SIXTH FRAMEWORK PROGRAMME, PRIORITY 1.6

«Sustainable energy systems»

Project: ENhanced Geothermal Innovative Network for Europe

ENGINE

Potsdam, 12 January 2007, ENGINE Mid-term Conference

POWER EXTRACTION FROM HDR SYSTEMS

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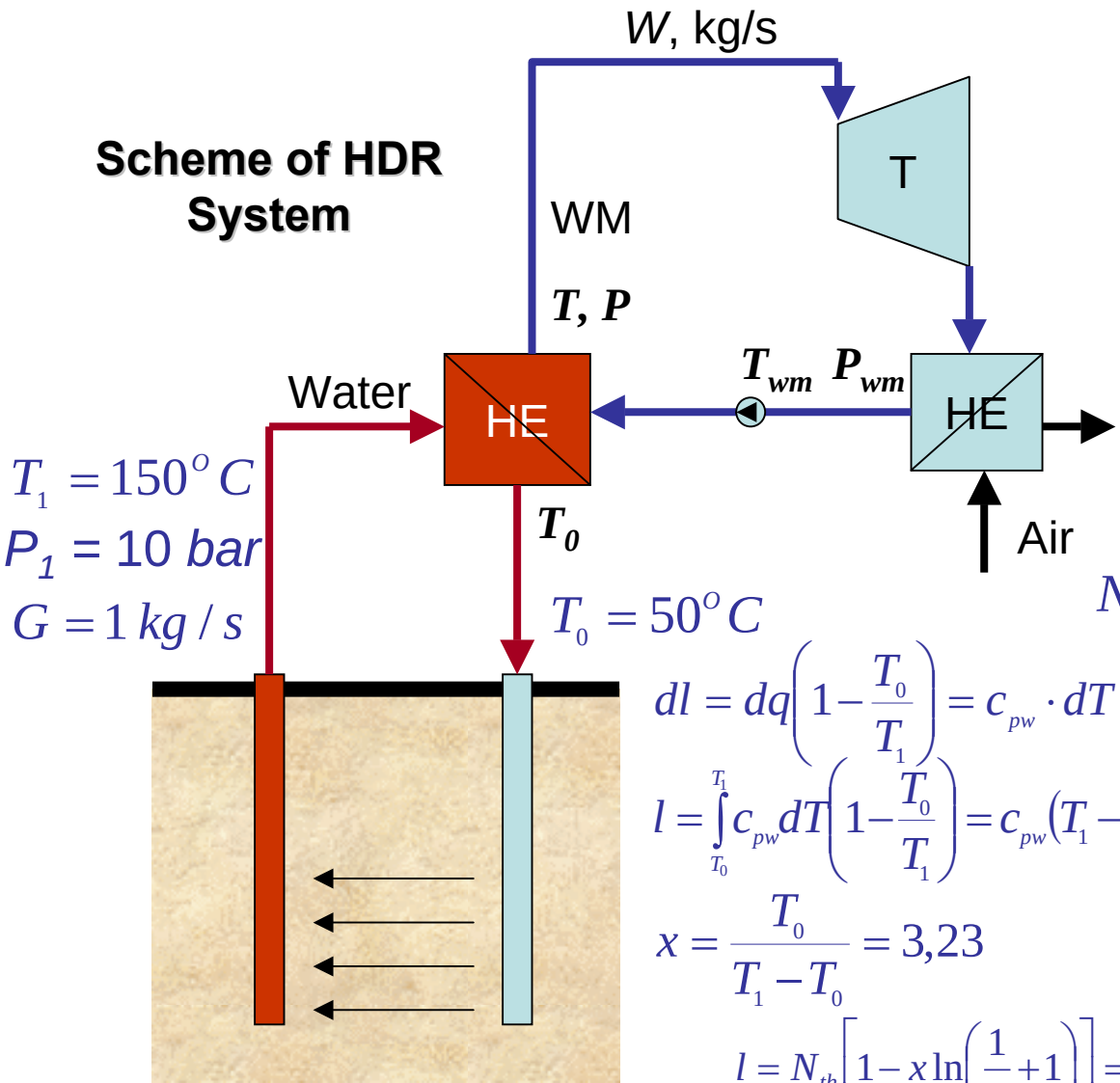
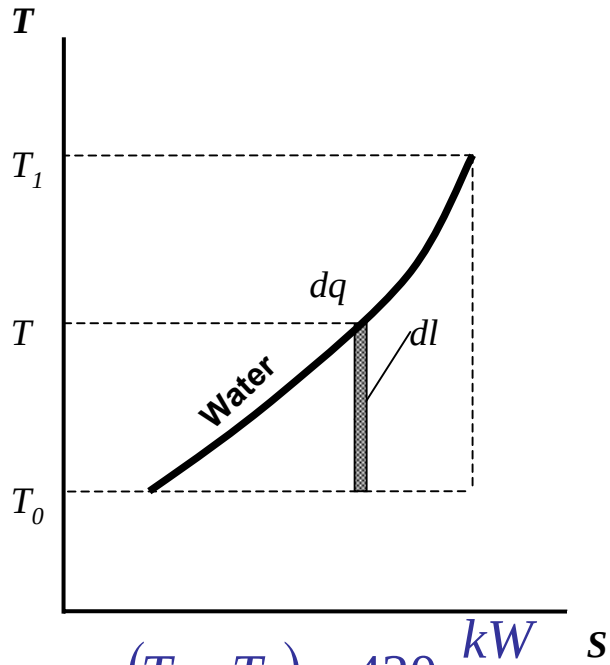
Scheme of HDR System





$$N_{th} = c_{pw}(T_1 - T_0) = 420\frac{kW}{kg/s}$$

$$dl = dq\left(1-\frac{T_0}{T_1}\right) = c_{pw}\cdot dT\cdot\left(1-\frac{T_0}{T_1}\right)$$

$$l = \int_{T_0}^{T_1} c_{pw}dT\left(1-\frac{T_0}{T_1}\right) = c_{pw}(T_1-T_0) - c_{pw}T_0\cdot\ln\frac{T_1}{T_0} = N_{th}\left[1-\frac{T_0}{T_1-T_0}\ln\left(\frac{T_1-T_0}{T_0}+1\right)\right]$$

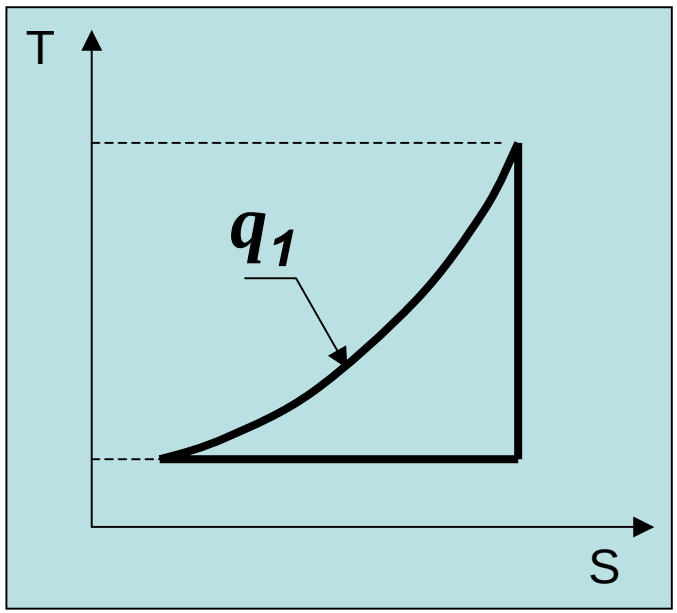
$$x = \frac{T_0}{T_1-T_0} = 3{,}23$$

$$l = N_{th}\left[1-x\ln\left(\frac{1}{x}+1\right)\right] = N_{th}(1-0{,}872) \approx 0{,}128N_{th}$$

$$\eta_{\max} = \frac{l}{N_{th}} = 12{,}8\%$$

The thermal power of the water flow is transmitted to a working media (**WM**).

The optimal thermodynamic cycle should have the heat admission curve (in most cases an isobar) which shape is similar to the water cooling down curve shape: constant heat capacity along the heat admission isobar.



Since generally $C_{pwm} \neq C_{pw}$, the specific **WM** flow rate in the heat exchanger should be

$$W = C_{pw} / C_{pwm}$$

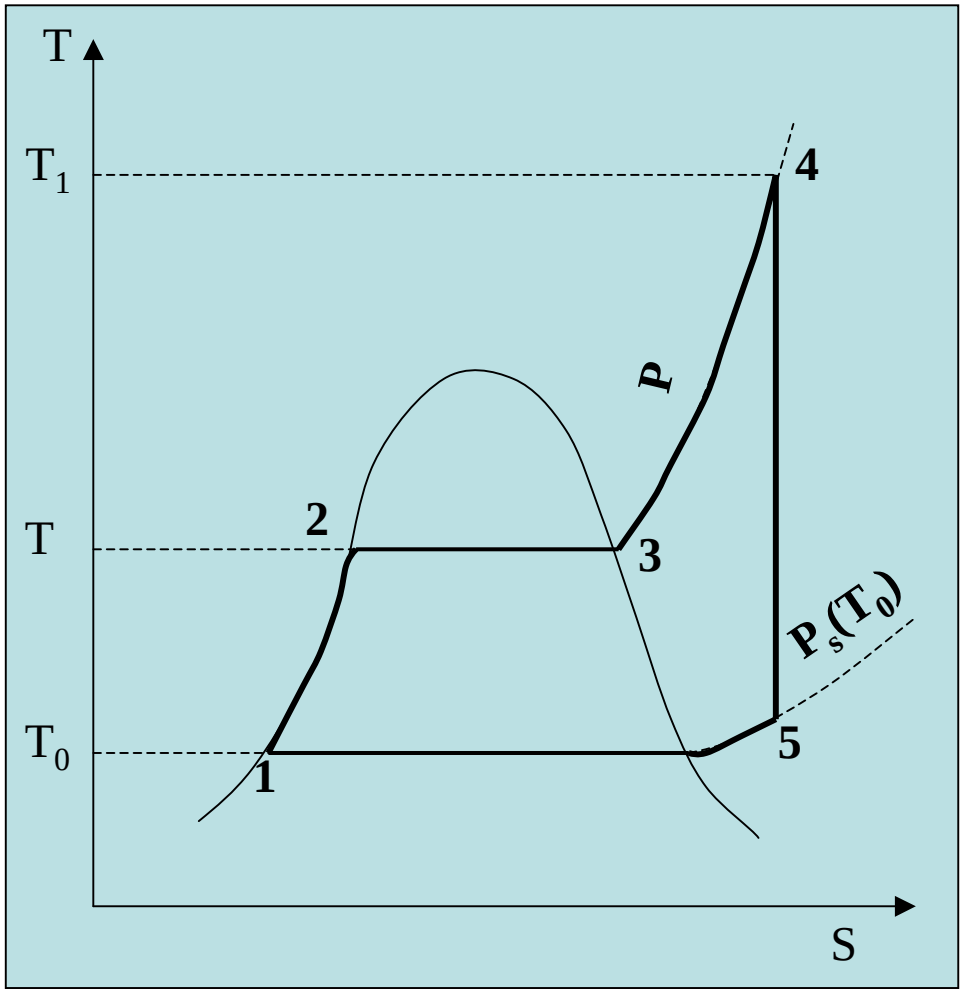
The specific work l, *kJ/kg* of the WM cycle is

$$l = q_1 \times \eta_t$$

Hence the total installation power N *[kW]* = l *[kJ/kg]* $\times$ W *[kg/s]*

In a real cycle $C_{pwm} \neq const$, there arises a problem with **WM** flow rate.

