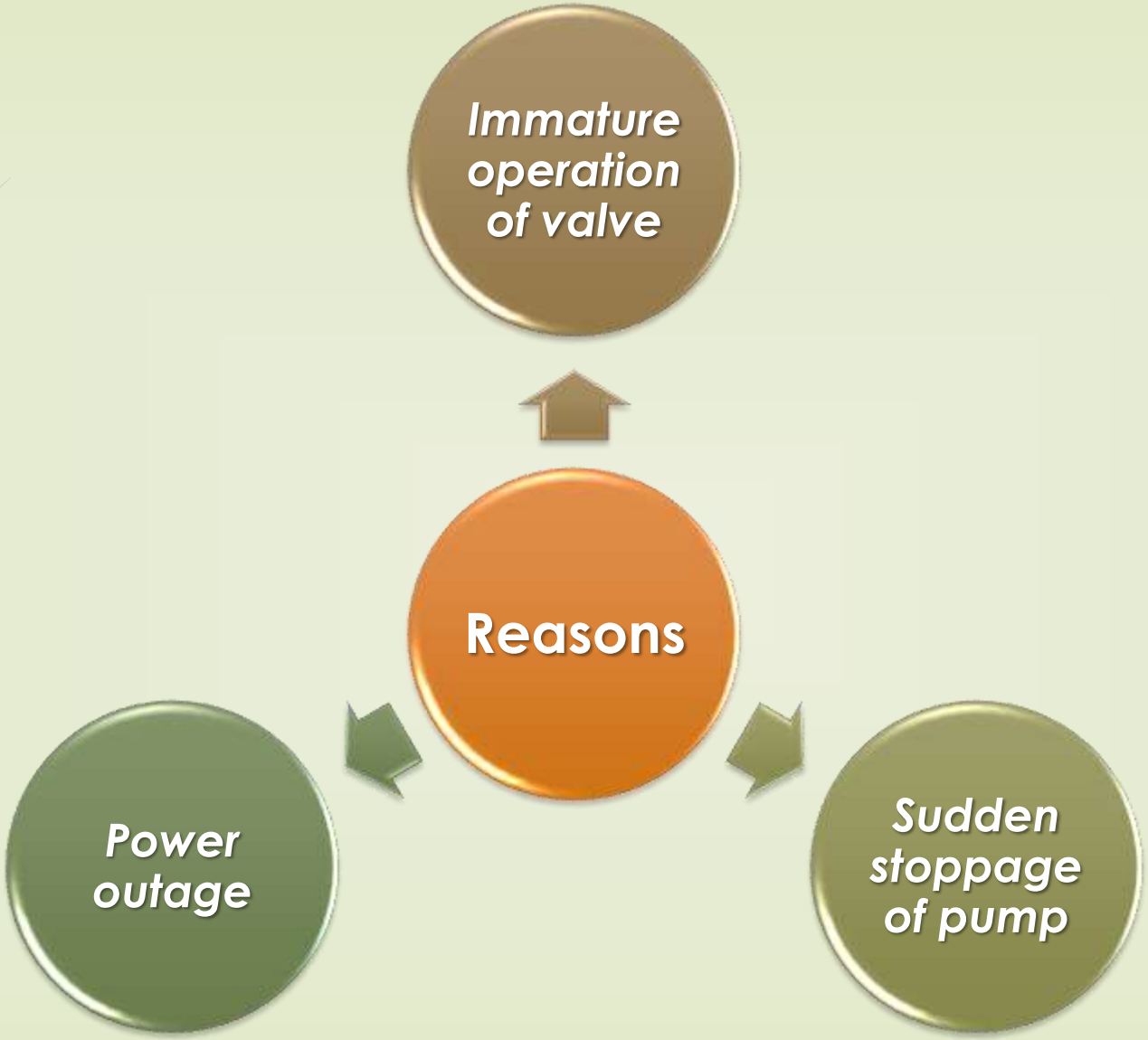
