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NCC 8 -115

ABSTRACT

Thermographic Inspection of Metallic Honeycomb Sandwich Structures

IN-38
372713

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The X-33/VentureStar has a Thermal Protection System (TPS) consisting mainly of brazed metallic honeycomb sandwich structures. Inspection of these structures is challenging as a result of the extremely thin (less than 200 μm) skins, the small critical defect size (less than 2 mm long by 100 μm wide) and the large number (more than 1000) of parts to be inspected.

Pulsed Infrared Thermography has been determined to be the most appropriate inspection method for manufacturing inspection based on performance comparison with other methods, cost, schedule and other factors. The results of the assessment of the different methods will be summarized and data on the performance of the final production inspection system will be given.

Finite difference thermal methods have been used to model the whole inspection process. Details of correlation between the models and experimental data will be given and data on the use of pulsed infrared thermography on other metallic honeycomb sandwich structures will be given.

This work was supported in part under NASA Cooperative Agreement NCC8-115 and Lockheed Martin Corporation Recipient Team Member Cooperative Agreement 96-RHR-0001.

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THERMOGRAPHIC INSPECTION OF METALLIC HONEYCOMB SANDWICH STRUCTURES

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OUTLINE

- Introduction
- Inspection Methods
- Probability of Detection Results
- BFGoodrich PIRT System
- PIRT Model Development/Verification
- Model Predictions
- Summary

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HONEYCOMB SANDWICH

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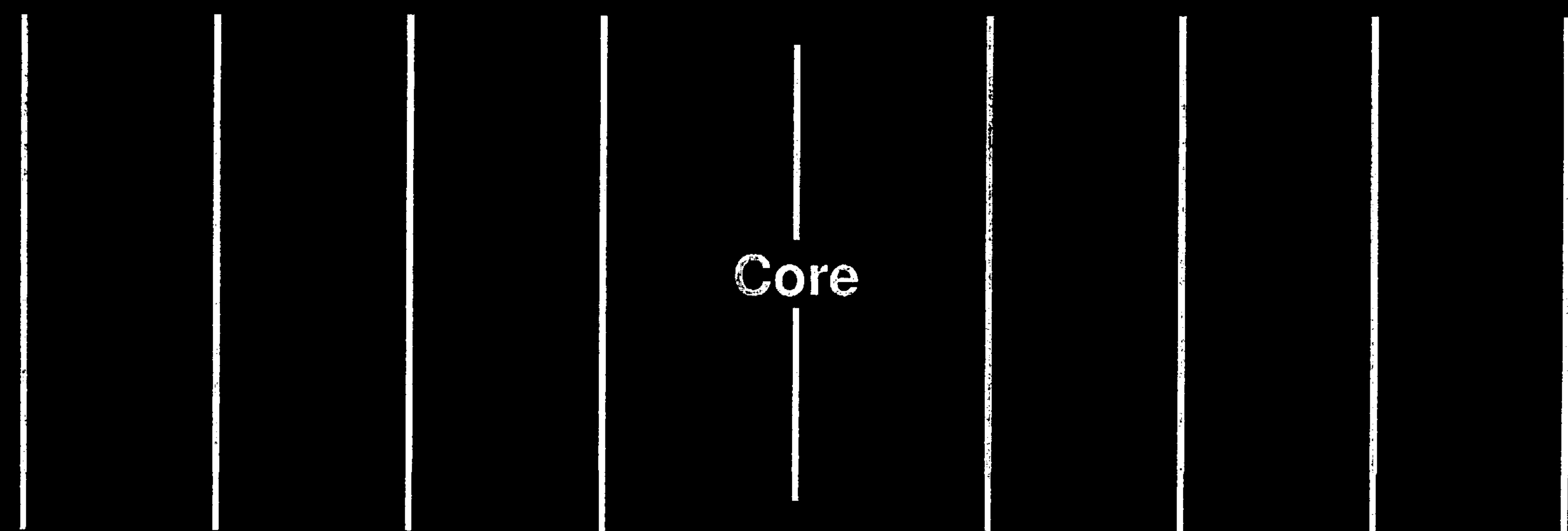

	Skin Thickness (mm)	Core Thickness (µm)	Core Height (mm)
Ti	0.5 – 1	37 – 88	12 – 25
Inconel 625	0.5 – 1.5	37 – 88	12 - 25
Inconel 617	0.15	50	12

INSPECTION METHODS

- Ultrasonic
  - Pulse Echo
  - Through Transmission
- Pulsed Infrared Thermography
- Optical
  - Holography
  - Shearography

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ULTRASONIC DATA

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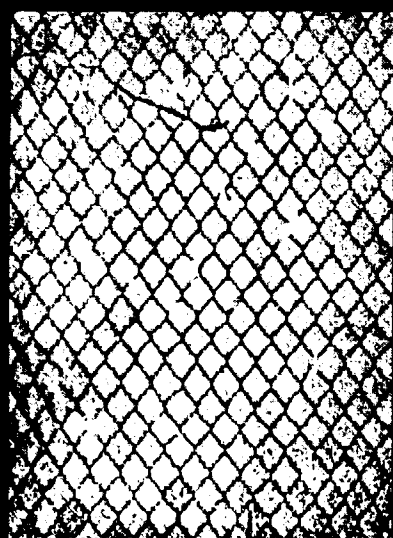
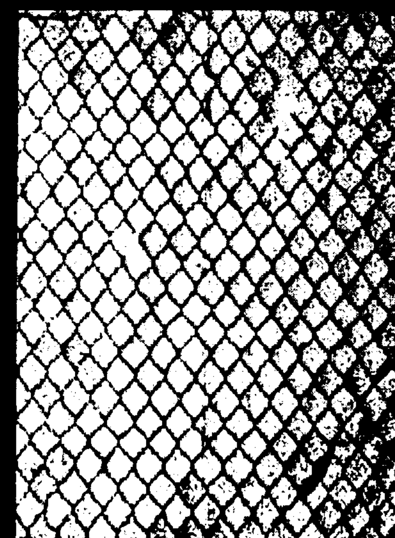
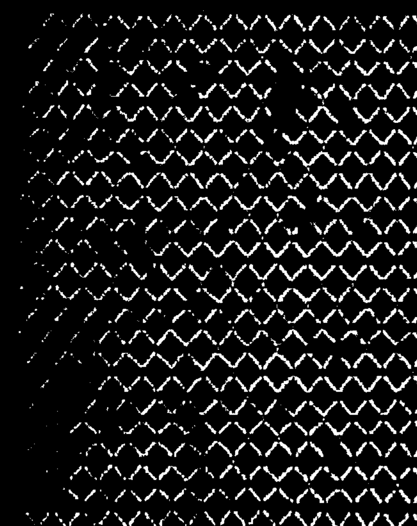


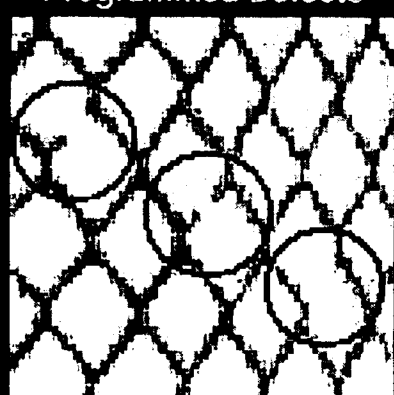




PULSE ECHO
Programmed Defects

PULSE ECHO
Natural Defects

THROUGH TRANSMISSION
Programmed/Natural Defects



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THERMOGRAPHIC DATA

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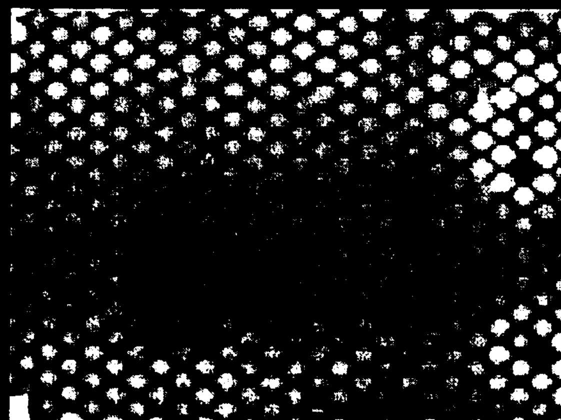
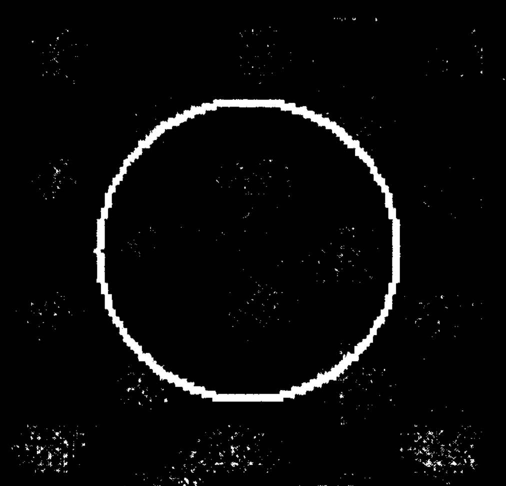
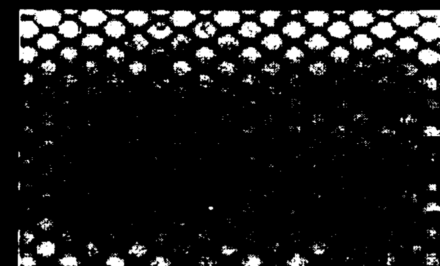
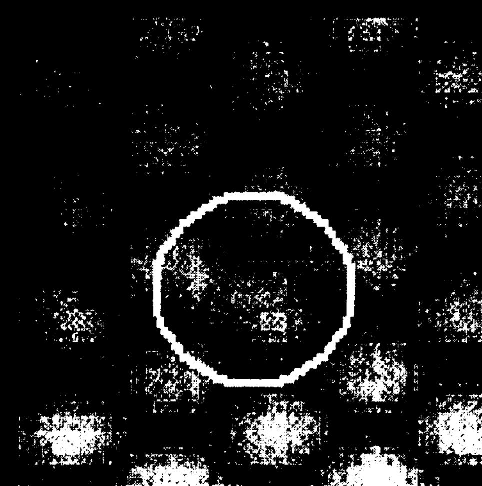


Thermography
Programmed Defects





Thermography
Natural Defects



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OPTICAL DATA

Shearography
Vibration Excitation

Holography
Vacuum Excitation

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TEST SAMPLES

- 216 Programmed Defects
  - 1.25 - 6.25 mm Long
  - 0.05 mm Wide
  - 0.15 mm Deep (Below Surface)
- 35 Natural Defects
  - 0.5 - 6.25 mm Long
  - 0.05 mm Wide
  - 0.15 mm Deep (Below Surface)