SUBCRITICAL RANKINE CYCLE

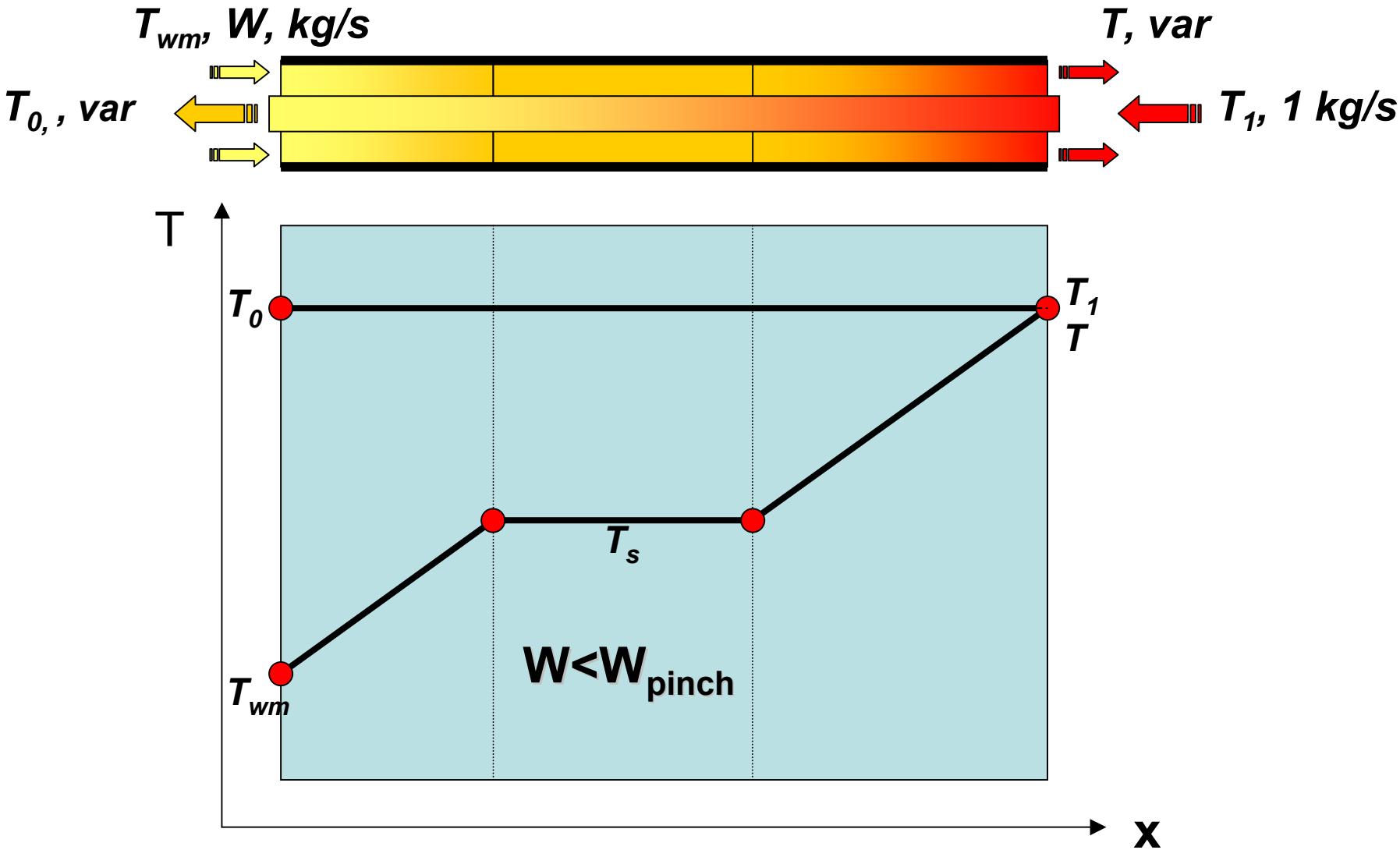


$$q_1(kJ/kg) = (h_4 - h_1)$$

$$l(kJ/kg) = (h_4 - h_5)$$

$$\eta_t = l/q_1 = (h_4 - h_5)/(h_4 - h_1)$$

TEMPERATURE PINCH EFFECT IN HEAT EXCHANGER



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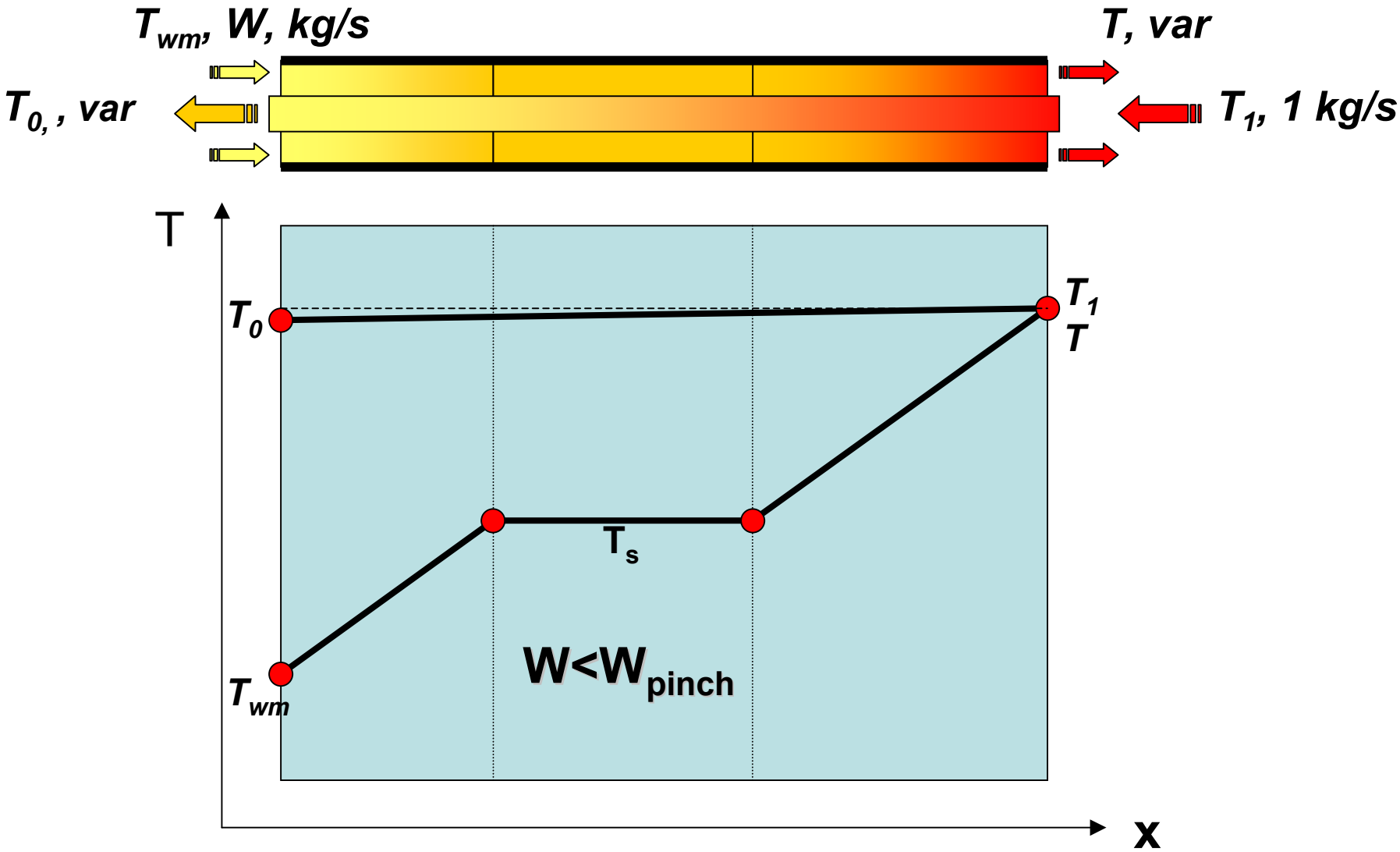

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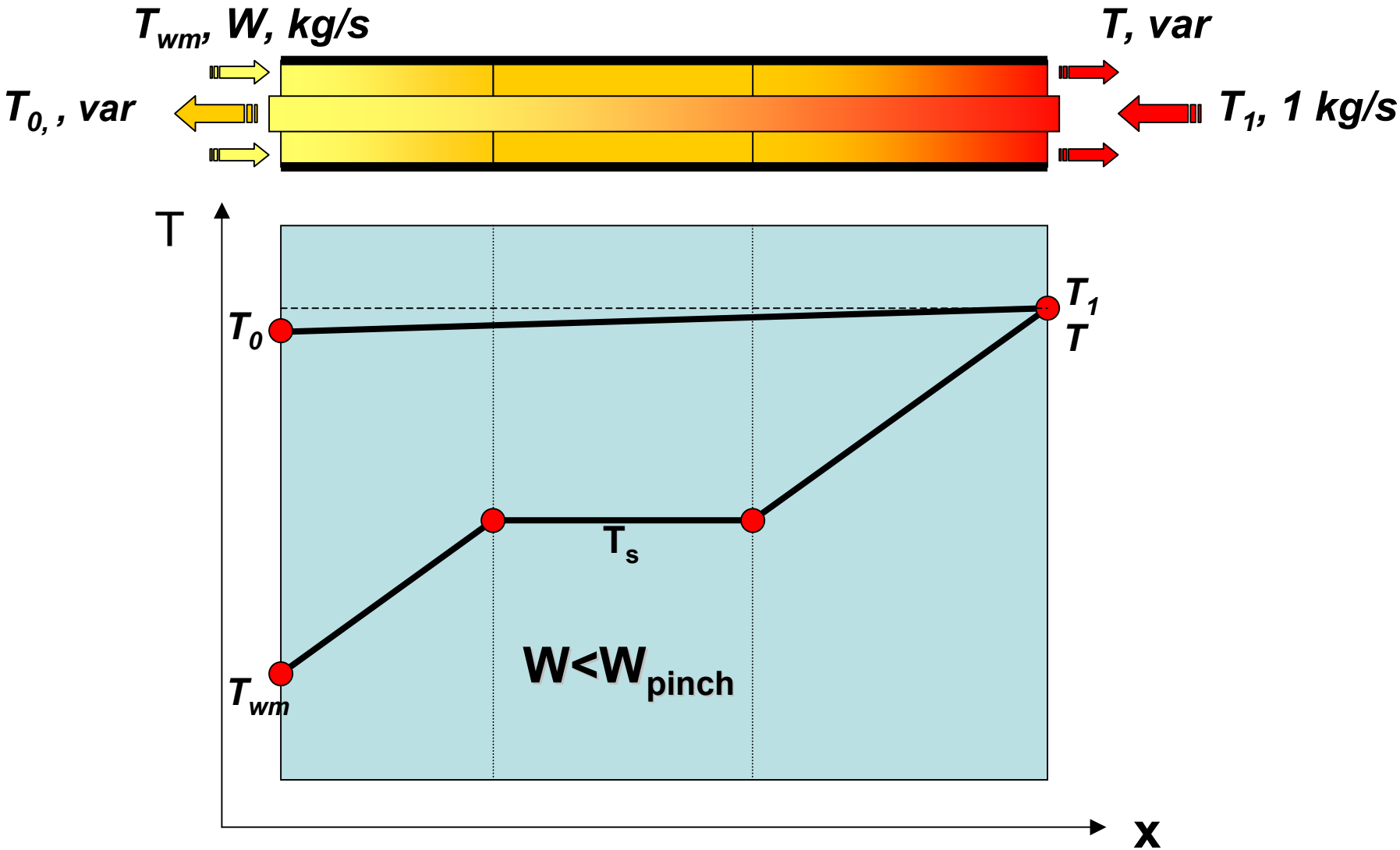

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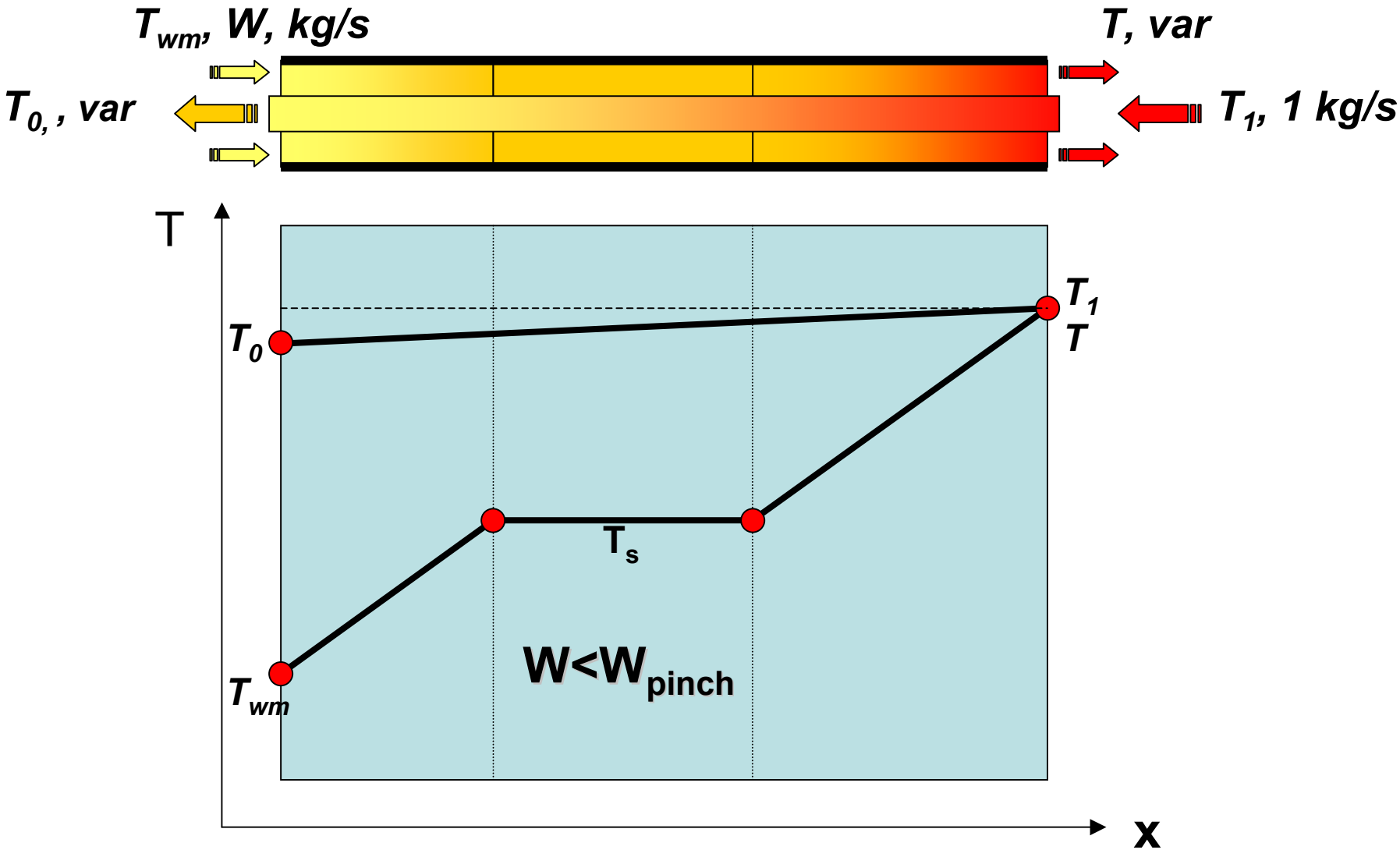

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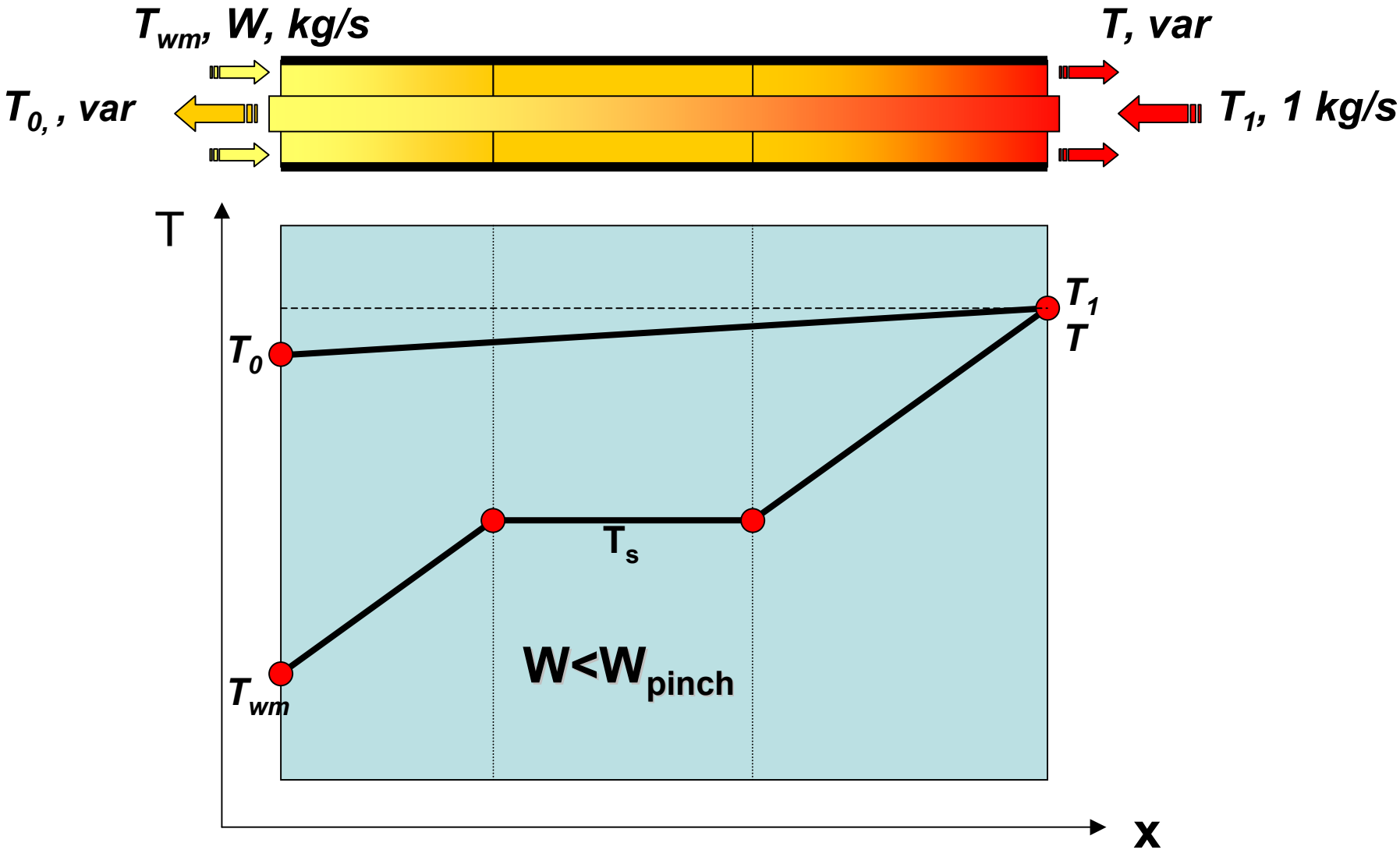

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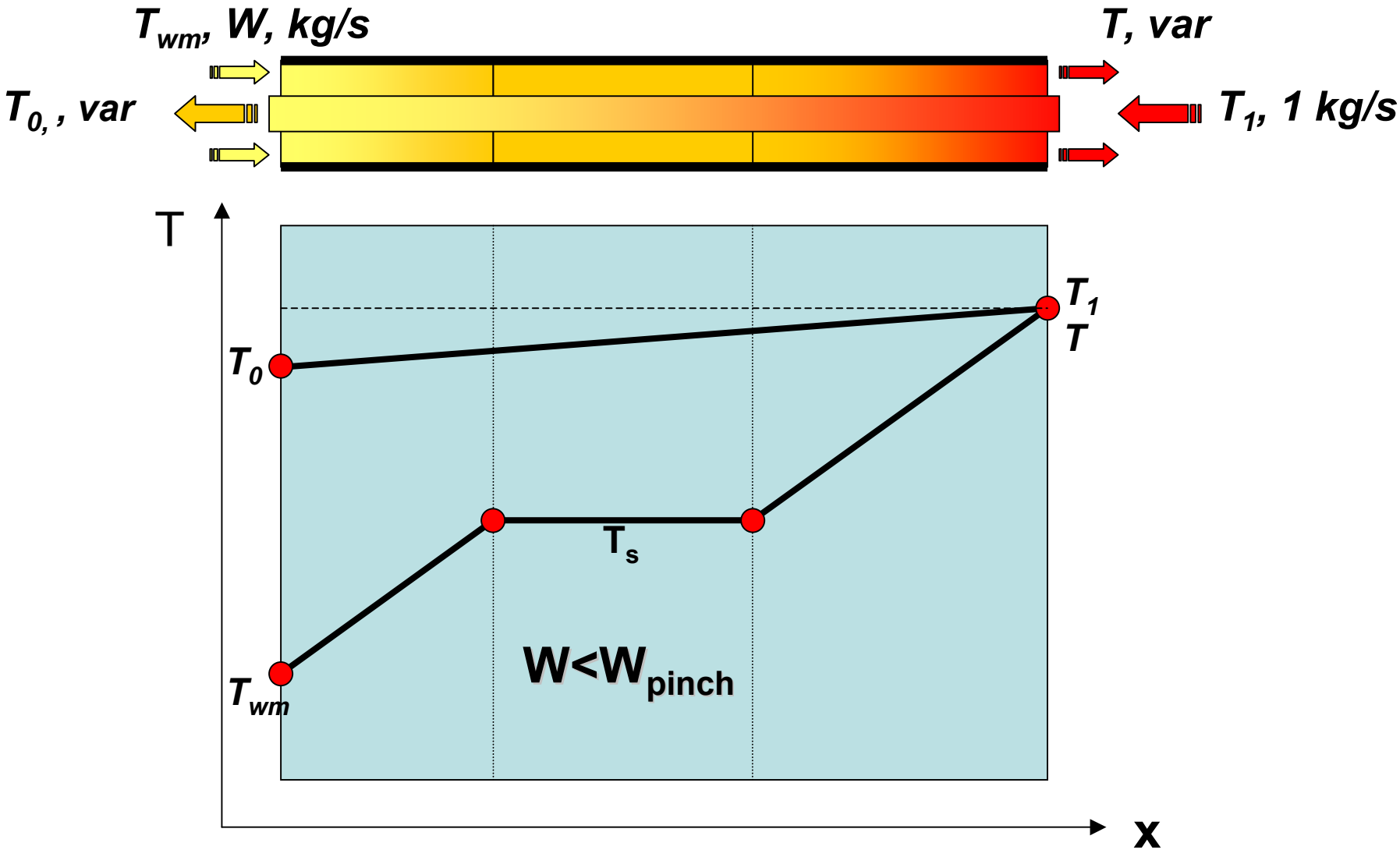

