ADVANCES IN THE USE OF THERMOGRAPHY TO INSPECT COMPOSITE TANKS FOR LIQUID FUEL PROPULSION SYSTEMS

Matthew D. Lansing*, Samuel S. Russell**, and James L. Walker**

*Ceramics and Ablatives Team/ED34
**Nondestructive Evaluation Team/ED32
Marshall Space Flight Center
Huntsville, Alabama

ADVANCES IN THE USE OF THERMOGRAPHY TO INSPECT COMPOSITE TANKS FOR LIQUID FUEL PROPULSION SYSTEMS

- Background
- Thermographic Inspection System
- Thermographic Analysis Method
  RP-1 Graphite/Epoxy Tank
  Scan and Defect Map
  Method of Inspection
  Defect: Inclusions, Ply Wrinkle, Delaminations
- Graphite Composite Cryogenic Feedline
  Method
  Image Map
  Defects: Inclusions (Shallow/Deep), Resin rich area
- Material Degradation NDE
- Summary

- DETECT DEFECTS
  - After manufacture.
  - Prior and after use.
- WHAT IS A DEFECT?
  - Determined by Experience: manufacturing, testing, analysis, and use.
- USUAL SUSPECTS
  - Foreign Objects-tape, bagging film, release cloth, human debris, etc. IBSG
  - Delamination. IBSG
  - Microcracking UB
  - Porosity UB
  - wrinkles
- Note: IBSG = Island of Bad, Surrounded by Good. UB = Uniformly Bad.

NONDESTRUCTIVE EVALUATION OF COMPOSITES

- Usual Nondestructive Tools for Composites
  1. Visual
  2. Ultrasound

     Moderate Frequency (0.5-20 MHz)

     Spectroscopy (Ultraspec, 0.5- 2 MHz)

     Acoustic Microscope (5-500 MHz)
  3. Radiography
  4. Coin Tap
  5. Thermography
  6. Acoustic Emission
  7. Computer Tomography-(X-ray)
  8. Shearography
  9. Eddy Current

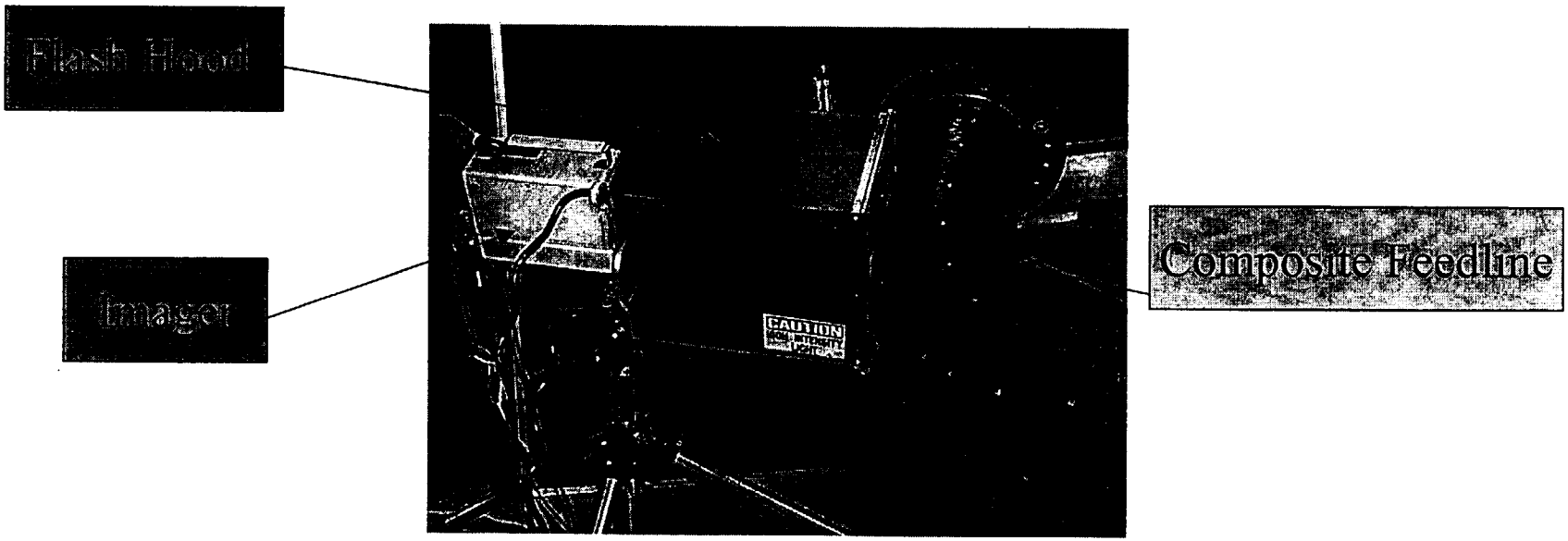
Why use thermography?

- Area Method—covers area relatively quickly.
- Inspect normal and unusual shapes.
- No contamination of the surface.
  - May require removable coating if surface is shiny.
  - May be noncontact.
- Directly size anomalies using video caliper.

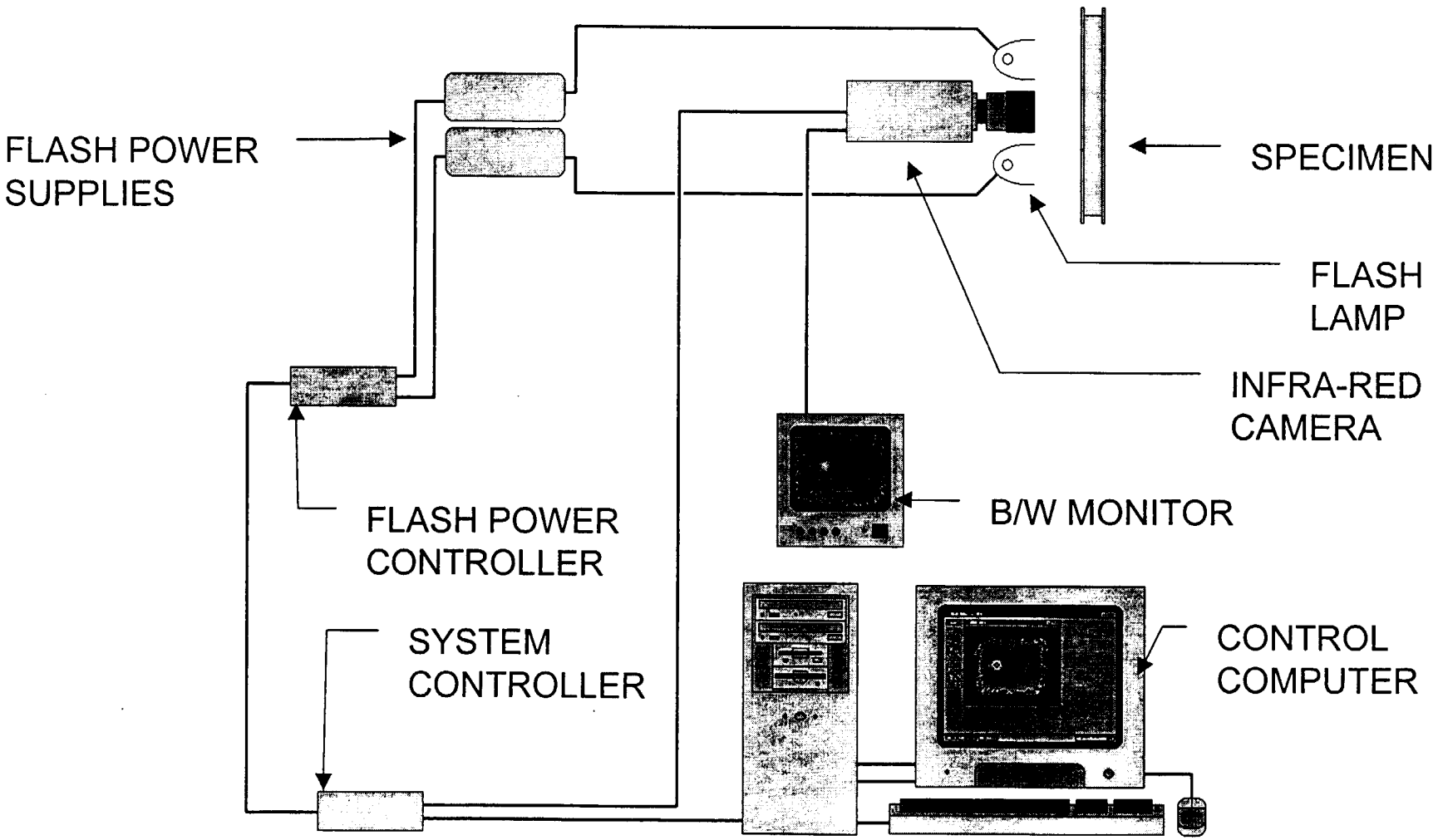
THERMOGRAPHIC INSPECTION SYSTEM

- Imager: Indigo Merlin Mid
- Detector => Indium Antimonide
- Detector resolution => 256 x 256
- Spectral Response => 3 - 5 μm
- Sensitivity => 0.025 °C NEΔT
- Lens => 25 mm

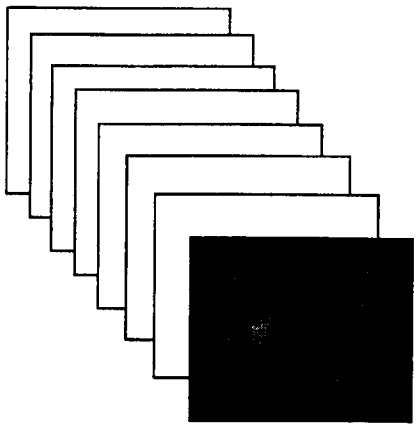
- Software: ECHOTHERM® 32 (Thermal Wave Imaging, Inc.)