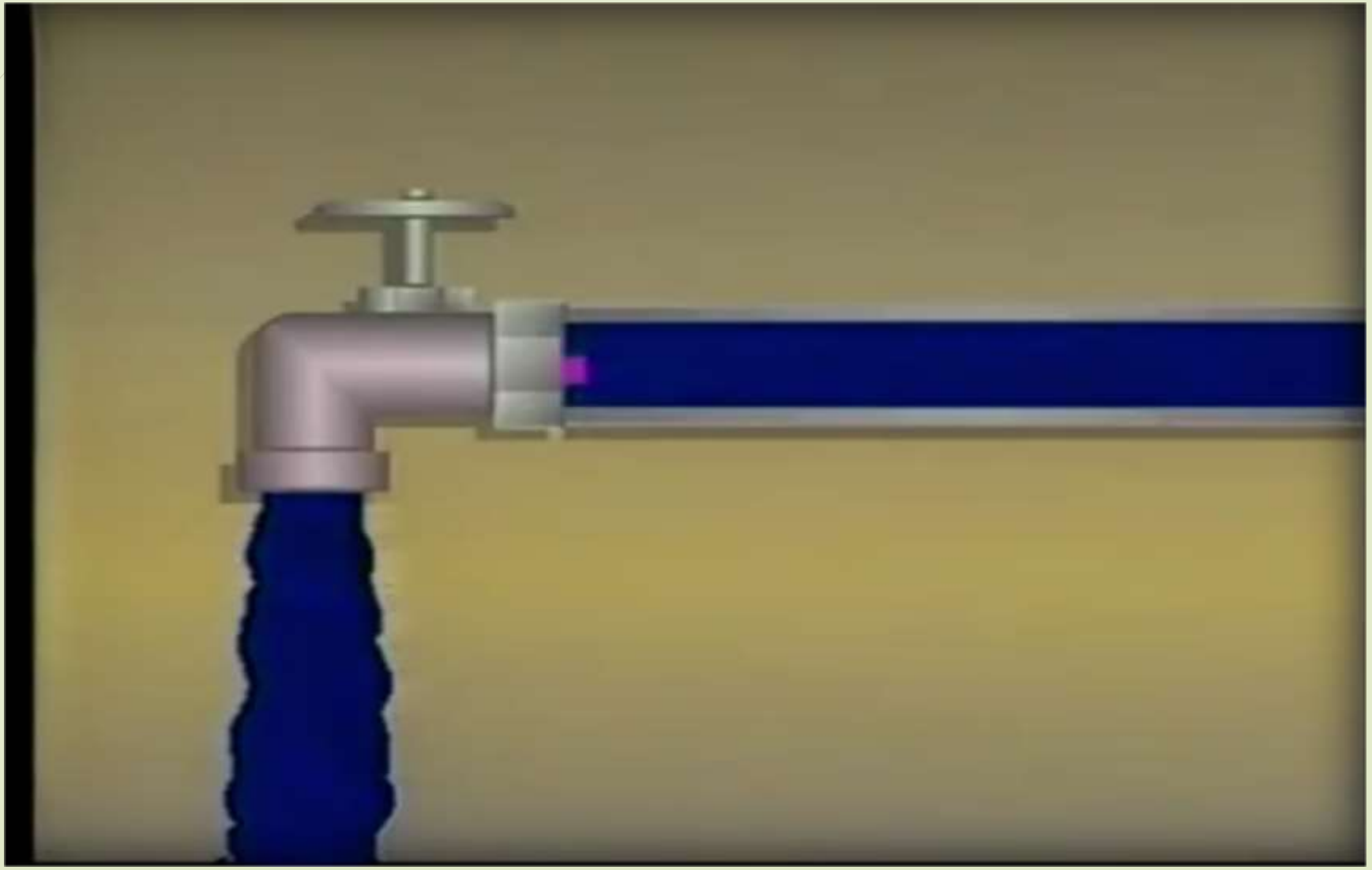
What is Water Hammer?