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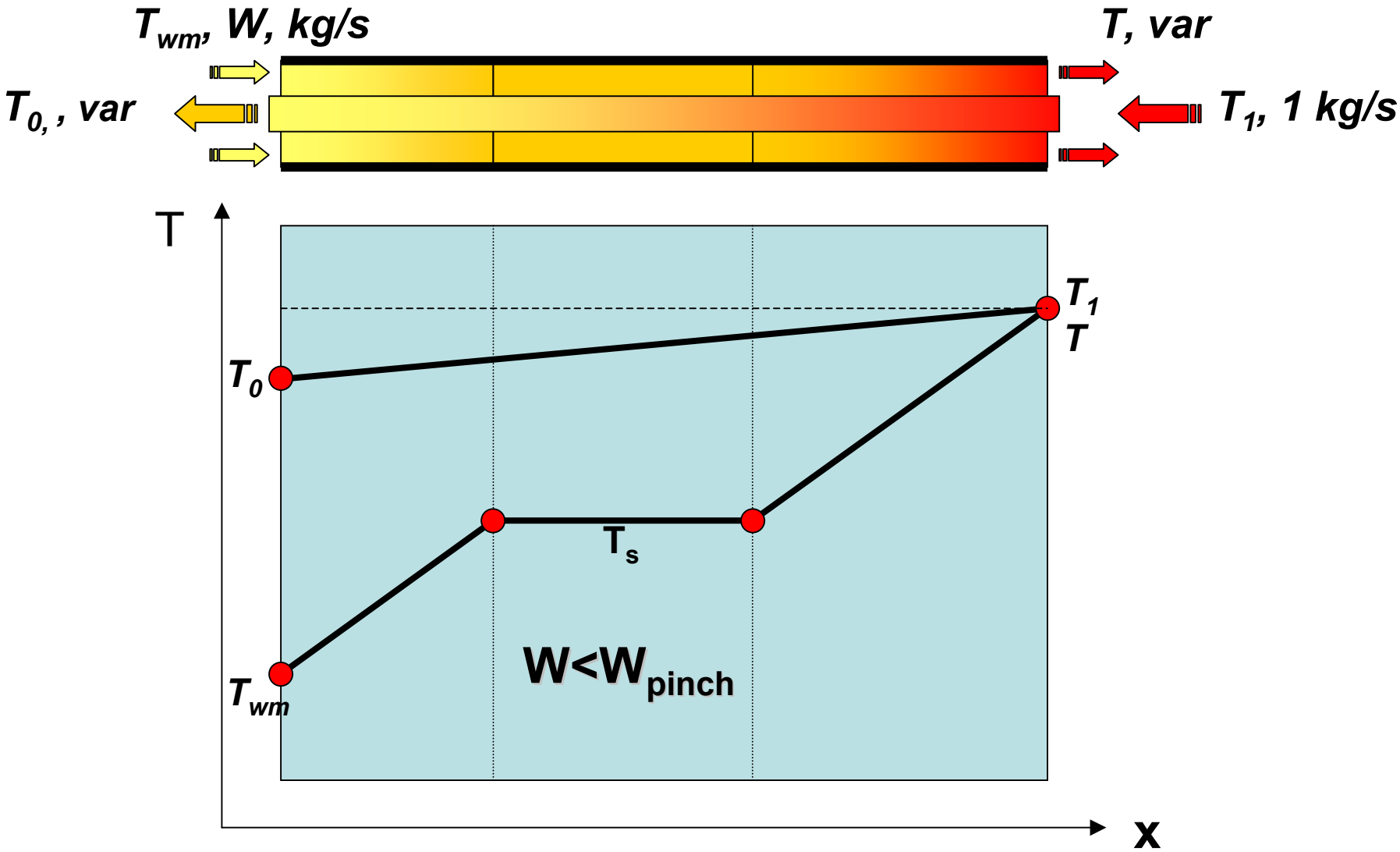

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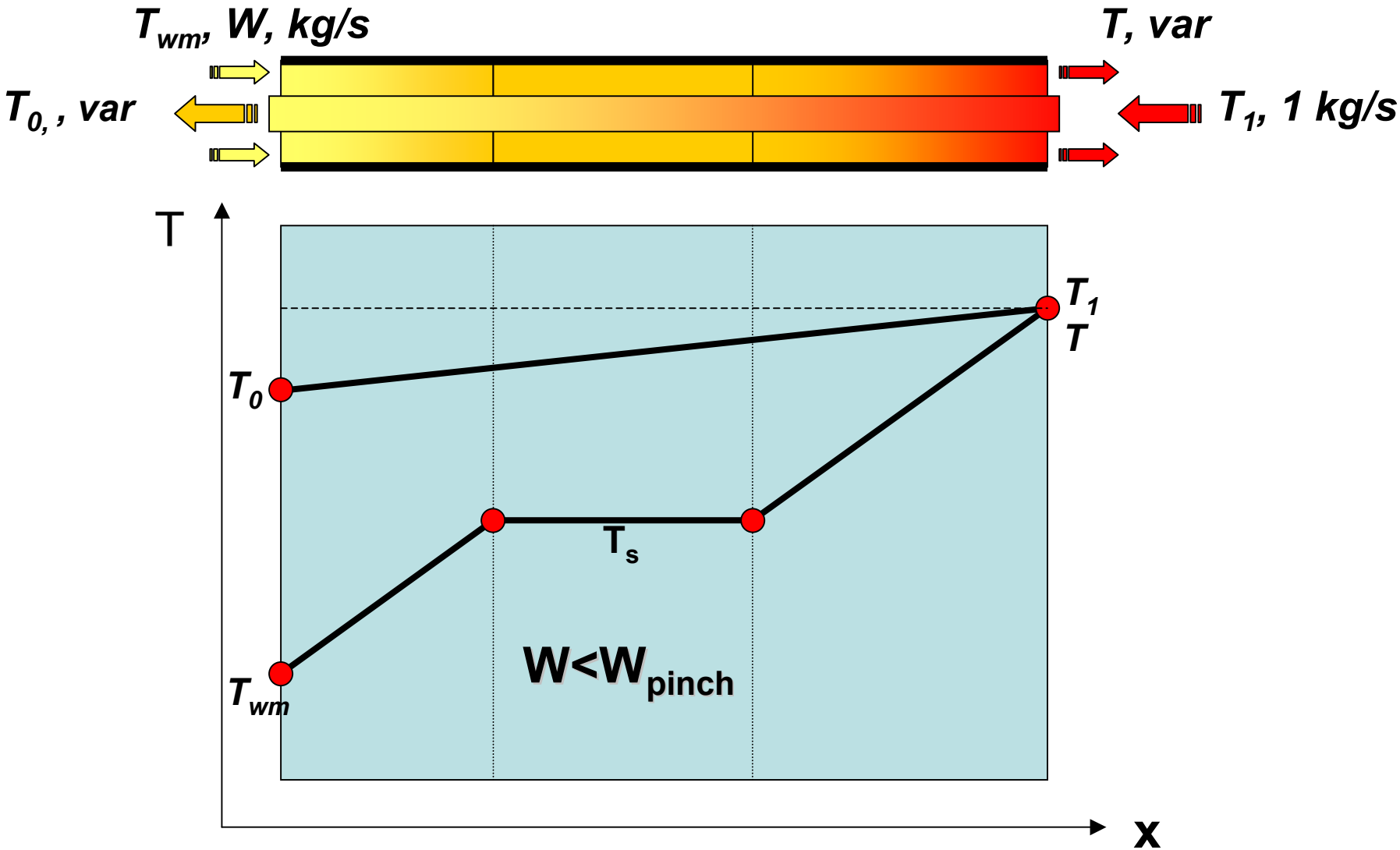

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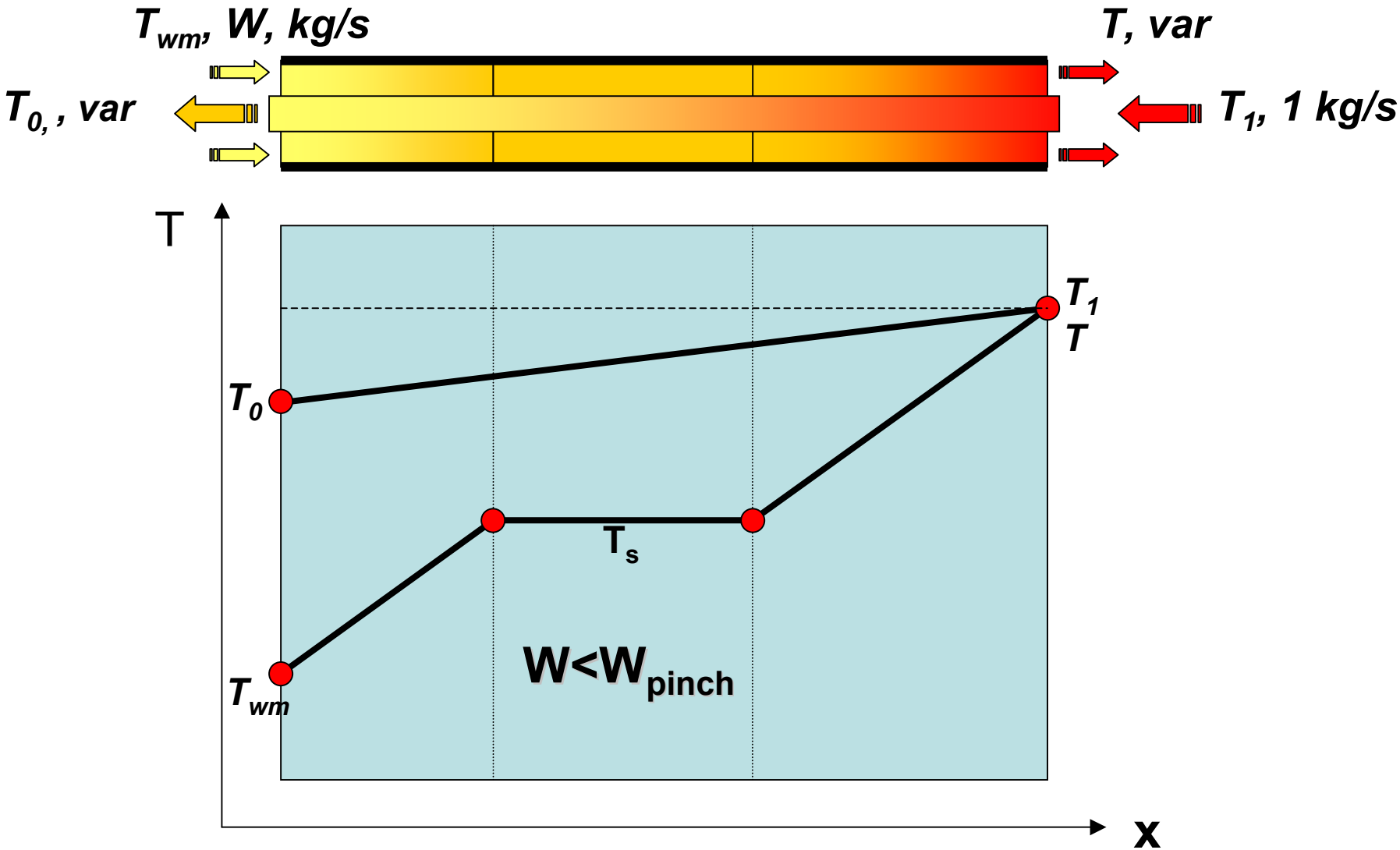

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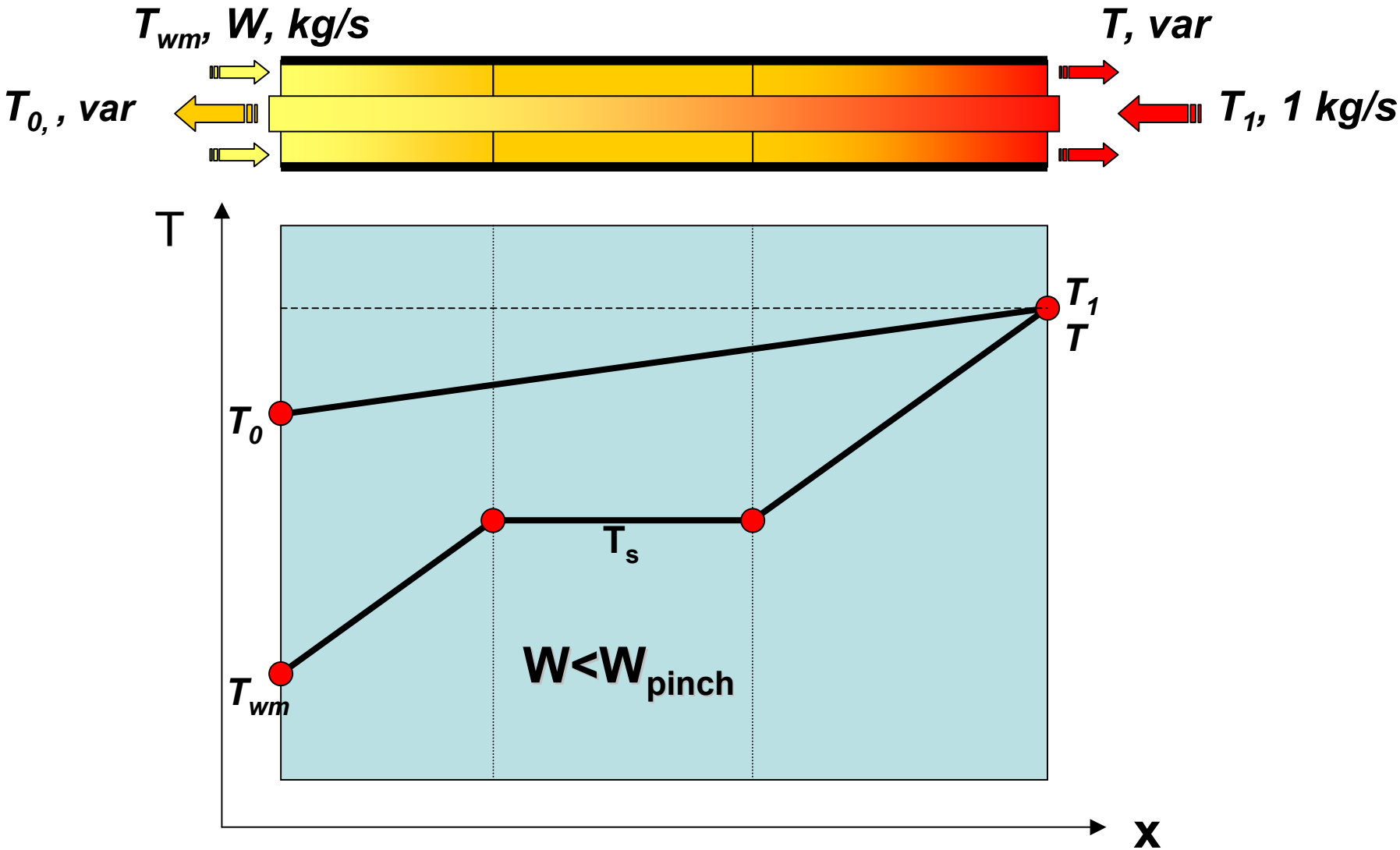