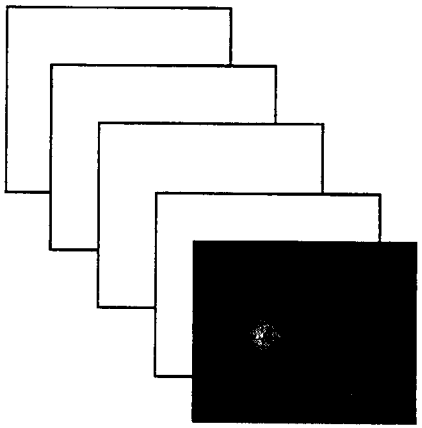
THERMOGRAPHIC ANALYSIS METHOD



THERMOGRAPHIC ANALYSIS METHOD



Thermography Image Sequence



Averaged Images

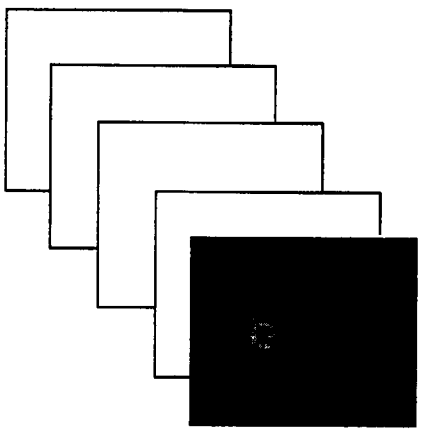
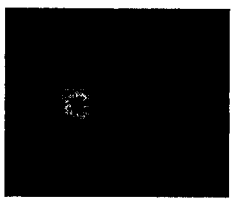
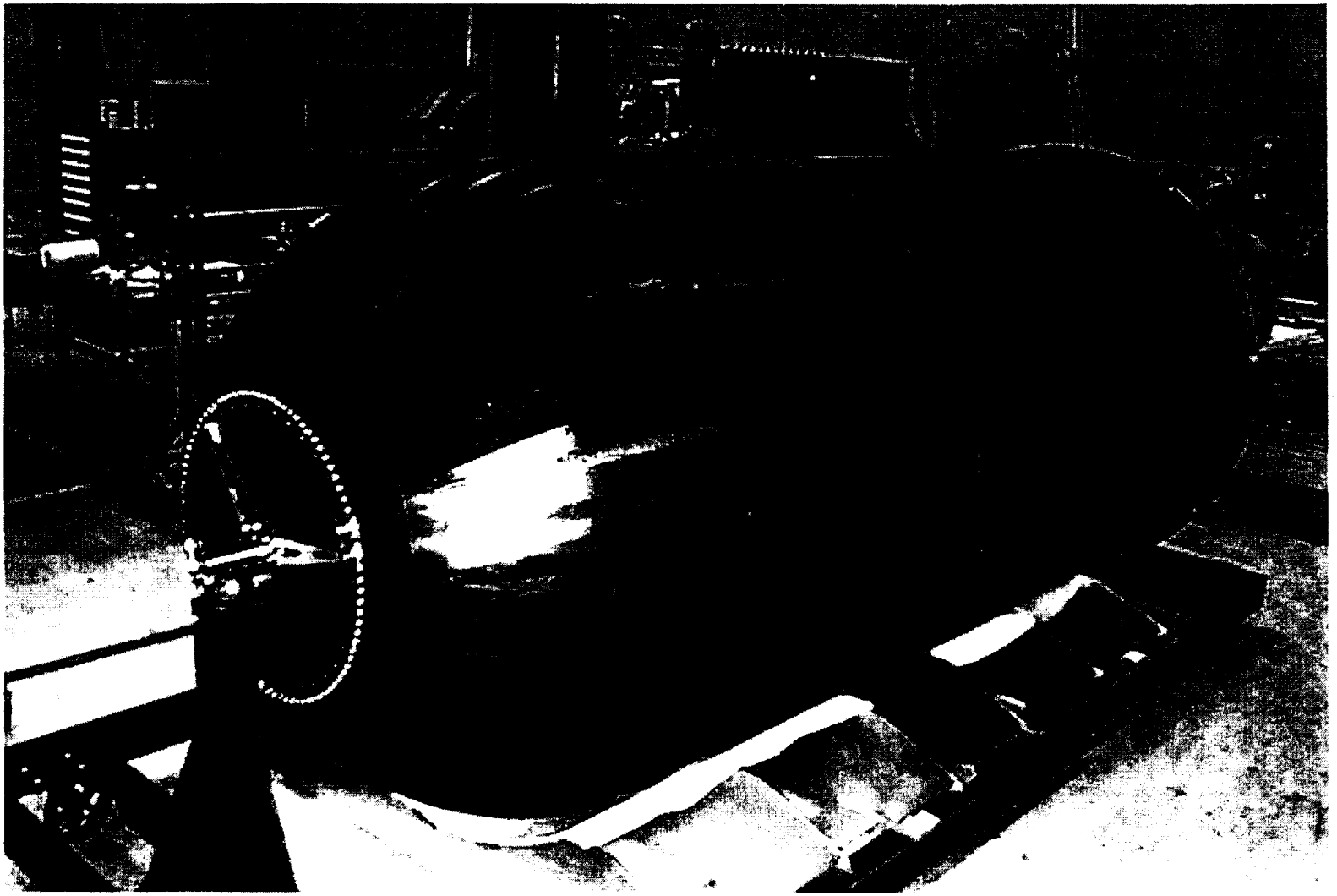


Image subtraction (Image N – Pretrigger)

