Chapter 17 Problem 58 [†]

Given

$m = 4.5 \times 10^5\ kg$
$T_0 = 10°C$
$Power = 200\ MW = 2.00 \times 10^8\ W$

Solution

Find the time until half of the water is boiled away.

First the heat from the reactor will need to bring all of the water to the boiling point. The magnitude of this value is

$$\Delta Q = mc\Delta T = (4.5 \times 10^5\ kg)(4184\ J/kg)(100 - 10°C) = 1.69 \times 10^{11}\ J$$

The heat needed to boil half of the water is

$$\Delta Q = mL_v = (2.25 \times 10^5\ kg)(2257\ kJ/kg) = 5.08 \times 10^8\ kJ = 5.08 \times 10^{11}\ J$$

Adding the two together gives

$$\Delta Q = 1.69 \times 10^{11}\ J + 5.08 \times 10^{11}\ J = 6.77 \times 10^{11}\ J$$

Power is defined to be energy per time; therefore,

$$time = \frac{Energy}{Power} = \frac{6.77 \times 10^{11}\ J}{2.00 \times 10^8\ W} = 3385\ s$$

This corresponds to 56.4 minutes.

[†]Problem from Essential University Physics, Wolfson