Ultrasonics Equipped Crimp Tool- A New Technology for Aircraft Wiring Safety

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Introduction

Overview of Crimp Quality and Possible improvements with this technology

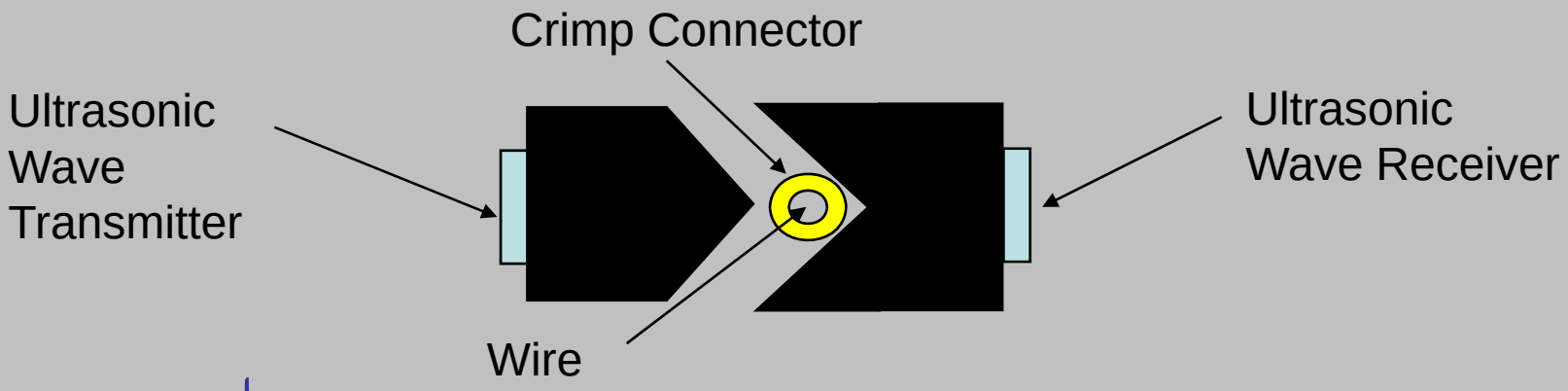
- Crimp Failures occur for many reasons.
  - At installation
    - Wrong connector, wire size or tool used
    - Improper technique
    - Crimp tool failure (worn jaws), etc.
  - During service life
    - Corrosion effects
    - Wire under stress
- Crimp installation are clearly indicated with the Ultrasonics Equipped Crimp Tool (*patent applied for*).
- Recertification of existing crimps (during service life) is possible

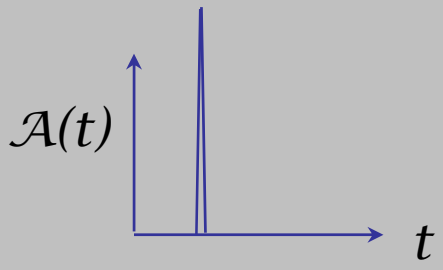
Present Practices

- Procedures
  - Detailed crimping procedures, with QA verification on procedures, are used to ensure good initial crimp quality
- Certification / Calibration
  - Destructive pull-testing of similarly crimped connectors is used to certify tools and procedures
  - *There is no direct verification of a good crimp*
- Verification
  - *No crimp recertification is possible*