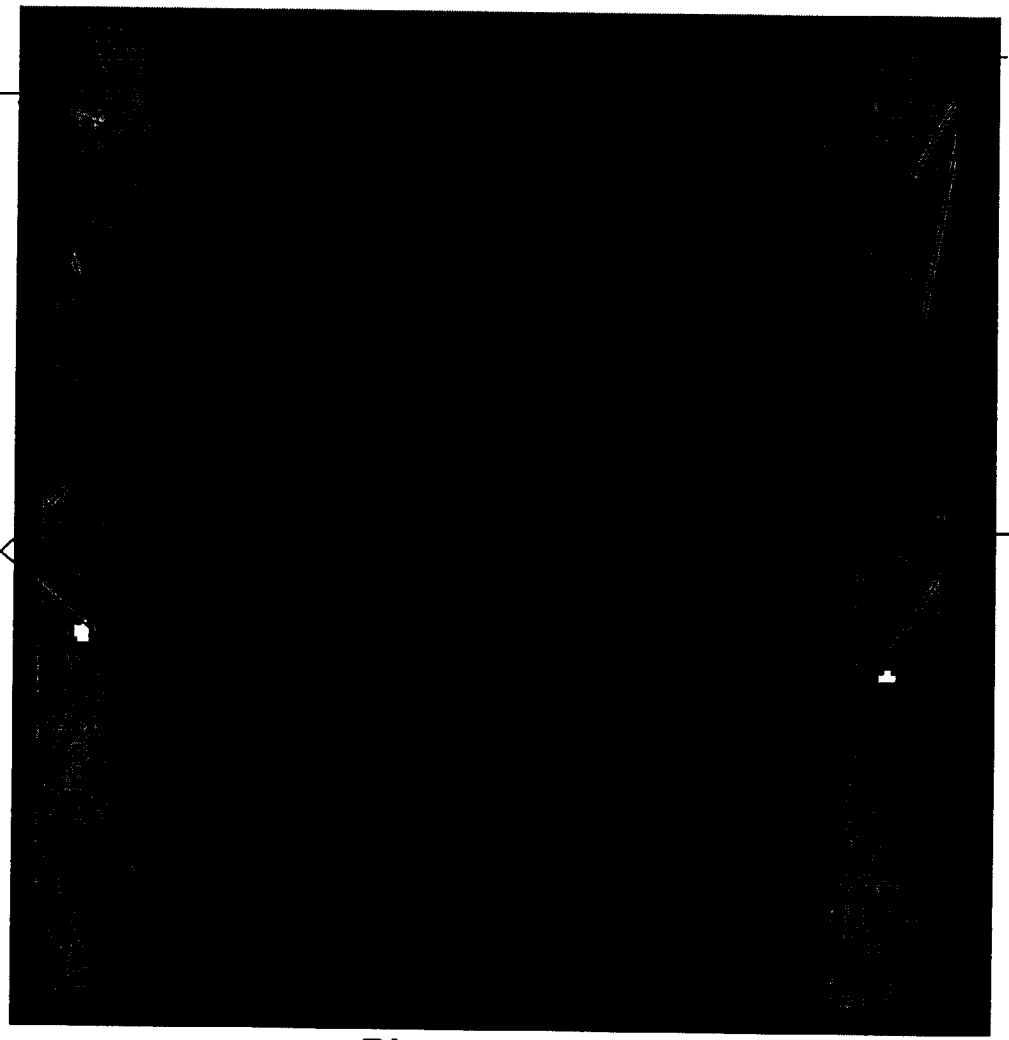


Enhanced Image

RP1 Tank

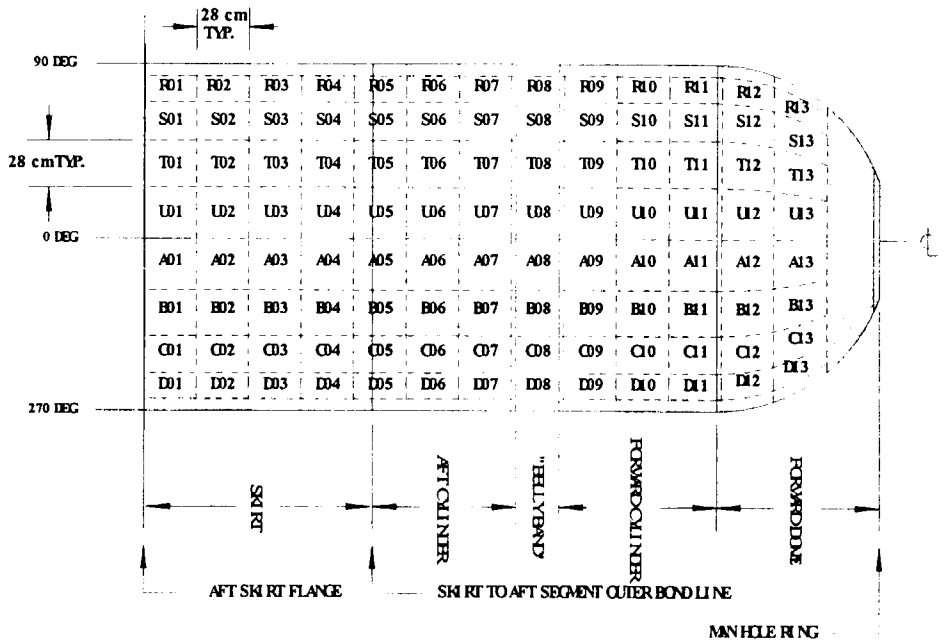


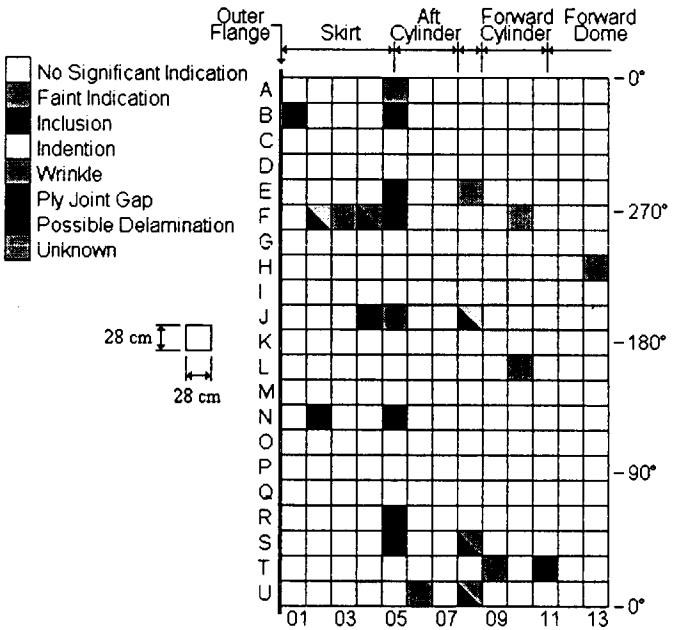
TANK DEFECT STANDARD



Ply step section

RP-1 TANK IMAGE/DEFECT MAPS

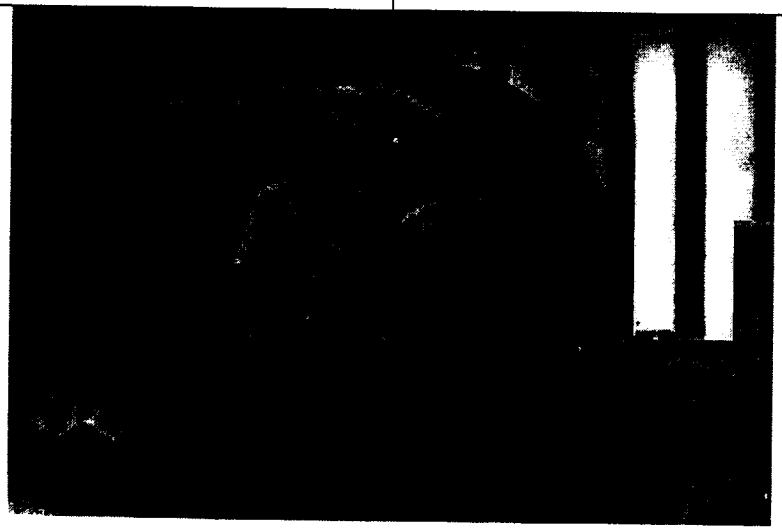




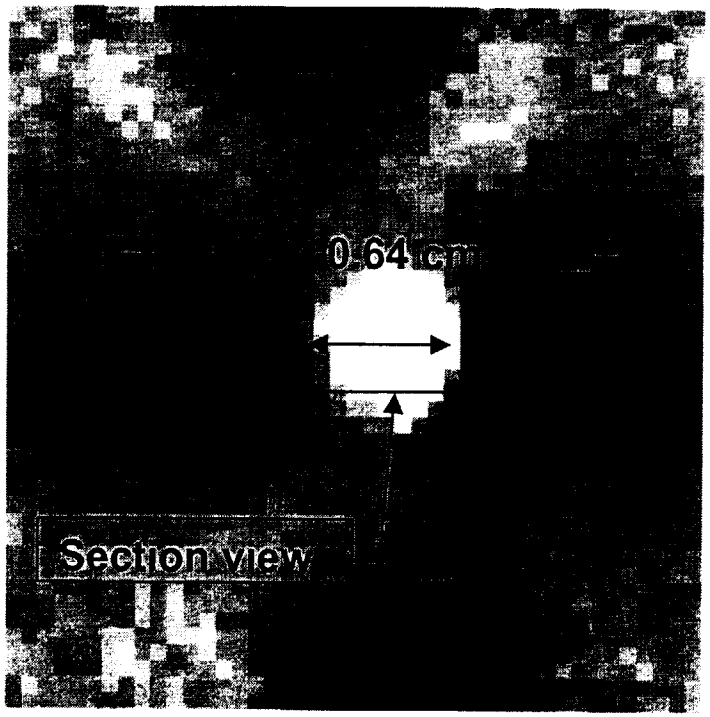
