PUMP SYSTEM ANALYSIS AND SIZING

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Foreword

One of my goals in writing this book was to make sense of the various terminology, equations and miscellaneous tips and tricks that are published in the general literature on centrifugal pump sizing and system head calculations. There is no lack of articles or books on the subject but usually only certain isolated aspects of the topic are treated. It seems that so far nobody has put all the relevant concepts and principles together.

I had some difficulty starting this book. For starters, I was concerned about the quality of my writing skills, I think they have improved. Then I wondered if I had anything original to say. That was more difficult. At first, I believed that I could simply write down what I knew on the subject. I asked myself a few tough questions, and quickly discovered major gaps in my knowledge. That was a good starting point. Another source of inspiration came from conversations with colleagues on pump system problems (I was not much help), another gold mine. I found that most books on the subject just do not give the big picture, so here is the big picture.

Introduction

The purpose of this book is to describe how pressure can be determined anywhere within a pump system. The inlet and outlet of a pump are two locations where pressure is of special interest. The difference in pressure head (the term pressure head refers to the energy associated with pressure divided by the weight of fluid displaced) between these two points is known as the Total Head. A system equation will be developed based on fundamental principles from which the Total Head of the pump can be calculated, as well as the pressure head anywhere within the system. These principles can be applied to very complex systems.

Friction loss due to fluid flow in pipes is the most difficult component of Total head to calculate. The methods used to calculate friction loss for different types of fluids such as water and viscous fluids of the Newtonian type and wood fiber suspensions (or stock) will be explained.

The fluids considered in this book belong to the categories of viscous and non-viscous Newtonian fluids. Wood fiber suspensions are a special type of slurry. There is an excellent treatment on this subject by G.G. Duffy in reference 2. For the reader's benefit, a condensed version is provided. Slurries, which are an important class of fluids, are not considered. I recommend reference 7, which provides a complete treatment of the subject. However, all the principles for Total Head determination described in this book apply to slurry fluid systems. The only exception is the methods used to calculate pipe friction head.

Centrifugal pumps are by far the most common type of pump used in industrial processes. This type of pump is the focus of the book. The challenge in pump sizing lies in determining the Total Head of the system, not the particular pump model, or the materials required for the application. The pump manufacturers are generally more than willing to help with specific recommendations. Information on models, materials, seals, etc., is available from pump manufacturer catalogs.

Often when approaching a new subject, our lack of familiarity makes it difficult to formulate meaningful questions. Chapter 1 is a brief introduction to the components of Total Head. I hope it proves as useful to you as it did to me.

Symbols

Variable nomenclature		Imperial system (FPS units)	Metric system (SI units)
A	area	in^2 (inch square)	mm^2 (mm square)
C_W	solids concentration ratio by weight in a slurry	non-dimensional	
C_V	solids concentration ratio by volume in a slurry	non-dimensional	
D	pipe diameter	in (inch)	mm (millimeter)
F	force	lbf (pound force)	N (Newton)
f	pipe friction factor	non-dimensional	
g	acceleration due to gravity: 32.17 ft/s^2	ft/s^2 (feet/second squared)	m/s^2 (meter/second squared)
E	energy	Btu (British Thermal Unit)	kJ (kiloJoule)
$\bar{E}$	specific energy	Btu/lbm	kJ/kg
ΔEn	enthalpy variation of the system	Btu	kJ
H	head	ft (feet)	m (meter)
ΔH_P	Total Head	ft	m
ΔH_{DS}	discharge static head	ft	m
ΔH_{EQ}	equipment head difference	ft	m
ΔH_F	friction head difference	ft	m
ΔH_{SS}	suction static head	ft	m
ΔH_{TS}	total static head	ft	m
ΔH_v	velocity head difference	ft	m
ΔKE	kinetic energy variation of the system	Btu	kJ
L	length of pipe	ft	m
m	mass	lbm (pound mass)	kg (kilogram)
M	mass flow rate	tn/h	t/h
ΔPE	potential energy variation of the system	Btu	kJ
p	pressure	psi (pound per square inch)	kPa (kiloPascal)
P	power	hp (horsepower)	W (watt)
R_e	Reynolds number	non-dimensional	
SG	specific gravity; ratio of the fluid density to the density of water at standard conditions	non-dimensional	
T	temperature	°F (degrees Fahrenheit)	°C (degrees Celsius)
Q	heat loss	Btu	kJ
q	volumetric flow rate	ft^3/s	m^3/s
ΔU	internal energy variation of the system	Btu	kJ
V	volume	ft^3	m^3
v	velocity	ft/s	m/s
W	work	Btu	kJ
z	vertical position	ft	m

Variable nomenclature		**Imperial system (FPS units)**	**Metric system (SI units)**
	Greek terms		
Δ	delta: the difference between two terms		
ε	epsilon: pipe roughness	ft	m
ν	nu: kinematic viscosity	SSU (Saybolt Universal Second)	cSt (centiStoke)
η	eta: efficiency	non-dimensional	
μ	mu: dynamic viscosity		cP (centiPoise)
ρ	rho: density	lbm/ft^3	kg/m^3
γ	gamma: specific weight	lbf/ft^3	N/m^3

Note: A dot above the symbol (i.e. $\dot{m}$, $\dot{Q}$, $\dot{W}$) indicates the rate of change of the variable. A term with multiple subscripts such as $\Delta H_{EQ1\text{-}2}$ means the total or sum of all equipment head between points 1 and 2.

*FPS: Foot-pound-second system (Imperial) used in the U.S. and anglophone countries.

**SI: Système internationale, the metric system.