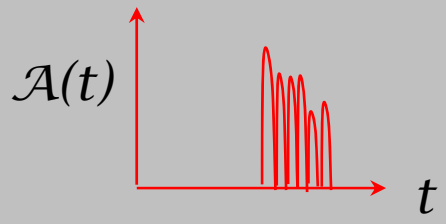
The Concept

Basic Concept of Ultrasonic Equipped Crimp Tool





Input to crimp

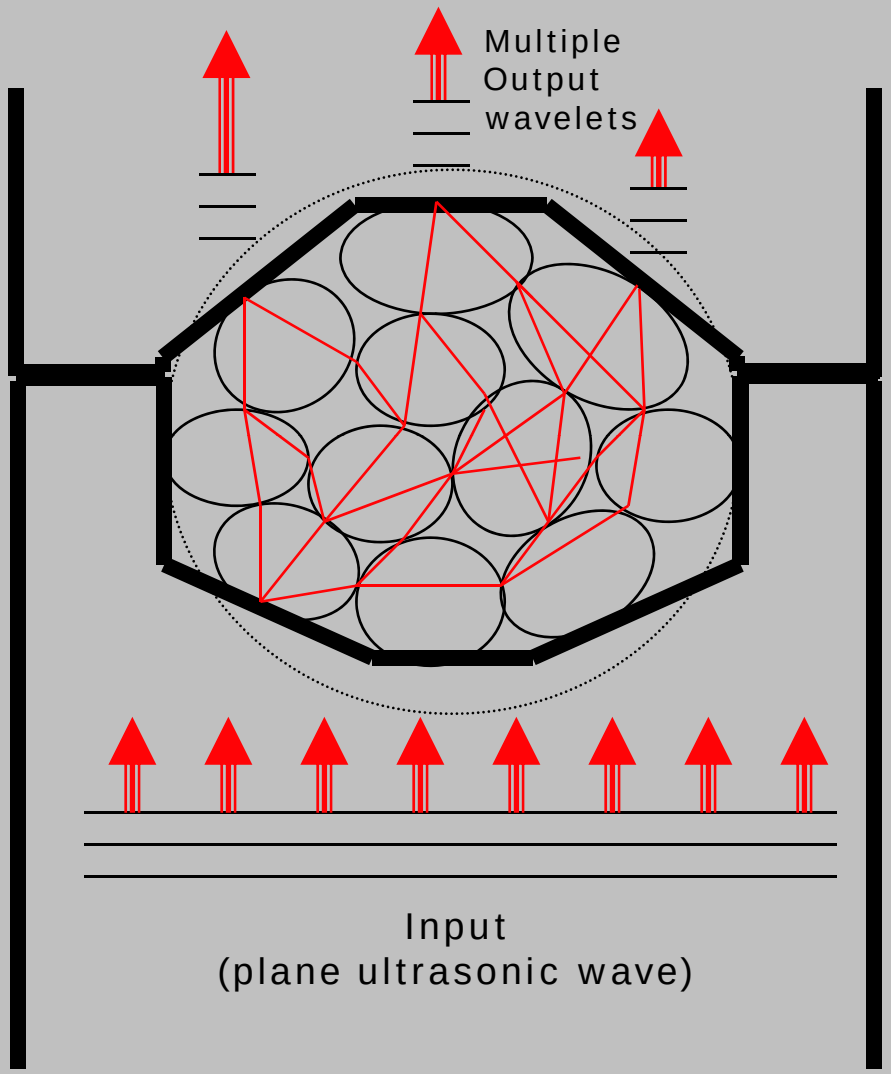


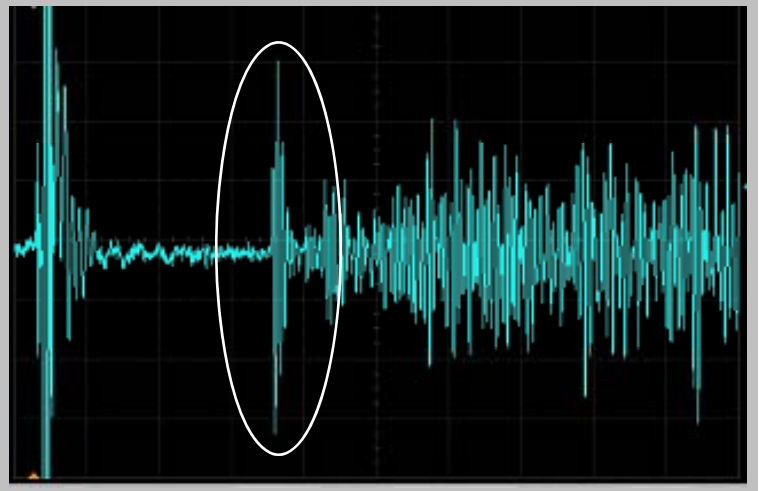
Output from crimp

$\mathcal{A}(t)$ *is the ultrasonic wave amplitude as a function of time*

Operational Signals

Basic Concept – A Good Crimp!

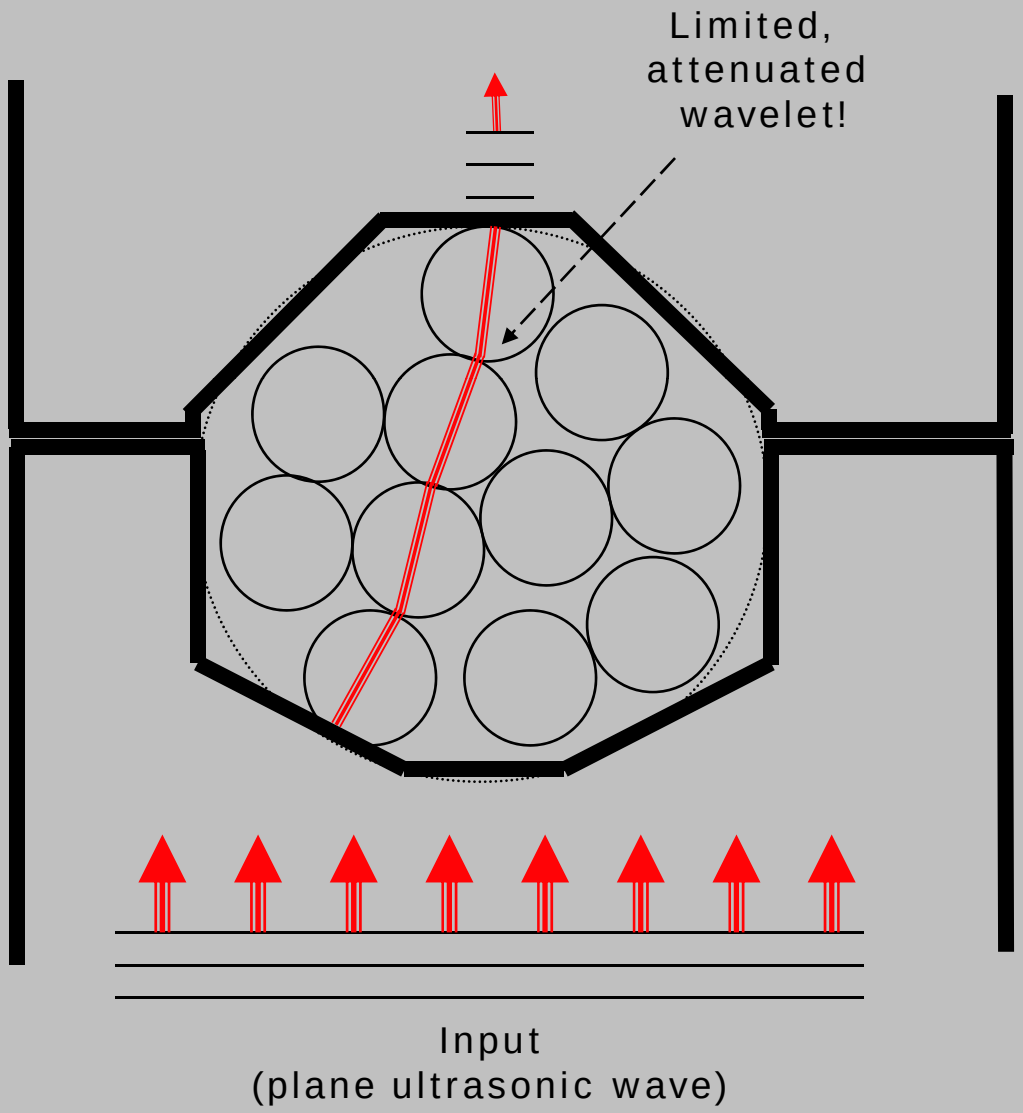


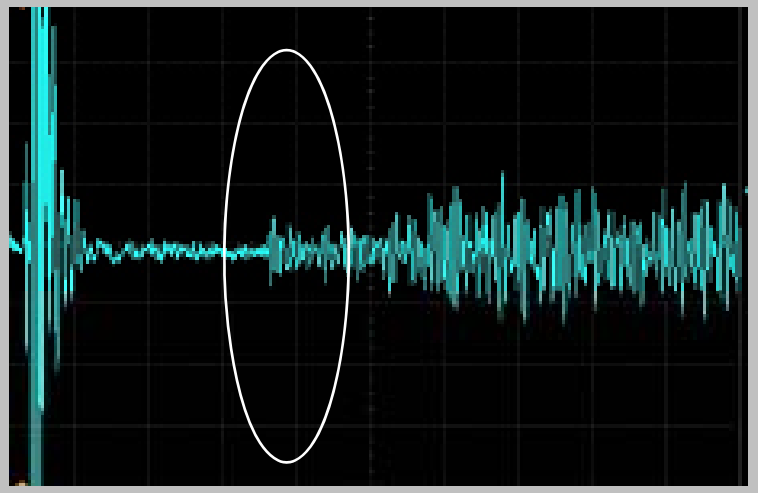


Ultrasonic Features Of a Good Crimp:

1. Multiple signal paths thru crimp
2. Higher amplitude on time record
3. Low spectral variation in Fourier Transform

Basic Concept – A Bad Crimp!



