Cover Page for Precalculations – Individual Portion

Pump Performance

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Precalculations	**_____ / 30**

Comments (For instructor or TA use only):

Precalculations

We start with a quick review of dimensional analysis. For simplicity, assume that the same fluid (i.e., water) is always used in our family of geometrically similar centrifugal pumps. In general, the pump impeller diameter *D* can vary, and rotation speed $\dot{n}$ is also a variable. The brake horsepower bhp is thus expected to be a function of *Q* or $\dot{V}$ (the volume flow rate), $\dot{n}$ (rpm), *D* (impeller diameter), and ρ (the density of the fluid).

(5) 1. Beside each variable below, list its dimensions in terms of the M,L,t (mass, length, time) system:

Variable	Description	Dimensions
bhp	brake horsepower	
D	impeller diameter	
Q	volume flow rate	
ω	angular velocity (rad/s)	
ρ	density	

(1) 2. There are 5 variables and 3 primary dimensions (M, L, and t). How many dimensionless parameters (Pi's) do you expect, according to the Buckingham Pi theorem?

(8) 3. Choosing *D*, ω, and ρ as your repeating variables, work through the method of repeating variables, showing all your work in the space below. List your resulting Pi's in the spaces provided.

Π_1 = Π_2 =

Now consider the net head *H*. To remain consistent with most textbooks, we group gravitational constant *g* with *H* prior to performing the dimensional analysis. We suspect again that *gH* will vary with *Q*, ω, *D*, and ρ.

(1) 4. The dimensions of *gH* (in terms of the M,L,t system) are:

(8) 5. Perform a dimensional analysis on gH as a function of Q, ω, D, and ρ, using the method of repeating variables. For consistency, again choose D, ω, and ρ as your repeating variables. Show all your work in the space below, and list your Pi's in the spaces provided.

Π_3 = Π_4 =

(2) 6. Name your Pi's and adjust and "massage" them, if necessary, to obtain the following:

Power coefficient = C_P = bhp/($\rho\omega^3D^5$) = function of C_Q
Head coefficient = C_H = $gH/(\omega^2D^2)$ = function of C_Q
where C_Q = capacity coefficient = $Q/(\omega D^3)$

(2) 7. Efficiency η_{pump} is already dimensionless. Re-write Eq. (6) of the Introduction in terms of the dimensionless coefficients defined above. Prove that η_{pump} is a function of C_Q only.

The significance of the above analysis is as follows: A performance chart like that shown in Figure 3 of the Introduction can be generated for several shaft rotation speeds $\dot{n}$ for a certain pump. If a geometrically similar pump were manufactured with, say, an impeller of twice the size, *new* performance curves would have to be generated for each shaft rotation speed. After dimensional analysis, however, one can instead plot C_P, C_H, and η_{pump} as functions of C_Q. For geometrically similar pumps, this one nondimensional performance chart should be valid for *any* shaft speed and for *any* size impeller!

In this lab experiment, we have only one pump, but it can be operated at variable speeds. You will determine if the data do indeed collapse onto one nondimensional performance chart.

Dimensional analysis is also useful in design. Namely, one can predict the performance of a geometrically similar pump, once the performance of an existing pump is measured.

(3) 8. Suppose the performance of a certain centrifugal pump operating at $\dot{n}$ = 1750 rpm is tested. At its best efficiency point, Q^* is found to be 5.8 gallons per minute. You are asked to design a geometrically similar pump which will operate most efficiently at 8.7 gallons per minute, when the rotational speed is 850 rpm. Estimate the ratio of impeller diameter required, i.e., find $D_{\text{new}}/D_{\text{existing}}$. Show all your work below.

$D_{\text{new}}/D_{\text{existing}}$ =

Experimental Objectives

a. Calibrate an electronic pressure transducer so that net head can be measured on-line via computer.
b. Measure and plot the dimensional pump performance curves for a given centrifugal pump at two rotational speeds. Calculate and plot the pump efficiency as a function of volume flow rate for each rotational speed.
c. Condense the data onto nondimensional performance charts to see if dimensional analysis is valid for this pump.