Retardant tank calculations

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Chapter 1

Mass of retardant

Density of retardant = 9 lb/gallon
1 lb = 0.45kg

1.1 3000 gallons

$$\begin{aligned} m &= \rho * V \\ m_{3000} &= 9 * 3000 \\ &= 27000 \; lbs \\ &= 12150 \; kg \end{aligned} \tag{1.1}$$

1.2 5000 gallons

$$\begin{aligned} m &= \rho * V \\ m_{5000} &= 9 * 5000 \\ &= 45000 \; lbs \\ &= 20250 \; kg \end{aligned} \tag{1.2}$$

Chapter 2

Gravity drop

2.1 Required retardant exit area

2.1.1 Methodology

Instantaneous mass flow rate

The Instantaneous mass flow rate can be found using this equation:

$$\dot{m} = \rho v A \tag{2.1}$$

where:
ρ = density of retardant (kg/m^3)
v = velocity of retardant (m/s)
A = area of escape of retardant (m/s)

Finding the required exit area

Using equation 2.1 for a given A we can find the mass flow at each time step using the velocity at that time step. This can be integrated with respect to time to find the total mass that flowed through the exit area over the duration. The mass flow increases linearly over the duration, because the velocity is linear. This means the integration can be done using the area of the triangle under the graph.

Using Matlab the total mass that flows though the exit can be calculated for a range of values of A. Then the smallest value of A that can reach the required total mass flow can be found.

2.1.2 Matlab

Code

The Matlab code to calculate the required exit area for volumes of 3000, 4000 and 5000 gallons is shown below:

```
clear;
clc;

t_end=8; %simulation lasts 8 seconds
t=0:0.1:t_end; %create time array
rho=1078.44; %retardant density in kg/m3

for V_gallons=[3000,4000,5000] %loop over desired gallon values

    V=V_gallons/220; %convert gallons to m^3
    m_target=V*rho; %calculate mass of retardant

    g=9.81;
    v=g*t; %velocity over time due to gravity

    masses=[]; %empty array to store mass
    A=0:0.001:0.5; %testing values of area from 0 to 0.5 m^2
    for current_A=A %loop over values of area
        %current_A is the area that is being tested this loop
        m_dot= rho.*current_A.*v; %calculate m_dot for this current_A
        total_m=(1/2)*m_dot(length(m_dot))*t_end; %calculate total mass that left the tank with current_A by integrating m_dot
        %g is constant so total_m is linear over time, so can be found with the area of a triangle
        masses=[masses,total_m]; %append total_m for this current_A to an array
    end

    %algorithm to find the area for which the total mass through the exit is closest to m_target
    closest=inf; %initial value for closest to m_target
    for i=1:1:length(masses) % loop over all values of masses
        if abs(masses(i)-m_target)<closest %check if value at masses(i) is closer than closest
            closest=abs(masses(i)-m_target); %set new closest to current closest
            required_area=A(i); %save area for closest value
        end
    end
    %print to command window
    fprintf('%.0f gallons of retardant requires %.3f m2 area\n',V_gallons, required_area);
end
```

Output of code

```
3000 gallons of retardant requires 0.043 m2 area
4000 gallons of retardant requires 0.058 m2 area
5000 gallons of retardant requires 0.072 m2 area
»
```

Chapter 3

Bernoulli simulation

3.1 Methodology

3.1.1 rearranging bernoulli

$$\begin{aligned}
p_{top} + \frac{1}{2}\rho V_{top}^2 + \rho g h_{top} &= p_{bot} + \frac{1}{2}\rho V_{bot}^2 + \rho g h_{bot} \\
\Delta P + \rho \Delta h + \frac{1}{2} &= \frac{1}{2}\rho V_{bot}^2 \\
2\Delta P + \rho(2\Delta h + V_{top}^2) &= \rho V_{bot}^2 \\
\frac{2\Delta P}{\rho} + 2\Delta h + V_{top}^2 &= V_{bot}^2 \\
V_{bot} &= \sqrt{\frac{2\Delta P}{\rho} + 2h + V_{top}^2}
\end{aligned} \tag{3.1}$$

Done iteratively:

$$V_{bot}(t) = \sqrt{\frac{2\Delta P}{\rho} + 2h(t) + V_{top}^2(t)} \tag{3.2}$$