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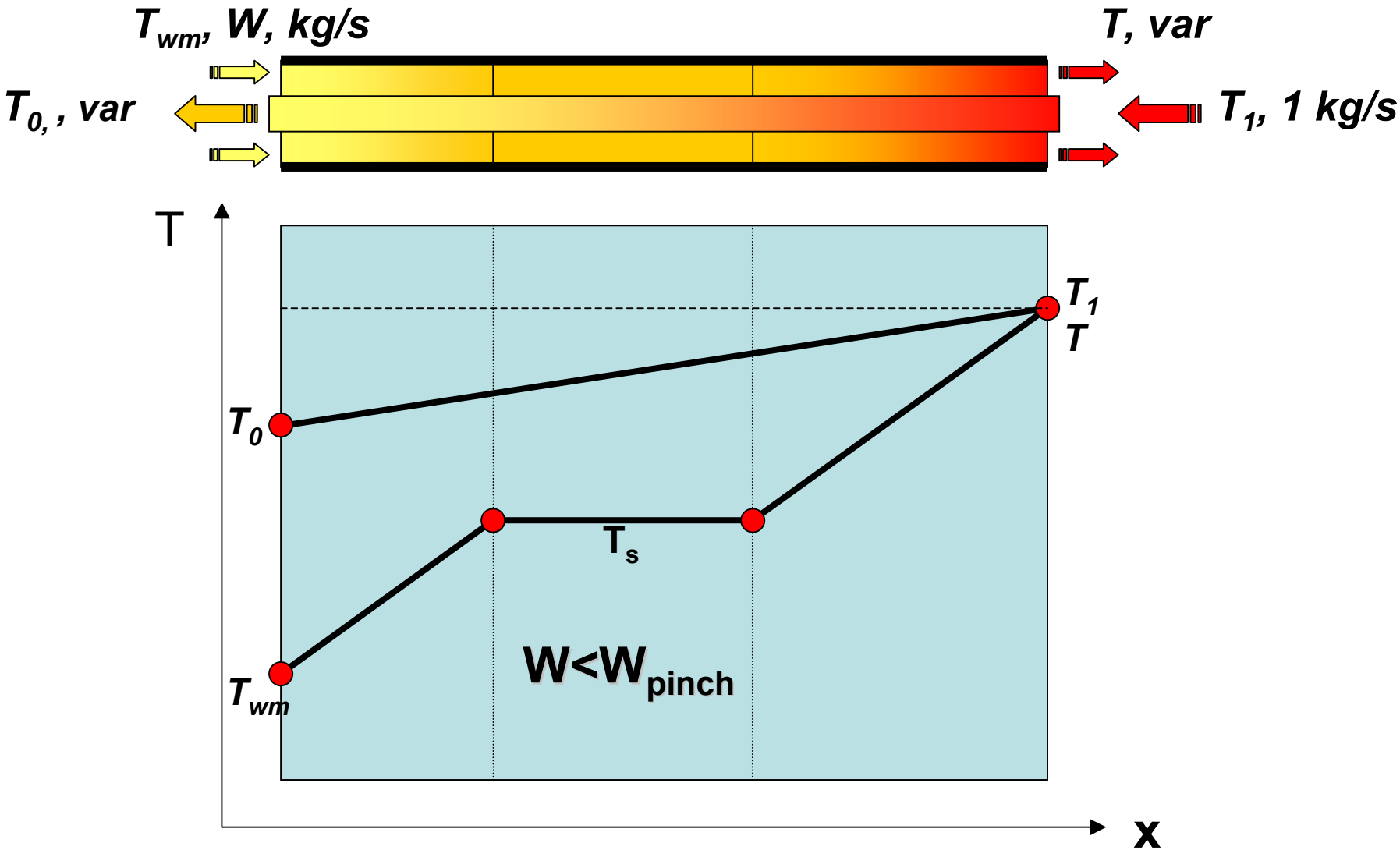

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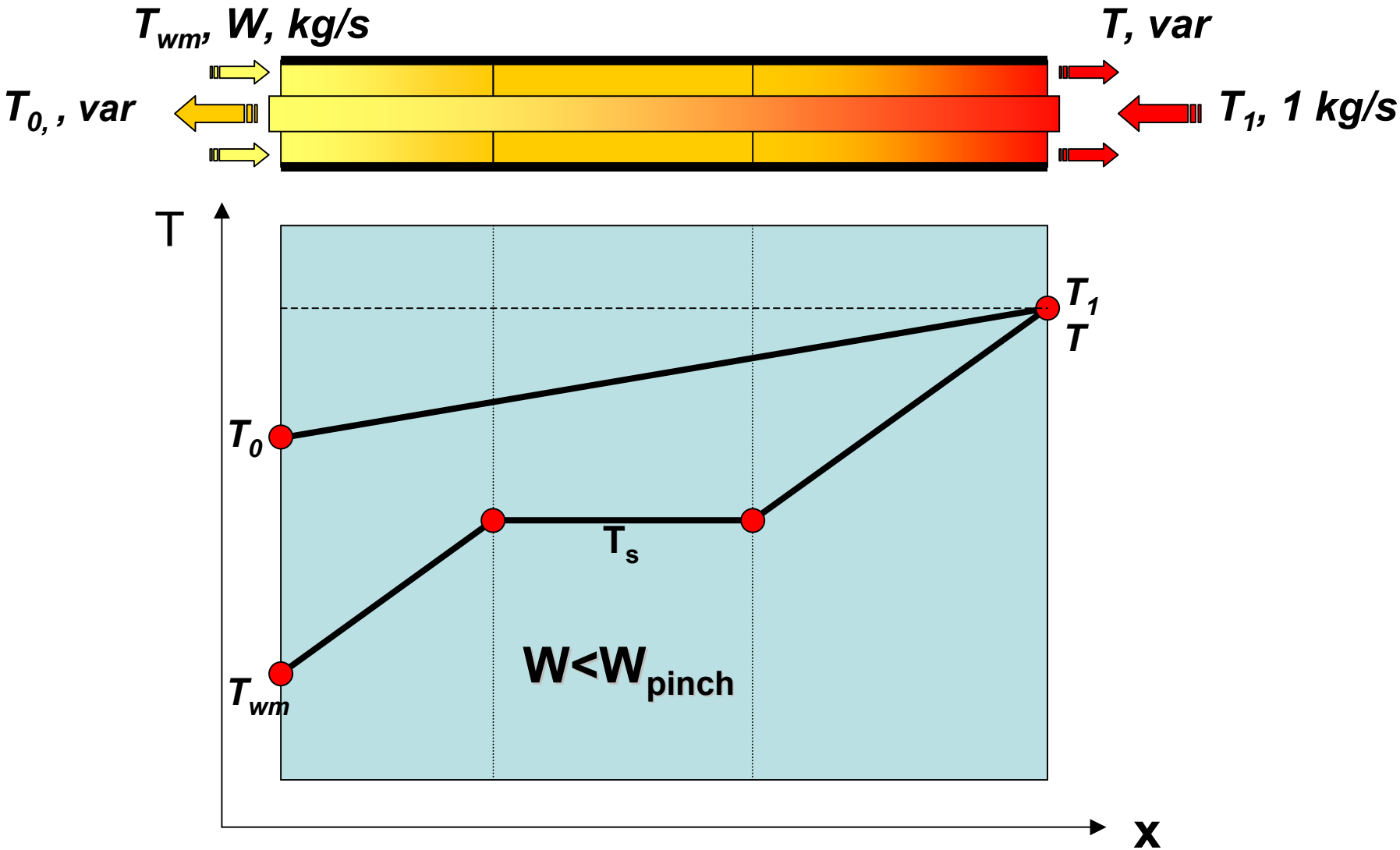

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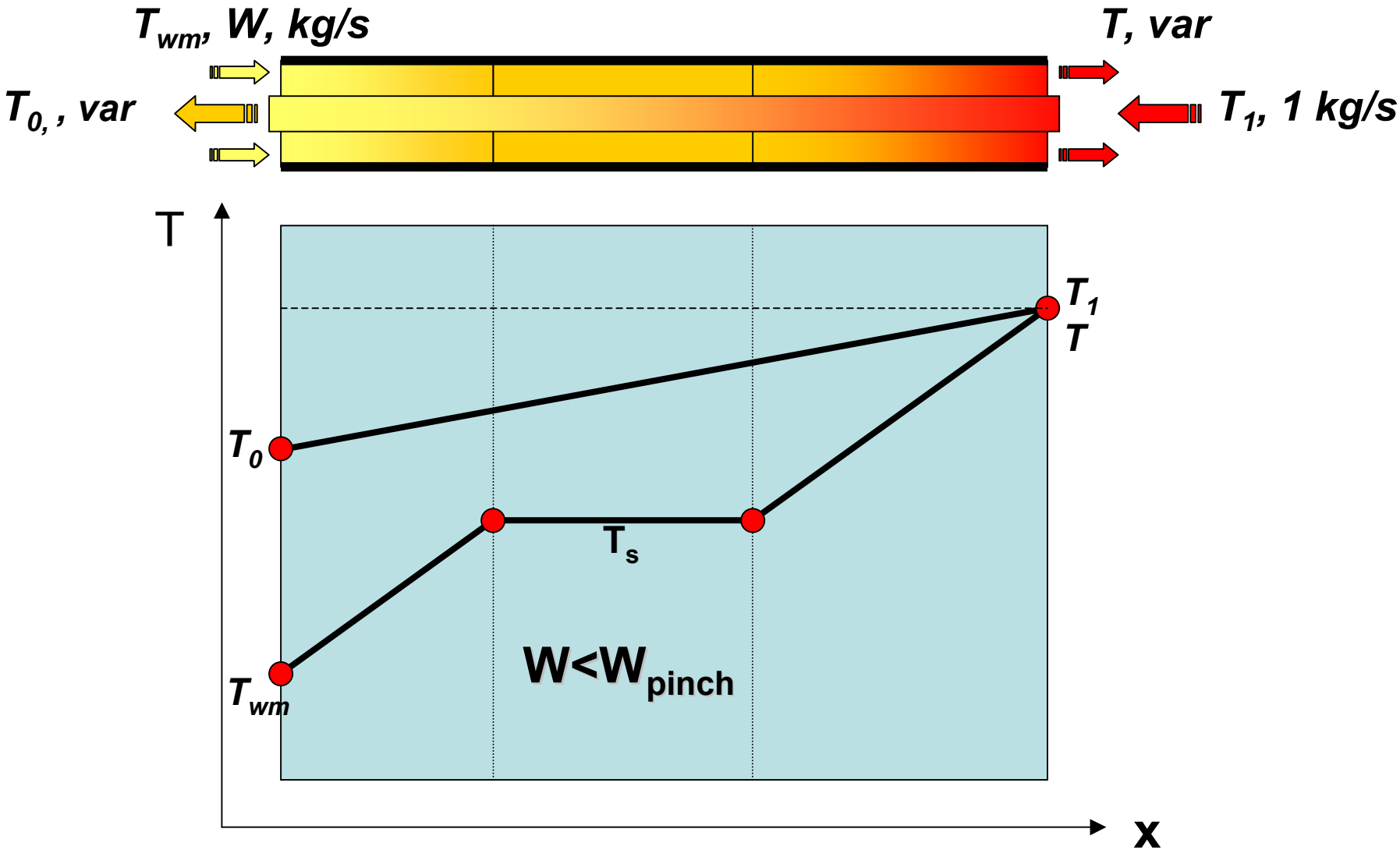

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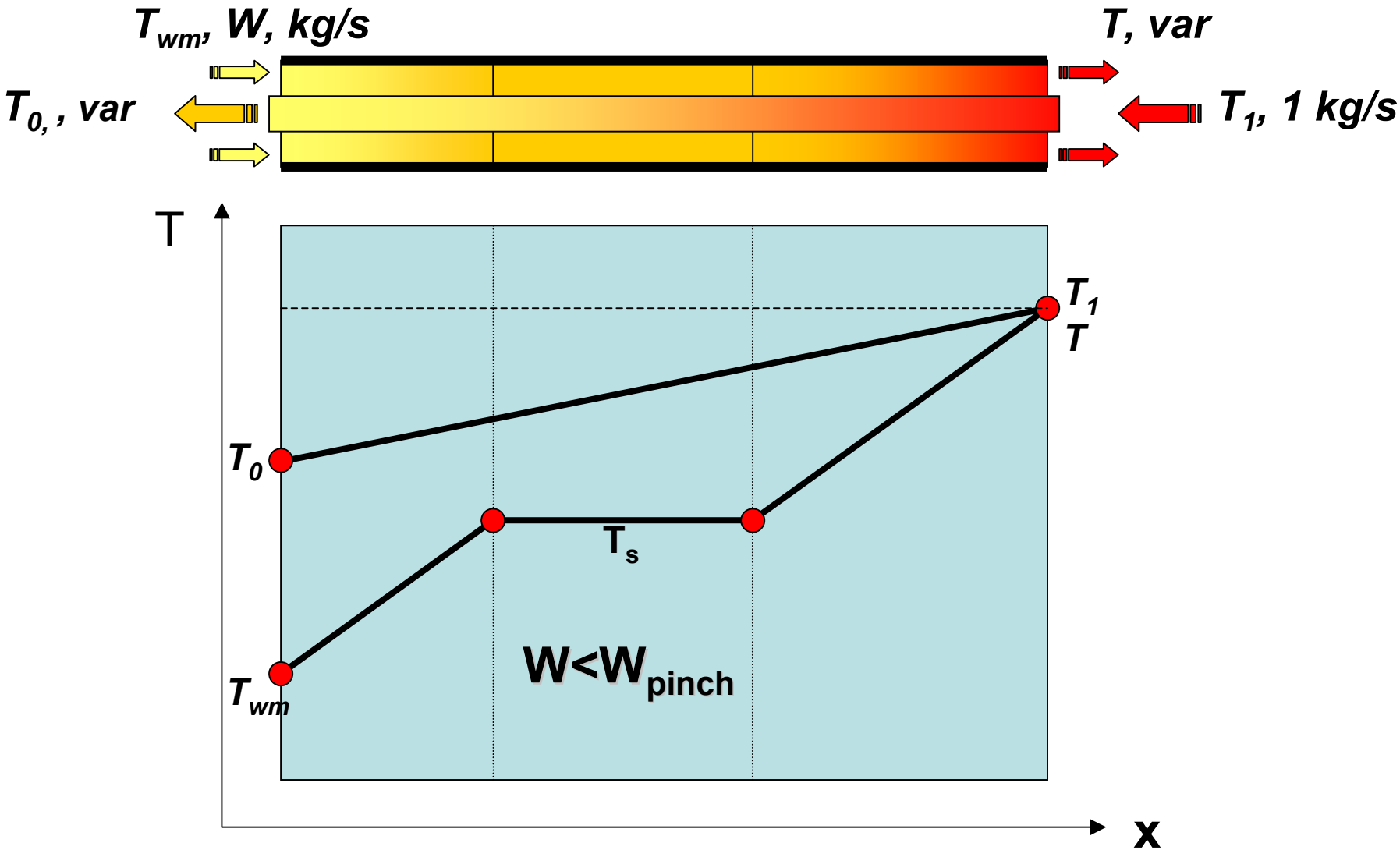

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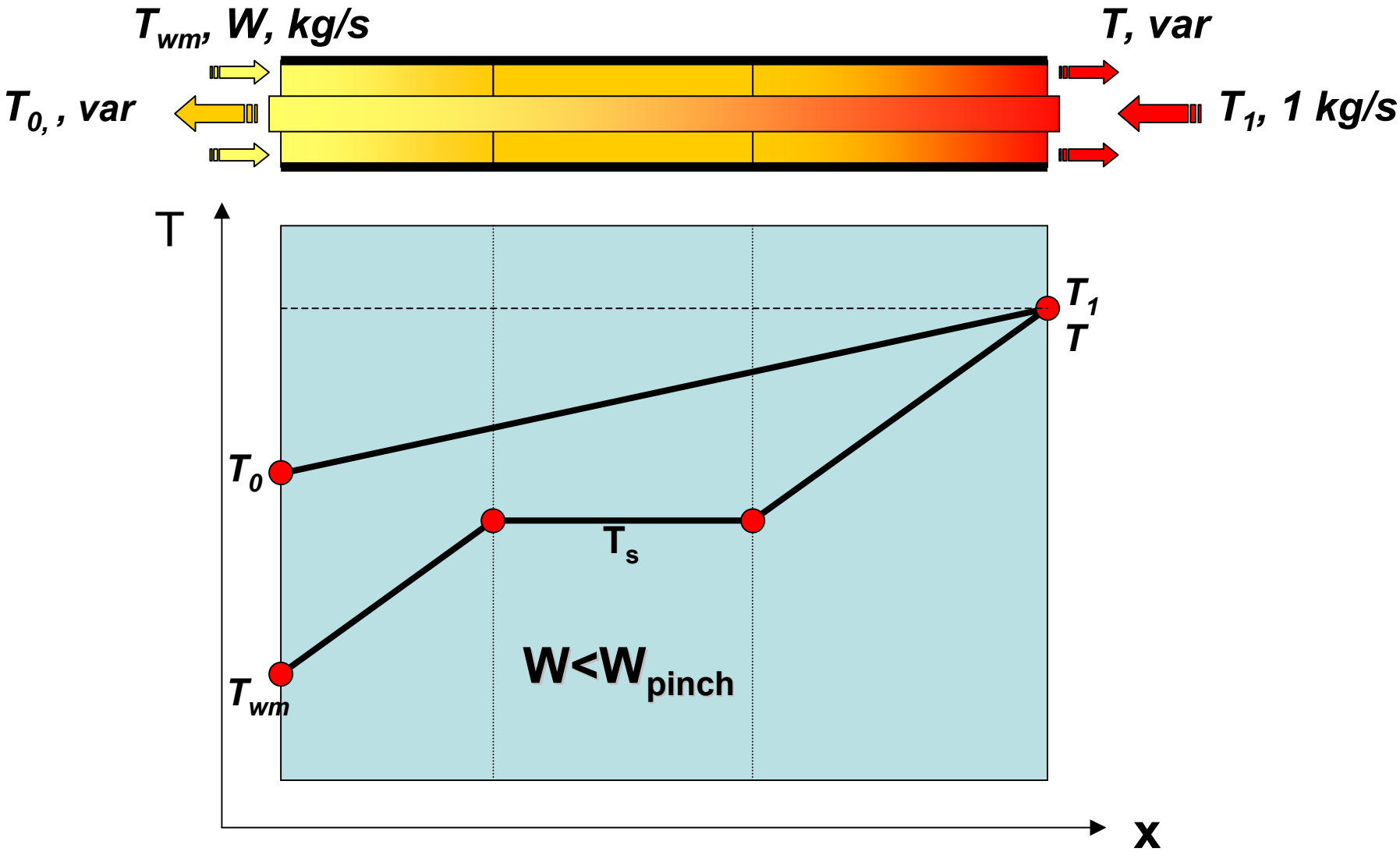

