Physical Injury Modes

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Learning Outcomes

- Identify common modes of physical injury in processing, including chemical exposure, heat flux, and overpressure.
- Calculate or estimate injury thresholds, such as the time to onset of 2nd-degree burns from heat flux.
- Distinguish between acute and chronic hazards and their long-term effects on the body (e.g., carcinogens vs. neurotoxins).

Reading

- Foundations of Spiritual and Physical Safety: with Chemical Processes; Chapter 3, Sections 2 (Heat/Overpressure) through the end of Chapter 3

Heat flux and burns; Overpressure and blast injuries; case studies

1 Heat Flux Hazards

Flames, hot metal surfaces, and other heat sources can cause burns. The heat flux is the amount of heat energy transferred per unit area per unit time. The heat flux is measured in W/m2.

From Handbook of Chemical Hazards Analysis Procedures (1989), Table 4.2

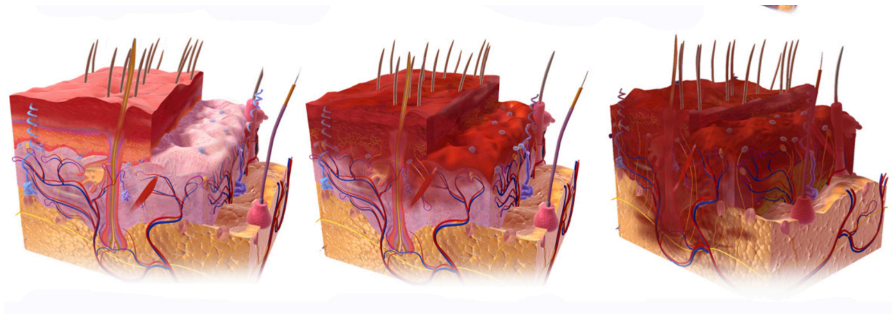


Figure 1: Industrial Hygiene Tools Image Reference

Heat Radiation Intensity (kW/m2)	Time for pain (seconds)	Time for 2nd Degree Burn (seconds)
1	115	663
2	45	187
3	27	92
4	18	57
5	13	40
6	11	30
8	7	20
10	5	14
12	4	11

Reference Link

You may have to click the 'reference link' twice to get it to work.

Initial Source
The initial source of the above table is Buettner, K, "Effects of Extreme Heat and Cold on Human Skin, II Surface Temperatures, Pain and Heat Conductivity in Experiments with Radiant Heat," Journal of Applied Physiology, 1951, 3, 703.

```
import pandas as pd
data = {'Radiation (kW/m2)':[1,2,3,4,5,6,8,10,12],
        'Pain time (sec)':[115,45,27,18,13,11,7,5,4],
        '2nd Degree Time (sec)':[663, 187,92,57,40,30,20,14,11]}
df = pd.DataFrame(data)
```

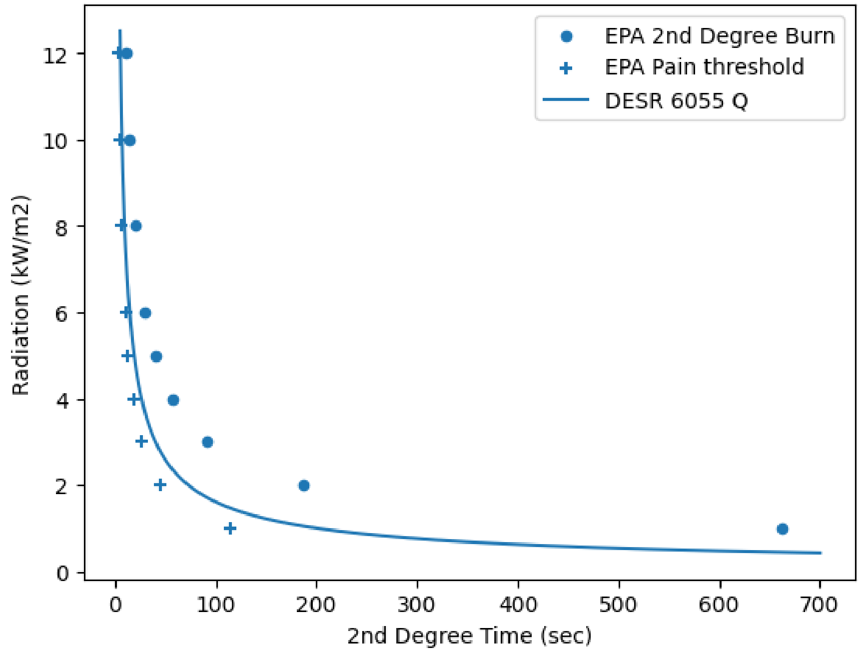
DESR 6055.09 is the handbook for the Department of Defense and gives the following relationship for heat flux (q, kW/m2) and time,t, before a 2nd degree burn:

$$t = 200 \cdot q^{-1.46} \tag{1}$$

```
#Causitive variable from Probit correlations from death from burning
import numpy as np
time = np.linspace(5, 700, 1000)
def Q2(t):
    return (t/200)**( -1/1.46)

import matplotlib.pyplot as plt
df.plot(x='2nd Degree Time (sec)', y='Radiation (kW/m2)', kind = 'scatter', label='EPA 2nd Degree Burn')
```

```
plt.scatter(df['Pain time (sec)'], df['Radiation (kW/m2)'], marker = '+', label = 'EPA Pain threshold')
plt.plot(time, Q2(time), label = 'DESR 6055 Q')
plt.legend(); plt.show()
```



The above plot shows that the relationship used for the military (DESR 6055) is conservative relative to the EPA's Handbook of Chemical Hazards Analysis Procedures. Considert that in full sun, the approximate radiation is 1 kW/m2. Would it really take 660 seconds (11 minutes) to get a sunburn that blisters? No, it would take longer indicating that both relationships are conservative.

200/60

```
3.3333333333333335
```

1.1 Estimating thermal flux from a fire

The radiation from a fire or fireball descreases with the square of the distance from the fire. The heat flux is given by:

$$q = \frac{P}{4\pi r^2} \tag{2}$$

where P is the power of the fire in watts and r is the distance from the fire in meters.

Thus, if a fire has a power of 1 MW and you are 10 meters away, the heat flux is:

'Your answer here'

How long would you have before a 2nd degree burn?

2 Overpressure Hazards

3 Noise

Sound pressure level (SPL) is used as an intensity measure. The lowest SPL that can be heard by the human ear is near 2E-5 Pa. Thus in the below equation I_o is 2E-5 Pa.

$$\text{dB} = 10 \log_{10}\left(\frac{I}{I_o}\right) \tag{3}$$

where P is the sound pressure and I is the intensity.

See "Permissible Noise Exposures," https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.95 where you can use the combination rule of $\sum \frac{D_i}{\text{MTA}_i} > 1?$ to determine if the worker is overexposed, where D_i is the duration at the given dB sound level and MTA is the maximum time allowed at that level.

Industrial hygienists help protect workers from over exposure: Industrial Hygienists.

4 Acute vs. Chronic

5 Elimination of Toxins

6 Process Injuries

7 Common Injury Frequencies

Action Items

1. Estimate the heat flux from a burning burst natural gas pipeline (shown here: https://www.youtube.com/watch?v=EverTT2D0NM). Estimate the heat flux at a distance of 50 feet from such a scenario. Assume a flow of natural gas of 0.25 kg per second.
2. Pick a needed chemical that is used in the plastics or rubber industry. Find and read a toxicology report on its effects on the body and summarized what you learned.
3. Pick a chemical that is a toxin and review the literature to determine teh pathway or process by which the body removes that specific chemical.
4. Review the "Green Beans Canning Procedure"Example Scenario: Canning Green Beans and detail three specific potential physical injury modes (e.g., thermal, overpressure, or blunt force) that could occur during this home process.
5. Read, watch a video, or otherwise learn about an incident as described by the US Chemical Safety Board (CSB) as detailed at csb.gov. Document some of the details of the event and what should happen in the future to prevent a similar accident.