About this document

This document contains screenshots of software available from Cheresources.com. You can find this title in our online store at:

http://www.cheresources.com/cheplusstore/catalogue.php

Clicking the above link should activate your default browser and launch the site.

We recommend using our search feature to find the title.

If you haven't visited our site before, you can find the main page at:

http://www.cheresources.com

Thanks for visiting our site,

Chris Haslego
President
Cheresources, Inc.

1422 Goswick Ridge Road
Midlothian VA 23114

Fax: 561-658-6489
Email: support@cheresources.com

Content Based
Chemical Engineering

Water Hammer Pressure Development

This calculation procedure will find the pressure developed from water hammer and the minimum recommended valve closing time to avoid damage to piping systems.

Both english and metric units of measure are available.

Sheets are protected, but protection may be turned off.

Revision History :

Water Hammer Pressure Development

Applicable to : Liquids flowing in a single size line that is assumed to be rigid

Calculation Details:

Pressure developed when a control valve closes (hydraulic shock):

$$h_{hs} = \frac{v_{pr}\ v_{act}}{g} \quad (1)$$

$$v_{pr} = \sqrt{\frac{(E_v / \rho)}{(1 + K B_r)}} \quad (2)$$

$$v_{act} = \frac{V}{A_x} = \frac{M}{A_x \rho} \quad (3)$$

$$t_s = \frac{2 L}{v_{pr}} \quad (4)$$

Nomenclature

- h_{hs} = maximum pressure developed by hydraulic shock (ft water)
- v_{pr} = velocity of propogation of elastic vibration (ft/s)
- v_{act} = actual fluid velocity in pipe (ft/s)
- g = gravitational constant (32.2 ft/s^2)
- E_v = bulk modulus of elasticity for the liquid (psi)
- ρ = liquid density (lb/ft^3)
- M = mass flow rate (lb/h)
- V = volumetric flow rate (GPM)
- A_x = pipe cross sectional area (ft^2)
- K = ratio of elastic modulus of liquid to pipe material
- B_r = ratio of pipe inside diameter to wall thickness
- L = length from source to control valve (ft)
- t_s = time required for the pressure wave to travel back and forth in the pipe (s)

Begin by Selecting Your Pipe Size

Define Problem

A pipe having an inside diameter of 258.8 inches is transferring **3500** GPM of **Water** to another location **3000** ft away. Find the maximum pressure developed at the control valve (3000 ft from the pump) by water hammer, if the line pressure at that point is **70** psig.

Enter the value for E_v for your fluid in the space below:

E_v = **312000** psi (water is 312000 psi) Other Liquids

Enter the density of your fluid in the space below:

ρ = **64.2** lb/ft^3 (water is 64.2 lb/ft3) Other Liquids

Enter the bulk modulus for the pipe material in the space below:

Pipe Bulk Modulus = **31200000** psi (CS is 31200000 psi) Other Materials

Evaluating (E_v / ρ) :

$$\frac{E_v}{\rho} = \frac{312000\ \text{lb}}{\text{in}^2} \left| \frac{\text{ft}^3}{64\ \text{lb}_m} \right| \frac{31.274\ \text{lb}_m\ \text{ft}}{\text{s}^2\ \text{lb}_f} \left| \frac{144\ \text{in}^2}{\text{ft}^2} \right| = 21885954.39\ \text{ft}^2 / \text{s}^2$$

Evaluating $(1 + K B_r)$:

$$(1 + K B_r) = 1 + \frac{312000\ \text{psi}}{31200000\ \text{psi}} \left| \frac{258.8\ \text{in}}{7.1\ \text{in}} \right| = 1.36450704$$

Evaluating Equation 2 :

$$v_{pr} = \sqrt{\frac{(E_v / ?)}{(1 + K B_r)}} = \sqrt{\frac{21885954.4 \text{ ft}^2/\text{s}^2}{1.36450704}} = 4004.9 \text{ ft/s}$$

Evaluating Equation 3 :

$$v_{act} = \frac{V}{A_x} = \frac{3500 \text{ gal}}{\text{min}} \left| \frac{}{0.0526 \text{ ft}^2} \right| \frac{\text{ft}^3}{7.48 \text{ gal}} \left| \frac{\text{min}}{60 \text{ s}} \right. = 148.25 \text{ ft/s}$$

Evaluating Equation 4 :

$$t_s = \frac{2 L}{v_{pr}} = \frac{2}{} \left| \frac{3000 \text{ ft}}{} \right| \frac{\text{s}}{4004.9 \text{ ft}} = 1.4982 \text{ s}$$

If the shutoff time for the valve or pump is less than approximately 1.50 s the resulting system pressure will be :

$$P_{sys} = h_{hs} + \text{exisiting system pressure}$$

Evaluating Equation 1 :

$$h_{hs} = \frac{v_{pr} \; v_{act}}{g} = \frac{4004.9 \text{ ft}}{\text{s}} \left| \frac{148.25 \text{ ft}}{\text{s}} \right| \frac{\text{s}^2}{32.2 \text{ ft}} = 18439 \text{ ft liquid}$$

Convert head to static pressure :

$$\frac{18439 \text{ ft liquid}}{} \left| \frac{64.2 \text{ lb}}{\text{ft3}} \right| \frac{\text{ft3}}{64.2 \text{ lb}} \left| \frac{\text{psi}}{2.306 \text{ ft liquid}} \right. = 7996.1 \text{ psi}$$

$$P_{sys} = 7996.1 + 70 = 8066.1 \text{ psi}$$

The valve or pump shutoff time should be more than 1.50 s to avoid the system pressure shown above.

Select Pipe Size (be sure to select the units corresponding the the calculation page)

Units of Measure	Metric	
Type of Piping	Carbon Steel	
Nominal Pipe Size	250	
Schedule	40	
Enter Custom Pipe Values		
Outside Diameter	273	mm
Wall Thickness	7.1	mm
Inside Diameter	258.8	mm
Flow Area	0.05260396	m2

Fluid Data (English Units)

Liquid	Bulk Modulus (psi)	Density (lb/ft^3)
Carbon Tetrachloride	191000	99.4
Ethyl Alcohol	154000	49.2
Typical Gasoline	190000	42.5
Glycerin	656000	78.5
Mercury	4140000	846.2
SAE 30 Oil	220000	56.9
Seawater	339000	64.0
Water	312000	62.4

Fluid Data (Metric Units)

Liquid	Bulk Modulus (bar)	Density (kg/m^3)
Carbon Tetrachloride	13169	1593
Ethyl Alcohol	10618	789
Typical Gasoline	13100	680
Glycerin	45229	1258
Mercury	285442	13554
SAE 30 Oil	15168	912
Seawater	23373	1026
Water	21512	1000

Source : Fundamentals of Fluid Mechanics, Wiley & Sons, 1994
Munson, Young, and Okiishi

Piping Data (English Units)

Piping Material	Bulk Modulus (psi)
Copper	18350000
Carbon Steel	31200000
Brass	18350000
Wrought Iron	26000000
Malleable Cast Iron	26000000
Aluminum	10400000

Piping Data (Metric Units)

Piping Material	Bulk Modulus (bar)
Copper	1265184
Carbon Steel	2151157
Brass	1265184
Wrought Iron	1792631
Malleable Cast Iron	1792631
Aluminum	717052

Source : Applied Process Design, Volume 1, Gulf Publishing, 1999
Ludwig