Chapter 16 Problem 50 [†]

Given
$P = 10\%\ of\ 3.0\ GW$
$V = 420\ m^3$
$T = 20\ °C$
$c = 1\ kcal/kgK$
$\rho = 1000\ kg/m^3$

Solution
Find the time for the water to reach the boiling point.

First find the amount of heat required to reach the boiling point.

$$\Delta Q = mc\Delta T$$

The mass of water is equal to its volume times density

$$\Delta Q = \rho V c\Delta T$$

$$\Delta Q = (1000\ kg/m^3)(420\ m^3)(1\ kcal/kg \cdot K)(80\ °C)$$

$$\Delta Q = 3.36 \times 10^7\ kcal$$

Convert the kcal to joules

$$\Delta Q = 3.36 \times 10^7\ kcal \left(\frac{4184\ J}{1\ kcal}\right) = 1.41 \times 10^{11}\ J$$

The heat flow is equal to the energy provided by the reactor. Since power is energy per time we have

$$P = \frac{\Delta Q}{\Delta t}$$

The power provided to warm up the water is 10% of 3 GW. This comes out to

$$P = 3 \times 10^8\ W$$

Solving for time gives us

$$\Delta t = \frac{\Delta Q}{P} = \frac{(1.41 \times 10^{11}\ J)}{(3.0 \times 10^8\ W)} = 469\ s$$

This would be 7.81 minutes.

[†]Problem from Essential University Physics, Wolfson