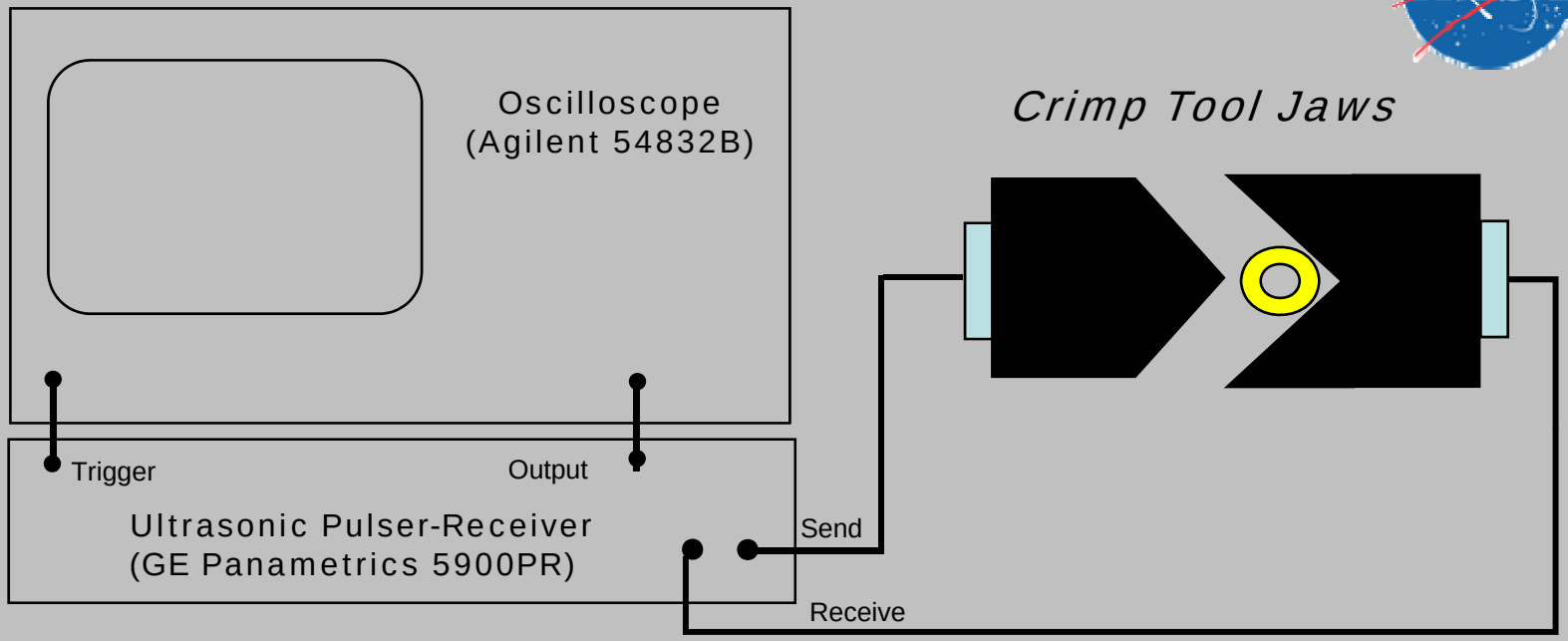


Ultrasonic Features Of a Bad Crimp:

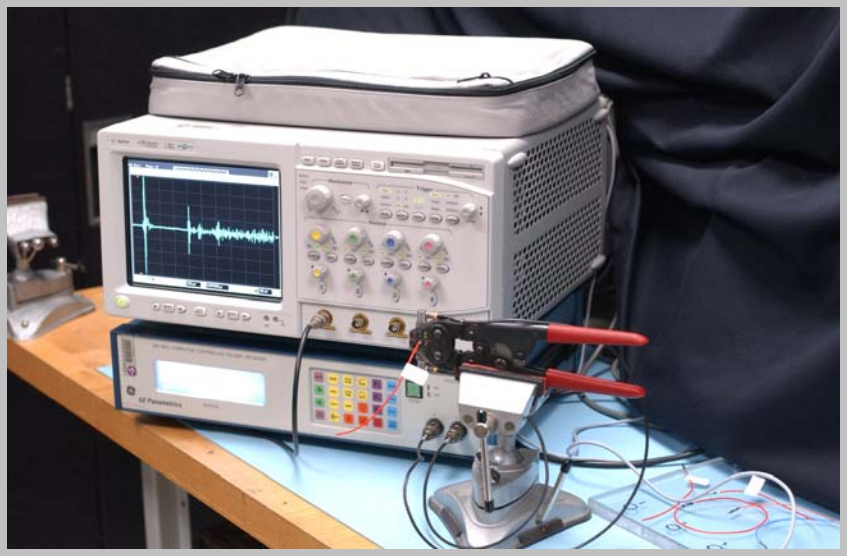
1. Single (or no) signal paths thru crimp
2. Low amplitude on time record
3. High spectral variation in Fourier Transform