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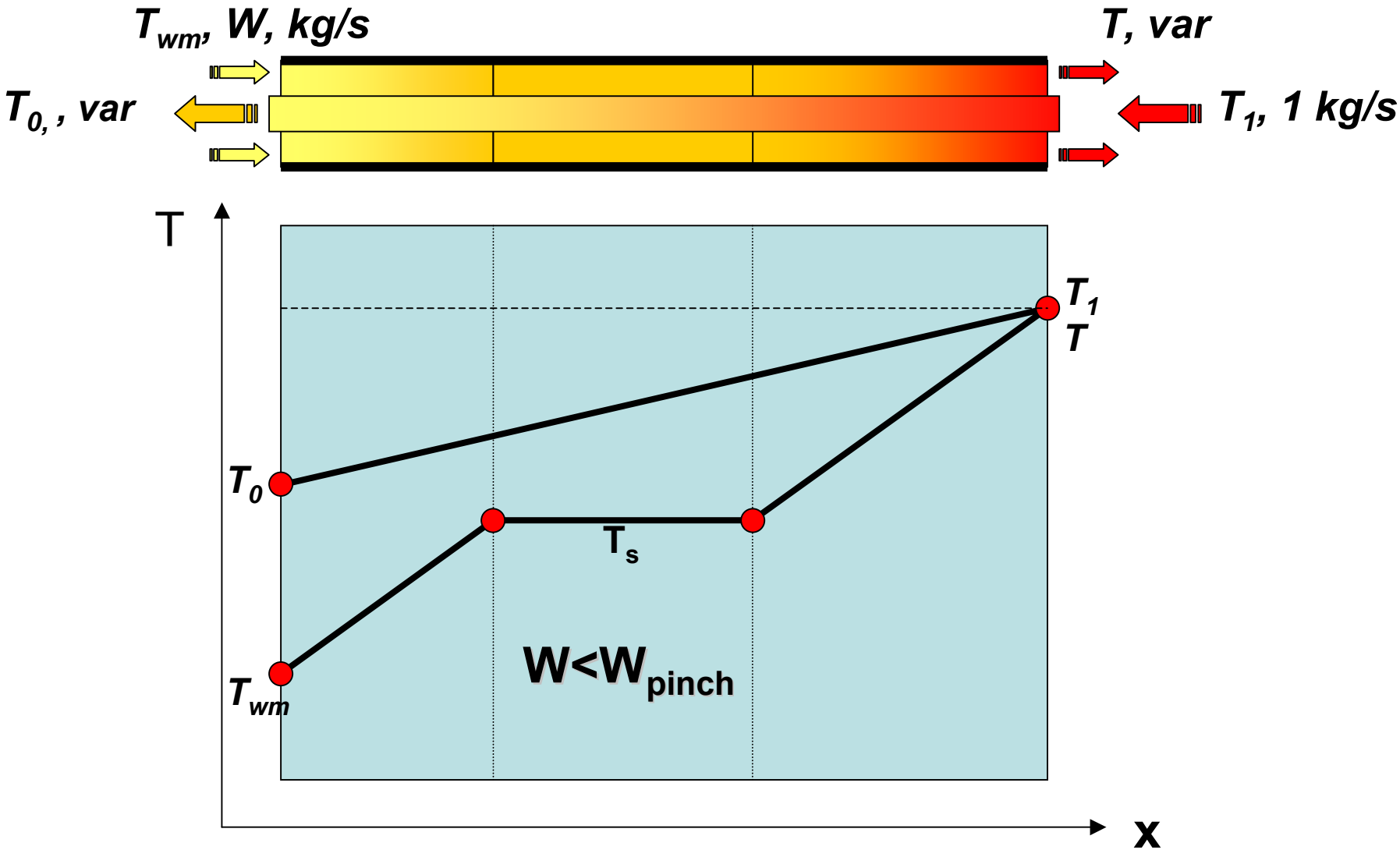

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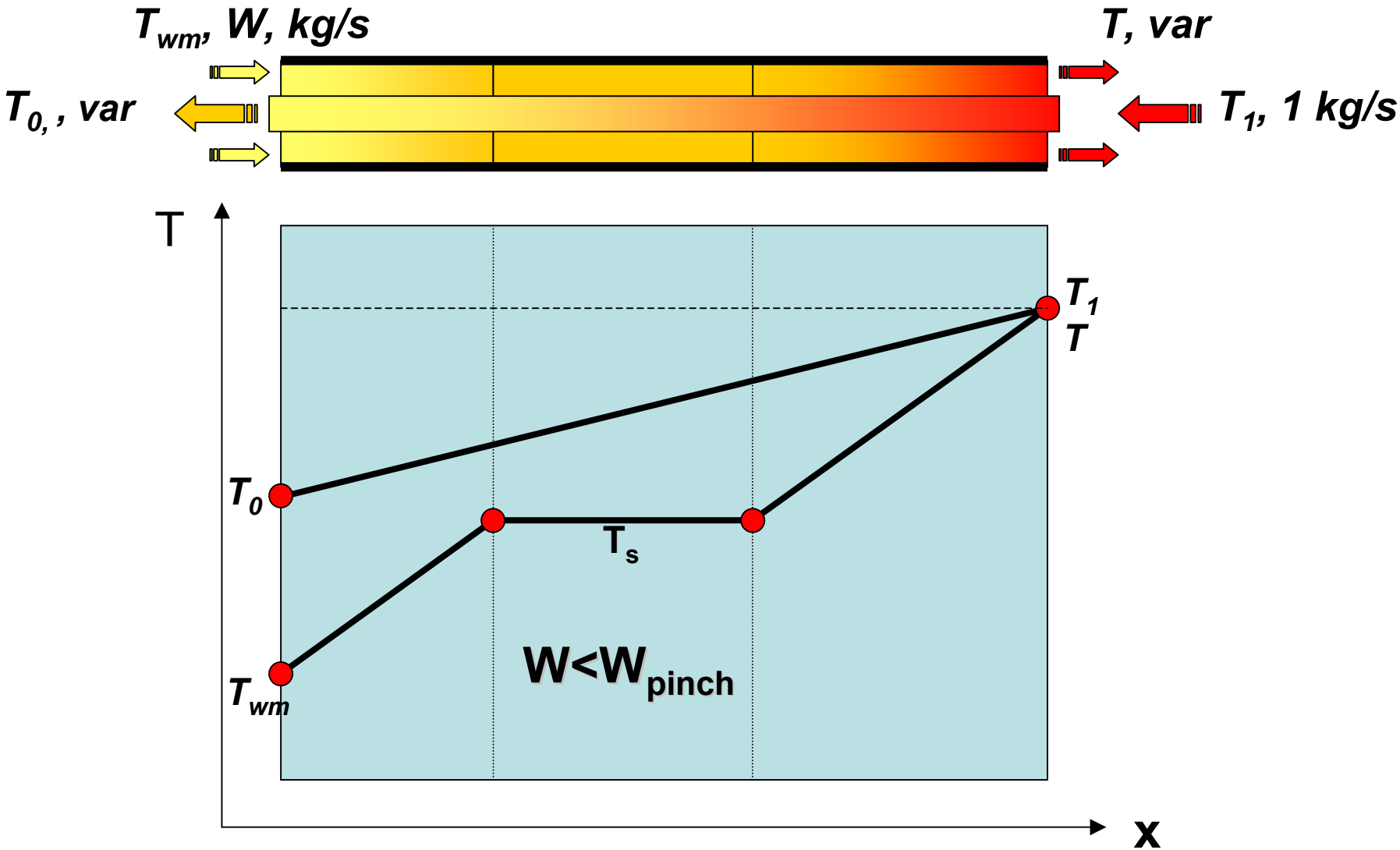

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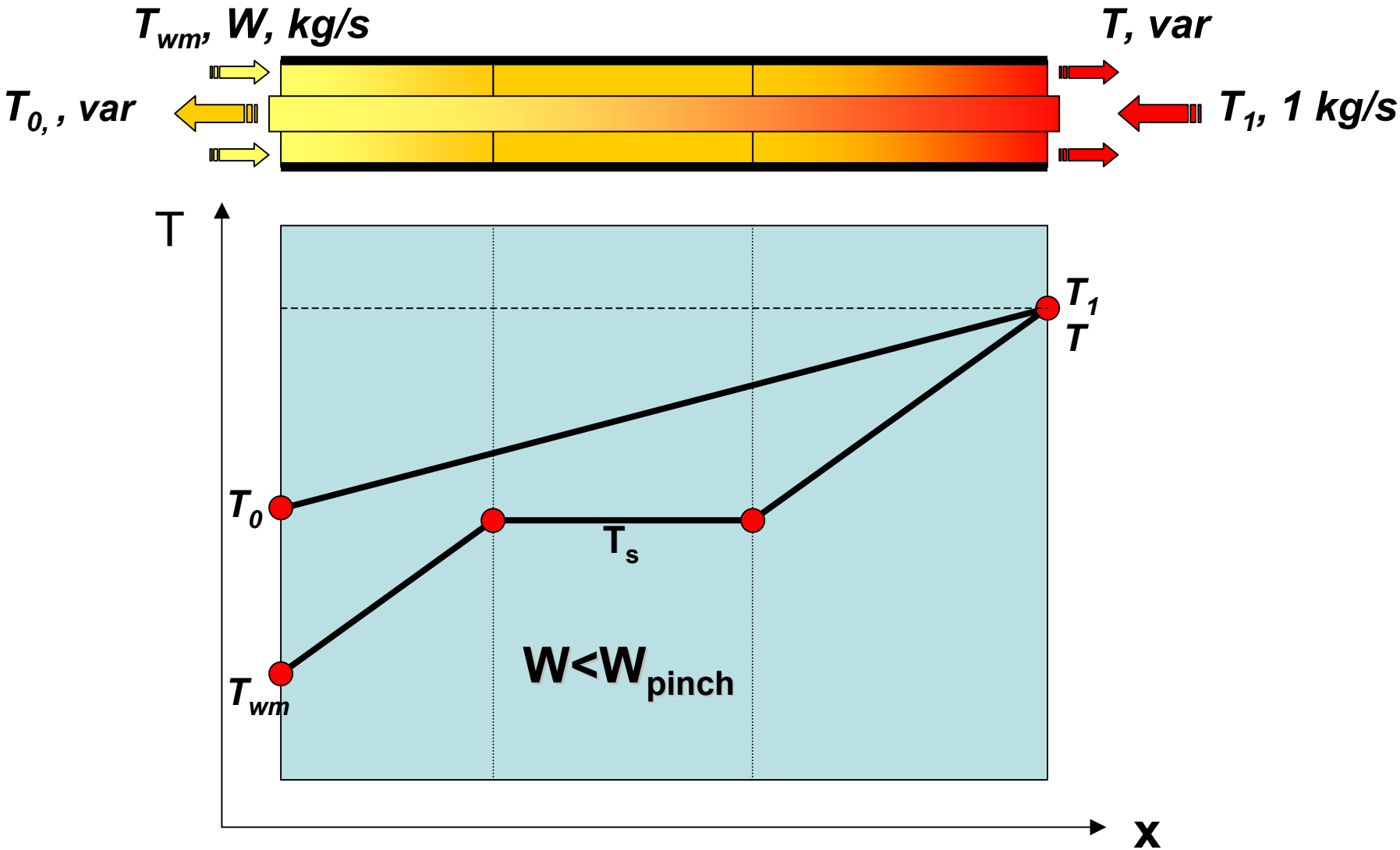

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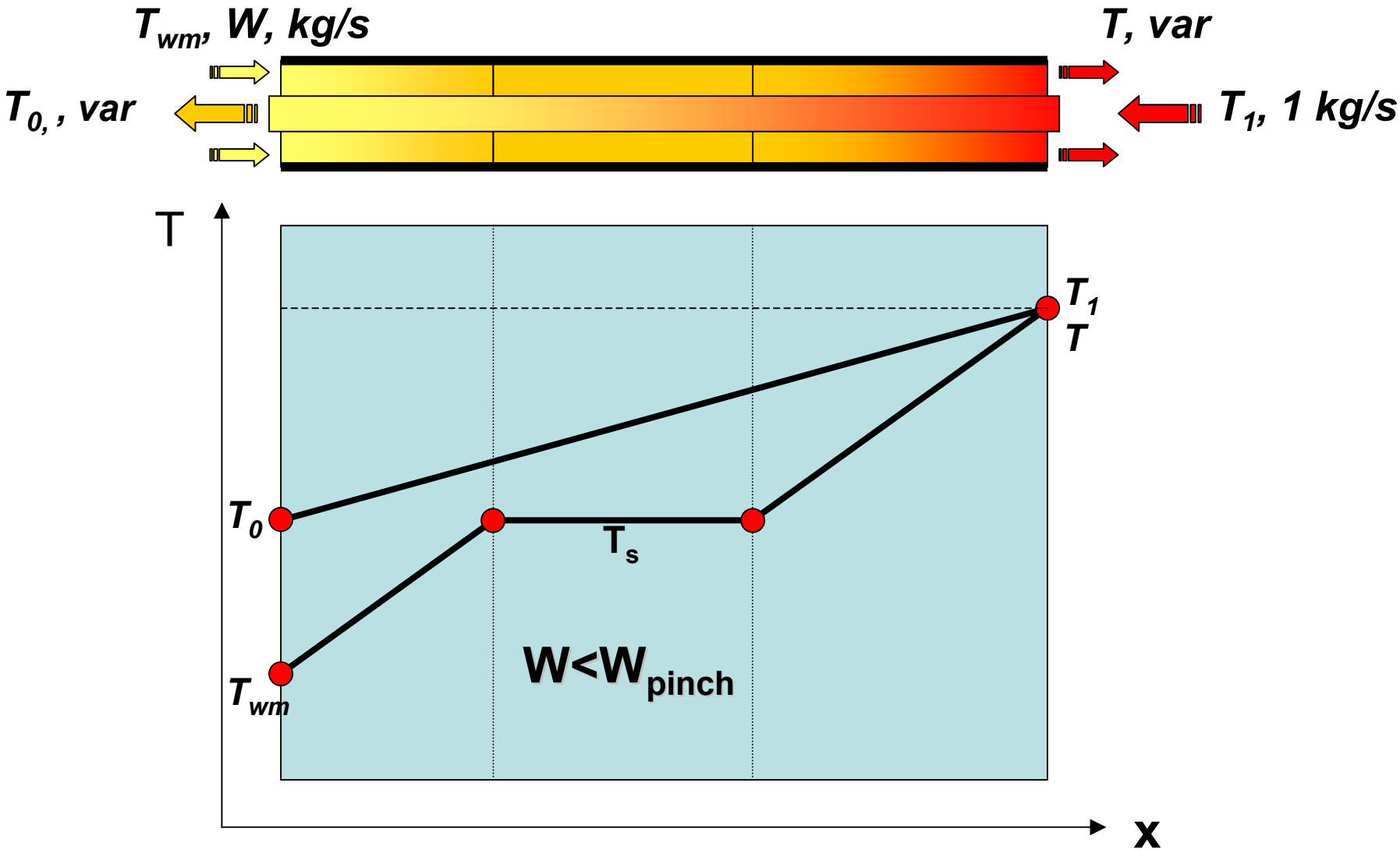