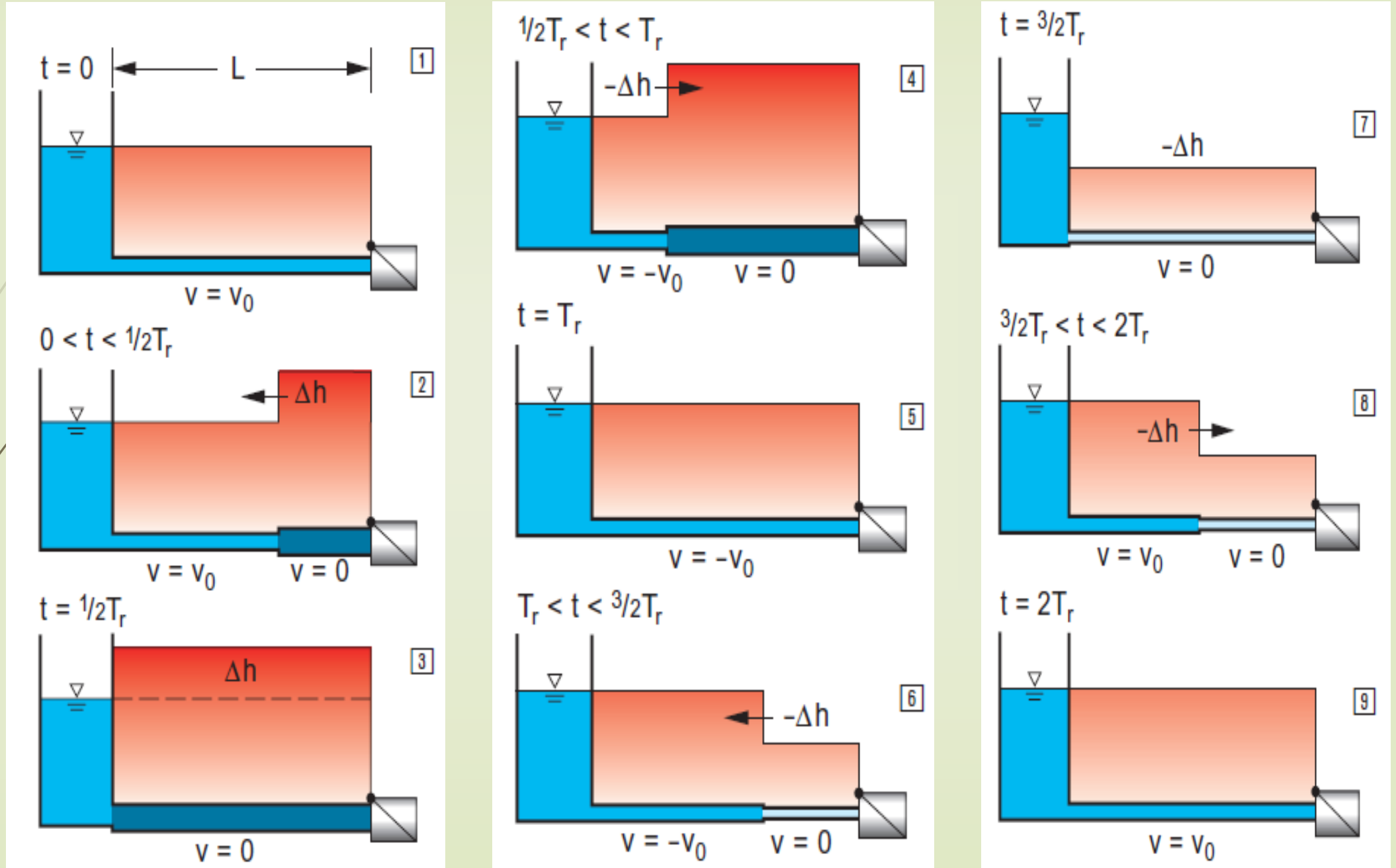
- **Water hammer** is a pressure surge or wave resulting when a fluid in motion is forced to stop or change the velocity
- A water hammer commonly occurs when a valve closes suddenly at an end of a pipeline system, and a pressure wave propagates in the pipe. It is also called *hydraulic shock*.