Test of Concept

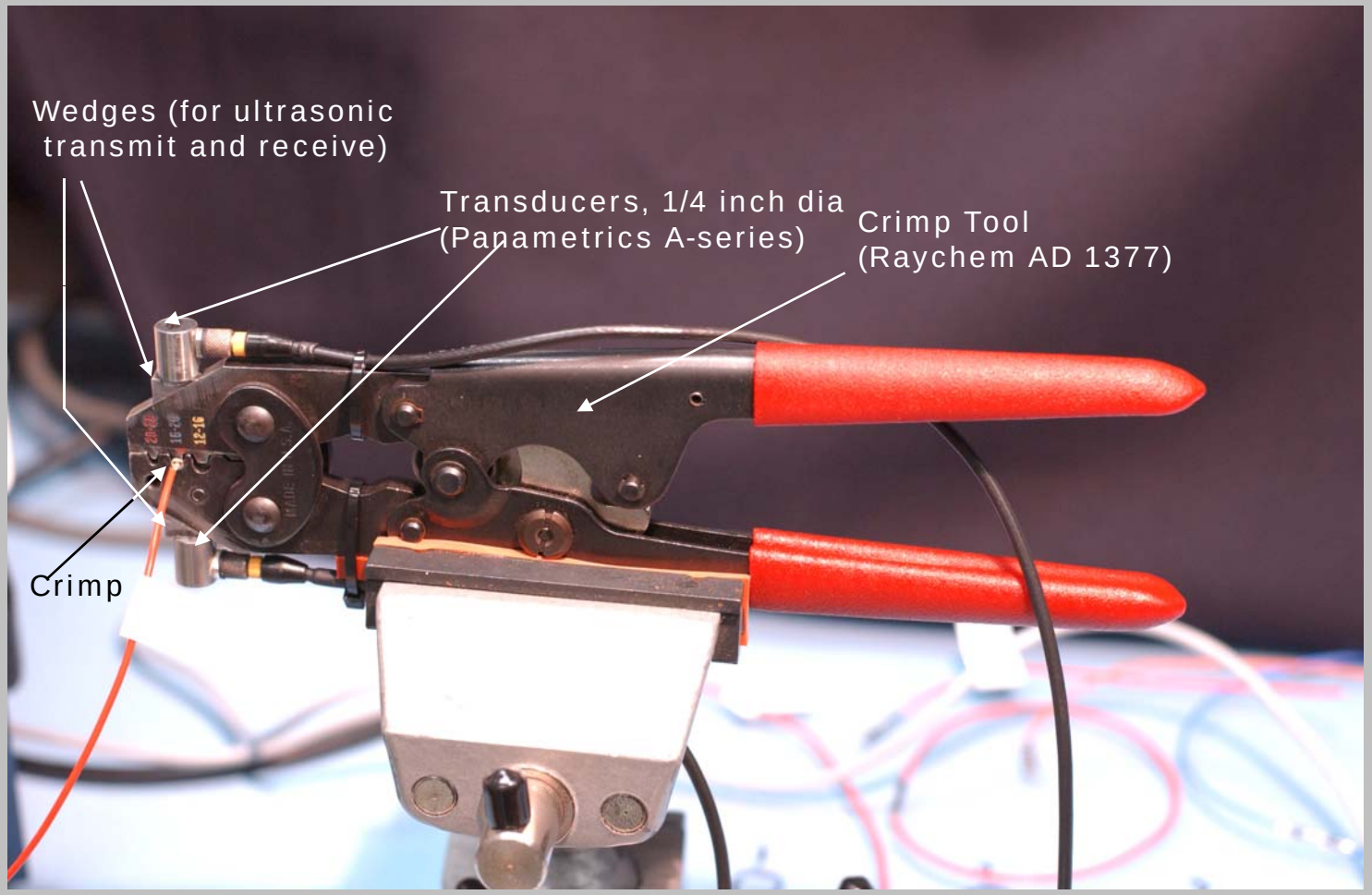
Test of Concept Arrangement



Simple Electronics that can easily be miniaturized to produce a self contained ultrasonics equipped crimp tool



