Problem of the Day

2014.Nov.15

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 continuing 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, as WWTT suggests. **And**, if you remember two important conversion factors.

Most, but not all, of these problems start with calculating the water power by multiplying the flow rate of the pump by the total dynamic head. In many instances, the ultimate calculation that is required is the cost of running the pump. Therefore, the water power has to first be divided by the pump efficiency, expressed as a decimal, to get the brake power. The brake power is then divided by the motor efficiency, expressed as a decimal, to get the motor power which is what is passing through the electric meter. The usage charge is determined by the local power company by multiplying the motor power by the number of hours per billing cycle that the motor/pump is running. Today's Problem of the Day demonstrates.

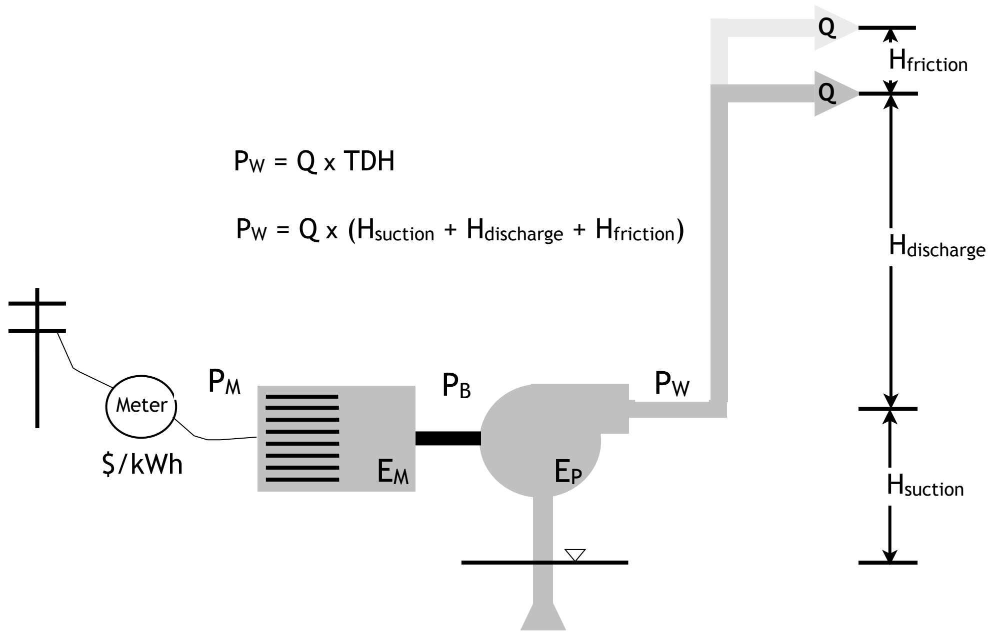
Problem of the Day

Given the following information, calculate the monthly cost difference between the old and new motors (assume a 30-day month):

- Pumped flow = 1,200 gpm
- Total dynamic head = 145 feet
- Pump efficiency = 85%
- Motor efficiency, old = 87%
- Motor efficiency, new = 94%
- Pump operation = 16 hours per day
- Cost of electricity = $0.075/kWh
- **Calculate: monthly cost difference between the old and new motors**.

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 always expressed in 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 and is equal to the amount of power actually delivered to the water.
- The water power, P_W, 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

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

All of us tied to the electrical grid pay the local power company by how many kilowatt·hours we use over a billing period. This is the **usage fee** paid to the power company and is **different from the demand charge** that WWTPs and other large users of electricity pay the power companies (the demand charge is **not** part of today's Problem of the Day). Electricity is typically the second greatest cost (after labor) for WWTPs, so **it's a really big deal**. Because our ratepayers pay for the construction and operation of our WWTPs—yes, the ones that give us our paychecks—cost containment should be on every operator's mind. I am reminded here of the Mission Statement of Cascade Energy (https://cascadeenergy.com/): **make energy conservation happen**. This should be the mindset of all water and wastewater operators.

Who would think that there would be much savings changing out a motor that is 87% efficient with one that is 94% efficient? That is the subject of today's Problem of the Day.

Problem of the Day. Given the following information, calculate the monthly cost difference between the **old** and new motors (assume a 30-day month):

- Pumped flow = 1,200 gpm
- Total dynamic head = 145 feet
- Pump efficiency = 85% = 0.85
- **Motor efficiency, old = 87% = 0.87**
- Motor efficiency, new = 94% = 0.94
- Pump operation = 16 hours per day
- Cost of electricity = $0.075/kWh
- **Calculate: monthly cost difference between the old and** new **motors**.

$	=	1,200 ~~gal~~	145 ~~ft~~	~~min·HP~~	8.34 ~~lb~~			0.746 ~~kW~~	$0.075	16 ~~h~~	30 ~~d~~
mo		~~min~~		33,000 ~~ft·lb~~	~~gal~~	0.85	0.87	~~HP~~	~~kWh~~	~~d~~	**mo**

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

1,200 x 145 x 8.34 x 0.746 x 0.075 x 16 x 30 ÷ 33,000 ÷ 0.85 ÷ 0.87 = **$1,597/mo**.

We have just calculated the monthly cost of the old motor. Now we will calculate the monthly cost of the new motor.

Problem of the Day. Given the following information, calculate the monthly cost difference between the old and **new** motors (assume a 30-day month):

- Pumped flow = 1,200 gpm
- Total dynamic head = 145 feet
- Pump efficiency = 85% = 0.85
- Motor efficiency, old = 87% = 0.87
- **Motor efficiency, new = 94% = 0.94**
- Pump operation = 16 hours per day
- Cost of electricity = $0.075/kWh
- **Calculate: monthly cost difference between the** old **and new motors**.

$	=	1,200 ~~gal~~	145 ~~ft~~	~~min~~ ~~HP~~	8.34 ~~lb~~			0.746 ~~kW~~	$0.075	16 ~~h~~	30 ~~d~~
mo		~~min~~		33,000 ~~ft~~ ~~lb~~	~~gal~~	0.85	0.94	~~HP~~	~~kWh~~	~~d~~	**mo**

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

1,200 x 145 x 8.34 x 0.746 x 0.075 x 16 x 30 ÷ 33,000 ÷ 0.85 ÷ 0.94 = **$1,478/mo**.

The monthly cost difference between the old ($1,597/mo) and new ($1,478/mo) motors, therefore is:

1,597 − 1,478 = **<u>$119/mo</u>**.

Notice in the two calculations we had to divide the water power (Q x TDH with necessary conversions) to motor power first by dividing by the pump efficiency (**0.85 in both railroad tracks**) and then by the motor efficiencies (**0.87 in the first railroad track and 0.94 in the second railroad track**). Horsepower (HP) had to be converted to kW because the cost of electricity is calculated based on $/kWh. Let the units tell you what to do.

Keep in mind $119/month is $1,428/year and $42,840 over the life of the motor (30 years). It all adds up!

Happy calculating!