FG RFEC Technique for Thick Multilayer Aircraft Structures Inspection

Part II Crack Detection

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Part II – Deeply hidden crack detection

Topic 1 Challenges

Topic 2 Raster scan using a sliding probe

Topic 3 Rotational scan using a rotary probe minimizing noise from fasteners

- 0.200" thru crack under 0.5" Al layer, Fe fastener, edge effect

Topic 4 Automated rotary scanner ensuring constant speed for online signal processing and crack identification

- 0.133" corner crack under 0.25" Al layer, Ti fastener, edge effect
- 0.150" corner crack under 0.25" Al layer, Fe fastener, edge effect

Topic 5 Study # 1 – edge effect

Topic 6 Study # 2 – edge + ferromagnetic fasteners

Topic 1 - Challenges in Thick & Multilayer Structure Crack Detection

1. Requirement of deep penetration in multilayer structure
2. Structure variations around a fastener – background noise comparable or greater than crack signal
3. Material property variations, such as permeability variation of a steel fastener.
4. Extremely weak crack signal submerged in background noise and structure variation signals
5. Signal magnitude is not necessarily be the indication of existence of a crack. Other parameters, signal phase angle or signal shape must be used for crack identification
6. Signal processing or/and pattern recognition is needed for crack identification and quantification

Topic 2 - Raster Scan Using a Sliding Probe

A. Photos of FG RFEC Sliding Probes for Crack Detection

RF4 V3
Footprint: 0.85” x 2.15”
Coil Center-to-Center Distance, CCD = 1.15”

RF2 V3
Footprint: 0.3” x 0.62”
Coil Center-to-Center Distance, CCD = 0.3”

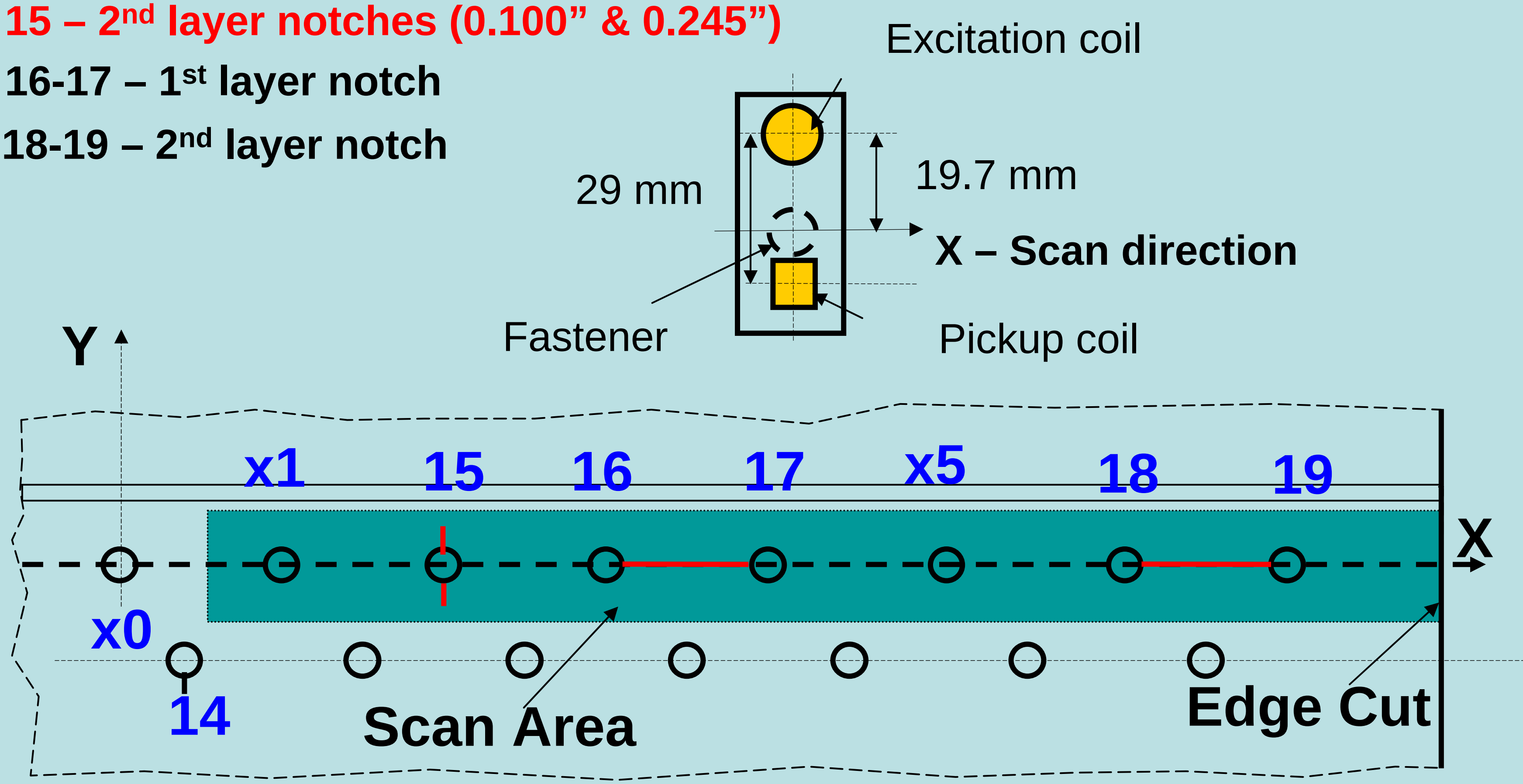
Part II – Deeply hidden crack detection

Sliding Probe Example 1
Detecting 2nd Layer Notches in 0.25" + 0.25" Thick B-52 Wing Spar Structure

15 – 2nd layer notches (0.100" & 0.245")

