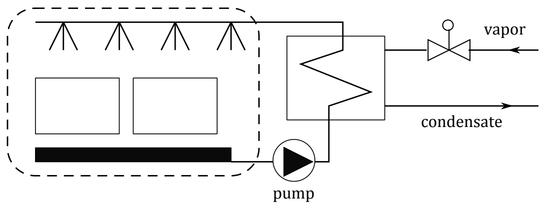
Temperature control

Autoclave for food sterilization under pressure consists of 0.9 t potato and 0.4 t water. Autoclave construction weight is 1.1 t. The autoclave is heated by the steam which consumption is adjustable (signal $0-100\%$) between $0\ldots1300\ kg/h$.

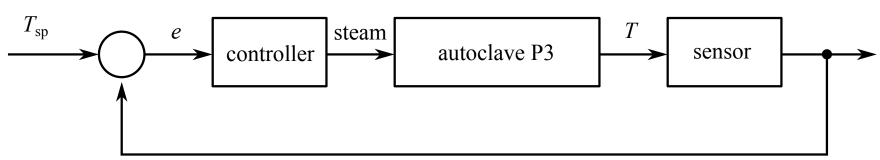


Specific heat capacities: of water 4.18 and iron 0.44 $kJ/(kg\cdot\ ^\circ C)$, water heat of evaporation is 2256 kJ/kg, potato and water features are similar.

With 5% of steam consumption autoclave reaches the temperature of 90 $^\circ C$ (if temperature of environment is +20 $^\circ C$).

See solution of Practice 4.

Controller for autoclave



Additional information:

- Autoclave heat exchanger's Time Constant is $T = 5\ min$ and delay si $\tau = 2\ min$;
- Temperature sensor's Time Constant is 1 min

Set point for the controller T_{sp} is changing as follows

1. rise of the temperature from temperature of environment (+20 $^\circ C$) up to +80 $^\circ C$ with changing rate 5 $^\circ C$;
2. temperature remains +80 $^\circ C$ for 10 min.

- Find a model of the autoclave. Provide the model parameters.
- Find a controller parameters. Provide aperiodic characteristic of the system behavior.
- Simulate the control system (controller + autoclave + sensor). Provide a graph of the temperature error $e = T_{sp} - T$.

Comments /back to basics/

Continuous SISO	controller	P, PI, PD, PID
	object	first order, second order, with delay, FOPDT, etc.
	requirements	stability, offset, time of control

Simulate closed system, change parameters, observe

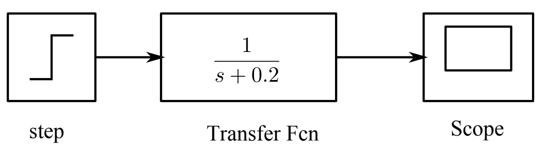
1. Simulate behavior of the object (Matlab, Simulink)

   ✓ Describe object `/transfer function/` with the parameters: zeros $[z]$, poles $[p]$, gain K_{zp};

   ✓ Set Gain as $K_o = 1$, and Time Constant as $T_o = 5\ s$

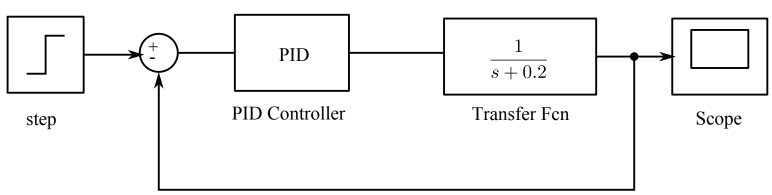
   NB! if we change values of the poles, static gain changes also
   $\frac{K_o}{1+T_o s} = \frac{K_{zp}}{s+p}$ or $K_o = \frac{K_{zp}}{p}$, $T_o = \frac{-1}{p}$

   ✓ Observe step response on `/scope/`



2. Design a Control loop with PID controller and the Object

   (a) P Controller ($K = 1, I = 0$ and $D = 0$) and first order object



   ✓ Measure close-loop system output (offset?) and Time Constant T_{cl}

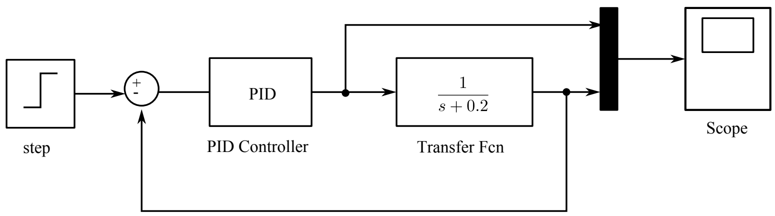
   ✓ Change the Gain K of the controller; What/how is changing?

   ✓ Can we make the system response quicker? Is it still stable?

   ✓ Change the sign of feedback and value of the Gain, how output and the Time Constant is changing?

   ✓ Observe both signals: object input and output.

   ✓ Does the closed-loop system settle 10× quicker, what has changed? Is it unstable?



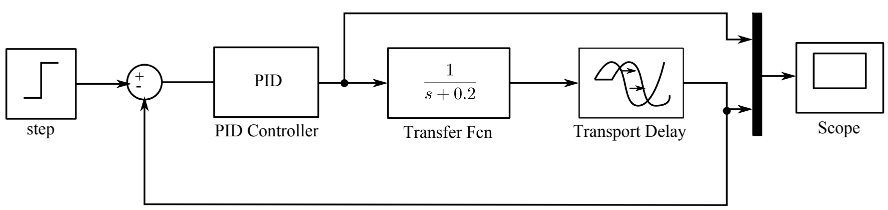
(b) PI controller and first order object

In open-loop the zero of the controller compensates for the pole of the object, and changes it into an integrator.

✓ Make the system settle 10× quicker.

If compensation is not accurate (10 % difference), then on output we have component with Time Constant $-1/p$

(c) P Controller and delayed object.



✓ Design control loop with PID controller, which parameters are: $K = 1, I = 0$ and $D = 0$ and delayed object `/Transport Delay/` with value $L = 1\ s$.

Observe step response.

✓ What should be the Gain of the system if it is unstable?

✓ What is the frequency of oscillations?

✓ What should be the Gain if system is stable (oscillating or aperiodic)?

(d) PID control and FOPDT object

✓ Tune the parameters of controller with an object, which parameters are $K_o = 1, T_o = 5\ s, L = 1\ s$. Choose the control requirements, simulate system.

✓ At what conditions P control is unstable? What are the margins of the unstable system oscillation frequency f, if object Time Constant T_o is changed?