ULTRASONIC TEMPERAUTRE AND HEAT FLUX TECHNOLOGY

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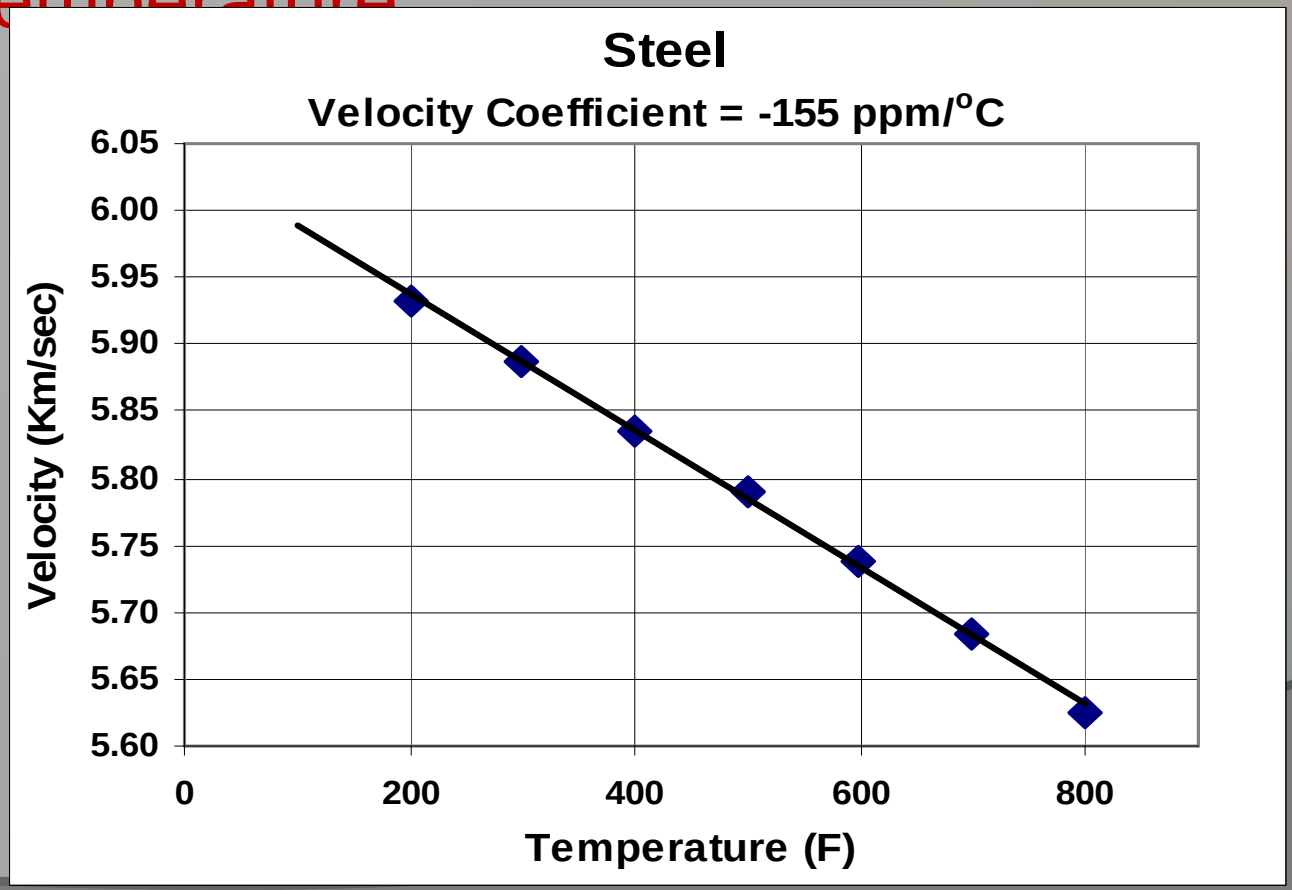
PROBLEM STATEMENT

Improved Gun Safety

- Auto ignition or “cook-off” is one of the most serious safety concerns when firing large caliber guns.
- Researchers inability to perform measurements at locations where they are needed

FUNDAMENTALS

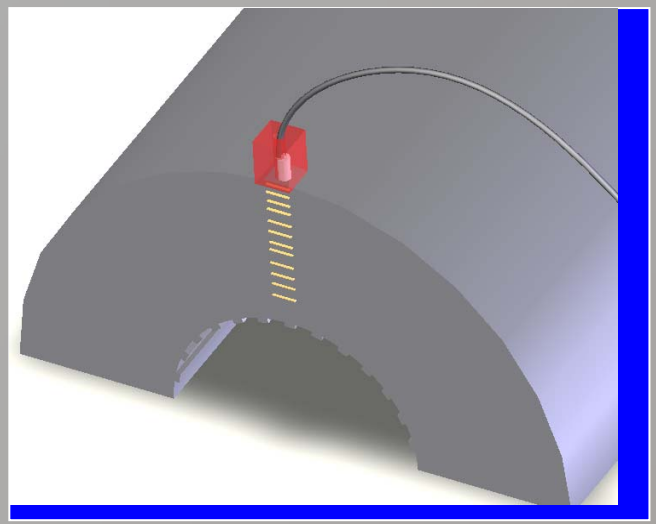
- Velocity of Sound is a Function of Temperature

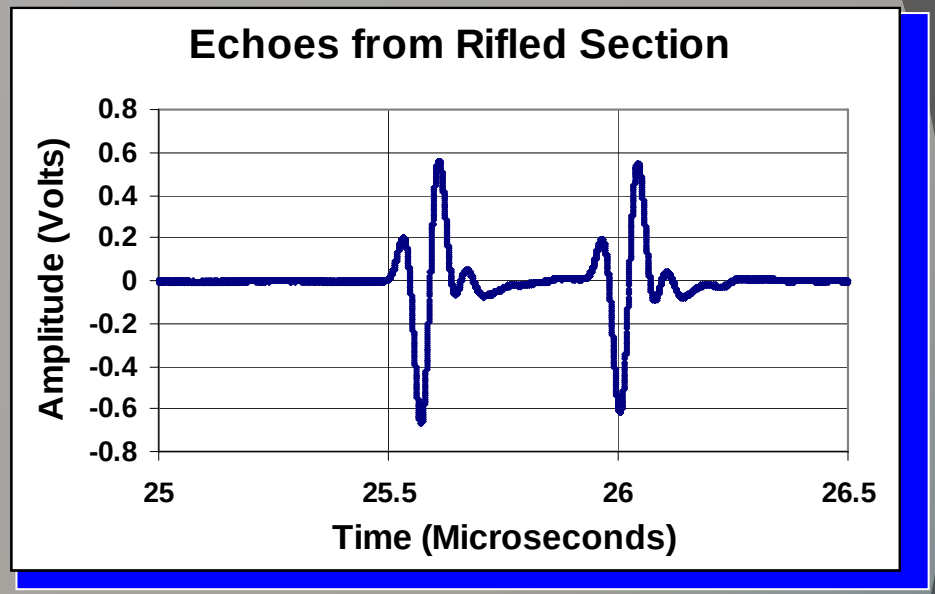


MEASUREMENT CONCEPT

Temperature Localization

- Precise Timing Measurements to Measure Temperature & Erosion





Determining Inner Chamber Surface Temperature

$$\frac{\text{Change of Echo Separation}}{(\text{Velocity Temperature Coefficient}) \times (\text{Echo Separation})}$$