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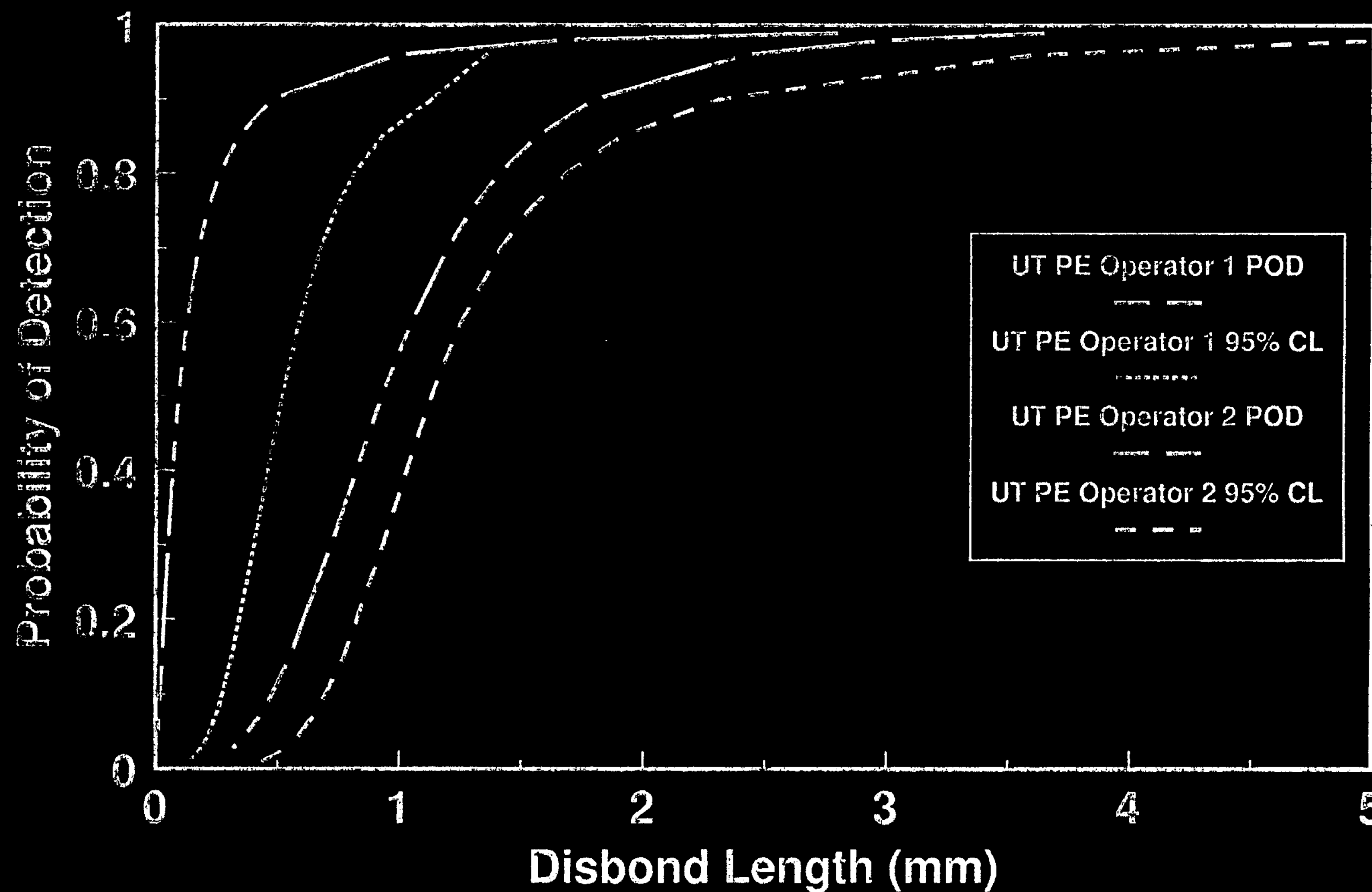
UT OPERATOR EFFECT ON POD



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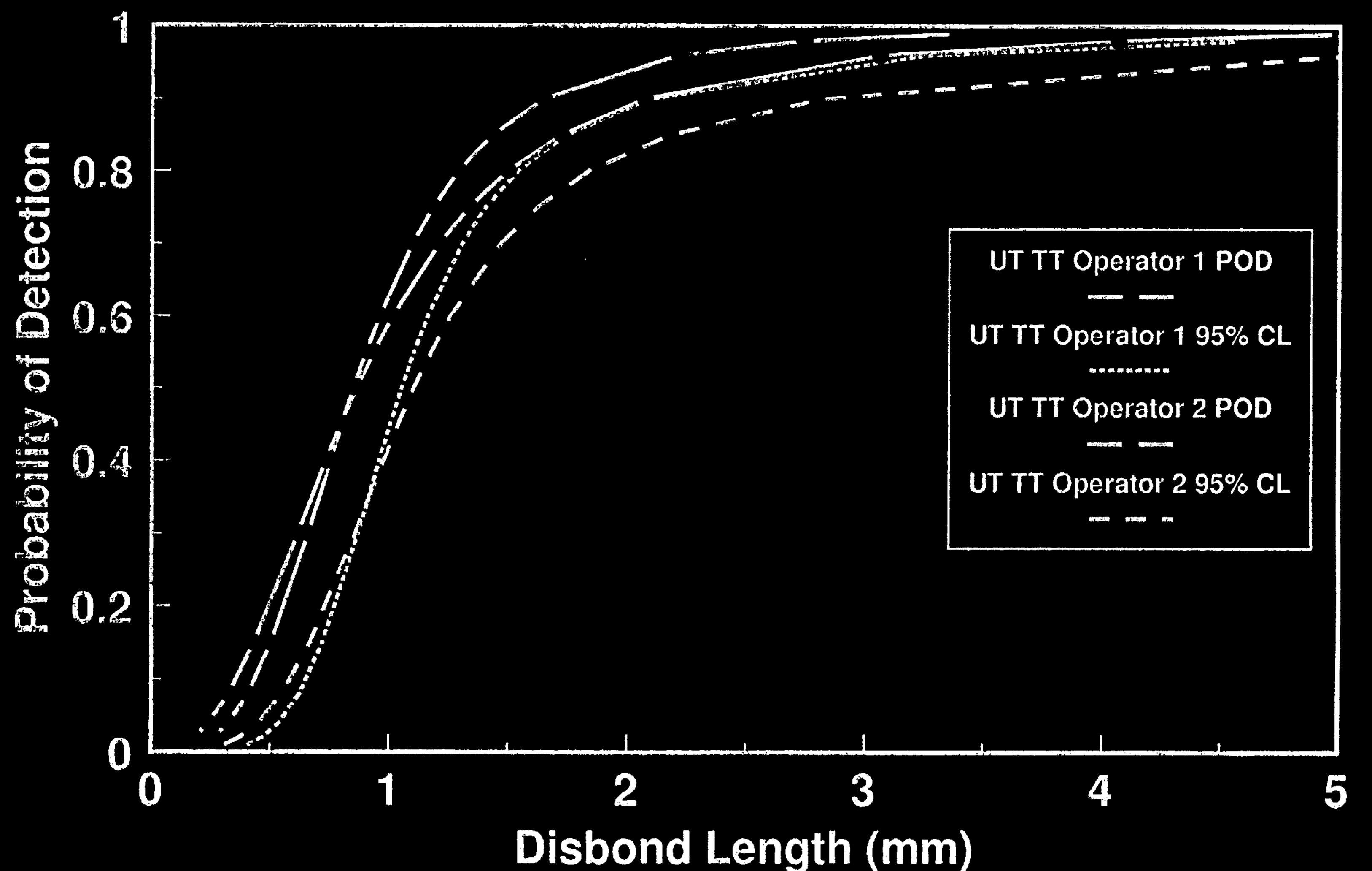
UT OPERATOR CHARACTERISTICS

NDE



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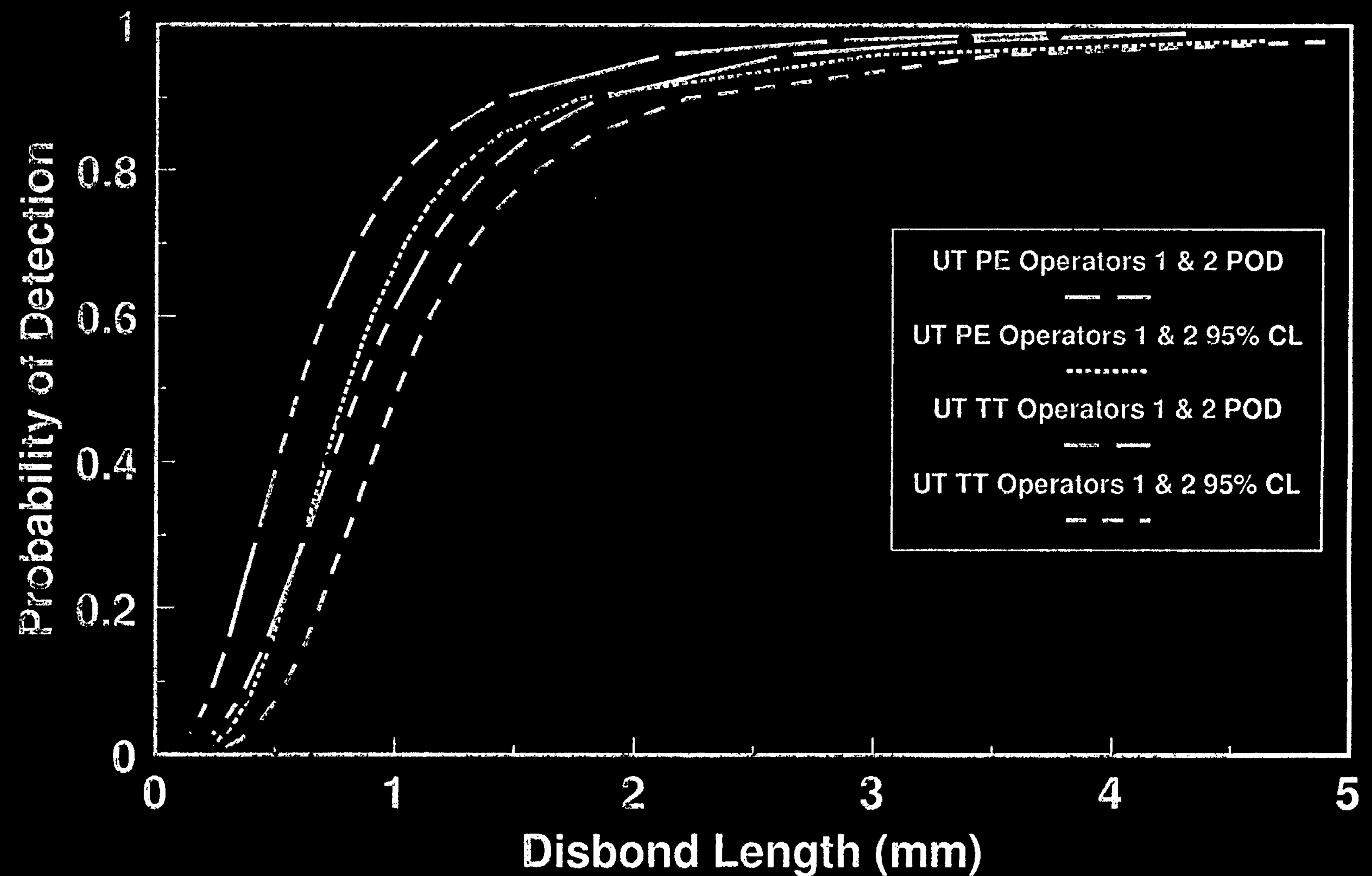
ULTRASONIC TESTING PE VS TT