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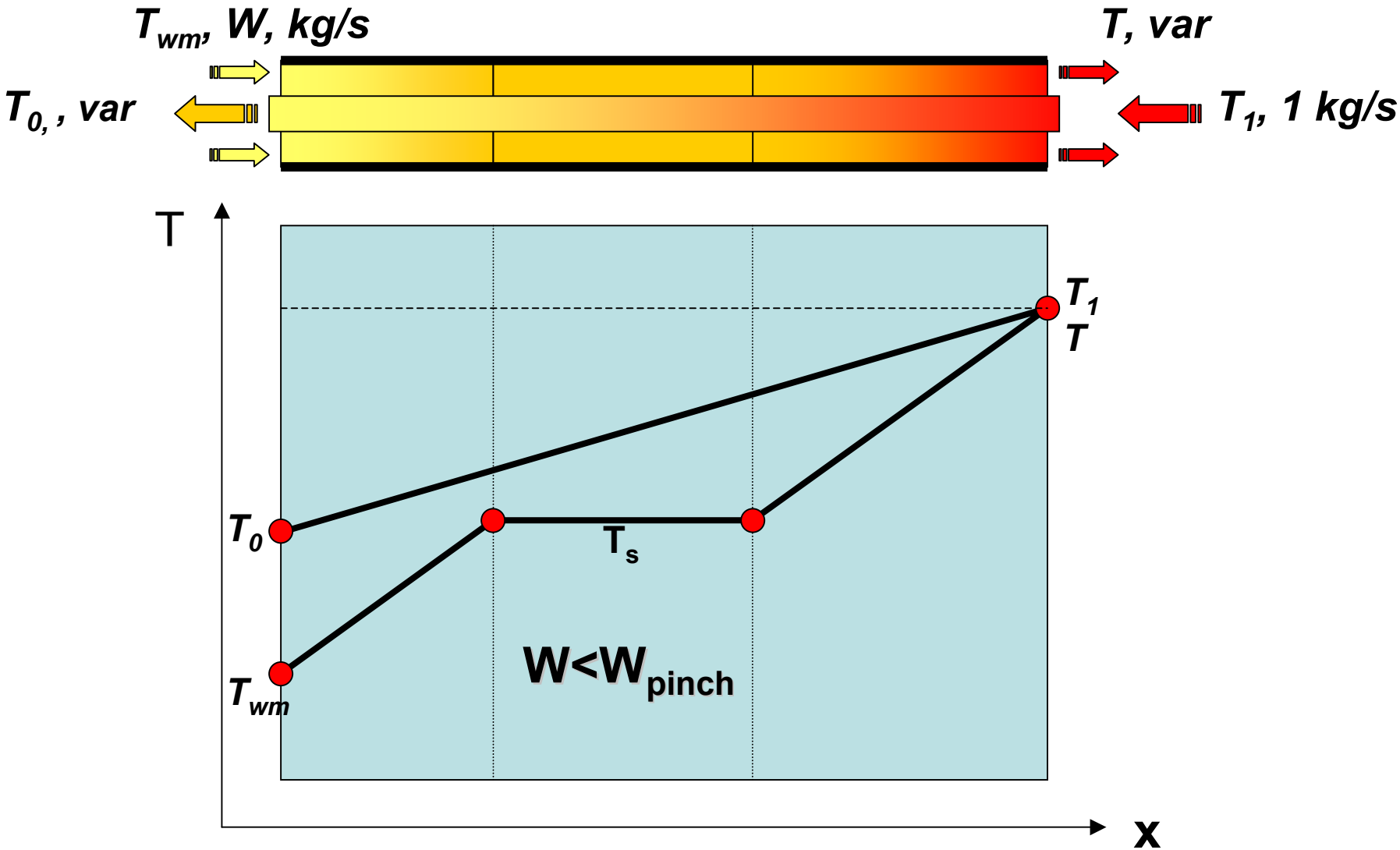

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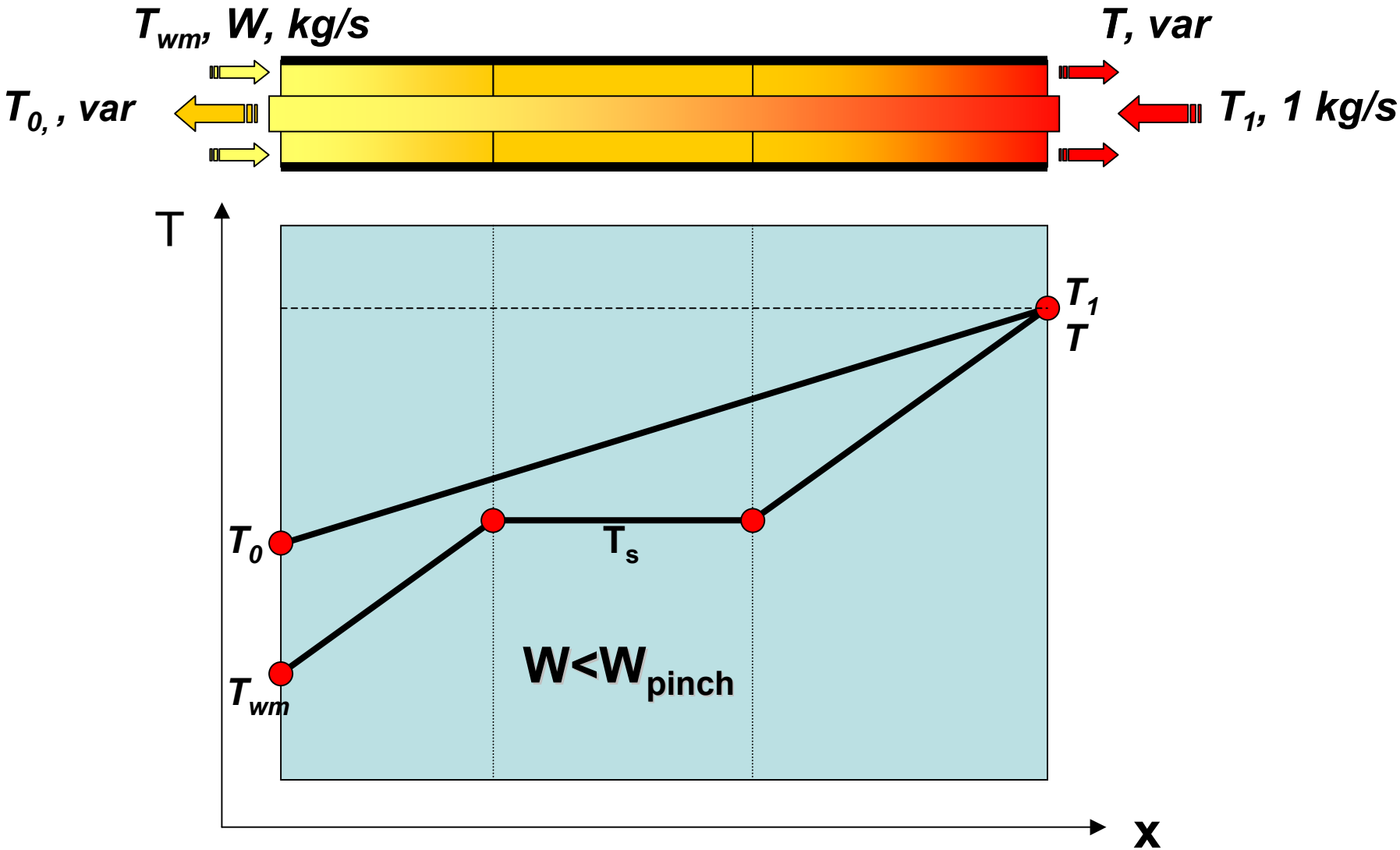

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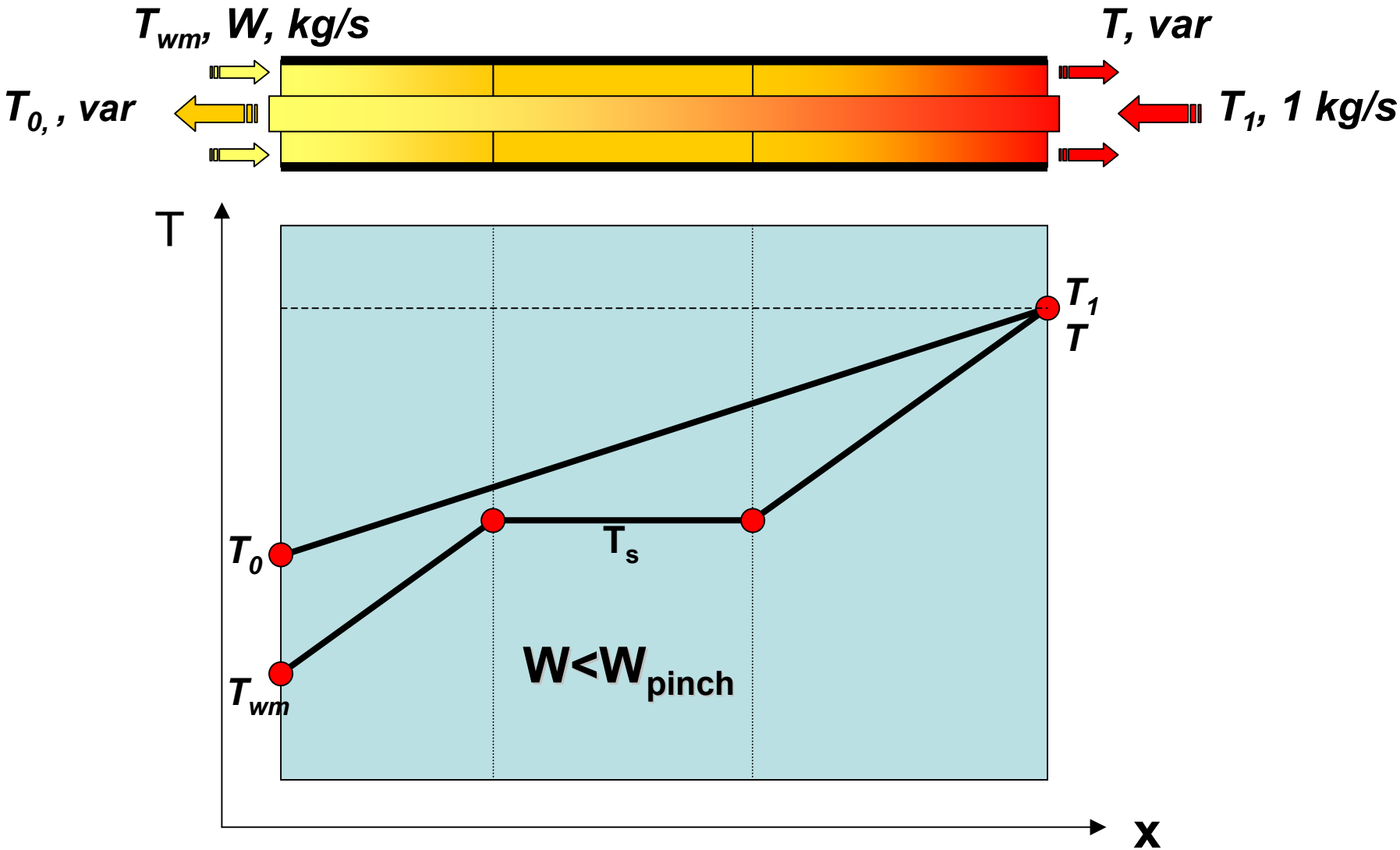

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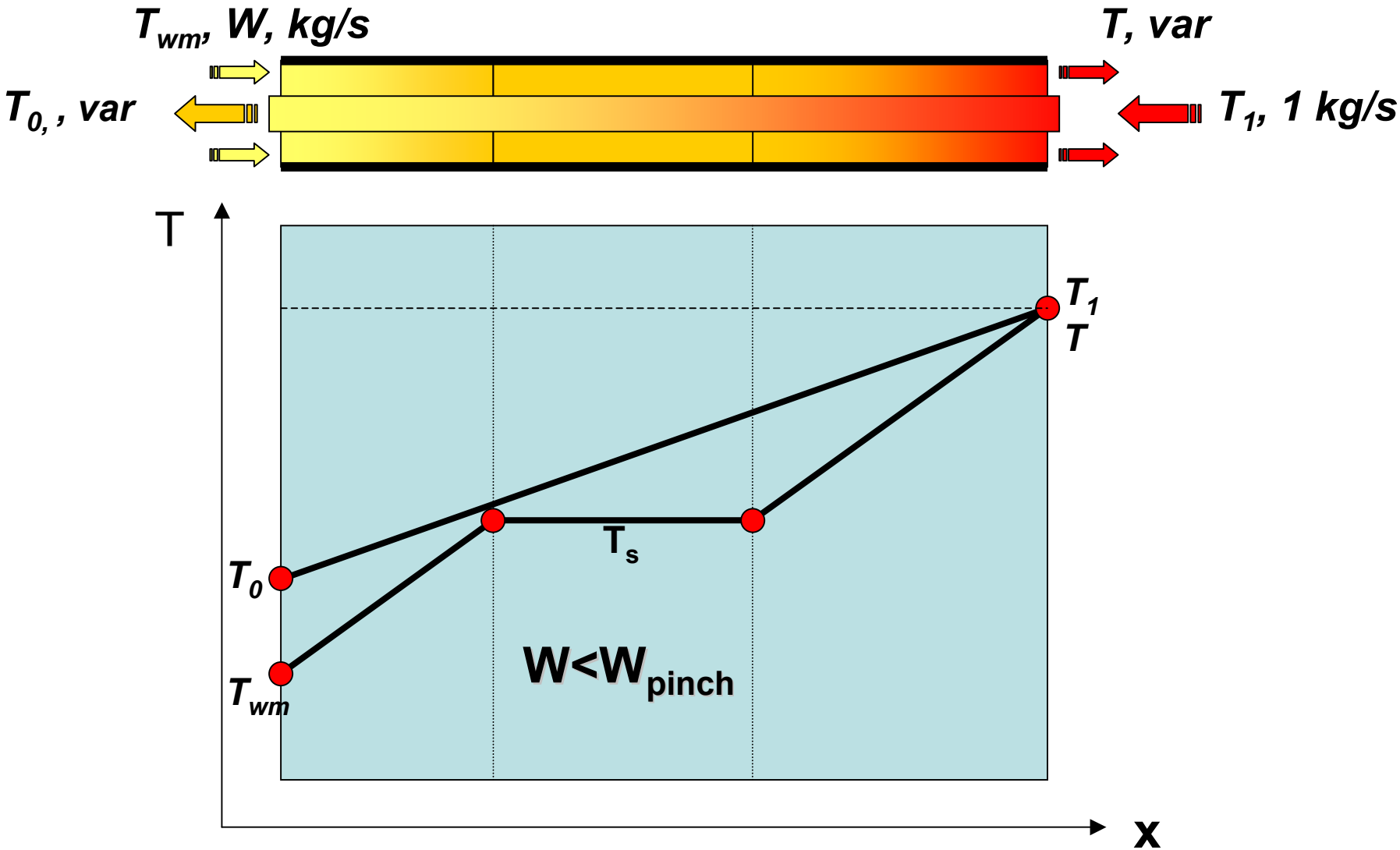

