Problem of the Day

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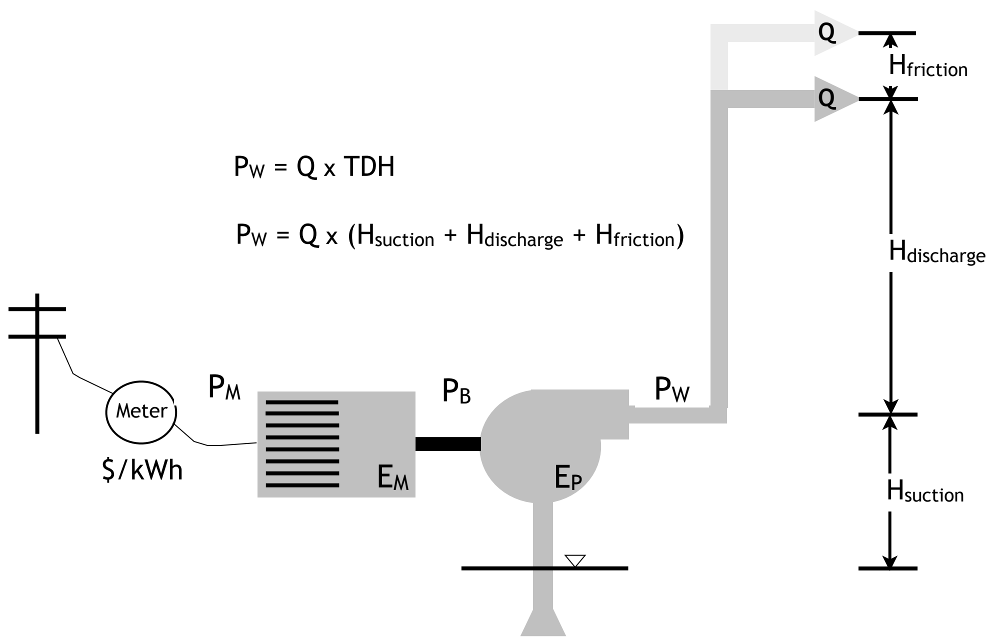
When asked why the RAS flow rate at his plant is set at 100% of the influent flow, the chief plant operator responded, "Because that's what our engineer told us to do and we've always done it that way." Using a state point analysis, an operator-in-training determined that the RAS flow rate could be lowered to 52% of the influent flow with no process consequences. If the average influent flow is 28.0 MGD, how much money could be saved each 30-day month by lowering the RAS flow rate as suggested by the OIT? 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

Drawing the same picture for similar problems helps to understand what you need to know to solve the 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 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 as 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):

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

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

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, current = 100% × 28.0 MGD = 28 Mgal/d
6. RAS flow, proposed = 52% × 28.0 MGD = 14.56 Mgal/d
7. Difference in RAS flows = (28.0 − 14.56)Mgal/d = 13.44 Mgal/d
8. Density of RAS = 8.34 lb/gal (assumed since not given)

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 $P_W = Q \times TDH$ (using the difference in RAS flows):

$$\left| P_W\ (\text{kW}) \right| = \frac{13.44\ \cancel{\text{Mgal}}}{\cancel{\text{d}}} \cdot \frac{20\ \cancel{\text{ft}}}{} \cdot \frac{\cancel{\text{min·HP}}}{33{,}000\ \cancel{\text{ft·lb}}} \cdot \frac{10^6\ \cancel{\text{gal}}}{\cancel{\text{Mgal}}} \cdot \frac{8.34\ \cancel{\text{lb}}}{\cancel{\text{gal}}} \cdot \frac{\cancel{\text{d}}}{1{,}440\ \cancel{\text{min}}} \cdot \frac{0.746\ \textbf{kW}}{\cancel{\text{HP}}}$$

$P_W = 13.44 \times 20 \times 1{,}000{,}000 \times 8.34 \times 0.746 \div 33{,}000 \div 1{,}440 =$ **<u>35.19 kW</u>**.

Calculate $P_B = P_W/.E_P$:

$P_B = 35.19 \div 0.86 =$ **<u>40.92 kW</u>** (the brake power has to be greater than the water power).

Calculate $P_M = P_B / E_M$:

$P_M = 40.92 \div 0.92 =$ **<u>44.48 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 $/mo, can now be calculated.

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$$\frac{\$}{\text{mo}} = \frac{\$0.08}{\cancel{\text{kWh}}} \times \frac{44.48\ \cancel{\text{kW}}}{} \times \frac{24\ \cancel{\text{h}}}{\cancel{\text{d}}} \times \frac{30\ \cancel{\text{d}}}{\text{mo}}$$

$0.08 \times 44.48 \times 24 \times 30 =$ **<u>$2,562.05/mo</u>**.

Discussion

Many operators have a lot of heartache over these kinds of “pumping” problems. But they are really very straightforward; they just have some conversion factors that we don’t typically use, so they feel awkward to us. What really helps to understand these problems is to draw the graphic shown here and label it accordingly with the information in the problem statement. And then, of course, practice, practice, practice.

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.