Immature operation of valve
Reasons
Power outage
Sudden stoppage of pump

Sudden Closure Of A Valve



Mechanism



Fluid Mechanics with Engineering applications by Joseph B Franzini & E.John Finnemore

Mechanism

At the Reservoir

- Unbalanced condition
- Due to Negative pressure in the pipe
- Flow towards pipe starts(4L/a)

Sudden Closure of the valve

- Fluid lamina near to the valve compressed
- This compression reaches upstream end of the pipe(t=L/a)

At the Reservoir

- Unbalanced condition at the reservoir pressure
- Flow from pipe to reservoir starts as the wave moves downstream
- Reservoir pressure unchanged(2L/a)

Low pressure moves upstream as waves

- Makes the velocity of flow zero again
- But the fluid in the pipe will be expanded(3L/a)

Fluid Mechanics by Victor L Streeter, E Benjamin Wylie & Keith W Bedford

Water Hammer Equations

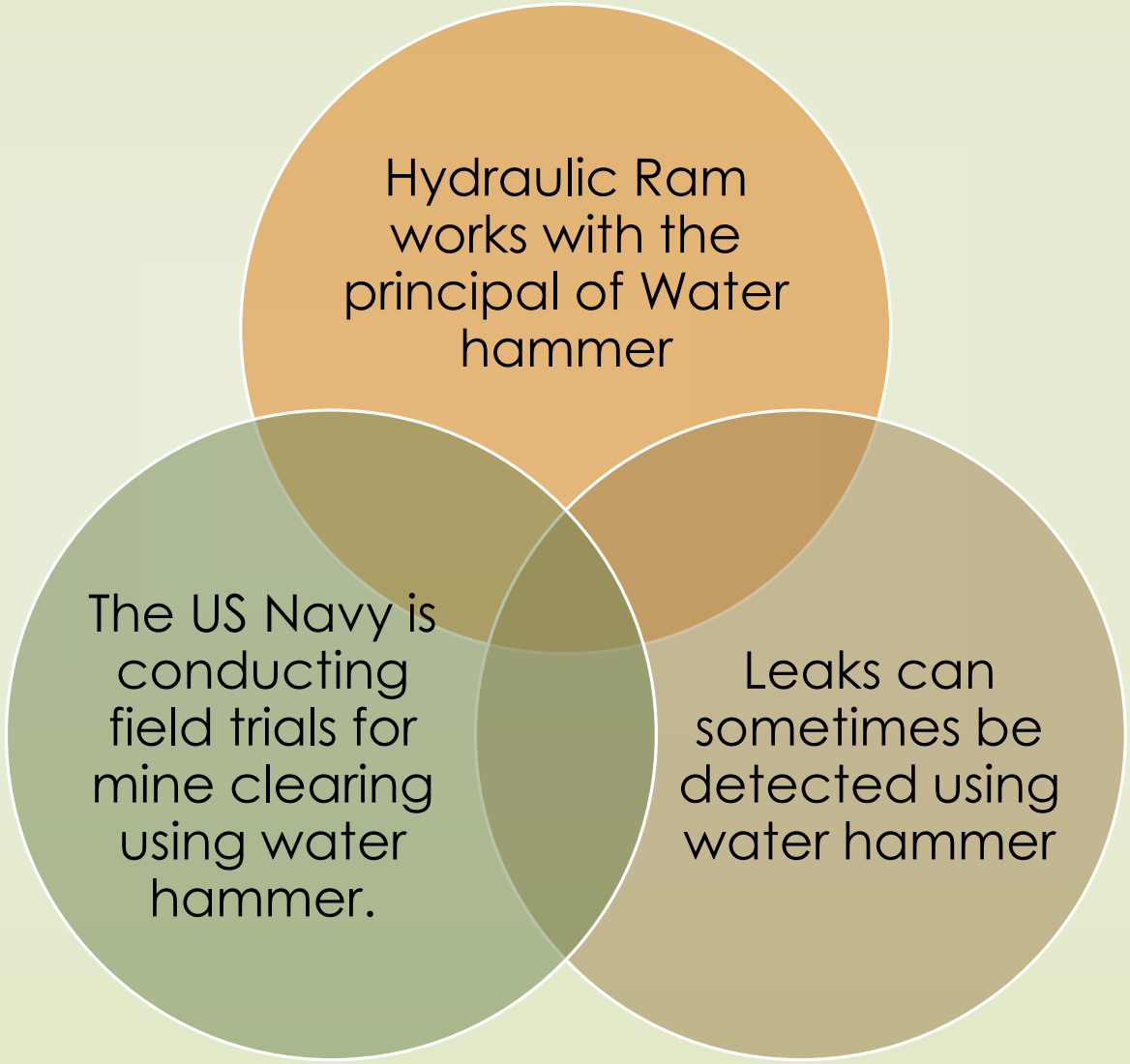
- Joukowsky (1898) eqn

$$\Delta P = \rho C_p \Delta V$$

  - Where ΔP is change in pressure
  - ρ density
  - C_p is the velocity of wave (1496 m/s at 25°C in water)
  - ΔV is change in velocity
  - This equation can be used only for rapid closure(t < 2L/C_p)

- Water hammer equations for all conditions:
  - Equation of motion
  - $\frac{\partial V}{\partial t} + g\frac{\partial H}{\partial x} + \frac{fV|V|}{2D} = 0$
  - Equation of continuity
  - $\frac{\partial H}{\partial t} + \frac{a^2}{g}\frac{\partial V}{\partial x} = 0$
- These two pde are solved using method of characteristics.

Applications



Effects of Water Hammer

- Damage to pipes, fittings, and valves, or any connected equipment causing leaks and shortening the life of the system
- Bursting of pipes can occur if the pressure is high enough
- Water hammer can have devastating effects on pump system

Example of piping damaged by water hammer

Devices for Protection from Water Hammer

- Soft Starters

- Slow closing valves

- Variable Frequency Devices

- Water Hammer Arrestors

- Surge Tanks

- Pressure Release Valves

Conclusions

- Water hammer can cause severe problems in the system if not designed properly. So at the time of designing of the system potential water hammer problems should be considered for thorough analysis. And proper methods or devices are to be used so as to assure the proper functioning of the system and to lessen the effect of water hammer
- Water hammer is useful in certain cases as hydraulic ram, mine clearing etc.