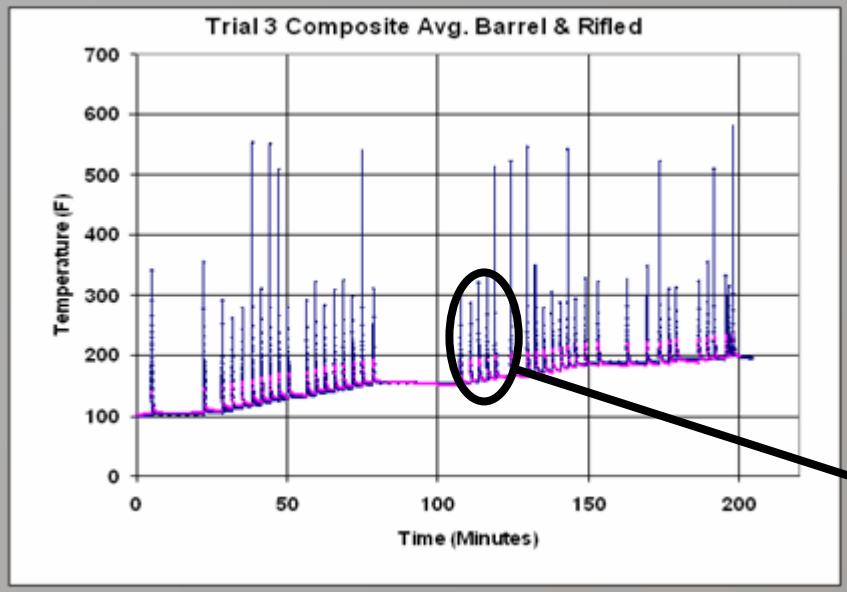
CONCEPT TO PRACTICE

Multiple Successful Live Fire Trials

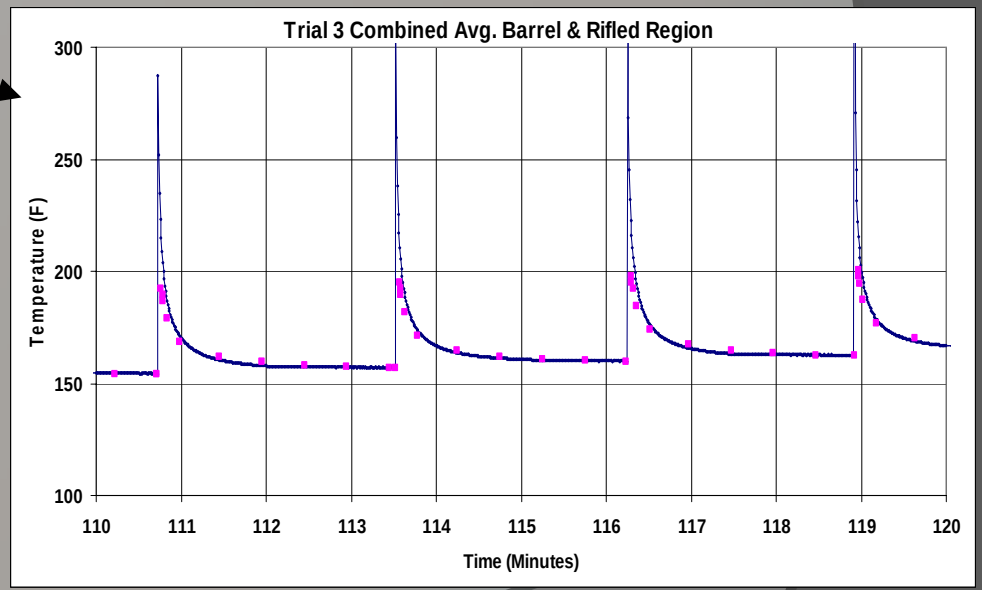
NETS (Non-Intrusive Erosion and Temperature Sensor) prototype installed on the MK45 MOD 4 Gun at NSWCDD and NLOS-C at Yuma, Az. For live fire experiments in 2005-2007

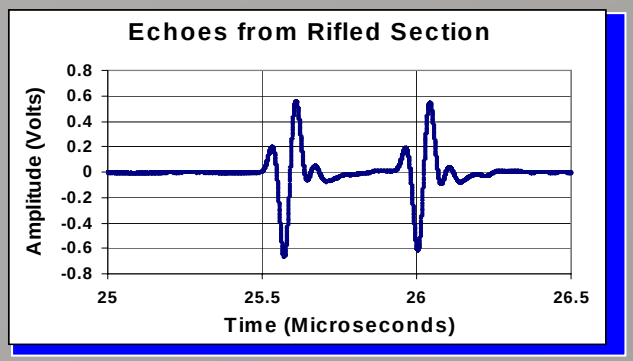
- Accurate Internal Temperature Measurement
- Transient Temperature Measurement
- Off-line Heat Flux Calculations