a. Image map **b. Defect map**

Inspection of Inner belly Band

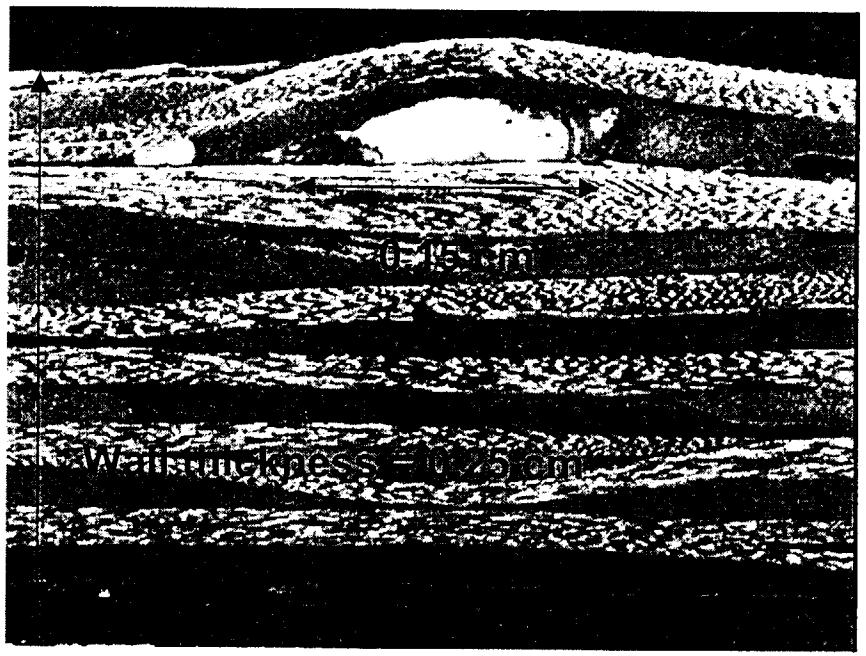
Access port



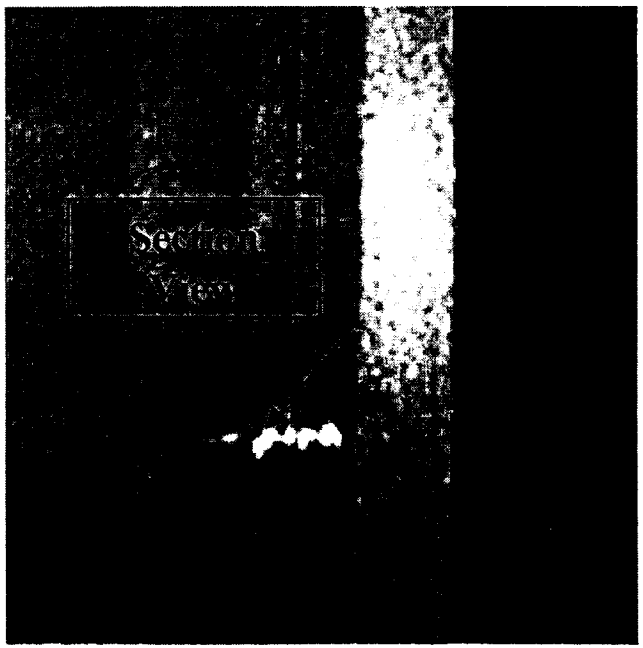
Flash system utilized on tank exterior



a. Thermogram



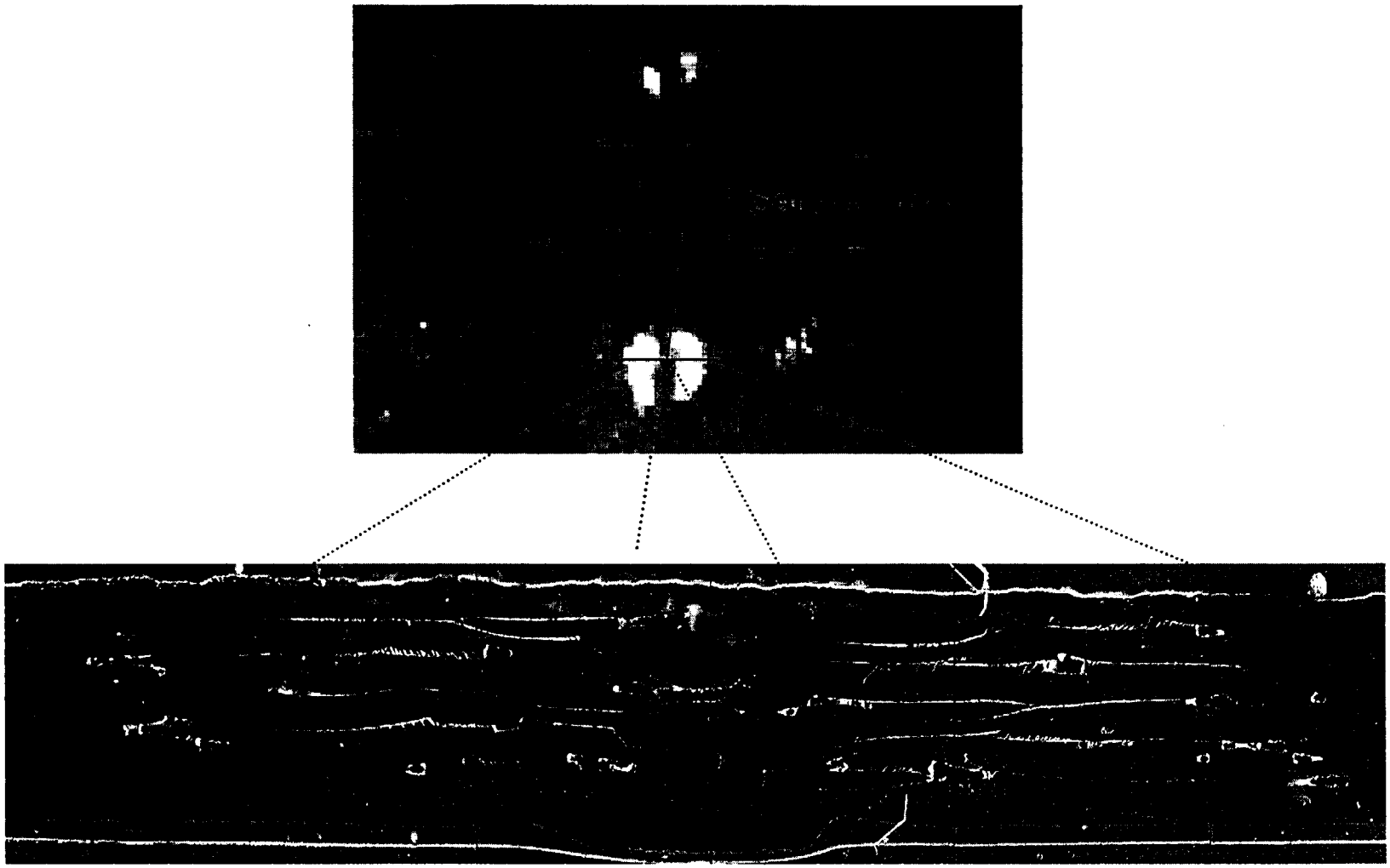
b. Photomicrograph



a. Thermogram

b. Photomicrograph (Fluorescent Penetrant)

