Design of intermittent heating systems

Magnus Wessberg
Tor Broström

Center for Energy Efficiency in Historic Buildings

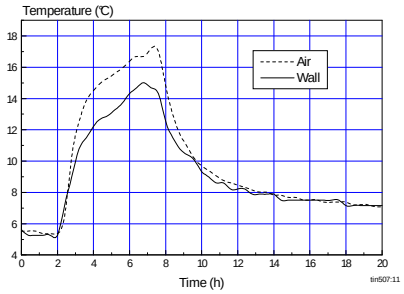
Gotland University
Passion for Science

Stånga Church

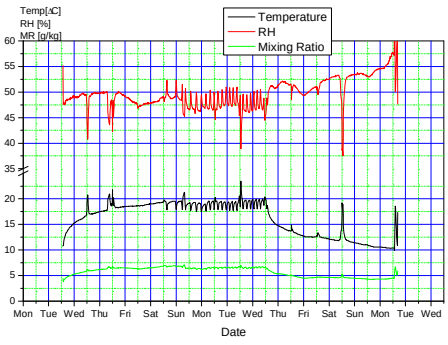
Problem

- New heating system in 2007
- Direct electric heating
- 38 kW heating power
- Heating time 3-4 days!

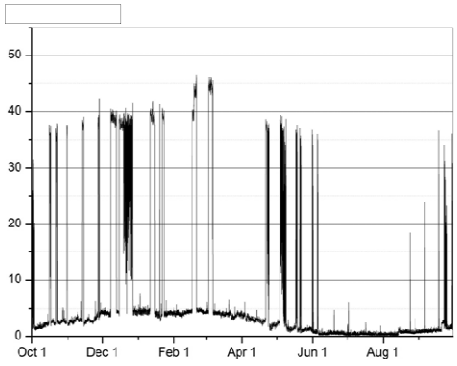
Intermittent heating



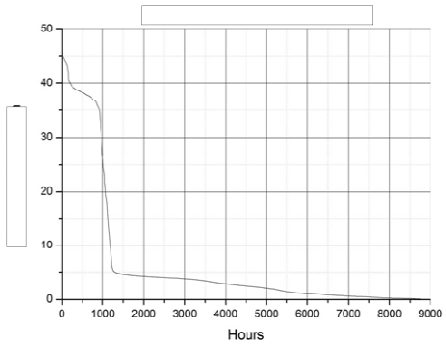
Intermittent heating



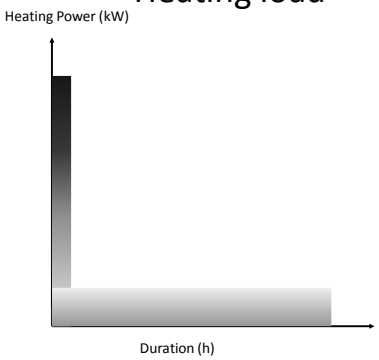
Power demand



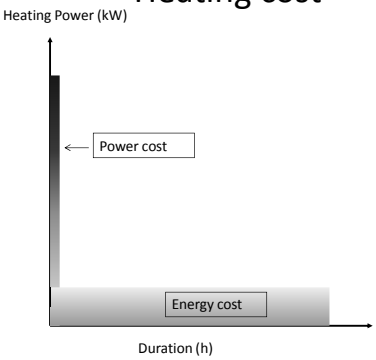
Load duration



Heating load



Heating cost

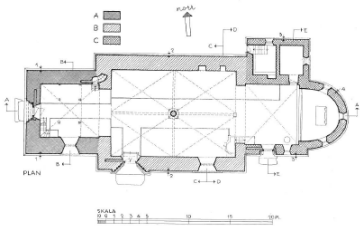


Area and volume

Volume is around 2300 m^3

Area

- Walls 370 m^2
- Ceiling 400 m^2
- Doors 27 m^2
- Windows 29 m^2



Heating the air

Heating the air only, 10 degrees.

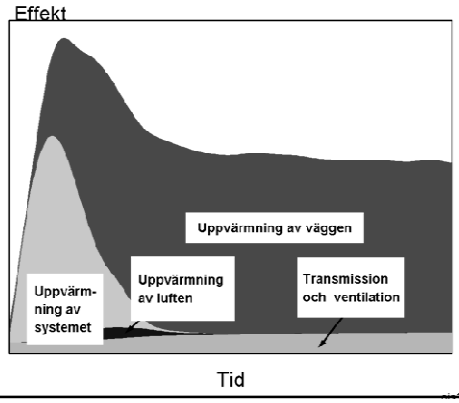
10K * 2300 m^3 * 1,2kg/m^3 *1kJ/(kg*K) = 27600 kJ = 7,7 kWh

With a heating power of 38 kW this would take 12 minuter.

