Exercises:

1. Model of a boiler.

In this exercise we use the same boiler as in the previous mini-module.

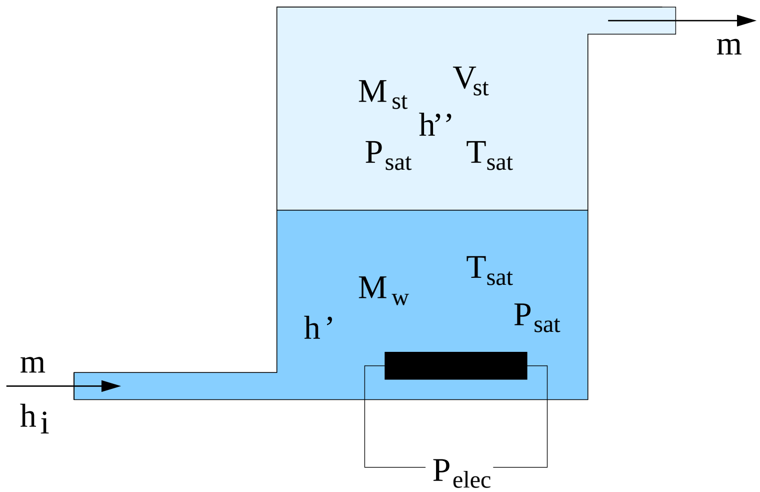

Figure 1: *Electric boiler*

It is assumed that there is saturation in the boiler and the pressure in the steam and in the water is the same; this implies that the pressure is the same all-over. The mass flow in and out are assumed equal, and it is also assumed that the mass of water in the boiler is constant, implying that the steam volume is constant. So the constants are M_w, V_{st} and h_i all others are time varying.

It was found that the energy balance could be written as

$$= \underbrace{[M_w \frac{d(h'(T_{sat}(t))}{dT_{sat}(t)} + V_{st}\rho''(T_{sat}(t))\frac{d(h''(T_{sat}(t))}{dT_{sat}(t)} + V_{st}h''(T_{sat}(t))\frac{d(\rho''(T_{sat}(t)))}{dT_{sat}(t)}]}_{=\mathrm{E}} \frac{dT_{sat}(t)}{dt}$$

$$= m(t)(h_i - h''(T_{sat}(t))) + \mathcal{P}_{elec}(t)$$

The load of the system is given by a standard equation for turbulent flow

$$\Delta P = P_{sat} - P_{atm} = Rm^2$$

where R is a resistance coefficient that has values in the interval $[R_{min}..\infty]$, and $P_{atm} = 1\ \ bar$ is the atmospheric pressure.

- Download XSteam.

- It is assumed that the operating point is $T_{sat} = 150^oC$. The max. mass flow is $m_{max} = 10e-3kg/sec$. The input temperature is 50 ^oC. The pressure in the input is nearly the same as the saturation pressure in the boiler. The water mass in the boiler $M_w = 100kg$. The steam volume is $V_{st} = 1m^3$. Find the necessary power in the heater. Find R_{min}
- Plot $h'(T_{sat})$, $h''(T_{sat})$ and $\rho''(T_{sat})$ for the T_{sat} interval between 100 and 200 ^oC.
- Make a Matlab function that can determine

  $$\frac{d(\rho''(T_{sat}))}{dT_{sat}}$$

  for the T_{sat} interval between 100 and 200 ^oC.
- Find a linear model of the boiler where the inputs are (electric power $\mathcal{P}_{elec}$, resistance R) and the output is the saturation temperature. All is of course in small signal variables.
- Make a Matlab program that can simulate the non–linear model. Use XSteam and a forward approximation of the derivative

  $$\frac{dT_{sat}(t)}{dt} \approx \frac{T_{sat}(t+\Delta t) - T_{sat}(t)}{\Delta t}$$