MULTIPLE FIRING EVENTS



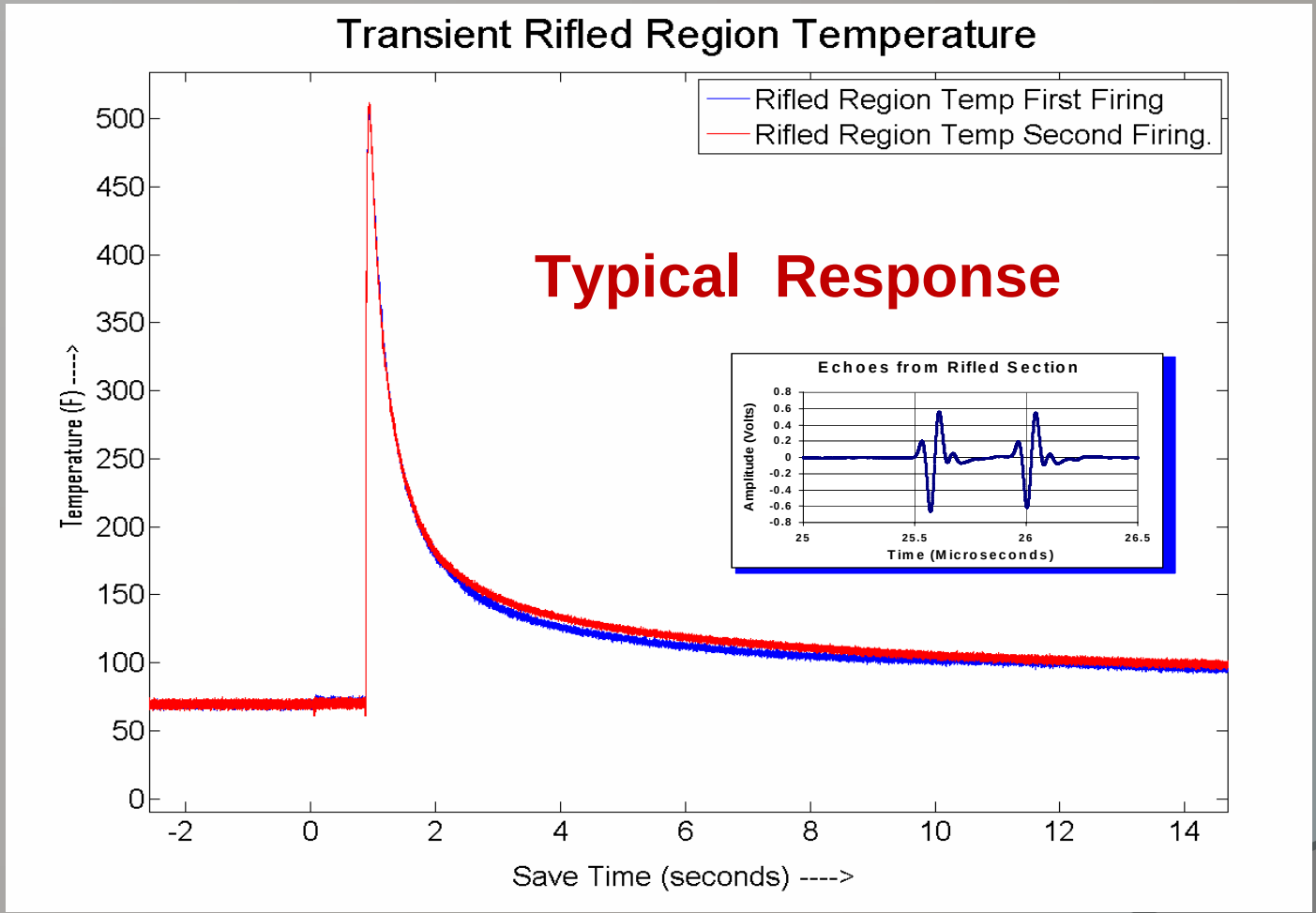
Long Term Stability





Local & Average barrel Temperature for 40 Firings of Mark 45 Mod 4 Gun

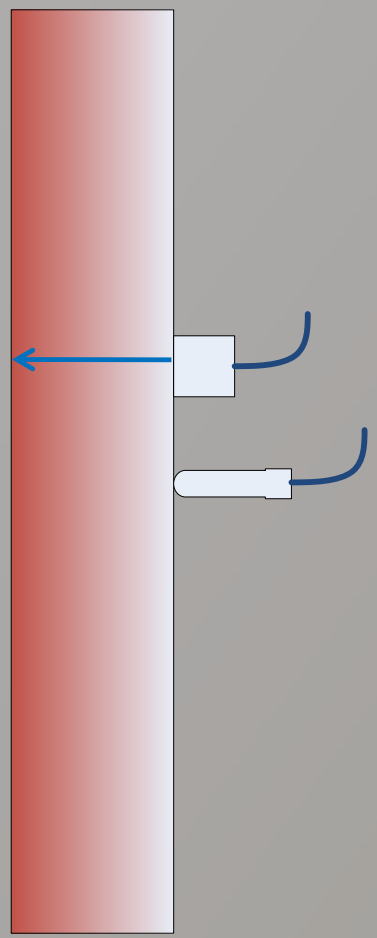
SINGLE FIRING EVENT



Ultrasonic Temperature for Two Firings of Mark 45 Mod 4 Gun Normalized to 70 degrees Fahrenheit.

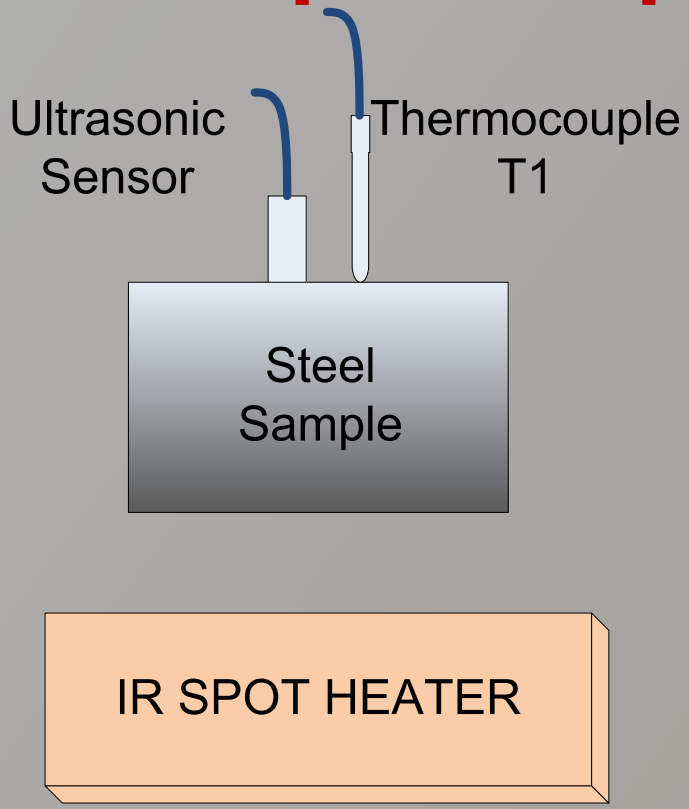
ELEMENTS OF THE TECHNOLOGY

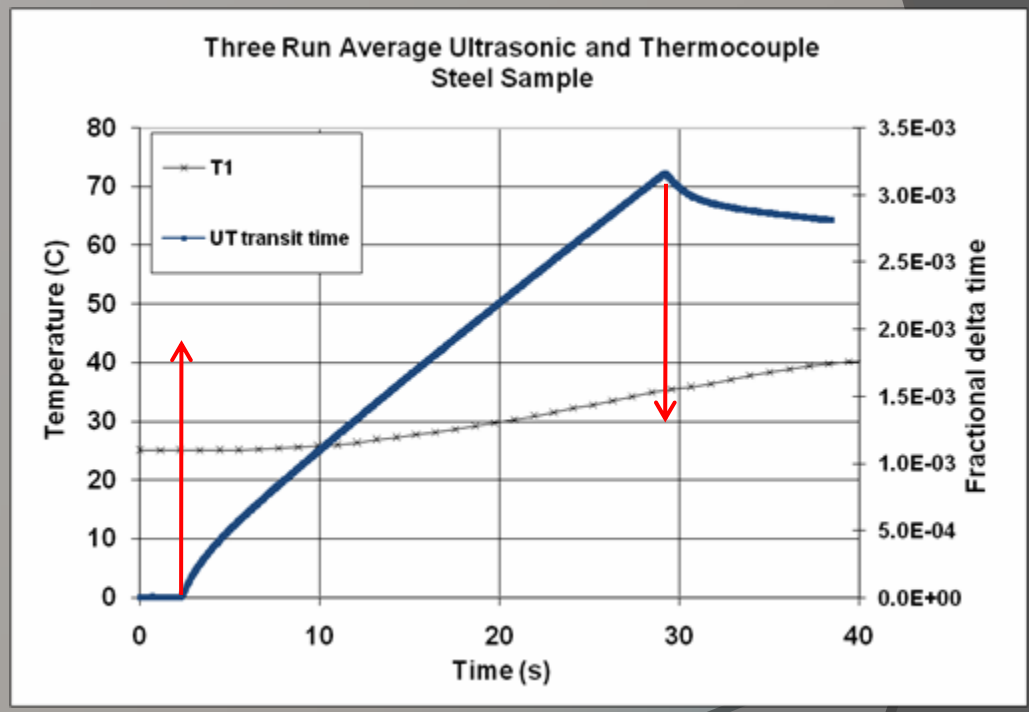
Essential Components



- Ultrasonic Sensors
- High Speed Data Acquisition
- High Bandwidth Ultrasonic Instrumentation
- High Speed Data transfer/Storage
- Independent Temperature Sensor /Normalization
- Cooperative/Characterized Materials

Rapid Response (no lag/lead)





Technology offers the potential for temperature measurement on a microsecond timeframe.

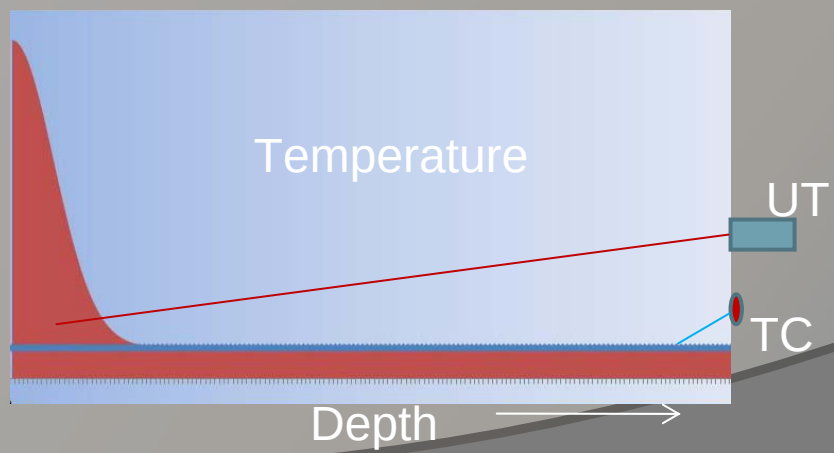
(Graphic depicts Ultrasonic Temperature data collected every 200 usec.)

