

3.10 Test interference

There are various types of interference that can cause false PIND test results. These can be from external as well as internal sources and must be minimized in order to achieve reliable results when performing PIND test.

3.10.1 External

3.10.1.1 Electrical

External electrical interference may create spikes that will falsely trip the detection indicator during testing.

The problem may be caused by other equipment located in the same general area that share the same electrical power supply as the PIND equipment. Unwanted signals may be electromagnetically coupled to the PIND detection system, corrupting the desired particle detection signal levels. Ground loop conditions in the same electrical supply system conduct and produce unwanted noise to the system as well. Improper signals are also transmitted through the common power lines, particularly when the line filtering/conditioning is inadequate.

Some typical examples of noise generating equipment are: test equipment, computers, radio/TV transmitters, ovens, fluorescent lights, air conditioning systems, compressors, fans, heavy machines, equipment movers (e.g., forklifts), etc.

The power source to be used for PIND test equipment must be monitored continuously for a period of time. PIND test will be performed during normal conditions for interference to determine ideal equipment location in the selection of proper power line isolation, shielding and filtering.

The use of an electrical isolation interface, such as a line conditioner is strongly recommended to eliminate electrical interference.

3.10.1.2 Acoustical

Sound-waves and noise-conditions created by various equipment can also indicate false results during testing. This is due to the extremely sensitive nature of the acoustical transducers and the associated electronics (signal gain of 60 dB) of the system. Some conditions that may cause interference are compressors, pressurized tanks being released, oven doors opening and closing, air guns being used, etc. Even when acoustic-waves are weak and/or located remotely from the PIND tester in the same open area, this noise can often cause false indications.

3.10.1.3 Mechanical

Traffic in areas where PIND test is performed is a source of the mechanical noise interference. Fans, air conditioning units, various equipment in operation, and personnel in the vicinity generate mechanical vibration noise. Some examples of operator-generated interference are talking, sneezing, coughing, keys, coins or jewelry jingling, slamming doors, etc. Due to the high-sensitivity of the transducer, sharp sounds may be detected by the PIND test equipment.

3.10 Test interference (cont'd)

3.10.1.3 Mechanical (cont'd)

In some cases, to prevent acoustical or mechanical noise from interfering with the proper operation of PIND test, the equipment may have to be located in an isolated room which has been insulated against extraneous acoustical, EMI and RFI noise.

The PIND test equipment should be placed on a bench free from nonessential objects and equipment. The equipment must be mounted on a stable base. The room for PIND testing should have provisions for storage of devices, logs and records, and other necessary materials, separate from the bench of the PIND test equipment.

The test devices should be free of external noise producing particles. Leads of certain mass and length may produce undesirable resonance, but lead dress should be such that leads do not touch during test.

3.10.2 Internal

Some noise is generated from the equipment itself, from the digital circuitry, microprocessor and from the analog systems, such as amplifiers, preamplifiers and comparators, detectors, etc.

The noise level may be minimized with proper grounding, and the use of low-noise amplifier components in the preamplifier gain section of the system.

The internal noise should be monitored on the continual basis, to determine if adjustment (such as threshold, or correcting improper grounding) are necessary.

3.10.2.1 Area suitability check

The following method may be used to determine whether a test area is free of interference. The PIND equipment should be operated in a manual vibration mode for an extended period of time at 0.1 g @ 60 Hz test condition. Any threshold voltage change exceeding the set levels is an indication of excessive interference.

SECTION 4

4.1 Operator education and training

4.1.1 Introduction

Expertise in the various device-mounting-techniques, care and handling of equipment and knowledge of the operations of the PIND system, are primary requisites for an operator (4) . In addition, his or her background knowledge of the reasons for PIND test and reject identification requirements is also essential to the reliability of PIND testing.

The training of operators to perform PIND test is intensive. This may require approximately 10 to 20 hours (six hours of this may be classroom instruction) , depending upon the equipment set up and experience level of the operator and the individual’s ability to grasp concepts and demonstrate proficiency. Operator selection is also an important factor, since there are physical requirements regarding vision, hearing and manual dexterity.

