Problem of the Day

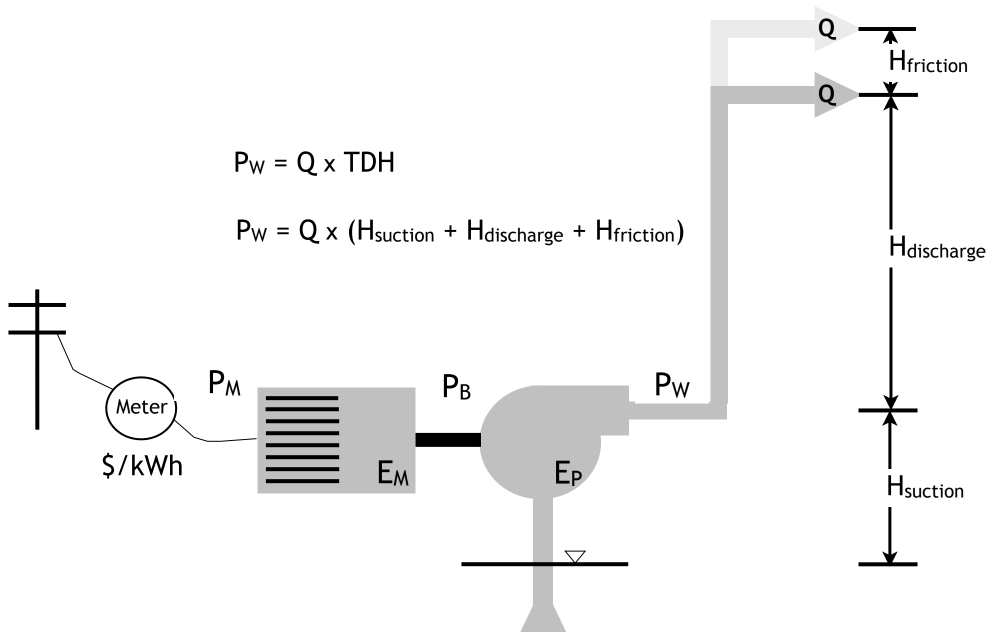
2015.Dec.08

Problem of the Day

After two months saving his agency nearly $2,600/month in reduced RAS pumping costs, the chief plant operator in yesterday's Problem of the Day really got motivated. Working with his Operations staff with a new found commitment to improving sludge quality, cost savings were being realized in lower aeration costs, lower chemical costs (better WAS thickening and dewatering performance), and lower biosolids hauling and disposal costs. Working with the OIT who originally showed him why a reduced RAS flow would work, he realized that sludge quality was so improved that a RAS flow of just 30% of the influent flow could be used. He ran some numbers. The average influent flow for the last 12 months was 31.6 MGD. Calculate the savings he would have realized over the last 12 months, when the RAS flow averaged 92% of the influent, if he had operated at the 30% RAS flow. The cost of electricity is $0.08/kWh. The total dynamic head through the RAS piping is 20 feet. The RAS pumps are 86% efficient and the motors are 92% efficient. The RAS pumps run continuously.

Introduction

Repeating from yesterday's Problem of the Day, drawing the same picture for similar problems helps to understand what you need to know to solve a problem. WasteWater Technology Trainers puts **every** pumping problem in terms of the following graphic:



*Generic graphic for all pumping problems. From left to right: telephone (utility) 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 units of 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. ($.E_M$ indicates motor efficiency expressed as a decimal.)
- **Pump efficiency** (E_P) is calculated by dividing water power (P_W) by brake power (P_B) and multiplying by 100. ($.E_P$ indicates pump efficiency expressed as a decimal.)

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 either as **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):

$$\frac{33{,}000\ \text{ft·lb}}{\text{min·HP}} \quad \text{or} \quad \frac{\text{min·HP}}{33{,}000\ \text{ft·lb}}$$

and

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

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, they are 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. Like today's Problem of the Day.