NDE



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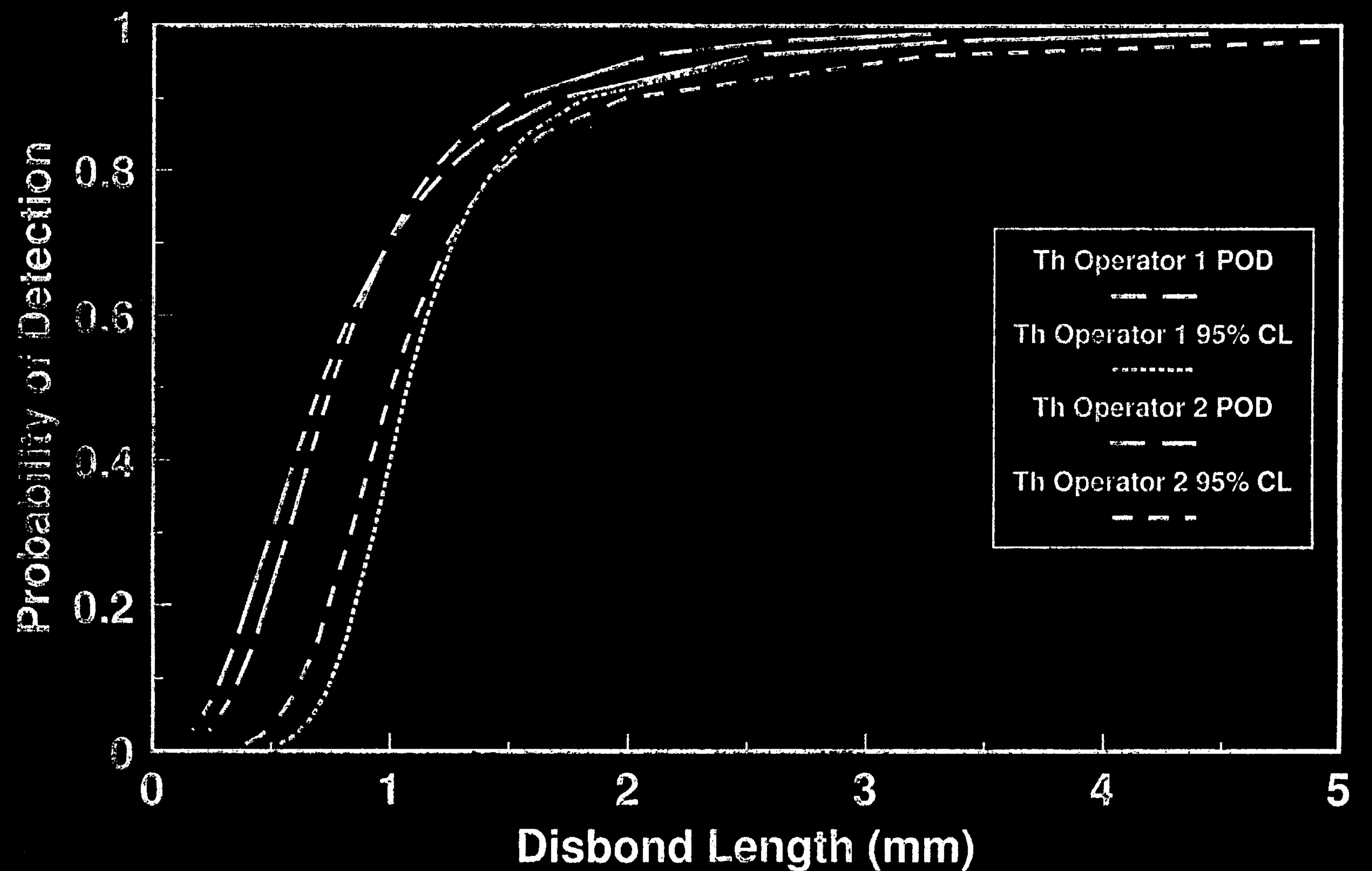
THERMOGRAPHY POD

NDE



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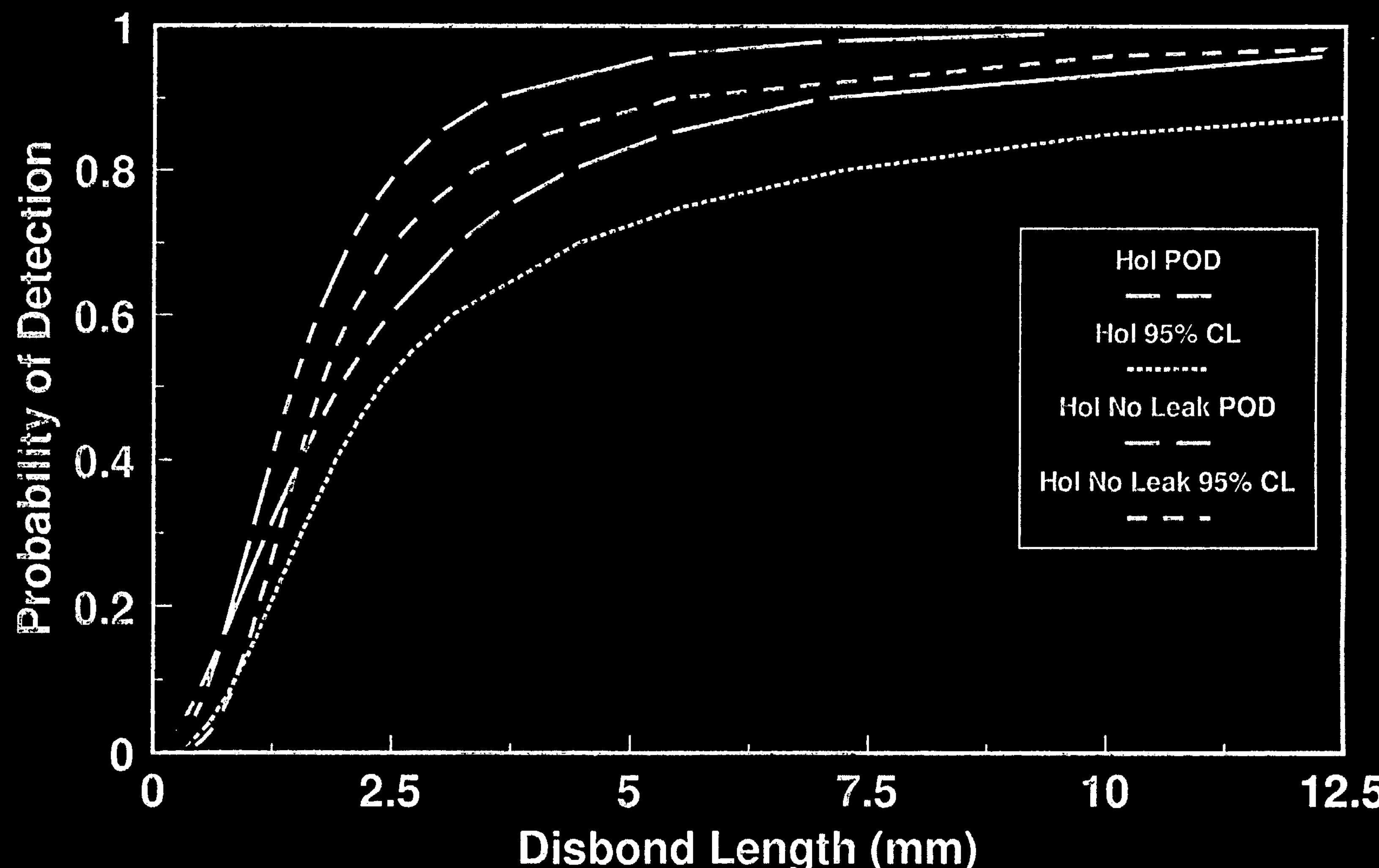
HOLOGRAPHY POD