SINGLE INTERFACE

Surface Temperature & Heat Flux

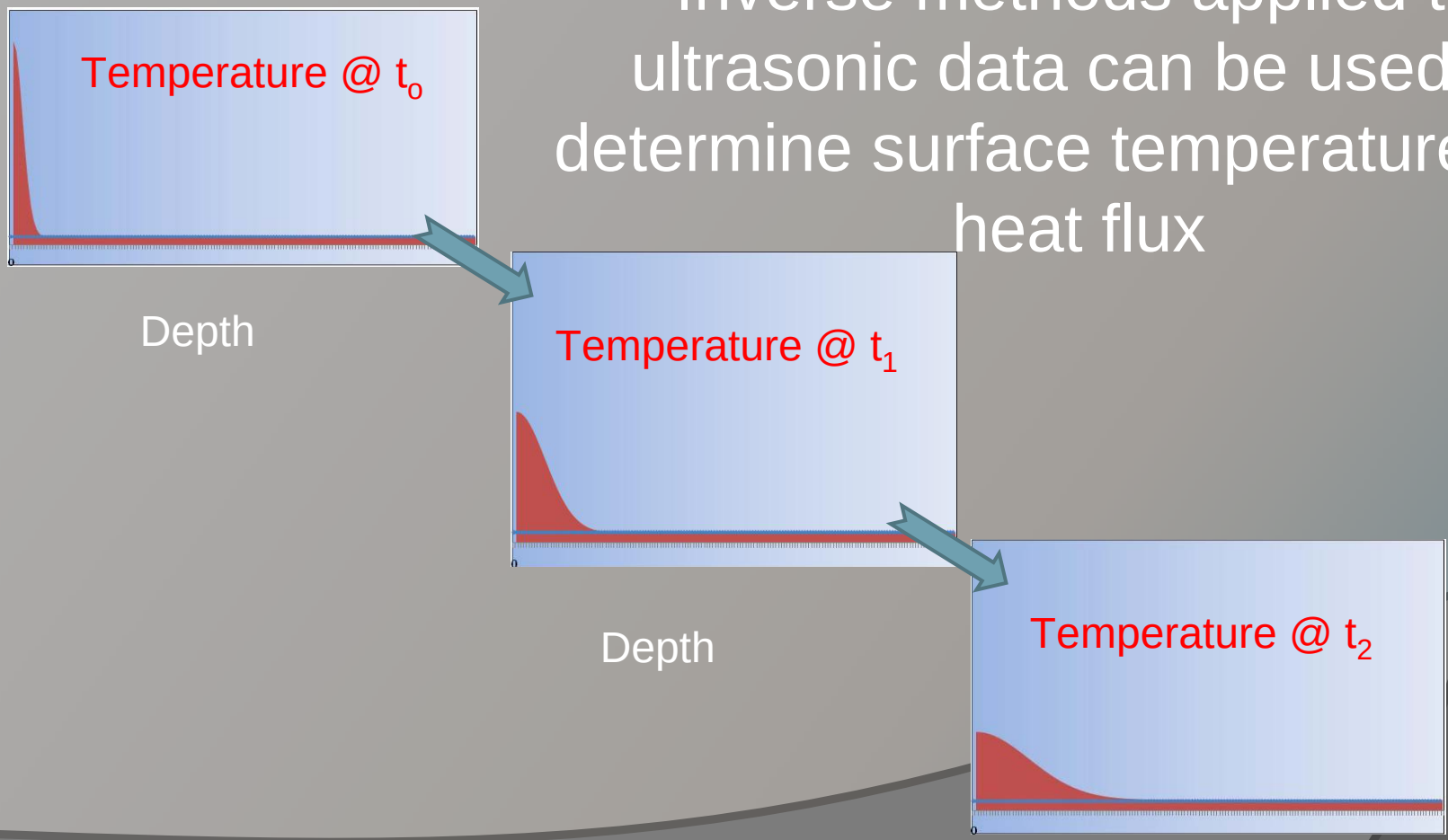
The Integral relation between ultrasonic time-of-flight and temperature is advantageous for inversion methods)

$$G(x) = 2\int_0^x \frac{1+\alpha(\xi)\delta\theta(\xi)}{c(\xi,\theta(\xi))}d\xi$$



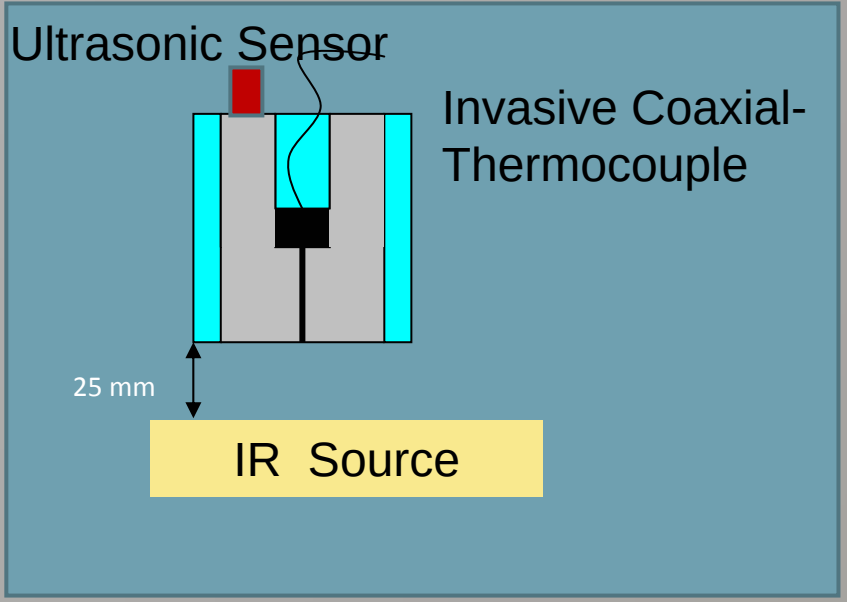
SINGLE INTERFACE

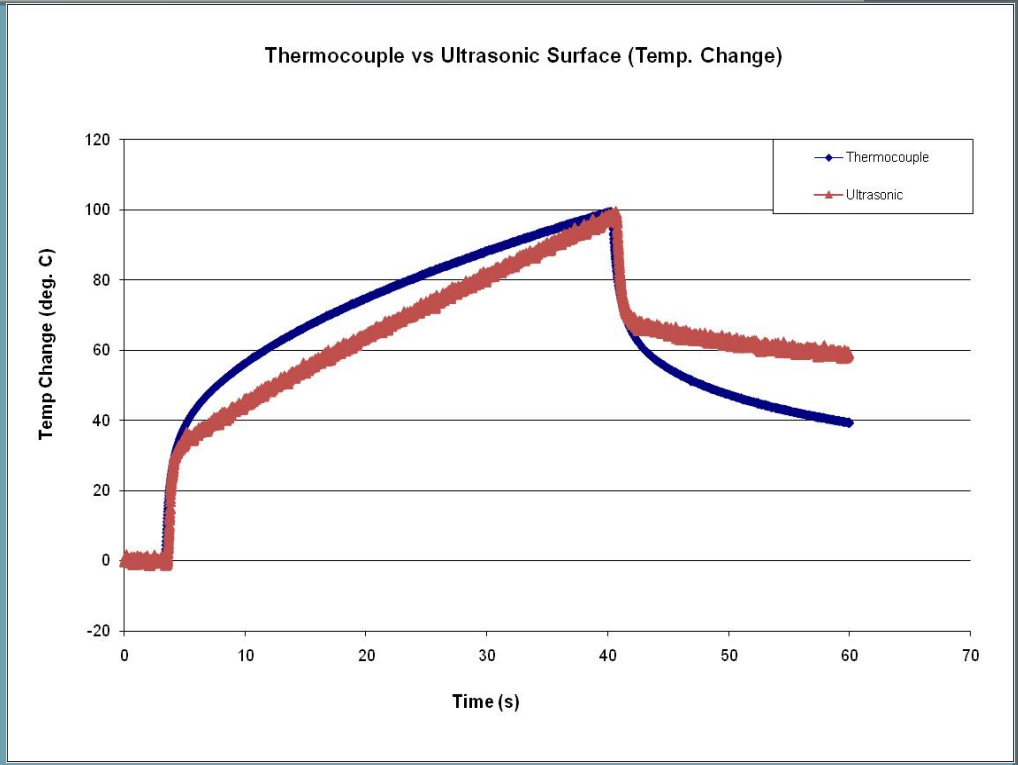
Surface Temperature & Heat Flux

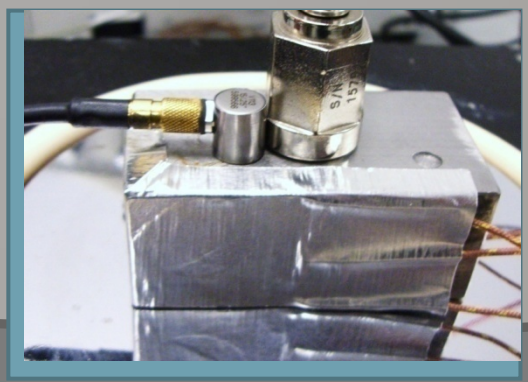


Inverse methods applied to ultrasonic data can be used to determine surface temperature and heat flux

