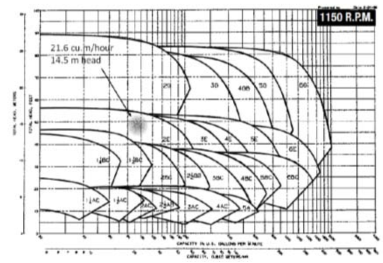
ENGR 292 Fluids and Thermodynamics

Scott Li, Ph.D., P.Eng.
Mechanical Engineering Technology
Camosun College

Feb.10, 2017

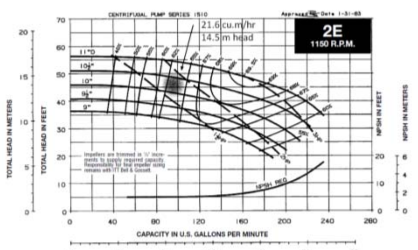
Review of Last Class

- **Pump Selection by Pump Curves**



Review of Last Class

- **Pump Selection by Pump Curves**



Review of Last Class

- **NPSH: Net Positive Suction Head**
  - $NPSH_A$: **NPSH available**
  - $NPSH_R$: **NPSH required**

Review of Last Class

- $NPSH_A$: **NPSH available**

$$NPSH_A = \frac{P_{atm}}{\gamma} - h_e - h_f - \frac{P_v}{\gamma}$$

$\frac{P_{atm}}{\gamma}$: *atmospheric pressure or absolute pressure at the fluid surface*

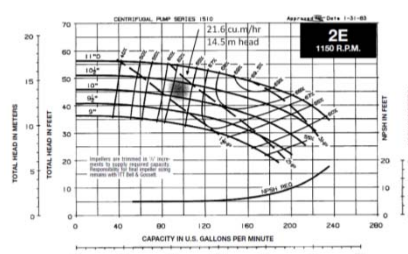
h_e : *Lift from fluid surface to pump*

h_f : *Suction line head loss*

P_v: *Fluid vapor pressure*

Review of Last Class

- $NPSH_R$: **NPSH required**



Review of Last Class

- **Check the Suction Design:**

$$NPSH_A > NPSH_R$$

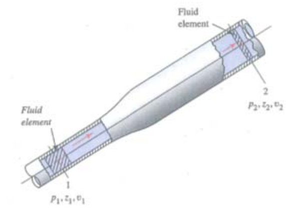
The pump is happy ☺

7

Review of Last Class

- **Bernoulli's equation**

$$\frac{p_1}{\gamma} + z_1 + \frac{v_1^2}{2g} = \frac{p_2}{\gamma} + z_2 + \frac{v_2^2}{2g}$$



8

Review of Last Class

- **General Energy Equation**

$$\frac{p_1}{\gamma} + z_1 + \frac{v_1^2}{2g} + h_A - h_R - h_L = \frac{p_2}{\gamma} + z_2 + \frac{v_2^2}{2g}$$

9

Fluid Dynamics

- ***Main topics of Fluid Dynamics:***
  - *Conservation of mass*
  - *Momentum and energy*
  - *Bernoulli's equation & Navier-Stokes equation*
  - *Laminar & Turbulent flow in pipes*
  - *Turbo-machinery*

10

Learning Outcomes of Fluid Dynamics

- ***Explain why and when control volume analysis is used in fluids (and thermodynamics)***
- ***Identify an appropriate control volume***

11

Learning Outcomes of Fluid Dynamics

- ***Apply control volume analysis of mass and momentum conservation to solve problems in steady and unsteady fluid mechanics (and thermodynamics)***
- ***Apply Bernoulli's equation***

12

Learning Outcomes of Fluid Dynamics

- *Explain the physical significance of each of the terms in the Navier-Stokes equations*
- *Determine the non-dimensional parameters for a problem from a list of relevant dimensional parameters*

13

Learning Outcomes of Fluid Dynamics

- *Apply scaling to predict full-scale behavior from experimental data on a model*
- *Describe the fundamental differences between laminar and turbulent flow*

14

Learning Outcomes of Fluid Dynamics

- *Use the Moody diagram to determine pressure loss in a fully-developed pipe flow*
- *Account for minor losses in a pipe system*

15

Learning Outcomes of Fluid Dynamics

- *Determine a system curve for a pipe system*
- *Use a pipe system curve and pump performance data to predict performance and select an appropriate pump*