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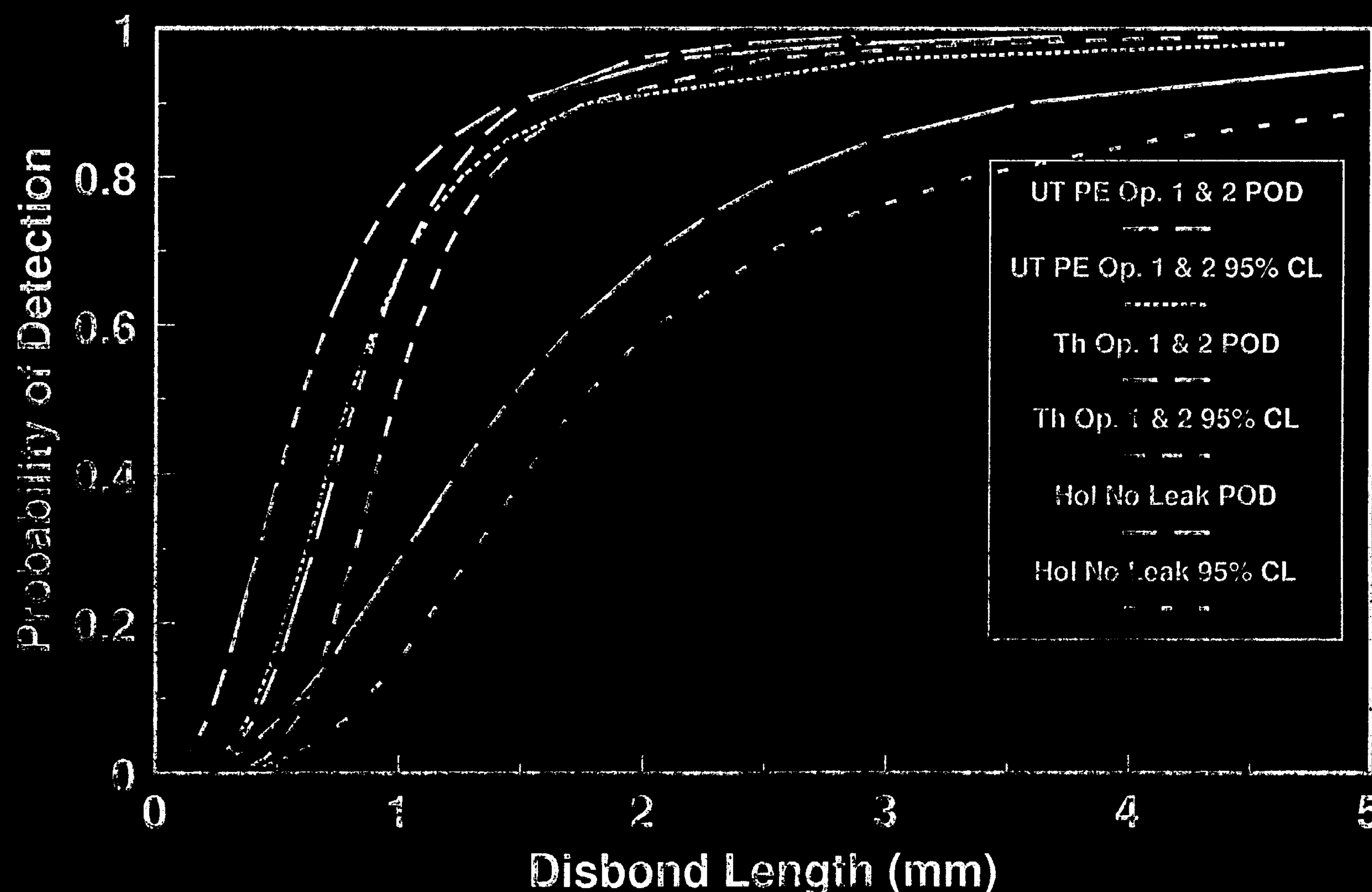
POD CURVES FOR ALL METHODS

NDE



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POD CURVES FOR ALL METHODS

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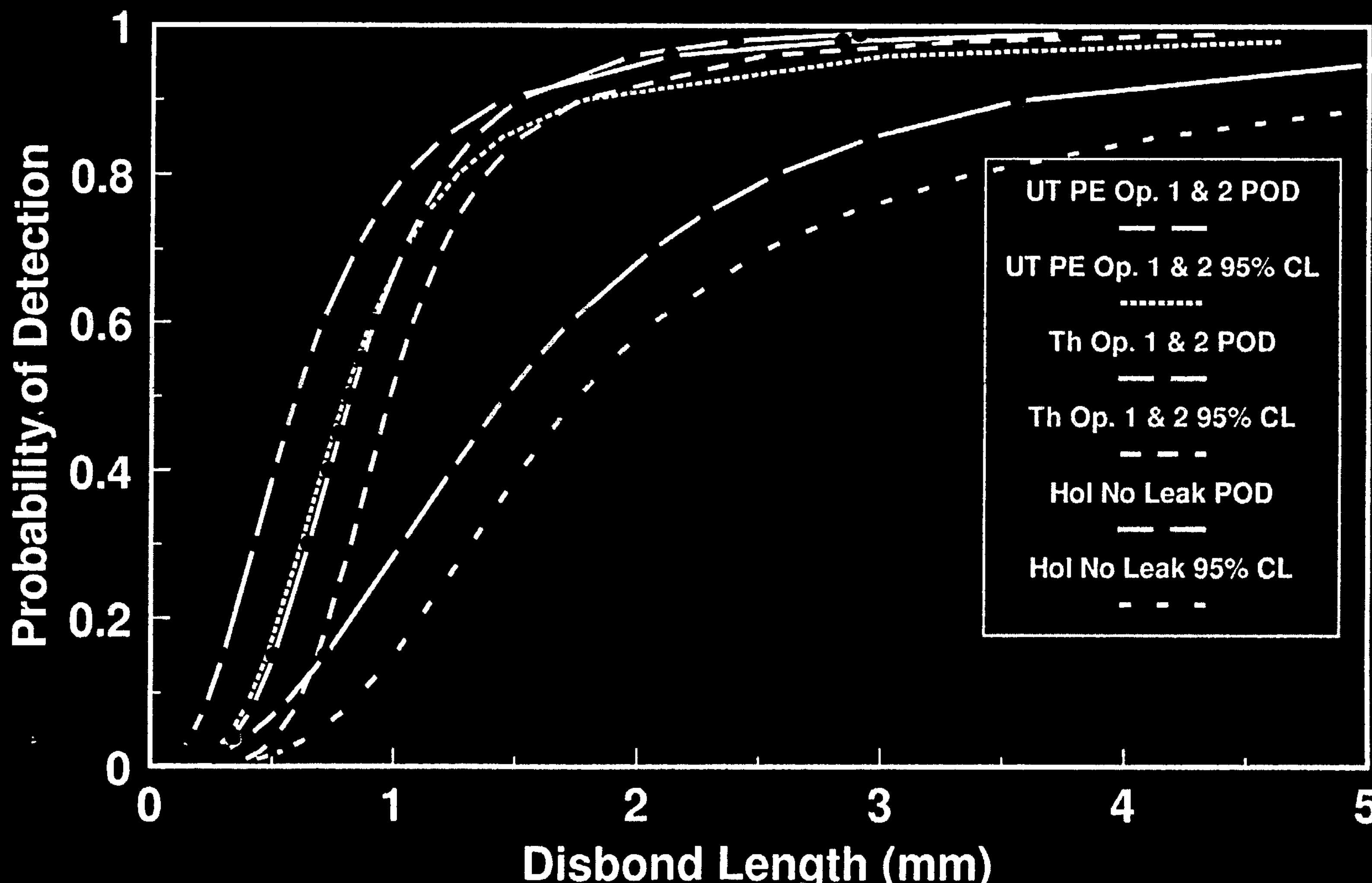

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PROBABILITY OF DETECTION DATA

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Method	% Found	A90 (mm)	A90/95 (mm)
Pulse Echo Ultrasonics	98.2	1.45	1.78
Through Transmission Ultrasonics	96.8	1.85	2.21
Pulsed Infrared Thermography	99.3	1.50	1.75
Holography (Including Leaks)	62.0	6.99	15.37
Holography (Excluding Leaks)	77.5	3.56	5.44

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BFG PULSED INFRARED SYSTEM

NDE

- 640 X 512 InSb Camera, LN_2 Dewar
- >87 Frames/second
- 10 mK NEDT
- Snapshot Mode, Variable Integration Time
- Gain, Offset, Pixel Replacement in Real Time
- 12.8 kJ, 5 ms Flash Lamps
- EchoTherm® Software

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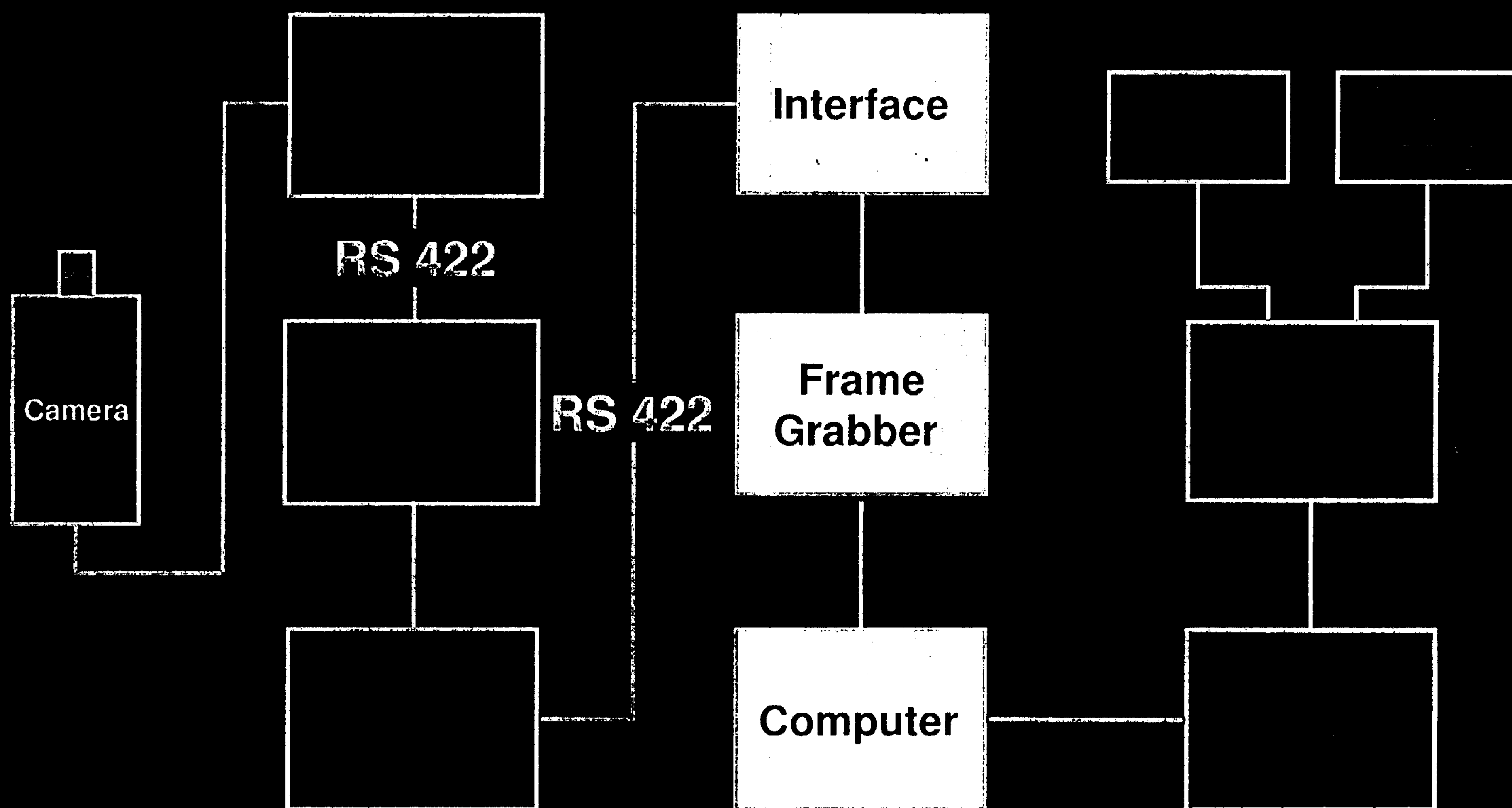
BFG SYSTEM CONFIGURATION