16-17 – 1st layer notch

18-19 – 2nd layer notch



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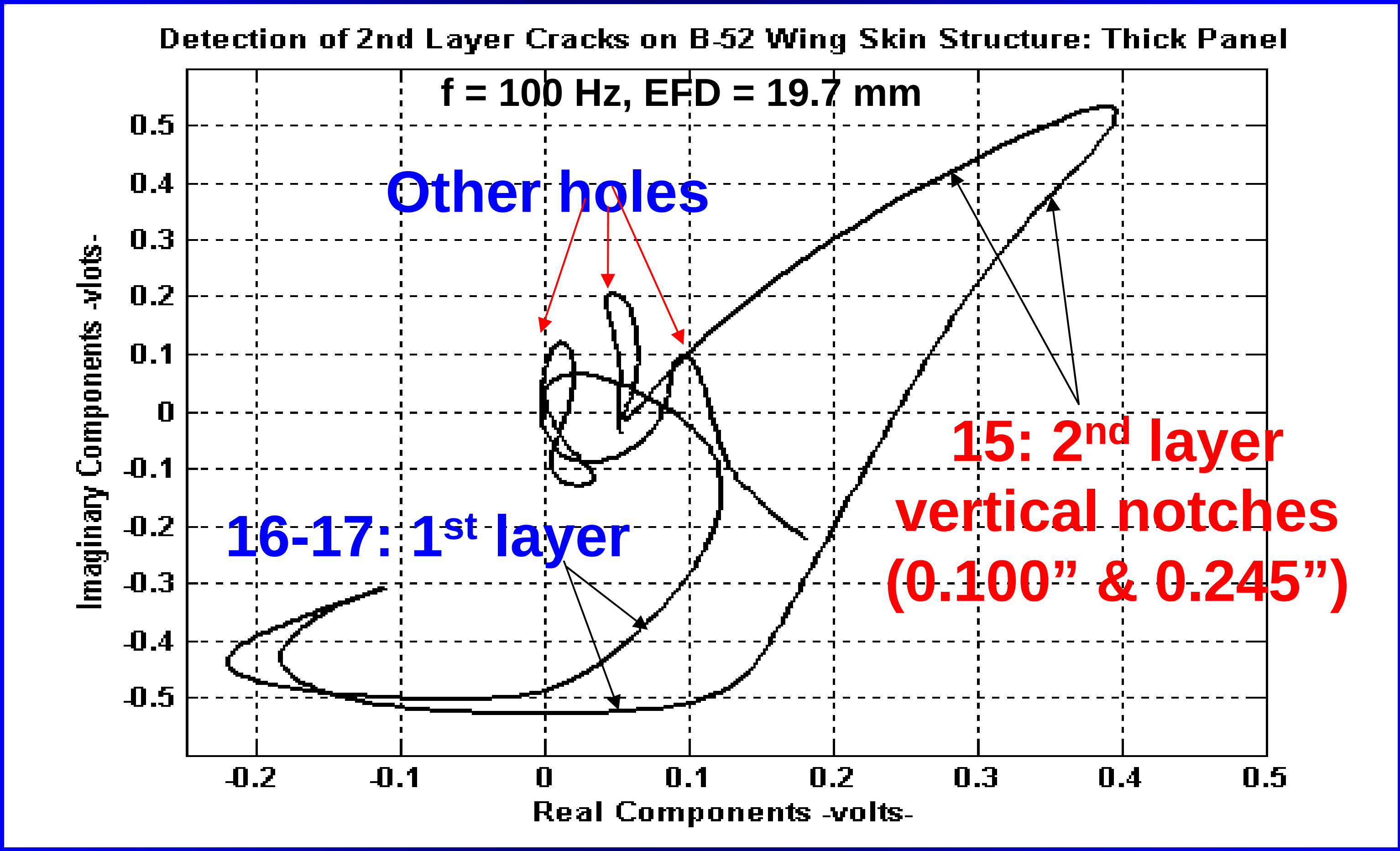
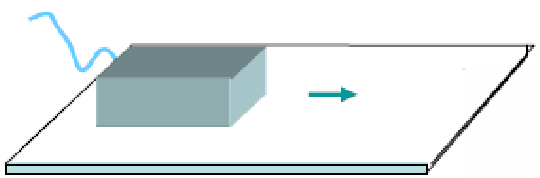
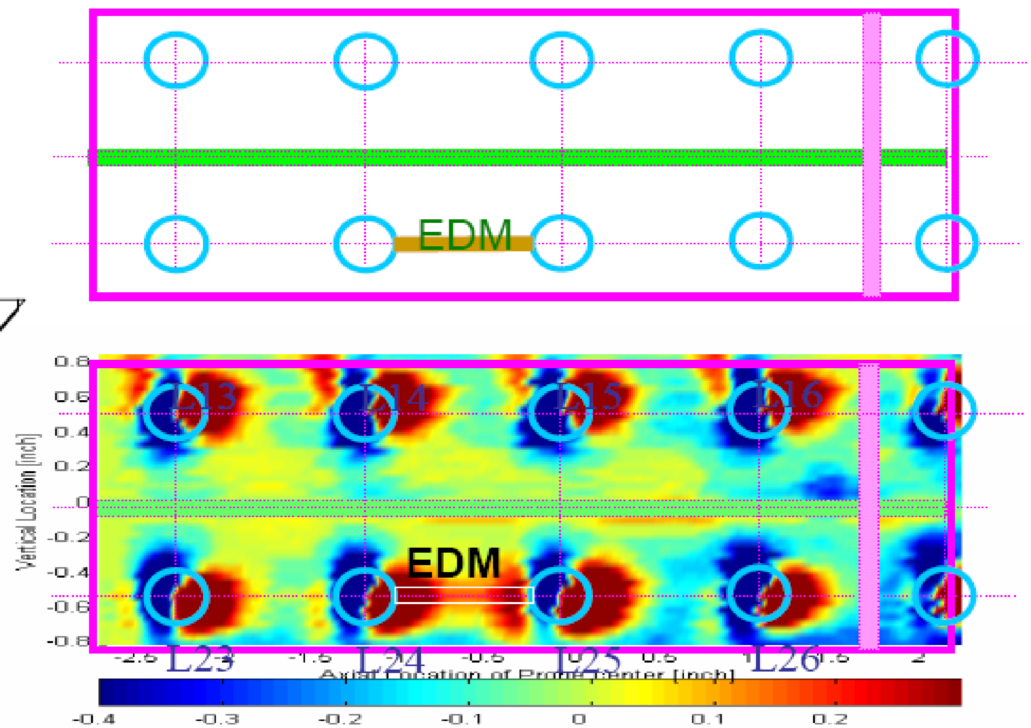
Detecting Crack in 0.25" + 0.25" Thick B-52 Wing Spar Structure



Limitation of Sliding Probe Raster Scan - Strong Noise from Fasteners
Signal from deep crack submerged by noise