Heating demand for continous heating

- Transmission and ventilation losses
- 1, 5 kW/K
- 20 C inside O C outside: 30 kW

Intermittent heating



Theoretical model

$$\Delta\theta_i = \frac{P_v u\sqrt{\tau}}{A} + \frac{P_v}{\alpha A}$$

$$\Delta\theta_v = \frac{P_v u\sqrt{\tau}}{A}$$

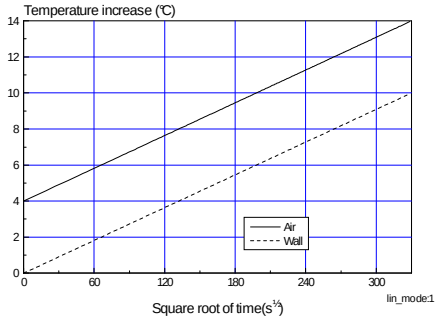
$$u = \sqrt{\frac{4}{\pi\lambda c\rho}}$$

$\Delta\theta_v$	Wall temperature increase (°C)
$\Delta\theta_i$	Air temperature increase (°C)
P	Power input (W)
t	time (s)
A	Wall area (m²)
α	Heat-transfer coefficient(W/m²°C)
λ	Heat conductivity (W/m°C)
c	Specific heat (J/kg°C)
ρ	Density (kg/m³)

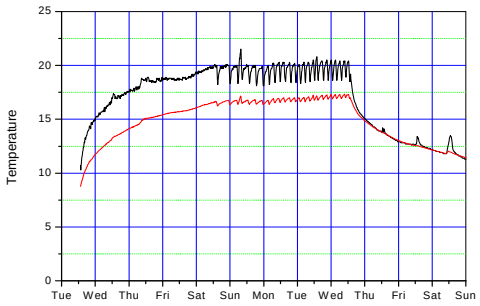
Temperature increase

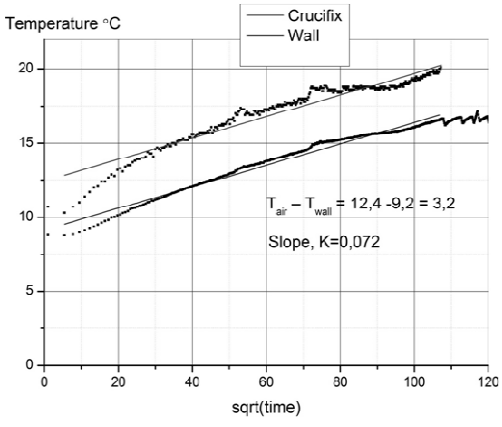
$$\Delta\theta_i = \frac{P_v u\sqrt{\tau}}{A} + \frac{P_v}{\alpha A}$$

$$\Delta\theta_i = a\sqrt{\tau} + b$$



The test





Temperature increase

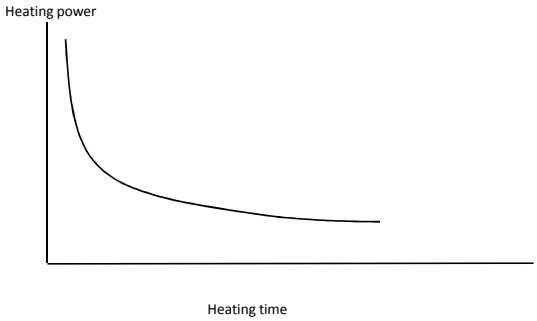
$$\Delta\theta_i = \frac{P_v u\sqrt{\tau}}{A} + \frac{P_v}{\alpha A}$$

$$\Delta\theta_i = a\sqrt{\tau} + b$$

The new heating power can be calculated as a function of the heating time

$$P_{new} = \Delta T \cdot \frac{1}{K \cdot \sqrt{time} + (T_{air} - T_{wall})} \cdot P_{old}$$

The new heating power can be calculated as a function of the heating time



Power needed for 1 C per hour

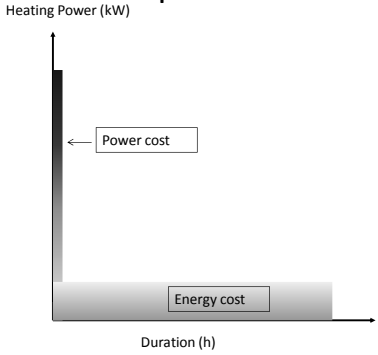
- $P_{new} = 107\ kW$

Higher power -> less energy!

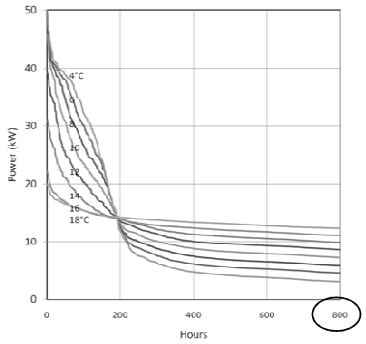
20 heating episodes per year

- 38kW = > 72 960 kWh
- 107kW => 51 360 kWh

Optimization



Heating load



Design of intermittent heating systems

Magnus Wessberg
Tor Broström

Center for Energy Effeciency in Historic Buildings

Gotland University
Fossum & Science