Find the mass flow rate in $\frac{lb}{hr}$. Use the Properties of Water table to obtain the density at State 1.

$$\dot{m} = \rho Q$$

$$\dot{m} = \left(61\frac{lb}{ft^3}\right)\left(20\frac{gal}{min}\right)\left(\frac{1ft^3}{7.48gal}\right)\left(\frac{60min}{1hr}\right) = 9786\frac{lb}{hr}$$

Determine the heat added by the boiler. Find the converstion factor from $\frac{Btu}{hr}$ to *boiler hp* in the Measurement Relationships table.

$$\dot{Q} = \dot{m}\Delta h$$

$$\dot{Q} = \frac{\left(9786\frac{lb}{hr}\right)\left(1150.25\frac{Btu}{lb} - 128.2\frac{Btu}{lb}\right)}{\left(33,470\frac{Btu}{hp\cdot boiler\ hp}\right)} = 299 boiler\ hp$$

Answer D

46.74 A three-phase AC generator supplies $700A$ at $480V$ with a power factor of 0.8 and an efficiency of 90%. The engine speed is $3600rpm$. What is the torque needed to drive the generator?

A. $610 ft\cdot lb_f$

B. $750 ft\cdot lb_f$

C. $820 ft\cdot lb_f$

D. $1010 ft\cdot lb_f$

Adapt the last formula in the table Power for Different Motor Phases for a generator. Normally the formula is used to calculate the output horsepower from a motor that receives a certain input of electricity, hence the efficiency is placed in the numerator to account for the motor's losses. However, in this case the generator receives horsepower as its input and produces electricity as its output, therefore it is appropriate to *divide* by the efficiency to account for the generator's losses.

$$P_{[hp]} = \frac{\sqrt{3}IV\,(pf)}{746\eta}$$

$$P = \frac{\sqrt{3}\,(700A)\,(480V)\,(0.8)}{(746)\,(0.9)} = 693.4hp$$

On the same page in reference handbook under Torques, use the formula relating the torque to the horsepower and rotational speed. Provided the speed is in rpm, the torque will be in $ft\cdot lb_f$. No additional unit conversion is neeeded. Calculate the torque.

$$T = 5250\left(\frac{hp}{rpm}\right)$$

$$T = 5250\left(\frac{693.4}{3600}\right) = 1011 ft \cdot lb_f$$

Answer D

46.75 The output shaft of an engine accelerates from $1000rpm$ at idle to $6000rpm$ at red line in $5seconds$. What is the rotational acceleration?

A. $105\frac{rad}{s^2}$

B. $521\frac{rad}{s^2}$

C. $727\frac{rad}{s^2}$

D. $1000\frac{rad}{s^2}$

Use the definition for rotational acceleration under Rigid Body Rotation. Re-write the derivative expression as a change in rotational velocity over time. No calculus is required.

$$\alpha = \frac{d\omega}{dt}$$

$$\alpha = \frac{\Delta\omega}{t}$$

Subtract to find the change in rotational velocity and convert units to $\frac{rad}{s}$.

$$\Delta\omega = \omega_2 - \omega_1 = 6000rpm - 1000rpm = 5000rpm$$

$$\Delta\omega = 5000\frac{rev}{min}\left(\frac{2\pi rad}{rev}\right)\left(\frac{1min}{60s}\right) = 523.6\frac{rad}{s}$$

Divide by the time to determine the rotational acceleration.

$$\alpha = \frac{523.6\frac{rad}{s}}{5s} = 104.7\frac{rad}{s^2}$$

Answer A