Residual Heat Estimation by Image Processing Using Cherenkov Radiation in TRR

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RRFM 2007
Lyon-France
AIM

• Initial Approach
  – Using existing CCTV camera system
  – Derive a relationship between core light intensity vs. power
  – Later, due to saturation problem & auto iris, another approach employed

• Present Approach
  – PC-camera to look after shutdown glow
  – Check if Cherenkov light fits with decay heat
INSTRUMENTATION

• CMOS sensor at the heart of camera
• Core image formed on an array 640 x 480
• Each color of RGB : 0-255
• Pixels are scanned : bit-map-format
• Output signal : total intensity of core image
  – If all pixels are ON,
  – If all colors at peak,
  – Then \((signal)_{\text{max}} = 3 \times 255 \times (640 \times 480)\)
    \[= 235,008,000\]
• All numbers are normalized WRT total intensity right after shutdown
Imaging System prior to deployment
Collimator length ~ 1.4 m
Imaging System prior to deployment (within wooden frame)
Housing to protect camera & circuit
Experimental Setup

Diagram showing the connections between a computer, camera, mirror, collimator, glass, and water.
Technical Specification of Setup

**CAMERA**
- High-quality VGA CMOS sensor
- Manual control (no auto Iris)
- Video capture: 640 480 pixels
- Frame rate: 15 frame/sec at QVGA resolution
- USB port

**PC SYSTEM**
- Windows 2003, XP
- Pentium IV 2.8 GHz, full cash, Intel
- 512 MB RAM
- Programming environment: Delphi 7
TRR core configuration #23

Core Configuration 23

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TRR core top view

Core ~ 8 m below pool level
Image of core seen by PC-camera
Decay Heat After Shutdown
Way-Wigner Vs. ORIGEN

$P(t)/P_0$ (%)

Time After Shutdown (Sec)

$P_0 = 4$ MW
$T = 96$ hours
Heat Rate After Shutdown
Delayed Neutronic Vs. Decay Heat

Po=4 MW
Λ=45 μsec
β=0.0077
Measured Cherenkov Light Vs. Total Heat Rate Release in TRR

- **PC-Camera Response (Cherenkov Light)**
- **PC-Camera Response (B/G Subtracted)**
- **Total Heat generation after shutdown**

The graph shows the decay of Cherenkov light and total heat release with time after shutdown. The x-axis represents time in seconds, while the y-axis shows the normalized response of the PC-camera. The data points indicate a significant decrease in both Cherenkov light and total heat generation over time.
RESULTS & DISCUSSIONS

- Continuous run of 96 hours at Po= 4 MW
- Reactor scram with all 4 shim rods
- Cherenkov radiation monitored after shutdown up to 100 hours
- Total heat rate estimated:
  \[ \text{Decay heat + Neutronic power} \]
- PC-camera response are recorded by computer
- General trends are satisfactory
- Contribution of gammas to heat are NOT the same for: Neutronic & decay heat
CONCLUSIONS

• Real time monitoring for open pool reactors
• Independent channel for post shutdown
• Indirect measurement for decay heat
• Long distance from core
• Out of water system
• Low price