16

Navier-Stokes Equation

- *The governing equation of fluid statics, called the hydrostatic equation, is relatively simple and may always be solved to find the pressure distribution in the fluid.*

17

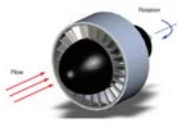
Navier-Stokes Equation

- *On the other hand, the governing equation of fluid dynamics, called the Navier-Stokes Equation, would never be described as simple.*
- *Navier-Stokes Equation will be covered later in this course.*

18

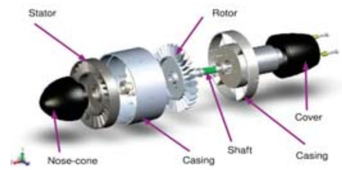
Turbo-machinery

- **A turbomachine is a device that exchanges energy with a fluid using continuously flowing fluid and rotating blades.**
- **Examples:**
  - ***Aircraft engines***
  - ***Wind turbines***



Turbo-machinery

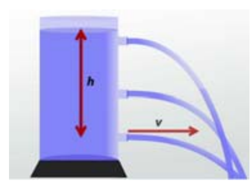
- ***If the device extracts energy from the fluid it is generally called a turbine.***



Turbo-machinery

- ***If the device delivers energy to fluid it is called a compressor, fan, blower, or pump***

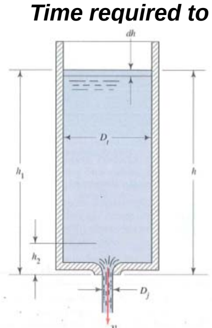
Torricelli's Theorem



$$\mathrm{v} = \sqrt{2gh}$$

Flow due to a Falling Head

Time required to drain a Tank:



$$t_2 - t_1 = \frac{2\left(\frac{A_t}{A_j}\right)}{\sqrt{2gh}}\left(\sqrt{h_1} - \sqrt{h_2}\right)$$

Midterm Review

- ***Key Equations:***
  - ***Volume Flow Rate:***

    $$\boldsymbol{Q = A\mathrm{v}}$$

  - ***Weight Flow Rate:***

    $$\boldsymbol{W = \gamma Q}$$

  - ***Mass Flow Rate:***

    $$\boldsymbol{M = \rho Q}$$

Midterm Review

- **Key Equations:**
  - ***Continuity Equation for any Fluid:***

$$\rho_1 A_1 v_1 = \rho_2 A_2 v_2$$

  - ***Continuity Equation for Liquids:***

$$A_1 v_1 = A_2 v_2$$

25

Midterm Review

- **Key Equations:**
  - ***Bernoulli's Equation:***

$$\frac{p_1}{\gamma} + z_1 + \frac{v_1^2}{2g} = \frac{p_2}{\gamma} + z_2 + \frac{v_2^2}{2g}$$

  - ***Torricelli's Theorem:***

$$v_1 = \sqrt{2gh}$$

26

Midterm Review

- **Key Equations:**
  - ***Time required to drain a tank:***

$$t_2 - t_1 = \frac{2\left(\frac{A_t}{A_j}\right)}{\sqrt{2gh}}\left(\sqrt{h_1} - \sqrt{h_2}\right)$$

27

Midterm Review

- **Key Equations:**
  - ***General Energy Equation:***

$$\frac{p_1}{\gamma} + z_1 + \frac{v_1^2}{2g} + h_A - h_R - h_L = \frac{p_2}{\gamma} + z_2 + \frac{v_2^2}{2g}$$

  - ***Reynolds Number – Circular Sections:***

$$N_R = \frac{vD\rho}{\mu}$$

28

Midterm Review

- **Key Equations:**
  - ***Darcy's Equation for Energy Loss:***

$$h_L = f\,\frac{L}{D}\frac{v^2}{2g}$$

  - ***Hagen-Poiseuille Equation:***

$$h_L = \frac{32\eta L v}{\gamma D^2}$$

  - ***Friction Factor for Laminar Flow***

$$f = \frac{64}{N_R}$$

29

Midterm Review

- **Key Equations:**
  - ***Power Added to A Fluid by A Pump:***

$$P_A = h_A \gamma Q$$

  - ***Pump Efficiency:***

$$e_M = \frac{\text{Power delivered to fluid}}{\text{Power put into pump}} = \frac{P_A}{P_1}$$

30

Midterm Review

- **Key Equations:**
  - *Power Removed from a Fluid by a Motor:*

$$P_R = h_R \gamma Q$$

  - *Motor Efficiency:*

$$e_M = \frac{Power\ output\ from\ motor}{Power\ delievered\ by\ fluid} = \frac{P_O}{P_R}$$