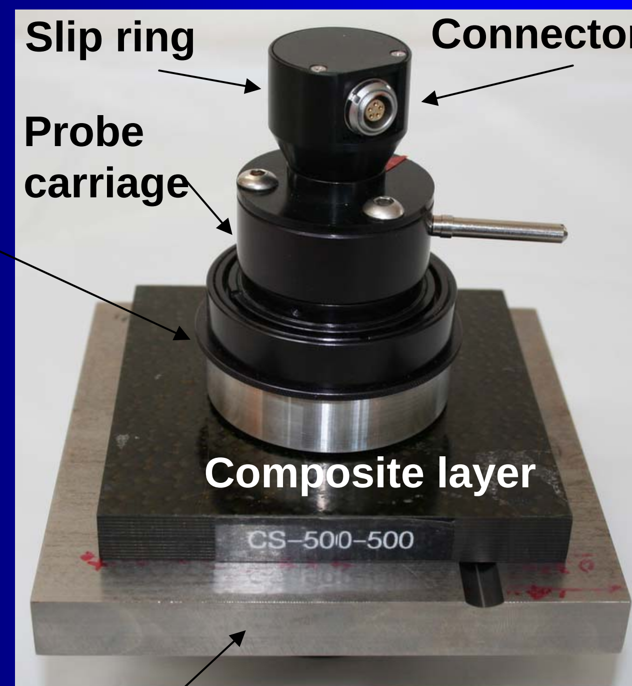




Part II – Deeply hidden crack detection

Topic 3 - Rotational Scan Using A Rotary Probe Minimizing Noise from Fastener

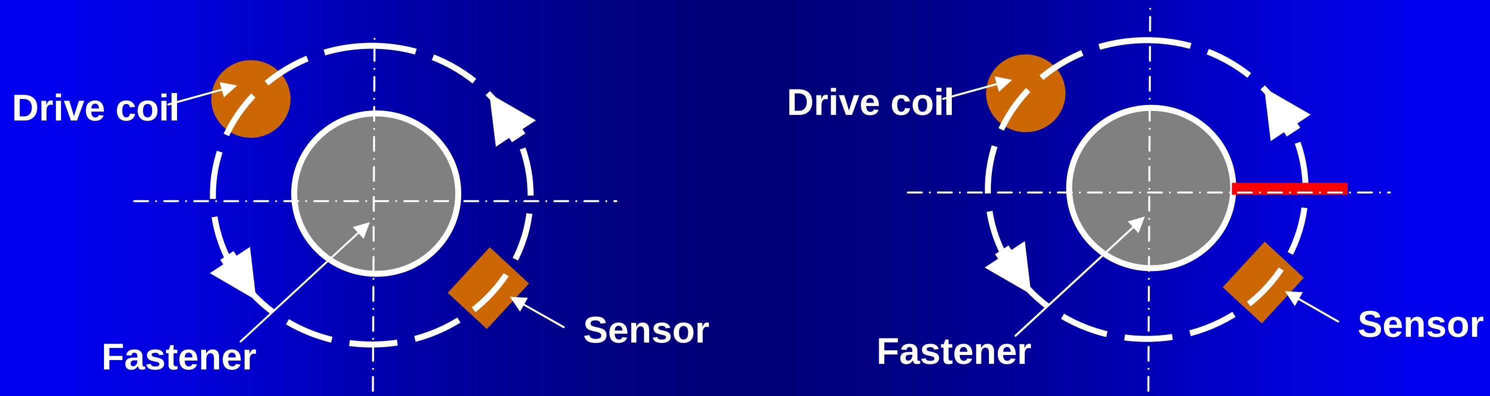
Probe head with centering pin



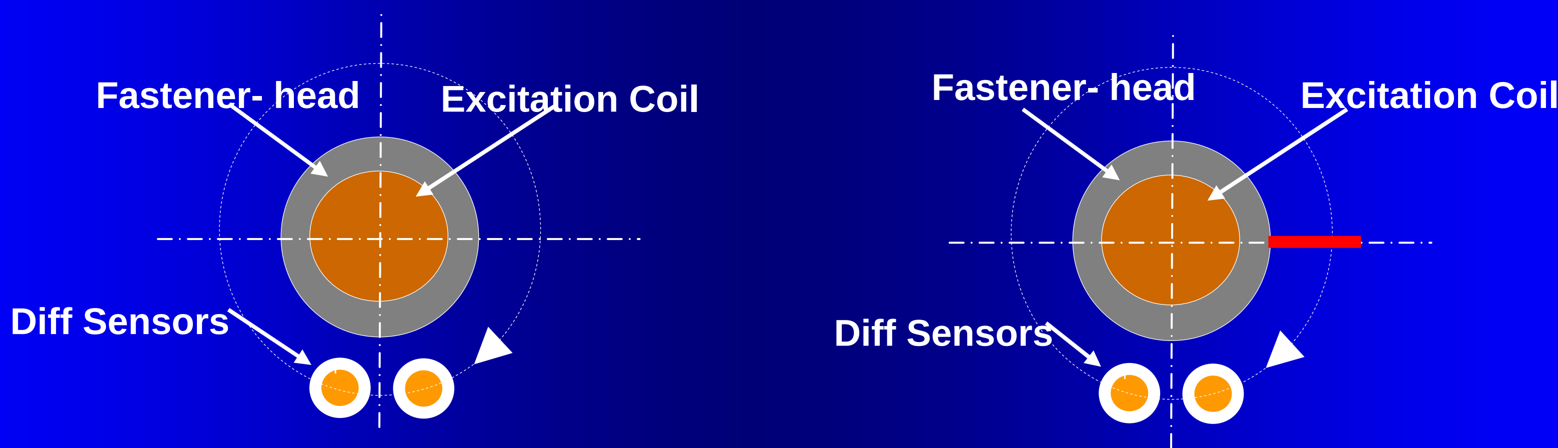
Titanium layer under inspection

Part II – Deeply hidden crack detection

Rotational Scan – Minimizing noise from fastener

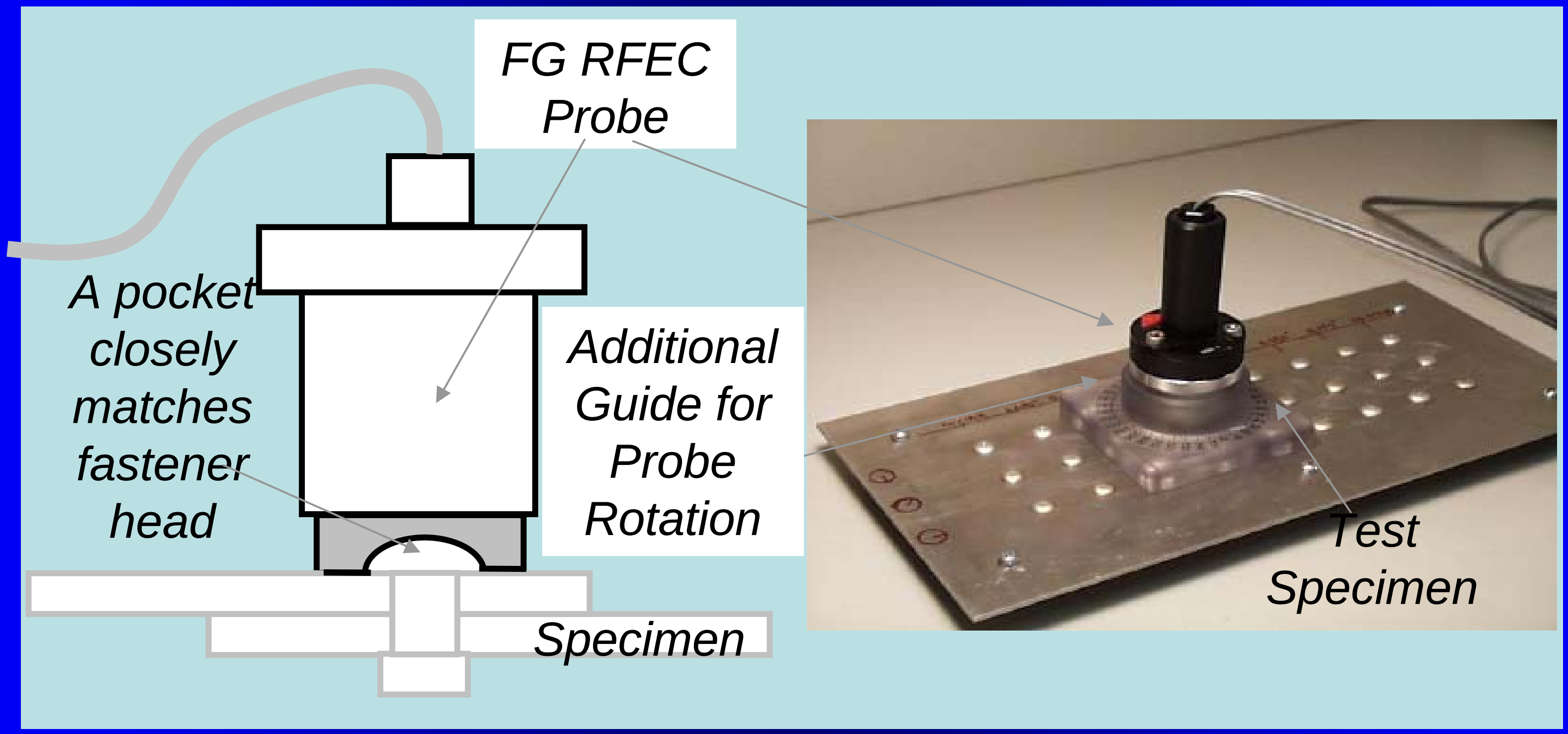


Probe 1 – Constant signal unless there is a crack



Probe 2 – No signal unless there is a crack

Success Example 1
Detecting Cracks in Raised-Head Fastener holes

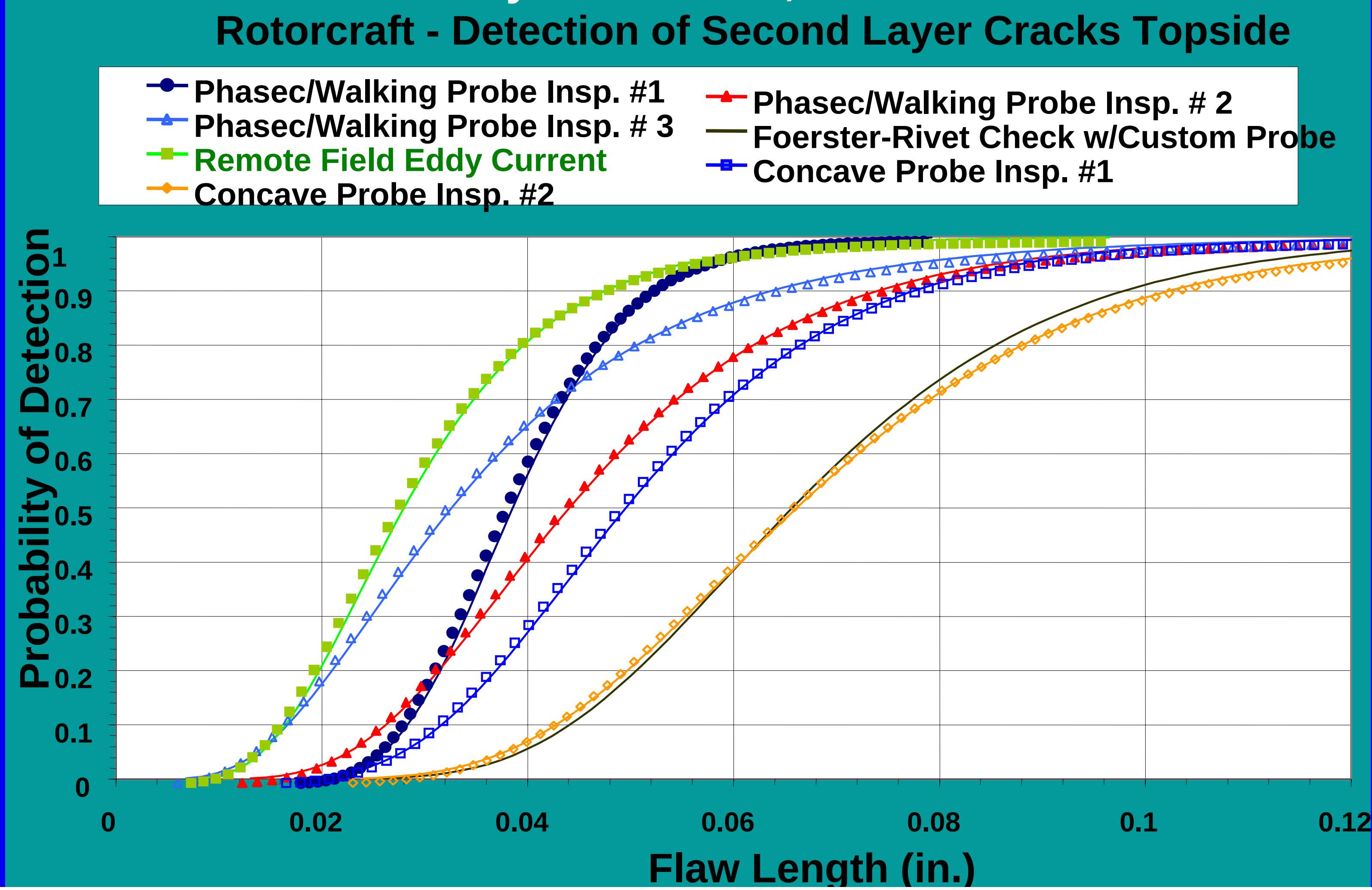


A round probe head serves as a guide for probe rotation

Part II – Deeply hidden crack detection

Comparison of POD with other NDI Techniques

Carried out by FAA AANC, Sandia Labs



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Success Example 2
Detecting Lower Layer Cracks in Boeing 723 Lap-Joint

PoD Record
By Sandia Lab (FAA/AANC)

Date: 10/06/2006
Total fastener tested: 239
Crack size (POD 90/95): 85.8mil