Comparison of Remote Ultrasonic and Intrusive Thermocouple Data







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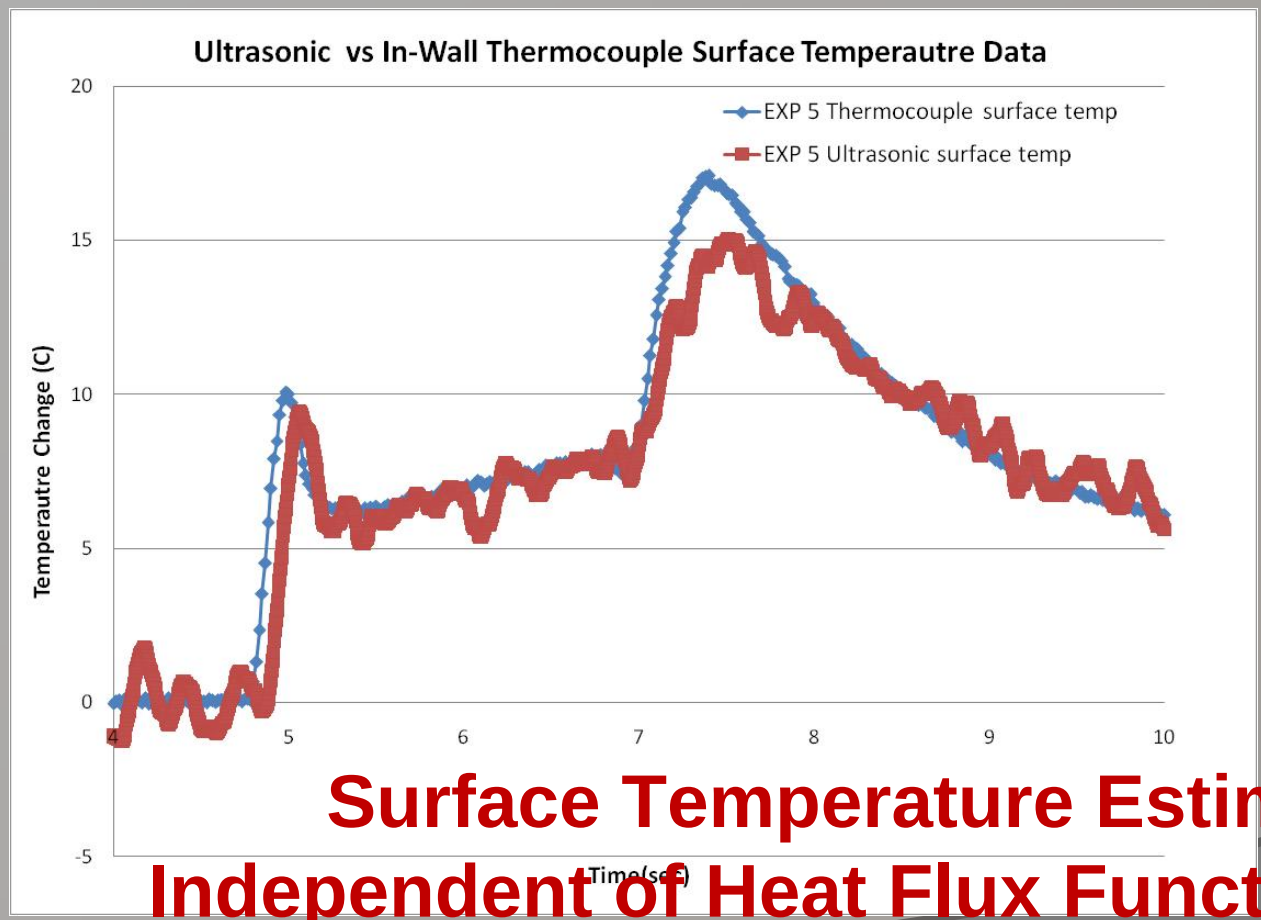
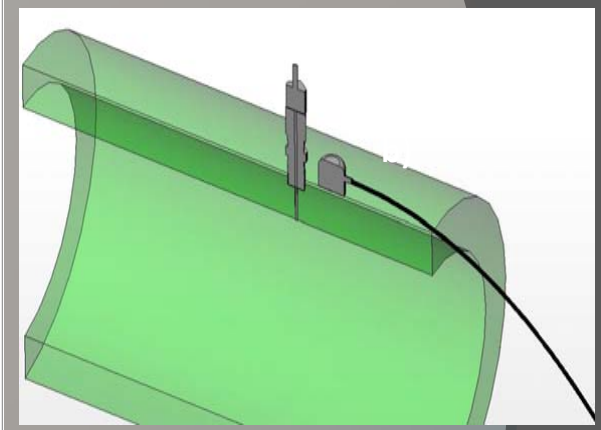


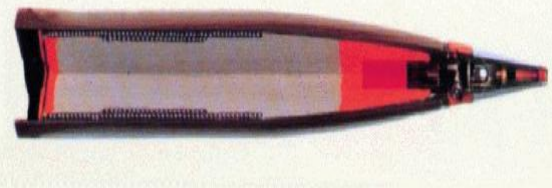


Surface Temperature Estimates Independent of Heat Flux Functional Form

OPPORTUNITIES

Ultrasonic Temperature and Heat Flux Sensor

- Gun Safety and Research
- Casting / molding Heat Transfer Studies
- Combustion Chamber Instabilities
- Jet Engines
- Hypersonic Aeroshells



MEASUREMENT POSSIBILITIES

Attributes

Features, Advantages, and Benefit of the Ultrasonic Technology

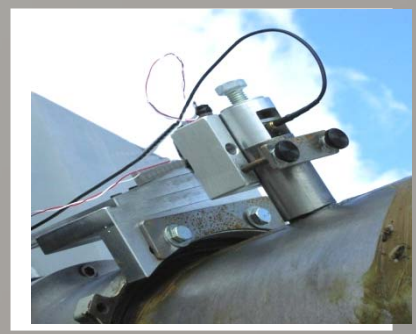
Features	Advantages	Benefits
Temperature	Non-Intrusive Direct Measurment	Remote sensing in harsh environments
Erosion	At Sea Measurement Continuously Monitor	Long term integrity reliability
Transient Temperature	Non-Intrusive High Speed Measurements	Very Rapid Remote measurements to aid in R/D
Heat Flux	Non-Intrusive High Speed Response	Instantaneous Response to Flow

STATE OF DEVELOPMENT

Ultrasonic Temperature and Heat Flux Sensor

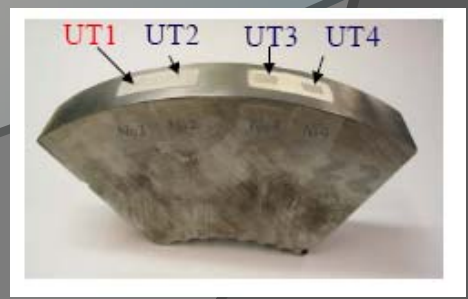
Summary:

- **Local temperature measurements in live fire experiments on MK 45 Mod 4 and NLOS C Platforms**
- **Rapid response (no lag)**
- **Single reflector Inversions for surface temperature and heat flux estimates.**



NEXT STEP:

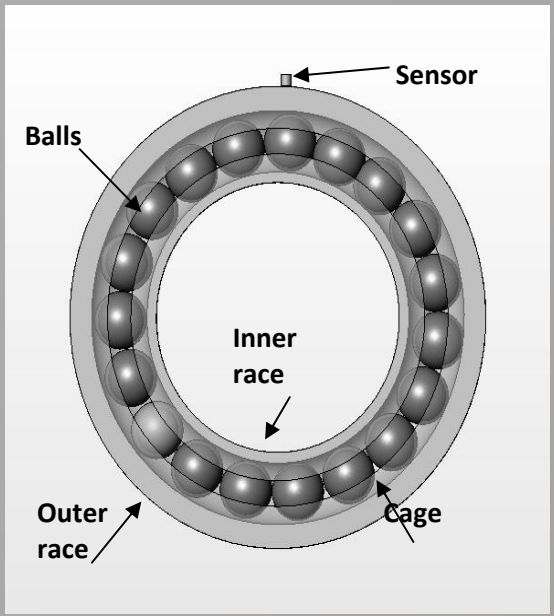
- **Improve Inversion Methods**
- **Alternate Structures**
- **Alternate Materials**
- **Incorporate Direct-Deposited Sensors**
- **More Extensive Field Testing**

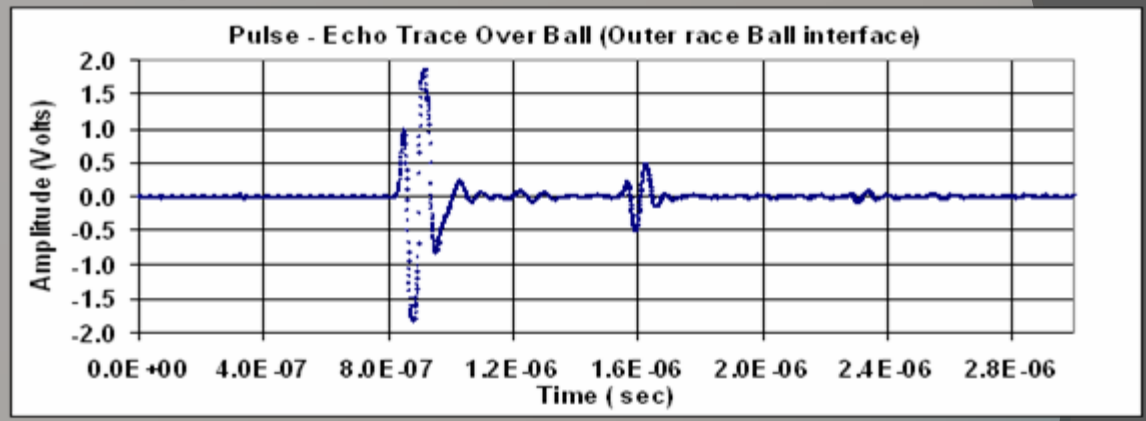


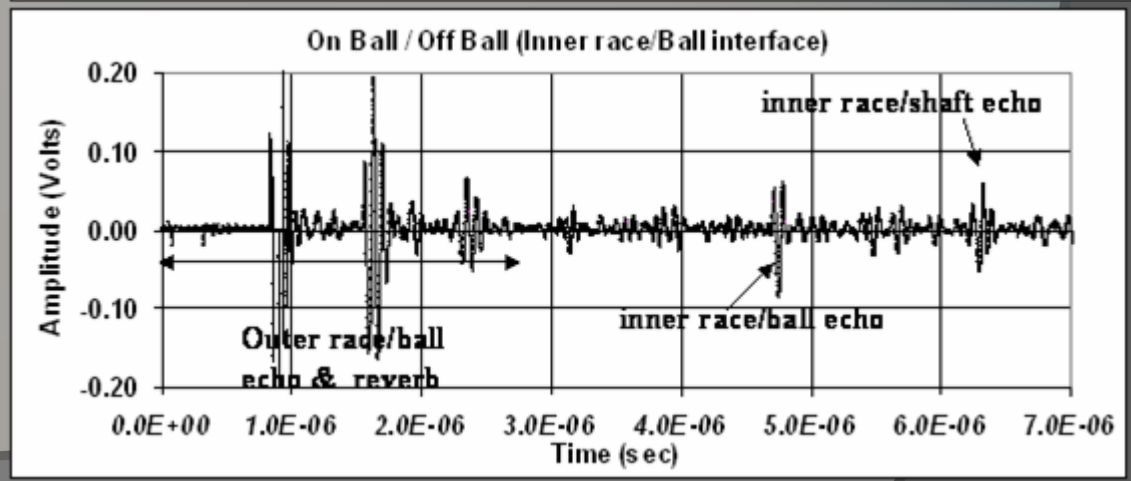
INTERESTING POSSIBILITY

Temperature Measurements in Inaccessible Places

Non-destructive nature of the measurements allows for easy implementation without disruption to ongoing tests.

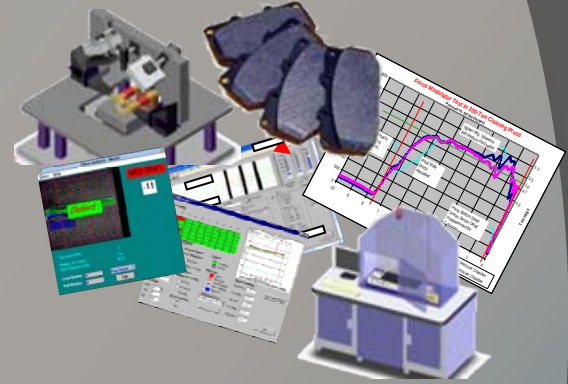






Ultrasonic Temperature and Heat Flux Sensor Technology

Thanks For Listening!



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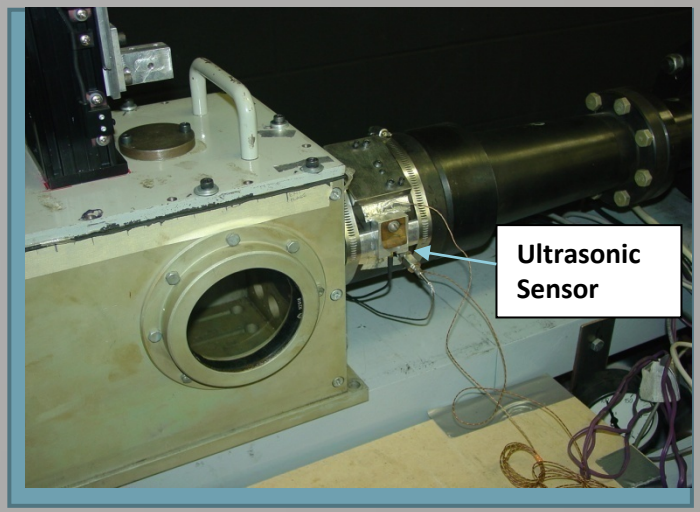
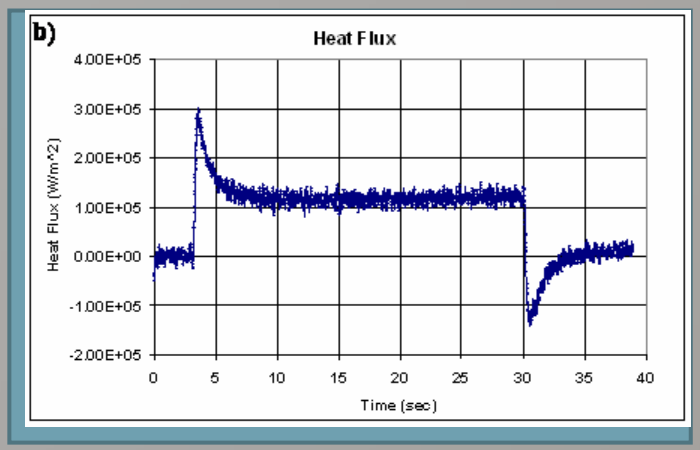
BACKUP SLIDES

