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Solutions Manual for

Chemical Process Safety

Fundamentals with Applications

Third Edition

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Chapter 1

1-1 FAR = 4 @ 10^8 exposed hours

Deaths per person per year,

$$= \left(\frac{4 \text{ hrs}}{\text{shift}}\right)\left(\frac{200 \text{ shifts}}{\text{year}}\right)\left(\frac{4 \text{ deaths}}{10^8 \text{ hrs}}\right)$$

$$= \underline{3.2 \times 10^{-5}} \text{ deaths/person-year}$$

1-2 Three process units – FAR's: 0.5, 0.3, 1.0

a) Assuming exposure to all three units

Net FAR = Σ FAR's = 0.5 + 0.3 + 1.0 = <u>1.8</u>

b) 20% of time in area 1 with FAR 0.5
40% " " " " 2 " " 0.3
40% " " " " 3 " " 1.0

Net FAR = (0.2)(0.5) + (0.4)(0.3) + (0.4)(1.0)

= <u>.62</u>

1-3 From Table 1-4, FAR travelling by car

= 57 deaths/10^8 exposed hours

or 1 death per $\frac{10^8}{57} = 1.75 \times 10^6$ hours

$$(1.75 \times 10^6 \text{ hours})\left(\frac{50 \text{ miles}}{\text{hour}}\right) = \underline{87.5} \text{ million miles}$$

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1-4 Normal working hours are approximately 2000 hours per year. For 500 years, we have

$$(500 \text{ years})\left(\frac{2000 \text{ hrs}}{\text{year}}\right) = 1 \times 10^6 \text{ hours}$$

We can assume 1 death every 10^6 exposed hours. But FAR's are based on 10^8 exposed hours. This means

$$\frac{10^8}{10^6} = 100 \text{ deaths per } 10^8 \text{ hours} \quad \therefore \text{FAR} = 100$$

The workers should be alarmed! For an average chemical plant, FAR = 4 deaths/10^8 hrs

$$\text{Deaths per year} = (2000 \text{ hrs})\left(\frac{4 \text{ deaths}}{10^8 \text{ hrs}}\right) = 8 \times 10^{-5}$$

$$\text{Years per death} = \frac{1}{8 \times 10^{-5}} = 12{,}500$$

Chances should be 1 in 12,500 years of exposure.

1-5 Total working hours per year

$$= (1500 \text{ workers})\left(\frac{2000 \text{ hrs}}{\text{worker}}\right) = 3 \times 10^6 \text{ hrs}$$

$$\text{Deaths per year} = (3 \times 10^6 \text{ hrs})\left(\frac{5 \text{ deaths}}{10^8 \text{ hrs}}\right)$$

$$= .15 \text{ deaths}$$

A death can be expected every 6.6 years.

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1-6 FAR of rock climbing = 4000
FAR of travelling by car = 57

$\frac{4000}{57}$ = 70.2 hrs travel by car

1-7 a) Initiation - cutting into 10-inch propane line

Propagation - leakage of propane
- formation of vapor cloud
- ignition of vapor cloud
- destruction of fire pump equipment

Termination - blocking in of the propane

b) Initiation - improper closing of valve
- cleaning of strainer with escape of butane

Propagation - ignition of vapor cloud
- rupturing of pipeline
- falling of fractionation tower and breaking of pipeline

Termination - isolation of fuel source

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1-8 Airline industry has fewest deaths per passenger mile, <u>but</u>, due to high rate of speed of the aircraft, many miles are accumulated. From Table 1-4, FAR for:

Car - 57

Bicycle - 96

Air - 240

Thus, on a <u>per hour</u> basis, travelling by plane is almost <u>5 times</u> more dangerous than travelling by car.

To compute the FAR, we need the total hours exposed. This would require an average speed. Suppose the average speed is 200 MPH.

$$\text{Total hours exposed} = \frac{10 \times 10^6 \text{ miles}}{200 \text{ mi/hr}}$$

$$= 50{,}000 \text{ hrs}$$

$$\text{FAR} = \frac{4 \times 10^8}{50{,}000 \text{ hrs}} = \underline{8{,}000}$$ which is larger than the 240 reported in Table 1-4.

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A fatality rate would require the total number of passengers in the 10^7 miles. Suppose each trip averaged 300 miles.

$$\text{Total passengers} = \frac{10^7 \text{ miles}}{300 \text{ mi/person}} = 33,333 \text{ passengers}$$

$$\text{Fatality rate} = \frac{4}{33,333} = 1.2 \times 10^{-4}, \text{ which is high}$$

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1-9 A university had about 1200 full-time employees. In a particular year, this university had a total of 38 reportable lost time injuries with a resulting 274 lost workdays. Compute the OSHA incidence rate based on injuries and lost workdays.

Solution:

(a) $$\text{OSHA injury rate} = \frac{\text{No. of Injuries}}{\text{Total hours worked}} \times 200{,}000 \text{ hrs}$$

Total hours worked

$$= (1200 \text{ employees})\left(2000 \frac{\text{hours}}{\text{employee}}\right)$$

$$= 2.4 \times 10^6 \text{ Hours}$$

$$\text{OSHA injury rate} = \left(\frac{38 \text{ injuries}}{2.4 \times 10^6 \text{ Hours}}\right)(200{,}000 \text{ hours})$$

$$= 3.17$$

(b) OSHA LOST WORKDAYS

$$= \left(\frac{274 \text{ LOST workdays}}{2.4 \times 10^6}\right)(200{,}000 \text{ hours})$$

$$= 22.8$$

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1-10 Based on . . workplace fatalities (Figure 1-4) and assuming you are responsible for a safety program of an organization, what would you emphasize?

Solution:

You could probably dedicate 45% of your time on transportation safety, 17% on violent acts, 17% on equipment safety, 13% on falls, 10% on exposures and 3% on fires and explosions. Fires and explosions, however, . . should be given more effort because a single fire or explosion could be a catastrophic event (many injuries and fatalities) and the concepts are relatively difficult to comprehend learn, and apply.

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1-11 Based on the causes of the largest losses, Figure 1-7, what would you emphasize in a safety program?

Solution:

Based on these statistics, it is clear that emphasis needs to be given to mechanical and process designs and to operator training. Additionally, it should be recognized and emphasized, that all accidents are ultimately the result of people making mistakes. Design and Training require a significant effort, because small errors in the beginning of a project may evolve into major problems.

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