Hot air church heating and damage to the monumental interior

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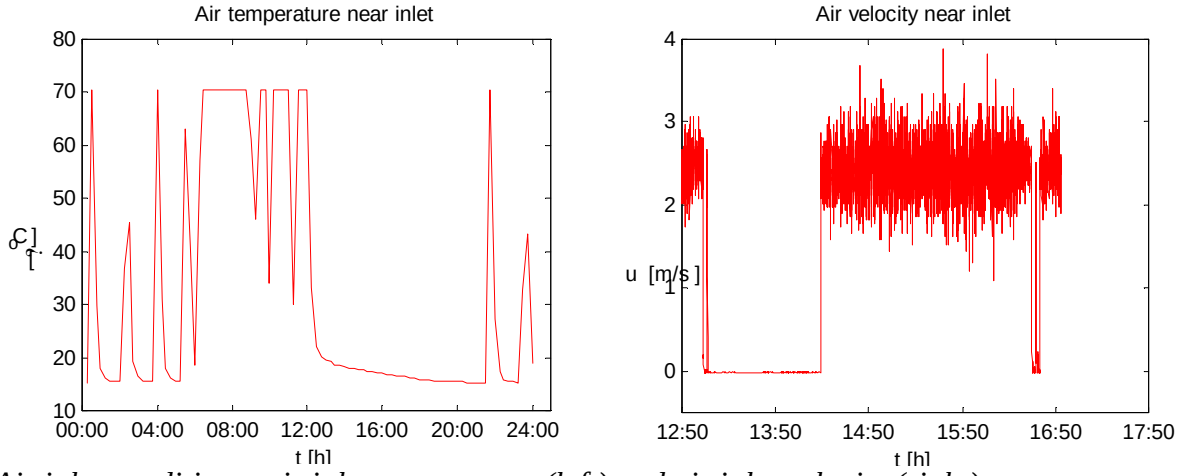
ABSTRACT
In a PhD study on the heating of monumental churches one of the problems, which was encountered, was the damage to wooden interior parts due to the changing of the indoor climate. Particularly warm air heating frequently leads to sudden changes in relative humidity, which turned out to be dramatically hard for monumental organs during wintertime.

Cracks in the wooden parts of the monumental organ

The warm air inlet conditions and their result on the airflow and air conditions were examined experimentally and by CFD-simulation. These results provided boundary temperature and humidity conditions, to which the monumental organ was exposed.



Air inlet conditions: air inlet temperature (left) and air inlet velocity (right)

The Archimedes number is defined as:

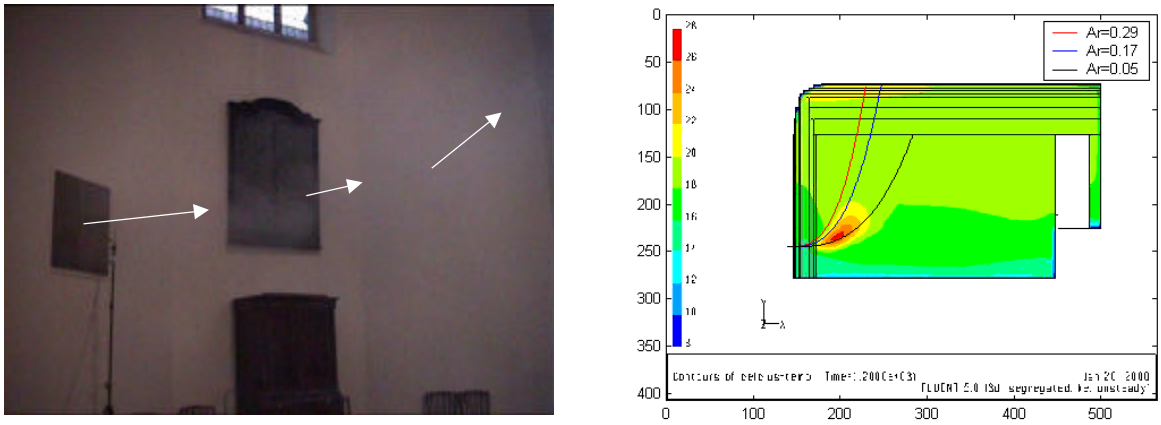
$$Ar = \frac{g \beta \Delta T_0 D_h}{T_i u_0^2}$$

where

g	=	gravitational acceleration	[m/s^2]
ΔT_0	=	temperature difference air - inlet	[K]

D_h	=	hydraulic diameter inlet grille	[m]
T_i	=	indoor air temperature	[K]
u_0	=	air supply velocity at inlet	[m/s]

Concluded was that a high Archimedes number indicates a high thermal upward component at high air inlet temperatures in combination with low air inlet velocities: the flow will rise to the ceiling quickly. A low Archimedes number represents airflow deep into the church.



Visualization of flow at the hot air inlet by smoke (left) and hot air trajectories by CFD analysis for different Archimedes numbers (right)

Reducing the Archimedes number can reduce the temperature stratification. This can be accomplished by reducing the temperature difference between inlet air and indoor air to e.g. 25 K and to increase the inlet air velocity. The latter is needed to keep up the heating capacity. A new air heating system was proposed. The new inlet conditions were based on a combination of low inlet air temperatures (up to 40 ^oC) and high air velocities (up to 4 m/s), leading to an Archimedes number less than 0.05. Afterwards the air stratification proved to be less than 2 K over the total height of the church.

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