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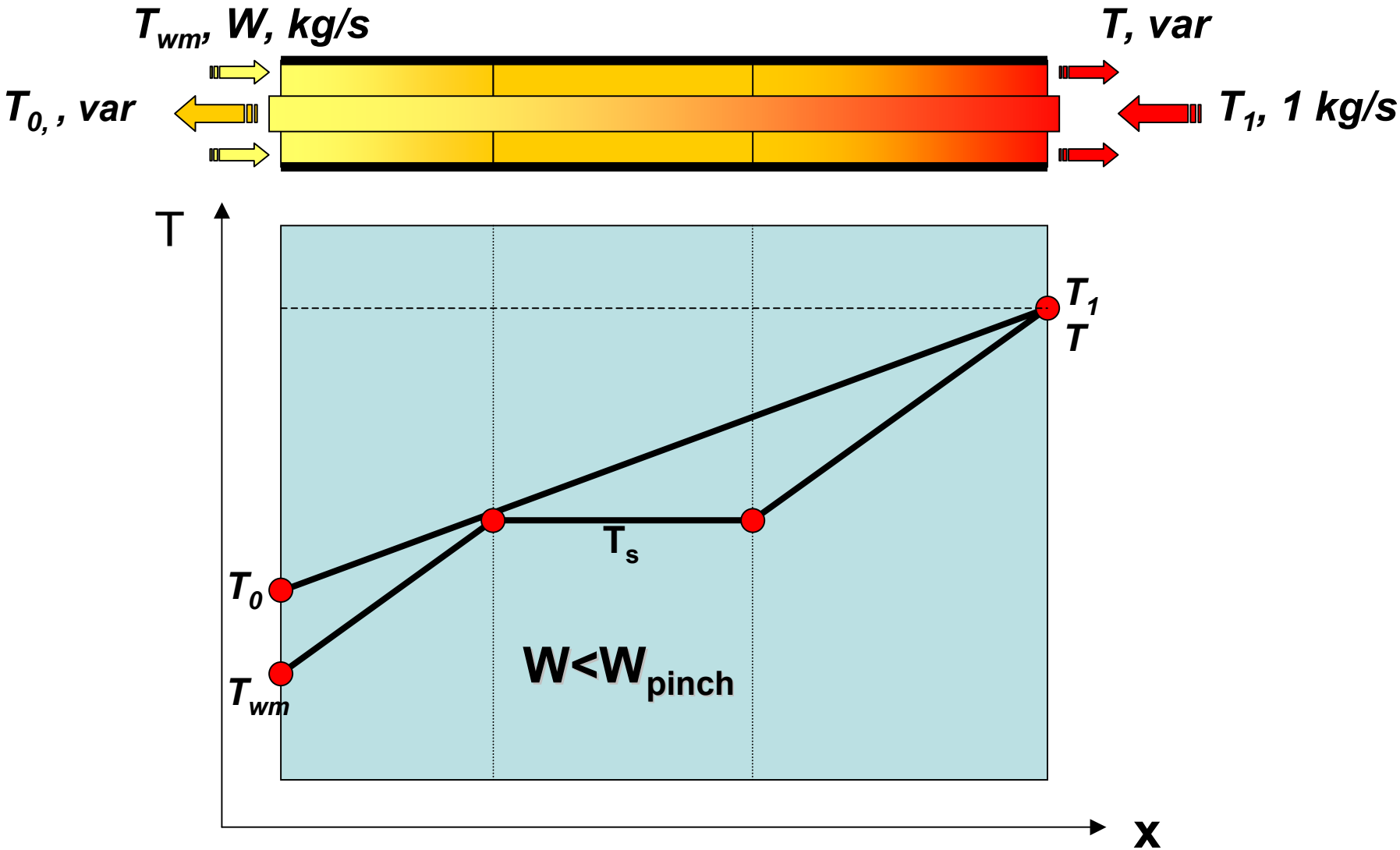

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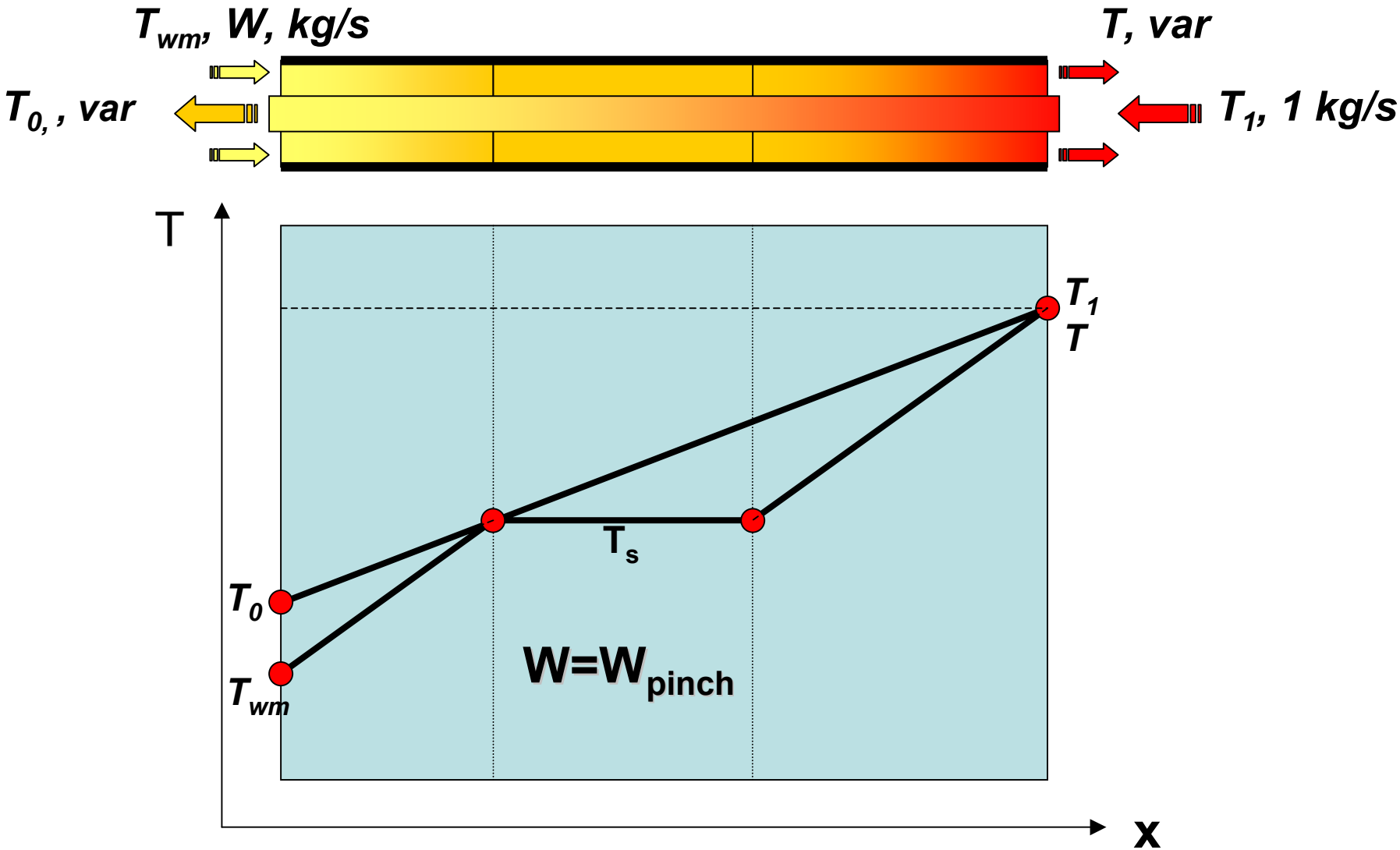

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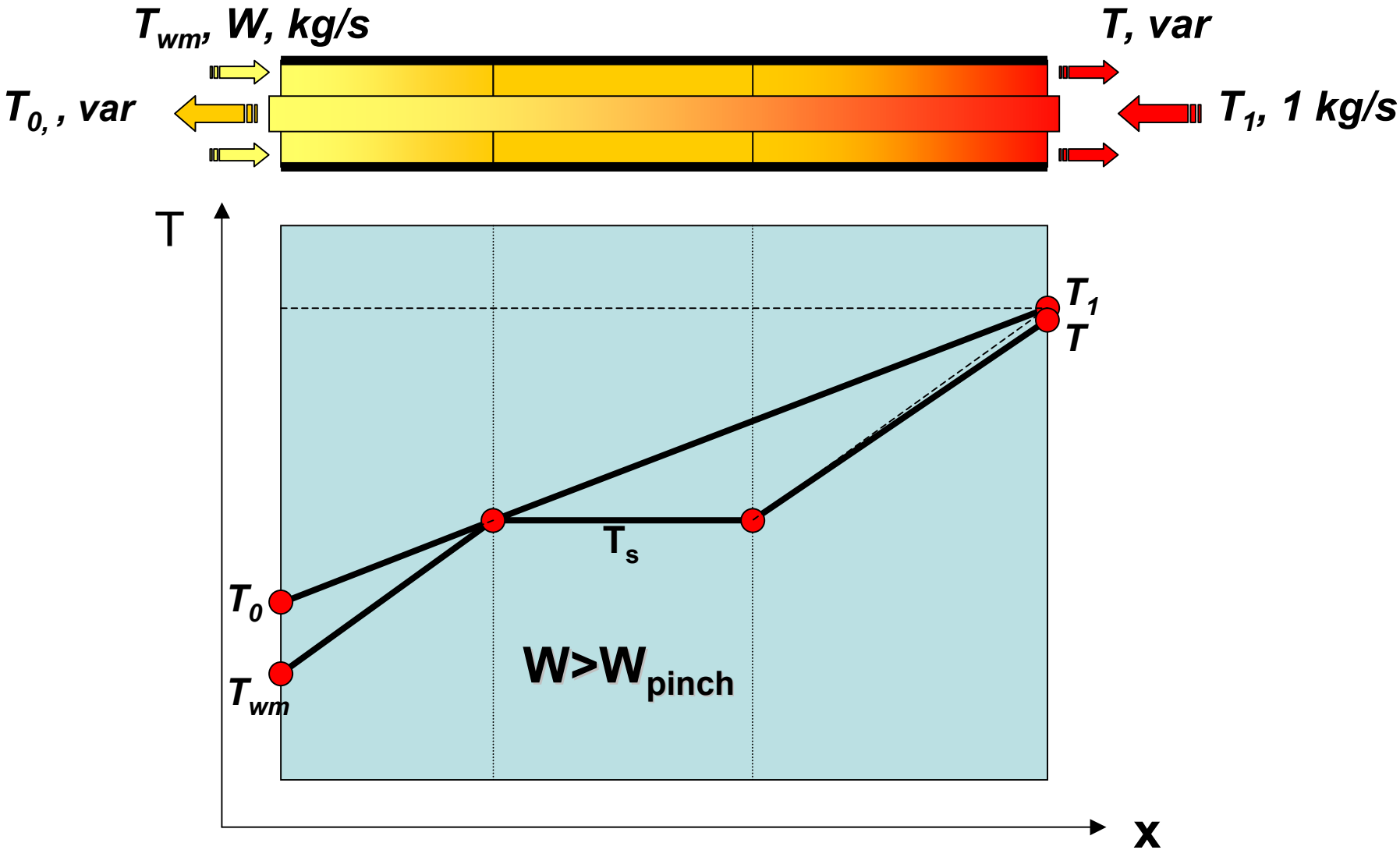

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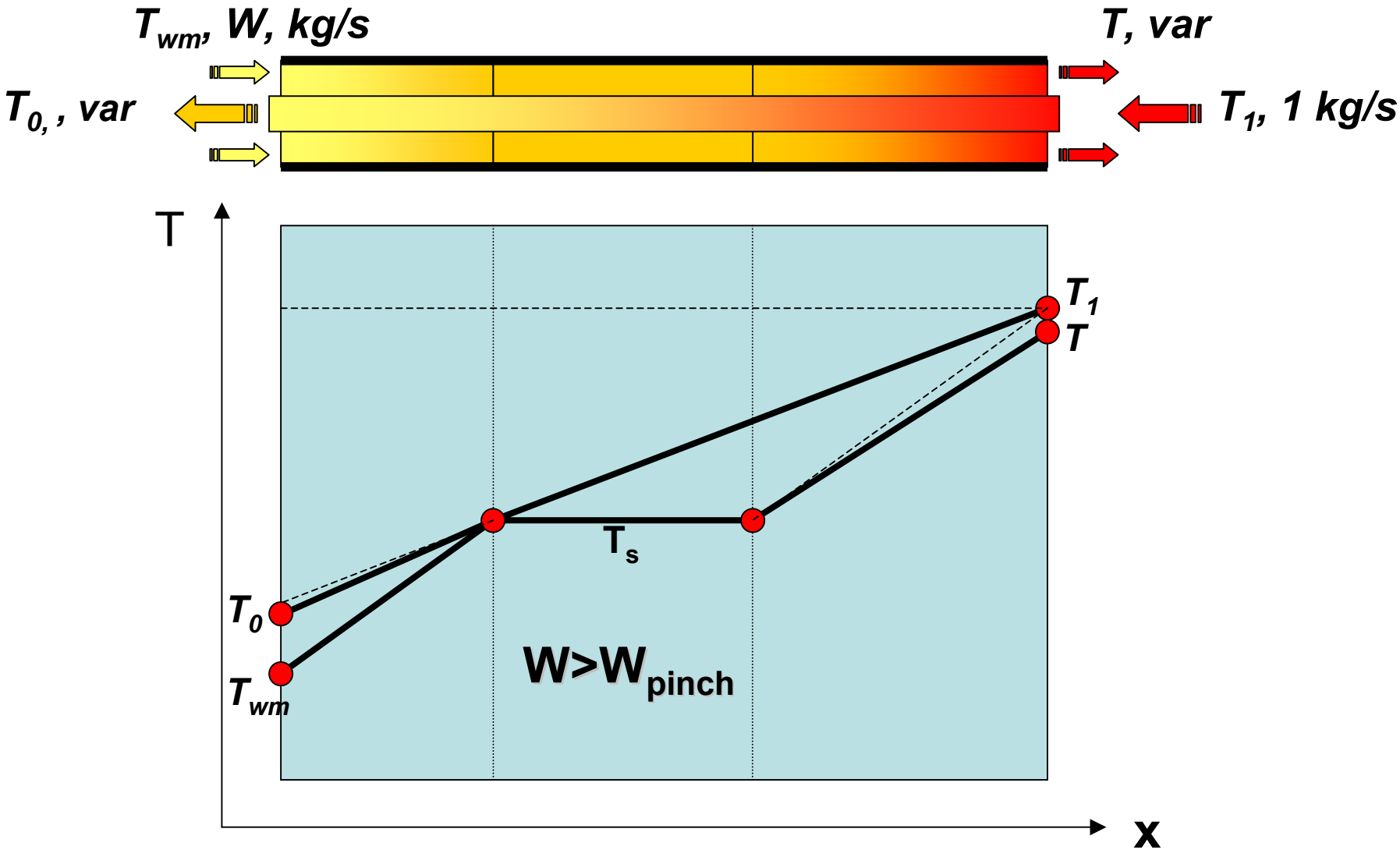

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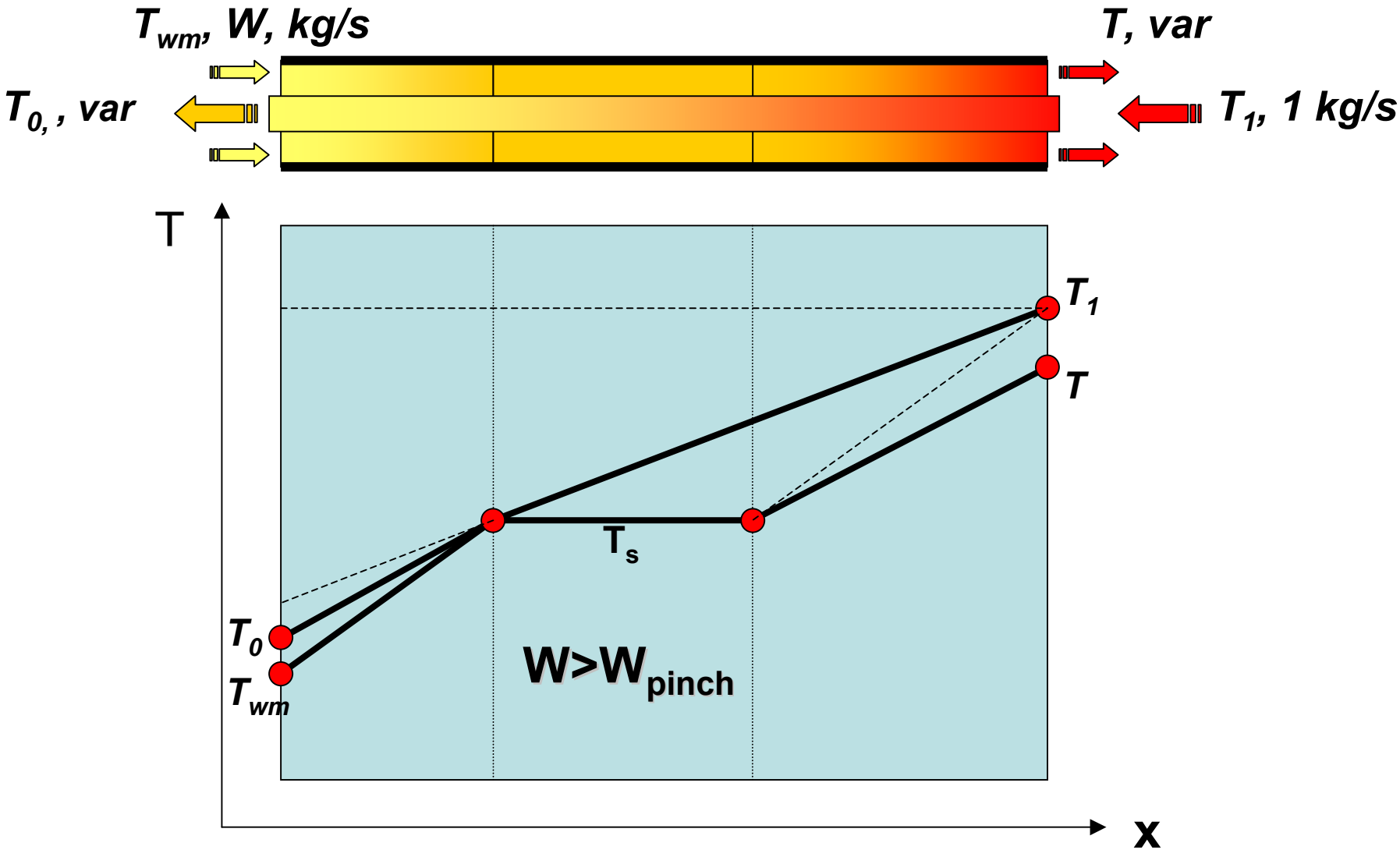