Device: IMTT Auto-center RFEC scanner
Crack size (POD 90): 75.7mil
False call rate: 1.67%

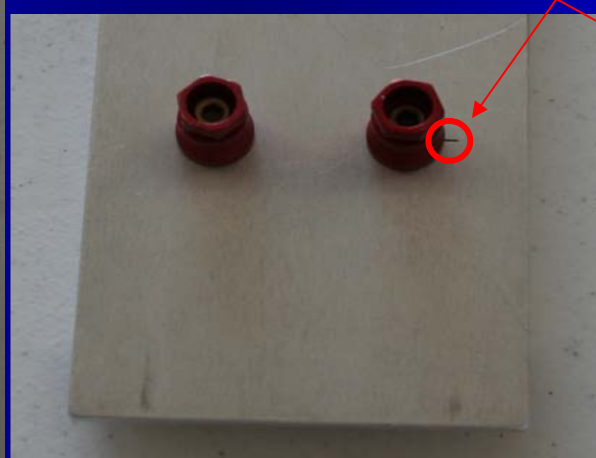
New Challenge in Deep Crack Detection With Edge Effect and Steel Fastener

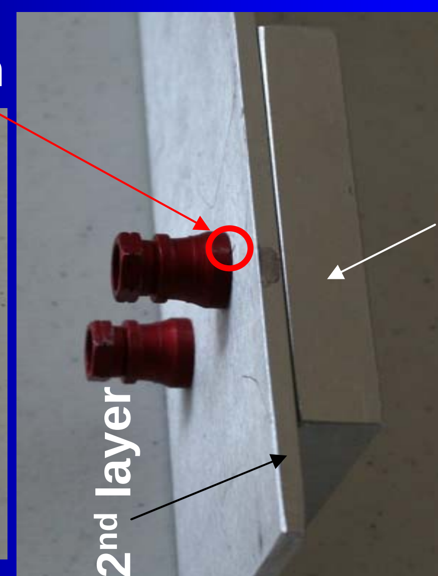
1. Signal magnitude is no longer an indication of existence of a crack
2. Other parameters, such as phase angle and/or shape of impedance plane must be used for crack identification
3. Concept of pattern recognition is needed

Part II – Deeply hidden crack detection

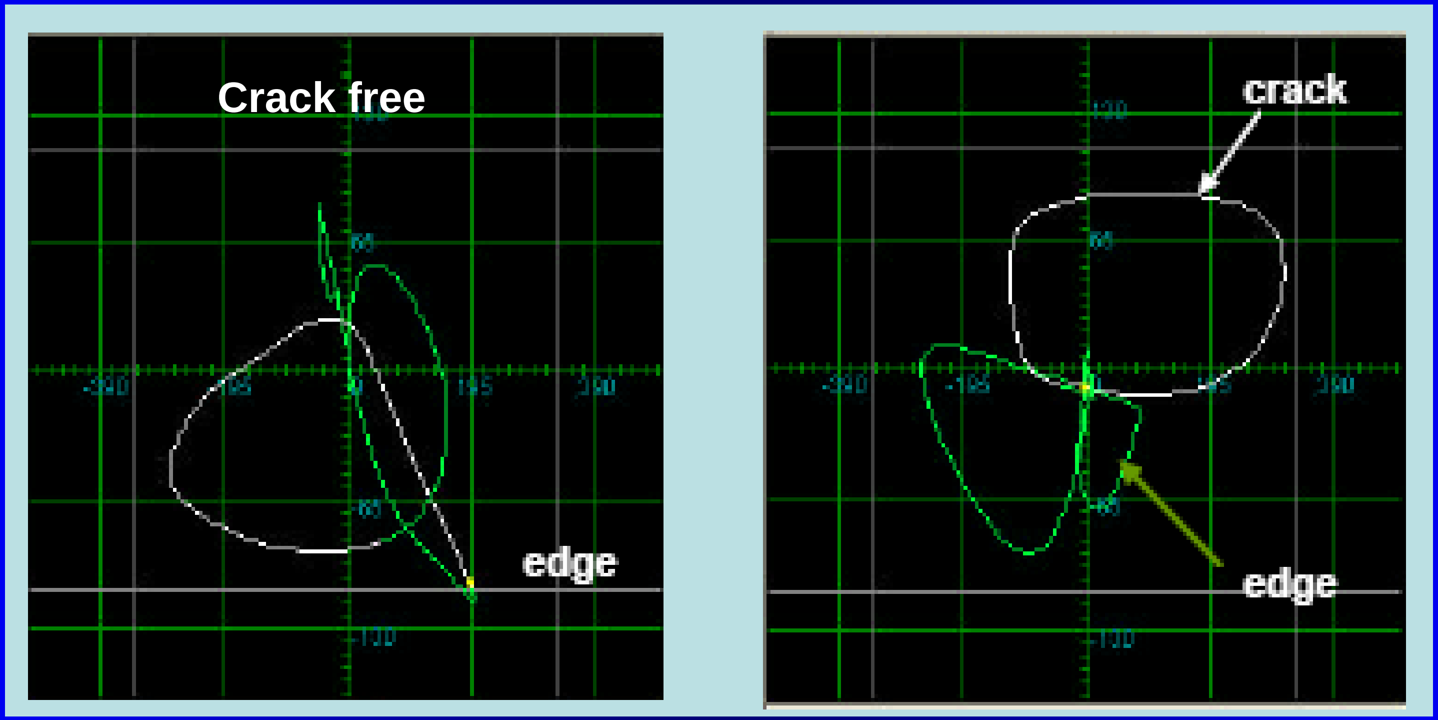
Example
Detecting 0.200” 2nd Layer EDM Notch in A Specimen Simulating 0.500” + 0.140” C-130 Wing Structure Specimen provided by Canadian Air Force

Front View **Bottom View** **Side View**





Topic 4- Rotational Scan: Result of the Example



Observation:

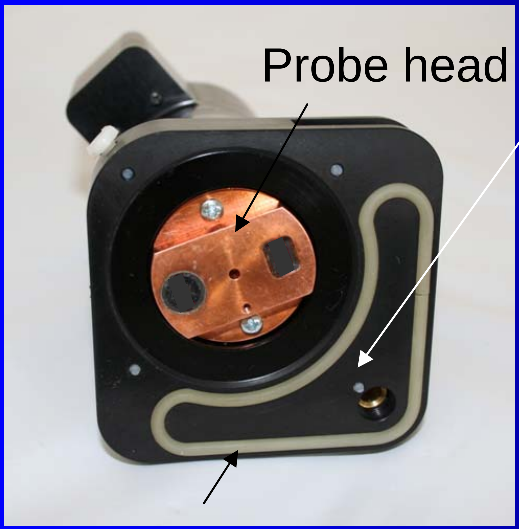
In deep crack detection signal magnitude is no longer the indication of existence of a crack, other parameters, such as phase angle and/or shape of impedance plane must be used for crack identification. Concept of pattern recognition is needed.