31

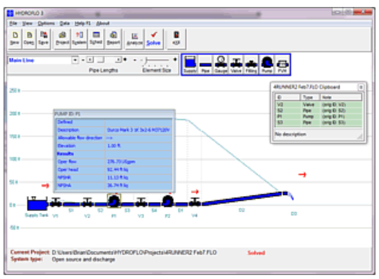
Fluid Dynamics

- ***Use of Software for Pipe Flow Problems***
  - ***Piping System Design Software from Tahoe Design Software (www.tahoesoft.com)***
    - ***HYDROFLO for Piping System Analysis***
    - ***PumpBase for Advanced Pump Selection***
    - ***HCALC for Pipe Calculator and Unit Converter***

32

Fluid Dynamics

- ***HYDROFLO***



33

Fluid Dynamics

- ***HYDROFLO***

HYDROFLO™ for piping system analysis

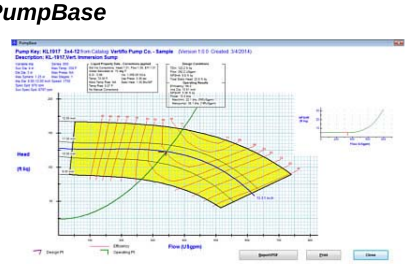
Solve for flows and pressures in complex piping systems.

Features...
- Drag-and-drop single or groups of elements using clipboard
- Analyze up to 10 parallels containing up to 20 pumps
- Graphics of pipelines, system, pump, and NPSHR curves
- Group editing with tagging of elements
- Cavitation calculations
- Large selection of check and control valves and fittings
- Starts PumpBase and transfers data

34

Fluid Dynamics

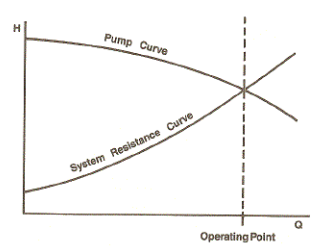
- ***PumpBase***



35

Fluid Dynamics

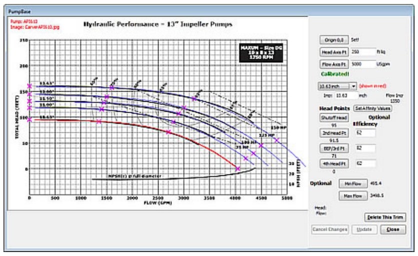
- ***Pump Curve vs. System Resistance Curve***



36

Fluid Dynamics

- PumpBase



37

Fluid Dynamics

- PumpBase

PumpBase™ – Advanced Pump Selection

Analysis of pump systems with pump selection. Input: TDH, flow, NPSHA, system curve, and viscous liquid properties. 40+ selection criteria (speed, orientation, features, and recommended application type).

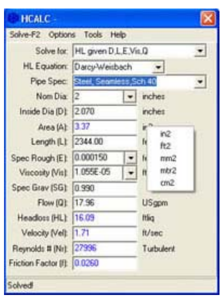
Features...

- Pump curve database editor
- Efficiency and NPSHR curve plots
- Automatic and manual viscosity corrections
- Affinity law conversions
- Ability to solve for variable trim/speed
- Selected pumps sorted by efficiency
- 1000+ curves from dozens of manufacturers

38

Fluid Dynamics

- HCALC



39

Fluid Dynamics

- HCALC

HCALC™ – Pipe Calculator and Unit Converter

Solves for head loss, diameter, flow, pipe area, velocity, Reynolds number, and friction factor using the Darcy-Weisbach, Hazen-Williams, or Manning's equations. HCALC converts values between various common units. Run HCALC as a stand-alone application or have it load at startup and always be available on system tray. A very useful tool for engineers.

40

Fluid Dynamics

- Use of Software for Pipe Flow Problems
  - PIPE-FLO from Engineering Software Inc. (ESI)
  - Students and Instructors can access the special version of PIPE-FLO at this site:
  - http://www.eng-software.com/appliedfluidmechanics

41

What is next?

- Any Questions?
- Next week, Reading Break
- Feb.21: Thermodynamics 1
- Feb.24: Midterm Review (Fluid Statics and Fluid Dynamics) + Thermodynamics
- Assignment 2 Due: Feb.24
- Midterm: Feb.28

42