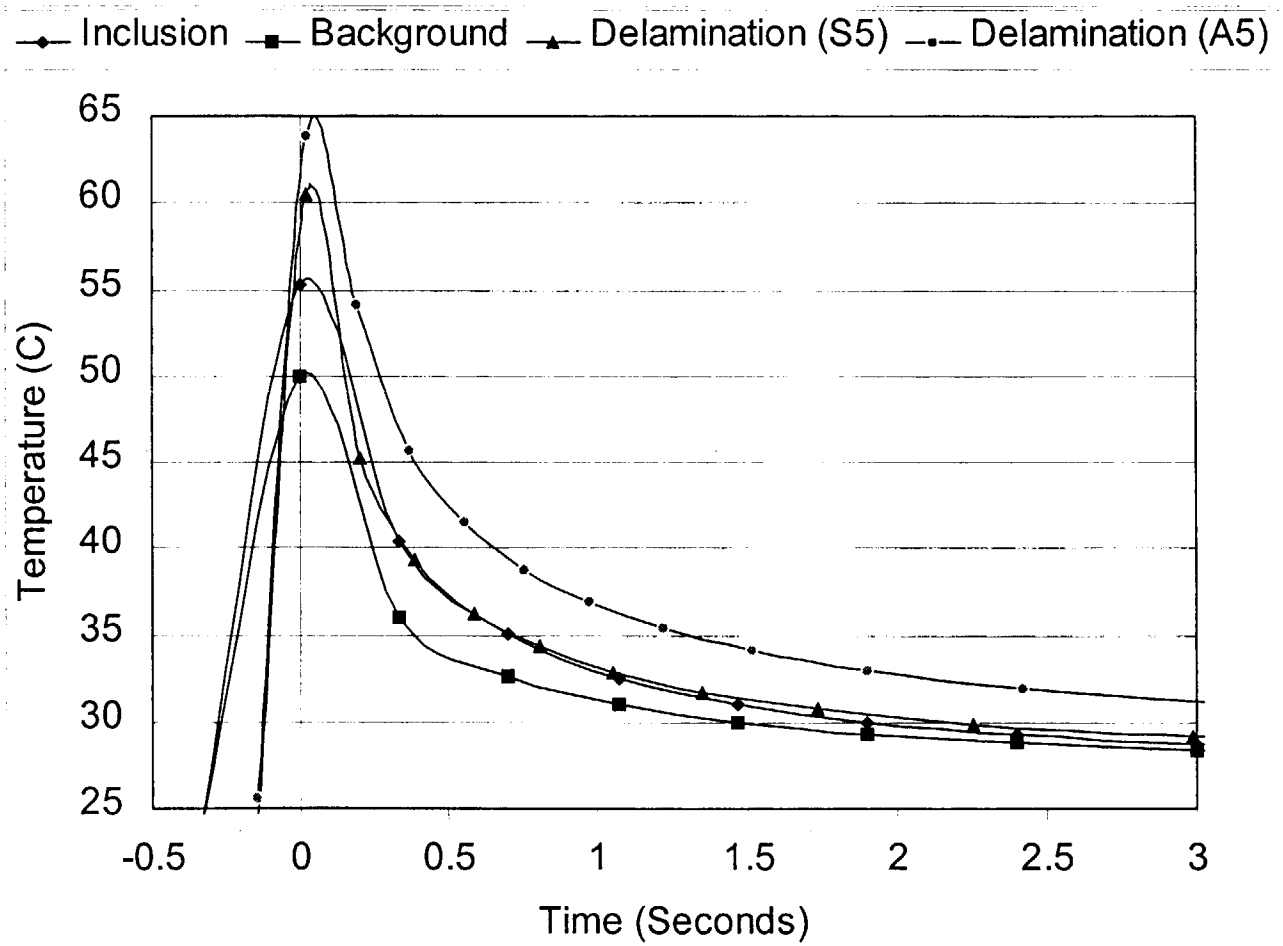
Wrinkle at zone A5



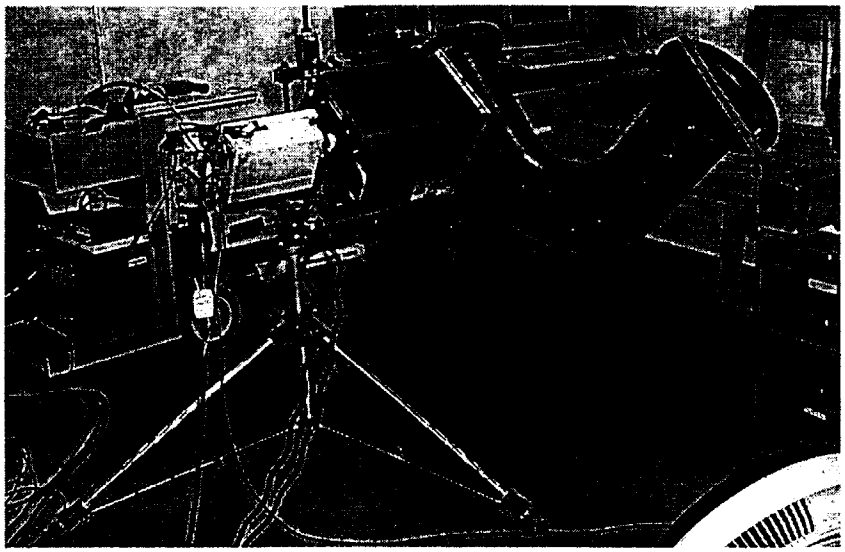
Photomicrograph (Fluorescent Penetrant)

Delaminations at region S5

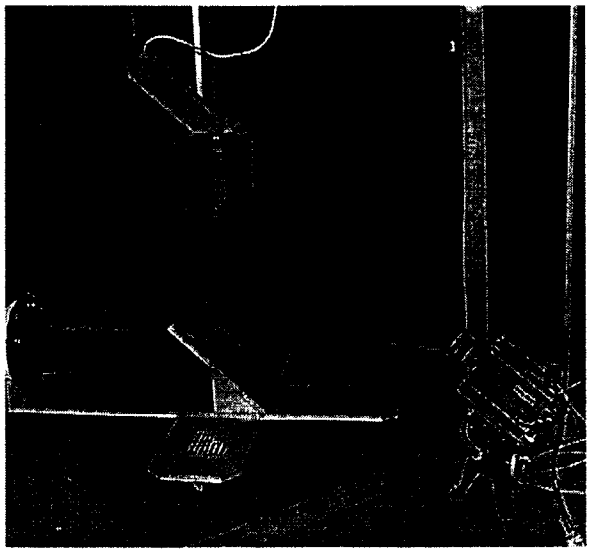
Time-Temperature Comparison for Inclusion and Delaminations



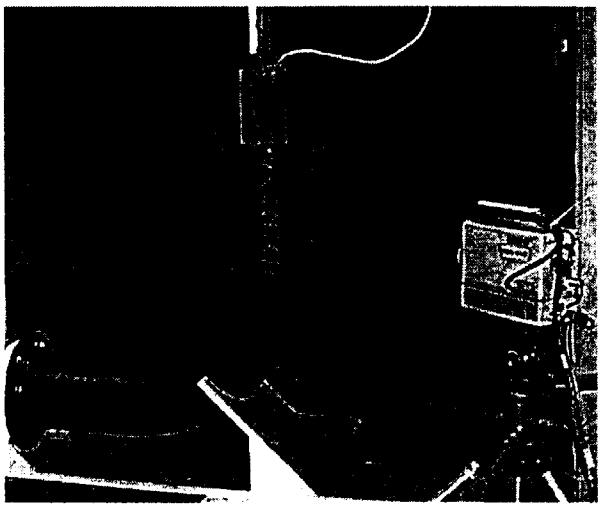
Cryogenic Feedline Thermography



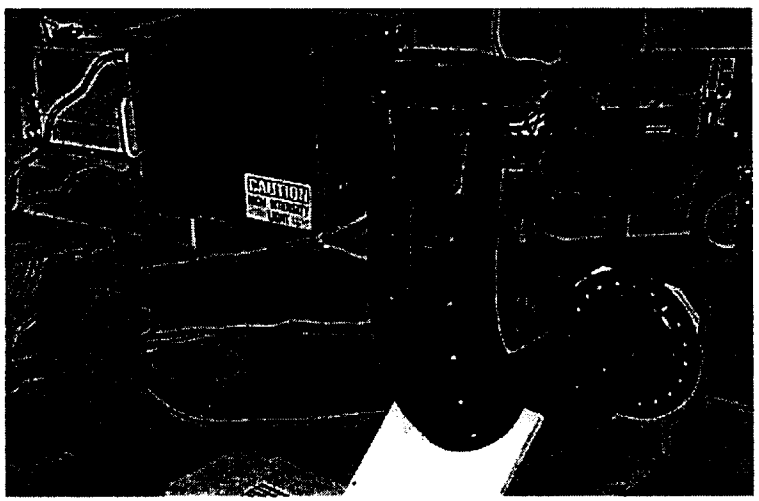
A. Acreage (Flash)



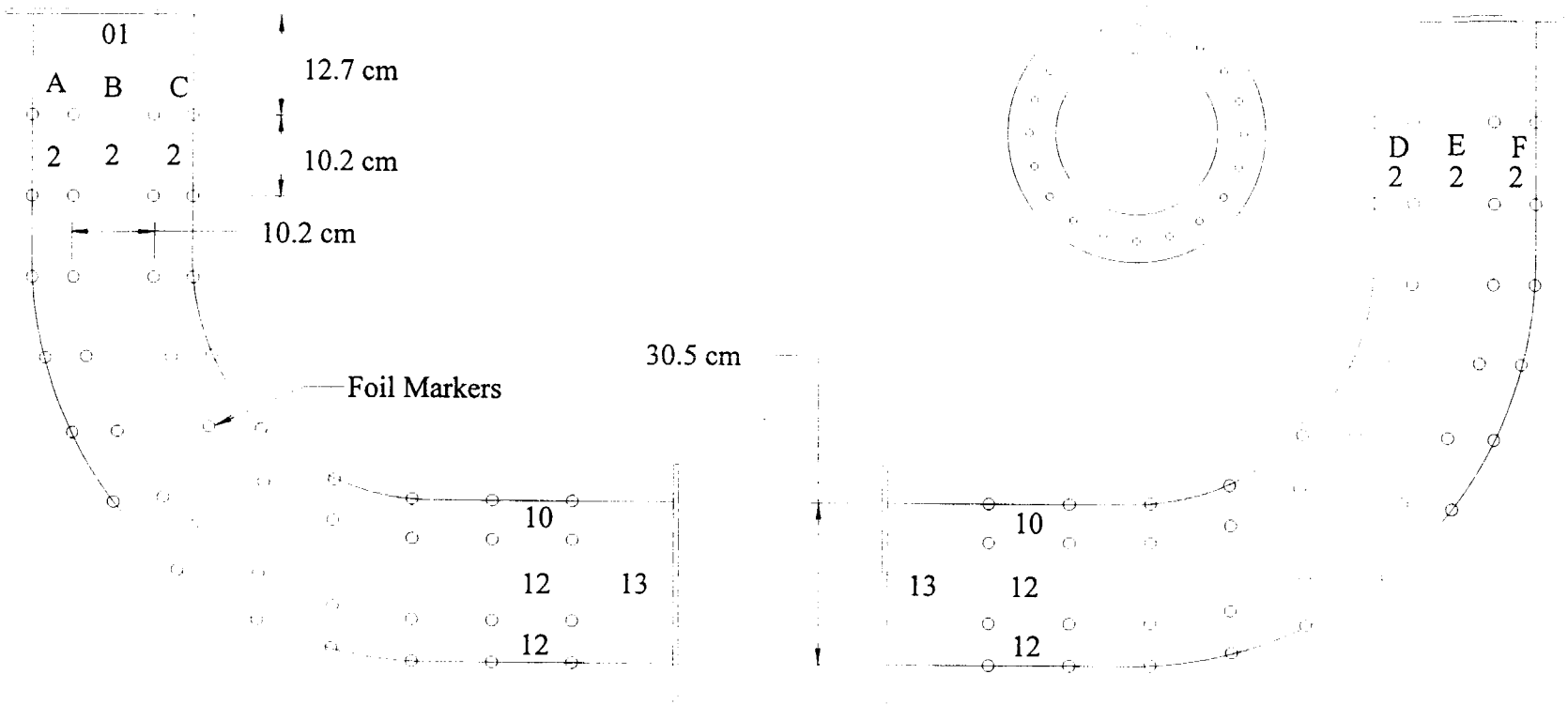
B. Fillet (Lamp)



