ED&G 100 **Design Project II** **Spring 2000**

Energy Use & Cost Fact Sheet

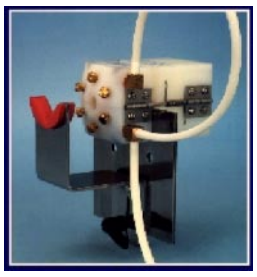
Why is energy important to consider?

1. MONEY: Energy use costs money and can affect profit.
2. RESOURCES: Energy primarily comes from non-renewable energy sources, so reducing energy use also conserves these resources, e.g. coal, oil, and natural gas.
3. POLLUTION: The conversion of resources into end-use forms of energy creates unusable and often hazardous by-products.

End uses of energy in the project:

- The hot plastic jacket that is applied to the cable must be cooled (quickly) for uniform thickness and product quality, therefore, a certain amount of ***thermal energy***, or ***heat,*** must be transferred from the cable jacket.
- Currently, this cooling is done by the water bath that in turn heats and must therefore be cooled as well. The water is circulated by **pumps** that use ***electricity*** to turn a motor (***mechanical energy***) that drives the pumps.
- This water is cooled by a **chiller** which is a refrigeration machine that extracts ***heat*** from water, transfers that ***heat*** internally to a refrigerant, and then transfers that ***heat*** to a cooling medium, usually outdoor air, or water circulated by **pumps** through a **cooling tower**. A cooling tower takes advantage of the cooling effect of evaporating water to more effectively ***cool*** the water and hence, the refrigerant. Both a cooling tower and outdoor air heat exchanger require **fans** to circulate the air. These energy uses for fans and pumps are usually considered along with the compressor energy via the chiller coefficient of performance, COP (see next section).

- The chiller moves thermal energy from the chilled water to the outdoor air or cooling tower, typically from water at 50 °F to air at 80°F. In effect it moves heat to a higher level. Refrigeration machines are often called "**heat pumps**" because of their similarity to a fluid pump that moves fluid to a higher pressure level. The chiller accomplishes this with a **compressor** that uses ***electricity*** to turn an electric motor (***mechanical energy***) that drives the compressor.
- The "**air wipes**" (***fluid energy***) used in the current production line run off compressed air that requires ***electricity*** to run a motor (***mechanical energy***) to drive the compressor. Similarly, the **vacuum systems** (***fluid energy***) use ***electricity*** to run a motor (***mechanical energy***) to drive the **vacuum fans**.



Metered energy flows:

There are three major users of metered energy in this project (as currently operated):

1. Chiller: uses ***electricity*** that costs for both the overall usage (kilowatt-hours, or kwh) and the peak demand (kilowatts). To find the electric energy use:

   $E_{chiller} = E_{cooling} / COP$

   where: $E_{cooling}$ = amount of thermal energy transferred to the water bath
   $= m\ c\ (T_i - T_f)$
   m = mass of plastic cooled
   c = plastic specific heat (assuming no heat of fusion)
   T_i = initial plastic temperature
   T_f = final plastic temperature
   COP = chiller Coefficient of Performance, generally around 3 for air-cooled and 4 for water-cooled systems.

   To find power, replace E with P for power where:

   $P = E/t$ t = time

2. Pumps for the cooling bath water: The electric power use of pumps can be estimated from the flowrate and pressure rise across the pump:

   $P_{pump} = Q\ \Delta p / \eta$

   where: Q = water volumetric flowrate
   Δp = pressure rise across the pump
   η = pump and motor combined efficiency, typically 0.5-0.8

3. Air compressor and vacuum fans: The same type of equation applies as for pumps, but combined efficiency is typically much lower, 0.2-0.4.

Energy costs:

Utilities charge a customer each month for metered usage and for peak demand. Monthly charges for usage in this area of the country are \$0.05-0.12 / kwh, and from \$5 - \$20 / kW for demand. Utilities in eastern Pennsylvania are on the higher side and those in western PA are on the lower side.

Pollution:

The production of electricity comes mainly form coal, then nuclear, natural gas, and hydropower. The fossil-fuel powered plants burn the fuel and routinely emit various pollutants. The regional average emissions in the southeast are:

CO_2 1.5 lb CO_2 / kWh of electricity produced annually
SO_2 6.9 g SO_2 / kWh of electricity produced annually
NO_x 2.5 g NO_x / kWh of electricity produced annually.

Links:

Product information on the air wipes, Huestis Machine Corporation Model AMS – 0750,
http://www.huestis.com/airwipe.htm
Software, EMISS, that calculates emissions from power plants:
http://www.eren.doe.gov/femp/techassist/softwaretools/softwaretools.html

Resources:

Mitchell, John W., *Energy engineering*, New York : John Wiley, 1983. (On reserve)