Part II – Deeply hidden crack detection

Topic 4 - Automated Rotary Scanner Ensuring Constant Speed for Online Signal Processing & Crack Identification

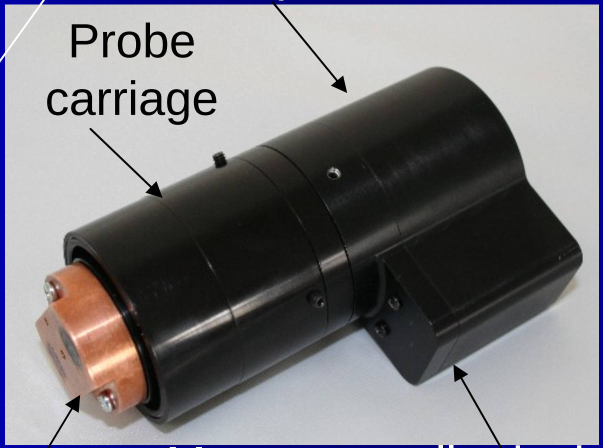
Ball bearing rotation guide with suction base

Vacuum area



Sealing rubber tube

Step motor inside



Motor controller inside

Probe head

Connectors

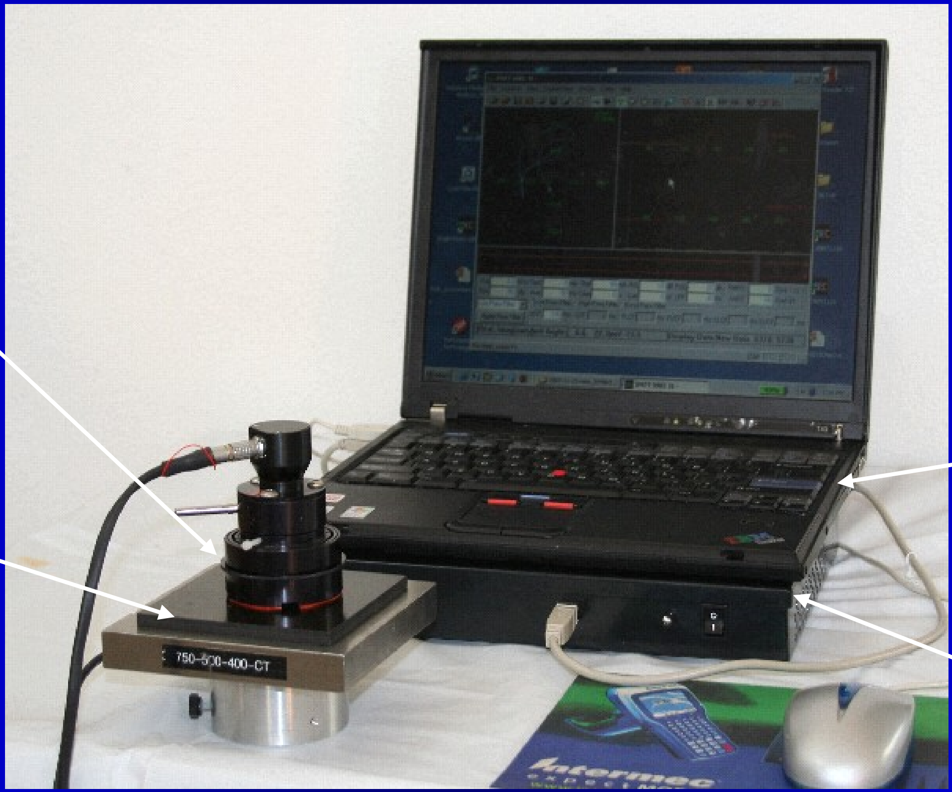
suction base

Part II – Deeply hidden crack detection

Computerized SSEC Instrument Enabling Online Signal Processing

Rotary Scanner

Specimen under inspection



Laptop

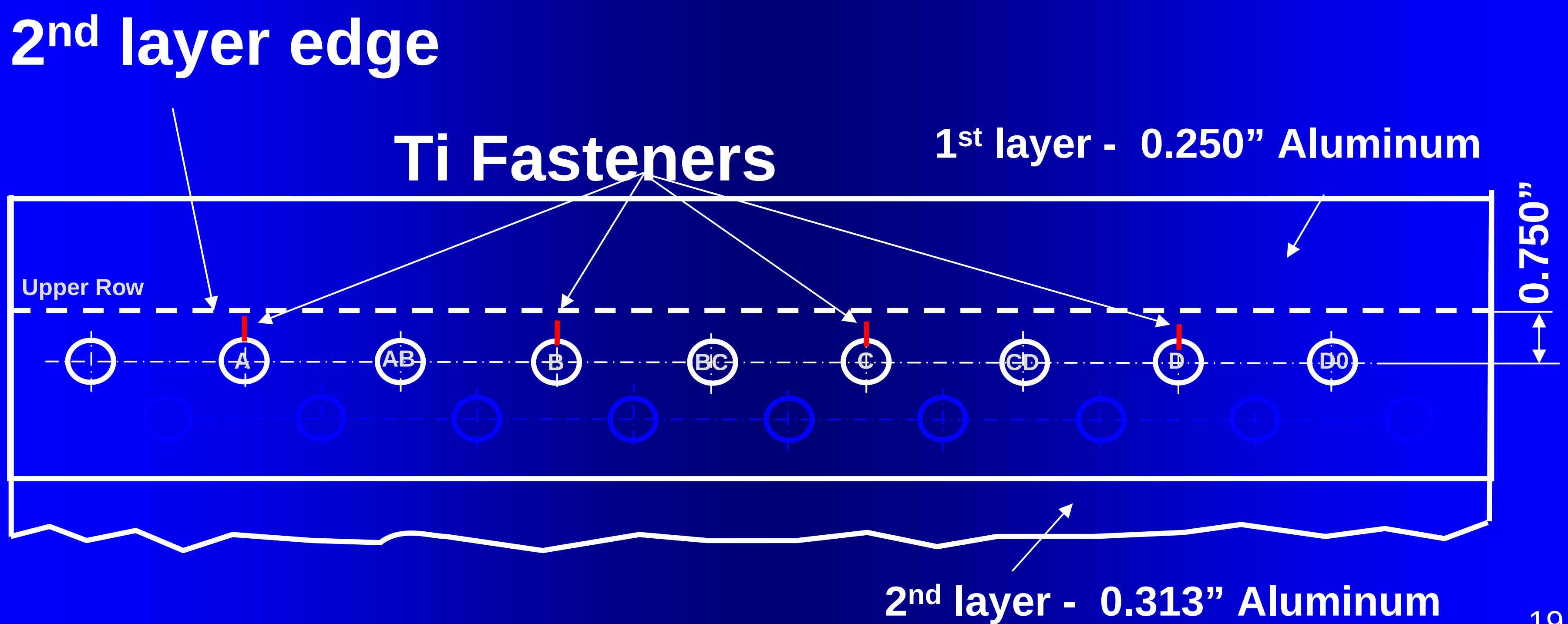
Instrument SSEC II-S

Topic 5 - Study # I
Edge effect

Example 1 – Simulating Boeing 707 Wing Structure

Detection 2nd layer vertical cracks with Ti fasteners, crack very close to 2nd layer edge