Solution

This problem is nearly identical to yesterday's. There are just a few "tweaks." Here is the list of information given in the problem following the graphic above starting on the left and moving right:

1. Cost of electricity = $0.08/kWh
2. Motor efficiency = 92% = 0.92
3. Pump efficiency = 86% = 0.86
4. TDH = 20 ft
5. RAS flow, average existing = 92% × 31.6 MGD = 29.07 Mgal/d
6. RAS flow, proposed = 30% × 31.6 MGD = 9.48 Mgal/d
7 Difference in RAS flows = (29.07 − 9.48)Mgal/d = 19.59 Mgal/d
8. Density of RAS = 8.34 lb/gal (assumed since not given)

Just like yesterday, these kinds of "pumping" problems often follow a very typical sequence: (1) calculate $P_W = Q \times TDH$, (2) calculate $P_B = P_W/.E_P$, (3) calculate $P_M = P_B/.E_M$, (4) determine how many hours per day the system is operated and (5) calculate cost.

Calculate P_W (saved) = Q (saved) × TDH (using the difference in RAS flows):

P_W (kW)	=	19.59 ~~Mgal~~	20 ~~ft~~	~~min·HP~~	10^6 ~~gal~~	8.34 ~~lb~~	~~d~~	0.746 **kW**
		~~d~~		33,000 ~~ft·lb~~	~~Mgal~~	~~gal~~	1,440 ~~min~~	~~HP~~

P_W = 19.59 × 20 × 1,000,000 × 8.34 × 0.746 ÷ 33,000 ÷ 1,440 = **<u>51.30 kW</u>**.

Calculate $P_B = P_W/.E_P$:

P_B = 51.30 ÷ 0.86 = **59.65 kW** (the brake power has to be greater than the water power).

Calculate $P_M = P_B/.E_M$:

P_M = 59.65 ÷ 0.92 = **<u>64.84 kW</u>** (the motor/meter power has to be greater than the brake power).

Since the RAS pumps run "continuously," they are running 24 h/d. The final answer, in $/yr, can now be calculated.

Problem of the Day. After two months saving his agency nearly $2,600/month in reduced RAS pumping costs, the chief plant operator in yesterday's Problem of the Day really got motivated. Working with his Operations staff with a new found commitment to improving sludge quality, cost savings were being realized in lower aeration costs, lower chemical costs (better WAS thickening and dewatering performance), and lower biosolids hauling and disposal costs. Working with the OIT who originally showed him why a reduced RAS flow would work, he realized that sludge quality was so improved that a RAS flow of just 30% of the influent flow could be used. He ran some numbers. The average influent flow for the last 12 months was 31.6 MGD. Calculate the savings he would have realized over the last 12 months, when the RAS flow averaged 92% of the influent, if he had operated at the 30% RAS flow. The cost of electricity is $0.08/kWh. The total dynamic head through the RAS piping is 20 feet. The RAS pumps are 86% efficient and the motors are 92% efficient. The RAS pumps run continuously.

$	=	**$0.08**	64.84 ~~kW~~	24 ~~h~~	365 ~~d~~
yr		~~kWh~~		~~d~~	**yr**

0.08 × 64.84 × 24× 365 = **<u>$45,440/yr</u>**.

Discussion

All I can say to this result is, "Wow!"

We always have to be on the guard and question whenever you hear someone say anything like:

"We've always done it that way."

"We've never done it that way."

"That will never work at this plant."

"We tried that once and it didn't work."

"That's not our responsibility."

And the list goes on.

Google "signs of company stagnation" and see for yourself (for example, http://www.racohenconsulting.com/2012/09/24/seven-stages-of-stagnation/). Don't let your agency stagnate: a lot depends on the jobs we do, so we always want to get better at doing them!

Happy calculating! Let us know, by leaving a comment, if you want us to do a specific problem, if you see a mistake, or if you have a question on any of the Problems of the Day you are looking at.