Innovations in PPE/Controls for Nonionizing Radiation

PPE for Infrared Radiation Environments

Thomas E. Bernard
University of South Florida
College of Public Health
Tampa FL
Acknowledgments

University of South Florida
✓ NIOSH Supported Sunshine ERC

ACGIH®
✓ John Leonowich, UNLV

AIHA Non-Ionizing Radiation Committee
Case Example

Loading unheated ceramic molds into a conveyor furnace. The operator views the interior of the heated furnace during the task.

- Temperature: 1235 °C (2250 °F)
- Duration of each view: 1 min every 15 min
- Distance from operator to door: 3 m (9 feet)
- Opening: 1.5 x 1.3 m (58" tall x 53" wide)
- Profile of molds: 40%
What it looks like
Assumptions

Pure Blackbody Radiation
Effective Source Profile: 1.3 x 0.4 m
Near Field

Results

✓ $L_R = 2.0 \text{ W/cm}^2 \text{ sr}$
✓ $E_{IR} = 0.028 \text{ W/cm}^2$
✓ $E_{\text{total}} = 2.4 \text{ W/cm}^2$
Notes

Sources
✓ Black Body Radiators
✓ Others (e.g., lamps)

Hierarchy of Controls
✓ Engineering Controls
  ▪ Case Study: Mesh Screen (50% reduction)
✓ Administrative Controls
✓ Personal Protection
Target Organs

Eyes
✓ Retina
✓ Cornea/Surface

Skin
✓ Uncovered
✓ Covered

Whole Body -- Heat Stress
Eyes
Thermal Exposure Limits

ACGIH® TLVs®

Retinal Injury

✓ Thermal Hazard Function
✓ For $t > 0.25$ s: $L_R < 45 \text{ W/cm}^2 \text{ sr}$

Corneal/Lenticular

✓ Less than 17 minutes: $E_{IR} < 1.8/t[s]^{0.75} \text{ W/cm}^2$
  ▪ For $t = 60$s: $E_{IR} < 1.8/t[s]^{0.75} \text{ W/cm}^2 = 0.083 \text{ W/cm}^2$
✓ Greater than 17 minutes: $E_{IR} < 0.01 \text{ W/cm}^2$
  ▪ Repeated exposures for 30 min / day
Exposure Assessment

Thermal Effects to the Retina
✓ $L_R = 2.0 < 45 \text{ W/cm}^2 \text{ sr}$
✓ Low Risk

Thermal Effects to Cornea/Lens
✓ $E_{IR} = 0.028 > 0.01 \text{ W/cm}^2$
✓ Risk after about 4 cycles
Eye Protection

Safety Glasses / Face Shields

✓ Use manufacturer’s data
✓ Case Study: < 1 order of magnitude (OD = 1)
Skin
Thermal Injury/Pain

For $t < 10$ sec (ICNIRP)

✓ $H [J/cm^2] < t^{1/4}$
✓ At $t = 5$ s, $0.30$ W/cm$^2$; At $t = 10$ s, $0.18$ W/cm$^2$
✓ Protective of Pain
✓ Influenced by Ambient Temperature

Pain Threshold for Prolonged Exposures

✓ Approximate: $E_{\text{total}} < 0.08$ W/cm$^2$

Good Warning Properties
Exposure Assessment

\[ E_{\text{total}} = 2.4 > 0.08 \text{ W/cm}^2 \]

Risk for pain or burn
Personal Protection

Face Shield -- Face

Clothing -- Body

✓ Types
  ▪ Single Layer
  ▪ Multiple Layers
  ▪ Reflective (Selective Areas)

✓ Insulation
  ▪ Data available
  ▪ Add for layers
  ▪ Very dynamic -- Depends on clothing surface temperature -- Iterative

Warning properties make it easy to adjust.
Heat Stress
Burden

Resting Metabolic Rate
✓ 115 W
✓ 0.06 W/cm²

Oven Example
✓ 1/4 of the body at 2.4 W/cm²
✓ 1200 W
✓ Clothing confounds the problem
WBGT

Heat stress is often high in high IR conditions.

Assume WBGT accounts for high radiant heat environments.

Two layer FR clothing adds about 3 °C-WBGT
Personal Cooling

Circulating Air
Circulating Water
Ice Garments
## Cooling Rate [W]

<table>
<thead>
<tr>
<th>Item</th>
<th>Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control II and I</td>
<td>15 / 38</td>
</tr>
<tr>
<td>Liq Cooling Vest - Model 1</td>
<td>99</td>
</tr>
<tr>
<td>Liq Cooling Vest - Model 2</td>
<td>114</td>
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<tr>
<td>Ice Vest</td>
<td>165</td>
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<tr>
<td>Liq Cooling Vest</td>
<td>200</td>
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<tr>
<td>Liq Cooling Jacket</td>
<td>216</td>
</tr>
<tr>
<td>Liq Cooling Suit</td>
<td>235</td>
</tr>
<tr>
<td>Vortex-Cooled Air</td>
<td>235</td>
</tr>
</tbody>
</table>

Tukey’s hsd = 108 W
Cooling Performance

M = 260 W
Service Life of Ice Systems

Step 1. Compute the Amount of Ice [kg] -- IW

Step 2. Estimate Cooling Efficiency -- Eff
- Ice Vest: Eff = 0.5
- T suit configuration: Eff = 0.8

Step 3. Estimate Average Metabolic Rate [kcal/hr]

Step 4. Estimate the Cooling Time -- $t_{cool}$
- $t_{cool}$ [min] = 60 [min/hr] * 80 [kcal/kg] * Eff * IW [kg] / MR [kcal/hr]

Step 5. Estimate Time Limit -- $t_{limit}$
- $t_{limit}$ [min] = $t_{cool}$ + 15 min
Questions

Thomas E. Bernard
✓personal.health.usf.edu/tbernard/

NIOSH Sunshine ERC
✓heath.usf.edu/publichealth/erc

USF College of Public Health
✓heath.usf.edu/publichealth