Problem of the Day

2014.Nov.13

Introduction

The Water Environment Federation is the trade organization for water professionals, including wastewater treatment operations professionals (http://wefcom.wef.org/home). Individual states, or groups of states, sponsor local chapters. On October 29, 2014, I gave a 6-hour Math for Operators Workshop at the annual conference of the Pacific Northwest Clean Water Association (PNCWA). PNCWA represents Idaho, Oregon and Washington (http://www.pncwa.org/). All operators should seriously consider joining their local association. In California it is the California Water Environment Association (http://www.cwea.org/).

Long story short: I randomly covered a series of math problems in the PNCWA workshop, and I have been requested by several attendees to send them the problems. Instead, I am going to post them here (starting with the 2014.Nov.04 Problem of the Day). They are good practice for all visitors to WWTT's Problem of the Day.

For those of you who may be new to WWTT's Problem of the Day, we insert a page break before and after the problem statement so you can print it without looking at the solution. **See what you can do to solve the problem before looking at the solution**.

We are switching gears today and focusing on pumping problems. I remember when I was studying for my Colorado Wastewater Treatment Plant Operator Certification exams and **hating** pumping problems. They are really not that bad, especially if you set them up the same way every single time.

Problem of the Day

Given the following information, calculate the power delivered to the water.

- Pumped flow = 5.75 MGD
- Static head = 45 feet
- Friction head = 2.5 feet
- **Calculate: water power in kilowatts**.

18030 Brookhurst Street, PMB 573 · Fountain Valley, California 92708 · 866-773-WWTT ·
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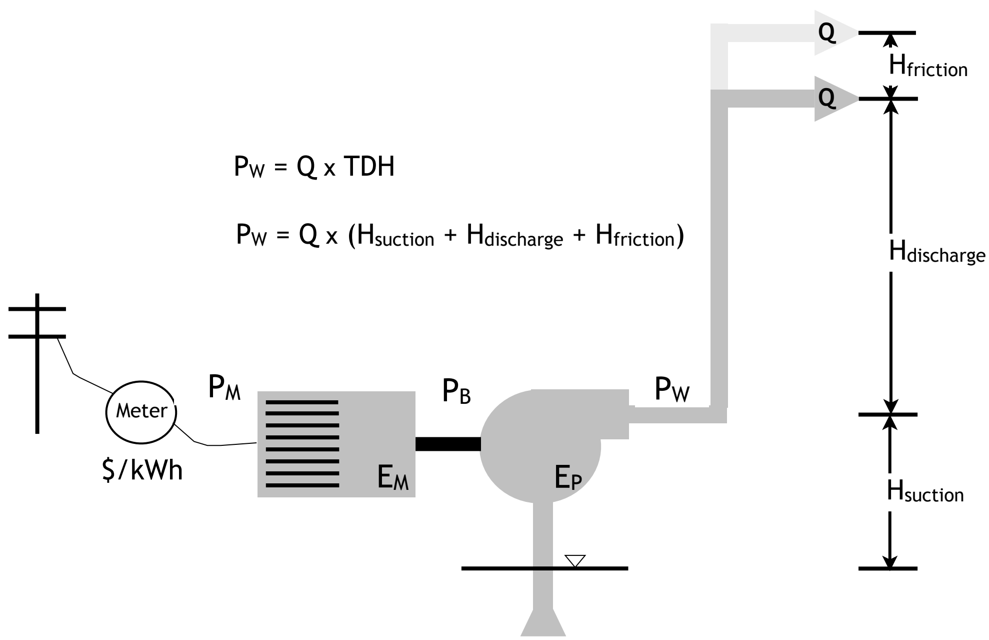
Solution

WWTT puts **every** pumping problem in terms of the following graphic:



Generic graphic for all pumping problems. From left to right: telephone pole, electric meter, motor (complete with air-cooling fins), pump, pump suction (negative suction shown), and pump discharge. Abbreviations: kWh = kilowatt hours (kilowatts times hours ***never*** *kilowatts per hour), P_M = input power to motor, P_B = brake power (output power from motor same as input power to pump), P_W = output power from pump = power delivered to the water), Q = pumping flow rate, $H_{suction}$ = suction head, $H_{discharge}$ = discharge head, $H_{friction}$ = friction head, and TDH = total dynamic head = $H_{suction}$ + $H_{discharge}$ + $H_{friction}$.*

This schematic shows a typical pumping system. Definitions of terms and need-to-know information are as follows [**note: power can be expressed in either horsepower (HP) or kilowatts (kW)**]:

- **Motor power** (P_M) is the **input** power to the motor. The electric meter (Meter) records the connected power and the duration that power is consumed (power times time = energy). When calculating electrical cost, the motor power is almost always converted to kW which is then multiplied by the number of connected hours over a billing cycle. Electrical usage is determined by the amount of kWh used.
- **Brake power** (P_B) is the **output** power of the motor, which is the same as the **input** power to the pump.
- **Water power** (P_W) is the **output** power of the pump; that is, the amount of power actually delivered to the water.
- The water power is determined by multiplying the flow rate of the pump discharge (Q) by the **total dynamic head** (TDH) which is the sum of the suction head ($H_{suction}$), the discharge head ($H_{discharge}$), and, when provided, the friction head ($H_{friction}$).
- The efficiency of all mechanical equipment is calculated by dividing the output power by the input power; efficiency is often expressed as a percentage. **Motor efficiency** (E_M) is calculated by dividing brake power (P_B) by motor power (P_M) and multiplying by 100.
- **Pump efficiency** (E_P) is calculated by dividing water power (P_W) by brake power (P_B) and multiplying by 100.

The equation given in the graphic for calculating the water power (P_W) is very straightforward and is used over and over again (for example, in today's Problem of the Day):

$$P_W = Q \times TDH$$

While ft·lb/min are units of power, in water and wastewater problems power is expressed in either **HP** or **kW**; the two are interchangeable because they are both units of power. The two most important conversion factors for doing these problems are (WWTT suggests you memorize these):

$$\frac{33{,}000\ \text{ft}\cdot\text{lb}}{\text{min}\cdot\text{HP}}$$

and

$$\frac{0.746\ \text{kW}}{\text{HP}}$$

Problem of the Day. Given the following information, calculate the power delivered to the water.

- Pumped flow = 5.75 MGD
- Static head = 45 feet
- Friction head = 2.5 feet
- ★ TDH = $H_{static} + H_{friction}$ = (45 + 2.5)ft = 47.5 ft
- **Calculate: water power in kilowatts**.

P_W (kW)	= Q x TDH =	5.75 ~~Mgal~~	47.5 ~~ft~~	10^6 ~~gal~~	8.34 ~~lb~~	~~d~~	~~min·HP~~	0.746 **kW**
		~~d~~		~~Mgal~~	~~gal~~	1,440 ~~min~~	33,000 ~~ft·lb~~	~~HP~~

All the units have canceled except those needed in the answer, **kW**. The arithmetic gives the answer:

5.75 x 47.5 x 1,000,000 x 8.34 x 0.746 ÷ 1,440 ÷ 33,000 = **<u>35.8 kW</u>**.

Happy calculating!