NDE



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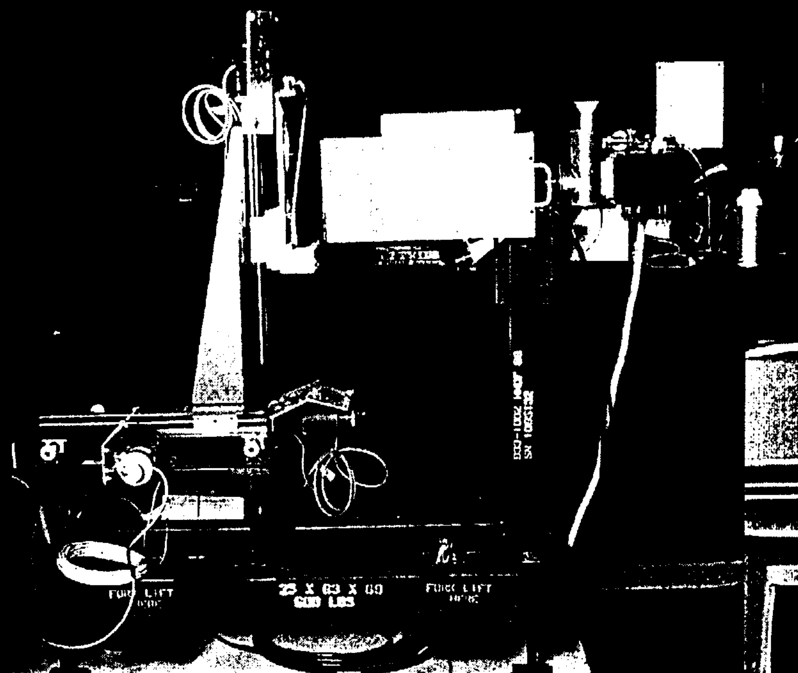
BFG PIRT SYSTEM

NDE



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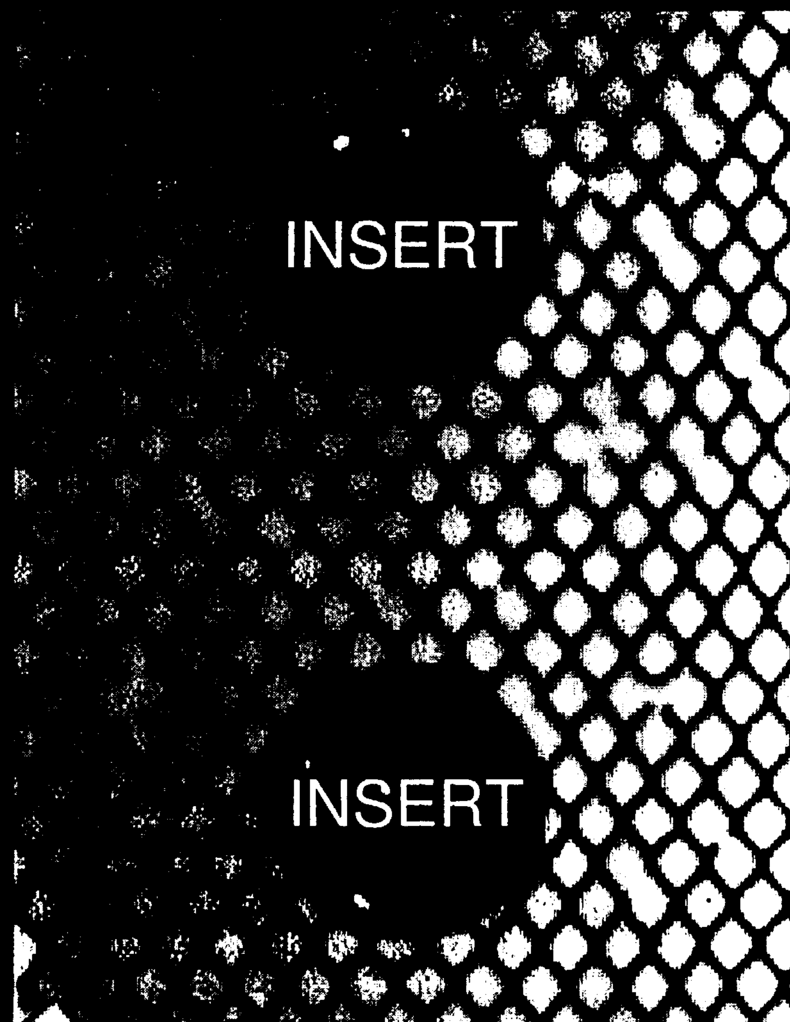
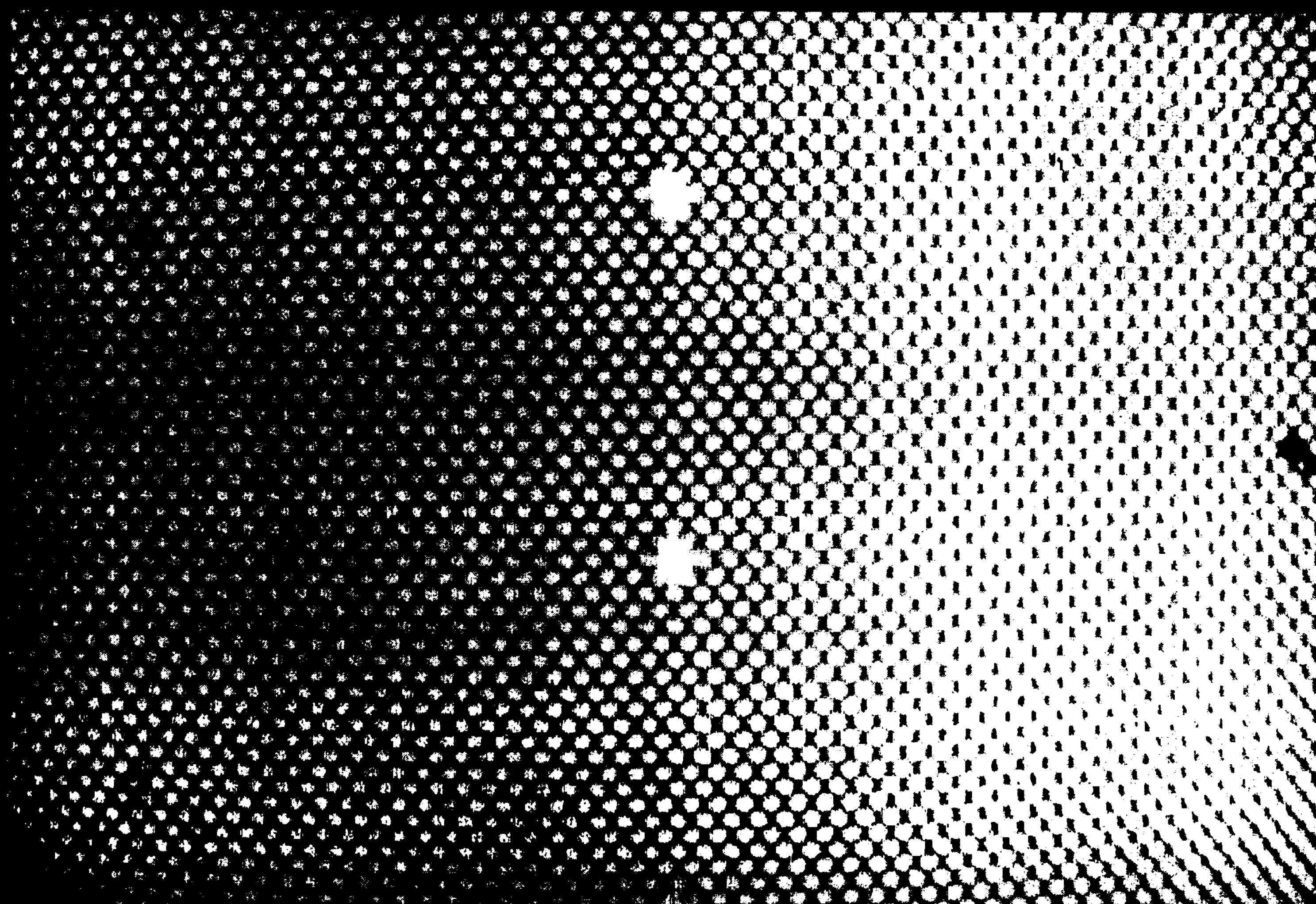
HIGH RESOLUTION IMAGE

NDE



LARGE AREA IMAGE



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PIRT MODELING

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- P 4560F Thermal Analyzer FD Software
- Time Steps Vary From 10^{-9} to 10^{-4} s
- Maximum ΔT Between Time Steps 0.006 K
- 208 Nodes
- 481 Thermal Pathways
- Radiation, Conduction & Convection
- Includes System and Test Part Geometry, Flash Temporal Profile, Material Properties
- Validated Against Test Data