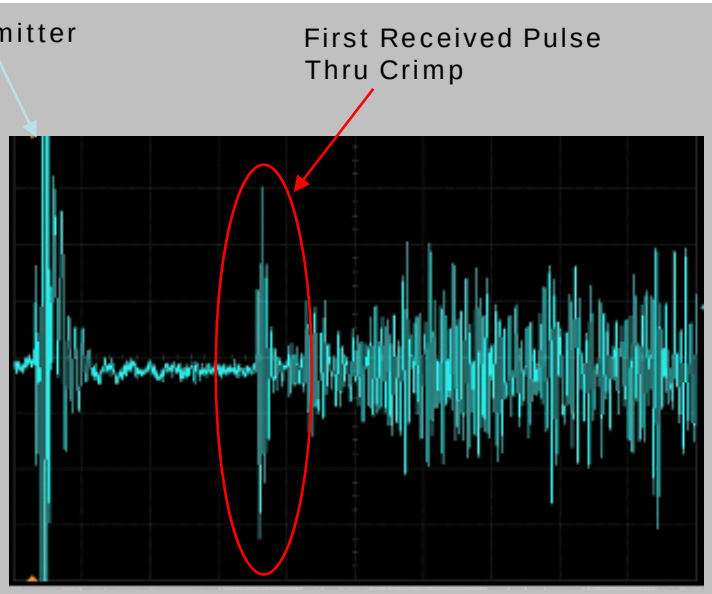
Test of Concept
Instrumented Crimp Tool



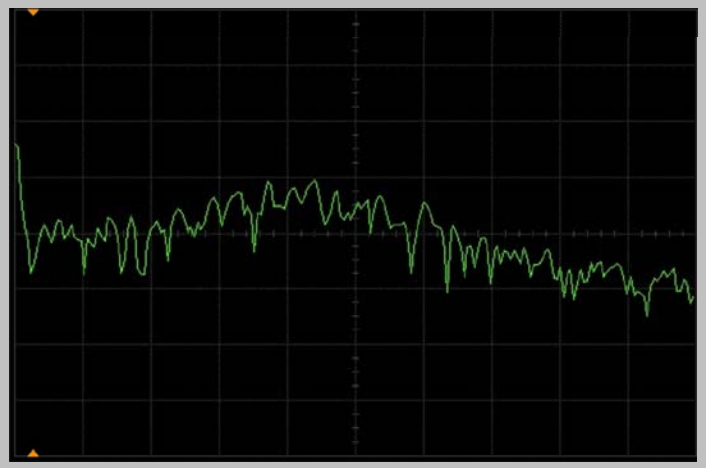
Test of Concept Results

- *Based on using 10 Mhz transducers*
- *16-20 gauge wires used for connections*

Test of Concept: Typical Oscilloscope Waveforms of Good Crimp



Received Signal Waveform

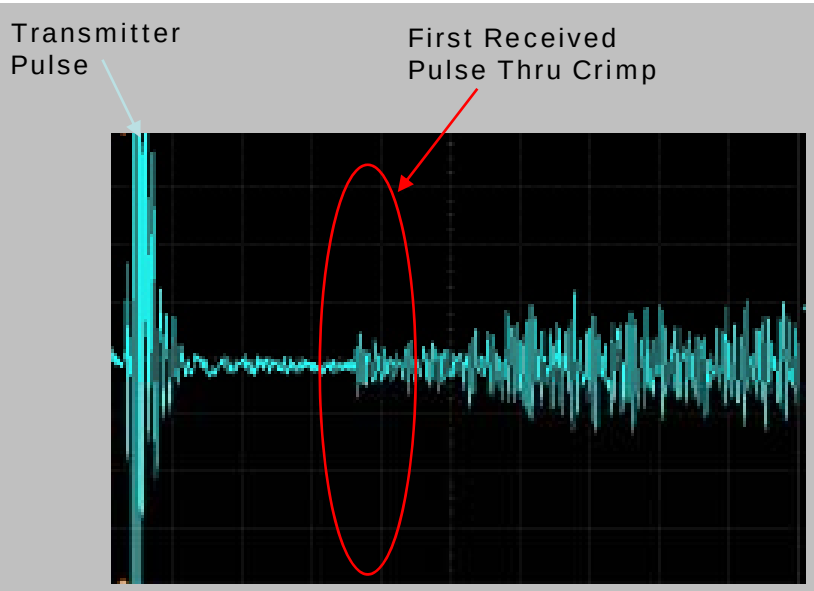


Fast Fourier Transform

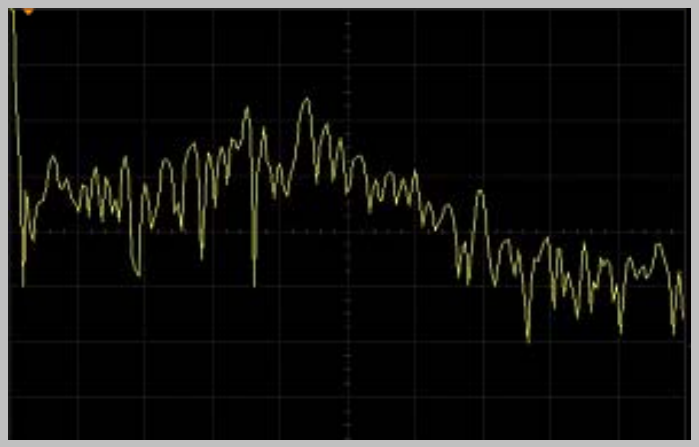
Transducers - 10 Mhz
Pitch - Catch Mode

<u>Destructive Pull-Test Confirmation</u>

Wire gage - 20 AWG. Minimum load to pass - 19 Lbs. Actual load reached - 34 Lbs. Type of failure - wire breakage (***<u>not crimp failure</u>***).



Received Signal Waveform



Fast Fourier Transform

Test of Concept: Typical Oscilloscope Waveforms of Bad Crimp

Transducers - 10 Mhz
Pitch - Catch Mode

Destructive Pull-Test Confirmation

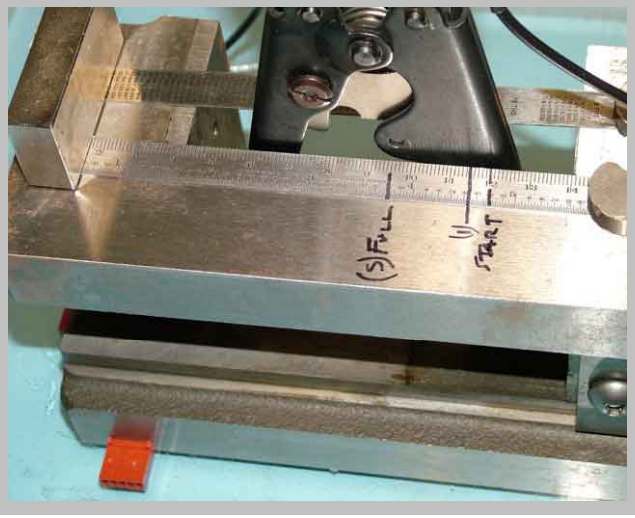
Wire gage - 20 AWG. Minimum load to pass - 19 Lbs. Actual load reached - 10.4 Lbs. Type of failure - wire pullout (***crimp failure***).

Data: Experimental Results

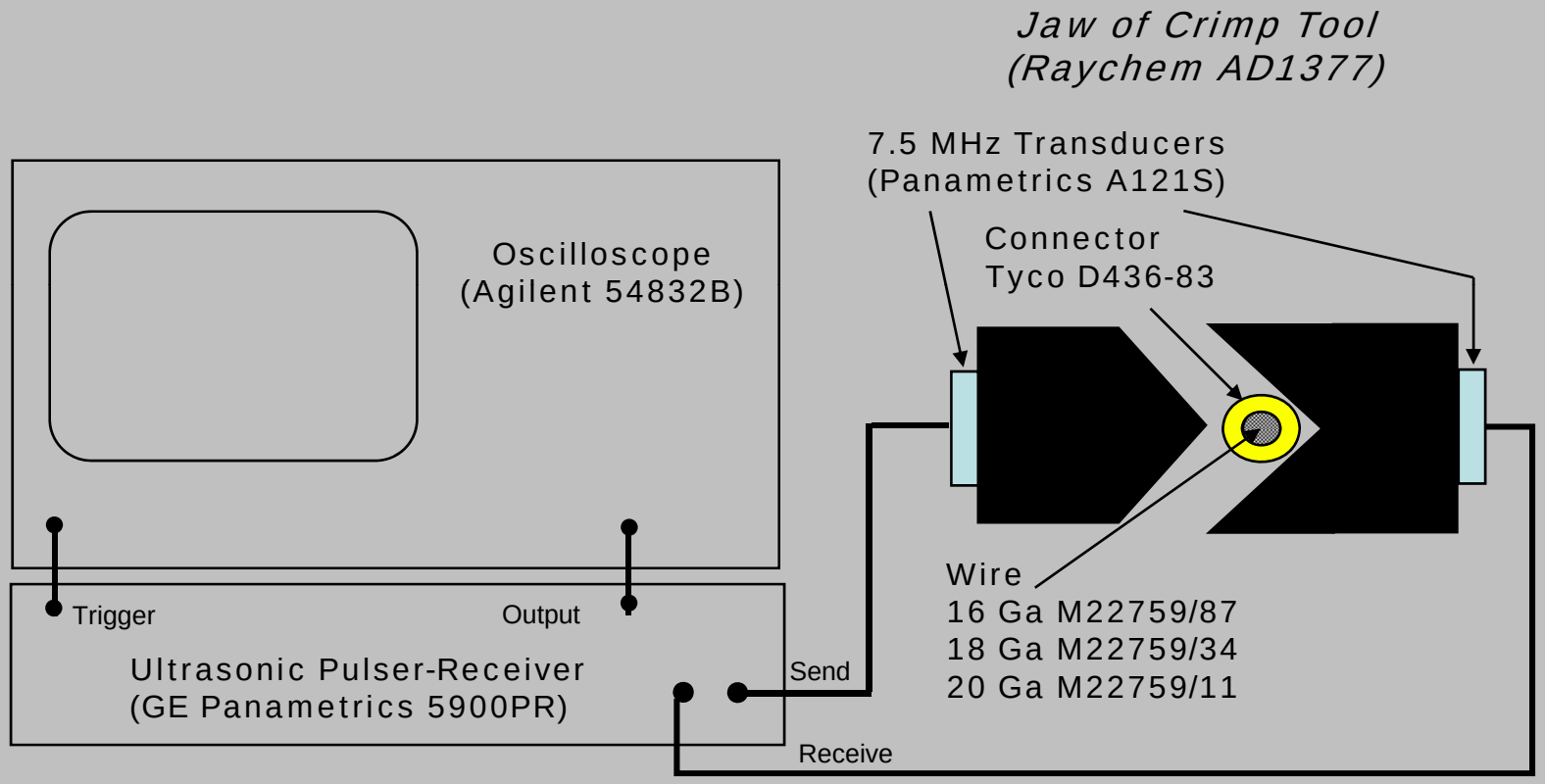
- *Based on using 7.5 Mhz transducers*
- *16-20 gauge wires used for connections*