HEAT FLUX RANGE

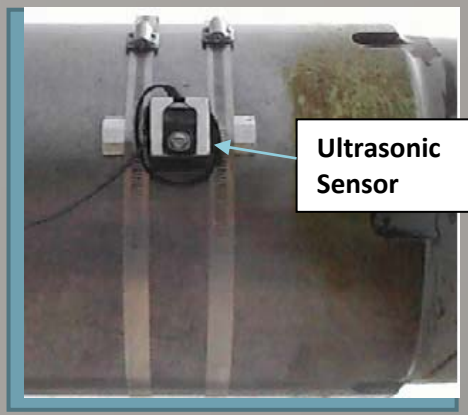
Mach 6 Wind Tunnel

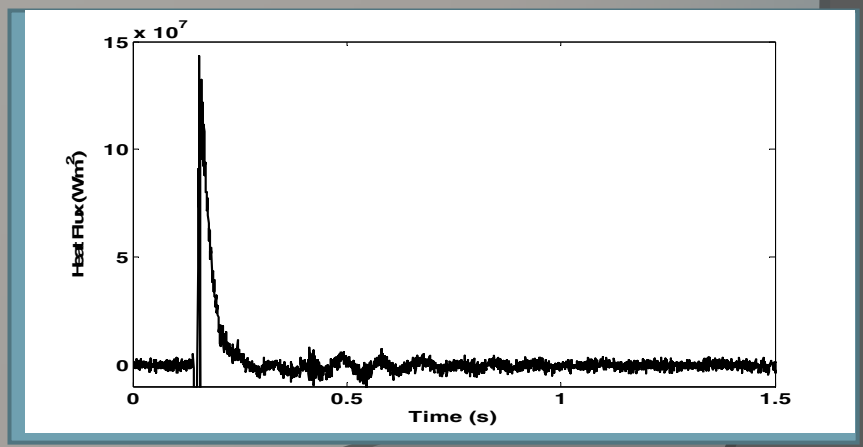




100KW/m^2

Mark 45 Mod 5

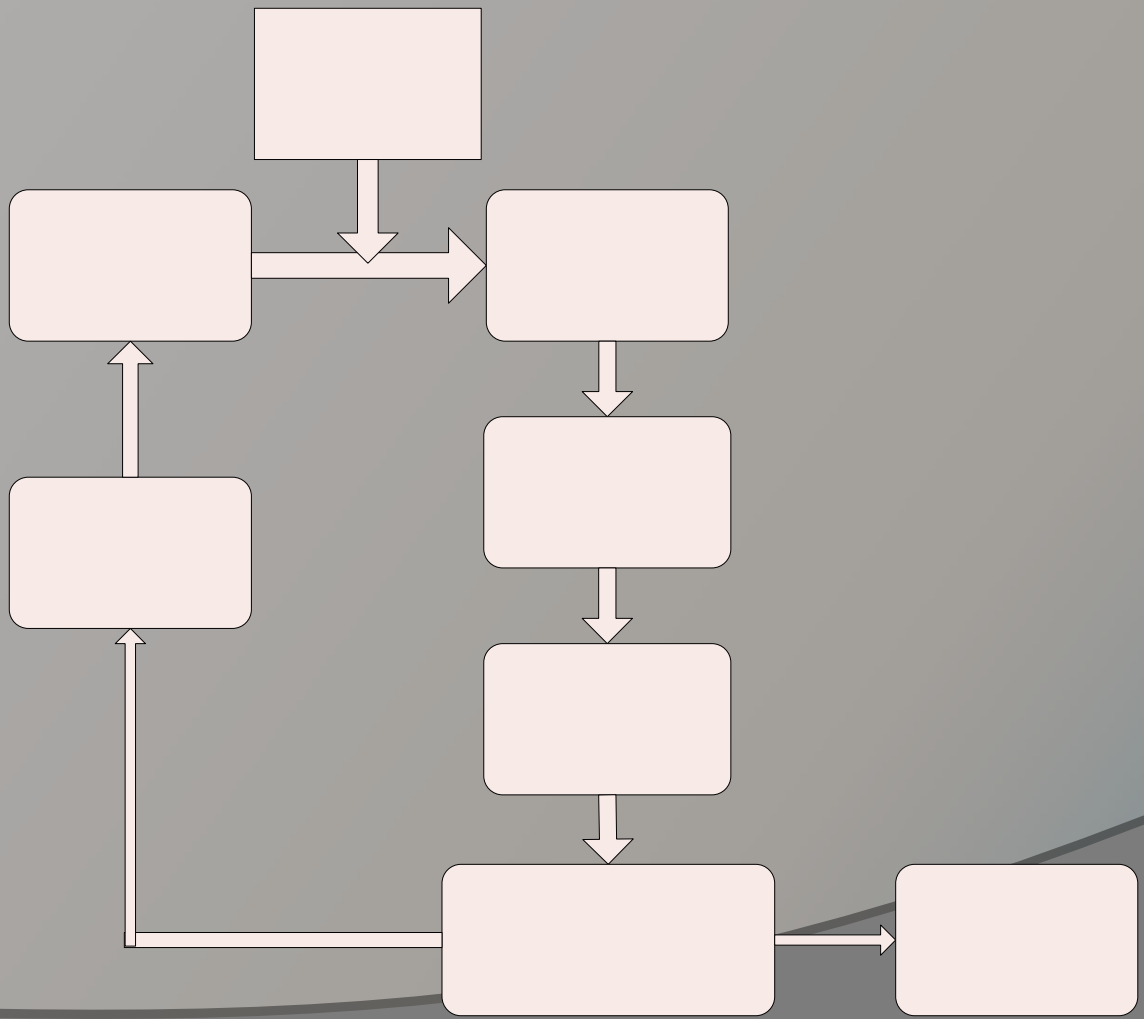




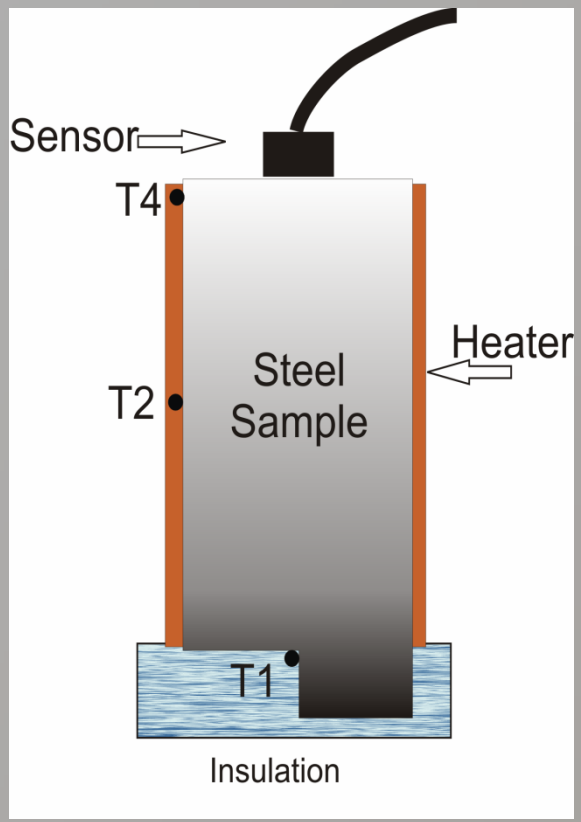
140MW/m^2

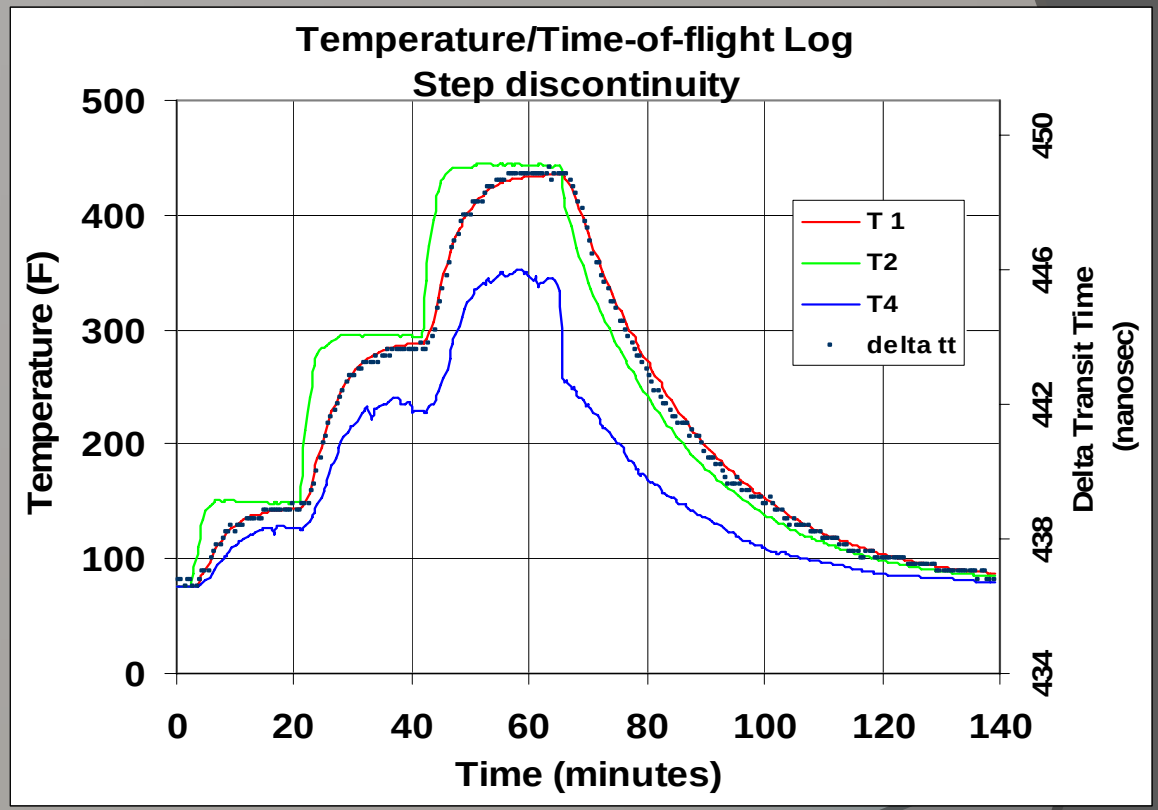
HEAT FLUX CONVERSION OVERVIEW

Inverse Solution