The following paragraphs outline a method of training, testing and certification of operators to perform PIND test. Periodic on-the-job training and audit checks on the test results and performance may be done to provide feedback to operators to improve their knowledge and testing skills. The procedures and training methods are suggested as guidelines. Refinements and changes may be made to suit a given company’s needs based on work environment and internal practices and procedures.

Instructors should have sufficient knowledge on most aspects of PIND testing, equipment set-up and should possess good communication skills. Familiarity with related assembly processes and basic failure analysis steps are also desirable.

4.1.2 Particle impact noise detection test training

The following training method may be used to certify operators to perform PIND test in order to establish a method of documentation and training standards of this operation. Information material from manufacturer’s equipment operation manuals, test methods from military specifications and references listed in this Publication will be useful in the preparation of operator training materials and procedures.

4.1.3 Materials and equipment needed

1) Particle Impact Noise Detection (PIND) Operator Procedure.
2) Equipment as referenced in PIND Operator Procedure.
3) Training Certification Form.
4) Certification Test.
5) General Overview of PIND testing "principles, philosophy, requirements, etc.

4.1.4 Procedure

4.1.4.1 General overview (Classroom)

a) Give trainees a thorough explanation of the reason for and requirements of PIND testing.
b) Explain the philosophies and principles of PIND testing.
c) Impress upon trainees the delicacy of the equipment and the hazards associated with its misuse.

4.1.5 Certification and training records (Classroom)

a) Trainees are to fill out the applicable sections of the PIND Test Training/Certification form after an explanation of its purpose.
b) Record the date, time and length of the class as well as the names of the training instructor and trainees in attendance and retain this information.

4.1.6 Explanation of PIND test operator procedure (at equipment site)

a) Read with the trainees the PIND operator procedure explaining each step in detail.
b) Demonstrate the entire procedure one step at a time allowing each trainee to perform each portion of the procedure.

Example:

4.1.7 Process control verification

1) The instructor performs the verification as outlined in the PIND Test Operator Procedure while reading each step.
2) Each trainee performs the verification as outlined in the PIND Test Operator Procedure while reading each step.
3) Respond to all questions before proceeding to the next step.

4.1.8 On-the-job training

a) Trainees should perform the PIND test function.
b) All lots tested by trainees shall be randomly sampled to 1% AQL by a certified training instructor for proper test verification.
c) After the required number of hours of training the trainee shall be tested for certification.

4.1.9 Certification

a) At completion of "On-the-Job Training” a test must be given prior to certification. The test should consist of questions and answers relating to the proper use/operation/care of the PIND test equipment, PIND testing techniques and requirements. In addition, sample specimens with known pass or fail categories for particles should be tested by the trainee for proper test verification and correlation.
b) Operator certification is given with a score of 85% in the test and with correlation results of 95% of the test samples.
c) The test results along with the completed Training Certification form should be kept on file as documentation of completed training.
d) A Certificate for PIND test will then be issued to the operator.

SECTION 5

5.1 Loose particle recovery and failure analysis

A proven effective and simple method of extracting arid analyzing loose particles was developed and published (12, 13) in 1980. This method has proven to be an invaluable tool in identifying the source of particles in the assembly process. Once the cause and sources of particles are known, process controls should be implemented to eliminate particles in the devices.

In order to extract the loose particle from the device failing PIND test, the lid of the device must be punctured in such a way as to ensure that no particles during the recovery process will be introduced and/or wrongly identified as the cause of the PIND failure.

To accomplish this, a 0.060” diameter blind hole should be drilled in the lid, or the lid lapped to within 0.002 inch of the lid thickness. It is recommended that the area of the blind hole should then be thoroughly cleaned (removing all external particles) and marked with a colored paint. In the event of a fragment of lid material being trapped inside during lid puncturing, the colored marking will help identify the external particle from others. A puncturing stylus should be placed at a 90° angle over the location of the blind hole and the lid pierced with one quick motion. The puncturing stylus and surrounding environment should also be examined for cleanliness prior to the puncturing to prevent particles from being introduced during puncture. The stylus size and pierce force should be capable of producing a 0.025" diameter hole without damaging the internal components. The location of the hole should be away from internal components such as integrated circuits, capacitors, etc., to prevent damage from the puncturing tool. A piece of tape should be placed over the hole and the device PIND tested until all the particles are trapped on the tape as evidenced by the successful passing of the PIND test. In the event that the particle is too large to recover through the hole, the device should be carefully delidded, peeling the lid back under clean room conditions. Internal examination may reveal, in most cases, the type of large loose particles.