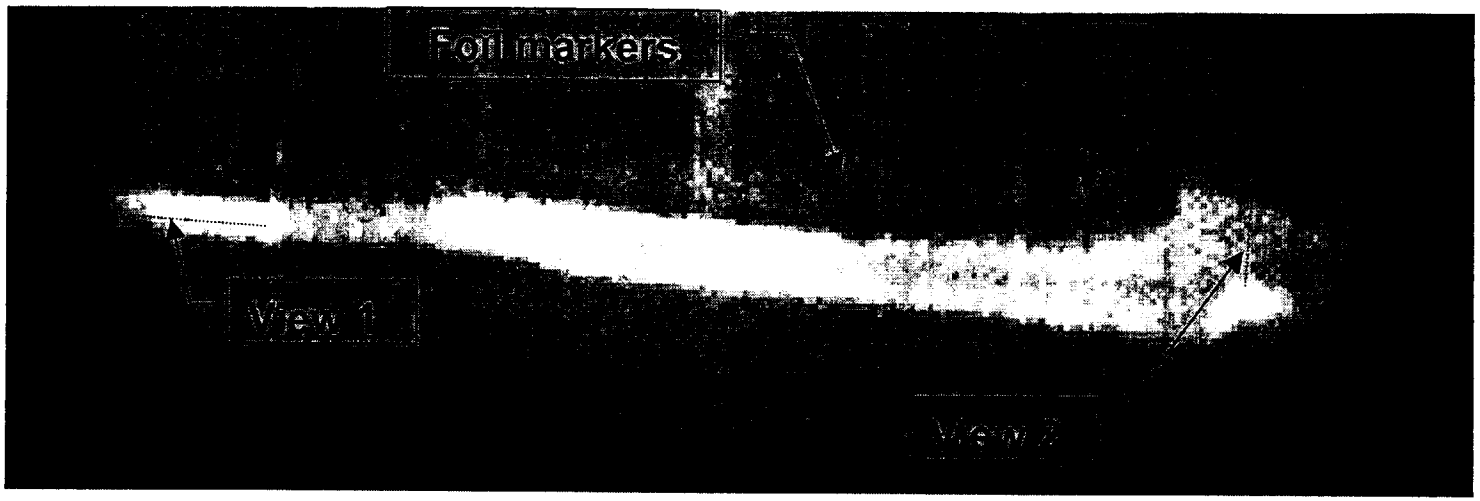
C. Build-up (Lamp)



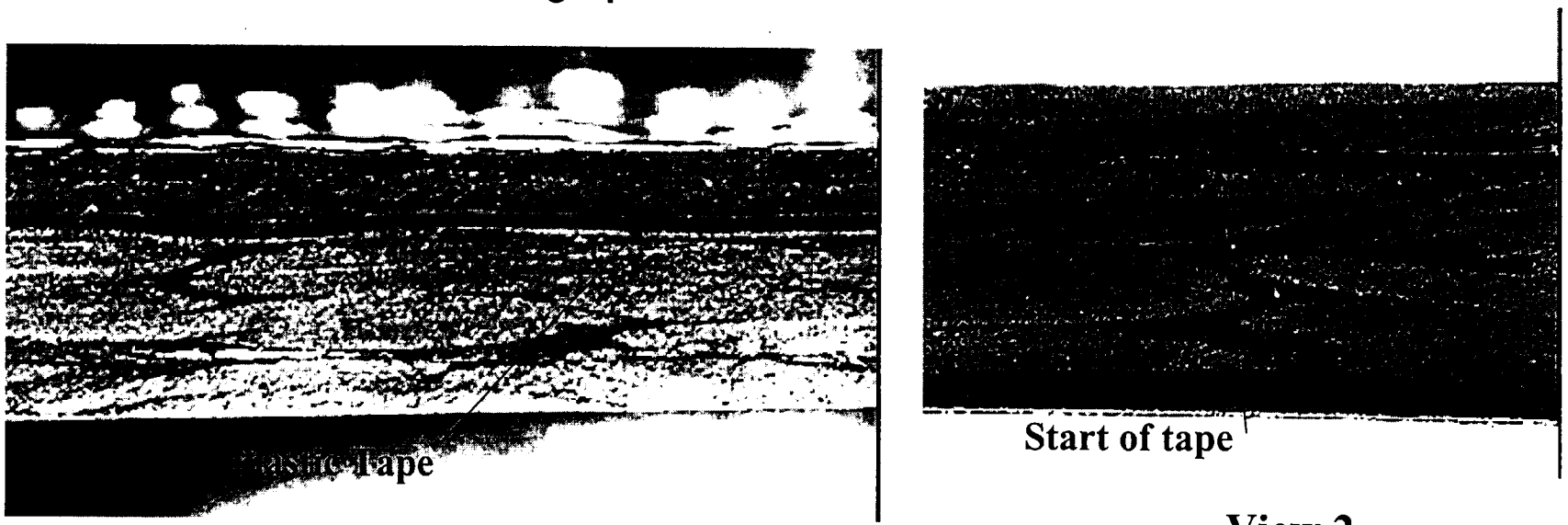
D. Build-up (Flash)