LAB VALIDATION EXPERIMENT

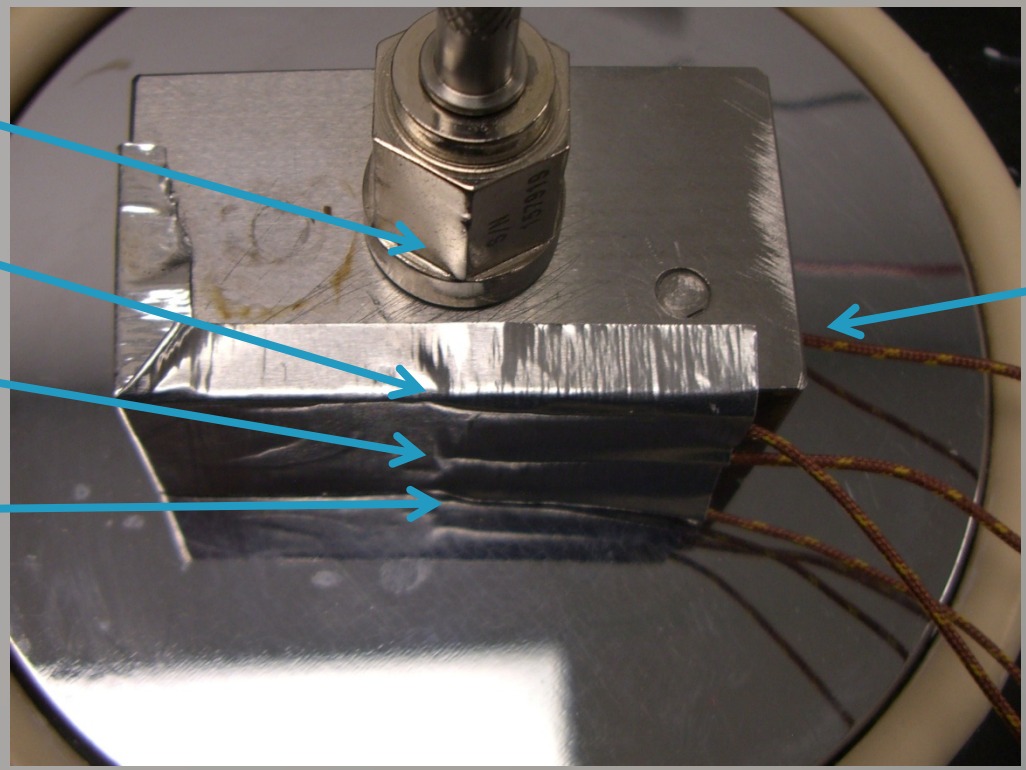




- Three Thermocouples Vs Time of flight of ultrasonic pulse

PROBLEM STATEMENT

In-Wall RTD 0.05” from Heated Surface



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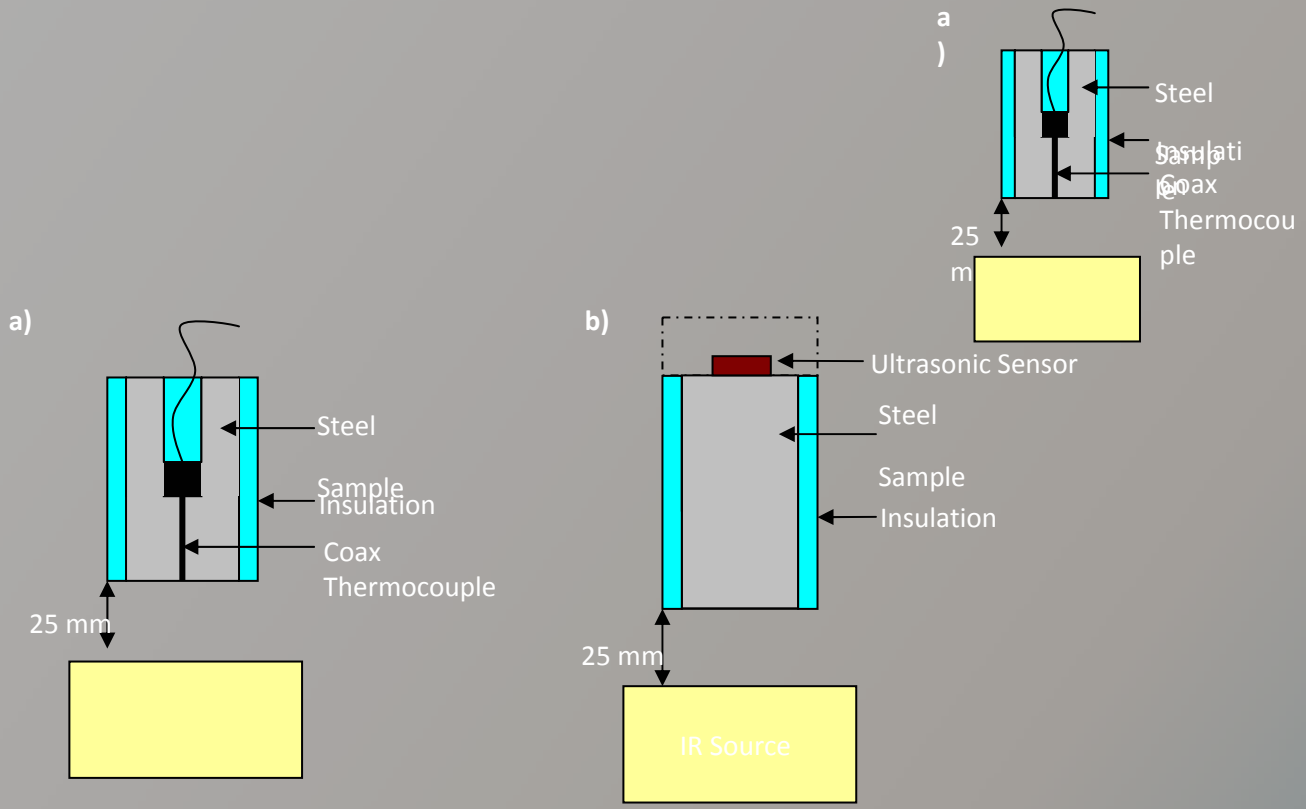

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