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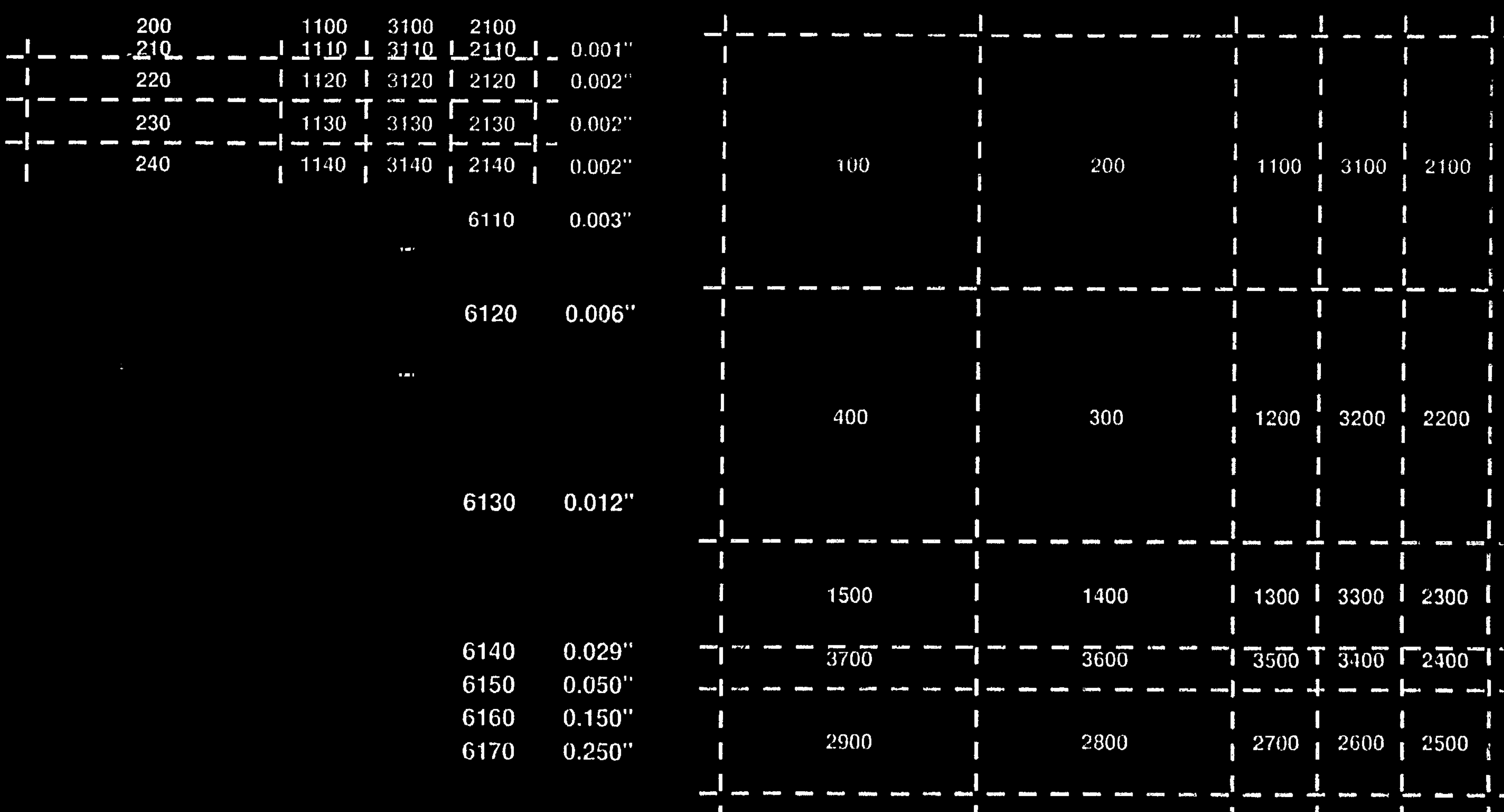
THERMAL MODEL

NDE



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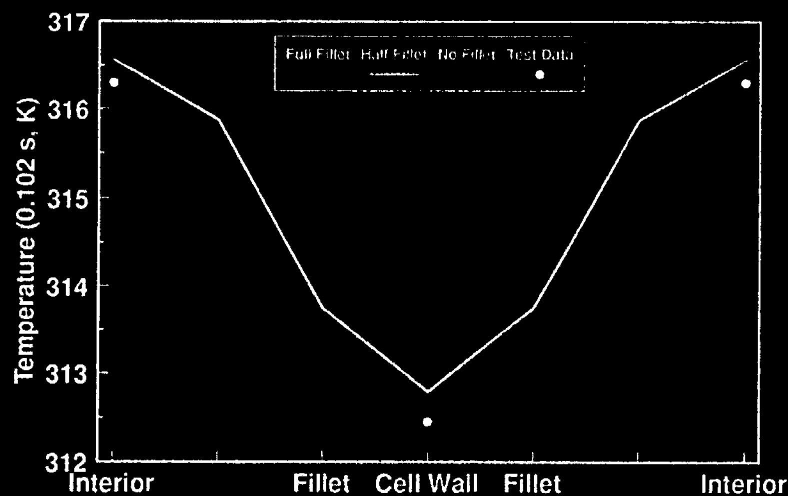
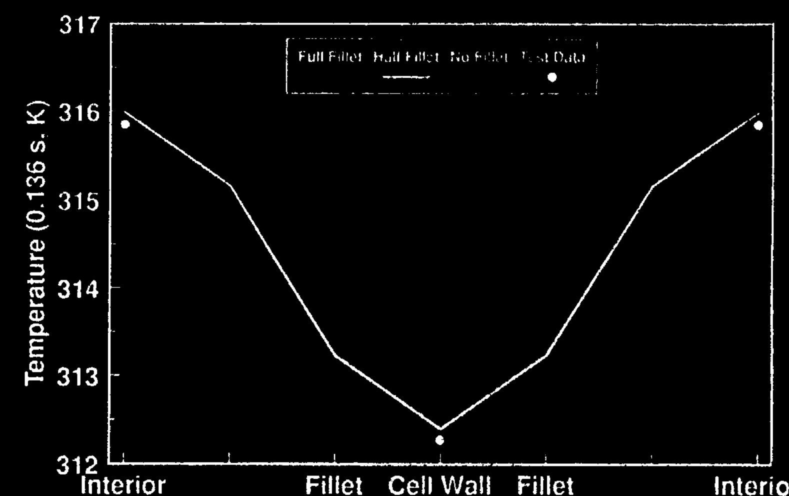
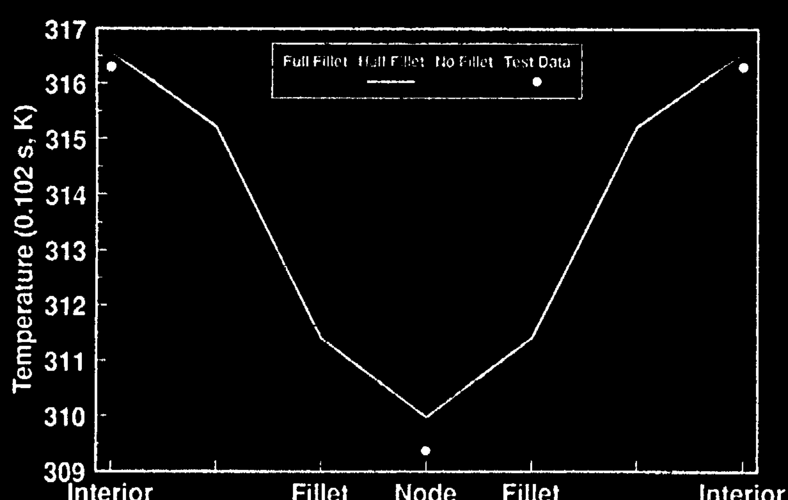
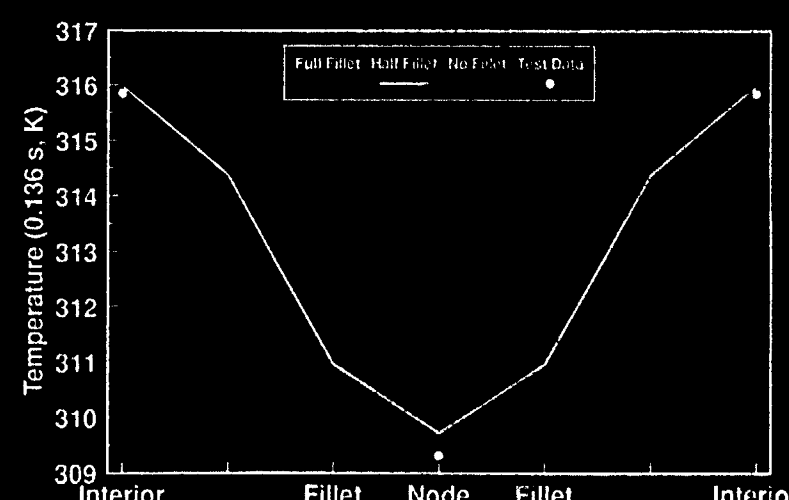
CONTRAST FROM MODEL AND DATA

NDE









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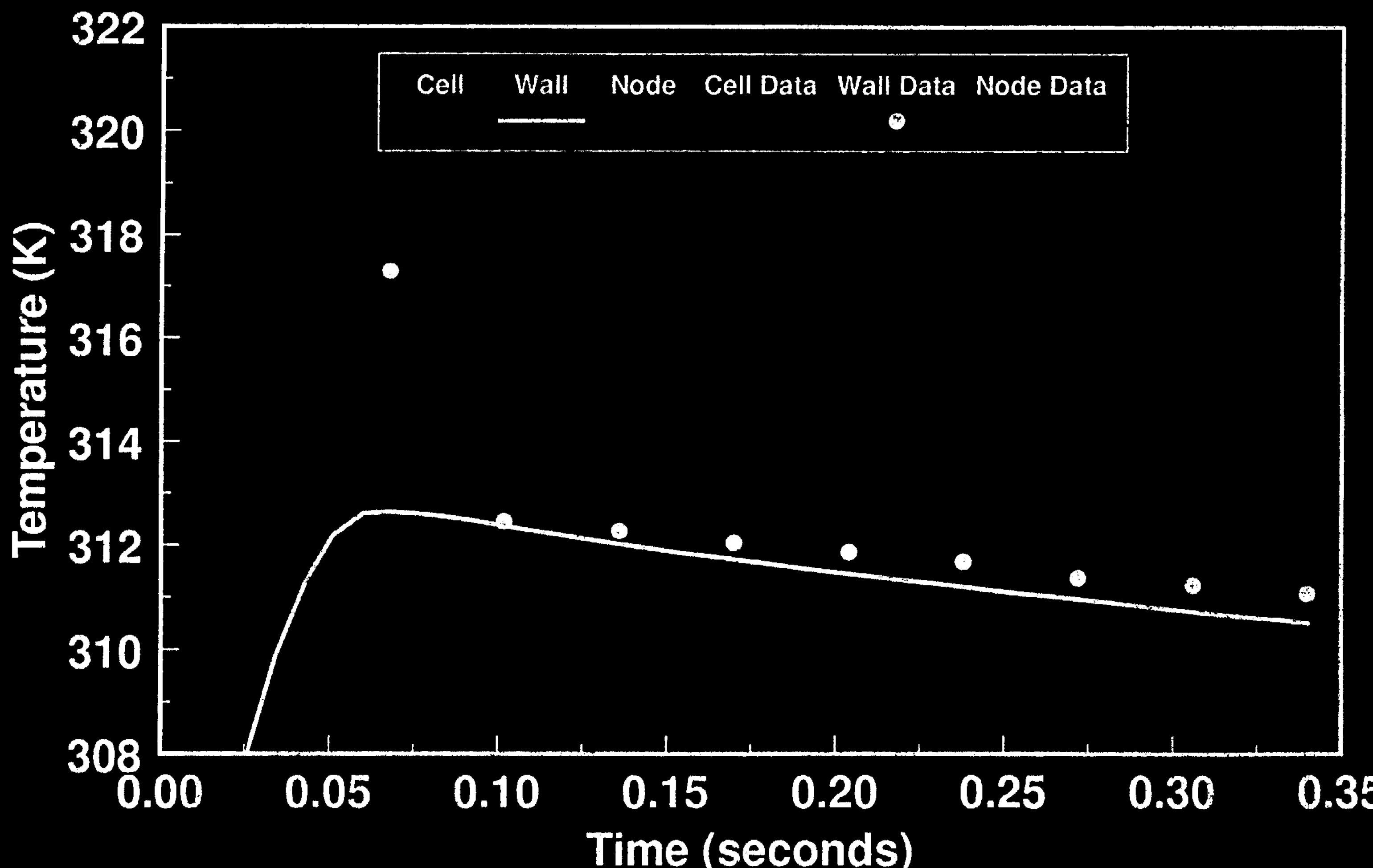
TEMPORAL DATA FROM MODEL