Feedline image map



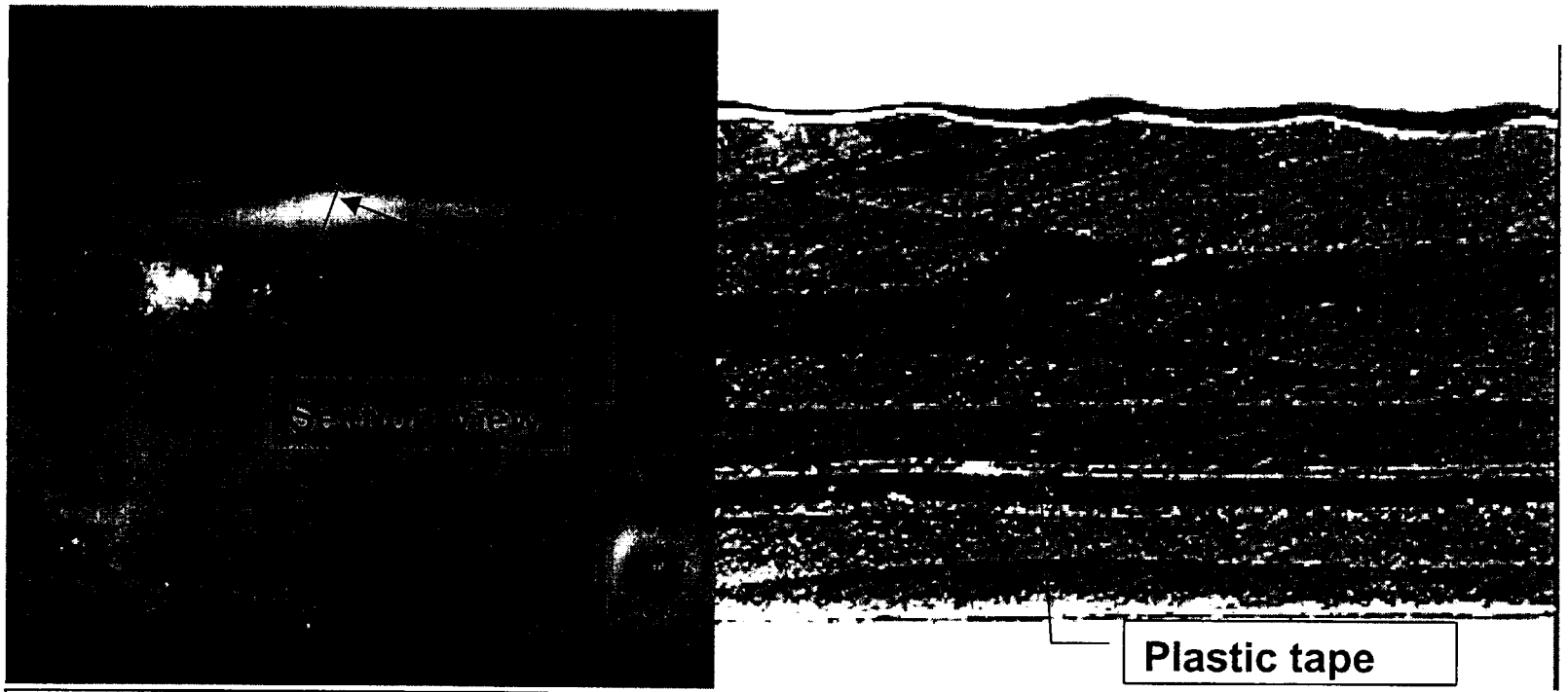
Thermographic indication of inclusion



View 1

View 2

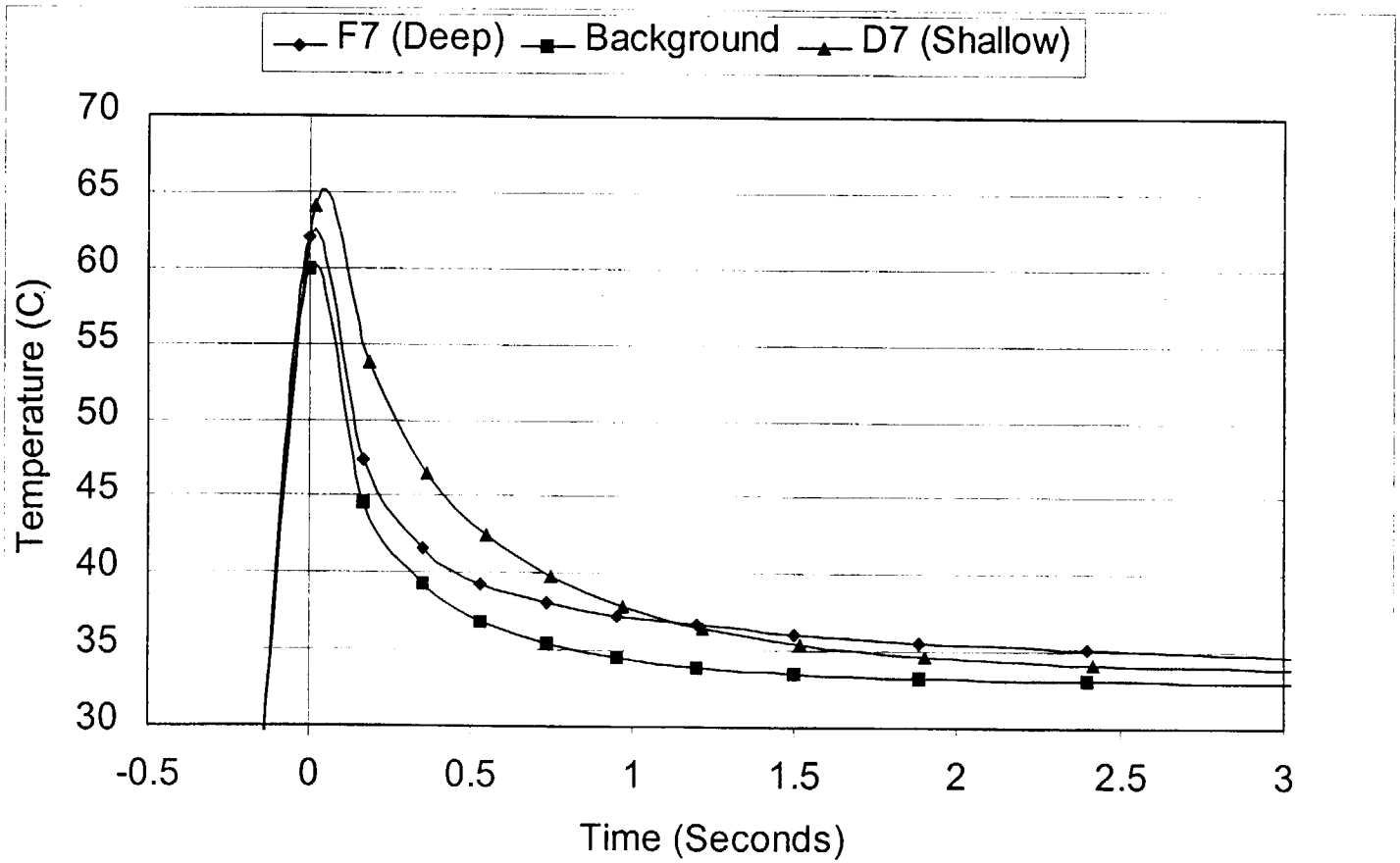
Photomicrographs of Teflon tape inclusions