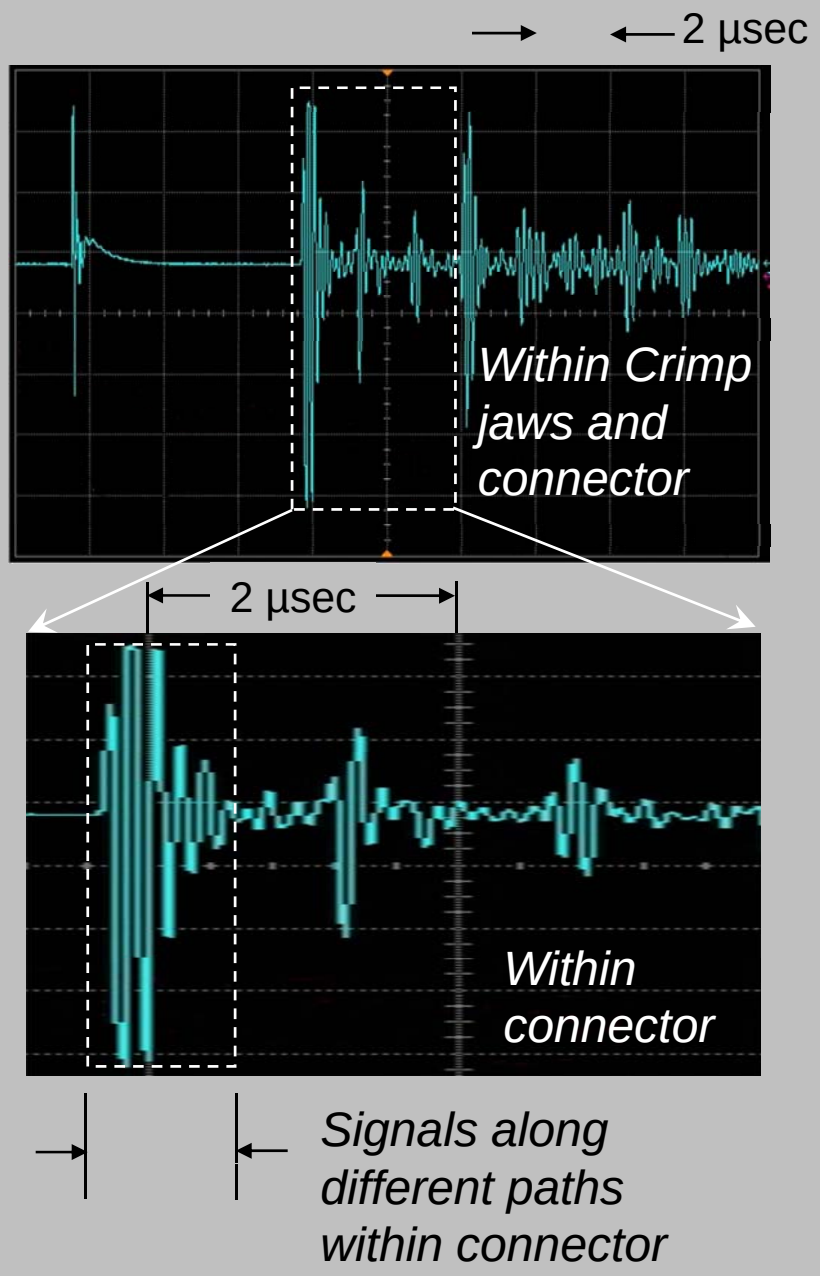
Experimental Setup: Crimp-tool and Tester

- The “Jaw”
- *This study uses incomplete jaw closure to make the “bad” crimps*
- Handle closure is performed in 5 mm increments through standard jaw closure
- Wires and connectors are crimped together
- Crimp tester (Alphatron MPT200A) is used to measure force needed to pull wire-connector crimp apart



Experimental Set-up: Electronics and Ultrasonics





Experimental Results: Path Analysis

Transducers - 7.5 Mhz
Pitch - Catch Mode
16 Gauge wire and connectors

Path Analysis within jaws

- *multiple reflections*
- *Path length measures 35 mm (34.7mm from ultrasonics)*