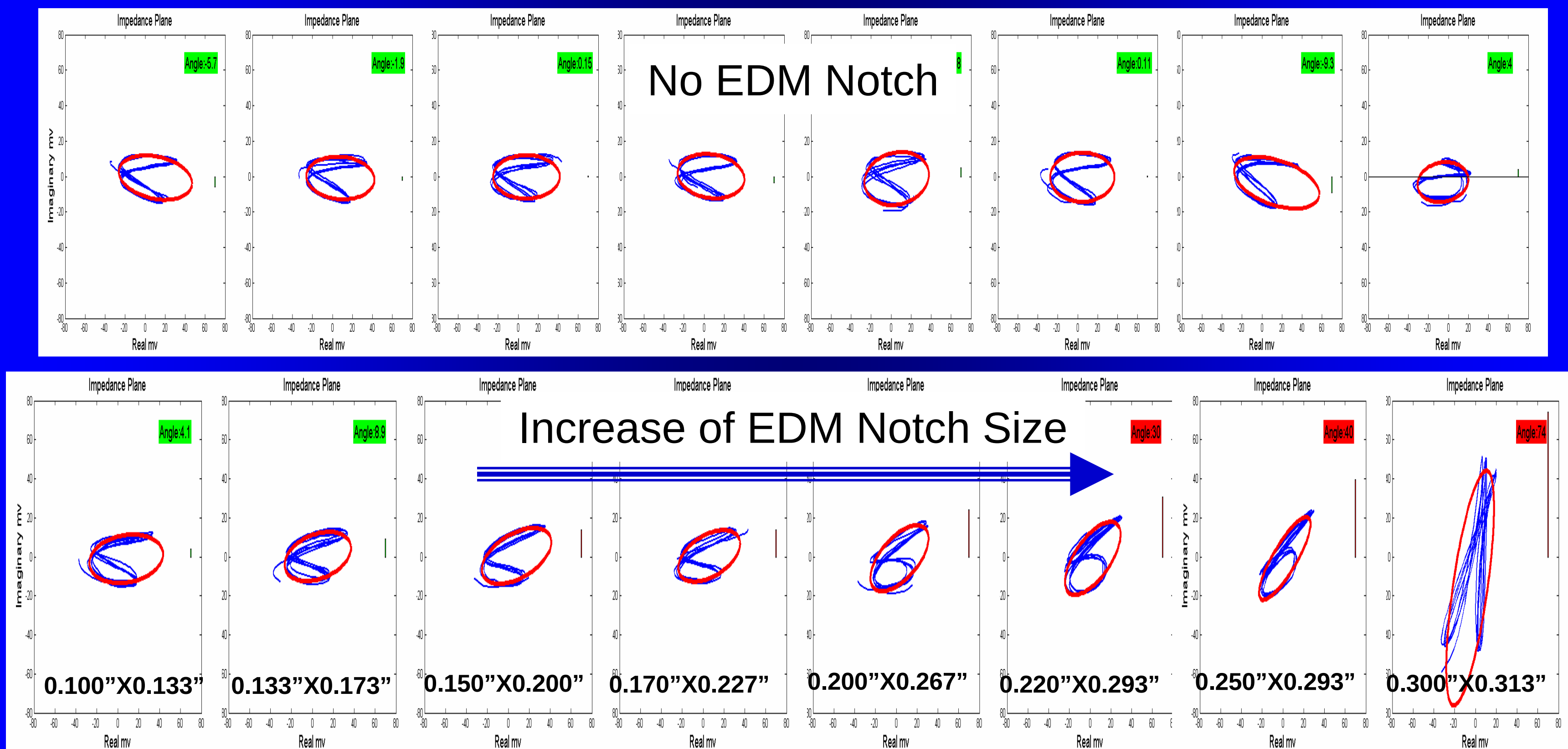
Specimen provided by Boeing Phantom Work



Part II – Deeply hidden crack detection

Example 1 - Impedance plane & ellipse fitting

2nd Layer Crack near 2nd Layer Edge Non-ferromagnetic Fastener

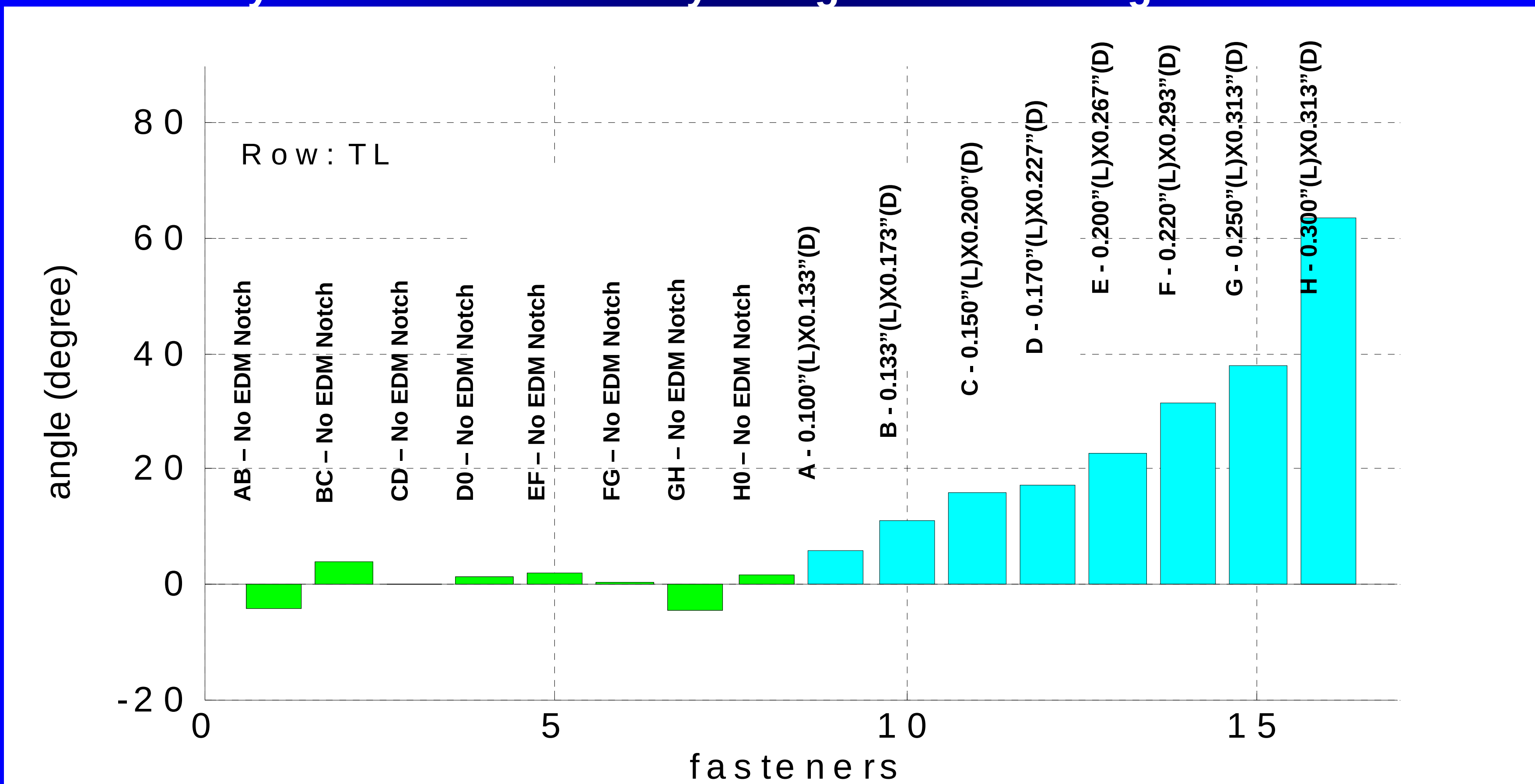


Observation: without signal processing reliably detected EDM notch size > 0.250”(L)