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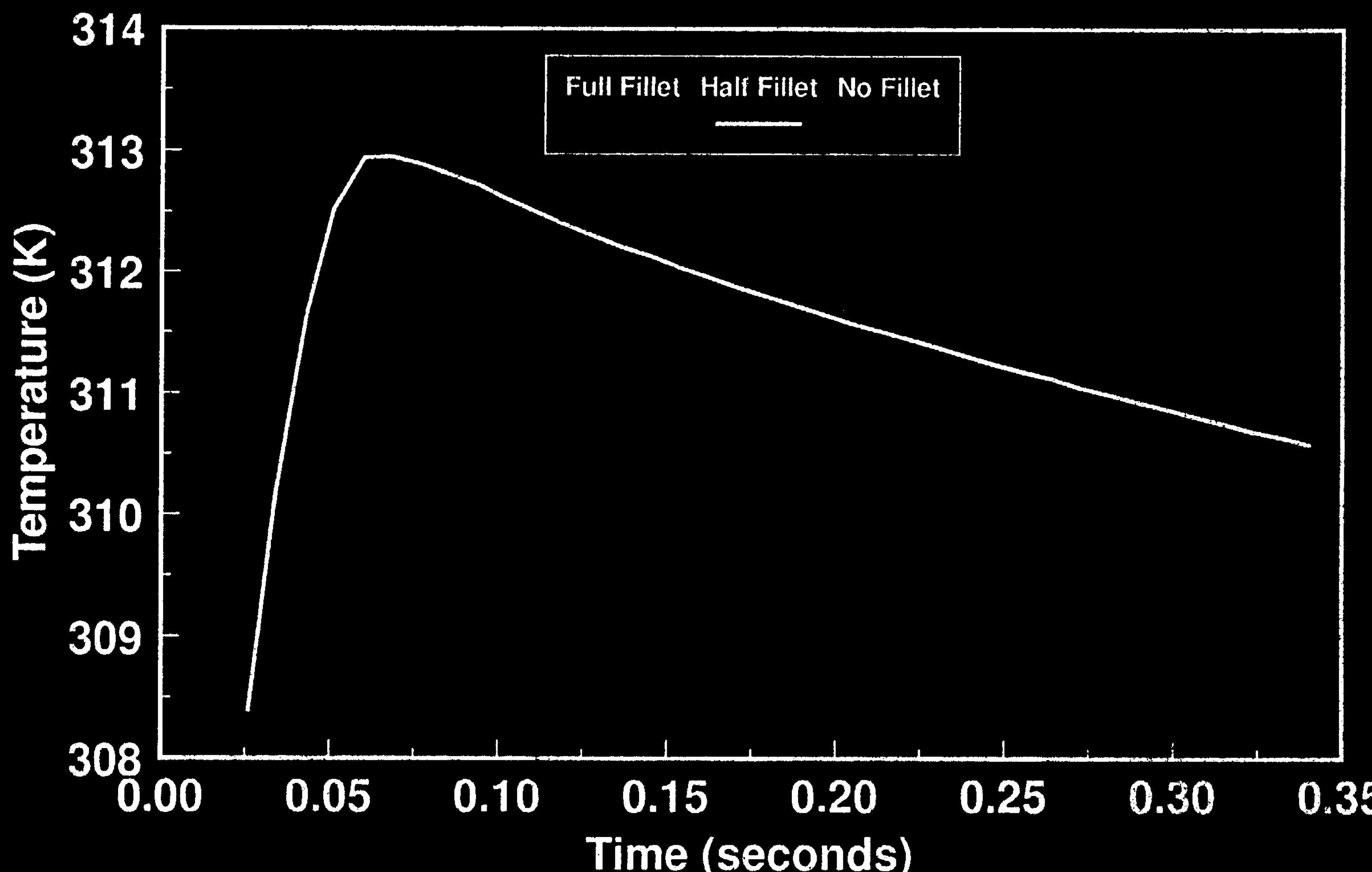
EFFECT OF FILLET SIZE

NDE



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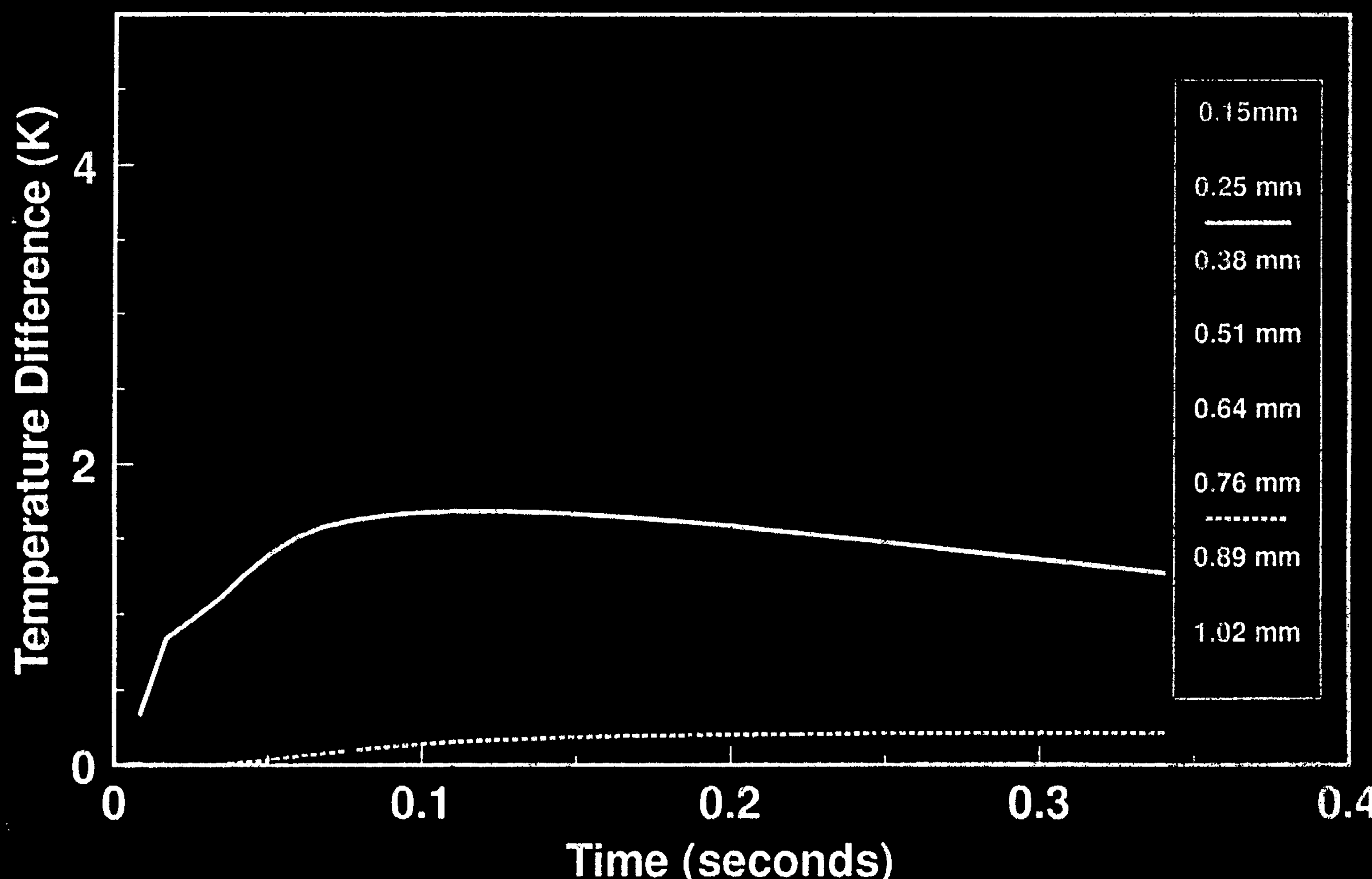
SKIN THICKNESS EFFECT IN INCONEL

