Fire Protection Hydraulics and Water Supply Analysis

FPST2483

Chapter 3: Hydrokinetics

LEARNING OBJECTIVES

- Upon completing this module, the student should be able to:
  1. Understand the principles of conservation of matter;
  2. Explain the importance and relevance of kinetic energy on water
  3. Describe the principles of Conservation of Energy and Conservation of Matter

CONSERVATION OF MATTER

- MATTER CAN NEITHER BE CREATED OR DESTROYED
- THE QUANTITY OF WATER ENTERING ONE END OF A PIPE IS EQUAL TO THE QUANTITY LEAVING THE OTHER END.

Principles Of Water Flow In Piping Or Hose Systems

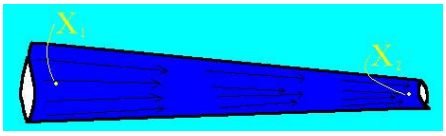
- *Derivatives of conservation of matter:*
  - *Principle 1. If the pipe or hose size remains constant, water velocity within a system will be constant.*
  - *Principle 2. Within the same system, an increase in pipe or hose diameter will result in a reduction in water velocity.*

$$Q = A \cdot v = \text{constant}$$

Principles Of Water Flow In Piping Or Hose Systems

- *Principle 3. Within the same system, a reduction in pipe or hose size will result in an increase in water velocity.*
- *Principle 4. If pipe or hose size within a system remains constant, water flowing uphill will travel with the same velocity as water flowing downhill.*

$$Q = A \cdot v = \text{constant}$$



SO: $Q_1 = Q_2$
OR: $A_1V_1 = A_2V_2$
$Q_2 = A_2V_2$
$V_2 = Q_2 / A_2$

THE QUANTITY OF WATER FLOWING THROUGH A PIPE, NOZZLE, OR ORIFICE IS EQUAL TO THE CROSS SECTIONAL AREA OF THE PIPE, ETC. MULTIPLIED TIMES THE WATER VELOCITY.

Q = A V , WHERE:

A = AREA IN FT^2 OR IN^2

V = WATER VELOCITY IN FT/SEC, FT/MIN, IN/SEC, ETC

Q = QUANTITY OF FLOW RATE IN FT^3/SEC, FT^3/MIN, IN^3/SEC, ETC.

(MOST OFTEN CONVERTED TO GPM)

HYDRAULIC KINETIC ENERGY IS:

1. ENERGY POSSESSED BY WATER IN MOTION.
2. RELATED TO THE VELOCITY OF THE WATER AND IS OFTEN REFERRED TO AS “VELOCITY HEAD”.
3. IF WATER IS AT REST,
   KINETIC ENERGY = 0

ENERGY = WORK

$$W = F \cdot d = mad =$$

$$= m \cdot \frac{v_2 - v_1}{t} \cdot \frac{v_2 + v_1}{2} \cdot t = \frac{m}{2}\left(v_2^2 - v_1^2\right)$$

$$KE = \frac{mv^2}{2}$$

KE= Kinetic Energy

W= Work

m = a mass of water

v = the velocity of the water

ADD GRAVITY

- When gravity is causing movement of water we can say:

$$W = m \cdot g$$

- W = weight of the particle
- g = gravity (32.2 ft/sec^2)

$$KE = \frac{Wv^2}{2g}$$

- Represents the Kinetic energy of water

FROM PHYSICS, FOR ANY FALLING BODY:

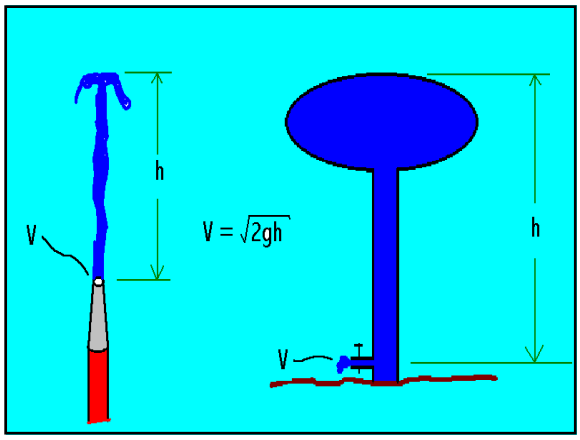
$$V = \sqrt{2gh}$$

Where: V = VELOCITY IN FT/SEC
g = ACCELERATION DUE TO GRAVITY (32.2 FT/SEC^2)
h = HEIGHT IN FEET

FOR ANY VELOCITY OF WATER, FROM

$$V = \sqrt{2gh}$$

THE HEIGHT FROM WHICH WATER MUST BE DROPPED TO ACHIEVE THAT VELOCITY CAN BE CALCULATED. THIS HEIGHT IS A MEASURE OF THE KINETIC ENERGY AND IS THE “VELOCITY HEAD”.