Part II – Deeply hidden crack detection

Example 1 - Signal Rotation Angle

2nd Layer Crack near 2nd Layer Edge Non-ferromagnetic Fastener



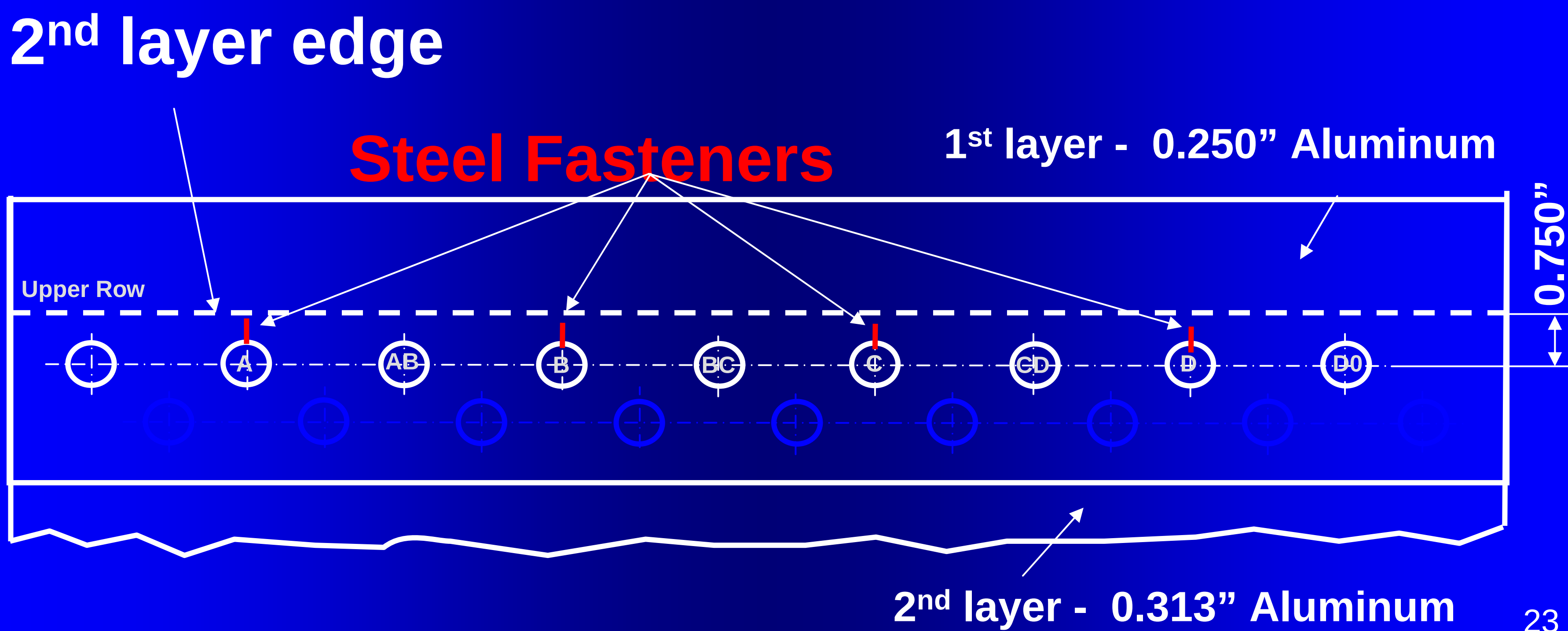
Observation: with signal processing reliably detected EDM notch size ≥ 0.133”(L)

Topic 5 - Study # 2

Edge + Ferromagnetic Fastener

Example 2 – Simulating Boeing 707 Wing Structure

Detection 2nd layer vertical cracks with Steel fasteners, crack very close to 2nd layer edge



Example 2

Detection 2nd layer vertically aligned cracks with steel fasteners & crack close to 2nd layer edge

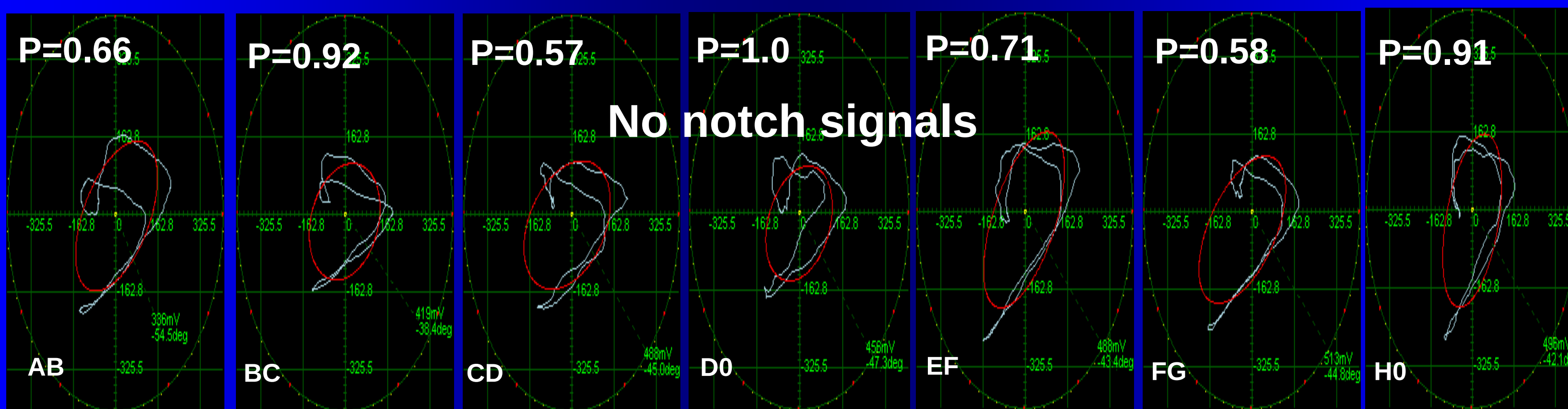
Challenges:

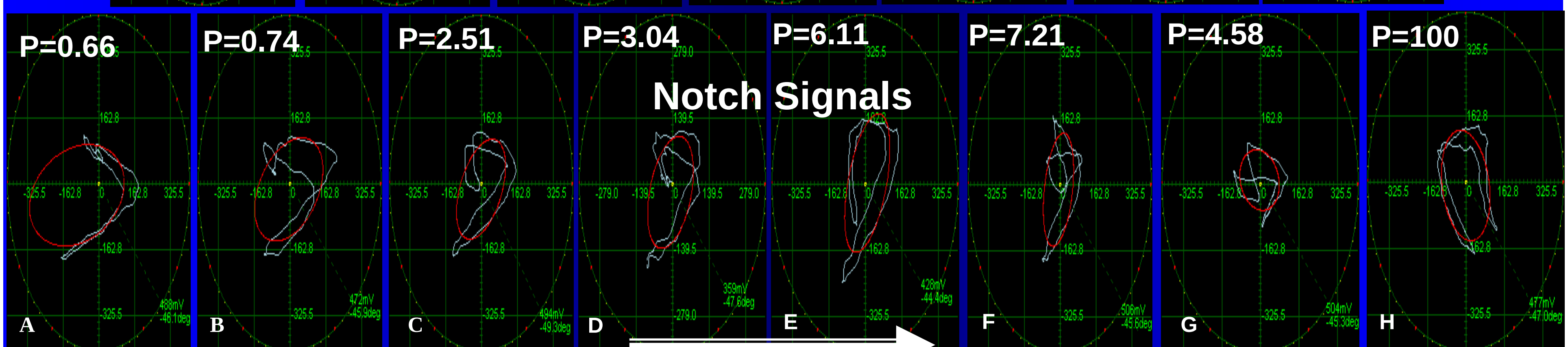
1. Unlike the case of Example 1 where the fasteners are made of non-ferromagnetic material, in Example 3 the fastener is made of steel. In this particular case crack signal DECREASES with increase of notch size as shown in next page.
2. The underline physics of this phenomenon so far remains unknown.
3. A notch can not be identified by any single parameter of detected signal. A Shape Factor P, which is a combination of a few features of the shape of the impedance plane, is used for identification of a notch.