Under a laminar flow hood or similar clean room conditions, peel back the tape and examine the trapped particles under magnification of 20X to 200X. Detailed analysis such as SEM (Scanning Electron Microscopy) or ESCA (Electron Spectroscopy for Chemical Analysis) may be necessary in order to positively identify particles, but in most cases a visual examination will indicate the type of the particles and the possible sources since they originate from known materials and assembly environments.

Knowledge of the type of particles, assembly processes and methods will allow one to determine the cause of the problem and to define proper corrective actions.

SECTION 6

6.1 Summary

The information in this Publication describes relevant topics pertinent to PIND equipment, calibration and maintenance, operator training and certification, source of particles, recovery and analysis, etc. When a manufacturer focuses on correcting the manufacturing process to minimize particles, a great deal of effort will be spent towards achieving this goal.

It is very naive to assume that the process will remain corrected after the initial efforts. The sustaining activities to keep the processes and PIND measurements under control on a continual basis is also an essential ingredient in achieving the true quality characteristic of particle-free microelectronic devices (17).

Since the particles could come from a variety of sources and are generated from critical internal processes, preventive measures and controls must be emphasized all the more (17). These may include taking periodic steps in the inspection of materials and handling devices, environmental cleanliness controls, education and recertification of personnel, line audit and controls for individual processes, preventive maintenance and calibration of equipment.

In the context of PIND measurements, it is worthwhile to consider a very important cause factor and variable, namely the “environmental noise”. All three noise categories and sources (electrical, mechanical vibration and acoustic) should be studied to determine the PIND equipment location. The equipment site should be located where the noise is minimized and controlled. In this aspect, the PIND detector’s threshold levels (at site) is a key measure and indicator of the noise environment of the equipment. Control charts are recommended for these two threshold voltage levels as monitors of the noise environment.

The data, particle analysis, investigation and corrective action findings generated from:

1) Periodic process qualification (such as QML testing of MIL-PRF-38534)
2) Manufacturer-imposed process controls and audits
3) Screening and lot acceptance data

Will provide very valuable information in order to continuously improve the manufacturing processes.

The long term benefits are attractive, resulting in quality products and processes and better yields.

6.2 References

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Annex A (informative) Differences between JEP114.01 and JEP114

This table briefly describes most of the changes made to entries that appear in the publication, JEP 114.01, compared to its predecessor, JEP 114 (December 1989). If the change to a concept involves any words added or deleted (excluding deletion of accidentally repeated words), it is included. Some punctuation changes are not included.

Page	Term and description of change
ALL	Formatted document in accordance with JM7, JEDEC Style Manual
ALL	Renumbered document section numbers, clause numbers and subclause numbers to align with JEDEC formatting guidelines.
i-ii	Contents updated
iv	Added section IV to tie into the contents.
iv	Added section V and VI to tie into the contents.
1-1	In 1.1c; updated specification call outs.
1-1	In 1.1e; updated specification call outs.
1-1	In 1.2.1; updated specification call out and added ‘for microcircuits’ at the beginning of the paragraph.
1-1	In 1.2; added new 1.2.2 for MIL-PRF-38534.
1-1	In 1.2; added new 1.2.3 for MIL-PRF-19500.
1-2	In 1.2; renumbered 2.2, 2.3, and 2.4 to 3.2.4, 3.2.5 and 3.2.6 and generically call out MIL-PRF documents.
3-2	In 3.2.3: Updated shock range from “200 g’s to 1500 g’s” to “800 g’s to 1200 g’s”.
6-1	In 6.1, paragraph 5, item 1; Updated example to reflect QML

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   - ☐ Test method number ____________ Clause number ____________

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