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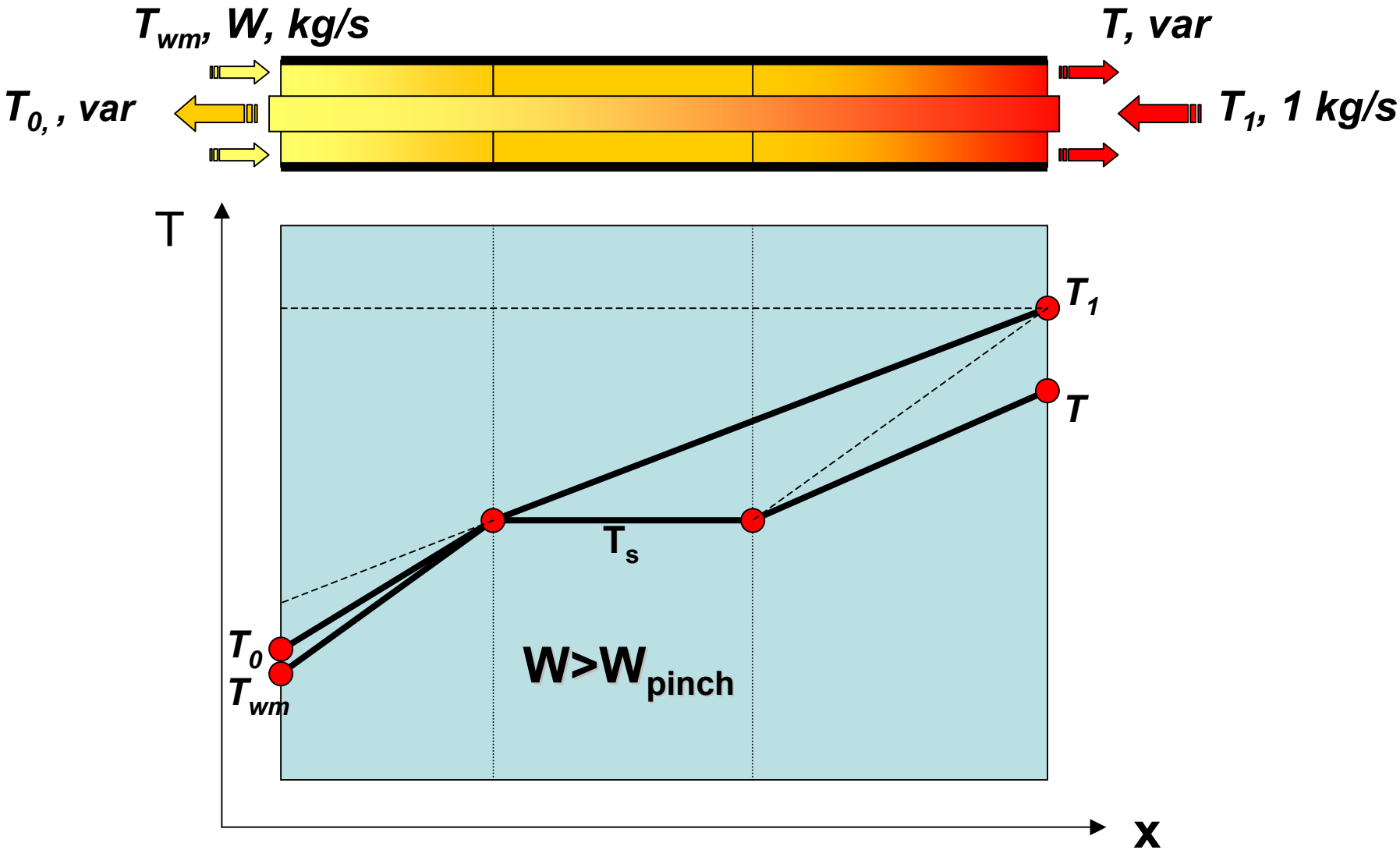
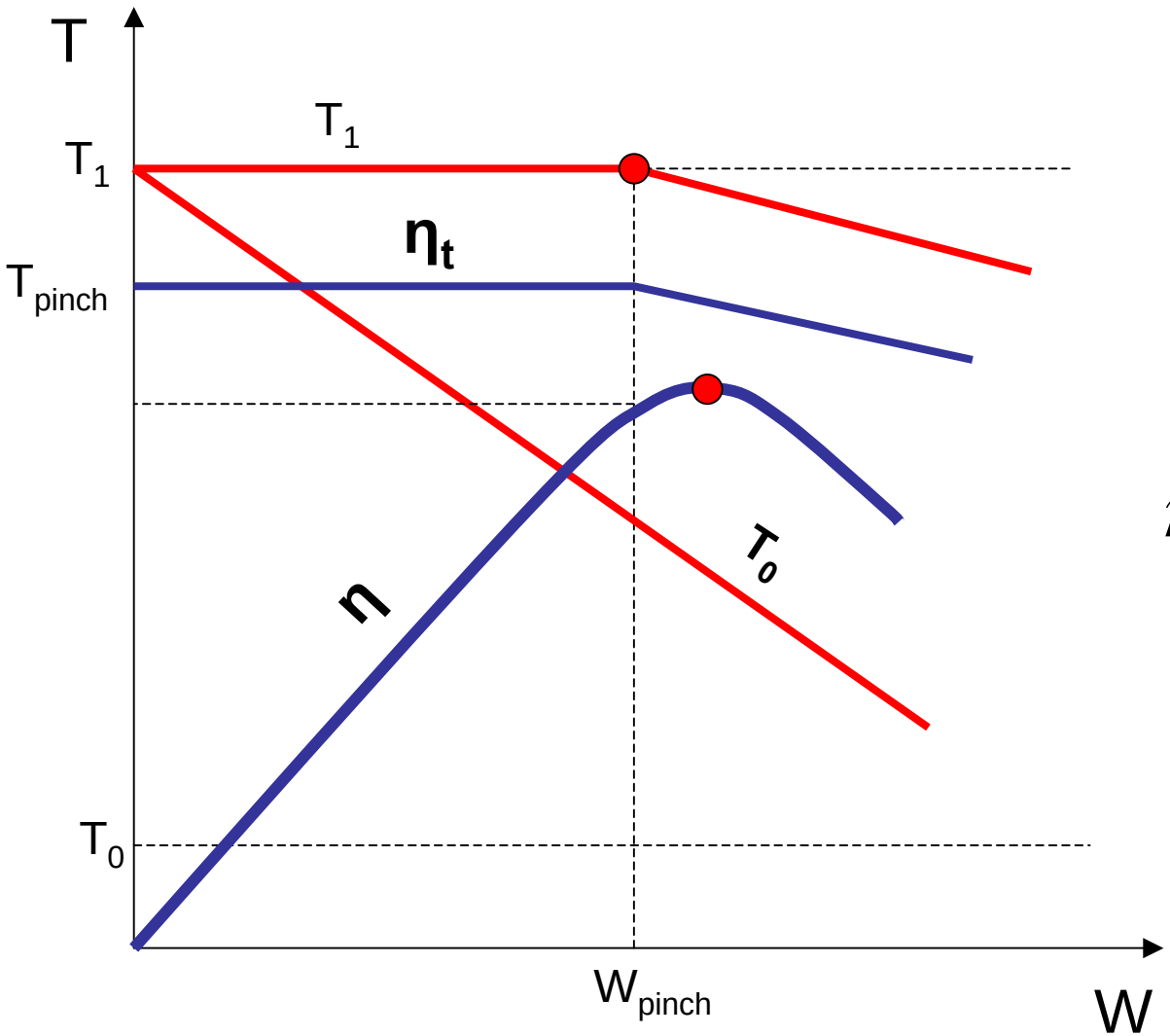
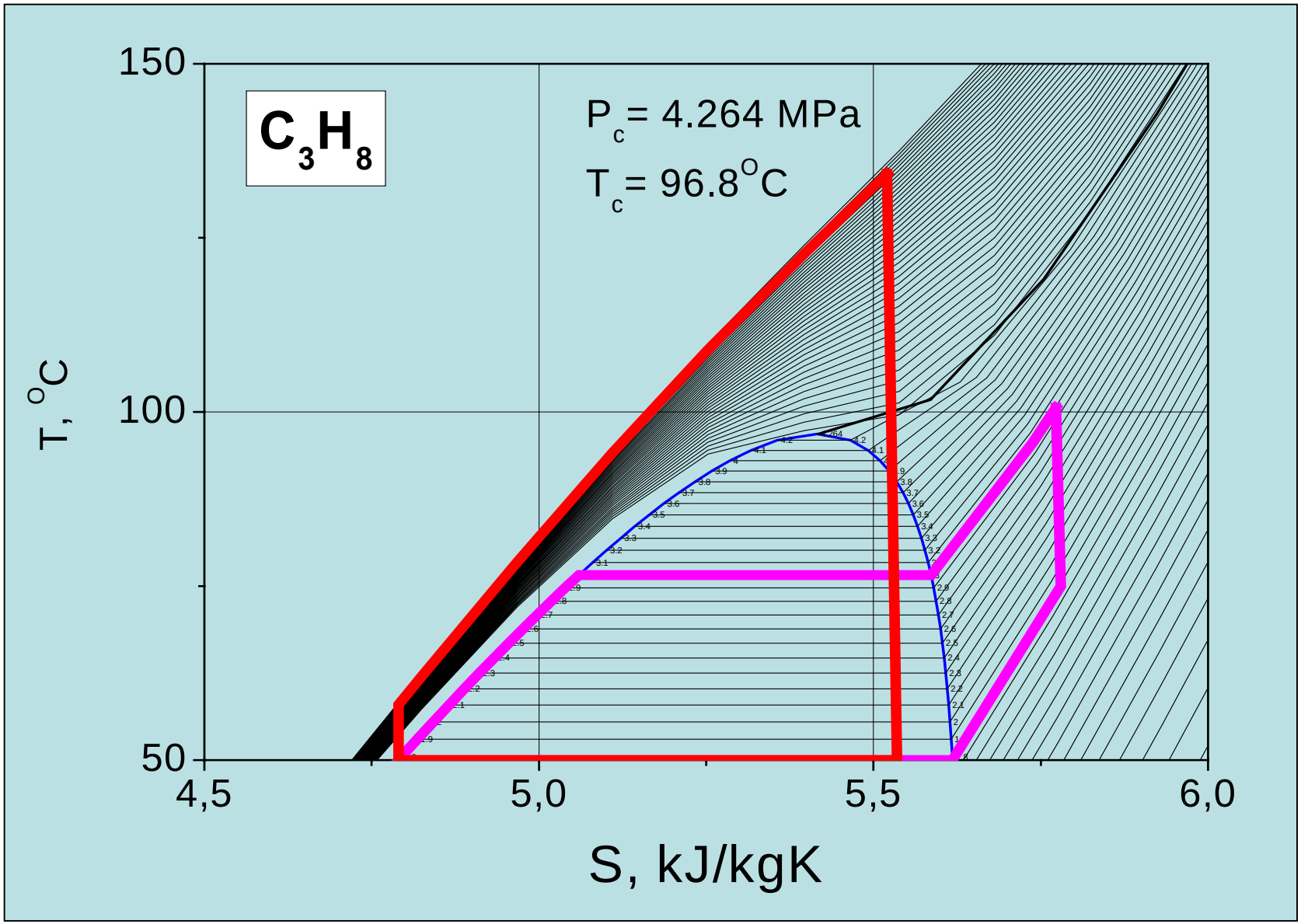
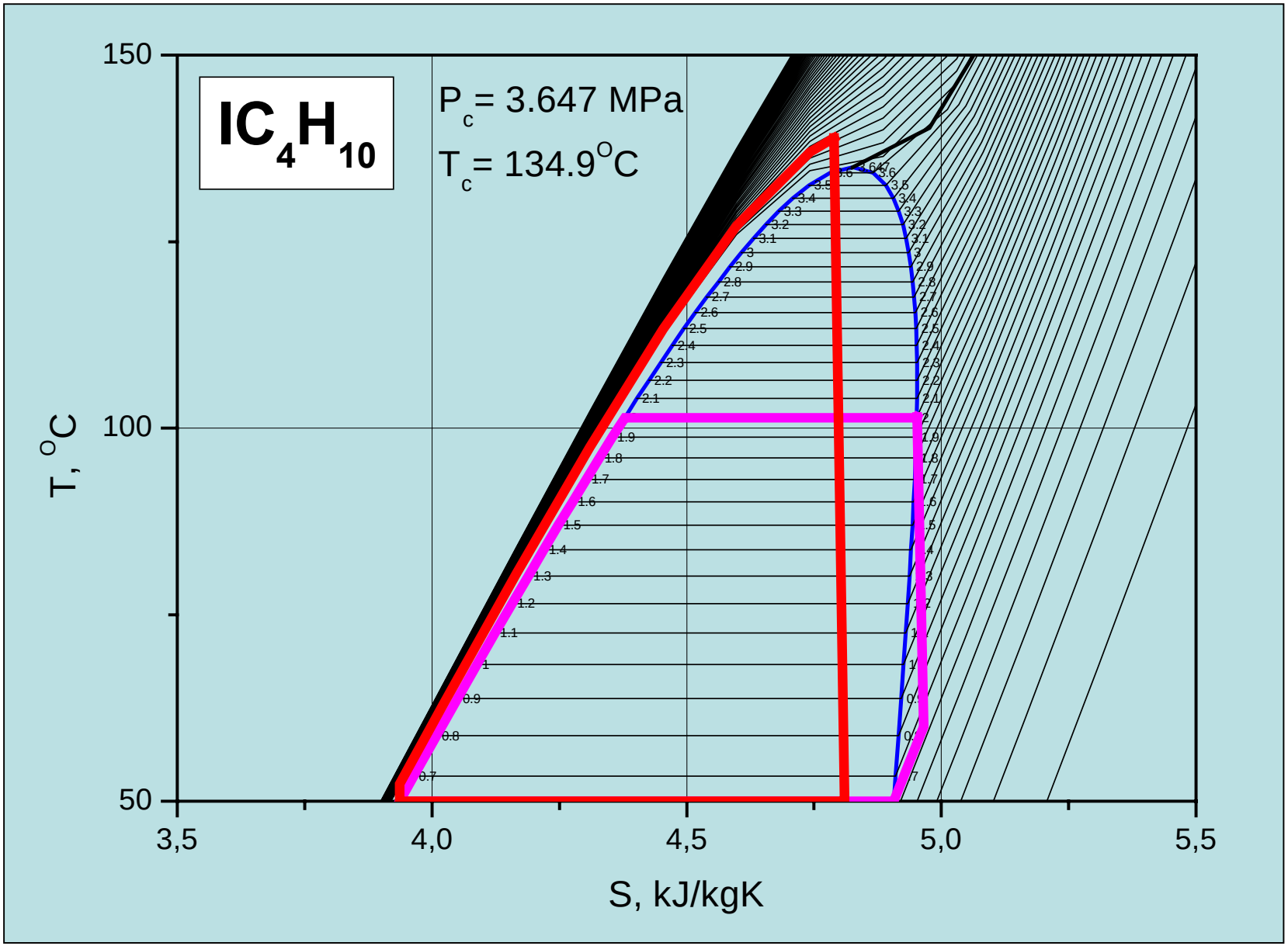


EFFICIENCY VERSUS FLOW-RATE



$$\eta = \eta_t \frac{q_1 \times W}{N_{th}}$$


C3H8
Pc= 4.264 MPa
Tc= 96.8OC
150
100
50
T, OC
4,5
5,0
5,5
6,0
S, kJ/kgK


IC4H10
Pc = 3.647 MPa
Tc = 134.9°C
150
100
50
T, °C
3,5
4,0
4,5
5,0
5,5
S, kJ/kgK

CONCLUSIONS:

1. There exist a thermodynamic limit of installation efficiency, defined by the outlet temperature of geothermal water;
2. An optimal thermodynamic cycle should have the heat admission curve similar to the cooling down curve of geothermal water;
3. This condition can be realized with a supercritical Rankine cycle;
4. To provide for maximum installation efficiency it is not enough to maximize the cycle thermal efficiency. It is necessary to look for maximum of the $\eta_t W$ product;
5. The optimal working media flow rate is governed by the temperature pinch in the heat exchanger.