SO,

$V = \sqrt{2gh}$

$V^2 = 2gh$

$h = V^2 / 2g$

AND,

KINETIC ENERGY = VELOCITY HEAD = $V^2 / 2g$

NOTE: IF YOU NEED KINETIC ENERGY IN TERMS OF "VELOCITY PRESSURE", JUST REMEMBER h = P / w,
TO GET $V = \sqrt{((2gP) / w)}$

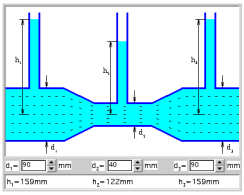
CONSERVATION OF ENERGY & BERNOULLI'S EQUATION

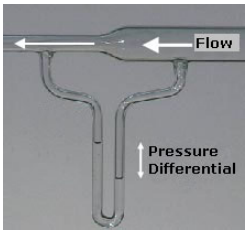
LAW OF CONSERVATION OF ENERGY:

"ENERGY CANNOT BE CREATED OR DESTROYED SINCE THE TOTAL AMOUNT OF ENERGY AVAILABLE IS CONSTANT."

Bernoulli's Theorem

- ***In a steady flow without friction, the sum of the velocity head, pressure head, and elevation head is constant for any incompressible fluid particle throughout its course.***





TOTAL ENERGY = POTENTIAL ENERGY + KINETIC ENERGY

OR: TE = PE + KE

AND:

TE = $(PE)_{\text{PRESSURE HEAD}}$ + $(KE)_{\text{VELOCITY HEAD}}$ + $(PE)_{\text{ELEVATION HEAD}}$

SO:

$$TE = P / w + V^2 / 2g + h$$

Conditions for Bernoulli's equation

- Incompressible flow
- Low-speed flow
- Laminar invisid flow (non-Newtonian fluids)

BERNOULLI

APPLYING THE LAW OF CONSERVATION OF ENERGY, DEDUCTED THAT WITHIN A HYDRAULIC SYSTEM THE TOTAL ENERGY IS THE SAME AT ALL POINTS.

SO: $TE_1 = TE_2$

OR….

BERNOULLI'S EQUATION

$$h_1 + \frac{P_1}{w} + \frac{v_1^2}{2g} = h_2 + \frac{P_2}{w} + \frac{v_2^2}{2g}$$

potential pressure kinetic

Given:
h = head in feet
P = pressure in psi
w = the specific weight of the fluid (62.4 lbs/ft^3 for water)
g = the acceleration of gravity
v = velocity in feet per second

BERNOULLI'S EQUATION:

$P_1 / w + V_1^2 / 2g + h_1 = P_2 / w + V_2^2 / 2g + h_2$

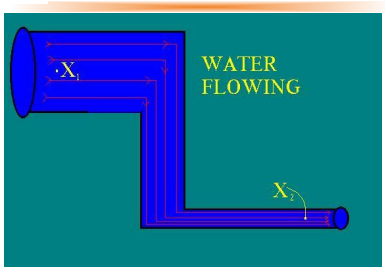
FOR WATER:

$P_1 / 0.433 + V_1^2 / 2g + h_1 = P_2 / 0.433 + V_2^2 / 2g + h_2$

and

$P_1 / 0.433 = 2.31 P_1$

CONSIDER:



$TE_1 = TE_2$

$PE_1 \neq PE_2$

$KE_1 \neq KE_2$

- AT POINTS X_1 AND X_2 TOTAL ENERGY IS THE SAME

FRICTION LOSS IN PIPING SYSTEMS

THE BERNOULLI EQUATION IN ITS ORIGINAL FORM DOES NOT CONSIDER ENERGY LOSSES DUE TO FRICTION. HOWEVER, THESE LOSSES ARE VERY REAL AND MUST BE ACCOUNTED FOR. THUS THE ENERGY BALANCE EQUATION BECOMES:

$P_1 / w + V_1^2 / 2g + h_1 = P_2 / w + V_2^2 / 2g + h_2 + h_f$

NOTE: h_f = FRICTION LOSS IN UNITS OF FEET

Hydrokinetics

- Energy in a hydraulic system can neither be created nor destroyed:
  - **Total Energy = Potential Energy + Kinetic Energy**
- Principle of Conservation of Energy:
  - ***The total energy within a system will remain constant.***

Summary

- The study of fluids in motion is called hydrokinetics.
- The principle of energy conservation is expressed in Bernoulli's Equation.
- The principle of the conservation of matter states that matter can neither be created nor destroyed.
- Bernoulli's equation has many applications