45.11 A nominal $2in$ chilled water pipe ($D_o = 2.375in$, $D_i = 2.067in$) is filled with water and simply supported with pipe hangers located $18ft$ apart. Steel has a specific weight of $0.284\frac{lb_f}{in^3}$ and a modulus of elasticity of $29 \times 10^6 \frac{lb_f}{in^2}$. What is the maximum deflection of the pipe?

A. $0.03in$

B. $0.26in$

C. $0.43in$

D. $0.63in$

Search for the table for Deflection of Beams of Uniform Cross Section, Under Various Conditions of Loading. The pipe can be modeled as a Simple Beam with a Uniform Load. The maxmum deflection occurs at the center of the span and is given by the formula below where W is the uniform load per unit length, l is the length of the span, E is the modulus of elasticity for the pipe, and I is the moment of inertia.

$$y = \frac{5Wl^4}{384EI}$$

The span and modulus of elasticity are given.

$$l = 18ft$$

$$E = 29 \times 10^6 \frac{lb_f}{in^2}$$

The uniform load can be determined by finding the weight of the pipe and the water contained within it and dividing by the span. However, it is more convenient and faster to use the table Schedule 40 Steel Pipe which provides the total weight per linear foot for various pipe sizes. Convert to weight per inch for ease of use in the deflection formula.

$$W = \left(5.11\frac{lb_f}{ft}\right)\left(\frac{1ft}{12in}\right) = 0.426\frac{lb_f}{in}$$

The moment of inertia can be determined using the geometry of the pipe cross section and a formula found in the table Properties of Various Shapes under the column Area Moment of Inertia. However, again the Schedule 40 Steel Pipe table saves time by providing the moment of inertia directly. Note the moment of inertia is a function of the cross sectional area only, so there is no need to consider the length. The value from the table should be taken and used directly.

$$I = 0.666in^4$$

Find the maximum deflection.

$$y = \frac{5Wl^4}{384EI} = \frac{5\left(0.426\frac{lb_f}{in}\right)(216in)^4}{384\left(29\times10^6\frac{lb_f}{in^2}\right)(0.666in^4)} = 0.625in$$

Answer D

45.12 The displacement of a hydraulic press is $3in^3$ per revolution and the pump speed is $1800rpm$. The hydraulic pressure is $600psig$. The positive displacement pump is 80% efficient and is driven by a 3-phase, 208V AC motor that is 95% efficient. The power factor is 0.9. What size circuit breaker should be selected to protect the system?

A. $20A$

B. $30A$

C. $40A$

D. $50A$

By default, it is common practice to apply the formulas for hydraulic horsepower based on rules of thumb. However, fundamentally the power produced by a pump is the product of the pressure added by the pump, ΔP, and the volume flow rate, Q. The other details are unit conversions and efficiencies. It is possible and occassionally necessary to build up the formulation from this fundamental concept, as with this problem.

Suppose hydraulic horsepower may be expressed simply as below, provided we address units and efficiencies later on.

$$WHP = \Delta P \times Q$$

In this case, the hydraulic pressure is generated entirely by the pump and ΔP may be taken as $600psi$. The volume flow rate is not given, however the displacement of the hydraulic press, i.e. volume, is given as well as the rotational speed. This can be developed into volume per unit time, i.e. volume flow rate.

Determine the hydraulic horsepower delivered. Convert units to KW for convenience in the subsequent step.

$$WHP = \left(600\frac{lb_f}{in^2}\right)\left(3\frac{in^3}{rev}\right)\left(1800\frac{rev}{min}\right)\left(\frac{1min}{60s}\right)\left(\frac{1ft}{12in}\right)\left(\frac{1hp}{550\frac{ft\cdot lb_f}{s}}\right)\left(\frac{0.7457KW}{1hp}\right) = 6.1KW(delivered)$$

Apply the pump and motor efficiencies to determine the electrical power consumed by the motor in producing the power which was delivered.

$$\dot{W}_{elec} = P_{KW} = \frac{WHP}{\eta_p\eta_m} = \frac{6.1KW}{(0.8)(0.95)} = 8.03KW(consumed)$$