NDE



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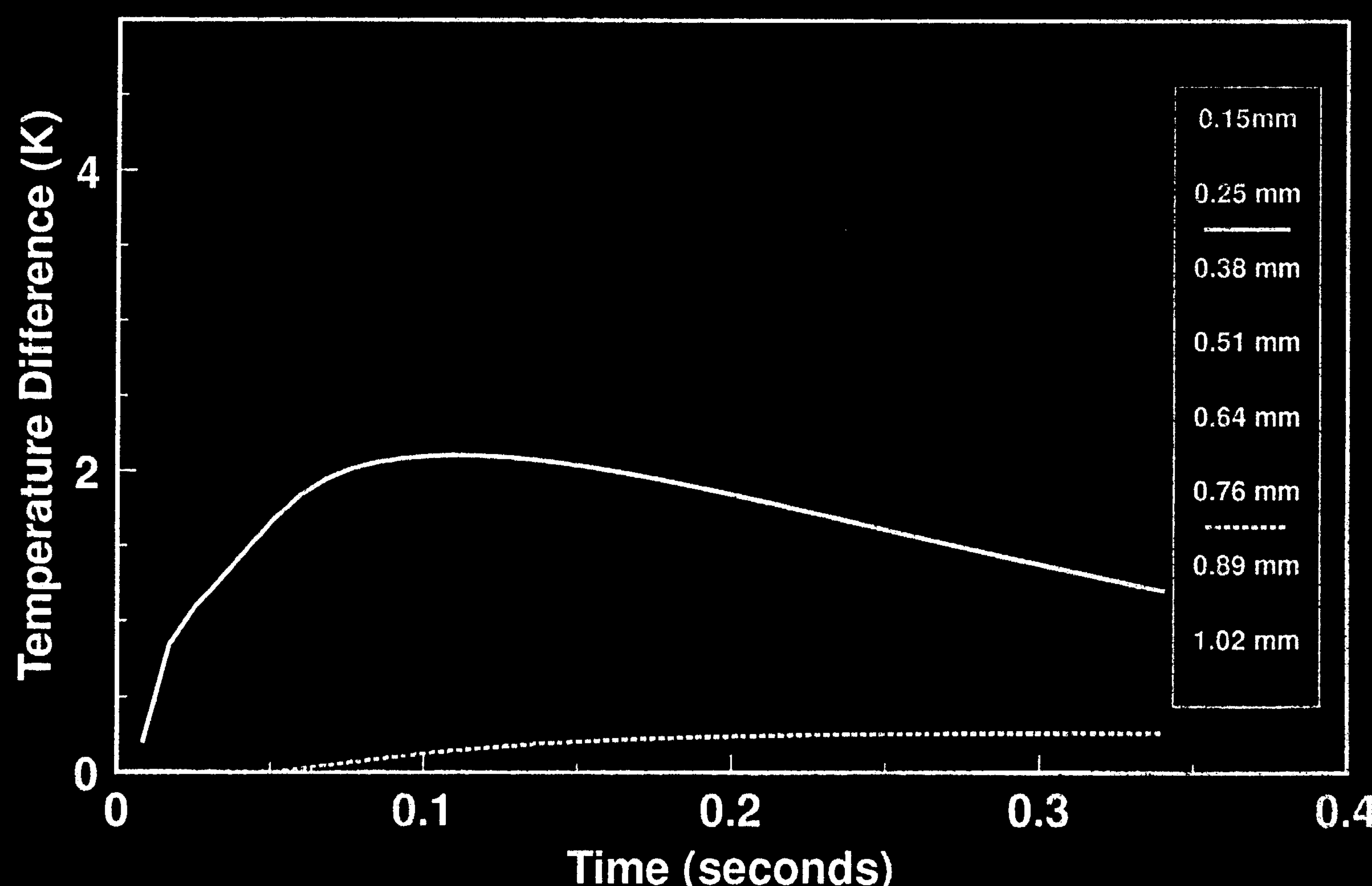
SKIN THICKNESS EFFECT IN TITANIUM

NDE



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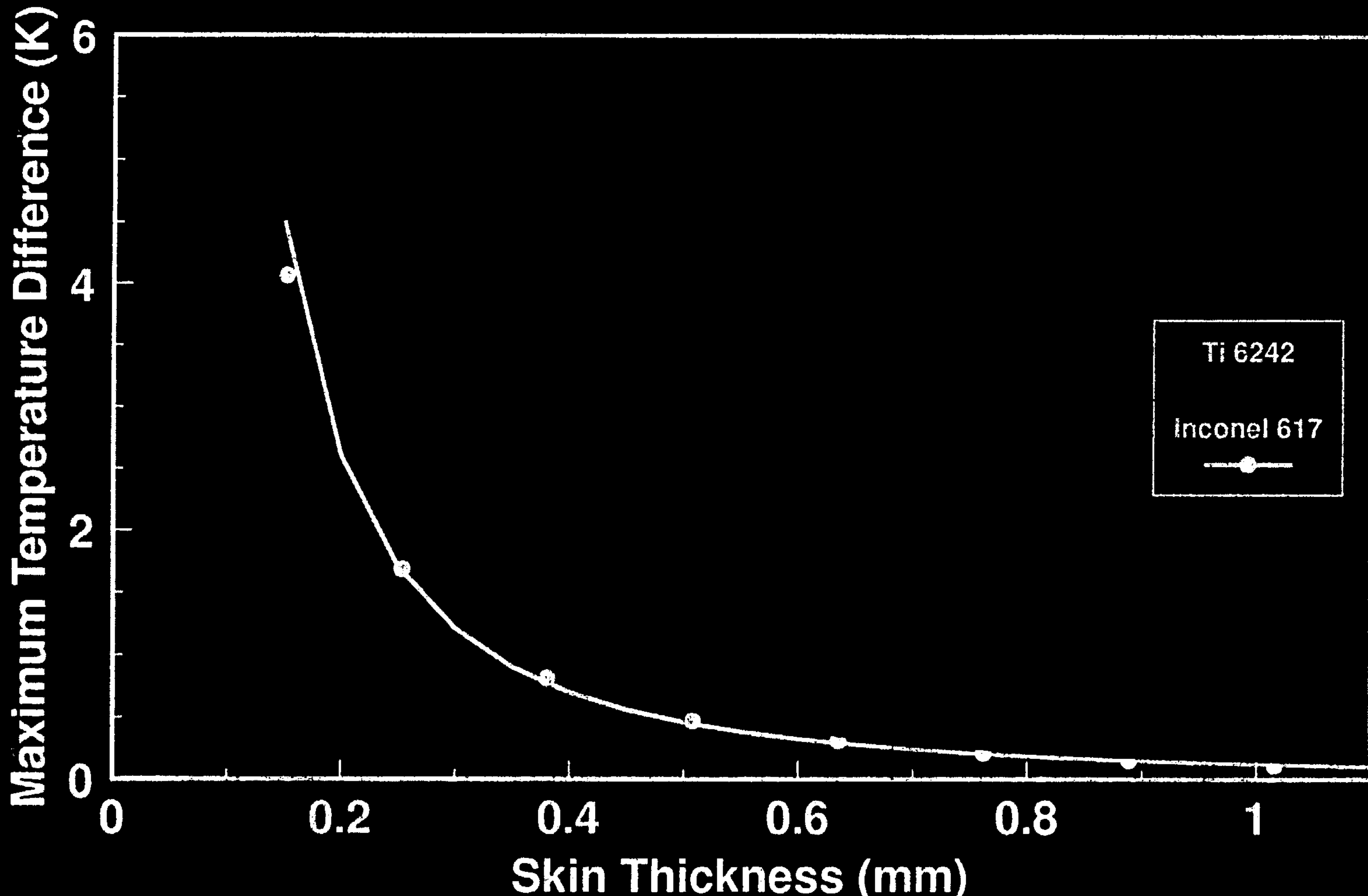
MAXIMUM CONTRAST



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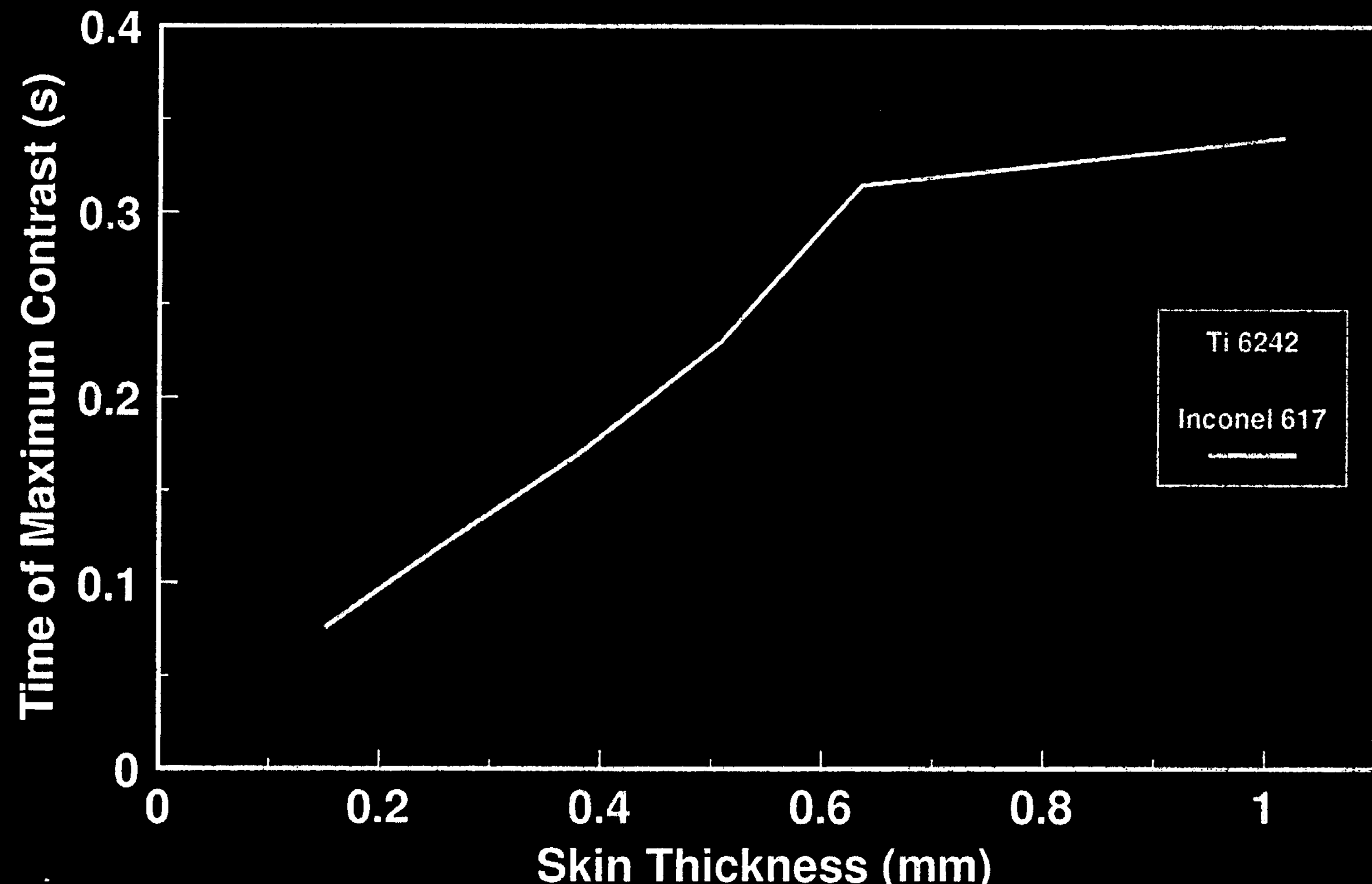
TIME OF MAXIMUM CONTRAST

NDE



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LIMITS OF INSPECTION

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	Maximum Skin Thickness (mm)	
	Minimum Temperature Difference	
	0.5 K (50 x NETD)	0.25 K (25 x NETD)
Inconel	0.48	0.69
Titanium	0.54	0.78

SUMMARY

- PE UT and PIRT Are Equally Effective at Inspecting Thin Metallic Honeycomb Sandwich TPS
- PE UT Is Significantly Better Than TT
- Holography and Shearography Are Not Effective
- Operator Effects on POD Can Be Subtle
- The Use of PIRT Results in Significant Cost Savings
- Modeling is Effective at Predicting PIRT Performance
- Maximum Inspectable Skin of ~0.6 mm Thick Predicted
- Time of Maximum Contrast Increases With Thickness