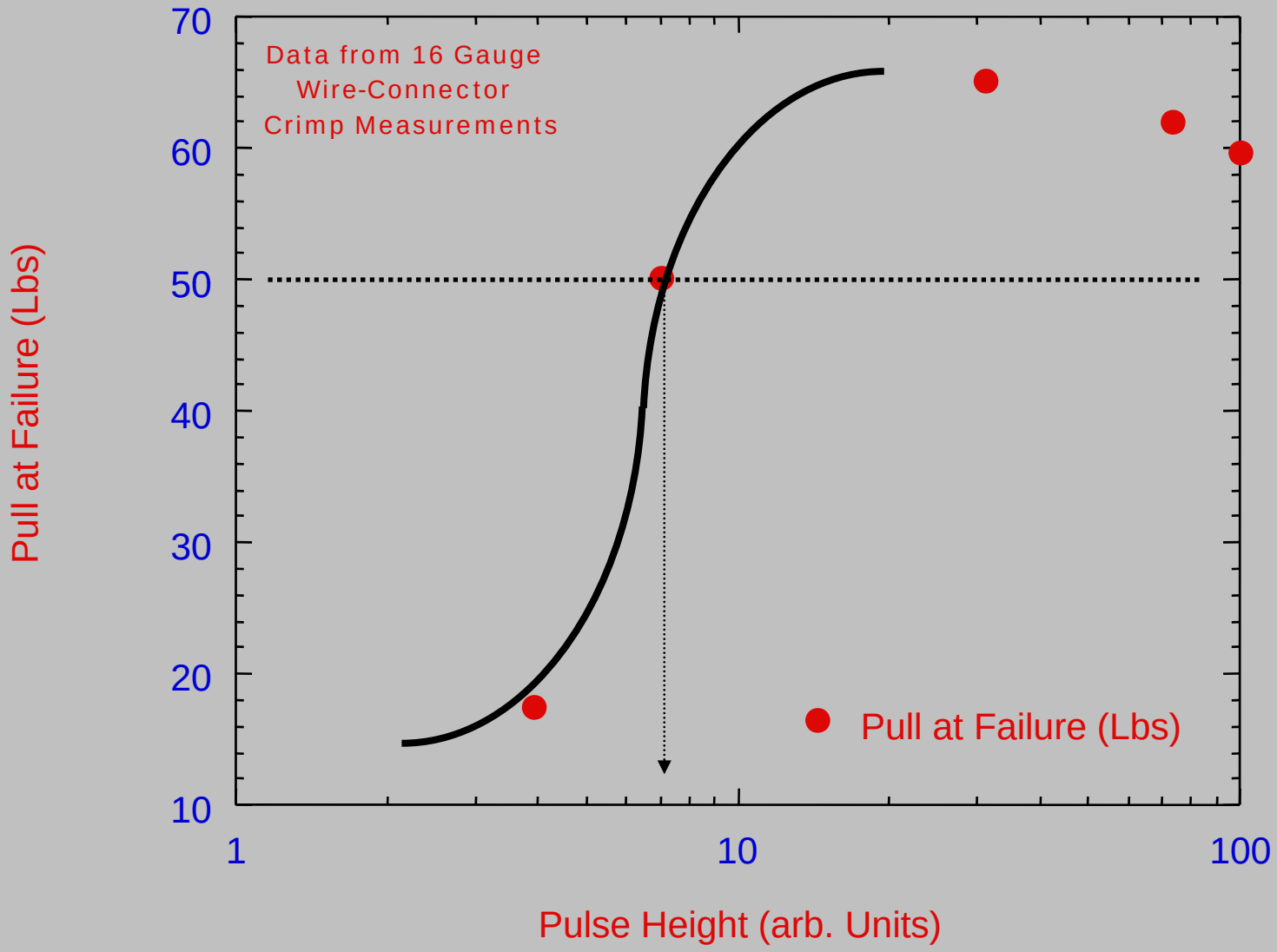
Path Length Analysis within connector

- *~ 7 to 8 distinct paths*
- *Length variation among paths ultrasonically measures 0.7mm (16 ga)*

Data from 16 Gauge Wire-Connector Crimp Measurements

Wire Gauge/ Compression Level	Pulse Height (arb units)	Pulse Width (arb units)	Failure Mode	Pull at Failure (lbs) (Spec=50)
16/1	3.9	2	Pull-out	17.5
16/2	7	2.5	Pull-out	50.2
16/3	31	8	Break (at crimp)	65.1
16/4	73	5	Break (at crimp)	62.0
16/5 (full crimp)	100	6.7	Break (at crimp)	59.7

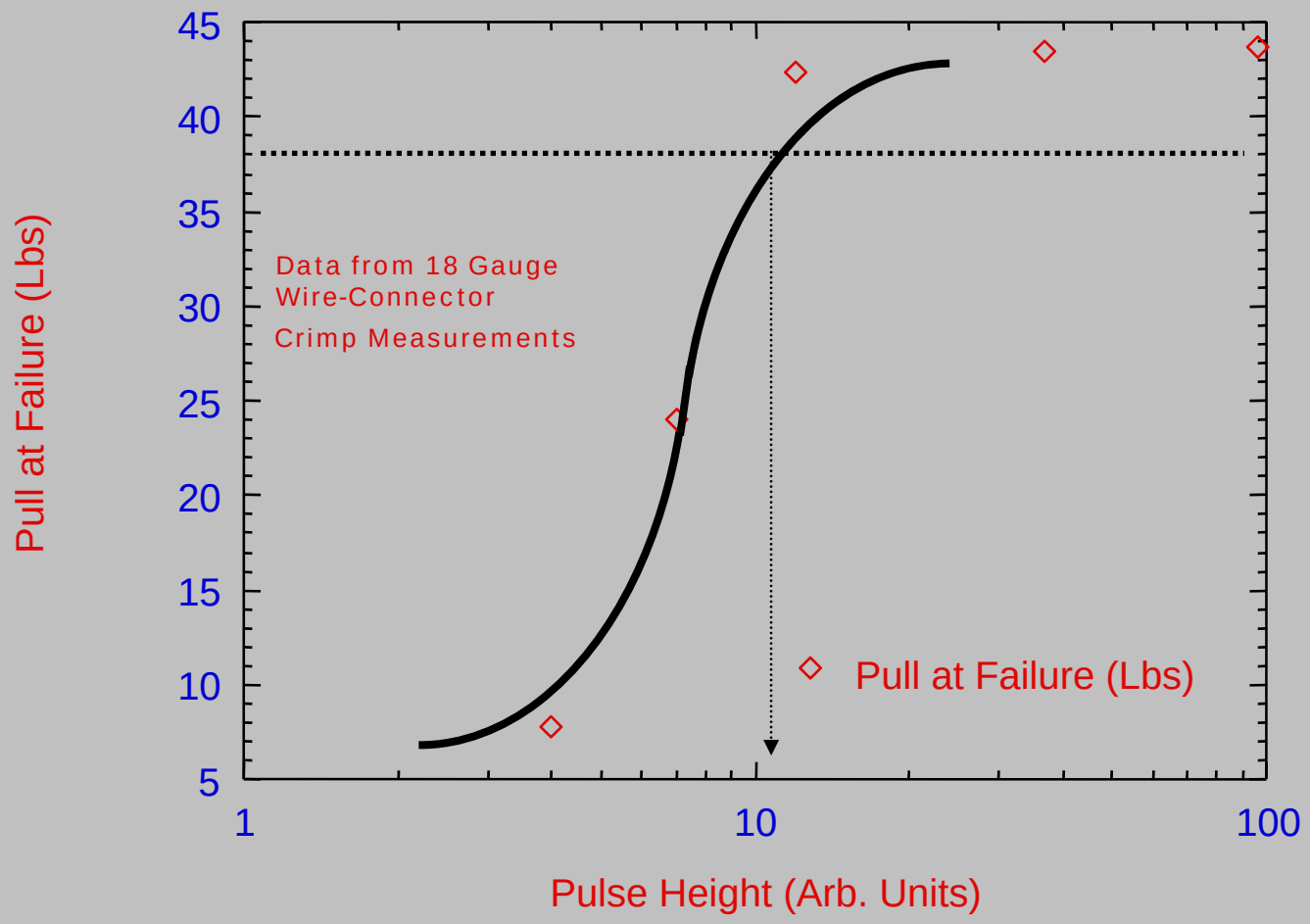
A Plot of Pull at Failure vs. Ultrasonic Pulse-Height through Crimp-Connector Junction (16 Gauge)



Data from 18 Gauge Wire-Connector Crimp Measurements

Wire Gauge/ Compression Level	Pulse Height (arb units)	Pulse Width (arb units)	Failure Mode	Pull at Failure (lbs) (Spec=38)
18/1	4	1.7	Pull-out	7.8
18/2	7	2	Pull-out	24
18/3	12	5.5	Break (at crimp)	42.4
18/4	37	5.5	Break (at crimp)	43.5
18/5 (full crimp)	96	7	Break (at crimp)	43.7

