GUIDELINES FOR OPTIMIZING GRAPHITE EVAPORATOR EFFICIENCY

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The rising demand for fertilizers, caused by the exponential growth of population, is forcing today's manufacturer to continually increase the output of existing plants. This is accomplished by replacing obsolete equipment with new and improved designs, and by removing the bottle-necks that exists in the processes. Without proper operating procedures many of these improvements are nullified by unnecessary and unscheduled downtime. One critical item in the manufacturing of phosphoric acid is the evaporator. Optimizing the efficiency of the evaporator should be a consideration in any fertilizer plant operation.

Regardless of which material is used in the construction of an evaporator, the overall efficiency of the unit can be optimized by examining the basic heat transfer equation:

$$Q = A \times U \times LMTD$$

Q = Duty
A = Area of Evaporator
U = Overall Heat Transfer Coefficient
LMTD = Log Mean Temperature Difference

Q is the component of the equation that you are trying to optimize. In order to optimize the amount of heat you can transfer from the steam to the acid using a fixed heat transfer area you must consider practical ways to maximize the overall heat transfer coefficient, U, and the temperature difference, LMTD.

The "U" value can be defined as the following:

$$U = \frac{1}{L/K + 1/h_i + 1/h_o + F}$$

L = Tube Wall Thickness
K = Thermal Conductivity of Tube Material
h_i = Tube Inside Film Coefficient
h_o = Tube Outside Film coefficient
F = Fouling Total

By using materials with high thermal conductivity the L/K can be optimized. Based on the materials currently being utilized in the construction of phosphoric evaporators, this component is a small component of the "U" value normally only accounting for 3-5% of the total. In regard to graphite evaporators, the presence of carbon within the material composite will lower the thermal conductivity. A much more influential and controllable component is the inside film coefficient, h_o.

The inside film coefficient can account for as much as 50% of the total "U" value. The inside film coefficient is a function of the tube dimensions, fluid physical properties, and the flow rate or velocity. An increase in fluid velocity from 2 FPS to 10 FPS increases the film coefficient by more than 50%. This is indicated in figure 1 below.

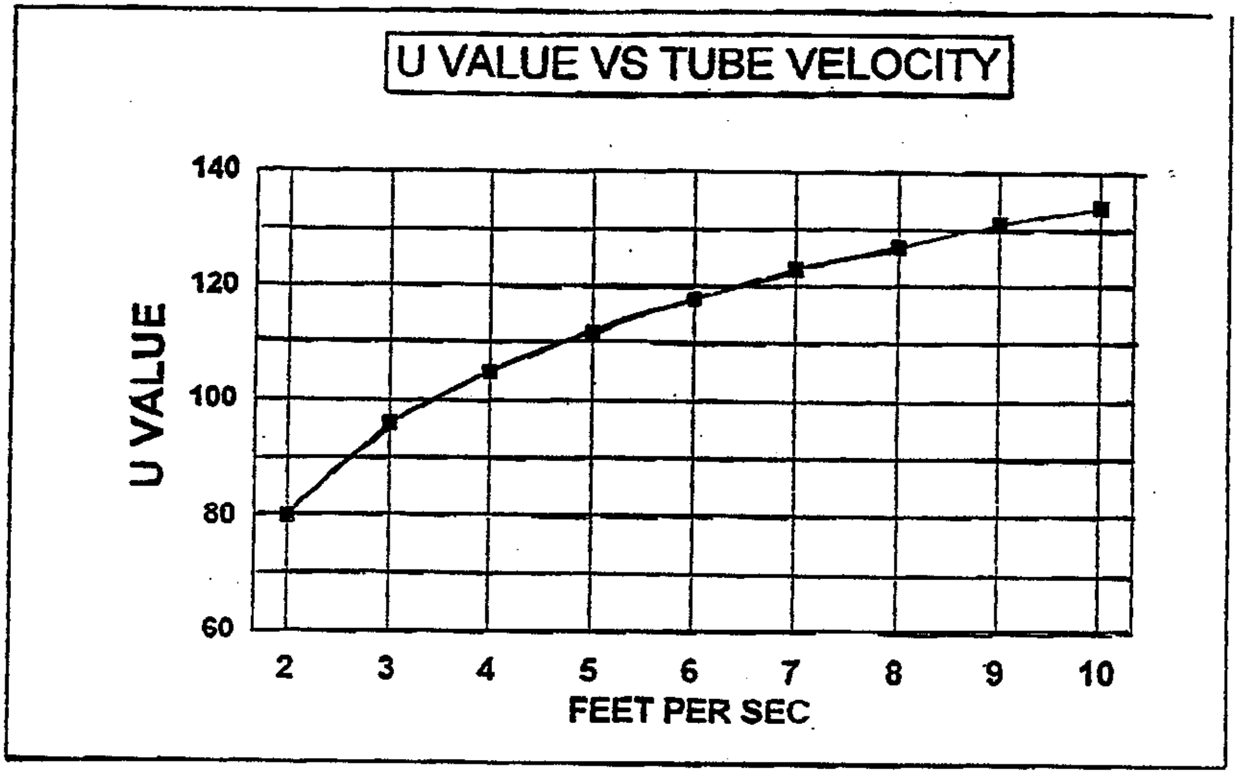

Figure 1 - Film Coefficient vs. Fluid Velocity

By increasing the acid recirculation rate the fouling rate is decreased. This is a result of the high turbulent flow achieved wear the tube wall. A target velocity of 6-10 FPS is desired during unit operation. In order to maximize the inside film coefficient, care should be taken not to allow the acid to vaporize in the tube. This occurs when the pressure in the vapor pot is not maintained correctly.

The outside film coefficient, h_o, can be maximized by avoiding two situations; condensate build up and superheated steam. Condensate build up reduces the effected tube length by a minimum of a factor of four. During steam condensation the film coefficient is around 1500-2000 BTU/hr ft(2). Condensate build up reduces this value along the tube length equivalent to the condensate height. The other problem with this situation is the strong possibility of violent tube vibration during system start-up.

The use of superheated steam creates two problems. The first is that because the steam must first be cooled before it will condense, part of the evaporator tube length becomes very ineffective when considering the film coefficient. The second problem is the high velocity of the steam because of its superheated nature. The velocity of superheated steam versus saturated steam at the same pressure can be a factor of two.

The LMTD is a direct function of the steam temperature. The higher the steam pressure, the higher the LMTD or driving force, behind the heat transfer. Higher steam pressure also increases the wall temperature resulting in increased fouling rates.

In summary, by increasing the acid circulation rates, avoiding superheated steam, and maintaining proper evaporator pot pressure, the efficiency and the operating time of het unit can be optimized.