Part II – Deeply hidden crack detection

Example 2 - Signals from Fastener Holes w/ and w/o a Notch

Signal decreases with increase of notch size and varies in its size and shape



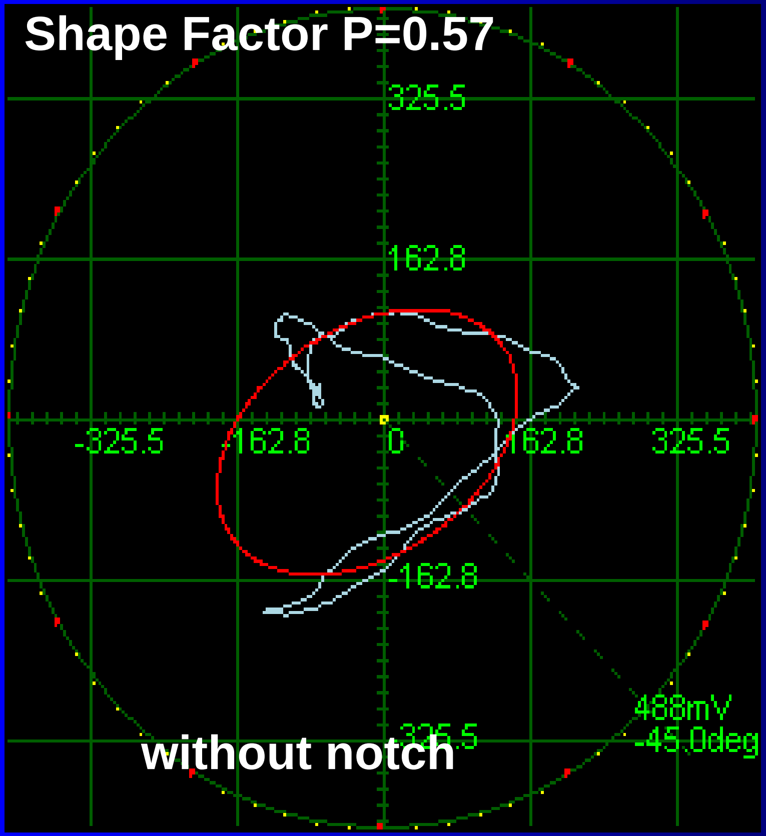


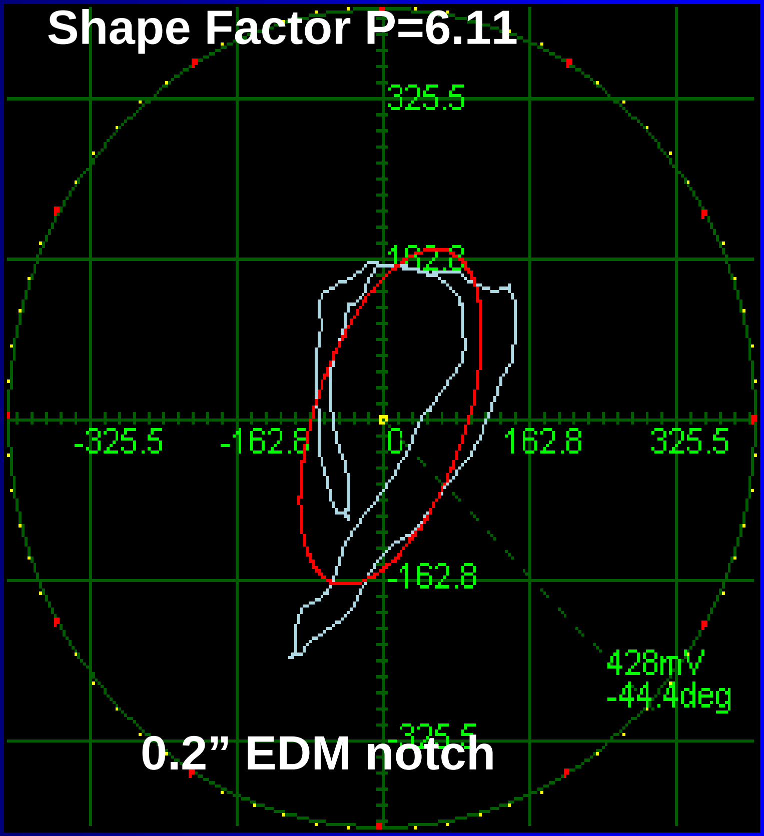
Increase of notch size

Part II – Deeply hidden crack detection

Example 2 - Signals from Fastener Holes w/ and w/o a Notch

Signal decreases with increase of notch size and varies in its size and shape

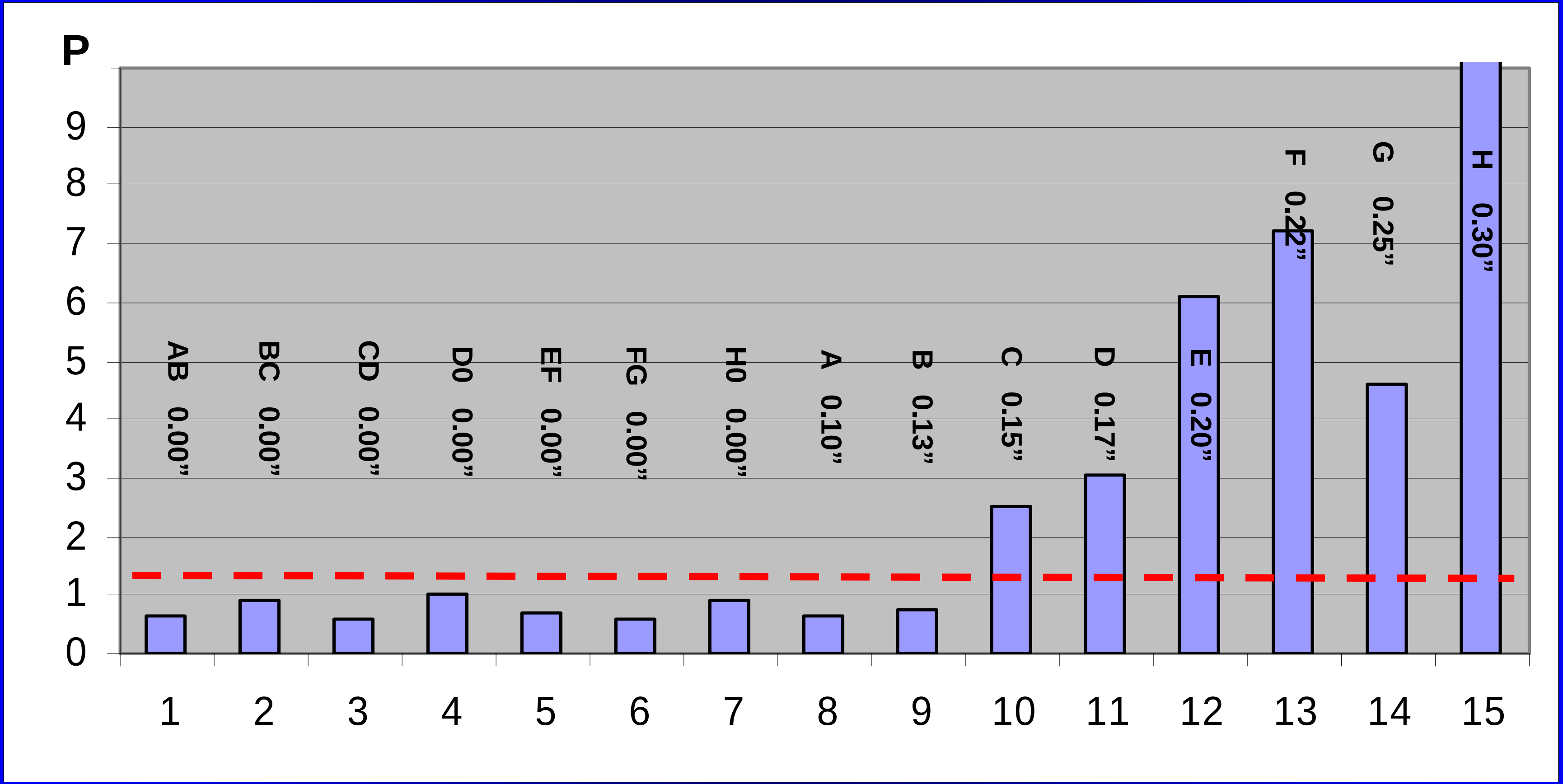




Part II – Deeply hidden crack detection

Example 2

Shape Factor P is used for Notch Identification



Good fasteners

Notched fasteners

Summary on Study #2

1. Signal obtained in detection 2nd layer vertically oriented crack that is close to a 2nd layer edge has abnormal behavior. The signal decreases with the increase of 2nd layer crack size.
2. It is impossible to identify a crack using a conventional approach of signal processing and crack identification.
3. The concept of pattern recognition is utilized in this case.
4. Automated rotary RF_RFEC probe provides highly repeatable signal that enables the use of online signal processing and pattern recognition.