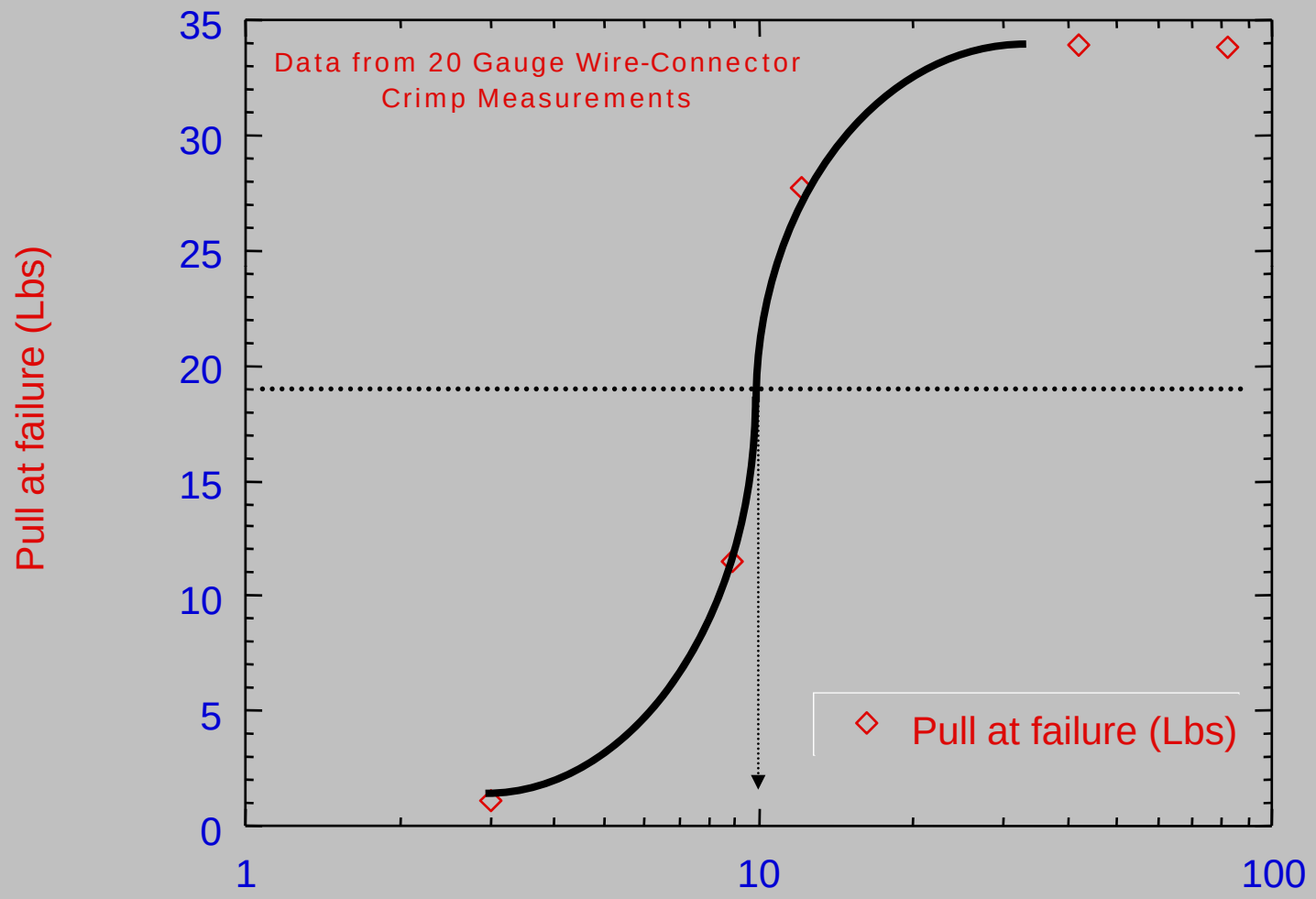
A Plot of Pull at Failure vs. Ultrasonic Pulse-Height through Crimp-Connector Junction (18 Gauge)



Data from 20 Gauge Wire-Connector Crimp Measurements

Wire Gauge/ Compression Level	Pulse Height (arb units)	Pulse Width (arb units)	Failure Mode	Pull at Failure (lbs) (Spec=19)
20/1	3	2.5	Pull-out	1.1
20/2	8.9	2.5	Pull-out	11.5
20/3	12.1	2	Pull-out	27.7
20/4	42	7	Break (at crimp)	33.9
20/5 (full crimp)	82	5	Partial Break	33.8

A Plot of Pull at Failure vs. Ultrasonic Pulse-Height through Crimp-Connector Junction (20 Gauge)

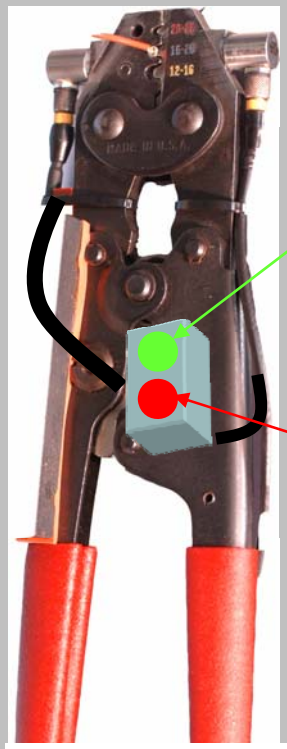


Results and Conclusions from Data

- Data was presented that examines the use of ultrasonics to evaluate crimp quality for incomplete crimps.
- Ultrasonic interrogation of crimp predicts crimp quality
  - Ultrasonic Pulse Height correlates very well with pull-test results for 16, 18, and 20 AWG wire-crimp connections
  - Ultrasonic pulse width is also a possible predictor for pull-test results
- Ultrasonic Pulse Height indicating a quality crimp is relatively independent of wire gauge

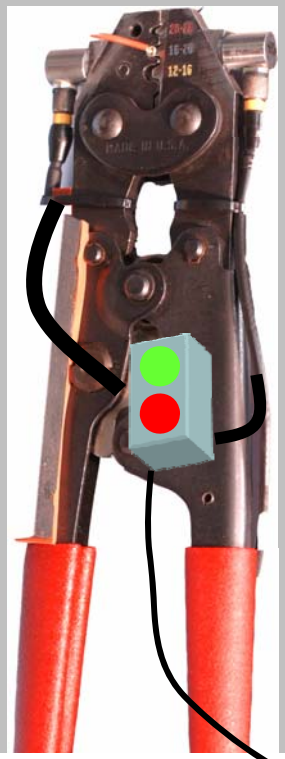
Concept for a Possible Commercial Instrument

Artist Conception of Two Versions of a Commercial Instrument



Good Crimp

Bad Crimp



Optional Data Collection and Archival

Self-contained Instrument

Simple Pass/Fail Indications

Waveform Analysis Embedded in Instrument

Summary and Future Directions

- No current instrument for crimp quality assessment
- Ultrasonic instrument can be used to assess and/or verify crimp mechanical integrity and hence crimp quality
- Technique allows for re-inspection / recertification
- A fully developed system will permit improved data and record keeping on critical crimp connections.
- Additional measurements are underway to substantiate these and investigate frequency-dependency of ultrasonic signals used to evaluate crimp quality.
- Investigate wide range of crimp failure modes