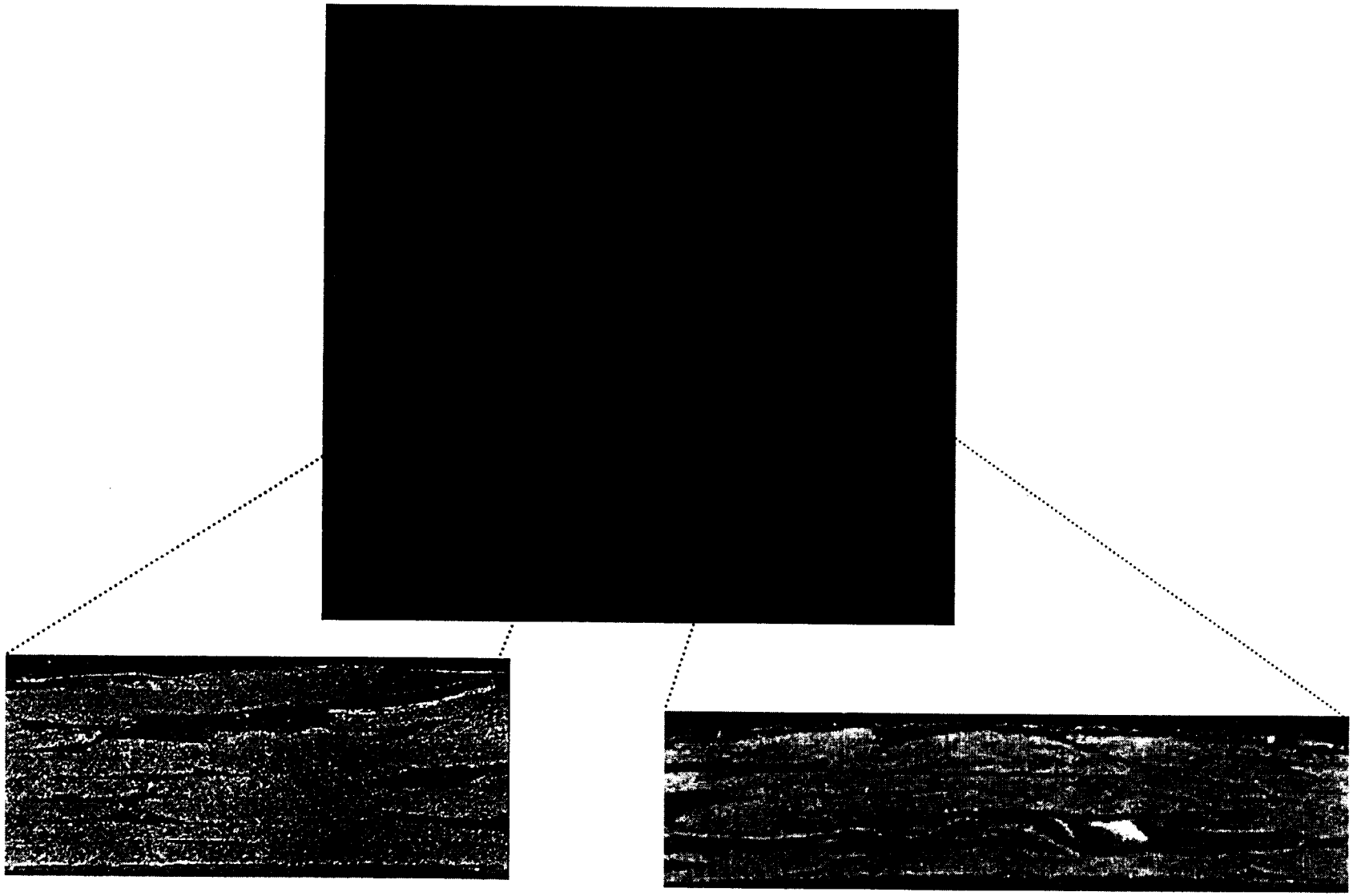


Thermogram | Micrograph

Deeply embedded plastic tape inclusions

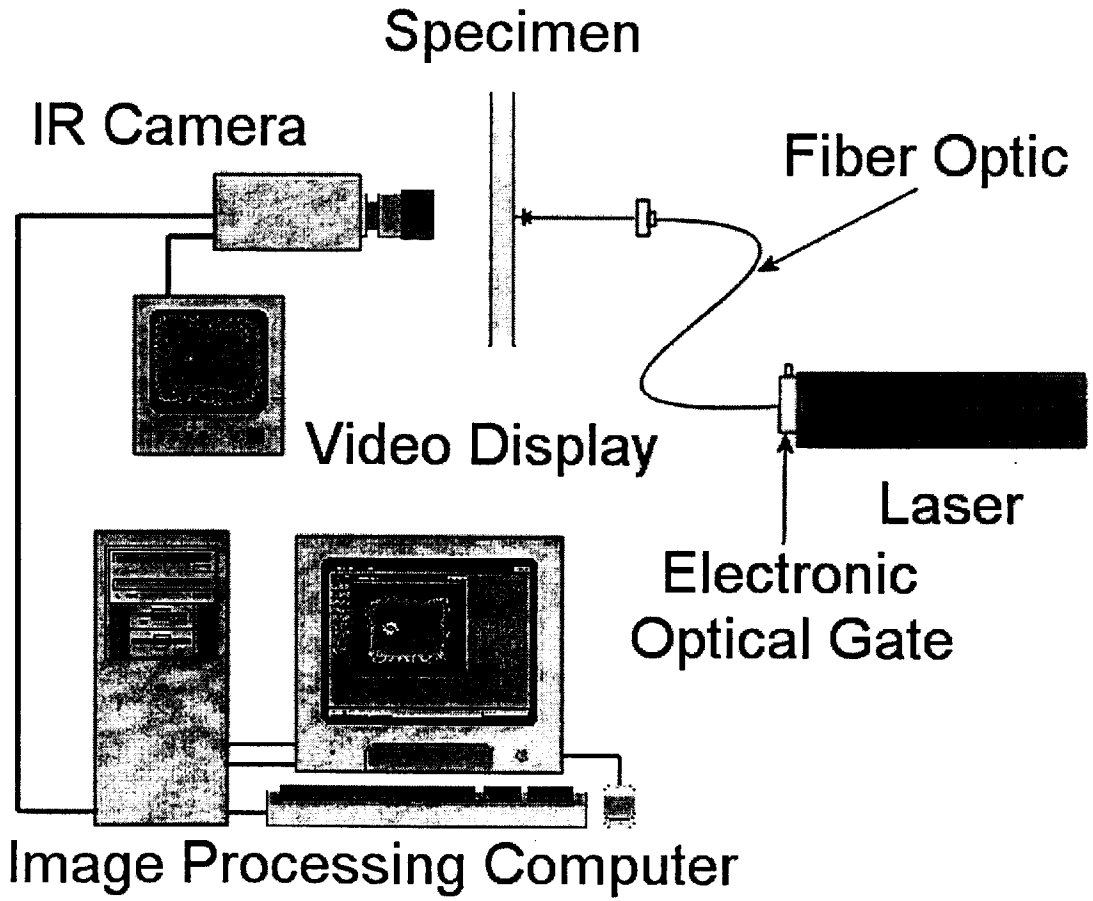
Time-Temperature Comparison for Inclusions at Different Depths





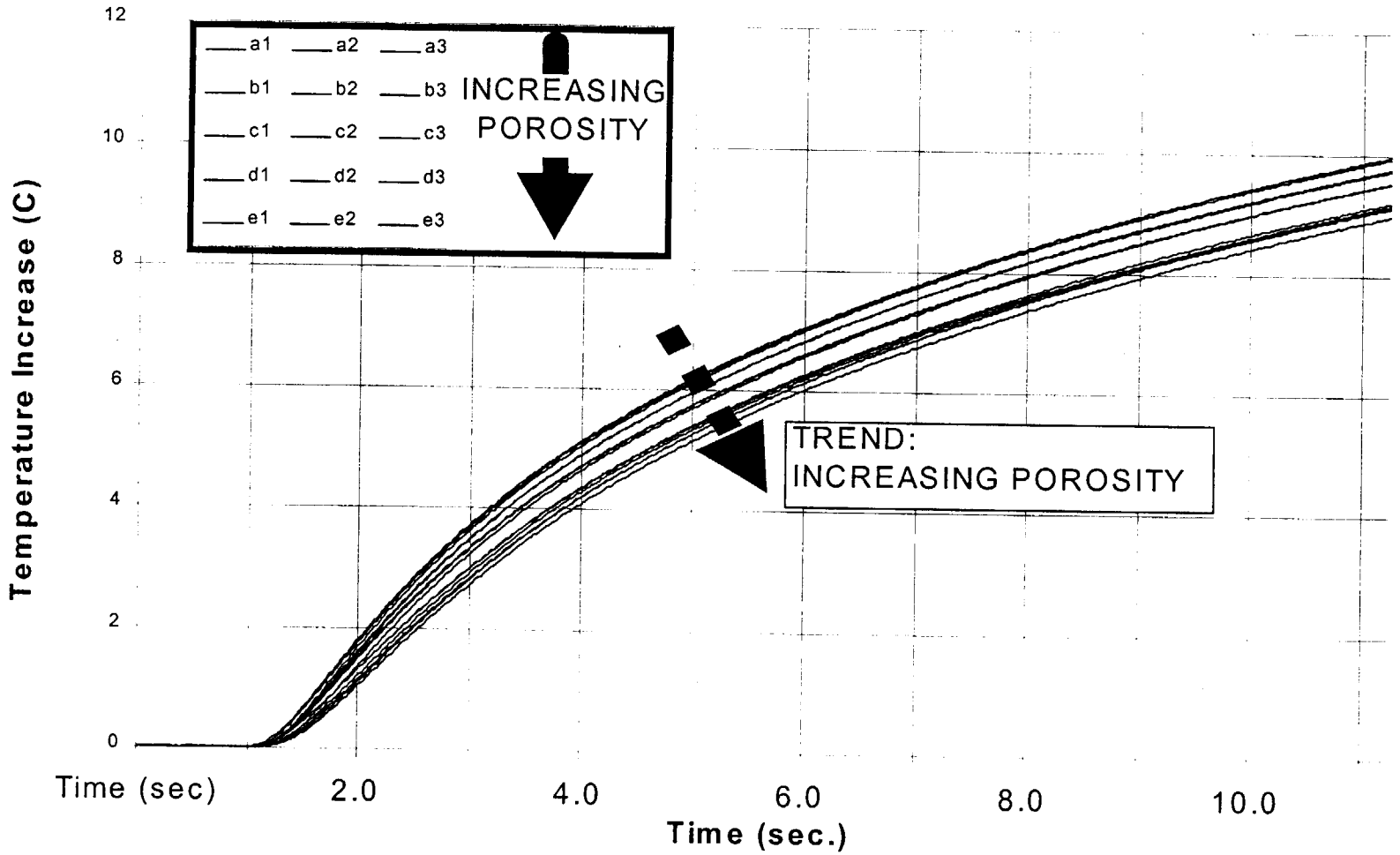
Defect at position A4

TO TRACK MATERIAL DEGRADATION



Thermal Diffusivity Measurement for Material Condition Measurement

POROSITY IN GRAPHITE EPOXY



SUMMARY

- Thermography is a useful tool for field evaluation of large complex composite structures
- Identification and characterization of manufacturing and service related defects/damage by thermographic methods pose two entirely different challenges to nondestructive testing personnel
- Much research has been placed on developing alternative ways for performing thermographic inspections to locate and size abnormalities, but it is the interpretation of such findings that ultimately determine the usefulness of such testing
- The microstructure of several commonly found defects in composite structures (graphite/epoxy RP-1 fuel tank and a graphite composite cryogenic fuel feedline) have been related to their thermographic image counterpart
- The results show the challenges a thermographer faces when trying to evaluate defects; i.e. determining the type, size and location of irregularities in a material
- Methods to track the over all degradation of material needs development. Tanks may wear out relatively uniformly due to exposure to low temperatures and stress.